20 Other environmental impacts

20.1 Geology and soils

Geotechnical investigations have been carried out based upon the developing concept design of the proposed upgrade. The purpose of these investigations was to provide technical information on the prevailing ground conditions in the area to assist with route selection and concept design. The investigations were also used to identify geotechnical and soils issues for this environmental assessment.

The geotechnical investigations carried out were undertaken between 2005 and 2007. These investigations comprised a review of existing information, geological and geomorphological mapping, drilling boreholes, excavating test pits, cone penetration testing, seismic surveys, in situ testing, measurement of ground water levels, sampling of soils, rock and ground water and geotechnical laboratory testing on the samples recovered.

20.1.1 Overview of existing geology and soils

Topography

The proposed upgrade crosses the Alstonville Plateau, an area higher than the surrounding regions. The plateau is characterised by low rolling hills which are cut by a number of gullies and valleys. The northern and eastern edges of the plateau are marked by steep hillsides that descend to the coastal plane below.

The proposed upgrade would need to cross a number of creeks. The larger creeks to be crossed include: Emigrant Creek, south of Newrybar; Skinners Creek just north of Broken Head Road; Byron Creek, north of Bangalow Road; and a tributary of Tinderbox Creek, north of Bangalow Road.

Geology and soils

The geological materials that make up the Alstonville Plateau comprise largely basalt rock and soils derived from the basalt. The basalt is known as the Lismore Basalt. It was formed from a series of lava flows from the now extinct Mt Warning volcano about 20 million years ago during the Tertiary Period.

The individual lava flows that make up the Lismore Basalt were formed progressively over a long period of time. Weathering of each new lava flow took place before the next lava flow was formed. This has resulted in each lava flow having different characteristics from those above and below and in some instances has resulted in individual lava flows being separated by soil layers.

Ongoing weathering of the Lismore Basalt since its formation has created a mantle of soils at the ground surface. The character of the soils formed varies depending on the composition of the basalt from which it was derived and the geomorphological processes to which is has been exposed. The published soil landscape map for the area (DNR 1994) indicates three types of soil: residual soils on valley floors and at the base of the northern slopes of the plateau; erosional soils on the rolling hills of the plateau; and colluvial soils on the steep northern and eastern facing slopes at the edge of the plateau. These colluvial soils have been identified as having a mass movement (landslide) hazard.

Below the Lismore Basalt lie a series of sedimentary and metamorphic rocks which are collectively known as the Neranleigh-Fernvale Group. This group of rocks is generally only encountered in deep boreholes and is not known to be exposed at the ground surface of the Alstonville Plateau.

20.1.2 Impact of changes to surface and subsurface conditions

Soft soils

Soft soils are largely absent from the proposed upgrade. However, small areas of soft soil may exist locally, particularly near creeks. The construction of embankments would increase the stress on the soil below. As soft soils are highly compressible, this increased stress would, if not properly managed, lead to significant compression of the soil, settlement of an embankment above and possibly additional loads being imposed on adjacent structure foundations.

Hillsides

The proposed upgrade would need to cross many hillsides. The construction of embankments on hillsides can, if not properly managed, cause changes in the subsurface soil conditions which may lead to instability in an embankment and the soil below. These changes result from the increased stress imposed by the embankment and can lead to the disturbance of the natural drainage pattern within the soil. These changes can be particularly problematic where natural springs or potentially unstable colluvial soils exist.

Cut slopes

The proposed upgrade would require a number of cut slopes to be excavated into hillsides and ridges. Additional cuttings would be required to form the proposed tunnel portals. The deepest of the cut slopes would be about 36 m (subject to detailed design refinements). These would be excavated into a number of different materials including a range of soils and rocks which have been weathered to varying degrees.

Excavating the ground to form cuttings can lead to instability of the ground. This instability could occur both on the hillside immediately above a cutting and within the cutting its self.

The excavation of cuttings below the ground water table may affect the existing groundwater regime by drawing down the water table. These impacts are discussed in greater detail in **Chapter 11 - Groundwater.**

Tunnel

The proposed upgrade includes a section of tunnel beneath St Helena Hill. The tunnel would be excavated within a series of variably weathered and fractured basaltic lava flows of the Lismore Basalt. The maximum cover of soils and rock above the tunnel would be approximately 40 m (subject to detailed design refinements). .

The risk of settlement of the ground surface in response to the excavation of a tunnel below was investigated and found to be low.

The excavation of a tunnel below the groundwater table may affect the existing groundwater regime. Drawdown of the groundwater table could occur if water is allowed to drain into the tunnel. These impacts are discussed in greater detail in **Chapter 11 - Groundwater.**

Contaminated land

An investigation into the potential for contaminated land along or adjacent to the proposed upgrade was carried out. The investigation focussed primarily on agricultural sources of contamination as this was considered the most likely, given the land use in the area.

The proposed upgrade passes near a number of disused cattle tick dip sites. These sites have all been filled and capped. However, if disturbed, these sites could become sources of contamination.

The results of testing for soil contamination resulting from the use of agricultural pesticides and fertilisers were below the existing adopted assessment criteria. It is therefore considered unlikely contaminants are present along the proposed upgrade at levels that could pose a risk to construction workers, road users or the general public.

Acid sulfate soil

Soils that contain sulfate minerals such as pyrite can, when exposed to the air, cause the production of weak acid solutions. These acids may impact on the surrounding environment. Typically, potentially acid sulfate soils are found in low lying areas made up of young estuarine soils. Road construction can cause these materials to be exposed to the air if either the ground water table is lowered or if soils are excavated from below the ground water table and placed above it.

The proposed upgrade does not cross the type of countryside that is normally associated with acid sulfate soils. Consequently the potential for acid sulfate soils is considered to be low. Field and laboratory testing encountered only one location, at Byron Creek, where acid sulfate soil was identified.

The proposed works at Byron Creek comprise the construction of embankments and piling for a bridge across the creek and a railway line. These activities would be unlikely to cause large enough quantities of soil to be exposed to the air for acid to be generated.

Acid sulfate rock

Like soils, some rocks contain sulfate minerals that when exposed to the air can cause the generation of weak acid solutions, which can impact on the surrounding environment. For significant acid generation to occur sufficient quantities of sulfate minerals must exist in the rock and the sulfate minerals must be exposed to the air. The rate of acid generation from a rock is usually considerably slower than that from an acid sulfate soil. The rate of acid generation plays a very significant part in determining whether any significant impact would result.

The vast majority of tests carried out during the investigations indicate that the rock sampled had an acid consuming potential. This means that the rock contains minerals that could actually neutralise acids that they come in contact with. Only one sample identified potentially acid forming rock.

Erosion

Soils and weak weathered rocks may be at risk of erosion if not protected, particularly from concentrated flowing water. Erosion, if not prevented, may in time lead to instability of cut or fill slopes. The eroded material may impair or block drains or, if allowed to escape into the wider environment, cause sedimentation and turbidity in nearby creeks and rivers.

Testing of the clay soils that dominate the proposed upgrade indicate that the soils have a low potential for dispersion (a form of erosion).

20.1.3 Management of impacts

Soft soils

The impact of local areas of soft soils can be successfully managed. The management technique adopted would depend upon the local ground conditions, construction scheduling, and the availability of materials. Where the extent and depth of soft soil is small, it could be partially or totally removed and replaced with a bridging layer of more competent material.

Other techniques exist which could, if necessary, be considered if the soft soil is more extensive or thicker than is currently anticipated. These other techniques typically involve accelerating the consolidation of the soft soil, so that the majority of any expected movement takes place before the road is completed and hence damage is avoided. This outcome can be achieved by surcharging with additional temporary fill and / or the installation of wick drains.

Where unsuitable materials such as compressible top soil or wet softened soil exist beneath a pavement or embankment, they would be removed and where necessary replaced with engineered fill prior to any construction taking place. Excavated top soil would be stockpiled during construction and reused for landscaping.

The expected subgrade materials would generally be suitable subgrade for embankments once unsuitable materials are removed. However, consideration would be given to stability, drainage, moisture content and pavement design.

Bridges, underpasses and culverts would be required at a number of locations along the proposed upgrade.

The settlement of bridge approach embankments in most cases is not expected to be a major issue. However, embankment settlement at the crossing of Tinderbox Creek would be checked as deeper firm soils are anticipated.

Foundations for structures would depend on local ground conditions but at most locations bored cast-in-place piles founded on weathered rock are likely to be feasible. Shallow spread footing may also be feasible where rock is shallow – Emigrant Creek and Watson's Lane. Driven piles may however be more suitable where saturated soils would required the casing of pile bores or where disturbance of soil is to be minimised due to other constraints, like acid sulfate soil – Byron Creek.

Drainage culverts are likely to be feasibly founded on shallow spread footings in stiff soils. Where deep softer soils exist, piled support may be required.

Hillsides

Construction of embankments on hillsides can cause unstable slopes by disturbing the natural soil drainage and by imposing additional stress on soils which may only be marginally stable in the natural state.

These impacts would be managed by the provision of sub-surface drainage and by excavating benches into the soil beneath embankments. Sub-surface drainage would be designed to suit the local conditions and could be provided by a rock fill drainage blanket where springs are found, or by trench or pipe drains.

Cut slopes

Stable cut slopes can generally be formed by designing batters to existing RTA engineering criteria and by taking into account the prevailing sub-surface conditions during the detailed design. Typically, cuts in soils and more highly weathered rock would be cut to 2 m horizontal (2H):1 m vertical (1V). Cuts in material suspected to be derived from old landslides would be excavated to 4H:1V. Cuts in more competent rock would be cut to 1.5H:1V to 0.75H:V depending on local conditions. Cut slopes would be refined in detailed design.

Individual batter heights would be restricted to up to 10 metres in slopes cut to 2H:1V or shallower and 7 metres or less in slopes steeper than 2H:1V. Cuttings which require more than one batter to achieve the design depth would be provided with benches between the batters, these would typically be 4 m wide. The purpose of limiting batter angles and heights is to ensure long term stability of the cutting, reduce the risks of failure and minimise maintenance requirements.

In some locations where sub-surface conditions are adverse, this cut slope geometry design alone may not be sufficient to achieve a stable slope and additional stabilisation measures may be required locally. These additional measures may take the form of rock bolts, wire mesh or shotcrete.

Retaining structures may be required where corridor widths are restricted or where other constraints dictate that the width of the proposed upgrade needs to be reduced. This is most likely at interchanges, bridges and at the proposed tunnel portal. The selection of the type of retaining structure would depend largely on the local ground conditions and space constraints. Reinforced earth walls, gabion walls, crib walls, reinforced concrete gravity walls, soldier pile walls and soil nailed walls are all considered feasible.

At the tunnel portals the cut slope geometry would need to be varied from that used at other cut slopes. A steep angle and increased batter height are likely to be required to maintain the equivalent of at least one tunnel diameter of cover above the tunnel.

Structural support of these portal cuts would be required. Depending on the material in the cut, this support is likely to comprise rock bolts or dowels installed in a regular triangular pattern grid. Areas of lower strength rock would also need to be protected with reinforced shotcrete and the installation of drains.

Tunnel

The rock surrounding the tunnel would need to be supported to prevent collapse. The type and amount of support required would be determined during the detailed design and would depend on the quality of the rock and the method chosen for the construction of the tunnel.

Contaminated land

If cattle tick dip sites are disturbed by construction, further investigation, remediation or disposal to an appropriately licensed landfill of potentially contaminated materials may be required. No cattle dip sites have been recorded within the proposed acquisition boundary. There is however, a small possibility that previously unrecorded cattle tick dip sites may occur. Appropriate induction and management procedures would be implemented as part of the construction environmental management plan, to minimise the risk from disturbance of a site during construction.

If soils are disposed off-site, then routine testing would be undertaken to assess the appropriate waste classification of the soils according to DECC guidelines.

Acid sulfate materials

Potential acid sulfate soils were identified in only one sample at one location - Byron Creek, along the proposed upgrade. They are not anticipated at other locations.

Further testing at this location during the detailed design stage would be carried out to confirm the lateral extent of any potentially acid sulfate soils. An assessment would then be carried out, considering the proposed construction activities, whether an acid sulfate soil management plan is required.

Erosion

The potential for erosion to take place during the construction of the proposed upgrade can be reasonably mitigated by following the guidance given in documents such as Landcom's *Managing Urban Stormwater: Soils and Construction* (2004).

In the longer term soil erosion would be managed by providing vegetation cover to exposed soils.

20.2 Climate change - effect of the proposed upgrade

An assessment of the greenhouse gas emissions associated with proposed upgrade has been carried out to identify the impact of the proposed upgrade on processes affecting climate change.

20.2.1 Assessment approach

Greenhouse gases (GHG) attributable to the proposed upgrade may be assigned as either Scope 1, Scope 2 or Scope 3 emissions depending on their sources. These categories and the likely sources of a result of the upgrade are described in **Table 20.1**.

Table 20.1 - GHG emissions categories

Emission	Definition	Likely sources
Scope 1 emissions	> Direct emissions generated on site	> Construction plant and equipment > Road maintenance plant and equipment > Land clearing
Scope 2 emissions	> Use of steam, heat or power on site where emissions are generated off site (usually in a power plant)	> Electricity use on site office > Electricity use in mechanical and electrical systems including lighting
Scope 3 emissions	> Downstream emissions from supply chain > Upstream emissions from use of product	> Embodied energy in construction materials > Transport of materials to and from site > Embodied energy in maintenance materials > Vehicles travelling on road > Emissions associated with wider development generated by road upgrade

The RTA is likely to be obliged under the National Greenhouse and Energy Reporting Act 2007 to report emissions over which it has operational control (i.e. Scope 1 and Scope 2 emissions). However for the purposes of this development assessment, Scope 3 emissions are also considered where there is a proximate link between the development and the emission source *(Gray v The Minister for Planning,* LEC 2006). The GHG assessment for the proposed upgrade therefore considers the following emission sources for the construction and operational phases of the proposed upgrade.

Construction:

Scope 1 – Fuel use in construction plant and equipment; land clearing.

Scope 2 – Electricity use on site office.

Scope 3 - Embodied energy in construction materials.

Operation:

Scope 1 - Fuel use in road maintenance plant and equipment.

Scope 2 - Electricity use in mechanical and electrical systems including lighting.

Scope 3 - Embodied energy in maintenance materials, vehicles travelling on road.

20.2.2 Greenhouse gas emissions during construction

Scope 1

Fuel use by construction plant and equipment, including consumption and extraction

Fuel use was estimated based the average fuel consumption per kilometre of road constructed on other Pacific Highway Upgrade Program projects. An average fuel consumption of 481 kilolitres of diesel fuel per kilometre was determined (RTA 2007b).

Therefore, fuel consumption for the proposed 17 km upgrade is estimated at 8,177 kL. Direct greenhouse gas emissions based on the calculated fuel consumption would be 22,078 t CO_2-e (carbon dioxide equivalent).

Land clearing

In addition to vehicle emissions, the project would generate emissions associated with land clearing. There are two types of emissions associated with this process. Firstly, the carbon which is currently stored in soil and vegetation is released into the atmosphere. The mechanism for this process would depend upon the ultimate disposal methodology and is essentially a waste related emission. Secondly, the potential of the vegetation to sequester carbon in the future would be affected.

For the purposes of this assessment the waste related emissions have been determined using the Australian Greenhouse Office's (AGO) FullCAM model and the AGO Factors and Methods Workbook (2006). The FullCAM model was used to calculate the quantity of stored carbon based upon the vegetation type and age, the soil type, and land use practices that have been applied. It was also assumed that all vegetation is disposed of to landfill and ultimately vented to the atmosphere as methane which has a global warming potential 25 times that of carbon dioxide. In reality, a proportion of the vegetation would be mulched and used in landscaping. Mulching would increase the aerobic conversion of carbon to carbon dioxide rather than the anaerobic conversion to methane. Furthermore, the fate of methane at landfill sites is dependant on the type of management. Flaring, combusting or composting management techniques would result in conversion of methane to carbon dioxide and a reduction in the equivalent t CO_2-e emitted. For the purposes of this assessment is has been assumed that no flaring or combustion would occur and that all methane is emitted which is considered the worst case scenario.

In addition to the equivalent emissions generated during land clearing, the potential of the cleared vegetation to sequester carbon in the future is also diminished. However, as part of the upgrade, revegetation works would occur within the median strips and road reserve as well as significant environmental enhancement works in strategic locations as part of the remnant land strategy. It is therefore considered that the revegetation works proposed would result in an overall insignificant change and possible improvement in the ongoing carbon sequestration potential within the construction footprint.

Scope 2 and 3

Indirect emissions were also estimated for the construction of the proposed upgrade, in particular emissions associated with the previously estimated diesel use and those embodied in the demand for on-site materials, in particular steel and concrete.

Indirect emissions associated with diesel extraction and supply

Indirect emissions associated with diesel extraction and supply were assessed at a rate of 0.2 kilograms CO2-e per litre (AGO, 2006). This would result in an additional 1,635 t CO_2-e, with a total emission (full fuel cycle) of 23,713 t CO_2-e.

Electricity use

Electricity use is anticipated to be a minor source of emissions and would be associated with lighting and appliance use within site offices. For the purposes of this assessment, it was assumed that two site offices equipped with computers, air conditioning, refrigeration, kitchen appliances, fluorescent and security lighting would be operating over a 150 week construction period purchasing electricity from the grid. This gives total GHG emissions of 32 t CO_2-e (using a full fuel cycle emission factor incorporating including emissions associated with transmission and distribution, fuel extraction and production).

Embodied energy in material

Greenhouse gas emissions associated with embodied energy in concrete, steel, asphalt, bitumen and steel were calculated using the RTA's *Carbon Estimation Tool for Road Construction Projects*.

Construction quantity estimates and associated embodied greenhouse gas emissions are shown in **Table 20.2** below.

Table 20.2 - GHG emissions from embodied energy in materials

Material	Quantity (tonnes)	GHG emissions (tCO2e-)
Cement	81,553	76,660
Fly ash	27,169	270
Aggregate	217,625	1,740
Sand	113,994	910
Steel (reinforcement)	12,090	28,170
Asphalt	53,653	2,150
Bitumen	1,191	60
	TOTAL	**109,960**

Transport to and from site

Fuel use for the transportation of materials to site was estimated based on the construction quantity estimates above, the likely trip length, the number of loads and rate of fuel combustion of trucks. This resulting GHG emissions were then calculated using the RTA's *Carbon Estimation Tool for Road Construction Projects* using a full fuel cycle emission factor. This results in 885 t CO_2-e.

Transport of construction and demolition waste from site to landfill would be minimised to the extent possible by maximising re-use on site and recycling. Emissions associated with this transportation have therefore been excluded from the assessment.

Summary of construction emissions

A summary of the GHG emissions associated with the construction period is presented in **Table 20.3.**

Table 20.3 - GHG emissions during construction period

Source	GHG emissions (t CO2-e).
Fuel use (including diesel extraction)	23,713
Land clearing	58,300
Electricity	32
Embodied energy	109,960
Transport to site	885
TOTAL	**192,890**

20.2.3 Greenhouse gas emissions during operation

Scope 1

Fuel use in road maintenance plant and equipment

While road maintenance activities constitute direct emissions, such emissions are considered to be very minor compared with the high traffic volumes expected. Furthermore, as a result of the upgrade, ongoing maintenance is anticipated to decrease compared to the base case (no build) scenario. These emissions have therefore been excluded from the assessment.

Scope 2 and 3

Embodied energy in maintenance materials

Similarly, embodied energy in maintenance materials would constitute a relatively small source of operational emissions compared with the high traffic volumes. The quantity of material required for ongoing maintenance of the highway is also likely to decrease as a result of the upgrade compared to the base case (no build) scenario. These emissions have therefore been excluded from the assessment.

Electricity use in lighting and other mechanical and electrical systems

The upgrade would require the installation of lighting systems including street lighting, tunnel lighting and variable message signs. It is assumed that all of these systems would be powered from mains electricity. In reality, there are likely to be opportunities for some of these systems to be solar powered. Solar powered devices would have zero associated greenhouse gas emissions and would be adopted where possible.

The upgrade would require the operation of a new street lighting system. For the purposes of this assessment, the GHG emissions associated with street lighting were calculated using the AGO's Public Lighting Calculator and the AGO Factors and Methods Workbook. It was assumed that the upgrade would require the installation of approximately 210 street lights at interchanges (Ivy lane interchange, Bangalow interchange, Ewingsdale interchange and parts of Ross Lane interchange) at the on / off ramps, local roads in the vicinity of the interchanges only and on the main carriageway for a length of 300 m past the connection point at 50 m spacings. For the purposes of this assessment the lights were assumed to be 400 W High Pressure Sodium lights.

The tunnel lighting requirements would be determined during detailed design to meet the International Commission on Illumination (CIE) guidance for the lighting of roads, tunnels and underpasses (CIE 88-1990) This requires detailed consideration of the level of light outside and on the point inside the tunnel at which visual adaptation of drivers must occur as they pass through the various lighting zones (threshold zone transition zone, interior zone and exit zone). For the purposes of this assessment lighting requirements were estimated based on typical lighting requirements for similar length tunnels including:

> 94 × 400 W lamps within the threshold zones.
> 44 × 250 W lamps within the transition zones.
> 271 × 100 W lamps within the interior zone.

Two 1 kW variable message signs would also be installed at either end of the tunnel and would operate for 24 hours a day.

The combined GHG emissions from lighting sources are presented in **Table 20.4**. This assumes that the electricity is purchased from the grid.

Table 20.4 - GHG emissions associated with lighting systems

Item	Annual energy consumption (GJ/year)	GHG emissions (t CO2-e/year)[1].
Street lighting	1,444	425.9
Tunnel lighting	256	75
Variable Message Signs	63	18.6
Total	**1,251**	**519.5**

[1]. Full fuel cycle emissions including transmission and distribution, fuel extraction and production

There are a number of other mechanical and electrical systems whose operation would result in GHG emissions including CCTV, communication systems and ventilation systems in the tunnel for emergencies. The energy and GHG emissions associated with these systems is anticipated to be minor compared to other emission sources and have not been included in the quantitative assessment.

Vehicles travelling on road

To assess the GHG emissions as a result of the use of the road by vehicles a comparison of the base case (no build) was made against the operation of the proposed upgrade.

GHG emissions were calculated for both cases over a 30 year period from 2012 to 2041 (30 years from opening) using RTA's REVS software. This software predicts the overall diesel and petrol consumption taking into account urban conditions, road conditions and fleet growth predictions. The overall fuel consumption estimate for diesel and petrol was then used to determine an estimate of greenhouse gas emissions. An analysis of the traffic model shows that the proposed upgrade is anticipated to reduce travel times through a reduction in highway length, as well as by bypassing steep grades and circuitous sections of the existing highway and therefore reduced GHG emissions associated with vehicles travelling on the road.

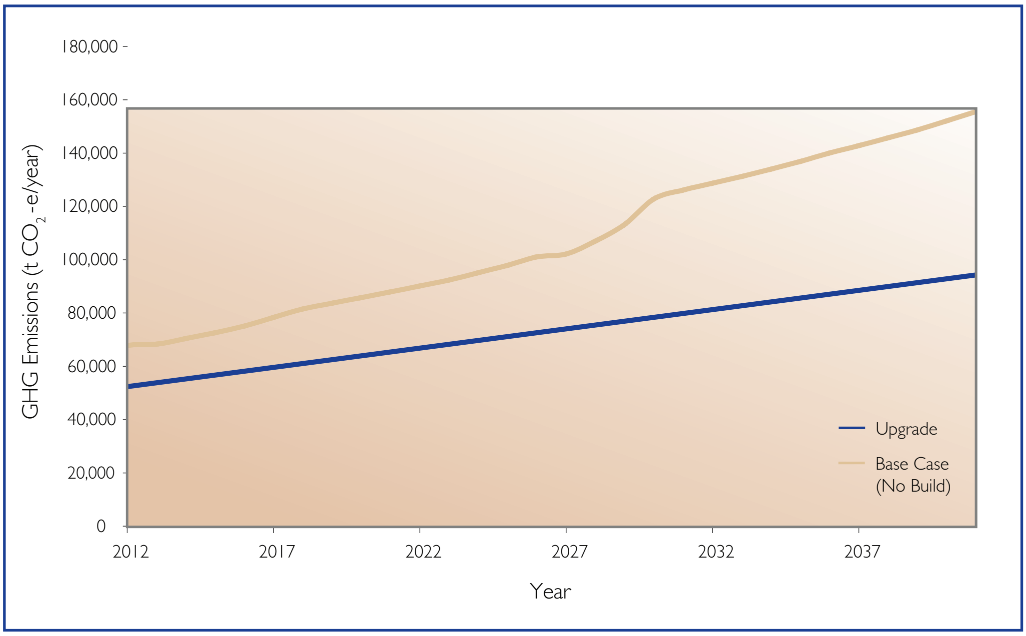
The results of the GHG savings are shown in **Table 20.5** and **Figure 20.1**.

Table 20.5 - GHG emissions attributed to vehicles travelling on road

GHG emissions (t CO_2-e)				
	2012	2041	Total (30 yr period)	Annual Average
Base Camp (no build)	68,100	155,600	3,235,500	107,900
Proposed upgrade	52,300	94,000	2,185,700	72,900
Saving	15,800	61,600	1,049,800	35,000

1. Full fuel cycle emissions including transmission and distribution, fuel extraction and production

Figure 20.1 - GHG emissions for vehicles travelling on the road network



The proposed upgrade is anticipated to reduce greenhouse gas emissions by around 15,800 t CO_2-e in 2012, rising to a reduction of 61,600 t CO_2-e in 2041.

The traffic model considers vehicle travel for the network based on historical trends and expected fleet growth as well as an additional growth factor for directed and induced travel from as a result of the entire PHUP.

The model does not account for changes to travel patterns for such varied reasons as other road network upgrades or issues, provision of public transport alternatives and cycleway, changes to road user behaviour (for example, those resulting from fuel prices), changes to technology, or the introduction of different vehicle types. Furthermore the conversion of fuel to GHG emissions assumed that there would be no change in fuel types or greenhouse intensity over the 30 year period and hence did not take into account increased uptake of renewable fuels, or improvements in vehicle efficiency. These would affect the absolute GHG emission savings but since such changes would occur regardless of whether the proposed upgrade goes ahead, the relative fuel savings would not be affected.

Emissions associated with wider development

The improvement in travel time along the proposed upgrade itself is not considered significant enough so as to promote development within its immediate vicinity. However the Pacific Highway Upgrade Programme (PHUP) cumulative improvement in travel time may result in increased residential, commercial and/or industrial development accessing the highway. Therefore GHG emissions associated with the construction and operation of such developments may be in some part attributable to the PHUP. However, the drivers for such developments incorporate many different factors not related to the PHUP. Therefore associated emissions are extremely difficult to quantify and have not further been considered in this assessment.

Notwithstanding, the directed and induced traffic along the highway as a result of the entire PHUP has been incorporated into the assessment of emissions associated with vehicles travelling along the road.

20.2.4 Cumulative impacts

Cumulative greenhouse gas emissions for the project were calculated for each year over the 30 year period as follows

$$E_i = E_{c_t} + ixE_{L_i} - \sum_{1}^{i} E_{s_i}$$

E_i - Cumulative GHG emissions at year i

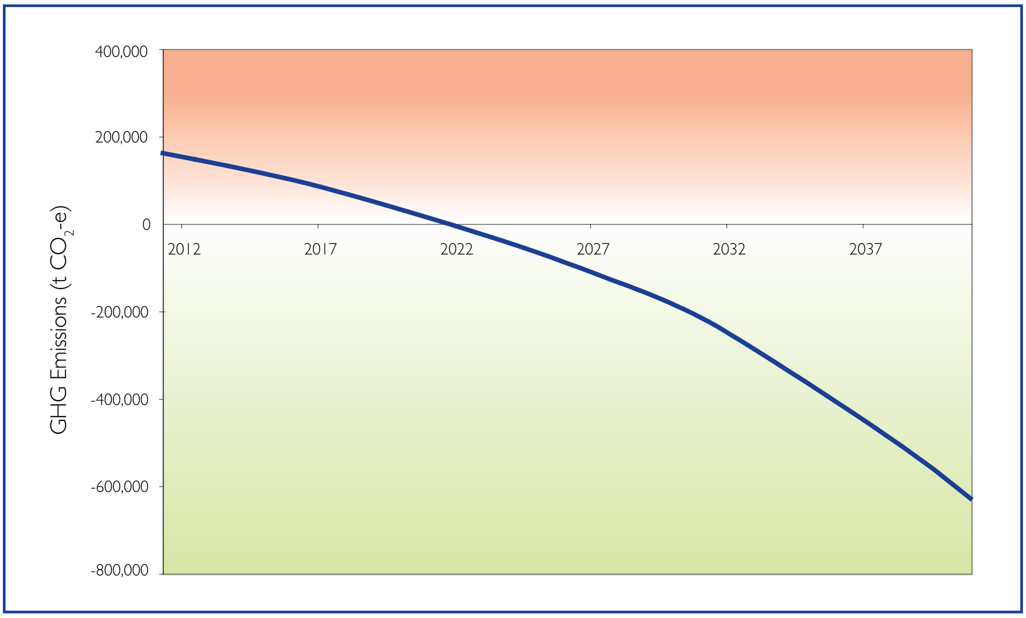
E_{c_t} - Total construction GHG emissions

E_{L_i} - GHG emissions attributable to lighting for year i

$\sum_{1}^{i} E_{s_i}$ - Sum of GHG emission savings from year 1 (2012) to year i.

The overall impact can therefore be established as shown in **Figure 20.2**

Figure 20.2 - Cumulative GHG emission impact and payback period



Based on the method applied, the proposed upgrade would result in annual greenhouse savings, with a net saving or break-even reached in 2022 when the emissions generated during construction would be offset by the operational savings. Over the project life, (i.e. by 2041), cumulative savings are expected to be in the order of 800,000 t CO_2-e.

20.2.5 Management measures

Greenhouse gas emissions can be reduced at both the construction and operational stages of the proposed upgrade. At the construction stage, the following management measures would apply:

- Assess energy (fuel/electrical) efficiency when selecting equipment.
- Maintain equipment to retain high levels of energy efficiency.
- Where feasible, use biofuels (biodiesel, ethanol, or blends such as e10 and b80), to reduce greenhouse gas emissions from construction plant and equipment.
- Minimise vegetation clearance as far as possible and replant vegetation where feasible.
- Where feasible, mulch cleared vegetation for re-use on site.
- Revegetate cleared areas to the extent feasible.
- Use local materials and local staff wherever possible, to reduce transport-related emissions.
- Use recycled materials, for example replacing cement with fly ash, using recycled aggregate, and recycled content in steel, to minimise the lifespan impact of greenhouse gas emissions in production. This would be undertaken where feasible and reasonable, in line with the RTA's specifications, particularly 'design, construct, maintain' requirements.

During the operational phase, fuel consumption of motor vehicles is directly proportional to emissions of carbon dioxide and other greenhouse gases from motor vehicles. Emissions cannot be reduced by control technologies, except where they result in improved fuel consumption. RTA programs that encourage better vehicle maintenance and, therefore, improved fuel economy, would be beneficial in reducing fuel usage and greenhouse gas emissions. Any programs that otherwise reduce fuel use would also be encouraged, such as clear signage, provision of facilities that encourage public transport use, solar powered telephones and lighting and maintenance of a quality road surface.

In addition, an energy audit for the street lighting system would be conducted in accordance with AS/NZS 1158.1.1:2005. The purpose of the audit would be to demonstrate that the design of the lighting scheme has minimised the life cycle energy of the scheme, commensurate with reliability and cost.

20.3 Climate change - effect on the proposed upgrade

The effects of climate change on the proposed upgrade can be assessed in terms of:

- Sea level rise and storm surges.
- Weather changes.
- Storm intensity and flooding.

Sea level rise and storm surges are not relevant to the proposed upgrade due to its elevation above seal level. The remaining two factors are however discussed below.

Climate change has the potential to change weather patterns for the study area. This could be in the form of temperature increases and higher winds. The Commonwealth Scientific and Industrial Research Organisation (CSIRO), in conjunction with the Bureau of Meteorology, has published a technical report titled *Climate change in Australia: technical report 2007*.

In this report, the best estimate for temperature change in Australia is warming of between 0.7 and 1.2 degrees Celsius by 2030, depending on the location. Coastal regions are not expected to warm to the same degree as inland areas. An increase of extreme temperatures (hot days and warm nights) is predicted (CSIRO and BoM 2007).

Climate change could also lead to an increase in the intensity of rainfall events. Essentially, this would mean that the rainfall expected to occur in a 1 percent annual exceedance probability (AEP) flood event would occur more frequently. Rainfall projections and intensity have also been included in the CSIRO report and a number of scenarios can be accessed at the climate change website (http://www.climatechangeinaustralia.gov.au/index.php) with variable emission levels and for different future years. By selecting annual changes for 2030 and assuming low emission levels, the changes in rainfall pattern for the area of the proposed upgrade could vary from -10 to +5 percent relative to the 1990 baseline (CSIRO and BoM 2007).

There is still a large fluctuation in data, which makes it difficult to provide any solid conclusions on the expected increases in rainfall intensity. However, in terms of the impact on the proposed upgrade, it could mean that the design immunity of the road (currently beyond 1 percent AEP) would reduce as a consequence. It is not possible to quantify this potential effect.

Given the high level of flood immunity associated with the proposed upgrade, any disruption to the proposed upgrade in terms of flooding is likely to remain highly infrequent.

The uncertainty surrounding climate change impacts and the likelihood that current management measures would be adequate for a considerable period of time, suggests that an adaptive management strategy would be appropriate to ensure that the proposed upgrade is not unexpectedly affected by climate change. Ongoing monitoring of storm frequency and intensity, and other weather changes would allow changes to the hydrologic and water quality management to occur in the future as needed. This would have the added benefit of utilising the best available technology at the time it is needed.

20.4 Non-indigenous heritage

Non-Indigenous consultation

In response to the publication of the *Route Options Development Report* (RTA 2005) and *Preferred Route Report* (RTA 2006a), a number of submissions were received from individual landowners who drew attention to items that they felt had local heritage significance. The project team reviewed these submissions and on occasion Navin Officer Heritage Consultants visited the respective landowners to confirm the significance of the items. In some cases this allowed the project team to include items of low local significance in the assessment of the proposed upgrade.

Additionally, information relating to the presence and location of non-Indigenous sites and heritage values was collected during the community consultation program and incorporated as applicable into this assessment. Inputs were provided through:

- > Contributions from the corridor assessment workshop (July 2005) and value management workshop (December 2005).
- > Landowner meetings following the Route Option Development Report (October 2005) as noted above.
- > Phone consultation and on-site liaison with land-owners prior to and during the archaeological field survey of the preferred upgrade route.
- > Representatives from the Ballina and Byron Shire councils attending various community and stakeholder consultation forums.

Recording parameters – Non-Indigenous heritage

Non-Indigenous heritage relates to a period during and following contact between Aboriginal and European or Southeast Asian peoples. The identification and assessment of non-indigenous cultural heritage in Australia is primarily an exercise that draws upon historical archaeology, documentary and data records, and oral history.

In the context of the proposed upgrade an historical archaeological site may fall into domestic, agricultural, transport, commercial and industrial categories.

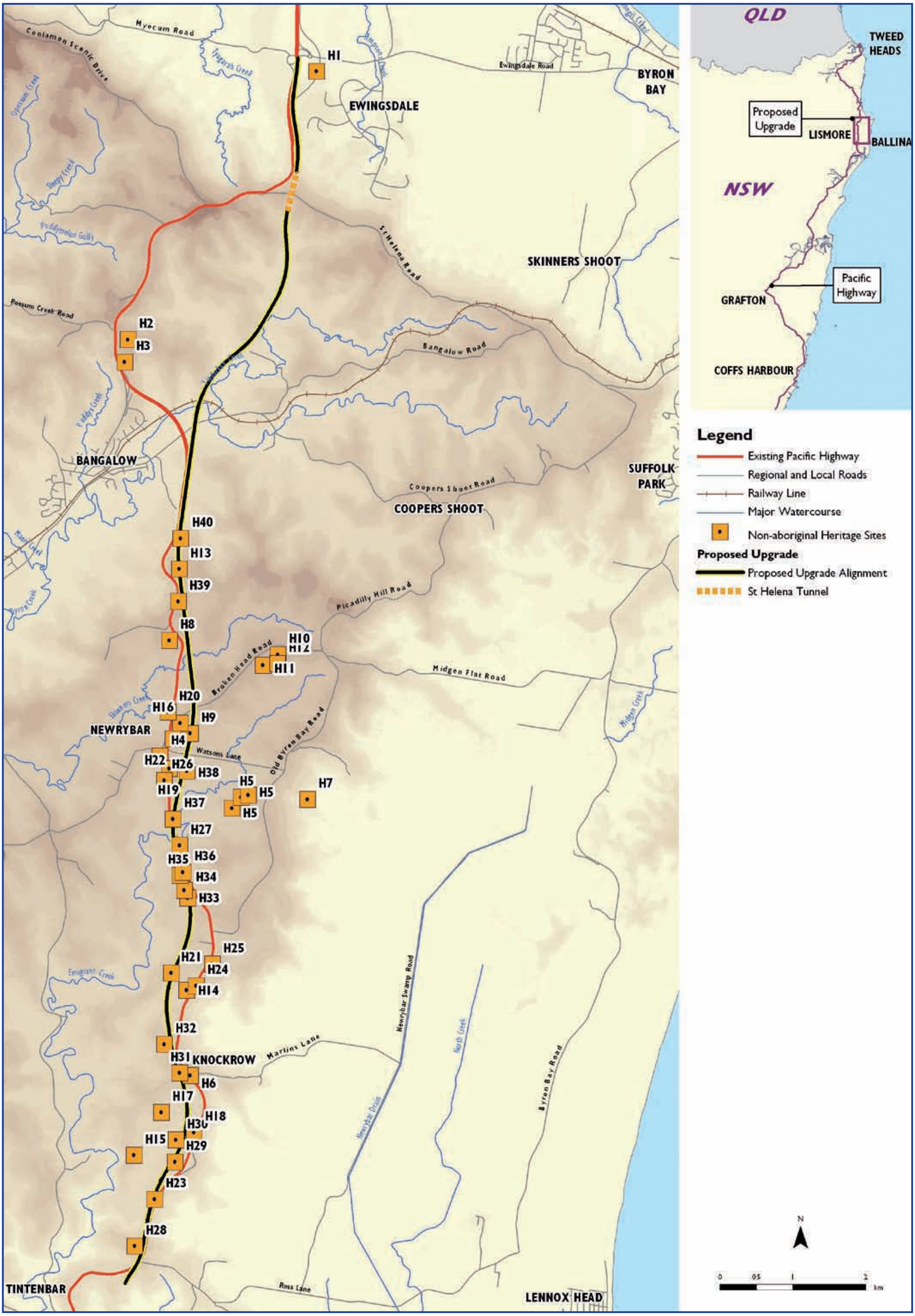
20.4.1 Existing non-Indigenous heritage conditions

None of the heritage recordings within the area of the proposed upgrade appear on Commonwealth government heritage registers, the NSW State Heritage Register, the current heritage schedules on the Ballina or Byron Local Environmental Plans, or the North Coast Regional Environmental Plan 1988. During April 2007 and previous surveys for the project 18 non-indigenous sites were recorded. A brief description of the sites is provided in **Figure 20.3** while their location is shown**.** A full description of the sites is provided in *Working Paper 9 - Cultural Heritage Assessment.*

Table 20.6 - Non-Indigenous cultural heritage recordings

Site ID	Site description
T2E H9	Cricket pitch and ground.
T2E H13	Arundel farm complex and plantings.
T2E H18	Former Knockrow School site and teachers residence.
T2E H21	Corn-Brae Lodge.
T2E H23	Weatherboard house.
T2E H28	Fig tree.
T2E H29	Forestry stump.
T2E H30	Derelict farm building – possible former dairy.
T2E H31	Remnant yards and two rail fencing.
T2E H32	Weatherboard cottage.
T2E H33	Weatherboard cottage.
T2E H34	Site of former dairy.
T2E H35	Family memorial.
T2E H36	Property entrance.
T2E H37	Car remnants.
T2E H38	Tree plantings.
T2E H39	Scatter of glass and ceramic fragments.
T2E H40	Concrete floor and footings.

Figure 20.3 - Non-Indigenous cultural heritage recordings



The methodology used to assess the cultural significance of non-Indigenous items and places follows that defined by the NSW Heritage Office. The heritage assessment criteria are those set out for listing on the State Heritage Register. A full description of the methodology and assessment criteria and how they apply to each site is provided in *Working Paper 9 - Cultural Heritage Assessment.*

20.4.2 Impacts to non-Indigenous heritage

A summary of the heritage significance and extent of impact to non-Indigenous sites is provided in **Table 20.7** below.

Table 20.7 - Impact to non-Indigenous heritage sites

Site ID	Site type	Heritage significance	Development impact
T2E H9	cricket pitch and ground	Below threshold	Direct impact on the pitch and roller location, the fig tree is located 40 west of a proposed fill embankment and there is potential for the retention of the fig tree, alive and in situ within the highway easement
T2E H13	Arundel farm complex and plantings	Moderate, local	Direct impact on whole complex
T2E H18	Former Knockrow School site and teachers residence	Moderate, local	Not affected, either directly or by property acquisition
T2E H21	Corn-Brae Lodge	Below threshold	The western cottage will be directly affected, the eastern and older cottage will not be directly affected or subject to property acquisition
T2E H23	Weatherboard house	Moderate, local	Direct impact
T2E H28	Fig tree and reported location of milk bottlery	Below threshold	Direct impact to most of reported site area, there is potential for fig tree to be retained, live and in situ within highway easement
T2E H29	Forestry stump	Below threshold	Cut and fill would occur in close proximity to tree, there may be potential for tree to be retained, live and in situ within highway easement
T2E H30	Derelict farm building	Moderate, local	Structure occurs 18 m west of a proposed service road, and would be affected by property acquisition, there is potential to retain structure within highway easement
T2E H31	Remnant yards and fencing	Below threshold	Direct impact
T2E H32	Weatherboard house	Moderate, local	Not directly affected or subject to property acquisition
T2E H33	Weatherboard cottage	Below threshold	Direct impact
T2E H34	Site of former dairy	Below threshold	Direct impact
T2E H35	Family memorial	Below threshold	Direct impact on memorial and all but the far western end of tree plantings
T2E H36	Property entrance	Below threshold	Direct impact
T2E H37	Car remnants	Below threshold	Direct impact
T2E H38	Tree plantings	Below threshold	Not directly affected or subject to property acquisition
T2E H39	Scatter of glass and ceramic fragments	Below threshold	Not directly affected, but in close proximity to construction zone, and subject to property acquisition
T2E H40	Concrete floor and footings	Below threshold	Direct impact

Only two sites above the heritage significance threshold will be directly affected (that is destroyed) by the construction of the proposed upgrade. These sites are The ***Arundel*** farm complex (T2E H13) and a weatherboard house (T2E H23).

Cumulative impacts

With regard to non-Indigenous heritage items, the agricultural lands affected by the proposed upgrade do not display any degree of rarity or representativeness which are of higher value than the majority of the adjacent plateau lands.

Relative to surrounding lands the attrition or deterioration of heritage items does not appear different The economic effect of the existing highway may have acted to increase the rate of demolition and renewal of structures through higher property values and commercial potential, which may lead to fewer surviving heritage items than in areas with lesser access. The surviving resource is typified by early twentieth century pastoral and horticultural site types and dominated by dairying residential infrastructure. All of these site profiles can be expected to be well represented elsewhere across the plateau lands.

The proposed upgrade would directly affect on two sites classified as having heritage significance (moderate significance in the local context). Recognising this and aspects outlined above, it is determined that the level of impact, when combined with the conduct of the proposed cultural heritage management strategies (Section 16.5) will not be substantial.

20.4.3 Management of impacts

The following management measures would be undertaken in relation to non-Indigenous heritage.

> An archival recording of sites H13, 23 and 30 would be conducted, consistent with the standards and guidelines published by the NSW Heritage Office prior to the commencement of any demolition and construction works.

> An assessment of the viability of a conservation management strategy for site H30 would be conducted and a decision made and followed regarding an appropriate management strategy.

> Provision would be made for the potential salvage of timbers and other architectural elements for adaptive reuse, during and following the demolition of sites H13 & 23, (and from H30 in the event that conservation is considered to be unviable).

> An archival record of limited scope would be conducted at sites H9, 21, 31, 33 & 40 prior to the commencement of any demolition and construction works. Such a record may consist of annotated photographs and descriptive notes where necessary.

> Where feasible, consideration would be given to retaining the trees alive and *in situ* at sites H28 and 29.

> The concrete grass roller at the former Newrybar cricket ground (H9) would be recovered and placed with an appropriate local institution, historical society, or repositioned in an appropriate local public space.

> The remnants of old agricultural machinery around the western *Corn Brae* cottage (H21) would be recovered and repositioned.

> If still present at the time of acquisition, the private family memorial (H35) and iron fencing within the property entrance at H36 would be carefully recovered and returned to the current property owners.

- In the event that there is an assessed risk of accidental damage from construction works to sites H18 and 32, then a temporary fence would be erected between the site and area of construction for the course of the construction period.
- Protocols which specify the required actions in the event of the discovery of previously unrecorded non-indigenous relics (including human remains) would be established and followed for the period of construction works.

20.5 Hazards

The environmental risk assessment summarised in **Chapter 8 - Environmental risk analysis** regarded hazards as environmental risks associated with transport or storage of dangerous goods, as well as broader traffic safety issues. It can also refer to risks to the operation or construction of the proposed upgrade due to natural events such as floods.

These hazards are addressed in a number of different chapters within the environmental assessment. The risk of spills associated with transport and storage of dangerous goods is discussed in **Chapter 10 – Water quality**. Flooding risk is discussed in **Chapter 9 – Hydrology**. Traffic safety issues are discussed in **Chapter 13 – Traffic**.

20.6 Resources and waste

The environmental risk assessment summarised in **Chapter 8** identified a number of issues under the heading of resources and waste. These included adequacy of the supply of construction resources, waste produced during construction (including excess fill material), and greenhouse gas emissions during construction and operation.

The supply of construction resources and disposal of excess material are discussed in **Section 6.5**. Greenhouse gas emissions during construction and operation are discussed in **Section 20.2.**