Collinswell Land Ltd.

Collinswell Park Development

Kirkton Burn
Hydraulics and Hydrology

August 2004

DETAILED DESIGN REPORT

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CONTRACT

This report describes work commissioned by Collinswell Land Ltd under Letter of Instruction dated 4 May 2004. Collinswell Land Ltd's representatives for the contract were Zander Williamson and Ian McCully. Ed. McKenna, Helen Silk, and Fiona Dow of JBA Consulting carried out the work.

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- Mike Gemmell of Construction Management Scotland
- Peter Dunmow of Farningham McReadie Partnership
- John Dunne of George Wimpey East Scotland Ltd
- Julian Jack and Graham Ballantyne of David R Murray Associates
- Allan Patterson of Stewart-Milne Ltd

EXECUTIVE SUMMARY

Purpose

This Report is written to accompany the detailed planning application which is to be made for the infrastructure works for the Collinswell Park development in Burntisland, Fife. The Report deals specifically with the "day-lighting" of the Kirkton Burn and describes the work which is required and the design proposals. It is the intention that final detailed design of the works will be carried out in accordance with this Report which will be adopted as the Design Brief for the works. All of the works described in this Report are intended to secure the development against flooding by the 0.5 % Annual Exceedance Probability flood – the 1 in 200 year flood.

The works required for day-lighting of the Kirkton Burn are closely related to the proposed landscaping works and surface water sewerage works, both being designed by others. This Report must be read in conjunction with the submissions made in respect of these other works.

Flood Estimates

The fundamental principle on which the works have been designed is that the valley of the Kirkton Burn will be used for flood storage with a maximum water level of 6.4 m. AOD at the critical design event. The key flood parameter is volume of the 0.5% AEP flood of the critical duration. Because flood volume and hydrograph shape are key issues floods have been estimated using the FEH/FSR rainfall runoff model. Winter floods have been adopted in preference to summer floods since these produce the greater volume.

For flood calculation purposes the natural catchment area of the Kirkton Burn has been enlarged to include the proposed development since it is intended that surface water run-off from the site will be discharged to the Kirkton Burn. Similarly, the FEH URBEXT parameter has been adjusted to reflect the increased urban area.

The propose flood storage area in the valley of the Kirkton Burn will provide attenuation of the surface water run-off from the proposed development in broad compliance with the principles of Sustainable Urban Drainage. Agreement has been reached with SEPA that treatment of surface water run-off will be by means of filter trenches and/or swales.

The critical duration has been identified as 4.75 hours by routing a number of floods of varying durations through the proposed flood storage area. The valley storage Stage/Area relationship used in the flood routing was provided to the landscape architect so that land forms within the valley could be designed to provide the required relationship between water level and surface area.

The estimated maximum water level at the critical design event is 6.438 m AOD.

Seamill Pond

After leaving the development site via an existing culvert under the Edinburgh to Dundee railway the Kirkton Burn enters the Seamill Pond the outlet from which to the sea is a DN 900 pipe. Water level in the pond will fluctuate in accordance with tide level and inflow from the Kirkton Burn. The Seamill Pond has a routing affect on flood inflows. The design of the upstream works within the development site has taken account of the routing affect of the pond and the flood regulating works have been configured to ensure that at the critical design event of the 0.5% AEP flood the pond water level does not rise above 3.50 m AOD when the flood inflow coincides with the rise of a mean annual tide.

Upper Reach of Kirkton Burn

Outwith the valley storage area the Kirkton Burn will run in part open channel and part DN 900 pipe culvert to connect with an existing culvert under Kirkton Road.

The open channel section will be 1.2 m wide contained between mass concrete gravity retaining walls to give a channel depth of about 2 metres. However, the channel is hydraulically steep and in order to provide opportunity for some ecological interest the bed will incorporate large rocks in order to reduce the flow velocity and provide pools which will trap silt.

The proposed piped section, replacing an existing culverted section, lies in close proximity to proposed apartment blocks and piping of the stream is necessary to provide appropriate access and parking. The pipe is sized to accommodate the peak flood flow from the catchment area of the Kirkton Burn draining to the development site boundary. There will be no drainage discharges from the site to the piped section of the burn.

Seepage Control

The area through which the Kirkton Burn will flow and which will be used for flood storage will be constructed partly in cut through existing soils and partly on infilled material.

The material through which the stream channel will be cut is described as "made ground comprising sandy clay with fine to coarse gravel and soft to firm clayey ash ". The stream bed level at about 4.00 m AOD coincides with the top of a layer with a relatively high clay content which is anticipated to be reasonably impermeable. In order to prevent seepage into the cut slopes it is intended to install a proprietary bentonite mat carried up to above maximum water level and protected by a topsoil layer.

An area towards the eastern end of the Kirkton Burn valley will be constructed on infilled material available on site. The material is essentially granular being the arisings from crushing of demolition material. The material will be placed and compacted in 200 mm thick layers. The topmost layer, immediately below the topsoil layer, will be treated with bentonite granules to increase impermeabilty and reduce seepage through the fill materials. The specified requirement will be to achieve a coefficient of permeability of 10^{-6} cm/sec., equivalent to a silty clay.

Risk Assessment and Risk Mitigation

An assessment has been carried out to identify residual flood risk. The design proposals have been assessed in relation to the residual risk and appropriate mitigation measures have been identified. The principal of these is the provision of a minimum 600mm freeboard between the estimated maximum design water level and the lowest ground level within the developed area with a recommendation that house floor levels be further a 150 mm above ground level.

Since the overall design is based on the concept of flood storage it is inevitable that there will be areas of open water at various times. The hazard that these present and the likelihood of accidents have been assessed to quantify the risk which could result from these water bodies. It is concluded that they are unlikely to be used for water-based activities so that the likelihood of accidents is very low and the overall risk tolerable when the risk is assessed according to RoSPA guidance.

The flood storage area within the valley of the Kirkton Burn is capable of holding less than 25,000 cubic metres of water and is therefore not a "large raised reservoir" within the meaning of the Reservoirs Act 1975.

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ABBREVIATIONS

AEP	Annual Exceedance Probability
AOD	Above Ordnance Datum
ATT	Admiralty Tide Tables
BS	British Standard
FEH	Flood Estimation Handbook
FSR	Flood Studies Report
ISIS	Hydrology and hydraulic modelling software
JBA	JBA Consulting – Engineers & Scientists
Tr	Return Period (years)
URBEXT	FEH index of fractional urban extent

1 INTRODUCTION

1.1 The Proposed Development

Collinswell Park is a proposed housing development on the site of the former Alcan Chemicals Alumina Plant at Burntisland, Fife. The site location is shown on Figure 1.

The Kirkton Burn is presently culverted through the factory site and a key feature of the proposed development is the "day-lighting" of the burn, ie diverting the burn to run in open channel through the site. The Kirkton Burn, whether in culvert or not, presents a potential flood risk to the development. This Report describes the investigations, assessments and design proposals required to ensure that the potential flood risk is reduced to an acceptable level.

The proposals for the Kirkton Burn submitted for Outline Planning Consent were based on a Hydrological Assessment[1] which assumed that an enlarged Seamill Pond would be used for flood attenuation purposes. However, subsequent to completion of the Hydrological Assessment and submission of the Outline Application, it became apparent that for a number of reasons enlargement of the Seamill Pond would not be practicable. The proposals for flood attenuation were therefore modified to provide additional flood attenuation on the Kirkton Burn within the site whilst fully utilising the flood storage capacity of the existing Seamill Pond.

The various elements of proposed works described in this Report are shown in Figure 3.

1.2 This Report

Outline planning consent for the development, based on the modified flood storage proposals, was obtained on 29 June 2004 subject to certain conditions which include, *inter alia,* the following:-

*"**Condition 8**. Surface water from the site shall be dealt with using Sustainable Urban Drainage techniques advocated in the design manual for Scotland and Northern Ireland (CIRIA C521 2000). Full details of the methods to be employed, including, where appropriate, calculations, along with details of how these measures will be maintained shall be submitted for approval in writing by this Planning Authority prior to the commencement of any works on site.*

***Condition 9(a)** Full details of measures to be employed to prevent the approved development from flooding, along with details of how these measures will be maintained and by whom, shall be submitted for approval in writing by the Planning Authority before any work starts on site. Thereafter the development shall be carried out in accordance with the details approved.*

***Condition 9(b**) Prior to commencement of work, a scheme for the day-lighting (opening up)of the Kirkton Burn shall be submitted to and agreed in writing by this Planning Authority. This scheme shall take account of best practice in respect of flooding, channel design and stability and seek to provide opportunities for habitat creation, and have reference to conditions 8 and 9(a)."*

This Report describes the scheme for day-lighting of Kirkton Burn to demonstrate compliance with Conditions 9(a) and 9(b).

This Report should be read in conjunction with the other separate submissions in respect of landscaping and surface water sewerage, particularly the former since the landform within the Kirkton Burn valley is key to the provision of adequate flood storage.

[1] JBA Consulting Collinswell Park Burntisland, Hydrological Assessment, Final Report March 2004

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2 FLOOD HYDROLOGY

2.1 Standard of Protection

In accordance with SPP 7[2] the 0.5% AEP flood (1 in 200 years) has been adopted as the flood protection standard. Within the development lowest ground level will be set at a minimum of 600 mm above the estimated 0.5% AEP flood level. It is anticipated that minimum house floor level will be 0.15m above ground level giving a total freeboard above flood level of 0.75m.

2.2 Flood Estimation

2.2.1 Method

Since flood attenuation storage is a key feature of the proposed scheme determination of the flood volume is of principal interest. Flood estimation is therefore based on the FEH/FSR rainfall-runoff method using the FEH boundary module in the ISIS software package.

Calculations for the critical design flood are included as Appendix A of this Report.

2.2.2 Catchment Area

Floods generated on the catchment area down to the point where the Kirkton Burn passes under the railway have been calculated. The catchment area derived directly from the FEH CD-ROM is not correct. The FEH catchment area has been adjusted following site inspection and extended to include the whole of the Collinswell Park development. The URBEXT value in the FEH CD-ROM generated catchment descriptors has been adjusted to reflect the change in catchment area and the new development. The adjusted URBEXT value is 0.261 which places the catchment in the "very heavily urbanised" category according to FEH Vol 5. The total catchment area down to the railway culvert and amounting to 0.99 km^2 is shown on Figure 2.

The upper part of the Kirkton Burn within the site will receive no run-off from the development. The proposed works affecting that part of the Kirkton Burn have been designed to deal with the flood from the catchment area of the burn down to the point at which it passes under Kirkton Road. The catchment area to that point is 0.69 km^2.

2.2.3 Flood Volume

The standard storm duration determined by catchment parameters is 1.25 hours. However, for any flood return period the flood volume is related to storm duration. It is therefore necessary to identify the critical duration which is defined, in this case, as the duration of that flood which, when routed through the flood storage area, results in the maximum water level. The critical flood duration thus depends on the stage/area characteristic of the storage area and the stage/discharge characteristic of the storage outlet. Determination of the critical duration is therefore an iterative process. It is proposed to provide flood storage at two locations:-

- Within the development area upstream of the railway culvert utilising the "valley storage" of the Kirkton Burn, and
- Within the existing Seamill Pond.

Since use of flood storage within the development site will impact upon the area available for development it is necessary to optimise the allocation of storage volume between the two locations. That requires detailed consideration of the flood attenuation capacity of the existing Seamill Pond. That is dealt with in 3.1.5 below.

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[2] Scottish Executive Development Department Scottish Planning Policy No 7: Planning and Flooding, Edinburgh February 2004

Although summer storms are usually regarded as being more appropriate in calculating the peak run-off from relatively highly urbanised catchment areas, flood volume is the more important factor in this instance and that will be maximised by using winter storms. Table 2-1 below summarises the flood calculation results for winter storms with a selection of durations and return periods. These are the unattenuated flood peaks and volumes.

Since the URBEXT value for the catchment exceeds 0.125 floods are generated using a rainfall return period equal to the flood return period.

The actual critical duration cannot be identified until flood routing is carried out and that is dependent on the storage area and outlet characteristic both of which are dealt with in 4 below.

Table 2-1 WINTER STORM FLOOD PEAK FLOWS and VOLUMES

STORM	RETURN PERIOD (years)							
DURATION	2		5		50		200	
(hrs)	Qm^3/s	Vm^3	Qm^3/s	Vm^3	Qm^3/s	Vm^3	Qm^3/s	Vm^3
1.25	1.47	4691	2.17	6887	3.81	12040	4.98	15688
2.25	1.37	6052	2.00	8760	3.45	15009	4.53	19650
3.25	1.25	7108	1.81	10193	3.08	17239	4.10	22897
4.25	1.14	7999	1.63	11392	2.78	19272	3.70	25557
5.25	1.04	8704	1.48	12440	2.54	21169	3.36	27864
6.25	nc	nc	1.37	13381	2.35	22836	3.09	29925
7.25	nc	nc	nc	nc	2.19	24330	2.72	31803
8.25	nc	nc	nc	nc	2.05	25747	2.67	33537
nc means that no value was calculated								

3 SEAMILL POND

3.1.1 General

The existing Seamill Pond is of local historic importance being a relic of an old tide-mill which existed on the site until the early years of the 20th century. The pond is also a valuable environmental resource and there are current proposals to carry out environmental improvements in the area around the pond.

The Kirkton Burn flows into the pond through a masonry culvert under the Edinburgh to Dundee railway. The outlet from the pond to the sea is via a DN 900 pipe fitted with a flap valve at its seaward end. Water level in the pond at any time is consequently a function of both flow in the Kirkton Burn and concurrent sea level.

3.1.2 Flood Storage Capacity

The existing pond has been surveyed by Aird Geomatics on behalf of Collinswell Land Ltd. The surveyed pond bed contours are shown on Figure 4.

The pond outlet pipe has an invert level of 0.55 m AOD. The land around the west and south sides of the pond varies in level from about 4.00 m AOD to about 3.00 m AOD. However, as part of the proposed development it is intended to upgrade the existing footpath linking the railway underpass with Haugh Road and it has been assumed that the minimum finished level will be 4.00 m AOD. Accordingly, an allowable maximum water level in the pond of 3.5 m AOD has been adopted thus providing 0.5 m freeboard at the 0.5% AEP flood. This is considered to be appropriate in the circumstance where no habitable properties are at risk. The usable flood storage volume thus lies between the levels 0.55 m AOD and 3.5 m AOD. The Stage/Area characteristic for the pond is shown on Figure 5.

3.1.3 Sea Level and Tide Height

Since water level in the pond is a function of both sea level and Kirkton Burn flow rate determination of the water level is a joint probability problem. It is reasonable to assume that flow in the Kirkton Burn is independent of sea level. The joint probability of independent events is the product of the individual event probabilities. Thus, to preserve an overall event probability of 0.5% the 0.5% AEP flood in the Kirkton Burn should be combined with a sea level having an exceedance probability of 100%. However, sea level will fluctuate in accordance with the normal tidal cycle and in order to take account of that fluctuation the inflow flood needs to be combined with a representative tide cycle. For design purposes a tide with a high water height equal to the mean of neap and spring high waters has been fitted to a standard tide curve. Strictly speaking this tide has an AEP of 50% so that the joint probability of occurrence is less than the nominal design probability of 0.5%. This, however, errs on the side of safety and is thus acceptable. The tide data, extracted from the Admiralty Tide Tables[3] is as follows:-

Table 3-1. Design Tide Level

Tide	Height (m above Chart Datum)	Level (m AOD
MHWS	5.70	2.85
MHWN	4.40	1.55
Mean Tide	5.05	**2.20**
Chart Datum is -2.85m OD (A.T.T. TABLE III)		

[3] Hydrographer of the Navy   Admiralty Tide Tables: Volume 1 –United Kingdom and Ireland

The mean high tide is fitted to a normal sinusoidal tide curve with a tide cycle duration of 12.5 hours based on the tide curves for various ports on the Firth of Forth.

3.1.4 Pond Outlet

The outlet from the pond comprises a DN 900 pipe 381 m long fitted with a flap valve at its seaward end as shown on Photograph 1 below. Head loss in the outlet pipe was calculated using a Ks value 0.6mm in the Colebrook-White equation based on the fact that the pipe has fairly recently been subject to a major cleaning exercise.

Photograph 1 - Flap valve on Seamill Pond Outlet

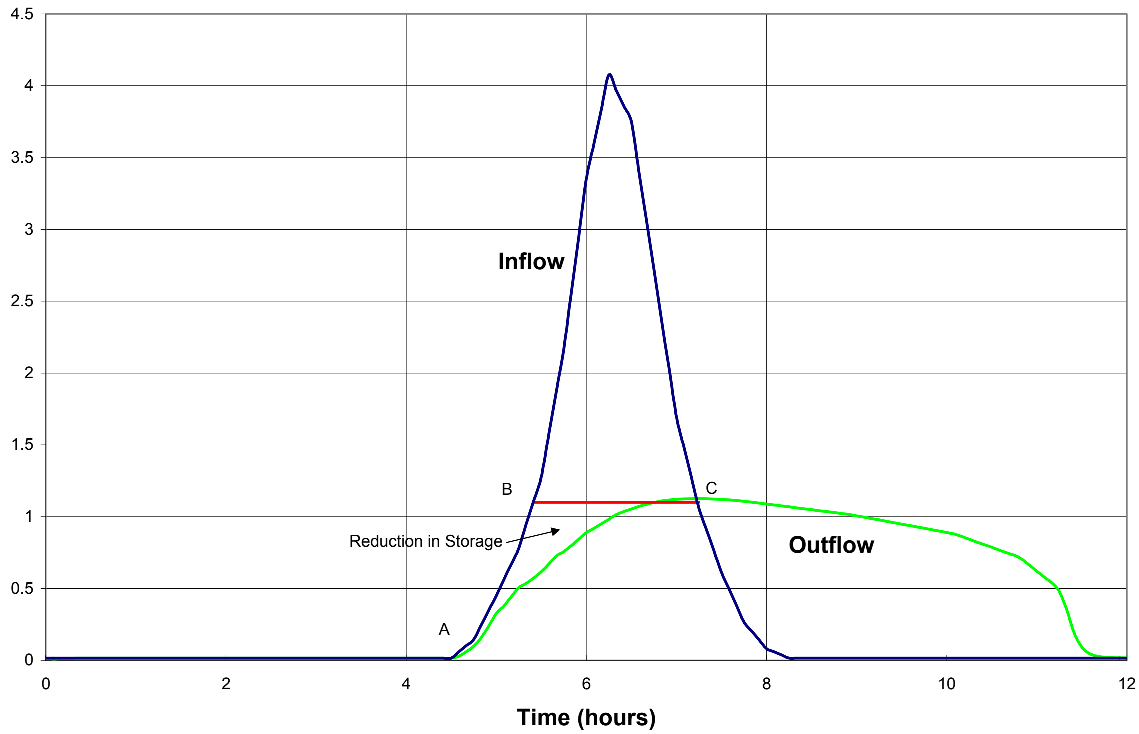
Due to the presence of stones in the invert the flap valve cannot fully close, as it should do, with the result that Seamill Pond is currently tidal. That situation cannot be allowed to continue without compromising security against flooding and it is proposed to modify the outlet structure around the flap valve to provide greater protection against vandalism or other unauthorised interference. An outline of the proposed work is shown on Figure 6.

3.1.5 Flood Routing Through Pond

The maximum level to which water in the pond will rise during the 0.5% AEP design event is obtained by routing the Kirkton Burn inflow hydrograph through the pond using the reservoir module in ISIS and based on the pond Stage/Area relationship of Figure 5. In this case the inflow hydrograph is the outflow hydrograph from the Kirkton Burn valley storage which is shown on Figure 12.

The peak flow rate, hydrograph duration, and total flood volume under the hydrograph are conditioned by routing the flood through the valley storage and its outlet control. The nature of the latter can have a significant affect on the characteristics of the Seamill Pond inflow hydrograph and it is necessary to consider the outlet control characteristic which will optimise the division of flood storage between the Seamill Pond and the Kirkton Burn valley with a view to minimising the storage in the latter.

The diagram below shows the normal routing affect of an unregulated outlet from storage. The total storage volume is represented on the diagram by the area between the inflow hydrograph and the outflow hydrograph. However, if the outflow can be regulated in such a way that the outflow hydrograph follows the line A-B-C on the diagram then some reduction in the volume stored will be achieved.



In order to apply this principle to the Kirkton Burn storage problem it is necessary to determine the maximum constant flow which could enter Seamill Pond during a tidal cycle without water level in the pond exceeding 3.5 m AOD.

A series of trial constant inflows was routed through the pond with the result shown on Figure 7. This indicates that a constant inflow of 1100 l/s can enter the pond over a full tide cycle without the prescribed maximum water level being exceeded. This flow rate is relevant to design of the outlet from the Kirkton Burn valley storage which is dealt with in 4.3 below. Adopting a constant inflow hydrograph for the Seamill Pond also means that the critical storm duration will be determined only by reference to the storage in the Kirkton Burn valley.

In respect of Seamill Pond Figure 8 shows the relationship between inflow and outflow hydrographs, tide level and pond water level for the 0.5% AEP design condition. The maximum water level is slightly lower than the prescribed maximum of 3.5 m AOD.

3.1.6 Proposed Works at Seamill Pond

As part of the proposed environmental improvement works around the Seamill Pond the developer has agreed to make a contribution by providing bank strengthening adjacent to Haugh Road and by regrading the east bank of the pond. In addition, the Fife Coastal Footpath around the west and south sides of the pond is to be upgraded.

The works within the pond area are designed to a have a neutral affect on the Stage/Area relationship so that the curve of Figure 5 remains relevant.

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4 KIRKTON BURN

4.1 General Principles

As explained in 2.2.1 above, the design of the new channel for the Kirkton Burn is based on the provision of flood storage within the valley. Channel conveyance of high flood flows, or any flow for that matter, is not the ruling design criteria.

The key design issues therefore are the need to maximise storage within the valley, landscaping, public access, public safety particulary in respect of flood risk, and geotechnical aspects in respect of slope stability and seepage. In considering these issues it has been necessary to take account of other requirements in respect of surface water sewerage, street lighting of adoptable pathways, road levels and house floor levels. These issues have been considered in consultation with the various other consultants engaged on the project. As a result of these discussions certain ruling parameters have been adopted as follows:-

- Invert level of outlet control structure not higher than 4.00 m AOD to accommodate surface water sewerage outfall
- Invert level of outlet structure not lower than 3.60 m AOD to avoid backwater affects from Seamill Pond
- Valley width along southern boundary of site not to exceed 15 m exclusive of coastal path
- Top of valley side slopes not to exceed nominal level of 7.00 m AOD
- Minimum nominal freeboard of 600 mm to top of valley sides
- Maximum valley side slope adjacent to public area not steeper than 3 horizontal to 1 vertical.
- For geotechnical reasons, slide slopes not steeper than 2.5 horizontal to 1 vertical.
- Minimum house floor level assumed to be 7.15 m AOD
- Length and height of retaining walls to be minimised for cost and safety reasons.
- Surface water sewerage from the development to discharge to the Kirkton Burn upstream of the outlet structure thus utilising valley storage for attenuation
- Consideration to be given to flooded-area/ frequency relationship as it impacts on planting proposals.
- A desire to achieve a “non-engineered” appearance to day-lighting of the burn adopting, so far as practicable, the principles of the River Restoration Manual[4].

This Section of the Report describes how it is intended to apply these principles to that part of the Kirkton Burn lying between the inlet to the Railway Culvert and the outlet of the culvert under the road linking the development to Kirkton Road.

In carrying out the design of the various works it is assumed that construction will be carried out generally in accordance with the Civil Engineering Specification for the Water Industry, 5th Edition (CESWI 5).

[4] River Restoration Centre Manual of River Restoration Techniques 2002.

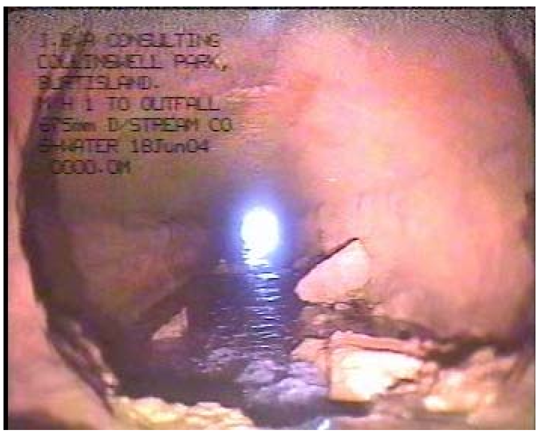
4.2 Connection to Railway Culvert

4.2.1 Existing Railway Culvert

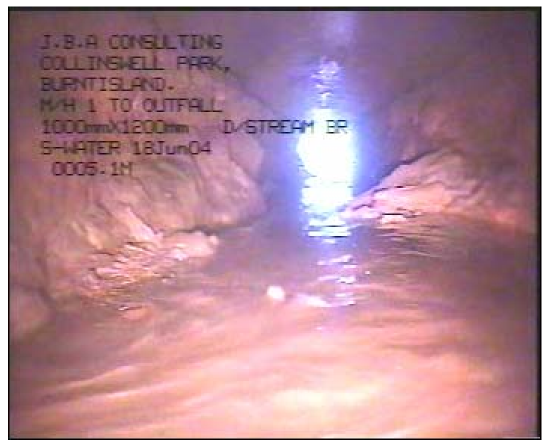
Description

The existing culvert is a masonry arched structure dating, presumably, from opening of the Forth Bridge to Burntisland railway line in 1890. A CCTV survey of the culvert was carried out by DCS Ltd on 18 June 2004. Screen shots from the survey are shown in Photographs 2 and 3 from which it is apparent that the culvert is structurally sound although there are significant quantities of silt, assumed to be bauxite dust, banked along the sides of the waterway and encrusted on the walls and roof. Masonry blocks lying in the bed are thought to be the remains of the original entrance headwall which was removed when a pipe from the Alcan site was connected to the culvert.

Photograph 2 – Railway Culvert Interior



Photograph 3 – Railway Culvert Interior



The culvert is nominally 1.21 m wide by 1.21 m high (presumably constructed as 4 feet square) with a segmental arch roof having a 0.20 m (8inch) rise. When running full the effective cross-sectional area is 1.635 m^2 and the wetted perimeter 4.526 m giving a hydraulic radius of 0.36 m equivalent to a pipe of DN 1445. On the assumption that the culvert is cleared of silt it is estimated that the ks value will be in the order of 3mm for smooth masonry. The invert level of the culvert is 1.05 m AOD and it is about 21 m long. The proposed works include cleaning out the existing culvert.

4.2.2 Culvert Extension

The location of the control structure on the outlet from the Kirkton Burn storage area is dictated by considerations of house, road and footpath layouts. It will be necessary to provide a culverted link some 40 m long from the upstream end of the railway culvert.

In order to avoid the construction of a complex transition between the old and new culverts the most appropriate form of the latter would be a standard pre-cast concrete box culvert 1200 mm square laid from the upstream invert level of the existing culvert. It is proposed to lay the new culvert at a nominal slope of 1 in 400 giving a rise in invert level of 100 mm.

At the ultimate design condition of 3.5 m AOD water level in Seamill Pond the culvert will be surcharged. Standard pre-cast box culverts are not normally used to flow full and subject to internal water pressure. It will therefore be necessary to caulk the internal joints to prevent leakage. A 2.4m diameter precast concrete ring manhole will be located on the culvert where it bends through about 90^0.

4.2.3 Hydraulic Analysis of Proposed System

The proposed connection between the Seamill Pond and the outlet from the Kirkton Burn storage area has been analysed as a continuous single hydraulic system for various flows and tail water levels using InfoWorks CS software. The results are shown on Figure 9 which indicates a maximum water level of 3.55 m AOD behind the flow regulator which, if located above the proposed minimum level of 3.60 m AOD, will have a free discharge at all conditions.

It is therefore concluded that the proposed arrangement described above is appropriate.

4.3 Flow Regulator

4.3.1 Purpose

The purpose of this structure is threefold:-

- It provides a transition between the open channel and the culvert
- It provides a facility for installing a trash screen
- It provides a definable Stage/Discharge characteristic regulating storage within the upstream valley.

4.3.2 Regulating Device

The General Principles, set out in 4.1 above, require that the 0.5% AEP flood level within the Kirkton Burn valley should not exceed a nominal level of 6.4 m AOD.

There are number of ways in which flow can be controlled. The simplest, and therefore cheapest, option is to use a passive control such as an orifice, notch, weir or flume. However the ultimate level to which flood water will be stored upstream of the regulator is highly sensitive to the stage discharge characteristic of the regulating device and appropriate selection of the type of device is critical to achieving acceptable maximum water levels. Passive control devices have no theoretic upper limit to the Stage /Discharge characteristic although, in practice, a device such as an orifice which is small in relation to the head upon it will have a characteristic which approaches near vertical with very little increase in discharge for large increases in depth. Such a property in a control device would be valuable in this instance since it would, if sized appropriately, restrict the flow entering the Seamill Pond. The problem here, however, is that it would result in an orifice so small that it would be prone to blockage. Similarly, other passive devices such as notches, weirs and flumes do not provide the necessary amount of regulation without being unacceptably small or unduly complex in form.

As reported in 3.1.5 above, investigation of the optimum balance of storage provision between Seamill Pond and the Kirkton Burn valley has indicated that the design conditions for the Seamill Pond can be met using a constant inflow of 1100 l/s. The regulating device therefore needs to be able to restrict the flow entering the Seamill Pond to 1100 l/s irrespective of the water level in the upstream storage. This indicates that some form of active (ie mechanical) control device is required. A range of options has been considered and it is concluded that the most suitable device is the Steinhardt Hydroslide Flow Control Gate. The device was developed in Germany for regulating sewer flows and has been in use throughout Europe since 1984. It is essentially a stainless steel vertical sliding gate directly coupled to a float through a lever. There is no external power source. The Stage/discharge characteristic for the valve is shown on Figure 10. An outline design for the regulator structure is shown on Figure 13.

It is appreciated that a non-mechanical device would be the preferred option thus reducing the maintenance burden. However, since maintenance will be required to remove trash from screens it is no great additional task to inspect the flow regulator on a regular basis.

4.4 Valley Storage

Upstream of the regulating device storage for flood attenuation is provided within the valley of the Kirkton Burn. The valley contours have been designed to maximise the storage volume subject to certain constraints regarding side slopes as set out in 4.1, above.

The Stage/Area characteristic for the whole valley between the Outlet Structure and the Kirkton Road link road is shown on Figure 11. A tabular version of this curve was passed to the Farningham MacReadie Partnership, the project landscape architects, to ensure that the ground forms produced in the landscaping proposals provide the required valley storage. The Stage/Area characteristic provided by the proposed ground contours is also shown on Figure 11 which indicates very close agreement between the "as specified" and "as provided" curves.

4.4.1 Maximum Flood Levels

Flood levels within the Kirkton Burn valley have been determined by reservoir routing of the design flood using the ISIS reservoir module incorporating the outlet Stage/Discharge characteristic of Figure 10 and the "as provided" Stage/Area characteristic of Figure 11.

Floods resulting from winter storms of various return periods and durations were routed with results as shown in Table 4-1.

Table 4-1 – FLOOD ROUTING RESULTS

Storm Duration (hours)	Maximum Water Level in Kirkton Burn Valley (m AOD)				
	Tr = 2	Tr = 5	Tr = 10	Tr = 50	Tr = 200
1.25	5.059	5.260	5.461	5.863	-
2.25	5.065	5.287	5.509	5.947	-
3.25	5.034	5.246	5.481	5.943	6.371
4.25	-	-	-	5.899	6.435
4.75	-	-	-	5.875	6.438
5.25	-	-	-	5.863	6.435
6.25	-	-	-	-	6.407
7.25	-	-	-	-	-
Critical durations and water levels are highlighted					

The results of the flood routing showing inflow and outflow hydrographs and storage area water level for the critical 0.5% AEP event are shown on Figure 12.

The maximum extents of the flooded area at the various return periods are shown on Figures 14, 15, 16, 17 and 18.

The maximum water level does not quite comply with the nominal maximum level of 6.4 m AOD but the exceedance is only 38 mm and could, if necessary, be accommodated by a slight raising of the level of the coastal footpath.

4.4.2 Seepage Control

Part of the new valley of the Kirkton Burn will be formed by excavation through existing soils whilst part, towards the eastern end of the valley, will be located on infill. It is necessary to assess the vulnerability of these soils to seepage of water impounded in the valley.

The open cut section will be excavated through soils which are variously described in the driller's log as "made ground, slightly gravely ash" and "made ground slightly sandy ash and fine to coarse gravel". Although the ground investigation in which these results were obtained did not include any permeability tests it is probable, on the basis of the descriptions given, that these soils will be permeable; there is therefore a risk of high seepage rates when water is impounded above these soils possibly leading to reduction in slope stability and underground water flows.

The open cut section terminates at a depth of about 3 m below existing ground level. At that horizon there is an apparent change of material to a soil described as "firm red clay/silt" which should provide an impermeable base to the stream channel. It is proposed to limit seepage through the side slopes by providing a proprietary bentonite mat protected by topsoil. The proposed cross section is shown on Figure 19.

At the eastern side of the valley the stream and flood storage will be located in an area which will have to be infilled to achieve the required levels. It is anticipated that the bulk of this infill material will be obtained from crushed demolition material available on site. All of the available material is granular in nature and it will be compacted in 200 mm thick layers. It is unlikely, however, that the infilled material will be impermeable and measures will be required to prevent seepage of impounded flood water. It is proposed to increase subsoil impermeabilty to a K value of about 10^{-6} cm/sec by incorporating bentonite granules or powder in one of the compacted layers. This will be carried out by a specialist ground treatment contractor and will involve spreading bentonite granules over the compacted soil layer, harrowing and then recompacting and watering if necessary. The bentonite will swell on contact with water thus providing a seal against water penetration. Planting of trees and shrubs can be made through the bentonite layer which will be self-healing.

The bentonite soil treatment system described above may be dispensed with if a source of suitable high clay content soil is available in which event seepage control will be by appropriate compaction.

4.5 Kirkton Burn Upper Reach

4.5.1 Definition

This reach extends from the Kirkton Road link road, at the upper end of the Kirkton Burn valley, upstream to the existing culvert under Aberdour Road near its junction with Kirkton Road.

Within the reach the burn presently runs partly in pipe and partly in open channel a section of which comprises a steep waterfall. The proposed works will open up that section of the burn downstream of the waterfall while the culvert under Kirkton Road will be extended through an area of proposed new flats to the top of the waterfall. The existing waterfall will be retained in its present condition.

4.5.2 Design Flood

Since the upper reach contains no storage provision the culvert and channel capacity is designed to convey the peak of the 0.5% AEP flood. This is calculated for the catchment area down to the Kirkton Road crossing since there will be no discharges from the development site to this reach of the burn. Flood calculations are included in Appendix A. The results are set out in Table 4-2.

Table 4-2 Upper Reach Design Floods

Season	Flood Peak Discharge (m^3/s) for various Return Periods				
	Tr = 2	Tr = 5	Tr = 10	Tr = 50	Tr = 200
Winter	0.58	0.85	1.02	1.48	1.78
Summer	0.60	0.78	0.93	1.36	1.74
Calculated using FSR/FEH Rainfall-Runoff model					

4.5.3 Channel Form

Below Waterfall

The stream must be taken under the new road linking the development to Kirkton Road. At the crossing point the proposed road level is about 9.5 m AOD. Allowing for sufficient cover depth to accommodate services and allowing for a 1200 mm high culvert an invert level in the order of 6.1 m AOD is indicated. The existing stream bed level at the bottom of the waterfall is 8.51 m AOD. The distance between the waterfall and the road crossing is about 52 m which implies a channel bed-slope of 1 in 21.6. This is a supercritical slope for any practicable size of channel and normal roughness with the result that flow will be shallow and fast. This is not the best flow regime for stream ecology. At the 0.5% AEP design event the maximum water level in the Kirkton Burn valley storage will be above the culvert invert so that there will be a weak hydraulic jump at the culvert inlet. There is more than enough freeboard to accommodate this jump.

The proposed new channel must occupy a narrow corridor between a block of town houses and a development road. The corridor must also accommodate the Whinnyhall Tip leachate pipe so that a narrow channel would be preferred. On the other hand a narrow channel will be more difficult to construct, unless pre-cast, and will be vulnerable to blockage.

The proposal is to provide a channel 1200 mm wide between mass concrete side walls with the bed artificially roughened by incorporating rocks and large stones. These will allow the formation of small pools which will trap sediment thus encouraging some ecological interest. At a flowof 1.78 m^3/s and a roughness of 300mm, equivalent to a rough rock-cut, the flow depth will be about 605 mm with a velocity of about 2.5 m/s. The total channel depth is likely to be in the order of 2 m so that there is more than adequate freeboard to accommodate the extreme flood.

The channel width and slope will be continued through the culvert under the link road terminating in a steep cascade into the Kirkton Burn valley.

Above Waterfall

In order to accommodate the proposed development of the north east corner of the site the stream will be culverted upstream from the top of the waterfall to connect with the existing culvert under Kirkton Road. The greater part of this reach is presently culverted through two shallow DN 450 pipes which do not have sufficient capacity to carry the design flood. The existing culvert under Kirkton Road is also shallow so a drop structure will be required at the development site boundary in order to provide sufficient cover through the site. The drop will be within a manhole located at the north east boundary of the development site.

For the design flood of 1.78 m^3/s a DN 900 concrete pipe laid at a slope of 1% from the top of the waterfall will suffice. This will provide a drop of 1.02 m at the connection to the existing culvert thus ensuring that backwater from the new pipe does not affect flow through the existing culvert under Kirkton Road. The final route of this pipe will be determined in conjunction with the architect responsible for the proposed apartment block in the north east corner of the site.

4.6 Residual Risk

4.6.1 Sources of Risk

Extreme Floods

The flood protection proposals around which design of the Kirkton Burn channel and valley storage are based identify the critical storm duration and volume for the selected 0.5% AEP flood. However, larger floods occurring within the lifetime of the development are possible and these larger floods present a residual risk.

Trash

Since the lower reach of the Kirkton Burn is designed for storage rather than conveyance there is little risk arising from blockage of the stream channel. The most vulnerable point is the screen in front of the outlet structure. Since this is intended to trap any trash washed down the stream it will need to be inspected and cleaned on a regular basis. Failure to do this will present a risk.

Mechanical Failure

The proposed outlet regulating valve, being a mechanical device, can fail if not properly maintained. Although the valve will be normally fully open the mode of operation requires it to partially close to regulate flow; failure of the valve to reopen fully could present a risk.

4.6.2 Residual Risk Mitigation

Extreme Floods

The principal mitigation measure to reduce residual risk from this cause is the provision of freeboard above the design maximum water level. In accordance with the principles set out in 4.1, above, there will be a minimum freeboard of 600 mm to the top of the valley sides with a further 150 mm minimum to finished floor level of houses.

The existing culvert under Kirkton Road also provides a degree of risk mitigation since it will control the maximum flow which can pass down the Kirkton Burn into the development site. However, it is normal practice to ignore upstream capacity restrictions on the basis that they could be removed at any time in the future. The sole risk mitigation factor in the upper reach of the Kirkton Burn is the fact that part is contained within a buried pipe and part in relatively deep open channel. Flood water escaping from the upper piped section, a remote possibility, is likely to flow downhill by way of the site roads to the valley of the Kirkton Burn without impounding around buildings.

A further mitigation measure is found at the southern boundary of the valley, adjacent to the flow regulator, where the bank at a level of 7.00m AOD could be over-topped thus providing an escape route for water which would then flow away from the site, through the railway underpass, and thence to Seamill Pond. If this mechanism is to be used as a means of mitigating residual risk to the development it will be necessary to ensure that elsewhere along the southern boundary of the site the finished ground level is above 7.00 m AOD to avoid flooding of the eastern end of Haugh Road and adjacent areas. The same affect can be achieved by ensuring that the "escape route" to the railway underpass is set at a level slightly below 7.00 m AOD. That is the preferred option and will be incorporated in the design.

Trash

The main defence against trash-blockage flooding is to provide a large screen area which is regularly maintained. Public education also has a role to play. The proposed screen area is about 14m^2 normal to the flow or about 20 m^2 in the plane of the screen. These areas are well in excess of recommended minimum areas given by current guidance[5].

Mechanical Failure

The only real defence against mechanical failure is regular inspection and maintenance. However, the flow regulating mechanism has been selected for its simplicity and robustness both factors providing a high degree of reliability. The particular valve selected is widely used in sewerage applications which provide a much more testing environment than the current application. While the risk of mechanical failure is likely to be relatively high the consequences of failure are low given the other mitigation measures in place.

4.6.3 Reservoir Safety Legislation

The Reservoirs Act 1975 which deals with the safety of large raised reservoirs defines a raised reservoir as "designed to hold, or capable of holding, water above the natural level of any part of the land adjoining the reservoir." The "valley storage" of the Kirkton Burn will store water above the natural level of the land alongside Haugh Road where it abuts the south-eastern corner of the site. It would appear therefore that the proposed flood protection works fall within the legal definition of a raised reservoir. However, the provisions of the Reservoirs Act apply only to large raised reservoirs which are defined as "a raised reservoir … designed to hold, or capable of holding, more than 25,000cubic metres…". At the maximum retention level of 7.00 m AOD the volume of water which can be stored within the Kirkton Burn valley is 18,700 m^3. The proposed storage area is not, therefore, a large raised reservoir and the provisions of the Reservoirs Act do not apply.

Although not subject to the requirements of the Reservoirs Act it would be prudent to regularly inspect the earthworks adjacent to Haugh Road to ensure their integrity, make good any defects, and control the activities of burrowing animals.

4.6.4 Maintenance

A key component of any risk mitigation strategy is maintenance. The developer, Collinswell Land Ltd., intends to establish a trust with specific responsibility for the ongoing maintenance of all landscaped areas within the development. The responsibilities of the trust will include maintenance of trash screens, flow regulator, culverts and embankments which are essential components of the flood protection works. The Trust will be maintained in perpetuity by conditions contained within the missives of each property developed.

[5] Posford Haskoning Trash Screens Design and Operations Manual, Environment Agency, Bristol 2001

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5 WATER SAFETY

5.1 Risk Assessment and Mitigation

5.1.1 General Approach

In designing the proposed works public safety considerations have been taken into account in accordance with recognised current standards[6].

Risk is defined as the product of likelihood and consequence. In the absence of statistical data, the level of risk is usually calculated on a qualitative (ie subjective) basis. A simple risk level estimator, for example BS 8800:1996, grades risk as either trivial, tolerable, moderate, substantial or intolerable. The approach adopted here is to carry out a risk assessment based on the known, or anticipated, hazards and then devise mitigation measures which will reduce the risk to a tolerable level.

A major problem in carrying out a risk assessment in respect of surface water bodies is that there is virtually no gradation of consequences. The outcome is either trivial or fatal unless there is a risk of contracting a water-borne disease when the consequences may lie somewhere in between those extremes.

5.1.2 Seamill Pond

Although it lies outside the boundary of the Collinswell Park development the Seamill Pond is an integral part of the site flood protection measures and the hazard presented by the pond needs to be addressed, particularly since the Fife Coastal Footpath will be routed around the pond.

At low water level the pond is about 2m maximum depth. The depth will increase to a maximum of about 5m at the extreme design event. The setting and nature of the pond are such that it is improbable that it will be used for water-based activities; the probability of accidents occurring is therefore low.

The Fife Coastal Footpath will run around the west side of the pond which is near vertical being formed by the old seawall. However there is a roughly vegetated marginal strip about 2 m wide between the edge of the pond and the path so that the public will not be walking in direct proximity to the edge of the pond. It is proposed to provide a fence 1100 mm high alongside the path to further discourage access to the edge of the pond.

The public footpath on the north side of Haugh Road will run directly alongside the pond. Protection will be provided by a continuation of the fence and the erection of appropriate hazard warning signs.

5.1.3 Kirkton Burn

The nature of the Kirkton Burn and its proposed setting are such that it is likely to feature in waterside activities rather than water-based activities thus reducing risk by making accidents highly unlikely.

In its natural low-flow condition the Kirkton Burn presents a negligible hazard although the creation of parkland alongside it will increase the likelihood of an accident and therefore increase the level of risk. In high flow conditions the basis of the design is that water will impound within the valley of Kirkton Burn therefore increasing the depth while reducing the velocity. Increased depth increases the likelihood of harmful consequences so that while the likelihood of an accident may be less – for example due to bad weather reducing the number of people using the park - the risk may well increase.

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[6] RoSPA Safety at Inland Water Sites – Operational Guidelines, Royal Society for the Prevention of Accidents, Birmingham, 1999

The principal risk mitigation measure proposed is the provision of relatively flat slopes in areas where the public is likely to have access to the stream channel. This provision will allow people to move easily upslope and means that water level will rise slowly. Where, for space reasons, slopes have been made steeper the risk is mitigated by ensuring that the general public will have no direct access by using appropriate planting. The RoSPA guidance recommends use of a rule–of-thumb which states that a person should be able to stand with their head above water at a distance two body lengths from the shore, an implied slope of about 2 to 1. The proposed slopes are nowhere steeper than 2.5 to 1 and therefore flatter than the RoSPA recommended maximum slope.

Since water-based activities are unlikely it is not proposed to erect hazard warning notices. The outlet structure will be protected on three sides by a parapet wall 1100 mm high and appropriate notices will be fixed to the wall.

5.1.4 Conclusions

Given the other facilities and opportunities for water-based activities available elsewhere within Burntisland it is considered that the day-lighting of the Kirkton Burn will not appreciably increase the risk of water related accidents.

FIGURES

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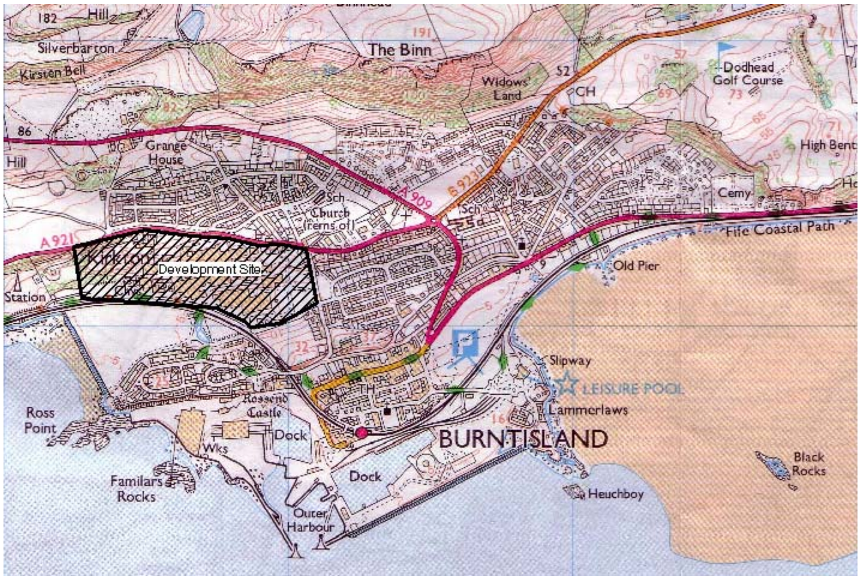

Figure 1 – Site Location Plan

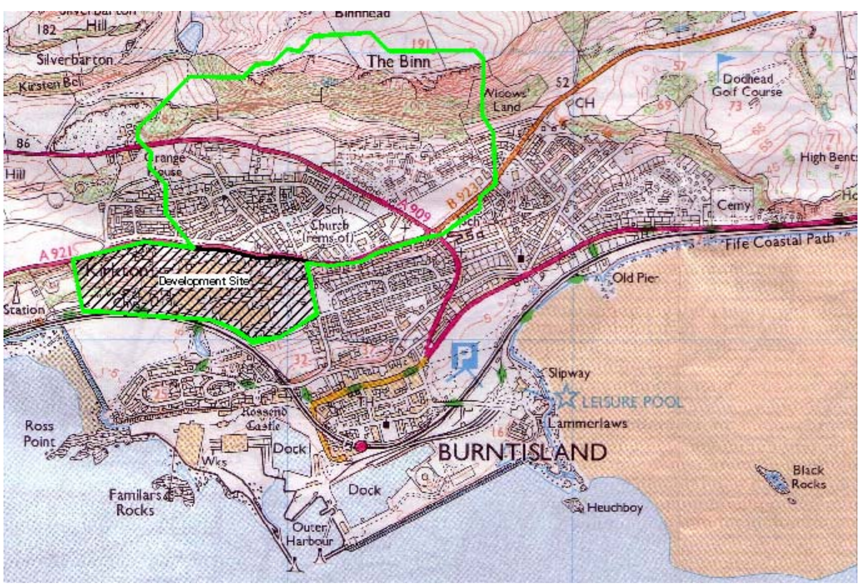

Figure 2 – Kirkton Burn Catchment Area- Post Development

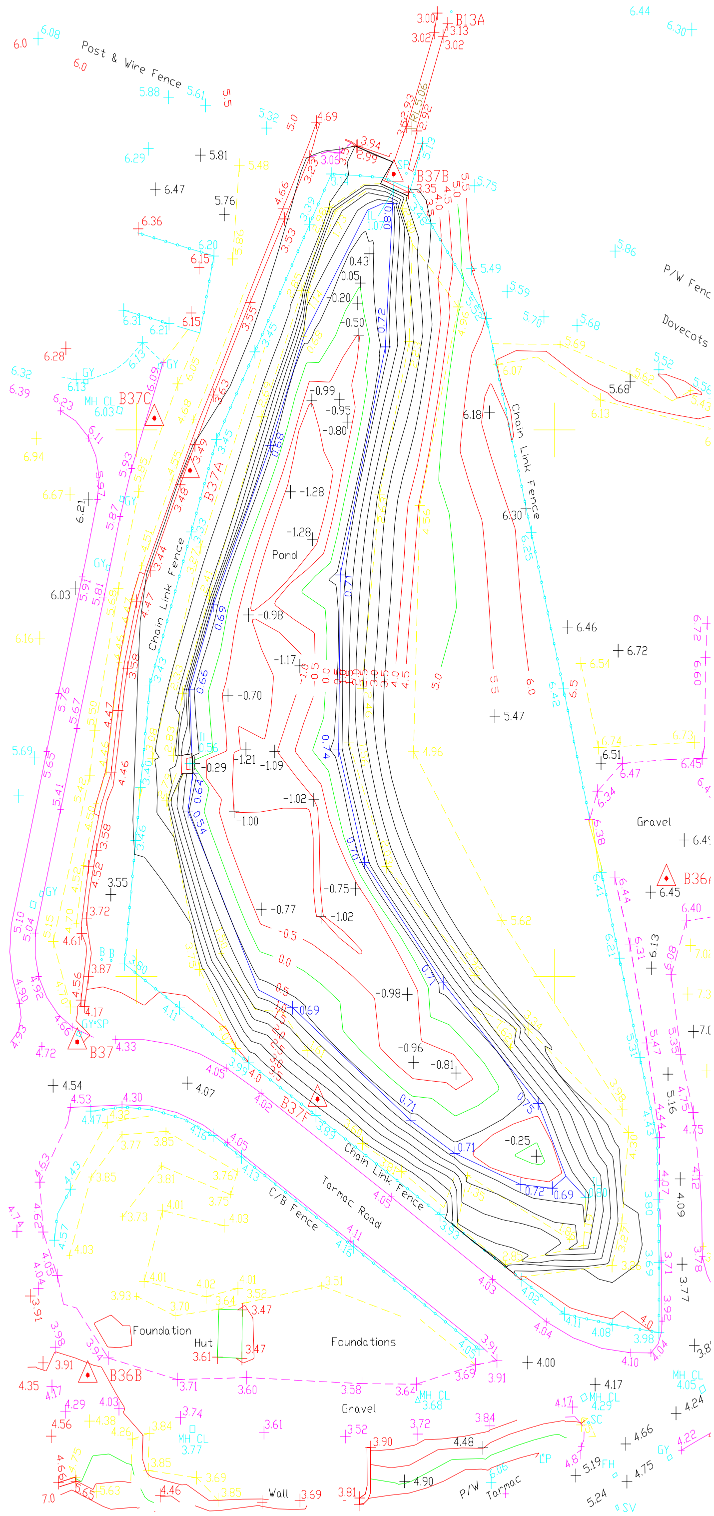

Figure 3 – Seamill Pond Hydrographic Survey

(not to scale)

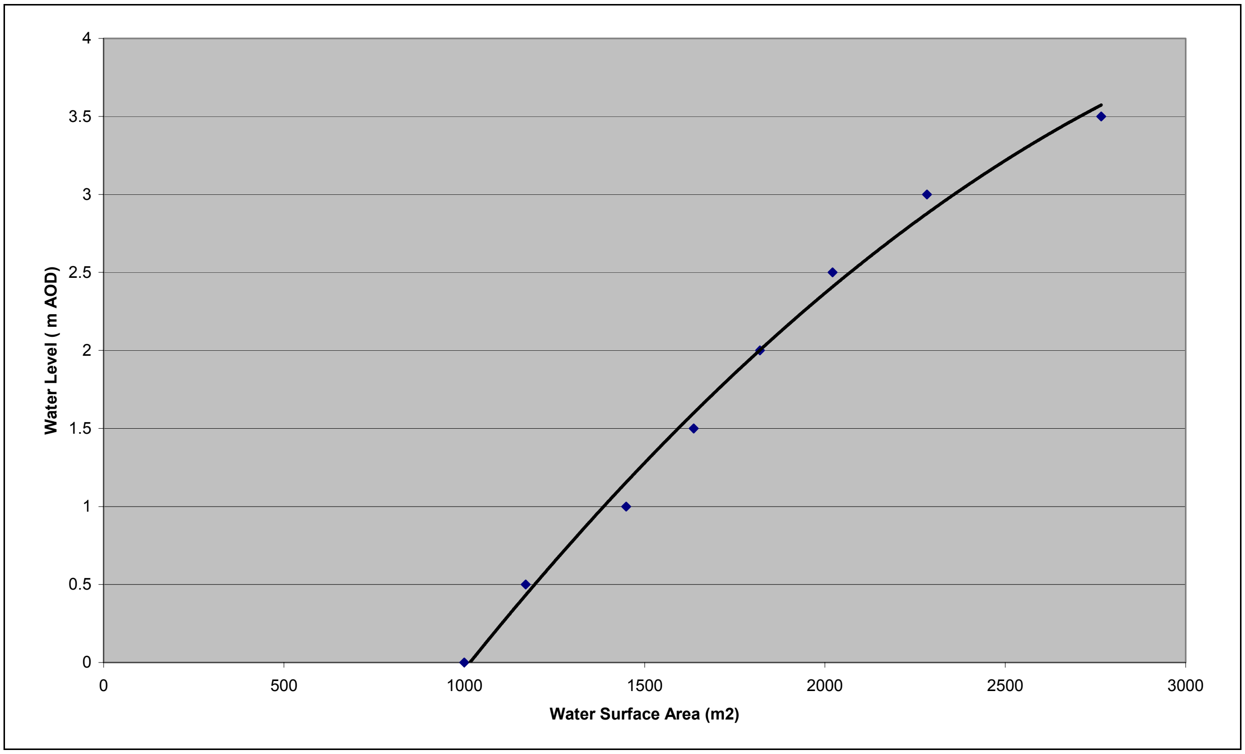

Figure 4 – Seamill Pond Stage/Area Curve

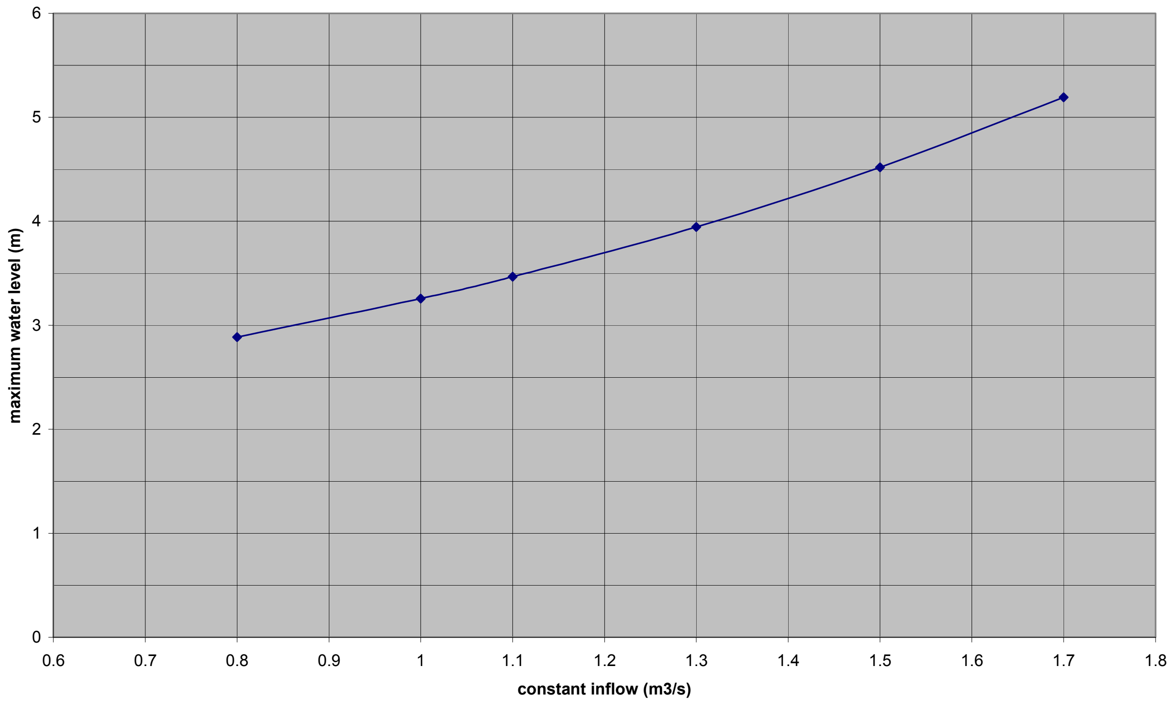

Figure 5 – Seamill Pond Optimum Constant Inflow

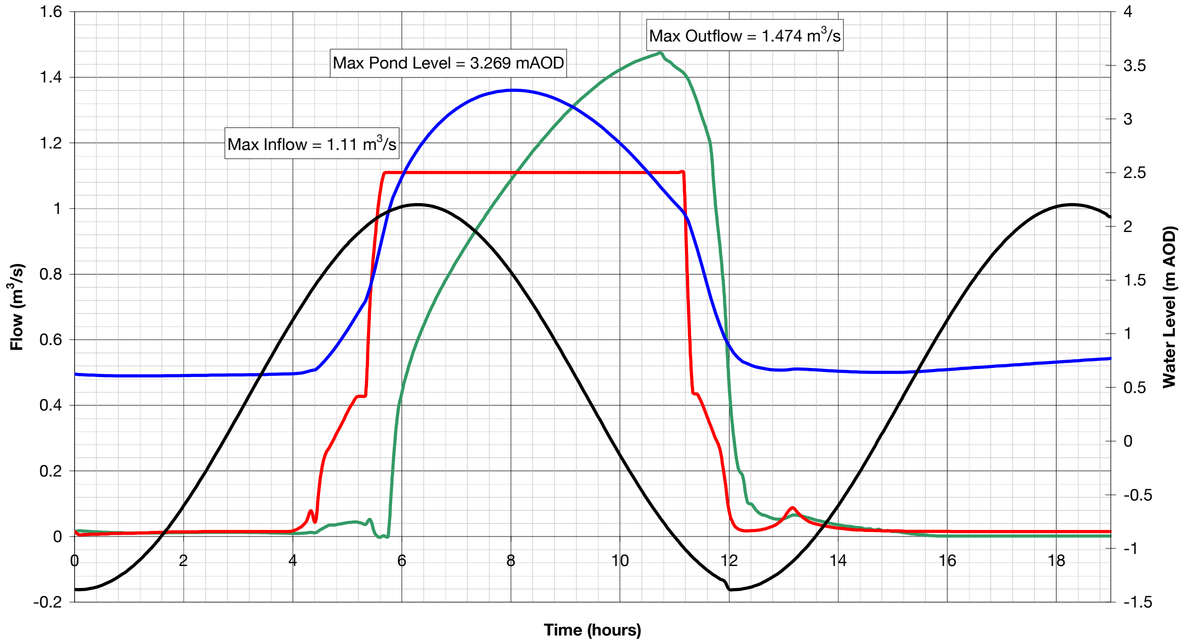

Figure 6 – Seamill Pond – Design Flood Condition

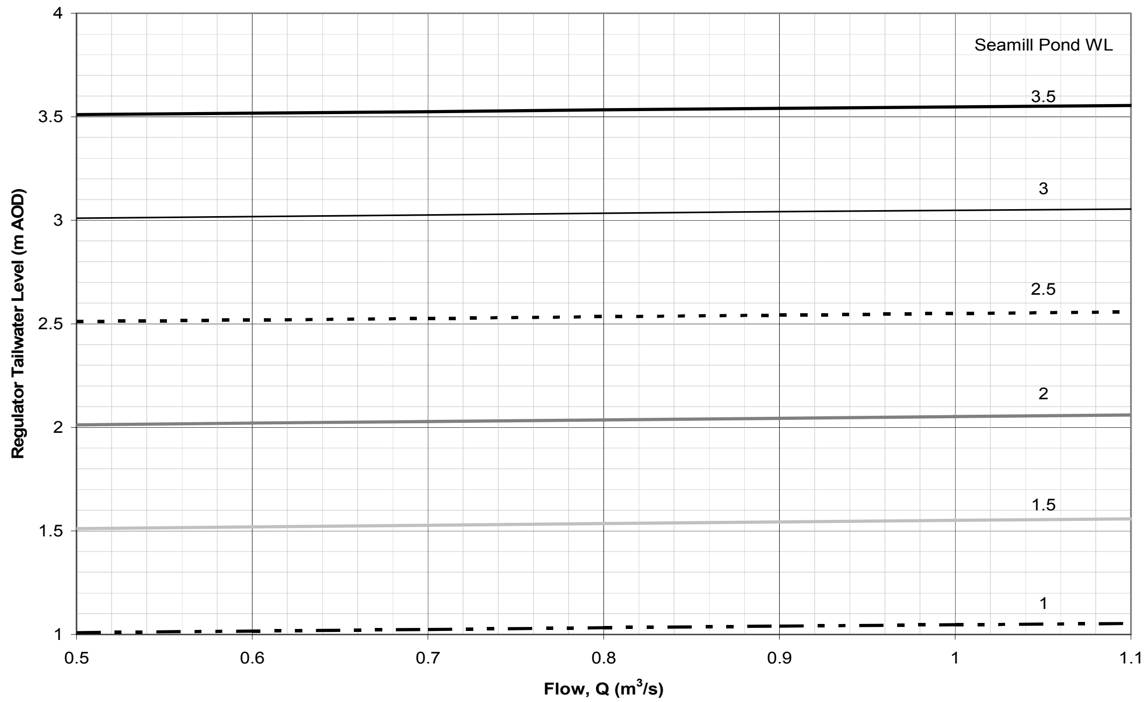

Figure 7 – Flow Regulator Tailwater Levels

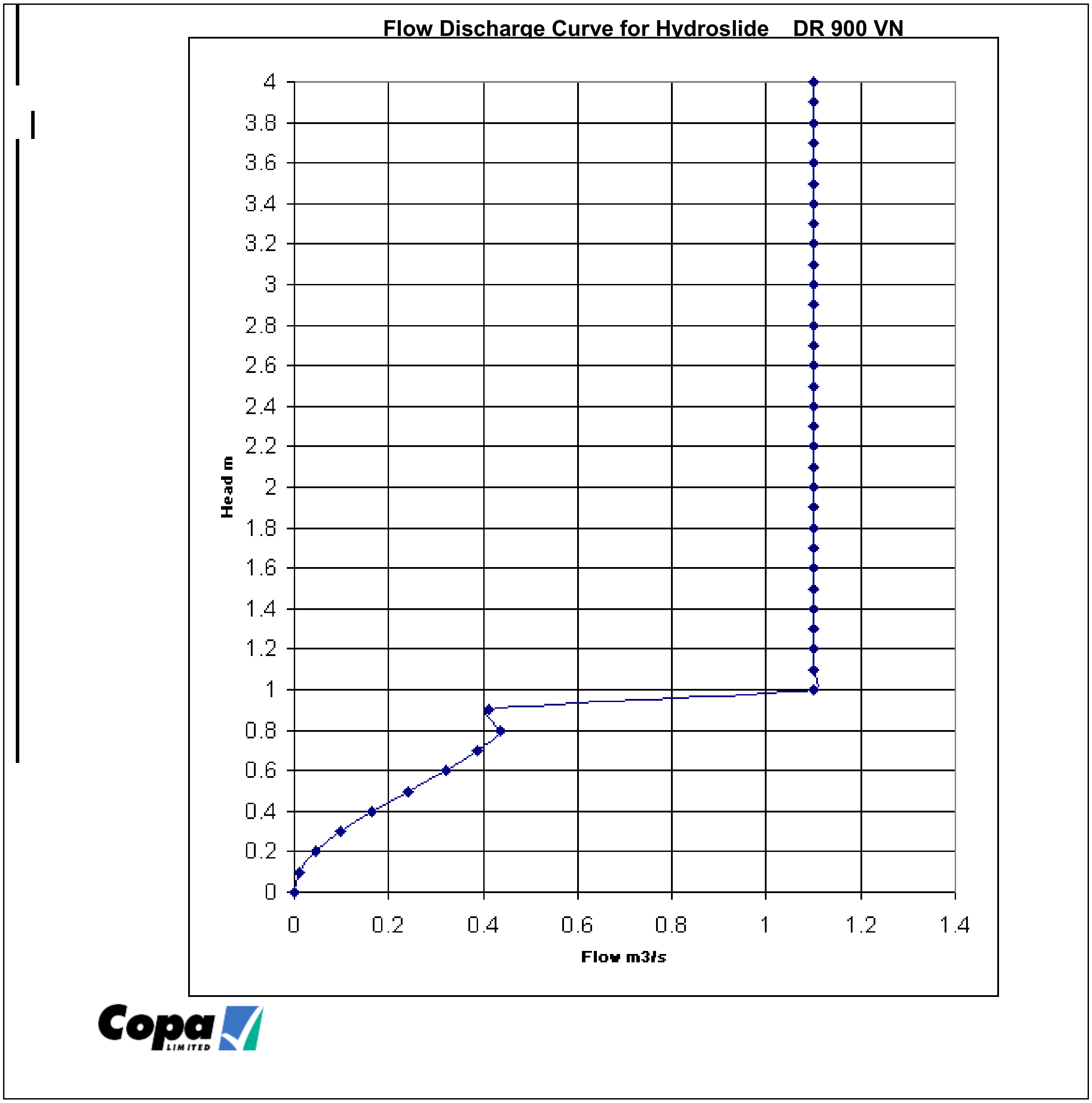

Figure 8 – Hydroslide Valve Stage/Discharge Curve

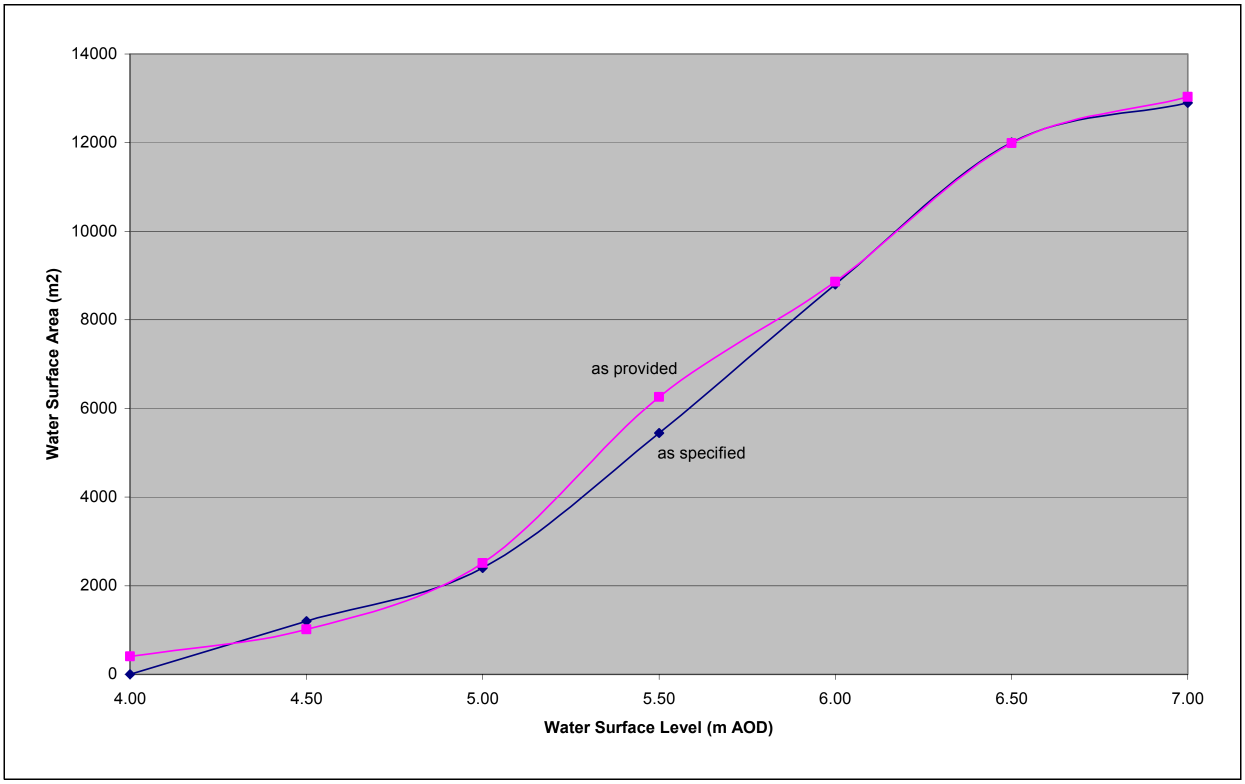

Figure 9– Valley Storage Stage/Area Curve

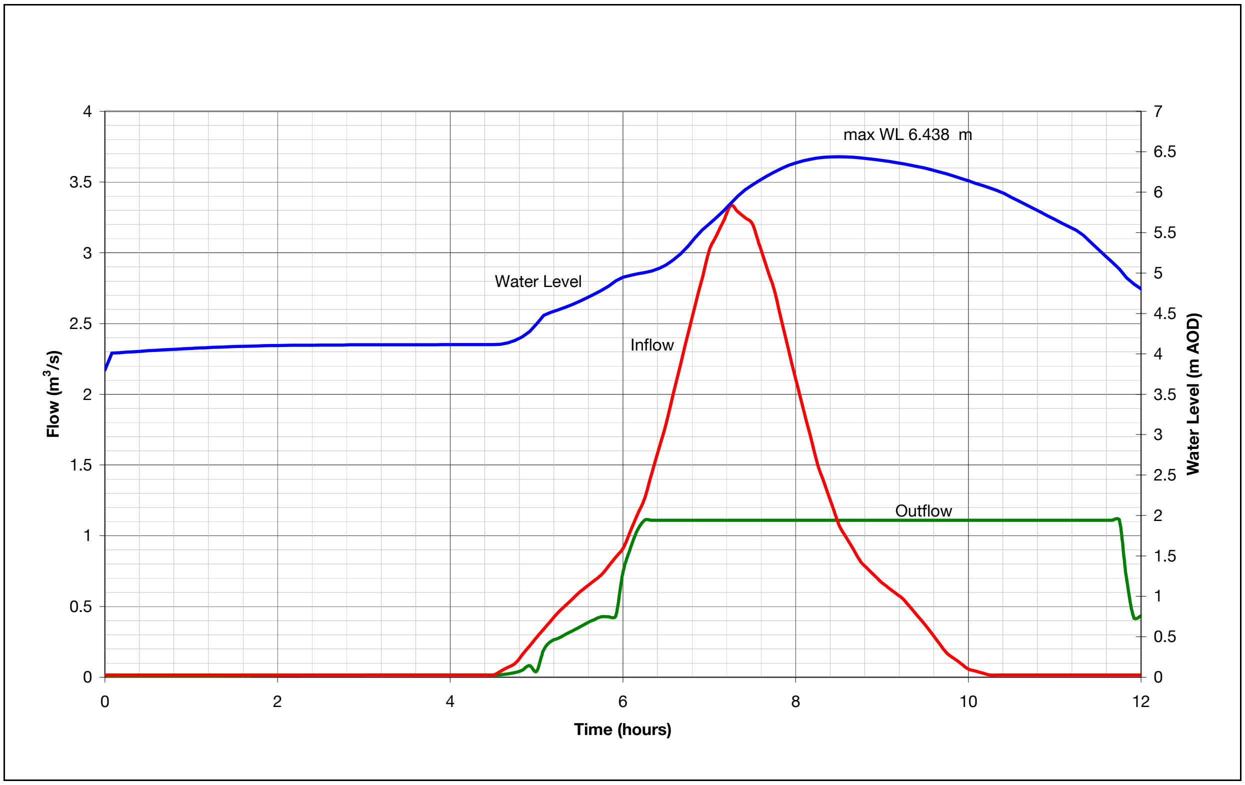

Figure 10– Valley Storage Routing of Critical Design Flood

Appendix A: - Flood Calculations

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HYDROLOGICAL DATA

Catchment: Total to Railway Culvert modified to include Development

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Catchment Characteristics

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Easting : 322750
Northing : 686100
Area : 0.990 km2
DPLBAR : 1.040 km
DPSBAR : 184.500 m/km
PROPWET : 0.450
SAAR : 718.000 mm
Urban Extent : 0.261
c : -0.014
d1 : 0.434
d2 : 0.422
d3 : 0.276
e : 0.242
f : 2.150
SPR : 46.300 %

****

Summary of estimate using Flood Estimation Handbook rainfall-runoff method

****

Estimation of T-year flood

=========================

Unit hydrograph time to peak : 0.474 hours
Instantaneous UH time to peak : 0.349 hours
Data interval : 0.250 hours
Design storm duration : 4.750 hours
Critical storm duration : 0.814 hours
Flood return period (not used) : 200.000 years
Rainfall return period : 200.000 years
ARF : 0.972
Design storm depth : 52.662 mm
CWI : 106.160
Standard Percentage Runoff : 46.300 %
Percentage runoff : 48.384 %
Snowmelt rate : 0.000 mm/day
Unit hydrograph peak : 0.459 (m3/s/mm)
Quick response hydrograph peak : 3.319 m3/s
Baseflow : 0.015 m3/s
Baseflow adjustment : 0.015 m3/s
Hydrograph peak : 3.334 m3/s
Hydrograph adjustment factor : 1.000

Flags

=====

Unit hydrograph flag : FSRUH
Tp flag : FEHTP
Event rainfall flag : FEHER
Rainfall profile flag : WINRP
Percentage Runoff flag : FEHPR
Baseflow flag : F16BF
CWI flag : FSRCW

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Catchment: Total to Railway Culvert – Critical Duration

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Rainfall Profile - Unit and Flow Hydrograph Using
FEH rainfall-runoff method

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Hydrograph adjustment factor = 1.000

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TABULAR RESULTS

time (hours)	areal rainfall (mm)	net rainfall (mm)	unit hydrograph (m3/s/mm)	flow hydrograph (m3/s)
0.000	0.700	0.339	0.000	0.015
0.250	0.991	0.479	0.242	0.097
0.500	1.150	0.557	0.443	0.281
0.750	1.386	0.671	0.283	0.458
1.000	1.656	0.801	0.124	0.602
1.250	2.404	1.163	0.000	0.724
1.500	3.603	1.743		0.911
1.750	4.920	2.380		1.263
2.000	6.070	2.937		1.793
2.250	6.902	3.339		2.420
2.500	6.070	2.937		3.016
2.750	4.920	2.380		3.334
3.000	3.603	1.743		3.204
3.250	2.404	1.163		2.739
3.500	1.656	0.801		2.108
3.750	1.386	0.671		1.514
4.000	1.150	0.557		1.079
4.250	0.991	0.479		0.819
4.500	0.700	0.339		0.667
4.750				0.551
5.000				0.370
5.250				0.171
5.500				0.057
5.750				0.015

****

Volumetric analysis of results

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Total volume of rainfall : 52135.6 m3
Total volume of net rainfall : 25225.2 m3
Total volume of rain loss : 26910.5 m3
Total volume of baseflow : 328.8 m3
Total volume of quick runoff : 25059.2 m3
Total volume of runoff : 25388.1 m^3

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HYDROLOGICAL DATA

Catchment: Upper burn to Kirkton Road
****
Catchment Characteristics
****
Easting : 323050
Northing : 686200
Area : 0.690 km2
DPLBAR : 0.740 km
DPSBAR : 241.200 m/km
PROPWET : 0.450
SAAR : 728.000 mm
Urban Extent : 0.018
c : -0.014
d1 : 0.432
d2 : 0.420
d3 : 0.276
e : 0.242
f : 2.156
SPR : 45.800 %
****
Summary of estimate using Flood Estimation Handbook rainfall-runoff method
****
Estimation of T-year flood
==========================
Unit hydrograph time to peak : 1.034 hours
Instantaneous UH time to peak : 0.909 hours
Data interval : 0.250 hours
Design storm duration : 1.750 hours
Critical storm duration : 1.787 hours
Flood return period (not used) : 200.000 years
Rainfall return period : 200.000 years
ARF : 0.972
Design storm depth : 36.946 mm
CWI : 107.360
Standard Percentage Runoff : 45.800 %
Percentage runoff : 41.707 %
Snowmelt rate : 0.000 mm/day
Unit hydrograph peak : 0.147 (m3/s/mm)
Quick response hydrograph peak : 1.765 m3/s
Baseflow : 0.011 m3/s
Baseflow adjustment : 0.015 m3/s
Hydrograph peak : 1.776 m3/s
Hydrograph adjustment factor : 1.000

Flags
=====
Unit hydrograph flag : FSRUH
Tp flag : FEHTP
Event rainfall flag : FEHER
Rainfall profile flag : WINRP
Percentage Runoff flag : FEHPR
Baseflow flag : F16BF
CWI flag : FSRCW

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Catchment: Upper burn to Kirkton Road – Peak Flow

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Rainfall Profile - Unit and Flow Hydrograph Using
FEH rainfall-runoff method

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Hydrograph adjustment factor = 1.000

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TABULAR RESULTS

time (hours)	areal rainfall (mm)	net rainfall (mm)	unit hydrograph (m3/s/mm)	flow hydrograph (m3/s)
0.000	1.742	0.726	0.000	0.015
0.250	3.008	1.255	0.035	0.037
0.500	7.627	3.181	0.071	0.107
0.750	12.192	5.085	0.106	0.290
1.000	7.627	3.181	0.142	0.654
1.250	3.008	1.255	0.127	1.093
1.500	1.742	0.726	0.103	1.508
1.750			0.080	1.776
2.000			0.057	1.761
2.250			0.033	1.544
2.500			0.010	1.237
2.750			0.000	0.893
3.000				0.567
3.250				0.297
3.500				0.126
3.750				0.048
4.000				0.018
4.250				0.015

****

Volumetric analysis of results

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Total volume of rainfall : 25492.6 m3
Total volume of net rainfall : 10632.1 m3
Total volume of rain loss : 14860.5 m3
Total volume of baseflow : 179.7 m3
Total volume of quick runoff : 10601.3 m3
Total volume of runoff : 10788.0 m3