REDROW

BAE SYSTEMS

ROYAL ORDNANCE, BISHOPTON

OUTLINE PLANNING APPLICATION FOR THE REGENERATION OF THE SITE TO FORM A MIXED USE COMMUNITY GROWTH AREA

FLOOD RISK ASSESSMENT

May 2006

RO BISHOPTON

FLOOD RISK ASSESSMENT

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APPENDICIES

1.0 INTRODUCTION

The Royal Ordnance Factory at Bishopton is around 1,000ha in extent and is located to the south west of Bishopton in Renfrewshire. The RO Bishopton site is separated from the main part of the village of Bishopton by the Glasgow to Greenock railway line. The site has over 2200 buildings across it's area and has been extensively developed over the years. Due to the nature of production on site there is a reasonable amount of separation on site with several areas of mature woodland being present within the grounds.

For the past century the site has been used, to different levels of intensity, for the production of explosives. The owners of the site, BAE Systems, announced their intention to cease manufacturing at the plant in December 1999.

Following this announcement a working group was established by the Scottish Executive to investigate the feasibility of remediating and redeveloping the site. The resulting study from the working group set out a number of differing development scenarios in relation to the core objectives set by the working group. Subsequent to this study further investigation was commissioned by BAE Systems to undertake a more detailed analysis of the regeneration proposals and in particular to consider in more detail the scale and mix of development which would satisfy both strategic planning requirements and be commercially viable.

The proposals from this additional study identified the potential for an expansion to the existing Bishopton settlement to the west with a mix of residential, commercial, business, community and recreational uses, with the majority of the site retained as undeveloped land with public access.

The proposed redevelopment comprises

- around 2,500 residential units
- about 150,000 m^2 of new employment floor space
- multi-modal transport junction
- local retail expansion
- local expansion of community facilities
- potential for a new primary school
- Woodland Park
- Landfill and Associated Buffer

A site plan and proposed land use plan is provided within Appendix 1 of this strategy report.

The proposed areas of land use within the application are as detailed below

Land Use	Area (Ha)
Residential	90.77
Employment (Business Park)	40.31
Commercial	1.91
Mixed Use (community, commercial, residential)	7.62
Total Development Area	**140.61**

Upton McGougan were commissioned by Redrow Homes (Scotland) Limited and BAE Property Investments Limited to prepare a Flood Risk Assessment (FRA) and strategy for the inclusion of sustainable urban drainage systems within the proposed redevelopment of the site.

The redevelopment of the site is envisaged to be undertaken over a period of up to 15 years. It is therefore possible that the options identified as the main strategy to be followed at this time may require to change over time to reflect changes in the regulatory regime.

2.0 EXISTING SURFACE WATER REGIMES

Two main watercourses flow through the boundary of the site.

Craigton Burn enters the site along the southern boundary of Bishopton village through a culvert within the railway embankment and flows generally west and south to its confluence with the Dargavel Burn.

Dargavel Burn flows into the north west corner of the site and flows generally south and east, leaving the site in the south east corner near to its confluence with the River Gryffe.

The Ordnance Survey sheet for the site and historical site records indicate that some other minor watercourses may flow into the site. These watercourses were not always identifiable as such on the ground and consequently may represent seasonal watercourses. The existing watercourses and drainage ditch network is identified within Appendix 2.

The existing surface water drainage regime within the site boundary generally comprises a series of interconnected drainage ditches flowing generally south and east which discharge into the Craigton Burn. It is possible that some surface water is conveyed within a piped combined system to discharge at the existing private wastewater treatment works on the site. Historical Ordnance Survey maps indicate that the system of ditches generally predate the development of the Royal Ordnance Factory at Bishopton although some alterations were undertaken to suit the factory use.

Three ponds are present along the eastern side of the site to the south of the main site access from Station Road. These ponds are the remains of an historic brickworks present on the site prior to it's use as an ordnance factory. The ponds would originally appear to have been fed by ground water however during the life of the factory the ponds were utilised as storage ponds to service the fire mains around the site. A system was implemented which results in flow from the Dargavel Burn being diverted by pipe to the ponds by means of a weir system to ensure that the ponds remained topped up. The three ponds are interlinked by pipework and overflow, as necessary, into the Craigton Burn which flows between the ponds. The ponds are known as either the Brick Ponds or Fire Ponds in reference to their historic uses.

A low resolution indicative flood plain map has been prepared by the Institute of Hydrology for the wider area of the River Gryffe and White Cart Water catchments. This map shows that the Dargavel and Craigton Burns may be at risk of flooding and gives 1 in 100 year block flood contours in 1.0m flood depth increments (refer to Appendix 3). The development area within the site is shown on the indicative flood plain map as potentially being flooded to depths exceeding 2m under 1 in 100 year return. The site is therefore recognised as being potentially at risk of flooding.

3.0 APPROACH TO FLOOD RISK ASSESSMENT

With the Institute of Hydrology flood plain map indicating that the site was potentially at risk of flooding, a scoping study was undertaken by Upton McGougan to identify and outline current planning policy in relation to flood risk and surface water drainage and to set a framework around which a Flood Risk Assessment could be developed.

The scoping study included a desk exercise reviewing

- Scottish Planning Policy (SPP) 7: Planning and Flooding, published by the Scottish Executive
- Renfrewshire Local Plan, published by Renfrewshire Council
- SEPA Policy 41: Development at Risk of Flooding: Advice & Consultation
- SEPA Policy 15: Regulation of Urban Drainage

Following the desk review of the available documents, consultations took place with Renfrewshire Council, SEPA and BAE Systems to identify any historic information related to flooding of the site which may be available and agree with Renfrewshire Council and SEPA, as statutory consultees, the extent of any required Flood Risk Assessment for the site.

The scoping study concluded that

1 A Flood Risk Assessment was required in support of the outline planning application for redevelopment of the site

2 Survey work would be required along the full length of the main watercourses traversing the site to assist in the hydraulic modelling of the site. Surveys and modelling work required to extend outwith the site upstream for the Craigton Burn and downstream on the Dargavel Burn to it's confluence with the River Gryffe. The survey was to be tied into a full topographical survey of the site already underway.

3 Detailed hydraulic models would be prepared and validated using information obtained from SEPA on flow gauges present on the River Gryffe.

4 The validated hydraulic model would be used to assess the existing site conditions for flooding under return rainfall events of 1 in 200 year (+20% climate change factor), 1 in 500 year (+20% climate change factor) and 1 in 1000 year (+20% climate change factor).

5 Should the hydraulic modelling indicate flood issues affecting the proposed development areas then outline mitigation measures would be explored and quantified in broad terms.

The scoping study was issued in July 2005 for comments and confirmation was obtained from both SEPA and Renfrewshire Council that the proposed

methodology for undertaking the FRA was acceptable to them. The study can be found in Appendix 4.

The flood risk modelling was implemented and topographic and walkover surveys were undertaken for both the Craigton and Dargavel Burns and a hydraulic model prepared along with a Digital Terrain Model. Unit Hydrograph and Index Flood estimation was undertaken utilising the rainfall-runoff method in line with the Flood Estimation Handbook published by the Institute of Hydrology as no suitable donor sites could be identified to derive the index flood. Refer to Appendix 5 for a copy of the model.

Flood risk envelopes for the three return event periods (plus climate change factor) were developed from the hydraulic model.

The flood risk envelopes are shown in Appendix J of the model. These indicate that large areas of the development area are prone to flooding under the current hydraulic system due to flooding from the Craigton Burn.

A copy of the Flood Risk Model defining the survey work undertaken, assumptions adopted and flood estimation information was issued to both SEPA and Renfrewshire Council in November 2005 for comment and agreement on the acceptability of the developed model.

Renfrewshire Council advised us on the 23rd Nov 2005 that the Flood Model issued would provide an acceptable basis for preparation of the FRA.

On 20th January, SEPA provided comments on the Flood Risk Model and noted the following points

1 The site is a strategic 'brownfield' development site

2 SEPA hold no record of flooding for the site other than the Institute of Hydrology Indicative Flood Risk Map (see App 3)

3 The estimates of design flow from the Flood Risk Model are generally consistent with SEPA's own estimates

4 The Index Flood used is considered to be broadly correct

5 The hydraulic model use of steady state flow and maximum Manning's 'n' adopted ensure a robust model

6 The flow in the Craigton Burn is restricted within the site by the presence of the railway culvert and either control of the structure should be guaranteed or full design flow (assuming no culvert) should be modelled.

7 The strategy document should outline reasons for allowing development within the floodplain.

8 Level for Level compensatory storage would be adopted and could include reprofiling of the southern areas of the site outwith the development zone to avoid negative flood impacts

A copy of the SEPA memorandum dated 20th January 2006 is included within Appendix 6. Following receipt of this memo, discussions took place with SEPA and the following amendments to SEPA's requirements were agreed on 14th February 2006.

- For the determination of flood compensation storage, the restriction of the railway culvert on inflow to the Craigton Burn could be assumed to be in place.

- A sensitivity analysis will be undertaken with the railway culvert removed from the model and full catchment flow in the Craigton Burn. This would be used to assess freeboard requirements.

- Conveyancing of floodwater through a reprofiled Craigton Burn channel to a flood storage area outwith the development area but within the site boundary would be acceptable provided that it can be shown through modelling that no adverse impact occurs to watercourses outwith the site boundary

Copies of the correspondence with SEPA on this matter are included within Appendix 7 of this report.

From the basis of the agreements with SEPA and Renfrewshire Council, the hydraulic modelling of the Craigton and Dargavel Burns to provide flood protection to the development area and flood compensation storage for the remodelled scheme were undertaken. Sections 4.0 and 5.0 of this report detail the requirements of this approach.

In agreeing the methodology of the FRA with SEPA, a request was made to provide an explanation of the requirement to develop areas within the functional floodplain and utilise improved conveyancing and flood compensation storage outwith the development area but within the site boundary.

Initially we will consider the Masterplan Principles which were agreed for this development which, amongst others, include

1 The scale of development should be set at a level which enables the full remediation of the site whilst addressing fundamental long-term development needs.

2 There is a need for close integration with the existing community of Bishopton through a process of managed urban expansion. The Structure Plan (draft) Alteration strengthens this principle through designation of the site as a Community Expansion Area requiring integration with the community and infrastructure of the exissting Bishopton settlement.

3 Accessibility to the site and within the site should facilitate ease of movement by modes other than the private car

These basic principles, alongside other technical reasons, form the main basis for proposing that the functional floodplain for the site is altered to allow flood protection through conveyancing and flood compensation storage outwith the development area.

From the Flood Risk Envelope (Appendix 4) it can be seen that in order to move the development areas outwith the functional flood plain identified, it would be necessary to move significant elements of the development southwards, the area north of the Craigton Burn flood plain being constrained by the site boundary to the north and other functional flood plain from the Dargavel to the west.

Moving these areas would effectively create two development area with the northern one generally integrated into the existing community and in close proximity to the existing public transport infrastructure and hubs but with the southern area being isolated and cut off from both the transport links and community. This form of development would be socially exclusive and would not lend itself to a sustainable development.

A key technical driver for the development location and form within the site is the ground conditions below the site. Along the northern area of raised ground there exists more competent strata from a geotechnical point of view however the southern flatter areas generally comprise of up to around 25m of weak alluvial silts and layers of peat in areas. These areas require ground improvement techniques to allow development to proceed.

A key driver in the scale of development is the requirement to generate sufficient value from redevelopment to enable the remediation of the site. Moving large areas of development southwards brings areas of peat and poorer soils to bear on more of the proposed developed areas which increases the cost of developing in these areas and reduces the value which can be released for site remediation.

It can be therefore be seen that to deliver a sustainable socially inclusive development at an economic level which delivers the value required to ensure remediation of the site it has been necessary to place the development in the northern area of the site which encompasses the Craigton Burn flood plain.

With this in mind and to protect the development from flooding the use of measures to improve conveyance of flow through the Craigton Burn channel allied with flood compensation storage outwith the development area represents the most sustainable solution.

4.0 FLOOD PROTECTION

It has been established that a large proportion of the development area lies within the flood plain of the Craigton Burn therefore the requirements of SPP7 cannot be met without introducing a method of flood protection for the areas affected.

The floodplain envelopes that were established during the flood risk modelling extend out to encompass the low-lying areas surrounding the Craigton. The 1 in 200 year flood inundates the low lying areas, the 1 in 500 year flood represents a marginal increase in flood area and the 1 in 1000 year flood extends further upstream on the Cordite Burn.

The proposed method of flood protection is to improve the dynamics of the Craigton Burn such that it has the capacity to convey flood flows without breaching thereby ensuring all flood flows are contained with the river banks.

It has been necessary to develop the original steady state flow model into a dynamic model for both burns using the hydrographs derived in Appendix D of the Flood Risk Model. The T200+20% hydrograph has been applied as the upstream boundary condition using a fixed start time for both burns, this has enabled a full assessment of the disparity between the Dargavel and Craigton catchments and has provided a more accurate representation of the effects of the railway culvert.

A copy of the dynamic model results for the existing burn geometry can be found in Appendix 8. It can be seen that the maximum water surface elevation on the Craigton just downstream of the railway culvert has increased by 300mm over the steady state model and this is largely attributable to the head water upstream of the culvert.

The dynamic model and steady state model start to exhibit uniformity just upstream of the existing ponds to a point downstream of the ponds, thereafter the levels from the dynamic model start to reduce as the catchment disparity becomes more prominent and the effects of the flood plain storage are accumulated.

The flow area of the Craigton Burn will need to be increased to accommodate the flood flows. The bed will also need to be re-profiled to provide a uniform gradient from the railway culvert down to the confluence with the Dargavel.

This reworking of the Craigton channel will require all the existing bridge crossings to be removed.

The model geometry has been revised to provide a uniform channel width and bed gradient. The Mannings 'n' values have been retained from the existing model so that the behaviour of the channel after vegetative establishment can be assessed.

The channel bed width has been increased to 4.0m wide and the banks have been extended out to 2.0m wide each side of the bed. This gives an overall channel width of 8.0m.

The results of the improved Craigton geometry can be found in Appendix 9. It can be seen that the 1 in 200 year +20% flood flow is contained within the banks of the Craigton and therefore does not inundate the development area.

It has been necessary to assess the effects of removing the railway culvert thereby subjecting the Craigton to the full flood flow. It has been advised that this assessment would facilitate the establishment of an additional level of protection over and above the restricted flood flows.

Appendix 10 contains the model results with the culvert removed as compared to those with the culvert. It can be seen that the maximum increase in water surface elevation is 450mm at river station 745.

It is proposed to provide a soft defence in the form of a bund along the banks of the Craigton. The bund is to be built up 500mm higher than the 1 in 200 year + 20% flood level. This bund will ensure adequate protection of the development zones during high order floods and the eventuality of the culvert being opened up.

The bund could take the form of a soft landscaped feature with gentle slopes and could be utilised as a footpath / cycleway along the river bank.

The flood protection proposals will result in the widening of the Craigton as it passes between the existing ponds. The proposed 8.0m total width is sufficiently narrow as to not encroach onto the pond margins. The ponds will remain linked to the Craigton and consequently within the 1 in 200 year floodplain therefore the additional bunded protection will need to encompass them.

Any new bridges over the Craigton will require a soffit level no lower than the top of bund level to ensure flood flows are not impeded.

Cross sections through the Craigton that show the existing topography together with the proposed flood protection works and resultant 1 in 200 year + 20% flood level are contained in Appendix 11.

5.0 FLOOD COMPENSATION AND MITIGATION

In order to fully satisfy the requirements of SPP7 an assessment has to be made of the downstream impact resulting from the flood protection works as described in Section 3.0.

This assessment has been carried out at southern most extremity of site as the Dargavel Burn flows beneath the boundary fence. This point has a station reference of Dargavel 2 547 on the model results. The results of the dynamic model give a maximum water surface elevation of 4.33m with a flow rate of 10.42m^3/s for the existing geometry.

The modification of the Craigton Channel and subsequent loss in floodplain storage has increased the maximum flow rate of the Dargavel as it flows off site. The model results have returned a maximum water surface elevation of 4.46m with a flow rate of 12.21m^3/s.

The improvements to the Craigton Burn will therefore result in a possible increase in offsite flooding due to the improved conveyance and elevated flow rates. The water surface elevation will increase by 130mm whilst the flow rate will increase by 1.79m^3/s.

To mitigate this potential increase in the risk of offsite flooding an area of compensation is proposed downstream of the development zones. This area forms part of the old ordinance facility and has very little ecological value. It is developed land which is now overgrown with insignificant vegetation, it is also sufficiently high up in the catchment to allow any velocity effects to return to normal before the Dargavel reaches its confluence with the Gryffe.

It is proposed to force the flooding of the Dargavel during high order events by introducing a flow restriction on the Dargavel South reach. This forced flooding will inundate an area of artificial floodplain.

The artificial floodplain is to be created by reducing levels either side of the Dargavel channel. This basin will be allowed to flood thus mobilising the compensation volume. The ground levels are to be lowered sufficiently to reduce the head upstream of the flow restriction.

A flume type structure is to be installed within the main channel. The top of the structure will be approximately at existing ground level. A throat width of 1.0m has been calculated as that required to fully compensate the flood flows. This will force the Dargavel to flood out to a point approximately 300m upstream of the flume.

Sketch proposals showing the flood compensation and flume details can be found in Appendix 12. The detailed design of the flume is to consider its usage for flow measurement therefore the flume is to be rated and a simple stage gauge is to be installed so that the Burn flows may be monitored in the future.

The flume is to be constructed from reinforced concrete to ensure its resistance to erosion. Safety features are to be provided as part of the detailed design to protect against risk of harm to people falling in.

The geometric model has been further developed so that a full assessment of the improved Craigton dynamics and the introduction of the flow restriction can be made. The results of which can be found in Appendix 13.

The flume has been modelled as a culvert with flared wing walls and of sufficient height such that the soffit does not impede flows therefore the contraction and expansion effects are accurately represented.

The results show that the maximum water surface elevation of the Dargavel as it flows out from the site in 4.32m with a flow rate of 10.30m^3/s during the 1 in 200 year + 20% event. The flood levels are comparable with the model of the existing geometry and there is a 0.12m^3/s reduction in the flow rate. The main channel velocities are also comparable. The following table summarises the effects of the flood compensation proposals.

Flow characteristics at downstream site boundary	**Existing Burn Geometry**	**Improved Craigton Geometry**	**Improved Craigton Geometry with Flood Compensation**
Flood Level	4.33m	4.46m	4.32m
Flow Rate	10.42m^3/s	12.21m^3/s	10.30m^3/s
Velocity	1.5m/s	1.6m/s	1.49m/s

6.0 DRAINAGE ASSESSMENT

The investigations undertaken during the data gathering exercise for the Flood Risk Assessment have revealed that the existing surface water drainage systems will not be suitable for re-use within the development proposals.

The existing development is dispersed over a wide area and much of the runoff generated from the hardstandings and buildings drains to small ditches and channels. These small surface water features ultimately discharge to the Burns.

The system is in a poor state of repair and will be subjected to considerable remediation prior to any implementation of the development proposals.

The existing ditches and channels will therefore be abandoned and removed and are not considered suitable for re-use.

The principles outlined in the FRA Scoping Study are to be employed to ensure that all planning requirements are met. A review of the various drainage techniques has been made and the optimum solution has been chosen based on the prevailing site conditions.

In accordance with the SUDS management train and principle of subsidiarity, consideration has been given as to how the management train can be implemented for the development at an outline planning stage.

Within the confines of an outline planning application, source control measures for surface water run off cannot be guaranteed to be practical. Ideally, infiltration methods of surface water disposal would be the preferred method of dealing with surface water at source, however the ground conditions and existing hydrology of the site do not generally lend themselves to such systems. The site is predominantly overlain by silts and clays with a high ground water table therefore infiltration devices are likely to prove ineffective at a strategic level. In addition detailed issues related to contaminants within the ground may preclude the use of infiltration measures across the site. Treatment options combined with conveyance in the form of filter trenches may prove suitable however these are subject to detailed layouts of the development plots.

Consequently it has been necessary to consider SUDS treatment and storage for the outline planning application in terms of site and regional control measures. These options for storage and treatment effectively ensure a robust solution for which confidence exists at outline planning stage that SUDS measures can be delivered for the site.

This approach was discussed with SEPA in November 2005. SEPA accepted that for the outline planning application it was important to ensure that a deliverable robust SUDS strategy was in place and accepted that at this stage in the development process the strategy could not specifically deal with source control. In terms of the management train however there is a wish not to lose source control from the SUDS management strategy for the site but an acceptance that it requires to be considered later in the design process when

detailed designs are being progressed for the development plots. This would ensure that source control measures appropriate for each plot could be determined based upon proposed layouts, topography and ground conditions.

From the starting point of a robust development of site and regional measures for surface water storage and treatment, the overall master planning philosophy has been developed around the water environment playing an important role in the success of the project. Existing surface water features are to be enhanced and new features are to be created that will promote the water theme throughout the development.

The development is mixed use and is split into zones of housing, employment and commercial therefore each zone has been considered in isolation in order to develop the overall master plan strategy.

Storm water quantity and amenity are to be considered at a regional level so that a uniform strategy may be developed throughout the scheme. Storm water quality is considered at more of a site control level due to the treatment requirements of each zone.

In accordance with design standards for water quality, residential zones will receive one level of treatment for quality. Whilst this may be provided at source from the detailed design of local systems, at this time this is to be combined with the quantity control to provide a regional control in the form of retention ponds.

The commercial and mixed use zones will require silt removal before storm water is discharged to the retention ponds as a consequence of two levels of treatment being required for these areas. It is proposed to introduce source control devices to facilitate this prior to attenuation. Filter trenches and permeable surfaces could be incorporated into the detailed development proposals for these zones. Again these will require more detailed consideration later in the design process to accommodate specific design aspects of these zones.

Three levels of treatment are to be provided for the employment zones. Again, source control measures are to be utilized as part of the detailed development proposals. The second level of treatment will be provided by silt control basins, these basins are to be sited immediately upstream of the final level of treatment, this being the retention ponds.

As the site falls within the 13km safeguarding zone for Glasgow Airport , British Airports Authority (BAA) are a statutory consultee to the proposed outline planning application. Consequently meetings were arranged with BAA to discuss the proposed SUDS proposals for the development and ascertain from the outset any issues which BAA may have in respect to the proposals for SUDS.

Meetings took place in November and December 2005. From these meetings, BAA accepted the need for SUDS to be incorporated as part of the development infrastructure however they remain concerned that the design and layout of the SUDS system is undertaken in a manner which minimises the attraction of hazardous bird species.

It was explained to BAA that ground conditions on the site combined with a generally shallow ground water table across the site reduced the possibilities for infiltration style SUDS and that water features would be required for storage and treatment areas across the site.

Consequently, the detailed design of SUDS storage and treatment ponds along with their associated conveyance systems will be developed to comply with the Civil Aviation Authority Advice Note 3: Potential Bird Hazards from Amenity landscaping and Building Design insofar as is possible to balance the needs of public safety around the ponds with the requirements to minimise the attractiveness of the ponds and their surrounding landscaping to hazardous bird species.

To determine where site and regional control systems should be placed, the three dimension digital terrain model that was created for the flood risk modelling has been used to establish generally the surface water flow paths throughout the development area. These natural flow paths have been respected in the drainage strategy and therefore the SUDS devices have been positioned according to a natural catchment area.

Using this method to position the SUDS ponds has enabled the development zone that it serves to be established. The current masterplan proposals showing the SUDS areas and their associated drainage paths is contained in Appendix 14.

It can be seen that the ponds serve one or more zones of development on a site or regional basis. Where employment zones are served an upstream treatment pond is shown to allow for a second level of treatment.

During remediation of the site there will be a requirement for silt control measures to be adopted to avoid water quality issues within the existing watercourses. In discussion with BAE Systems, the remediation contractor, consideration is being given to utilising site or regional treatment ponds from the SUDS design as part of the temporary silt control measures. It is unlikely that remediation phasing would impact upon development phasing for sizing of such ponds and this aspect will be considered further at detailed design stage.

In discussion with SEPA it has been advised that the assessment of the allowable discharge rate from the retention ponds should be made against the existing development in its green field state and no allowance should be made for the existing impermeable areas.

The ADAS 345 method has been used to establish the greenfield runoff rate for each development zone. These runoff rates have been summed together to establish the total allowable discharge rate for each retention pond depending on its catchment area. Appendix 14 contains a table, which identifies the catchment of each pond and its design criteria.

The retention ponds have been sized to store the volume generated from a storm with a 1 in 25 year return period when attenuated down to the 1 in 2 year greenfield runoff rate. This volume will be held in 250mm of freeboard over the permanent water level. It has been assumed that approximately 40% of the residential zones, 85% of the employment zones and 100% of the mixed-use zones will be impermeable and therefore served by the ponds.

The treatment volumes have been determined from the graph contained in appendix C of the SUDS Design Manual, such that 90% of the annual storms can be contained.

The treatment volume (Vt) has been determined from the impermeable area draining to each pond, therefore $75m^3$/ha of Vt is required for the residential zones, $100m^3$/ha of Vt for the employment zones and $115m^3$/ha of Vt for the mixed-use zones.

An assessment has been made of the volume required to satisfy the quantity criteria against that required to satisfy the treatment criteria. The permanent water volume within each retention pond should be at least 4 times that required for treatment, (the 4 Vt rule). Therefore the permanent water depth in all of the retention ponds should be no less than 1.0m.

The treatment basins that are required to serve the employment zones have been sized to satisfy 1 Vt.

The development zones will need to be linked to each regional control using a suitable method of conveyance. It is proposed to use a combination of filter trenches, piped systems and swales to achieve an appropriate level of conveyance that will contain and channel storm runoff to the regional controls.

7.0 SUMMARY AND CONCLUSIONS

It has been established that RO Bishopton redevelopment site lies within the 1 in 200 year flood plain for the Dargavel and Craigton Burns and therefore is deemed to be at medium to high risk of flooding in the context of the SPP7 Risk Framework.

Discussions have taken place with SEPA and Renfrewshire Council through the scoping study and development of a hydraulic model which have ensured that the FRA developed meets their needs.

Detailed hydrological and hydraulic models have been produced in order to quantify the level and extent of risk and to position the development zones more accurately within the risk framework.

Justification has been provided for siting the development within an area deemed to be at risk. In order to satisfy the requirements of SPP7 a scheme of flood protection has been developed that will significantly reduce the flood risk such that the development zone is classified as being at little or no risk within the context of SPP7.

The protection proposals include the improvement of the Craigton Burn to such a degree that all flood waters will be conveyed within the channel during the high order rainfall events.

An assessment has been made of the removal of an existing railway culvert. This culvert presents a significant restriction to the flood flows upstream of the development site and it has been advised that an assessment of its removal would dictate the additional level of protection required over and above the restricted flood flows. This protection is to be provided in the form of a soft landscaped bund raised 500m above the flood levels.

The proposed protection works will result in a loss of floodplain storage and subsequent increased risk of off-site, downstream flooding.

In order to fully satisfy the requirements of SPP7 a scheme of flood mitigation and compensation is proposed that will return the offsite flows to their natural characteristics thus mitigating and compensating the flood risk.

A permanent flow restriction is to be established on the downstream section of the Dargavel Burn that will force upstream flooding. The flow restriction will be in the form of a flume structure, the detailed design of which will be subject to the requirements of SEPA and the WFD.

Existing ground levels upstream of the restriction are to be reduced so as to facilitate the flooding and mobilisation of the compensation volume. This lowering of levels will also lower the headwater which, in turn, further reduces the flow rate.

The detailed dynamic modelling that has been undertaken has demonstrated that the compensation scheme will fully mitigate the effects of improving the Craigton. Offsite flows are returned to their natural condition with a minor reduction in the peak flow rate.

Agreement was reached with SEPA and Renfrewshire Council through the development of the flood protection and mitigation system that improved conveyancing and flood compensation measures of this style would be acceptable provided no adverse downstream effects could be shown through modelling.

A SUDS strategy has been developed that fits well within the master planning objectives and the prevailing site conditions. Full use of the water environment is to be made thus providing excellent amenity opportunities. Existing minor watercourses and open surface water drains that are to be retained within the masterplan are to be incorporated with the SUDS scheme and the conveyance routes will be sized to accommodate any existing minor inflows.

A system of storm water retention and treatment ponds is proposed based upon the delivery of site and regional control measures. The ponds have been sized using relevant design criteria as set out in the SUDS Design Manual for Scotland and Northern Ireland. Source control options within the SUDS management train and higher levels of treatment for the Employment and Commercial/ Mixed Use areas will be considered further at detailed development design stage to ensure that the options adopted meet the detailed design requirements.

It has been demonstrated that the methods of surface water disposal proposed will provide a robust solution in terms of surface water run-off attenuation and treatment that can be delivered as part of the outline planning application.