Dunoon Surface Water Management Plan - Options Appraisal Sandhaven

Final Report

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Revision history

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P01 09/08/19	-	Grant Whyte
P02 17/10/19	ABC Comments	Grant Whyte

Contract

This report describes work commissioned by Grant Whyte on behalf of Argyll & Bute Council by Purchase Order number AB315359. Argyll & Bute Council's representative for the contract was Grant Whyte. Steven Thomson of JBA Consulting carried out this work.

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Purpose

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Contents

1 Introduction

1.1 Site location

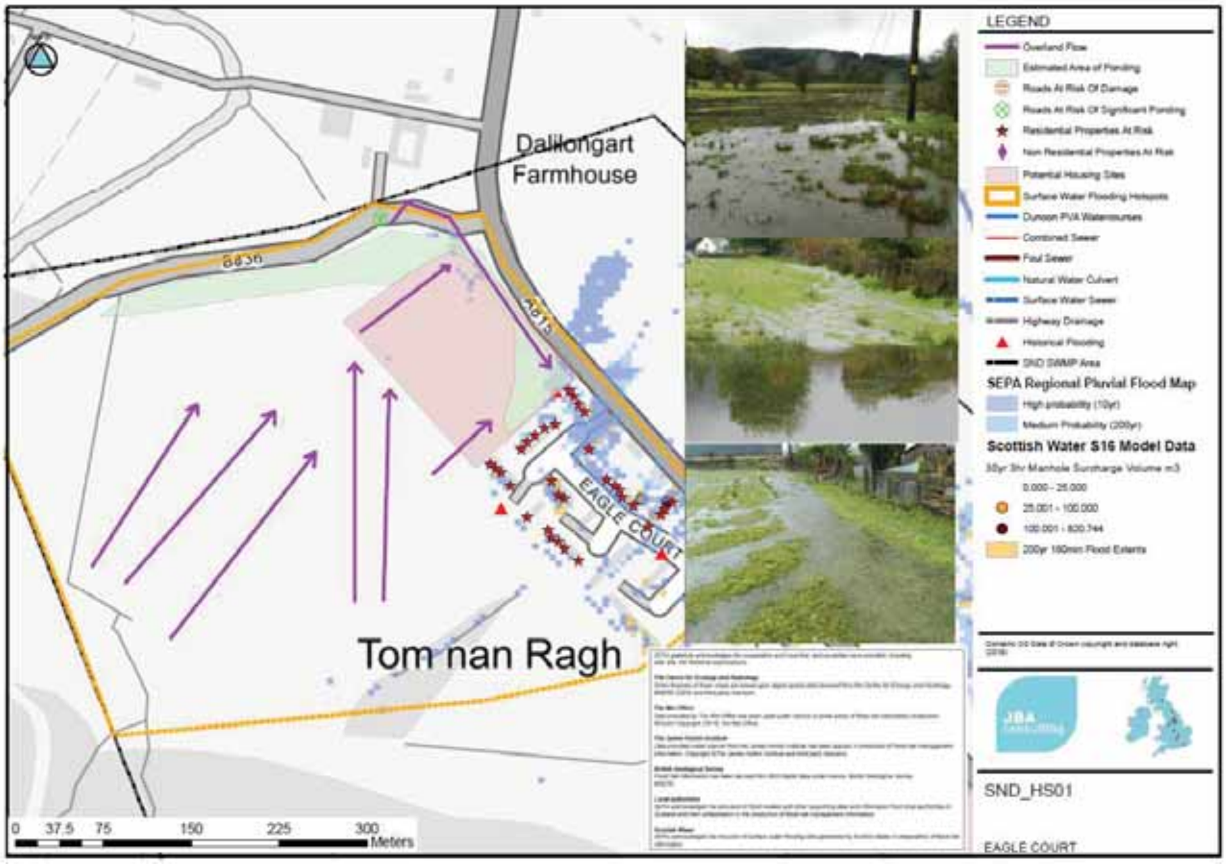
Sandhaven in Sandbank is a residential development which was originally built for American military personnel circa 1950. The estate is situated between the Holy Loch to the east and a steep hillside to the west and north. During periods of intense rainfall substantial overland flow paths develop directing surface water to a topographic low point adjacent to the northern extent of the estate. An informal embankment has been constructed in this corner to retain flood waters. The integrity and robustness of the defence is poor and the embankment has breached on occasions.

1.2 Objectives of the study

The objective of this options appraisal study is to:

- Undertake a hydrological assessment of the contributing catchments.
- Undertake a hydraulic model to understand overland flow paths and peak flows reaching the existing embankment.
- Develop options that can mitigate flood risk to the vulnerable properties in the area.
- Undertake a cost benefit analysis of the proposed options.
- Present a preferred option and suggest next steps.

Figure 1-1: Sandhaven Hotspot 01 from Dunoon Surface Water Management Plan (SWMP) 2019



2 Existing conditions

2.1 Site visit

On Tuesday 30th January 2019 Steven Thomson and Rene Dobson of JBA Consulting undertook site walkover surveys of 3 surface water flooding hotspots in the Dunoon area and 1 in Kilcreggan. The sites that were visited are those that had been highlighted in the Dunoon and Kilcreggan 2018/19 SWMPs as high priority (2018s0549_Dunoon_SWMP_Report, JBA Consulting, 2019).

2.2 Existing Artificial Drainage Infrastructure

The estate has a separate surface water network designed to mitigate flooding from hillside runoff. This network is maintained by Argyll and Bute Council and is separate from the Scottish Water network which consists of a combined sewer in this area.

The majority of the surface water network was surveyed as part of a flood study undertaken by Grontmij in 2010. The network is understood to work well during low return period events. However, the north east corner of the estate is completely unprotected.

Here hillside runoff and overtopping water from a small watercourse flow towards the south east corner of the field adjacent to the estate which then ponds against an informal embankment.

The survey undertaken as part of the Grontmij study indicates that the pipework in the far north of the estate operates via a separate outfall to the rest of the network. The outfall discharges to a drainage channel in the field on the far side of the A815 under normal base flow conditions.

Under normal conditions it is assumed that all flows upstream of Manhole 5 will join the main network by flowing to Manhole 4. Within Manhole 5 a high-level overflow pipe will take excess surface water to Manhole 6 which then conveys flows to Outfall 2 via the northern branch. As such the flows entering this northern branch network are expected to be low.

Figure 2-1: Surface water drainage network in north Sandhaven (Annotated extract from drawing No. 102740-003-DRG-9600-0B, Grontmij, 2010 – See Appendix B for original drawing)

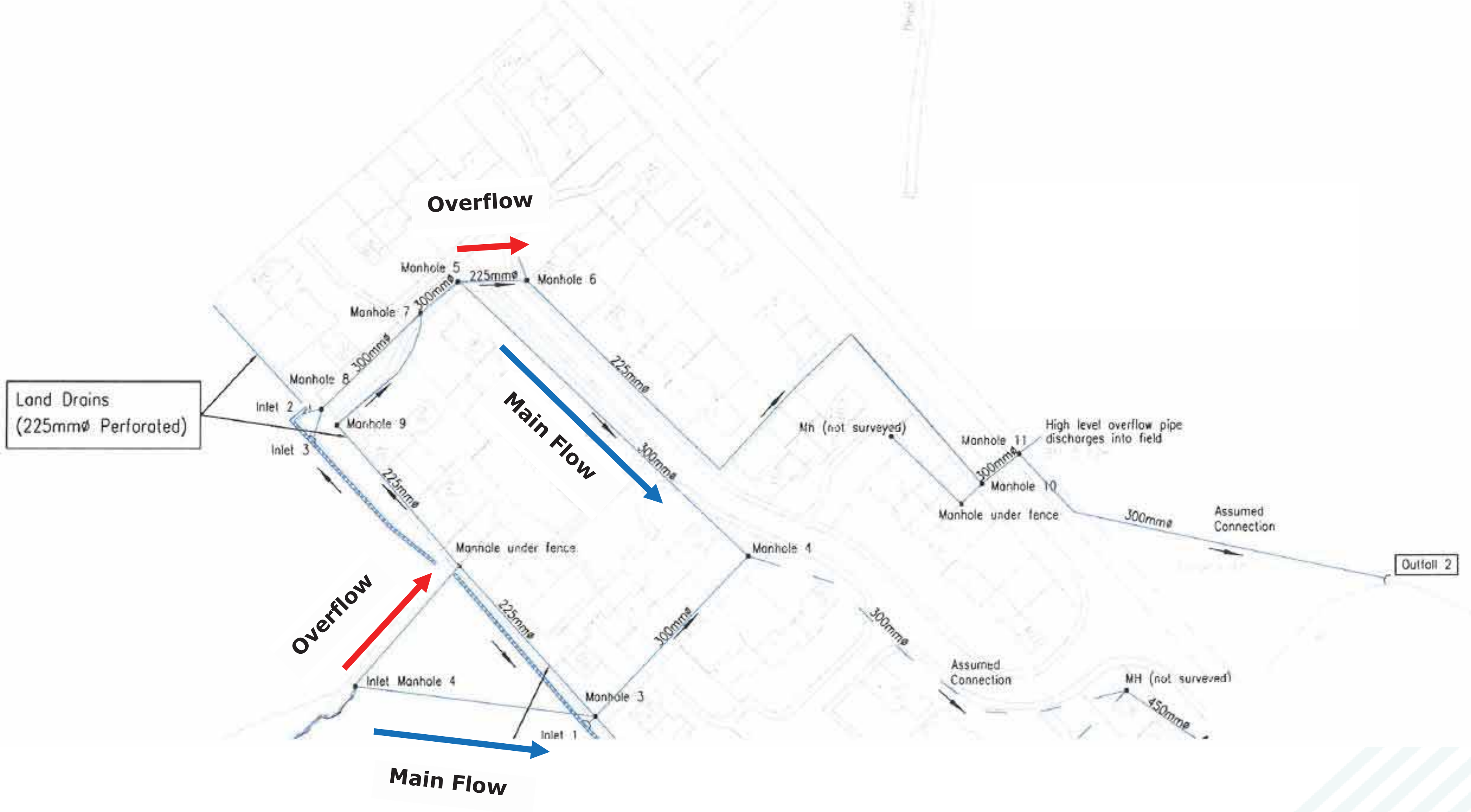


Figure 2-2: Scottish Water network with assumed connection to the combined sewer

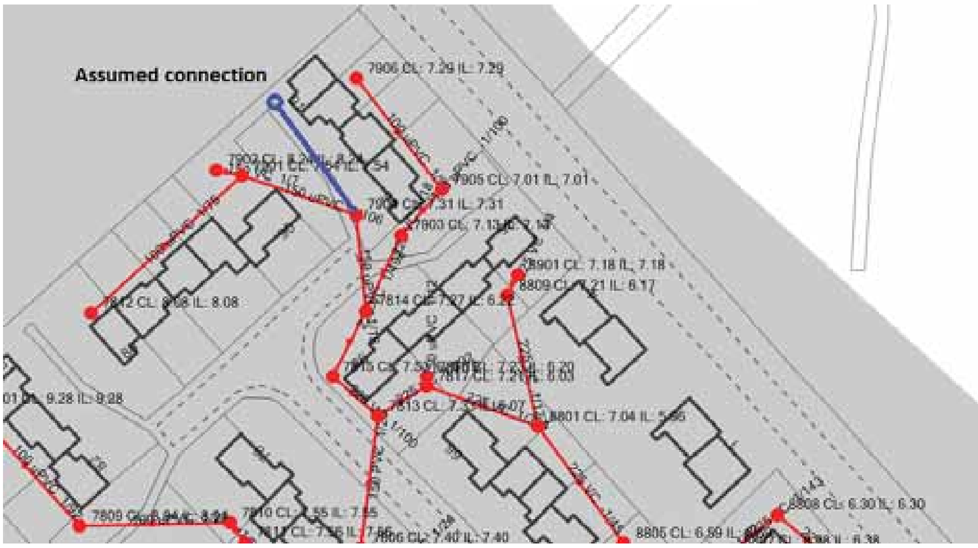


Figure 2-3: Inlet to existing drainage network on the west of the estate

Figure 2-4: The headwall/chamber at which the watercourse west of Sandhaven (shown as inlet 4 on drawing No. 102740-003-DRG-9600-0B, Grontmij, 2010 – See Appendix B) enters the surface water network is blocked by upto 1m of silt and debris which should be removed to allow that channel to flow freely and reduce flood risk (this does not affect the properties in the north east of Sandhaven)

Figure 2-5: Outfall 2 from surface water drainage network fully submerged with channel infilled by silt

2.3 Existing Open Channel - Northwest drainage ditch

The north west drainage channel is a ditch that intercepts flows from the forestry land to the west of the site as shown on figure 2.6 below. Once in the channel the surface water flows north towards the B836 before there a spilt in the channel. The majority of flow is conveyed to the east and ultimately below the B836 and into the Little Eachaig River to the north. An overflow channel will convey any excess flows in a drainage ditch east following the B836 to a twin culvert. Beyond the twin culvert under the B836 the channel is blocked by an earth mound. At present there is no onward connection to the Little Eachaig River.

Figure 2-6: Northwest drainage channel and overflow channel layout

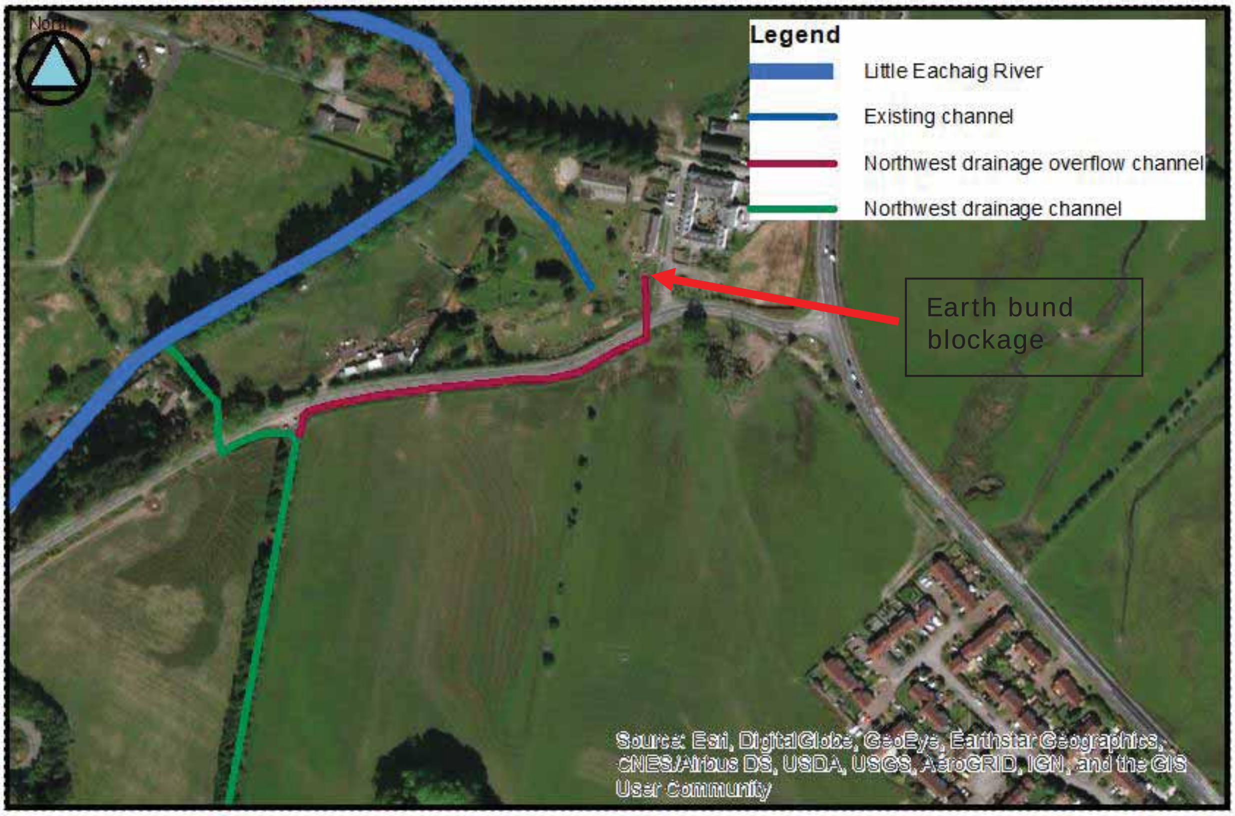


Figure 2-7: Twin culvert under B836

Figure 2-8: Earth mound obstructing channel approximately 5m downstream of culvert

2.4 Existing Mitigation Measures – Informal Flood Embankment

An informal embankment has been constructed to prevent flooding of neighbouring properties. The composition and stability of the bund is unknown, featuring timber bracing throughout, similar to a terraced slope, with sandbags at the crest. The bund is L-shaped, up to 2m in height and approximately 50m in length (total). The bund has breached in the past. The primary function of the bund is to store water and allow it to infiltrate into the ground although there are no formal soakaways are evident. During the site visit multiple small diameter pipes and hoses were found to pass through embankment close to crest level. These pipes then lead to a manhole in front of the adjacent property. This manhole features 2 surface water inlets and a single outfall flowing south. Unfortunately, this manhole is not shown on the drainage survey drawings or on Scottish Water's plans. It is assumed to connect to the combined sewer but this should be investigated during the detailed design phase.

Figure 2-9: Existing informal embankment

Figure 2-10: Typical construction of existing bund

Figure 2-11: Bund during flood conditions (ponding water on dryside suggests seepage/piping risk)

Figure 2-12: Ground level on opposite side of A815 is approximately level with that of the crest of the informal embankment

Figure 2-13: Collection pit for multiple small pipes which drain the upper levels of the embankment

Figure 2-14: Assumed drainage connections (see also Figure 2-2)

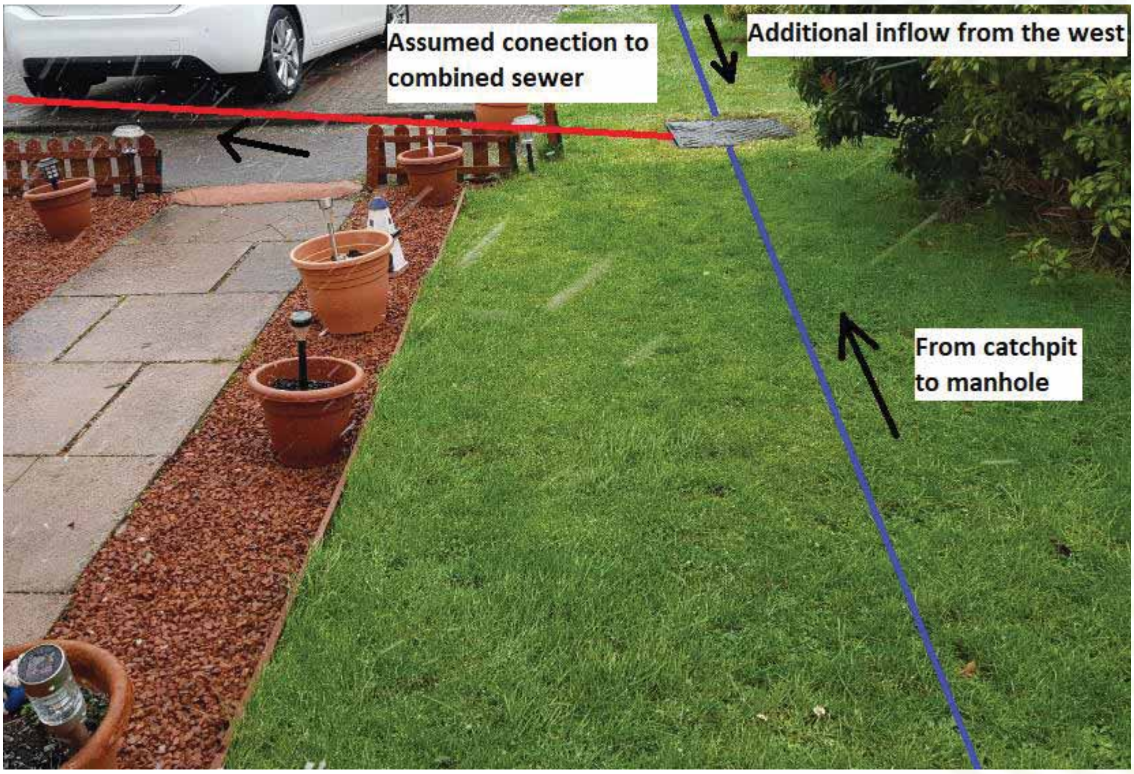


Figure 2-15: Manhole in front of house adjacent to bund

2.5 Existing flood risk

The primary source of the overland flow originates from the hillside to the west of the estate. Here any runoff arising between the north west or south east drainage channels will flow over the surface towards the informal embankment.

Additional contributions of runoff arise when the drainage channel along the B836 overtopps before the twin 300mm diameter steel culverts convey flows under the B836 to the north. Historically the channel downstream of the culvert would have conveyed flows north and into the Little Eachaig River. However, as discussed, approximately 5m downstream of the culvert the channel has been infilled by an earth mound completely blocking the watercourse. This causes water to back up and come out of bank upstream of the culvert which subsequently flows on to the carriageway of the B836. Due to the camber in the road, flood waters flow along the south side of the carriageway before flowing back into the field where it flows towards the low point at the north east of the of the Sandhaven Estate.

Figure 2-16: Overland flow path routes

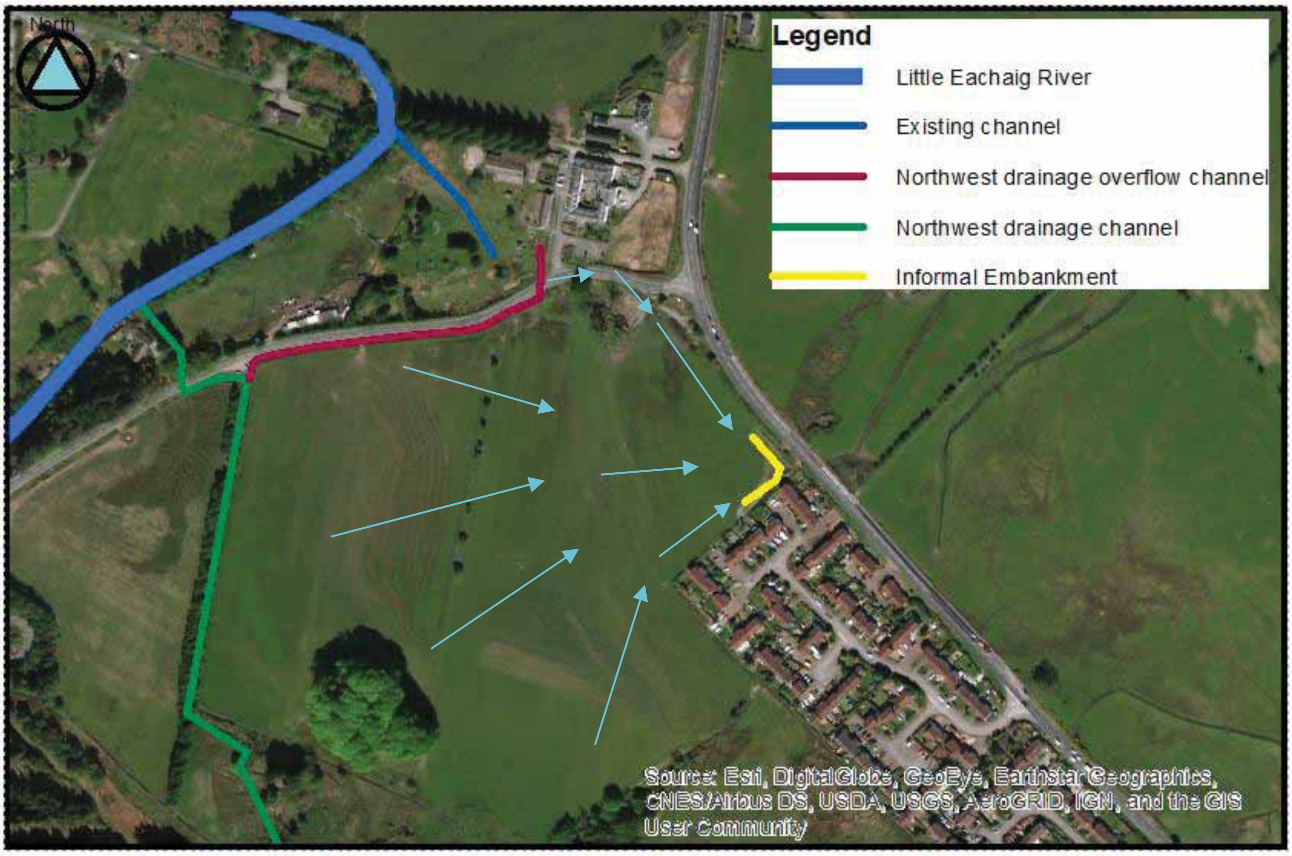


Figure 2-17: Typical overland flow paths (observed from western extent of existing embankment)

2.6 Site surveys (Topography, drainage etc)

A drainage survey of the surface water network in Sandhaven was undertaken as part of the Grontmij Study in 2010. The findings of this study have been used in order to understand flood risk and create the drainage model.

3 Hydrology

3.1 Background and Scope

Sandhaven Estate in Sandbank is a residential development which was built for American military personnel circa 1950. The estate is situated between the Holy Loch to the east and a steep hillside to the west and north. The estate has a separate surface water network designed to mitigate flooding in the estate from hillside runoff. This network is maintained by the Argyll & Bute Council and is not connected to the Scottish Water network which consists of a combined sewer in this area.

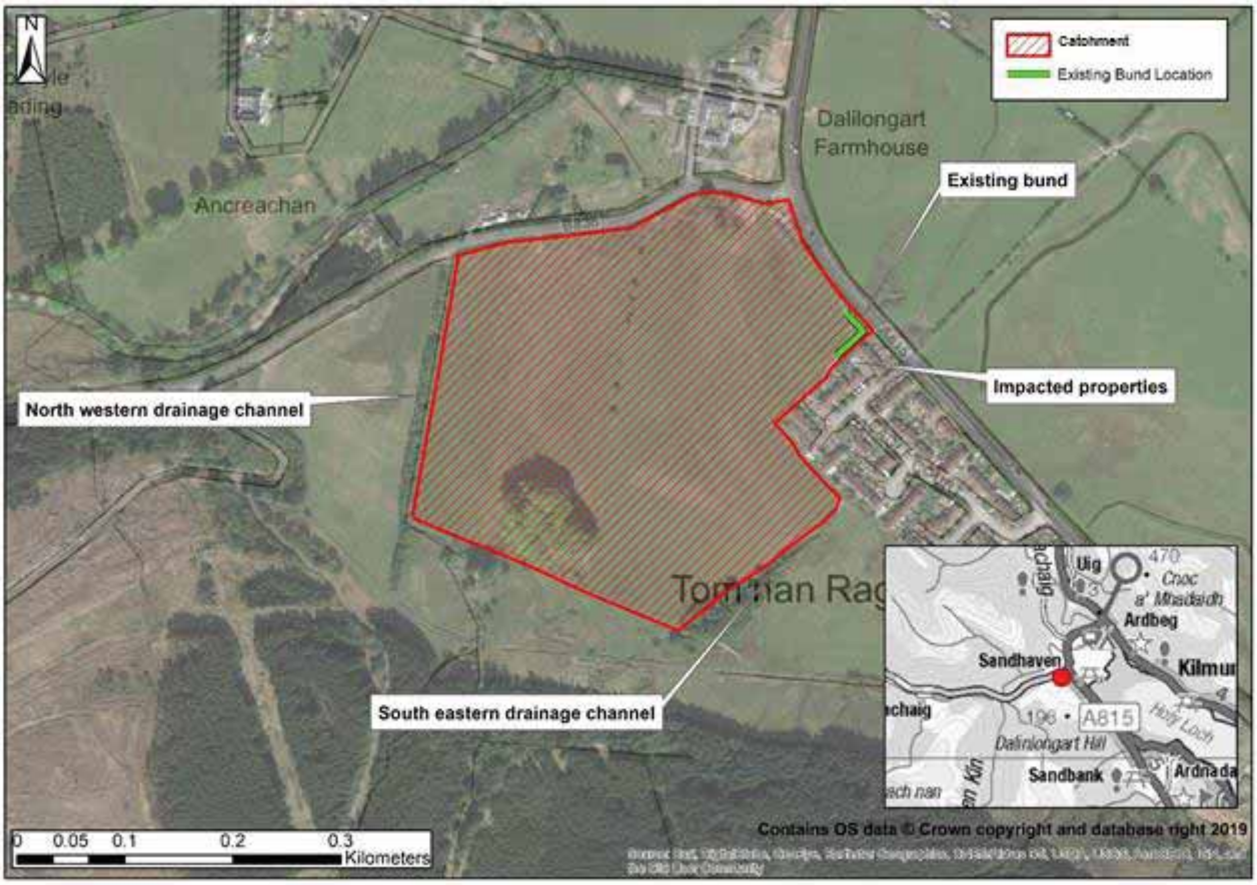
In 2010, Grontmij were appointed by Argyll & Bute Council to survey and appraise the surface water network at Sandhaven due to hillside runoff flooding which affected much of the estate. The study did not account for the overland flow effecting properties to the north east of the estate which are not protected by the surface water sewer network.

The primary mechanism of flooding in the north east of the Sandhaven Estate is overland surface water flow, originating from the north and west from the open hillside and from fluvial overtopping of a small watercourse which is located adjacent to the north east of the adjacent field and flows over the B836 toward the Sandhaven Estate.

In order to alleviate flooding to the residential properties on Eagle Court, an informal embankment was constructed in 2014. The embankment is approximately 50m in length has a crest level around 2m above ground level in some sections.

The purpose of this study is to assess the overland flows that impound behind the informal embankment using an appropriate 2D hydraulic model. As well as an assessment of the existing bund, an additional assessment will be undertaken to determine the remaining capacity in the existing surface water piped network in the estate and an estimation of the storage volume required to alleviate flooding, taking into account inflows and a pass forward rate governed by the remaining capacity of the existing sewer will also be made. The return periods required are the 1-in-2 year, 1-in-5 year, 1-in-10 year, 1-in-30 year, 1-in-50 year, 1-in-100 year, 1-in-200 year and 1-in-200 year + CC (climate change) events. In the context of this review climate change uplifts have been applied at 20% in accordance with SEPA's Technical Flood Risk Guidance for Stakeholders, Version 12, 2019.

Figure 3-1: Study Location and significant features



3.2 Methodology

3.2.1 Hydraulic modelling

In order to assess the flood risk and the overland flow paths affecting the north of the Sandhaven estate, a surface water hydraulic model was constructed in Infoworks ICM. ICM allows for a single model that can incorporate urban, pluvial and fluvial catchments and enables the hydraulics of both to be assessed in a single model. It is considered the most suitable software where flood risk to a site may arise from multiple sources. The inputs to ICM assessing surface water flood risk are a Digital Terrain Model (DTM) and a design rainfall event.

Three scenarios were considered within the hydraulic model:

- Scenario 1 - Baseline Scenario to represent the flood risk to the Sandhaven Estate with no protection in place (i.e no embankment, or significant embankment breach/failure).
- Scenario 2 - Protection Scenario to represent the flood risk to the Sandhaven Estate with improvements undertaken to the existing embankment to create a formal flood defence.
- Scenario 3 - Protection Scenario to allow for an estimation of the storage volume required to alleviate flooding to Eagle Court. In this scenario the model uses an oversized embankment to catch all of the water which flows toward the low point hence it is much longer and taller than the embankment in scenario 2.

3.2.2 Digital Terrain Model and 2D mesh

To assess surface water flood risk, the contributing catchment must be included in the model, to determine flow entering the site. Therefore, a DTM was created by combining freely available elevation-based data and LiDAR data, obtained from the Scottish Remote Sensing Portal (SRSP). ICM builds a mesh of triangular elements with varying cell size base on the terrain which allows for flat areas to be modelled with large elements and undulating areas to be represented with small elements. The mesh parameters were set so that the minimum element size and maximum mesh triangle area set to $1m^2$ for the whole of the study area. Boundary Points were set to Normal Condition and the Rainfall Percentage value was changed from the default of 100% to 75% to represent the surface water which will be soaked up by permeable ground.

Built structures utilised for this study were derived by using OS Open Map Local data to create a shapefile of buildings located within the 2D mesh zone. Buildings were imported into the model as porous polygons with a height of 300mm and a porosity of 30%. The roads were exported as roughness zones and were given a roughness co-efficient of 0.005.

All DTM scenarios accounted for a minor drainage ditch which is located adjacent to the north western boundary of Sandhaven Estate. This ditch flows adjacent to the B836 to the north and included two culverts to feed it underneath the road network and a blockage at the end of the ditch to reflect existing conditions.

Two additional mesh zones were created to simulate Scenarios 2 and 3. For Scenario 2, an embankment was included within the model that matched the geometry of the existing informal embankment. The level of the bund was set at 8.64 mAOD which is 2m above the lowest ground level shown on the LiDAR.

As with Scenario 2, for Scenario 3, a bund was included within the model. However, unlike Scenario 2, the crest level parameter was set to infinite and the bund length extended so that the bund would store all the surface water flowing into the north east corner of the Sandhaven estate (Eagle Crescent). This will allow for analysis to be undertaken to determine the amount of storage required for each return period.

The drainage network including drainage sub catchments, pipes, manhole cover locations and details were also included into Scenario 3 (Figure 3-2 and Figure 3-3). Drainage sub catchment impermeable areas were manually calculated and imported into the model.

Figure 3-2: Drainage sub catchments

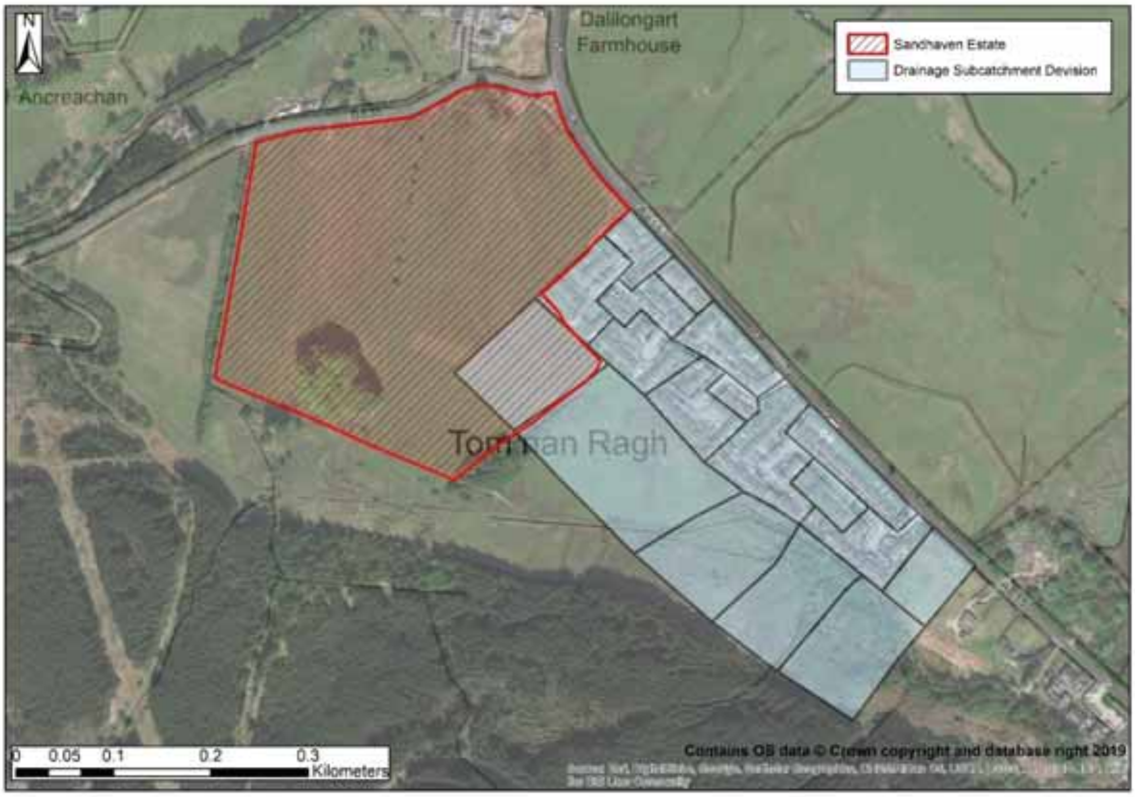


Figure 3-3: Drainage network

3.2.3 Design Rainfall Events

Rainfall estimates were generated using the FEH with Depth-Duration-Frequency (DDF) Modelling used to generate baseline rainfall. Catchment Descriptors were obtained for the site from the FEH Web Service in February 2019. 1 km² DDF parameters are included within the FEH Web Service catchment descriptors and were used to inform the InfoWorks FEH rainfall generator available within the ICM software (DDF parameters are provided in Table 2-1). To simulate surface water flooding across the area of interest, the hydraulic model uses a Direct Rainfall approach which consists of applying a rainfall hyetograph representative of a storm event to every individual element within the 2D surface model (across the 2D zone). The design events modelled are listed in Section 3.1.

The base model was run for a number of storm durations to determine the critical storm duration by determining which storm event achieved the highest peak water level at the headwalls, and thereby the greatest volume. Following a review of the peak flows, it was established that the 2-hour (120 minute) duration event is the critical storm duration for the residential properties at Eagle Court (Table 2-2). The model simulation time was set to 5 hours to show the extent of each return period and to allow water in high topographical areas to flow throughout the model, giving more accurate results of the extent of flooding.

Table 3-1: 1 km² DDF parameters

DDF Parameter	Value
C(1 km)	-0.018
D1(1 km)	0.539
D2(1 km)	0.398
D3(1 km)	0.469
E(1 km)	0.256
F(1 km)	2.51

Table 3-2: Critical Storm Duration Results

Scenario	Duration (min)	Depth (m)
Base	30	0.371
Base	60	0.4
Base	90	0.419
Base	120	0.423
Base	180	0.418
Base	240	0.409
Base	300	0.399
Base	360	0.39
Base	420	0.383
Base	480	0.376
Base	540	0.37
Base	600	0.365
Base	720	0.359
Base	840	0.353
Base	960	0.348
Base	1080	0.343
Base	1200	0.338
Base	1320	0.333
Base	1440	0.329

3.3 Hydraulic Model results

3.3.1 Flood Outlines

Modelled flood depths were capped to a minimum depth of 0.1m, as flood depths modelled below this level are considered insignificant and unlikely to result in any significant damage within the area. Flood depths and extents for each return period were imported into ArcGIS to visually show how pluvial flooding of each design event could impact the site.

3.4 Scenario 1

Infoworks ICM v8.5 mapping indicates that there may be extensive flooding to number properties at Eagle Court during a 1:30 year flood event during a scenario where there is no formal embankment to offer protection. Pluvial flood depths towards the northern and eastern properties of Eagle Court are modelled to range between 0.1 and 0.3m above ground levels during a 1:30 year flood event. Pluvial flood depth range towards the northern and eastern properties of Eagle Court are expected to rise to between 0.1 and 0.4m above ground levels during a 1:200year flood event in which the number of properties at risk of flooding increases. It should be noted that minor flow paths originating from the south west shown in the figure below are not included within the option appraisal as they will be intercepted by existing drainage network. The performance of the existing network to the south is out with the scope of this report.

Figure 3-4: Surface water flood depths for the 1:30 year flood event – Scenario 1.

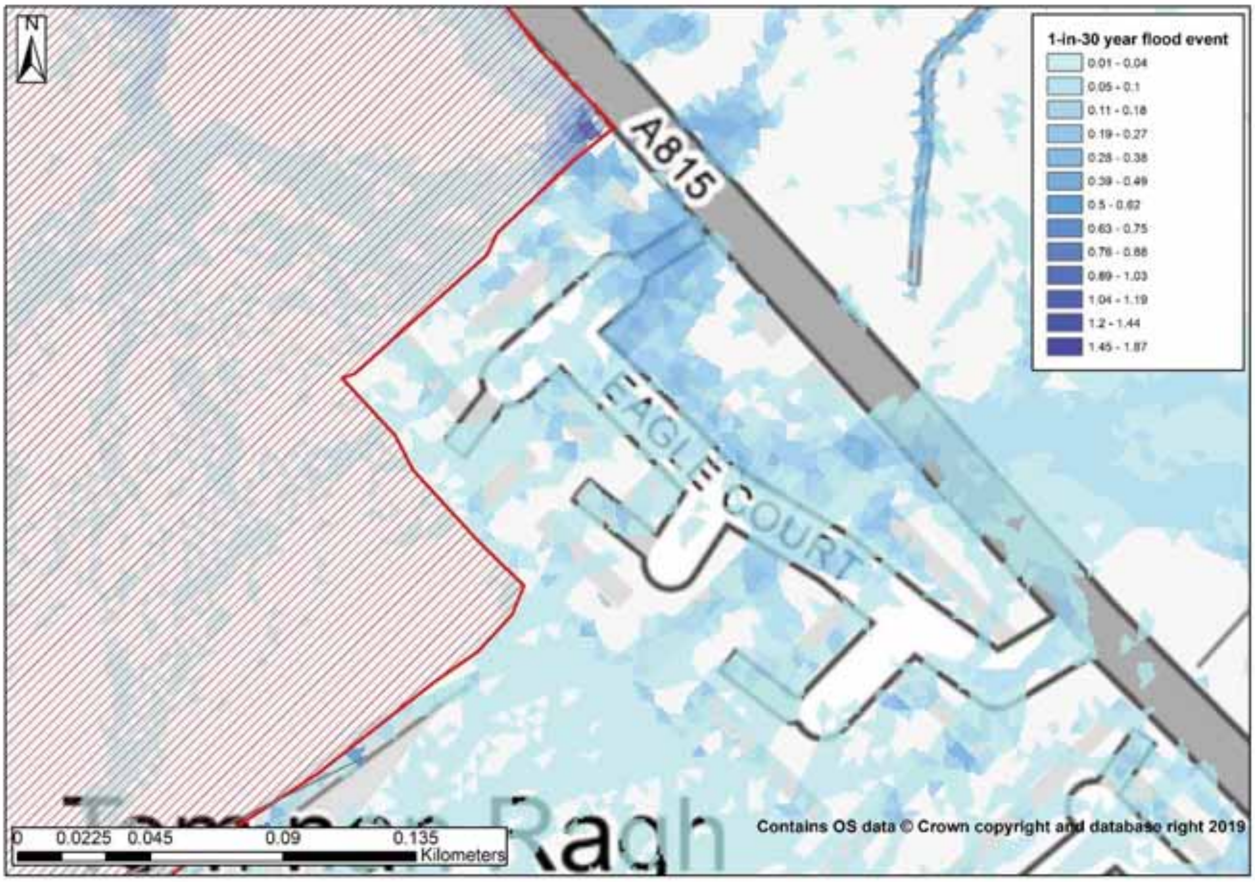
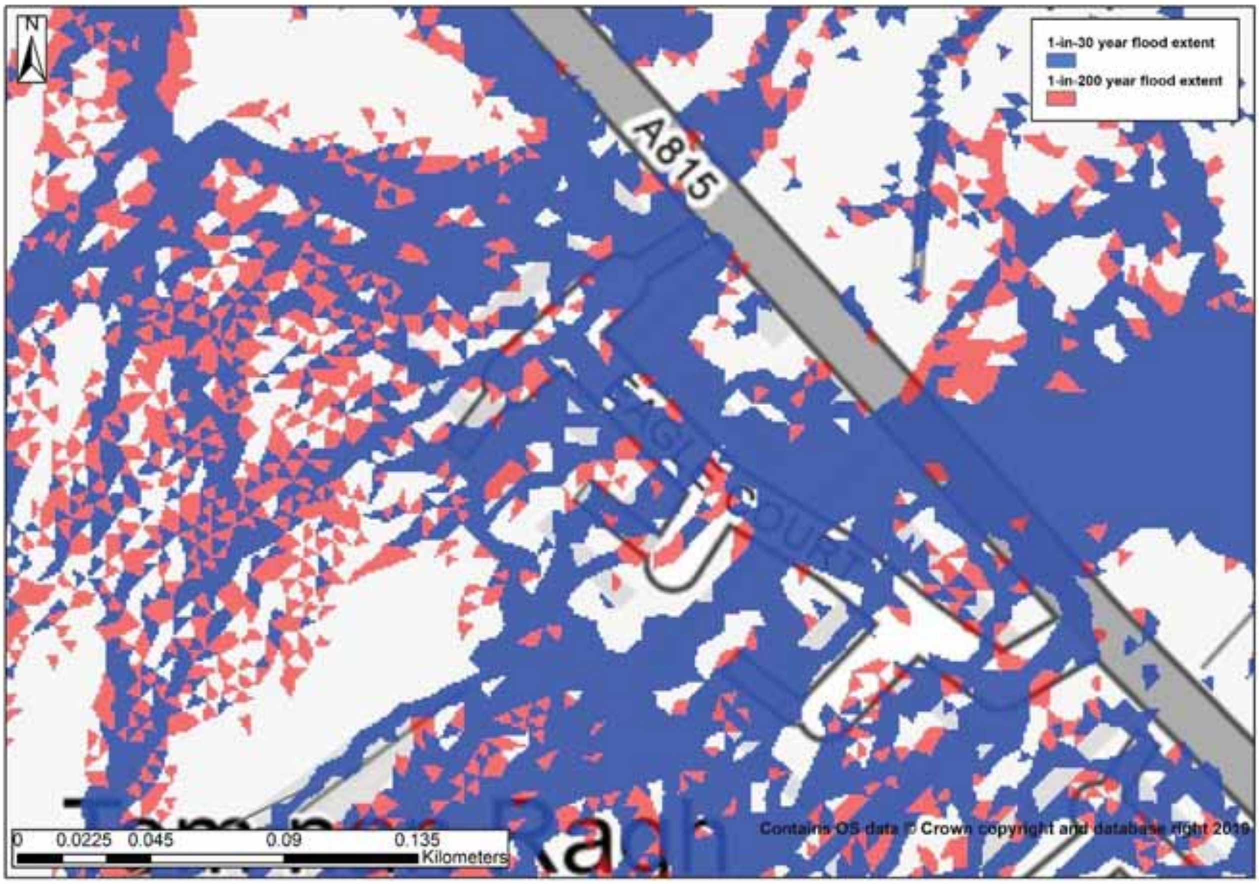


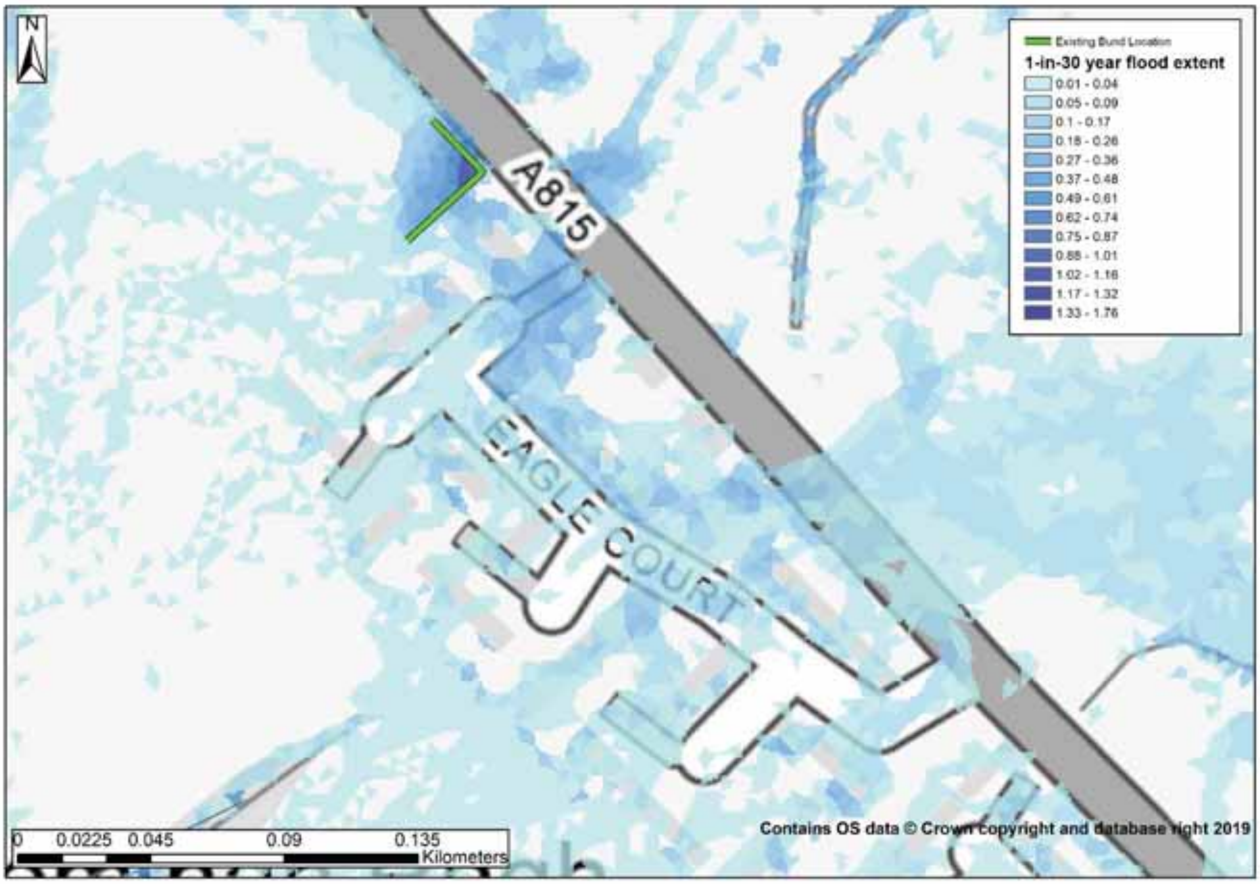
Figure 3-5: Surface water flood extent comparison– Scenario 1.



3.5 Scenario 2

Mapping indicates that, while the existing bund does work to retain some water within the estate boundary, surface water is able to flow around the bund and impact properties to the north and west of Eagle Court. The bund offers some protection in comparison to pluvial flood extents modelled for Scenario 1 up to a 1:30year event. Pluvial flood depths towards the northern and eastern properties of Eagle Court are modelled to range between 0.01 and 0.3m above ground levels during a 1:30year flood event, suggesting that the presence of the existing bund offers minimal impact and protection during a 1:30year event or greater.

Figure 3-6: Surface water flood depths for the 1-in-30 year flood event – Scenario 2.



3.6 Scenario 3

Scenario 3 was undertaken to establish the volume of surface water storage required in order to substantially reduce the pluvial flood risk to the properties of Eagle Court and to assess the effectiveness of the existing drainage network.

3.6.1 Surface water storage

With an extended bund in place, the required surface water storage volume per return period are shown in Table 3-1 for a 1:30year event pluvial flood depths. Pluvial flood depths towards the northern and eastern properties of Eagle Court are vastly reduced due to the implementation of the extended bund.

Figure 3-7: Surface water flood extent comparison– Scenario 1 and Scenario 3.

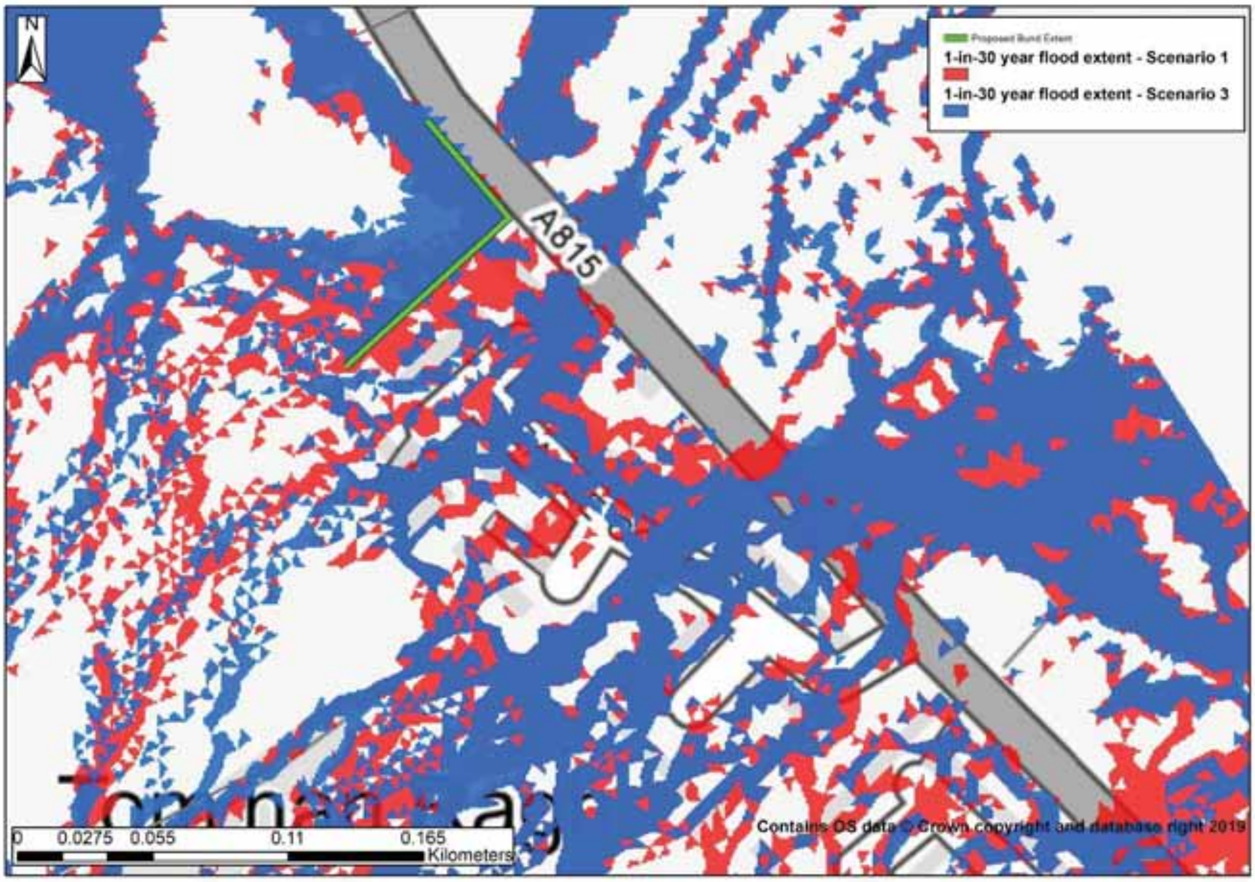


Table 3-3: Required surface water storage per return period

Return period	Storage (m3/s)
2	503
5	807
10	1060
30	1526
50	1774
100	2146
200	2581
200+cc	3524

Table 3-4: Peak flows reaching existing embankment per return period

Return period	Peak flow (m3/s)
2	0.11
5	0.161
10	0.196
30	0.265
50	0.292
100	0.324
200	0.365
200+cc	0.552

3.6.2 Capacity of the Drainage Network

For Scenario 3, the northern section of the existing drainage network has been modelled to determine the capacity of the network at key points. The remaining capacity of the surface water drainage network was established in order to determine a suitable discharge rate from the impounded area directly into the existing drainage network without increasing flood risk. To determine the remaining capacity of the network, the peak flow flowing through the pipe where the proposed connection would occur was extracted for all return periods (Table 3-5).

Table 3-5: Capacity of the surface water drainage network

Return Periods	Estimated pipe capacity (m3/s)	Peak flow entering pipe (m3/s)	Remaining capacity (m3/s)
2	0.052	0.041	0.011
5		0.046	0.006
10		0.048	0.004
30		0.052	0
50		0.052	0
100		0.054	0
200		0.055	0
200+CC		0.056	0

There is minimal capacity left in the surface water network that drains Eagle Court. During a 1:2year, 1:5year and a 1:10year event, while there is additional capacity within the drainage network, the small pass forward rate is minimal. The drainage network currently floods at each of the other return periods, which indicates that there is no capacity left in the network for any additional water.

Further analysis of the network shows that MH11 (North eastern branch manhole located east of A815 upstream of the outfall Figure 2-1) has the capacity to accommodate flows up to and including the 1:50year return period. Therefore, an outfall from the embankment can be implemented which would allow surface water to drain and flow to the surface water network via a connection to a new manhole (MH6.2) which would be placed into the existing pipes between MH6 and MH10 as shown in figure 4-2.

If the 1:50year flow was passed forward this would lower the overall storage volume required for the 1:200year+CC event from 3524m^3 to 1750m^3.

3.7 Estimated Properties at Risk

Using the knowledge gained from the site visit and the output of the 1 in 30year and 1 in 200year hydraulic model as shown in Figure 3-2 and Figure 3-3, the following properties are understood to be at direct risk of flooding.

Table 3-6: Estimated properties at risk

Street Name	Residential	Non-Residential
Eagle Court	16	-
Total	**16**	**0**

Figure 3-8: Estimated properties at risk

4 Options appraisal

Given the flooding mechanisms and topography at the Sandhaven estate the possible mitigation methods are limited to formal storage or drainage capacity improvements or a combination of both. The options below will explore the mitigation options available.

Due to the ad-hoc nature of the existing embankment all options will involve removing this feature. The materials shall be reused where possible in the new structures.

4.1 Option 1: Small embankment with outfall to existing surface water network

This option involves creating a small embankment approximately 1m tall and 50m in length in the footprint of the existing informal embankment. The purpose of the embankment is to channel flows toward a new headwall created in the corner of the L shaped embankment. A precast concrete headwall will connect to a new 450mm diameter surface water pipe which will flow south along the grass verge of the A815. A new manhole will be constructed between manhole 6 and 10 of the existing surface water network. From here flows will be conveyed to outlet 2 with the existing flows from the northern branch of the surface water network. This will also require silt removal from the outfall and downstream channel. See Figures 4-1 & 4-2 below for details.

Figure 4-1: Indicative embankment detail

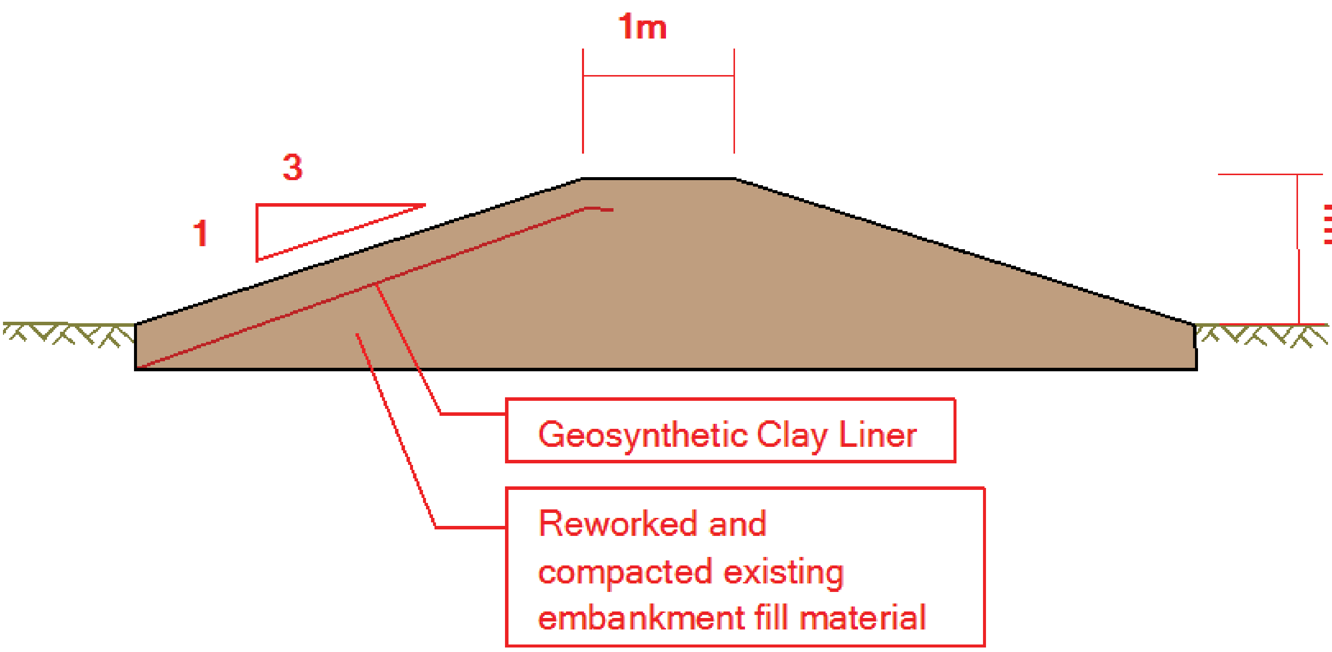


Figure 4-2: Option 1 indicative plan

Table 4-1 Manhole details

Manhole / inspection chamber	Ground Level (mAOD)	Invert Level (mAOD)	Manhole depth (m)
X1 (new)	7.94	6.64	1.3
MH 6.2 (retrofit/replace)	6.67	4.6	2.07

Table 4-2: Pipe details

Pipe run	U/S Invert Level	D/S Invert Level	Length (m)	Gradient	Pipe size (θ mm)	Capacity (m3/s)
X1-6.2	6.64	4.6	140	1:70	450	0.380

This option will consist of the following actions:

- Removal of the existing informal flood embankment (approximately 400m^3).
- Creating a new lower embankment in the footprint of the existing informal embankment (approximately 305m^3). The primary purpose of this embankment is to channel overland flows to a new headwall. The L-shaped embankment will measure approximately 50m in length, 1m in height, 1m wide crest with 1 in 3 slopes. The embankment shall be formed

of reworked material from the existing informal embankment and a Geosynthetic Clay Liner (GCL) to prevent seepage.

- Install at new precast concrete headwall in the corner of the new embankment with an invert level of 6.64mAOD.
- Construction of a new precast concrete manhole up to 2m deep (manhole X1) with in the embankment footprint.
- Construct approximately 140m of 450mm diameter concrete pipe to connect the new manhole to the existing manhole 6.2. Which then runs to mh11 and outfall with pipe diameter of 300mm.

Benefits of proposed scheme

- This will offer a level of protection of up to 1:50 year event for all properties known and predicted to be affected in Eagle Court.
- Sustainable approach as surface water is removed from the combined sewer network which will help to lower flood risk downstream in the network. This will also remove a substantial volume of surface water which would have been stored and treated.
- No Land take required for new pipe route (assuming A815 verge is council owned).
- Makes use of existing assets i.e. the existing surface water drainage network and reuse of site won material to form the embankment.
- Any excess material from site could be stored at the rear of the embankment resulting in a cut/fill balance.
- Conventional construction methods.
- Although not the primary function the embankments will store surface water if the network is surcharging. However, this could easily be adapted to suit if required during the detailed design stage.

Assumptions and risk

- That the land in the corner of the field and A815 verge is available to the council.
- That the existing surface water sewer is free of blockages and is a good condition.
- That the drainage network within Eagle Terrace is owned by the council and the invert levels provided are correct.
- That the proposed surface water pipe is able to pass over/under any other services found in the verge of the A815.
- That the material from the existing informal embankment is of sufficient quality to be reworked to form fill for the new embankment.
- That the headwall structure will be fitted with flat bars rather than a full debris screen as the debris risk is very low.
- A 4m x 120m temporary access road will be constructed in the field from the junction of the A815/B836.
- For simplicity, the connection to the existing network has been included in the costing as a new precast concrete manhole up to 2m deep.
- That the outfall will be influenced by extreme tidal events and coastal change.

4.1.1 Cost Estimate

Item	Quantity	Units	Unit cost	cost	Source
General					
Site welfare	12	weeks	425	5100.00	CESMM3 Unit Costs
Site store	12	weeks	105.06	1260.72	CESMM3 Unit Costs
Traffic management	6	weeks	1500	9000.00	Estimate
Site supervision	6	weeks	1422	8532.00	CESMM3 Unit Costs
Temporary access road	480	m2	20	9600.00	Highway Unit Costs
Small embankment construction					
Excavation of existing embankment	400	m3	4.9	1960.00	CESMM3 Unit Costs
Screening of material	400	m3	2.5	1000.00	Estimate
Deposition of fill material	400	m3	1.42	568.00	Highway Unit Costs
Compaction of fill material	400	m3	0.95	380.00	Highway Unit Costs
Install GCL Lining	200	m2	5.43	1086.00	Naue + Highway Costs
Hyrdroseeding	375	m2	1.92	720.00	CESMM3 Unit Costs
Precast Concrete Headwall	1	No.	2500	2500.00	Estimate
Pipework and connection to existing network					
Precast Concrete Manhole chambers less than 2m deep	2	No.	1532.1	3064.20	CESMM3 Unit Costs
Supply of 450mm diameter concrete surface water pipe	140	m	84	11760.00	Estimate based on current retail costs
Install 450mm diameter concrete surface water pipe upto 2m deep	140	m	78.42	10978.80	CESMM3 Unit Costs
Silt removal at existing outfall					
Excavation of silt	40	m3	4.9	196.00	CESMM3 Unit Costs
Move excavated (non-hazardous) material to tip not more than 5km for site inclds tipping charges + tax	40	m3	8.59	1943.60	Highway Unit Costs
Subtotal				**66856.32**	
Construction inflation index adjustment (2016 to 2019)	10.1	%		73608.81	
Optimism Bias	60	%		117774.09	OFNS
Detailed design costs	19	%		22377.08	
Total				**140,150**	

4.2 Option 2: Small embankment with outfall to existing channel north of Holy Loch

This option uses the same infrastructure as Option 1 but has a different outfall. From the new embankment and headwall, flows will be conveyed to an existing surface water channel in the field to the south east. This option will involve passing below the A815. A precast concrete headwall will connect to a new 450mm diameter surface water pipe which will flow to a new head wall discharging to an existing open channel.

The proposed route of the new surface water pipe is shown in the figure below. The subsequent table shows the indicative pipe geometry details based on the available LiDAR data and the pipe sizing charts utilising the Colebrook-White formula.

Figure 4-3: Option 2 indicative plan

Table 4-3 Manhole details

Manhole / outfall	Ground Level (mAOD)	Invert Level (mAOD)	Manhole depth (m)
X1 (new)	7.94	6.64	1.3
OUTX1 (new outfall)	-	4.0	-

Table 4-4: Pipe details

Pipe run	U/S Invert Level	D/S Invert Level	Length (m)	Gradient	Pipe size (θ mm)	Capacity (m3/s)
X1-OUTX1	6.64	4.0	110	1:40	450	0.50

This option will consist of the following actions:

- Removal of the existing informal flood embankment (approximately 400m^3).
- Creating a new lower embankment in the footprint of the existing informal embankment (approximately 305m^3). The primary purpose of this embankment is to channel overland flows to a new headwall. The L-shaped embankment will measure approximately 50m in length, 1m in height, 1m wide crest with 1 in 3 slopes. The embankment shall be formed of reworked material from the existing informal embankment and a Geosynthetic Clay Liner (GCL) to prevent seepage.
- Install at new precast concrete headwall with debris screen for a 450mm diameter pipe in the corner of the new embankment with an invert level of 6.64mAOD.
- Construction of a new precast concrete manhole up to 2m deep (manhole X1) with in the embankment footprint.
- Construct approximately 110m of 450mm diameter concrete pipe to connect the new manhole to the new outfall OUT1. This will involve excavation through the carriageway and in the fields to the south east.

Benefits of proposed scheme

- This will offer a level of protection of up to 1:200 year event for all properties known and predicted to be affected in Eagle Court (approximately 0.22m3/s away from providing protection for the 1:200year + CC event, this may be offset by the storage offered by the embankments. Alternatively, a 525mm pipe diameter may be selected which could convey 720l/s which is well in excess of the 1:200yr flow of 525l/s.
- Sustainable approach as surface water is removed from the combined sewer network which will help to lower flood risk downstream in the network. This will also remove a substantial volume of surface water which would have been stored and treated.
- Makes use of existing assets I.e. reuse of site won material form the existing embankment.
- Any excess material from site could be stored at the rear of the embankment resulting in a cut/fill balance.
- Conventional construction methods.
- Although not the primary function the embankments will store surface water if the network is surcharging.

Assumptions and risk

- That the land in the corner of the field, A815 and opposite field is available to the council is/owned by the council. Land take costs have not been included.
- That the proposed surface water pipe is able to pass over/under any other services found in the A815.
- That the material from the existing informal embankment is of sufficient quality to be reworked to form fill for the new embankment.
- The open channel is known to be effected by extreme tidal events and as such it may affect the performance of the outfall.

- That the headwall structure will be fitted with flat bars rather than a full debris screen.
- A 4m x 120m temporary access road will be constructed in the field from the junction of the A815/B836.

4.2.1 Cost Estimate

Item	Quantity	Units	Unit cost	cost	Source
General					
Site welfare	12	weeks	425	5100.00	CESMM3 Unit Costs
Site store	12	weeks	105.06	1260.72	CESMM3 Unit Costs
Site supervision	6	weeks	1422	8532.00	CESMM3 Unit Costs
Traffic Management	3	weeks	1500	4500.00	Estimate
Temporary access road	480	m2	20	9600.00	Highway Unit Costs
Small embankment construction					
Excavation of existing embankment	400	m3	4.9	1960.00	CESMM3 Unit Costs
Screening of material	400	m3	2.5	1000.00	Estimate
Deposition of fill material	400	m3	1.42	568.00	Highway Unit Costs
Compaction of fill material	400	m3	0.95	380.00	Highway Unit Costs
Install GCL Lining	200	m2	5.43	1086.00	Naue + Highway Costs
Hyrdroseeding	375	m2	1.92	720.00	CESMM3 Unit Costs
Precast Concrete Headwall	1	No.	2500	2500.00	Estimate
Pipework and connection to new outfall					
Precast Concrete Manhole chambers less than 2m deep	1	No.	1532.1	1532.10	CESMM3 Unit Costs
Supply of 450mm diameter concrete surface water pipe	140	m	84	11760.00	Estimate based on current retail costs
Install 450mm diameter concrete surface water pipe upto 2m deep	110	m	78.42	8626.20	CESMM3 Unit Costs
Install concrete headwall for new outfall	1	No.	500	3500.00	Estimate
Road Resurfacing					
200mm sub base (Type 1)	4	m3	8.14	152.56	CESMM3 Unit Costs
HRA Binder Course 80mm	20	m2	8.23	364.60	CESMM3 Unit Costs
HRA Surface Course 60mm	20	m2	6.27	325.40	CESMM3 Unit Costs
Subtotal				**60947.58**	
Construction inflation index adjustment (2016 to 2019)	10.1	%		67103.29	
Optimism Bias	60	%		107365.26	OFNS
Detailed design costs	19	%		20399.40	
Total				**127764**	

4.3 Option 3: Large embankment with outfall to existing surface water network

This option builds on Option 1 by increasing the size of the embankment to store the 200year+CC event whilst passing forward the 1:50year flow. The modelling results have shown that to achieve this the embankment must be able to store 1750m^3. Due to the sloping nature of the ground the geometry of the proposed embankment has been derived by simplifying the storage volume geometry to:

0.5 x 2.6 x 1346 = 1750m^3

Where:

0.5 = accounts for the sloping nature of the ground and allows the embankment to get smaller as it ties into the slope.

2.6 = depth of stored water (total embankment height at deepest point)

1346 = area 1 quarter of circle with a diameter of 42m (hence 84m is the total length of the embankment)

0.6m of freeboard must also be accounted for bringing the total height of the embankment at its deepest point to 3.2m resulting in a volume of 2154m^3.

Using the cross-sectional area at the deepest point of 34m^2 and an embankment length of 84m the total volume = 2856m^3 however, as the embankment feathers into the existing ground a deduction of 20% can be applied by way of approximation to account for this, giving a net total embankment volume of 2285m^3.

Figure 4-4: Option 3 indicative plan

Table 4-5 Manhole details (as per Option 1)

Manhole / inspection chamber	Ground Level (mAOD)	Invert Level (mAOD)	Manhole depth (m)
X1 (new)	7.94	6.64	1.3
MH 6.2 (retrofit/replace)	6.67	4.6	2.07

Table 4-6: Pipe details (as per Option 1)

Pipe run	U/S Invert Level	D/S Invert Level	Length (m)	Gradient	Pipe size (θ mm)	Capacity (m3/s)
X1-6.2	6.64	4.6	140	1:70	450	0.38

This option will consist of the following actions:

- As per Option 1 with the exception the changes to the embankment geometry. Construct a new L-shaped embankment measuring approximately 82m in length with a 1m wide crest and 1 in 3 side slopes. The height of the embankment varies from 3.2m at its greatest before feathering into the slope. Approximate total volume of new embankment 2285m^3 utilising approximately 400m^3 of site won material. The new crest level is expected to be slightly above the road level of the A815. A new layby/access point for the embankment will be constructed to facilitate maintenance. A wide spillway will direct flows over the A815 away from the residential properties in the event of an exceedance event or blockage in the sewer/headwall. The spill flow will be very wide so that flows are shallow and low velocity prevent damage/disruption to the road. A freeboard of embankment above the spillway level will be required.

Benefits of proposed scheme

- This will offer a level of protection of up to 1:200year+CC event for all properties known and predicted to be affected in Eagle Court.
- Sustainable approach as surface water is removed from the combined sewer network which will help to lower flood risk downstream in the network. This will also remove a substantial volume of surface water which would have been stored and treated.
- Reuse of site won material to form part of the proposed embankment.
- Conventional construction methods.
- Any exceedance flows will be directed on to the A815 and away from the properties.

Assumptions and risk

- That the land in the corner of the field and A815 verge is available to the council is/owned by the council. Cost of land take has not been included.
- That the existing surface water sewer is free of blockages and is a good condition.
- That the drainage network within Eagle Terrace is owned by the council and the invert levels provided are correct.
- That the proposed surface water pipe is able to pass over/under any other services found in the verge of the A815.
- That the material from the existing informal embankment is of sufficient quality to be reworked to form fill for the new embankment.

- That the headwall structure will be fitted with flat bars rather than a full debris screen.
- A 4m x 120m temporary access road will be constructed in the field from the junction of the A815/B836.
- For simplicity, the connection to the existing network has been included in the costing as a new precast concrete manhole up to 2m deep.

4.3.1 Cost Estimate

Item	Quantity	Units	Unit cost	cost	Source
General					
Site welfare	12	weeks	425	5100.00	CESMM3 Unit Costs
Site store	12	weeks	105.06	1260.72	CESMM3 Unit Costs
Site supervision	6	weeks	1422	8532.00	CESMM3 Unit Costs
Temporary access road	480	m2	20	9600.00	Highway Unit Costs
Large embankment construction					
Excavation of existing embankment	400	m3	4.9	1960.00	CESMM3 Unit Costs
Screening of material	400	m3	2.5	1000.00	Estimate
Import class 1 fill material	1885	m3	23.7	44674.50	Highway Unit Costs
Deposition of fill material	2285	m3	1.42	3244.70	Highway Unit Costs
Compaction of fill material	2285	m3	0.95	2170.75	Highway Unit Costs
Install GCL Lining	1345	m2	5.43	7303.35	Naue + Highway Costs
Hyrdroseeding	1600	m2	1.92	3072.00	CESMM3 Unit Costs
Precast Concrete Headwall	1	No.	2500	2500.00	Estimate
Pipework and connection to existing network					
Precast Concrete Manhole chambers less than 2m deep	2	No.	1532.1	3064.20	CESMM3 Unit Costs
Supply of 450mm diameter concrete surface water pipe	140	m	84	11760.00	Estimate based on current retail costs
Install 450mm diameter concrete surface water pipe upto 2m deep	140	m	78.42	10978.80	CESMM3 Unit Costs
Silt removal at existing outfall					
Excavation of silt	40	m3	4.9	196.00	CESMM3 Unit Costs
Move excavated (non-hazardous) material to tip not more than 5km for site inclds tipping charges + tax	40	m3	8.59	1943.60	Highway Unit Costs
Subtotal				**118360.62**	
Construction inflation index adjustment (2016 to 2019)	10.1	%		130315.04	
Optimism Bias	60	%		208504.07	OFNS
Detailed design costs	19	%		39615.77	

Item	Quantity	Units	Unit cost	cost	Source
Total				**248120**	

4.4 Option 4: Future Development

The Local Development Plan 2015 for Dunoon lists a strip of land in line with Eagle Court extending to the B836 to the north which is available for a future housing development (H10001). At the time of writing there were no plans or information on available regarding proposed housing developments in this area, as such the proposed options are generalised. As there are no current plans for this site to be developed in the immediate future this option will not be taken forward to the appraisal stage but may revisited in the future if an opportunity arises.

Figure 4-5: Local Development Plan 2015 H-1001 – Site allocated for future housing developments

4.4.1 This option will consist of the following actions:

Areas of improvement that maybe delivered through future development:

- Design out surface water runoff collecting at the north east corner of Eagle Court through development.
- New development drainage to intercept surface water and attenuate using SUDS this will reduce the peak flow into critical points in the network. With a pass forward flow not exceeding the 1 in 2 year greenfield runoff rate.

- It would be prudent to intercept as much of the runoff as possible above the proposed site using a new drainage channel flowing south to north, potentially discharging to the Little Eachaig River beyond the B836. Alternatively, development drainage could be directed toward the north east corner of Eagle Court and contained within a formal detention basin.
- It will be essential that the new development considers exceedance events as the site is steep this should be assessed based on the most sensitive aspect of the drainage network. It is assumed this will be the interception using gullies.

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5 Damages and benefits assessment

5.1 Guidance

In accordance with the Scottish Government's Appraisal Guidance, benefits are taken as Annual Average Damages (AAD) avoided by scheme options expressed as their Present Value (PV) using Treasury discount rates.

5.2 Damage methodology

Flood losses for this site can be broken down into two key aspects: direct flood damage to the 16 residential and no non-residential properties at risk; and indirect road damage repairs and clean up costs. Wider health and wellbeing aspects may also be applicable, along with road disruption and delay, but these are not considered to be significant at this stage.

Flood damages to properties are usually assessed for individual events and properties, or using higher level 'weighted annual average damage' datasets. SEPA's SPAADE dataset is recommended for SWMP studies and has been used here. The standard value of £1,100 (2010 values) has been updated to 2019 values using the Government GDP deflator series (2019 estimate of £1,284).

In order to determine the benefits of the scheme for a range of different standards of protection, the SPAADE value has been scaled using a weighting derived from FHRC's Weighed Annual Average Damage (WAAD) dataset.

The SPAADE values have been applied to each property and total present values over the appraisal period have been estimated by discounting future flood losses over a 100 year period.

5.3 Business case

In order to assess the economically viability of each option an analysis of the estimated construction costs versus the present value damages has been undertaken. The benefit-cost ratio is the total present value benefits divided by the total present value costs. A value above unity suggests that the scheme is economically viable. Further details on the cost analysis undertaken can be found in appendix A.

Table 5-1: Benefit-cost analysis of options

	Do Nothing	Option 1	Option 2	Option 3
Level of protection offered	0	1:50	1:200yr+CC	1:200yr+CC
Estimated construction cost	0	£140,150	£127,765	£248,120
Annual average damages	£612,653	£39,097	£4,935	£4,935
Present Value damages	£731,905	£39,097	£4,935	£4,935
Total PV damage	£731,905	£39,097	£4,935	£4,935

	Do Nothing	Option 1	Option 2	Option 3
Total PV benefits	-	£692,808	£726,970	£726,970
Cost benefit ratio	-	4.9	5.7	2.9

All options have a benefit cost ratio greater than 1, thus all are considered to be cost effective. Option 2 has the highest benefit-cost ratio and would be considered to be preferred option economically.

6 Choosing the Preferred Option

6.1 Method of assessing and prioritising options

The assessment process aims to scope measures that will achieve multiple objectives in the context of site constraints and future development. A Multi-Criteria Assessment (MCA) screening exercise has been completed to consider the relative merits of each measure. It is recognised that it is important to ensure options are compared thoroughly, consistently and carefully reviewing options against the following criteria:

- Technical Feasibility – is it easily implemented?
- Relative Cost – how expensive is it in comparison to other measures?
- Economic Viability – is it expensive to implement?
- Social Impact and Acceptability – how will it impact on residents?
- Environmental – how will it impact the environment?
- Sustainability – is it a sustainable approach?

Detailed cost estimates have not been prepared as the funding and delivery mechanisms are not yet known. Each management option will be scored against each of the criteria set out above using relative indicator, in line with UK guidance:

- **U** - not applicable or unacceptable outcome
- **-2** - severely negative outcome
- **-1** - moderately negative outcome
- **0** - neutral outcome
- **+1** - moderately positive outcome, or
- **+2** - strongly positive outcome

The measures with the lowest overall combined scores from the MCA will be screened out to produce a short list of preferred options. The short-listed mitigation measures provide the starting point for a more detailed economic assessment should the Partners wish to take any of the sites further and implement surface water management measures.

Mitigation Measures	Technical	Relative Cost	Economic	Social Impact	Environment	Sustainability	Overall	Shortlist?
Option 1 Small Embankment Discharge to Existing Sewer	+1	+1	+1	+1	+1	+1	6	Yes
Option 2 – Small Embankment Discharge to Open Channel	+2	+1	+1	+2	+1	+2	9	Yes
Option 3 – large Embankment Discharge to Existing Sewer	+1	-1	-1	+2	+1	+1	1	No

6.2 Determining the preferred option

The results of the MCA analysis above has shown that Option 2 is the most favourable however, Options 1 should also be considered further.

The viability of option 2 depends greatly on the availability of the land to the east of the A815 which is currently used for grazing. If the construction could take place without compulsory purchase it is likely to be the most favourable option. It also poses the lowest risk of the 3 options as it does not rely on the capacity and performance of the existing network. Option 2 is able to deliver the same standard of protection as option 3 (1:200year+CC) with significantly smaller embankments and deliver an overall cut/fill balance.

7 Further studies

In order to progress to the preferred options, it would be prudent to undertake additional investigations to ensure the feasibility of the proposed options before the detailed design stage.

- Topographic survey of the study area and the proposed discharge route/location.
- Confirm service location and depths in A815 and its verge using a ground penetrating radar (GPR) survey and/or inspection pits.
- Create a hydraulic model of the proposed design using software such as micro drainage to confirm levels, flows and pipe geometry.
- Undertake a small ground investigation to inform reuse of insitu material and pipe material suitability.
- Investigate the current route of the north west drainage channel overflow with an aim on reconnecting it to the Little Eachaig River.

8 Conclusion

The analysis undertaken in this options appraisal study on flood risk mitigation measures at Sandhaven, Dunoon, has provided a preferred option based on the information available. The preferred option is Option 2 which involves:

- Removal of the existing informal flood embankment (approximately 400m^3).
- Creating a new lower embankment in the footprint of the existing informal embankment (approximately 305m^3). The primary purpose of this embankment is to channel overland flows to a new headwall. The L-shaped embankment will measure approximately 50m in length, 1m in height, 1m wide crest with 1 in 3 slopes. The embankment shall be formed of reworked material from the existing informal embankment and a Geosynthetic Clay Liner (GCL) to prevent seepage.
- Install at new precast concrete headwall with debris screen in the corner of the new embankment with an invert level of 6.64mAOD.
- Construction of a new precast concrete manhole up to 2m deep (manhole X1) with in the embankment footprint.
- Construct approximately 110m of 450mm diameter concrete pipe to connect the new manhole to the new outfall OUT1. This will involve excavation through the carriageway and in the fields to the south east.

This option has an estimated construction cost of approximately £127,765 includes an optimism bias of 60% which is standard at this level of design. The option explained above and indeed all of the options require further information and design in order to analyse detailed costs and risks.

Appendix

A Cost-Benefit Analysis

Project Summary Sheet

Client/Authority				Prepared (date)	02/07/2019
Argyll and Bute Council				Printed	23/10/2019
Project name				Prepared by	ST
Dunoon options appraisal - Sandhaven				Checked by	AEP
Project reference		2018s0549		Checked date	03/072019
Base date for estimates (year 0)		Jun-2019			
Scaling factor (e.g. £m, £k, £)		£	(used for all costs, losses and benefits)		
Year		0	30	75	
Discount Rate		3.5%	3.00%	2.50%	
Optimism bias adjustment factor		60%			

Costs and benefits of options

	Costs and benefits £				
Option name	Do-nothing	Option 1	Option 2	Option 3	0
AEP or SoP (where relevant)	50%	2.0%	0.5%	0.5%	
COSTS:					
PV capital costs	0	87,594	79,853	155,075	
PV operation and maintenance costs	0	0	0	0	0
PV other	0	0	0	0	0
Optimism bias adjustment	0	52,556	47,912	93,045	0
PV negative costs (e.g. sales)	0	0	0	0	0
PV contributions					
Total PV Costs £ excluding contributions	0	140,150	127,765	248,120	0
BENEFITS:					
PV monetised flood damages	612,653	39,097	4,935	4,935	
PV monetised flood damages avoided		573,556	607,718	607,718	
PV road drainage and clearing	119,252	0	0	0	0
PV road drainage and clearing avoided		119,252	119,252	119,252	
Total monetised PV damages £	731,905	39,097	4,935	4,935	0
Total monetised PV benefits £		692,808	726,970	726,970	
PV damages (from scoring and weighting)					
PV damages avoided/benefits (from scoring and weighting)					
PV benefits from ecosystem services					
Total PV damages £	731,905	39,097	4,935	4,935	0
Total PV benefits £		692,808	726,970	726,970	
DECISION-MAKING CRITERIA:					
Based on monetised PV benefits (** *ex* ***cludes benefits from scoring and weighting and ecosystem services)					
Net Present Value **NPV**		552,658	599,205	478,850	0
Average benefit/cost ratio **BCR**		4.9	5.7	2.9	
			Highest bcr		

Brief description of options:

Option 1	Do-nothing
Option 2	Option 1
Option 3	Option 2
Option 4	Option 3
Option 5	

Comments and assumptions:

Assumptions detailed in options appraisal report.

CLIENT	**Argyll and Bute Council**		Mandatory input by user
PROJECT	**Dunoon options appraisal - Sandhaven**		Optional input by user
SUMMARY			Calculated by spreadsheet

PART 1: PROJECT DESCRIPTION

Project name	Dunoon options appraisal - Sandhaven
Project reference	2018s0549
Project location	**Dunoon options appraisal - Sandhaven**

PART 2: GENERALITIES

Test discount rate	3.5%	3.0%	2.5%
Appraisal period (years)	100		
PV factor for appraisal period	29.813		

PART 3: CALCULATION OF BENEFITS

3.1 Define the benefit area

Residential properties at risk for 200 year event (nr)	16	
Average property value (£)	149,036	
Flood warning? (None/<8 hour/>8 hour)	None	0

3.2 Direct damage to residential properties

	Standard of protection (return period)	Properties at risk	Properties protected (default)	Properties protected (default)	AAD per property	Total AAD
		nr	%	nr	£	£
1	No protection	0	n/a	0	£ 1,284	£ -
0.5	50% (2-years)	16	n/a	0	£ 1,284	£ 20,550
0.2	20% (5-years)	0	5%	0.8	£ 780	£ -
0.1	10% (10-years)	0	10%	0.8	£ 402	£ -
0.04	4% (25-years)	0	25%	2.4	£ 192	£ -
0.02	2% (50-years)	0	80%	8.8	£ 82	£ -
0.01	1% (100-years)	0	93%	2.08	£ 20	£ -
0.005	0.5% (200-years)	0	100%	1.12	£ 10	£ -
	Total	**16**		**16**		**£ 20,550**
	PV damage (PVd)					**£ 612,653**
	Write-off value					£ 2,384,576
	PVd capped					**£ 612,653**

3.3 Direct damage to non-residential properties

Properties protected

Standard of protection (return period)	Retail	Offices	Warehouses	Leisure	Playing Field	Sports Centre	Marina	Sports Stadium	Public Buildings	Industry	Car park	SubStation	NRP sector average	Total AAD
	2	3	4	51	521	523	526	525	6	8	910	960		
	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	£
No protection														£ -
20% (5-years)														£ -
10% (10-years)														£ -
4% (25-years)														£ -
2% (50-years)														£ -
1% (100-years)														£ -
0.5% (200-years)														£ -
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**£ -**
PVd non-residential														**£ -**

3.4 Other flood losses: road disruption and emergency costs

		Property Count	Percentage Properties	Percentage Damage	
Direct damage: residential		16	100.0%	100.0%	£ 612,653
Direct damage: non-residential		0	0.0%	0.0%	£ -
Sub-total: direct damage	**Total**	**16**	**100%**	**100%**	**£ 612,653**
TOTAL PVd					**£ 612,653**

CLIENT	**Argyll and Bute Council**		Mandatory input by user
PROJECT	**Dunoon options appraisal - Sandhaven**		Optional input by user
SUMMARY			Calculated by spreadsheet

PART 1: PROJECT DESCRIPTION

Project name	Dunoon options appraisal - Sandhaven
Project reference	2018s0549
Project location	**Dunoon options appraisal - Sandhaven**

PART 2: GENERALITIES

Test discount rate	3.5%	3.0%	2.5%
Appraisal period (years)	100		
PV factor for appraisal period	29.813		

PART 3: CALCULATION OF BENEFITS

3.1 Define the benefit area

Residential properties at risk for 200 year event (nr)	16	
Average property value (£)	149,036	
Flood warning? (None/<8 hour/>8 hour)	None	0

3.2 Direct damage to residential properties

	Standard of protection (return period)	**Properties at risk**	**Properties protected (default)**	**Properties protected (default)**	**AAD per property**	**Total AAD**
		nr	**%**	**nr**	**£**	**£**
1	No protection	0	n/a	0	£ 1,284	£ -
0.5	50% (2-years)	0	n/a	0	£ 1,284	£ -
0.2	20% (5-years)	0	5%	0.8	£ 780	£ -
0.1	10% (10-years)	0	10%	0.8	£ 402	£ -
0.04	4% (25-years)	0	25%	2.4	£ 192	£ -
0.02	2% (50-years)	16	80%	8.8	£ 82	£ 1,311
0.01	1% (100-years)	0	93%	2.08	£ 20	£ -
0.005	0.5% (200-years)	0	100%	1.12	£ 10	£ -
	Total	**16**		**16**		**£ 1,311**
	PV damage (PVd)					**£ 39,097**
	Write-off value					£ 2,384,576
	PVd capped					**£ 39,097**

3.3 Direct damage to non-residential properties

Standard of protection (return period)	**Retail**	**Offices**	**Warehouses**	**Leisure**	**Playing Field**	**Sports Centre**	**Marina**	**Sports Stadium**	**Public Buildings**	**Industry**	**Car park**	**SubStation**	**NRP sector average**	**Total AAD**
	Properties protected													
	2	**3**	**4**	**51**	**521**	**523**	**526**	**525**	**6**	**8**	**910**	**960**		
	nr	**nr**	**nr**	**nr**	**nr**	**nr**	**nr**	**nr**	**nr**	**nr**	**nr**	**nr**	**nr**	**£**
No protection														£ -
20% (5-years)														£ -
10% (10-years)														£ -
4% (25-years)														£ -
2% (50-years)														£ -
1% (100-years)														£ -
0.5% (200-years)														£ -
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**£ -**
PVd non-residential														**£ -**

3.4 Other flood losses: road disruption and emergency costs

	Property Count	**Percentage Properties**	**Percentage Damage**	
Direct damage: residential	16	100.0%	100.0%	£ 39,097
Direct damage: non-residential	0	0.0%	0.0%	£ -
Sub-total: direct damage **Total**	**16**	**100%**	**100%**	**£ 39,097**
TOTAL PVd				**£ 39,097**

CLIENT	Argyll and Bute Council		Mandatory input by user
PROJECT	Dunoon options appraisal - Sandhaven		Optional input by user
SUMMARY			Calculated by spreadsheet

PART 1: PROJECT DESCRIPTION

Project name	Dunoon options appraisal - Sandhaven
Project reference	2018s0549
Project location	**Dunoon options appraisal - Sandhaven**

PART 2: GENERALITIES

Test discount rate	3.5%	3.0%	2.5%
Appraisal period (years)	100		
PV factor for appraisal period	29.813		

PART 3: CALCULATION OF BENEFITS

3.1 Define the benefit area

Residential properties at risk for 200 year event (nr)	16	
Average property value (£)	149,036	
Flood warning? (None/<8 hour/>8 hour)	None	0

3.2 Direct damage to residential properties

	Standard of protection (return period)	Properties at risk	Properties protected (default)	Properties protected (default)	AAD per property	Total AAD
		nr	%	nr	£	£
1	No protection	0	n/a	0	£ 1,284	£ -
0.5	50% (2-years)		n/a	0	£ 1,284	£ -
0.2	20% (5-years)	0	5%	0.8	£ 780	£ -
0.1	10% (10-years)	0	10%	0.8	£ 402	£ -
0.04	4% (25-years)	0	25%	2.4	£ 192	£ -
0.02	2% (50-years)	0	80%	8.8	£ 82	£ -
0.01	1% (100-years)	0	93%	2.08	£ 20	£ -
0.005	0.5% (200-years)	16	100%	1.12	£ 10	£ 166
	Total	**16**		**16**		**£ 166**
	PV damage (PVd)					**£ 4,935**
	Write-off value					£ 2,384,576
	PVd capped					**£ 4,935**

3.3 Direct damage to non-residential properties

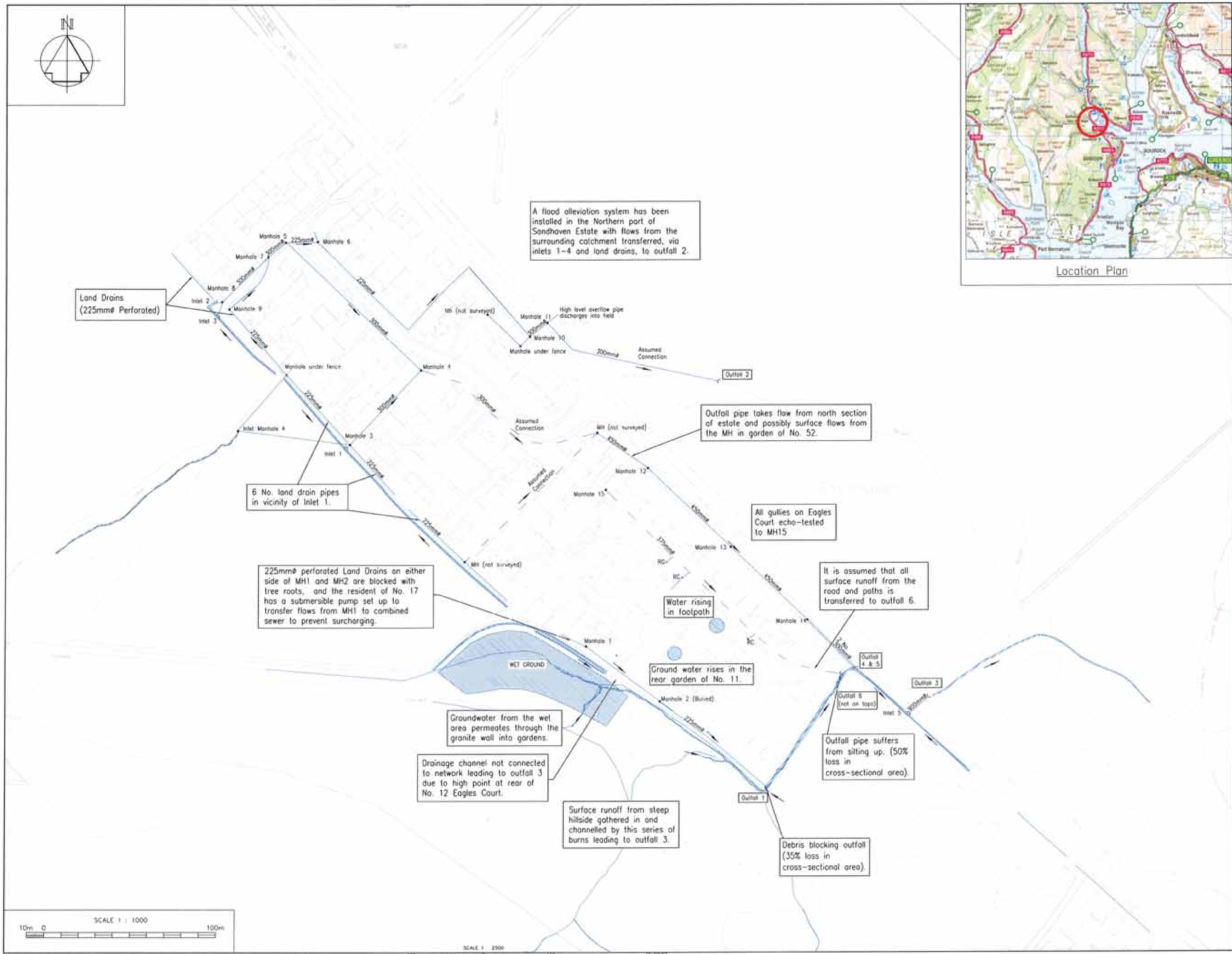
Properties protected

Standard of protection (return period)	Retail	Offices	Warehouses	Leisure	Playing Field	Sports Centre	Marina	Sports Stadium	Public Buildings	Industry	Car park	SubStation	NRP sector average	Total AAD
	2	3	4	51	521	523	526	525	6	8	910	960		
	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	£
No protection														£ -
20% (5-years)														£ -
10% (10-years)														£ -
4% (25-years)														£ -
2% (50-years)														£ -
1% (100-years)														£ -
0.5% (200-years)														£ -
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**£ -**
PVd non-residential														**£ -**

3.4 Other flood losses: road disruption and emergency costs

		Property Count	Percentage Properties	Percentage Damage	
Direct damage: residential		16	100.0%	100.0%	£ 4,935
Direct damage: non-residential		0	0.0%	0.0%	£ -
Sub-total: direct damage	**Total**	**16**	**100%**	**100%**	**£ 4,935**
TOTAL PVd					**£ 4,935**

B Drawing 102740-003-DRG-9600-0B, Grontmij, 2010



A1

1. All dimensions in millimetres and all levels in metres AOD unless shown otherwise.
2. The drainage information contained on this drawing is based on survey works completed by Dene Tech Services in April 2010.
3. In severe storms it is anticipated that rainwater running off the hillside to the west of the network will be collected by the network of channels leading to outfall 3.
4. Details of all existing manholes and connections can be found in the survey pack supplied by Dene-Tech Ltd. April 2010.

102740-003-DRG-9601 Proposed Layout
102740-003-DRG-9602 Access & Land Clearance

Surface Water Drainage Pipes
Assumed Surface Water Drainage Pipes
Surface Water Drainage Channels
Wet / Marshy Ground
Direction of Flow
Existing MH

Current issue information:
OA Provided for information

REV	DESCRIPTION	DRAWN	CHKD	APPD	DATE
0B	FOR INFORMATION	RSH	SC	CW	22.08.10
0A	FOR INFORMATION	JP	SC	CW	04.08.10

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CLIENT
Argyll & Bute Council

PROJECT
FLOOD MANAGEMENT PROGRAMME PHASE 1

TITLE
SANDHAVEN - DUNOON
EXISTING DRAINAGE PLAN

STATUS
FOR INFORMATION

ORIGINATED	DRAWN	CHECKED	APPROVED
DA	JP	SC	CW
DATE 04.06.10	DATE 04.06.10	DATE 02.08.10	DATE 02.08.10

DRAWING SCALE 1:500
ORIGINAL DRAWING SIZE A1
DRAWING No. 102740-003-DRG-9600
REV 0B

JBA consulting

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