Forth Energy

Appendix F

Flood Risk Assessment

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Flood Risk Assessment

Executive Summary

SKM Enviros has been appointed by Forth Energy to perform a Flood Risk Assessment (FRA) for a proposed Renewable Energy Plant on a site at the Port of Grangemouth, adjacent to the Grangemouth Refinery and petrochemical complex. The proposed development is referred to as the Grangemouth Renewable Energy Plant. This FRA, which address the statutory requirements of the Scottish Planning Policy (SPP), issued by the Scottish Government, makes a detailed assessment of the flood risk across the site from all potential sources of inundation and provides recommendations to mitigate these risks, taking into account the potential effects of climate change. This FRA accompanies an application to the Scottish Ministers for Consent (under Section 36 of the Electricity Act 1989) for the proposed Renewable Energy Plant.

The application site (18.05 ha) is located adjacent to the Western Channel within the Port of Grangemouth, the largest container port in Scotland, and contains five distinct areas:

- the main plant area;
- an area of search for the installation of the cooling water intake (within the Western Channel);
- two alternative infrastructure corridors for the installation of cooling water discharge pipes, ;
- an area of search for the installation of the cooling water outfall (in the River Carron); and
- an infrastructure corridor for the fuel transfer conveyor (along the North Shore Road).

Topographical survey data shows current elevations across the site are generally low ranging from approximately 3.93 m to 8.48 m AOD (Above Ordnance Datum). A site inspection confirmed that levels across the site were generally consistent with the adjacent land and surrounding features.

Floodplain and flood level details provided by the Scottish Environment Protection Agency (SEPA) show the site to be partially within the 200-year flood outline, indicating a medium to high risk of coastal flooding. The main risks to the proposed development are considered to be from tidal inundation from the Forth Estuary, Grange Burn and the surrounding land drainage network.

Flood defences have been installed along the Forth Estuary to the east of the site for the protection of the LPG terminal. Bunds have also been installed along North Shore Road and the banks of the River Carron north of the site to protect the road from flooding. The possibility of flooding from other sources other than the Forth Estuary represents a lesser risk to the site and proposed development. Observations on site noted that current surface water infiltrates to ground, with excess water flowing overland to adjacent drains and into the docks.

Mitigation recommendations for the site include consideration of personnel safety, safeguarding of sensitive equipment and drainage infrastructure design. The site datum for safety of personnel and positioning of sensitive equipment will be at a minimum level of 5.50 m AOD. This is defined by the 1 in 50 year exceedence storm surge scenario combined the highest astronomical tide, plus a 0.6 m freeboard allowance.

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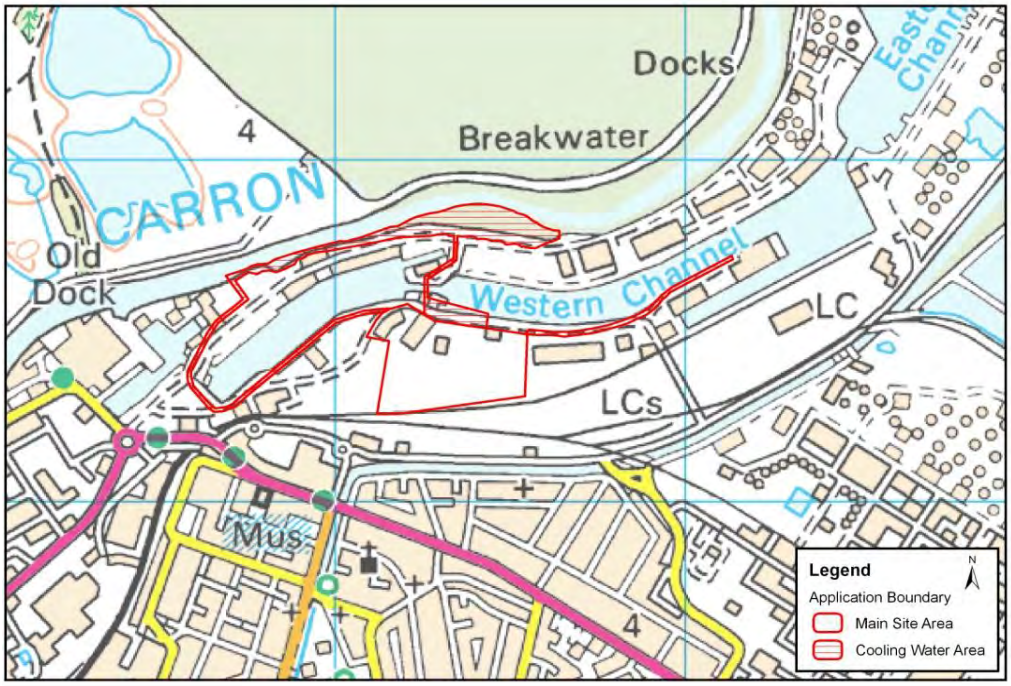
F.1 Introduction

SKM Enviros has been appointed by Forth Energy to perform a Flood Risk Assessment (FRA) for a proposed Renewable Energy Plant on a site at the Port of Grangemouth, adjacent to the Grangemouth Refinery and petrochemical complex.

A detailed assessment of flood risk has been made in accordance with the requirements of Scottish Planning Policy (SPP) and following consultation with the SEPA and Falkirk Council. This report provides an overview of flood risk issues within the context of relevant planning policy. This FRA is part of an Environmental Statement which accompanies an application to the Scottish Ministers for Section 36 Consent under the Electricity Act 1989 for the proposed Renewable Energy Plant.

The site, which is shown in Figure 1, is located adjacent to the Western Channel, within the Port of Grangemouth. The Port sits 5 km north east of Falkirk, where the River Carron meets the Firth of Forth and is approximately 4.5 km downstream of the Kincardine Bridge.

Figure 1: Site Location Plan



F.2 Methodology

F.2.1 Statutory and General Guidance

F.2.1.1 Scottish Planning Policy 2010

The consolidated Scottish Planning Policy (SPP) 2010 provides a shorter, clearer and more focused statement of national planning policy than the individual Scottish Planning Policies and NPPG series it replaces. As part of the commitment to proportionate and practical planning policies, the Scottish Government has rationalised national planning policy. The SPP supersedes Scottish Planning Policy 7: Planning and Flood Risk.

The SPP details the aims of the Scottish Government with regard to development and flood risk, to ensure that flood risk is taken into account at all stages of the planning process and to avoid inappropriate development in areas potentially at risk of flooding. One of the key roles of the policy is to provide for positive planning to facilitate delivery of sustainable development, whilst ensuring adherence to the Government's policy on flood risk management. Avoidance, reduction and management of flood risk is to be achieved through the consideration and analysis of present flood risk, future flood risk, consequence of flooding and the wider implications for flood risk across land located outside the development area.

Although the site has areas shown to be within the current indicative floodplain as defined by SEPA, the SPP states that there may be exceptions for infrastructure if a specific location is essential for operational reasons or it cannot be located elsewhere. In the case of the Renewable Energy Plant, the port location is classed as essential for delivery of the fuel by sea. In such cases, the development should be designed to remain operational in times of flood and not impede water flow and the effect on the flood water storage capacity should be kept to a minimum. Policy states that development should not take place on land that could otherwise contribute to managing flood risk, for instance through managed coastal realignment, washland creation or as part of a scheme to manage flood risk. The site does not currently contribute to any form of flood risk management scheme.

F.2.1.2 Falkirk Council Structure Plan, 2007

Environmental Quality Policy 4: Coastal Planning and Flooding states that:

"The Council will apply the following general principles with regard to coastal planning and flooding issues:

a) There will be a general presumption against development in the underdeveloped coastal zone (as indicated generally on the key diagram), unless it is clearly demonstrated that a coastal location is essential for that development;

b) In assessing proposals for development within the coastal zone or coastal defence measures on the developed coast, particularly attention will be paid to the likely implications in terms of flooding, existing and future coastal defence works, nature conservation, landscape impact, water pollution and the need to work in partnership with other agencies to promote the integrated management of the estuary and its resources.;

c) The Coastal zone north of the River Carron will be a priority area for evaluating the feasibility for management retreat and other coastal zone management measures.; and

d) In areas where there is a significant risk of flooding, there will be a presumption against new development. Where necessary the council will require applicants to submit supplementary information to assist in the determination of planning applications."

Environmental Quality Policy 15: Water Quality states that:

"The council will contribute to the improvement of water quality in local rivers and lochs. Specifically, subject to appropriate maintenance agreements, the adoption of "Sustainable Urban Drainage Manual" as advocated by the Scottish Environment Protection Agency will be supported in all major new developments."

F.2.1.3 Grangemouth Local Plan, 1985

Environmental Resources Policy 4: Flooding and Development states that:

The strategy of the Plan is one of 'stabilisation', with no further expansion of the urban area permitted along with the protection of the Green Belt. Substantial land has however been allocated for the expansion of the chemical and petrochemical industries in the town. It should be noted that the Grangemouth Local Plan is dated and the Finalised Falkirk Local Plan is to be formally adopted in the very near future.

F.2.1.4 Falkirk Council Local Plan Finalised Draft (Deposit Version), April 2007

Environmental Quality Policy 27: Watercourses states that

"The council recognises the importance of watercourses within the Council area in terms of their landscape, ecological, recreational and land drainage functions. Accordingly:

a) There will be a general presumption against development which would have a detrimental effect on the landscape integrity, water quality, aquatic and riparian ecosystems, or recreational amenity of watercourses. Development proposals adjacent to a watercourse should provide for a substantial underdeveloped and suitably landscaped riparian corridor to avoid such impacts;

b) Watercourses will be promoted as recreational corridors, with existing riparian access safeguarded and additional opportunities for ecological enhancement, access and recreation encouraged where compatible with nature conservation objectives; and

c) There will be a general presumption against the culverting of watercourses."

Environmental Quality Policy 28: The Coastal Zone states that:

"The Council will promote an integrated approach to the management of the coastal zone, and will support the provisions of the Forth Integrated Management Strategy. Development and other land management proposals within the coastal zone will be assessed in terms of:

a) Impacts on the amenity, ecology and water quality of the coastal environment;

b) The requirement to safeguard the underdeveloped coast, as defined on the Proposals Map, from further development unless it is proven that the development is essential, a coastal location is essential, and no suitable sites exist within the developed coast;

c) Long-term flooding risk and compatibility with existing coastal defence strategies, including the desirability of working with natural coastal processes where possible and the need to recognise the wider impacts where intervention is unavoidable; and

d) Appropriate promotion of the recreational potential of the coastal zone, including the development of the Forth Foreshore Path and the linked coastal access networks, providing it is compatible with Policy EQ24 and the protection of coastal habitats and species."

Sustainable Transport and Infrastructure Policy 11: Sustainable Urban Drainage states that:

"Surface water management for new development should comply with current best practice on sustainable urban drainage systems, including opportunities for promoting biodiversity through habitat creation. A drainage strategy, as set out in PAN 61, should be submitted with planning applications and must include flood attenuation measures, details for the long term development of any necessary features and a risk assessment."

Sustainable Transport and Infrastructure Policy 12: Flooding states that:

"In areas where there is significant risk of flooding , there will be a presumption against new development which would be likely to be at risk, would increase the level of risk for existing development or would be likely to require high levels of public expenditure on flood protection works. Applicants will be required to provide information demonstrating that any flood risks can be adequately managed both within and outwith the site."

F.2.1.5 Falkirk Council Supplementary Planning Guidance Note: Flooding and Sustainable Urban Drainage Systems, October 2009

The guidance sets out:

1) *The nature of the folding problems generally and in the Falkirk Council area in particular, the roles and responsibilities of Falkirk Council and other key agencies and the requirements placed on developers to comply with flooding policy when proposing new development.*

2) *The requirement for drainage assessments to accompany planning applications for new development.*

3) *The Council's requirements in relation to provision of Sustainable Urban Drainage Systems in new development.*

F.2.2 Other General Guidance

The following general guidance was also referred to in preparing this FRA and developing recommendations to mitigate potential flood risks:

F.2.2.1 The Flood Risk Management (Scotland) Act 2009

The Act is currently being implemented and its intention is to introduce a more sustainable and modern approach to flood risk management, suited to the needs of the 21st Century and to the impact of climate change. It will facilitate a more joined up and coordinated process to manage flood risk at a national and local level.

F.2.2.2 Water Environment and Water Services (Scotland) Act 2003 (WEWS Act)

The aim of the WEWS Act is to protect and improve the water environment while also supporting the social and economic interests of those who depend on it. Under this act, the Scottish Ministers, SEPA and the responsible authorities must promote sustainable flood management.

F.2.2.3 The Water Environment (Controlled Activities) Regulations, 2005 (CAR)

These regulations bring into effect the requirements of Section 20 of the WEWS Act with respect to control over the following activities which can relate to flood defence or flood mitigation works:

- Activities liable to cause pollution of the water environment;
- Abstraction of water from the water environment;
- The construction, alteration or operating of impounding works in surface waters or wetlands;
- Carrying out building, engineering or other works: in inland water other than groundwater, or wetlands; or in the vicinity of inland water or wetlands, and likely to have a significant adverse effect on the water environment; and
- Artificial recharge or augmentation of groundwater.

F.2.2.4 Planning Advice Note PAN 61: Planning and Sustainable Drainage Systems

PAN69 provides good practice advice on planning and building standards in areas where there is a risk of flooding. The PAN fulfils a commitment made in SPP and supports the policy set out in the SPP. It also supports the Technical

Handbooks published by the Scottish Building Standards Agency which provide guidance for the Building (Scotland) Regulations 2004. Advice extends to guidance on developments that can benefit from selecting designs, forms of construction and materials which may help to minimise the effects of a flood event on the project.

F.2.2.5 National Planning Framework for Scotland 2, June 2009

The second National Planning Framework (NPF2) sets out a strategy for Scotland's development and guides spatial development to 2030, setting out strategic development priorities to support the Scottish Government's central purpose – promoting sustainable economic growth.

F.2.2.6 Falkirk Council Flood Report, November 2009

The Development Services department of Falkirk Council is responsible for preparation of a Flood Report on a biennial basis to inform planning decisions and the future development of the area. The 2009 report details findings of periodical inspection and assessment of all watercourses in non-agricultural areas within the region. Information is also presented on areas affected by flooding and actions taken to reduce the risk of future flooding.

F.2.2.7 Forth Integrated Management Strategy, 1999

The strategy's seeks to address the key issues facing the Forth by basing future use and management on a series of 'Guidelines' and 'Actions' which will influence the contents of:

- Structure Plans;
- Local Plans;
- Good Practice Plans;
- Corporate Plans; and
- Individual Work Plans.

'Guidelines' and 'Actions' are presented to address issues around sustainable resource management, environmental protection and management, integrated management and education and personal responsibility.

F.2.3 Sources of Information

The following sources of information were consulted in the preparation of this FRA:

- Ordnance Survey (OS) Mapping - Digital map extract (1:50,000 and 1,10,000);
- Scottish Environment Protection Agency website, http://www.sepa.org.uk/;
- Scottish Climate Change Impacts Partnership, www.sniffer.org.uk;
- UK Climate Projections (UKCP09), http://www.ukcip.org.uk.
- British Geological Survey (BGS) *Solid and Drift Geological Map of Scotland* (1:50,000): Sheet 31E, Grangemouth;
- Site topographical survey, Millennium Civil Engineering, February 2002; and
- Site walkover inspection.

F.2.4 Statutory and Non-Statutory Consultation

SEPA, Falkirk Council, the Port of Grangemouth and Scottish Water were consulted as part of the FRA to identify existing flood defence measures and the nature and extent of any previous occurrences of flooding in the area. Records of correspondence are provided in **Error! Reference source not found.** Table 1 summarises the responses from these consultees.

Table 1: Consultee Responses

Consultee	Summary of Comments
Scottish Environment Protection Agency	■ The location of the proposed development, adjacent to the Firth of Forth, shows the site to be within the 1 in 200 year (0.5% annual probability) coastal flood envelope on SEPA's Indicative River & Coastal Flood Map (Scotland). An approximate 1 in 200 year water level for the area is 4.62 m AOD based on extreme still water level calculations using the POL 112 Method. This does not take into account the potential effects of wave action at this location. ■ The latest sea level rise predictions due to climate change in the recently published UKCIP09 estimates that sea level rise will be approximately 24.4cm by 2080 taking the medium emissions scenario ■ Records show that the highest recorded still water level at Grangemouth was 4.47mAOD in 1959. ■ Standard freeboard levels of 600mm should be included in the development plans for this site.
Falkirk Council	■ The development is in Grangemouth Docks, on land in the ownership of Forth Ports and it is therefore Forth Ports who determine flood protection/risk to their facilities.
Port of Grangemouth	■ Historical tidal records provided.
Scottish Water	■ Plans indicating the approximate position of Scottish Water's existing public infrastructure provided.

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F.3 Site Details

F.3.1 Site Walkover

A hydrologist undertook a site walkover inspection on 21st January 2010 to identify the following:

- local hydrological conditions and features;
- hydraulic controls affecting fluvial and overland flow;
- likely risk of flooding; and
- presence and nature of any existing drainage infrastructure or flood defences.

Observations recorded during the site walkover are summarised below:

Weather during the site walkover was overcast and dry following a period of heavy rainfall. It was noted that the ground was damp in parts and that standing water was present in the central section of the proposed plant area.

Surface water drainage for the majority of the site discharges to ground by infiltration or passes to the docks along the northern boundary of the main site area. It is understood however, from liaison with Forth Ports, that some site drainage is routed directly to Grange Burn which is situated to the south of the site. This comprises a reed banked watercourse which progressively becomes more estuarine to the east of the site. Discharge piping and culverts were noted to be entering Grange Burn from both the north and south banks.

Forth Ports confirmed that the South Shore Road, between the docks and Grange Burn, to the west of the site, has previously been closed due to flooding (estimated to occur once every 20 years).

A small infiltration pond was observed to the rear of the Forth Port Office, outside the site boundary, to the east of the main site area. This was noted to be dry at the time of the site visit.

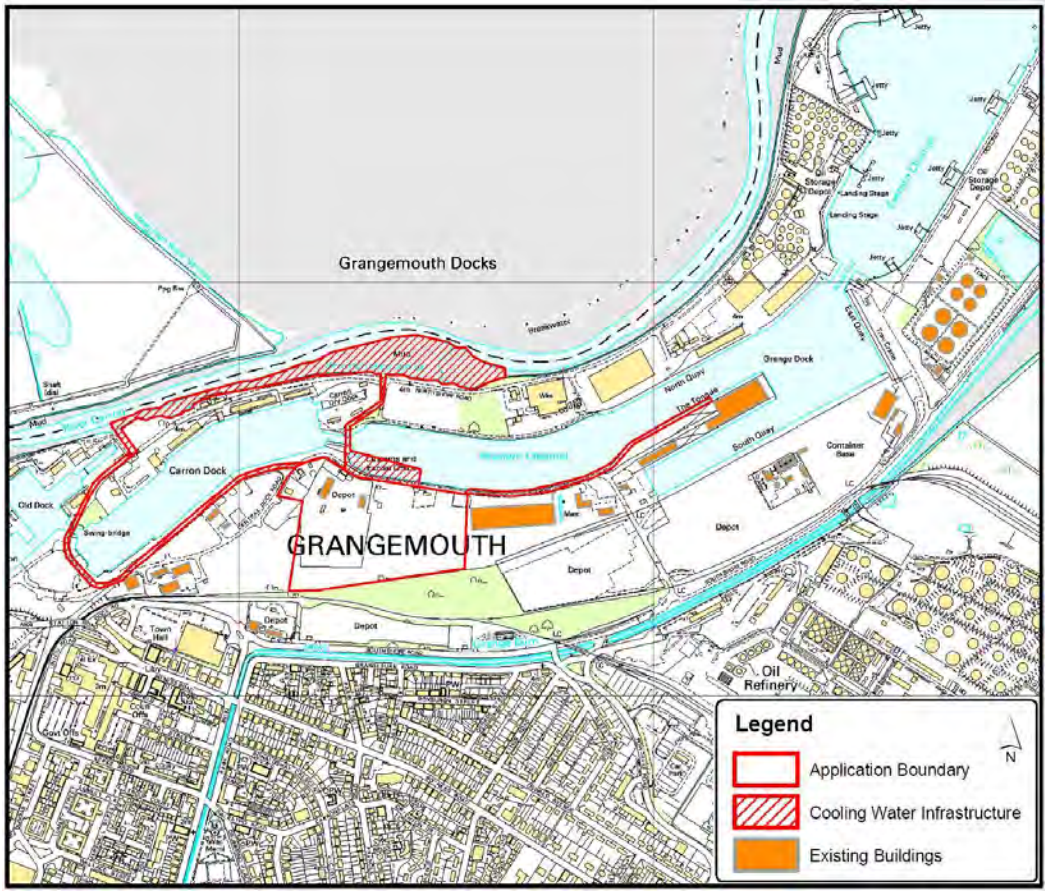
Photographs from the site walkover are provided in Appendix B.

F.3.2 Existing Site Layout

The proposed main plant area of the site is low lying and covers an area of 10.3 ha within the operational area of the Port. The site is bounded by Central Dock Road and the Western Channel to the north; Central Dock Road to the west; a railway line to the south; and industrial works to the east.

The site is predominately covered by a mix of hardstanding surfaces and roughly vegetated scrubland, used primarily for general cargo activities, container storage and the stockpiling of aggregates and other materials. There are small areas of scattered shrubs to the east of the site. The existing site layout is shown in Figure2 below.

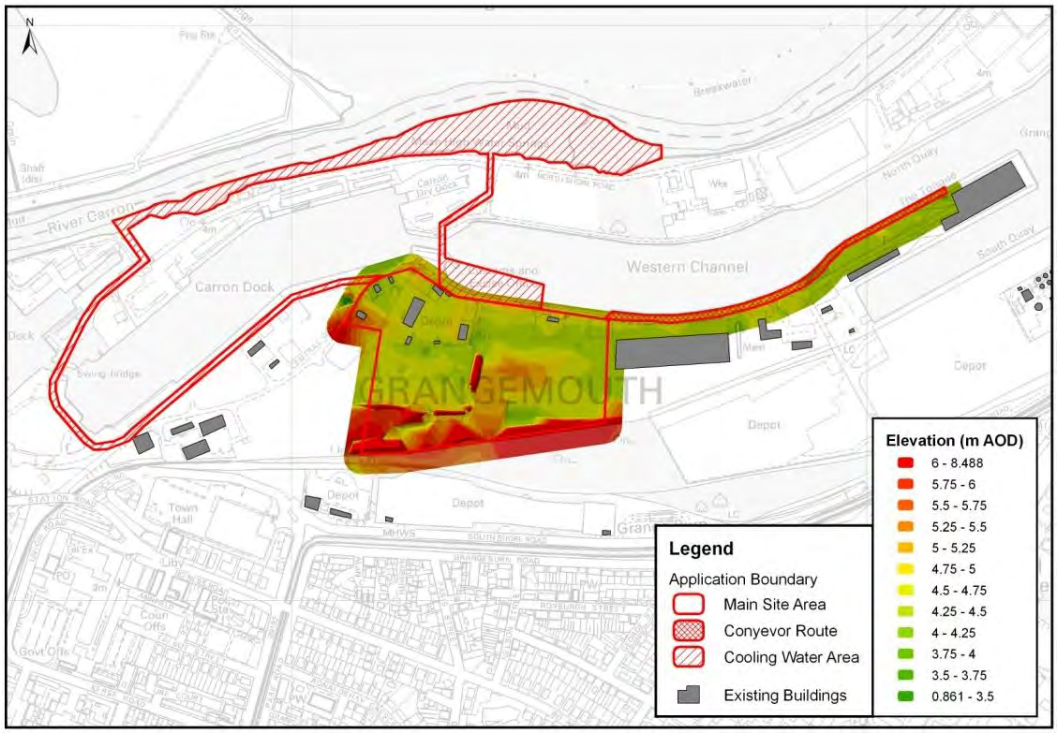
Figure 2: Existing Site Layout



F.3.3 Site Topography

The site is a relatively low-lying area of land located adjacent to the Western Channel in the Port of Grangemouth, adjacent to the Forth Estuary. Topographical survey data shows current elevations across the site are low ranging between approximately 3.93 m to 8.48 m AOD being higher on the south western border of the site. Figure 3 illustrates the site topography in the main plant area and fuel transfer conveyor corridor.

Figure 3 - Site Topography – Main Plant Area and Fuel Transfer Conveyor Corridor



F.3.4 Proposed Site Layout

The proposed development will comprise development in five operational areas as follows:

- the main plant area;
- an area of search for the installation of the cooling water intake (within the Western Channel);
- two alternative infrastructure corridors for the installation of cooling water discharge pipes;
- an area of search for the installation of the cooling water outfall (in the River Carron); and
- an infrastructure corridor for the fuel transfer conveyor (along the North Shore Road).

The plant is intended to operate as a base-load plant, operating continuously except during maintenance downtime. The site will incorporate fuel storage areas within the main plant area, with fuel being transferred to the power plant via a covered conveyor system. A new onsite 132 kV substation will be built to transform and transmit the electrical output from the plant to the local 132kV network at Bainsford substation via a 132 kV underground electrical connection onto the main national transmission network. The electrical connection is not within the scope of the Section 36 Application and the Environmental Impact Assessment (EIA).

The conclusions in this report are based on the proposed development plans at the time of writing.

Figure 4a: Proposed Site Layout (with open stockpile)

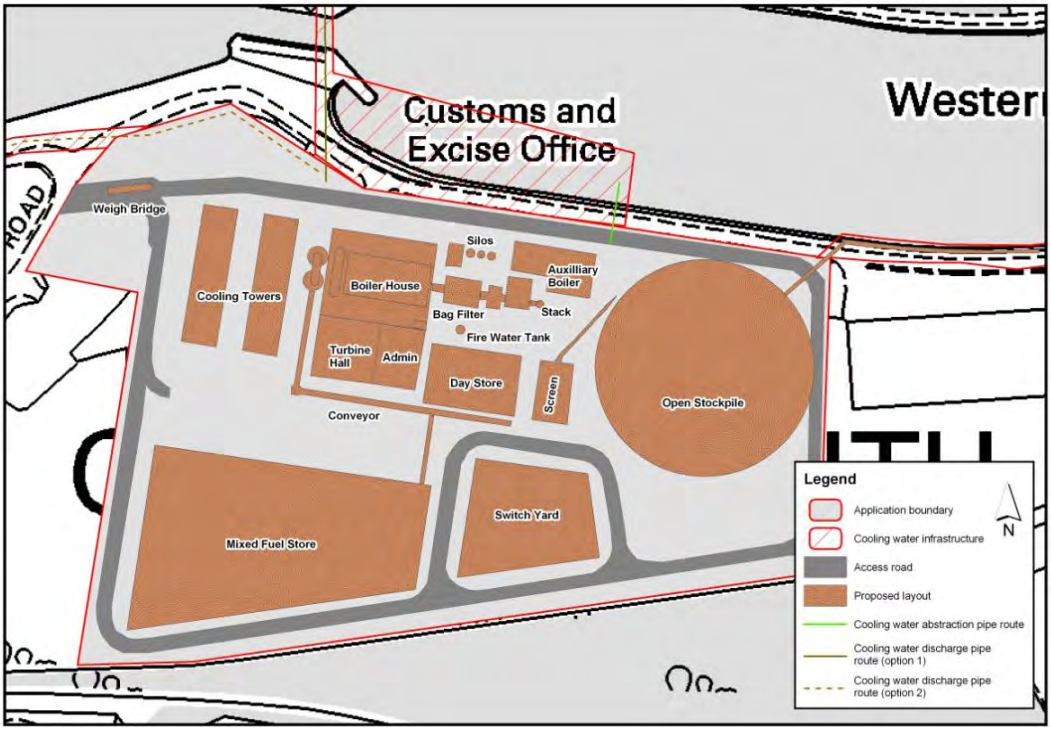
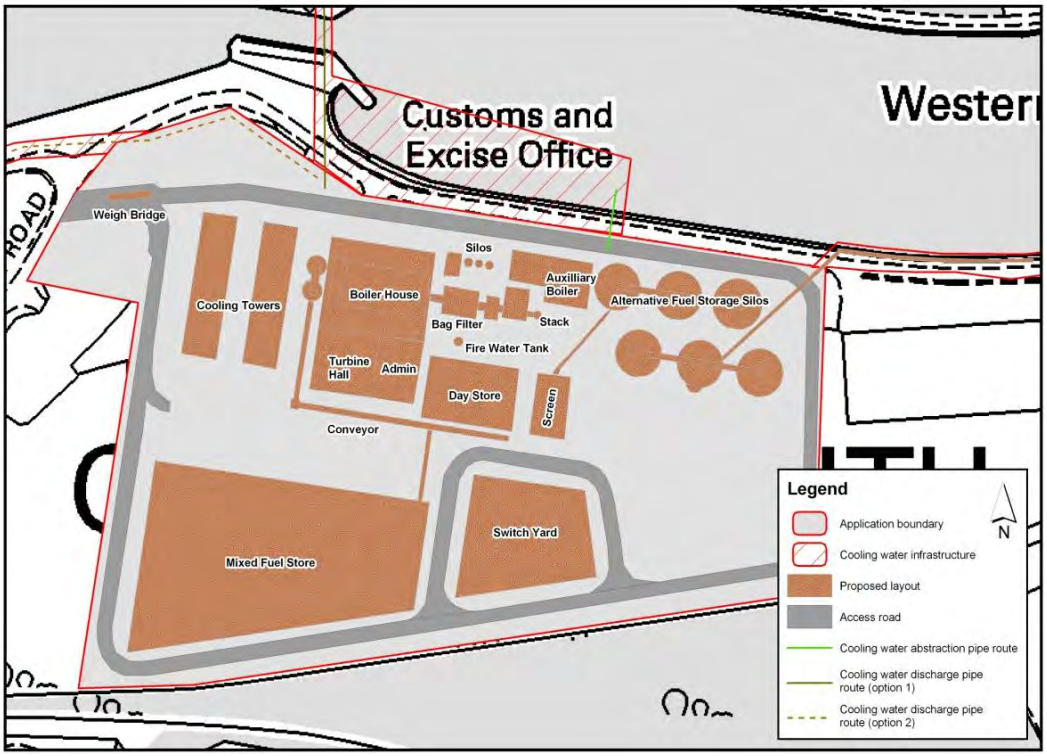


Figure 4b: Proposed Site Layout (with fuel storage silos)



F.4 Flood Risk Assessment

This section outlines the results of the Flood Risk Assessment (FRA), which has been carried out to satisfy the requirements of SPP.

F.4.1 Risk Assessment Methodology

The risk framework contained within the SPP has been used to define the level of risk in this assessment as follows:-

- Little or no risk area (less than 0.1% (1:1000)) – no general constraints (defined in this assessment as negligible);
- Low to medium risk area (0.1% to 0.5% (1:1000 – 1:200)) – suitable for most development but not essential civil infrastructure (defined in this assessment as slight); and
- Medium to high risk area (0.5% (1:200) or greater) – in built up areas with flood prevention measures most brownfield development should be acceptable except for essential civil infrastructure; undeveloped and sparsely developed areas are generally not suited for most development (defined in this assessment as major).

F.4.2 Potential Sources of Flooding

The main risks to the proposed development are considered to be from tidal inundation, originating from the Firth of Forth and fluvial inundation from Grange Burn. The possibilities of flooding from other sources such as extreme rainfall or groundwater are assessed below, but are considered to represent a lesser risk to the site.

F.4.2.1 Existing Flood Alleviation Measures

Flood defences have been installed along the Forth Estuary to the east of the site for the protection of the LPG terminal. Bunds have also been installed along North Shore Road and the banks of the River Carron north of the site to protect the road from flooding. Anecdotal evidence indicates that South Shore Road on the approach to the LPG Terminal has previously been closed due to flooding.

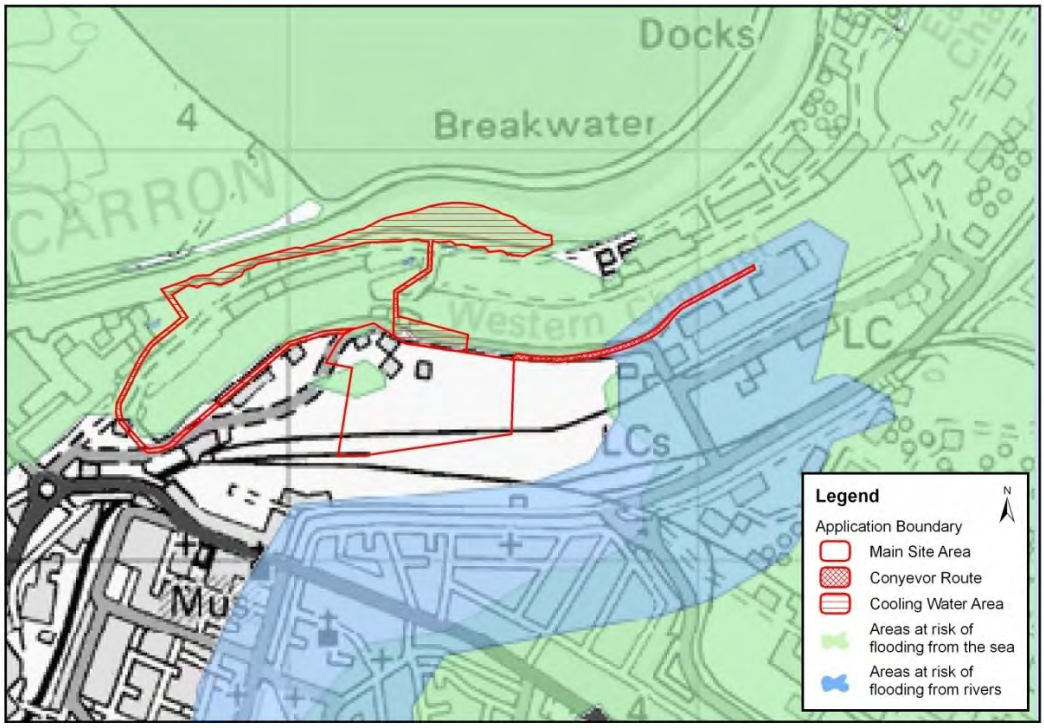
Other than the protection outlined above and the existing raised ground elevations of reclaimed land within the Port of Grangemouth, no other flood protection schemes are in place along the Forth Estuary within the vicinity of the development.

F.4.2.2 Plan Indicating Flood Risk

Indicative floodplain mapping provided by SEPA shows some areas of the main site to be within the 1 in 200 year flood outline of tidal flooding of the Forth Estuary, indicating a medium to high flood risk. This flood outline corresponds to a 0.5% annual probability of tidal flooding. This does not take into consideration the risk of flooding from storm surge or wave action. The mapping also details a floodplain associated with fluvial flood risk from Grange Burn to the south of the site however this area of risk does not extend onto the main area of the site.

The mapping supplied by SEPA does not account for flooding arising from sources such as surface water runoff, surcharged culverts or drainage systems. In addition, the methodology used to produce the floodplain maps was not designed to quantify the impacts of factors such as flood alleviation measures, buildings and transport infrastructure on flood conveyance and storage.

Figure 5 - Indicative Scottish Environment Protection Agency Floodplain Mapping



F.4.2.3 Tidal Flood Risk

Floodplain mapping provided by SEPA shows some areas of the site to be at risk of a 0.5% annual probability (1 in 200 chance) or greater of tidal flooding from the Forth Estuary. Risk of tidal flooding from the estuary is greater than the risk of fluvial flooding from upstream catchment flows due to the proximity of the site to the mouth of the estuary and its discharge into the North Sea. The present day extreme tide still water levels associated with a 0.5% return period event are estimated by SEPA to be 4.62 m AOD. Ground levels across the site are currently between 3.93 m and 8.48 m AOD, indicating that some areas of the site are currently below the current flood risk datum for a 0.5% probability event, and are potentially at risk from tidal inundation.

F.4.2.4 Fluvial Flood Risk

The closest significant watercourses to the site other than the Forth Estuary are the River Carron to the north of the site and Grange Burn to the south. The River Carron flows in a west to north east direction approximately 200 m north of the site, joining the Forth Estuary on the northern boundary of the Port of Grangemouth. SEPA indicates that the flood risks associated with the lower reaches of the River Carron are tidal. The upstream catchment of Grange Burn includes Westquarter Burn to the south west of the site, with flows passing from west to east in Grange Burn through a maintained channel within the Port of Grangemouth. Some fluvial flood risk is associated with the Burn, upstream of the confluence with the Forth Estuary, immediately south of the Eastern Channel of Grangemouth Docks. The flooding is shown not to present any risk to the proposed development.

A site walkover inspection and a desk study of available drainage information revealed no further watercourses or open drainage channels in the vicinity of the site. The existing surface water drainage is discussed further below. Fluvial flooding is not considered to present a significant flood risk to the main plant area.

F.4.2.5 Surface Water

The majority of surface water runoff from within the site currently passes to ground through infiltration, with runoff during extreme events having the potential to follow topographic gradients towards the Carron Dock and Western Channel along the northern boundary of the main plant area.

Detailed drainage plans from Forth Ports indicate that current hardstanding surfaces on the site discharge directly to the adjacent dock or to a reticulated drainage system that ultimately outfalls to the dock. Some areas of reticulation are noted to the south and south east of the site, beyond the railway line, with outfalls discharging to Grange Burn.

Development of the site will include a new surface water drainage system designed to manage runoff from the development. The proposed drainage strategy is discussed further in Section 5. Design of a surface water drainage system for the proposed development will ensure that risk of flooding from surface water is negligible.

F.4.2.6 Foul Water

The proposed Renewable Energy Plant will generate around 1 m3 per day of foul water drainage from toilets, showers, and hand basins which will be discharged to the local sewerage system or via a package treatment plant (e.g. a biocube) prior to discharge to the Estuary. Public combined sewers are present along North Shore Road and Central Dock Road. Blockage or failure of the combined sewers within North Shore Road and Central Dock Road is considered highly unlikely, however if this were to occur flows could potentially back up into the proposed site drainage system.

Any risk of flooding from an overloaded or burst sewer main will be minor on the site with any flows passing overland to existing surface water drainage systems or discharging directly to the Firth of Forth. Any flooding from sewers would be very shallow in nature and would follow topographic profiles. Foul water flooding does not present a significant flood risk to the development.

F.4.2.7 Groundwater

A review of the British Geological Society (BGS) solid and drift geological map for the area shows the site to be underlain by a concealed aquifer or aquifer of limited local potential of quaternary coastal and river alluvium, comprising fine grained sands, silts and clays with occasional sand, gravel and cobble deposits. Based on the anticipated ground conditions, it is expected that shallow groundwater may be present, perched upon the Marine Deposits comprising mainly silt and clay of former intertidal flats (Carse Clay).

There is the potential for perched groundwater or seepage within the Made Ground. Water levels within these materials would be expected to be relatively shallow (i.e. less than 1 to 2 m bgl) but would only be present in limited volume.

Further investigative works will be undertaken following receipt of a Section 36 consent, if granted, following detailed design and will include assessment of groundwater levels and flow. However based on the current information, the proximity of adjacent waterbodies and a lack of any historical incidence of groundwater flooding at the site, groundwater is not considered to present a flood risk to the development.

F.4.3 Impact on Fluvial and Coastal Morphology

The proposed Renewable Energy Plant will not result in any impact on fluvial or coastal morphology. The site is located within an area with some existing drainage and well maintained watercourse channels. These are unlikely to change as a result of inundation or site development.

F.4.4 Adjustments for Climate Change

When assessing the flood risk to any potential development site, consideration must be made of any potential for change to that risk throughout the life of the development. The life of the development has been considered here to be 25 years, however reporting has considered a 60 year lifespan to cover all eventualities with respect to flooding. Indicative floodplain mapping provided by SEPA makes no consideration for climate change; however UK Climate Projections (UKCP09) provides guidance on allowances for potential climate change impacts on sea levels and rainfall intensity. UKCP09 is the fifth generation of climate information for the UK and is the most comprehensive package produced to date. The data includes probabilistic projections of climate change based on quantification of the known sources of uncertainty.

F.4.4.1 Relative Sea Level

Consultation with SEPA confirms recommendations within UKCP09 which states that current predictions indicate a relative sea level rise of 24.4 cm over the life of the development, based on the medium emissions scenario. This increase will return a peak still water level of 4.864 m AOD during an extreme tidal event towards the end of the development life.

UKCP09 also provides data relating to storm surge and projected increases in storm surge due to climate change. It is generally rare for a storm surge to occur at exactly the same time as an extreme tidal level. In the design of developments in areas at risk of tidal inundation it is the expected total water level that is important (i.e. the sum of the predicted tidal water level and any residual/surge). Storm surge for the Forth Estuary is defined as 1.25 m within UKCP09, based on observed data for a 1 in 50 year exceedence.

For the purpose of this assessment, the risk of a 1 in 50 year exceedence storm surge in combination with a Highest Astronomical Tide (HAT) has also been considered for determination of risk to the site. Tidal levels experienced around the Scottish coastline are made up of two components, an astronomical component, due to the effects of the Moon, Sun and planets and a residual component, due to weather including storm surge effects. The HAT for Grangemouth is stated as being 3.65 m AOD (Admiralty Tide Tables, Volume 1, 2010). The combination of a HAT level and storm surge returns a peak water level of 4.90 m AOD.

F.4.4.2 Rainfall Intensity

SPP advises that the proposed drainage scheme should have a neutral or better effect on the risk of flooding both on and off the site and should be approved by SEPA. Consideration should also be made for potential future changes to the UK climate over the life of the development. Current scenarios indicate an overall increase in the number of rain-days and average rainfall intensity, with wetter winters and drier summers. Design of the surface water drainage system will incorporate an allowance of a 20% increase on peak rainfall intensity for climate change. This increase in surface water will mean increased water levels within the proposed and existing drainage infrastructure and an increased discharge to the Forth Estuary during more extreme events.

Guidance also states that where practical, surface water runoff from a development should be fully or partially drained by sustainable drainage system (SUDS) and where flooding is an issue, SUDS should be designed to deal with a storm inflow very soon after a flood subsides. In terms of management of surface water runoff, the site is situated within the port environment on the Forth Estuary and all stormwater will be discharged directly to the docks or to Grange Burn. The location constitutes the end of the hydraulic train for management of runoff, with no reticulation or managed drainage channels downstream of the site outfalls and as such the use of SUDS is not considered appropriate for this site, however oil interceptors and silt filters will be included within the drainage design.

F.5 Mitigation Measures

F.5.1 Operational Personnel Safety

Taking into consideration the risks associated with the potential for tidal inundation of the site during extreme events, personnel working at the plant must be provided with safe access and egress or an area of safe refuge within the site. Assessments indicate that during extreme conditions a peak still water level of 4.864 m AOD (including an allowance for climate change over the life of the development) could be achieved during a 0.5% probability tidal event and a peak water level of 4.90 m AOD could be reached during an extreme tidal event combined with a 1 in 50 year exceedence storm surge. Either of these scenarios would have the potential to inundate some areas of the operational site based on current ground levels.

The Applicant will raise ground levels as necessary across the site to ensure personnel can operate safely during potential flood scenarios. Consultation with SEPA confirmed that a freeboard of 600 mm should be applied to the peak predicted water level for the site. To ensure safety of personnel at the site, safe refuge within the application boundary will therefore be provided in the form of designated areas within administration or control buildings with a minimum floor level of 5.50 m AOD (extreme event with storm surge on the site plus 0.6 m freeboard). Any areas of the plant that would require attendance by personnel during normal operating practice would also be made accessible with ground levels above 5.50m AOD.

F.5.2 Operational Plant Equipment

To facilitate the continued operation of the plant during extreme conditions, further mitigation is proposed in respect of those elements of the operation that may be vulnerable to damage during any breach of flood defences. Sensitive plant and equipment will be bunded and/or situated above the 5.50 m AOD threshold where appropriate. Non-sensitive equipment and buildings will be permitted below this level; however flood proofing and flood resilience measures will be applied.

F.5.3 Site Drainage Provisions

The Port of Grangemouth is located on the Forth Estuary and it is therefore deemed appropriate to discharge surface water runoff from the development site to the Forth via the docks, allowing the peak surface water discharge from the site to be managed prior to the receipt of the peak discharge from the upstream catchment. Apparatus such as oil and silt interceptors and trapped gullies will also be incorporated to provide treatment to surface water prior to discharge.

Proximity of the site to the Forth Estuary, which would be the end point for discharge of surface water from the site (via the docks), and also the industrial nature of the site, makes the use of SUDS inappropriate. All stormwater will be discharged to the docks and subsequently in to the estuary which constitutes the end of the hydraulic train for management of runoff, with no reticulation or managed drainage channels downstream of the site outfalls.

Drainage infrastructure within the application site will be designed and constructed with due consideration given to the risk of flooding from rainfall runoff. Taking into consideration the existing site conditions, mitigation measures will include but not be limited to:

- a stormwater drainage network capable of containing with no surcharge above ground level, runoff from a 3.3% probability rainfall event, including an additional allowance for climate change; and
- a site-wide system capable of managing flows from a 1% probability rainfall event, including an additional allowance for climate change, including provision for overland channelling of excess flows to the docks.

F.6 Residual Flood Risk

Development of the site includes for raised ground levels for sensitive equipment and safety of personnel. Proposed drainage plans will take account of future climate change impacts on rainfall runoff, with reticulation designed to cope with the increased runoff. Provided these measures are implemented at the design stage of the project and built into the final development, residual risk to the site in terms of flooding will be negligible.

F.7 References

Scottish Planning Policy, Scottish Government, February 2010;

The Flood Risk Management (Scotland) Act 2009, Scottish Parliament;

The Water Environment (Controlled Activities) Regulations, 2005 (CAR);

Water Environment and Water Services (Scotland) Act 2003 (WEWS Act);

Flood Report, Falkirk Council, November 2009;

Centre for Ecology and Hydrology (1999). Flood Estimation Handbook, digital data (FEH CD-ROM);

Planning Advice Note PAN 69: Planning and Building Standards Advice on Flooding, Scottish Executive, August 2004;

Admiralty Tide Tables, Vol 1:United Kingdom and Ireland, Admiralty Charts and Publications, 2010

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Appendix A: Correspondence

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From: Scott, Heather
Sent: 02 February 2010 08:53
To: Treagus, Catherine (SKM)
Subject: FW:
Attachments: RE: Request for Information - Port of Leith; RE: Request for Information - St Margaret's Hope, Rosyth

From: Corry, Eleanore
Sent: 29 January 2010 14:11
To: Scott, Heather
Subject: FW:

Hello Heather,

Please find below our response for the data request on the proposed biomass sites at Leith, Grangemouth and Rosyth Ports.

Cheers,
E

Kind Regards
Eleanore Corry
Hydrogeologist
Direct dial: [redacted]

From: Corry, Eleanore
Sent: 29 January 2010 14:09
To: Access to Information Enquiries
Subject:

Hello,

Please find our response for the Grangemouth site below. Responses for the Port of Leith and Rosyth sites have already been sent, please see attached emails.

Kind Regards
Eleanore Corry
Hydrogeologist
Xtn [redacted]

Grangemouth

- The sites lie within a Drinking Water Protected Area (Groundwater).
- SEPA does not monitor groundwater levels within 2km of the sites.
- The Stirling and Falkirk bedrock and localised sand and gravel aquifers have been classified at poor qualitative status and good quantitative status.
- The following abstraction and discharges are licensed within 2km of the sites:

Authorisation	Activity	NGR
CAR/R/1033884	Sewage (private) secondary	NS 294281 682756
CAR/L/1001334	Surface water (SW) commercial, industrial and other	NS 94212 83112
CAR/L/1001367	Other effluent	NS 94213 83113
CAR/L/1001473	Other effluent	NS 94305 83394
CAR/L/1001160	Other effluent	NS 95304 82201
CAR/L/1001160	Other effluent	NS 95309 82201
CAR/L/1000997	Other effluent	NS 94265 83203
CAR/L/1001289	Sewage (private) primary	NS 94277 83249
CAR/L/1001289	Other effluent	NS 94279 83276
CAR/L/1004615	Industrial or commercial: evaporative cooling. GW abstraction	NS 93994 79974
CAR/R/1014879	Industrial or commercial; process water. GW abstraction	NS 93823 82444
CAR/R/1016870	Sediment removal	NS 9354 80018
CAR/R/1027573	Sewage (private) secondary	NS 94528 82486
CAR/R/1027574	Sewage (private) secondary	NS 94050 82206
CAR/R/1030869	Sewage (private) primary	NS 94871 83958

Please note SEPA only registers abstractions of more than 10m³/day. Please contact the local council for information on private drinking water supplies.

From: Scott, Heather
Sent: 28 January 2010 16:10
To: Treagus, Catherine (SKM)
Cc: McLean, Lauren
Subject: FW: Re: Data request for the proposed biomass sites at Leith, Grangemouth and Rosyth Ports

Many thanks Lauren,

Heather

From: McLean, Lauren
Sent: 28 January 2010 16:07
To: Scott, Heather
Subject: Re: Data request for the proposed biomass sites at Leith, Grangemouth and Rosyth Ports

Hi Heather,

Flood Risk Information for Firth of Forth, Various Sites

Please find the Flood Risk information for Leith, Rosyth and Grangemouth below.

Grangemouth
Review of the Indicative River & Coastal Flood Map (Scotland) 200-year flood outline (i.e. the flood with a 0.5% chance of occurring in any single year) indicates that this area lies within this envelope and as such is potentially at medium to high risk of coastal flooding.

The estimated 1 in 200 year water level for the Firth of Forth at Grangemouth is 4.62mAOD based on extreme still water level calculations using the POL 112 Method. This does not take into account the potential effects of wave

action at this location. The latest sea level rise predictions due to climate change in the recently published UKCIP09 estimates that sea level rise will be approximately 24.4cm by 2080 taking the medium emissions scenario

Our records show that the highest recorded still water level at Grangemouth was 4.47mAOD in 1959.

We currently maintain a gauging station on the River Carron at Headswood. Further information from this site can be provided on request.

Standard freeboard levels of 600mms should be included in the development plans for this site.

With respect to site discharge, the requirement for site discharge is dependant upon the water body that is being discharge to.

I would recommend that you contact the Roads Department of Falkirk Council who, as Flood Prevention Authority, should be able to provide further information regarding flooding and flood alleviation in the area.

The Indicative River & Coastal Flood Map (Scotland) has been produced following a consistent, nationally-applied methodology for catchment areas equal to or greater than 3km2 using a Digital Terrain Model (DTM) to define river cross-sections and low-lying coastal land. The outlines do not account for flooding arising from sources such as surface water runoff, surcharged culverts or drainage systems. The methodology was not designed to quantify the impacts of factors such as flood alleviation measures, buildings and transport infrastructure on flood conveyance & storage. The Indicative River & Coastal Flood Map (Scotland) is designed to be used as a national strategic assessment of flood risk to support planning policy in Scotland.The flood advice contained in this letter is supplied to you by SEPA under the Environmental Information (Scotland) Regulations 2004 in response to your request for information under these regulations.

I hope this is of use.
Yours sincerely
Lauren McLean
Hydrologist (Flood Risk)

From: Scott, Heather
Sent: 28 January 2010 12:18
To: Treagus, Catherine (SKM)
Subject: RE: Data request for the proposed biomass sites at Leith, Grangemouth and Rosyth Ports
Attachments: CraigforthQDayMean.xls; Polmonthi1QDayMean.xls; MurrayfielQDayMean.xls; HeadswoodQDayMean.xls; 04 AMS (19006).xls; 55 AMS (18011) Rating Ed 4.xls; 30 AMS (17005).xls; 32 AMS (17001).xls

Catherine,

Please find attached AMS data and MDF data for the stations closest to Leith, Grangemouth and Rosyth. Please note that Craigforth is measuring the fresh water input into the Firth of Forth from the River Teith and Forth.

Kind regards,

Heather

From: Condron, Emma
Sent: 15 April 2010 14:10
To: Treagus, Catherine (SKM)
Cc: Webster, Graeme; Whittle, Bernard
Subject: EIR for Carron Dock

Contaminated Land Enquiry: Carron Dock, Grangemouth

Dear Catherine,

Further to your recent enquiry (received on 14 April 2010) regarding the above site (Ref: Letter Ref: EE10480), Falkirk Council's Contaminated Land Team has reviewed available in-house databases (M3 and GIS) and can offer the following comments:

Hydrological Assessment

1) There are no details of any private or public water supplies, with regard to the site, within the Contaminated Land Team's available databases.

2) There are no records of any licensed abstractions and discharge consents with regard to the site, within the Contaminated Land Team's available database and suggest that you contact SEPA accordingly.

3) There are no available records within the Environmental Health Unit, which indicate current landfill sites within 2km of the study area. However, it should be noted that records indicate significant areas of made ground, possibly associated with the expansive areas of reclaimed land and the infill of former basins. It should also be noted that there are some other backfilled features within 2km of the site boundaries, which may possibly have historically been recorded or unrecorded landfill sites. We would suggest that you contact other departments within Falkirk Council such as Development Management, Food & Safety, Building Standards and Corporate Commercial Services and also SEPA, who may have further information.

4) Researches of historical information have indicated numerous historical and current industrial activities within the site boundaries and the surrounding area, over a long period of time. The site would appear to be part of the Grangemouth docks which included numerous oil depot storage areas, docks, transport and cargo handling areas, electricity substations, numerous depots and warehouses, Custom and Excise offices and several other offices and petrochemical industries. Historical industrial activities were indicated to include foundries, engineering works, sawmills, timber yards, a hospital, sand and gravel quarrying, railway depots and numerous railway lines, sidings, goods sheds, engine sheds, depots, smithies, warehouses and works of an unspecified nature. Expansive areas of reclaimed land were also indicated within close proximity.

Numerous industrial activities were also indicated in the surrounding area and included mining, sawmills and timber yards, gas manufacturing and storage facilities, several oil refineries, railways and sidings and associated buildings, road haulage, petrochemical industries, warehouses and depots and several works of an unspecified nature. Residential and commercial land uses were also noted in the surrounding area.

In addition, there may be several other contaminative sources not identified during the limited researches of in-house data.

5) The Contaminated Land Team has no available records of previous site investigations undertaken within the site or adjacent land.

6) There are no records of any contamination issues or specific contamination incidents, with regard to the site, within the Contaminated Land Team's available databases.

7) At the current time there are no entries within the Contaminated Land Register relating to contaminated land for the site or close proximity. However, it should be noted that Falkirk Council is currently undertaking prioritisation works under the Contaminated Land Regime (Part IIA), and given the historical background of the site and the surrounding area, it is considered that prioritisation/designation could be possible, if circumstances arise.

8) The historical background of the site and surrounding area indicates numerous potential sources of contamination. Consequently, there are likely to be potential contamination issues/constraints. For any proposed development, redevelopment or change of use for the site, a land contamination risk assessment should be undertaken in accordance with current guidance and regulations.

In order for an adequate land contamination assessment to be undertaken, a desk study (Phase 1) should be completed. The desk study should assess ground conditions at the site and include information such as the current and historical usage of the site and surrounding area, geology, hydrogeological and hydrological conditions underlying the site. Any potential source-pathway-receptors should be identified. Should any significant chemical contamination risks be identified, then an intrusive (Phase 2) site investigation will be required. Under the Planning Regime, these assessments would be subject review and approval by the Planning Authority.

9) As previously mentioned, we would suggest that you contact other relevant units within Falkirk Council (e.g. Development Management, Food & Safety, Building Standards, Roads and Development), and also contact Scottish Water and SEPA.

We trust that this meets with your current requirements, however, please do not hesitate to contact us should you have any queries.

Kind regards

Emma Condron
Senior Contaminated Land Officer
Contaminated Land Team
Falkirk Council

From: Whittle, Bernard
Sent: 14 April 2010 15:37
To: Treagus, Catherine (SKM)
Subject: Grangemouth Biomass

Catherine
Further to our telephone conversation I can confirm that the Council's Roads Development Control and Flooding Team comment that the development is in Grangemouth Docks, land in the ownership of Forth Ports and it is therefore Forth Ports who determine flood protection/risk to their facilities. Your email was also sent to the Council's Environmental Protection Unit. Comments are awaited. The contact is Graeme Webster (tel 01324 504762). I have spoken to Graeme and I understand he expects to be able to provide you with comments tomorrow. I have asked him to email these to you direct.

Regards

Bernard Whittle

Development Management Co-ordinator
Falkirk Council
Development Services
Abbotsford House
Falkirk
FK2 7YZ

Tel: [redacted]
Fax: 01324 504747

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Appendix B: Walkover Inspection Photographs

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Photograph 1: Tidal reach of Grange Burn to the south east of the site, facing east

Photograph 2: Tidal reach of Grange Burn to the east of the site, facing east.

Photograph 3: Eastern section of main site area. Mossy scrubland with rushes, evidence of Made Ground and some standing water. Bund/embankment to the south parallel with the railway siding. View faces west.

Photograph 4: South western section of the site, comprising of stockpiles of materials, facing north east

Photograph 5: Eastern end of Carron Dock with swing bridge, facing north east.

Photograph 6: Southern side of the Western Channel, facing east.

Photograph 7: Parking area along the edge of the Western Channel by the swing bridge, facing north.

Photograph 8: Chain fenced gravel parking area to the south of the swing bridge, facing south.

Photograph 9: Gravel and mud surfaced parking/depot area in the central section of the site. Access not permitted to this area at the time of visit. View faces south.

Photograph 10: Fenced area of former building. Concrete building footprint still in situ, facing west.

Forth Energy

Appendix G

Cultural Heritage Supporting Information

Contents

Cultural Heritage Supporting Information

G.1 Gazetteer and Concordance of Cultural Heritage Features within the Inner, Middle and Outer Study Areas

F No	Name	Reference	Description	NGR	Status
1	Iron Foundry	N/A	Not present on the first edition Ordnance Survey Map (surveyed 1860). Established by the time of the 2nd Edition survey (revised in 1895-96) but absent from the subsequent Ordnance Survey map of 1915.	293310, 682410	Non-designated
2	Hospital	N/A	Not present on the first edition Ordnance Survey Map (surveyed 1860). Established by the time of the 2nd Edition survey (revised in 1895-96) and is also depicted on the Ordnance Survey map of 1915, although labelled there as 'Smithy'. This was possibly an isolation hospital for infectious diseases.	293190, 682420	
3	Zetland St Row of houses	N/A	Not present on the first edition Ordnance Survey Map (surveyed 1860). Established by the time of the 2nd Edition survey (revised in 1895-96) but absent from the subsequent Ordnance Survey map of 1915. The Earl of Zetland was instrumental in the building of Grangemouth. It is likely that this was a row of workers' cottages.	293130, 682373	Non-designated
4	Grangemouth Dock, Former Workshop Building	LB 50868	Late 19th century brick-built structure with classical detailing; former workshop/smithy	292609, 682586	C(S) Listed
5	Swing Bridge, Western Channel and Carron Dock, Grangemouth Docks	LB34048	Opened 1906, this is a single span hydraulically-operated swing bridge	293697, 681637	B Listed
6	Former La Scala Cinema	LB50873	Built 1913, purpose-built cinema Scots Renaissance style	292755, 682109	C(S) Listed
7	Dundas Church	LB34041	Rectangular plan church Romanesque style opened 1894	292913, 681991	A Listed
8	Ronaldshay Crescent and Park Road Grange Church and Church Hall	LB 34046	1900-1903 Arts and Craft style Church	292988, 681859	B Listed
9	Zetland Parish Church	LB 34047	Built 1910, cruciform plan church	293038, 681836	B Listed
10	Sacred Heart RC Church	LB 34048	1927,Gothic Revival style church	292996, 681683	C(S) Listed
11	Abbotsgrange Middle School	LB 34045	Built 1908 Former Grangemouth High School. Classically detailed, 2-storey school	293150, 681722	B Listed
12	Avondhu House Hotel and Gate Piers	LB 34043	Built 1878, Baronial house	293625, 681602	B Listed
13	Avon Hall and Gatepiers	LB 34042	Built 1877-78, Baronial House	293684, 681574	B Listed
14	The Antonine Wall World Heritage Site		Part of the Frontiers of the Roman Empire World Heritage Site. The Antonine Wall was the north-western frontier of the Roman Empire. It comprised a line of forts and fortlets connected by a continuous rampart wall and ditch and stretched across Scotland from Old Kilpatrick in the west to Bo'ness in the east.	NS458 730 – NT032 807	World Heritage Site and Scheduled monuments

G.2 Desk Based Assessment of Palaeoenvironmental Potential of Deposits, Grangemouth.

Dr Stephen Lancaster

Headland Archaeology (UK) Ltd

Introduction

G.2.1 The site of the proposed Renewable Energy Plant at Grangemouth lies within an estuarine environment. There are a number of archaeological issues peculiar to this environment that need to be considered when assessing the possible impact of a development, and that may affect the scope and nature of any archaeological mitigation that the development will entail:

- The potential for waterlogged sediments (and therefore exceptional archaeological preservation);
- The potential for archaeological deposits and structures well-below modern ground level;
- The potential for significant palaeoenvironmental data (both local environment and whole-catchment data).

G.2.2 The extent to which this potential may be realised is primarily controlled by the depositional regime, the date of deposition of the alluvial sediments and the emergence of these sediments to terrestrial conditions. There are a variety of pre-existing sources of evidence that allow an assessment of this potential through a desk-based approach. This report presents a model of the deposition and emergence of the alluvial sediments. The proposed development lies within an area that has been well studied by geologists and Quaternary scientists and it is on the basis of this work that the model has been generated. The report then applies the results of the application of other forms of evidence (primarily data from engineering borehole logs) to the model, and the consequent conclusions concerning the archaeological potential of the alluvium.

Methods

G.2.3 A number of types of evidence have been used in this assessment. The most important forms of evidence have been expert opinion, primarily in the form of published research, and the engineering core logs. Additional evidence has been sought from aerial photographs, maps and a site visit.

Review of Quaternary Science Literature

G.2.4 A review of the relevant published literature[1,2,3] has been undertaken. On this basis a model of environment of deposition, sea-level change, and emergence of surfaces has been generated.

Core Logs

G.2.5 Core logs are available from two engineering studies of the area[4,5] and a set of transects depicting the Holocene and Late Glacial deposits have been prepared from the existing data (Figures G1 - Transect Location and Figures G2 and G3 – transects). This allows the evidence derived from the core logs to be

[1] Shennan, I and Horton B, 2002 Holocene land- and sea-level changes in Great Britain Journal of Quaternary Science, Vol. 17, 511-526.

[2] Paul, M A, Peacock, J D and Barras, B F 1995 Flandrian stratigraphy and sedimentation in the Bothkennar-Grangemouth area, Scotland Quaternary Newsletter 75, 22-35, London, QRA.

[3] Browne, M A E, Graham, D K and Gregory, D M 1984 Quaternary estuarine deposits in the Grangemouth Area, Scotland BGS Report Vol. 16 No. 3, London, HMSO.

[4] Nicholson Site Investigation 2002 Site Investigation of Location 192028, Grangemouth, for Buchanan(CE) Ltd.

[5] White Green Young Environmental 2001 Ground Contamination Assessment of the Proposed Storage Facility at Grangemouth Docks for Simon Storage Ltd.

applied to the model derived from the published literature to explain the sedimentary history in the area of the proposed development in terms of the depositional regimes of the sediments and the effects of landscape change due to relative sea level fluctuations. Positioning of transects has been based on the available geotechnical logs.

G.2.6 Geotechnical records were selected on considerations of data quality, e.g. completeness of record, detail of core recording, closeness to the development area. The deposits recorded in each borehole were classified into units belonging to two categories: made ground and clay and silt. Made ground includes any definitely human formed deposits, primarily roads and embankments, excluding the soft sediment deposits that constitute reclaimed land, which are classified as clay and silt.

G.2.7 Boreholes were positioned along the length of each transect. The appropriate units were placed in each borehole to scale. After all the borehole records in a transect had been depicted in this way, unit correlations were made where possible. These are the current land surface and the top of the silt and clay deposits.

Site Visit

G.2.8 All safely accessible parts of the proposed development area were included in a walkover. Evidence for possible geomorphological features that might inform the assessment, such as the former position of watercourses and recent sediment deposition and erosion, was sought.

Results

Review of Quaternary Science Literature

G.2.9 The three main aspects relating to the understanding of the formation of the Forth carseland, which the site is positioned on or next to, with respect to archaeological potential are the depositional regime, the dates of deposition and the emergence of the sediments to terrestrial conditions. The depositional regime includes the environments of primary deposition, re-working and erosion of deposits.

Depositional Regime

G.2.10 The Quaternary deposits of the Forth Estuary have been described and systematised into a formal lithostratigraphy, most fully in a British Geological Survey Report[6]. More cursory treatments of these deposits have added little to these reports[7,8]. More specialist reports have refined certain aspects of the depositional sequence[9,10]. The lithostratigraphy noted in the geotechnical logs probably belongs to a single formation. This formation is the Skinflats Member of the Grangemouth Formation, whose formal lithological description is

[6] Browne, M A E, Graham, D K and Gregory, D M 1984 Quaternary estuarine deposits in the Grangemouth Area, Scotland BGS Report Vol. 16 No. 3, London, HMSO and subsequently modified by Paul, M A, Peacock, J D and Barras, B F 1995 'Flandrian stratigraphy and sedimentation in the Bothkennar-Grangemouth area, Scotland' Quaternary Newsletter 75, 22-35, London, QRA.

[7] Browne, M A E 1987 The physical geography and geology of the estuary and Firth of Forth, Scotland Proceedings of the Royal Society of Edinburgh, 93B, 235-244.

[8] Browne, M A E, Mendum, J R, Monro, S K 1993 Geology in Corbet, L and Dix, N J (eds), Central Scotland, Forth Naturalist and Historian, Stirling, Stirling University, 1-17.

[9] Barras, B F and Paul, M A 1999 Sedimentology and depositional history of the Claret Formation ('carse clay') at Bothkennar, near Grangemouth Scottish Journal of Geology vol. 35 part 2, 131-144.

[10] Barras, B F and Paul, M A 2000 Post-reclamation changes in estuarine mudflat sediments at Bothkennar, Grangemouth, Scotland in Pye, K, and Allen, J R L (eds) Coastal and estuarine environments : sedimentology, geomorphology and geoarchaeology, Geological Society Special Publications 175, 187-199 London, Geological Society.

as soft to very soft greyish brown to blackish brown well laminated silty clays and clayey silts, with many laminae and thin bands of fine-grained sand. There are beds of course grained sand and structureless clay. The sediments contain variable amounts of decaying vegetable matter. The environment of deposition for this formation is an intertidal estuarine environment in temperate climate conditions. The attribution of environment of deposition is based on faunal analyses, a combination of gastropods, bivalves, ostracods and foramanifera.

G.2.11 It should be noted that although no peat was located in the available core logs, peat deposits have been noted in boreholes from the Grangemouth Docks at a depth of around –2 m OD, which is deeper than many of the boreholes available to this study penetrated[11].

G.2.12 The main impact of the sedimentary processes since the Holocene maximum transgression (see below) has been to infill the till-lined bedrock basin in which the Forth Estuary is seated, with the Skinflat deposit being the last significant natural deposit in the estuary[12]. Reclamation of land for agricultural purposes was undertaken in the area of Grangemouth, forming the Saltgreen Member of the Grangemouth Formation. Mapping evidence indicates that this reclamation is likely to account for the upper sequences of made ground (or Saltgreen formation) contained in the borehole records, the development site lying within the reclaimed area[13].

Chronology of Deposition

G.2.13 The overlying Grangemouth Formation, including the Skinflats Member, is dated to 3045 ± 80 BP to 4025± 85 BP. The depositional regime of the area near the channel therefore was a low intertidal estuarine mudflat setting by c. 4000 BP uncal. Significant net accumulation of sediment by natural processes had ceased by c. 3000 BP uncal[14].

Relative Sea-level Change and Emergence

G.2.14 The knowledge of the depositional regimes needs to be placed in the context of the research published on relative sea-level change in the Forth Estuary. The beginning of the Main Postglacial rise of sea level has been dated to c. 8500 BP uncal., with the culmination of the Main Postglacial Transgression occurring c. 6400 BP uncal.[15] . It is during the period between these dates that, under Barras and Paul's model[16], the deposition of the Claret Formation largely occurred at the margins of the Forth basin[17]. From c. 6400 BP

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[11] Browne, M A E, Graham, D K and Gregory, D M 1984 Quaternary estuarine deposits in the Grangemouth Area, Scotland BGS Report Vol. 16 No. 3, London, HMSO.

[12] Browne, M A E 1987 The physical geography and geology of the estuary and Firth of Forth, Scotland Proceedings of the Royal Society of Edinburgh, 93B, 235-244.

[13] Cadell, H M 1913 The story of the Forth James Maclehose, Glasgow.

[14] Paul, M A, Peacock, J D and Barras, B F 1995 Flandrian stratigraphy and sedimentation in the Bothkennar-Grangemouth area, Scotland Quaternary Newsletter 75, 22-35, London, QRA.

[15] Robinson, M 1993 Microfossil analyses and radiocarbon dating of depositional sequences related to Holocene sea-level change in the Forth valley, Scotland Transactions of the Royal Society of Edinburgh: Earth Sciences, Vol. 84, 1-60.

[16] Barras, B F and Paul, M A 1999 Sedimentology and depositional history of the Claret Formation ('carse clay') at Bothkennar, near Grangemouth Scottish Journal of Geology vol. 35 part 2, 131-144.

[17] Paul, M A, Peacock, J D and Barras, B F 1995 Flandrian stratigraphy and sedimentation in the Bothkennar-Grangemouth area, Scotland Quaternary Newsletter 75, 22-35, London, QRA.

uncal. relative sea-level has fallen, during which period the deposition of the Claret Formation towards the centre of the Forth basin, and therefore the site of the proposed development, would have occurred. The fall of relative sea-level has broadly continued until recently, although there have been minor sea-level oscillations, for example that are thought to have eroded the upper Claret Formation at c. 4000 BP[18]. The main point to emerge is that the site of the proposed development is now at its highest point on the estuary since the end of the last glacial period i.e. marine influences have been important throughout the Holocene depositional history of the Forth in this area.

G.2.15 Sea-level curves reconstruct mean sea-level, and therefore when trying to estimate the dates that surfaces emerge, the depth of the modern tidal range should be taken into account. The role of the tidal range in determining the nature of environments should also be noted: a greater range will mean a larger area of mudflat and high salt marsh. Most of the studies use a tidal range based on the modern range of 5.2-5.5 m, and Robinson provides evidence in terms of the relative position of shell beds used for dating to confirm the validity of this assumption[19]. This information is referred to in the discussion of the emergence of the current land surfaces.

G.2.16 From the published literature the following model has been derived. The basin of the Forth has undergone net infilling with sediment from the late Pleistocene until the mid to late Holocene. In the area of the proposed development, the environment of deposition would have been sub- tidal from at least 7000 BP until around 3400 BP, when the depositional environment would have changed to intertidal conditions. The change in deposition environment reflects the effects in changes in relative sea-level and water depth resulting from relative sea-level regression and sediment accumulation. The regression of sea-level continued from the Holocene Main Transgression (c. 6400 BP uncal.) until recent times. The regression occurred in stages, resulting in a succession of planation surfaces[20,21].As sea-level regression occurred in stages, so did the emergence of the sediments to the succession of mud flats, high salt marsh and fully terrestrialised surfaces, with the date of these changes varying with the height of the planation surfaces and the rate of relative sea-level regression. With the emergence of the surfaces above mud flat conditions significant sediment deposition through estuarine processes ceased.

Borehole Transects

Transect 1 (NS 92765 82326 to NS 93764 82495) (Figure G2)

G.2.17 This area has a fairly uniform elevation of between 4 and 5 m OD. This reflects the use of this area for the extensive railway network which serviced the port. This transect records the made ground deposits varying in depth between 3 and 0.5 m. The silts and clays correspond to the Skinflats member of the Grangemouth Formation. It has not been possible to consistently distinguish these two units, but it does appear, on the basis of colour, that the lower silts and clays may belong to the earlier Claret Formation.

Transect 2 (NS 92752 82158 to NS 93753 82394) (Figure G3)

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[18] Browne, M A E, Graham, D K and Gregory, D M 1984 Quaternary estuarine deposits in the Grangemouth Area, Scotland BGS Report Vol. 16 No. 3, London, HMSO.

[19] Robinson, M 1993 Microfossil analyses and radiocarbon dating of depositional sequences related to Holocene sea-level change in the Forth valley, Scotland Transactions of the Royal Society of Edinburgh: Earth Sciences, Vol. 84, 1-60.

[20] Barras, B F and Paul, M A 1999 Sedimentology and depositional history of the Claret Formation ('carse clay') at Bothkennar, near Grangemouth Scottish Journal of Geology vol. 35 part 2, 131-144.

[21] Robinson, M 1993 Microfossil analyses and radiocarbon dating of depositional sequences related to Holocene sea-level change in the Forth valley, Scotland Transactions of the Royal Society of Edinburgh: Earth Sciences, Vol. 84, 1-60.

G.2.18 This area has a fairly uniform elevation of between 4.5 and 5 m OD. This probably reflects levelling activity resulting from the operations of the port, the results of which can be seen in the transect with the made ground deposits varying in depth between 1 and 2 m. The silts and clays probably correspond to the Skinflats member of the Grangemouth Formation and the Claret Formation. It has not been possible to distinguish these two units, with the possible exception that the deeper (-0.25 m OD) deposits in borehole log N17 appear, on the basis of colour, to correspond to the Claret Formation.

Aerial Photographs

G.2.19 No palaeochannels or related features were noted in the area of the proposed development: the high degree of modification of the landscape in the area makes this unsurprising.

Maps

G.2.20 The only significant changes in the watercourses noted in the Ordnance Survey map series from the 1st Edition maps onwards are those associated with the redirection and canalisation of the Grange Burn. Historic maps at the National Library of Scotland show, approximately, the original route of the Grange Burn. The map evidence suggests that the former course of the Grange Burn would not have crossed the proposed development site, but joined the Carron further to the north west of the site.

Site Visits

G.2.21 The walkover of the site confirmed the absence of surface features relating to the past formation of the landscape: extensive levelling and ground raising during the life of the port have probably eliminated or obscured whatever features may have existed.

Discussion

Lithostratigraphy and Chronology

G.2.22 It has proved possible to correlate the deposits observed in the core logs with known lithostratigraphic formations, which are of sub-tidal and intertidal estuarine origin. This has demonstrated that in the area of the site there are Holocene deposits of at least 10 m depth at the western end of the site, and of at least 5 m depth at the eastern end of the site: it is probable that the deposits at the eastern end of the site are at least the same depth as the western end, however the borehole logs at this end of the site do not penetrate to the same depth. No palaeochannels were noted from maps or aerial photographs, or detected in the borehole data transects.

G.2.23 The dates of deposition of the Holocene sediments have been presented above, and the date range for the end of deposition is between 3000 BP and 7000 BP[22] . It should be noted that the dates relate to sites close to the channel of the river. The upper sediments closer to the river will tend to be more recently deposited than those further away[23]. On the basis of the published dates and the age trend towards the river the most recent significant deposition of Holocene deposits would have been around 2000-2500 BP, on the basis of data derived from Robinson[24] and Barras and Paul's [25] sea-level curves.

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[22] Paul, M A, Peacock, J D and Barras, B F 1995 Flandrian stratigraphy and sedimentation in the Bothkennar-Grangemouth area, Scotland Quaternary Newsletter 75, 22-35, London, QRA.

[23] Ibid

[24] Robinson, M 1993 Microfossil analyses and radiocarbon dating of depositional sequences related to Holocene sea-level change in the Forth valley, Scotland Transactions of the Royal Society of Edinburgh: Earth Sciences, Vol. 84, 1-60.

[25] Barras, B F and Paul, M A 1999 Sedimentology and depositional history of the Claret Formation ('carse clay') at Bothkennar, near Grangemouth Scottish Journal of Geology vol. 35 part 2, 131-144.

Emergence of surfaces

G.2.24 As noted above, in an estuarine setting the tidal range is important in establishing the areas of different environments as surfaces emerge, and in conjunction with the rate of emergence, the rate of terrestrialisation. The influence of the tidal range means that initial emergence does not equate with full terrestrialisation of a ground surface. If a ground surface is between the mean low water spring tide and mean sea-level, it is a mud-flat, being submerged twice a day, between mean sea-level and the mean high water spring tide it is a high salt marsh environment, flooding on a frequent basis. Applying the current tidal range (see above) as the basis of calculation, the date for emergence to a lower intertidal mudflat environment is that given above (2000-2500 BP). The date of emergence to high salt marsh environment is most likely around 1500 BP, with a fully or near fully terrestrial environment emerging as recently as 1000 BP[26] .The fall in relative sea-level was not uniform: the presence of peat at approximately –2 m OD suggests a sea level oscillation sufficient for areas of mudflat to become high salt marsh, before sea level rose again sufficiently for these areas to revert to mud flat (Browne *et al*. 1984). This peat has not been dated, but the depth at which it occurs suggests that it formed in the early Holocene, and is unlikely to contain cultural remains.

Archaeological Potential

G.2.25 In the introduction it was noted that the archaeological potential of the alluvial deposits were as follows:

- The potential for waterlogged sediments (and therefore exceptional archaeological preservation);
- The potential for archaeological deposits and structures well-below modern ground level;
- The potential for significant palaeoenvironmental data (both local environment and whole-catchment data).

G.2.26 The potential for waterlogging of the sediments and therefore exceptional preservation in the sediments can be assessed by reference to the original environment of deposition and the subsequent post-depositional changes which the sediments have undergone. The sub-tidal and low intertidal environments of deposition of the Holocene sediments would favour the preservation of some organic materials, particularly wood. The subsequent land use of the carse has affected this position. Although the surface drainage of the carseland is relatively poor, extensive drainage has been in place long enough to cause some oxidation of the upper part of the sediments. On the basis of recorded water strikes in the core logs, the oxidised zone could extend as deep as 0.5 m into the natural sediments, though the pattern is highly variable, and in some places the whole depth of the natural sediments is likely to be waterlogged. In the deposits below the oxidised zone there would be scope for exceptional preservation, through waterlogging, of archaeological materials.

G.2.27 The potential for significant archaeological deposits and structures below modern ground level depends on both the environment and date of deposition of the sediments, in that these determine the possible range of activities that could be carried out in an area and the types of archaeological remains likely to be found. The environment of deposition of the uppermost natural sediment across the site is intertidal. The date range for the end of sediment accumulation is around 2000-2500 BP uncal. i.e. the uppermost deposits date from the Iron Age. Across this period any remains associated with the intertidal zone would be likely to be fish traps and boats. Both would relate to low intensity activity in the landscape, and thus have a relatively low frequency of occurrence in large volumes of sediment. However, the potential for such archaeological material surviving is rendered negligible by the previous port construction, which is likely to have destroyed archaeological finds in this location, with the exception of a small area on the banks of the River Carron. Deeper Holocene deposits, probably below 10 m from the current surface, are of subtidal origin, and as such would have been deposited in conditions of near permanent submersion. These deposits are therefore less

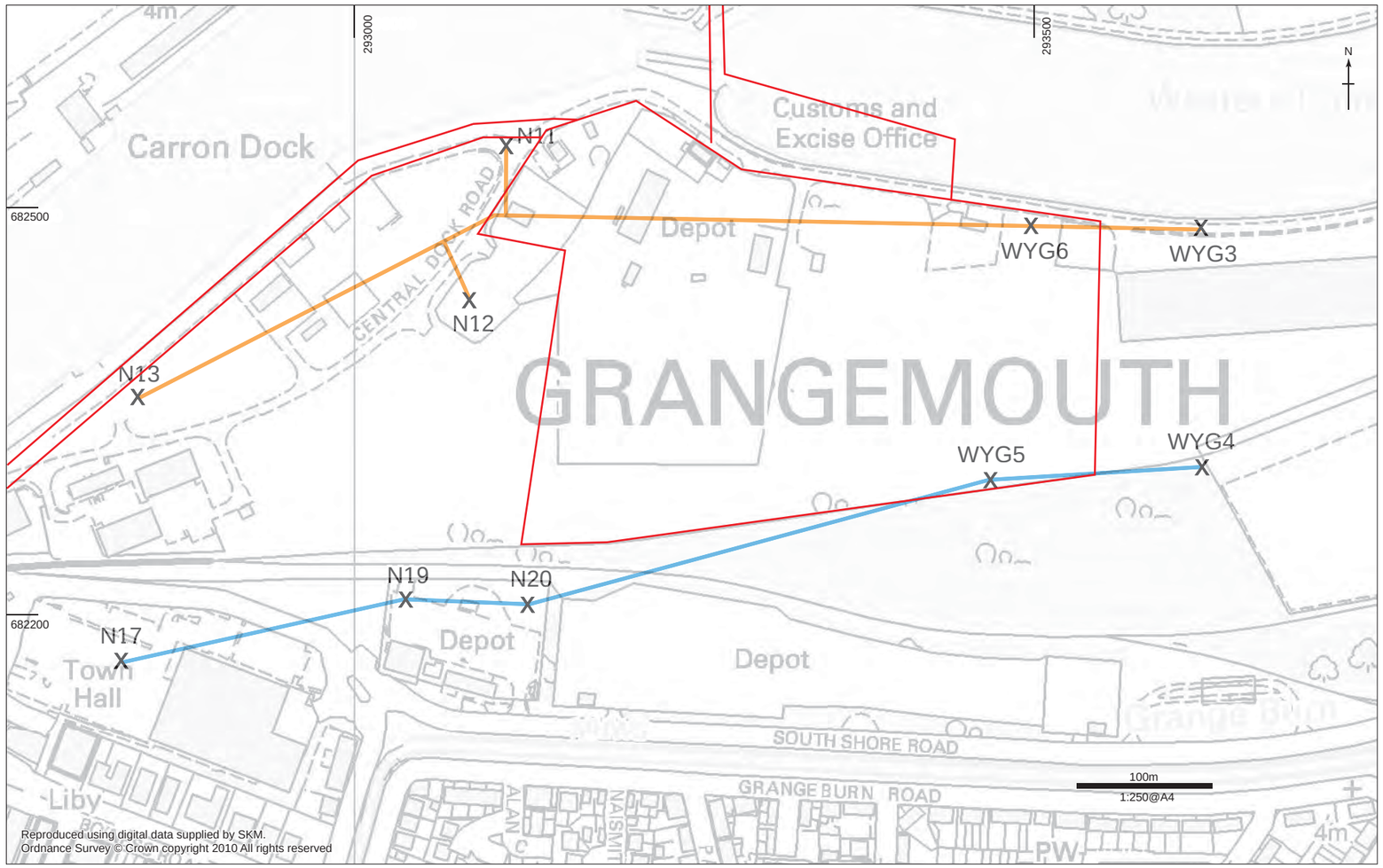
[26] Shennan, I and Horton B, 2002 Holocene land- and sea-level changes in Great Britain Journal of Quaternary Science, Vol. 17, 511-526.

likely to produce archaeological remains resulting from deliberate human exploitation of the environment, although exceptional situations, e.g. the sinking of a boat, might produce a deposit. Moreover, the deeper deposits, particularly those further from the channel, are likely to date from the early Holocene, which would also limit the potential for evidence of human activity. It should be noted that no buried fully terrestrialised surfaces were recorded in the Holocene sediments, which also accords with the findings of the Quaternary science literature, which suggest a relatively steady rate of relative sea-level regression from the mid Holocene, with the exception of the possible oscillation evidenced by the peat deposits discussed above.

G.2.28 With respect to the potential for palaeoenvironmental data, that pertaining to the local environment has high potential for the reconstruction of changes in the estuarine setting. The sediments are known to preserve macro and microfossils, e.g. gastropods, bivalves and ostrocods and foramanifera that would relate to local conditions. The tendency for disturbance and reworking of sediments, noted in the review of the Quaternary science literature, would make reconstructions more difficult, though by no means impossible.

Conclusion

G.2.29 In summary, it is considered that the Inner Study Area has, over the course of the Holocene, moved from a sub-tidal to an intertidal and onshore environment. Therefore there is potential for waterlogged sediments, archaeological deposits and structures well-below modern ground level and for these to hold significant palaeoenvironmental data. Upon examining the available published research and engineering core logs it is likely that within the upper deposits archaeological remains would be limited to those traces that might be associated within an intertidal environment such as fish traps; however, the area for the preservation of such artefacts would be limited due to the previous port construction works. There is potential for the preservation of macro and microfossils that could give palaeoenvironmental evidence for reconstructing the local environment at the time of deposition. However, such material in the upper levels of the deposit may have undergone tidal reworking and thus there may be some disturbance to these sediments, especially from previous construction activities. The presence of peat bands noted within the core logs (although at depth) would be of particular palaeoenvironmental interest for providing not only past vegetational information but also sea-level index points, which can help in reconstructing sea-level curves for this area. However, these deeper sediments are considered to be of low potential in yielding cultural heritage materials.



Forth Energy

Grangemouth Renewable Energy Plant

Figure G.1a

Transect Location

Key

- Borehole
- Transect 1 (Figure G.2)
- Transect 2 (Figure G.3)
- Application boundary (inner study area)

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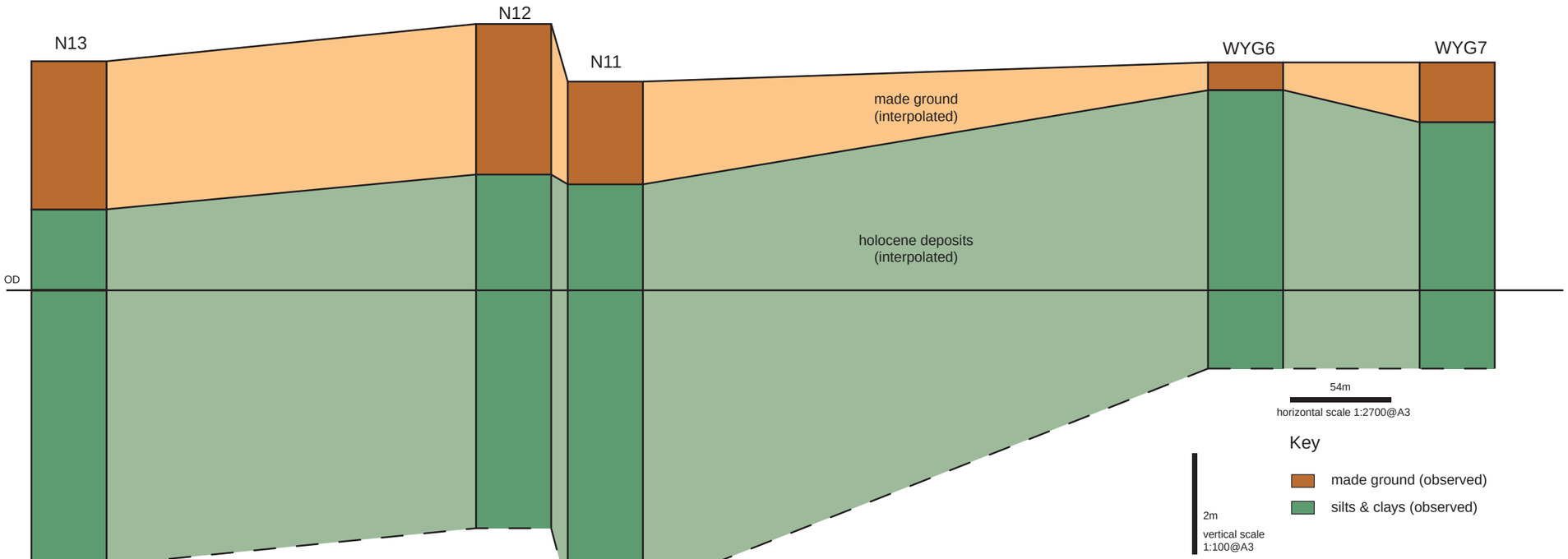

Figure G.2 - Transect 1 across the proposed Renewable Energy Plant area

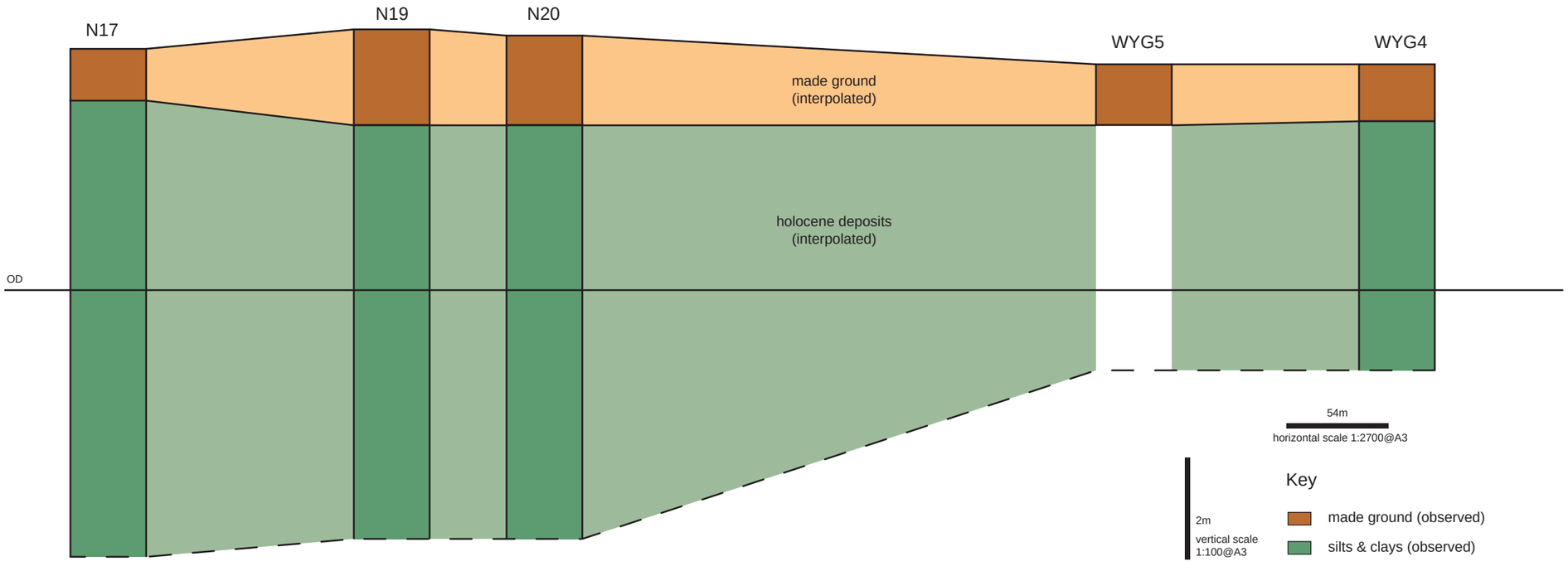

Figure G.3 - Transect 2 across the proposed Renewable Energy Plant area

Forth Energy

Grangemouth Renewable Energy Plant

Figure G.2
and
Figure G.3

Transects across the proposed Renewable Energy Plant

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