J&M Murdoch

Commercial Development, Shillford, East Renfrewshire

Flood Risk Assessment

February 2024

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Table of Contents

List of Figures

List of Photographs

List of Tables

1 Introduction

Kaya Consulting Limited was commissioned by Stevie Sinclair of Ironside Farrar Ltd on behalf of J&M Murdoch to undertake a Flood Risk Assessment in support of a commercial development at Shillford in East Renfrewshire Council.

The proposed development comprises a transport depot, office, museum, workshops, drainage works, landscape works, access, parking, and associated development. Commercial developments are classed as a 'Least Vulnerable' land use under SEPA Land Use Vulnerability Guidance. Based on NPF4, commercial development must be situated out with the 1 in 200-year + climate change floodplain.

The site is largely greenfield and measures approximately 3.65ha in area.

An unnamed drain bisects the site and is fed by several tributary drains which run near the site.

The SEPA flood maps indicate the site is at risk from these unnamed drains and this fluvial flood risk requires further study.

The scope of work includes the following:

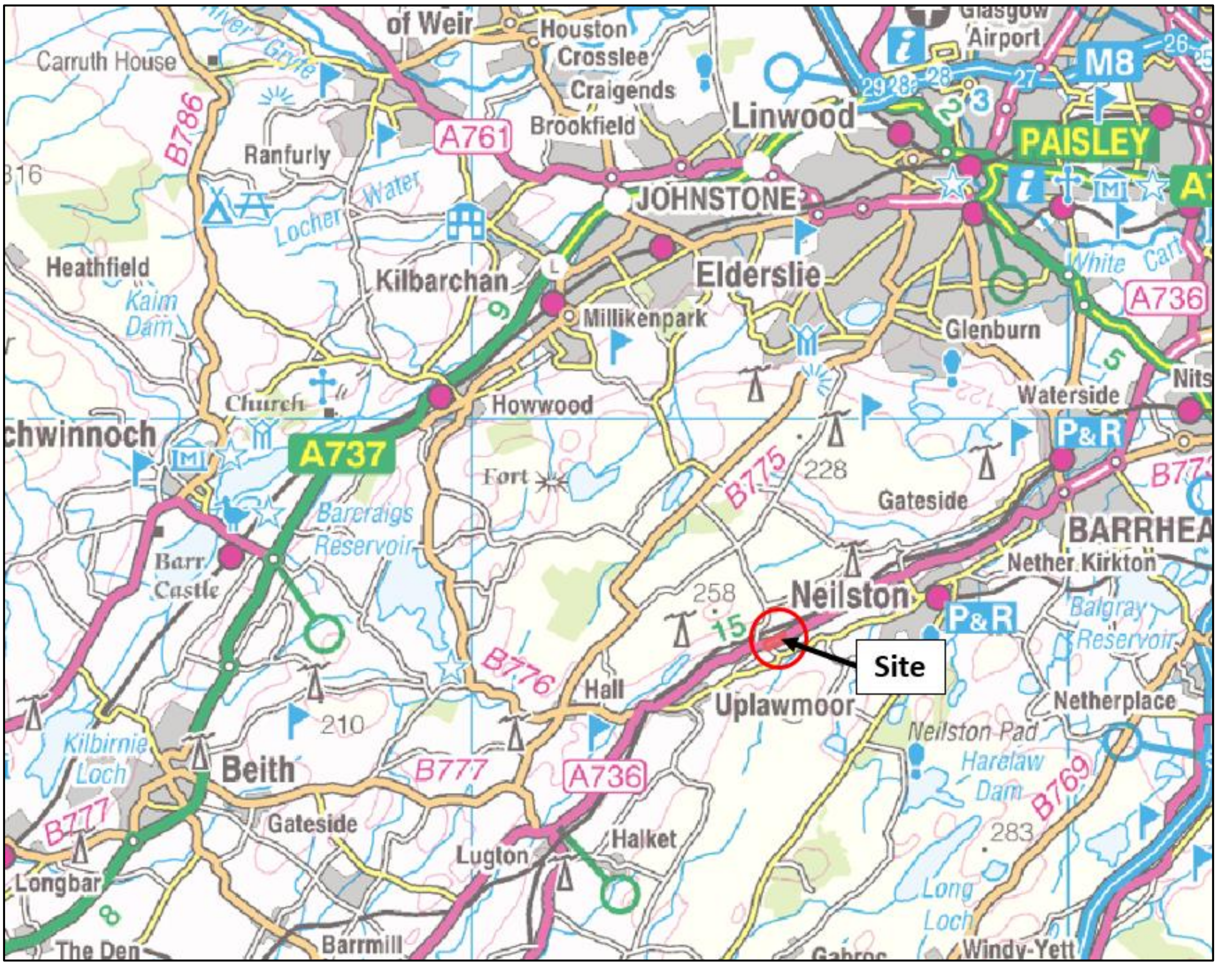
- Walkover site visit;
- Review of historical flood maps and any other relevant sources;
- Liaise with local council to obtain information on known flood risks or existing studies in the area;
- Hydrological assessment to predict catchment and extreme flows able to reach the various drains at the site;
- 1D-2D mathematical modelling of the drains;
- Prediction of the 200-year + climate change flood extents and water levels at the site;
- Model sensitivity analysis;
- Assessment of risk from other sources; including surface water and groundwater;
- Assessment of post development flood risk; and
- Preparation of report suitable for submission with Planning Application.

Information made available to Kaya Consulting Limited for the study includes the following:

- Site location map;
- Detailed site layout plan;
- Surveyed cross sections of the drains in the vicinity of the site; &
- LiDAR DTM data.

A general location map of the site is shown in **Figure 1**.

Figure 1: General Site Location



2 Legislative and Policy Aspects

2.1 National Planning Framework 4 (NPF4)

Under NPF4 Flood Risk Management requires explicit consideration of climate change, consistent with the key over-arching policies of NPF4, for example;

Climate mitigation and adaptation – Policy 2

Under 2b) NP4 notes 'Development proposals will be sited and designed to adapt to current and future risks from climate change'

In addition, development leading to improvements to channels and river habitats should be encouraged as shown by;

Biodiversity – Policy 3

Under 3a NPF4 notes 'Development proposals will contribute to the enhancement of biodiversity, including where relevant, restoring degraded habitats and building and strengthening nature networks and the connections between them. Proposals should also integrate nature-based solutions where possible'

Furthermore, numerous policies point towards assisting in the re-development of brownfield and other previously developed sites.

In terms of flood risk, the definition of flood risk area or at risk of flooding is;

For planning purposes, at risk of flooding or in a flood risk area means land or built form with an annual probability of being flooded of greater than 0.5% which must include an appropriate allowance for future climate change.

This risk of flooding is indicated on SEPA's future flood maps or may need to be assessed in a flood risk assessment. An appropriate allowance for climate change should be taken from the latest available guidance and evidence available for application in Scotland. The calculated risk of flooding can take account of any existing, formal flood protection schemes in determining the risk to the site.

Where the risk of flooding is less than this threshold, areas will not be considered 'at risk of flooding' for planning purposes, but this does not mean there is no risk at all, just that the risk is sufficiently low to be acceptable for the purpose of planning. This includes areas where the risk of flooding is reduced below this threshold due to a formal flood protection scheme.

In contrast to SPP, NPF4 defines a flood risk area as one that lies within the 200-year + climate change floodplain.

Consistent with SPP assessments need to consider flooding from all sources including;

- *Watercourse/Fluvial Flooding*
- *Pluvial Flooding*
- *Sewer Flooding*
- *Groundwater Flooding*
- *Coastal Flooding*

Access to sites during flooding is defined as;

Egress (safe, flood free pedestrian access and egress), A route for the movement of people (not vehicles) of all abilities (on foot or with mobility assistance) between the development and a place of safety outwith the design flood level.

The key policy related to flood risk management is;

Flood Risk and Water Management – Policy 22

Policy Intent – To strengthen resilience to flood risk by promoting avoidance as a first principle and reducing the vulnerability of existing and future development to flooding

a) Development proposals at risk of flooding or in a flood risk area will only be supported if they are for:

i. essential infrastructure where the location is required for operational reasons;

ii. water compatible uses;

iii. redevelopment of an existing building or site for an equal or less vulnerable use; or.

iv. redevelopment of previously used sites in built up areas where the LDP has identified a need to bring these into positive use and where proposals demonstrate that long term safety and resilience can be secured in accordance with relevant SEPA advice

The protection offered by an existing formal flood protection scheme or one under construction can be taken into account when determining flood risk.

In such cases, it will be demonstrated by the applicant that:

- *all risks of flooding are understood and addressed;*
- *there is no reduction in floodplain capacity, increased risk for others, or a need for future flood protection schemes;*
- *the development remains safe and operational during floods;*
- *flood resistant and resilient materials and construction methods are used; and*
- *future adaptations can be made to accommodate the effects of climate change.*

Additionally, for development proposals meeting criteria part iv), where flood risk is managed at the site rather than avoided these will also require:

- *the first occupied/utilised floor, and the underside of the development if relevant, to be above the flood risk level and have an additional allowance for freeboard; and*
- *that the proposal does not create an island of development and that safe access/ egress can be achieved.*

b) Small scale extensions and alterations to existing buildings will only be supported where they will not significantly increase flood risk.

c) Development proposals will:

i. not increase the risk of surface water flooding to others, or itself be at risk.

ii. manage all rain and surface water through sustainable urban drainage systems (SUDS), which should form part of and integrate with proposed and existing blue-green infrastructure. All proposals should presume no surface water connection to the combined sewer;

iii. seek to minimise the area of impermeable surface.

d) Development proposals will be supported if they can be connected to the public water mains. If connection is not feasible, the applicant will need to demonstrate that water for drinking water purposes will be sourced from a sustainable water source that is resilient to periods of water scarcity.

e) Development proposals which create, expand or enhance opportunities for natural flood risk management, including blue and green infrastructure, will be supported

Under NPF4 avoidance of land at risk from the 1 in 200-year flood event is the first principle, i.e., no development in areas at risk from the 1 in 200-year + climate change event; but given the focus on brownfield development it would appear NPF4 will give more flexibility in terms of changing the land form within the site to allow development, while promoting natural flood management measures (opening of culverts) and improvements to biodiversity.

For sites close to the coast Policy 10 considers risks from erosion and flooding.

Coastal Development – Policy 10

a) Development proposals in developed coastal areas will only be supported where the proposal:

i. does not result in the need for further coastal protection measures taking into account future sea level change; or increase the risk to people of coastal flooding or coastal erosion, including through the loss of natural coastal defences including dune systems; and

ii. is anticipated to be supportable in the long term, taking into account projected climate change.

ii. Development proposals in undeveloped coastal areas will only be supported where they:

i. are necessary to support the blue economy, net zero emissions or to contribute to the economy or wellbeing of communities whose livelihood depend on marine or coastal activities, or is for essential infrastructure, where there is a specific locational need and no other suitable site;

ii. do not result in the need for further coastal protection measures taking into account future sea level change; or increase the risk to people of coastal flooding or coastal erosion, including through the loss of natural coastal defences including dune systems; and

iii. are anticipated to be supportable in the long-term, taking into account projected climate change; or

iv. are designed to have a very short lifespan

ii. Development proposals for coastal defence measures will be supported if:

i. they are consistent with relevant coastal or marine plans;

ii. nature-based solutions are utilised and allow for managed future coastal change wherever practical; and

iii. any in-perpetuity hard defence measures can be demonstrated to be necessary to protect essential assets.

i. Where a design statement is submitted with any planning application that may impact on the coast it will take into account, as appropriate, long-term coastal vulnerability and resilience

2.2 Local Authority Policy and Guidance with Respect to Flood Risk

Key points on flood risk from East Renfrewshire Council's Local Development plan (2014) are outlined below:

- All development proposals will require to demonstrate compliance with Scottish Planning Policy and the Flood Risk Management guidance set out by the Scottish Government and the Scottish Environment Protection Agency;
- Development must not increase the risk of flooding;
- It must be demonstrated that the site can be satisfactorily drained and, where possible, incorporate Sustainable Urban Drainage System techniques;
- The capacity of the functional flood plain to store water must not be reduced;
- Development must not result in additional discharge of surface water;
- The resulting development must not increase the risk of flooding elsewhere;
- The risk of flooding to the development itself can be satisfactorily mitigated;
- Developments should maximise the amount of permeable surfaces;

- Unnecessary engineering works in the water environment will be resisted, including culverting of existing water sources. Opening up existing culverts will be welcomed and encouraged;
- Where additional flood protection mechanisms are required there should be consideration of soft/natural devices which can be integrated into the site;
- Land raising will not be accepted unless compliance with national policy can be demonstrated.

2.3 SEPA Technical Flood Risk Guidance

SEPA are a statutory consultee to the planning process concerning flood risk. To support its role and to give guidance to practitioners and local authorities SEPA has published a series of guidance documents. The key documents with direct relevance to flood risk assessment are;

1. SEPA (2018a), Flood Risk and Land Use Vulnerability Guidance, July 2018. https://www.sepa.org.uk/media/143416/land-use-vulnerability-guidance.pdf
2. SEPA (2019a), *Technical Flood Risk Guidance for Stakeholders – SEPA requirements for undertaking a Flood Risk Assessment*, May 2019. https://www.sepa.org.uk/media/162602/ss-nfr-p-002-technical-flood-risk-guidance-for-stakeholders.pdf
3. SEPA (v3, 2023)*, Climate change allowances for flood risk assessment in land use planning*, April 2023. climate-change-guidance.pdf (sepa.org.uk)
4. SEPA (2018b), *Land Use Planning System, SEPA Development Plan Guidance Note 2a*, July 2018. https://www.sepa.org.uk/media/306609/lups-dm-gu2a-development-management-guidance-on-flood-risk.pdf
5. SEPA (2018c) *Planning Information Note 4: SEPA Position on development protected by a Flood Protection Scheme. https://www.sepa.org.uk/media/306610/planning-information-note-4-sepa-position-on-development-protected-by-a-flood-protection-scheme.pdf*
6. SEPA (2020), *SEPA Flood Risk Standing Advice for Planning Authorities. November 2020.* sepa-flood-risk-standing-advice-for-planning-authorities-and-developers.pdf

Reference 1 provides SEPA's assessment of land use vulnerability which allows the identification of the appropriate return period to be considered in any flood risk assessment, based on the type of development proposed.

Reference 2 is a technical guidance document intended to outline methodologies that may be appropriate for hydrological and hydraulic modelling and sets out what information SEPA requires to be submitted as part of a Flood Risk Assessment.

Reference 3 outlines the most recent SEPA guidance in terms of flow, rainfall and sea level uplifts for climate change.

Reference 4 provides additional planning guidance with respect to flood risk.

Reference 5 provides additional planning guidance with respect to built-development behind flood defences.

Reference 6 provides standing advice for developments where SEPA aren't normally consulted, such as surface water only modelling and extensions.

In addition, The Water Environment (Controlled Activities) (Scotland) Regulations 2013 (as amended) (CAR) describes requirements for any works at or near watercourses that require licensing. SEPA are responsible for the implementation of the Regulations. SEPA's CAR Practical Guide (SEPA, 2021) provides an overview of the regulations, definition of the regimes, levels of authorisation for activities and outlines the General Binding Rules (GBRs). The latest version of the CAR Practical is available online and is regularly updated (https://www.sepa.org.uk/media/34761/car_a_practical_guide.pdf).

With relevance to all developments, the Regulations include a requirement that surface water discharge must not result in pollution of the water environment. It also makes Sustainable Drainage Systems (SuDS) a requirement for new development, except for runoff from a single dwelling and discharges to coastal waters.

In addition, SEPA (2017) Background Paper on the Water Environment, LUPS-BP-GU2b requires that "*A buffer strip of a minimum of 6m on either side of the watercourse is recommended and should be proportional to the bank width, with wider rivers having a larger buffer strip than a narrow burn*."

SEPA's (2017) table with recommended buffer strip widths is provided below. It is also noted that *"a buffer strip is still required for ditches, however, there is some discretion to reduce the buffer strip to a minimum of 3m depending on requirements for access for maintenance"*

Width to watercourse (top of bank)	Width of buffer strip (either side)
Less than 1m	6m
1-5m	6-12m
5-15m	12-20m
15m+	20m+

2.4 Guidance and Policy Constraints with Relevance to Current Site

Based on relevant policies and guidance, the following sections outlines the principles and constraints under which the flood risk assessment is undertaken.

2.4.1 Land Use Vulnerability and Design Event

The proposed development is for the construction of a transport depot, office, museum, workshops, drainage works, landscape works, access, parking, and associated development.

Based on SEPA (2018a), the proposals would be classified as a 'Least Vulnerable' land use. Under NPF4, developments of this type should be assessed for the 1 in 200-year + climate change event, with all development of this vulnerability situated outwith this floodplain.

The design event for this development is the 1 in 200-year + climate change event.

2.4.2 Constraints on Developable Area

2.4.2.1 River Flooding

Based on NPF4, commercial development is not appropriate within the 1 in 200-year + climate change floodplain.

SEPA (2017) in their land use planning guidance for new development state "*A buffer strip of a minimum of 6m on either side of the watercourse is recommended and should be proportional to the bank width, with wider rivers having a larger buffer strip than a narrow burn*." And provide the following table for guidance:

Width to watercourse (top of bank)	**Width of buffer strip (either side)**
Less than 1m	6m
1-5m	6-12m
5-15m	12-20m
15m+	20m+

The assessment will identify the 1 in 200-year + climate change floodplain from any watercourse. Suitable buffer widths should be discussed with SEPA and East Renfrewshire Council.

2.4.2.2 Surface Water Flooding

Land affected by surface water flooding can generally be developed assuming the surface water flood risk can be managed through the development of the site drainage system and land drainage to manage surface water entering the site from outside its boundaries. However, in some cases, where sites currently act to store surface water, development could displace surface water and increase flood risk elsewhere. In these cases, there may be a need to leave areas of surface water storage undeveloped and/or provide storage of equivalent volumes of surface water elsewhere in the site.

The assessment will consider surface water flooding risks and identify constraints on development.

2.4.3 Climate Change Considerations

The development should be resilient against the impacts of climate change, such that properties are not predicted to flood for the design event plus climate change.

SEPA guidance indicates that, for the Clyde drainage basin, the impact of climate change on catchments <30km^2 is a 41% increase in rainfall totals.

The assessment will consider increases in rainfall intensity due to climate change based on the SEPA guidance and will consider a climate change allowance of 41%.

2.4.4 Development Levels and Finished Floor Levels

SEPA (2019a and 2019b) notes that adequate freeboard should be provided for developments involving the erection of new buildings and in the majority of cases an adequate freeboard allowance would be 600mm above the design flood level (separate from any climate change allowance applied). It is noted that other freeboards can be recommended if supported by appropriate modelling. For re-developments of existing buildings, the freeboard allowance is considered a recommendation and should be applied as far as practicable.

The assessment will consider Finished Floor Levels based on the 1 in 200-year + climate change flood levels + freeboard.

2.4.5 Site Access Considerations

It is important that developments can be accessed and left during flood events so that developments do not form islands within flooded areas.

SEPA (2018b) requires the provision of a safe and flood free route during the design event for any development that introduces overnight accommodation onto a site, which enables the free movement of people of all abilities (on foot or with assistance) both to and from a secure place that is connected to ground above the design flood level and/or wider area. This refers to river or coastal flooding.

SEPA requires flood free pedestrian access/egress to a site during a river or coastal flood event.

During extreme events, there will be surface water flooding on most roads if the event is higher than design conditions. SEPA does not provide specific guidance for surface water flooding. When considering surface water flooding, local councils generally look for 'safe' access to a site, where flood depths are less than approx.. 0.3m. However, these requirements vary depending on the size and nature of the site, and the type of development.

Access requirements concerning flooding will be considered in this assessment.

It is noted that this assessment can only consider the local access restrictions to the site and cannot consider wider, regional access issues, e.g., access to hospitals remote to the site. These wider access issues need to be considered by the appropriate local authority within local plans.

2.4.6 Other Flooding Risks

2.4.6.1 Coastal Flooding

This site is not considered to be at risk of coastal flooding.

2.4.6.2 Reservoir Flooding

Reservoir inundation maps prepared by SEPA (https://map.sepa.org.uk/reservoirsfloodmap/Map.htm) suggest that there is no risk of inundation due to an "*uncontrolled release of water from all possible dam failure scenarios*".

Reservoirs are subject to strict regulation and maintenance in Scotland according to their risk category. Therefore, flooding of this type is highly unlikely in Scotland and the risk of flooding from reservoir breach or failure at the site is considered low.

The available reservoir flooding inundation maps indicate the site is not at risk of flooding from nearby reservoirs.

2.4.6.3 Site Drainage and Sewer Flooding

The design of the site drainage system will be undertaken by others.

2.4.6.4 Culverts and Watercourses

East Renfrewshire Council requires that existing access points/routes to culverts and watercourses are maintained or repositioned in agreement with the council’s Flood Team. The council also reserves the right to request the construction of additional access points/routes to a watercourse to enable the council to meet its statutory responsibilities.

An unnamed drain culverts to the west of the site and daylights at the western edge of the site.

2.4.6.5 Existing Flood Defences

SEPA (2018c) provides guidance with respect to development behind flood prevention schemes.

This site is not thought to be protected by any existing formal flood defences.

2.4.6.6 Canal Flooding

Canals in Scotland are operated and managed by Scottish Canals. Failures and overtopping of canals are rare and areas at risk are generally known by Scottish Canals who should be consulted for developments located close to any canal.

No canals lie in the vicinity of the site.

2.4.6.7 CAR Regulations

Any crossings or changes to watercourses within the site may require a CAR licence. CAR licences are not required as part of a planning application and are generally conditioned as part of planning consent. However, during the planning process, sufficient information should be provided in a planning application so SEPA can identify whether it is likely that a CAR licence would be granted.

Two crossings of the watercourse through the site are proposed. The impact of crossings on flood risk are considered in Section 7, but this report does not cover a CAR license application, which should be discussed with SEPA.

3 Site Location and Description

The site is located immediately south of the A736 in Shillford in East Renfrewshire and measures approximately 3.65ha in area. **Photos 1** and **2** show the site in its current state, with around 0.5ha of the total area presently devoted to commercial use as a bus depot. The site is bounded to the north by the A736, with an unnamed drain and local road to the west and grassland to the east and south. The proposed access is via the A736 to the north.

As illustrated in **Figure 2**, an unnamed drain is culverted under the local road through a 900mm pipe and the existing bus depot through a 750mm pipe and daylights near the western boundary of the site. This drain bisects the site, running from west to east (**Photo 3**). A tributary ditch to this unnamed drain runs north along the western boundary of the site (**Photo 4**) after being culverted under the local road via a 215mm culvert and joining with the main drain in a short open section between the 900mm and 750mm culverts. Downstream of the site two culvert outlets were identified as possible connections for north of the road and rail lines.

Figure 3 shows the topography of the site and the surrounding area based on LiDAR DTM (Digital Terrain Model). Ground levels in the site fall from the north and south towards the unnamed drain which runs through the site. More generally, ground levels fall eastward. Levels within the site range formal high of 138.6m AOD in the south-west to a low of 129.4m AOD in the south-east.

Historical Mapping viewed on 23/06/2023 from the National Library of Scotland indicate the site was historically greenfield with no additional water features at the site. The existing drain at the site is shown.

Scottish Water mapping of the site shows existing sewer networks existing within the site.

Figure 2: Detailed Site Location

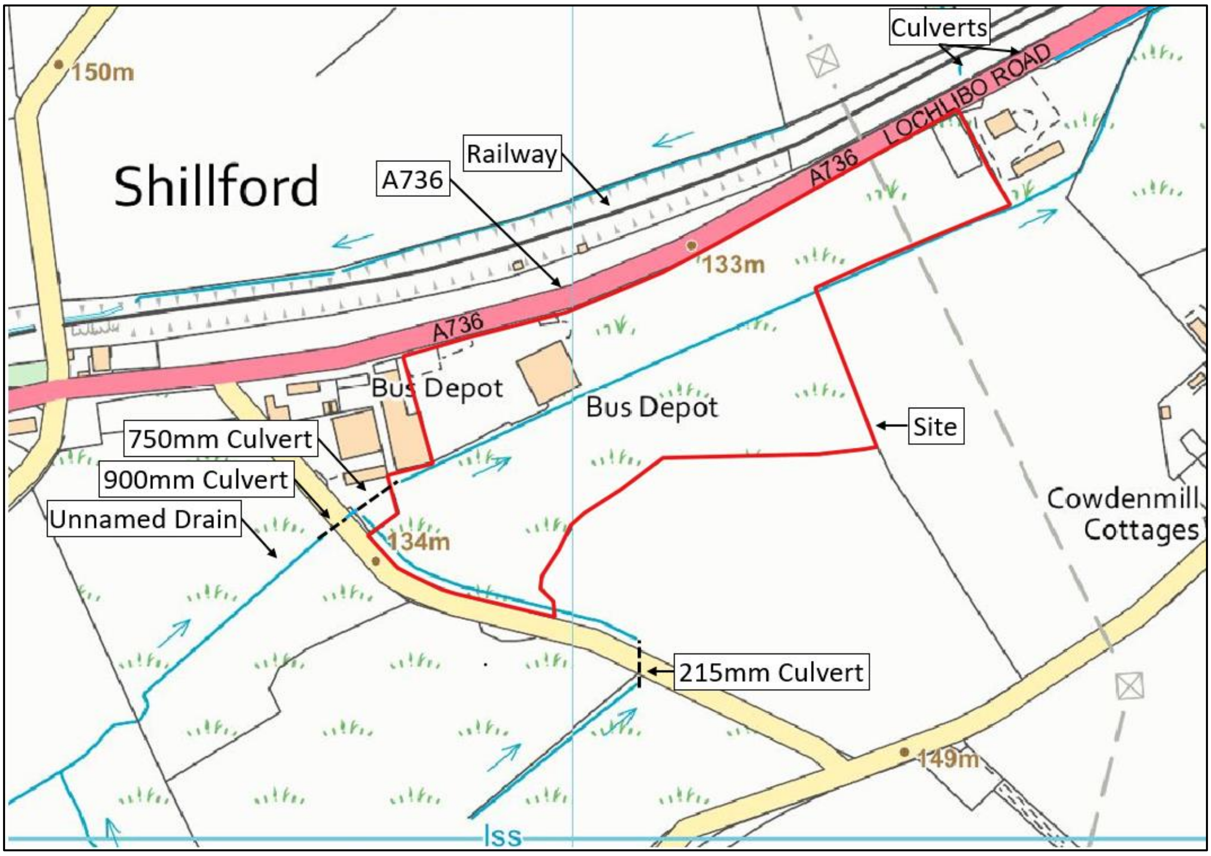


Figure 3: Site Topography

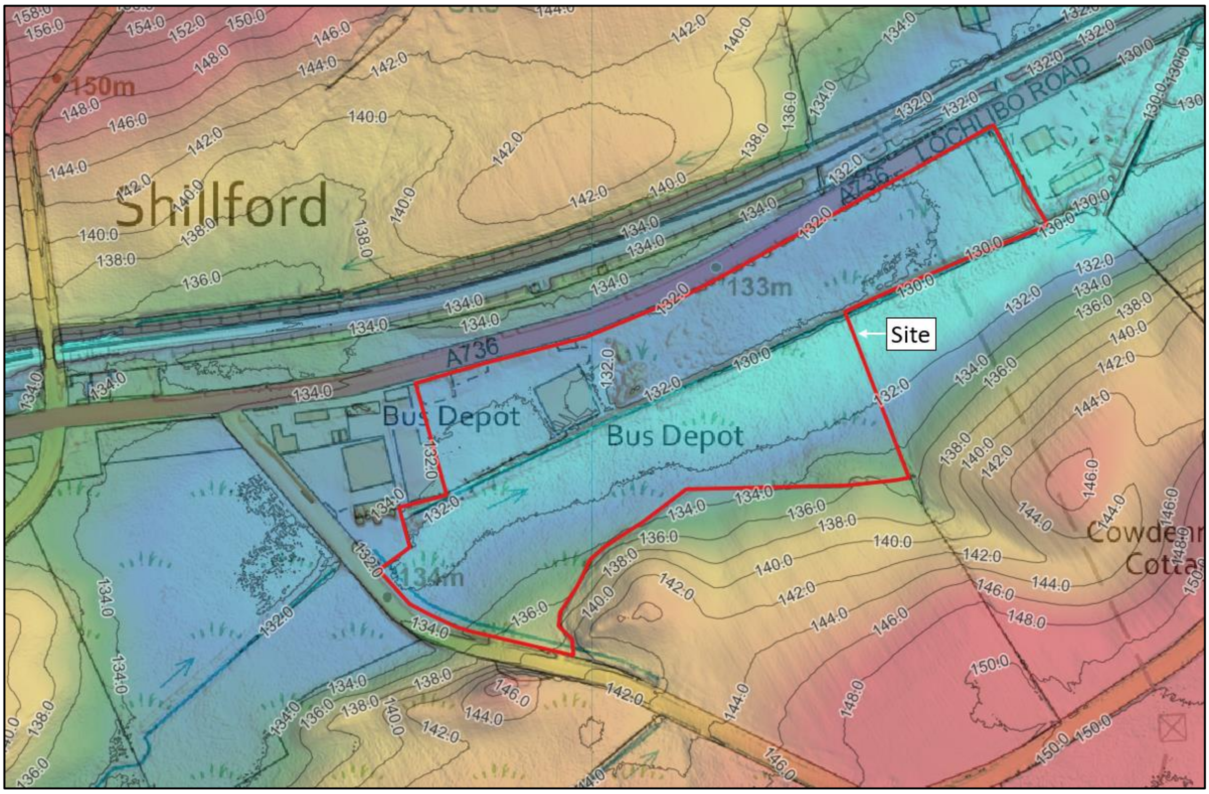


Photo 1: Current Site Condition (looking north-east from western boundary)

Photo 2: Overgrown Unnamed Drain South of Site

Photo 3: Culvert Inlet Under Road Immediately Upstream of Site

Photo 4: Unnamed Drain Flowing from Culvert Outlet into Site

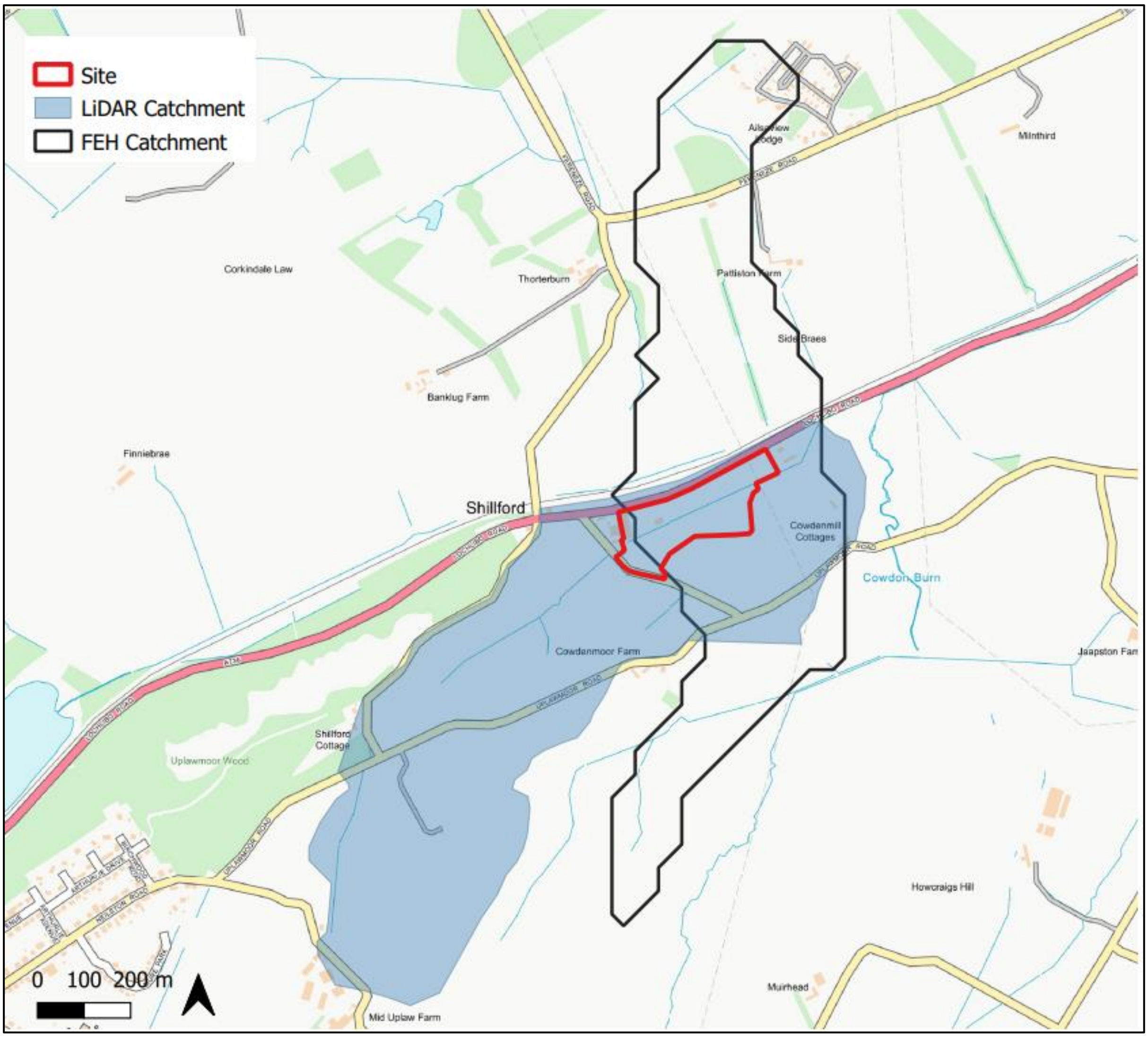
4 Hydrology

A hydrological assessment was undertaken to estimate the design flows in the drains at the site. The catchment boundary and characteristics were obtained from the FEH (Flood Estimation Handbook) webservice for the unnamed drain just downstream of the site. However, it was found that when comparing the catchment generated with the 0.5m resolution LiDAR DTM there was a significant discrepancy; therefore, the catchment area was re-delineated using the LiDAR DTM data and a digital flow pathway analysis.

A map of both catchments is shown below in **Figure 4**.

The area to the north of the A736 has been removed from the manual catchment as flows would be unlikely to drain over the road. During site visits possible connections to the burn via 0.5m culverts were identified. Therefore, this catchment will be considered separately. The catchment highlighted in blue shows the manually delineated catchment based on LiDAR data, this measures 57ha in area compared to the FEH which is 51ha.

Figure 4: FEH Catchment



The full list of catchment descriptors used to estimate flows is tabulated below in **Table 1**.

Table 1: Catchment Descriptors

Parameter	Unnamed Drain
EASTING (m)	245300
NORTHING (m)	656450
AREA (km²)	0.57*
ALTBAR (°)	165
ASPBAR	111
ASPVAR	0.15
BFIHOST	0.439
DPLBAR (m)	0.74*
DPSBAR (m/km)	81.6
FARL	1
FPEXT	0.2146
FPDBAR	12.18
FPLOC	0.498
LDP	1.39
PROPWET	0.61
SAAR (mm)	1511
SAAR4170 (mm)	1439
SPRHOST	35.2
URBCONC2000	0
URBEXT2000	0
URBLOC2000	0

**altered from the FEH webservice export*

As no gauged data exists for the unnamed drain near the site, flow estimates were produced using the FEH Rainfall-Runoff and ReFH2.3 methods, based on the descriptors obtained from the FEH web service. Given the size of the catchment (<10km²) FEH recommends these rainfall-runoff approaches as the most appropriate methods for flow estimation on ungauged catchments.

Climate change uplifts were calculated based on an increase in rainfall intensity of 41%.

The results of this analysis are shown below in **Table 2**. The FEH Rainfall Runoff method produced the most conservative result therefore has been taken forward for this assessment.

Table 2: Unnamed Drain Flow Estimates

Method	1 in 200-year Flow (m^3/s)	1 in 200-year + Climate Change Flow (m^3/s)
FEH Rainfall Runoff*	1.95	2.94
ReFH2.3**	1.67	2.49
FEH small catchment scaling	1.59	2.38***
IH 124	1.49	2.23

** 3.1hr Critical Storm Duration*

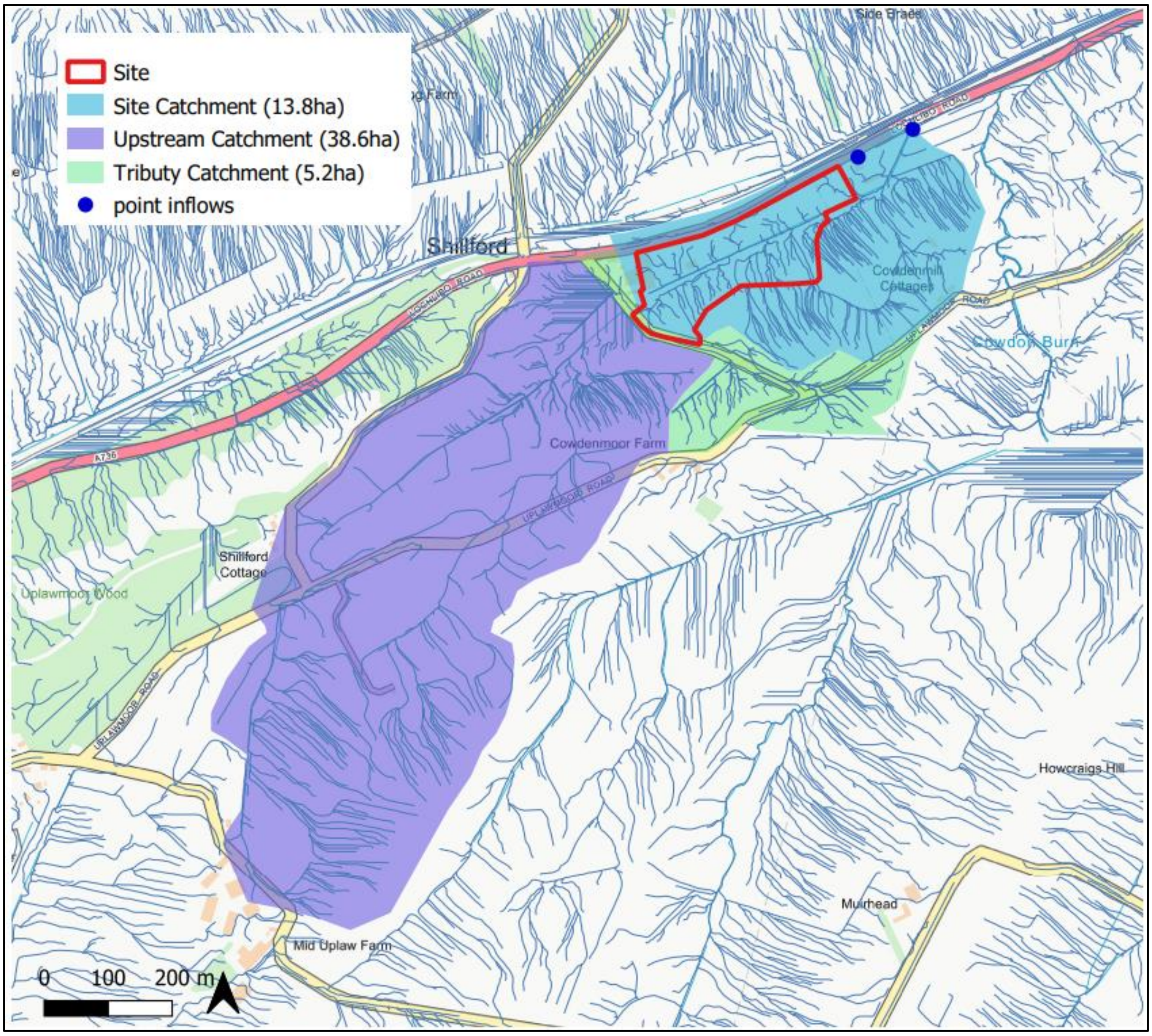
*** 2.75hr Critical Storm Duration*

**** rainfall is not possible in increase by 41% therefore average uplift of other methods applied to flows*

Catchments of the internal tributaries were also delineated. Flows were scaled by catchment area to provide the model inflows for the various catchment areas shown in **Figure 4**.

The possible culvert inflow connections from north of Lochlibo Road and the railway were included to be conservative as full-bore flow with a velocity of 2m/s due to the inability to locate their upstream locations. Two culverts were identified downstream of the railway and measured to be approximately 0.5m in diameter. Therefore, a constant inflow of $0.4m^3/s$ per culvert was included.

Figure 5: Drain Catchments



5 Hydraulic Modelling

A 1D-2D linked Flood Modeller Pro Hydraulic Model of the drain was developed for the purpose of this assessment. The model was developed using cross-sections surveyed for this study.

5.1 Model Build

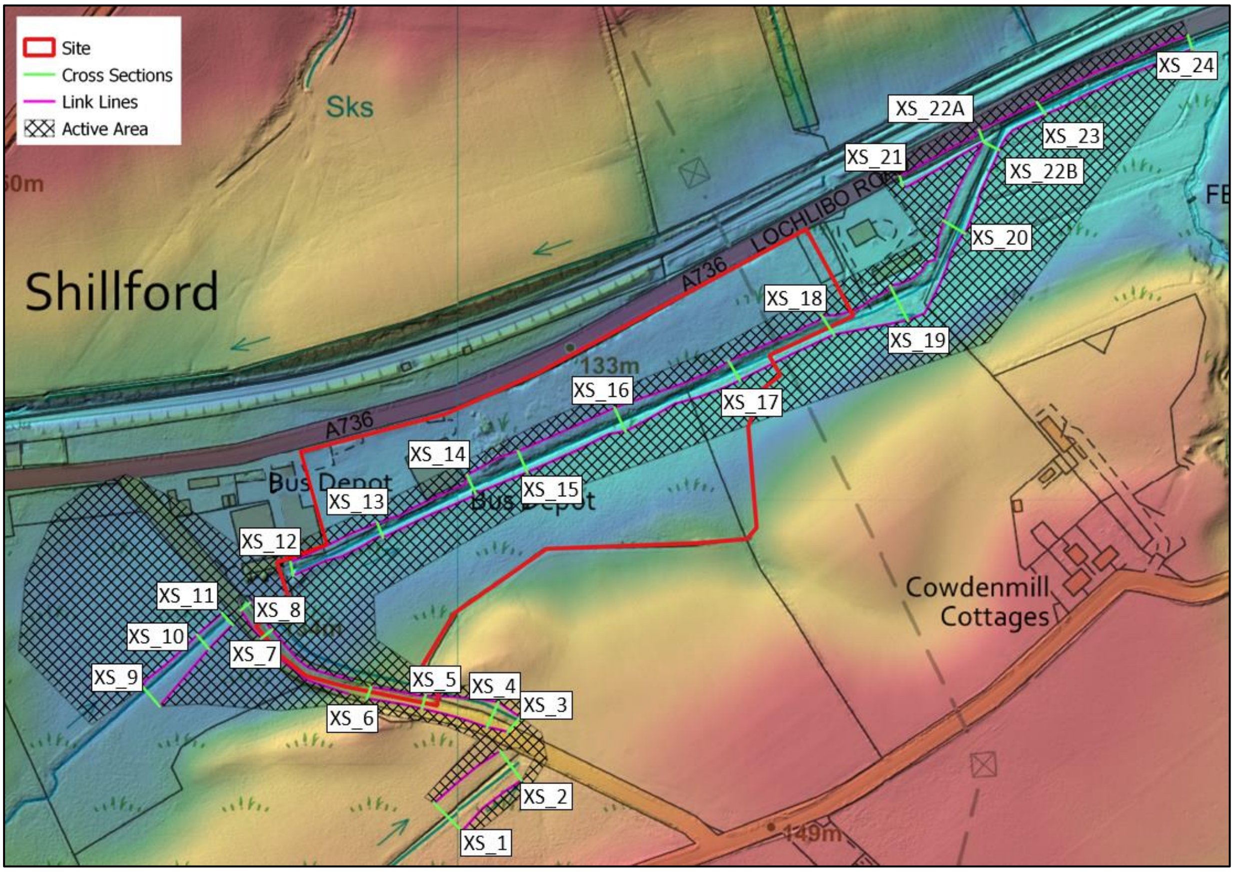
The 1D-2D hydraulic model was constructed using Flood Modeller Pro software package. In total 21 cross sections of the drains within and around the site were surveyed specifically for this assessment.

The location of the surveyed cross sections used to develop the model are shown in **Figure 6**. Two structures were also included in the model:

- A 0.9m diameter culvert downstream of cross section 11
- A 0.75m diameter culvert between cross-sections 12 and 13.

Due to the small size of the 0.215m diameter culvert upstream of XS4 this was not included in the final model. Its small size means it could easily block and therefore the full flow was applied at XS4, assuming no attenuation upstream of the road before overtopping and flowing into the channel. 2D modelling was conducted and it verified that the flow would re-enter the channel instead of flowing over the land.

Figure 6: 1D-2D Model Set-up



The 2D model domain covers the areas where overbank flows (also shown in **Figure 6**) can travel and is connected dynamically to the 1D at the top of bank using link lines which allow free flow of water between the two domains.

The model topography is based on 0.5m horizontal resolution Phase 6 LiDAR DTM captured in 2021 and 2022 supplemented with survey data where available including top of bank levels surveyed in 2023.

The following model parameters were used:

- 0.5 second timestep;
- 5hr run time;
- Interpolates were included between sections to improve model stability as well as initial condition files based on constant low flow inflows;
- 1m 2D grid cell size;
- Friction value (Manning's n) of 0.035 on the bed of the channel and 0.05 across the banks in the 1D and 2D domain to represent the long grass in the floodplain and channels;
- Buildings were represented by an increase in ground levels of 0.3m;
- Normal depth downstream boundary slope of 0.0045 consistent with downstream topography; and
- Model inflow boundaries are based on the flows and hydrographs estimated in **Section 4**.

5.2 Results

The results of the modelling can be seen in **Figure 7** and **Table 3**. These show that the waters are predicted to pond upstream of the local road, reviewing of the model shows this is due to both the backing up at the culvert inlet and due to the channel being undersized, the capacity of the local road culvert was 1.3m^3/s. The road is approximately 700mm higher than the fields to the west; however, this high ground continues through the existing bus depot rather than just the road, so the road does not act as a defence (model runs considering the removal of the culvers is considered in the sensitivity analysis). Throughout the site, flood waters are generally contained within the channel and surrounding low-lying land.

The tributary is shown to be under capacity upstream of the confluence with waters overtopping the right-hand bank and flowing parallel to the main drain before re-entering it.

The model mass balance error was <1%.

Figure 7: 200yr + Climate Change Maximum Flood Extent

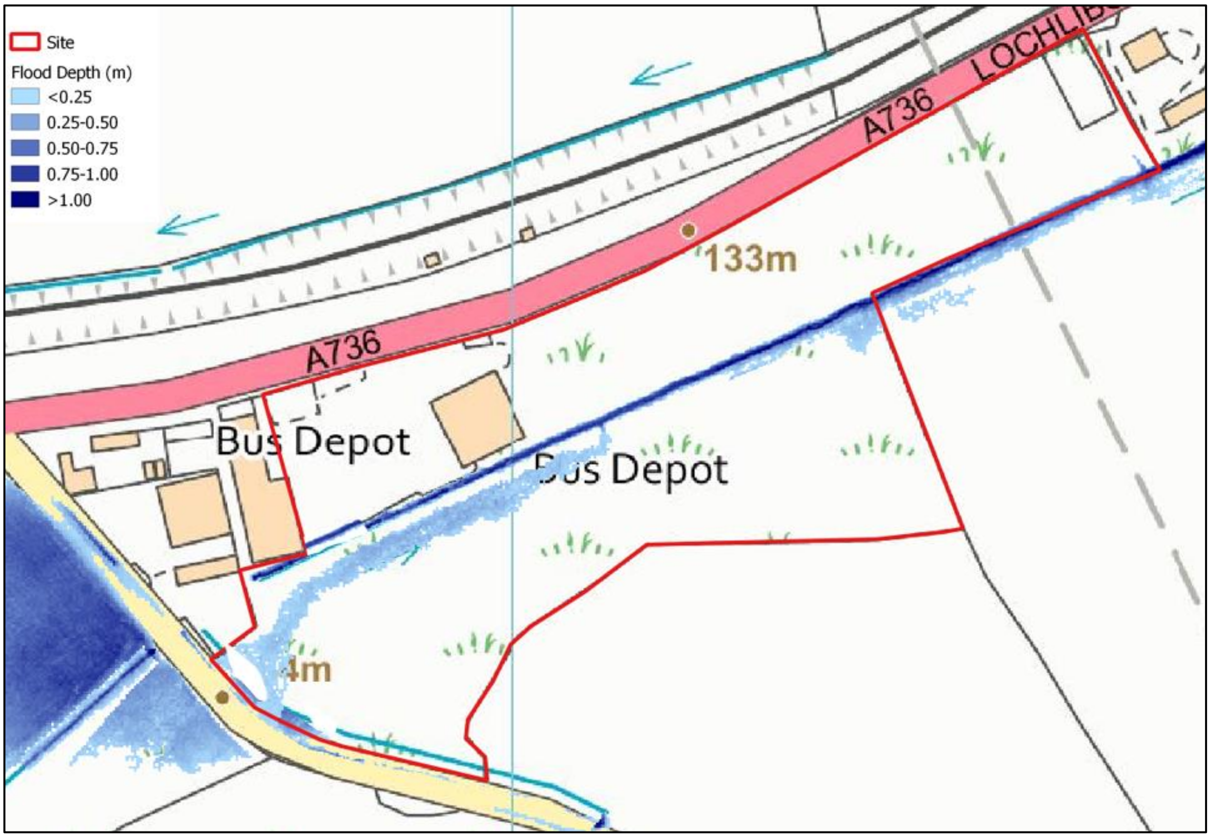


Table 3: 1D Model Outputs

	1 in 200-year + Climate Change		
Label	**Max Stage (m AOD)**	**Max Velocity (m/s)**	**Max Froude**
XS4	139.91	1.31	1.00
XS5	137.64	1.25	0.88
XS6	136.58	0.61	0.42
XS7	132.30	1.16	1.00
XS8	132.31	0.22	0.18
XS9	132.65	1.29	0.85
XS10	132.62	0.58	0.43
XS11	132.64	0.32	0.99
XS12	131.30	0.65	0.27
XS13	130.98	1.13	0.56
XS14	130.62	1.08	0.46
XS15	130.56	0.83	0.33
XS16	130.45	0.88	0.44
XS17	130.27	0.93	0.42
XS18	130.11	0.86	0.40
XS19	130.08	0.45	0.18
XS20	130.06	0.46	0.17
XS21	130.76	1.45	0.72
XS22L	130.02	1.70	1.07
XS22R	130.04	0.53	0.20
XS23	130.01	0.94	0.36
XS24	129.77	0.95	0.45

5.3 Sensitivity Analysis

A model sensitivity analysis provides an illustration of the effects of changing key model parameters on the important model outputs (in our case flood levels). By re-running the model and changing one input parameter at a time, the effect of that input on the model results can be isolated.

Repeating this process to account for several model parameters of interest within the range of their possible input values gives a sensitivity analysis that, when compared with the model assumptions and knowledge of realistic inputs, can provide an indication of the uncertainty associated with the model predictions.

This sensitivity analysis was run on a base case 200-year + climate change scenario and considers the following:

- Model roughness increased by 20%;
- Culvert upstream of the site modelled 25% blocked;
- Culverts upstream of the site removed (upsized); &
- Model boundary slope decreased by 20%.

These results indicate the model operates as expected:

- An increase in roughness raises levels throughout the model by up to 0.11m
- Blockage of the culvert upstream of the site increased the level upstream by 0.05m this had no significant effect on the 2D flood extent
- Removal of the two culverts upstream of the site caused a reduction in flooding upstream of the A736 but reduced flooding still occurred, it also removed the 2D flooding from the tributary due to removing the backing up at the small open section. Water levels increased in the channel through the site however these remain mainly within the channel, although little to no freeboard is remaining.
- Raising of the downstream boundary slope only affected the final two cross sections and did not impact levels within the site.

The full results of this analysis are shown in **Table 4** below.

Table 4: Sensitivity Analysis Results

Label	Base Case	Variance from Base Case (m)			
	1 in 200-year + Climate Change Maximum Water Level (m AOD)	20% Model Roughness Increase Scenario	25% Culvert Blockage Scenario	Removal of Culverts	20% Model Boundary Slope Decrease Scenario
XS4	139.91	0.02	0.00	0.00	0.00
XS5	137.64	0.03	0.00	0.00	0.00
XS6	136.58	0.00	0.00	0.00	0.00
XS7	132.30	0.00	0.04	-0.21	0.00
XS8	132.31	0.00	0.04	-0.46	0.00
XS9	132.65	0.00	0.05	-0.26	0.00
XS10	132.62	0.01	0.06	-0.52	0.00
XS11	132.64	-0.01	0.05	-0.57	0.00
XS12	131.30	0.06	-0.06	0.16	0.00
XS13	130.98	0.07	-0.03	0.15	0.00
XS14	130.62	0.09	0.02	0.15	0.00
XS15	130.56	0.09	0.02	0.15	0.00
XS16	130.45	0.09	0.01	0.16	0.00
XS17	130.27	0.10	0.02	0.16	0.00
XS18	130.11	0.11	0.02	0.16	0.00
XS19	130.08	0.10	0.01	0.15	0.00
XS20	130.06	0.10	0.02	0.15	0.00
XS21	130.76	0.06	0.00	0.00	0.00
XS22L	130.02	0.10	0.01	0.11	0.00
Xs22R	130.04	0.10	0.02	0.14	0.00
XS23	130.01	0.09	0.01	0.13	0.016
XS24	129.77	0.08	0.01	0.11	0.051

6 Flood Risk Assessment

The flood risk assessment considers the risk from:

- Fluvial Flooding
- Surface Water Flooding
- Groundwater Flooding
- Drainage Infrastructure
- Safe Access

6.1 Fluvial Flooding

An unnamed drain bisects the site after being culverted under the local road and bus depot. A Flood Modeller Pro 1D/2D linked mathematical model of the unnamed drain was developed to assess the risk of flooding predicted to occur during 1 in 200-year + climate change event. The results are shown in **Figure 7**.

Based on NPF4 land outwith the 200-year plus climate change event flood extent would be suitable for most types of development including commercial land use. Guidance suggests that it is good practice to raise finished floor levels above the 200-year + climate change water level + an appropriate freeboard (usually 600mm). This is a requirement for residential development and an aspiration for commercial uses.

The impact of proposals on flood risk is considered in Section 7.

Any crossing of the watercourse should not impede flow and show be designed to pass the 200-year + climate change flows. CAR licences may be required if changes to the channel are proposed.

It is recommended that a standoff is provided to allow access to the drain for maintenance, SEPA guidance suggests for a watercourse between 1 – 5m wide a standoff of between 6 and 12m is required.

6.2 Surface Water Flooding

SEPA flood maps indicate that there may be a surface water flooding risk at the site therefore a 2D rainfall-runoff model was developed in Flood Modeller Pro software to assess the surface water risk.

The upstream area draining to the site was reviewed using LiDAR DTM data which allowed a simple watershed analysis to be undertaken, i.e., identify the areas positively draining towards the site (**Figure 5**). The results of the assessment were used to delineate the model components. A model Plan can be seen in **Figure 8**. The model was run with a 2m DTM (Digital Terrain Model) grid resolution and a 0.5 second time step. A representative rainfall hyetograph was estimated using FEH web-service 2022 rainfall data. 1, 3, and 5-hour storm hyetographs were developed for the 1 in 200-year + climate change return period. The percentage runoff was set to 0.5 based on the SEPA guidance for rural areas and the model friction value was set to a global 0.1 to represent overland obstacles. A climate change factor of 41% was used in line with SEPA guidance as this site fell within the ‘Clyde’ river basin.

Figure 8: Surface Water Model Plan

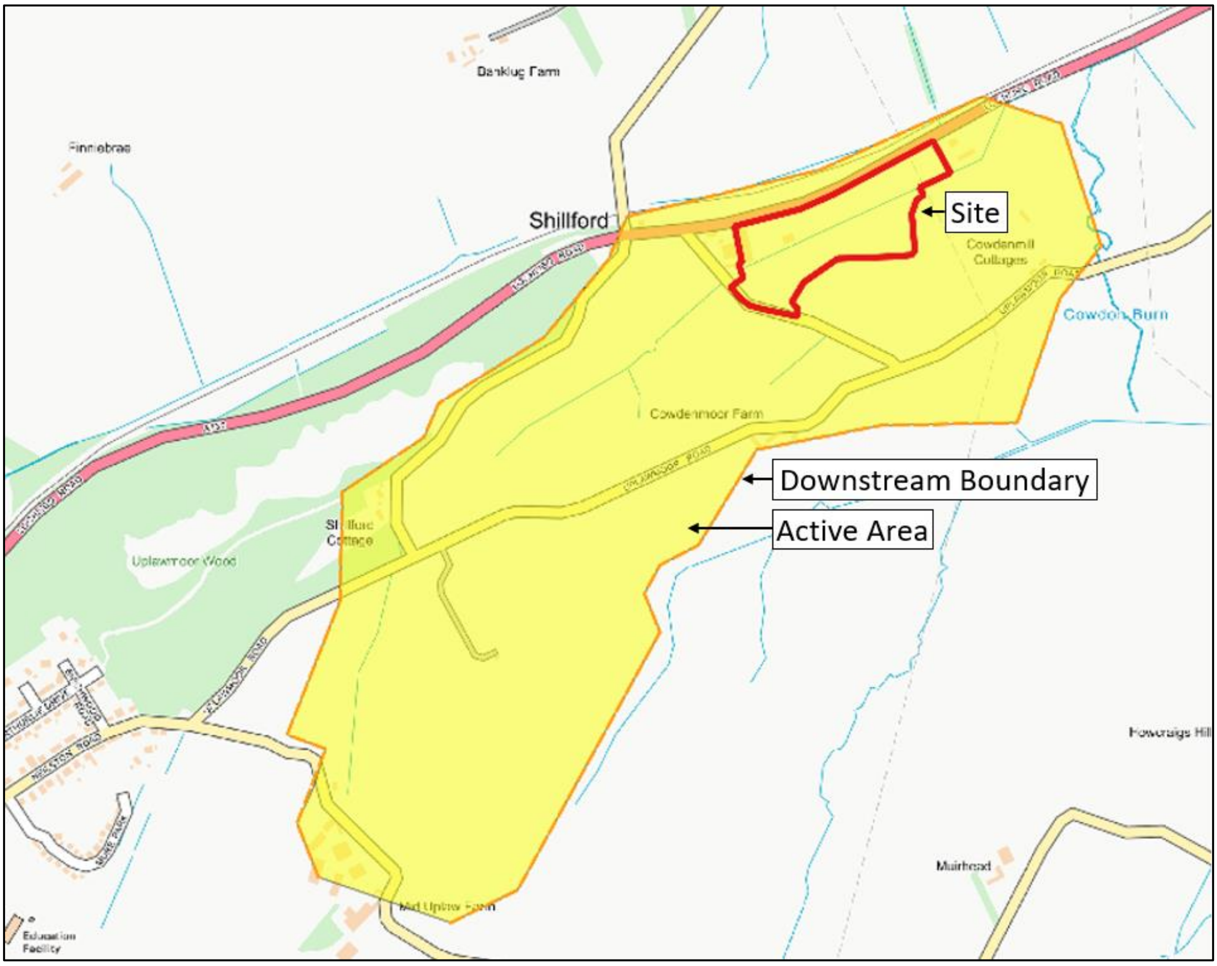


Figure 9 shows the results of the 1 in 200-year + climate change 1-hour storm event, which produced the highest flood depths. During this event, three main surface water pathways have been identified and named 'Flow Line 1, 2, and 3'. Flow Line 1 was considered as part of the fluvial assessment **Table 5** shows the flow which enters the site at the 2 remaining locations. In addition, **Table 6** shows the water surface elevation at a series of reference points. The 3-hour and 5-hour storm durations to assess the sensitivity of the model. The results of the sensitivity analysis can also be seen in **Tables 5** and **6**.

Figure 9: 1 in 200-Year + Climate Change Surface Water Flood Event (1-hr)

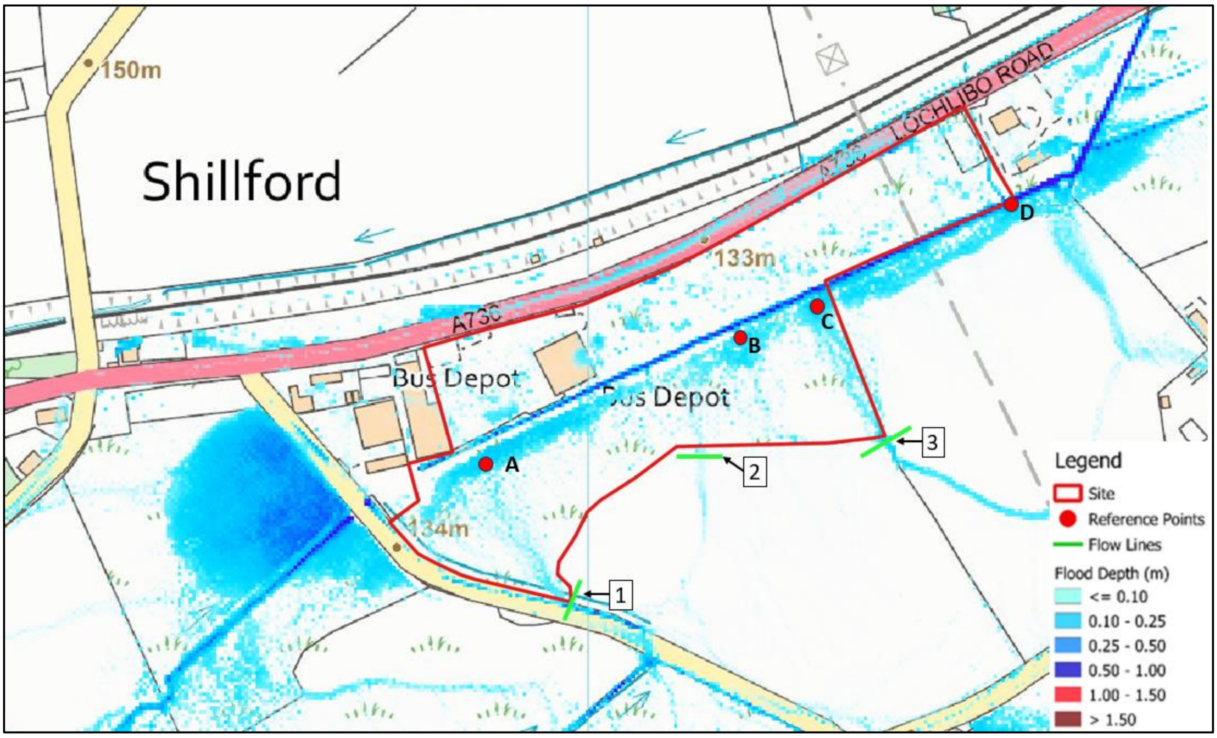


Table 5: Flows Entering the Site During the 1 in 200-Year + Climate Change Event Under Various Storm Durations

	Flows (m³/s)		
Flow Line	**1 Hour**	**3 Hour**	**5 Hour**
2	0.045	0.03	0
3	0.35	0.32	0.17

Table 6: Water Surface Elevations at Reference Points Under Various Storm Durations

	Water Surface Elevation (m AOD)		
Reference Point	**1 Hour**	**3 Hour**	**5 Hour**
A	131.65	131.62	131.60
B	130.78	130.76	130.75
C	130.66	130.63	130.60
D	130.48	130.44	130.43

The greatest estimated surface water flood level is 131.65m AOD at reference point 1. Generally, surface water flows north at a maximum flow of 0.35m^3/s (flow line 3) from higher ground in the south to the watercourse which runs through the site.

Based on the above, there is a risk of surface water ingress from the south. It is recommended that surface water is either intercepted at the site boundary and routed to suitable storage or discharge locations. Finished landscaping should encourage surface water away from buildings and to an appropriate point of discharge or into the proposed site drainage system.

6.3 Groundwater Flooding

The SEPA groundwater flood map suggests that the site is not at risk from groundwater flooding. Flooding from groundwater as a primary source is uncommon in Scotland.

Local groundwater levels are likely somewhat controlled by the unnamed drain which runs through the centre of the site. The majority of the site lies above this feature.

Groundwater monitoring is generally undertaken as part of the geotechnical investigation. If it is determined that there is a high groundwater table in this area, suitable mitigation measures should be employed to mitigate against the risk of flooding. Alterations to foundations and the positioning of drainage measures to operate effectively may be necessary if the groundwater table is found to be high.

6.4 Drainage Infrastructure

The design of the site drainage system is not part of this commission. However, as part of the development of the site, a suitable drainage system employing SuDS will be required to manage surface water within the site.

Scottish Water Drawings indicate there is no existing drainage infrastructure within the site.

As with any drainage system, it should be designed to take into account risks if the system is blocked, or rainfall events occur that are larger than the design event. In such cases, excess surface water should be routed through the site to the SuDS features without impacting buildings.

6.5 Safe Access

The regulatory authorities recommend that safe access and egress be provided during extreme flood events so that residents and visitors can be safely evacuated without any undue risk to life.

Under NPF4, access to sites during flooding is defined as:

> *Egress (safe, flood free pedestrian access and egress), A route for the movement of people (not vehicles) of all abilities (on foot or with mobility assistance) between the development and a place of safety outwith the design flood level.*

The proposed site access is from the A736 to the north of the site. **Sections 5.2** shows that there is no fluvial flood risk to access. **Section 6.2** presents some surface water on the A736; however, the depths generally do not exceed 0.1m. In any areas where this depth is exceeded, a site walkover supports that it is unlikely that these surface water flood depths will occur as the road has camber which would shed surface water off the road and this small-scale impact is not represented fully in the modelling assessment.

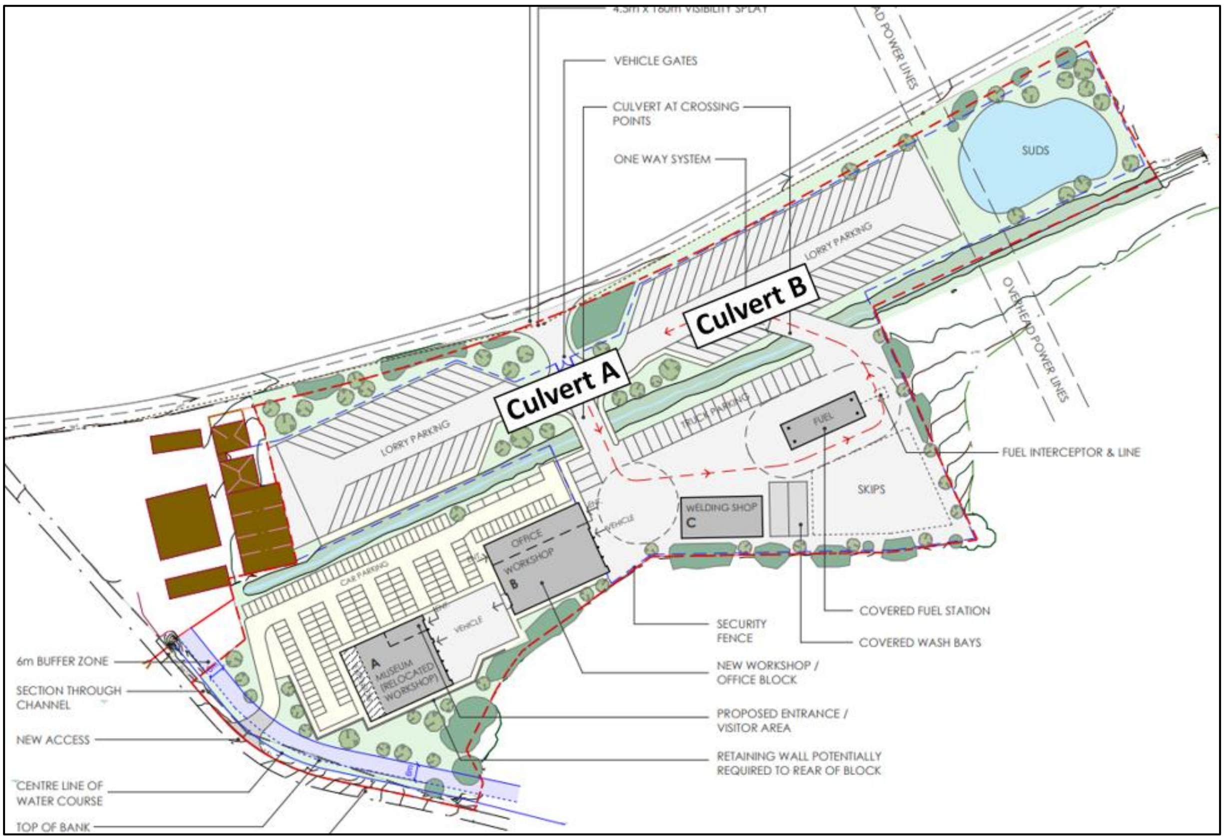
Safe access, therefore, is likely to be achievable via the A736 for vehicles preferably, but also pedestrians. Care should be taken when designing the main site access not to route additional surface water towards the site.

7 Post-Development Flood Risk

The client proposes to develop the site as an office, workshop, museum, fuel station and associated parking. Two crossings of the watercourse are proposed to link the main site with car parks. **Figure 10** below illustrates where the client proposes to cross the drain. The drain is culverted immediately upstream of the site through a 750mm pipe. This culvert is insufficiently sized to convey the 1 in 200-year + climate change flow.

The existing 1D-2D model of the site was amended to include these two culverts. A variety of culvert dimensions were considered and an iterative approach was used to identify a design capable of passing the 1 in 200-year + climate change flow within the constraints of the existing channel dimensions.

Figure 10: Post-Development Layout with Proposed Crossings



Culvert A was modelled as 9m long. The channel is presently capable of conveying the modelled 1 in 200-year + climate change flow. Culvert dimensions should be matched as closely as possible to the upstream and downstream channel to prevent excessive deposition or erosion due to changes in stream flow velocity. A 1.5m x 1.5m box culvert would be proportional to the existing channel dimensions here. The modelling conducted indicates that a culvert of this dimension would be sufficient to pass the 1 in 200-year + climate change flow. This design provides a freeboard of 200mm.

Culvert B was modelled as 10.5m long. A 1.5m x 1.5m box culvert is proportional to the existing channel dimensions and sufficient to pass the 1 in 200-year + climate change flow with a freeboard of 300mm in this location.

As the proposed culverts modelled can convey the full 1 in 200-year + climate change flow, there is no change to the flood extent shown previously in **Figure 7**.

The site design places all buildings outwith the predicted 1 in 200-year + climate change flood extent, with car and lorry parking proposed in areas of the floodplain within the site. Ground levels within the floodplain should ensure flood waters are not routed towards buildings but can flow parallel to the watercourse as at present. As illustrated in **Figure 7**, flood depths here are <300mm and vehicular access through these areas would be maintained during such an event. The proposed alterations of ground levels in the vicinity of the burn were modelled in the post development scenario and had no discernible impact on the peak flood level or flow rate downstream of the site. An 8m buffer is provided along the tributary drain which runs through the south-western portion of the site.

8 Summary and Conclusions

Kaya Consulting Limited was commissioned by Stevie Sinclair of Ironside Farrar Ltd on behalf of J&M Murdoch to undertake a Flood Risk Assessment in support of commercial development at Shillford in the East Renfrewshire Council area.

The proposed development comprises a transport depot, office, museum, workshops, drainage works, landscape works, access, parking, and associated development. Commercial development is classed as 'Least Vulnerable' under SEPA Land Use Vulnerability Guidance. Based on NPF4, commercial development must be situated out with the 1 in 200-year + climate change floodplain.

An unnamed drain bisects the site and is fed by several tributary drains which run near the site.

Detailed fluvial modelling indicated that small areas of low-lying land parallel to the main channel and tributary are at risk from shallow fluvial flooding. Most of the site remains outwith the flood extent. Based on NPF4 areas land outwith the 1 in 200-year + climate change extent is suitable for most types of development including commercial.

The effect of the development on fluvial flood risk is assessed in **Section 7**.

Two main surface water flow pathways have been identified through the site. Surface water should be intercepted at the site boundary in a channel which can convey the water to the proposed site drainage system or through the site to an appropriate point of discharge. Landscaping should encourage surface water away from buildings and to an appropriate point of discharge or into the proposed site drainage system.

The regulatory authorities recommend that safe access and egress be provided during extreme flood events so that residents and visitors can be safely evacuated without any undue risk to life.

The proposed site access is from the A736 to the north of the site. There is no fluvial flood risk to access. The modelling conducted shows some surface water on the A736, however the depths generally do not exceed 0.1m. In any areas where this depth is modelled to be exceeded, a site walk over indicates this is unlikely as the road is cambered to shed surface water. Safe access is, therefore, achievable via the A736. Care should be taken when designing the main site access not to route additional surface water towards the site.

Section 7 provides a discussion of the impact of the proposals on flood risk.

It should be noted that the risk of flooding can be reduced, but not eliminated, given the potential for events exceeding design conditions and the inherent uncertainty associated with estimating hydrological parameters for any given site.

Appendix A – SEPA Checklist

Flood Risk Assessment (FRA) Checklist

(SS-NFR-F-001 - Version 14 - Last updated 28/05/2019

This document must be attached within the front cover of any Flood Risk Assessments issued to Local Planning Authorities (LPA) in support of a development proposal which may be at risk of flooding. The document will take only a few minutes to complete and will assist SEPA in reviewing FRAs, when consulted by LPAs. This document should not be a substitute for a FRA.

Development Proposal Summary					
Site Name:		Shillford			
Grid Reference:	Easting:	45300	Northing:	56450	
Local Authority:		East Renfrewshire Council			
Planning Reference number (if known):					
Nature of the development:		Commercial	If residential, state type:		
Size of the development site:		4	Ha		
Identified Flood Risk:	Source:	Fluvial	Source name:	unnamed	
Land Use Planning					
Is any of the site within the functional floodplain? (refer to SPP para 255)		No	If yes, what is the net loss of storage?		m³
Is the site identified within the local development plan?		Select from List	Local Development Plan Name:		Year of Publication:
			Allocation Number / Reference:		
If yes, what is the proposed use for the site as identified in the local plan?			If Other please specify:		
Does the local development plan and/or any pre-application advice, identify any flood risk issues with or requirements for the site.			If so, please specify:		
What is the proposed land use vulnerability?		Least Vulnerable	Do the proposals represent an increase in land use vulnerability?	Yes	
Supporting Information					
Have clear maps / plans been provided within the FRA (including topographic and flood inundation plans)?		Yes			
Has sufficient supporting information, in line with our Technical Guidance, been provided? For example: site plans, photos, topographic information, structure information and other site specific information.		Yes			
Has a historic flood search been undertaken?		Yes	If flood records in vicinity of the site please provide details:		
Is a formal flood prevention scheme present?		No	If known, state the standard of protection offered:		
Current / historical site use:		Grassed land			
Is the site considered vacant or derelict?		No			
Development Requirements					
Freeboard on design water level:			m		
Is safe / dry access and egress available?		Vehicular and Pedestrian	Min access/egress level:	-	m AOD
Design levels:	Ground level:	-	m AOD (cross-section tables)	Min FFL: -	mAOD
Mitigation					
Can development be designed to avoid all areas at risk of flooding?		Yes			
Is mitigation proposed?		No			
If yes, is compenstory storage necessary?		No			
Demonstration of compensatory storage on a "like for like" basis?					
Should water resistant materials and forms of construction be used?					

SEPA Scottish Environment Protection Agency

Flood Risk Assessment (FRA) Checklist

(SS-NFR-F-001 - Version 14 - Last updated 28/05/2019)

Hydrology

Is there a requirement to consider fluvial flooding?		Yes			
Area of catchment:		0.5	km²	Is a map of catchment area included in FRA?	Yes
Estimation method(s) used (please select all that apply):		Pooled Analysis ☐		If Pooled analysis have group details been included?	
		Single Site Analysis ☐			
		Enhanced Single Site ☐			
		ReFH2 ☑			
		FEH RRM ☑			
		Other ☐		If other (please specify methodology used):	
Estimate of 200 year design flood flow:		1.95	m^3/s		
Qmed estimate:		-	m^3/s	Method:	
Statistical Distribution Selected:				Reasons for selection:	Most conservative

Hydraulics

Hydraulic modelling method:		Linked 1D 2D		Software used:	Flood Modeller
				If other please specify:	
Number of cross sections:		21			
Source of data (i.e. topographic survey, LiDAR etc):		Survey		Date obtained / surveyed:	Jul-05
Modelled reach length:		Varbale	m		
Any changes to default simulation parameters?		No		If yes please provide details:	
Model timestep:		0.5			
Model grid size:		2m			
Any structures within the modelled length?		Culvert		Specify, if combination:	
Maximum observed velocity:		1.7	m/s		
Brief summary of sensitivity tests, and range:					
variation on flow (%)		41	%	Please specify climate change scenario considered:	
variation on channel roughness (%)		20	%		
blockage of structure (range of % blocked)		25	%		
boundary conditions:		**Upstream**			**Downstream**
(1) type		Flow			Normal depth
	Specify if other	41% rain		Specify if other:	
(2) does it influence water levels at the site?		Yes			No
Has model been calibrated (gauge data / flood records)?		No			
Is the hydraulic model available to SEPA?		No			
Design flood levels:	200 year		m AOD*	*see tables*	m AOD
Cross section results provided?		Yes			
Long section results provided?		No			
Cross section ratings provided?		No			
Tabular output provided (i.e. levels, velocities)?		Yes			
Mass balance error:		0.63	%		

Coastal

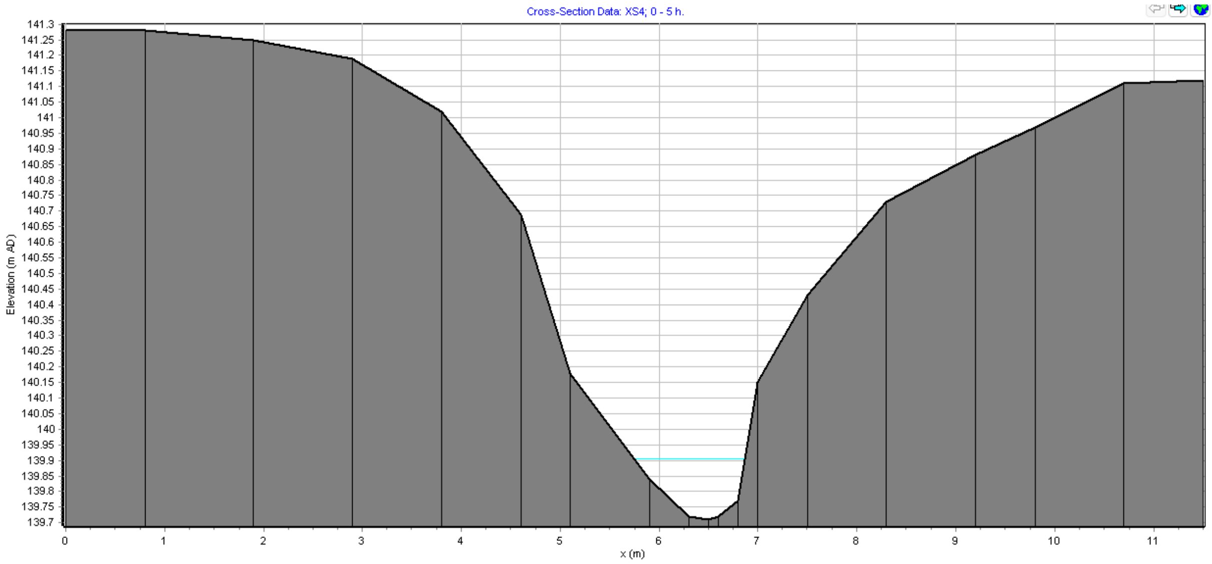
Is there a requirement to consider coastal / tidal flooding?	No			
Estimate of 200 year design flood level:		m AOD		
Estimation method(s) used:	[illegible]		If other please specify methodology used:	
Allowance for climate change (m):		m		
Allowance for wave action etc (m):		m		
Overall design flood level:		m AOD		

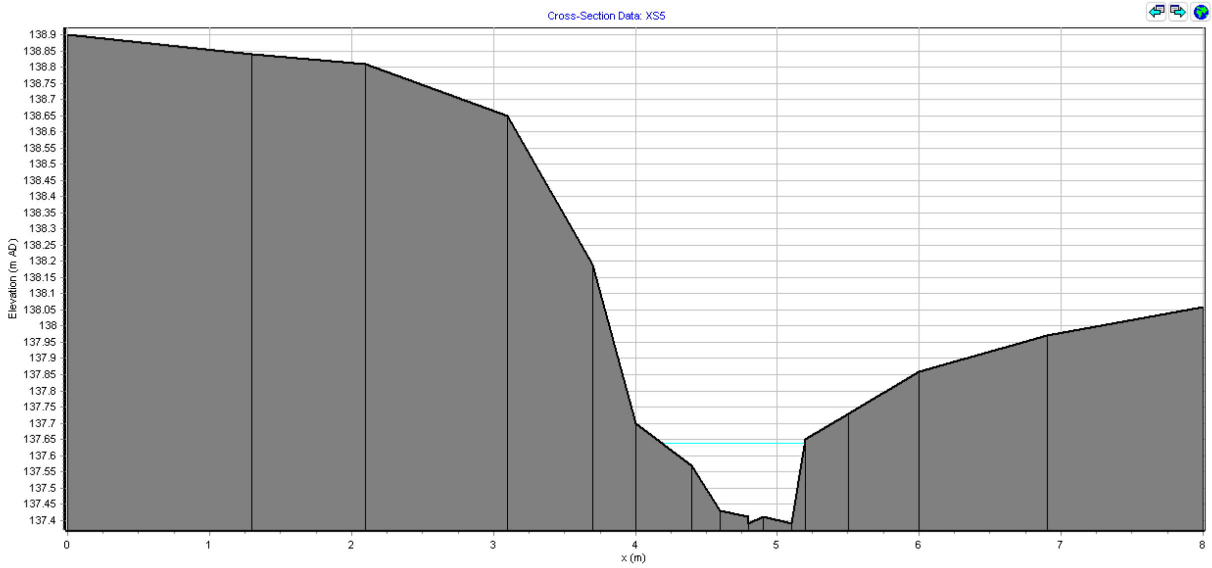
Comments

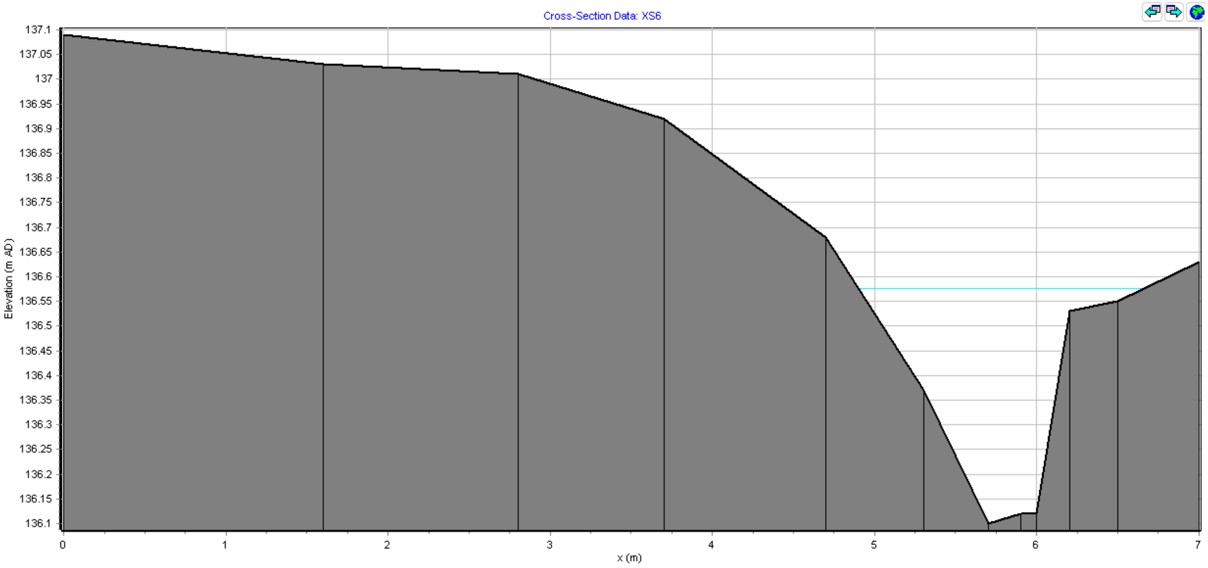
Any additional comments:	

Approved by: **N Rosbon**
Organisation: **Kaya Consulting Ltd.**

Appendix B – Additional Flood Model Results



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137.05
137
136.95
136.9
136.85
136.8
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136.7
136.65
136.6
136.55
136.5
136.45
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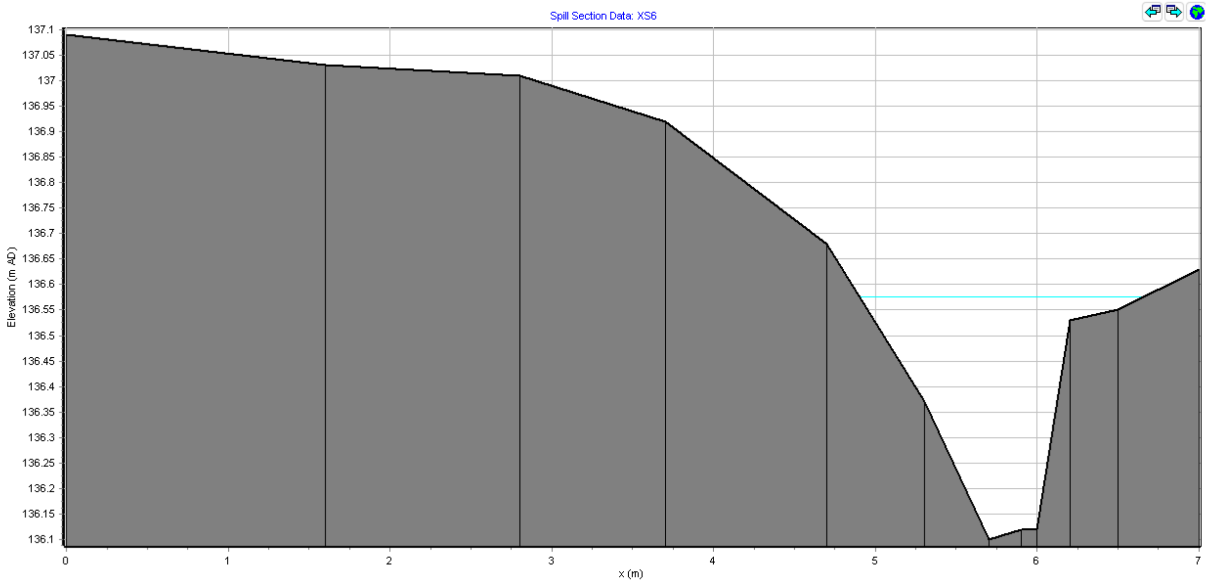
6
7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x (m)
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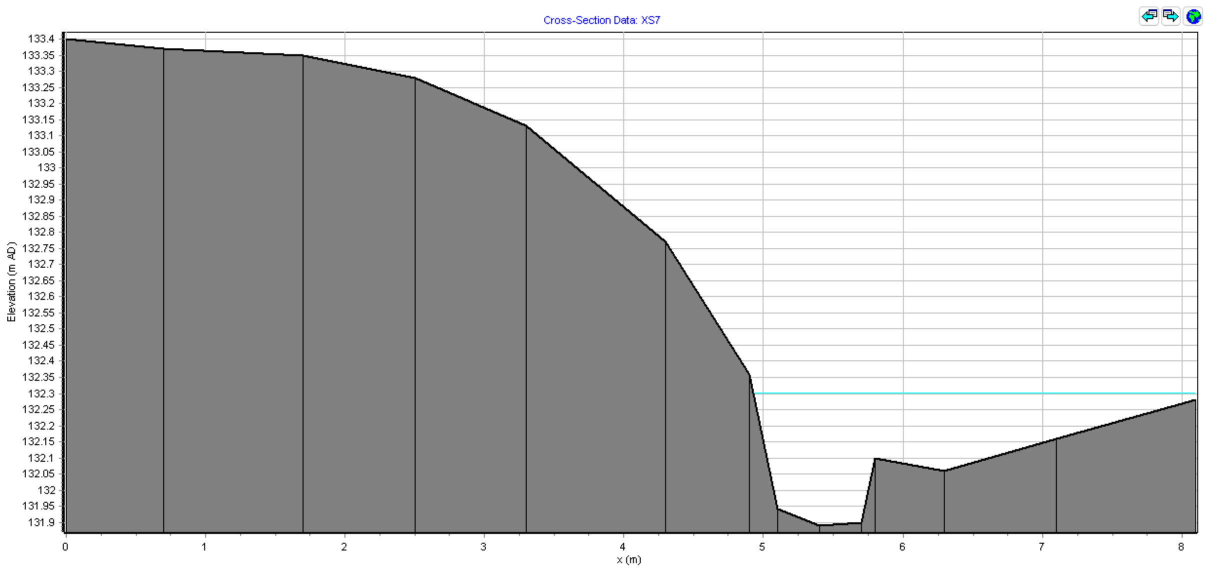
3
4
5
6
7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Elevation (m AD)
x (m)
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133.25
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133.15
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133.05
133
132.95
132.9
132.85
132.8
132.75
132.7
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132.55
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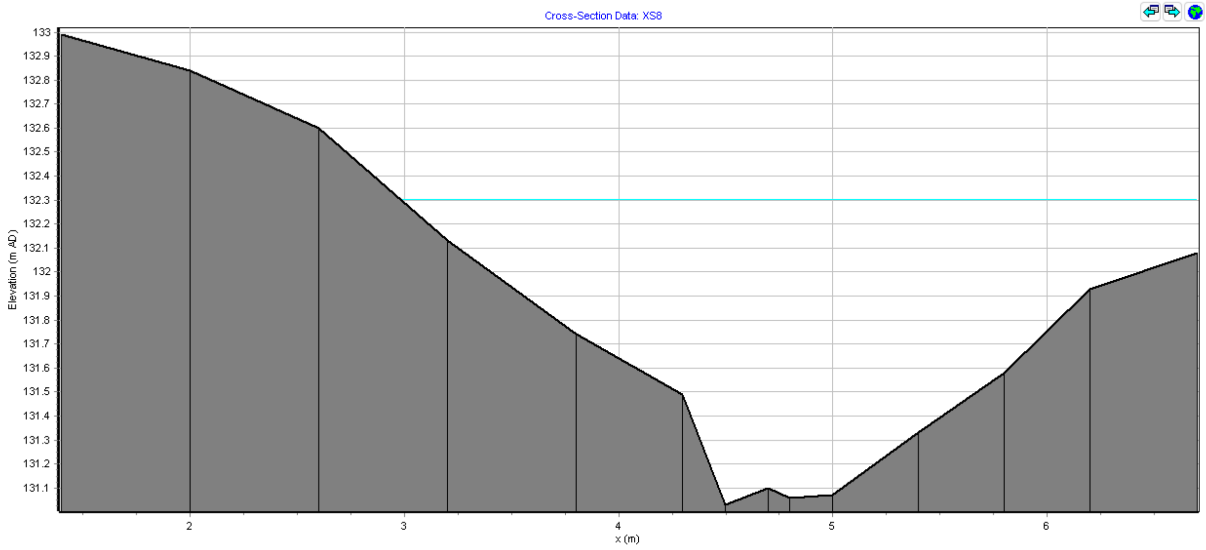
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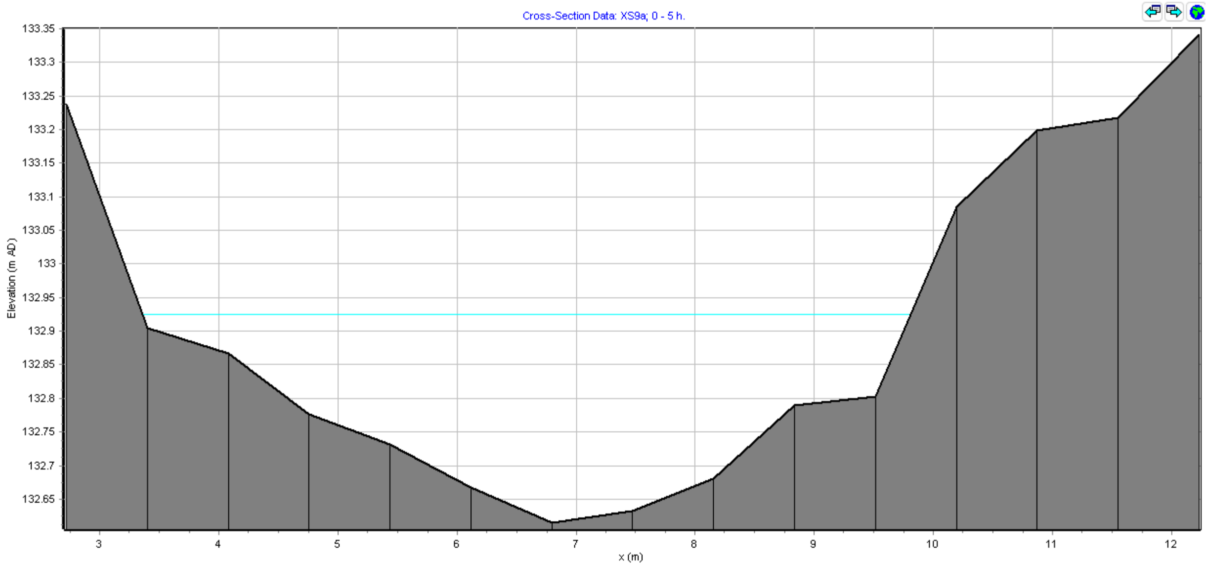
Elevation (m AD)
x (m)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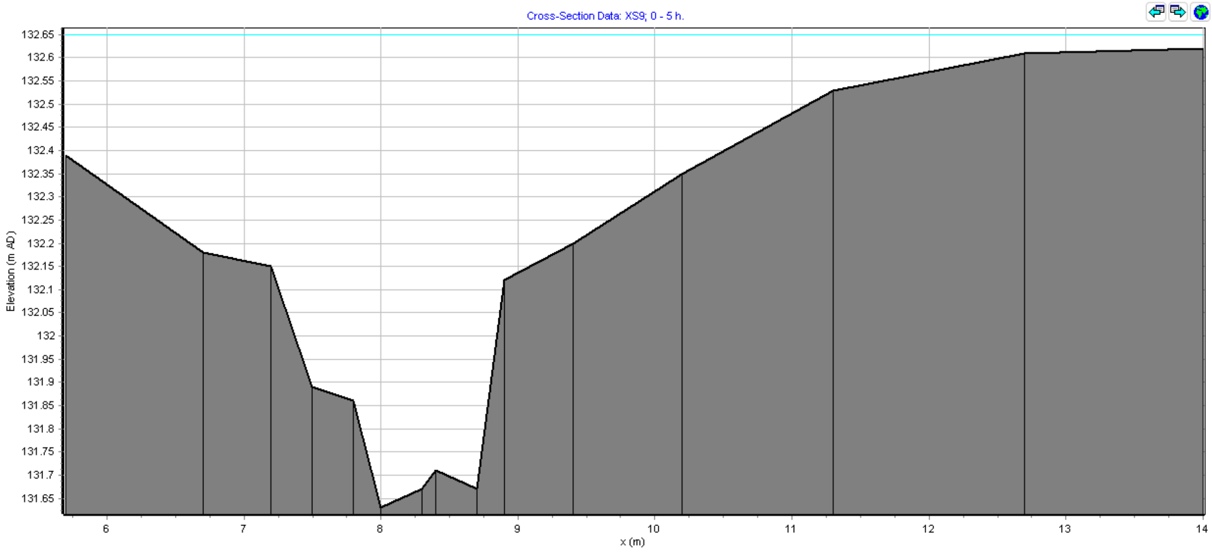
x (m)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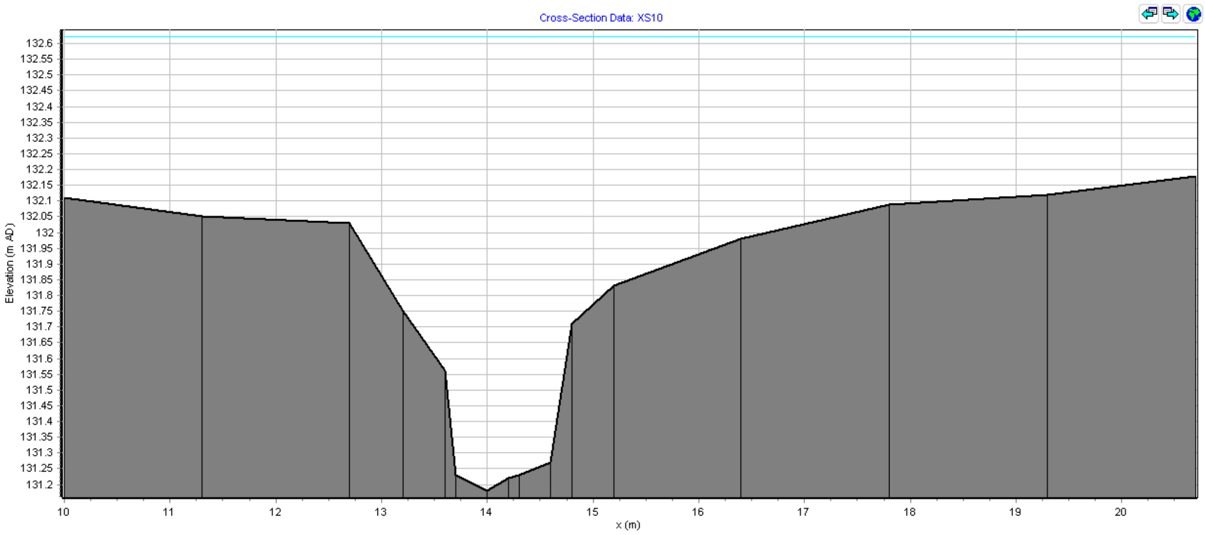
x (m)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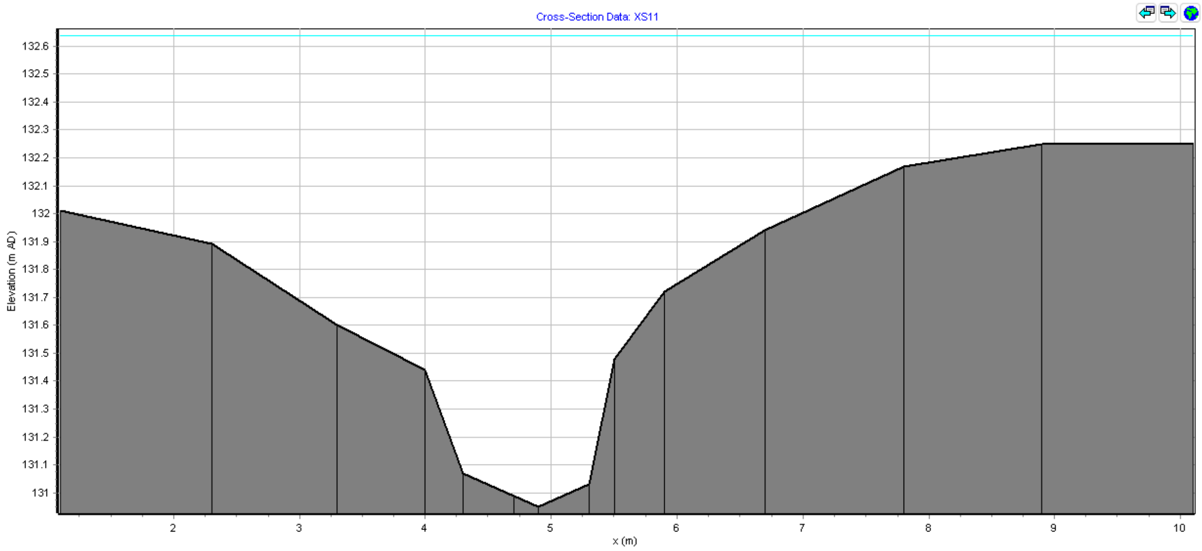
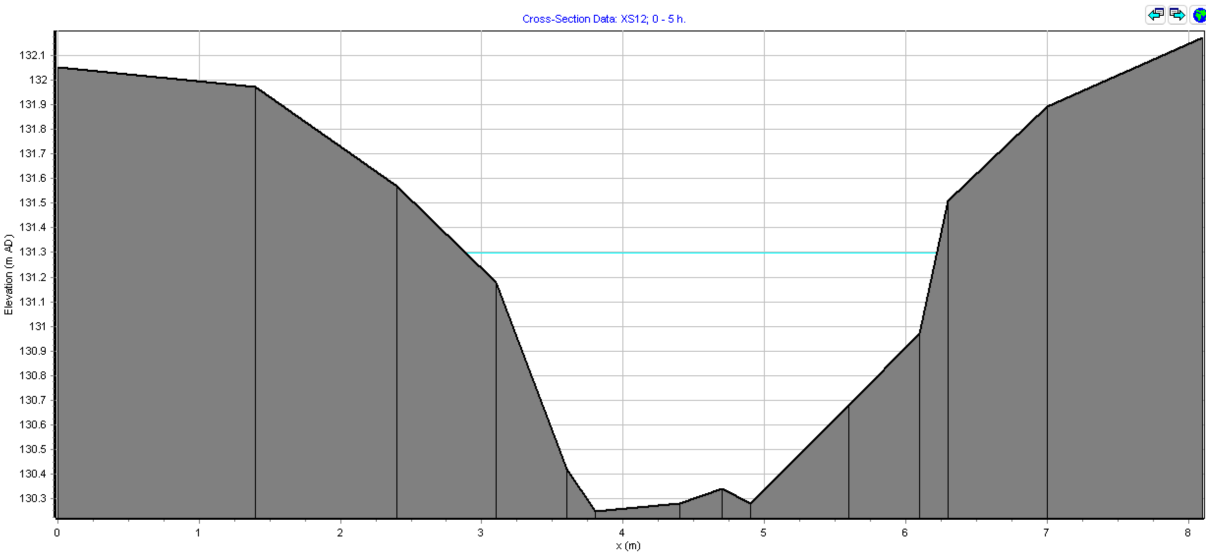
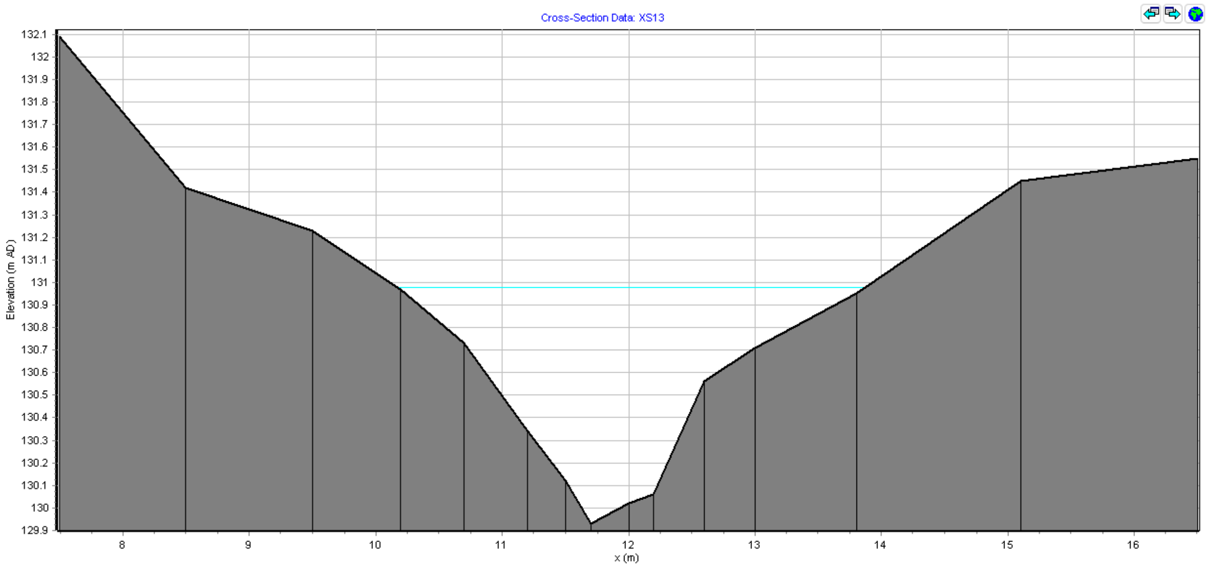
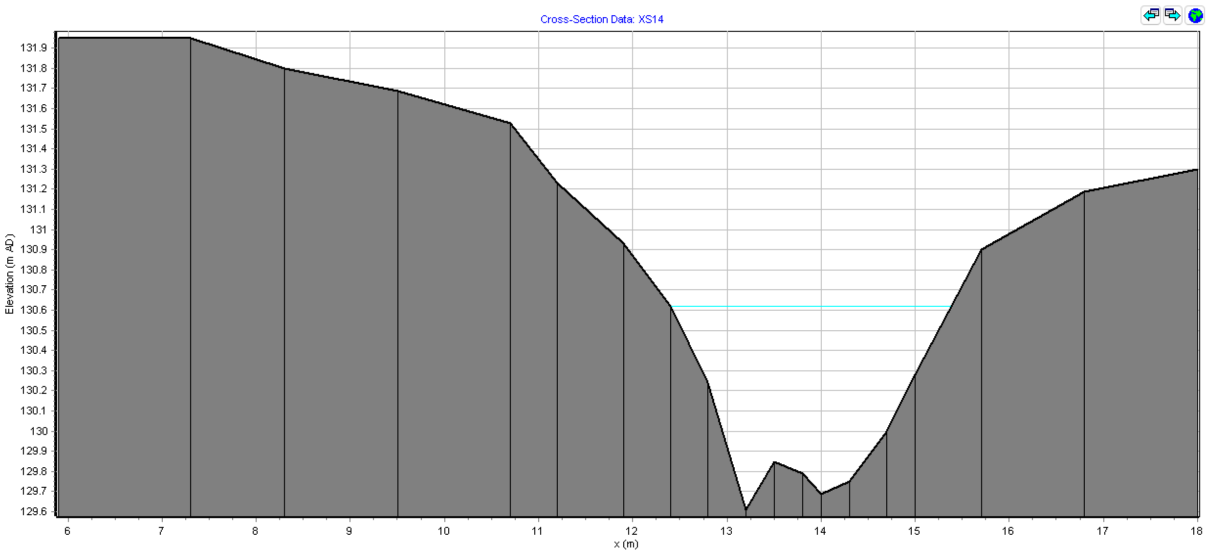
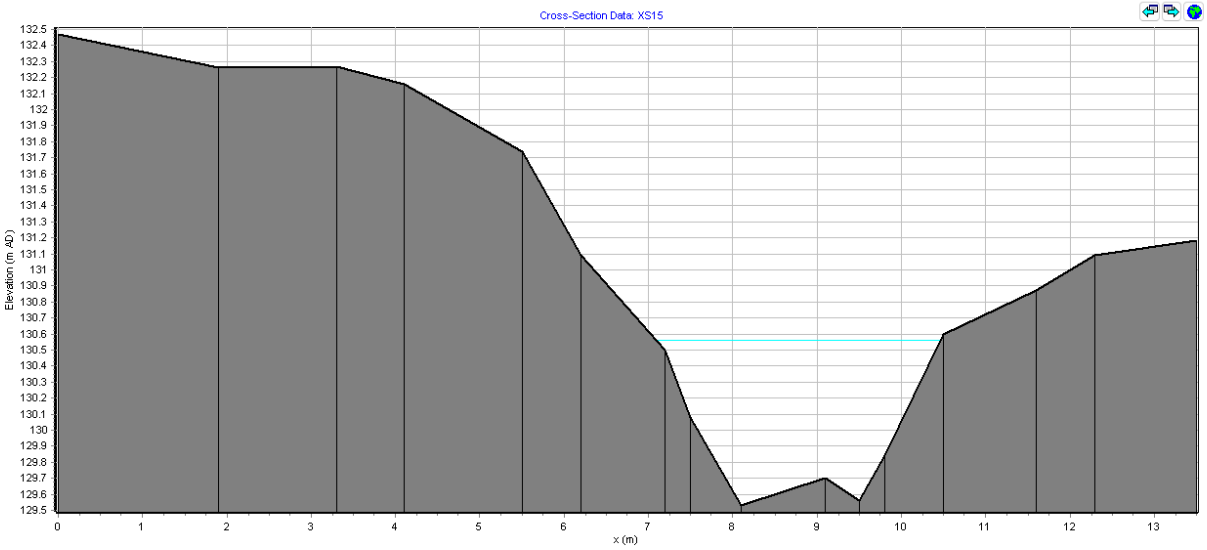
132.5
132.45
132.4
132.35
132.3
132.25
132.2
132.15
132.1
132.05
132
131.95
131.9
131.85
131.8
131.75
131.7
131.65
131.6
131.55
131.5
131.45
131.4
131.35
131.3
131.25
131.2
10
11
12
13
14
15
16
17
18
19
20
x (m)

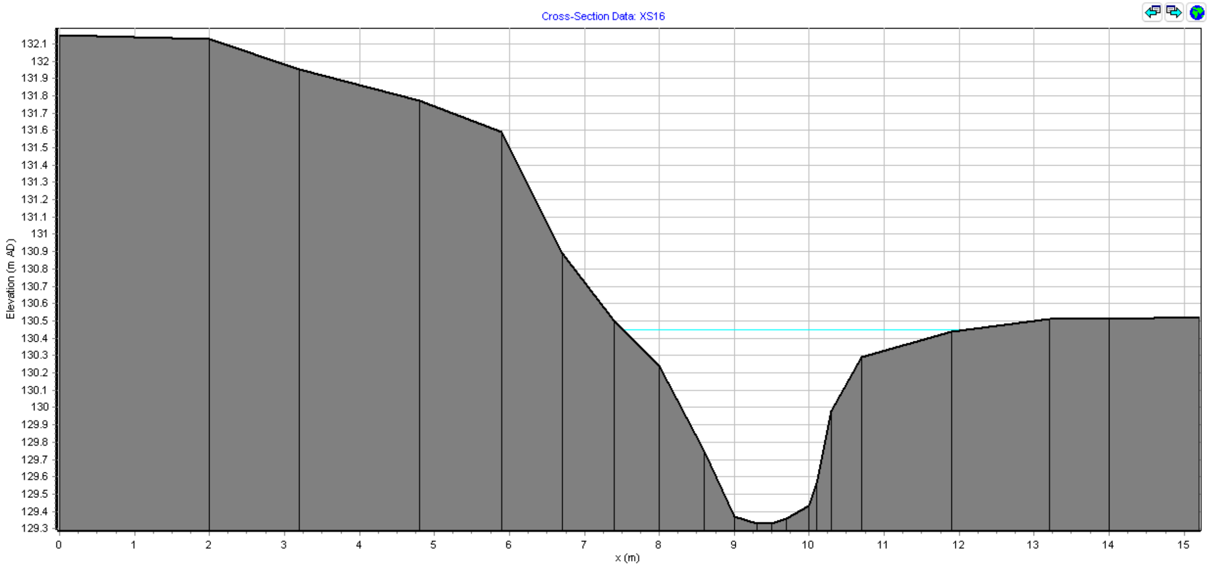

Cross-Section Data: XS11
Elevation (m AD)
132.6
132.5
132.4
132.3
132.2
132.1
132
131.9
131.8
131.7
131.6
131.5
131.4
131.3
131.2
131.1
131
2
3
4
5
6
7
8
9
10
x (m)

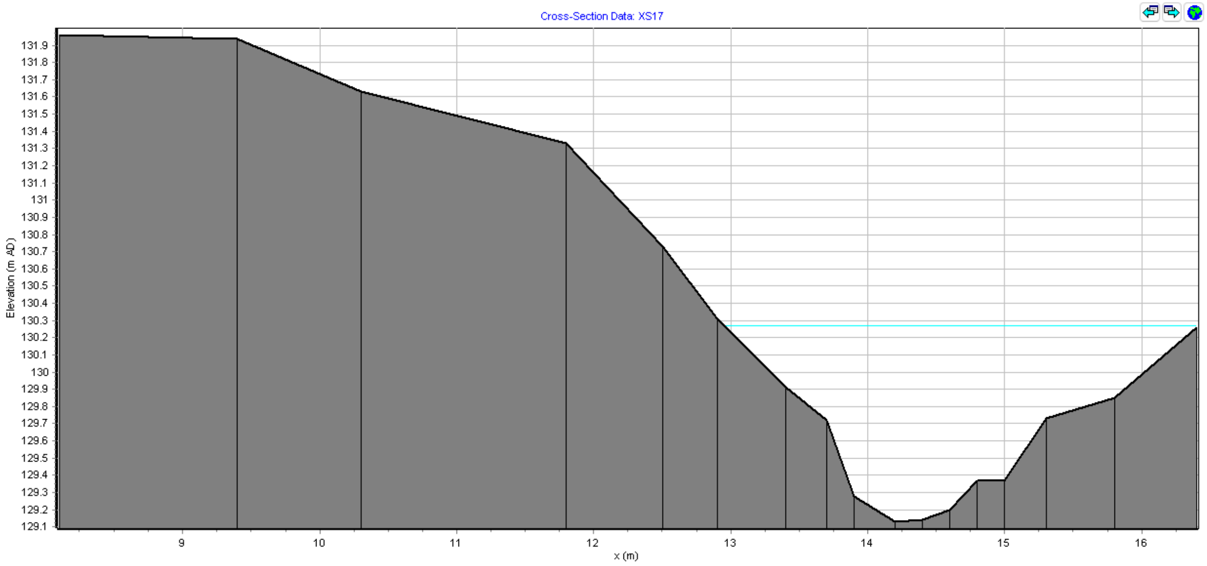

Cross-Section Data: XS12; 0 - 5 h.
Elevation (m AD)
132.1
132
131.9
131.8
131.7
131.6
131.5
131.4
131.3
131.2
131.1
131
130.9
130.8
130.7
130.6
130.5
130.4
130.3
0
1
2
3
4
5
6
7
8
x (m)

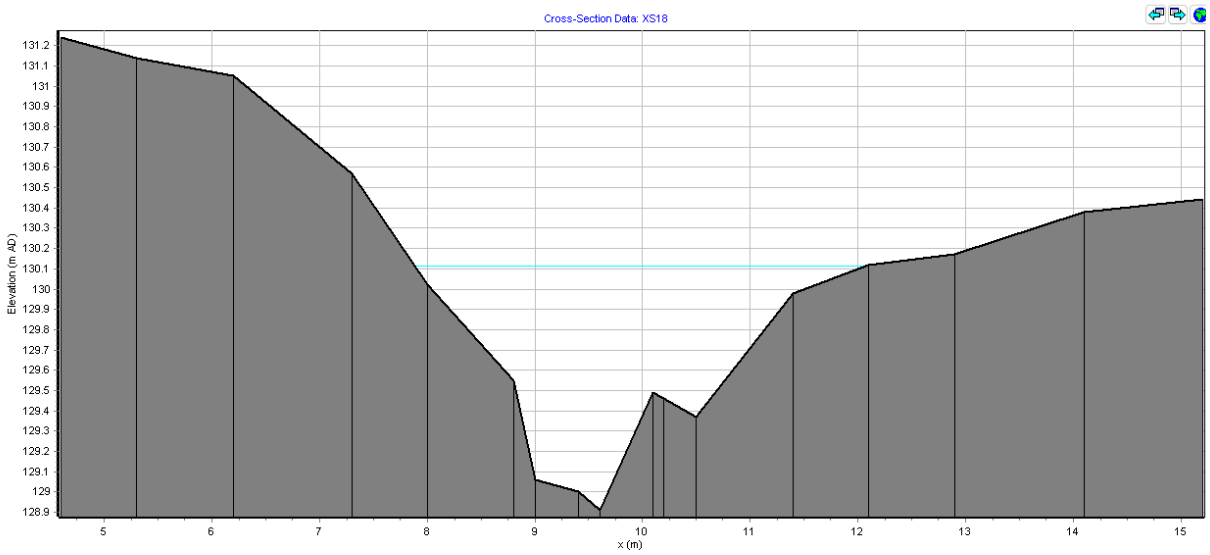

Cross-Section Data: XS13
Elevation (m AD)
132.1
132
131.9
131.8
131.7
131.6
131.5
131.4
131.3
131.2
131.1
131
130.9
130.8
130.7
130.6
130.5
130.4
130.3
130.2
130.1
130
129.9
8
9
10
11
12
13
14
15
16
x (m)

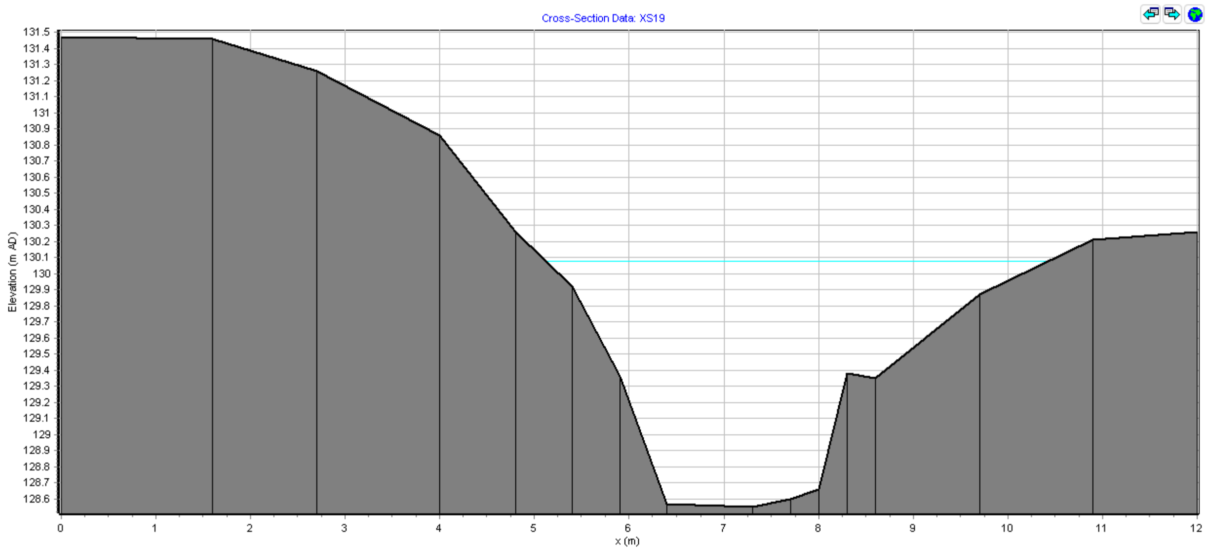

Cross-Section Data: XS14
Elevation (m AD)
131.9
131.8
131.7
131.6
131.5
131.4
131.3
131.2
131.1
131
130.9
130.8
130.7
130.6
130.5
130.4
130.3
130.2
130.1
130
129.9
129.8
129.7
129.6
6
7
8
9
10
11
12
13
14
15
16
17
18
x (m)

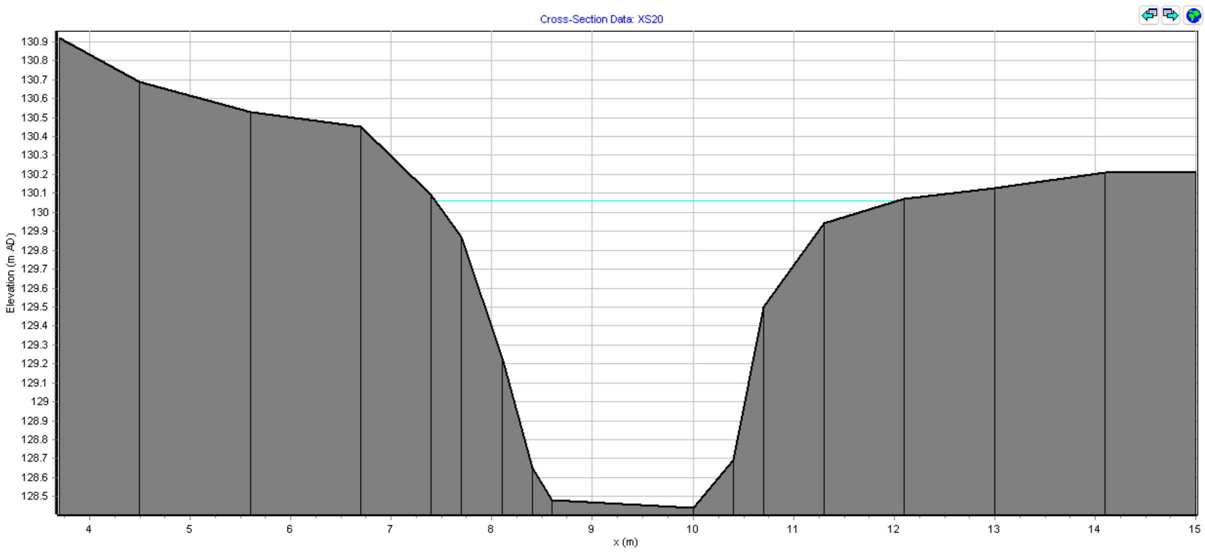

Cross-Section Data: XS15
Elevation (m AD)
x (m)

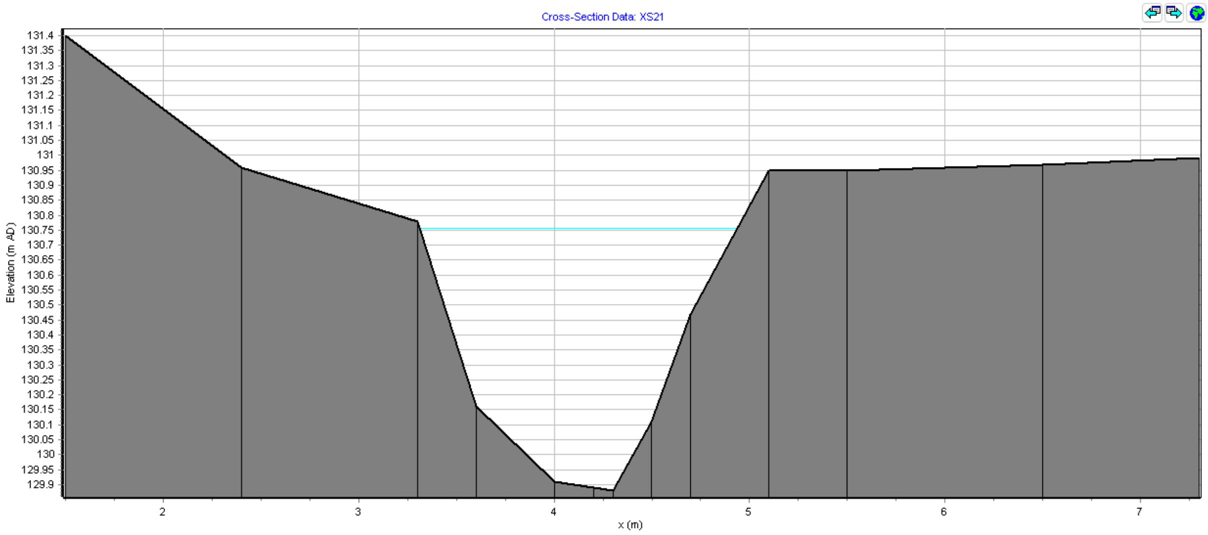

Cross-Section Data: XS16
Elevation (m AD)
x (m)

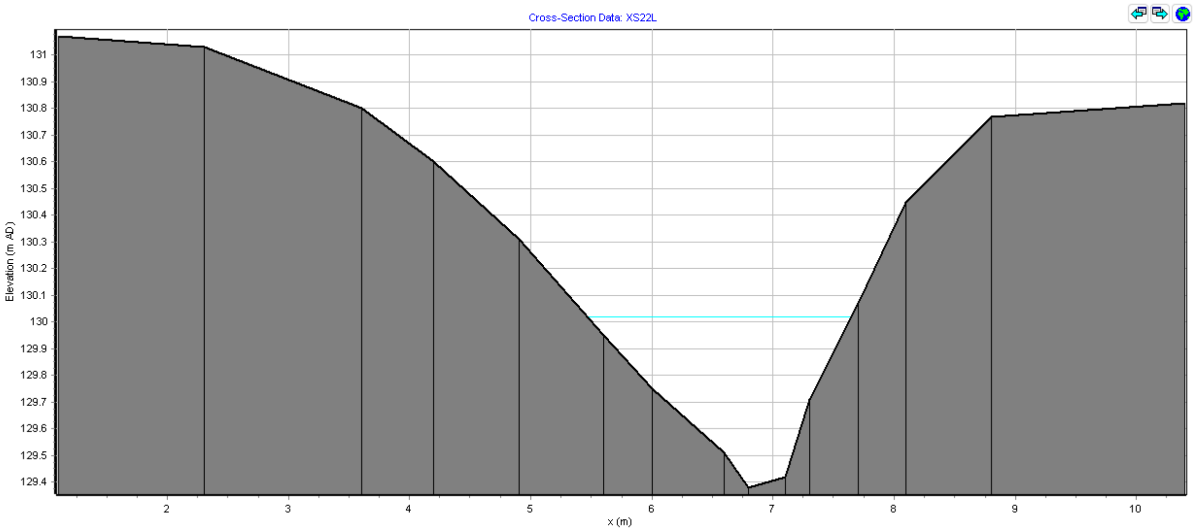

Cross-Section Data: XS17
Elevation (m AD)
x (m)

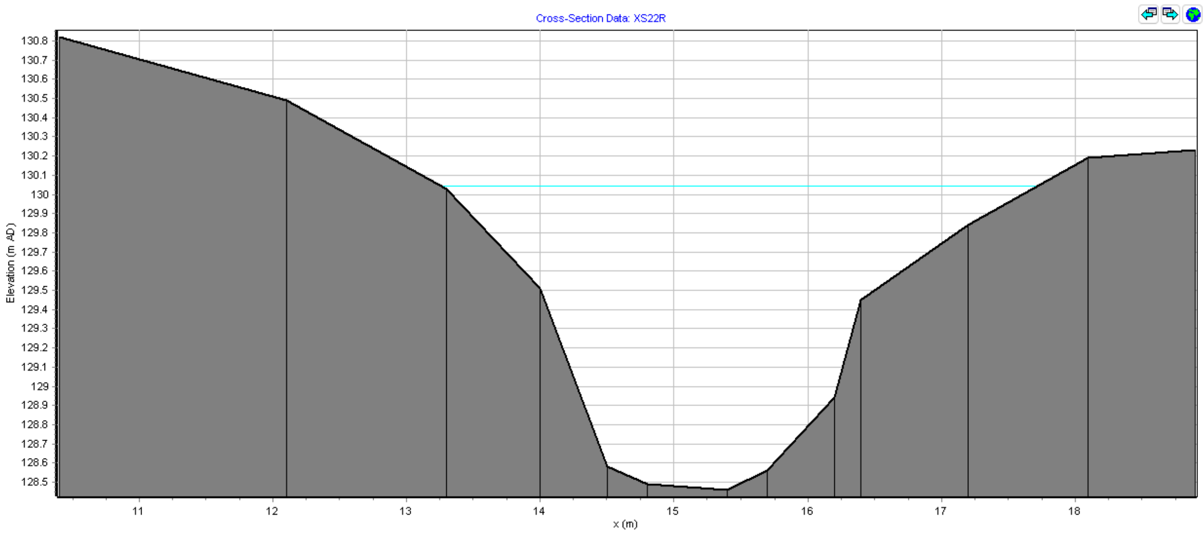

Cross-Section Data: XS18
Elevation (m AD)
x (m)

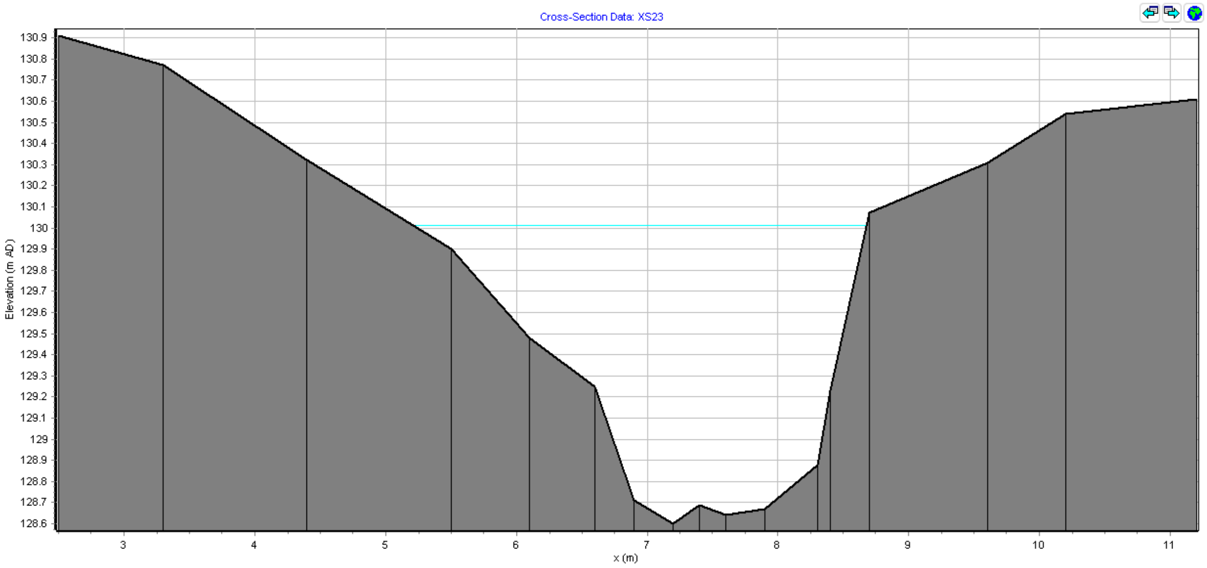

Cross-Section Data: XS19
Elevation (m AD)
x (m)

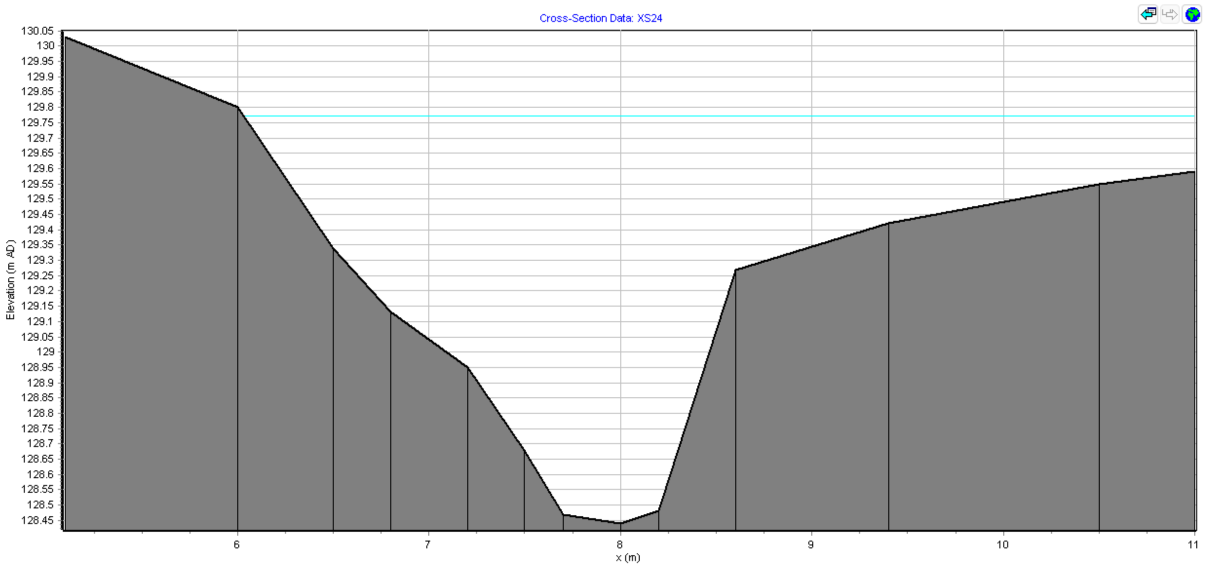

Cross-Section Data: XS20
Elevation (m AD)
x (m)


Cross-Section Data: XS21
Elevation (m AD)
x (m)


Cross-Section Data: XS22L
Elevation (m AD)
x (m)


Cross-Section Data: XS22R
Elevation (m AD)
x (m)


Cross-Section Data: XS23
Elevation (m AD)
x (m)


Cross-Section Data: XS24
Elevation (m AD)
x (m)