

7. Topography, geomorphology, geology and soil and geotechnical conditions

7.1 Introduction

Understanding the natural environment such as the topography, geomorphology, geology and soil is essential when examining the overall issues and impacts of a major public transport infrastructure project on an area.

It is important for engineers to know whether the properties of the soils and rocks (geology) and/or the general topography and geomorphology (i.e. watercourses and vegetation) will adversely affect a project's design and construction — for example, whether there is a need to consider a corridor shift or a change in design for environmental reasons.

The potential issues surrounding topography, geomorphology, soil, geology and geotechnical conditions that could impede or enhance the successful implementation of the South East Busway extension from Rochedale to Springwood therefore need to be examined as part of this Concept Design Study. Of particular interest are:

- the properties of the rock and soils of the wider area affecting the environment, foundation design and construction
- the topography and geomorphology which could influence design or economically related design decisions
- the general topography and geomorphology of the wider area affecting available access for construction vehicles and plant during busway construction
- the presence of acid sulfate soils.

7.2 Methodology

The assessment of the natural environment within or close to the South East Busway extension from Rochedale to Springwood has previously been undertaken as part of South East Transit Project and the Pacific Motorway Transit Project. A desktop assessment of previous geotechnical investigations within the study area have been carried out and are considered appropriate for the Concept Design Study.

Detailed geotechnical site assessment of subsurface ground conditions along the extension will be required in later stages of the project.

7.2.1 Previous investigations

South East Transit Project

The South East Transit Project included examination of a busway along the South East Freeway and Pacific Motorway corridors, in particular between Woolloongabba and Loganholme. This corridor included the area of the South East Busway extension from Rochedale to Springwood.

Geology and soils, potential for contaminated land and acid sulfate soils as well as other geotechnical issues were assessed and reported on. Components of these investigations relevant to the extension were used to formulate predictions about the corridor in regards to the soil conditions and possible geotechnical issues.

This information can be found in South East Transit Project, Volume 3 (Connell Wagner 1997). This project delivered the original South East Busway to Eight Mile Plains from the Brisbane central business district. Sections of transit lanes and other sections of previously proposed works on the Pacific Motorway were not delivered at the time. This has been considered in the Pacific Motorway Transit Project — further planning is currently being undertaken as part of the Pacific Motorway Upgrade project.

Pacific Motorway Transit Project

The Pacific Motorway Transit Project included within its proposal an Environmental Approval Report (Connell Wagner 2006) and a factual report on geotechnical investigations (Department of Main Roads 2005) for Section A, Gateway Motorway to Springwood South. Section A of the Pacific Motorway Transit Project covered the study area of the South East Busway extension from Rochedale to Springwood.

Within the Environmental Approval Report the topography, geology and soils associated with the section were assessed and information relevant to the extension was used within this Concept Design Study.

The factual report on geotechnical investigations includes factual data from geotechnical investigations undertaken along Section A of the Pacific Motorway Transit Project from June 2005 to December 2005. The field investigation results identified soil and rock types along sections of the extension and laboratory testing on these soils and rocks determined their properties. Based on this data, properties and potential behaviour characteristics of the soil and rock likely to be encountered along the busway extension were assessed and included in this report.

South East Busway Stage 2 Pre-Feasibility Study

The South East Busway Stage 2 Pre-Feasibility Study (Connell Wagner 2008) focuses on further extending the South East Busway from Stage 1 (between Eight Mile Plains and Rochedale) to Springwood.

Regional geology and potential geotechnical issues were assessed and reported on. The descriptions of the conditions from the South East Busway reports have been used in the Concept Design Study to make predictions about the geological and geotechnical nature of the extension.

7.2.2 Additional investigations

All currently available resources (as listed above) contain information relevant to the South East Busway extension from Rochedale to Springwood. Additional desktop investigations were required to resolve conflicting geological assessments of the previous reports and investigations. Overall geotechnical predictions were made for the busway extension.

A contaminated land search was undertaken in accordance with the following:

- National Environment Protection (Assessment of Site Contamination) Measure (National Environment Protection Council Service Corporation 1999).
- Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland (Queensland Environmental Protection Agency 1998).

This search comprised a review of current and historical data including:

- Department of Environment and Resource Management's Environmental Management and Contaminated Land registers
- historical aerial photographs.

7.3 Preliminary analysis

7.3.1 Existing conditions

Topography and geomorphology

The topography along the extension to Springwood — as described by the Pacific Motorway Transit Project Environmental Approval Report — varies between 15 and 60 metres Australia Height Datum. The upper and mid hill slopes are generally gently inclined, and steep slopes are associated with shallow open gullies. These gullies receive and direct surface run-off and drainage towards the major surface water tributaries within the area, including Bulimba and Slacks creeks to the north and south of the extension respectively.

The majority of buildings along the extension are residential and four shopping centres and two primary schools exist within the wider area. The existing Pacific Motorway road construction consists of a mix of cut sections, elevated bridge structures and fill embankment.

The general topography and geomorphology of the area is unlikely to play a major part when considering the overall impacts of the South East Busway extension from Rochedale to Springwood.

Geology

Based on information from previous reports, Table 7-1 lists geology likely to be encountered in the wider area within the vicinity of the busway extension. Figure 7-1 is a geological plan showing the distribution of soils.

In summary, the Tertiary and Triassic age rocks have been deposited in layers within valleys formed by older Palaeozoic (<248 million years) aged rocks. Deposition of Quaternary alluvium is associated with the floodplains of the Brisbane and Logan river systems and their associated creeks. Associated creeks include Bulimba Creek at Eight Mile Plains and Slacks Creek at Springwood.

No major geological faults have been identified within the wider area surrounding the extension.

Table 7-1: Geology within the extension corridor

Units	Name	Symbol	Age (million years)	Geotechnical unit	General description
Soil units	Fill		<200 years	Landfill	Miscellaneous rubbish and concrete fragments.
				Engineered fill	Road infrastructure embankments comprising clay, sand and gravel including rock fragments/drainage layers.
				Fill	Various
	Quaternary alluvium	Qa	Quaternary (<2 million years)	n/a	Alluvium, mainly clay, sands, silt and gravel, some surficial peat.

Units	Name	Symbol	Age (million years)	Geotechnical unit	General description
Rock units	Tertiary sediments (Oxley Group)	Ts	Tertiary (2 million to 65 million years)	n/a	Claystone, sandstone, mudstone, conglomerate and basalt.
	Woogaroo subgroup	Rjo	Late Triassic to Early Jurassic (213m yr)	n/a	Sandstone, conglomerate, siltstone, shale and coal.
	Tingalpa formation	Ri	Late Triassic	n/a	Sandstone, conglomerate, shale and occasional coal seams and some tuff beds.
	Neranleigh Fernvale beds	Pzn	Palaeozoic (<248 million years)	n/a	Phyllite, meta-greywacke, arenite, quartz arenite and quartzite.

Alluvium

Two alluvial sequences of differing ages could be present along the extension. Both would comprise similar material — mainly clay, sands, silt and gravel with some surficial peat. The density of the layers can be expected to vary due to their differing ages and degree of consolidation overtime. The more recent younger alluvium tends to be softer and more compressible than the older alluvium. According to the South East Transit Project up to 0.5 metres of surficial peat has been encountered in the Bulimba Creek floodplain. Peat commonly has properties of large settlement and poor bearing capacity.

Tertiary sediments

Rock types within the Tertiary sediment unit comprise mudstone, siltstone, shale, sandstone and some lenses of basalt. The material within the group can often be very weathered and behave like soil. The soils developed from the unit (residual soils) comprise stiff to hard sandy clays and clayey sands. According to the South East Transit Project some of these soils have been identified as being dispersive in nature. Dispersive soils have the potential to cause environmental harm by rapid erosion, thereby polluting local streams and or/destabilising engineering structures.

It has been reported that slope failure within the group appears to be a function of rock type, bedding attitude and natural gradient.

Woogaroo subgroup

The Woogaroo subgroup comprises sandstone, siltstone, shale conglomerate and coal. Due to variable cementing, some higher-strength bands can occur within the sandstones and conglomerate. These bands can generally be difficult to rip. The soils developed from this unit typically comprise clayey sands and sandy clays. According to the South East Transit Project the clayey soils of this subgroup are also susceptible to erosion because of their dispersive nature.

Tingalpa formation

This formation comprises a sequence of alternating conglomerates, sandstones, shales, occasional coal seams and some tuff beds. This formation is unlikely to be encountered during surface and subsurface works for the South East Busway extension from Rochedale to Springwood because regional information indicates that it occurs below the proposed works.

Neranleigh Fernvale beds

This unit comprises weakly metamorphosed marine sediments, resulting in variable rock types including argillite, phyllite, greywacke and greenstone. Some of the rock types can have a very high strength. This rock unit is unlikely to be encountered during surface and subsurface works for the extension because regional information indicates that it occurs below the proposed works.

Soils

Four soil types likely to exist in the wider area of the corridor have been identified as:

- Birkdale — Krasnozems, prairie soils located on low hills of weathered basalt
- Runcorn — prairie soils, dark acid clays, shallow black earth on low hills of highly weathered basalt
- Coopers Plains — red-yellow podzolic soils, lateritic podzolic soils on dissected plateau edge, on sandy clays and sandstones (Beckman et al 1987)
- Carbrook — yellow podzolic soils, alluvial soils on low terraces and floodplains of alluvium.

Figure 7-1 shows the distribution of the soils along the busway extension corridor.

The black earth soils (Runcorn) are considered to be 'highly reactive' with a high shrink swell potential and are highly plastic. With highly reactive soils there is a high potential for surface movement.

It is the podzolic soils that may be potentially dispersive and are at risk to erosion and other associated instabilities. Dispersive soils are likely to be in areas underlain by either sedimentary rocks or alluvium compared to the black soils where they are likely to be underlain by basaltic or volcanic rock.

Subsurface conditions likely to be affected by surface and cut-and-cover works

Some of the materials likely to be encountered during construction of the South East Busway extension from Rochedale to Springwood include:

Soils

Topsoil typically comprises a brown and red silty sand, and silty clay, and is likely to be encountered to about 0.2 metres depth from the natural ground surface.

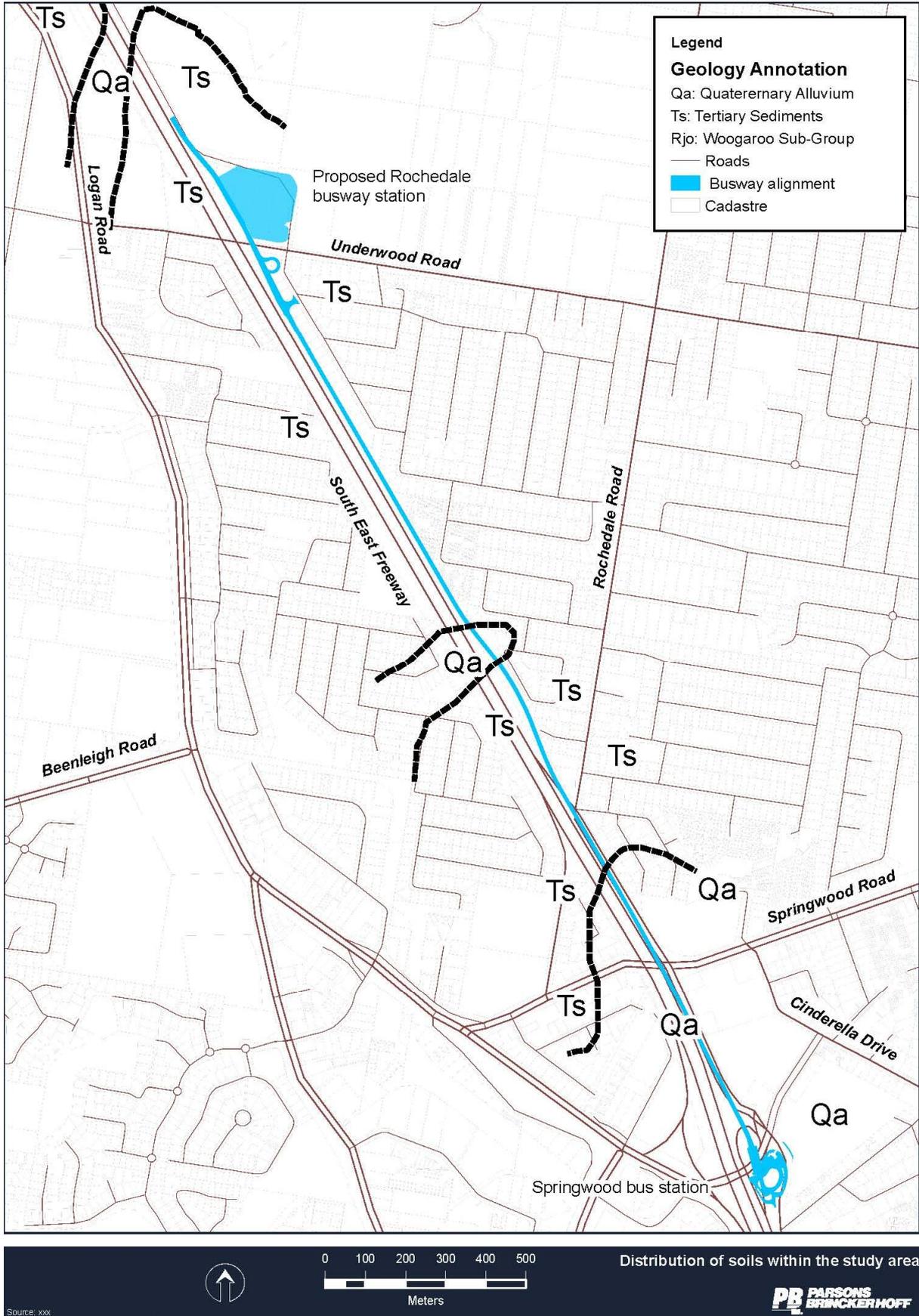


Figure 7-1: Distribution of soils within the study area

Residual soil developed from the weathering of in situ rock may comprise red-brown and grey-brown sandy and silty clay, firm to stiff, medium to high plasticity, and green-grey clay of extremely high plasticity. These soils can be expected down to a depth of about 1 metre to 2 metres below natural ground surface.

Dispersivity testing of one soil sample from the previous investigations indicated that those soils may not be dispersive. However, other reports have identified dispersive soils within the vicinity of the extension. The green-grey extremely high plasticity soil, identified in one area is underlain by basalt rock and is considered likely to be 'black soil'. Future field investigations are required to further characterise soil properties and determine the extent of dispersive and black soils.

Rock

Basalt of very low strength to high strength can be expected. Weathered basalt is pale green-grey to mottled red and is likely to be encountered from a depth of about 1 metre to a depth of about 5 metres from the natural ground surface. Less weathered basalt is typically pale green to blue and is high strength making it difficult to rip. This basalt may be encountered at about 3 metres depth from the natural ground surface, but is more likely to be encountered at a depth of around 5 to 6 metres.

Tuff has been identified in boreholes and test pits located along the alignment. However, a review of the logging data and regional geology suggests that tuff is more likely to be either a sedimentary rock or basalt. Future investigations will confirm this rock type.

Weathered tuff is typically mottled grey/red/yellow and is likely to be encountered from a depth of about 3 metres to about 8 metres and up to 10 metres from the natural ground surface. The less weathered tuff is typically encountered from about 8 to 10 metres depth and is pale grey and orange or yellow and higher in strength, making it more difficult to excavate. The tuff appears to have a deeper weathering profile than the basalt. Excavation of the tuff is unlikely to be difficult; however, erosion of potentially dispersive residual soils and associated slope instability in cuts may develop.

Groundwater

Groundwater issues are discussed in detail in Chapter 8 of the Concept Design Study.

Earthworks and excavation characteristics

Conventional earthmoving equipment is expected to be used for the excavation of the soils and weathered rock during construction of the South East Busway extension from Rochedale to Springwood. Excavation of less weathered, high-strength rocks such as some sedimentary units, tuff and basalt is likely to be more difficult and may require heavy ripping, hydraulic rock-breaking equipment or possibly drill-and-blast techniques. Any trench excavations deeper than 1.5 metres should be either supported or battered back to a safe angle. This will reduce the risk of instability and increase personnel safety. For this reason machinery or material removed from the excavations should not be placed so as to surcharge the trench excavation walls.

Trafficability on topsoil, 'black soil' and high plasticity residual soil is expected to be difficult during wet conditions.

Most materials obtained from excavation could be used for general fill as part of the construction. However, excavated clayey materials are unlikely to be suitable for reuse as select fill as they are unlikely to meet the required specifications.

Acid sulfate soils

Acid sulfate soils are soils that contain iron sulfides. When these soils are exposed to the air after being disturbed, sulfuric acid and toxic quantities of iron, aluminium and heavy metals are produced.

Acid sulfate soils are only likely to occur in low-lying areas of mangroves, salt marshes, river floodplains, swamps, wetlands, estuaries and brackish or tidal lakes, generally at elevations less than about 10 metres above mean sea level.

A review of the geology and topography suggests that there are areas of floodplain alluvial soils within the Quaternary alluvial unit, associated with Bulimba Creek and Slacks Creek. Along the South East Busway extension from Rochedale to Springwood soils occur at elevations greater than 10 metres above sea level. Previous site inspections (undertaken as part of the South East Transit Project) indicate there are no significant mangrove communities associated with creeks within the corridor alignment. A review of the Department of Environment and Resource Management's Acid Sulfate Soils Map 1 Tweed Heads to Redcliffe (Department of Natural Resources and Water 2002) also indicates that there is low potential for the presence of acid sulfate soils within the corridor area.

Consequently the potential for acid sulfate soils in the corridor area is considered low.

Mineral, energy and extractive material resources

The South East Transit Project identified a clay deposit suitable for brick making at Rochedale. It is understood that this deposit is within the vicinity of the extension; however, these deposits cannot be developed along the road reserve where construction works are likely to take place.

Contaminated land

Land contamination refers to land or water contaminated by hazardous substances that may pose a risk to human health or to the environment. A preliminary site history investigation has been undertaken to determine properties within the extension investigation area that may have the potential to contain sources of contamination.

Environmental Management Register and Contaminated Land Register status

A search of the Environmental Management and Contaminated Land registers was conducted on 14 August 2008. In total 180 property lots were searched, of which none were listed in either register. As such, no potentially contaminating activities were identified within the investigation area as a result of the searches conducted of the registers.

Historical aerial photography

A review of available historical aerial photography between 1955 and 2002 at intervals of roughly 10 years was undertaken to identify potential contaminated land. For the purposes of the aerial photograph review, the South East Busway extension from Rochedale to Springwood was split into four zones. These zones are shown in Figure 7-2. The aerial photography review for each of the four zones is presented in Table 7-2. Copies of the aerial photographs are supplied in Appendix E.

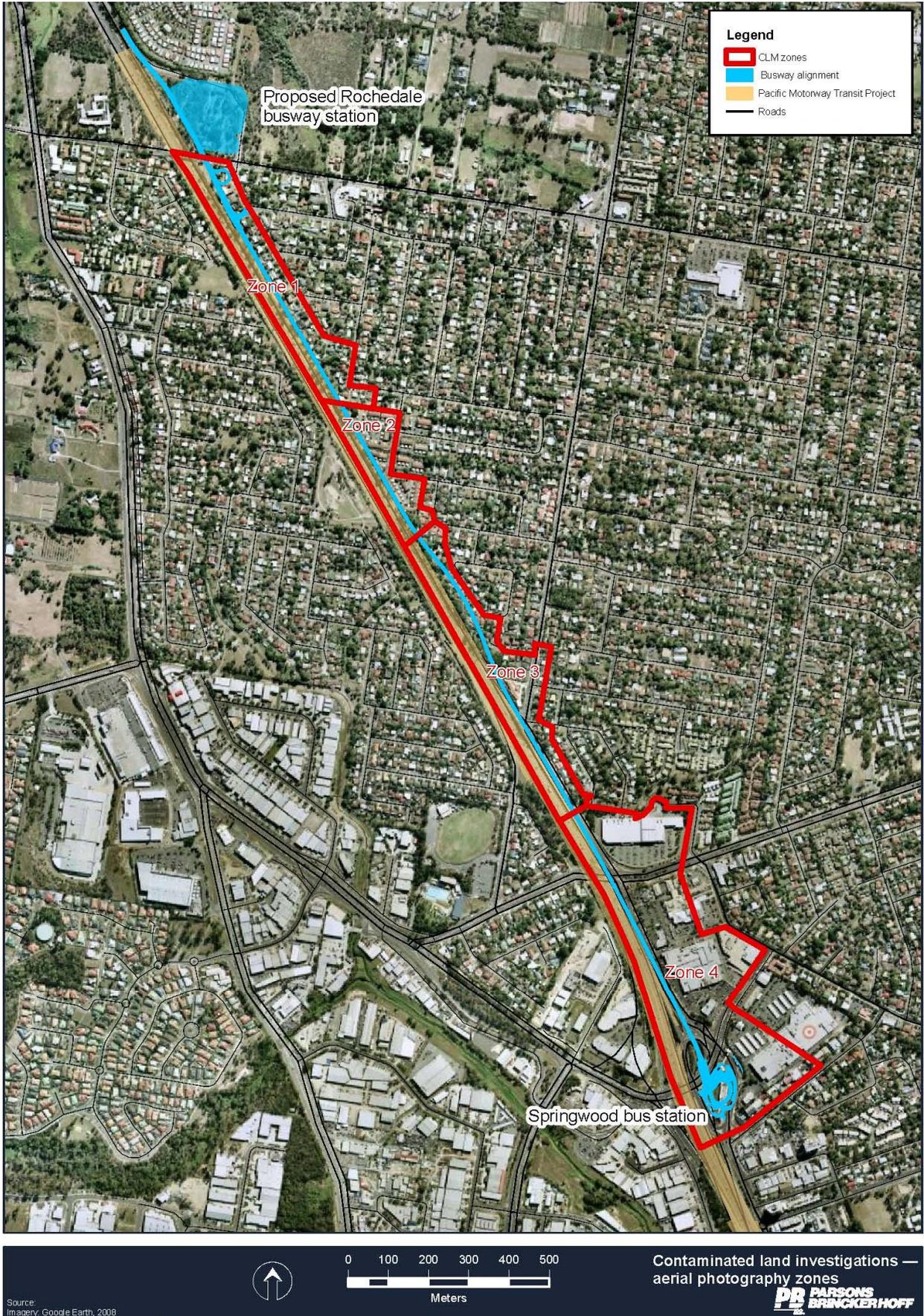


Figure 7-2: Contaminated land investigations — aerial photography zones

Table 7-2: Summary of aerial photography review

Year	Photograph	Zone	Description of immediate zone area	Description of surrounding area
27 Jul 1955	Q537-124 and Q538-22	Zone 1	A majority of the zone is remnant vegetation, with some minor cleared areas.	Immediately west is cleared land with some rural properties followed by Logan Road, which appears to be an unsealed road. To the east are more remnant vegetation corridors. Further north, south east and west are market gardens/intensive agricultural lots.
6 May 1968	Q1858-57		The semi-cleared corridor reserved for the Pacific Motorway is evident. Three properties are evident immediately east of the corridor. Some local (unsealed) road infrastructure is also evident. The remainder of the site remains cleared.	Immediately surrounding the zone is suburban road infrastructure (new housing estate) for Rochedale South. A manmade dam appears to be present immediately west of the zone near Roseland Avenue (southern portion of the zone). Further west remains as rural/agricultural properties.
29 Apr 1974	Q2668-75		The Pacific Motorway road reserve is now clearly visible. Rothon Drive, Roseland Avenue, and other surrounding Rochedale South streets are evident, with residential properties evident along both streets.	To the east and west, residential development has increased. The north remains as cleared land with patches of remnant vegetation.
28 Aug 1983	Q4268-83		No significant changes are observed. The investigation area comprises Pacific Motorway road reserve and residential housing.	Residential development has increased in all directions.
9 Aug 1993	Q4648-120 and Q4658-158		No significant changes are observed.	No significant changes are observed.
11 Feb 2002	Q5930-56		The Pacific Motorway has been constructed.	A majority of the market gardens to the west and north have been redeveloped as residential estates. A majority of the land to the east has been developed as residential estates.
27 Jul 1955	Q537-124 and Q538-22		Zone 2	A majority of the zone is remnant vegetation, with some minor cleared areas.
6 May 1968	Q1858-57	Area appears cleared with rural properties present.		Immediately west and east is remnant vegetation, with the Pacific Motorway corridor visible. Further east/west are rural/agricultural properties.
29 Apr 1974	Q2668-75	The Pacific Motorway road reserve is now clearly visible. Chamberlin Avenue, Woora Street and Narrawong Street		Residential housing estates are present immediately to the east of the site. To the west is a small patch of vegetation followed by

Year	Photograph	Zone	Description of immediate zone area	Description of surrounding area
			are all evident; however, the remainder of the area is cleared with no infrastructure.	more residential development.
28 Aug 1983	Q4268-83		No significant changes are observed. The investigation area comprises Pacific Motorway road reserve and residential housing.	Residential development has increased in all directions
9 Aug 1993	Q4648-120 and Q4658-158		No significant changes are observed.	No significant changes are observed.
11 Feb 2002	Q5930-56		The Pacific Motorway has been constructed. No other significant changes are observed.	The majority of the land to the east has now undergone residential development.
27 Jul 1955	Q537-124 and Q538-22	Zone 3	A majority of the zone is remnant vegetation, with some minor cleared areas.	Immediately west is cleared land with some rural properties followed by Logan Road, which appears to be an unsealed road. To the east are more remnant vegetation corridors. Further north, south east and west are market gardens/intensive agricultural lots.
6 May 1968	Q1858-57		Some portions of the zone are cleared, containing properties. Some portions remain as remnant vegetation corridors.	Immediately surrounding the zone is suburban road infrastructure (new housing estate) for Rochedale South. Further west has remained as rural/agricultural properties.
29 Apr 1974	Q2668-75		Karoonda Crescent, Rochedale Road and Kuranga Street are evident, with some residential housing constructed along them to the north and south of the zone. The centre of the zone remains remnant vegetation.	Some remnant vegetation is present to the east and west of the site, followed by residential development.
28 Aug 1983	Q4268-83		No significant changes are observed. The investigation area comprises Pacific Motorway road reserve and residential development.	Residential development has increased in all directions. A commercial estate is also evident to the west.
9 Aug 1993	Q4648-120 and Q4658-158		No significant changes are observed.	Commercial development comprising construction of large buildings to the west has occurred.
11 Feb 2002	Q5930-56		The Pacific Motorway has been constructed. No other significant changes are observed.	The majority of the land to the east has undergone residential development.

Year	Photograph	Zone	Description of immediate zone area	Description of surrounding area
27 Jul 1955	Q537-124 and Q538-22	Zone 4	A majority of the zone is remnant vegetation, with some minor cleared areas.	Immediately west is cleared land with some rural properties followed by Logan Road, which appears to be an unsealed road. To the east are more remnant vegetation corridors. Further north, south east and west are market gardens/intensive agricultural lots.
6 May 1968	Q1858-57		Some portions of the zone are cleared, containing rural properties. Some portions remain as remnant vegetation corridors.	Immediately surrounding the zone is suburban road infrastructure (new housing estate) for Rochedale South. Further west has remained as rural/agricultural properties and some remnant vegetation.
29 Apr 1974	Q2668-75		The northern portion of this zone contains remnant vegetation as well as areas of cleared land containing some residential properties. The southern portion of the site contains a large cleared area containing two large commercial buildings.	Some remnant vegetation is present to the east, west and south of the zone in addition to residential development.
28 Aug 1983	Q4268-83		A couple of smaller commercial buildings are evident in the vicinity of the existing commercial buildings.	Residential development has increased in all directions. A commercial estate is also evident to the west.
9 Aug 1993	Q4648-120 and Q4658-158		A large commercial building has been constructed in the northern portion of Zone 4. Further buildings have been erected in the vicinity of the existing buildings within the southern portion of Zone 4.	Further construction of large buildings in the commercial estate to the west.
11 Feb 2002	Q5930-56		The Pacific Motorway has been constructed. Further commercial development has occurred around the commercial areas both in the north and southern portions of Zone 4.	The majority of the land to the east has undergone residential development.

In summary, the aerial photography review determined that prior to development for residential and commercial purposes and the Pacific Motorway, the South East Busway extension from Rochedale to Springwood was generally observed to be either remnant vegetation or used as rural properties. As such, an additional investigation is required for the areas within the extension that historically or currently relates to commercial land use. Based on the investigative works undertaken it is considered that the portion of land within Zone 4 used for commercial use requires an additional investigation.

Summary of search information

The preliminary site history investigation undertaken comprised the review of searches conducted on the Environmental Management and Contaminated Land registers for 180 property lots and the review of historical aerial photography from 1955 to 2002. No property lots were listed on the Environmental Management or Contaminated Land registers as having

potentially contaminating activities undertaken on the property lots. The historical aerial photography review identified areas of the extension that had been used for commercial purposes. The areas identified to have been used for commercial purposes (i.e. storage of liquids etc) may have a potential to impact on the land with regard to contamination. As such, it is considered that an additional investigation should be undertaken in the areas of the busway extension identified to have been used for commercial purposes.

7.3.2 Managing issues and opportunities

Possible construction difficulties may include:

- high-strength rock zones within the Tertiary sediments and Woogaroo subgroup
- very high-strength basalt at shallow depth
- workability difficulties of high and extremely high-plasticity clayey soils
- slope failure of cut batters and trench collapse
- variable depths of very soft to firm cohesive materials and very loose to loose granular materials, significant amounts of groundwater and acid sulfate soils issues within the areas where alluvium is present
- problematic clay mineralogy associated with the basaltic residual soils causing variations in soil water retention and consequently behavioural compaction properties
- potential contamination of the soil by historical activities undertaken on the land will require determination of the contamination status of the soil prior to disturbance to limit environmental and human health risk.

These issues are detailed further below.

Soil erosion and sedimentation

The disturbance of soil and/or alluvium during construction will initiate erosion. Erosion of the soils by water, wind and general weather conditions can result in localised bank instability and sedimentation in creeks, changed local flood patterns and instability of construction cuts and fills.

Dispersive clay materials that are more susceptible to erosion have been previously identified within the Tertiary sediments and the Woogaroo subgroup. The alluvium soils where exposed are also susceptible to erosion with associated localised bank instability. Future field investigations along the extension will confirm the extent and location of these erodible materials.

There are a number of management strategies that can be used to reduce soil erosion. Some recommended management measures have been detailed in Table 3-7 of the Pacific Motorway Transit Project Environmental Approval Report. The development and implementation of an erosion and sediment control plan in accordance with relevant standards and guidelines for any surface works, embankments and excavation work, water crossings and stormwater pathways to be applied through all the phases of project delivery is one recommendation.

During construction, measures such as the use of sediment control and the minimisation of exposed area and exposure time in areas of dispersive erodible materials will help to minimise erosion. Permanent works will require the emplacement of erosion protection such as revegetation, shotcreting and appropriate drainage to divert surface water run-off away from erodible surfaces.

Instability of embankments and cut batters

Embankment settlement can occur if founded on loose sands, low-density materials and zones of compressible clay/peat comprising the Quaternary alluvium and on recent fill. Similarly there is a high potential for surface movement and subsequent settlement issues if the embankment is founded on high-shrink swell, high-plasticity 'black soils' and residual soils.

Future embankment foundation investigations to identify the presence of these materials will be required to assess differential settlement. Ground improvement measures such as preloading, removal of black soil and liming to improve soil properties can be employed to reduce the risk and impact of embankment settlement.

Batters formed at a slope of 1:1 and cut through erodible soils of the Tertiary sediments around Underwood Road have been subject to slope instability. It is suggested that a slope of 1:4 be used. Where this is not feasible steeper cuts generally require retaining systems ranging from retaining walls to anchoring/soil nailing with shotcreting.

As the materials of the Woogaroo subgroup are dispersive and prone to erosion, cut batter instability is also an issue. Erosion control measures such as shotcreting can be used for steep cuts to improve stability.

Excavation difficulties

Construction of the South East Busway extension from Rochedale to Springwood will involve excavation into soil and variable strength rock. Excavation of the soils and weathered rock is likely to be carried out by conventional earthmoving equipment. However, excavation of less-weathered rocks such as some sedimentary units, and volcanic tuff and basalt is likely to be more difficult. These rocks may require heavy ripping, hydraulic rock breaking equipment or possibly drill-and-blast techniques to excavate.

Any excavation could result in the generation of noise, dust and, if blasting is required, the generation of vibration and fly rock. The drill-and-blast technique may be employed in preference to heavy ripping and hydraulic rock breaking as it is relatively quick and much less intrusive with respect to noise for example.

Management strategies to reduce the effects of blasting include using a blast design with minimal vibration and reduced fly rock, small trial blasts prior to bulk production blast, vibration monitoring and the use of fly rock covers that confine blast rock to a selected work area. There are many ways to reduce overall generation of silt dust and noise during excavation. These include fitting vehicles with silencers, keeping engines properly tuned, the use of water for dust suppression, silt traps to collect run-off, and water baths to clean vehicles when exiting the construction area.

Trafficability on topsoil, 'black soil' and high-plasticity residual soil is expected to be difficult during wet conditions. The use of a trafficable layer and or excavation in drier conditions can be used to solve this issue.

Transportation of excavated and imported materials

Certain materials such as clayey materials, retained from required excavations may not be suitable for reuse during construction — for example, select fill. Alternative fill sources together with disposal areas may need to be found, usually off site, for unwanted excavated soils. The size of these and material cartage method will impact on transport corridors adjacent to the route.

Management strategies to reduce the impact may include processing some or all of the required excavated material to meet tight select fill specification. More detailed studies may establish the most appropriate method of dealing with the excavated material.

Acid sulfate soils

Impacts of soil and groundwater associated with acid sulfate soils arise from the effect of the oxidation products on the water quality in the pore-water, ground water, drainage water and streams. Based on the review of available information it is unlikely that acid sulfate soils constitute a significant potential problem along the extension. Sampling and testing of soils before commencement of construction will identify their presence. There are guidelines and management techniques for dealing with soils that produce acid as a direct result of construction operations.

Contaminated land

Impacts to soil and groundwater associated with contaminated land in general arise from activities undertaken on the land or adjoining properties. The preliminary site history investigation undertaken identified that commercial operations have been undertaken on areas of land within the alignment of the South East Busway extension from Rochedale to Springwood. Commercial operations may have included the storage of liquids. Additional site history information is required and soil sampling and analysis may be required prior to the commencement of construction in order to determine management options.

7.4 Future investigations

Detailed studies and field investigations to clarify the extent of the geological conditions, and to determine the significance and impact of identified geotechnical issues on the South East busway extension are likely to be undertaken in the next phase of the project study. These investigations may require all or some of the following:

- field investigations incorporating test pitting, borehole drilling, cone penetrometer testing and laboratory testing to characterise the subsurface geotechnical conditions in the areas where only limited or no investigation was carried out previously, particularly in areas that are design sensitive such as areas of cut and cover
- review and analysis of future field investigations and previous investigations to determine soil and rock properties for design purposes
- acid sulfate soils testing, spread out along the corridor to determine the extent of possible acid sulfate soils and management strategies
- an additional contaminated land investigation is required within the areas identified to have been used for commercial purposes. The additional contaminated land investigation should include but not be limited to the following:
 - review of historical titles associated with the commercial areas identified
 - site walkover of the commercially developed areas
 - limited soil sampling within the commercially developed areas identified as having a potential for land contamination based on the review of certificate of titles and site walkover.

7.5 References

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