Appendix 10 – Water, Hydrology and Flood Risk

Appendix 10.1 – Figures

Legend

Site Boundary

Water Features

Do not scale this map

Client	TSL Contractors Limited
Project	West Riverside Balloch
Title	Figure 11.1 Basline Water Features and Watercourses
Status	FINAL
Drawing No.	168659-011
Revision	
Scale	1:5,000
	A3
Date	Jan 2018
Drawn	DW
Checked	LL
Approved	LL

ENVIRO Centre

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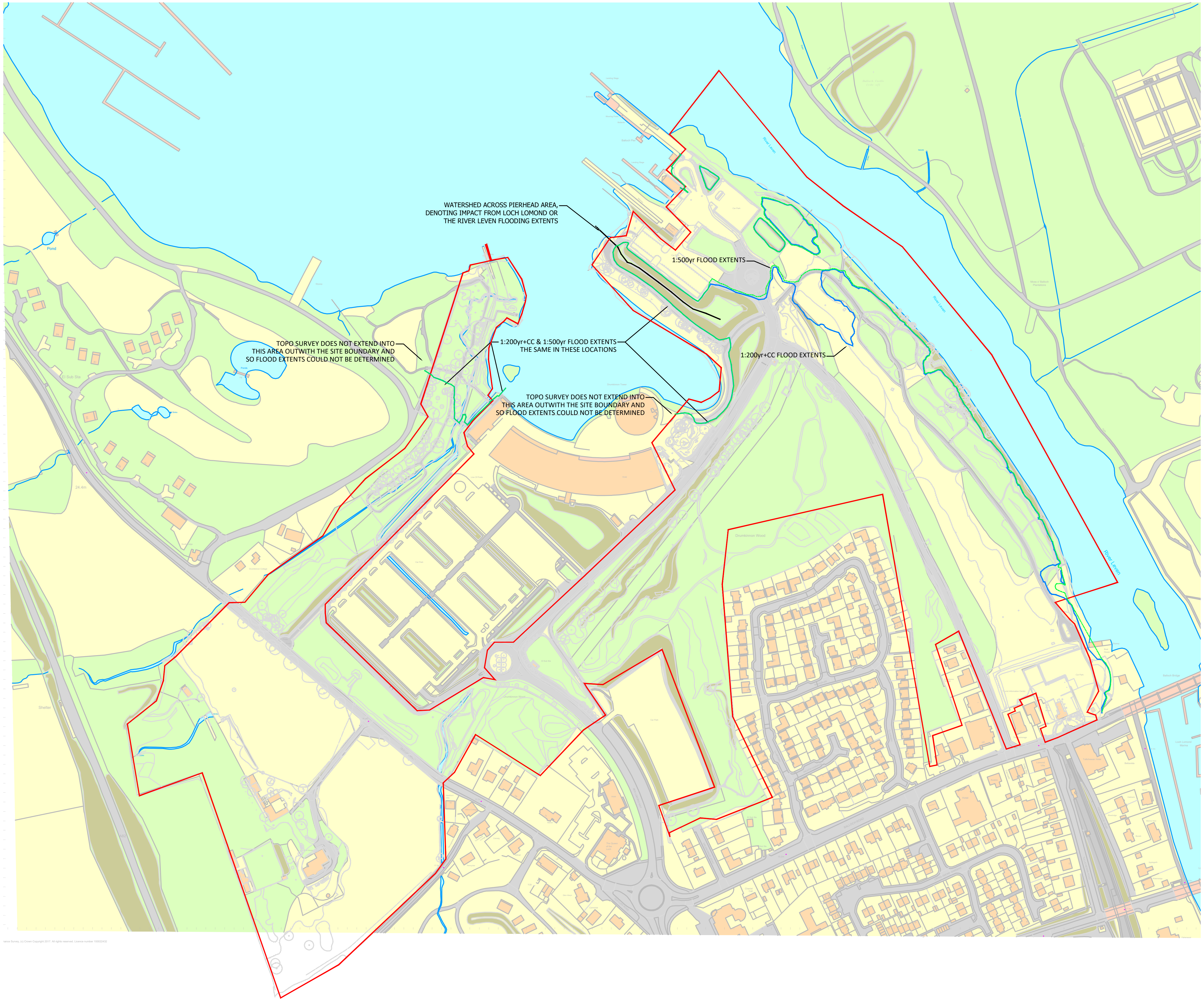

Notes

LEGEND

1 IN 200yr + 20%CC FLOOD EXTENTS

1 IN 500yr FLOOD EXTENTS

SITE BOUNDARY

Do not scale this drawing

Rev	Date	Amendment	Initials

ENVIRO Centre

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Client
TSL Contractors Limited

Project
West Riverside Balloch

Title
Figure 11.2
Combined Flood Extents Map

Status
FINAL

Drawing No.
168659-018

Revision

File path: k:\168659j riverside west\drgs\cad

Scale
1:4000

A3

Date
Jan 2018

Drawn
DW

Checked
LL

Approved

Appendix 10.2 – Flood Risk Assessment

West Riverside, Balloch
Flood Risk Assessment

March 2018

West Riverside, Balloch
Flood Risk Assessment

Client:	Flamingo Land
Document number:	7621
Project number:	168659
Status:	Final - Revision 1
Author:	David Warren
Reviewer:	Neil Gordon/Kenneth MacDougall
Date of issue:	9 March 2018
Filename:	West Riverside FRA_180309

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1 INTRODUCTION

1.1 Terms of Reference

EnviroCentre Ltd was commissioned by Flamingoland to undertake a flood risk assessment (FRA) for the proposed development on the southern shores of Loch Lomond, Balloch. This report has been produced to support the Environmental Impact Assessment (EIA) being undertaken for the development.

1.2 Scope of Report

The aim of this report is to present an assessment of the risk of flooding to the site from all potential sources including fluvial, pluvial, coastal, groundwater and sewer flooding.

1.3 Methodology

The following methodology has been adopted for this study:

- Consultation with the Scottish Environment Protection Agency (SEPA) and West Dunbartonshire Council to obtain any records of historical or relevant flooding information on or adjacent to the site that they may hold, and to ensure that any concerns they may have are addressed;
- Site walkover to confirm existing drainage patterns and likely flood mechanisms;
- Review of all available existing information with regards to flooding on site;
- Assessment of flooding from all potential sources;
- Provision of comments outlining any potential change in flood risk as a result of the proposed development; and
- Production of a flood risk assessment report detailing all of the above.

1.4 Regulatory Framework

1.4.1 Scottish Planning Policy

Scottish Government planning policy on flooding is provided by Scottish Planning Policy (SPP) paragraphs 254–268 (Scottish Government, 2014). This policy is based on the following principles:

- Developers and planning authorities must give consideration to the possibility of flooding from all sources;
- New development should be free from significant flood risk from any sources;
- In areas characterised as “medium to high” flood risk for watercourses and coastal flooding new development should be focused on built up areas and all development must be safeguarded from the risk of flooding;
- The storage capacity of functional flood plains should be safeguarded from further development. The functional floodplains comprise areas generally subject to an annual probability of flooding greater than 0.5% (1 in 200 year return period event);

Drainage is a material consideration and the means of draining a development should be assessed. Any drainage measures proposed should have a neutral or better effect on the risk of flooding both on and off the site.

SPP proposes a Risk Framework approach which identifies flood risk in three main categories:

- Little or no risk area (annual probability of flooding less than 0.1%): No constraints to development due to flood risk.
- Low to medium risk area (annual probability of flooding between 0.1% and 0.5%): Usually suitable for most developments but not essential civil infrastructure.
- Medium to high risk area (annual probability of flooding greater than 0.5%): Generally not suitable for essential civil infrastructure such as hospitals, fire stations, emergency depots, etc.; as well as schools, care homes and ground-based electrical telecommunications equipment unless subject to an appropriate long term flood risk management strategy.

In this report, annual exceedance probability (AEP) is used to define the likelihood of a flood event with a certain magnitude. The relationship between AEP and the concept of "return periods" is documented in Appendix A for reference purposes.

1.4.2 SEPA Guidance

SEPA has issued guidance in relation to preparing FRAs (SEPA, 2015). Technical requirements for FRAs depend on the complexity of the site with more complex or high risk sites requiring detailed assessments. In summary, FRAs must include the following:

- Background site data, including suitable plans and/or photographs;
- Historic flood information;
- Description of methodologies used;
- Identification of relevant flood sources;
- In the case of river flooding: assessment of river flows, flood levels, depths, extents, displaced flood storage volumes, etc;
- Assessment of culverts, sewers or other structures affecting flood risk;
- Consideration of climate change impacts;
- Details of required flood mitigation measures; and
- Conclusions on flood risk related to relevant national and local policies.

In addition to reporting requirements, the document also provides technical guidance on Flood Estimation Handbook (FEH) (CEH, 2008) methodologies and on land raising and compensatory storage.

1.4.3 Loch Lomond and Trossachs National Park Guidance & Policies

The Loch Lomond and Trossachs National Park (LLTNP) Local Development Plan was issued in December 2016 and covers the period from 2017-2026. This plan guides new development within the park and sets out policies which will be used to determine planning applications. A number of these polices with regards to the natural environment are relevant to this report, and so the assessment will take cognisance of the following policies:

- Natural Environment Policy 11 – Protecting the Water Environment
- Natural Environment Policy 12 - Surface Water and Waste Water Management
- Natural Environment Policy 13 – Flood Risk.

In addition to the local plan, the Supplementary Guidance document on Design & Placemaking produced by the LLTNP will also be taken into account.

2 SITE DESCRIPTION

2.1 Site Location

The development site is located immediately to the north of the town of Balloch, West Dunbartonshire, and is situated on the southern shores of Loch Lomond. The National Grid Reference (NGR) for the centre of the site is NS 38600 82178. A site location plan is presented as Figure 2.1. The total site area is approximately 36.3ha.

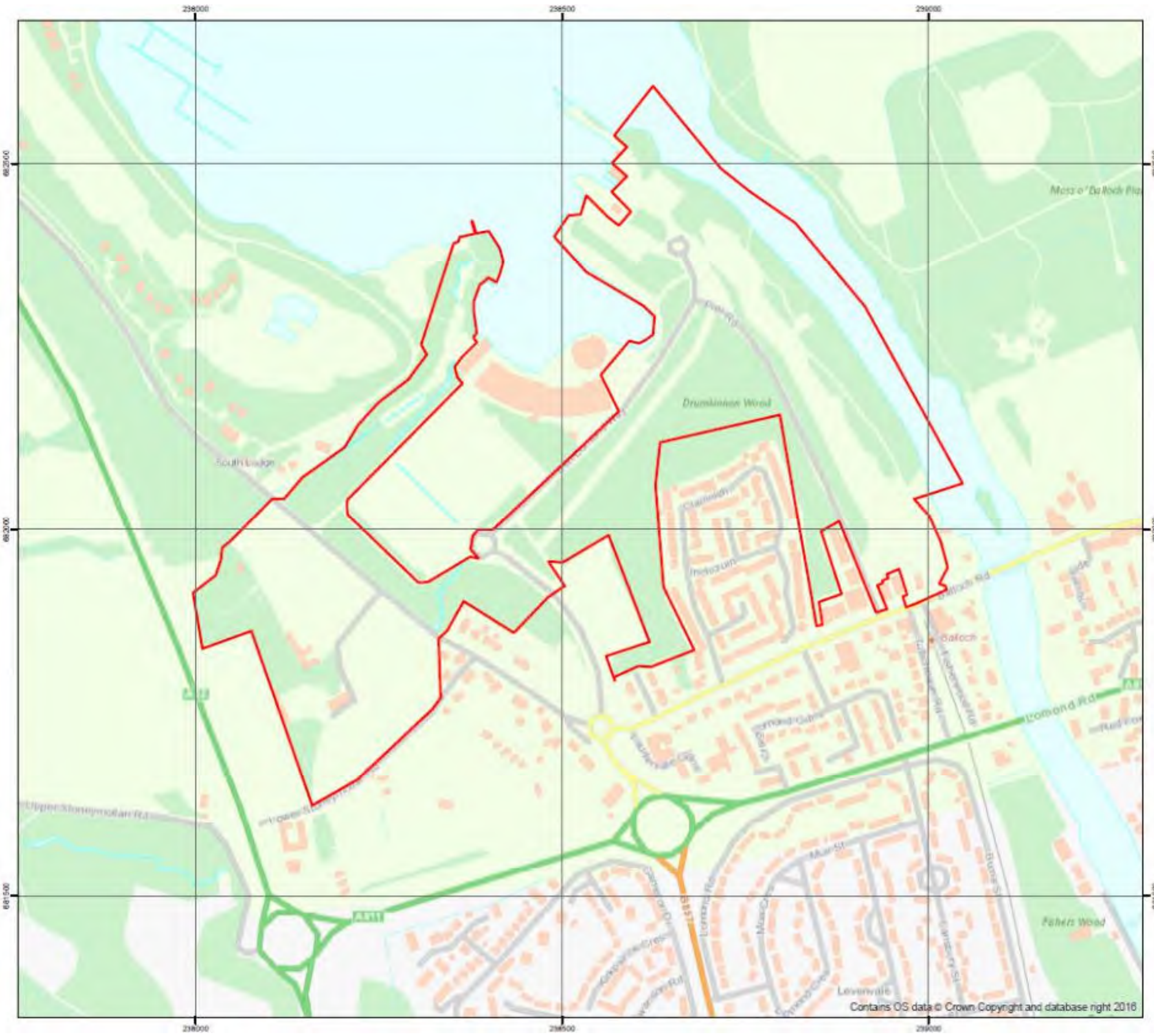

Figure 2.1: Site Location Plan

The site covers a large area and has a mix of existing uses, but at the outermost boundaries of the site it is bound by:

- Loch Lomond to the north;
- The River Leven to the east;
- Residential housing to the south; and
- Open fields and beyond this the A82 to the west.

2.2 Existing Site Layout

A site walkover for the flood risk assessment was undertaken on 3rd March 2017. The weather on the day was sunny and fine, and there had been little precipitation in the days prior to the site visit. A photographic record of this site walkover is presented in Appendix B.

The site currently consists of a range of different uses including leisure and recreation (water sports) along the shores of the loch, several areas of car parking which serve the public slipways as well as the neighbouring Loch Lomond Shores development, areas of woodland through Drumkinnon Woods and open parkland along the banks of the River Leven.

The tourist information and visitor centre is located at the south eastern point of the site, opposite Balloch train station and Sweeney's Cruises.

Woodbank House, which is currently lying derelict, is located in the west of the site and is surrounded by open fields and areas of woodland.

2.3 Watercourses

Figure 2.2 illustrates the layout of watercourses across the site, with the watercourses described in more detail below.

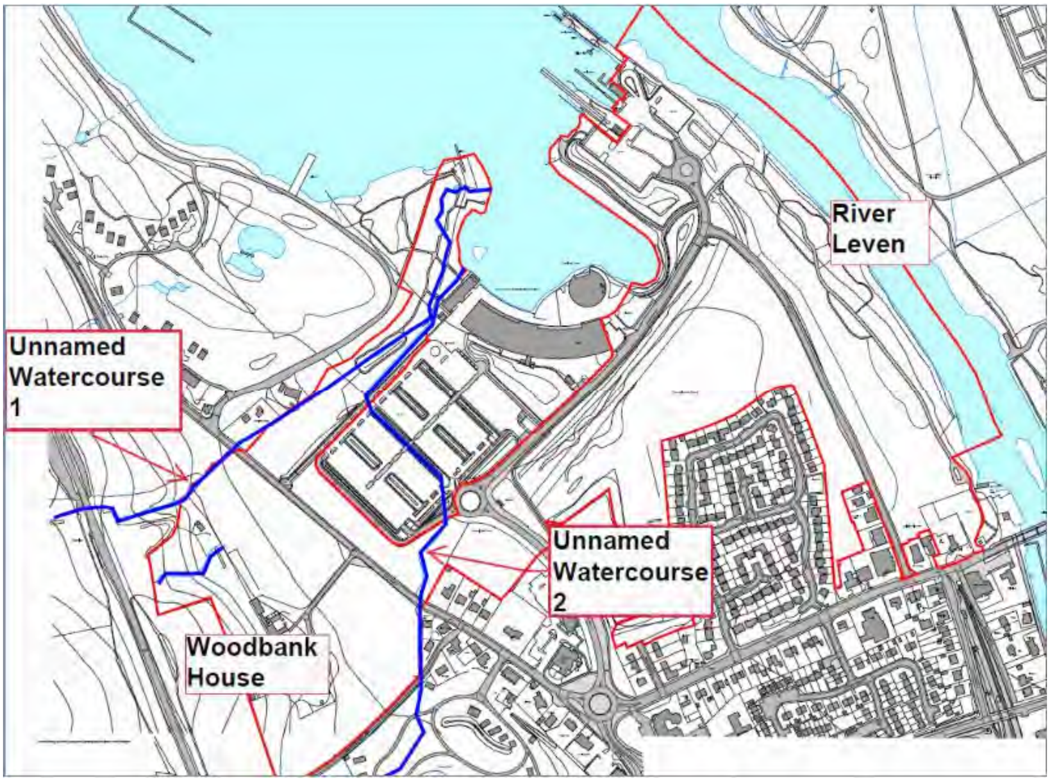

Figure 2.2: Watercourses on site

2.3.1 River Leven

The River Leven flows to the east of the development site in a southerly direction. It rises at the outflow from Loch Lomond to the north of the development site, and routes south through the towns of Balloch and

Alexandria to outfall into the River Clyde at Dumbarton. The river is approximately 11.5km long and has coastal influence for approximately 5km upstream from its confluence with the River Clyde.

Adjacent to the development site, the river is approximately 85-90m wide and contains a number of floating pontoons for mooring boats. Approximately 550m downstream of the Balloch Station area of the site, the River Leven Barrage is located. This is operated by Scottish Water and controls the outflow from the loch limiting the discharge and maintains water levels within Loch Lomond between 7 and 7.6m Above Ordnance Datum (AOD). It is not formally operated as a flood prevention structure.

2.3.2 Unnamed Watercourse 1

The unnamed watercourse 1, as illustrated on Figure 2.2, rises in the hills to the west of the A82. The burn flows in an easterly direction along the north-western boundary and passes beneath Old Luss Road before routing north of the existing car park and Loch Lomond Shores development. It outfalls into Loch Lomond at the end of a small headland in the bay north of the site.

Within the Woodbank House site a small watercourse is shown on plan routing in an easterly direction before it sinks, with no downstream route marked on the maps. During the site walkover there was water present within the channel however there was very little flow. The channel appeared to route into a culvert structure, but it is not known where this routes to or if it discharges into the unnamed watercourse 1. There were no visible signs of a culvert downstream across this area of the site.

2.3.3 Unnamed Watercourse 2

Unnamed watercourse 2 also rises in the hills to the west of the site and the A82, and routes in an easterly direction towards Drumkinnon Farm. The burn flows through a small caravan park to the south of the development site and below Lower Stoneymollan Road before routing along the boundary of the Woodbank House area of the site. The burn then passes below Old Luss Road and routes north towards the car park of the Loch Lomond Shores complex. The burn routes through a number of culverts as it passes beneath access roads, however it flows through an open channel through the car park area. This is illustrated in Photograph 8 in Appendix B.

Downstream of the car park the burn routes to the east and flows parallel with unnamed watercourse 1 towards Loch Lomond where it outfalls adjacent to the aerial adventure course.

2.4 Proposed Development

The proposals for the site is for a tourism and leisure-led mixed used development including:

- Refurbished tourist information building
- 60-bedroom Apart-hotel
- 32-bedspace budget accommodation
- Up to 105 self-catering lodges
- 20 houses
- 900m² brewery
- Leisure / pool /water park area up to approximately 2,500m²
- Restaurants/Cafe & Retail areas up to 1,100m² in total
- Visitor reception areas & hub building up to approximately 2,000m²
- External activity areas including tree top walk, events/ performance areas, children's play areas, monorail, forest adventure rides, picnic / play areas
- Staff and service area of up to approximately 900m²

- Associated parking (up to 320 additional spaces), landscaping and infrastructure development works
- Access to be taken from the surrounding road network including Ben Lomond Way and Pier Road

The site has been split into distinct areas which are outlined below, and for reference these areas have been used for the assessment in Section 3 of this report.

Figure 2.3 - Outline Development Proposals

2.4.1 Site A - New Station Square

This area which surrounds the tourist information centre and is opposite Balloch train station is proposed to house a cycling friendly hostel, brewery, restaurant and as well as public realm areas.

2.4.2 Sites B - Leven Riverfront

Located along the banks of the River Leven to the north of the Balloch Station Square area, this area is proposed to house a maximum of 43 high quality single storey lodges, picnic, BBQ and play areas as well as managed woodland areas.

2.4.3 Site C - The Pierhead

This area which is located around the existing Balloch Pier would be regenerated to be a visitor destination area. This would include an apart hotel with a maximum of 60 bedrooms, a water park, restaurant and visitor hub. This area would include high quality multi-user public realm.

2.4.4 Site D – Drumkinnon Woods & Bay

Within this area of the woods it is proposed to retain a large number of the existing trees, but also include the development of small accommodation lodges and woodland visitor attractions.

2.4.5 Site E - Woodbank Site

The Woodbank site would be developed for a mix of low density residential dwellings and visitor accommodation including up to 28 holiday lodges and the renovation of Woodbank House. The majority existing trees and woodland in this area would be retained.

3 ASSESSMENT OF FLOOD RISK

3.1 Previous Flooding Reports

3.1.1 River Leven Flood Study information and flood levels (Jacobs, 2009)

A hydraulic study of the River Leven has previously been undertaken by Jacobs which identified the potential flood risk from Loch Lomond and the River Leven along the full length of the river through the Vale of Leven. The original flood study was undertaken in 2001 and was then updated in 2003.

In December 2006, Loch Lomond experienced its highest recorded water level and this subsequently produced the highest flow in the River Leven at the Linnbrane gauging station, approximately 2km south downstream of the site. This event caused significant flooding in the areas surrounding the river. In 2009 the hydraulic model of the River Leven was updated to include more recent hydrological analysis as well as calibration of the model using the December 2006 event.

Plans showing the maximum modelled extents adjacent to the site from this river study are presented in Appendix C.

The results of the modelling identified peak water levels for a range of return periods. These peak levels for the three cross sections adjacent to the site at the head of the river as presented in Table 3.1 below.

Table 3.1 - Peak water levels from Jacobs Flood Study

Cross Section Reference	Peak Water Level (m AOD)				
	50% AEP	*10% AEP*	*1% AEP*	*0.5% AEP*	*0.5% AEP +CC*
XS_116	9.15	9.59	10.08	10.23	10.56
XS_227	9.15	9.59	10.08	10.24	10.57
XS_338	9.14	9.58	10.07	10.25	10.57
XS_412	9.13	9.57	10.06	10.22	10.55
XS_486	9.12	9.56	10.05	10.20	10.54
XS_579	9.11	9.55	10.03	10.19	10.53
XS_658	9.10	9.53	10.02	10.18	10.51
XS_749	9.08	9.52	10.01	10.16	10.50
XS_841US	9.07	9.50	9.99	10.14	10.48

This modelling has identified that the peak water levels in the 0.5% AEP+CC event range from 10.56-10.48 metres Above Ordnance Datum (mAOD) across the length of the development site.

3.1.2 Hydrological Update

Following the review of the Jacobs Flood Study, an assessment was then undertaken to determine whether the design flows derived in early 2009 remain valid taking into account more recent flow records since then. Additional flow data was requested from SEPA for the Linnbrane Gauging station on the River Leven, which was in the form of Annual Maximum (AMax) flow data and covered the period from 2000-2015. A copy of this up to date flow data, along with the previous AMax data is presented in Appendix D.

The modelling within the Jacobs report was calibrated based upon the peak flood event in 2006, and so any subsequent peak flow events since then may have had an impact upon the flow estimation for the River Leven.

Figure 3.1 illustrates the AMax flow data for the full records of the Linnbrane Gauging station and shows that since the event in 2006, there have been no significant flood events of a similar or greater magnitude. Additional information received as part of this update is highlighted in red in the graph below.

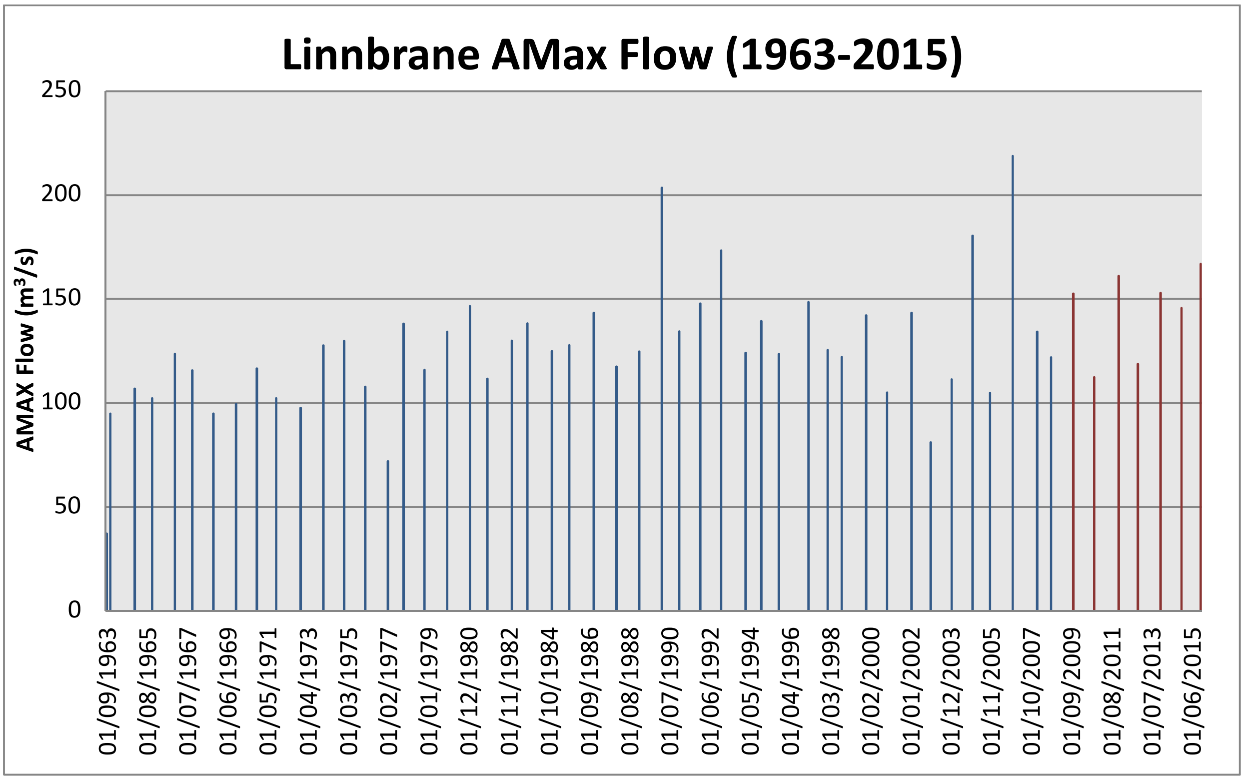

Figure 3.1 - AMax Flow from Linnbrane Gauging Station

The value of the median annual maximum flow (Qmed) from the dataset used in the Jacobs Flood Study in 2009 was estimated to be 124.173m^3/s, and with the additional years data included in the calculations the Qmed increased to 124.945m^3/s. This is an increase of only 0.6%. Applying the growth curve used in the Jacobs Flood Study to this revised figure of Qmed gives a difference in peak 0.5% AEP flow of 1.44m^3/s. Based upon the relationships within the Jacobs Flood Study and the previous modelling between the 0.5% AEP event and the 0.5% AEP+CC, where an additional 20% was added to the flows, the estimated impact on peak flood levels from the updated Qmed calculations is estimated to be only 2mm.

As the flood levels within the Jacobs report are listed to the nearest centimetre it is considered that this updated hydrological assessment will have no impact upon the peak levels listed within the Jacobs Flood Study, and so they would appear representative of the flood risk to the site at present.

In addition to the above hydrological update, further correspondence with SEPA identified that their hydrometry team has flagged concerns with relation to the gauged data due to lack of spot gauging data with which to validate the ratings curve, and that there may be areas of unstable bed which could skew the ratings curve. In order to provide more confidence in the flows used in our assessment we have undertaken additional hydrological analysis and compared this with both the data from the gauging station and the data within the Jacobs flood study. This is presented in Appendix F.

3.1.3 SEPA Flood Risk Management Strategy (2015)

Flood Risk Management Strategies (FRM Strategies) were published by SEPA in 2015[1] for each of the 14 Local Plan Districts within Scotland. These FRM Strategies identify the causes and consequences of flooding within the district areas, and locate the Potentially Vulnerable Areas (PVAs). Agreed objectives and flood risk management actions are also included in the strategies, and these form the basis of the Local Flood Risk Management Plans produced by each local authority within the districts.

Within the Clyde and Loch Lomond Local Plan District, *PVA 11/01 – Loch Lomond and Vale of Leven* was listed, which identified that a large number of residential and non-residential properties along the length of the River Leven were at risk of flooding.

This PVA also highlighted the objective to "Reduce the risk of flooding from the River Leven and Firth of Clyde to residential properties, non-residential properties and community facilities in Vale of Leven and Dumbarton."

3.1.4 Local Flood Risk Management Plan – Clyde and Loch Lomond Local Plan District (June 2016)

Based on the FRM Strategy noted above and the identified objectives, the Clyde and Loch Lomond Local Plan District published their Local Flood Risk Management Plan (LFRMP) in June 2016[2]. This LFRMP highlighted specific actions with relation to PVA 11/01 which were:

- Loch Lomond & Trossachs National Park are to lead a Natural Flood Management study (by 2019);
- West Dunbartonshire Council to study further feasibility of a flood protection scheme on River Leven, including the potential for additional flood storage in Loch Lomond utilising the existing barrage.

These future actions may potentially have impacts upon the development site on the shores of Loch Lomond, however it is not considered that they would result in additional flooding of properties.

3.1.5 SEPA Online Flood Maps[3]

The SEPA Flood Maps, available to view online, highlight that the development site at Balloch Pier and along the River Leven would be at risk of fluvial flooding during the 0.5% AEP event. Along the riverside area of the site, the SEPA flood maps indicate an estimated flood depth of 0.3-1m. Small areas of surface water flooding were also noted across the site, however these are considered to be low spots within the topography. It is noted that the SEPA Flood Maps are indicative and of a strategic nature, and so this assessment takes into account all available data in the assessment of flood risk.

3.2 Potential Sources of Flooding

Potential sources of flooding are summarised in Table 3.2 and are discussed in the following sections. For the purposes of this assessment the site has been split into the areas of the proposed development identified in section 2.4. The potential flood risk is then assessed as a whole for each of these areas.

[1] http://apps.sepa.org.uk/FRMStrategies/clyde-loch-lomond.html
[2] https://www.glasgow.gov.uk/CHttpHandler.ashx?id=33977&p=0
[3] http://map.sepa.org.uk/floodmap/map.htm

Table 3.2 - Summary of potential flood sources

Flood source or mechanism	Flood risk	Comments	Adopted measures
Tidal Flooding	No risk	Lowest ground level on site approx. 8.0-8.5mAOD, however site located approx. 6.5km from the tidal limit of the River Leven.	None
River Flooding	Medium to high risk In northeast of site	Area surrounding Pierhead, and at the north of the Leven Riverside site at risk during the 0.5% AEP event. Large majority of site not at risk.	Locating new development outwith the functional floodplain where possible, and raising of finished floor levels to be able peak flood levels, plus freeboard.
Surface Water Flooding	Low to medium	Some localised areas of flood risk identified on SEPA Maps.	Ensure appropriate surface water drainage installed, do not locate new development at localised low spots in the site, and elevate finished flood levels above the surrounding ground levels.
Groundwater flooding	Low	Limited information available, however risk across site considered to be low.	None
Sewer Flooding	Low	No records of sewer flooding on site. Large areas currently undeveloped (Drumkinnon Woods) and so unlikely to be at risk.	Ensure appropriate drainage network installed, and elevate finished flood levels above the surrounding ground levels.

3.3 Site A – New Station Square

This area of the site is considered to be at high risk of fluvial flooding from the River Leven to the east. Pluvial, coastal, groundwater and sewer flooding are considered to be a negligible risk in this location.

Based upon the Jacobs flood report (Jacobs, 2009), the peak water levels in a range of return periods would route out of bank and would affect a large portion of this site area. The peak water levels at the cross section adjacent to the site are presented in Table 3.3.

Table 3.3 - Peak water levels from Jacobs River Leven study

Return Period (% AEP)	Peak Flood Level (mAOD)
10	9.50
2	9.84
1	9.99
0.5+CC	10.48

The ground levels within this area of the site vary from approximately 11.45 mAOD adjacent to the existing tourist information centre, down to approximately 8.40 mAOD adjacent to the river banks and the jetty, however the areas of the jetty and riverbank are outwith the development boundary. The potential risk for flooding of the development site in this location is considered to be **high**.

3.3.1 Potential Mitigation

Due to the high risk of fluvial flooding, mitigation and flood protection measures are recommended for this area of the site. These include:

- Setting finished floor levels of any new buildings at a level above the 0.5% +CC AEP peak flood level plus an allowance for freeboard, typically taken as 600mm. This would be at 11.08 mAOD;
- Any existing buildings that are being retained/refurbished on site that are at a level which may be at risk of flooding could install property level protection, such as removable flood gates, or include flood resistant construction in any works undertaken.

3.4 Sites B – Along the Leven Riverfront

Along the western banks of the River Leven only a small strip of land is considered to be affected by potential fluvial flood flows. The fluvial flood risk in this area is therefore considered to be **medium/high**, however the flood risks from pluvial, groundwater and sewer flooding are considered to be low to negligible in this location.

Peak water levels in the river during the 0.5% +CC AEP event are estimated to be between 10.57 mAOD in the north through to 10.50 mAOD at the south of this site area. The ground levels along the top of the banks of the river, taken from the topographical survey, are approximately 10.5-11.0 mAOD along the full length of the site area. However the ground levels to the west of the banks are marginally lower by approximately 0.5m, meaning that should any flood waters overtop the banks they would inundate this area.

In the most northern part of site 3, where the footpath routes from the riverbanks through to the Loch Lomond Shores development and pierhead area, the maximum flood outline from the Jacobs flood study shows inundation during the 0.5%+CC AEP event. Based upon the surveyed levels, the maximum depth of flooding is estimated to be approximately 0.2-0.4m.

Within the area set back from the riverbank where the ground levels are marginally lower, there is the potential for ponding of surface water. It is not considered that this would be a high risk to any proposed developments as depths would likely be minimal and water would only pond within localised low spots.

3.4.1 Potential Mitigation

New development within this area of the site is recommended to be elevated at a level higher than the peak flood levels, plus freeboard, and so the finished floor levels are recommended to be at a level of 11.17 mAOD and above.

In order to prevent any surface water flooding of new development on site, suitable drainage should be provided across the site in order to collect and convey runoff, and any buildings should not be located within any localised low spots in the topography.

3.5 Site C – The Pierhead

The Pierhead area of the site is located on the shore of Loch Lomond, and so could potentially be affected by the rising water levels within the loch. The maximum recorded water level in Loch Lomond was 10.37 mAOD, which was recorded during the December 2006 flood event, and based upon the ground levels from the topographical survey, this would affect a large portion of this area of the site.

Ground levels to the east of the lagoon vary from 8.5 – 10.5 mAOD, and so should the water levels within the loch rise to these levels again, this area would be at **medium to high risk** of fluvial flooding.

The Jacobs flood study of 2009 also notes that this area would be at risk of flooding from the River Leven in the 0.2% AEP event, with flood waters routing west from the river should they overtop the banks. The high point in the ground within this area of the site is at the roundabout at the end of Ben Lomond Way, and along the road carriageway. Peak water levels in the 0.5% AEP event from this modelling were estimated to be 10.57 mAOD.

Surface water flood risk in this location is considered to be low due to the small catchment area for any rainfall runoff and the existing development on this area of the site already being served by drainage infrastructure such as road drainage.

Groundwater within this area of the site is likely to be the highest across the whole development area due to its proximity to both Loch Lomond and the River Leven, however it is not considered that groundwater flooding alone would be a high risk. Should the water levels in the loch and river rise, groundwater would likely rise as a consequence, but it is considered that fluvial flooding from the surface features would affect the site prior to any groundwater issues occurring.

3.5.1 Potential Mitigation

Within this area of the site it is proposed to locate an apart hotel, visitor hub and water park. Development should aim to avoid being located within the functional floodplain, which is defined as the extent of the 0.5% AEP event. The ground levels along Ben Lomond Way and the roundabout at its end are raised slightly higher than the surrounding ground in this site area, and so it is recommended that the hotel is situated adjacent to this, at an elevation greater than the peak flood levels.

Sustainable drainage systems (SuDS) would be required for the hotel and car parking within this area of the site, but these will also require to be located outwith the functional floodplain, and so features such as permeable paving would be unlikely to be acceptable.

Playground facilities and waterfront access may be located within the functional floodplain, however it is considered that this is acceptable providing that they are constructed using flood resilient materials, and would not be functional during times of extreme flood.

3.6 Site D – Drumkinnon Woods & Bay

Site D Drumkinnon Woods area is located immediately to the south of Ben Lomond Way, and to the west of Pier Road. The ground levels in this area undulate significantly, but in general the site slopes from the west to the east towards Pier Road, from a level of approximately 16 mAOD down to approximately 12 mAOD. Along the northern edge of this parcel of the site, the ground levels are significantly higher than on Ben Lomond Way at approximately 3m, rising to 5m in places. Due to these level differences and the elevation of the site, it is considered that the risk of fluvial flooding from the river or loch is low.

Due to the undulating ground topography in this area, there is the potential for surface water ponding at localised low spots. The SEPA Online Maps indicate some very localised areas which could potentially be at risk, and these are linked to the low points within the ground. As such, pluvial flooding in this area of the site is considered to be at **low to medium risk.**

The area of Site D surrounding Drunkinnon Bay to the northwest is proposed to be managed woodland with a pedestrian path network routing through it. Peak levels in Loch Lomond are estimated to be approximately 10.37m AOD and so an area of this woodland would be at high risk of flooding from Loch Lomond in the 0.5% AEP event. As no built development is proposed to be located within this area, and the land use is considered to be water compatible, no mitigation measures would be required.

3.6.1 Potential Mitigation

Due to the surface water flooding risk it is recommended that any new buildings or lodges are not located at low spots within the topography, and that the finished floor levels of buildings be raised above the surrounding ground. It should also be ensured that sufficient surface water drainage is provided to capture rainfall and runoff through this area.

3.7 Site E - Woodbank Site

SEPA's Online Flood Maps do not show any risk of fluvial flooding through this area of the site, however it should be noted that the maps do not show flooding from catchments smaller than 3km². Based upon the FEH web mapping (CEH 2015), the catchments of the watercourses flowing through this area are approximately 0.6-1.6km².

Detailed Ordnance Survey (OS) mapping indicated that there are 3 watercourses which run through this part of the site, however during the site walkover only two were noted as having significant flows, as detailed in section 2.3.2.

The unnamed watercourse 1 which flows along the north of the Woodbank site runs in a steeply sloping channel within a defined channel corridor. Photograph 1 in Appendix B shows the watercourse in this location. The watercourse then passes below Old Luss Road in a small stone culvert which was estimated to be approximately 0.35-0.4m wide by approximately 0.6-0.7m high. Although the flows may not be large within the burn during storm events, there is the possibility of the small culvert becoming blocked with debris and restricting the flows. Should flows back up from this culvert, they would inundate the area surrounding the culvert inlet until they overtopped onto the road above. A stone wall is located above the right bank, along the northern boundary of the Woodbank site, which would prevent flows from routing into the development site, and would direct flows onto Old Luss Road. Once on the road they would route in a south-easterly direction with the fall in the road, however they would not route into the site due to the stone wall continuing around its boundary.

The unnamed watercourse 2 flows through the south east corner of the site, in a northerly direction. The watercourse routes from the caravan park to the east, and is culverted beneath Lower Stoneymollan Road in a twin pipe arrangement, estimated to be approximately 0.5-0.6m in diameter (each barrel). The burn then flows in a straightened canalised section with stone walls on either bank until it reaches Old Luss Road.

The inlet to this culvert beneath Old Luss Road was submerged during the site walkover and so no dimensions could be taken, however the banks on either side at this location were approximately 1m high. A stone wall is located above the culvert inlet, along the length of Old Luss Road, and this would prevent any flows which may back up at this culvert from routing onto the road.

Should the culvert become blocked it is anticipated that flows would accumulate around the inlet and spill into both the Woodbank site, and also into the existing residential gardens to the east before escaping through these gardens due to the general topography. Due to the sloping nature of the Woodbank site, it is not considered that flooding would extend far into the site and so only a small corner of the development area may potentially be affected.

With regards to both watercourses noted on site, the fluvial flood risk is therefore considered to be **low to medium**.

The site slopes relatively steeply in an easterly direction, and surface water ponding was not evident during the site walkover. To the west of the site the ground rises sharply towards the A82, however this is covered by dense woodland and so runoff from this area is not likely to be in large volumes. Therefore surface water flood risk to the Woodbank site is considered to be low.

3.7.1 Potential Mitigation

Although the flood risk to the site is considered to be generally low, the risk of blockage at the culvert beneath Old Luss Road on unnamed watercourse 2 could mean that a small area of the site may be at risk of inundation. As such it is recommended that no development is located immediately adjacent to this watercourse and the culvert inlet, and a buffer of at least 5m is maintained. This buffer is required for all development adjacent to waterbodies, however in this location, if feasible, this buffer should be maximised. This will ensure that any new development would not be affected by the watercourse, and conversely the development would have no impact upon the water environment.

Additionally it may be beneficial to ensure the inlet arrangement to the culvert beneath Old Luss Road for the unnamed watercourse 2, includes measures to prevent blockages, such as a trash screen to trap debris. This would aim to ensure that the culvert pipes below the road would not become blocked and would reduce the fluvial flood risk to both the new site and the adjacent existing properties.

With regards to surface water on the site, it is recommended that cut off drains could be located along the western, upslope boundary of the site in order to capture any overland flows which may route onto the site, and appropriate surface water drainage will also be required within the site to manage any flows generated from the new development.

4 CONCLUSIONS

This flood risk assessment was undertaken for the proposed development of a mix of leisure uses, tourism related retail and holiday accommodation on the shores of Loch Lomond, Balloch, West Dunbartonshire. A walkover survey, together with a desktop assessment and review of previous studies associated with the site were all undertaken to assess the flood risk from fluvial, pluvial, coastal and groundwater sources.

The assessment has identified that the areas in the northeast of the site adjacent to the head of the River Leven and Loch Lomond would be at risk of fluvial flooding during the 0.5% AEP event, and the area surrounding the existing tourist information centre is located immediately adjacent to the 0.5% AEP flood extents. Potential mitigation measures have been identified, including locating the development outwith any floodplains, raising of finished floor levels above the surrounding ground and constructing effective drainage and appropriate landscaping to direct any flooding away from buildings.

Surface water flooding may affect some localised low points on site, but this risk can be managed through the provision of appropriate sustainable drainage systems (SuDS) and landscaping.

REFERENCES

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APPENDICES

A ANNUAL EXCEEDANCE PROBABILITY-RETURN PERIOD CONVERSION

Table A1: Relationship between annual exceedance probability and return periods

Annual exceedance probability, AEP (%)	Return period, T (year)	Probability of occurrence over a 50 year period (%)	Comment
50	2	100	Median annual flood, in the long-term this occurs every other year, on average.
20	5	100	
10	10	99	
5	20	92	
3.3	30	82	Typical design standard for urban drainage systems.
2	50	64	
1	100	39	
0.5	200	22	Typical design conditions standard for river or coastal flooding for most developments. Defines “functional floodplain” under Scottish Planning Policy.
0.2	500	10	
0.1	1,000	4.9	Typical design conditions standard for sensitive or vulnerable developments/contexts.

The annual exceedance probability of particular flood conditions is the chance these conditions (or more severe) occur **in any given year**.

The return period of a flood is the **long-term average** period between flood conditions of such magnitude (or greater).

B SITE PHOTOGRAPHS

Number	Photo	Description
1		Unnamed watercourse 1 to the west of the site, north of the Woodbank site. Looking west towards the A82.
2		Small culvert below Old Luss Road routing the above watercourse below the road towards Drumkinnon Cottages.

Number	Photo	Description
3		Looking northwest across Woodbank site.
4		Unnamed watercourse passing beneath Lower Stoneymollan Road. Looking South.

Number	Photo	Description
5		Unnamed watercourse downstream of Lower Stoneymollan Road. Routing along the eastern boundary of the Woodbank site, looking north (downstream).
6		Unnamed watercourse downstream of the culvert beneath Old Luss Road as it routes towards the existing Loch Lomond Shores car park. Looking north.

Number	Photo	Description
7		Unnamed watercourse as it routes towards Loch Lomond Shores car park and passes beneath access road. Bank heights are approximately 2m on both sides at this point.
8		Unnamed watercourse as it flows through the car park area. Looking northwest (downstream).

Number	Photo	Description
9		Unnamed watercourse to the northwest of the Loch Lomond Shores development as it routes to its outfall into the loch. Looking northeast (downstream).
10		Southern shore of Loch Lomond adjacent to the Sea Life Centre. Looking west.

Number	Photo	Description
11		Looking northwest along the shore of the loch in the Shore area of the development.
12		Head of the River Leven where it flows from Loch Lomond to the north. Looking north.

Number	Photo	Description
13		Looking downstream along the River Leven from the Pierhead area of the site.
14		Looking north along footpath running parallel with the River Leven. This is within the 'Leven Riverfront' area of the site.
15		Looking north from the Balloch Station area of the site, along the corridor of the River Leven area.

Number	Photo	Description
16		Slipway and jetty on the River Leven adjacent to the Balloch Station site area. Looking south.
17		Looking north along Pier Road with the lower ground to the east alongside the River Leven.

Number	Photo	Description
18		Undulating ground in the Drumkinnon Woods area of the site. Looking south.
19		River Leven Barrage which is used to controls water levels within Loch Lomond and in the River Leven. Looking downstream.

C RIVER LEVEN FLOOD STUDY (JACOBS, 2009) – FLOOD EXTENTS PLANS

Drawing number / Rev
B1888300-LP-001

Key

- 1% AEP (100 year return period)
- 0.5% AEP (200 year return period)
- 0.2% AEP (500 year return period)
- New Flood Wall
- New Flood Embankment
- 0.5m Depth of water for 1%AEP

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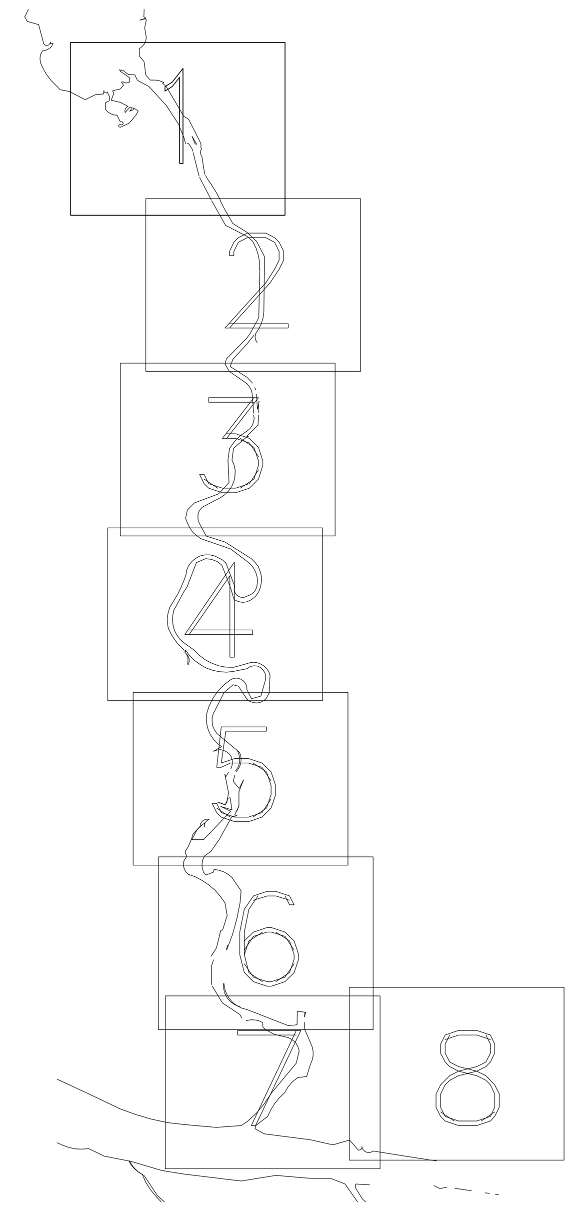
2. The extent of inundation is indicative only, and is based on limited ground level survey information.



Rev	Rev. Date	Purpose of revision	Drawn	Checked	Approved
0	DEC 08	REVIEW OF FIRST ISSUE	DL	JS	BS

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Project
RIVER LEVEN FLOOD STUDY
REVIEW & UPDATE OF ORIGINAL WORK

Drawing title
LOCATION PLAN AND
INDICATIVE EXTENT OF INUNDATION AND
LOCATION OF POSSIBLE FLOOD DEFENCES
SHEET 1 OF 8

Drawing status

Scale	1:2500 @ A1	DO NOT SCALE
Jacobs No.	B1888300	
Client no.		

Drawing number: B1888300-LP-001 Rev: 0

- C:\surveys\Birol\Leven_PLOT\B1888300-LP-001.dwg - 26/01/2009 14:49 - 1 - laddd

Predicted Peak Water Level (mAOD)

Node	50%AEP Q&T	20%AEP Q&T	10%AEP Q&T	4%AEP Q&T	2%AEP Q&T	1%AEP Q&T	0.5%AEP Q&T	0.2%AEP Q&T	0.5%AEP+CC Q&T	0.5%AEP+ Narrow Channel	0.5%AEP Q&T
XS_0	9.17	9.45	9.62	9.81	9.96	10.11	10.27	10.48	10.61		10.27
XS_116	9.15	9.43	9.59	9.78	9.93	10.08	10.23	10.44	10.56		10.23
XS_227	9.15	9.43	9.59	9.78	9.93	10.08	10.24	10.45	10.57		10.24
XS_338	9.14	9.42	9.58	9.77	9.92	10.07	10.23	10.44	10.57		10.23
XS_412	9.13	9.41	9.57	9.76	9.91	10.06	10.22	10.43	10.55		10.22
XS_486	9.12	9.40	9.56	9.75	9.90	10.05	10.20	10.41	10.54		10.20
XS_579	9.11	9.38	9.55	9.74	9.89	10.03	10.19	10.40	10.53		10.19
XS_658	9.10	9.37	9.53	9.73	9.87	10.02	10.18	10.39	10.51		10.18
XS_749	9.08	9.36	9.52	9.71	9.86	10.01	10.16	10.37	10.50		10.16
XS_841US	9.07	9.34	9.50	9.69	9.84	9.99	10.14	10.35	10.48		10.14
XS_841DS	9.06	9.33	9.49	9.68	9.83	9.98	10.13	10.34	10.46		10.13
XS_968	9.04	9.31	9.47	9.66	9.80	9.94	10.10	10.31	10.43		10.10
XS_1039U	9.01	9.29	9.44	9.63	9.77	9.91	10.06	10.26	10.39		10.06
XS_1039D	9.01	9.28	9.43	9.62	9.76	9.90	10.05	10.25	10.38		10.05
XS_1136	8.98	9.25	9.41	9.59	9.73	9.87	10.02	10.22	10.34		10.02
XS_1136U	8.91	9.19	9.34	9.53	9.67	9.80	9.95	10.15	10.27		9.95
XS_1136D	8.90	9.17	9.32	9.51	9.65	9.78	9.92	10.12	10.22		9.94
XS1	8.89	9.16	9.31	9.49	9.63	9.76	9.91	10.10	10.20		9.91
XS2	8.85	9.14	9.30	9.48	9.62	9.76	9.91	10.10	10.21		9.91
XS3	8.63	8.90	9.05	9.22	9.35	9.47	9.61	9.78	9.88		9.61
XS4	8.52	8.81	8.96	9.14	9.27	9.40	9.54	9.72	9.82		9.54
XS5	8.38	8.68	8.84	9.03	9.16	9.30	9.44	9.63	9.73		9.44
XS6	8.27	8.57	8.74	8.92	9.06	9.20	9.34	9.53	9.63		9.34
XS7	8.16	8.46	8.63	8.81	8.95	9.09	9.24	9.42	9.53		9.24
XS8	8.03	8.32	8.50	8.68	8.82	8.96	9.10	9.28	9.37		9.10
XS9	7.89	8.18	8.36	8.55	8.70	8.84	8.98	9.16	9.25		8.98
XS10	7.83	8.10	8.28	8.47	8.62	8.76	8.90	9.08	9.17		8.90
XS11	7.76	8.05	8.23	8.43	8.58	8.72	8.87	9.06	9.16		8.87
XS12	7.69	7.97	8.15	8.35	8.50	8.64	8.79	8.97	9.06		8.79
XS13	7.65	7.93	8.11	8.32	8.46	8.61	8.76	8.94	9.04		8.76
XS14	7.61	7.89	8.07	8.27	8.42	8.57	8.72	8.91	9.00		8.72
XS15	7.52	7.79	7.96	8.15	8.29	8.43	8.57	8.74	8.82		8.57

Predicted Peak Water Level (mAOD)

Node	50%AEP Q&T	20%AEP Q&T	10%AEP Q&T	4%AEP Q&T	2%AEP Q&T	1%AEP Q&T	0.5%AEP Q&T	0.2%AEP Q&T	0.5%AEP+CC Q&T	0.5%AEP+ Narrow Channel	0.5%AEP Q&T
XS16	7.35	7.62	7.78	7.96	8.10	8.24	8.38	8.54	8.62		8.38
XS17	7.25	7.52	7.67	7.84	7.98	8.12	8.26	8.43	8.51		8.26
XS18	7.07	7.34	7.48	7.65	7.78	7.91	8.05	8.22	8.30		8.04
XS19	7.01	7.30	7.44	7.62	7.73	7.84	7.97	8.13	8.21		7.97
XS20	6.92	7.21	7.35	7.53	7.66	7.79	7.94	8.13	8.22		7.94
XS21	6.74	7.04	7.18	7.35	7.47	7.59	7.74	7.93	8.02		7.74
XS22	6.55	6.85	6.97	7.12	7.21	7.30	7.41	7.56	7.63		7.41
XS23	6.39	6.71	6.81	6.94	7.03	7.12	7.22	7.35	7.42		7.21
XS24	6.35	6.67	6.78	6.91	7.00	7.09	7.19	7.32	7.39		7.18
XS25	6.26	6.63	6.76	6.90	7.01	7.11	7.22	7.38	7.45		7.22
XS26	6.17	6.52	6.65	6.80	6.91	7.01	7.13	7.29	7.36		7.13
XS27	6.03	6.34	6.45	6.59	6.69	6.78	6.88	7.01	7.08		6.88
XS28	5.88	6.23	6.34	6.50	6.60	6.70	6.82	6.98	7.05		6.82
XS29	5.82	6.19	6.31	6.47	6.57	6.68	6.81	6.96	7.04		6.80
XS30	5.74	6.08	6.20	6.36	6.46	6.57	6.71	6.87	6.95		6.70
XS31	5.58	5.91	6.03	6.19	6.28	6.40	6.55	6.74	6.82		6.55
XS32	5.39	5.65	5.76	5.89	5.97	6.06	6.18	6.34	6.43		6.18
XS33	5.32	5.53	5.63	5.74	5.80	5.86	5.93	6.04	6.10		5.93
XS34	5.20	5.39	5.48	5.57	5.60	5.64	5.69	5.76	5.80		5.69
XS35	5.11	5.27	5.34	5.43	5.44	5.47	5.50	5.57	5.62		5.50
XS36	5.06	5.24	5.32	5.44	5.46	5.49	5.54	5.66	5.73		5.54
XS37	4.97	5.20	5.33	5.49	5.52	5.57	5.64	5.77	5.84		5.64
XS38	4.87	5.06	5.15	5.26	5.38	5.49	5.62	5.77	5.85		5.62
XS39	4.63	4.90	5.05	5.22	5.36	5.48	5.61	5.77	5.85		5.62
XS40	4.62	4.87	5.02	5.21	5.35	5.47	5.60	5.77	5.85		5.61
XS41	4.46	4.75	4.94	5.16	5.30	5.44	5.58	5.75	5.83		5.59
XS42	4.36	4.65	4.84	5.08	5.22	5.36	5.50	5.68	5.77		5.51
XS43	4.29	4.51	4.67	4.89	5.03	5.19	5.33	5.52	5.62		5.34
XS44	4.23	4.46	4.61	4.80	4.92	5.04	5.17	5.34	5.43		5.19
XS45	4.03	4.27	4.44	4.65	4.78	4.92	5.04	5.21	5.29		5.06
XS46	3.94	4.19	4.35	4.57	4.71	4.85	4.97	5.14	5.21		5.00
XS47	3.91	4.14	4.31	4.52	4.66	4.80	4.93	5.09	5.17		4.95

Predicted Peak Water Level (mAOD)

Node	50%AEP Q&T	20%AEP Q&T	10%AEP Q&T	4%AEP Q&T	2%AEP Q&T	1%AEP Q&T	0.5%AEP Q&T	0.2%AEP Q&T	0.5%AEP+CC Q&T	0.5%AEP+ Narrow Channel	0.5%AEP Q&T
XS48	3.77	4.01	4.17	4.37	4.50	4.63	4.75	4.89	4.96		4.81
XS49	3.67	3.89	4.04	4.24	4.36	4.48	4.57	4.69	4.75		4.69
XS50	3.58	3.79	3.93	4.14	4.26	4.42	4.55	4.71	4.79		4.70
XS51	3.50	3.70	3.84	4.03	4.15	4.29	4.40	4.54	4.60		4.60
XS52	3.48	3.68	3.83	4.03	4.15	4.19	4.29	4.44	4.52		4.57
XS53	3.46	3.66	3.82	4.02	4.14	4.18	4.26	4.37	4.50		4.48
XS54	3.45	3.66	3.82	4.01	4.13	4.18	4.25	4.37	4.50		4.48
XS55	3.44	3.65	3.81	4.01	4.13	4.17	4.25	4.36	4.49		4.44
XS56	3.43	3.64	3.80	4.00	4.12	4.17	4.25	4.36	4.49		4.39
XS57	3.41	3.63	3.79	3.99	4.11	4.16	4.24	4.35	4.48		4.24
XS58	3.40	3.62	3.79	3.99	4.12	4.16	4.24	4.35	4.49		4.29
XS59	3.40	3.62	3.79	3.99	4.11	4.16	4.24	4.35	4.48		4.27
XS60	3.40	3.62	3.79	3.99	4.12	4.16	4.24	4.35	4.49		4.29
XS61	3.39	3.62	3.79	3.99	4.11	4.16	4.24	4.35	4.48		4.27
XS62	3.38	3.61	3.78	3.98	4.11	4.15	4.23	4.34	4.48		4.24
XS63	3.38	3.61	3.77	3.97	4.10	4.14	4.23	4.33	4.47		4.24
XS64	3.37	3.60	3.76	3.96	4.09	4.13	4.23	4.33	4.46		4.24
XS65	3.36	3.59	3.76	3.95	4.08	4.13	4.22	4.32	4.46		4.22
XS66	3.35	3.58	3.74	3.94	4.07	4.11	4.21	4.32	4.45		4.21
XS67	3.34	3.57	3.74	3.93	4.06	4.11	4.21	4.31	4.45		4.21
XS69	3.33	3.56	3.72	3.92	4.05	4.10	4.20	4.31	4.44	4.20	4.20
XS70	3.31	3.54	3.71	3.90	4.04	4.09	4.19	4.30	4.43	4.20	4.19
XS73	3.27	3.50	3.67	3.87	4.00	4.06	4.15	4.25	4.39	4.15	4.15
XS74	3.26	3.49	3.66	3.86	4.00	4.05	4.14	4.24	4.38	4.14	4.14
XS75	3.25	3.48	3.65	3.85	3.99	4.04	4.13	4.23	4.37	4.13	4.13
XS76	3.24	3.47	3.64	3.84	3.98	4.03	4.12	4.22	4.36	4.12	4.12
XS77	3.24	3.47	3.64	3.84	3.98	4.03	4.12	4.22	4.36	4.12	4.12

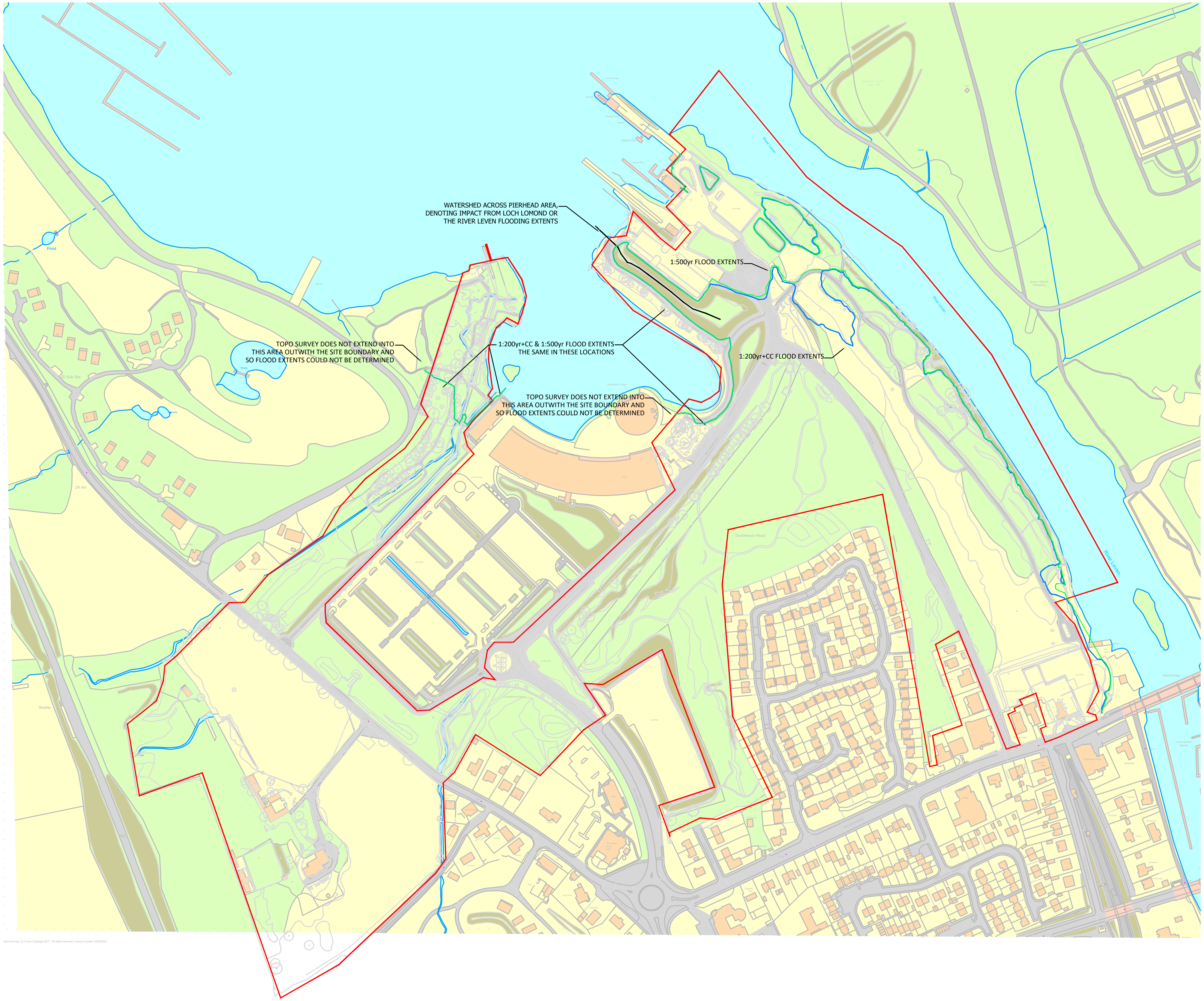
3.24	indicates that the water level is determined by the tide only
4.60	indicates that the water level is determined by the tide and the flow
9.17	indicates that the water level is determined by the flow only

D RIVER LEVEN UPDATED HYDROLOGICAL CALCULATIONS

Time stamp	AMax [m^3/s]
30-Sep-63	37.265
25-Nov-63	94.977
17-Jan-65	107.01
02-Nov-65	102.306
19-Dec-66	123.705
27-Oct-67	115.714
20-Oct-68	94.977
12-Nov-69	99.529
05-Nov-70	116.7
22-Oct-71	102.306
13-Dec-72	97.697
30-Jan-74	127.79
31-Jan-75	129.855
23-Jan-76	107.962
10-Feb-77	72.058
10-Nov-77	138.261
18-Nov-78	116.009
10-Dec-79	134.344
03-Jan-81	146.683
27-Nov-81	111.808
12-Jan-83	130.126
19-Oct-83	138.447
08-Dec-84	124.991
07-Oct-85	127.916
05-Dec-86	143.398
13-Jan-88	117.524
07-Feb-89	124.9
11-Mar-90	203.581
06-Jan-91	134.59
08-Jan-92	147.929
24-Jan-93	173.425
14-Mar-94	124.173
13-Dec-94	139.489
27-Oct-95	123.629
02-Mar-97	148.608
16-Feb-98	125.629
25-Oct-98	122.182
09-Dec-99	142.154
13-Dec-00	105.156
12-Feb-02	143.398
28-Jan-03	81.082
13-Jan-04	111.363

10-Jan-05	180.584
12-Nov-05	104.901
14-Dec-06	218.845
01-Feb-08	134.365
26-Oct-08	122.029
27-Nov-09	152.652
13-Nov-10	112.453
05-Jan-12	161.108
31-Dec-12	118.784
04-Jan-14	152.926
15-Jan-15	145.763
10-Dec-15	166.972

E 0.5% AEP FLOOD EXTENTS PLAN



Notes

LEGEND

1 IN 200yr + 20%CC FLOOD EXTENTS

1 IN 500yr FLOOD EXTENTS

SITE BOUNDARY

Do not scale this drawing

Rev	Date	Amendment	Initials

ENVIRO Centre
Craighall Business Park, Eagle Street, Glasgow, G4 9XA
Tel: 0141 341 5040
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Client
TSL Contractors Limited

Project
West Riverside Balloch

Title
Figure 11.2
Combined Flood Extents Map

Status
FINAL

Drawing No.
168659-018

Revision

File path: k:\168659j riverside west\drgs\cad

Scale
1:4000

A3

Date
Jan 2018

Drawn
DW

Checked
LL

Approved

F ADDITIONAL HYDROLOGICAL ANALYSIS

West Riverside Hydrological analysis

1.1 Introduction

Further to the Flood Risk Assessment that was undertaken in July 2017 (EnviroCentre report no: 7621), and meetings between Peter Brett Associates and SEPA, there were concerns raised by SEPA regarding the gauged data used within the previous modelling (Jacobs, 2009), and the confidence in the results output from this.

It was proposed that to provide confidence in the gauged data, and with the results from the Jacobs study, additional hydrological analysis would be undertaken, and this technical note covers the outputs from this analysis.

1.2 Linnbrane Gauging Station

The SEPA gauging station No. 85001 (Leven @ Linnbrane) is located approximately 1.3km downstream on the River Leven from the Loch Lomond Barrage at Balloch. The size of the catchment at the gauging station is 786.1 km2 with the predominant feature being Loch Lomond. The station uses a velocity-area relationship to determine flows in a channel approximately 35 m wide. The flow regime was natural until loch outfall control weir was built in 1971, it is now substantially regulated during summer. The Barrage does not operate in winter, and does not affect high flows. The normal surface area of Loch Lomond is estimated at 70 – 71 km^2.

Figure 1.1 shows the overview of the location of the Loch Lomond and River Leven catchment at Linnbrane, it is shaded light semi-transparent grey. It stretches from Crianlarich in the north to Stirling in the east to Dumbarton in the south.

Figure 1-1: Overview of the Loch Lomond & River Leven catchment Linnbrane

1.2.1 Gauging Station Limitations

SEPA's Hydrometry team have flagged concerns with relation to the gauged data from the Linnbrane station due to lack of spot gauging data with which to validate the ratings curve, and that there may be areas of unstable bed which could skew the ratings curve.

SEPA have installed new equipment at the gauge, but this has only been in place for a short period and so this will take another few years to gather enough data to be able to calibrate it sufficiently.

In order to improve confidence in the flow data used within the flood risk assessment, additional hydrological analysis has been undertaken.

1.3 Flood Frequency & Flow magnitude Estimation

For the purposes of the proposed development it is required to estimate the flows corresponding to various flood frequencies in order to predict the probable flood levels and therefore aerial extents. Annual maximum (AMAX) flow data at Linnbrane gauging station (85001) was requested from SEPA. The flow estimations will be affected by the presence of a large loch upstream which would affect the outflows by delaying the arrival of peak flows which will also be naturally attenuated as they are routed through the loch-reservoir. For this station this is complicated further because the outflows from Loch Lomond are regulated in summer by the River Leven Barrage. Therefore, rainfall-runoff methods that are purely based on catchment descriptors would tend to deviate quite substantially from the observed or gauged flows.

The above notwithstanding, it was decided to estimate flows using Flood Estimation handbook (FEH) methods that SEPA approves of in order to carry out a comparative analysis in selecting the flows to be used for estimating flood levels with more confidence. Invariably, all the methods do use catchment descriptors (CDs) in some way, either quantitatively or qualitatively. Therefore, the FEH Web Service (CEH, 2015) was utilised to obtain the necessary CDs. FEH vol. 4 restates and shows situations in which the Flood Studies Report (FSR) rainfall-runoff (R-R) method can be applied. In Section 7.3.2 FEH (vol. 4) states the following: "*Where there is a real choice between the FSR R-R method and the statistical approach, the decision is a matter of judgement and in many cases users will wish to consider both. Indeed, for practical application, it is often necessary to reconcile, over the return periods of interest, the flood frequency curve synthesised by the FSR R-R method, preferably augmented by flood event analysis, with that observed or synthesised by statistical techniques*."

For determining flood levels for the site of interest, which is on the southwestern shores of Loch Lomond, the following three FEH methodologies have been adopted.

1. WINFAP FEH Single Site analysis;
2. WINFAP FEH Pooled Site analysis; and
3. FSR Rainfall-Runoff analysis.

The first two are statistical techniques while the 3rd uses CDs to derive certain critical parameters like time-to-peak to synthesise a flood hydrograph. The FSR R-R has an in-built benefit of including the lag time due to the reservoir to allow for some of the flood water going into storage before flowing out, however as noted above the outputs from this are likely to be affected by the restricted flows from the loch from the River Leven Barrage.

1.3.1 WINFAP Single Site Analysis

Using the WINFAP FEH 4 software, the AMAX flow data that was requested and obtained from SEPA, which was 54 years long was analysed to produce a flood frequency curve. Two distributions, the Generalised Logistic

(GL), which is considered suitable for most of the UK flow data and the Generalised Extreme Value (GEV) distribution, which often produces good results were used to provide an internal check of the analysis outcome. Some of the relevant output print outs from this analysis are included in Appendix B.

1.3.2 WINFAP Pooled Analysis

Using the WINFAP FEH 4 software, the same AMAX flow data that was requested and obtained from SEPA, which was 54 years long for the Linnbrane gauging station was pooled together with other similar stations based on their CDs to create a longer AMAX series of up to 500 years. This is an enhanced pooled analysis as it included the subject site's record in the analysis. Similarly, a flood frequency curve was accordingly produced using the same two distributions, GL and GEV. Again, some of the relevant output print outs from this analysis are included in Appendix C.

1.3.3 FSR Rainfall-Runoff Analysis

Design flood estimation using the FSR R-R method involves applying and appropriate design storm and associated antecedent conditions to a unit hydrograph and losses model of the catchment. It is appreciated that the presence of the Loch Lomond reservoir can lead to some difficulties in methodology. The effect of the reservoir is to lag (i.e. delay) and attenuate (i.e. reduce the amplitude, whilst maintaining the volume) the flood hydrograph from the catchment. For more information on the application of this method to reservoired applications reference can be made to FEH (vol. 4) Chapter 8. Suffice to state here that in reservoired applications, the design storm duration (D) is extended by adding the reservoir response time RLag to the catchment response time or time-to-peak, T_p. Where there is no reservoir $D = T_p(1+SAAR/1000)$; and with reservoir $D = (T_p + RLag)(1+SAAR/1000)$.

In the absence of the exact relationship between the storage in the Loch Lomond and outflow to carry out full reservoir routing calculations, a simplified approach has been used. The estimated surface area of Loch Lomond is approximately 70 km² (70*10^6 m²). An increase in the loch water level of 0.1 m (10 cm) will increase the volume stored by 7*10^6 m². The max peak flow at Linnbrane recorded on 14/12/2006 is 218.8 m³/s. Routing this rate of inflow into the loch to determine how long it will take to raise the water level in the Loch Lomond by 0.1 m as a measure of the minimum Rlag between the peak inflow hydrograph and peak of attenuated outflow hydrograph. This results in Rlag of 8.9 hours as a starting point. In reality an event of such magnitude is likely to result in a bigger change in the storage level which will take much longer than 9 hours to realise. The River Leven Barrage is designed to regulate water levels in Loch Lomond between 7 mAOD (min) and 7.6 mAOD (max), according to a SEPA document[1], which represents a change in the water level of 0.6 m.

For normal or regular flows it will take much longer than 9 hours to produce an increase of 0.1 m in the water level. For instance, for a QMED flow of 125 m³/s to produce 0.1 m in the water level, it will take approximately 15.6 hours. Consequently, the Rlag was set to 16 hours. The FSR R-R analysis was then carried out for a winter rainfall profile. It was observed that the FSR R-R values were significantly higher than their corresponding counterparts. To allow for a more realistic comparison the peak flows of the FSR R-R were rescaled using the ratio of the QMED (data) to the 2-year FSR R-R peak flow of 0.6883 as a scaling factor to the peak flows for all return periods.

[1]*Loch Lomond & Vale of Leven PVA (11/01) - Clyde & Loch Lomond, p.23.*

1.3.4 Comparison

From the two WINFAP analyses, both the GL and GEV distributions fitted the plot data reasonably well, but overall, the GL produce a better fit than the GEV, especially for higher return period events. Therefore, the peak flood flows produced by the GL frequency curve are used for comparison. The resulting flows obtained for all three methodologies, along with the flows used in the Jacobs study, are summarised in Table 1.1, which presents flood peak flows or design flows for a number of annual exceedance probabilities (AEP) corresponding to return periods of interest. Potential change in stream flows with climate change (CC) is normally accounted for by increasing the present 1 in 200 year (0.5% AEP) flood event flow by 20%, as standard for the UK (SEPA, 2015). Therefore, Table 1 also includes the 0.5% +CC flow estimate which is an increase of 20% over the 0.5% AEP flows.

Table 1-1: Estimated summer peak flood flow rates

Return period (years)	Annual Exceedance Probability (%)	Peak Flood Flows (m^3/s)			
		Jacobs Flood Study (2009)	WINFAP Single-site analysis	WINFAP Pooled analysis	FSR Rainfall-Runoff analysis (rescaled)
2	50	*123*	125.0	125.0	125.0
5	20	*146*	146.9	149.1	165.5
10	10	*161*	161.7	165.8	193.4
25	4	*180*	181.8	189.0	227.9
50	2	*196*	198.3	208.1	256.9
100	1	*213*	216.0	229.2	283.5
200	0.5	*231*	235.4	252.4	311.3
500	2	*257*	263.8	287.1	359.1
200 + CC	0.5 + CC	*277.2*	282.5	302.9	373.5

On comparison of the flow estimates obtained by the three methodologies, it is apparent that the flows derived by the FSR R-R approach are consistently higher than for the two statistical approaches, which compare reasonably well. The FSR R-R flows would be considered to be outliers and would serve only as the upper bound for sensitivity checks. Comparing the WINFAP estimates with the flows used within the Jacobs flood study, they also appear to tie up reasonably well, with only a marginal increase in flows in the more conservative Pooled analysis.

From the Jacobs flood study, an analysis of the relationship between peak flows and peak water levels has been undertaken to determine the impact of increasing flows on the peak water levels at differing return periods. Based upon this, the peak water levels in the 200 yr+CC event only increase by 30-40 mm with the Single Site analysis and up to 180mm for the Pooled Analysis. Based upon the topography of the site and the previously plotted flood extents, this would only have the impact of offsetting the maximum flood extents by approximately 1-3m in some localised areas within the site. The proposed masterplan has been developed to ensure that all new development is outwith the functional floodplain, and building finished floor levels have a minimum level of 11m AOD across the site.

A copy of the flood extents plan showing the 1 in 200 year+CC and 1:500 year extents is included within Appendix D.

APPENDICES

A ANNUAL EXCEEDANCE PROBABILITY-RETURN PERIOD CONVERSION

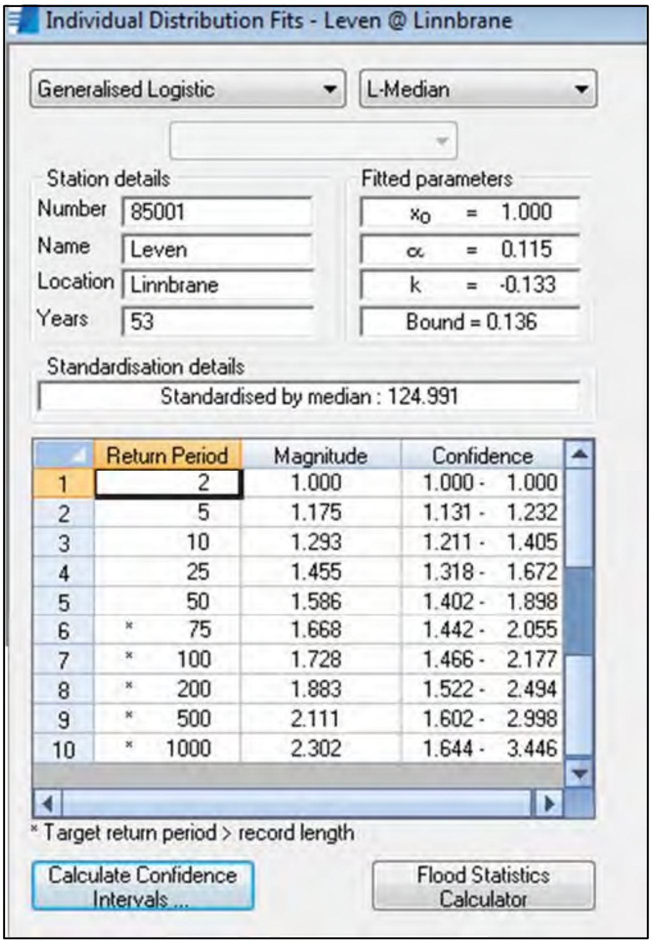
Relationship between annual exceedance probability and return periods

Annual exceedance probability, AEP (%)	Return period, T (year)	Probability of occurrence over a 50 year period (%)	Comment
50	2	100	Median annual flood, in the long-term this occurs every other year, on average.
20	5	100	
10	10	99	
5	20	92	
3.3	30	82	Typical design standard for urban drainage systems.
2	50	64	
1	100	39	
0.5	200	22	Typical design conditions standard for river or coastal flooding for most developments. Defines “functional floodplain” under Scottish Planning Policy.
0.2	500	10	
0.1	1,000	4.9	Typical design conditions standard for sensitive or vulnerable developments/contexts.

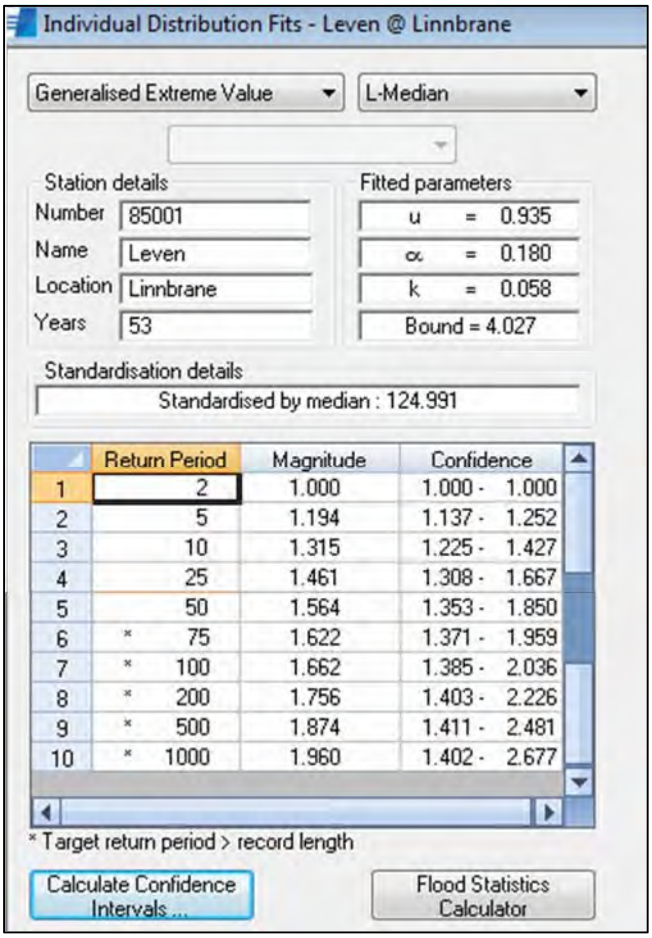
The annual exceedance probability of particular flood conditions is the chance these conditions (or more severe) occur **in any given year**.

The return period of a flood is the **long-term average** period between flood conditions of such magnitude (or greater).

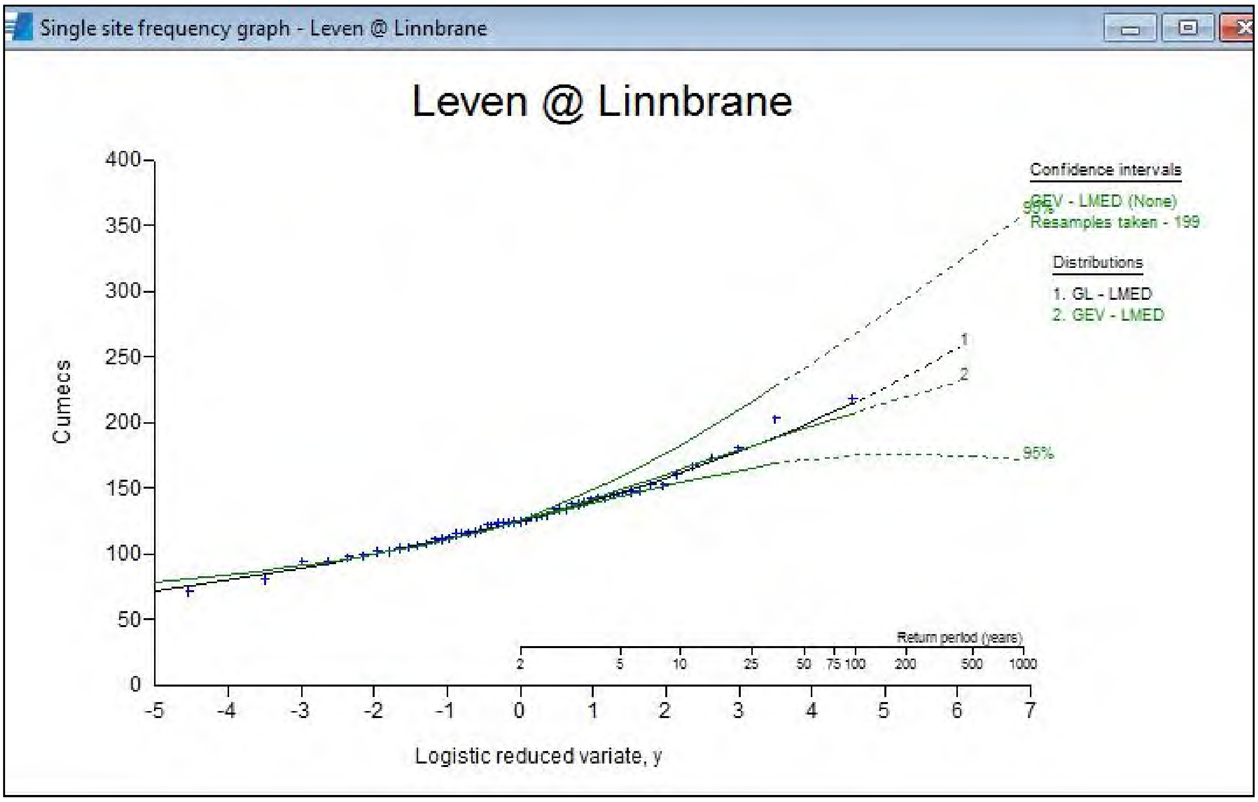
B OUTPUT OF WINFAP FEH SINGLE SITE ANALYSIS



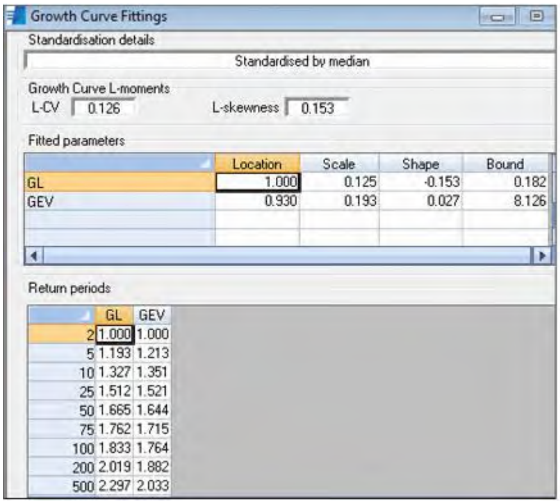
	Return Period	Magnitude	Confidence
1	2	1.000	1.000 - 1.000
2	5	1.175	1.131 - 1.232
3	10	1.293	1.211 - 1.405
4	25	1.455	1.318 - 1.672
5	50	1.586	1.402 - 1.898
6	* 75	1.668	1.442 - 2.055
7	* 100	1.728	1.466 - 2.177
8	* 200	1.883	1.522 - 2.494
9	* 500	2.111	1.602 - 2.998
10	* 1000	2.302	1.644 - 3.446



	Return Period	Magnitude	Confidence
1	2	1.000	1.000 - 1.000
2	5	1.194	1.137 - 1.252
3	10	1.315	1.225 - 1.427
4	25	1.461	1.308 - 1.667
5	50	1.564	1.353 - 1.850
6	* 75	1.622	1.371 - 1.959
7	* 100	1.662	1.385 - 2.036
8	* 200	1.756	1.403 - 2.226
9	* 500	1.874	1.411 - 2.481
10	* 1000	1.960	1.402 - 2.677



C OUTPUT OF WINFAP FEH POOLED ANALYSIS



Growth Curve Fittings

Standardisation details

Standardised by median

Growth Curve L-moments

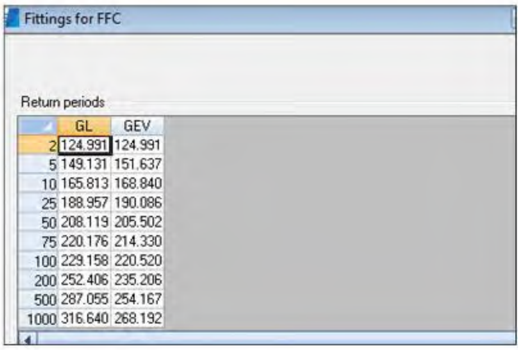
L-CV 0.126 L-skewness 0.153

Fitted parameters

	Location	Scale	Shape	Bound
GL	1.000	0.125	-0.153	0.182
GEV	0.930	0.193	0.027	8.126

Return periods

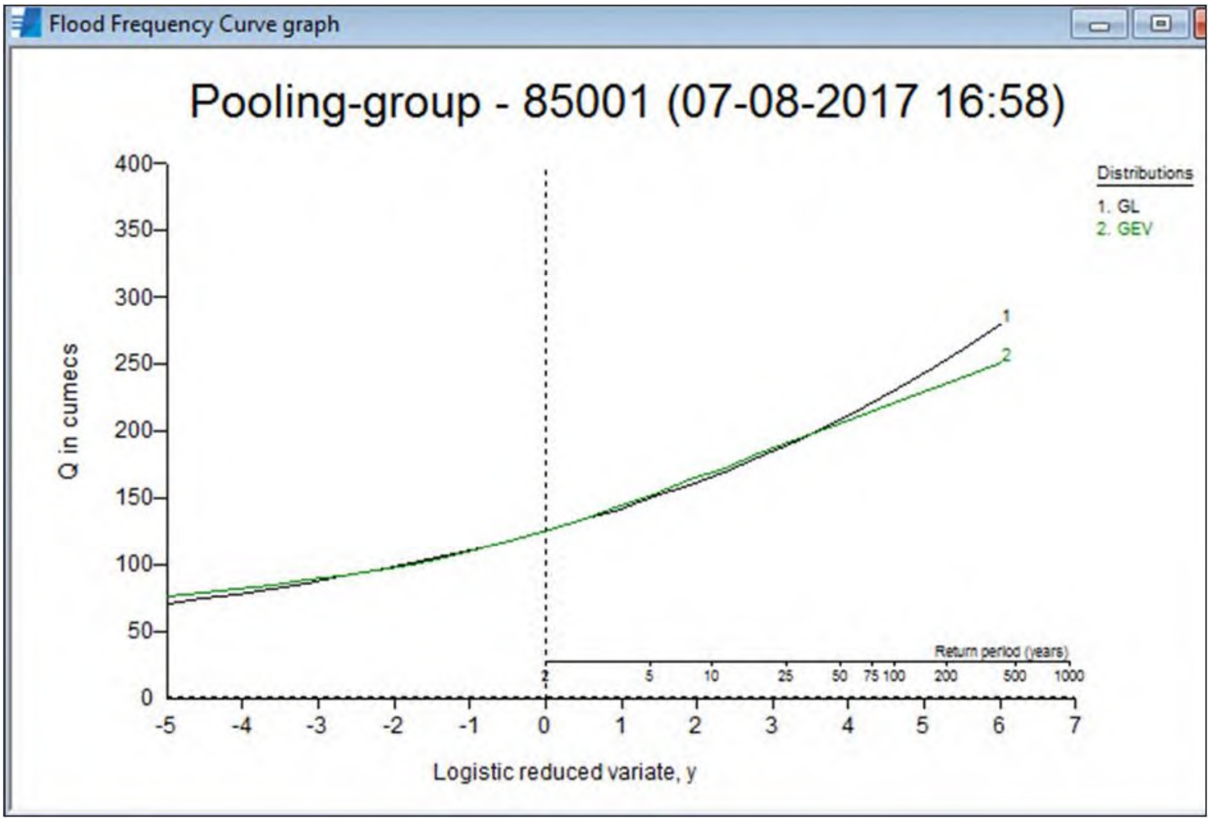
	GL	GEV
2	1.000	1.000
5	1.193	1.213
10	1.327	1.351
25	1.512	1.521
50	1.665	1.644
75	1.762	1.715
100	1.833	1.764
200	2.019	1.882
500	2.297	2.033



Fittings for FFC

Return periods

	GL	GEV
2	124.991	124.991
5	149.131	151.637
10	165.813	168.840
25	188.957	190.086
50	208.119	205.502
75	220.176	214.330
100	229.158	220.520
200	252.406	235.206
500	287.055	254.167
1000	316.640	268.192



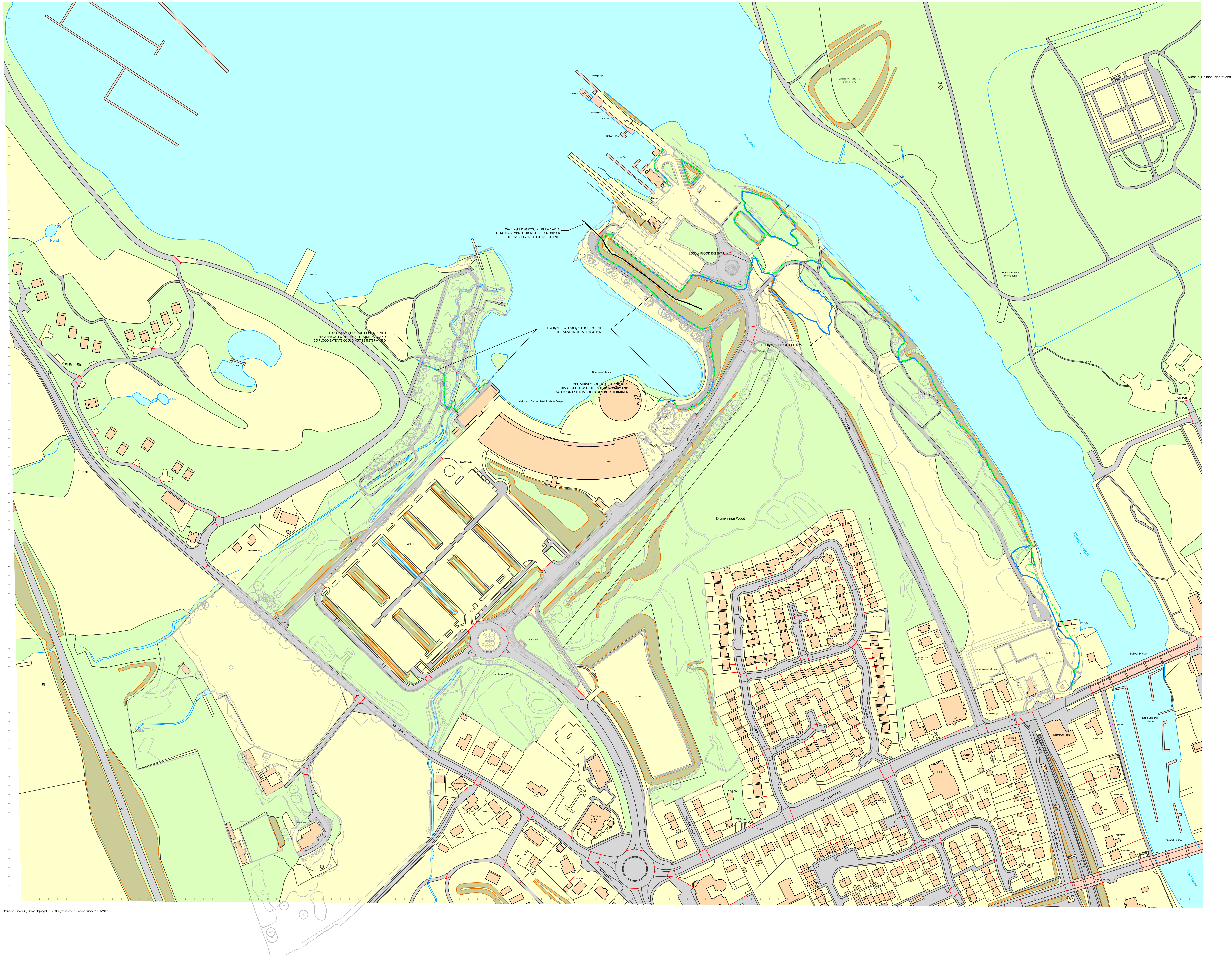
APPENDIX D – FLOOD EXTENTS PLAN

Notes

LEGEND

1 IN 200yr + 20%CC FLOOD EXTENTS

1 IN 500yr FLOOD EXTENTS



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Rev	Date	Amendment	Initials

ENVIRO Centre
Craighall Business Park, Eagle Street, Glasgow, G4 9XA
Tel: 0141 341 5040
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Client
TSL Contractors Limited

Project
West Riverside Balloch

Title
Combined Flood Extents Map

Status
FINAL

Drawing No.
168659-018

Revision

File path: k:\168659\drgs\cad

Scale
1:500 @ A1

A1

Date
07/08/2017

Drawn	Checked	Approved
DW	CGF	CGF

SEPA
Scottish Environment Protection Agency
Buidheann Dìon Àrainneachd na h-Alba

Our ref: PCS/157036
Your ref:

If telephoning ask for:
Brian Fotheringham

Mr D Warren
EnviroCentre Limited
Craighall Business Park
8 Eagle Street
Glasgow
G4 9XA

07 February 2018

By email only to: DWarren@envirocentre.co.uk

Dear Sir

Hydrological Analysis – West Riverside Site, Balloch
Jacobs Study & River Leven Gauging Station
Pre-application advice

Thank you for your consultation email which SEPA received on 17 January 2018, in respect of the above issues.

We have given due consideration to the further information you provided and would offer the following revised comments for your information.

1. Flood risk comments

1.1 We would confirm based on the information supplied with this consultation that if we were to be formally consulted through the planning process on the proposed development we would be unlikely to object on flood risk grounds. Notwithstanding this we would expect West Dunbartonshire Council to undertake their responsibilities as the Flood Risk Management Authority.

1.2 Our pre-application advice relies on the accuracy and completeness of the information supplied with this consultation. Should finalised development proposals differ in any future planning application we reserve the right to alter our position if we are of the opinion that the amended proposals would not meet with the principles of Scottish Planning Policy.

Technical Report

1.3 We acknowledge our involvement in pre-planning discussions on a potential development in the Balloch area. As part of these proposals a previously undertaken Flood Risk Assessment (FRA) has been used to assist in determining the potential flood risk issues at the site. In this respect we raised concerns about the quality of the gauged data used as part of the hydrological modelling. We accept that further hydrological analysis has subsequently been done and we would make the following comments on this additional information.

1.4 The design flows have considered Rainfall Runoff or the Statistical method (single site and Pooling Group). We have also undertaken a comparison using ReFH2.2. The flow estimates are in line with our calculations and a number of return periods have been considered. We would be in agreement that the Statistical method is the most appropriate and sensitivity analysis has been undertaken to determine how any changes in flow effect flood levels. The analysis suggests that flood levels would only be increased by between 30-180mm. This should not lead to a significant alteration of the existing flood conditions given the existing topography of the site.

1.5 Whilst we maintain some concerns about the quality of the gauged data the updated analysis has suggested no major variation in design flows or extents. We would therefore be in agreement with the recommendation that all development should be outwith the functional floodplain. It is assumed that in this instance the floodplain will be defined as the 200 year plus climate change.

Caveats & Additional Information

1.6 The SEPA Flood Maps have 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 maps are indicative and designed to be used as a strategic tool to assess flood risk at the community level and to support planning policy and flood risk management in Scotland. For further information please visit http://www.sepa.org.uk/environment/water/flooding/flood-maps/.

1.7 Please note that we are reliant on the accuracy and completeness of any information supplied by the applicant in undertaking our review, and can take no responsibility for incorrect data or interpretation made by the authors.

If you have any queries relating to this letter, please contact me by telephone on 01698-839336 or by e-mail to planning.sw@sepa.org.uk

Yours faithfully

Brian Fotheringham
Senior Planning Officer
Planning Service

Disclaimer
This advice is given without prejudice to any decision made on elements of the proposal regulated by us, as such a decision may take into account factors not considered at this time. We prefer all the technical information required for any SEPA consents to be submitted at the same time as the planning or similar application. However, we consider it to be at the applicant's commercial risk if any significant changes required during the regulatory stage necessitate a further planning application or similar application and/or neighbour notification or advertising. We have relied on the accuracy and completeness of the information supplied to us in providing the above advice and can take no responsibility for incorrect data or interpretation, or omissions, in such information. If we have not referred to a particular issue in our response, it should not be assumed that there is no impact associated with that issue. For planning applications, if you did not specifically request advice on flood risk, then advice will not have been provided on this issue. Further information on our consultation arrangements generally can be found on our website planning pages.

Appendix 10.3 – Drainage Strategy

TECHNICAL NOTE

Job Name: West Riverside Development

Job No: 35854

Note No: 35854/2007/TN/002

Date: 24/03/2018

Prepared By: Derick Macleod

Reviewed By: Jim McGuire, Dougie McDonald

Subject: **Drainage Assessment**

Item	Subject

1. **Introduction**

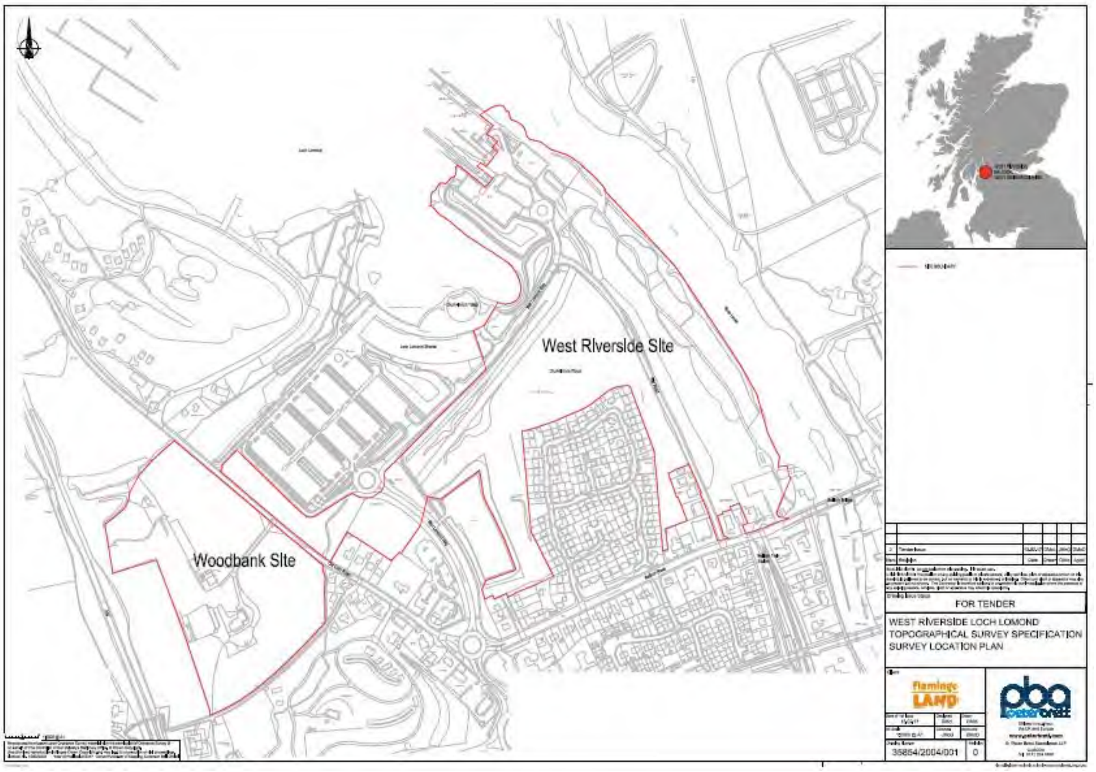
Peter Brett Associates LLP (PBA) has been appointed by Flamingo Land to support it with progressing plans to develop the West Riverside site at Loch Lomond, West Dunbartonshire.

The purpose of this Technical Note is to document the developing foul and surface water strategies for the site.

The Note also documents the feedback received from key stakeholders on the current proposals and provides recommendations for the next steps to be taken in order to progress the plans for the site.

2. **Site Location**

The location of the proposed development is illustrated in Figure 1 below.



Item	Subject
	Figure 1 - Site Location Plan
3.	**Foul Water Strategy** Much of the existing foul drainage in the area is captured in combined sewers, which carry wastewater to the Ardoch Wastewater Treatment Works in Dumbarton. The intention for the proposed development is for the foul and surface water drainage to be captured separately, with only foul drainage entering the wastewater network. The site is approximately 33.5Ha and therefore significant lengths of new wastewater infrastructure would be required to service the various facilities proposed for the site. The intention would be for Scottish Water to adopt the new wastewater drainage infrastructure on the site. All foul drainage would therefore need to be designed to the standards contained in Sewers for Scotland, 3rd Edition, 2015. The Woodbank, and Drumkinnon Wood sections of the site can be drained under gravity and it is proposed that the foul sewers would connect into Scottish Water's existing combined sewers on Old Luss Road and Pier Road respectively. However, this would be subject to confirmation that there is sufficient capacity in the existing network to accept the flows from the development. The proposed network would generally follow the alignments of proposed and existing access roads and tracks before tying into the existing combined sewer network. The riverfront section of the site presents a challenge for foul drainage as this area is extremely flat. The ground undulates with levels ranging between 10.0m and 11.0m AOD across the length of the Riverfront development area (approx. 500m). The gradients across sections of this area are as flat as 1:750 (0.13%). Providing a gravity sewer at an appropriate gradient for the expected flows, which can tie into the invert levels of the existing sewer network, is not possible without land raising or Scottish Water's approval to use oversize pipes laid at shallower gradients. This presents an issue, as SEPA has advised that they would oppose any proposal for land raising which encroaches on the fluvial flood plain of the River Leven. Impacts on the flood plain could be avoided by reducing the platform areas such that the earthworks do not extend beyond the modelled extents of the flood plain. However, this would reduce the developable area. In addition, Scottish Water is unlikely to approve the use of oversize pipes laid at shallower gradients when the expected flows are unlikely to generate self-cleansing velocities in the sewer. As a gravity based system is unlikely to be a practical solution for connecting into the existing combined sewer network, it would be necessary to install a pumping station in the riverfront section of the site. A gravity sewer would capture foul drainage from the Riverfront and Pierhead areas of the site and direct it to the pumping station. This would pump the wastewater up a rising main to a connecting manhole on the existing combined sewer network at Balloch Road. The existing pumping station on site is owned by Scottish Enterprise (SE) but is managed on their behalf by Saltire Property Management Ltd (SPM), who have a service agreement with the proprietors of Loch Lomond Shores. There may be an opportunity to connect the new drainage to this existing pumping station, thereby potentially removing the requirement for a new pumping station. Limited information is however available on the capacity or service agreements for the existing pumping station. The strategy therefore makes provision for a new pumping

Item	Subject
	station at this time. This is subject to change should more information on the existing pumping station become available and it can be ascertained that the proposed development can be accommodated within it. . Scottish Water were generally supportive of the foul drainage proposals but noted that they could not give any definitive feedback until modelling had been undertaken to evaluate the impact of the additional flows from the development on the network. Scottish Water recommend that a Pre-Development Enquiry (PDE) be lodged so that modelling of the development flows can be undertaken as part of a Network Impact Assessment (NIA). The NIA would establish whether the existing network can accommodate the increased flows from the proposed development or if network reinforcements are required. They advised that this should be undertaken as soon as possible. PBA has since lodged a PDE with Scottish Water.
4.	**Surface Water Strategy** As noted in the previous section, much of the existing foul drainage in the area is captured in combined sewers and it is the intention for the proposed development to capture foul and surface water drainage separately, with surface water being treated and discharged back into the water environment using a variety of SuDS techniques. This has been discussed with SEPA and Scottish Water who are supportive of the approach. The site is approximately 33.5Ha and therefore significant new surface water drainage infrastructure is required to service the various facilities proposed for the site. The current proposals for the Woodbank area of the site include lodges as well as residential development. As the proposals are for less than 50 homes it is likely that only one level of SuDS treatment will be required prior to discharge into a receiving watercourse. The proposals require a number of access roads to facilitate access to the different elements of the development and roadside swales are proposed to treat and attenuate the surface water runoff from the site before discharging to the watercourse at the southwest corner of the Woodbank site. Based on the current level of detail and the site uses, SEPA were unable to confirm that a single level of treatment would be acceptable but they were open to further discussion once the proposals become more defined and a layout is prepared for the development. SEPA advised that their preference would be for dry swales incorporating an underdrain. The Drumkinnon Wood area of the site will not be accessed by cars, with only occasional access for maintenance vehicles. SEPA agreed that surface runoff in this area would not require treatment, however, roof runoff would require one level of treatment. An infiltration trench could be constructed alongside the proposed access track to capture surface water and roof runoff and provide the single level of treatment required. An alternative solution would be for the surface and roof runoff to be conveyed to the SuDS pond which treats the car park drainage. Both are viable options which could provide the required level of SuDS treatment and attenuation. Surface water drainage of the Riverfront area of the site has the same issues as the foul drainage in that the site is very flat. Significant land raising would be required to provide a piped network with an outfall above the flood level. The proposed strategy

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	therefore is for infiltration solutions that manage treatment and attenuation of runoff, thereby avoiding land raising. An infiltration trench would run through the middle of the riverfront area from north to south. This would be aligned with an access road. This would capture surface runoff and provide treatment to the roof runoff from the lodges west of the access road . A second infiltration trench would be provided to the east of an access road to capture surface runoff and protect the access road from damage by water flowing towards what is a low point in the site. Each lodge would have with its own catchpit and soakaway system to allow the roof runoff to infiltrate into the ground. A filter drain connected to a SuDS basin would provide the two levels of treatment and the attenuation required prior to discharge into the River Leven for the surface water runoff from proposed car parking areas adjacent to Pier Road. A similar SuDS treatment approach is proposed for car parking areas at the Pierhead. The outfalls for these SuDS basins are likely to be below the 1:200 Year + Climate Change flood level but efforts would be made to achieve the highest level possible to allow free flow from the basins in most situations and limit the attenuation needed during high return period events. Non-return duckbill or flap valves would be required to prevent the basins and drainage network from being surcharged by flood waters from the river.

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