CHAPTER

09

Land resources

Helidon to Calvert Environmental Impact Statement

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

Contents

Figures

Tables

9. Land resources

9.1 Summary

This chapter provides an assessment of land resources for the Project. The existing environment, potential risks arising from the disturbance and excavation of land, as well as the disposal of soil has been considered. A quantitative assessment (desktop and field-based) of soil properties was undertaken, including agricultural and potential problematic soils. A qualitative assessment (desktop) of contaminated land was also undertaken. The risk assessment addresses the construction, operation and decommissioning (as it relates to construction) phases of the Project. Mitigation measures to be implemented during the three phases of the Project are identified for inclusion in appropriate management plans (refer Chapter 23: Draft Outline Environmental Management Plan).

The land resources chapter assesses the following land resources aspects:

- Topography
- Geology
- Acid sulfate soils (ASS)/acid rock
- Naturally occurring asbestos
- Saline, dispersive and reactive soils
- Erosion risk
- Contaminated land
- Agricultural land
- Unexploded ordnance (UXO).

An assessment of land resource aspects identified several adverse impacts to potentially occur as a result of Project activities. These impacts may occur during each Project phase and include:

- A permanent change in landform and topography in catchments influencing their ability to retain and move water
- Loss of natural soil resources including Class A, Class B agricultural land and Important Agricultural Areas (IAAs)
- Unexpected disturbance of ASS
- Introducing weeds which may change physical and chemical properties of soil
- Feral animal impedance
- Increased salinity of the landscape causing water table salting, irrigation water salting and erosion scalding
- Disturbance of contaminated land (soil and groundwater)
- Project activities leading to the generation of new contaminated land (soil and groundwater).

The risk assessment identified changes to landform and topography, loss of soil resources and disturbance of existing contaminated land during the construction phase of the Project to present a medium residual risk.

The mitigation measures detailed in Section 9.8 will sufficiently manage identified potential impacts for land resources as a result of Project activities.

This chapter should be read in conjunction with the following components of the draft EIS:

- Appendix T: Spoil Management Strategy
- Appendix V: EMR Search Certificates and Laboratory Certificates
- Appendix W: Geotechnical Factual Report
- Volume 3: Drawings.

9.2 Scope of chapter

The purpose of this chapter is to provide an assessment of the Project's impact on land resources. This assessment includes an evaluation of the existing environment to identify and assess the risks arising from the disturbance and excavation of land and the disposal of soil. The assessment includes contaminated land, IAAs and soil properties.

The existing environment for the Project was investigated through desktop assessment of publicly available information. Field investigations of soil for salinity, ASS, sodic, dispersive and cracking clay soils, were undertaken to provide input to the assessment.

A quantitative compliance risk assessment was undertaken for soil properties, including agricultural and problematic soils. A qualitative risk assessment of contaminated land was completed. Risks that may be present from a construction or operational perspective have been documented.

Following the identification and assessment of the potential risks and associated impacts arising from the Project, appropriate mitigation measures were developed.

9.3 Terms of Reference requirements

The objectives and scope of the impact assessment are in line with the requirements of the *State Development and Public Works Organisation Act 1971* (Qld) (SDPWO Act) administered by the Coordinator-General. Table 9.1 identifies the key requirements and a reference to where the relevant ToR requirements are addressed within this chapter. Compliance of the EIS against the full ToR is documented in Appendix B: Terms of Reference Compliance Table.

TABLE 9.1: TERMS OF REFERENCE REQUIREMENTS—LAND RESOURCES

Terms of Reference requirements		Where addressed
Site description		
10.4.	Describe and illustrate the topography of the preferred alignment and surrounding area, and highlight any significant features shown on the maps. Include and name all waterways, including watercourses, rivers and creeks. Maps should include a scale, and have contours at suitable increments relevant to the scale, location, potential impacts and type of project, shown with respect to Australian Height Datum (AHD) and drafted to GDA94.	Section 9.6.1.1 and Figure 9.3
10.5.	Describe and illustrate specific information about the proposed Project including the precise location of the preferred alignment in relation to designated area, such as transport corridors, protected areas and areas for regional interest and agricultural land uses identified in the Queensland Agricultural Land Audit. Consideration should also be given to Key Resource Areas (KRAs), petroleum and gas pipelines, explosive magazines (Storage and manufacturing facilities) abandoned mines and mining (exploration and production) tenures	Sections 9.6.5 and 9.6.7.2 Chapter 8: Land use and tenure
10.6.	Where relevant, describe and map in plan and cross-sections the geology and landforms, including catchments, of the Project area. Show geological structures, such as aquifers, faults and economic resources (such as coal, mineral and petroleum resources, agricultural products and KRAs) that could have an influence on, or be influenced by, the Project's activities	Section 9.6.1, Figure 9.4, Figure 9.5 and Figure 9.14 Chapter 8: Land use and tenure Chapter 13: Surface water and hydrology Chapter 14: Groundwater Appendix N: Groundwater Technical Report Appendix W: Geotechnical Factual Report
10.7.	Where relevant, describe, map and illustrate soil types and profiles of the Project area at a scale relevant to the proposed Project. Identify soils that would require particular management due to wetness, erosivity, depth, acidity, salinity, contamination or other relevant features	Sections 9.6.4, 9.6.6 and Figure 9.6 to Figure 9.13 Chapter 13: Surface water and hydrology Appendix L: Surface Water Quality Technical Report
Impact assessment		
11.46.	Undertake a salinity risk assessment in accordance with Part B of the Salinity Management Handbook, Investigating Salinity. In particular, consider how the project will change the hydrology of the project area and provide results of the risk assessment.	Sections 9.6.4.5 and 9.7.5 Figure 9.7 to Figure 9.13 Chapter 13: Surface water and hydrology Appendix L: Surface Water Quality Technical Report
Mitigation measures		
11.48.	Describe appropriate management and mitigation strategies and provide contingency plans for: (d) management of acid sulfate soils and acid producing rock and associated leachate from excavations and disturbed areas.	Section 9.8.2 Chapter 13: Surface water and hydrology Chapter 14: Groundwater Chapter 23: Draft Outline Environmental Management Plan Appendix L: Surface Water Quality Technical Report Appendix N: Groundwater Technical Report
11.51.	Where a salinity risk is identified, detail strategies to manage salinity ensuring the development must be managed so that it does not contribute to the degradation of soil, water and ecological resources or damage infrastructure via expression of salinity. See Part C of the Salinity management handbook second edition, Department of Environment and Resource Management 2011.	Sections 9.6.4.5, 9.7.5 and 9.8.2 Chapter 13: Surface water and hydrology Appendix L: Surface Water Quality Technical Report
11.90.	The assessment of impacts on topography, geology and soils will be in accordance with the Department of Environment and	Sections 9.6.1, 9.6.4, 9.7 and 9.9

Terms of Reference requirements		Where addressed
	Heritage Protection (DEHP) information guideline for an environmental impact statement – Land	
11.91.	Discuss the Project's impacts on Important Agricultural Areas as per the SPP – state interest guideline – Agriculture with reference to Agricultural Land Use & Property Categories under the Queensland Agricultural Land Audit methodology	Sections 9.6.5 and 9.7 Chapter 8: Land use and tenure
11.92.	Identify and investigate areas of salinity, ASS, sodic, dispersive and cracking clay soils and potential and actual areas of ASS. Where potential areas are identified, further investigations (including field surveys) should be undertaken in accordance with accepted industry guidelines and the requirements of the relevant SPP – State interest guideline – Water quality are followed	Section 9.6.4
11.93.	Provide details, including maps, of the location of Project works/infrastructure with respect to soil conservation works (contour banks, waterway discharge point, etc.)	Section 9.6.6.1. Chapter 13: Surface water and hydrology Appendix L: Surface Water Quality Technical Report There are no soil conservation property plans within the EIS investigation corridor
11.94.	Identify activities or operations likely to impact soil conservation property plans approved under the *Soil Conservation Act 1986*	There are no soil conservation property plans within the land resources study area
11.95.	Measures to avoid or mitigate potential impacts of the Project on soil values must be described	Section 9.8.2 Chapter 23: Draft Outline Environmental Management Plan
Land contamination		
11.161.	Detail any known or potential sources of contaminated land within or adjoining the Project area, including the location of any potential contamination identified by landholders. Provide results of searches of the Environmental Management Register (EMR) and/or the Contaminated Land Register (CLR) under the *Environmental Protection Act 1994* for the preferred rail alignment and disturbance areas	Section 9.6.7 Appendix V: EMR Search Certificates and Laboratory Certificates
11.162.	Describe how any proposed land use may result in land potentially becoming contaminated. Provide a description of the nature and extent of contamination at identified site(s)	Sections 9.6.7, 9.7.6 and 9.7.7
11.163.	Describe the proposed management of any contaminated land either previously identified or encountered during construction activities and the potential for contamination from construction, commissioning, operation and decommissioning	Section 9.8.2 Chapter 23: Draft Outline Environmental Management Plan
11.164.	Describe strategies and methods to be used to present, manage or remediate any land contamination resulting from the Project. Including but not limited to the management of any acid generation or management of chemicals and fuels to prevent spills or leaks	Section 9.8.2 Chapter 23: Draft Outline Environmental Management Plan Appendix W: Geotechnical Factual Report
11.165.	Describe how the presence of any known potential UXO will be identified on maps of an appropriate size and scale and assessed within or adjoining the Project area. Describe how any known or potential UXO will be managed	Section 9.6.7.2
11.172	Describe the quantity, and physical and chemical characteristics of waste rock, any attributes that may affect its dispersal in the environment, and its associated risk of causing environmental harm.	The physical and chemical characteristics of geology and soils are addressed in Section 9.6.

9.4 Legislation, policies, standards and guidelines

The land resources assessment was undertaken in accordance with the legislation, policies, standards and guidelines intended to protect and manage land resources as detailed in Table 9.2, which are intended to protect and manage land resources.

Further information on legislation, policy, standard and guidelines relevant to the Project are provided in Chapter 3: Project approvals.

TABLE 9.2: REGULATORY CONTEXT

Legislation, policy or guideline	Relevance to the Project
Commonwealth	
National Environment Protection (Assessment of Site Contamination) Measure 1999 (Cth) (ASC NEPM)	The *Assessment of Site Contamination National Environment Protection Measure* (ASC NEPM) is the national guidance document for the assessment of site contamination in Australia, which aims to establish a nationally consistent approach to assess site contamination to ensure sound environmental management practices are adopted. The desired outcome of ASC NEPM is to protect human health and the environment. Contaminated land in Queensland is expected to be assessed in accordance with the processes and guidance detailed in ASC NEPM. The Project included a Tier 1 desktop assessment of the land resources study area.
Guidelines for Surveying Soil and Land Resources (McKenzie et al., 2008)	The *Guidelines for Surveying Soil and Land Resources* aims to promote the development and implementation of consistent methods for conducting soil and land resource surveys in Australia. The guidelines provide information on how to best undertake field surveys to identify, describe, map and evaluate various soils or land resources. The Project considered the guidelines during the assessment of soil within the land resources study area.
Australian Soil and Land Survey Field Handbook (National Committee on Soil and Terrain, 2009)	The *Australian Soil and Land Survey Field Handbook* provides specific methods and terminology for soil and land surveys. It is widely used throughout Australia to provide one reference set of definitions for the characterisation of landforms, vegetation, land surface, soil and substrate. The Project considered information provided in the handbook during the assessment of soil within the land resources study area.
State	
Environmental Protection Act 1994 (Qld) (EP Act)	The EP Act aims to protect Queensland's environment by legislating activities relevant to land resources including: - Soil testing activities - Contaminated land/soil management processes (including removal and treatment or disposal of contaminated soil) as well as grounds for including land on environmental registers. The Project traverses, or is in proximity to, environmentally relevant activities (ERAs) and EMR-listed properties prescribed under the EP Act.
Environmental Protection Regulation 2019 (Qld)	The Environmental Protection Regulation 2019 regulates activities relevant to land resources including: - A prescribed process for soil testing - Regulatory requirement for activities involving Acid Sulfate Soil (ASS) and acid producing rock - Prescribed management of contaminants and contaminated land.
Soil Conservation Act 1986 (Qld)	The *Soil Conservation Act 1986* governs the conservation of soil resources and the implementation of soil conservation measures by landowners for the mitigation of soil erosion. Under the Act, the Project will need to meet the requirements of the legislation with respect to soil conservation. The Project does not contain approved soil conservation plans (property or project) within the land resources study area.

Legislation, policy or guideline	Relevance to the Project
Soil Conservation Guidelines for Queensland (Department of Science Information Technology and Innovation (DSITI), 2015)	*Soil Conservation Guidelines for Queensland* provide information on soil degradation and practical tools for its prevention from water-based erosion. They also provide tools and techniques to remediate degraded areas. The Project does not contain approved soil conservation plans (property or project) within the land resources study area.
State Planning Policy (SPP) State Interest Guideline, Agriculture (Department of Infrastructure, Local Government and Planning (DILGP), 2016b)	The SPP was established by the Queensland Government to define specific matters of State interest in land use planning and development. Agriculture is identified as a State interest within the SPP. Specifically, the resources on which agriculture depends are protected to support the long-term viability and growth of the agricultural sectors. Audit information has been used to support the identification and mapping of Important Agricultural Areas, and Agricultural Land Class A and Class B, which intersect the land resources study area.
Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines 2014 (Dear et al., 2014)	The *Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines 2014* provide risk-based management measures, with a variety of 'preferred' or 'high risk' strategies that can be used to manage documented ASS. If ASS is disturbed directly or indirectly during Project activities, an ASS Management Plan is required to be prepared. The technical manual was considered during the assessment of soil within the land resources study area.
Salinity Management Handbook, 2nd edition (Department of Environment and Resource Management (DERM) 2011)	The *Salinity Management Handbook* provides a guide to salinity processes, investigating salinity risks within landscapes, and developing integrated management strategies should saline soils be encountered. The technical manual was considered during the assessment of soil within the land resources study area.
Guidelines for Soil Survey along Linear Features (Soil Science Australia, 2015)	The *Guidelines for Soil Survey along Linear Features* addresses soil survey techniques required for linear features, which are generally considered 10–100 m wide, and include rail. The guideline identifies varying scales of soil mapping are required for different stages of a project. The guidelines recommend soil information for an environmental impact statement to require a scale of 1:250,000, while for the construction stage of a project, a scale of 1:5,000 is considered more appropriate. The Project considered the scale of mapping required under the guideline for the assessment of soil within the land resources study area, at the current project stage (i.e. EIS). ARTC has committed to completing detailed soil investigations at a suitable sampling intensity to inform the development of detail design. Subject to land access, the soil sampling will be of an intensity to enable mapping at a 1:10,000 scale (refer Section 9.8.2 and Appendix E: Proponent Commitments).
Environmental Impact Statement Information Guideline—Land (DEHP, 2016a)	The Queensland *Environmental Impact Statement Information Guideline—Land* describes information required to support applications for statutory approvals concerning land related matters for resource projects. The guideline describes the information required for an EIS for land-related aspects of a resource project such as topography, geology and geomorphology and description of soil.
Environmental Impact Statement Information Guideline—Contaminated Land (DEHP, 2016a)	The Queensland EIS *Environmental Impact Statement Information Guideline—Contaminated Land* describes the information required to support an EIS for resources projects, including: ▸ Existing contamination, potential impacts and management measures to be implemented during the Project ▸ The extent to which Project activities would cause soil contamination, and how that would be managed ▸ The risks to human health and the environment posed by existing and potential soil contamination. The guideline also prescribes the information required should ASS be encountered for a resources project.

9.5 Methodology

9.5.1 Data sources

This assessment has been prepared in reference to published datasets and literature, in addition to site-specific geotechnical and soils data collected during investigations undertaken to inform the development of the reference design and draft EIS for the Project.

Other information sources used for the assessment of existing conditions for land resources included:

- *Detailed solid and surface geology* (DNRME, 2017b)
- *Atlas of Australian Soils* (Northcote, 1960–68)
- *Queensland Agricultural Land Audit* (Department of Agriculture, Fisheries and Forestry (DAFF) 2013, updated in 2018 by the Department of Agriculture and Fisheries (DAF) (DAF, 2020))
- Contour mapping (DNRME, 2017a)
- *Australian Soil Resource Information System* (Commonwealth Scientific and Industrial Research Organisation (CSIRO), CSIRO, 2014)
- Australian Government, Department of Defence (DoD) UXO mapping
- Department of Resources (former DNRME) Soil Conservation Plans (under the *Soil Conservation Act 1986* (Qld))
- DES Contaminated Land Register and Environmental Management Register.

An assessment of land resources was undertaken to identify and assess the risks arising from the disturbance and excavation of land and the disposal of soil and spoil. The assessment was conducted in accordance with statutory requirements and guidelines identified for QLD as shown in Table 9.2, which included the *Guidelines for Soil Survey Along Linear Features* (Soil Science Australia, 2015). The guideline recommends a 1:250,000 scale of soil mapping for characterisation of soil for an environmental impact statement.

The development of a reference design is an interactive process and the Project footprint remains subject to confirmation through the detail design process. Soil sampling and analysis at a more intensive scale during the reference design stage was therefore not undertaken.

In acknowledging the preliminary nature of geotechnical and soil investigations undertaken to date, ARTC has committed to completing detailed soil investigations at a suitable sampling intensity to inform the development of detail design. Subject to land access, the soil sampling will be of an intensity to enable mapping at a 1:10,000 scale (refer Section 9.8.2 and Appendix E: Proponent Commitments).

The methodology for the detailed soil investigation will be developed in consultation with the Department of Resources (former DNRME) and will meet the requirements of the: *Guidelines for surveying soil and land resources* (McKenzie et al., 2008); *Australian soil and land survey field handbook* (National Committee on Soil and Terrain, 2009); and, *Guidelines for Soil Survey along Linear Features* (Soil Science Australia, 2015).

Soil investigations will be conducted under the supervision of a suitably qualified soil practitioner.

9.5.2 Geotechnical and soil investigations

Geotechnical, soils and hydrogeological investigations were undertaken within the Project disturbance footprint with the objective of obtaining data to inform development of the reference design and the draft EIS.

The geotechnical and soils components of these investigations included the following:

- 26 seismic refraction surveys
- 14 geotechnical boreholes (which included 1 auger hole and 5 boreholes for soil investigations)
- 13 groundwater monitoring wells.

Fourteen holes were drilled, using a solid stem auger, before being progressed by a rotary drilling (water flush) technique. Soils that rose on the auger were described, and the auger was lifted to the surface at intervals to allow nominally undisturbed (U50) tube sampling and standard penetration testing (SPT) to be undertaken in the uncased borehole. Soil descriptions were based on drill cuttings and recovered samples.

9.5.3 Laboratory testing

The geotechnical investigation undertaken as input to the concept design included drilling 14 boreholes. Five boreholes were targeted for soil investigations with depths between 0.0 m and 1.0 m below ground level (bgl) at varying intervals, dependent on subsurface conditions (refer Figure 9.1). A total of 14 soil samples were analysed from the five soil sampling locations by a National Association of Testing Authorities (NATA)-accredited laboratory. A summary of these results is in Section 9.6.4.1 and Table 9.4.

Soil samples were analysed for the following analytes:

- Sodium adsorption ratio—a measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste
- Cation exchange capacity—the total capacity of a soil to hold exchangeable cations. It influences the soil's ability to hold onto essential nutrients and provides a buffer against soil acidification
- Exchangeable sodium percentage—measure of sodium ions relative to other cations.

The geotechnical analysis included a suite of analytes, including the following, which are relevant to the land resources chapter:

- Moisture content
- Particle size distribution (grading)
- Atterberg Limits and Linear Shrinkage
- Shrink/swell properties
- Emerson Class Number
- Aggressivity Testing Suites.

Borehole logs, core photography and certificates of analysis for geotechnical testing are included in Appendix W: Geotechnical Factual Report. Laboratory results from soil analysis are included in Appendix V: EMR Search Certificates and Laboratory Certificates.

The soil physical and chemical analyses have been used to complement published soil data from previous soil assessments of relevance to the land resources study area, and to verify soil mapping at a 1:250,000 scale. The geotechnical and soil investigation also informed the assessment of existing conditions for problematic soils (saline, dispersive and reactive) and erosion risks. The scope for sampling and analysis included soil properties and not potential contaminants.

The initial geotechnical investigation scope had to be reduced due to land access issues. The development of a reference design is an interactive process and the Project footprint remains subject to confirmation through the detailed design process. Consequently, it was considered to be of limited value to undertake soil sampling and analysis at a more intensive scale during the reference design stage for a Project of this nature. In acknowledging the preliminary nature of geotechnical and soil investigations undertaken to date, detailed geotechnical and soils investigations within the confirmed Project footprint are planned to inform the detailed design process. Soil investigations will be in accordance with the *Guidelines for surveying soil and land resources* McKenzie et al., 2008), the *Australian soil and land survey field handbook* (National Committee on Soil and Terrain, 2009) and the *Guidelines for Soil Survey along Linear Features* (Soil Science Australia, 2015).

9.5.4 Contamination assessment

The land resources assessment included a Tier 1 Preliminary Site Investigation (contaminated land assessment), in accordance with ASC NEPM. A Tier 1 Preliminary Site Investigation was undertaken to identify the potential for contamination within the land resources study area. This type of assessment is used to assess the potential for the land to pose a risk to ecological and human health receptors due to potentially contaminating activities. The assessment of contaminated lands was conducted by a suitably qualified person in accordance with the relevant Department of Environment and Science requirements.

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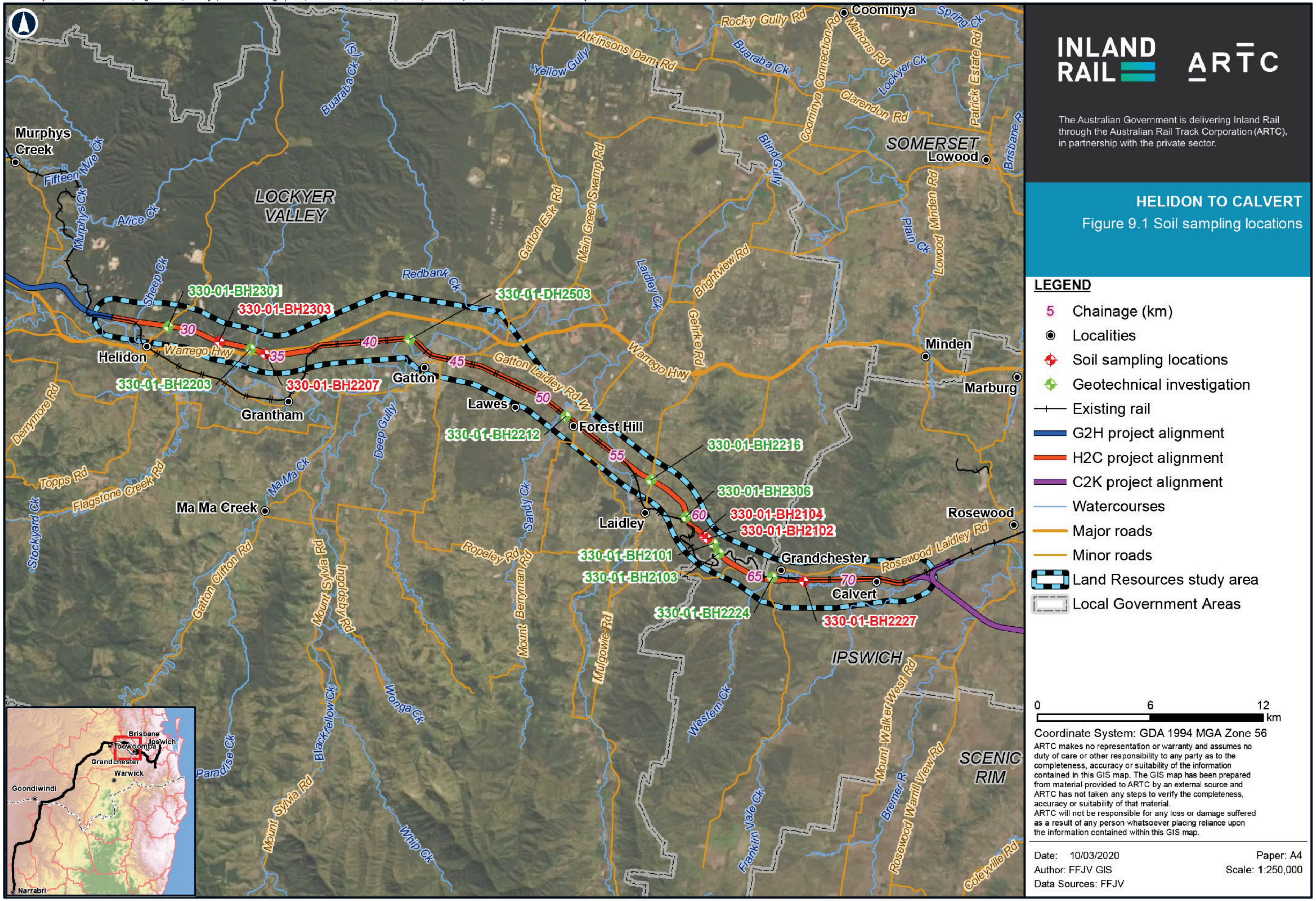

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9.5.5 Land resources study area

The land resources study area in Figure 9.2 extends from Helidon (approximately 15 kilometres (km) east of Toowoomba) after deviating from the existing Queensland Rail (QR) West Moreton System rail corridor and progresses towards Calvert (28 km west of Brisbane). The alignment consists of approximately 47 km single track dual gauge railway with four crossing loops, and an approximately 850 metre (m) tunnel through the Little Liverpool Range. Approximately 50 per cent of the proposed rail corridor runs parallel with the existing West Moreton System rail corridor. Further information related to the Project description is presented in Chapter 6: Project description.

The study area adopted for the land resources impact assessment is the EIS investigation corridor (land resources study area), which consists of an approximately 2 km wide study area. The land resources study area includes the proposed alignment, which encompasses the permanent operational and temporary construction disturbance footprint, and land within an approximately 1 km radius either side of the rail corridor. The land resources study area includes the location of all Project infrastructure, the area that would be directly disturbed by the movement of construction plant and machinery, and the location of the storage areas/compound sites, that would be used for construction support purposes.

The permanent operational and temporary construction disturbance footprints (collectively referred to as the disturbance footprint) include the following:

- Permanent operational disturbance footprint: the rail corridor, which includes the rail tracks and associated infrastructure as well as other permanent works associated with the Project (e.g. where changes to the road network are required)
- Temporary construction disturbance footprint: the permanent operational disturbance footprint and any temporary storage and laydown areas to be used on a temporary basis during the construction phase.

The land resources study area also assessed additional areas (in close proximity to or adjoining properties within the EIS investigation corridor) outside the EIS investigation corridor where intensive industrial activities or other potentially contaminating activities are identified which may pose a risk to the Project. These were assessed for due diligence and to provide context for potential impacts from the Project. Minimal risk from proximal activities was identified during the desktop assessment. Commercially operated quarries are excluded from this assessment as they operate under their own environmental approvals/permits.

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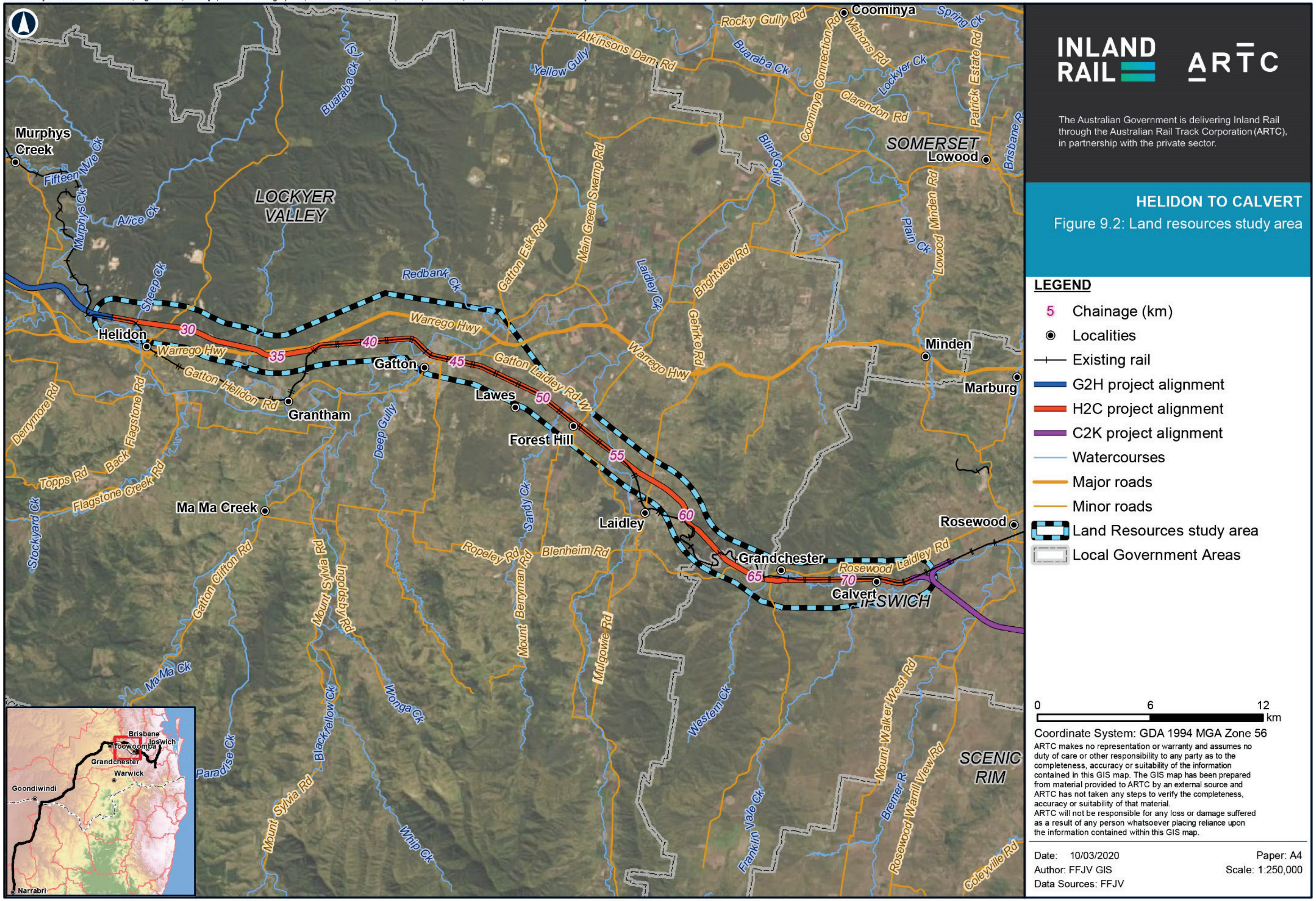

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9.5.6 Impact assessment methodology

Impact assessment was undertaken using both quantitative compliance assessment and qualitative risk assessment methodologies, assessing potential impacts within the land resources study area during construction, operational and decommissioning (as it relates to construction) phases.

A quantitative compliance assessment was undertaken for:

- Soil properties, including:
  - Erosion and sedimentation
  - Problematic soils (i.e. saline, dispersive and reactive soils).

A qualitative risk assessment was undertaken for:

- Contaminated land, including:
  - Existing contaminated land
  - Construction risks (e.g. hydrocarbon spills)
  - Operational risks (e.g. hydrocarbon spills, use of pesticides/herbicides)
- Agricultural, including Soil Conservation Plans
- Geology, topography and geomorphology
- ASS/acid rock
- Naturally occurring asbestos
- UXO.

Chapter 4: Assessment methodology, describes the qualitative and quantitative assessment methodology in further detail. Following an assessment of potential risks for the Project, appropriate mitigation measures were developed.

9.6 Description of existing land resources

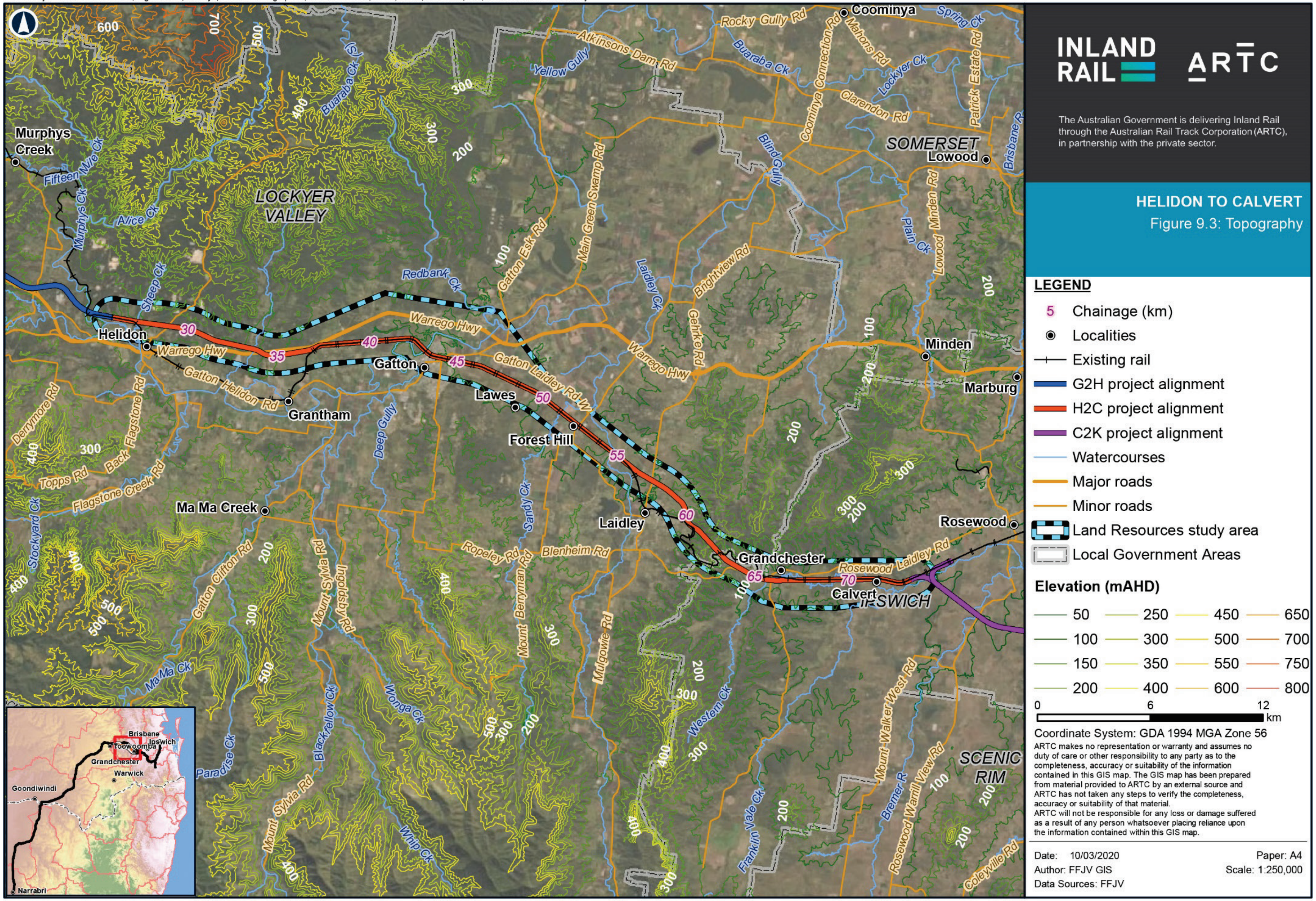
9.6.1 Geological and topographical setting

9.6.1.1 Topographical setting

The land resources study area consists predominantly of flat and flood prone terrain with one distinct area of rugged topography at Little Liverpool Range.

The topography surrounding Helidon features undulating hills with moderate to low elevation as the land resources study area passes through the declining slopes of the Lockyer National Park towards Placid Hills. Between Placid Hills and Laidley, flat terrain at approximately 100 m elevation exists along the alignment, leading to the base of the Little Liverpool Range. The peak elevation of the land resources study area is reached as the alignment climbs Little Liverpool Range to an approximate elevation of 240 m, and then rapidly begins to descend towards Grandchester and Calvert, where the lowest elevation of the land resources study area, at approximately 54 m elevation, is located at Western Creek (refer Figure 9.3).

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



HELIDON TO CALVERT

Figure 9.3: Topography

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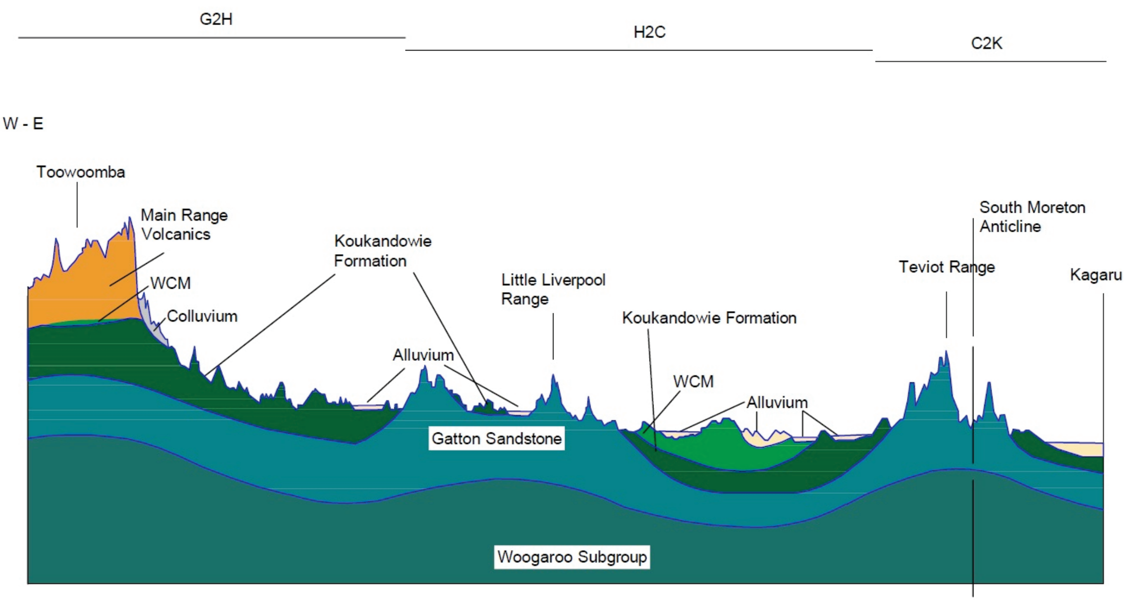
9.6.1.2 Geological setting

The 1:100,000 scale detailed surface and solid geology mapping (DNRME, 2017a) indicates that the disturbance footprint is underlain by eight geological layers, as illustrated in Figure 9.5 and summarised in Table 9.3. A cross-section schematic distribution of the main geological units between Toowoomba and Kagaru is presented in Figure 9.4.

TABLE 9.3: GEOLOGICAL UNITS

Geological unit	Location	Age	Description
QPA-QLD	▸ South of Adare	Pleistocene	A layer of clay, silt, sand and gravel on flood-plain alluvium on high terraces. The dominant rock type within this layer is alluvium.
Koukandowie Formation	▸ West of Laidley to Calvert	Early Jurassic to Middle Jurassic	A layer of lithofeldspathic labile and sub-labile to quartzose sandstone, siltstone, shale, minor coal and ferruginous oolite marker dominated by arenite-mudrock.
TD-QLD over Woogaroo Subgroup	▸ North of Helidon	Tertiary	A layer of duricrusted old land surface containing ferricrete, silcrete and indurated palaeosols at the top of a deep weathering profile on the Woogaroo Subgroup. The dominant rock within the layer is ferricrete.
QA-QLD	▸ Helidon ▸ Gatton to Forest Hill ▸ Grandchester to Calvert	Quaternary	A layer of clay, silt, sand and gravel on a flood-plain dominated by alluvium.
Gatton Sandstone	▸ Helidon ▸ North of Grantham to Gatton ▸ Fringe sections north of Laidley	Early Jurassic	A layer of lithic labile and feldspathic labile sandstone dominated by arenite rock.
QR-QLD	▸ North of Helidon ▸ Ringwood ▸ South of Lawes ▸ Fringe sections north of Laidley ▸ East of Grandchester	Quaternary	A layer of clay, silt, sand, gravel and soil of colluvial and residual deposits dominated by colluvium rock.
Walloon Coal Measures	▸ Calvert	Middle Jurassic	A layer of shale siltstone, sandstone and coal seams dominated by arenite-mudrock.
Woogaroo Subgroup	▸ Helidon to Ringwood	Late Triassic to Early Jurassic	A sub-labile to quartzose sandstone, siltstone and quartz rich granule to cobble composed conglomerate also featuring coal. The dominant rock type within the layer is sedimentary rock.

Source: DNRME, 2017a



Legend: G2H:Gowrie to Helidon; H2C: Helidon to Calvert; C2K: Calvert to Kagaru

FIGURE 9.4: SCHEMATIC DISTRIBUTION OF THE MAIN GEOLOGICAL UNITS BETWEEN TOOWOOMBA AND KAGARU

The geological investigation indicated that the land resources study area is dominated by sandstone geology and predominantly underlain by a Jurassic Marburg Formation with scattered small areas of Quaternary alluvium and colluvium. The Little Liverpool Range tunnel is anticipated to intersect the competent sedimentary bedrock material that is the Koukandowie Formation. The current tunnel drive length is approximately 850 m with a maximum cover of approximately 90 m.

Alluvial and colluvial deposits were the dominant rock type present within the geological layers and can be attributed to recent Tertiary and Quaternary denudation (Willey, 2003). The main form of alluvium deposit in the region was likely caused by prairie soils, black earths and grey clays that have developed on finer-grained sediment. Alluvium deposits in the region will potentially lead to the deposition of sand, silt or silty clay at the base of hillslopes and along floodplains (Department of Science, Information Technology, Innovation and the Arts (DSITIA, 2012).

Arenites are another rock present within the geological layers of the region. Arenites are identified as texturally clean matrix-free or matrix-poor sandstone that allow cement precipitates to form in what were originally empty intergranular pores (UPRM Geology Department, 2012).

Earthworks and truck movements over unpaved surfaces expected to occur during construction (e.g. land clearing and blasting) may result in the disturbance of surface material, which may generate airborne contaminants. Details regarding potential silica impacts feature in Chapter 20: Hazard and risk.

A study of the soil distribution and physical properties indicated that parent material strongly influences soil development in the area.

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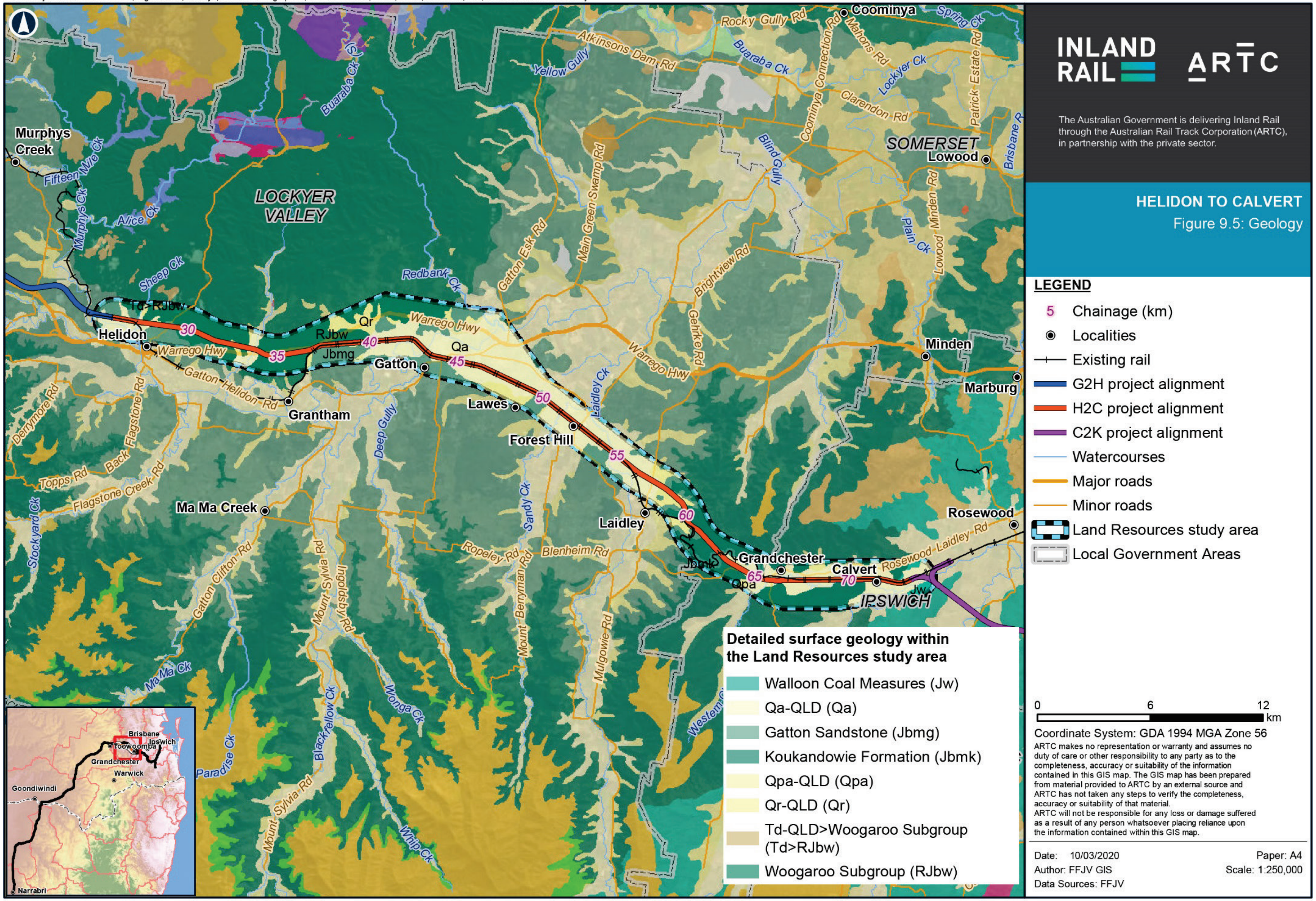

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9.6.1.3 Naturally occurring asbestos

The geotechnical investigation undertaken found no naturally occurring asbestos to be present (refer Appendix W: Geotechnical Factual Report). A review of available geological mapping (DNRME, 2017a) indicated no naturally occurring asbestos within the land resources study area.

9.6.2 Surface water

The land resources study area travels through the Lockyer Creek catchment between Helidon and Laidley and through the Bremer River catchment between Grandchester and Calvert situated within the two local government areas (LGAs) of Lockyer Valley and Ipswich. Both catchments are located within the wider Moreton hydrological basin.

The Bremer River catchment is situated west of Brisbane within the LGAs of Ipswich and Scenic Rim and expands to an area of approximately 2,030 square kilometres (km^2) with the main Bremer River channel surrounded by smaller sub-catchments (DES, 2016a). Rainfall in the catchment is considered higher along its steeper sections, which are situated to the south and east while the remainder of the catchment experiences average rainfall of under 1,000 millimetres per year (mm/yr). The catchment supports a diverse range of land uses including agriculture, grazing and urban areas as well as featuring steep slopes (DES, 2016a).

The Lockyer Creek catchment is located west of Brisbane and east of Toowoomba, within the LGAs of Lockyer Valley, Somerset, Ipswich and Toowoomba. The catchment covers an area of approximately 3,000 km^2 with the main Lockyer Creek surrounded by several sub-catchments (DES, 2015b). The Lockyer Creek catchment experiences high rainfall in the south and parts of the north. The rest of the catchment has moderate to low rainfall. However, due to the steep slopes in the upper reaches of the catchment, many streams can experience high flows despite the relatively low rainfall (DES, 2015b). Dominant land uses within the Lockyer catchment include: native bushland, grazing, intensive agriculture and rural residential. The upper catchment remains mostly forested whereas the mid and lower catchment has been largely cleared.

Assessment of surface water quality identified increased debris, altered water quality and hydrology, increased salinity, increased erosion and sedimentation and an introduction of contaminants as potential impacts from Project activities. Assessment of the flooding regime identified potential impacts generally in areas of agricultural land or local roadways and minor changes in flow velocity to impact the land resources study area.

Further information regarding surface water is included in Chapter 13: Surface water and hydrology as well as Appendix L: Surface Water Technical Report.

Hydrology and flooding information is provided in Appendix M: Hydrology and Flooding Technical Report.

9.6.3 Groundwater

The water table is typically a subdued version of topography, with the depth to groundwater increasing beneath topographic highs and shallower groundwater in lower-lying reaches. The water table occurs in the alluvial sediments of Laidley Creek and Lockyer Creek through much of the central part of the land resources study area, and Western Creek alluvial sediments east of Little Liverpool Range. The Woogaroo Subgroup (west), Gatton Sandstone (central) and Koukandowie Formation (east) will form the water table aquifer where they outcrop along limited sections of the land resources study area. Depths to groundwater in the alluvial sediments were found to be in the range between 5 m and 15 m, with shallow groundwater typically occurring near active watercourses where fill/embankments and/or bridges are proposed. Groundwater levels have been recorded for monitoring bores, installed along the alignment, with a maximum depth to groundwater at approximately 82 m below ground surface level.

Typically, groundwater in the alluvium is fresher than groundwater in the underlying sedimentary bedrock (primarily the Gatton Sandstone in the land resources study area), but spatially and temporally highly variable—ranging from fresh to very saline—in the Lockyer Valley alluvium. The primary controls of the spatial variability are the nature of connectivity of the alluvial aquifer with surface water and the underlying bedrock. It is likely that yields from bores in the alluvium will vary considerably across the land resources study area due to the variable extent and nature of alluvial sediments that can range from coarse gravels to silty clays.

A search of the Department of Resources (former DNRME) groundwater database (accessed online March 2019), identified a total of 510 groundwater bores were within the land resources study area. Two were of unknown status, 124 decommissioned, abandoned or proposed, and the remaining 384 are designated as 'existing'. The number and distribution of bores reflects the heavy utilisation of groundwater in the land resources study area for water supply purposes, particularly from the alluvial aquifers of the Lockyer Valley.

The main potential long-term impacts identified beyond the construction stage are: changes to groundwater levels and flow associated with loading from embankments and ongoing discharge/draining of the Little Liverpool Range tunnel and deep cuts; and management of discharge from dewatering/drainage of the tunnel and deep cuts.

Chapter 14: Groundwater and Appendix N: Groundwater Technical Report, provides further details regarding groundwater and investigation results.

9.6.4 Soil

9.6.4.1 Soil descriptions

Australian soil classification

Australian Soil Classification Level 4 (1:250,000) mapping (CSIRO, 2014) indicated four distinct soil types including vertosols, sodosols, dermosols and chromosols to occur in the land resources study area (refer Figure 9.6).

The low hills of Helidon are underlain by large areas of vertosols and chromosols and remain a regular occurrence as the alignment reaches Laidley and the dense vegetation of the Little Liverpool Range.

Vertosols are identified as a cracking clay soil with a clay field texture and a crusty surface horizon at a depth of 0.03 m or less in thickness (Isbell & National Committee on Soil and Terrain, 2016). Vertosols are often found in imperfectly drained sites with annual rainfall up to 1,150 mm and in well-drained sites with annual rainfall up to 900 mm. As the soil has a strong water holding capacity and high chemical fertility, the soil is considered to have a high agricultural potential (Gray & Murphy, 2002).

Chromosols in the land resources study area, however, have moderate agricultural potential due to moderate chemical fertility, water holding capacity and susceptibility to soil acidification causing structural decline (Gray & Murphy, 2002). The soils are also defined as strong textural contrast soils that are neither strongly acidic nor sodic in the upper B horizon. At imperfectly drained sites, chromosols can be found in areas of annual rainfall between 250 mm and 900 mm, while in well-drained sites, annual rainfall between 350 mm and 1,400 mm is necessary for chromosols to be present.

Minor layers of dermosols, at Helidon and Lawes, and sodosols, nearing Citrus Valley, intercept the major soil types along the land resources study area between Helidon and Laidley.

Dermosols are red, brown, yellow, grey or black and have loam to clay textures with a well-structured B2 horizon containing low levels of free iron. The soils are normally found in areas of imperfectly drained sites with annual rainfall between 550 mm and 1,350 mm and in well-drained sites, having annual rainfall between 450 mm and 1,200 mm. Dermosols generally have a high agricultural potential given their good structure, moderate to high chemical fertility and high water holding capacity (Gray & Murphy, 2002).

Sodosols, however, are predominately found in poorly drained sites with annual rainfall between 50 mm and 1,100 mm. The soil is defined by a clear or abrupt textural B horizon with a major part of the upper 0.2 m of the B horizon being sodic and not strongly acidic (pH > 5.5) (Isbell & National Committee on Soil and Terrain, 2016). The high sodicity of the soil makes it highly erodible with poor structure and low permeability and is often associated with saline soils. As such, sodosols have very low agricultural potential (Gray & Murphy, 2002).

Where the alignment crosses over the Little Liverpool Range towards Grandchester, fringes of dermosols occur on the downhill slopes, breaking up the landscape between the range and Calvert, which is entirely dominated by sodosols.

A comparison of soil pH between soil samples collected during the soil investigation and Australian Soil Classification mapping indicated a good correlation. Soil samples collected east of Helidon and north of Grantham found more acidic soils consistent with chromosol mapping, while alkaline soils were found between Grandchester and Calvert, consistent with sodosol mapping. Soil pH for samples collected between Laidley and Grandchester, however, identified relatively neutral pH soils, despite mapping identifying this area to be underlain by sodosols.

A summary of the soil chemistry investigation results for the land resources study area undertaken during the soil investigation is provided in Table 9.4 and laboratory certificates are provided in Appendix V: EMR Search Certificates and Laboratory Certificates.

TABLE 9.4: SOIL CHEMISTRY INVESTIGATION RESULTS

Soil parameter	Range
pH	5.7 to 8.5
Sodium Adsorption Ratio	3.2 to 31.2
Electrical conductivity (μS/cm)	4 to 383
Exchangeable Calcium (meq/100g)	8.7 to 10.2
Exchangeable Magnesium	8.7 to 9.4
Exchangeable Sodium (meq/100g)	3.5 to 4.4
Exchangeable Sodium (%)	15.6 to 19.6
Cation exchange capacity (meq/100g)	22.7

Table notes:
μs/cm = microsiemens per centimetre.
meq/100g = milliequivalents per 100 grams of soil.
Refer Figure 9.1 for soil sampling locations.

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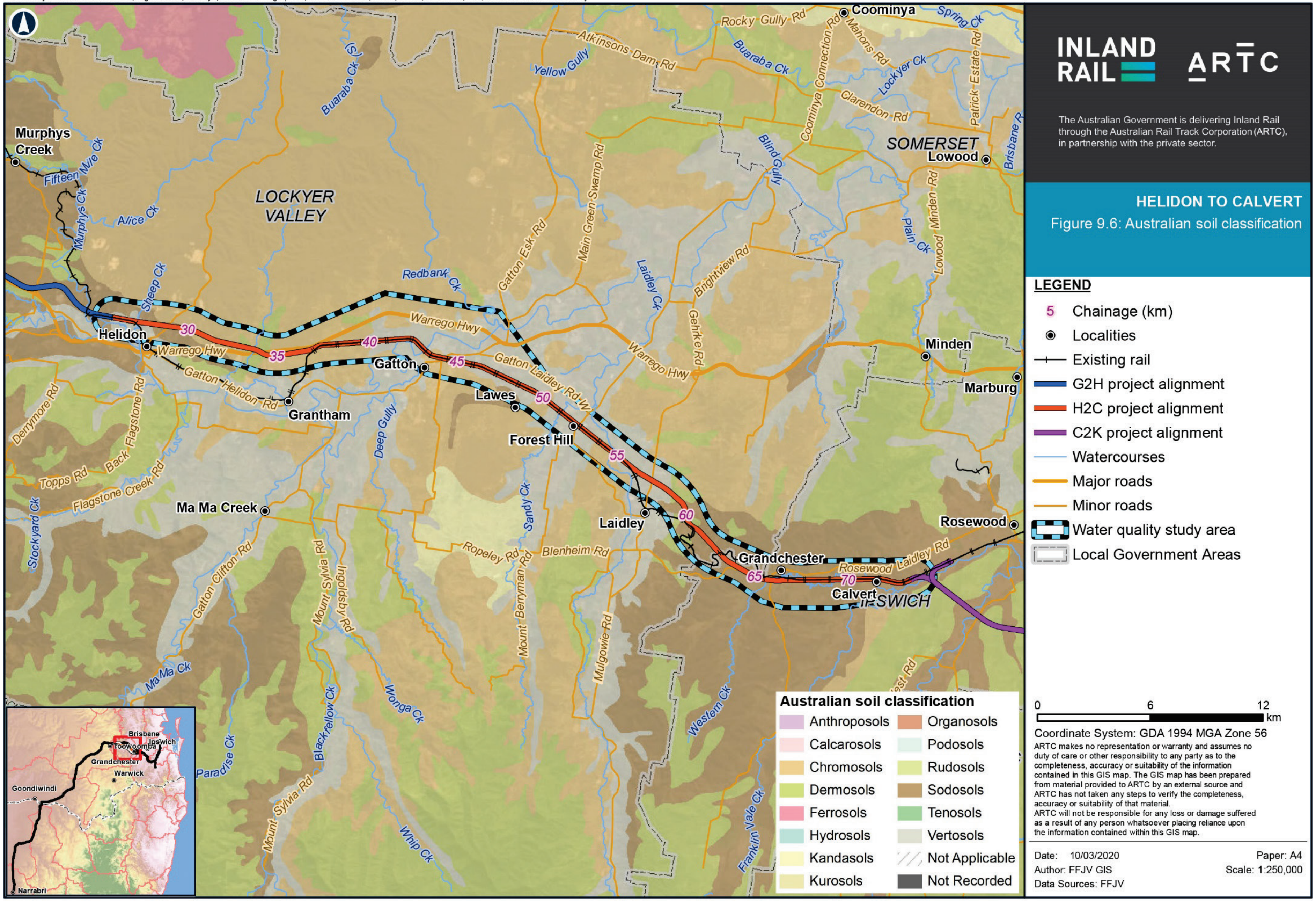

Figure 9.6: Australian soil classification

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Table 9.5 summarises results from 18 samples, analysed as part of the geotechnical suite relevant to land resources between 0.50 m and 3.96 m bgl depth. The results indicate samples where dispersive soils are mapped, such as sodosols, had Emerson class ranges between 2 (high dispersion potential) to 6 (not dispersive).

Soil samples collected from areas mapped as vertosols were generally categorised as high plasticity clays in accordance with the Unified Soil Classification System, while sodosols in general were categorised as high and low plasticity clays.

Shrink-swell properties were evident in two soil samples collected from within the Project disturbance footprint. A sample at 330-01-BH2216, between 3.50 and 3.96m bgl, mapped as vertosols produced an index percentage of 1.5 per cent and a sample at 330-01-BH2306, between 0.50 and 0.95m bgl, produced an index percentage of 3.3 per cent. The laboratory tests indicate the soils are moderate–highly reactive.

Soil pH was also analysed as part of the geotechnical suite, which ranged from 5.8 (moderately acidic) to 9.0 (strongly alkaline), with soil samples collected from areas mapped as sodosols generally having a more alkaline pH (between 6.9 and 8.7). Appendix W: Geotechnical Factual Report provides further details of the geotechnical analysis.

Variations between geotechnical investigation results and mapping could potentially be attributed to the scale of mapping or soil chemistry changing across a landscape due to various factors (e.g. climate, land use). Sampling also only captures a specific point along the land resources study area.

TABLE 9.5: SUMMARY OF GEOTECHNICAL ANALYSIS RELEVANT TO LAND RESOURCES

Sample ID	Depth (m bgl)	Australian Soil Classification (1:250,000)	Unified Soil Classification System	Soil description	Moisture content (%)	Shrink-Swell index (%)	Soluble sulfate (mg/kg)	Chloride (mg/kg)	pH	Emerson class number
330-01-BH2103	0.50 – 0.95	Sodosols	CL	Sandy CLAY	7.3		20	<10	7.7	6
	3.50 – 3.95		CL	Sandy CLAY	13.8		20	<10	8.4	3
330-01-BH2104	0.50 – 0.95	Sodosols	CL	Sandy CLAY	9.3		<10	<10	6.9	6
	3.50 – 3.94		CL	Sandy CLAY	11.6		10	30	8.2	
330-01-BH2203	3.50 – 3.95	Dermosols	SC	Clayey SAND	10.8					
330-01-BH2207	0.50 – 0.95	Dermosols	SC	Clayey SAND	3.9		10	<10	5.8	
330-01-BH2212	0.50 – 0.85	Vertosols	CH	CLAY			130	220	9.0	
	2.00 – 2,45		CH	CLAY	24.6					
330-01-BH2216	2.00 – 2.45	Vertosols	CH	CLAY	34.1		130	2,870	8.8	
	3.50 – 3.96		CH	CLAY		1.5				
330-01-BH2224	3.50 – 3.95	Sodosols	CH	CLAY			<10	10	8.7	
330-01-BH2227	0.50 – 0.95	Sodosols	CH	CLAY			40	320	8.4	
	2.00 – 2.45		CH	CLAY	25.8					
	3.50 – 3.90		CH	CLAY	22.9					
330-01-BH2306	0.50 – 0.95	Sodosols	CH	CLAY	15.0	3.3				2
330-01-DH2503	0.50 – 0.95	Vertosols	CH	Sandy CLAY	23.5					5
	2.00 – 2.45		CL	Sandy CLAY	15.6					3
	3.50 – 3.95		CL	CLAY	22.9		20	<10	7.7	5

Queensland soil survey sites

A further validation of the Australia Soil Classification mapping for the Project disturbance footprint, as shown in Figure 9.6, was undertaken in reference to previous soil survey data held in the Queensland Government's Soil and Land Information (SALI) database (Queensland Government, 2020l). In total, historical data obtained from 33 soil survey sites established for soil mapping and research activity were used to validate the Australia Soil Classification mapping for the Project disturbance footprint. Some soil survey sites within a 100 m buffer of the Project disturbance footprint and within the land resources study area were also included. Locations of the historical survey sites are shown in Figure 9.6.

This assessment was also undertaken to verify the applicability of potential soil limitations, as outlined in relevant the *Moreton Bay Land Management Manual* (Harms & Noble, 1996) (refer Table 9.7), to soils that can be encountered within the Project disturbance footprint.

A summary of the soil classifications and key findings and observations for the historical soil survey data is presented in Table 9.6.

TABLE 9.6: SUMMARY OF HISTORICAL SOIL SURVEY DATA OBTAINED FROM THE SALI DATABASE

Area	Historical soil survey sites (within Project disturbance footprint)	Australian Soil Classification	Soil findings and observations
Helidon	2	N/A	Loose sandy surface; Weak structure throughout horizon
Gatton	2	Vertosols	Periodic cracking; Self-mulching; Carbonate material in subsoils
Lawes	7	N/A	Periodic cracking; Self-mulching; Carbonate material in some subsoils
Forrest Hill	10	Vertosol	Self-mulching; Surface crust; Periodic cracking; Carbonate material in some subsoils
Laidley North	8	N/A	Periodic cracking; Self-mulching
Laidley	4	N/A	Periodic cracking; Surface crusting; Hardsetting; Self-mulching

Source: SALI database (Queensland Government, 2020l)

The historical soil survey data did not provide an Australian Soil Classification for a majority of the 33 soil samples located within the Project disturbance footprint. However, based on soil observations (refer Table 9.6) and historical soil survey sites (based on Great Soil Group Classifications), the soil types within the Project disturbance footprint correlate with Australian Soil Classification mapping.

Areas of Gatton, Lawes, Forest Hill, Laidley North and Laidley all indicate the presence of self-mulching and cracking clays, which are represented by vertosols in accordance with Australia Soil Classification mapping (refer Figure 9.6). Self-mulching clays have a uniform heavy clay texture from the surface to deeper into the soil profile. The surface soil, when dry, is self-mulching, being composed of easily disturbed small aggregates resulting from extensive swelling and shrinking from wetting and drying (Agriculture Victoria, 2017).

The soil survey data also indicated loose, weakly structured sandy soils to exist within the Project disturbance footprint near Helidon, which are typical of tenosols. Tenosols form from highly siliceous parent material and typically have a weak soil profile, which consists predominantly of sand (Gray & Murphy, 2002).

Department of Primary Industries datasets, in addition to ASRIS Australian Soil Classification mapping (CSIRO, 2014), soil mapping from the *Moreton Region Land Management Manual* (Harms & Noble, 1996), mapped at a scale of 1:250,000, has been assessed to understand the potential limitations of the soil types identified within the Project disturbance footprint and summarised in Table 9.7.

The general descriptions of soils within the Project disturbance footprint strongly correlate with the soil types identified from Australian Soil Classification mapping (refer Figure 9.6), data from geotechnical and soil investigation (refer Table 8.4) and with observations from historical soil survey sites (refer Table 9.6).

TABLE 9.7: SUMMARY OF SOIL DESCRIPTIONS AND LIMITATIONS FOR SOILS WITHIN THE PROJECT DISTURBANCE FOOTPRINT

Land resources area[1]	Approximate Project chainage	Broad landform description	General soil description	Potential soil limitations
Fine Textured Alluvial Plains (1b)	- Ch 0.0 km to Ch 2.5 km - Ch 15.5 km to Ch 18.0 km - Ch 20.5 to Ch 25.0 - Ch 25.5 km to Ch 29.0 km - Ch 30.0 km to Ch 33.5 km - Ch 40.0 km to Ch 41.5 km - Ch 42.5 km to Ch 45.0 km - Ch 47.0 km to Ch 48.5 km	Broad alluvial plains	Self-mulching black earths and grey clays.	- Seasonally cracking - Occasional gilgai development - Some soils with calcium carbonate present in subsoils - Some soils sodic at depth - Prone to waterlogging - Hardsetting surface - Prone to erosion (rill, sheet, streambank)
Marburg Forest (7a)	- Ch 2.5 km to Ch 5.0 km - Ch 14.5 km to Ch 15.5 km - Ch 18.0 km to Ch 20.5 km - Ch 25.0 km to Ch 25.5 km - Ch 29.0 km to Ch 30.0 km - Ch 34.0 km to 35.0 km - Ch 35.5 km to Ch 40.0 km - Ch 41.5 km to Ch 42.5 km - Ch 45.0 km Ch 47.0 km	Undulating hills and rises; steep hills and mountains.	Sandy and loamy solodics, soloths, yellow and red podzolics, non-calcic brown soils, lithosols.	- Generally hardsetting - Occasional gilgai development - Some soils strongly acidic (pH 4.5 to 6.5) at surface - Some subsoils strongly sodic and dispersible - Susceptible to erosion (sheet, tunnel and gully) - Some soils with highly saline subsoils
Elidon Forest (7b)	- Ch 5.0 km to Ch 8.0 km - Ch 8.5 to Ch 14.5	Undulating to steep hills.	Red and yellow earths, red, yellow and lateritic podzolics, earthy sands, lithosols.	- Some soils strongly acidic (pH 5.4 to 6.5) - Highly erodible on slopes - Potential to become hardsetting/hard surface
Mixed Alluvial Plains (1c)	- Ch 8.0 to Ch 9.5 km - Ch 33.5 km to Ch 34.0 km - Ch 35.0 km to Ch 35.5 km	Alluvial plains	Coarse structured clays, alluvial soils, solodics, soloths, red-brown and red earths, sands.	- Friable surface clays - Potential hardsetting surface - Prone to erosion (rill, sheet and streambank) - Subsoils potentially strongly alkaline (pH 8.5) or extremely acidic (pH 4.2) - Occasional gilgai development (on alluvial plains) - Some subsoils potentially sodic and dispersible - Subsoils may contain lime

Source: Harms & Noble, 1996

Table note:

1. Land resources area and number correspond to *Moreton Region Land Management Manual* (Harms & Noble, 1996) mapping.

9.6.4.2 Soil acidity

Queensland has more than 500,000 hectares of agricultural and pastoral land that has acidified or is at risk of acidification. Soils most at risk are lighter-textured sands and loams with low organic matter levels, and the naturally acidic red clay loam soils. Soils least at risk are the neutral to alkaline clay soils typically associated with brigalow soils and black clay soils (Soil Quality, 2020).

Many soils are naturally acidic, but agricultural practices have contributed to the increasing acidification of many neutral to slightly acid soils (Agriculture Victoria, 2017). These practices include:

- Use of some ammonium fertilisers, particularly ammonium sulfate
- Production of legumes that fix nitrogen, if that nitrogen is leached, rather than being taken up by plants
- Removal of nutrients in the form of produce.

An assessment of surface soil pH, using *Australian Soil Resource Information System* mapping (CSIRO, 2014) indicated the soil acidity of the land resources study area ranges between 4.8 and 6.5 pH. Areas of soil acidity of 4.8 to 5.5 pH dominate the underlaying surface at Helidon and Placid Hills, as well as the downhill slopes of the Little Liverpool Range.

Moderately acidic 5.5 to 6.0 pH soils feature at Gatton, Forest Hill and Laidley while three scattered patches of slightly acidic to neutral soils between 6.0 and 6.5 pH are located around Citrus Valley, Lawes and the downhill slopes of the range. The only patch of strongly acidic 3.0 to 4.8 pH soil was found to underlie the alignment from Grandchester to Calvert.

The laboratory analysis of 14 surface soil samples (<1.0 m bgl) in Table 9.4 indicates soil pH ranged between 5.7 (moderately acidic) to 8.5 (moderately alkaline), with samples collected from various Australia Soil Classification soil types. The geotechnical analysis of deeper soils (0.50 m to 3.96 m bgl) indicated soil pH ranged from 5.8 (moderately acidic) to 9.0 (strongly alkaline). The soil pH from the investigation generally correlates with the identified soil types from Australian Soil Classification mapping and ASRIS soil pH mapping.

9.6.4.3 Acid sulfate soils and acid rock

ASS are predominantly a coastal and near-coastal soil, sediment or other material containing iron sulphides, which generate acidic conditions when exposed to oxygen. ASS, in general, have a field pH of 4 or less and can be visually identified through the presence of jarosite or iron oxide in the soil horizon. They are often associated with low-lying areas below 5 metres Australian Height Datum (mAHD), such as alluvial plains where groundwater is generally close to the surface and materials are in reducing condition along coastal regions. ASS in non-coastal areas are commonly known as inland ASS (DSITIA, 2014).

In Queensland, inland ASS can also be found in parts of central Queensland at elevations above 5 mAHD if an anoxic, aqueous environment that consists of sulfate-reducing bacteria and available sulfate ions exist (DSITIA, 2014; EPHC and NRMMC, 2011). Inland ASS is generally associated with poorly drained inland basins with stagnant water bodies in distinctly seasonal, arid climates, but are not widely distributed in Queensland. However, inland ASS are known to occur in landscapes with high levels of salt, where significant concentrations of sulfate reside.

Acid rock occurs naturally when sulfide minerals are exposed to air and water and accelerated through excavation activities, which increase rock exposure to air, water and microorganisms.

An assessment of ASS using the *Atlas of Australian Acid Sulphate Soils* (Fitzpatrick et al., 2011) indicated 'no known occurrence' between Helidon and Gatton, a small section between Forest Hill and Laidley and again at Calvert. A 'low probability' of ASS underlies the southern area of the land resources study area between Gatton and Forest Hill and the complete extent of the land resources study area between Laidley and Grandchester, with a small patch at Calvert. Two shallow water bodies of 'high probability' ASS intercept the alignment north-east of Placid Hills and again on the southern border of the land resources study area south of Lawes (refer Figure 9.7).

The probability of encountering ASS and associated leachate is generally considered low for the land resources study area as mapped by the *Atlas of Australian Sulfate Soils* (CSIRO, 2014).

Based on the surface geology traversed by the Project alignment, sedimentary units such as the Woogaroo Subgroup and Koukandowie Formation, where earthworks cuts and the tunnel are proposed, may host disseminated sulfide minerals (i.e. pyrite), particularly within shale and mudstone units.

The geotechnical and soil investigation, which included site walkovers and geotechnical sampling, did not identify the presence of ASS or acid rock, within the land resources study area. .

In the unlikely event ASS or acid rock are present during the construction phase of the Project, an unexpected finds protocol/procedure will be implemented (refer Section 9.8).

9.6.4.4 Soil texture

Soil texture provides a guide to the proportions of gravel, coarse sand, fine sand, silt and clay in the soil. Texture is important because it affects the movement and availability of water and nutrients in the soil (Agriculture Victoria, 2017). Soil particles are grouped into five main size ranges: gravel, coarse sand, fine sand, silt and clay. A soil with a relatively even mix of particle sizes is called a loam.

Soil texture along the land resources study area was assessed using CSIRO (2014) textural clay content mapping. Mapping indicated a range of soil textures exist within the A horizon along the land resources study area from light clays (35 to 45 per cent clay composition) to sandy loam (10 to 20 per cent clay composition).

Light clay is the dominant texture of soil in the land resources study area featuring heavily within the soils of Helidon, Gatton, Forest Hill and Laidley. A small layer of reduced clay content soil, silty or sandy clay loam (20 to 30 per cent clay composition), occurs along the land resources study area between Helidon and Placid Hills, and Gatton and Forest Hill as well as featuring heavily beyond the Little Liverpool Range approaching Calvert.

Sand dominant soil textures, such as sandy loam (10 to 20 per cent clay composition), feature heavily in the northern portion of the land resources study area surrounding Ringwood and south Adare, as well as a small area through Grandchester and north of Calvert.

Data obtained from the Land Management Manual and historical soil surveys (SALI database) identified that the majority of the soils within the Project disturbance footprint demonstrate one, or more, of characteristics of hardsetting surfaces, self-mulching, periodic cracking, alkaline/acidic subsoils and potential areas of gilgai development (refer Table 9.6 and Table 9.7).

Areas of hardsetting surfaces, cracking, self-mulching clays with potential gilgai development are typically associated with areas of vertosol, around Helidon, Gatton, Forest Hill and Laidley. Areas of alkaline, sodic/saline subsoil and erosion prone soils are typically associated with areas of sodosols, around Helidon, Lawes and east of Laidley to Calvert.

Despite *Moreton Region Land Management Manual* (Harms & Noble, 1996) identifying potential gilgai development for the soils in the region, Queensland soil survey sites as well as the geotechnical and soil investigation did not identify gilgai development within the Project disturbance footprint. Gilgai are repeated mounds and depression that form on shrink-swell and cracking clay soils (or vertosols) (Queensland Government, 2020l).

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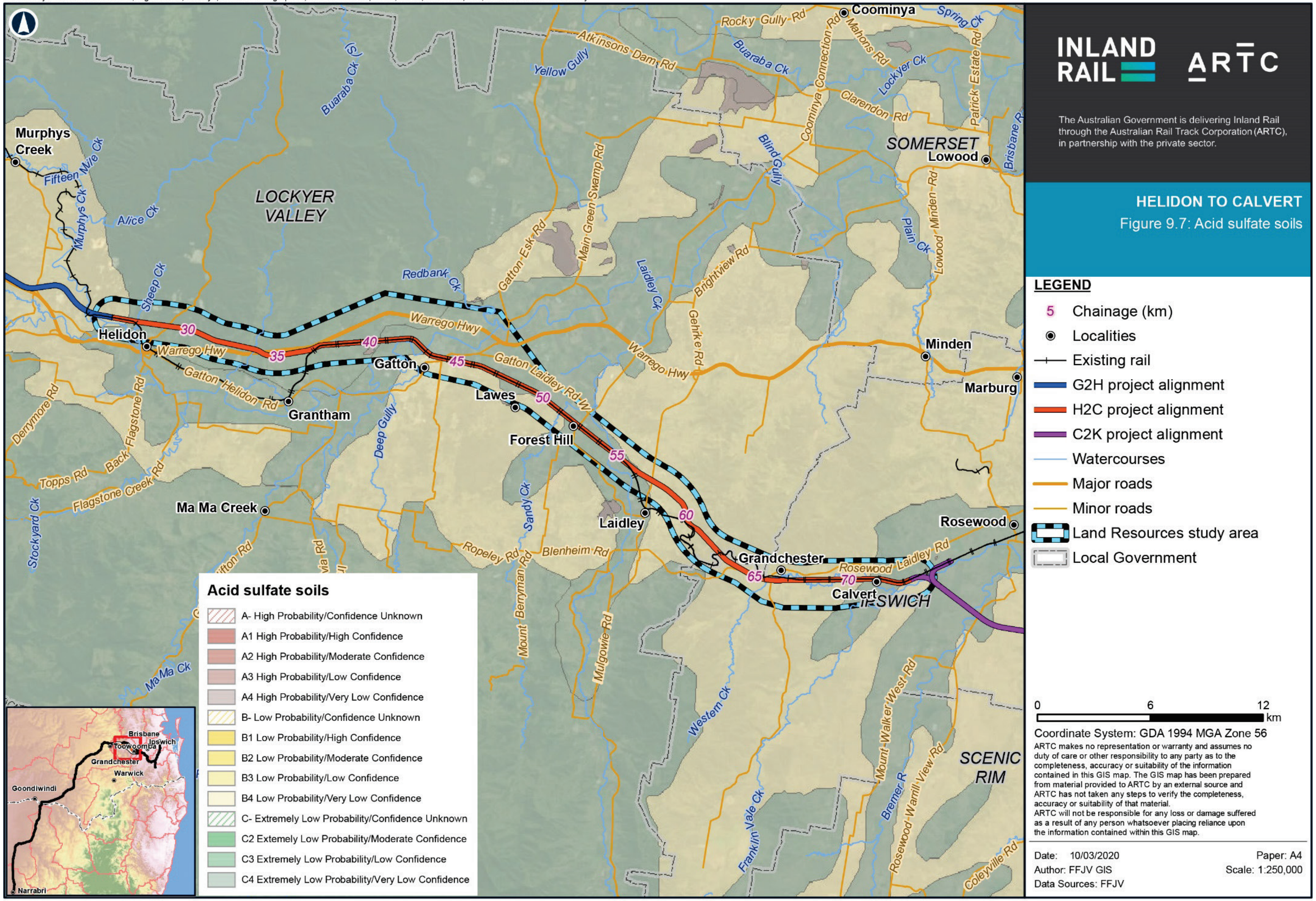

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9.6.4.5 Soil salinity

Salinity is the amount of salt in the soil or water. The dominant salt in most saline soil is sodium chloride (NaCl), although varying amounts of calcium, magnesium and potassium chlorides and sodium sulfates can also occur. There are two main types of salinity:

- Primary—naturally occurring salinity
- Secondary—resulting from human activities.

A salinity study directly applicable to the Lockyer Valley (Shaw, 2008), which identified the present and future emerging pressures to the area through salinity as:

- Developments on Winwill formation
- Increased rainfall
- Construction of dams on catchments
- Overgrazing
- Roads across valley areas
- Non-sewered subdivisions where hydraulic loadings exceed the capacity of the landscape to cope with additional water
- Vegetation management practices which increase recharge to groundwater
- Sedimentation of creeks and drainage lines.

Despite the study area adopted by Shaw (2008) only partially including the land resources study area, between Gatton and Grandchester, two small areas of known water table salinity were identified within the land resources study area near Laidley North.

The study concluded 50 per cent of sites were classed as having high or very high risk of salinity based on future emerging pressures to the region. Many sites assessed during the study where salinity was found to be a risk were associated with confluence of streams as the cause of salinisation. Forms of built infrastructure including roads and bridges were not presently affected by salinity; however, future emerging pressures may impact on future infrastructure in the region, if salinity is allowed to develop without remedial action or control of pressures.

Salinity hazard assessment

A targeted salinity hazard assessment was undertaken for the land resources study area to understand the existing primary salinity within the landscape, as well as potential for secondary salinity formation as a result of Project activities.

Primary salinity is the presence of salts within a landscape where salts are stored within the geology or soils and moved by the water that flows through a catchment area. Each catchment has a different level of stored salts, and how each landscape is managed, will depend on how severe the salinity may be. Predicting areas at risk from salinity is a complex exercise, which requires both determining the inherent salinity hazard in a landscape, and the effects of past, present and future land management practices.

A desktop salinity hazard assessment was conducted adopting the assessment methodology described in *Strategic Salinity Risk Assessment for the Condamine Catchment* (Searle et al., 2007) to meet the requirements of Part B of the *Salinity Management Handbook*.

The approach adopted for the Project analysed data that relates salinity risk to biophysical hazard, which consists of landscape processes and land systems. The factors considered relevant to understand the biophysical hazard to the Project's surrounding landscape and land systems included soil salt store, basalt contact potential expression areas (PEA), catena PEA, artificial restriction PEA and confluence of streams PEA. PEAs are locations where salinity has the potential to be expressed, either through natural or anthropogenic processes.

The land resources study area was broken down by the Australian Hydrologic Geospatial Fabric Catchment GIS layer, into smaller sub-catchments to enable a more precise analysis of the alignment. Particular consideration was given to how Project construction activities may alter the hydrology of the land resources study area.

The Salinity Management Handbook (DERM, 2011) describes several models that provide an excellent conceptual basis for describing different landscapes and different forms of salinity. These models provide and aid both the prediction of where salinity may occur, and the description of possible contributing factors. However, they do not provide a definitive answer to the cause of all salt outbreaks, and for conclusive proof, detailed site investigations will always be required.

Further detail on mobility of salinity in the catchment is described in Chapter 13: Surface water and Hydrology, Chapter 14: Groundwater, Appendix L: Surface Water Technical Report and Appendix N: Groundwater Technical Report.

Inherent soil salt store

Each sub-catchment through that the Project disturbance footprint traverses was overlain with Australian Soil Classification mapping (CSIRO, 2014) verified by Land Management Manuals, data from Project geotechnical and soil investigation and with observations from historical soil surveys (refer Section 9.6.4.1) to derive the dominant soil type in each sub-catchment.

Inherent salt store ratings were adopted from Searle et al. (2007) and applied to the salinity hazard assessment to give a low, moderate, or high rating to each dominant soil type which is further detailed in Table 9.8 and illustrated in Figure 9.8.

TABLE 9.8: INHERENT SALT STORE OF SOILS

Soil type	Soil salt store rating
Black Dermosol	Low
Black Vertosol	Moderate
Grey Vertosol	High
Chromosol	High
Brown Sodosol	Moderate

Source: Searle et al., 2007

Potential expression area: basalt and sandstone contact

The underlying geology of the land resources study area consists of potential expression area of basalt and sandstone contact. Basalt and sandstone PEA result in salts being transported through underlying basalt layers towards surface soils in an area of basalt and sandstone contact (Department of Natural Resources (DNR), 1997). Salinity in a basalt layer forms when both recent and highly weathered layers overlay a less permeable sandstone and mudstone layer at fairly shallow depths. Seepage and the visible expression of salt occurs at the contact point between the two rock types.

The percentage of basalt and sandstone contact PEA for each sub-catchment within the land resources study area was calculated and is shown in Figure 9.9 with further detail provided in Table 9.9. When analysing the risk of basalt and sandstone contact PEAs within the sub-catchments, a none to high hazard category rating can be applied based on the percentage of occurrence.

Calculation of basalt and sandstone contact was based on an analysis of the 25 m digital elevation model developed for the Project. Three derivatives were used: tangential curvature, relative elevation (kernel size 90) and slope percentage. These derivatives were calculated using ArcGIS Spatial Analyst functions.

The analysis was only applied to the Main Range Volcanics, Walloon Coal Measures, Koukandowie Formation, and the Gatton Sandstone landscapes, which were identified as the main geological types where salinity may be a potential issue. The basalt and sandstone contact PEAs are predicted to be where the following occurs (Searle et al., 2007):

- Tangential curvature is less than 0 (i.e. the downhill slope shape is concave—flow tends to slow and converge)
- Relative elevation is greater than 2 (i.e. there is typically a distinct break of slope)
- Slope is greater than 1 per cent and less than 10 per cent (i.e. typically mid slope positions).

TABLE 9.9: POTENTIAL EXPRESSION AREA: BASALT AND SANDSTONE CONTACT

Percentage of each sub-catchment containing basalt and sandstone contact PEA (%)	Hazard category
0	None
0–2	Low
2–5	Moderate
Greater than 5	High

Source: Searle et al., 2007

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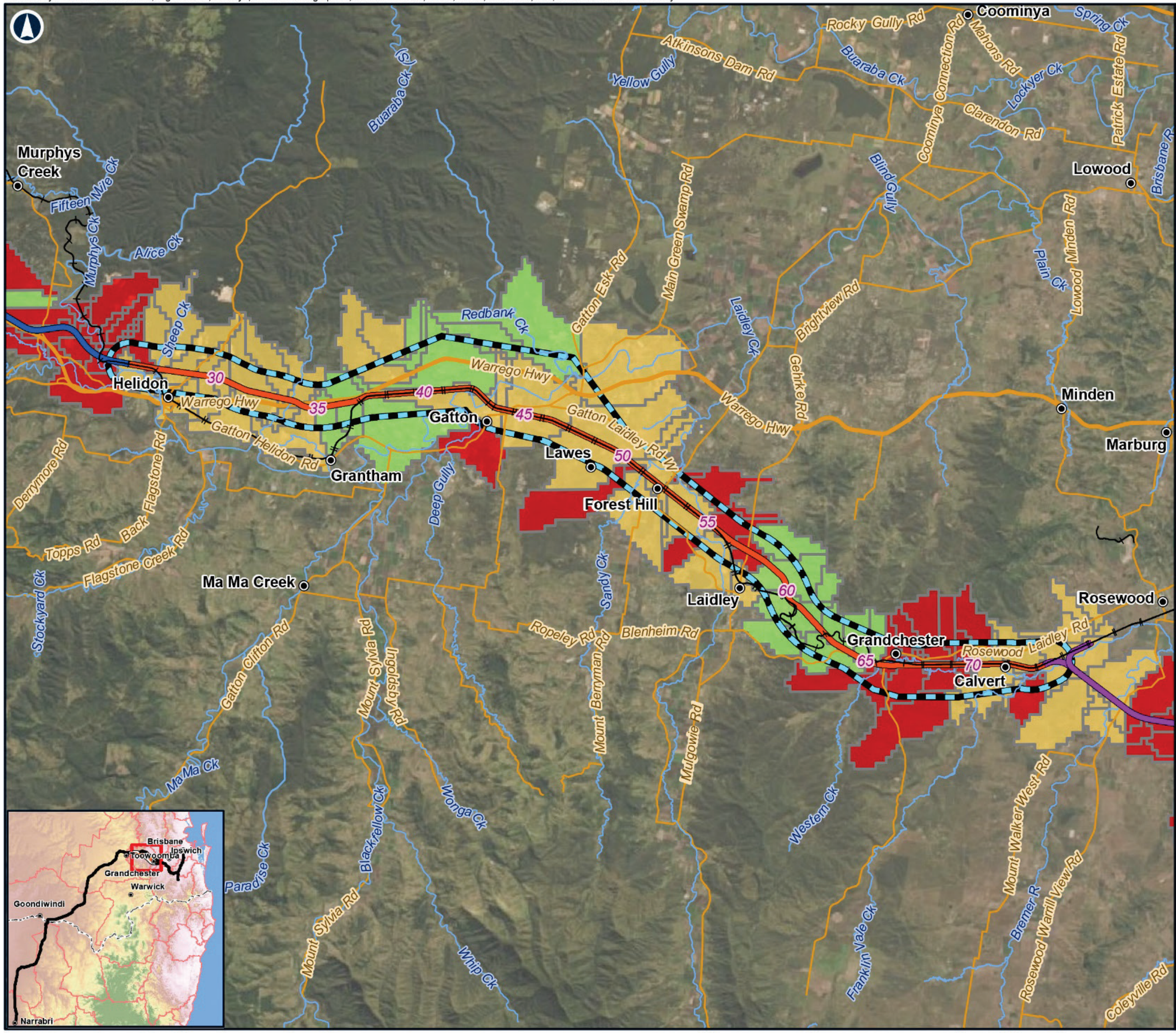

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HELIDON TO CALVERT

Figure 9.8: Inherent salt store

LEGEND

- 5 Chainage (km)
- Localities
- Existing rail
- G2H project alignment
- H2C project alignment
- C2K project alignment
- Watercourses
- Major roads
- Minor roads
- Land Resources study area
- Sub-catchment boundary

Soil salt store by catchment

- High (Sodosol, rudosol)
- Medium (Vertosol, kurosol)
- Low (Tenosol, ferrosol, chromosol, dermosol)

0 6 12 km

Coordinate System: GDA 1994 MGA Zone 56

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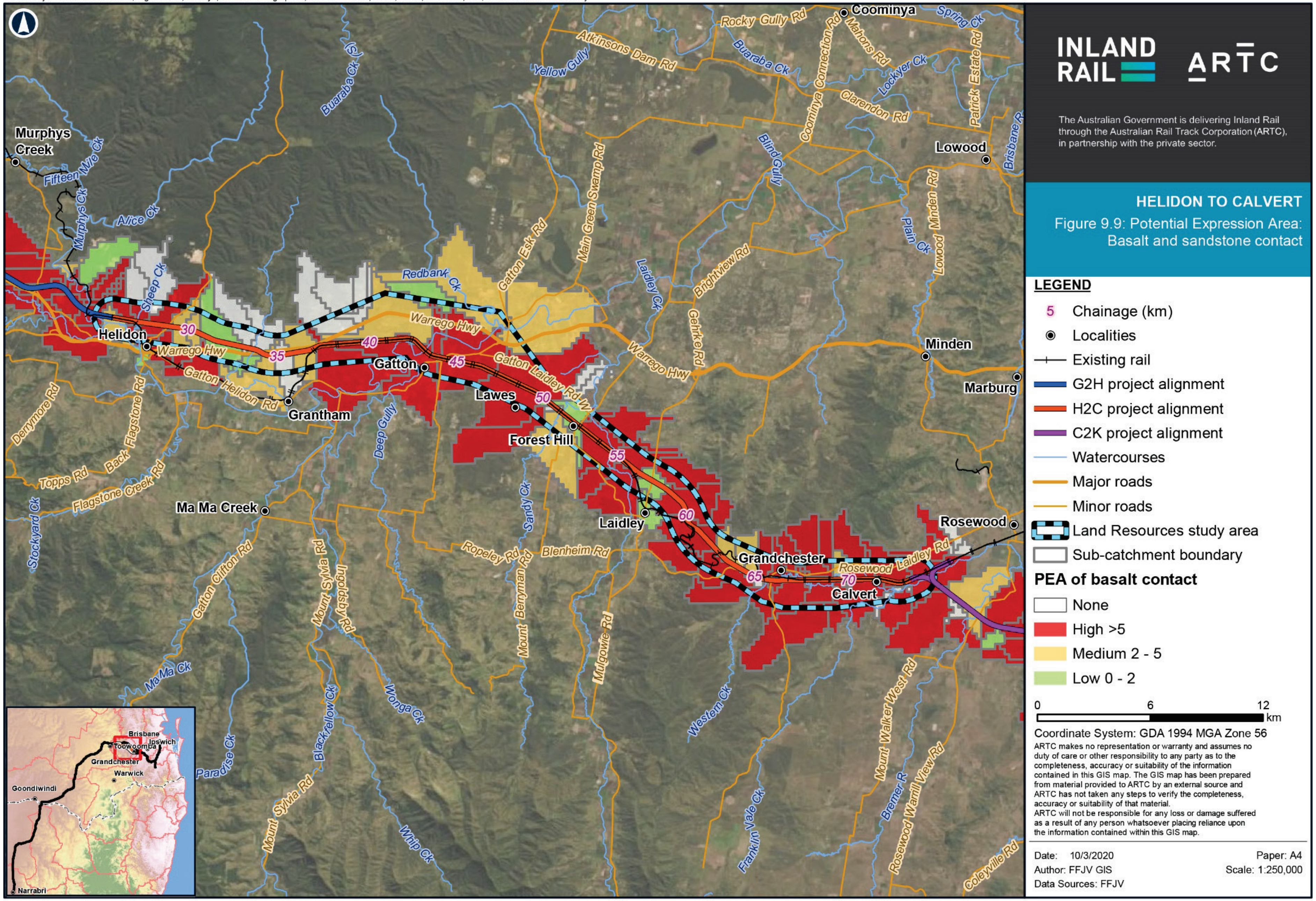

HELIDON TO CALVERT
Figure 9.9: Potential Expression Area: Basalt and sandstone contact

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Potential expression area: catena form

The land resources study area also features potential expression areas of catena form. Catena form occurs when shallow soils located upslope overlie weathered parent material which then extend out into flat heavy clay alluvial areas. These alluvial areas are characterised by high sodicity due to restricted permeability and result in the formation of salt as well as changing soil properties and water movement (DNR, 1997).

The percentage of catena form PEA for each sub-catchment within the land resources study area was calculated and is shown in Figure 9.10. Calculation of catena form was based on an analysis of the 20 m digital elevation model developed for the Project. Two digital elevation models' derivatives were used in this analysis being slope percent and a Multi Resolution Valley Bottom Floor index (Gallant and Dowling, 2003). The Multi Resolution Valley Bottom Floor index identifies areas that are both relatively flat and low in the landscape at different scales, which is interpreted as a map of valley bottom areas. This index is used to separate upland terrain dominated by erosional processes from lowland depositional terrain (Searle et al., 2007).

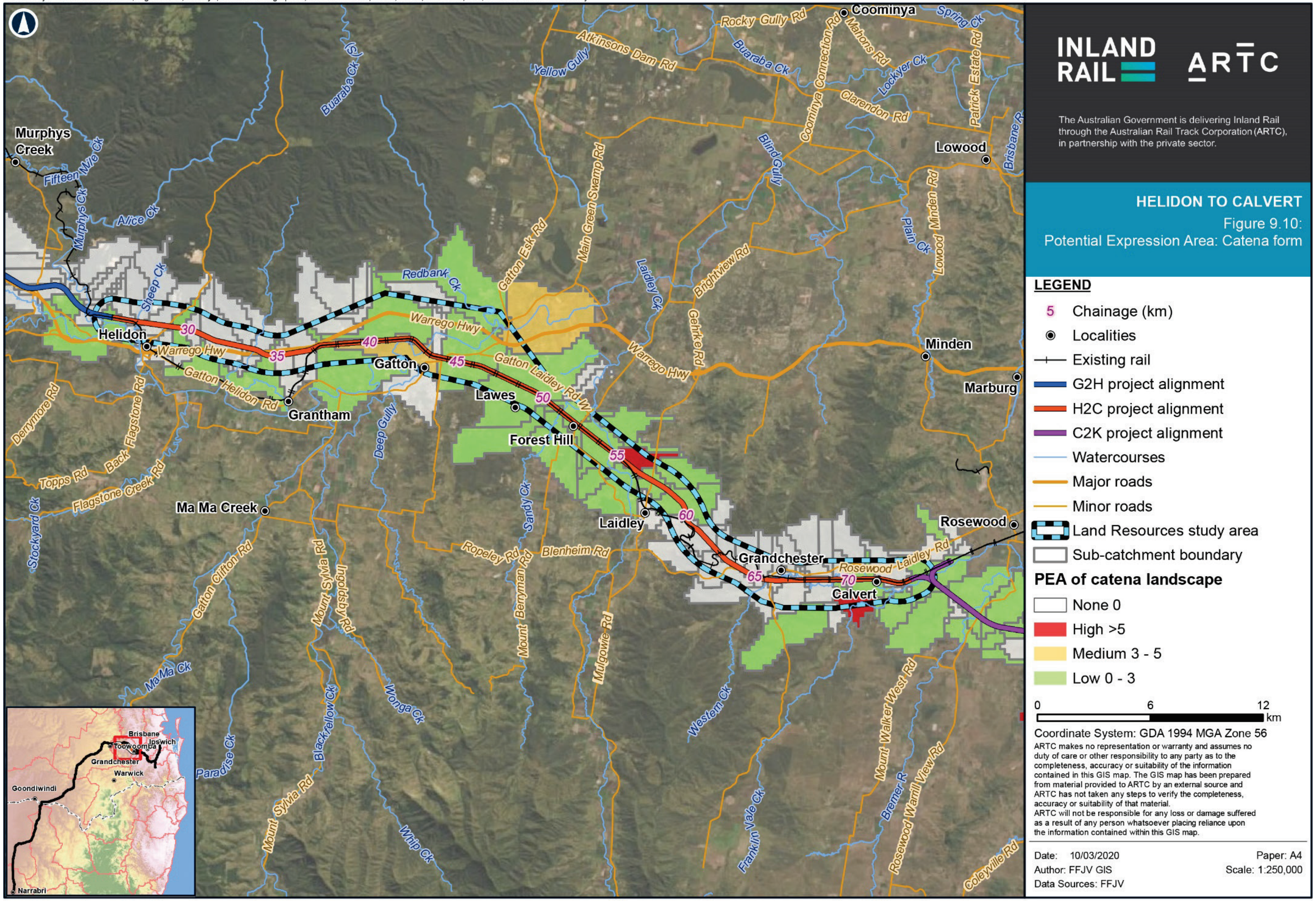
The analysis was only applied to the Main Range Volcanics, Walloon Coal Measures, Koukandowie Formation, and the Gatton Sandstone as these are the areas most susceptible to catena form salinity. When analysing the risk of the Catena landform within the sub-catchments a none to high-hazard category rating was applied as shown in Table 9.10.

TABLE 9.10: POTENTIAL EXPRESSION AREA: CATENA FORM

Percentage area of sub-catchments containing catena PEA (%)	Hazard category
0	None
1–3	Low
4–5	Moderate
Greater than 5	High

Source: Searle et al., 2007

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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Potential expression area: artificial restriction (roads)

The placement of roads within a landscape can restrict water flow as well as impede the soils ability to transmit water, leading to the uprising of groundwater with dissolved salts and waterlogging. This form of salinity is often associated with hillslopes consisting of textural contrast soils or shallow, sandy soils within drainage lines (Searle et al., 2007).

A 25 m digital elevation model was used with two derivatives to derive where the construction of roads in the landscape could potentially create salinity.

The two derivatives are (Searle et al., 2007):

- Compound Topographic Index. The Compound Topographic Index delineates those areas in a landscape that have high contributing area and relatively low slopes. In a general sense, these would tend to be the wetter areas within a landscape
- Slope (per cent).

The digital elevation model was generalised to 200 m for the slope calculations and 1,000 m for the Compound Topographic Index calculations. The analysis selected the areas that are generally low slope and where there is a general convergence of flow, low in the landscape. These areas are predicted to occur where:

- Slope is greater than 1 per cent
- Compound Topographic Index is greater than 2.

Figure 9.11 presents the potential risk of salinity development as a result of road placements. The hazard categories of the artificial restrictions were given a low to high rating, and these ratings are presented in Table 9.11.

TABLE 9.11: POTENTIAL EXPRESSION AREA: ARTIFICIAL RESTRICTION (ROADS)

Number of road PEA within sub-catchments	Hazard category
0	None
1–50	Low
51–100	Moderate
>100	High

Source: Searle et al., 2007

Potential expression area: confluence of streams

The confluence of streams form of salinity relates to where a major stream intersects with a minor stream. This intersection can create a reduction in flow velocity and a resultant deposition of the suspended particles at the junction including a precipitation of salts (Searle et al., 2007).

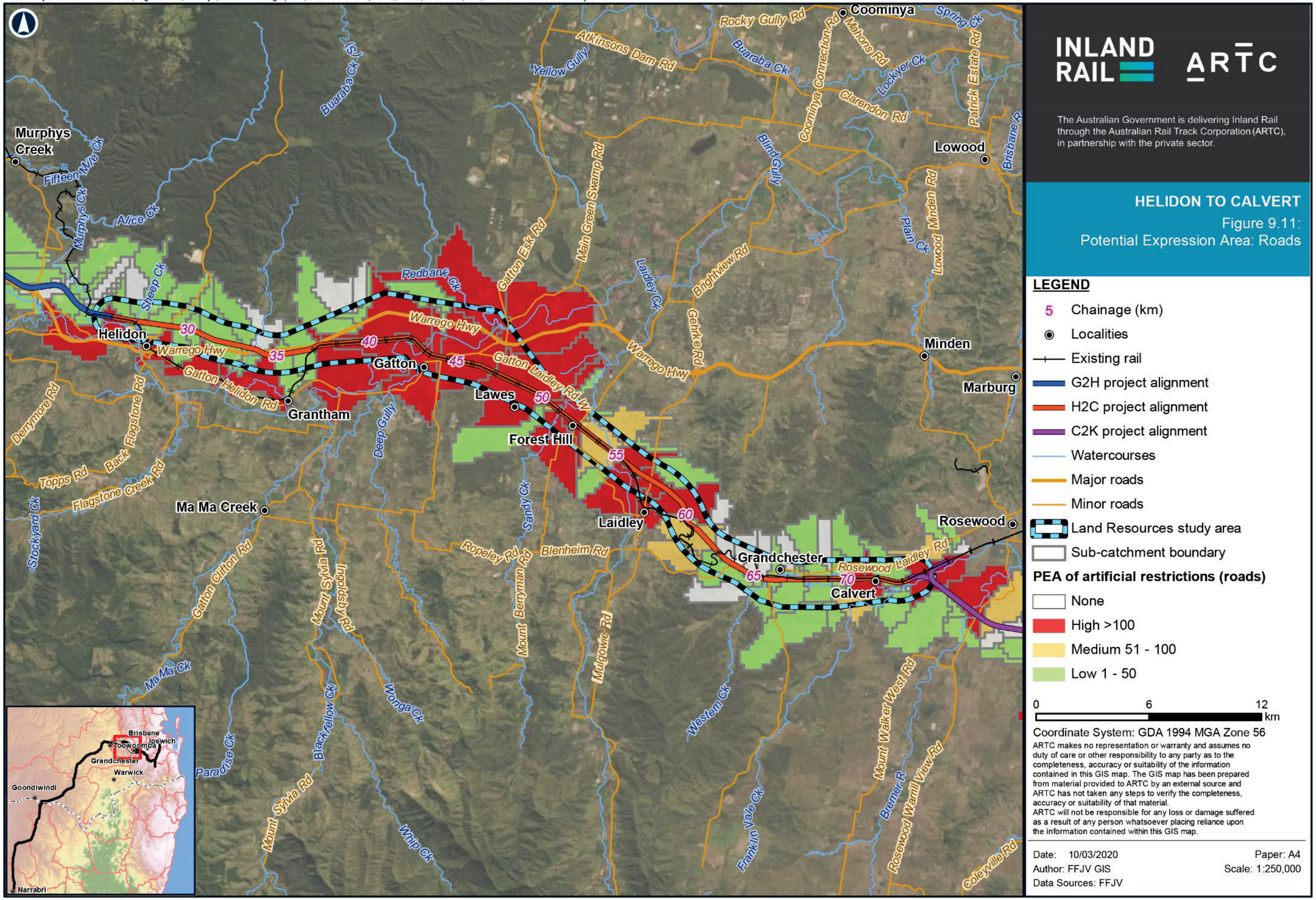
Confluence of streams were identified through manual interpretation of the Australian Hydrological Geospatial Fabric mapped streams layer (Australian Government, 2015), where watercourses intersected. The number of watercourse intersections were identified within a sub-catchment. When analysing the risk of PEAs due to the confluence of streams within the sub-catchment, a none to high hazard category rating can be applied, as shown in Table 9.12 and illustrated in Figure 9.12.

TABLE 9.12: POTENTIAL EXPRESSION AREA: CONFLUENCE OF STREAMS

Percentage of each sub-catchment containing confluence of streams (%)	Hazard category
0	None
1–3	Low
4–5	Moderate
Greater than 5	High

Source Searle et al., 2007

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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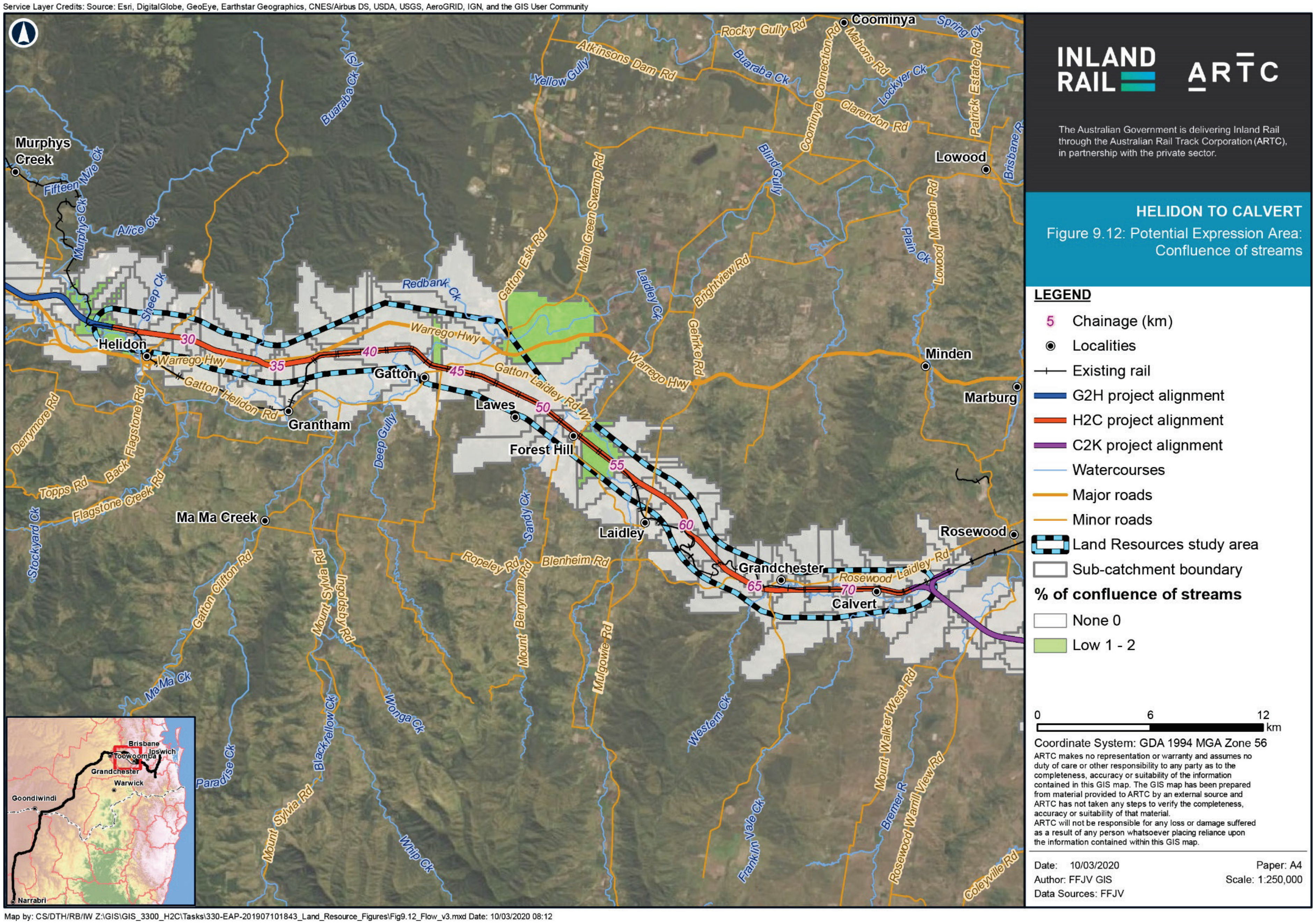

Figure 9.12: Potential Expression Area: Confluence of streams

Electrical conductivity

Electrical conductivity (EC) is a measurement of how well a medium can conduct an electrical current (in uS/cm). Salinity is an estimate of salt in the soil, derived from EC. Typically, the higher the EC the higher the salinity within soil.

Salinity hazard within the land resources study area was also assessed using the CSIRO (2014) EC mapping layer and EC results from the soil investigation undertaken.

EC mapping identified high to low patches of electrical conductivity between 2,000 microsiemens per centimetre (µS/cm) to 150 µS/cm to feature within the landscape between Helidon and Gatton. High EC areas, 1,000 µS/cm to 2,000 µS/cm, underlie Gatton, Forest Hill and Laidley with more moderate EC areas featuring within the land resources study area as the alignment approaches Calvert. An area of low EC, 80 µS/cm, intercepts the land Resource study area at Grandchester.

Soil investigation results revealed the EC of the soil between Helidon and Calvert to range between 4 µS/cm and 383 µS/cm, indicating low EC. The results also indicate that there is horizontal and vertical variance in electrical conductivity of soils within the land resources study area and that this variance cannot be closely correlated with soil classification mapping. Surface water salinity and groundwater salinity are detailed further in Chapter 13: Surface water and hydrology and Chapter 14: Groundwater, respectively.

Overall salinity hazard

Overall salinity hazard of the land resources study area was assessed using a desktop assessment of five factors, soil salt store as well as potential expression areas, and laboratory results from soil samples collected during the soil investigation. The assessment for salinity hazard modelled and mapped surface conditions only.

The desktop assessment of salinity hazard was developed with consideration of inherent soil salt store, basalt and sandstone contact, catena form, artificial restrictions and confluence of streams. The desktop assessment indicated a general medium to high potential hazard of salinity occurring within the land resources study area, when risks from each of the five individual potential expression areas was combined (refer Figure 9.13).

Soil sample results from the soil investigation analysed exchangeable sodium, calcium and magnesium in soil samples, as these salts generally are responsible for salinity. Soil sample results identified an availability of all three salinity causing salts to exist at generally high concentrations (refer Table 9.4).

The salinity hazard assessment also considered additional data from the Department of Resources (former DNRME) (received March 2020) of known salinity sites in South East Queensland (SEQ). Eight small areas of 'severe' to 'slight' salinity were identified within the land resources study area, with only a single area located within the Project disturbance footprint (refer Figure 9.13).

Table 9.13 provides a summary of the eight known salinity areas.

TABLE 9.13: SUMMARY OF DNRME (NOW DEPARTMENT OF RESOURCES) KNOWN SALINITY AREAS

Location	Salinity risk	Salinity type	Area (ha)
Ringwood—adjacent Warrego Highway (Inset A in Figure 9.13)	Severe	Catchment restriction (artificial)— Dams	3.71
Gatton—adjacent Woodlands Road (Inset B in Figure 9.13)	Severe	Catena form	0.07
Gatton—east of Woodlands Road (Inset B in Figure 9.13)	Moderate	Alluvial valley	0.6
Gatton—east of Woodlands Road (Inset B in Figure 9.13)	Moderate	Alluvial valley	0.07
Gatton—east of Woodlands Road (Inset B in Figure 9.13)	Slight	Dams	0.07
Lawes—south of West Moreton System (Rosewood to Miles) (Figure 9.13)	Severe	Alluvial valley	~ 6.22 (within land resources study area)
Laidley—north (Figure 9.13)	Severe	Alluvial valley	54.4 (~ 5.43 within Project disturbance footprint)
Laidley—east (Inset A in Figure 9.13)	Moderate	Alluvial valley	~1.4 (within land resources study area)

9.6.5 Agricultural land

The Queensland Agricultural Land Audit (the audit) identified land important to current and future agricultural production in Queensland. The audit identified agricultural potential using a rule-based approach that combines biophysical characteristics of the land, such as soil, climate and landform as well as native vegetation, and socio-economic spatial data. The characteristics of land/soil resources are a fundamental determinant of potential for most agricultural land uses. Soils are classified using a four-tier hierarchy ranging from Class A (arable land) through to Class D (land that is unsuitable for agriculture) (DAF, 2020).

Agricultural land classified as Class A or Class B land is the most productive land in Queensland, with soil and land characteristics that allow successful crop and pasture production.

The audit also identified 'important agricultural areas'. IAAs are defined by the Audit as land that has all the requirements for agriculture to be successful and sustainable, is part of a critical mass of land with similar characteristics and is strategically significant to the region or the State.

The land resources study area frequently traverses IAAs and Class A and Class B agricultural land between Helidon and Calvert, with several patches of larger agricultural land evident at Helidon, as well as between Gatton and Laidley (refer Figure 9.14). Two 'streams' of agricultural land occur across the land resources study area at Grandchester and Calvert (DAF, 2020).

A strong correlation is evident between these areas mapped for agricultural land and land used for the following activities:

- Annual horticulture
- Pasture production
- Native forestry
- Intensive livestock
- Hardwood plantation forestry
- Broadacre cropping
- Sown pasture.

Pasture production was significantly evident within these areas as well as along the full extent of the land resources study area. The dominant scale of pasture production was medium (1,500 kg/ha to 3,500 kg/ha) with two distinct sections of high pasture production (> 3,500 kg/ha) between Gatton and Laidley North and again along the alignment between Grandchester and Calvert.

The Audit found the SEQ region to support a range of agricultural industries with the largest being horticulture, poultry, cattle, dairy and cultivated turf. The soil of SEQ allows for a wide range of agricultural use due to its fertile nature (DAF, 2018b).

The land resources study area contains a large proportion of vertosol soils, specifically underlying the surface between Gatton and Laidley North, which has a strong correlation to areas of high agricultural productivity identified through the mapping of IAAs and Class A and Class B agricultural land (DAF, 2018b).

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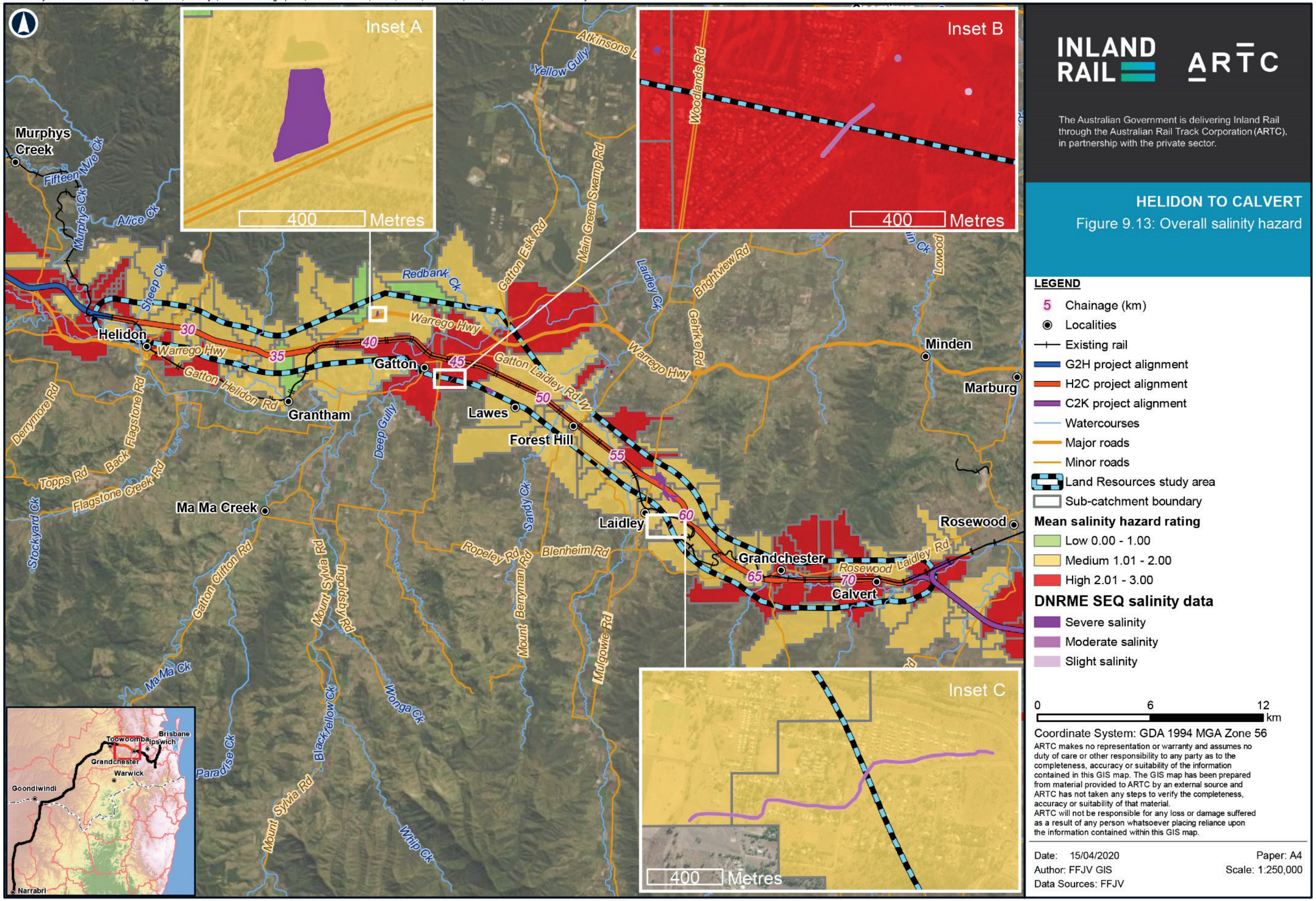

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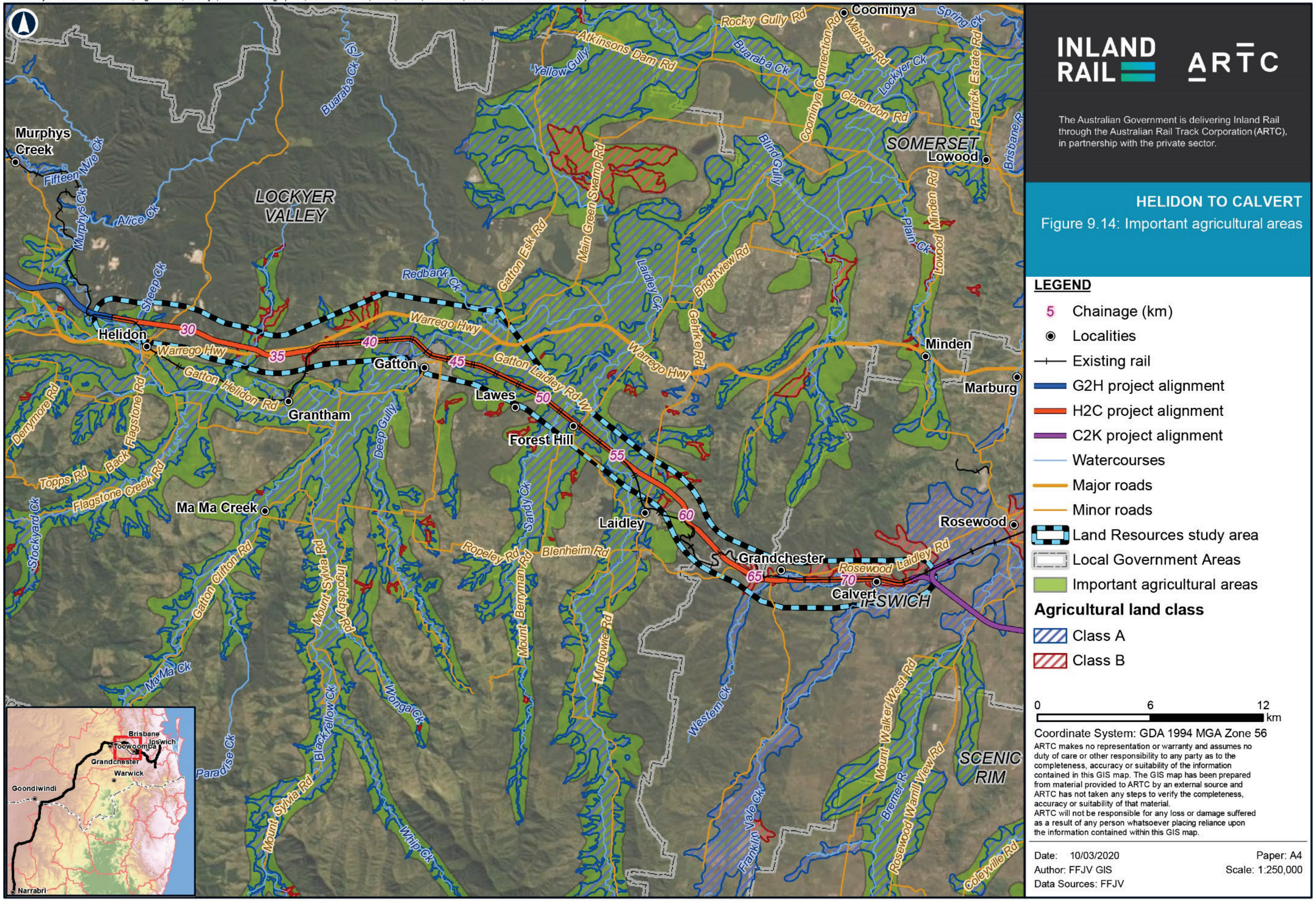

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9.6.6 Soil erosion

Erosion is the wearing away of the land surface by rain or irrigation water, wind, ice or other natural or anthropogenic agents that abrade, detach and remove geologic parent material or soil from one point on the Earth's surface and deposit it elsewhere (DSITI, 2015).

Erosion is a consequence of several factors, which include the presence of an erosional process (primarily water as rain or overland flow, but also wind), the erodibility of a soil type, the surrounding landform as well as land management practices. Erodibility is a function of the mechanical, chemical and physical characteristics of a soil, and describes the susceptibility of the soil particles to become detached and transported. A soil's overall inherent soil erodibility is a combination of the stability of the surface soil and the dispersibility of the subsoil.

The soil variability in the region is typically a reflection of the dominant presence of erosional and transportation surfaces on the slopes as opposed to the depositional environments of valleys and floodplains. The transitional zones of these soil environments can increase the complexity and variability of the soil types.

The types of erosion that have potential to occur within the land resources study area due to landforms and underlying geology include (Queensland Government, 2013):

- Sheet: occurs on hill slopes when a thin layer of topsoil is removed over a hillside
- Gully: occurs when a strong concentrated runoff of water detaches and moves soil particles creating gullies
- Rill: occurs on hill slopes when surface runoff forms small channels as it concentrates down a slope
- Aeolian: occurs predominantly in arid grazing lands of inland Queensland when winds blow over light, textured soils
- Tunnel: removal of subsoil when water travels through a soil crack or hole where a root decay has caused the soil to disperse.

Highly erodible soils are those where the individual particles are most easily detached and transported by erosive forces (Zund, 2017). The most erodible soils are those that are sodic and dispersive. Dispersive soils are usually predominantly composed of clays that readily break down into individual particles. Soils with a high proportion of silt may also be dispersive.

Sodosols, as encountered thought the land resources study area (refer Figure 9.6), have a particularly dispersive sodic clay subsoil. This is as a consequence of sodium ions that are attached to the clay particles. When exposed to water, the size of the sodium ions increases, forcing the individual clay platelets to separate and causing the soil to disperse (Zund, 2017).

The dispersive nature and presence of sodosols within the land resources study area is supported by the exchangeable sodium percentage (ESP) of soil samples analysed as part of the soil investigation. All soil samples analysed detected ESP above six per cent, which is generally regarded as high (Queensland Government, 2016).

Soils that are not dispersive, such as vertosols, can still be susceptible to erosion. Unlike soils that disperse, the aggregates of vertosols retain some of their natural structure after they have been removed by runoff (Zund, 2017). These relatively large particles are readily deposited when runoff velocity is reduced such as in a contour bank or waterway, and they generally travel only a limited distance.

As indicated in Table 9.6 and Table 9.7, some soils within the Project disturbance footprint have hardsetting surfaces that reduce the rate of infiltration during rainfall, but that also resist erosion. These soils can have low rates of erosion themselves. However, they can contribute to high rates of runoff with erosive power further down the slope where the soils may be less protected (Zund, 2017).

Geotechnical investigations identified potential for erosion and weathering for sandstone units encountered along the land resources study area. The investigation also identified lithologies along the Project alignment observed some claystone and mudstones within the Koukandowie Formation in particular to be susceptible to slaking. Road and rail cuttings in the area indicate that slaking and subsequent erosion of the rocks is common and frequently create undercutting and instability of batters. The Woogaroo Subgroup and the sandstones within that subgroup, however, are unlikely to be susceptible to slaking. Sodosols, chromosol and dermosols within the land resources study area were found to be susceptible to dispersion and potentially cause severe erosion on hillsides, particularly when exposed in cuttings or where they may be used as fill (in embankments) (refer Appendix W: Geotechnical Factual Report).

As part of the geotechnical analysis (refer Appendix W: Geotechnical Factual Report) an Emerson Aggregate Test was undertaken, which measures the dispersive characteristics of a soil when exposed to water (AS 1289.3.8.1-2006 (Standards Australia, 2006)). The investigations identified an Emerson class range between 2 (high dispersion potential) and 6 (not dispersive).

Erosion risks within the land resources study area, based on landform type and geology, are summarised in Table 9.14.

TABLE 9.14: EROSION RISK

Landform type	Geology	Erosion type	Erosion risk
Flood plains and river terraces subject to fairly regular overbank flooding, sandy banks and poorly defined levees and cobble plains. Supports grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands.	Quaternary alluvium	Sheet	Moderate
		Aeolian	Moderate
Erosional surfaces; ridges and plateaux remnants on basalt with steep stony slopes, restricted lower slopes, stony interfluves.	Koukandowie formation	Sheet	Moderate
		Rill	Moderate
	Heifer creek sandstone member	Tunnel	Low
		Aeolian	Moderate

Source: Damara Pty Ltd, 2013; Biggs et al., 2010

Erosion is a potential risk for the Project as the rail infrastructure, as well as other associated infrastructure, will require a stable base to operate safely. Adequate material assessment in the pre-construction phase should ensure that only durable materials are used in areas where breakdown could affect the final earthworks.

9.6.6.1 Soil conservation plans

Soil conservation plans may be approved under the *Soil Conservation Act 1986*. These plans facilitate the implementation of soil erosion control measures by landholders in Queensland through the use of property plans and Project area plans. Approved soil conservation plans may cover the whole of a property or just part of it (DSITI, 2015). The *Soil Conservation Act 1986* (Qld) allows for two types of plans: property plans and Project plans. Soil conservation plans aim to ensure soil capability is not exceeded and no adverse impacts occur onsite as well as offsite, such as polluting water resources and degrading aquatic habitats.

Approved property and Project area plans are binding on all present and future owners and the Crown. Both approved property plans and Project area plans can be modified to accommodate circumstances that differ from those applying at the time of approval. Plans may be amended, or their approval may be revoked.

The Project has assessed existing soil conservation plans (property and Project) through a review of current plans within the land resources study area (provided by DNRME (now Department of Resources)), and, at the time of writing, no approved soil conservation plans (property or Project) exist in the land resources study area.

9.6.7 Contaminated land

9.6.7.1 Contaminated land methodology

An assessment of contaminated land within the land resources study area was undertaken using a contaminated land risk assessment based on a contaminant (source)–pathway–receptor methodology where:

- **Contaminant (source):** A substance present in or on land, water or site at above background concentrations that presents, or has the potential to present, a risk to human health, the environment or any environmental value.
- **Pathway:** The route by which the source is brought into contact with the receptor. This can include the transport of contamination via water (surface and groundwater), aeolian deposition, vapours, excavation and deposition.
- **Receptor:** Humans, other living organisms, physical systems and built structures that could be affected by the source. A receptor will only be affected if a pathway from the source to the receptor is present. Groundwater and surface water systems can be considered as receptors in their own right as their quality is regulated by statutory bodies, as well as being pathways for contaminant migration to other receptors.

The source–pathway–receptor relationship allows an assessment of potential environmental risk to be determined, based on the nature of the source, the degree of exposure of a receptor to a source, and the sensitivity of the receptor.

The fundamental concept of contaminated land risk assessment according to AS NEPM is that an exposure pathway linking the source of contamination and the exposed population (humans or the environment) must be present for a risk to exist.

Identification of potential sources of contamination within the land resources study area was assessed through site inspections (including walkover) of the land resources study area, undertaken as part of the geotechnical and soil investigation, including borehole logs and a desktop assessment.

The desktop assessment identified potential sources of contamination within the land resources study area through a search and assessment of:

- ERAs listed on the environmental authorities register
- Queensland mining leases
- EMR and CLR for those ERAs identified
- Historical aerial imagery from areas of interest (e.g. potentially contaminated sites, infrastructure, environmentally significant areas)
- DoD (2017) online mapping for UXOs
- KRAs and other resource interests.

Potential sources of contamination identified from the assessment are detailed below as well as results from desktop assessments.

9.6.7.2 Potential sources

Based on the land uses within the land resources study area, findings of a desktop assessment and field investigations, the potential sources of contamination in the vicinity of the Project are considered to include:

- Agricultural activities: hydrocarbons (fuel and oil storage and use), pesticides and herbicides, asbestos and lead paint, arsenic (livestock dips or spray races), landfilling
- Quarries: hydrocarbons (fuel and oil storage and use), metals/metalloids, hazardous materials
- Landfilling, waste disposal: hazardous materials, hydrocarbons, metals/metalloids, phenols, polychlorinated biphenyls, phthalates, volatiles and pesticides and herbicides
- Existing rail corridor: metals, asbestos, hydrocarbons, pesticides/herbicides, poly aromatic hydrocarbons
- Road crossings: metals and hydrocarbons, poly aromatic hydrocarbons
- Unknown fill material: asbestos, metals/metalloids, hydrocarbons.

During the geotechnical site investigation, no visual contamination was identified, and no anthropogenic material was observed (refer Appendix W: Geotechnical Factual Report). A targeted contaminated land investigation will be undertaken following completion of detailed design, where the Project disturbance footprint intersects areas of medium to high risk to determine the likelihood of contaminated soils, the potential for risks to human health and the environment and required management measures.

Environmentally relevant activities

There are 32 properties within the land resources study area subject to environmental authorities for environmentally relevant activities listed on the environmental authorities register. A search of the 32 properties on the Queensland EMR and CLR registers, between February and July 2019, identified eight properties currently listed on the EMR, including one property within the disturbance footprint. No properties were listed on the CLR (refer Table 9.15 and Figure 9.15). These properties are recorded on the EMR for the following activities:

- Hazardous contaminants
- Explosive production or storage
- Landfill
- Waste storage, treatment or disposal.

The estimated risk potential for each property was categorised with consideration of distance to the Project alignment and potential for adverse impact (no potential, potential, or likely). The potential for adverse impact considered concentration of likely contamination at the source, type of contamination, contaminant mobility and potential transport pathways.

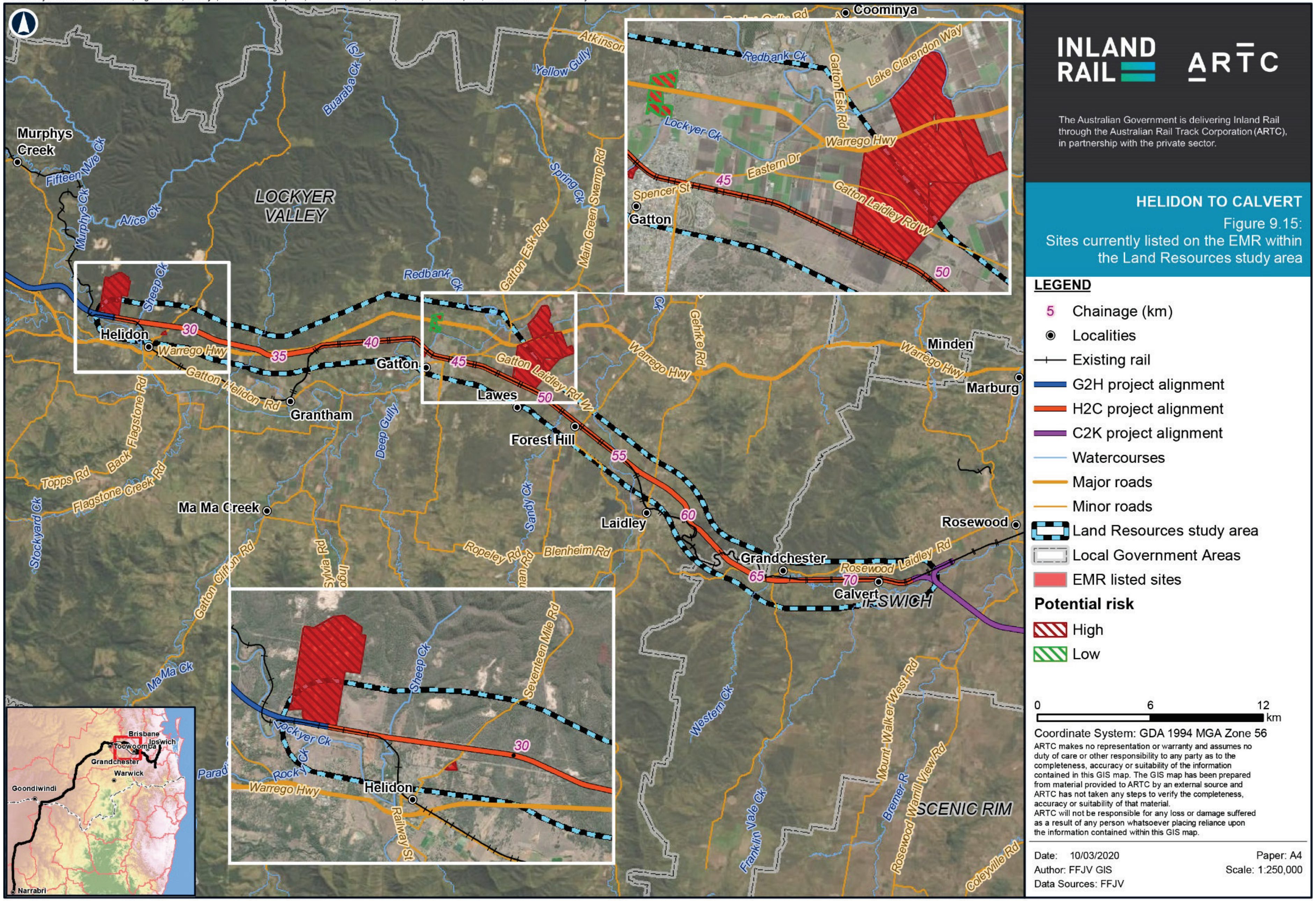
TABLE 9.15: PROPERTIES LISTED IN THE EMR LOCATED WITHIN THE LAND RESOURCES STUDY AREA

Lot and Plan	Location	Listing details	Approximate distance of activity to alignment	Estimated risk potential
125CP907566	North-west of Helidon	Explosives production or storage	Adjacent north	High
145CSH51	North-east of Helidon	Landfill	0.3 km south	High
11CC807888	William Kemp Park, Gatton	Landfill	Adjacent south	High
35CP846028	Anuha Tip and Recycling Centre, Gatton	Landfill	1.3 km north	Low
3SP235464	Lot adjoining Gatton Sewage Treatment Plant	Waste storage, treatment or disposal	1.3 km north	Low
4SP235464	Gatton Sewage Treatment Plant	Waste storage, treatment or disposal	1.3 km north	Low
362SP117133	West Moreton System Rosewood to Miles, Gatton	Hazardous contaminant (arsenic)	Along alignment (within disturbance footprint)	High
184CC3374	The University of Queensland, Gatton campus	Landfill	Adjacent north	High

Table notes:
Low risk: 1.5 to 2 km from alignment and/or with no potential adverse impact.
Medium risk: 1 to 1.5 km from alignment and/or with potential for adverse impact.
High risk: < 1 km from alignment (i.e. within study area) and/or with likely adverse impact

All properties with a current environmental authority for environmentally relevant activities have been included in Chapter 8: Land use and tenure. Appendix V: EMR Search Certificates and Laboratory Certificates, contains properties which were listed on the EMR.

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: CW/RB/IW Z:\GIS\GIS_3300_H2C\Tasks\330-EAP-201907101843_Land_Resource_Figures\Fig9.15_SitesListedOnEMR_v3.mxd Date: 10/03/2020 08:34

Unexploded ordnances

A search of the DoD (2017) online mapping for UXOs identified two areas of UXO categorised as 'other' in the land resources study area. The identified 'Other' UXO areas include an approximate 88 ha area at the Queensland Government explosives reserve, north of Helidon, and an approximate 14.8 ha area at Fred Gillam Park, south-east of Gatton. The identified UXO area at the Queensland Government explosives reserve, which was used for explosives storage during World War II (WWII) to present, is located adjacent the alignment, while the UXO area at Fred Gillam Park is located approximately 580 m from the alignment and historically used for mortar shoots during WWII. Neither 'Other' UXO area intersect temporary construction or permanent operational disturbance footprints of the Project.

The DoD categorises 'other' UXO areas as: 'Land which has been used for military training but not confirmed
as a site where live firing was undertaken. UXO or explosive ordnance fragments or components have not been recovered from these areas'.

If the Project disturbance footprint alters and is required to traverse identified 'other' UXOs areas or traverse directly adjacent to these areas, further assessment will need to be undertaken.

The remaining land resources study area had no identified records of UXO related material or activities, recommending 'All land usage and development, within these areas, should continue without further UXO investigation or remediation'.

Mining activity

A search of the DNRME (now Department of Resources) (2017a) resource authorities register for current and historical mining leases identified 15 permits within the land resources study area, with further details provided in Table 9.16.

TABLE 9.16: MINING LEASES WITHIN LAND RESOURCES STUDY AREA

Permit ID	Permit name	Status
ML50055	Gauci Sandstone	Non-current
ML50164	Sunking Sandstone	Non-current
ML 50181	Nevanna	Granted
ML 50202	Nevanna II	Granted
ML 50282	N/A	Granted
ML 50285	Stephens Bros	Granted
ML 50150	Regent	Non-current
ML 50005	Atidale Pty Ltd	Non-current
ML 50182	Regent	Granted
ML 50023	N/A	Non-current
ML 50097	Helidon Gold	Granted
ML 50102	Helidon Gem 1	Non-current
ML 50103	Helidon Gem 2	Non-current
ML 50094	Darling Downs Stone	Non-current
ML 50110	Darling Downs Stone No.2	Non-current

Source: DNRME, 2017a

Resource areas

There are no KRAs or coal resources located within the land resources study area.

9.6.7.3 Historical aerial imagery

An assessment of historical aerial imagery from areas of interest (e.g. potentially contaminated sites, infrastructure, environmentally significant areas) was undertaken to explore current potential sources, as well as historical sources of contamination within the land resources study area (refer Table 9.17).

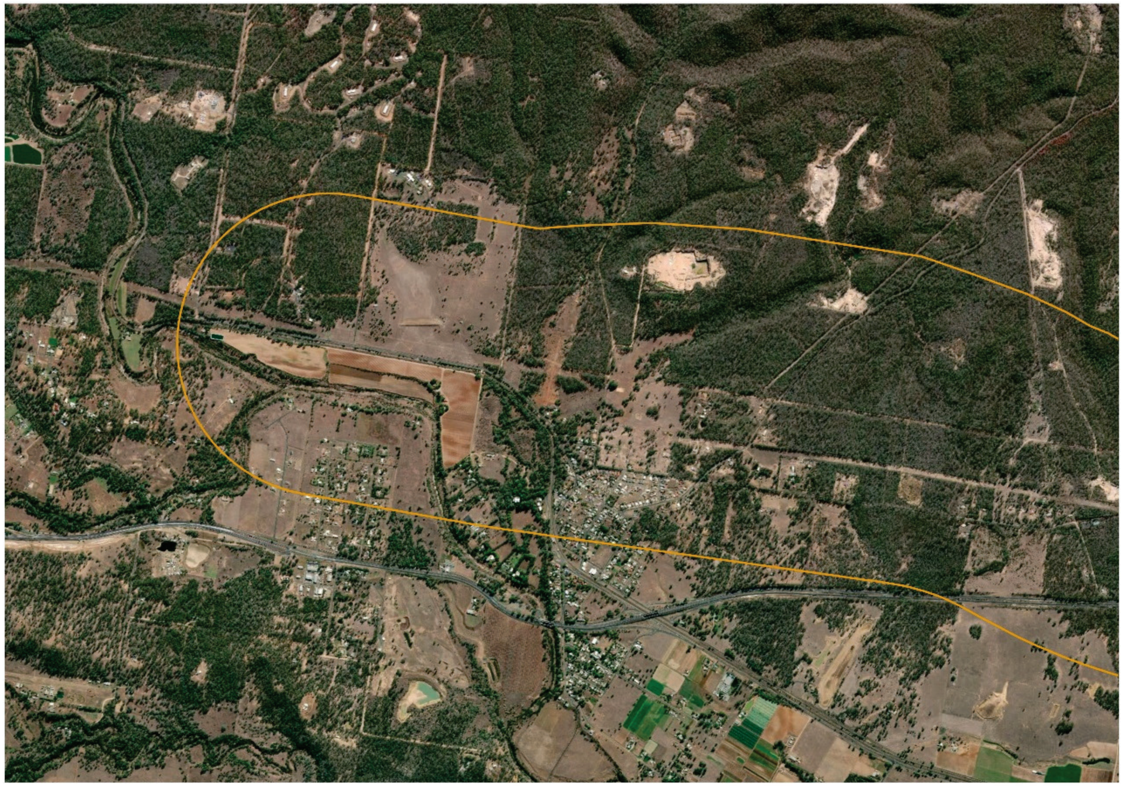
TABLE 9.17: HISTORICAL AERIAL PHOTOGRAPHS

Land resources study area	Details
Helidon area	
	**Year:** 1933 **Details:** The aerial image displays the existing West Moreton System rail corridor running through Helidon towards Grantham. The landscape is dominated by the Lockyer National Park to the north with scattered pastures for grazing and cropping featuring throughout the remaining land resources study area. A well-established town centre at Helidon already exists in the aerial image with road networks and residential properties featuring to the south, alongside Lockyer Creek. **Source:** QImagery, 2019

Land resources study area	Details
	**Year:** 1951 **Details:** Clearing of vegetation is evident when compared to the 1933 aerial image with cropping pastures emerging as a dominant land use within the land resources study area. A large ephemeral waterbody exists to the north of the West Moreton System rail corridor as well as significant, new residential development, north-west of Helidon. **Source:** DNRM, 2009

Land resources study area	Details
	**Year:** 1971 **Details:** More cropping pastures have emerged throughout the landscape, as well as residential dams. No other significant changes have occurred within the land resources study area. **Source:** DNRM, 2013

Land resources study area	Details
	**Year:** 1992 **Details:** Clearing of dense vegetation at the foothills of Lockyer National Forest is evident for potential quarries. The large ephemeral water body north-west of Helidon has become a large residential dam. No other significant changes have occurred within the land resources study area. **Source:** DNRM, 2014

Land resources study area	Details
	**Year:** 2019 **Details:** Several operational sandstone quarries have emerged since the 1992 aerial image with significant residential development occurring south of Lockyer Creek, west of Helidon. No other significant changes have occurred within the land resources study area. **Source:** Environmental Systems Research Institute (ESRI), 2019

Land resources study area	Details
Gatton area	
	**Year:** 1933 **Details:** The aerial image displays the existing West Moreton System rail corridor running through Gatton towards Forest Hill. The landscape of Gatton predominantly consists of cropping pastures with scattered bushland and grazing pastures featuring to the south of the land resources study area. A well-established town centre at Gatton already exists in the aerial image with road networks and many residential properties. Non-perennial waterways traverse grazing pastures and scattered bushland to the south of the land resources study area. **Source:** QImagery, 2019

Land resources study area	Details
	**Year:** 1951 **Details:** Cropping pastures have increased in area while grazing pastures to the south of the land resources study area show signs of partial clearing. A greater number of residential properties feature throughout the landscape compared to the 1933 aerial image. **Source:** DNRM, 2009

Land resources study area	Details
	**Year:** 1971 **Details:** Residential properties and cropping pastures have increased in number throughout the land resources study area. North of Lockyer Creek, the Gatton Sewage Treatment Plant has been constructed and is operational. The landfill site, current site of William Kemp Park, also features several buildings. No other significant changes have occurred within the approximate study area since the 1951 aerial image. **Source:** DNRM, 2013

Land resources study area

Details

Year: 1992

Details: The Gatton Sewage Treatment Plant has undergone expansion into the adjoining lot to the west, which has been cleared and contains two small ponds.

The current lot of the Anuha Tip and Recycling Centre has also undergone significant earth works, north of the Gatton Sewage Treatment Plant.

The landfill site (now William Kemp Park), along the bank of Lockyer Creek, has also expanded operations to feature several new buildings.

Several residential dams have also emerged throughout the landscape within the land resources study area.

Source: DNRM, 2014

Land resources study area

Details

Year: 2019

Details: The Anuha Tip and Recycling Centre has expanded and become fully operational consisting of several new buildings since the 1992 aerial image.

The landfill site (now William Kemp Park) has been decommissioned since the 1992 aerial image with only a few buildings remaining.

No other significant changes can be observed to have occurred within the land resources study area.

Source: ESRI, 2019

9.6.8 Contamination risk summary

Table 9.18 provides a summary of activities or risks identified and considered to be potential sources of contamination within the land resources study area. For the potential impacts to present a risk, there must be a linkage between the three following components:

- Source of contamination
- Exposure pathway
- Environmental values (receptor) that may be affected by this exposure.

Should one or more of these components be unavailable, or there is no complete linkage between the three, the risk of exposure to an environmental value is likely to be either minimal or non-existent, due to a break in the linkage between source, pathway and receptor. Where activities pose potential risks, these activities or risks have been advanced through to the impact assessment. Should further information be obtained during the detailed design stage of the Project indicating a potential risk for any of the activities, further assessment will be required if mitigation measures presented do not adequately address potential risk.

TABLE 9.18: POTENTIAL EXISTING SOURCES AND IDENTIFIED CONTAMINATION RISKS

Activity	Location	Potential contaminants	Potential risk
Within land resources study area			
Agricultural land	Multiple throughout the land resources study area	Hydrocarbons (fuel and oil storage and use) (agricultural storage and use)	Potential risk, due to proximity to agricultural buildings
		Pesticides and herbicides (agricultural storage and use)	Potential risk, due to proximity to cropping land
		Asbestos and lead paint (agricultural buildings/structures)	Potential risk, due to proximity to agricultural buildings
		Livestock dips or spray races arsenic, dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD) (agricultural storage and use)	Potential risk, due to proximity to agricultural land
		Landfilling (agricultural)	Low risk, historical aerials did not identify presence of agricultural landfilling (historic or current)
Housing/ sheds	Multiple throughout the land resources study area	Hydrocarbons (fuel and oil storage and use), pesticides and herbicides, lead paint and asbestos (agricultural and residential storage and use)	Potential risk, due to proximity to housing/sheds
Landfilling/ waste storage	Multiple throughout the land resources study area ▸ Anuha Tip and Recycling Centre ▸ Gatton Sewage Treatment Plant ▸ UQ Gatton	Hazardous materials, hydrocarbons, metals/metalloids, phenols, polychlorinated biphenyls, phthalates, volatiles and pesticides and herbicides (local council or commercial enterprise)	Potential risk, due to current and historical identification of landfills and EMR listed properties (landfill): ▸ 145CSH51 ▸ 11CC807888 ▸ 35CP846028 ▸ 3SP235464 ▸ 4SP235464 ▸ 184CC3374
Rail corridor	Existing West Moreton System rail corridor	Metals/metalloids, asbestos, hydrocarbons, pesticides/herbicides, polycyclic aromatic hydrocarbons (railway land use)	Potential risk, due to proximity to rail corridor and EMR listed property (hazardous contaminant—arsenic): ▸ 362SP117133

Activity	Location	Potential contaminants	Potential risk
Roads	Warrego Highway, Eastern Drive, Hunt Street, Glenore Grove Road, Laidley Plainsland Road, Rosewood Laidley Road, Airforce Road, Warrigal Road, Wrights Road, Seventeen Mile Road, Connors Road, Sandy Creek Road, Philps Road, Brooks Road, Jamiesons Road, Burgess Road, Smithfield Road, Old College Road, Off Beavan Street, Gaul Street, Golf Links Drive, Crescent Street, Hadwick Road, Dodt Road, Old Laidley Forest Hill Road, Cunningham Drive, Francis Road, Luck Road, Paroz Road, Range Crescent, Doonans Road Grandchester Mount Mort Road, School Road, Neumann Road, Calvert Station Road	Metals, hydrocarbons, pesticides/herbicides, polycyclic aromatic hydrocarbons (public roads)	Potential risk, due to proximity to roads
'Other' UXO areas	▶ Queensland Government explosives reserve—north of Helidon ▶ Fred Gillam Park—south-east of Gatton	UXO	Potential risk, due to proximity to UXO areas and EMR listed property (explosives production or storage): ▶ 125CP907566
Unknown fill material	Existing West Moreton System rail corridor	Asbestos, metals/metalloids, hydrocarbons (railway land use)	Low risk, anthropogenic materials not observed during geotechnical and soil investigation

The potential risk for EMR-listed properties has been assessed in Table 9.15.

9.7 Potential impacts

The construction, operation and decommissioning (as it relates to construction) phases of the Project has the potential to result in impacts to land resources within the land resources study area. Potential impacts to land resources associated with the Project are related to:

- Change to landform and topography
- Loss of soil resources
- ASS
- Degradation of soil resources through invasive flora and fauna
- Salinity hazard
- Disturbance of existing contaminated land
- Creation of contaminated land.

9.7.1 Change to landform and topography

Landform and topography are valuable for their ability to retain and move water within a soil catchment system. Project activities have the potential to change the landform and topography of each catchment the Project traverses, through increased erosion and landslip associated with specific landscapes. Project activities may also alter localised contours within the landscape. These potential impacts may be temporary during construction works (local changes to drainage) or permanent due to as-built infrastructure (variations to flow paths).

Changes to landform and topography may cause secondary impacts to surface water, such as changes to flow patterns and infiltration, as well as groundwater, flow direction, particularly in flood plain areas where railway infrastructure can significantly impede floodwaters and potentially redirect waters to sensitive receptors (refer Chapter 13: Surface water and hydrology).

Impacts to landform and topography will be an unavoidable result of the Project due to the need to maintain the operational gradient for the railway. However, these impacts will be limited within established rail corridor, such as the existing West Moreton System rail corridor and the protected Gowrie to Grandchester future State transport corridor, where the existing landform is more conducive to achieving the operating grade for the Project. Achieving this operating grade will require significant earthworks and structures (i.e. Little Liverpool Range Tunnel), a combination of cut and fill across the undulating landscape.

The total length of cut for the Project will be in the range of 7.6 km with a maximum cut depth of 38.8 m (3,638,000 m^3 of cuttings). The current construction methodology includes using the material from the cuts in the embankments works.

During construction and operation of the Project, there is potential for significant impact to landform and topography resulting from disturbance and exposure of subsurface soils vulnerable to accelerated erosion, dispersivity and/or salinity due to their physical and chemical characteristics.

Soils of particular concern for management and stability will be those that are dispersive, erosion-prone soils i.e. sodosols and, to a lesser extent, chromosols. The geotechnical investigation identified soils within the Little Liverpool Range and its foot-slopes to be dispersive and potentially subject to landslides.

However, regardless of soil type, erosion risk will be increased where the following activities occur:

- Clearing of vegetative cover
- Changes in topography, drainage patterns and localised concentration of storm water flows due to construction of both access tracks and the rail corridor
- Excavation or cuttings and stockpiling of material
- Construction during high rainfall events, particularly erosive rainfall events
- Constructing through areas with high soil erodibility risks (e.g. sodosols).

Where the Project is located within the proposed Little Liverpool Range tunnel, impacts to land uses aboveground are minimised. The design, construction, operation and decommissioning of a major rail route within various catchments will require careful planning to minimise impacts to the landform and topography. Appendix W: Geotechnical Factual Report further details impacts of the Little Liverpool Range tunnel on the landscape and geological hazards.

9.7.2 Loss of soil resources

Construction of rail infrastructure within (or adjacent to) Class A, Class B and IAAs will result in the loss of natural soil resources and affect farming activities. Poor land management practices can also cause loss of ground cover, leading to erosion from wind or water and increased dust levels and declining regional soil fertility over time within and in surrounding areas of the land resource study area.

Project activities can also lead to dust creation, compaction, contamination via foreign material, nutrient loss, leaching of soil, secondary salinisation of good quality soil and soil inversion, where mixing of subsoils and surface soils can potentially impact on natural soil processes and productivity and introduce contaminants into soil horizons.

In accordance with the audit, approximately 27 per cent of land within the permanent operational disturbance footprint is classified as Class A agricultural land, with a further 15 per cent classified as Class B agricultural land. This equates to a total of 42 per cent of land within the permanent operational disturbance footprint (outside the West Moreton System rail corridor and Gowrie to Grandchester future State transport corridor) as being classified as Class A or Class B agricultural land and that may be sterilised as a result of the Project (refer Chapter 8: Land use and tenure).

No agricultural activities are undertaken within the existing West Moreton System rail corridor and the future intent of land within the Gowrie to Grandchester future State transport corridor is recognised by the State as future railway land.

The Project disturbance footprint also includes land required on a temporary basis to enable construction of the Project, including for construction laydown, stockpile and storage areas. The temporary use of land for construction activities has the potential to result in damaged topsoil structure as well as compacted subsoil, due to increased traffic (vehicles, plant and pedestrians) and heavy loads. This is a particular risk in areas of clayey and silty soils, such as vertosols, particularly when wet.

Soil compaction can lead to:

- Poor root growth—which reduces crop yield through poor water and nutrient uptake
- Difficulties with soil cultivation and seedbed preparation
- A decrease in water entering the soil either as rain or irrigation
- A decline in soil structural stability
- A decline in fertiliser efficiency—as the large blocks of compacted soil provide few surfaces to retain and release fertiliser for crop growth
- A soil that requires more horsepower (and fuel) to cultivate—planting implements are less effective in compacted soil and poor germination is the result
- Land that is temporarily disturbed in support of construction activities construction (e.g. for access tracks, laydown areas etc.) will be rehabilitated at the end of its use for construction, unless otherwise agreed with the relevant landowner.

9.7.3 Degradation of soil resources through invasive flora and fauna

During the construction, operation and decommissioning (as it relates to construction) phases of the Project, introduction of weed seed material through human actions may present a potential risk to land resources, through soil degradation. Weed species have the potential to adversely impact soil, influencing critical factors such as soil stability and fertility. Weeds are known to increase the rate of erosion in soil through inadequate soil protection, alter the soil's physical structure and change soil nutrient status (Weidenhamer & Callaway, 2010).

The Project may also encounter potential impacts from feral animals burrowing or tunnelling in soil, causing soil degradation. Erosion of the soil, as well as adverse impacts to groundwater flow and/or infiltration of rainfall may result from invasive fauna activity. Five non-native fauna species have the potential to occur within the land resources study area, including:

- Goat *(Capra hircus)*
- Wild dog *(Canis familiaris)*
- Cat *(Felis catus)*
- European hare *(Lepus europaeus)*
- European rabbit *(Oryctolagus cuniculus)*.

Further detail is provided in Chapter 11: Flora and fauna.

9.7.4 Acid sulfate soils and acid rock

The desktop assessment and field investigations concluded a low probability of encountering ASS and acid rock within the land resources study area.

However, there could be acid generating sulfides present in spoil derived from the Walloon Coal Measures rocks that are assessed to remain obscured beneath the Western Creek alluvium along the alignment.

If ASS is present in permanent waterways within the land resources study area, it would only be encountered during works that involve sub-surface disturbance within, or immediately adjacent to these waterways. Additional geotechnical investigation undertaken during the detail design phase will target these locations in order to provide further details on the likelihood of occurrence of inland ASS in proximity to these waterways.

ASS have the potential to degrade ecosystems as metals, such as iron and aluminium, are mobilised under acidic conditions (Hicks et al., 1999). The mobilised metals, combined with acidic conditions, can result in degraded water quality, toxicity for fish and impacts to plant growth.

Project activities may expose potential ASS to oxygen through soil disturbance which, in turn, may result in the creation of sulfuric acid. In addition to the above-mentioned biological impacts, acidic conditions have the potential to corrode infrastructure built from concrete, steel and other materials (EPHC & NRMMC, 2011). Potential ASS may be located within the land resources study area, however, under general conditions, residing below the water table and present a risk during excavation of cuts.

Acid rock occurs when sulfide minerals are exposed to air and water. This process is accelerated through excavation activities ,which increase rock exposure to air, water, and microorganisms. Acid rock has potential to produce neutral to acidic drainage, which may occur with dissolved heavy metals and significant sulfate levels. Based on the geological conditions within the land resources study area, the likelihood of encountering acid rock is considered to be low.

Visual examination of surface outcrops along the Project disturbance footprint for sulfide minerals or remnant products, indicative of sulfide mineralisation, will occur prior to the commencement of construction.

9.7.5 Salinity hazard

The salinity hazard assessment in Section 9.6.4.5, undertaken in accordance with Part B of the *Salinity Management Handbook* (DERM, 2011), concluded that sub-catchments within the land resources study area have a low to high overall salinity hazard rating (refer Figure 9.13).

Project activities have the potential to cause secondary salinisation, which is salting caused by human activities, through processes such as the removal of vegetation, altering waterways and general land use changes. Secondary salinisation can cause water table salting, irrigation water salting and erosion scalding (DERM, 2011).

Geological features and past patterns of weathering result in some landforms having more potential to express salinity through the presence of restrictions to groundwater flow that may cause the water table to rise to near the soil surface, resulting in a discharge area with evaporative salts. During the desktop salinity hazard assessment (refer Section 9.6.4.5), potential landforms (naturally occurring and currently present) were identified within the land resources study area with a risk for salinity formation and are further detailed in Table 9.19.

TABLE 9.19: LANDFORMS WITH SALINITY FORMATION RISK IDENTIFIED DURING DESKTOP SALINITY HAZARD ASSESSMENT

Feature	Information contributing to salinity investigations	Potential impact	Existing salinity formation risk within land resources study area
Landform feature identification ▸ Geology ▸ Waters ▸ Wetland	PEA: Basalt over sandstone interface	Potential to have a more permeable basalt layer contacting with a less permeable sandstone geology underneath. This landform type can cause a restriction to downward water movement with seepages occurring at the interface area.	High
	PEA: Confluence of streams	Potential for the junction of a minor steam with a major stream to have a reduction in flow velocity and resultant deposition of suspended particles and salts.	Low
	PEA: Catena	Potential to have a change in hydraulic gradient similar to a barrier in water movement. Salting arising from infiltration of water into the soil and lateral movement through the weathered parent horizon or through more permeable soil.	Low
Soil properties	PEA: Soil Salt Store	Potential for soluble salts to be sitting within the soil profile.	Medium
	PEA: Artificial restriction, roads	Potential to have a reduction in water transmission, sufficient to cause salting upslope of the road.	High
Known salinity expressions	Known salinity expressions	Active or stable sites along the alignment.	Low
Overall salinity hazard	Total PEAs	Potential for various methods of salt build up and transportation.	Medium to high

Identified landforms (refer Table 9.19) with a medium to high risk of salinity formation were considered at risk from Project activities. The residual risk of Project activities to salinity hazard is presented in Section 9.9.

Salinity also presents a risk to infrastructure in saline areas predominantly through corrosion (Searle et al., 2007). A number of naturally occurring, as well as man-made, assets within the land resources study area, or adjacent, could potentially be affected by salinity. It should be noted, however, that rail corridors generally have a low potential in the creation of secondary salinity in the environment, as during the construction phase of the Project, compaction around the railway is expected to be limited and occurring over a short duration and surface water drainage will be included as part of the design to minimise ponding or creation of hydraulic barriers.

Problems associated with salinity or sodicity are greatest in drier climates where rates of evaporation are usually very high. Excessive amounts of water applied during construction or operation phases of the Project can have the potential to move past the root zone and contribute to rising water tables. Leakage from water storages may also contribute to rising water tables.

Sodic waters used during construction or operation may contain higher levels of sodium salts compared to calcium and magnesium salts and can result in soil dispersion, with consequent soil surface sealing, crusting, erosion and poor water entry.

The desktop salinity hazard assessment adopted a precautionary approach. This approach has been adopted to alleviate limitations in data availability (quantity/quality) as well as interpretation method at EIS stage. Soil sampling undertaken as part of the soil investigation were also limited and reflect only specific points along the land resources study area where salts are available in soil.

The creation of secondary salinity from Project activities along the alignment will be minimised adequately through mitigation measures proposed in Section 9.8 and is therefore considered low risk. Detailed investigations of areas of proposed disturbance within the finalised Project footprint will be required during the detail design phase to ensure that the physical and chemical characteristics of soils and subsurface materials understood.

9.7.6 Disturbance of existing contaminated land

Project activities have the potential to disturb existing contaminated land resources during each of the phases of Project development: construction, operation and decommissioning (as it relates to construction). The disturbance of contaminated soil or groundwater during Project activities has the potential to contaminate previously unaffected soil or groundwater and affect human health through ingestion as well as dermal contact with contaminants.

On a review of existing contaminated land in Section 9.6.7 and identifying potential sources of contamination within the land resources study area as well as their relative risk in Section 9.6.8, Table 9.20 links the identified potential sources, pathways and receptors derived from existing contaminated land, which may be further exacerbated through Project activities.

TABLE 9.20: POTENTIAL EXISTING CONTAMINATED LAND SOURCE, PATHWAY AND RECEPTOR LINKAGES

Potential source	Contaminants	Potential pathway	Potential receptor
Existing potential contamination			
Agricultural land	Pesticides and herbicides	▸ Direct contact ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users Ecological: ▸ Terrestrial—direct contact and consumption (including bioaccumulation) ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation)
	Hydrocarbons (fuel and oil storage and use)	▸ Direct contact ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff	Human health: ▸ Current and future site users, construction workers, site visitors, surrounding land users Ecological: ▸ Potential risk to surrounding cropping lands. ▸ Aquatic ecosystems
	Asbestos and lead paint	▸ Direct contact ▸ Ingestion ▸ Inhalation ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff	Human health: ▸ Current and future site users, construction workers, site visitors, surrounding land users Ecological: ▸ Terrestrial ecosystem ▸ Aquatic ecosystem
	Livestock dips or spray races arsenic, DDT, DDE, DDD	▸ Direct contact ▸ Ingestion ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users Ecological: ▸ Terrestrial—direct contact and consumption (including bioaccumulation) ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation)

Potential source	Contaminants	Potential pathway	Potential receptor
Housing/sheds	Hydrocarbons (fuel and oil storage and use), pesticides and herbicides, lead paint and asbestos	▸ Direct contact ▸ Ingestion ▸ Inhalation ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff	Human health: ▸ Landowners, current and future site users, construction workers, site visitors, surrounding land users Ecological: ▸ Terrestrial—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation)
Permanent rail corridor	Metals, asbestos, hydrocarbons, pesticides/ herbicides, polycyclic aromatic hydrocarbons 362SP117133	▸ Direct contact ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users Ecological: ▸ Terrestrial—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
Landfill/waste storage	Hydrocarbons, pesticides/ herbicides, metals, asbestos ▸ 145CSH51 ▸ 11CC807888 ▸ 35CP846028 ▸ 3SP235464 ▸ 4SP235464 ▸ 184CC3374	▸ Direct contact ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff ▸ Leaching	Human health: ▸ Current and future site users, site workers, site visitors, surrounding land users Ecological: ▸ Terrestrial—direct contact and consumption (including bioaccumulation) ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation)
Roads	Metals, hydrocarbons, pesticides/herbicides, polycyclic aromatic hydrocarbons	▸ Direct contact ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff	Human Health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
'Other' UXO areas	▸ UXO ▸ 125CP907566	▸ Surface water runoff ▸ Groundwater flow ▸ Dispersion of soil from excavation, water and wind	Human health: ▸ Inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial—direct contact ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).

Many of the potential sources identified in Table 9.20 do not impede on the disturbance footprint and as a result are unlikely to be a potential source of contamination during Project activities. The residual risk of Project activities to existing contaminated land is presented in Section 9.7.6.

The final Project footprint and construction methodology will be subject to confirmation through the detailed design phase. Subject to the outcomes of the detailed design, further consideration will be required for potential contaminated land issues — within the final Project footprint that will be disturbed by construction activities. Potentially contaminated sites, including the existing rail corridor, that will be disturbed may require specific identification, documentation and management controls to be developed. In some instances, further environmental site investigation may be warranted in accordance with ASC NEPM.

The disposal and management of spoil is further detailed in Appendix T: Spoil Management Strategy.

9.7.7 Creation of contaminated land

The following Project activities have the potential to contaminate land resources:

- Transport or movement of existing contaminated soil/groundwater leading to migration of contaminants to previously uncontaminated soil/groundwater and affecting human health through contact with contaminants
- Leaks or spills leading to migration of contaminants through surface water/soil/groundwater or exposure to human health risks through ingestion/dermal contact to contaminants from:
  - Permanent/mobile fuel/chemical storage
  - Waste storage areas/facilities (including storage tanks, sewage).

Table 9.21 details identified potential sources, pathways and receptor linkages resulting from Project activities.

TABLE 9.21 : POTENTIAL CREATION OF CONTAMINATED LAND SOURCE, PATHWAY AND RECEPTOR LINKAGES

Potential source	Contaminants	Potential pathway	Potential receptor
Construction			
Hydrocarbon leaks and/or spills	Hydrocarbons	▸ Direct contact	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption.
		▸ Overland flow/runoff to surface water bodies ▸ Migration to groundwater	Human health: ▸ Ingestion, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users (drinking water supply impacts). Ecological: ▸ Terrestrial—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption.
Leaks and or spills from waste storage areas/facilities (including storage tanks, sewage)	Biological waste (sewage), other wastes	▸ Direct contact	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption.
		▸ Overland flow/runoff to surface water bodies ▸ Migration to groundwater	Human health: ▸ Ingestion, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users (drinking water supply impacts). Ecological: ▸ Terrestrial—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption.

Potential source	Contaminants	Potential pathway	Potential receptor
Operation			
Hydrocarbon leaks and/or spills	Metals and hydrocarbons	- Direct contact	Human health: - Ingestion, inhalation, dermal contact - Current and future site users, construction workers, site visitors, surrounding land users. Ecological: - Terrestrial—direct contact and consumption - Aquatic ecosystems—direct contact and consumption.
		- Overland flow/runoff to surface water bodies - Migration to groundwater	Human health: - Ingestion, dermal contact - Current and future site users, construction workers, site visitors, surrounding land users (drinking water supply impacts). Ecological: - Terrestrial—direct contact and consumption - Aquatic ecosystems—direct contact and consumption.

From the desktop assessment, most soil existing in the rail corridor may potentially be suitable for reuse without treatment within the same area. Reuse of the soil, where contamination is suspected, will be dependent on sampling and laboratory analysis of soil samples, along with a comparison with applicable health and ecological guidance values/screening criteria.

Chapter 20: Hazard and risk, further details contamination that may arise as a result of Project activities and provides an assessment of impacts as well as mitigation measures.

9.8 Mitigation

This section outlines both the land resources mitigation measures included as part of the Project design and the mitigation measures that are proposed for the Project to manage predicted environmental impacts. The impacts are initially assessed with consideration of the design mitigation measures and then reassessed to determine residual risk after the inclusion of the proposed mitigation measures.

9.8.1 Design considerations

The mitigation measures and controls presented in Table 9.22 have been incorporated into the Project design. These design measures have been identified through collaborative development of the design and consideration of environmental constraints and issues. These design measures are relevant to both construction and operational phases of the Project.

TABLE 9.22: INITIAL MITIGATION—DESIGN

Aspect	Initial mitigation
Land resources	The Project is generally located within existing road–rail infrastructure where possible, minimising the need to develop land that has not previously been subject to disturbance for transport infrastructure purposes. This will minimise impacts of Project activities to land resources. The rail corridor width has been designed to minimise disturbance to existing land resources (e.g. refining vertical alignment and embankments where possible). Cut and fill balance and minimisation of transport requirements for import/disposal of spoil considered (refer Appendix T: Spoil Management Strategy).

9.8.2 Proposed mitigation measures

To manage Project risks during construction, a number of mitigation measures have been proposed for implementation in future phases of Project delivery, as presented in Table 9.23. These proposed mitigation measures have been identified to address Project-specific issues and opportunities, address legislative requirements, accepted government plans, policy and practice.

Table 9.23 identifies the relevant Project phase, the aspect to be managed, and the proposed mitigation measure, which is then factored into the assessment of residual risk in Table 9.24.

Chapter 23: Draft Outline Environmental Management Plan provides further context and the framework for implementation of these proposed mitigation and management measures.

TABLE 9.23: LAND RESOURCES MITIGATION MEASURES

Delivery phase	Aspect	Proposed mitigation measures
Detailed design	Erosion and sediment control	▸ Project clearing extents will be limited to the disturbance footprint, which will be minimised to that required to safely construct, operate and maintain the Project ▸ An Erosion and Sediment Control Plan (ESCP) will be developed by a Certified Practitioner in Erosion and Sediment Control (CPESC) in accordance with the *International Erosion Control Association Best Practice Erosion and Sediment Control* (IECA, 2008) and with reference to *Soil Conservation Guidelines for Queensland* (DSITI, 2015) and will be implemented during construction of the Project. The plan will detail the following procedures and protocols relevant to potential impacts identified within: ▸ Soil/land conservation objectives for the Project ▸ Temporary/permanent erosion and sediment control measures ▸ Workplace health and safety requirements relating to management of contamination and UXO risk ▸ Management of problem soils (e.g. acid sulfate soils, erosive, dispersive, reactive, acidic, sodic, alkaline soils) ▸ Stockpiling and management/segregation of topsoil where it contains native plants seedbank or weed material ▸ Vehicle, machinery and imported fill hygiene protocols and documentation ▸ Requirements for training, inspections, corrective actions, notification and classification of environmental incidents, record keeping, monitoring and performance objectives for handover on completion of construction.
	Hazardous materials Handling and Storage	▸ A Contaminated and Hazardous Materials Management Sub-plan will be included as a component of the Construction Environment Management Plan (CEMP) to eliminate, minimise and manage spills. ▸ Design of bunding containment is to be in accordance with *Australian Standard 1940:2017 The storage and handling of flammable and combustible liquids* (Standards Australia, 2017).
	Reinstatement and/or rehabilitation	▸ The Reinstatement and Rehabilitation Plan will align with the ESCP and include progressive stabilisation of earth materials and soil consolidation to prevent to erosion and sedimentation for areas within the disturbance footprint that do not form part of the permanent works (e.g. temporary construction compounds and laydown areas).

Delivery phase	Aspect	Proposed mitigation measures

Detailed design [continued]	Land and soil	▸ Soil conditions across the disturbance footprint will be appropriately characterised at a suitable scale (1:10,000) by a suitably qualified soil practitioner (Certified Professional Soil Scientist) through additional geotechnical surveys during the detailed design phase of the Project to inform design and environmental management measures. Soil investigations will be in accordance with the *Guidelines for surveying soil and land resources* (McKenzie et al., 2008), the *Australian soil and land survey field handbook* ((National Committee on Soil and Terrain, 2009) and the *Guidelines for Soil Survey along Linear Features* (Soil Science Australia, 2015). The methodology for the detailed soil investigation will be developed in consultation with the Department of Resources (former DNRME). The works will include:
		  ▸ Identification of potential/actual acid sulfate soils, acid rock, reactive soils, erosive soils, dispersive soils, salinity, acidic soils, alkaline soils, wetness, depth and contaminated land
		  ▸ Target locations where detailed design includes: cuts, embankments, and, bridge piers/abutments.
		▸ Additional soil data will be incorporated into the design of structures, embankments, erosion control measures (temporary and permanent), soil treatment and management and site rehabilitation planning are reflective of site-specific soil conditions.
		▸ Minimise risks through implementation of appropriate detailed design processes where reactive or problem soils are present or suspected (i.e. Helidon to Laidley and the Little Liverpool Range).
		▸ Cut and fill balance and minimisation of transport requirements for import/disposal of spoil will be considered as part of the design process.
		▸ Detailed design to demonstrate assessment and viability of opportunities for re-use of:
		  ▸ Local sources of aggregate and treatment of dispersive and reactive materials to improve mass haul
		  ▸ Material excavated below the rail embankment for less critical parts of infrastructure
		  ▸ Excavated material as a stabilised structural fill
		  ▸ Ballast as high-quality general fill or structural fill to minimise the import of rock amours.
		▸ A soil management plan will be developed to provide the framework for the stripping, storage, treatment and reuse of topsoil.
		▸ Where dispersive material may be allowed as part of the earth fill, adequate design and construction practices will be implemented to reduce the risk of damage to the embankment. Suitable mitigation measures may include containment of the dispersive soil by non-dispersive and low permeability outer layers, high level of compaction at optimum moisture content, lime stabilisation or other similar methods.
		▸ A Biosecurity Management Sub-plan will be developed and implemented and will include measures to address the risk of impacts from feral animals grazing, trampling, digging and/or burrowing in rehabilitated/landscaped areas. Movement of biosecurity matter and carriers across biosecurity zones will be in compliance with Biosecurity Regulations 2016 and Biosecurity Instrument Permits where applicable.

Delivery phase	Aspect	Proposed mitigation measures
Detailed design (continued)	Contamination, land and soil	▸ As required, a Contaminated Land Management Strategy will be developed and implemented by a suitably qualified professional, as recognised under the EP Act, incorporating consultation outcomes from landowners and other relevant stakeholders. This strategy will: . ▸ Be developed based on the contaminated land strategy presented in Figure 9.16 ▸ Specify controls for works on land that is known or suspected of being contaminated and will outline the process to identify, document and manage contaminated sites ▸ Seek to minimise soil disturbance in areas listed on the EMR (refer Table 9.15). A Soil Disposal Permit under the EP Act is required if contaminated soil is to be moved from a lot listed on the EMR ▸ Establish the methodology and sampling and analysis plan for environmental site investigation where soil disturbance is required on an EMR site in the potentially contaminated area ▸ Establish an unexpected finds protocol/procedure in the event that potentially contaminated materials, including UXO, are encountered during construction activities ▸ A contamination assessment of EMR-listed sites and other areas of potential contamination will be undertaken once detail design, Project footprint and the cut and fill balance are finalised, in accordance with the requirements of ASC NEPM ▸ Examples of soils that will require specific design consideration include the high naturally occurring sodicity of sodosols and vertosols cracking clays ▸ Any imported fill material will be clean, certified pest and contaminant-free ▸ Where geotechnical/drilling activities require drilling fluids or muds, environmentally neutral and biodegradable materials will be selected. Mobile plant, drill rigs and equipment will be maintained in accordance with manufacturer requirements and inspected frequently to minimise breakdowns and decrease the risk of contamination.
Pre-construction	Materials handling and storage, hazardous waste	The CEMP must contain the following provisions relevant to potential impacts of land resources: ▸ A Pollution Incident Response Plan for accidental spills, leaks and other polluting incidents. The supervisor or person in charge of the work activity will be notified immediately. The matter will be recorded on the reportable environmental incident checklist and in accordance with the Emergency Management Procedure. ▸ All bunding, hydrocarbon and chemical storage areas will be routinely checked, and their integrity and functionality maintained as per design capacity. ▸ Appropriate controls are in place to prevent environmental incidents including leaks/spills from refuelling activities and to protect the environment in the event that incidents occur. ▸ Personnel involved in ground-disturbing works will be familiar with the unexpected finds protocol/procedure and trained in: ▸ The identification of potential contaminated soil/ material and relevant controls such as how to recognise potential contaminated material (colour, texture, odour, presence of asbestos, metal, ash) from inert waste or materials ▸ Stop work and corrective/ containment actions ▸ Classification and notification of incidents procedures. ▸ Identification of contaminated, hazardous or potentially contaminated material on site (i.e. soil/formation) will be subject to a risk assessment. ▸ Assessment of contaminated, hazardous or potentially contaminated material encountered during Project works will be undertaken and recorded. ▸ Transportation of hazardous substances wastes and/or dangerous goods are to be undertaken by appropriately licensed contractors and a register of waste transfer certificates to be maintained for the Project.

Delivery phase	Aspect	Proposed mitigation measures
Pre-construction (continued)	Spoil management / excavated material	▶ A construction Spoil Management Plan will be developed and implemented to document and manage the stockpiling and storage, on-site reuse, removal, transport and disposal of excavated material. ▶ Any imported fill material will be clean, certified pest and contaminant free.
	Erosion and sediment control, land and water, water quality	▶ An Erosion and Sediment Control Management Plan will be prepared and implemented by a CPESC in accordance with International Erosion Control Association (IECA) guidelines to minimise potential impacts on land resources.
	Land and soil	▶ Closure or realignments of local roads will be undertaken in accordance with the Reinstatement and Rehabilitation Plan. ▶ Wherever practical, topsoil will be transferred directly to placement as planting media. ▶ Where stockpiling of topsoil is required, it will be carried out in accordance with the Soil Management Plan, and in a manner that ensures that the properties of the topsoil are not permitted to degrade such that it becomes unsuitable as planting media. The Soil Management Plan will establish: a) limitation for height of stockpiles b) limits for the width of the base of stockpiles c) requirements for adopting batter slopes, protective covers and drainage which reduce potential for erosion and/or segregation d) limiting the period of stockpiling to a minimum practical time e) requirements for carrying out herbicide spraying or other treatment of the stockpile at intervals required to prevent weed growth and ensure the stockpile faces are weed-free prior to use. Develop and implement a Biosecurity Management Plan as part of the CEMP to include: ▶ Compliance requirements including relevant biosecurity surveillance or prevention program authorised under the *Biosecurity Act 2014* (Qld) and any requirements of the *Vegetation Management Act 1999* (Qld) (VM Act), the *Planning Act 2016* (Qld) and the *Agricultural Chemicals Distribution Control Act 1966* (Qld) (ACDC Act) ▶ Requirement for pre-clearing survey to determine the risk of weeds or pest animals being present ▶ Map of the existing severity and extent of weed infestations and weed management requirements, including land adjacent to the disturbance footprint and construction access tracks ▶ Pest animal management (including fire ant and fire ant biosecurity zones) ▶ Site hygiene and waste management procedures to deter pest animals ▶ Weed surveillance and treatment during construction and rehabilitation activities ▶ Requirement in relation to pesticide and herbicide use and documentation, including any limitations on use, such as, restrictions on use in sensitive environmental areas, drainage lines that flow to waterways and aquatic habitats, and ensuring that broad scale use does not result in an increase erosion and sediment risk ▶ Vehicle, machinery and imported fill hygiene protocol and documentation ▶ Erosion and sediment control risk associated with broad scale weed removal or treatment ▶ Mitigation or remediation measures contained in the Biosecurity Management Plan will be developed in accordance with relevant agencies and local government.

Delivery phase	Aspect	Proposed mitigation measures
Pre-construction (continued)	Hazardous waste	▸ A contaminated and hazardous material survey will be undertaken prior to demolition of structures (e.g. sheds, housing/buildings). If asbestos or other hazardous materials are identified in these structures, a Contaminated and Hazardous Materials Management Plan will be developed and implemented. The Contaminated and Hazardous Materials Management Plan will contain procedures to ensure that removal is undertaken in accordance with How to Safely Remove Asbestos Code of Practice (Safe Work Australia, 2018a).
Construction and commissioning	Erosion and sediment control, land and water, water quality	▸ Appropriate erosion and sediment control measures are to be implemented and continuously reviewed for effectiveness for the construction works, in accordance with the construction ESCPs developed and maintained specifically for the Project.
	Contamination	▸ For work activities undertaken within the property identified on the EMR within the Project disturbance footprint or any other sites identified as part of the actions under the Contaminated Land Management Strategy, a Contaminated Site Management Plan will be developed and implemented to reduce the risk of adverse impacts to the existing and surrounding environments. ▸ If suspected contaminated land or material in drums, tanks, bags or plastic containers are encountered during excavation works, all work will stop in the affected area and measures to manage the contamination will be implemented, as per the Contaminated Site Management Plan. ▸ The reuse or retention of contaminated or potentially contaminated material encountered on site (i.e. soil, ballast) will be subject to a risk assessment.
	Materials handling and storage	▸ Appropriate registers and records of chemicals, hydrocarbons and hazardous substances and materials onsite will be maintained up to date (in the form of a current and accurate materials manifest and a Safety Data Sheet (SDS) Register). ▸ Where appropriate this will include a relevant risk assessment prior to the substance arriving, and being used, on site, ▸ Where an incident occurs that threatens or causes unlawful environmental harm, all reasonable steps, including allocation of additional trained resources or specialists, will be taken to remediate and manage the incident.
	Rehabilitation	▸ Reinstatement, stabilisation and rehabilitation of temporarily disturbed areas (such as laydown, site offices and temporary access tracks) will be undertaken progressively, consistent with the Project Reinstatement and Rehabilitation Plan and the Project Landscape and Rehabilitation Management Plan.
	Unexploded ordnance	▸ Implementation of an unexpected finds protocol/procedure will be implemented. ▸ Although unlikely, based on the UXO assessment for the Project, where a risk of encountering known or possible unexploded ordnance is identified, assessment and identification of management options will be carried out by a suitably qualified person.
	Hazardous waste	▸ Hazardous and/or dangerous waste (e.g. asbestos, chemicals, oils) will be correctly stored and managed on site and/or correctly disposed of by a licensed contractor to a registered waste facility and in accordance with the CEMP.
Operation	Land and soil Contamination	▸ Ongoing management and maintenance of the corridor to be accordance with existing Inland Rail Environmental Management System (EMS) and corridor management procedures.

9.8.2.1 Disturbance of existing contaminated land

The disturbance of existing contaminated land through Project activities presents a medium risk. As a result, additional mitigation measures will need to be implemented during the construction of the Project. The approach for the further assessment and investigation of contaminated land within the Project footprint will be documented in the Contaminated Land Management Plan Strategy, which is presented in Figure 9.16.

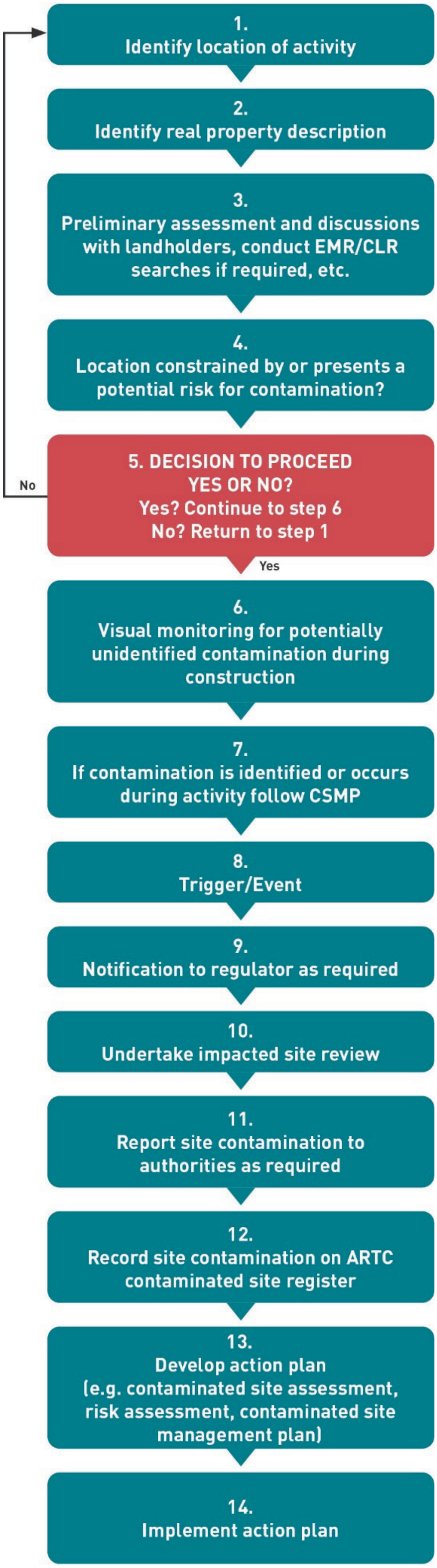


FIGURE 9.16: CONTAMINATED LAND MANAGEMENT PLAN STRATEGY

9.9 Impact assessment

Potential impacts to land resources associated with the Project in the construction and operational phases are outlined in Table 9.24. These impacts have been subjected to a risk assessment consistent with Chapter 4: Assessment methodology.

The initial risk assessment is undertaken on the assumption that the design measures (or initial mitigation) have been incorporated into the Project design (refer Table 9.22).

Proposed mitigation measures, including those listed in relevant subplans, were then applied as appropriate to the phase of the Project to reduce the level of potential impact.

The residual risk level of the potential impacts was then reassessed. The initial risk levels were compared to the residual risk levels to assess the effectiveness of the mitigation and management measures.

TABLE 9.24: IMPACT ASSESSMENT FOR POTENTIAL IMPACTS ASSOCIATED WITH LAND RESOURCES

Aspect	Potential impact	Phase	Initial risk[1]			Residual risk[2]		
			Likelihood	Consequence	Risk	Likelihood	Consequence	Risk
Land and soil	Change to landform and topography ▸ Erosion ▸ Loss of natural contours ▸ Landslip	Construction	Likely	Moderate	High	Possible	Moderate	Medium
		Operation	Possible	Minor	Low	Possible	Minor	Low
Erosion and sediment control, land and soil	Loss of soil resources ▸ Loss of Class A, Class B and IAAs within Project disturbance footprint ▸ Decline in soil fertility ▸ Loss of groundcover ▸ Soil inversion	Construction	Likely	Moderate	High	Possible	Moderate	Medium
		Operation	Possible	Minor	Low	Possible	Minor	Low
Land and soil	Disturbance of ▸ Existing ASS ▸ Potential ASS ▸ Acid rock	Construction	Unlikely	Moderate	Low	Rare	Moderate	Low
		Operation	Unlikely	Moderate	Low	Rare	Moderate	Low

Aspect	Potential impact	Phase	Initial risk[1]			Residual risk[2]		
			Likelihood	Consequence	Risk	Likelihood	Consequence	Risk
Erosion and sediment control	Disturbance of soil resources through invasive flora and fauna ▸ Invasion ▸ Reuse ▸ Erosion ▸ Disturb native species ▸ Alter soil properties or groundwater flow ▸ Infiltration	Construction	Likely	Minor	Medium	Possible	Minor	Low
		Operation	Likely	Minor	Medium	Possible	Minor	Low
Land and soil	Salinity hazard ▸ PEA: Basalt over Sandstone Interface ▸ PEA: Soil Salt Store ▸ PEA: Artificial Restriction (roads)	Construction	Possible	Moderate	Medium	Unlikely	Moderate	Low
		Operation	Possible	Minor	Low	Possible	Minor	Low
Contamination, land and soil	Disturbance of existing contaminated land ▸ EMR listed properties ▸ Agricultural land ▸ Housing/sheds ▸ Rail ▸ Landfill/waste storage ▸ Roads ▸ 'Other' UXO areas	Construction	Likely	Moderate	High	Possible	Moderate	Medium
		Operation	Possible	Moderate	Medium	Unlikely	Moderate	Low
Material handling and storage	Creation of contaminated land ▸ Leaks or spills ▸ Permanent and mobile fuel and chemical storage ▸ Waste storage areas and facilities ▸ Project infrastructure	Construction	Possible	Moderate	Medium	Unlikely	Moderate	Low
		Operation	Possible	Minor	Low	Possible	Minor	Low

Table notes:

1 Includes implementation of initial mitigation specified in Table 9.22.

Assessment of residual risk once the land resources mitigation measures and controls, as identified in Proposed mitigation measures Table 9.23, have been applied.

9.10 Cumulative impacts

The cumulative impacts of multiple projects in the vicinity of the Project may contribute to impacts on land resources if not managed appropriately. Based on the assessment of land resources, the risk of Project activities impacting on land resources is relatively low. However, the major potential impacts identified as a result of the Project are common to all projects throughout the region and are therefore cumulative in nature. Seven projects have been identified within the cumulative impact study area and are highlighted in Table 9.25.

TABLE 9.25: OTHER PROJECTS IN THE VICINITY OF THE PROJECT AREA

Project and proponent	Location	Description	Project status
Gowrie to Helidon (ARTC)	Immediately west of the Project, from Gowrie to Helidon	Comprises approximately 26 km single-track dual-gauge freight railway as part of the ARTC Inland Rail Project	Draft EIS being prepared by ARTC
Calvert to Kagaru (ARTC)	Immediately east of the Project, from Calvert to Kagaru	Comprises approximately 53 km single-track dual-gauge freight railway as part of the ARTC Inland Rail Project	Draft EIS being prepared by ARTC
Bromelton State Development Area (SDA) (Queensland Government)	Located south-east of the Project at Bromelton	Delivery of critical infrastructure within the Bromelton SDA will support future development and economic growth. This includes a trunk water main and the Beaudesert Town Centre Bypass. This infrastructure provides opportunities to build on the momentum of current development activities by major landowners in the SDA	Approved by Governor in Council, December 2017
Ipswich Motorway Upgrade Rocklea to Darra (Remaining sections) (Department of Transport and Main Roads)	Western Brisbane	Addressing of congestion and extensive delays in the Ipswich Motorway corridor by a range of road upgrades along 7 km of Ipswich Motorway between Rocklea and Darra	Project listed on Queensland Infrastructure Initiative List—EIS not yet initiated
RAAF Base Amberley future works (Department of Defence)	RAAF Base Amberley	White paper dedicated future upgrades to RAAF Base Amberley at a cost of $1 billion	N/A
Gatton West Industrial Zone (GWIZ) (Lockyer Valley Regional Council)	3 km north-west Gatton	Industrial development including a transport and logistics hub on the Warrego Highway	N/A
InterLinkSQ (InterLinkSQ)	13 km west of Toowoomba, located at the junction of the Gore, Warrego and New England Highways	200 ha of new transport, logistics and business hubs. Located on the narrow gauge regional rail network and interstate network	Under construction

The potential projects mostly comprise rail and road upgrades and high-density industrial infrastructure development. From this list, many of the Projects are not likely to contribute to cumulative impacts to land resources, due to their location in distant sub-catchments, as well as their limited extent of earthworks.

Provided that all of these projects apply appropriate mitigation measures no cumulative impacts are expected during the construction, operation and decommissioning (as it relates to construction) phases of the Project. Due to the distributed nature as well as likely stable landforms for the operation of these projects, it is unlikely that there would be any long-term cumulative impacts. Table 9.26 details the potential cumulative impacts for the Project.

The combined potential impact of these projects may further increase the land that is potentially affected by the localised land resources impacts of each Project. The Projects across the region may have different land use and tenure impacts to the Project.

Potential impacts that are likely to be common to each Project, if not managed, may include:

- Soil conditions not appropriately characterised
- Disturbance of existing contaminated land
- Leaks or spills leading to migration of contaminants

- Disturbance of ASS
- Changes to landform and topography
- Salinity and sodicity development
- Erosion potential—leading to increased total dissolved solids in run off
- Increase in weed migration.

The spoil that is generated for the Project alone and the adjacent Inland Rail projects have been assessed independently. Matters relating to the management of the spoil is provided in the Spoil Management Strategy (refer Appendix T: Spoil Management Strategy) and is consistent with the waste management hierarchy, which seeks to reuse the material for beneficial purposes in close proximity to the Project. Disposal to landfill will be avoided in the event that landfill is identified as the most appropriate location for the spoil, the material will be preferentially used as an interim cover in addition to final closure capping and rehabilitation.

TABLE 9.26: POTENTIAL CUMULATIVE IMPACTS

Potential cumulative impact	Aspect	Relevance factor*	Sum of relevant factors**	Impact significance	Comments
Soil conditions in the proposed area are not appropriately characterised to inform what the railway corridor will impact, how it will be impacted and when it will be impacted. This includes the identification of reactive soils, erosive soils, dispersive soils, saline and sodic soils, contaminated land.	Probability of the impact	1	4	Low	Once the final disturbance footprint is known, a suitably qualified person will undertake an assessment as to whether additional soil samples will be required to meet management requirements. Will be managed by Project CEMP and relevant sub-plans. Specific conditions unlikely to be necessary. Monitoring to be part of general Project monitoring program.
	Duration of the impact	1			
	Magnitude/intensity of the impact	1			
	Sensitivity of the receiving environment	1			
Leaks or spills leading to migration of contaminants through surface water/soil/ groundwater or increased human health risk through ingestion/dermal contact to contaminants from: ▸ Permanent/mobile fuel/chemical storage ▸ Waste storage areas/facilities ▸ Proposal infrastructure.	Probability of the impact	2	6	Low	Will be managed by a Contaminated Site Management Plan and Specific conditions unlikely to be necessary. Monitoring to be part of general Project CEMP.
	Duration of the impact	2			
	Magnitude/intensity of the impact	1			
	Sensitivity of the receiving environment	1			
Loss of soil resources	Probability of the impact	2	7	Medium	Mitigation measure likely to be necessary and specific management and design practices to be applied. Specific conditions are likely. Targeted monitoring program required through Project CEMP to identify IAA disturbance from works.
	Duration of the impact	2			
	Magnitude/intensity of the impact	2			
	Sensitivity of the receiving environment	1			
Acid sulfate soils, including the potential to disturb ASS	Probability of the impact	1	4	Low	Negative impacts need to be managed by standard environmental management practices. Special conditions unlikely to be necessary. Monitoring to be part of general Project monitoring program.
	Duration of the impact	1			
	Magnitude/intensity of the impact	1			
	Sensitivity of the receiving environment	1			
Change to landform and topography	Probability of the impact	2	7	Medium	Mitigation measure likely to be necessary and specific management practices to be applied. Specific conditions are likely. Targeted monitoring program required, where appropriate.
	Duration of the impact	3			
	Magnitude/intensity of the impact	1			
	Sensitivity of the receiving environment	1			
Salinity hazard (in-situ, soil)	Probability of the impact	2	6	Low	Negative impacts will be managed by standard environmental management practices. Special conditions unlikely to be necessary. Monitoring to be part of general Project monitoring program.
	Duration of the impact	2			
	Magnitude/intensity of the impact	1			
	Sensitivity of the receiving environment	1			

Potential cumulative impact	Aspect	Relevance factor*	Sum of relevant factors**	Impact significance	Comments
Erosion	Probability of the impact	2	7	Medium	Will be managed by an Erosion and Sediment Control Plan. Specific conditions are unlikely to be necessary. Monitoring to be part of the general Project monitoring.
	Duration of the impact	2			
	Magnitude/intensity of the impact	2			
	Sensitivity of the receiving environment	1			
Weed Management	Probability of the impact	2	7	Medium	Will be managed by Project CEMP and relevant sub-plans. Specific conditions unlikely to be necessary. Monitoring to be part of general Project monitoring program.
	Duration of the impact	2			
	Magnitude/intensity of the impact	2			
	Sensitivity of the receiving environment	1			
Feral Animal Management	Probability of the impact	1	4	Low	Will be managed by Project CEMP and relevant sub-plans. Specific conditions are unlikely to be necessary. Monitoring to be part of the general Project monitoring.
	Duration of the impact	1			
	Magnitude/intensity of the impact	1			
	Sensitivity of the receiving environment	1			

Table notes:

* Relevance factors between 1 and 3 were determined using professional judgement to select most appropriate factor for each aspect and summing.

** Sum of relevant factors definition:

- Low (1–6): Negative impacts need to be managed by standard environmental management practices. Special conditions unlikely to be necessary. Monitoring to be part of general Project monitoring program.
- Medium (7–9): Mitigation measure likely to be necessary and specific management practices to be applied. Specific conditions are likely. Targeted monitoring program required, where appropriate.
- High (10–12): Alternative actions will be considered and/or mitigation measures applied to demonstrate improvement. Specific conditions expected to be required. Targeted monitoring program necessary, where appropriate.

9.11 Conclusions

This chapter has been prepared to evaluate potential impacts of the Project on land resources. Existing conditions of the land resources study area have been identified in accordance with industry standard methodology and relevant legislation. Through an assessment of existing conditions, Project impacts with the potential to adversely impact land resources were outlined. Project activities, at different stages, can impact land resources via:

- Changing landform and/or topography
- Causing the loss of soil resources on farming and other economically valuable land
- Degrading soil resources through introduction of invasive flora and fauna (altering physical and chemical properties of soil)
- Expose potential ASS and acid rock to oxygen during excavation and earthworks
- Exacerbating existing soil salinity and sodicity or creating new impacts
- Disturbing existing contaminated land
- Contributing to creation of contaminated land (soil/groundwater).

The majority of potential impacts to land resources through Project activities were found to have low residual risk on implementation of initial mitigation measures during the design phase and proposed mitigation measures implemented during the detailed design to operations.

Change to landform and topography, loss of soil resources and disturbance of existing contaminated land during the construction phase of the Project, each remained a potential medium residual risk.

The disturbance footprint follows the existing West Moreton System rail corridor for approximately 50 per cent of the length of the Project. The Project is located within the existing rail corridor for approximately 18 per cent of the area required for the permanent operational disturbance footprint.

The Project alignment following the existing West Moreton System rail corridor will minimise disturbance to land resources.

The mitigation measures detailed in Section 9.8 will sufficiently manage all identified potential impacts for land resources as a result of Project activities.

ARTC has committed (refer Section 9.8.2 and Appendix E: Proponent Commitments) to completing detailed soil investigations at a suitable sampling intensity to inform the development of detail design. Subject to land access, the soil sampling will be of an intensity to enable mapping at a 1:10,000 scale. Soil investigations will be conducted under the supervision of a suitably qualified soil practitioner.

The additional soil data will be incorporated into the design of structures, embankments, erosion control measures (temporary and permanent), soil treatment and management and site rehabilitation planning are reflective of site-specific soil conditions.