8 Geology, Contaminated Land and Groundwater

This chapter identifies and describes the existing geology, contaminated land and groundwater within the study area. It assesses the impacts of the proposed scheme on these features and outlines measures for avoiding or mitigating these impacts wherever possible.

Within the study area, there are three geological/geomorphological Sites of Special Scientific Interest (SSSI). Several potential sources of contamination have been identified within the study area (including made ground, former landfills, backfilled quarries, waste treatment facilities, rail, former mining and industrial facilities). Baseline groundwater quality is of poor quality in places, mainly in the south. An aquifer of medium sensitivity has also been identified with a moderate yielding potential, as well as some private water supplies (PWS).

The Firth of Forth SSSI is not at risk from a geological point of view. Reprofiling of Ferry Hills SSSI rock cuts will require careful mapping of fracture networks and application of SNH recommendations, but residual impacts are assessed as Slight. At St. Margaret's Marsh SSSI, constructing the road embankment with permeable material to allow sub-surface and runoff flow and installation of a monitoring network both prior to and during construction will significantly reduce impacts to Slight significance.

The absence or presence of shallow former mining is currently being investigated. If required, stabilisation works will be undertaken and no residual impacts are anticipated.

A number of land contamination issues have been identified which will require mitigation, the detail of which may need to be adjusted once all GI data have been made available and risk assessments have been undertaken. The residual risk with mitigation is Very Low to Low.

Groundwater supplied PWS at potential risk will be surveyed and if required groundwater flow and quality monitoring will be installed in selected areas, or alternative supplies will be provided. The residual significance of impact is Negligible/Slight. It is also proposed that the road drainage/treatment systems will be lined in areas sensitive aquifers or nearby PWS, resulting in Negligible/Slight residual impacts.

During construction, there will be a need to discharge intercepted groundwater, which could pose a risk to the water environment. The 2009 GI is currently being assessed and the output will be used to inform Contractors and ensure that appropriate measures are put in place.

The proposed mainline road cutting to the southeast of South Queensferry is likely to generate a local groundwater drawdown which could result in settlement and impact on adjacent properties. The 2009 GI will provide further information to inform the detailed design, and condition surveys and monitoring of buildings and groundwater level will be put in place if required resulting in a residual impact of Negligible/Slight significance.

8.1 Introduction

8.1.1 This chapter presents the assessment of the proposed scheme in terms of geology, land contamination and groundwater issues. The chapter is supported by the following appendices, which are cross-referenced in the text where relevant:

- Appendix A8.1: Land Contamination Assessment; and
- Appendix A8.2: Private Water Supplies (PWS) Assessment Criteria.

8.1.2 Road schemes can have potentially adverse impacts on the geology, land contamination and groundwater, as summarised below.

8.1.3 Excavating or masking exposures of rocks or superficial geological deposits of particular scientific interest can represent an adverse impact if the features of interest are not reproduced elsewhere in the area. Impacts can also include restrictions on existing or potential commercial exploitation of resources. Another potential issue is that ground conditions can also impose constraints on a proposed road scheme, for example, where land has become unstable due to mining or has been contaminated by previous land uses.

8.1.4 There is an inherent risk of spillage or leakage of fuel or oil from storage tanks or construction plant. Without suitable mitigation measures, these pollutants could enter the aquifers and degrade

water quality. Similarly, once a new road is opened, runoff from the surface may contain elevated concentrations of pollutants such as oils, suspended solids, metals and in winter, salt and engine coolants (e.g. ethylene glycol) which may find their way into the groundwater system.

8.1.5 Construction works involving excavation can lead to dewatering and also to contamination of drift and bedrock aquifers.

8.1.6 This chapter presents the following:

- baseline conditions within the study area relating to solid and drift geology, mineral extraction, contaminated land, groundwater and location of private water supplies;
- potential impacts of the proposed scheme with regard to the identified baseline conditions;
- mitigation measures in order to prevent, reduce or offset the potential negative impacts of the proposed scheme; and
- a summary of the residual impacts taking into account proposed mitigation.

8.1.7 This assessment has been undertaken using the guidance contained in DMRB Volume 11 'Geology and Soils' (Highways Agency et al., 1993), taking into account updated guidance on contaminated land risk assessment where appropriate.

8.2 Approach and Methods

8.2.1 The assessment covers a study area, in terms of distance from the centreline of the proposed scheme, which is specific to each assessment category:

- 250m study area for geology and contaminated land; and
- 800m study area for groundwater resources and private water supplies (PWS).

8.2.2 The assessment has been undertaken for the following aspects of ground conditions:

- solid and drift geology;
- features of geological and geomorphological importance;
- mineral extraction and reserves;
- contaminated land, water and gas issues;
- groundwater environment; and
- groundwater PWS.

8.2.3 The assessment includes consideration of impacts on peat deposits as part of the assessment of drift geology. Agricultural soils are also considered sensitive and can deteriorate as a result of disturbance during construction, and their subsequent storage/reuse. Measures to address this issue are considered in the context of short-term and long-term impacts on agricultural land capability in Chapter 19 (Disruption Due to Construction) and Chapter 7 (Land Use) respectively. Other soils are not considered sensitive to impacts from this type of development and were therefore scoped out of the assessment.

8.2.4 Surface water supplies are assessed and reported in Chapter 9 (Water Environment).

Baseline Conditions

8.2.5 Baseline conditions were determined though a desk-based assessment, field surveys and consultation with statutory and non-statutory bodies.

Desk-based Assessment

8.2.6 The desk-based assessment included a review of the following information:

- British Geological Survey (BGS) data including BGS Drift and Solid Geological Maps, BGS Hydrogeological and Groundwater Vulnerability Maps;
- Department of Environment Industrial Profiles and Contaminated Land Report (CLR) 8 (DEFRA, 2002) to identify the character of potentially contaminated land;
- Ordnance Survey (OS) historical maps dating back to 1856 for information on former land use, any potential contamination and physical hazards and information on private water supplies;
- Scottish Environment Protection Agency (SEPA) Groundwater Vulnerability Maps (available at www.sepa.org.uk);
- Scottish Natural Heritage (SNH) designation database (SNH, 2008);
- previous reports commissioned by Fife Council on the St. Margaret's Marsh area for information on previous land use in the area (Envirocentre, 2003; Envirocentre, 2004; Environ 2007);
- results of previous studies including the Forth Replacement Study Initial Desk Study Report December 2007 (Jacobs/AECOM/Faber Maunsell, 2007); and
- Geological Conservation Review (GCR) database (JNCC, 2009).

Field Surveys

8.2.7 Field surveys were undertaken at specific locations within the study area, on the basis of the findings of the desk-based assessment. The surveys undertaken include:

- contaminated land site reconnaissance to identify any additional areas of potential contaminated land and to clarify current land use as identified from historical maps;
- geological site reconnaissance to identify any potential areas of geological/geomorphological importance and identify any in-filled quarry areas;
- hydrogeological survey to gather information relating to sensitive areas potentially supplied by groundwater within the vicinity of the proposed options and to record any features that may provide further information with regard to the importance of the quality and supply of groundwater in these areas; and
- walkover at St. Margaret's Marsh.

Consultations

8.2.8 Consultations were undertaken with a number of statutory and non-statutory bodies to inform the assessment of geological and hydrogeological impacts and to identify contaminated land. These included the following:

- BGS for information regarding the nature of geology and hydrogeology in the near vicinity of the proposed route options;
- Coal Authority for information on past, current and potential future mine workings within the route corridor and how they may affect future development;
- Fife Council, City of Edinburgh Council and West Lothian Council for information on former contaminated land use, Part IIA determinations, private and public water supplies, licensed fuel storage and any additional relevant information; and
- SEPA and SNH for information on the location and extent of environmental or historical sensitivities in the vicinity of the proposed route options and to establish any future development constraints.

Ground Investigations (GI)

8.2.9 Detailed land ground investigation (GI) took place in 2008, targeting areas that could be affected by the proposed scheme in the north and the south of the Firth of Forth, depending on the design. This 2008 GI consisted of gathering site specific geological descriptions, as well as sampling soil and groundwater for geotechnical testing and contaminants analysis and gas and groundwater level monitoring.

8.2.10 A detailed marine GI was also carried out in the Firth of Forth and consisted of sediment sampling and bedrock characterisation.

8.2.11 The results of the 2008 marine and terrestrial GI were reviewed to inform this Stage 3 assessment. It is considered that the results from these 2008 investigations provide sufficient information for this Stage 3 assessment.

8.2.12 As ongoing development of the scheme proposals altered the land that may be affected from that surveyed in the 2008 GI, an additional round of GI was undertaken in summer 2009 (referred to as 2009 GI). At the time of completing the ES, the 2009 GI results were still being assessed and are therefore not included in this assessment. This additional GI is however referred to in the mitigation section of this assessment as it will inform aspects such as the detailed design.

Impact Assessment

8.2.13 In accordance with the general approach set out in Chapter 5 (Overview of Assessment Process) and as described below, the significance of impacts on geology/geomorphology and contaminated land has assessed taking into account receptor sensitivity and impact magnitude.

Solid and Drift Geology

8.2.14 For the purposes of this assessment, the sensitivity of geological features of interest within the study area is defined for drift geology, solid geology and features of geological interest. Assessment was undertaken by applying the sensitivity and magnitude criteria given in Tables 8.1 and 8.2. The impact significance was then determined using Table 8.3.

Table 8.1: Sensitivity Criteria - Geological Features

Sensitivity	Description
High	Areas containing unique or rare geological or geomorphological features considered to be of national interest. e.g. Sites of Special Scientific Interest (SSSI).
Medium	Areas containing features of designated regional importance considered worthy of protection for their educational, research, historic or aesthetic importance. e.g. Regionally Important Geological Sites (RIGS).
Low	Features not currently protected but that may require specific protection in the future e.g. Geological Conservation Review (GCR).
Negligible	Features not currently protected and unlikely to require specific protection in the future.

Table 8.2: Magnitude Criteria - Geology

Magnitude	Description
High	Partial (greater than 50%) or total loss of a site, or where there would be complete severance of a site such as to affect the value of the site.
Medium	Loss of part (between approximately 15% and 50%) of a site, major severance, major effects to the setting, or disturbance such that the value of the site would be affected, but not to a major degree.
Low	Minimal effect on a site (up to 15%) or a medium effect on its setting, or where there would be a minor severance or disturbance such that the value of the site would not be affected.
Negligible	Very slight change from baseline condition. Change hardly discernible, approximating to 'no change' conditions.

Table 8.3: Matrix for Determination of Impact Significance – Geology

Sensitivity / Magnitude	Negligible	Low	Medium	High
High	Slight	Moderate	Moderate/ Substantial	Substantial
Medium	Negligible/ slight	Slight/Moderate	Moderate	Moderate/Substantial
Low	Negligible	Negligible/Slight	Slight/Moderate	Moderate
Negligible	Negligible	Negligible	Negligible/Slight	Slight

Mineral Extraction

8.2.15 Specific criteria were not defined for the assessment of mineral extraction as these aspects primarily represent engineering considerations for the scheme construction and their extent, nature and required mitigation will be assessed by specific GI undertaken by the Contractor prior to detailed design of the proposed scheme. However the occurrence and proposed management of these aspects has been considered, assessed qualitatively, and presented as part of this assessment.

Contaminated Land

8.2.16 The assessment focused on the potential for impacts on receptors (including construction workers) as a consequence of encountering contaminated land using a conceptual site model (CSM) developed for the proposed scheme. A receptor can be a person (including construction workers), the water environment, flora, fauna or building/structures. The CSM represents a network of relationships between potential sources from within the study area and exposure of the receptors through different pathways. For the purposes of this assessment, the CSM disregards those pathways that are incomplete and therefore cannot pose a risk to any of the identified receptors. Where a source, pathway and receptor combination exists this is referred to as a complete pollutant linkage, in which case a generic quantitative risk assessment was then undertaken.

8.2.17 Current DMRB guidance (Highways Agency et al., 1993) advises that contaminated land should be assessed in accordance with the Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL) guidelines when extensive contaminated land testing is undertaken. However, the ICRCL guidance note 59/83 has now been withdrawn by the Department for Environment Food and Rural Affairs (Defra), and SEPA recommends that authoritative and scientifically-based assessment criteria in a risk assessment framework be used instead. On this basis, Generic Assessment Criteria (GAC) have been defined.

8.2.18 Appendix A8.1 summarises the CSM for the purposes of informing the EIA process and includes a full rationale and detailed assessment of land contamination issues within the study area, including the definition of GAC and the results included as necessary for the purposes of DMRB Stage 3 assessment.

8.2.19 The output of the generic quantitative assessment can not be reported in terms of ‘sensitivity’. Instead, it is reported as the ‘likelihood‘ of a complete pollutant linkage being present, which is defined in CIRIA 552 (CIRIA, 2001) and summarised in Table 8.4. The magnitude, or ‘consequence’, of the effect of contaminated land on likely receptors is outlined in Table 8.5 and overall risk category taking account of both likelihood and consequence is identified with reference to the matrix in Table 8.6.

Table 8.4: Likelihood Criteria – Contaminated Land

Likelihood	Definition
High likelihood	There is a complete pollution linkage of an event that either appears very likely in the short-term and almost inevitable over the long-term, or there is evidence at the receptor of harm or pollution.
Likely	There is a complete pollution linkage and all the elements are present and available, which means that it is probable that an event will occur. Circumstances are such that an event is not inevitable, but possible in the short-term and likely over a long-term.
Low likelihood	There is a complete pollution linkage and the circumstances are possible under which and event could occur. However, it is by no means certain that even over a longer period such an event would take place, and is less likely in the shorter term.
Unlikely	There is a complete pollution linkage but circumstances are such that it is improbable that an event would occur even in the very long-term.

Table 8.5: Magnitude (Consequence) Criteria – Contaminated Land

Magnitude	Definition
Severe	Short-term (acute) damage to human health (significant harm). Pollution of sensitive water resources as a result of short-term exposure. Damage to a particular ecosystem as a result of acute exposure. Catastrophic damage to buildings/property.
Medium	Long-term (chronic) damage to human health (significant harm). Pollution of sensitive water resources as a result of chronic exposure. A significant change in a particular ecosystem, or organism forming part of such an ecosystem.
Mild	Pollution of non-sensitive water resources. Significant damage to crops, buildings, structures and services. Damage to sensitive buildings/structures/services or the environment.
Minor	Harm (not necessarily significant), which may result in financial loss or expenditure to resolve. Non-permanent health affects to human health. Easily repairable damage to buildings, structures and services.

Table 8.6: Matrix for Determination of Generic Quantitative Risk Assessment: Contaminated Land

Likelihood / Consequence	Unlikely	Low likelihood	Likely	High likelihood
Severe	Moderate/low	Moderate	High	Very high
Medium	Low	Moderate/low	Moderate	High
Mild	Very low	Low	Moderate/low	Moderate
Minor	Very low	Very low	Low	Moderate/low

Groundwater

8.2.20 The assessment considered groundwater sensitivity in the context of hydrogeological conditions including groundwater resources. Criteria for the definition of groundwater sensitivity are reported in Table 8.7.

8.2.21 Criteria for the definition of PWS sensitivity are based mainly on the proximity of the PWS to the proposed scheme. However, where appropriate, the topographic location with respect to the proposed scheme and the type of abstraction (i.e. well or spring) was also considered to refine the sensitivity. A decision tree for the classification of the sensitivity of PWS is reported in Appendix A8.2.

8.2.22 Criteria for the definition of magnitude of impact on groundwater resources are reported in Table 8.8.

8.2.23 Criteria for the definition of the magnitude of impact on PWS yield and quality are based primarily on the type of road profile (e.g. cutting, embankment or transition cutting-embankment) facing the PWS. However, where appropriate, the vulnerability of groundwater flow to sub-surface disruptions was also considered to refine the magnitude of impact. A decision tree for the classification of the magnitude of impact is reported in Appendix A8.2.

8.2.24 The impact significance was then determined using the same matrix as for geology/geomorphology as shown in Table 8.9.

Table 8.7: Sensitivity Criteria - Groundwater

Sensitivity	Description
High	Local aquifer(s) constitutes a valuable resource because of its high quality and yield, or extensive exploitation for public, private domestic, agricultural and/or industrial supply. Designated sites of nature conservation dependent on groundwater.
Medium	Local aquifer(s) are of limited value because quality does not allow potable or other quality sensitive uses. Exploitation of local groundwater is not extensive. Local areas of nature conservation known to be sensitive to groundwater impacts.
Low	Poor groundwater quality and/or low permeability make exploitation of groundwater unlikely. There no known past or existing exploitation of this water body. Changes to groundwater not expected to have an impact on local ecology.
Negligible	Very poor groundwater quality and/or very low permeability make exploitation of groundwater unfeasible. Private water supplies are abandoned. Changes to groundwater are irrelevant to local ecology.

Table 8.8: Magnitude Criteria - Groundwater

Magnitude	Description
High	Major permanent or long-term change to groundwater quality or available yield. Existing resource use is irreparably impacted upon. Changes to quality or water table level would have an impact upon local ecology.
Medium	Changes to the local groundwater regime are predicted to have a slight impact on resource use. Minor impacts on local ecology may result.
Low	Changes to groundwater quality, levels or yields do not represent a risk to existing resource use or ecology.
Negligible	Very slight change from groundwater baseline conditions approximating to a 'no change' situation.

Table 8.9: Matrix for Determination of Impact Significance – Groundwater

Sensitivity / Magnitude	Negligible	Low	Medium	High
High	Slight	Moderate	Moderate/ Substantial	Substantial
Medium	Negligible/Slight	Slight/Moderate	Moderate	Moderate/ Substantial
Low	Negligible	Negligible/Slight	Slight/Moderate	Moderate
Negligible	Negligible	Negligible	Negligible/Slight	Slight

Limitations to Assessment

8.2.25 Limitations to this assessment are as follows:

- The identification of potential contamination sources relies on the accuracy of historical mapping and the 2008 GI. Any potential contamination source not encountered during the 2008 GI or identified through desk-based assessment and consultation is not reported.
- The listings of wells and springs is based on information received from consultation with the local Councils, land owner consultation, historical and current OS maps and walkovers. Any

wells and springs not notified by the Councils or landowners, not identified during surveys or landowner consultation undertaken during the current study or not recorded on OS maps are not assessed or reported within the ES.

- Although some information on PWS is presented within this chapter, it should be noted that detailed consultation, risk assessment and mitigation design may continue as part of the pre-construction activities for the proposed scheme. As such the exact location and technical characteristics of some springs and wells is yet to be determined.

8.3 Baseline Conditions

8.3.1 This section describes the baseline conditions identified through the collection and review of information from existing sources, additional survey work, consultation responses, and the results of the 2008 marine and terrestrial GI.

Solid and Drift Geology

8.3.2 Information on geology and on geological/geomorphological features of importance has been sourced from relevant BGS geological maps (BGS, 1962 to 1994), SNH databases (2008), Geological Conservation Review (GCR) database (JNCC, 2009) and previous desk study reports (Jacobs et. al., 2007). General geological descriptions are complemented by the 2008 GI results.

8.3.3 Bedrock outcrops along and adjacent to the route have been surveyed and mapped, and are reported as discontinuity assessments in the Ground Investigation Reports (Jacobs Arup, 2009a; 2009b).

8.3.4 The geomorphology of littoral sediments is addressed in Chapter 9 (Water Environment).

Firth of Forth

8.3.5 The bedrock across the Firth of Forth is represented by a sedimentary sequence (Strathclyde Group) comprising mainly oil shales, sandstones and siltstones locally intruded at different levels by a dolerite/gabbro sequence. Volcanic rocks, limestone and coal are also present locally.

8.3.6 Rock outcrops are present at the surface at Beamer Rock but elsewhere the bedrock beneath the Firth is overlain by superficial deposits, which generally comprise an alluvial sequence of soft organic sandy silt and clay or loose organic clayey sand. The alluvium is underlain by a variable sequence comprising granular fluvio-glacial deposits and cohesive glacial till.

8.3.7 The presence of the Beamer Rock informally divides the Firth of Forth into three areas, namely the Southern Estuarine, Beamer Rock and the Northern Estuarine.

8.3.8 No areas of geological/geomorphological importance were identified within the Firth of Forth.

8.3.9 Benthic baseline surveys including sediment distribution are summarised in Chapter 11 (Estuarine Ecology).

Northern Estuarine

8.3.10 This area is defined as the channel (-33m AOD) between Beamer Rock and the northern shore of the Firth of Forth.

8.3.11 From the north channel, the river bed level rises at a gradient of approximately 1:10 northwards to the Rosyth Channel which is dredged to a depth of -12 to -16m AOD. The north margin of this channel rises at a gradient of about 1:28 towards the even more gently sloping north foreshore which extends for about 250m towards the northern landfall of the crossing corridor to the east of Cult Ness.

8.3.12 Findings reported in the draft Setting Forth Environmental Statement (ERM, 1996) investigations and the 2008 marine site investigation indicated that rockhead depth varies between -5m AOD to the north and about -32m AOD.

8.3.13 The superficial deposits in the area are almost absent at the north shore, increasing to a maximum of around 25m. The superficial deposits comprise a general downward succession of soft organic sandy silts and clays or loose organic clayey sands, these materials are described as Alluvium of Holocene (Recent) age. The alluvium is underlain by a variable sequence of granular fluvioglacial deposits and generally cohesive glacial till of Pleistocene age.

8.3.14 The underlying bedrock in the north channel generally comprises a varied succession of predominantly sedimentary rocks with volcanic rocks (Strathclyde Group).

8.3.15 However, the underlying bedrock near the shore mainly comprises volcanoclastic breccia of Visean age (Early Carboniferous) up to 33m thick. Below this breccia, one of the exploratory holes confirmed rocks of the Strathclyde Group, which is locally intruded by igneous material.

Beamer Rock

8.3.16 This area is defined as being between the topographic lows of the channel to the south (-45m AOD) and the channel to the north (-33m AOD).

8.3.17 The river bed rises steeply at Beamer Rock which reaches an elevation of about 2.3m AOD close to the existing lighthouse. The area of rock exposed varies with the tide, reaching about 45m by 95m at low water springs. The bathymetric surveys have shown that the south and east sides of Beamer Rock are extremely steep with near vertical faces. The north edge is less steep with gradients of around 1:2. The bedrock at this location comprises around 43m of igneous rock (dolerite and gabbro) underlain by a succession of predominantly sedimentary rocks with subordinate units of igneous and volcanic rocks (mainly tuffs), non-marine limestones and coal (Strathclyde Group).

8.3.18 The Admiralty Chart Sheet 736 shows a ‘spoil ground’ immediately upstream of Beamer Rock.

Southern Estuarine

8.3.19 This area is defined as the channel (-45m AOD) between Beamer Rock and the southern shore of the Firth of Forth.

8.3.20 The study area starts at the southern shore to the west of the Port Edgar Marina and crosses gently sloping tidal flats for a distance of about 500m at which point the river bed falls more steeply at a gradient of about 1:12, reaching a level of about -45m above Ordnance Datum (AOD) at the centre of the main channel.

8.3.21 The bedrock level follows a similar profile to the sea bed profile sloping to the north towards the proposed southern tower position at a gradient of about 1:10. The bedrock level is around - 3.5m AOD to the south falling to around -40m AOD at the southern tower location.

8.3.22 The superficial deposits in this area are very thin at the southern shore and increases to approximately 20m at the proposed southern tower location (ch5243). However the thickest drift was recorded at a distance of approximately two thirds of the way from the southern shore to the southern tower location, possibly indicating the presence of a buried channel.

8.3.23 In this area the marine GI indicated the presence of sedimentary rock of the Strathclyde Group which includes subordinate igneous and volcanic rocks. Below approximately -70m AOD the sedimentary sequence is intruded by an igneous sill composed of dolerite.

Northern Study Area

Solid Geology

8.3.24 The east-northeast to west-southwest trending Rosyth Fault crosses immediately to the north of the proposed route corridor. BGS data (1986) indicate that igneous rocks are mostly present to the south of the Rosyth Fault while sedimentary Carboniferous Strathclyde Group rocks are mostly present to the north of the fault. However, a small section of the western side of the proposed route in the vicinity of Castlandhill and a narrow corridor to the west of Ferry Hills also features Strathclyde Group bedrock. A series of faults generally trending east-west and intercepting the proposed route are indicated on the BGS map, one of them crossing near the limit between the northern study area and the Firth of Forth.

8.3.25 BGS data (1986) indicate that the Carboniferous Strathclyde Group comprises mainly sandstone with interbedded siltstones, mudstones and a few limestones. Amongst the igneous rocks, the main bedrock type comprises quartz and dolerite.

8.3.26 The 2008 GI confirmed the presence of igneous rocks comprising mainly of dolerite, rarely interbedded with sedimentary strata, with a thickness in excess of 35m at mainline ch7450. The igneous lithologies appear to be shallower between mainline ch6800-7100 and in proximity of ch8000, which corresponds to bedrock outcrops or near surface on BGS maps.

8.3.27 Sedimentary rocks, corresponding to the Strathclyde Group with an interbedding of sandstone, siltstone and mudstone, have been recorded by the GI approximately between mainline ch7200-7500 and ch8300-9300.

8.3.28 In the proximity of ch7150 the 2008 GI recorded pelite and psammite produced by contact metamorphism of the dolerite magma intruded within pre-existing sedimentary strata.

8.3.29 Black vitreous coal with a thickness of 0.3m has been recorded at depths between 29.5m and 29.8m below ground level (bgl) in the proximity of mainline ch7150 and between 23.0 and 23.3m bgl adjacent to the proposed northbound slip road from Ferrytoll Junction to the mainline (mainline ch8170) shown on Figure 8.5a.

8.3.30 Rockhead elevation contours have been produced using the 2008 GI logs and are shown on Figure 8.1. The contours suggest that rockhead tends to follow the topographic gradients of the region.

Drift Geology

8.3.31 The superficial deposits present beneath the route of the proposed scheme include made ground, lacustrine deposits, raised beach deposits and glacial till.

8.3.32 Made ground is indicated at the following locations in the northern study area as shown on Figure 8.4a:

- St. Margaret's Marsh: reclaimed land which may be variable in composition, and may include compressible material;
- embankments associated with the existing road and railway network;
- Belleknowes Industrial Estate;
- at the location of a number of former quarries including Welldean Quarry, to the east of St. Margaret's Marsh, and Ferrytoll Quarry, to the east of the existing A90;
- in the area occupied by Welldean Cottages; and
- to the east of the existing A90, south of Dunfermline Wynd.

8.3.33 BGS data (1986) indicate that the more widespread glacial till in this area typically comprises a firm to very stiff sandy silty clay with fine to coarse gravel and occasional cobbles and boulders (BGS, 1986). The 2008 GI confirmed the presence of mostly firm to very stiff (occasionally soft) slightly sandy slightly gravelly clay with occasional cobbles and boulders (glacial till). At ch7400 however the glacial till is predominantly a very soft to soft slightly sandy to slightly gravelly clay. Granular deposits (sand and gravel) are often recorded as interbedded within the clayey till sequence.

8.3.34 Lacustrine deposits are distributed as small patches between the A90 and Castlandhill Woods and nearby the Ferry Hills and are recorded as comprising laminated and locally organic-rich clay, silt and fine sand (BGS, 1986).

8.3.35 Marine beach deposits, located in the south-western part of Rosyth between the A90 and the B980 Junction, are described as comprising mainly loose to medium dense, occasional dense, sands and gravels, and may include very clayey and silty horizons with some cobbles (BGS, 1986).

8.3.36 During the 2008 GI, organic clay locally comprising pockets of peat have been recorded below 1.80m of made ground adjacent to the proposed FRC northbound slip road. This information correlates with logs from two nearby boreholes held at BGS map indicating clay-peat deposits but contradicts the BGS geological maps indicating lacustrine deposits instead.

8.3.37 Drift thickness contours have been plotted and are shown on Figure 8.2. A maximum drift thickness of 36m, comprising 18m of made ground and 18m of glacial till, has been recorded approximately at mainline ch7450. The drift thickness fluctuates between 0m and 10m in the area to the west of the Ferry Hills (between ch6800-7350) and from ch7650-8400, between 10 and 36m from ch7350-7650 and between 10 and 26m from ch8400-9300.

SSSI

8.3.38 A number of areas of geological importance have been identified within the study area and are listed in Table 8.10 and illustrated on Figure 8.3 (Geological Constraints).

Table 8.10: Geological Features of Importance in the Northern Study Area

Area Name	Designation	Cited Feature	Category
St. Margaret's Marsh	SSSI	Salt marsh	Littoral sediment (Coast)
Ferry Hills	SSSI	Carboniferous-Permian Igneous	Igneous petrology
Firth of Forth *	SSSI	Carboniferous-Permian Igneous	Igneous petrology
		Coastal Geomorphology of Scotland	Geomorphology

* Note: Firth of Forth SSSI designation covers shoreline areas in both northern and southern study areas, but not the Firth of Forth itself (SNH, 2008).

8.3.39 Ferry Hills was classified as a SSSI because of new bedrock exposure following the extensive road cuttings along the A90 (SNH, 2008). This cutting is considered to provide the best and most comprehensive fresh exposures of the Late Carboniferous age Midland Valley Sill complex which underlies much of the central Midland Valley of Scotland. The SSSI is located at the following approximate chainages, adjacent to the proposed scheme and shown on Figure 8.3a:

- ch6800-7300 (Ferry Hills);
- ch7500-7800 (southwest of Jamestown);
- ch8150- 8500 (northwest and west of the cemetery); and
- near Fairy Kirk (north of the proposed scheme).

8.3.40 St. Margaret's Marsh is classified by SNH as a SSSI due to the saltmarsh feature which falls within the category of 'littoral sediment' (SNH, 2008). This is a biological classification with no geological elements rated as sensitive in the citation. This interpretation was confirmed during an SNH consultation meeting that took place on 05 November 2008, in which SNH confirmed that St.

Margaret's Marsh is protected solely for its saltmarsh and reedbed habitats as detailed in Chapter 10 (Terrestrial and Freshwater Ecology). For this reason, St. Margaret's Marsh geology is not considered to be sensitive and is therefore assessed only in the general context of underlying geology, although its shallow groundwater conditions are likely to be linked to the protected habitats and therefore will be covered in the groundwater section (paragraphs 8.3.103-8.3.104).

8.3.41 Ferry Hills SSSI is the only GCR database site (JNCC, 2009) present in the northern study area.

Southern Study Area

Solid Geology

8.3.42 According to BGS information, the majority of the solid geology beneath the study area consists of sedimentary rocks of the West Lothian Oil-Shale formation of the Strathclyde Group, which mainly comprises sandstone, siltstone, mudstone, oil shale, thin coal seams and limestone. Igneous intrusive rocks comprising dolerite/teschenite, also of Lower Carboniferous age, are present within some areas, particularly near the coastline towards the north of the study area and in the vicinity of Dundas Loch-Dundas Castle and immediately to the southwest of Kirkliston where the igneous lithologies are outcropping or close to surface.

8.3.43 A fault trending southeast-northwest (Ochiltree Fault) is indicated on BGS maps at ch3300.

8.3.44 The 2008 GI confirmed that the solid geology below the proposed scheme consists of an interlayering of sedimentary lithologies comprising mudstones, sandstones, siltstones with occasional thin beds of limestones. Igneous sequences consisting of basalts, dolerite or gabbro, sometimes interbedded with sedimentary strata, have been recorded at variable depth between ch3100-4600 and again at the very southern end of the proposed scheme (ch1500, southeast of the M9 Junction 1A) with a thickness in excess of 17m of dolerite. The igneous lithologies of basaltic composition appear to be shallower from ch3600 to ch4600 (Figure 8.1), which would be in accordance with the BGS maps that show igneous lithologies close to surface or outcropping within or near to the proposed route land-take.

8.3.45 The 2008 GI recorded volcanic breccia and tuff within a sedimentary sequence of mudstone and limestone to the north of ch100 (M9 Spur).

8.3.46 Rockhead elevation contours have been produced using the 2008 GI logs and are shown on Figure 8.1. The contours suggest that rockhead tends to follow the topographic gradients of the region.

Drift Geology

8.3.47 The superficial deposits (drift) present beneath the route of the proposed scheme in the southern study area include the following as shown on Figure 8.2c-f:

- made ground located at embankments associated with the existing road and railway network. Made ground of thickness varying from less than 1m up to 1.4m has been found at ch2500 (Figure 8.4c), north of ch2130 (Figure 8.4b) and at ch4540 (Figure 8.4b);
- small areas of undifferentiated alluvium recorded along the Swine Burn and Niddry Burn;
- lacustrine deposits comprising silt and clay recorded to the northwest of Dundas Home Farm;
- marine beach and raised tidal deposits located in a thin strip parallel to the shoreline, and are described as comprising mainly sand, silt and gravel;
- glacial till covering the majority of the area beneath the proposed scheme, mainly consisting of stiff gravelly sandy clay (however it is not uncommon to find granular horizons i.e. sand and gravel within the till sequence). The thickness of these granular horizons is generally less than 3m. The upper section of the till (up to approximately 2m thick) consists mainly of soft to firm

sandy to gravelly clay with occasional cobbles. The till is in excess of 10m thick at approximately ch1490-2000 and ch2500-3200. A maximum thickness of 30.4m was recorded close to ch1800, in proximity to the Dundas Home Farm; and

- a small area of glaciofluvial deposits is indicated on the BGS map in the vicinity of ch0 of the M9 Junction 1A loop.

8.3.48 Drift thickness has been mapped using the 2008 GI logs and is shown on Figure 8.2. Maximum drift thickness has been recorded in proximity of the Dundas Home Farm as mentioned above. The drift thickness fluctuates between 2m and 10m in the area of the existing M9 Junction 1A, between 4 and 10m at mainline ch2000-2500, between 10 and 31m in the area of Dundas Home Farm (ch1490-2000), between 10 and 15m roughly parallel to the A904 (ch2500-3200) and between 0m and 10m in the northernmost section sloping towards the Firth of Forth ch3200-4600).

SSSI

8.3.49 Two features of geological/geomorphological importance have been identified within the Firth of Forth. These features are listed in Table 8.11 and illustrated in Figure 8.3.

Table 8.11: Geological Features of Importance in the Southern Study Area

Area Name	Designation	Feature	Category
Firth of Forth *	SSSI	Carboniferous-Permian Igneous	Igneous petrology (unusual rock type)
		Coastal Geomorphology of Scotland	Geomorphology

* Note: Firth of Forth SSSI designation covers shoreline areas in both northern and southern study areas, but not the Firth of Forth itself (SNH, 2008).

8.3.50 No GCR database sites (JNCC, 2009) are present within the southern study area.

Mineral Extraction

Firth of Forth

8.3.51 According to the Coal Authority consultation response, the Firth of Forth is not within an area which is likely to be influenced by past or present underground or open cast coal mining and associated workings. In addition, the Firth of Forth is not within an area for which the Coal Authority has granted, or is determining whether to grant, a licence to remove coal using underground workings (Coal Authority, 2008).

Northern Study Area

8.3.52 Historical pits and quarries have been identified following a review of historical maps (1856-2007). The quarries noted within the northern study area are listed in Table 8.12 (potential contaminant sources classified in the mineral extraction category) and illustrated on Figure 8.4a.

8.3.53 According to Coal Authority records (2008) and detailed review of potential past mining activities, the northern study area does not lie within an area which is likely to be influenced by past, present or future underground coal workings. The northern study area does not lie within the boundaries of any present or likely future open cast coal mines.

8.3.54 Limestone, fireclay and mudstone are understood to have been worked in the region of Fife. The Charleston Main Limestone outcrop extends north east from approximately up to 50m north of Fairy Kirk Quarry and is typically 3m thick and underlain by thin coal and 3m of 'seatearth' or 'fireclay'. Underground workings are known to exist outside of the study area under the current M90 at Middlebank. From these underground workings, the thin coal and underlying fireclay was extracted between approximately 1854 and 1877, with the limestone seam left in place to form the roof of the workings. The Maunsell Carl Bro (1995b) report indicates that it is not known to what extent any consolidation of the mine workings were undertaken during the construction of the

existing motorway. A coal seam and fireclay below the Charleston Main Limestone are indicated by a mine abandonment plan to have been worked underground at shallow levels at the northern end of the existing Masterton Junction, however this is beyond the study area.

8.3.55 In conclusion, there are no mining related issues in the northern study area.

Southern Study Area

8.3.56 Historical pits and quarries have been identified following a review of historical maps (OS, 1853-2007). The quarries noted within the southern study area are listed in Table 8.13 (potential contaminant sources classified in the mineral extraction category) and illustrated on Figure 8.4b-c.

8.3.57 A detailed mining assessment which included consultation with the Coal Authority and a review of geological maps, mine abandonment plans, publications and consultant's reports, is presented in the Ground Investigation Reports (Jacobs Arup, 2009a; 2009b) and the main conclusions are summarised below.

8.3.58 The proposed route to the south of the Firth of Forth traverses an area where historically there have been underground mining activities, principally for oil-shale within the Lower Carboniferous strata.

Mainline

8.3.59 The route of the proposed scheme between ch1500 and ch4300 is underlain by strata belonging to the West Lothian Oil-Shale Formation of Lower Carboniferous age, which includes a number of potentially economic mineral horizons (oil shales and occasional limestones). Three oil-shale seams have been recorded as worked in the past as part of No.3 Pit at Dalmeny. The oil-shales were worked using stoop and room methods where pillars or stoops of the mineral mined were left in place.

8.3.60 Past studies for the M9 Spur Extension and A90 upgrading identified significant voids in the workings, and mine working consolidation works were recommended to stabilise the underground workings for the proposed extension. It is estimated that the oil-shale mine workings associated with the Dalmeny No.3 Pit will underlie the area at depths of the order of 60 to 100m bgl. The possibility of unrecorded mine workings beyond the recorded limits is considered unlikely.

8.3.61 There are no records of any underground workings along the remainder of the proposed mainline, and the risk of possible unrecorded mine workings is considered to be low.

Queensferry Junction

8.3.62 No mining constraints have been identified in this area with regard to the known oil-shale horizons.

8.3.63 There is a history of workings in the Burdiehouse Limestone in this area, with a possibility of unrecorded working from the base of an old quarry located approximately 1km to the west of where the A904 would tie-in to the proposed scheme at Queensferry Junction. However, the risk of shallow mine workings being present is considered to be low as any workings, if present, would be expected to be localised and limited in extent. In addition, based on the indicated seam dip (10^0), any working would be at a significant depth beneath the proposed tie-in area.

M9 Junction 1A (M9 Spur) Improvements

8.3.64 The route of the proposed scheme crosses the sub-crop of a number of oil-shale seams which would appear to be poorly developed in the area. There is evidence that mineral investigations took place around the turn of the last century, presumably for oil-shales, however there are no records of any oil-shale mining, or indeed mining for any other minerals in this area. It is considered unlikely that unrecorded oil-shale mine workings are present, due to the generally well documented

and essentially complete nature of oil-shale mining records in general; this is also supported by more recent intrusive investigations.

8.3.65 There is evidence of surface quarrying within the horizon of the Burdiehouse Limestone in this area; however quarrying was undertaken locally and presumably was of a shallow nature located along the sub-crop of the limestone. Consequently, the possibility of localised surface workings within the Burdiehouse Limestone which are not documented on the historic OS maps or other information sources cannot be discounted.

A90 to A8000 Bus Link

8.3.66 An extensive area of oil shale workings (three oil-shale seams) associated with the former Dalmeny No 3 pit is located to the south and below the proposed bus lanes. There is no existing GI information of sufficient depth to have encountered these workings beneath the proposed bus route due to their considerable depth beneath the surface.

Contaminated Land

8.3.67 Potential sources of contamination are listed below for each area. These were identified through the examination of historical OS maps dating from 1856 until present, field survey and the 2008 GI.

8.3.68 The following sections summarise the currently available information on land contamination issues known or suspected to be present along the proposed route corridor. Detailed information is presented in Appendix A8.1.

Firth of Forth

8.3.69 The Firth of Forth has been dredged extensively throughout the course of the 20th century to ensure the free passage of shipping to Rosyth and Grangemouth. Extensive dredging has been undertaken by the Navy during the development of Port Edgar and Rosyth and over the past century approximately three million cubic metres of material has been removed from the sea bed at Rosyth alone (Jacobs et al., 2007).

8.3.70 Potential contamination in the sediments in the Firth of the Forth include radioactive contamination from authorised discharges from the Rosyth Naval Yard, hydrocarbon contamination from sea-going vessels and a wide range of contaminants from the various industrial processes that have been undertaken along the shores of the Forth. As there is regular maintenance and dredging at Rosyth and Port Edgar, contaminants have the potential to be mobilised from the sediments into the Firth of Forth. Re-suspension of sediments is reported in Chapter 9 (Water Environment).

8.3.71 Sampling and analysis of sediments was undertaken in this area during the marine GI and the presence of metallic, organic and inorganic contaminants were identified in sediments:

- the concentrations of chromium, copper, lead and ammoniacal nitrogen exceeded environmental acceptable levels for the marine environment in some samples analysed.
- total petroleum hydrocarbons exceeded the generic assessment concentrations for risks to humans; and
- soluble sulphates were assessed as potentially affecting structures.

8.3.72 Environmental acceptable levels are defined in the ‘Risks to Water Environment’ section of Appendix A8.1.

8.3.73 Benthic baseline surveys, including sediment-bound contaminant concentrations in shallow sediments, are summarised in Chapter 11 (Estuarine Ecology).

Northern Study Area

8.3.74 Potential contamination sources for the northern study area (source references N1 to N29) are described and labelled in Table 8.12 for each source category and are shown on Figure 8.4. Further details on St. Margaret's Marsh area are also provided in paragraphs 8.3.75 and 8.3.76.

Table 8.12: Potential Contamination Sources for the Northern Study Area

Source Ref.	Potential source	Existence on Historical Maps	GI evidence	Location of potential source relative to proposed route
Made ground				
N1	St. Margaret's Marsh reclaimed land	Pre 1927 breakwater. Starts to form in 1927. Infilled by 1967-current	Not investigated.	Realignment of B981 at the western edge of the reclaimed land.
N27	Made ground in the Welldean Cottage area	Not marked	Made ground identified to 0.85m bgl. Elevated metals in soils.	In route of the proposed scheme and existing A90
N28	Isolated made ground	Not marked	Hydrocarbon contamination.	In route of the proposed scheme and Ferrytoll Junction
N31	Made ground either side of the existing carriageway	Not marked	Made ground identified along existing route. Elevated metals and hydrocarbons in soils.	In route of the proposed scheme and Ferrytoll Junction
Refuse tip/landfill				
N2	St. Margaret's Bay landfill	1958-1972	Yes, described in paragraph 8.3.76.	Realignment of B981at the western edge of likely landfill area.
N5a	Ferrytoll Quarry North	1961-1994	Not investigated.	Approx 150m east of where upgrading of the existing A90 is proposed.
N5b	Ferrytoll Quarry South	1961-1991	Not investigated.	Approx 150m east of where upgrading of the existing A90 is proposed.
N6	Ferry Hills Landfill	1972-1982	Not investigated.	Approx 100m east of where upgrading of the existing A90 is proposed.
N7	Refuse tip (unnamed)	1951-current day	No visual/ olfactory contamination observed (GI open hole drilled straight into rockhead).	Approx 250m east of where upgrading of the existing A90 is proposed.
N30	East Tip	1972-current day	Not investigated.	Approximately 250m west of the B981 Realignment.
Mineral extraction				
N13	Old Quarry 1	1896-1915	Not investigated.	Approx 200m east of the main crossing viaduct area.
N14	Quarry 1	1915-1927	Not investigated.	Approx 200m east of the Main Crossing viaduct area.
N15	St. Margaret's Quarry	1896-1927 (1961 marked disused)	No contamination observed (GI open hole drilled straight into rockhead).	Approx 100m east of the Forth Road Bridge and A90 southbound slip road from Ferrytoll Junction.
N16	Quarry 2	1915-1961	Not investigated.	Approx 200m east of Forth Road Bridge and A90 southbound slip road from Ferrytoll Junction.
N17	Welldean Quarry	1856 (Quarry); 1896(Disused); 1915-1927 (Quarry); 1916 (pond)	Made ground identified to 7.0m bgl. No visual/ olfactory contamination observed. No elevated contaminants recorded in soil samples.	In route of the proposed scheme and B981 realignment.

Source Ref.	Potential source	Existence on Historical Maps	GI evidence	Location of potential source relative to proposed route
N18	Old Quarry 2	1896-1927(marked as 'Stone' from 1961-current day)	Not investigated.	In route of the proposed scheme and B981 realignment.
N19	Old Quarry (whinstone)	1856-1927(marked as 'Stone' from 1961-current day)	Not investigated.	In route of the proposed scheme and B981 realignment.
N20	Ferrytoll Quarry	1896-1927 (marked disused from 1961 to current day)	Made ground identified up to 18.5m bgl. No visual/olfactory contamination observed. No elevated contaminants recorded.	In route of the proposed scheme and A90 southbound slip road from Ferrytoll Junction
N21	Castlelandhill Quarry (potential former landfill – unconfirmed and no further data held by local authority)	1915-1927 (1961-1967 marked disused and small pond)	Not investigated.	Approx 225m west of route where upgrading of the existing A90 is proposed.
N22	Old Quarry 3	1896	Not investigated.	Approx 100m east of route where upgrading of the existing A90 is proposed.
N23	Old Quarry 4	1896-current day	Not investigated.	Approx 100m east of route where upgrading of the existing A90 is proposed.
N24	Old Quarry 5	1915-1926	Made ground identified up to 1.5m bgl. No visual/olfactory contamination observed. No analysis data available.	Approx 150m east of route where upgrading of the existing A90 is proposed.
N25	Fairykirk Quarry	1951-current day	Not investigated.	Approx 100m east of route where upgrading of the existing A90 is proposed.
N26	Unrecorded coal mines	Not marked	No evidence to date.	In route of the proposed scheme (Main Line A90) and Ferrytoll Junction.
Other				
N3	Wastewater treatment works (WWTW)	1980-current day	Made ground identified up to 7.5m bgl. Elevated concentrations of metal contaminants and asbestos fibres were identified in the soils.	Adjacent to the west of Ferrytoll Junction at the proposed B981 realignment. The B981 realignment would occupy the southwestern portion of the treatment works site.
N4	Belleknowes Industrial Estate	1982-current day	Made ground identified to 0.9m bgl. No visual/ olfactory contamination observed. No elevated contaminants recorded in soil samples.	Southernmost portion of the estate is within study area, approx 200m north of where upgrading of the existing A90 is proposed.
N8	Tanks 1	1961-1993	Not investigated.	Approx 100m east of the proposed scheme where upgrading of the existing A90 is proposed.
N9	Tanks 2	1967-1980	Not investigated.	Approx 200m west of the proposed scheme where upgrading of the existing A90 is proposed.
N10	Former railway lines and tunnels	1915-1927	Not investigated.	Traverses the proposed scheme from east to west.

Source Ref.	Potential source	Existence on Historical Maps	GI evidence	Location of potential source relative to proposed route
N11	Saltpans works	1896 -1927	Not investigated.	Approx 200m east of the proposed scheme where upgrading of the existing A90 is proposed.
N12	Little Hill Cemetery	1896-current day	Not investigated.	Approx 200m east of the proposed scheme where upgrading of the existing A90 is proposed.
N29	HM Naval Base	1972-1999	Not investigated.	Northwest of the proposed B981 realignment.

8.3.75 St. Margaret's Marsh (source reference N1) is located on the north shore of the Firth of Forth, immediately west of the Forth Road Bridge. This area originally comprised a natural intertidal zone, and was artificially infilled prior to the 1960s. The specific nature of the infill material is not known; however, it is believed to comprise marine sediments from the vicinity of the nearby Rosyth Naval Base. Low level radioactive waste has been historically discharged from the Rosyth Naval Base as part of nuclear submarine maintenance operations under formal discharge consent with SEPA. However, preliminary monitoring data undertaken during the 2008 GI and monitoring data from the nearby intertidal zone suggest that radiation levels are not elevated above background.

8.3.76 The eastern extent of St. Margaret's Marsh (St. Margaret's Bay) was used as a landfill between 1958 and 1972 (source reference N2), receiving general/domestic waste. The fill thickness is indicated in reports supplied by Fife Council as being up to 2-3m, overlying marine clays (part of the land reclamation activities described above) (Envirocentre, 2003). During previous investigations undertaken on behalf of Fife Council, no elevated concentrations of methane were identified; carbon dioxide was identified at concentrations of up to 1.7% v/v (volume of CO_2/total volume of gas) and risks to human health from toxic metals were identified at depths greater than 1m bgl (Envirocentre, 2004). There is no evidence to suggest that gas monitoring is currently taking place and no venting system appears to have been installed. However, based on the investigation results (Enviros, 2006), it is understood that the landfill vented in the past via the monitoring boreholes, allowing gas concentrations to decrease over time. The 2008 GI did not investigate the area previously understood to encompass the former landfill. However, the 2008 GI included the eastern boundary of St. Margaret's Marsh and identified extensive made ground and general refuse deposits. It is therefore considered likely that the actual footprint of the former landfill extends beyond St. Margaret's Marsh under the proposed scheme.

Southern Study Area

8.3.77 The land areas in the southern study area have largely remained undeveloped, with the exception of the shore area, which includes works and stores (source references S1 to S4), and mainly consist of open land or cultivated fields.

8.3.78 Oil shale mining is understood to have been undertaken within the study area up until 1901. Following a review of historical mining plans, a network of mine shafts were identified to the immediate east of the route alignment, west of the Scotstoun Junction (source reference S13). During the 2008 GI, elevated carbon monoxide gas concentrations were recorded in this area. In addition, groundwater samples analysed from this area were shown to be alkaline and contain concentrations of metal and inorganic contaminants above water environment guidance criteria. These contaminants may potentially be associated with the former oil shale mining works in the area.

8.3.79 Fly tipping has been recorded during ecological surveys in the near vicinity of the Swine Burn and the River Almond and in woodland in the Winchburgh Road and Port Edgar areas.

8.3.80 Potential contamination sources for the southern study area (source references S1 to S14) are described and labelled in Table 8.13 for each source category and shown on Figure 8.4b-c.

Table 8.13: Potential Contamination Sources for the Southern Study Area

Source Reference	Potential Source	Existence on Historical Maps	GI evidence	Location of potential source relative to the proposed route
Made ground				
S14	Isolated made ground	Not marked	Furnace waste identified in made ground. No analytical data available.	Along the route of the proposed scheme, south of the A90 to A8000 bus link.
Refuse tip/landfill				
S5	Refuse tip 1	1973-1983	Not investigated.	Approx. 250m west of the existing Echline Junction.
S6	Refuse tip 2	1973	Not investigated.	Approx. 50m to the south of the M9 westbound to M9 Spur northbound link.
Mineral extraction				
S7	Oil shale processing spoil heap	1973-current day	Not investigated.	Approx. 300m west of M9 Junction 1A and south of the existing M9.
S9	Old Quarries	1896-1916	Not investigated.	Approx. 225m east of Main Crossing and the southern approach viaduct.
S10	Three old Quarries (Lindsay's Craigs)	1855-current day	Not investigated.	Approx. 50m to the south of the M9 westbound to M9 Spur northbound link.
S11	Quarry 1	1855	Not investigated.	Adjacent to the cutting associated with the M9 eastbound to M9 Spur northbound link at the M9 Junction 1A.
S12	Quarry 2	1851-1917	Not investigated.	Approx. 50m west of the M9 Spur (ch150).
S13	Former oil shale mining area	last mined in 1901	Yes, described in paragraph 8.3.59.	South of the A90 to A8000 bus link.
Other				
S1	Sewerage pumping station	1993-current day	Not investigated.	Approx. 225m east of the Main Crossing viaduct.
S2	Barracks area	1966-current day	Made ground identified to 2.6m bgl. Ash and brick fill observed. No analytical data available.	Main Crossing and southern approach viaduct.
S3	Stores area	1966-current day	Not investigated.	Immediately to the east of the Main Crossing and southern approach viaduct.
S4	Dundas Lime Works	1856	Not investigated.	Approx. 200m east of the Main Crossing and southern approach viaduct.
S8	Bonded warehouse	1969-1995	Not investigated.	Approx. 150m east of the M9 Spur southbound to M9 eastbound link.
S15	Oil Storage Depot	1984-current day	Not investigated.	Approx. 200m southeast of the A90 southbound bus link.
S16	Sewerage Works	1957-current day	Not investigated.	Approx. 200m southeast of the A90 southbound bus link.

Groundwater

8.3.81 Information on groundwater has been gathered from the Hydrogeological Map of Scotland 1:625,000 (BGS, 1988d), the Groundwater Vulnerability Map of Scotland 1:625,000 (BGS, 1995), the Hydrogeological Map of Fife & Kinross scale 1:100,000 (1986) and the results of the 2008 GI.

8.3.82 Information provided by SEPA indicates that in the region there are two groundwater bodies with potential water resources in each area. These are identified as 'South Fife bedrock [i.e. sedimentary bedrock] and localised sand and gravel aquifers' to the north of the Firth, and 'Edinburgh and Livingston bedrock [i.e. sedimentary bedrock] and localised sand and gravel aquifers' to the south of the Firth of Forth. These aquifers are expected to have essentially similar hydrogeological characteristics in the northern and the southern study areas.

8.3.83 Information collected has not indicated any public groundwater or surface water supply in the vicinity of the study area.

8.3.84 The Hydrogeological Map of Scotland (BGS, 1988) does not report any sand and gravel aquifer in the vicinity of the proposed route, although localised areas of sand and gravel (glaciofluvial deposits) are indicated on the geological maps near to the River Almond (Figure 8.5e).

8.3.85 According to BGS (2004), alluvial deposits are locally classified as Intergranular High Productivity Drift Aquifers. Alluvial deposits occupy a significant area around the River Almond (Figure 8.5e) and may host important groundwater resources.

8.3.86 The hydrogeological characteristics of the different geological units in the study area are summarised in Table 8.14.

8.3.87 Table 8.14 indicates that drift groundwater in the region is of low sensitivity except in the vicinity of the River Almond, where it is of medium sensitivity. Igneous bedrock groundwater is determined as of low sensitivity and sedimentary bedrock of medium sensitivity.

8.3.88 Bedrock groundwater (both igneous and sedimentary) in the region generally is not regarded as highly vulnerable to potential pollution because it is largely covered by drift deposits, which are usually of significant thickness and low permeability (e.g. glacial till).

8.3.89 However, the igneous complexes are in places outcropping or are near to the surface and can host groundwater at shallow depths. The permeability characteristics (fracture flow mechanism) of these rocks and their low storage capacity and small extents may make some local aquifers extremely vulnerable to pollution and hydrodynamic disturbance.

Table 8.14: Hydrogeological Characteristics of Drift and Bedrock Units

Geological unit		Geological characteristics	Hydrogeological characteristics	Sensitivity
Drift Deposits	Alluvium	Fine sand, silt, some clay with thin peat bands in places and locally some gravel[1].	Groundwater supplies are limited[1] except where significant proportions of sand and gravel are present. Groundwater flow is intergranular.	Low sensitivity except where sand and gravels are present (i.e. alluvium associated with River Almond) where sensitivity is medium.
	Glaciofluvial deposits.	Mainly sand and gravel[1].	Groundwater potential of these deposits is generally poor because the water table is often near or below their bases[1]. Groundwater flow is intergranular.	Low sensitivity except where sand and gravels are present (none identified at this stage).
	Glacial till and undifferentiated drift	In large part represented by slightly gravelly sandy clay till with clasts up to boulder size (boulder clay) with subordinate marine beach and raised tidal deposits[1]. Made ground is locally important (e.g. St. Margaret's Marsh).	These deposits yield negligible groundwater[1]. However, shallow groundwater in made ground (dredged silts and clays) overlying natural marine silts and clays has been recorded in the St. Margaret's Marsh area (Envirocentre 2004; ENVIRONUK, 2007). This groundwater is influenced by tides near the coastline.	Low sensitivity except at St. Margaret's Marsh, where local areas of nature conservation are known to be sensitive to groundwater impacts (source reference N1 - medium sensitivity).

Geological unit		Geological characteristics	Hydrogeological characteristics	Sensitivity
Bedrock	Metamorphic rocks	Pelites and psammites derived from contact metamorphism of pre-existing sedimentary strata. Limited extent.	Units of limited extent and hydrogeological interest.	Low sensitivity
	Dinantian and Namurian sedimentary strata: Upper and Lower Oil-Shale Group, Calciferous Sandstone Measures (Strathclyde Group)	Sedimentary sequence comprising mainly sandstones, mudstones, siltstones and limestones. Beds of coals and oil-shales are present.	Moderately productive aquifers with fracture/ intergranular flow[2]. Calciferous Sandstone Measures: groundwater is in general of good quality and in East Fife numerous boreholes have recorded yields of 4 to 12 L/s[1]; direct recharge is available via loosing streams, outcrop and permeable drift cover where present; water quality is generally good: moderately mineralised calcium-bicarbonate type water or calcium-bicarbonate (sulphate) type. In places iron is present in solution[1].	Medium sensitivity
	Mid Valley Sill complex and Dinantian to Westphalian Sills of Lothians and Fife.	Fine to medium grained extrusive - sub volcanic - intrusive rocks.	These are considered as impermeable rocks, generally without groundwater except at shallow depth, where bedrock is fractured and weathered[3]. Small-scale private groundwater wells are sometimes present.	Low sensitivity

Table 8.14: Hydrogeological Characteristics of Drift and Bedrock Units Based on:

[1] Hydrogeological Map of Fife & Kinross (BGS, 1986);

[2] BGS Commissioned Report CR/04/04/7N;

[3] Hydrogeological Map of Scotland (BGS, 1988) and Groundwater Vulnerability Map of Scotland (BGS, 1995).

Northern Study Area

8.3.90 The number of groundwater monitoring points (piezometers) installed as part of the 2008 GI in the drift is similar to those installed in the bedrock (groundwater monitoring installations; 16 in drift, 14 in bedrock and seven in drift-bedrock).

8.3.91 Overall it appears that bedrock and drift groundwater follow the same pattern which broadly reflects the topographic gradients. Although no nested piezometers (piezometer with two individual standpipes with different response zones monitoring groundwater in different strata) are available, comparison of nearby bedrock and drift groundwater installations in three different locations indicate similar groundwater levels, which suggest a degree of continuity between the two groundwater bodies. On this basis all the available groundwater monitoring installations were grouped for analysis to generate local groundwater contours (Figure 8.5).

8.3.92 Localised artesian groundwater conditions were encountered at the edge of the northern boundary of the scheme, in an area characterised by thick drift deposits.

8.3.93 Groundwater monitoring was undertaken on a daily basis from 15 April 2008 to 25 February 2009, however the number of monitoring days per borehole varied between 7 and 24, depending when the monitoring started as the 2008 GI progressed. Large fluctuations of groundwater levels (up to 13.1m) were noted in some boreholes installed either in drift, in bedrock, or in both drift and bedrock at the same time. This may be attributable to the low storage capacity and/or a high degree of response in these aquifers to rainfall events. Average seasonal fluctuation in both drift and bedrock is of the order of magnitude of 2.5-2.9m.

8.3.94 The spatial distribution of the 2008 GI piezometers is linear, running as it does almost exclusively along the north-south corridor of the proposed scheme. It is therefore difficult to infer the general groundwater flow directions. From Figures 8.5a-b it would appear that between mainline ch6800-7800, shallow groundwater to the west of the existing A90 in inferred to flow in the direction

of St. Margaret's Hope-Cult Ness. However, the direction of groundwater flow to the east of the existing A90 is not known as no piezometers were installed in this area as part of the 2008 GI.

8.3.95 In much of the remainder of the northern study area, the general direction of groundwater flow is also unclear. However, according to the pattern of measured groundwater levels, it appears that shallow groundwater from Castlandhill and Muckle Hill is channelled in the small valley between Little Hills and Castlandhill Woods. Groundwater is inferred to be flowing southwards in the direction of St. Margaret's Marsh. Groundwater contours shown in Figure 8.5a indicate that in the northern end of the proposed scheme (ch9300) shallow groundwater flows to the north towards the Brankholm Burn valley.

8.3.96 Groundwater samples were also collected along the route of the proposed scheme as part of the 2008 GI. No List I substances were recorded at detectable concentrations in the northern study area. However, a few samples indicated chloride and iron concentrations above the GAC for the water environment, which are defined in paragraph 8.2.17. One borehole, located in proximity of ch7350 of the proposed scheme (northeast of Cult Ness), recorded also other List II substances such as selenium, ammoniacal nitrogen and chromium above GAC, which seems to be atypical for this area. Detailed groundwater screening is provided in Appendix A8.1.

Southern Study Area

8.3.97 Beneath the proposed scheme in the southern study area, the number of piezometers installed in bedrock is considerably greater than the piezometers installed in drift. The spatial distribution of piezometers in the drift and bedrock is thus very different, and consequently the groundwater contours generated with the two sets of data appear different in some areas. However comparison between groundwater levels in the only nested piezometer (BHS3002) suggests that the two sets of groundwater levels in till and till-bedrock are similar, at least at this location. On this basis piezometers in drift and bedrock (58 groundwater monitoring installations in total) were inferred to be in good hydraulic continuity and therefore grouped to generate local groundwater contours (Figure 8.5).

8.3.98 Groundwater monitoring was undertaken on a daily basis from 26 April 2008 to 25 February 2009; however, the number of monitoring days per borehole varied between four and 15. Large fluctuations of groundwater levels (up to 12.8m) were noted in some boreholes installed either in drift or in bedrock. This may be attributable to a low storage capacity and/or a high degree of response to rainfall events. Average fluctuation in both drift and bedrock is of the order of magnitude of 3m and 1.4m respectively.

8.3.99 Figure 8.5d suggests that groundwater flow in both drift and bedrock is radial from the area comprised between Barrencraig Wood, Dundas Hill and Dundas Castle. It is inferred that this is driven by topographic setting and bedrock at or near the surface in this area (the dolerite sill), acting as a recharge area. However, it must be noted that there is no conclusive evidence as no borehole has been drilled in this sill complex.

8.3.100 Elsewhere, the general pattern of the groundwater contours suggests that regional groundwater mirrors topography and generally flows towards the Firth of Forth and the River Almond as expected.

8.3.101 Artesian groundwater conditions were encountered during the 2008 GI at ch2700 (response zone in glacial till-mudstone) to the northwest of Dundas Home Farm, and at ch3850 (response zone in glacial till-mudstone) to the west of South Queensferry. Adjacent monitoring indicates that these artesian conditions are very localised.

8.3.102 Groundwater samples were also collected along the route of the proposed scheme as part of the 2008 GI. Background groundwater quality in the southern study area appears to be characterised by high levels (i.e. above GAC for the Water Environment) of aluminium, sulphide, metals and in particular iron. In addition, detectable concentrations of some List I substances, mostly total

petroleum hydrocarbons (TPH) and polycyclic aromatic hydrocarbon (PAH), were detected in most samples, which confirms a generally poor regional background groundwater quality in this study area. Ammoniacal nitrogen was also detected at high concentrations in the vicinity of the M9 Junction 1A.

Areas potentially supported by groundwater

8.3.103 During site visits to St. Margaret's Marsh, no obvious spring flows were observed in the marsh. The salt marsh ecosystem was well defined, as was a drainage channel connecting the salt marsh to a pipe designed to discharge to the Firth of Forth but currently appearing to be blocked. The flow in this channel varies; it was dry at the time of the May 2008 site visit and flowing in November 2008. The local hydrological system appeared to be bounded by exposed rock (promontory consisting of the dolerite sill) and the road to the east of the site and the sewerage treatment facility to the north. It appeared that surface water collecting within the marsh was the single source of the perched groundwater table.

8.3.104 Based on the available information it is inferred that three groundwater bodies exist at St. Margaret's Marsh. The generalised characteristics of these groundwater bodies are described in Table 8.15.

Table 8.15: Aquifer properties at St. Margaret's Marsh

Aquifer	Hydrogeological Description
Perched Aquifer	Made ground exists at the site at thicknesses of between 1.9 and 2.2m bgl. Made ground content consists of general rubbish containing ash, metal, glass bottles, plastic, clay pots, ash sand and gravel. This aquifer varies in depth from 0.86m bgl to a maximum of 2.2m bgl. Groundwater movement is predicted to be within the made ground moving to the south toward the Firth of Forth. The catchment for this is thought to be limited to the marsh itself.
Drift Upper Aquifer	An aquifer is present within the reclaimed drift deposits at depths ranging from 0.36 to 3.98m bgl. This aquifer is tidally influenced near the foreshore. It is inferred that the marsh receives a proportion of recharge from this aquifer. The continuity of the drift aquifers with the regional groundwater is not known. However, given the geological features to the east of the site and inconsistency in the depths of groundwater strikes, it is expected that this aquifer does not continue beyond the extents of the marsh.
Bedrock Lower Aquifer	A deeper aquifer at the site is present within the underlying bedrock. It was reported that groundwater within the bedrock aquifer was tidally influenced near the coast. Groundwater was at depths ranging from 0.67 to 4.26m bgl. The extents of this aquifer are not known, but it appears likely that it will be connected through a saltwater/freshwater interface to the Firth of Forth.

Groundwater Private Water Supplies (PWS)

8.3.105 Table 8.16 (for the northern study area) and Table 8.17 (for the southern study area) list the historical and currently active PWS identified in the vicinity of the proposed scheme. These are also indicated on Figure 8.5.

8.3.106 The presence of several past and current wells and some springs in the igneous rocks indicates that these PWS are likely to be sourced by the groundwater that flows in fissures and joints at shallow depths. The presence of faults at or close to wells N01, N02 and N03 suggests that the fracture network may be particularly well developed at these locations, creating favourable conditions for the movement of groundwater.

8.3.107 Based on the consultation output detailed in Tables 8.16 and 8.17, groundwater supplies N03, N05, N06, S01 to S04 and S07 now appear to be abandoned and no assessment will be required.

Table 8.16: Groundwater Supplies in the Northern Study Area

Supply No.	Location	Type	Source of Information	Hydrogeological assumptions (based on geological & hydrogeological maps)	Consultation output
N01	Main Road, North Queensferry	Well	Well shown on current OS map.	The well appears to be sourced by shallow groundwater in the fractured dolerite sill. It is not known if the well is operational.	No consultation was undertaken as the property would not be directly affected by the proposed scheme.
N02	Brock Street, North Queensferry	Spring	Spring shown on current OS map.	The spring appears to be sourced by shallow groundwater in the fractured dolerite sill. It is not known if the spring is used.	No consultation was undertaken as the property would not be directly affected by the proposed scheme.
N03	Ferry Loch, Ferry Hills	Well	Well shown on current OS map.	The well appears to be sourced by shallow groundwater in the fractured dolerite sill. It is not known if the well is operational.	Consultation suggests that no PWS is currently used in this area.
N04	Castlandhill House	Well	Well shown on historical map (1896-1968) only.	The well appears to be sourced by shallow groundwater in the dolerite sill. It is not known if the well is operational.	The landowner assumes that the water supply is part private, part Scottish Water. The landowner believes that some water originates from a large tank at Castlandhill and supplies the fire hydrant system and the cottages. The location of the groundwater abstraction point and of the pipe network is unknown.
N05	The Hills, Inverkeithing	Well	Well shown on historical map (1896-1968) only.	The well appears to be sourced by shallow groundwater in the fractured dolerite sill. It is not known whether the well is operational.	Consultation indicates that no PWS is present in this area.
N06	Mills, Inverkeithing	Well	Well shown on historical map (1896) only.	The well appears to be sourced by shallow groundwater in fractured the dolerite sill. However, the review of aerial photographs indicated the development of new industry and this supply is believed to be abandoned.	No consultation was undertaken as the property would not be directly affected by the proposed scheme.
N07	District offices, Inverkeithing	Well	Well shown on current OS map.	The well appears to be sourced by shallow groundwater in the fractured dolerite sill. It is not known whether the well is operational.	No consultation was undertaken as the property would not be directly affected by the proposed scheme.
N12	Belleknowes Industrial Estate	Well	Well shown on historical map (1896-1926) only.	It is unclear whether this supply is sourced from volcanic or limestone bedrock. It is not known whether the well is operational.	No consultation was undertaken as the property would not be directly affected by the proposed scheme.
N23	Castlandhill	Well	Well shown on historical map (1849-1899) only.	It is not known where the well is sourced from or whether it is operational.	No consultation was undertaken as the property would not be directly affected by the proposed scheme.

Table 8.17: Groundwater Supplies in the Southern Study Area

Supply No.	Location	Type	Source of Information	Hydrogeological assumptions (based on geological & hydrogeological maps)	Consultation output
S01	Milrig	Well	Well shown on current OS map.	Well at or adjacent to glaciofluvial deposits. BGS maps suggest that the underlying bedrock is of sedimentary nature. Unknown source of groundwater. It is also not known if the well is operational.	Consultation indicated that no PWS is present in this property.
S02	Newliston	Spring	Well shown on current OS map.	Spring at or adjacent to geological contact between intrusive and sedimentary rocks.	Conversation with the landowner of Newliston indicated that this property has no PWS.
S03	Overton	Well	Well shown on current OS map.	Well in area of sedimentary bedrock outcropping or near to ground surface. Potentially sourced by fractures in the sedimentary rocks.	The landowner of Overton indicated that that a water supply had recently been installed from the municipal supply in the nearby Overton Road. Consultation also indicated that there are no PWS in this property.
S04	Humbie Farm	Well	Well shown on current OS map.	The well is in an area of glacial till. BGS maps suggest that the underlying bedrock is of sedimentary nature. Source of groundwater and use of the well is not known.	Consultation indicated that no PWS is present in this property.
S06	Chapel Acre, Dundas Castle	Well	Well shown on historical map (1969-1996) only.	Well in area of dolerite outcropping or near to surface. Well possibly sourced by shallow groundwater circulating in the fractures of the bedrock. It is unknown if the well is operational.	Not available as the property would not be directly affected by the proposed scheme.
S07	B924, South Queensferry	Well	Well shown on historical map (1915) only.	Well in area of sedimentary bedrock outcropping or close to ground surface. Well possibly sourced by groundwater circulating in the fractures of the sedimentary rocks. It is not known whether the well is operational.	There are no wells/springs in this property. The Farm Manager of Dundas Estate indicated that water from Dundas Loch is occasionally used to irrigate crops, but only during particular dry weather. This surface water supply is considered in Chapter 9 (Water Environment).

8.4 Potential Impacts

8.4.1 This section discusses the potential impacts (i.e. those that could occur in the absence of mitigation) to geological and hydrogeological features and potential contamination from road construction and/or operational activities. Permanent construction and operational impacts are assessed together, as the majority of construction impacts (such as removal of material at Beamer Rock) would extend through the operational phase.

8.4.2 In addition to permanent impacts of construction, there are also two key temporary construction activities that could have potential impacts on geology, contaminated land or groundwater. These are summarised and assessed in this chapter with further detail provided in Chapter 19 (Disruption Due to Construction):

- construction compounds (large construction compound in the south located to the west of chainage ch3700-4300, one small compound located near M9 Junction 1A in the south and one to the west of Ferrytoll Junction in the north) and associated temporary access; and
- intertidal jetties to the north and south Main Crossing bridge abutments.

8.4.3 Suitable mitigation is identified and described in Section 8.5.

Solid Geology

Firth of Forth

8.4.4 Some bedrock at Beamer Rock will need to be excavated to enable the construction of a marine tower foundation. The rock is too hard to excavate without initial blasting to loosen and fracture the rock. A blasting assessment is included in paragraphs 8.4.27 to 8.4.32. However this hard rock intrusion is not a designated feature and is not likely to be protected in the future, and is therefore of negligible sensitivity. The foundation base will be placed at -5m AOD. The magnitude of impact is also expected to be medium, as 15-50% of the total exposed igneous intrusion would be removed. Overall the potential impact is assessed as of Negligible/Slight significance.

8.4.5 The construction of other tower marine foundations will require rock sockets and large pre-cast pile caps to spread the tower loads into the pile group. Large (approximately 3m) diameter piles would be installed deep into bedrock (up to 25m) to support the marine towers. The marine bedrock is of negligible sensitivity, and the magnitude of impact is assessed as negligible. The potential impact is therefore of Negligible significance.

8.4.6 The impact of the north and south viaducts are covered in the following north and south areas respective assessments.

Northern Study Area

8.4.7 For the north viaduct, one pier foundation would be located in water (i.e. subtidal N1), with one other (N2) and north abutment on land at St. Margaret's Hope. The marine pier foundation N1 would require a 3m steel tube to be vibrated down to rockhead. The land based foundations would be spread foundations into rock and blasting may be required for N2 construction to create a bench into the slope.

8.4.8 The temporary intertidal jetty structure would connect the shore embankment with the approach viaduct piers. Approximately twenty steel tubes will be driven into the seabed to form a trestle to the jetty structure using vibration techniques. Piles are likely to be installed from a barge and, at the end of construction are to be cut-off 0.5m below existing bed level and the top parts removed.

8.4.9 A temporary access system for the Main Crossing construction would connect the trestle, used for bridge erection, with an access area designed at 8m AOD, followed by a construction access platform designed at 20m AOD and an access road rising back to the existing level. All these elements would require a degree of bedrock excavation.

8.4.10 Table 8.18 below details the road excavation required for the north, indicating which new or vertically deepened cuttings are likely or not to intercept bedrock and groundwater.

8.4.11 Road cuttings less than 1m deep are not reported.

Table 8.18: Excavated Areas within the Northern Study Area

Design Cutting				Drift Thickness (m)	Does cutting intercept bedrock/ groundwater	Bedrock type
Mainline/ Link/ Junction	Approx. Chainage (m)	Approx. length (km)	Maximum Excavation Depth (m)			
Mainline	ch7010-7080	0.07	5.2	0.5-2	Yes/Unlikely	Igneous
Mainline	ch7950-8430	0.43	5.0	4-14	Not expected/Expected	Mixed sedimentary-igneous
A90 northbound slip road to Ferrytoll Junction	ch185-235 ch810-850	0.05 0.04	5.7 1.2	Assumed 2-4 and 8-9	Assumed Yes/Not expected No/No	Mixed sedimentary-igneous
B981 Realignment	ch110-935	0.83	8.8	0.2-24	Likely/Likely	Mixed igneous-sedimentary
FRC southbound slip road to Ferrytoll Junction	ch0-280	0.28	3.0	3-6	May be slightly intercepted/Not expected	Igneous
FRC southbound slip road from Ferrytoll Junction	ch5-190	0.19	5.6	2-10	May be slightly intercepted between ch10-50/May be intercepted around ch180	Igneous
FRC northbound slip road from Ferrytoll Junction	ch0-90 ch340-420	0.09 0.08	1.1 1.6	3-5 11-20	No/Unlikely No/Unlikely	Mixed sedimentary-igneous
Castlandhill Road	ch55-310	0.26	3.9	8-12	No/May be slightly intercepted around ch210-220	Mixed sedimentary-igneous
Ferrytoll Junction	ch0-120 ch195-220 ch350-420	0.12 0.02 0.07	8.1 4.6 9.6	0.3-4	Likely/Expected Likely/Not Expected Likely/Expected	Igneous
Ferrytoll Road	ch0-60	0.06	3.5	Assumed 6-8	Assumed No/Assumed No	Assumed mixed sedimentary-igneous
North Haul Road (including temporary access road, access area and construction access platform)	ch0-120 (access road main cutting) ch130-190 (access road minor cutting) ch840-900 (platform)	0.12 0.06 0.06	8 4 12	0.30-1.20	Yes/May be slightly intercepted between ch860-880 (in the access area)	Igneous

8.4.12 With the exception of the Ferry Hills and the Firth of Forth SSSIs, bedrock is considered to be of negligible sensitivity as no features of geological/geomorphological importance have been identified and no protection is likely in the future. Given the extent of the same lithologies across the region, the magnitude of impact of excavations for road construction, pier foundation and temporary access road/platform is negligible. The overall significance of potential impacts on the solid geology of the northern study area is therefore considered as Negligible except in the Ferry Hills as discussed below. Complementary impact of blasting is discussed in paragraphs 8.4.27 to 8.4.32.

8.4.13 The Firth of Forth SSSI (high sensitivity for bedrock geology) area lies in the intertidal mud area. The piers of the Main Crossing would be located outside the Firth of Forth SSSI. Equally, the

bedrock excavations required for the temporary access system relate to an area to the north of the Firth of Forth SSSI and the steel tubes of the temporary trestle would not reach bedrock. Consequently, potential impacts on the solid geology of the Firth of Forth SSSI is assessed as of negligible magnitude and Slight significance.

8.4.14 No mainline road cutting is proposed along the Ferry Hills SSSI. However, side road construction for the A90 southbound slip road from Ferrytoll Junction to the A90 and the southbound slip road from the A90 to Ferrytoll Junction (Figure 8.5) and widening would be required in two locations within the Ferry Hills SSSI:

- Central Ferry Hills facing mainline ch7500-ch7720: removing the top section of the outcrop and regrading (using blasting or other excavation method) into two faces of 70°, reaching 3-4m above the railway to the east of the cutting; and
- Northern Ferry Hills facing mainline ch8320-ch8445: the proposed profile cuts back into the current profile by approximately 2m but the overall slope profile and design would remain similar. A vertical wall may be added locally to the top of the rock outcrop to provide support to the adjacent cemetery.

8.4.15 Ferry Hills is a SSSI of geological interest based on bedrock being exposed by the construction of the existing road. Consequently, although the SSSI is of high sensitivity, the proposed reprofiling needs to be compared to the existing outcrop shape to define areas of negative and positive impacts:

- Central Ferry Hills is currently meshed and is mostly inaccessible. The proposed profile may result in providing better accessibility as meshing may be avoidable. However, detailed stabilisation assessment will be carried out during construction.
- Northern Ferry Hills: the proposed profile is similar in slope and shape to the existing one and no change is expected in terms of stability. Nevertheless, detailed stabilisation assessment will be carried out during construction.
- SNH indicated that the bedrock is homogeneous throughout the central and northern part of Ferry Hills and consequently the new exposure of rock will satisfactorily replace the existing exposure.

8.4.16 In geological terms as discussed in paragraphs 8.4.14 and 8.4.15, the magnitude of potential impact on Ferry Hills SSSI as a whole is considered as low and of Moderate significance.

8.4.17 For stability purposes, rock netting may also be required in areas along the B981 realignment, the A90 northbound diverge slip road, Ferrytoll Junction and the A90 northbound slip road from the Main Crossing to Ferrytoll Junction. However, these are outwith the boundary of the SSSI and are not considered to represent an adverse impact on geology.

Southern Study Area

8.4.18 The south viaduct would include four piled piers in the Firth of Forth (S1 to S4), while foundations nearer to the shore in the intertidal zone (S5 and S6) and on land (two foundations S7 and S8 and south abutment) would be spread foundations.

8.4.19 Excavation levels for piers S5 and S6 are -4.5 and -2.0m AOD respectively so as to reach bedrock. For construction purposes, an earth bund would be created around these piers. The weak material would be first excavated before placing a layer of gravel and build up a sand and rock armour bund. The bund will be removed upon completion of construction.

8.4.20 The temporary intertidal jetty structure would connect the shore bund with the approach viaduct piers. The temporary trestle bridge would be supported by driven steel tube piles. Piles are likely to be installed from a barge and at the end of construction are to be cut off 0.5m below existing bed level and removed.

8.4.21 To the northeast of Queensferry Junction, a temporary access route for construction purposes would follow the alignment of the proposed scheme and would include an embankment area near the shore and a cutting in the vicinity of Inchgarvie House.

8.4.22 Table 8.19 below details the road cuttings required for the southern study area, indicating that there would be at least three cuttings (including one mainline cutting) that are likely to intercept both bedrock and groundwater.

8.4.23 Road cuttings less than 1m deep are not reported.

Table 8.19: Excavated Areas within the Southern Study Area

Design Cutting				Drift Thickness (m)	Does cutting intercept bedrock/ groundwater	Bedrock type
Mainline/Link /Junction (Figure 8.5)	**Approx Chainage (m)**	**Approx length (km)**	**Maximum Excavation Depth (m)**			
Swine Burn realignment	ch40-430	0.47	9.5	3.5-6.5	Likely/Likely	Sedimentary
M9 (Existing earthworks slopes to be re-profiled)	ch1200-1600	0.40	4.0	Assumed 2.6-3.5	Assumed Yes/ Not expected	Mixed sedimentary-igneous
A904 west	ch40-150 ch330-440	0.11 0.11	1.1 1.3	2.3-4	Not expected/ Not expected	Assumed sedimentary
FRC southbound to A904 diverge slip road	ch0-440	0.44	8.1	Assumed 4.5-8.5	May be slightly intercepted/ Assumed Yes	Mixed sedimentary-igneous
M9 to A8000 northbound slip road	ch115-440	0.33	7.4	3.6-7	Slightly intercepted/ Likely	Assumed mixed sedimentary-igneous
A8000 to M9 southbound slip road	ch60-300	0.24	3.9	3-15	Not expected/May be intercepted	Sedimentary
A8000 northbound to M9 diverge slip road	ch0-190	0.19	1.6	0.5-2.5	May be slightly intercepted/ May be slightly intercepted	Sedimentary
Builyeon Road	ch230-390	0.16	2.6	2-4	May be slightly intercepted/ May be slightly intercepted	Sedimentary
Mainline	ch3025-4250	1.2	8.2	0.5-15	Yes/ Likely	Mixed sedimentary - igneous
Temporary access road cutting near Inchgarvie House	ch650-750	0.1	6.0	3-6	May be slightly intercepted/ Not expected	Mixed sedimentary-igneous

8.4.24 With the exception of the Firth of Forth SSSI, bedrock is considered to be of negligible sensitivity in the area as no features of geological/geomorphologic importance have been identified beneath or adjacent to the proposed scheme and protection is unlikely in the future. Given the extent of the same lithologies across the region, the potential impact is assessed as being of negligible magnitude resulting in Negligible significance.

8.4.25 The Firth of Forth SSSI (high sensitivity for bedrock geology) area lies to the east of the proposed route and it is not anticipated that it would be affected by the works.

8.4.26 For stability purposes, benching (i.e. creation of steps) may be required in areas along mainline ch5960-4260, southbound to A904 diverge slip road and A904 to northbound slip road (Figure 8.5).

Impact of Blasting

8.4.27 Potential impacts from blasting are the same for the northern and the southern study areas and are described below.

8.4.28 It is anticipated that rock blasting may be required where cuttings/excavations/reprofiling extend into bedrock. There are three major mechanisms where rock blasting can impact on rock structure:

- generation of new fractures in previously intact rock;
- dilation of existing joints and discontinuities by the action of high pressure explosive gases; and
- promotion of slip planes along favourably oriented joints and fracture surfaces.

8.4.29 All three mechanisms are vibration controlled. The generation of new fractures in previously intact rock and the dilation of existing joints and discontinuities occur close to the blast zone (termed 'near-field' effects), and the promotion of slippage along favourably oriented joints can occur several hundreds of metres from the blast (termed 'far-field' effects).

8.4.30 Blasting effects on rock mass as described above may result in consequential impacts on hydrogeology by creating or changing groundwater pathways. Potential impacts could therefore occur if the contractor opts to use explosives in the excavation of the cuttings where there are sensitive hydrogeological receptors and significantly contaminated sites in relatively close proximity. The impact of blasting on groundwater is assessed in the groundwater section. Blasting on solid geology is considered to be an impact of negligible magnitude.

8.4.31 On this basis the overall significance of potential impacts from blasting operations on solid geology is considered as Negligible, except at Ferry Hills. The impact on reprofiling Ferry Hills SSSI (which includes the use of blasting) is discussed in paragraphs 8.4.15 and 8.4.16. In addition, blasting could also destabilise blocks of rock over the railway line that run parallel to the proposed scheme to the west of Ferry Hills.

8.4.32 The potential impact of contamination on surface water features resulting from demolition activities is addressed in Chapter 9 (Water Environment) and those in terms of disruption are addressed in Chapter 19 (Disruption due to Construction).

Drift Geology (Superficial Deposits)

Firth of Forth

8.4.33 No sites or designated features of geological/geomorphological interest are present and the marine sediments are of negligible sensitivity.

8.4.34 For the viaduct construction, the impact of the construction of marine foundations and impact on dredging are assessed separately below.

8.4.35 Construction of marine foundations will locally disturb marine sediments. The potential magnitude of impact on drift geology is assessed as negligible and the significance as Negligible.

8.4.36 The dredging of the Firth of Forth at the northern and southern end of the Main Crossing includes:

- in the north, dredging around the marine pier foundation (area of about 120m by 180m) and pier N1 (area of about 60m by 60m); and
- in the south, dredging around foundations S1 to S4 (area of 60m by 60m around each foundation).

8.4.37 In total, it is estimated that a volume of around 120,000m^3 will be dredged. It should be noted that the dredging around pier N1 is likely to encroach slightly into the mud of the Firth of Forth SSSI.

The muds of the Firth of Forth SSSI are of geomorphologic interest only, and not of geological drift interest. Impact on the geomorphology is covered in Chapter 9 (Water Environment). The mud deposits in terms of geology are considered of low sensitivity. Given the distribution of marine sediments within the Firth of Forth the potential impact magnitude is expected to be low, and of Slight/Negligible significance.

8.4.38 The potential impacts on the Firth of Forth marine geomorphology are reported in Chapter 9 (Water Environment). The impact on disturbing potentially contaminated marine sediments is discussed in the contaminated land assessment of this chapter (paragraphs 8.4.52 to 8.4.54).

Northern Study Area

8.4.39 On the basis of the desk-based assessment and GI, glacial till covers the majority of the area with lacustrine and possibly raised beach deposits present only in very small localised areas. These deposits have no specific geological or geomorphological importance and are well represented in other parts of Scotland. They are therefore considered to be of negligible sensitivity. The magnitude of impact is estimated to be negligible to low, depending on whether there is partial or total removal of drift. The potential impacts on the drift geology in the northern study area are therefore assessed as of Negligible significance overall.

8.4.40 A temporary bund is to be constructed on land, on top of the mud of the Firth of Forth SSSI, to form an apron around the end of the trestle. As explained in paragraph 8.4.35, the mud deposits in terms of drift geology are considered of low sensitivity. The impact of the bund is expected to be localised, and therefore of low magnitude. The potential impact from the bund onto the drift geology of the Firth of Forth SSSI is therefore assessed as Negligible/Slight significance overall.

8.4.41 Impacts on the geomorphology are covered in Chapter 9 (Water Environment).

8.4.42 For stability purposes, soil nailing may be required along the mainline between ch8650 87800 and ch8860-9180.

Southern Study Area

8.4.43 Glacial deposits underlie the majority of the route, and Table 8.19 above indicates that cuttings are likely to partially or totally remove drift deposits in specific areas. Small areas of undifferentiated alluvium are also present, along with lacustrine deposits, marine beach and raised tidal deposits and a small area of glaciofluvial deposits. However none of these glacial, marine and alluvial deposits have any specific geological or geomorphological importance and are well represented in other parts of Scotland. They are therefore considered to be of negligible sensitivity. The magnitude of impact is estimated to be negligible to low, depending on whether there is partial or total removal of drift. The potential impacts on the drift geology in the southern study area are therefore assessed as of Negligible significance overall.

8.4.44 The Firth of Forth SSSI (low sensitivity for drift geology) area lies to the east of the proposed scheme and it is not anticipated that it would be affected by the works

Mineral Extraction

Firth of Forth

8.4.45 In relation to mineral extraction, no potential impacts are predicted from the development of the Main Crossing itself.

Northern Study Area

8.4.46 No former coal/limestone mining is expected to have taken place at shallow depth in the study area. There is no potential impact expected from past mining activities in the northern study area.

There is no future potential coal resource in this area according to the Coal Authority (Coal Authority, 2008b-e).

Southern Study Area

8.4.47 Where shallow mineworkings (oil-shale and/or limestone) are present, there is a risk of ground instability during both construction and operation. The detailed mining assessment conclusions are summarised in Table 8.20 below for each area of interest.

Table 8.20: Detailed mining assessment conclusions and recommendations

Area of interest	Mining assessment conclusion
Mainline relating to M9 J1A and A90 bus link	The steep inclination of the strata is a contributing factor to the potential for subsidence above oil-shale workings. The overall risk of recorded oil-shale workings resulting in surface subsidence is determined as relatively low but some uncertainty remains.
Other sections of mainline	Risk is low.
Queensferry Junction	No oil-shale mining constraints Low risk with regard to shallow workings in Burdiehouse Limestone but uncertainty remains.
Junction 1A (M9 Spur) Improvements	Low risk with regard to unrecorded oil-shale workings. Localised surface workings within Burdiehouse Limestone can not be discounted.
A90 to A8000 bus link	There are uncertainties with regard to the potential influence of abandoned oil-shale workings on the current route proposals.

8.4.48 Sterilisation of unexploited coal/oil shales beneath the proposed scheme can not be ruled out although have not been identified. Potential resources are of low sensitivity and if the impact did occur it would be localised and hence of low magnitude and Slight significance.

Contaminated Land

8.4.49 Potential pathways and receptors for land and marine contaminants are listed in Table 8.21 with their designated Pollutant Pathway reference.

Table 8.21: Potential Pathways-Receptors

Pollutant Pathway Reference	Pathway	Receptor
Construction		
PL1	Ingestion, inhalation and dermal contact with soils, soil dust, marine sediments, deep groundwater and /or shallow groundwater in the short term during construction activities e.g. drainage construction/blasting including the construction compounds	Construction workers
PL2	Migration of ground gases into confined spaces and/or cutting areas during construction posing a potential asphyxiation/explosion risk. Including preferential pathways created during construction of engineering structures e.g. during piling and including the construction compounds.	
PL3	Ingestion, inhalation and dermal contact with wind blown dust created during excavation works.	Off-site receptors (humans)
PL4	Migration of ground gases into homes/workplaces through preferential pathways created during construction posing a potential asphyxiation/explosion risk.	
PL5	Leaching and migration of contaminants from soils excavated during construction and reused/stored on site.	Shallow groundwater
PL6	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels created during the construction of engineering structures e.g. during piling or through leaching of contaminants from soils reused/stored on site through the shallow cohesive drift deposits. Ground improvement techniques such as mine grouting or piling pushing either contaminated materials from the near surface into the groundwater or placing materials below the aquifer.	Deep groundwater (potential drinking water source)

Pollutant Pathway Reference	Pathway	Receptor
PL7	Migration of: • Shallow groundwater, contaminated as a result of the reuse/storage of contaminated soils on site, through drift deposits or made ground. • Migration of shallow groundwater through existing services that may be intercepted by the proposed scheme. • Deep groundwater, contaminated as a result of the migration of shallow groundwater through artificial pathways created during construction. • Shallow and deep groundwater entering cuttings during blasting and construction. • Contaminated sediments disturbed during the construction of the bridge piers (Marine Study Area only).	Surface water
PL8	Inhalation, ingestion and direct contact with contaminated soils/sediments excavated and stored/reused on site during construction.	Ecological receptors (includes plants and animals)
PL9	Plant uptake from contaminated soils excavated and stored/reused on site during construction.	
Operation		
PL10	Ingestion, inhalation and dermal contact with soils, soil dust, marine sediments and /or shallow groundwater in the long term during routine maintenance activities e.g. drainage inspections	Maintenance workers
PL11	Migration of ground gases into confined spaces e.g. service pits, creating an asphyxiation/explosion risk	
PL12	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	End users (includes users of the proposed scheme)
PL13	Ingestion, inhalation and dermal contact with wind blown dust from contaminated soils reused within road features such as embankments and landscaped areas.	Off-site receptors (humans)
PL14	Migration of ground gases into homes/workplaces through preferential pathways remaining following construction thus posing a potential asphyxiation/explosion risk.	
PL15	Leaching and migration of contaminants from soils reused within the engineering structures e.g. embankments	Shallow groundwater
PL16	Vertical migration of contaminated shallow groundwater into the deeper rock aquifer through artificial channels remaining following construction of engineering structures e.g. band drains or piled structures or through leaching of contaminants from soils reused on site through the shallow cohesive drift deposits.	Deep groundwater (potential drinking water source)
PL17	Migration of : • Shallow groundwater contaminated as a result of the reuse of contaminated soils on site through drift deposits or made ground. • Migration of shallow groundwater through existing services that may be intercepted by the proposed scheme. • Contaminated shallow groundwater through drainage channels and associated granular bedding materials or engineered structures. • Contaminated surface water from the new road surface through drainage channels • Shallow groundwater entering cuttings	Surface water
PL18	Direct contact with contaminated soils and groundwater resulting in chemical attack.	Proposed structures and buildings
PL19	Contaminant ingress into potable water supplies laid as part of the infrastructure design.	
PL20	Inhalation, ingestion and direct contact with contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.	Ecological receptors (includes plants and animals)
PL21	Plant uptake from contaminated soils reused on site within engineering features e.g. embankments and landscaped areas.	

8.4.50 The potential sources (paragraphs 8.3.69 to 8.3.80) are combined with the potential pathways-receptors (Table 8.21) to assess the existence of the potential pollutant linkages. The pollutant linkages (where potentially complete) were then quantitatively assessed on the basis of the 2008 GI tests results and are summarised in Appendix A8.1.

8.4.51 The sections below describe the type of generic quantitative assessment that was undertaken in each area and highlights the main conclusions of the assessment. The full CSM and impact assessment conclusions are summarised in Appendix A8.1.

Firth of Forth

8.4.52 The following quantitative assessments have been undertaken for the marine study area:

- a generic human health quantitative screening assessment: it was considered unlikely that sediments present would pose a risk to human health via pollutant pathways PL1, PL2, PL3, PL4, PL10, PL11, PL12, PL13 and/or PL14 (for pathways refer to Table 8.21);
- a generic Water Environment quantitative screening assessment: some metals and ammoniacal nitrogen were identified above the screening values in leachate and therefore may pose a risk to the Water Environment following disturbance of sediments during construction (pollutant pathway reference PL7);
- an assessment of the effects of contaminants in shallow sediment on ecological receptors is included in Chapter 11 (Estuarine Ecology); and
- concentrations of sulphate need to be considered when concrete structures are designed to ensure the appropriate class of concrete in the marine area..

8.4.53 Low concentrations of contaminants were identified within the sediments located in the proposed locations of the bridge supports. Potential moderate/low risks to human health and proposed structures are present.

8.4.54 Construction activities, including dredging and piling, have the potential to re-suspend sediments and release sediment bound contaminants. The dredging and piling impact to the estuarine environment are assessed in Chapter 11 (Estuarine Ecology). The impact of the re-suspension of sediments is included in Chapter 9 (Water Environment).

Northern Study Area

8.4.55 The following quantitative assessments have been undertaken for the northern study area:

- a human health generic quantitative screening assessment: this assessment identified a number of contaminants, including heavy metals and hydrocarbons, which may pose a risk to human health via pollutant pathways PL1, PL2, PL3, PL4, PL10, PL11, PL12, PL13 and/or PL14 (for pathways refer to Table 8.21);
- a generic Water Environment quantitative screening assessment: iron, selenium, chloride and ammoniacal nitrogen were identified above the screening values in groundwater samples. Therefore the proposed scheme may pose a risk to the Water Environment via pollutant pathways PL6, PL7, PL16 and/or PL17 where groundwater is to be intercepted. The impact is discussed in further details in paragraphs 8.4.75 to 8.4.78;
- a generic ecological risk assessment: this was undertaken for the sensitive St. Margaret's Marsh Scientific Site of Special Interest (SSSI) area and identified a number of contaminants which could potentially pose a risk to ecological receptors via pollutant pathways PL8, PL9, PL20 and/or PL21;
- assessment of risks to concrete structures and buildings: concentrations of sulphate need to be considered for concrete structures to ensure the appropriate class of concrete; and

- assessment of risks posed by ground gas: a characteristic situation of 'very low' to 'low' risk has been derived for future buildings (pollutant pathway reference PL14).

8.4.56 The proposed scheme crosses a number of areas of land potentially affected by contamination. Following assessment of investigation and analytical data, a number of areas have been identified which may pose a risk to human health, the Water Environment, future buildings/structures and/or ecological receptors if mitigation measures are not undertaken (Appendix A8.1). The main outcomes of the assessment are discussed below.

8.4.57 The St. Margaret's Marsh landfill (source reference N2) is of concern as the realignment of B981 from North Queensferry to Ferrytoll road runs through the former landfill and the drainage basin from the Main Crossing infringes on marsh. There is a Medium to Very High risk from potentially contaminated soils, groundwater and gas to construction workers, offsite receptors, shallow groundwater, ecological receptors and maintenance workers.

8.4.58 Made ground identified at the locations of source references N1, N17 to N20, N27 to N29 and N31 identified a Moderate risk from ground gasses to construction and maintenance workers. In addition, source references N27-N29 and N31 identified a Moderate risk to construction and maintenance workers from ingestion, inhalation and dermal contact with soils, soil dust, marine sediments and shallow groundwater. Source reference N31 also identified offsite receptors having a Moderate risk from ground gasses.

Southern Study Area

8.4.59 The following quantitative assessments have been undertaken for the southern study area:

- a generic water environment quantitative screening assessment: some metals, ammoniacal nitrogen and hydrocarbons were identified above the screening values in groundwater samples. Therefore the proposed scheme may pose a risk to the water environment via pollutant pathways PL6, PL7, PL16 and/or PL17 where groundwater is to be intercepted. The impact is discussed in further details in paragraphs 8.4.89 to 8.4.94 (for pathways refer to Table 8.21);
- assessment of risks to concrete structures and buildings: concentrations of sulphate need to be considered for concrete structures to ensure the appropriate class of concrete; and
- assessment of risks posed by ground gas: a characteristic situation of 'Very Low' to 'Low' risk has been derived for future buildings (pollutant pathway reference PL14). However, significantly elevated methane and carbon monoxide concentrations have been identified which may pose a risk to human health, in particular construction workers via pollutant pathway PL2.

8.4.60 The proposed scheme would cross a number of areas of land potentially affected by contamination. Although analytical data are currently limited, the evidence available suggests that no hazardous materials will be encountered during the earthworks. In areas where potential sources of contamination are adjacent to the proposed road (source references S2, S3, S11 and S13) there is a Moderate risk from ground gasses to construction and maintenance workers or off site receptors. It is considered that Very Low to Moderate/Low risks to human health, the water environment, future buildings/structures and ecological receptors for all other pollutant linkages.

Groundwater

8.4.61 The impacts of the proposed scheme are considered below in relation to the presence of groundwater bodies with resources potential (as per information collected from BGS and SEPA), PWS and/or ecological receptors supported by groundwater.

8.4.62 The presence of embankments may result in localised compaction of superficial deposits. However, in groundwater flow terms, this would result in localised impacts of negligible magnitude (except in areas potentially supported by groundwater which are discussed separately). The overall potential impact of compaction from embankments on groundwater is assessed as being of Negligible significance.

8.4.63 Lowering of the groundwater table (temporal dewatering during construction or long-term effect during operations) may locally impact on groundwater flow, PWS yields, adjacent surface water features fed by groundwater base flow, ecological sensitive areas supported by groundwater and urban settlement.

8.4.64 There are no identified surface water features at risk from groundwater dewatering along the proposed road cuttings. This aspect is therefore not considered further in the impact assessment.

8.4.65 The scale of dewatering around a cutting is a function of the cutting depth, the depth of the water table and the hydraulic characteristics of the aquifer. As the scale of dewatering is likely to be localised around the cuttings, impacts on groundwater flow are discussed in relation to nearby PWS and/or ecological receptors and/or urban access.

8.4.66 Sensitivities of groundwater bodies are described in paragraphs 8.3.79 to 8.3.81 and Table 8.14. Potential impacts may occur in both the northern and southern study area and they are further discussed below with respect to each area.

8.4.67 Review of the existing groundwater quality revealed the presence of several contaminants. In some cuttings, groundwater is expected to be intercepted, resulting in a potential risk to the workers and to the water environment where abstracted groundwater will be discharged. Potential risk to workers is covered in the Contaminated Land paragraphs 8.4.49 to 8.4.51 – pollutant linkages PL1, PL10, PL7 and PL17. However impacts to the water environment are discussed here.

Firth of Forth

8.4.68 No impacts in relation to groundwater are predicted from the development of the Main Crossing.

Northern Study Area

Groundwater Quality

8.4.69 In the event of an accidental spillage during road construction or operational phases, potential contamination may either migrate through the unsaturated zone or discharge directly into groundwater in cuttings and impair groundwater quality, unless appropriate measures for the control of discharges and road drainage are taken. The areas at higher risk are the cutting areas listed in Table 8.18.

8.4.70 The magnitude of impact from accidental spillages is considered as medium where cuttings are likely to intercept groundwater (Table 8.18) as listed below. The potential impacts are assessed as being of Moderate to Slight/Moderate significance:

- Mainline (ch7900-8430) running above mixed sedimentary-igneous bedrock (Moderate);
- B981 realignment (ch110-935), running above mixed igneous-sedimentary bedrock (Moderate);
- FRC southbound slip road from Ferrytoll Junction, around ch180, running above igneous bedrock (Slight/Moderate);
- Castlandhill Road, around ch210-220, running above mixed sedimentary-igneous bedrock (Moderate); and
- North haul road (temporary access roads/platform excavations) running above igneous bedrock (Slight/Moderate).

8.4.71 The magnitude of impact from accidental spillages is assessed to be low where only a thin to moderate thickness (less than 10m) of drift deposits remains in a proposed cutting or is present below a proposed embankment. The approximate locations of these areas are listed below. The potential impacts are assessed as being of Slight/Moderate to Negligible/Slight significance.

- ch6800-7650 (mainline including associated slip roads and B981 realignment between these chainages) above mixed igneous-sedimentary bedrock (Slight/Moderate);
- ch7650-7900 (mainline) above igneous bedrock (Negligible/Slight);
- ch0-280 (A90 southbound slip road from Ferrytoll Junction to the A90) above igneous rocks (Negligible/Slight);
- ch0-190 (southbound slip road from the A90 to Ferrytoll Junction) above igneous rocks (Negligible/Slight);
- ch0-420 (Ferrytoll Junction) above igneous rocks (Negligible/Slight)
- ch0-290 (Ferrytoll Road) above mixed sedimentary-igneous rocks (Slight/Moderate);
- ch0-270 (Castlandhill Road) above mixed sedimentary-igneous rocks (Slight/Moderate); and
- ch0-200 (temporary access roads/platform excavations) running above igneous bedrock (Negligible/Slight).

8.4.72 In areas other than those listed in paragraphs 8.4.70 and 8.4.71, the magnitude of impact on groundwater from accidental spillages is determined as negligible. Consequently where sedimentary bedrock is present (medium sensitivity), the potential impact is of Negligible/Slight significance, and of Negligible significance where only igneous rock is present).

8.4.73 During operational phase, contaminants from storm water ponds and treatment facilities may percolate down and contaminate underlying groundwater. Magnitude is therefore assessed as high, and the potential impact is determined as being of Moderate to Moderate/Substantial significance.

8.4.74 The magnitude of impact of blasting on the overall quality of the bedrock aquifer is considered negligible, because dilution would significantly reduce the risk of contamination. The potential impact is therefore of Negligible significance for groundwater in igneous rock and of Negligible/Slight significance for groundwater in sedimentary rocks.

8.4.75 Cuttings which are likely/expected/suspected to intercept groundwater at depth are listed in Table 8.18. The groundwater quality in these locations is very similar and fits the general groundwater baseline description given in the baseline, mainly characterised fair quality as discussed in paragraph 8.3.96.

8.4.76 Road construction in this area is expected to occur over a period of up to three years and cuttings are scheduled at the beginning of the construction program. As construction progresses groundwater seepage will decrease as a new equilibrium establishes. Consequently, the highest groundwater discharge flows are expected during the first stages of construction.

8.4.77 Without appropriate mitigation measures, the discharge of dewatered groundwater in the first stages of construction could impact on the water environment in which it is being discharged. If discharged to the Firth of Forth (high sensitivity) directly, the dilution factor is such that the magnitude of impact is expected to be negligible and the potential impact is therefore assessed as being of Slight significance. If discharged to a local burn (high sensitivity), the dilution factor will be limited resulting in a magnitude of impact of low to medium and a potential impact of Moderate to Substantial/Moderate significance.

8.4.78 On completion of the construction phase, groundwater discharge is expected to be negligible in comparison to highways run-off. Consequently, discharge of abstracted groundwater into sensitive surface water features is assessed as being of negligible magnitude and Slight significance.

Private Water Supplies (PWS)

8.4.79 The sensitivity, magnitude and significance of impacts on PWS quality and yield are assessed in Table 8.22 and criteria are defined in Appendix A8.2. PWS that were not confirmed during the consultation process (Table 8.16) or that are believed to be abandoned are not assessed. Table 8.22 indicates that the quality of N03, N04 and N23 is potentially at risk without appropriate mitigation measures. However, only the yield of N04 is potentially at risk without mitigation measures.

8.4.80 PWS infrastructure (wells, underground water pipes and tanks) could be intercepted and destroyed by road cuttings, which could lead to the loss of water supply. However, given the location of the PWS of Table 8.22 in relation to the proposed scheme it is unlikely that this would occur.

8.4.81 Table 8.22 indicates that to date no PWS is at particular risk of contamination from blasting activity since all the PWS listed in Table 8.22 are more than 100m away from the proposed scheme. Above such distance the risk of short-term contamination as a consequence of blasting activities is reduced because of the dilution effect. However, PWS N04 could be impacted in terms of yield by blasting activities for cuttings intercepting groundwater (refer to paragraph 8.4.79).

Table 8.22: Potential Impacts on quality of PWS (without mitigation measures) in the Northern Study Area

PWS and Type	Mainline/ Link/ Junction	Indicative chainage (m)	Minimum distance from proposed scheme	Topographic position in relation to proposed scheme	Cutting/ Embankment /Transition Cutting Embankment	On or adjacent to existing A90 cutting	Does cutting intercept groundwater	Sensitivity	Potential Impact			
									Magnitude		Significance	
									Quality	Yield	Quality	Yield
N01: Well	A90 northbound slip road to Ferrytoll Junction	ch0-100	570m	On different slope	Embankment	n/a	n/a	Negligible	Medium	Negligible	Negligible/ Slight	Negligible
N02: Spring	A90 northbound slip road to Ferrytoll Junction	ch0-100	580m	On different slope	Embankment	n/a	n/a	Negligible	Medium	Low	Negligible/ Slight	Negligible
N03: Well	A90 northbound slip road to Ferrytoll Junction	ch185-235	250m	Up-slope	Cutting adjacent to existing cutting	Yes	Not expected	Medium	High	n/a	Moderate/ Substantial	n/a
N04: Well	Castlandhill Road	ch55-310	350m[1]	Upslope and on different slope	Cutting adjacent to existing cutting	Yes	May be slightly intercepted	Medium	High	Medium	Moderate/ Substantial	Moderate
N07: Well	Mainline	ch8750	580m	On different slope	Cutting	Yes	No	Negligible	High	n/a	Slight	n/a
N12: Well	Mainline	ch9150	900m	On different slope	Cutting	Yes	No	Negligible	High	n/a	Slight	n/a
N23: Well	FRC southbound slip road to Ferrytoll Junction	ch8600	350m	Upslope	Cutting	Yes	No	Medium	High	n/a	Moderate/ Substantial	n/a

[1] Location of abstraction point is not known and the distance has been assumed.

Areas Potentially Supported by Groundwater

8.4.82 St. Margaret's Marsh is a saltmarsh and reedbed habitat SSSI (high ecological sensitivity), which is believed to be supported by shallow groundwater percolating through the made ground to underlying deposits. The realignment of the B981 from North Queensferry to Ferrytoll Road runs through the eastern perimeter of the marsh and the proposed SUDS drainage basin infringes on the eastern boundary of St. Margaret's Marsh. The access road could act as a barrier to shallow groundwater flow and could reduce the catchment area for the perched aquifer by up to approximately 25%.

8.4.83 As the marsh is reported to be in poor condition, reduction in catchment volume could have a medium magnitude of impact. St. Margaret's Marsh is believed to be groundwater fed and is therefore highly dependant on groundwater levels and quality. The potential impact on St. Margaret's Marsh water level and water quality is therefore assessed as being of Substantial/High significance due to the high ecological sensitivity. Ecological impacts are assessed separately in Chapter 10 (Terrestrial and Freshwater Ecology).

Southern Study Area

Groundwater Quality

8.4.84 In the event of an accidental spillage, during the construction or operational phase, potential contamination may either migrate through the unsaturated zone or discharge directly into groundwater in cuttings and impair groundwater quality, unless appropriate measures for the control of discharges and road drainage are taken.

8.4.85 The magnitude of impact from accidental spillages is medium where cuttings are likely to intercept groundwater (Table 8.19) as listed below. In these cases, the potential impact is therefore assessed as being of Moderate significance:

- ch3200-4150 (mainline and associated side roads) running above a mixture of sedimentary and igneous bedrock.

8.4.86 The magnitude of impact from accidental spillages is assessed as low where only a thin thickness (less than 10m) of drift deposits remains in a proposed cutting or is present below a proposed embankment. The approximate locations of these areas are listed below. The potential impact is assessed as being of Slight/Moderate significance:

- The proposed scheme around M9 Junction 1A above mixed sedimentary-igneous bedrock.
- ch2000-2500 (Queensferry Junction) above sedimentary bedrock;
- ch4150-4600 (Mainline, including associated roads) above a mixture of sedimentary and igneous bedrock. This area partially includes the main construction compound; and
- ch0-1050 temporary access road running above mixed igneous-sedimentary rocks.

8.4.87 In areas other than those listed in paragraphs 8.4.85 and 8.4.86, the magnitude of impact on groundwater from accidental spillages is determined as negligible. Consequently where sedimentary bedrock is present (medium sensitivity), the potential impact is assessed as being of Negligible/Slight. Where igneous rock is present, the potential impact is assessed as being of Negligible/Slight significance and Negligible where igneous rock is present.

8.4.88 A small area encompassing glacio-fluvial deposits and alluvium (high sensitivity) draining into the River Almond (ch800-1120) is located below a proposed embankment. The magnitude of impact on this area is assessed as low and the potential impact of accidental spillages at this location is assessed as being of Slight/Moderate significance.

8.4.89 During operational phase, contaminants may percolate and contaminate underlying groundwater where drainage features (such as detention and attenuation basins). The magnitude of impact is high and the potential impact has been assessed as being of Moderate significance.

8.4.90 The magnitude of blasting on the overall quality of the bedrock aquifer is considered to be negligible because dilution would significantly reduce the risk of contamination. The potential impact has been assessed as being of Negligible significance for groundwater in glacial till and igneous rock and of Negligible/Slight significance for groundwater in sedimentary rocks.

8.4.91 Cuttings which are likely/expected/suspected to intercept groundwater at depth are listed in Table 8.19. There are three main locations where groundwater is expected to be intercepted: ch3025 to 4250 along the mainline, A904 to Queensferry Junction northbound slip road (MG1A WHS) and the Swine Burn realignment. Groundwater quality is the same along the mainline and the A904 junction; but slightly differs in the vicinity of the Swine Burn. However, the overall background groundwater quality in the south is characterised by the presence of TPHs, PAHs, selected list II substances and iron, as discussed in paragraph 8.3.101.

8.4.92 Road construction is expected to take place over a period of five years and cuttings are scheduled at the beginning of the construction program. As construction progresses groundwater seepage will decrease as a new equilibrium establishes. Consequently, the highest groundwater discharge flows are expected during the first stages of construction.

8.4.93 Without appropriate mitigation measures, the discharge of dewatered groundwater in the first stages of construction could impact on the water environment in which it is being discharged. If discharged to the Firth of Forth (high sensitivity) directly, the dilution factor is such that the magnitude is negligible to low and the potential impact is assessed as being of Slight to Moderate significance. If discharged to a local burn (high sensitivity), the dilution factor will be limited resulting in a magnitude of medium to high; the potential impact is therefore assessed as being of Substantial/Moderate to Substantial significance.

8.4.94 On completion of the construction phase, groundwater discharge is expected to be negligible in comparison with highways run-off. Consequently, the discharge of abstracted groundwater into sensitive surface water features is of negligible magnitude and the potential impact is assessed as being of Slight significance

Private Water Supplies

8.4.95 The sensitivity, magnitude and significance of impacts on PWS quality and yield are listed in Table 8.23 and criteria are defined in Appendix A8.2. PWS that were not confirmed during the consultation process (Table 8.17) or that are believed to be abandoned are not assessed.

8.4.96 Table 8.23 indicates that there are no PWS at risk of being impacted.

8.4.97 PWS infrastructures (wells, underground water pipes and tanks) could be intercepted and destroyed by road cuttings. This could lead to the loss of water supply (high magnitude of impact), resulting in a potential impact of Substantial significance. However, given the location of the PWS of Table 8.23 in relation to the proposed scheme it is unlikely that this will occur.

8.4.98 Table 8.23 indicates that to date no PWS is at particular risk of contamination from blasting activity since the PWS listed in Table 8.23 are more than 100m away from the proposed scheme. Above such distance the risk of short-term contamination as a consequence of blasting activities is reduced because of the dilution effect.

Table 8.23: Potential Impacts on quality of PWS (without mitigation measures) in the Southern Study Area

PWS and Type	Mainline/ Link/ Junction	Indicative chainage (m)	Minimum distance from proposed scheme	Topographic position in relation to proposed scheme	Cutting/ Embankment/ Transition Cutting Embankment	On or adjacent to existing A90 cutting	Does cutting intercept groundwater	Sensitivity	Potential Impact			
									Magnitude		Significance	
									Quality	Yield	Quality	Yield
S06: Well	Mainline	ch2900	540m	Up-slope	Embankment	n/a	n/a	Negligible	Medium	Negligible	Negligible/ Slight	Negligible

Areas potentially supported by Groundwater

8.4.99 No areas of ecological importance potentially supported by groundwater have been identified in the southern study area and therefore no impacts are anticipated.

Urban settlement

8.4.100 There is potentially dewatering along the mainline cutting running between ch3200 and ch1250 that could potentially result in differential settlement beneath loaded areas (e.g. buildings) and put adjacent properties at risk.

8.4.101 The nearest properties are located approximately 150m away from the deepest section of the proposed cutting. Using the principal of PWS sensitivity criteria based on distance, the nearest properties are considered to be of medium sensitivity. The magnitude is assessed as high, resulting in a potential Moderate/Substantial significance of impact.

8.5 Mitigation

8.5.1 The mitigation measures described below are proposed to avoid or reduce any significant potential impacts on geology, contaminated land and groundwater arising from the proposed scheme.

Solid Geology

Firth of Forth

8.5.2 The impact assessment indicates potential Negligible to Negligible/Slight significance impacts with respect to the marine solid geology and therefore no mitigation measures are required.

Northern and Southern Study Area

8.5.3 The impact assessment indicates that the overall significance of potential impact on solid geology except on Ferry Hills SSSI (including impact of blasting) is Negligible and therefore no mitigation measures are required outside the SSSI area.

8.5.4 The reprofiling of the central part of the Ferry Hills SSSI will include the removal of the meshing and excavation using blasting or other excavation techniques. Complementary rock mapping and inspections, with specialist supervision and as informed by SNH, will take place during this process (removal of the meshing and as the excavation progresses) so that the slope stability can be constantly reviewed to minimise the requirement for meshing or other stabilisation measures within the final profile. Materials that are geotechnically and environmentally suitable will be re-used within the proposed scheme where practicable (mitigation item G1).

8.5.5 Mitigation for potential impacts of blasting on groundwater is discussed in the groundwater section.

8.5.6 No mitigation for the potential impact of blasting on geology is required except at Ferry Hills. Health and Safety precautions will be taken as part of safe working practices which will include for example the closure of the nearby railway network during blasting (mitigation item G23).

Drift Geology (Superficial Deposits)

Firth of Forth

8.5.7 The impact assessment indicates potential Negligible to Negligible/Slight significance impacts in respect of marine drift geology and therefore no mitigation measures are required.

Northern and Southern Study Areas

8.5.8 The impact assessment indicates that the overall significance of potential impacts on drift geology is Negligible to Negligible/Slight and therefore no mitigation measures are required.

Mineral Extraction

8.5.9 No mitigation is required in the northern study area.

8.5.10 A number of uncertainties remain with regard to former mining activities in the southern study area and have been investigated as part of the 2009 GI (Table 8.24). However, the results of this GI are not available at the time of writing. In the eventuality of mining risks being confirmed by means of the 2009 GI, appropriate stabilisation/protection works will be implemented as part of the proposed scheme. If that is the case, a detailed assessment on the impact of grouting on groundwater and ground gas migration will be required (mitigation item G2).

Table 8.24: Detailed mining assessment conclusions and recommendations

Area of interest	Recommendation
Mainline relating to M9 Junction 1A and A90 bus link	Further investigation of mine workings has been integrated into the 2009 GI, and no further recommendations are therefore required.
Other sections of the mainline	No further action required.
Queensferry Junction	Confirmation of the depth and condition of the limestone beneath the western extremity of the proposed tie-in has been integrated into the 2009 GI, and no further recommendations are therefore required.
Junction 1A (M9 Spur) Improvements	Further investigation of the potential presence of localised workings has been integrated into the 2009 GI, and no further recommendations are therefore required.
A90 to A8000 Bus Link	Additional ground investigation in areas where workings are shallowest and where multiple seams appear to have been worked have been integrated into the 2009 GI, and no further recommendations are therefore required.

Contaminated Land

8.5.11 Following the contaminated land assessment undertaken as detailed in the Appendix A8.1, a number of potential pollutant linkages are identified. Where the risk to receptors has been assessed as equal to or greater than Moderate/Low risk, mitigation measures are considered necessary.

8.5.12 Tables 8.25, 8.26 and 8.27 detail the pollutant linkages in each part of the route which are considered to require mitigation along with details of the proposed mitigation measures. Disposal of dredged marine sediments are covered in Chapter 9 (Water Environment).

8.5.13 The 2009 GI may identify additional areas of contaminated land. Where remediation is identified a detailed options appraisal will be carried out in accordance with CLR11 and materials that are geotechnically and environmentally suitable will be re-used within the proposed scheme where practicable (mitigation item G29).

Table 8.25: Marine Study Area Mitigation Measures

Potential Pathway Receptors	Source Reference Requiring Mitigation	Mitigation Measures Required
Construction		
PL1	Marine study area	• Adoption and use of appropriate PPE (mitigation item G3). • Establishment of appropriate health and safety and waste management procedures (mitigation item G3). • Risks will be further mitigated by the careful selection of the contractor, appropriate workmanship and QA/QC measures (mitigation item G3).
PL8	Marine study area	• Mitigation associated with sensitive species are discussed in detail in Chapter 11 (Estuarine Ecology). • Mitigation associated with the suspension of sediments is discussed in detail in Chapter 9 (Water Environment).
Operation		
PL18	Long-term effect of sulphates within the Marine study area	• Appropriate construction materials should be used due to sulphates. Reference to appropriate guidance in the selection of construction materials such as BRE SD1:2005 and BS8500 where concrete materials are proposed (mitigation item G5).

Table 8.26: Northern Study Area Mitigation Measures

Potential Pathway Receptor	Source Ref Requiring Mitigation	Mitigation Measures Required
Construction		
PL1	N1, N2, N3, N5a, N5b, N6, N8, N10, N17- N20, N27, N28, N29, N31	• Additional investigation including soils and groundwater sampling (included in the 2009 GI) and additional assessment to be undertaken prior to construction (N1-N3 only) (mitigation item G4). • A radioactivity risk assessment shall be undertaken by the Contractor prior to construction to determine if monitoring is required during construction (N1-N3 only) (mitigation item G6). • The Contractor shall establish appropriate health and safety and waste management procedures for working with potentially contaminated soils (mitigation item G3). Waste management procedures will include but not be limited to: Waste Management Licence Regulations 1994 (as amended by Waste management licensing Amendment (Scotland) Regulations 2003), Asbestos: Medical guidance note MS13 (2005), the Health and Safety Commission Approved Code of Practice and Guidance Note. • The risks to construction workers will be mitigated by the adoption and use of appropriate PPE (mitigation item G3). • Access to contaminated areas should be restricted during construction (mitigation item G3). • Asbestos-contaminated material should be either left in place or if removal is required then it should be disposed of in accordance with current guidance (mitigation item G3). • The Contractor shall implement a 'watching brief' in order to take account of the fact that there may be isolated pockets of previously unidentified contamination (mitigation item G9).
PL2	N1-N31	• The Contractor shall assess gassing issues in accordance with CIRIA 665 following receipt of additional ground gas monitoring results at selected boreholes (mitigation item G8). • A ground gas monitoring program, to be produced by the Contractor prior to construction and adhered to during construction (mitigation item G8). • Following completion of the 2009 GI, a ground improvement risk assessment will be carried out including assessment of risks from ground gasses (mitigation item G8).
PL3	N2, N3, N17- N20, N27, N28, N31	• Control of dust generation will be required through damping-down with clean water during dry and/or windy periods (mitigation item G10). • Air quality monitoring, including occupational exposure and ambient air quality monitoring is to be undertaken by the Contractor (mitigation item G10).
PL4	N1, N2, N3, N10, N17-N20, N27, N28, N31	• Assessment of gassing issues by the Contractor in accordance with CIRIA 665 following receipt of additional ground gas monitoring results at selected boreholes (mitigation items G7-G8). • If significant ground gas issues identified, further monitoring will need to be undertaken and/or appropriate gas protection measures will be required to be incorporated into the final design by the Contractor (mitigation items G7-G8). • Following completion of the 2009 GI a ground improvement and mine grouting risk assessments will be required by the Contractor to support the detailed design of the proposed scheme, including assessment of ground gasses (mitigation items G7-G8).
PL5	N1, N2,N3, N27	• Assessment of shallow groundwater quality to be undertaken on receipt of groundwater monitoring results (mitigation item G12). • Further assessment of the groundwater regime at St. Margaret's Marsh (N1 and N2) to be undertaken prior to construction. This should include the installation of additional groundwater sampling wells and additional groundwater and soils analysis (included in the 2009 GI) (mitigation item G12). • Following completion of the 2009 GI, a ground improvement risk assessment will be required by the Contractor to support the detailed design of the proposed scheme, including assessment of risks from migration of ground water (mitigation item G14). • Any existing pathways through services (e.g. land drains) affected during construction will be sealed. The detailed design will ensure that no new pathways are created
PL7	N2	

Potential Pathway Receptor	Source Ref Requiring Mitigation	Mitigation Measures Required
		(mitigation item G27).
PL8	N1, N2, N3	• Additional investigation including soils and groundwater sampling to be undertaken prior to construction (included in the 2009 GI) (mitigation item G12). • The Contractor shall undertake further risk assessment of the groundwater on ecological receptors (mitigation item G4).
PL9	N1, N2, N3	
Operation		
PL10	N1, N2, N3, N10, N27, N28, N29, N31	• The proposed scheme should be designed to minimise the risks to future maintenance workers (mitigation item G3).
PL11	N1-N29, N31	• Ground gas monitoring of confined spaces e.g. service pits, should be undertaken prior to entry (mitigation item G11).
PL12	N1, N2, N3, N27	• Where risks to end users have been identified, the Contractor's detailed design will incorporate measures to prevent wind blown dust e.g. the use of hard standing areas to cap contaminated soils (mitigation item G3). • The Contactor will develop environmental quality criteria protective of end users to support reuse of contaminated excavation arisings including the use of clean cover and vegetation on embankment areas constructed using excavation arisings (mitigation item G3). • The Contractor will develop a materials management plan to track the excavation, storage and final placement of potentially contaminated arisings (mitigation item G3).
PL13	N2, N3, N31	• Where risks to end users have been identified, the Contractor's detailed design will incorporate measures to prevent wind blown dust, e.g. the use of hard standing areas to cap contaminated soils (mitigation item G3).
PL14	N1, N2, N3, N10, N17-N20, N27, N28, N31	• If significant ground gas issues identified, further post construction monitoring will be undertaken by the contractor and/or appropriate gas protection measures will be incorporated into the final design (mitigation items G7-G8).
PL15	N1, N2, N3, N27	• The Contractor will develop environmental quality criteria protective of end users to support reuse of contaminated excavation arisings (mitigation item G3). • The Contractor will produce a soils reuse assessment will be undertaken in order to identify any potential risks posed to the water environment from potentially contaminated soils used in embankments and associated structures (mitigation item G16). • The Contractor will develop a plan to track the excavation, storage and final placement of potentially contaminated arisings (mitigation item G3). • Prior to disposal, soils will be assessed by the Contractor in line with the WM2 document (Environment Agency, 2008) to determine whether they are hazardous or non-hazardous. Following receipt of the 2009 GI data, an assessment will be carried out by Jacobs Arup to confirm the suitability/quantity of soil material for use or disposal off site (mitigation item G16).
PL18	N1, N10, N17-N20, N27, N28, N31	• Reference to appropriate guidance in the selection of construction materials such as Building Research Establishment (BRE) SD1:2005 and British Standard (BS) BS8500 where concrete materials are proposed (mitigation item G5).
PL20	N1, N2, N3	• No additional mitigation required.
PL21	N1, N2, N3	

Table 8.27: Southern Study Area Mitigation Measures

Potential Pathway Receptor	Source Ref Requiring Mitigation	Mitigation Measures Required
Construction		
PL1	S2, S11, S13	• The Contractor shall establish appropriate health and safety and waste management procedures. Waste management procedures will include but not be limited to: Waste Management Licence Regulations 1994 (as amended by Waste management licensing Amendment (Scotland) Regulations 2003) and HSE Guideline Note MS13 Asbestos 1988, the Health and Safety Commission Approved Code of Practice and Guidance Note (mitigation item G3). • The risks to construction workers will be mitigated by the adoption and use of appropriate PPE (mitigation item G3). • Asbestos should be either left in place or if removal is required then it should be disposed of in accordance with current guidance (mitigation item G3). • The Contractor shall implement a 'watching brief' in order to take account of the fact that there may be isolated pockets of previously unidentified contamination (mitigation item G9). • Access to contaminated areas should be restricted during construction (mitigation item G3).
PL2	S1-S16	• The Contractor shall further assess gassing issues in accordance with CIRIA 665 following receipt of additional ground gas monitoring results including flow rates (mitigation item G8). • Ground gas to be monitored at regular intervals during construction by the Contractor (mitigation item G8). • Following completion of the 2009 GI, a ground improvement risk assessment will be carried out by the Contractor including an assessment ground gas risks (mitigation item G8).
PL3	S2	• Undertake additional soil sampling and human health risk assessment in S2 (included in 2009 GI) (mitigation item G17). • Control of dust generation will be required through damping-down with clean water during dry and/or windy periods (mitigation item G10). • In addition, air quality monitoring, including occupational exposure and ambient air quality monitoring is to be undertaken (mitigation item G10).
PL4	S2, S13	• Further assessment of gassing issues by the Contractor in accordance with CIRIA 665 following receipt of additional ground gas monitoring results incl. flow rates (mitigation item G8). • If significant ground gas issues identified, further monitoring to be undertaken by the Contractor, and/or appropriate gas protection measures incorporated into final design (mitigation item G8). • Following completion of 2009 GI, a ground improvement and mine grouting risk assessments will be required by the Contractor to support the detailed design of the proposed scheme including assessment of risks from ground gasses (mitigation items G2/G8).
PL7	S13	• Groundwater in the area to be further analysed and assessed. Nearby surface and groundwater monitoring to be undertaken during construction by the Contractor (mitigation item G13). • Following completion of 2009 GI, a ground improvement and mine grouting risk assessments will be required by the Contractor to support the detailed design of the proposed scheme, including assessment of risks from migration of groundwater (mitigation items G13-G14). • Any existing pathways through services (e.g. land drains) affected during construction to be sealed. The detailed design to ensure no new pathways are created (mitigation item G27).
Operation		
PL10	S2, S11	• The proposed scheme should be designed to minimise the risks to future maintenance workers (mitigation item G3).
PL11	S1-S16	• Ground gas monitoring of confined spaces e.g. service pits should be undertaken prior to entry (mitigation item G11).

Potential Pathway Receptor	Source Ref Requiring Mitigation	Mitigation Measures Required
PL13	S2	• Where risk to end users are identified, the detailed design will incorporate measures to prevent wind blown dust e.g. use of hard standing areas to cap contaminated soils (mitigation item G3).
PL14	S2, S13	• If significant ground gas issues identified, post construction monitoring will be undertaken by the Contractor and/or appropriate gas protection measures will be required to be incorporated into the final design (mitigation item G8).
PL17	S13	• Where necessary, post construction groundwater monitoring will be undertaken by the Contractor to compare with background groundwater quality (mitigation item G13). • Where necessary, lining of drainage to prevent the ingress of contaminated groundwater or lateral migration through granular backfill will be undertaken by the Contractor (mitigation item G28).

Groundwater

8.5.14 Specific mitigation measures for the potential impacts on groundwater in terms of quality, flow, water supply uses and habitat dependence and urban settlement are discussed below.

8.5.15 Mitigation for the potential impacts on PWS during construction (temporary dewatering) or operational (permanent dewatering) activities are included in the sections below. It should be noted however that the Contractor will also be required to adhere to the requirements detailed in The Water Environment (Controlled Activities) (Scotland) Regulations 2005 – A Practical Guide (SEPA, 2008b).

Firth of Forth

8.5.16 No impacts in relation to groundwater are expected from the proposed Main Crossing, therefore no mitigation measures are required.

Northern Study Area

8.5.17 Mitigation measures for groundwater as a whole and PWS are combined to provide measures that address all issues.

Groundwater Quality

8.5.18 Mitigation measures to prevent or reduce the potential for contamination of local groundwater during construction or operation proposed for surface water protection and detailed in Chapter 9 (Water Environment) are also applicable to protect groundwater.

8.5.19 During the operational phase, all detention/treatment basins should be lined to protect the surrounding water environment, unless risk assessment during design development indicates that lining is not necessary at specific locations (mitigation item G20).

8.5.20 In addition, the drainage of the proposed scheme (main and side roads) should be lined at the following chainages (mitigation item G19):

- ch6800-7650 (mainline and associated roads);
- ch0-290 (Ferrytoll Road);
- ch0-350 (Castlandhill Road);
- ch7900-8430 (mainline, including associated side roads); and
- ch8500-8800 (mainline).

8.5.21 No mitigation for the potential impacts of blasting on the quality of groundwater in bedrock aquifers in the northern study area is required, as explained in paragraph 8.4.75.

8.5.22 Prior to construction, surveys are required to confirm the presence and status of PWS at risk (N03, N04 and N23) (refer to Table 8.22). If PWS are confirmed, monitoring of the water quality of the PWS is required to determine background supply quality. Groundwater quality monitoring of these supplies should take place during construction and may extend to the start of the operational phase to ensure that the supplies are not adversely impacted (mitigation item G21).

8.5.23 With regards to cuttings intercepting groundwater, additional groundwater sampling has been included in the 2009 GI to complement knowledge on groundwater quality. The containment facilities and discharge location for abstracted groundwater during construction will be defined as part of the detailed design by the Contractor, and will take into account baseline groundwater quality characteristics (mitigation item G25).

8.5.24 In addition, permeability tests have been included in the 2009 GI to enable, if required, groundwater assessment and estimate the volumes of groundwater that will be dewatered during the first part of the construction phase. This information will be provided to the Contractor.

PWS

8.5.25 The survey of PWS N04 proposed in paragraph 8.5.22 also applies here. On completion of this survey, a revised assessment will be made if required in autumn/winter 2009 by Jacobs Arup. If the risks are confirmed, further mitigation measures may be proposed by Jacobs Arup, such as groundwater level monitoring measures prior, during construction and into the start of the operational phase. If yields of water supplies are shown to be reduced, mitigation measures would be likely to include an alternative or replacement supply (mitigation item G21).

8.5.26 If any water supply pipes are damaged during construction, they will be repaired or replaced (mitigation item G22).

8.5.27 Mitigation for the potential impacts of blasting on groundwater flow in the vicinity of PWS N04 (mitigation item G23) would include the use of low explosive loading densities, following the current British Standards and regulations. These include, but are not limited to, BS5228-2:2009, code of practice for noise and vibration control on construction and open sites (part 2- vibration), and the Scottish Development Department Planning Advice Note 50 [PAN 50] Annex D 'The Control of Blasting at Surface Mineral Workings'.

Areas Potentially Supported by Groundwater

8.5.28 To ensure there is no significant water loss due to the realignment of B981 acting as a barrier to shallow groundwater flow, the embankment should be designed to maintain the hydrological connectivity of the marsh whilst ensuring that the directional flow of groundwater is not affected (mitigation item G24).

8.5.29 The 2009 GI will provide additional background information on the hydrogeology of St. Margaret's Marsh, including information on groundwater quality, following which mitigation requirements for St. Margaret's Marsh will be confirmed.

8.5.30 Based on these data, a groundwater monitoring network will be put in place within St. Margaret's Marsh. Groundwater levels should be monitored for a minimum of one year prior to construction to ensure seasonal fluctuations in water levels are adequately assessed and groundwater levels should be monitored during construction (mitigation item G24).

<u>Southern Study Area</u>

8.5.31 Mitigation measures for groundwater as a whole and PWS are combined below to provide mitigation measures that address all issues.

Groundwater Quality

8.5.32 Mitigation measures to prevent or reduce the potential for contamination of local groundwater during construction or operation are the same as those required for surface water protection and are detailed in Chapter 9 (Water Environment).

8.5.33 During the operational phase, all detention/treatment basins should be lined to protect the surrounding water environment, unless risk assessment during design development indicates that lining is not necessary at specific locations (mitigation item G20).

8.5.34 In addition, the road drainage should be lined (mitigation item G19) at the following locations:

- ch2000-2500 (Queensferry Junction);

- ch3200-4600 (mainline including associated roads). This area partially includes the main construction compound;
- proposed scheme around M9 Junction 1A; and
- ch0-1050 (temporary access road).

8.5.35 No mitigation for the potential impacts of blasting on the quality of the groundwater in bedrock aquifer is required in the southern study area, as explained in paragraph 8.4.91.

8.5.36 The containment facilities and discharge location for abstracted groundwater during construction will be defined as part of the detailed design by the Contractor, and will take into account baseline groundwater quality characteristics (mitigation item G25).

8.5.37 With regards to cuttings intercepting groundwater, additional groundwater sampling has been included into the 2009 GI to complement knowledge on groundwater quality along the mainline cutting ch3200-ch4150 and the Swine Burn realignment cutting. The containment facilities and discharge location for abstracted groundwater during construction will be defined as part of the detailed design by the Contractor, and will take into account baseline groundwater quality characteristics (mitigation item G25).

8.5.38 In addition, permeability tests have been undertaken as part of the 2009 GI to estimate the volumes of groundwater that will be dewatered during the first part of the construction phase. This information will be provided to the Contractor (mitigation item G25).

PWS

8.5.39 The data currently available suggest the yield of PWS S05 and S06 is not at risk of being impacted, therefore no mitigation measures are required.

8.5.40 However, if any water supply pipes are damaged during construction, they will be repaired or replaced (mitigation item G22).

8.5.41 No mitigation for the potential impacts of blasting on groundwater flow is required.

Urban Settlement

8.5.42 The permeability tests proposed along the mainline cutting ch3200-4150 in paragraph 8.5.38, coupled with the installation of additional piezometers to the west of the cutting and adjacent to the Queensferry urban area, will form the basis upon which a detailed assessment will be carried out in Autumn/Winter 2009 by Jacobs Arup as part of the pre-construction advance works, to estimate the groundwater drawdown below the properties at risk. This will enable a quantitative stability analyses to be carried out and will determine whether some properties are at risk of settlement (mitigation item G26).

8.5.43 In the eventuality of some properties being confirmed as at risk, appropriate measures including condition surveys, and monitoring of buildings and groundwater level changes may be required (mitigation item G26).

8.6 Residual Impacts

8.6.1 Residual impacts are those that remain once the mitigation measures described in Section 8.5 have been implemented. If no mitigation measures are proposed then the residual impacts are equivalent to the potential impacts described in Section 8.4.

Solid Geology

Firth of Forth

8.6.2 The residual impact on marine solid geology is anticipated to be of Negligible to Negligible/Slight significance.

Northern and Southern Study Areas

8.6.3 The residual impact on the solid geology except on Ferry Hills SSSI, including residual impacts from blasting operations, is anticipated to be of Negligible significance.

8.6.4 With appropriate mitigation measures in place, the residual magnitude of impact on the Ferry Hills SSSI is expected to be negligible; resulting in a Slight significance of impact.

Drift Geology (Superficial Deposits)

Firth of Forth

8.6.5 The residual significance of impact on marine drift geology is anticipated to be of Negligible significance.

Northern and Southern Study Areas

8.6.6 The residual impact on solid geology is anticipated to be Negligible to be of Negligible/Slight significance.

Mineral Extraction

8.6.7 With appropriate measures in place, residual impacts in relation to mineral extraction due to the proposed scheme will either be avoided or be of Slight significance.

Contaminated Land

8.6.8 With appropriate mitigation measures in place, as listed in Tables 8.25 to 8.27, the residual risk (i.e. impact) from contaminated land is assessed to be Very Low to Low.

Groundwater

Firth of Forth

8.6.9 No impacts in relation to groundwater are expected from the proposed Main Crossing itself and therefore no residual impacts are anticipated.

Northern and Southern Study Areas

Groundwater Quality

8.6.10 With appropriate mitigation measures in place, the significance of all residual significance of impacts on groundwater quality is assessed to be Negligible/Slight.

Groundwater Flow

8.6.11 With appropriate mitigation in place, all residual impacts on groundwater flow and PWS yields are expected to be of Negligible/Slight significance.

Areas Potentially Supported by Groundwater

8.6.12 With appropriate mitigation, the residual impact on groundwater flow at St. Margaret's Marsh is assessed as being of Slight significance.

8.6.13 The residual impact with regards to the hydrology is assessed in Chapter 9 (Water Environment).

Urban Settlement

8.6.14 With appropriate mitigation measures in place, all residual impacts on urban settlement will be reduced to Negligible/Slight significance.

8.7 Ongoing Design Development

Alternative Construction Compound

8.7.1 An addition to the scheme proposals is the inclusion of an alternative location for the construction compound to the west of South Queensferry. This alternative was identified in response to concerns raised by local residents during the ongoing consultation process, and it locates the compound further to the west.

8.7.2 This alternative site was identified subsequent to the completion of the assessment of potential impacts of the proposed scheme on land use as reported in this chapter. A separate assessment of its impacts has been undertaken and is provided in Chapter 19 (Disruption Due to Construction).

Ferry Hills Rock Cuts

8.7.3 The proposed scheme design as assessed in this chapter includes significant rock cuts to the north and south of Ferrytoll Junction. Detailed design may allow these rock cuts to be avoided or reduced. Design development indicates that there could be potential for a westward shift of the proposed scheme alignment of up to approximately 15m between approximate chainage ch7500-7800 (southwest of Jamestown) and ch8150-8500 (west of Hope Street Cemetery) to allow the rock cuts to be avoided.

8.7.4 Environmental review of this refinement indicates that this could reduce adverse impacts associated with the rock cuts without materially increasing other environmental effects. If this option were taken forward it could avoid the need to remove an estimated 70,000 m^3 of rock. This would also avoid the predicted impacts on the areas of Ferry Hills SSSI associated with the rock cut.

8.8 References

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