Newton Stewart
FLOOD PROTECTION SCHEME

NEWTON STEWART FLOOD PROTECTION SCHEME – SUPPORTING DOCUMENT
SURFACE WATER FLOODING OPTIONS REPORT

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Sweco UK Limited

Dumfries & Galloway COUNCIL

SWECO

Change list

VER.	DATE	CHANGE CONCERNS	ORIGINATOR	REVIEWED	APPROVED
1	16.08.2018	DRAFT FOR COMMENT	IS	JF	DRL
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Summary

Sweco have investigated the interaction between the proposed Newton Stewart Flood Protection Scheme and the existing surface water and combined sewer systems.

This report has highlighted:

- areas that will be unable to drain to the river during the design flood. These were defined as ground levels that are at or below the top design water level of the proposed flood defences for the 1 in 200 year storm event;
- locations of sewer incapacity during a 1 in 200 year rainfall event resulting in manhole surcharge into the landscape, and excess flow entering the River Cree and the Penklin Burn;
- locations where predicted secondary flooding impacts the direct defences; and
- the measures required to address detriment from secondary flooding.

A summary outlining measures to address secondary flood risk at 5 locations has been provided. The six measures required are as follows:

- a combined outfall and flap valve system at the new defence walls/ embankment between the Penklin Burn and Cumloden Road;
- a combined kerb, drainage and outfall system at King Street;
- a combined kerb, drainage and outfall system at Michelle Terrance and King Street;
- a combined kerb, drainage and outfall system at Arthur Street;
- a surface water pumping station at Mortons Entry and Riverside Street; and
- a combined drainage system, underground surface water storage tank and pumping station at car park area at Riverside Road.

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1 Introduction

This section briefly introduces the secondary flooding issues with reference to flood prevention schemes.

1.1 Background

Sweco has been appointed by Dumfries & Galloway Council to design a flood protection scheme for the town of Newton Stewart. The aim of the scheme is to protect the town from events up to and including the 1 in 200 year flood, plus freeboard (hereafter referred to as ‘flood level’).

Backflow protection such as flap valves are currently used to prevent fluvial backflows into the existing drainage network. The hydraulic model predicts that, for high river flows, discharges to the river are blocked at some outfalls causing temporary backup in the drainage system. The model also predicts incapacity of the current system to hold water above the 1 in 30 year storm event. A combination of these factors results in manhole flooding.

While floodwater in the landscape can currently drain overland into the river (provided river levels are lower than flood levels and topography is favourable), the proposed direct defences for the flood protection scheme effectively creates a barrier for such overland drainage. Without mitigation, water will pond to greater depths than current conditions on the protected ‘dry’ side of the proposed defences, as shown in Figure 1.1, posing significant additional flood risk; this increase in flood risk cause by the primary defences is referred to as ‘secondary flooding’.

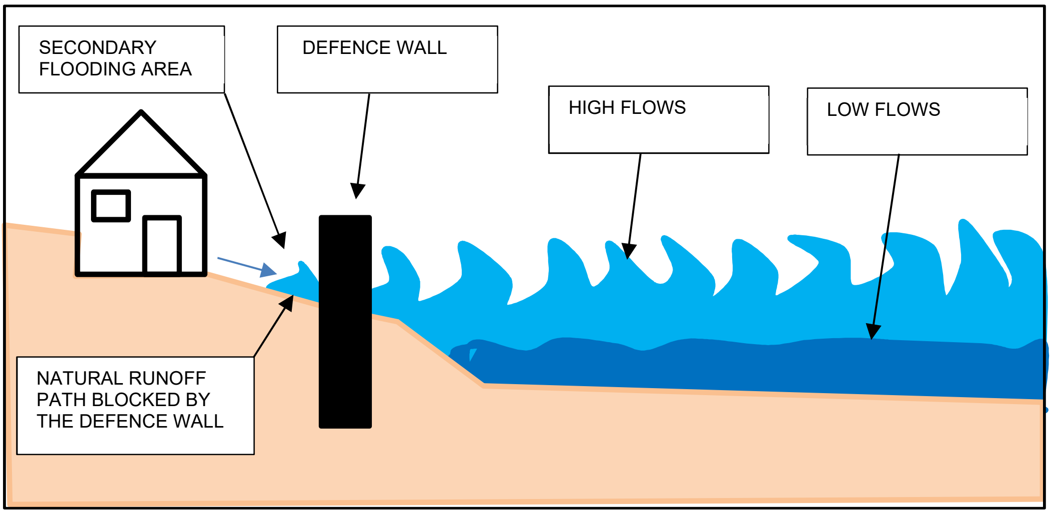


Figure 1.1 General representation of a secondary flooding

1.2 Purpose of the report

This report summarises the areas where a risk of surface water flooding could increase by implementation of the proposed river flood walls and embankments. It then proposes outline solutions for areas where the additional flooding volume increases by over 100 m^3.

2 Analysis

2.1 External data

The Scottish Water database and model network has been utilised for the surface water flooding analysis in Infoworks ICM, with LiDAR supplemented with topographic survey data used to construct a ground model of the area of interest. Hydraulic river modelling results supplied by Kaya Consulting have been applied for the river water levels at the existing outfall points.

2.2 Initial analysis

Initially, surface water flooding extents were estimated by calculating the 1 in 30 year event runoff volume (design event in accordance with Sewers for Scotland) from each selected areas (see Section 2.3), and applying this to an Integrated catchment network model (ICM) built for Newton Stewart by Sweco from the Scottish Water network model.

The analysis concluded that the combined sewer serving the majority of Newton Stewart suffers from a lack of capacity to handle the potential runoff from the areas it serves, at least in terms of the modern design standard of a 1 in 30 year level of service. This is regardless of water levels in the river. Analysis of this model showed the detriment in flood volumes for the 1 in 30 year event as a result of construction of new defence walls is negligible. Therefore, this scenario would generally not require flood mitigation, and detrimental events larger than this are to be mitigated.

2.3 Further analysis and areas selection

The detriment to flood volume in the landscape, with respect to the post-development model scenario, was estimated. The model predicted that significant increase in flood volumes (Figure 2.1) would result from the proposed flood defences.

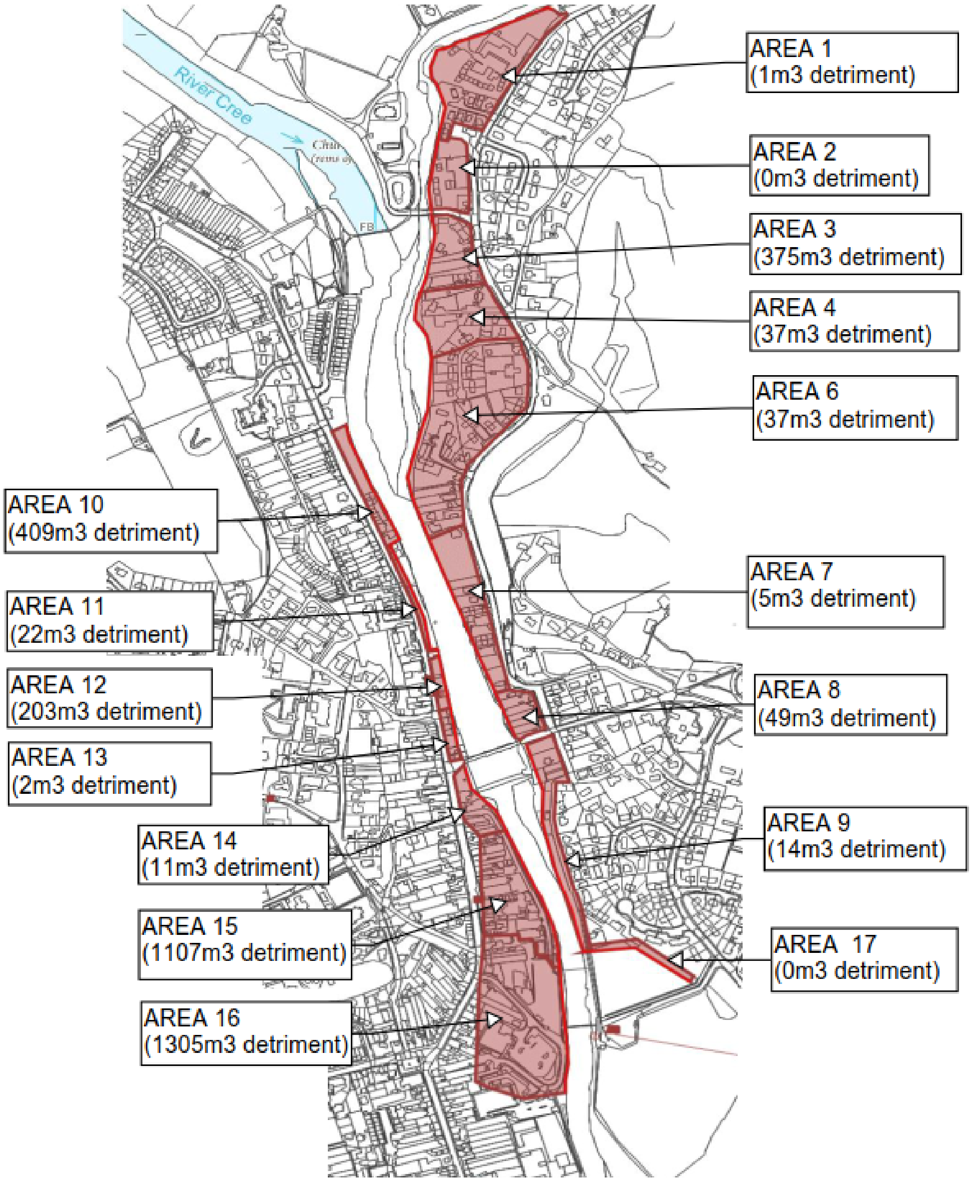


Figure 2.1 Areas selected for ponding analysis for the 1 in 200 year storm event in the network and 1 in 2 year storm event of the river, showing significant detriment in flood volumes

The area over which detriment was identified were screened for severity. Five areas were found to have volumetric detriments exceeding 100 m^3, see Figure 2.2, and were selected for further assessment. Areas 3 and 4 have been combined as they were found to be hydraulically linked. This new area has subsequently been referred to as 'Area 3/4'. The same principle has been applied for Areas 11 and 12 that became 'Area 11/12' for the purpose of optioneering. A summary of the flood volumes can be found in Table 2.1.

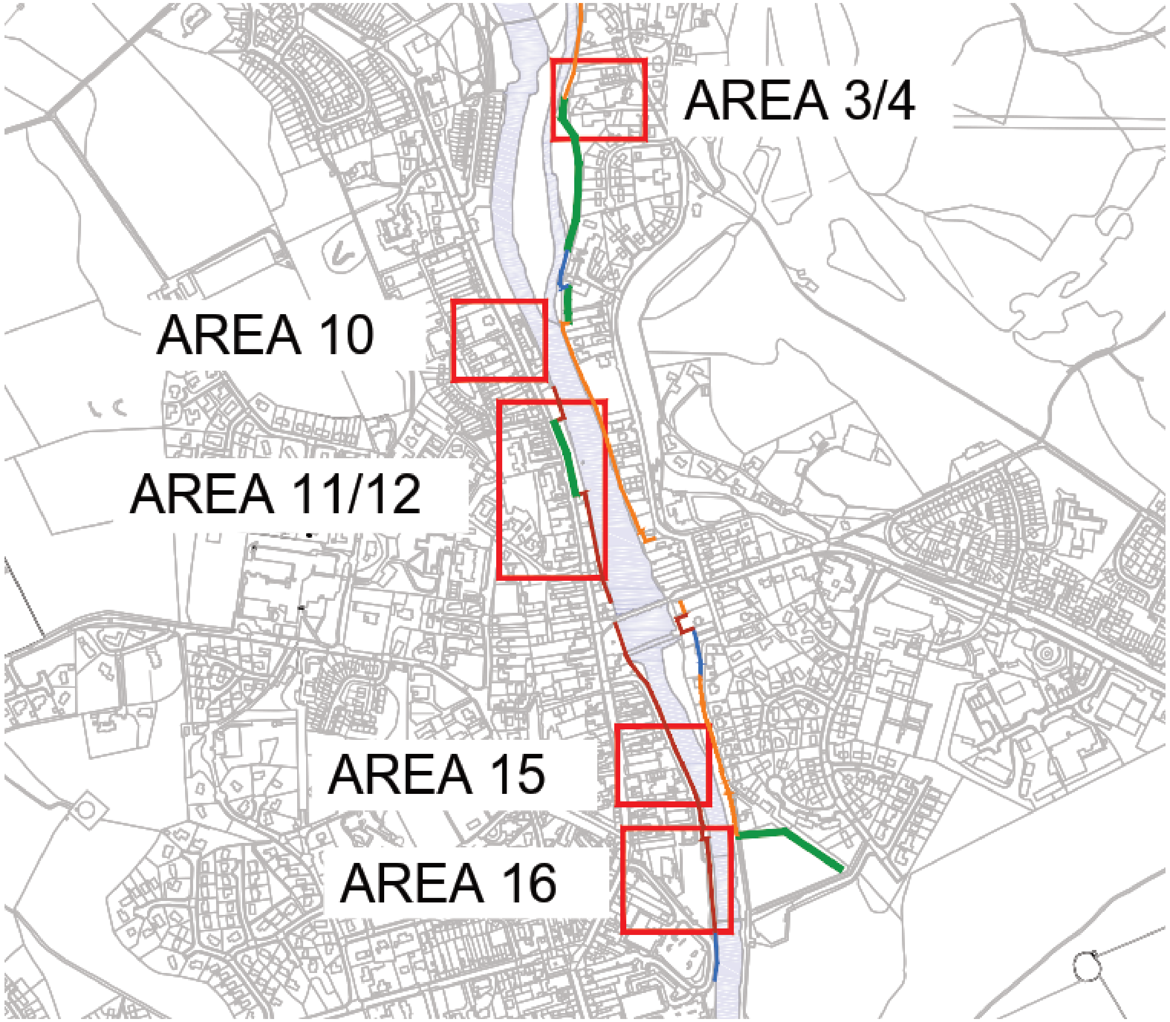


Figure 2.2 Five areas selected for secondary flooding mitigation

Table 2.1 Difference in flood volumes (m^3) in initial areas

Node ID	M200-15 Flood Volume (m^3)	M200-30 Flood Volume (m^3)	M200-60 Flood Volume (m^3)	M200-90 Flood Volume (m^3)	M200-120 Flood Volume (m^3)	M200-180 Flood Volume (m^3)	M200-240 Flood Volume (m^3)	M200-360 Flood Volume (m^3)	M200-420 Flood Volume (m^3)	M200-540 Flood Volume (m^3)	M200-720 Flood Volume (m^3)	M200-900 Flood Volume (m^3)	M200-1440 Flood Volume (m^3)
Area 1	0	0	1	2	1	1	1	1	1	1	1	1	4
Area 2	0	0	0	0	0	0	0	0	0	0	0	0	0
Area 3	1	1	18	49	55	58	59	61	63	64	67	67	1
Area 4	1	0	2	55	122	235	296	367	375	369	329	205	20
Area 5	2	-4	23	39	44	44	36	25	22	15	6	4	6
Area 6	2	11	21	29	32	37	36	33	28	18	5	3	3
Area 7	2	4	5	5	5	5	5	4	3	2	1	0	0
Area 8	11	20	29	36	40	45	47	49	48	45	38	28	0
Area 9	12	14	9	7	6	3	0	-5	-5	-5	-7	-9	-15
Area 10	74	103	139	165	186	225	255	300	318	349	387	402	409
Area 11	20	21	22	22	22	20	19	17	17	15	13	4	0
Area 12	134	172	193	203	199	193	175	158	153	143	130	125	131
Area 13	1	2	1	1	0	0	0	0	0	0	0	0	0
Area 14	11	10	3	0	0	0	0	0	0	0	0	0	0
Area 15	151	309	712	926	1031	1095	1107	1106	1094	1047	970	795	497
Area 16	-8	42	228	412	640	963	1096	1285	1305	1236	1108	889	402
Area 17	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	414	709	1384	1913	2339	2880	3096	3378	3400	3283	3042	2510	1451

3 Proposed solutions

This section describes the extent of predicted surface water drainage problems, and the proposed measures, in the six areas identified. The overall option relies on several new outfalls. To gauge the performance of the proposed measures, the invert of the proposed outfalls were compared to river levels for various fluvial events, as shown in Table 3.1. Nearly all outfalls are clear of the 1 in 5 year event, although performance is progressively impacted by more severe fluvial events.

Table 3.1 Comparison of the proposed outfall invert levels with the river levels

New Outfalls	Invert Levels (m AOD)	River Levels (m AOD)					
		1 in 2	1 in 5	1 in 10	1 in 25	1 in 50	1 in 200
Area 3/4							
Outfall 1	12.10	11.019	11.517	11.714	12.017	12.249	12.704
Outfall 2	12.37	10.897	11.378	11.580	11.856	12.054	12.511
Outfall 3	12.58	10.882	11.348	11.551	11.833	12.037	12.513
Outfall 4	11.60	10.796	11.167	11.320	11.538	11.684	12.018
Outfall 5	11.10	10.510	10.887	11.044	11.276	11.437	11.819
Area 10							
Outfall 6	10.00	9.642	9.975	10.141	10.414	10.596	11.049
Area 11/12							
Outfall 7	10.00	9.626	9.958	10.124	10.395	10.576	11.027
Outfall 8	8.4 **	9.481	9.825	10.000	10.288	10.483	10.978
Area 15							
(Pumped) Outfall 9	TBC *	8.294	8.652	8.809	9.040	9.183	9.494
Outfall 10	7.20	8.294	8.652	8.809	9.040	9.183	9.494
Area 16							
(Pumped) Outfall 11	TBC *	7.950	8.253	8.384	8.568	8.677	8.919
Outfall 12	5.900	7.950	8.253	8.384	8.568	8.677	8.919

* to be designed by a mechanical engineer at the detailed design stage
** the receptor's level (road) is at 9.8mAOD. This allows for free discharge at the 1 in 2 year river level.

3.1 Area 3/4

3.1.1 Predicted flooding

The existing combined sewer system serving the north-east part of Newton Stewart has been shown to have insufficient capacity to withstand the 1 in 30 year rainfall event without manhole flooding.

Flooding in Area 3/4 pools the private gardens, eventually flowing southwards to the river. The flood volume is a combination of combined sewer flooding and surface water from Cumloden Road, as shown in Figure 3.1 and Appendix A.

Construction of the proposed flood protection scheme would prevent the runoff flows from entering the river. The model predicts the peak secondary flooding volume to be 437 m³ during the 1 in 200 year plus climate change rainfall event (combined with the 1 in 2 year fluvial event). The proposed outline layout of Area 3/4 is presented in Appendix D.

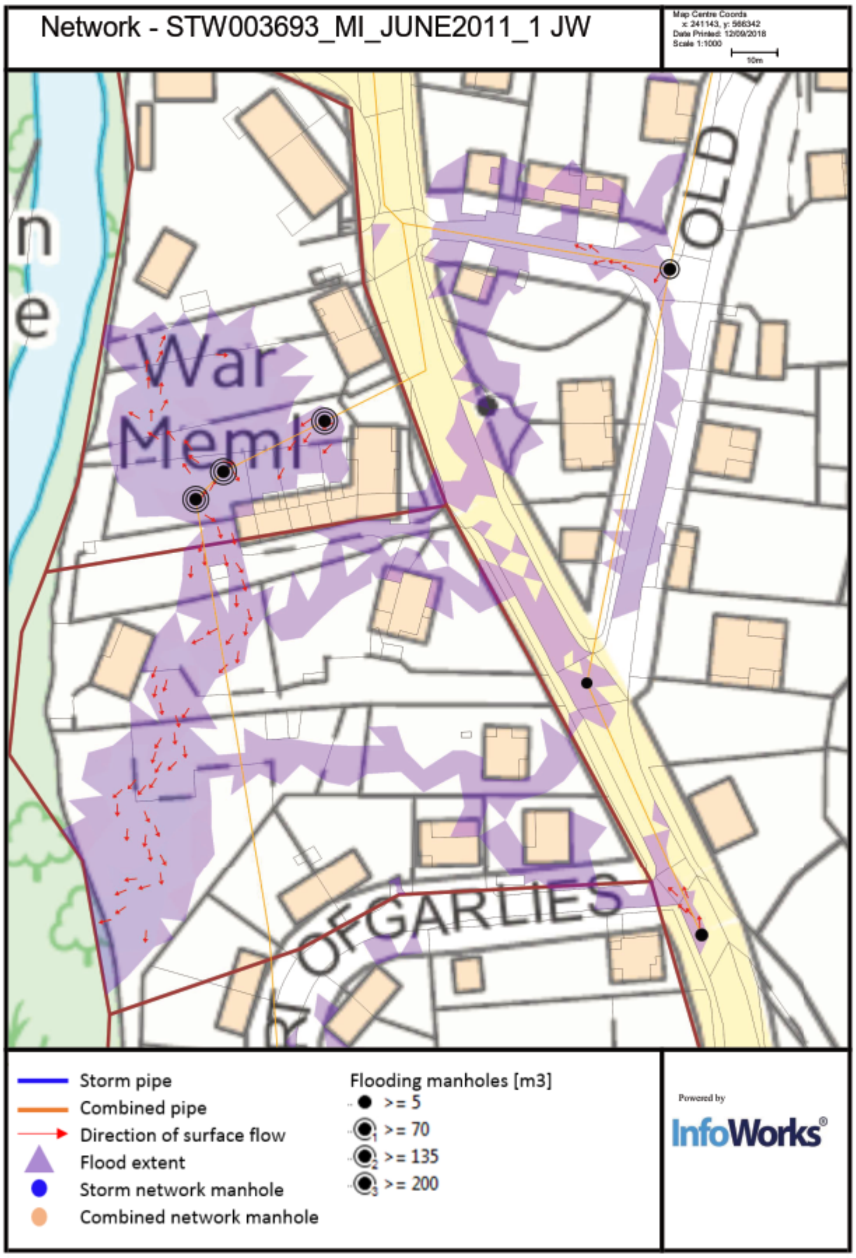


Figure 3.1 Surface water ponding at the Area 3/4 in the post-development situation without mitigation measures.

3.1.2 Preferred option: new outfall pipes with flap valves

The preferred measure at this location would include for the provision of:

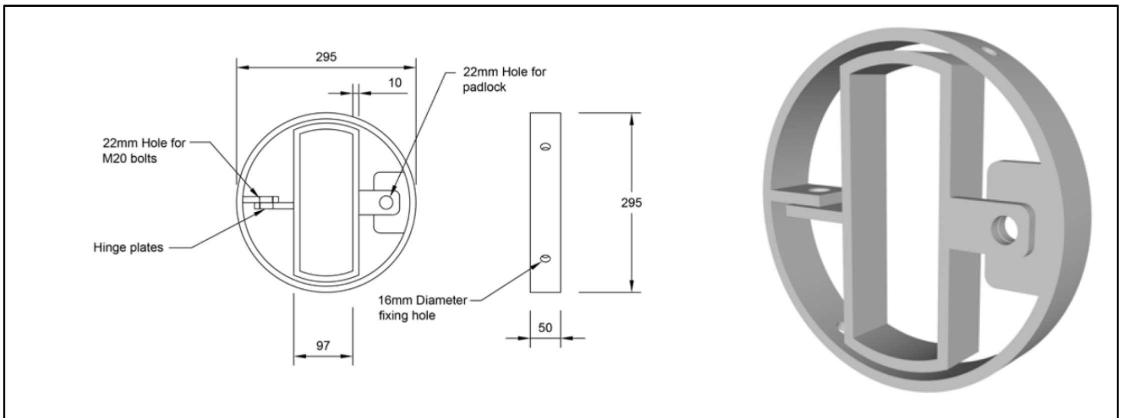
- 3 no. pipes with tide flap valves to be installed in the defence walls in private gardens; and
- 2 no. pipes with tide flap valves to be installed in the embankment with 2no. outfall headworks.

The proposed outline layout of this option is presented in Appendix D. Examples of the structures proposed have been given in Figure 3.2 and Figure 3.3. The benefits of this design are as follows:

- effective, reduces secondary flooding to 2 m³;
- low cost and low technology;
- utility diversions would not be required;
- traffic management would not be required; and
- no overpumping would be required.

Construction considerations for this option include:
- construction needs to be progressed together with the construction of the defence walls and embankments; and
- access to private gardens will be required.


Figure 3.2 Typical storm water headwall in an embankment with a safety grill and a typical storm water discharge pipe in a wall with a flap valve (reference: http://www.cpm-group.com/products/water-management/stormwater-management/stormwater-control/spillway-outfall; http://www.focalvalves.com/a/product/Flap_Valve/105.html)



Product Name	Max Pipe Opening Plastic / C'ware	Max Pipe Opening PCC
300mm Pipe Mounted Grating	300mm	300mm

Figure 3.3 Example of a safety grill at the inlet of the pipe (reference: https://www.althon.co.uk/products/300mm-pipe-mounted-grating/detail)

3.1.3 Discarded options

Other options were considered during the optioneering stage but were not progressed further, as they either did not reduce the detriment in secondary surface water flooding to a satisfactory level or significant constraints were identified during the buildability review (i.e. insufficient space). Some of the options also pushed the flood risk to the surrounding areas. The following options were considered and discarded:

- increase in the combined pipe diameter;
- increase the height of kerblines at the Cumloden Road;
- construction of a pumping station within the private gardens where the ponding occurs;
- construction of a pumping station at the Mealmill area; and
- construction of a pumping station at upstream areas to reduce levels in the combined network.

3.2 Area 10

3.2.1 Predicted flooding

The existing combined sewer system serving the north-east part of Newton Stewart has been shown to have insufficient capacity to withstand the 1 in 30 year rainfall event without manhole flooding.

Surface water, from combined sewer exceedance, flows down King Street and contributes to ponding located at Arthur Street (Area 11/12). The flowpaths are shown in Appendix B.

Flood water is predicted to overtop the road kerbline on King Street and flow along a private driveway to the back of several properties. The proposed flood defence will stop the water from discharging to the river causing ponding to occur within the properties back gardens. The model predicts an increase in flood volume at this location of 300 m³; the predicted flood extents are presented in Figure 3.4.

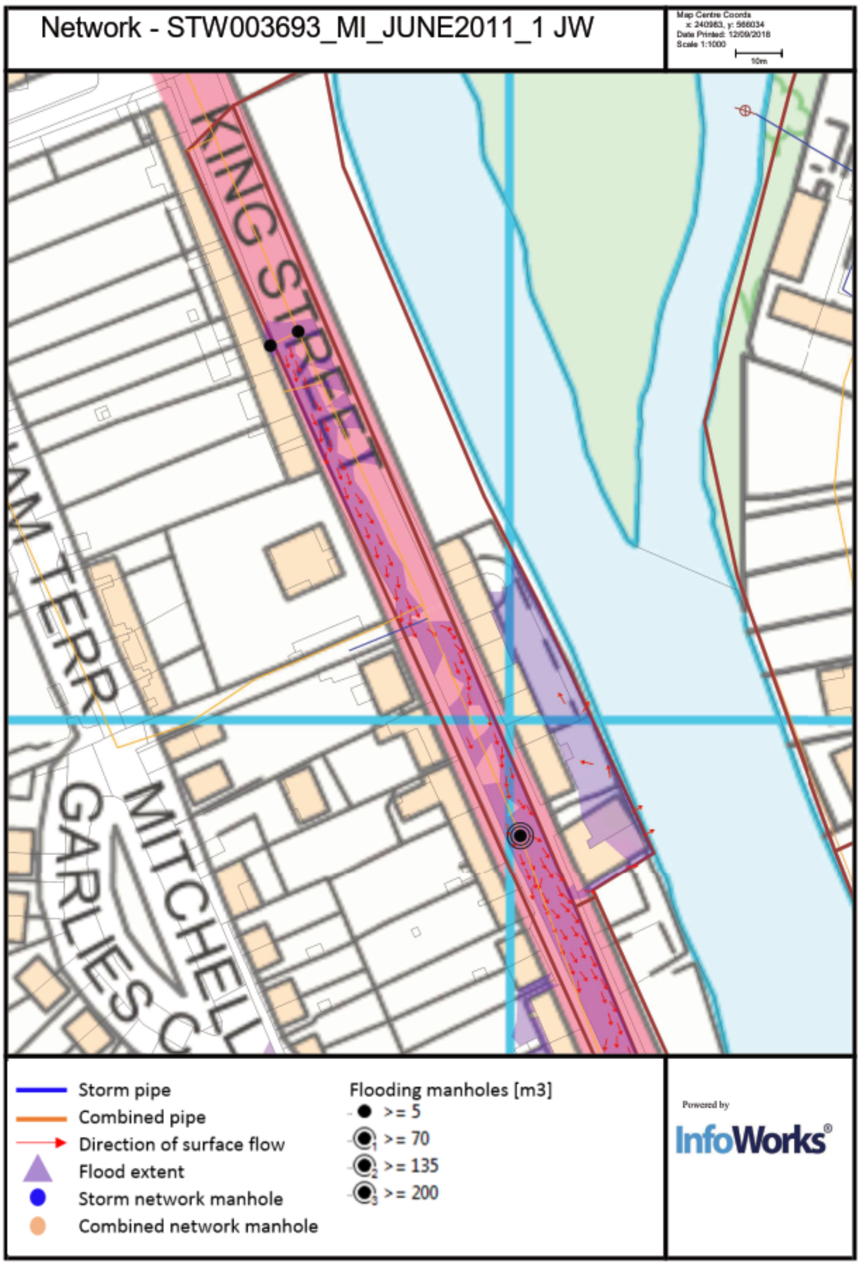


Figure 3.4 Surface water ponding at the Area 10 in the post-development situation without mitigation measures.

3.2.2 Preferred option: new drainage system with an outfall pipe

The preferred measure at this location would include for the provision of:

- 30m long drainage channel (Aco, Charcon type or similar); and
- 2 no. pipes with tide flap valves to be installed in the embankment with 2no.

The proposed outline layout of Area 10 is presented in Appendix E. Examples of the structures proposed are presented in Figure 3.4 and Figure 3.5. The benefits of this design are as follows:

- effective in eliminating the secondary flooding detriment;
- low cost and low technology; and
- no overpumping would be required.

Construction considerations for this option include :

- construction needs to be undertaken in parallel with the construction of the defence walls / embankments;
- utility diversions could be required at the location of the Aco drain;
- traffic management required; and
- Aco drain to be suitably designed to contain the runoff flows.

Figure 3.5 Photograph showing the location of the proposed Aco drain at Area 10

Figure 3.6 Typical drainage channel located at a kerbline of a road (reference: https://www.acodrain.com.au/news/drainage-products-camden-valley-way-upgrade.htm)

3.2.3 Discarded options

Other options were considered during the optioneering stage but were not progressed further as they either did not reduce the detriment in secondary surface water flooding to a satisfactory level or significant constraints were identified during the buildability review (i.e. insufficient space). Some of the options also pushed the flood risk to the surrounding areas. The following options were considered and discarded:

- increase in the combined pipe diameter;
- increase the height of kerb lines;
- construction of a pumping station within the private backyard where the ponding occurs; and

- construction of a pumping station at the green spaces at the upstream areas to reduce levels in the combined network.

3.3 Area 11/12

3.3.1 Predicted flooding

There are three major surface water flowpaths in this area (Appendix B):

1. From the undersized surface water network located to the west of the area. This system overtops its manholes at Windsor Terrace and the flood water runs down along Gilmour Terrace and Mitchell Terrace to finally cross King Street and discharge to the River Cree.
2. From the undersized combined water network located to the upstream section of King Street (Area 10). The floodwater flows down King Street and partially finds its relief to the river close to King Street and Mitchell Terrace. It also partially flows down King Street to Arthur Street to discharge to the river at the location of the existing CSO.
3. From the undersized combined water network located in Arthur Street. This system overtops its manholes and the flood water runs down Arthur Street to overtop its kerbline and to discharge to the river at the location of the existing CSO.

The proposed flood defences stop surface water spilling to the river, causing an increase in the surface water depths at Arthur Road and in the vicinity of the existing CSO chamber. The model predicts an increase in surface water flooding of 167 m^3 during the 1 in 200 year plus climate change rainfall event (1 in 2 year fluvial level on outfalls). Indicative flood extents can be seen in Figure 3.7.

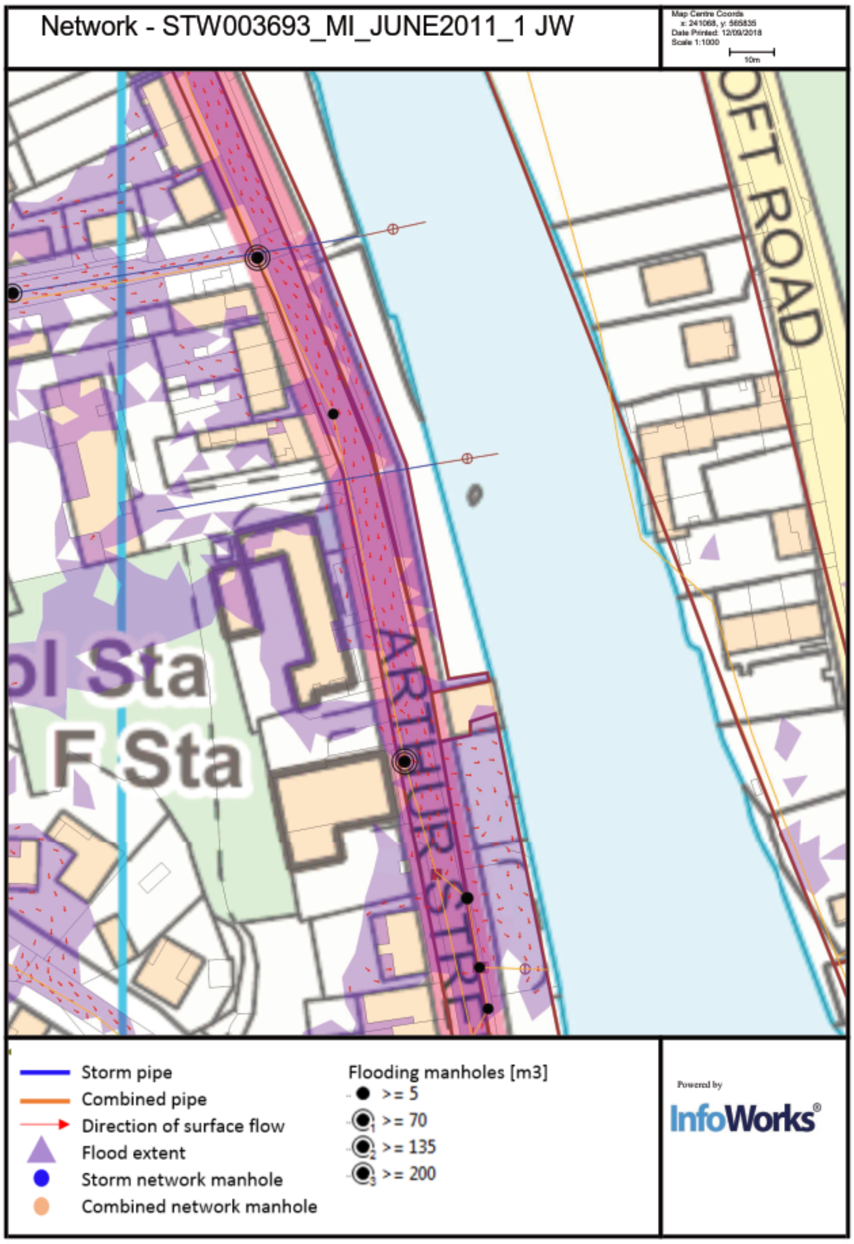


Figure 3.7 Surface water ponding at the Area 11/12 in the post-development situation without mitigation measures.

3.3.2 Preferred option: new drainage system with an outfall pipe

The preferred measure at this location would include for the provision of:

- 8m long heavy duty double drainage channel (Aco, Charcon type or similar) in Michell Terrace to capture surface water runoff into King Street.
- 300mm diameter, 32m long pipe with a tide flap valve to be installed in the new defence wall off King Street
- 10m long double drainage channel (Aco, Charcon type or similar) in Arthur Street to capture surface water runoff running down Arthur Street.
- 300mm diameter, 14m long pipe with a tide flap valve to be installed in the new defence wall off Arthur Street, next to the existing CSO outfall.

The proposed outline layout of Area 11/12 is presented in Appendix E. Examples of the structures proposed have been given in Figure 3.8 through to Figure 3.11. The benefits of this design are as follows:

- effective in eliminating detriment, providing betterment of 9 m^3;
- low cost and low technology; and
- no overpumping would be required

Construction considerations for this option include :

- construction needs to be undertaken in parallel with the construction of the defence walls / embankments;
- utility diversions could be required at the location of the Aco drains;
- utility crossings in King Street and Arthur Street;
- traffic management required; and
- Aco drain to be suitably designed to contain the runoff flows.

Figure 3.8 Photograph showing the location of the proposed heavy duty drain channel at Area 11

Figure 3.9 Photograph showing the location of the proposed drain channel at Area 12

Figure 3.10 Typical heavy duty large volume drainage channel (reference: https://www.aco.co.uk/products/s-range)

Figure 3.11 Example photograph showing heavy duty large volume drainage channel constructed across a street (reference: http://eric-sons.com/roadway.html)

3.3.3 Discarded options

Other options were considered during the optioneering stage but were not progressed further as they either did not reduce the detriment in secondary surface water flooding to a satisfactory level or significant constraints were identified during the buildability review (i.e. insufficient space). Some of the options also pushed the flood risk to the surrounding areas. The following options were considered and discarded:

- increase in the combined pipe diameter;
- increase the height of kerblines; and
- construction of a pumping station within the vicinity of the existing CSO chamber where the ponding occurs.

3.4 Area 15

3.4.1 Predicted flooding

Flow is supplied to this area by Victoria street via Mortons Entry. Flood water pooling in Victoria street is the result of the undersized combined network. Construction of the flood defences would stop the water spilling to the river and will cause increase in the water depths in Riverside Road. The model predicts flooding in this area would increase by 1107 m³ during the 1 in 200 year plus climate change rainfall event (1 in 2 year fluvial level on outfalls). Indicative flood extents are shown in Figure 3.12. Moreover, some surface water would flow to the south to pond in the car park in Area 16.

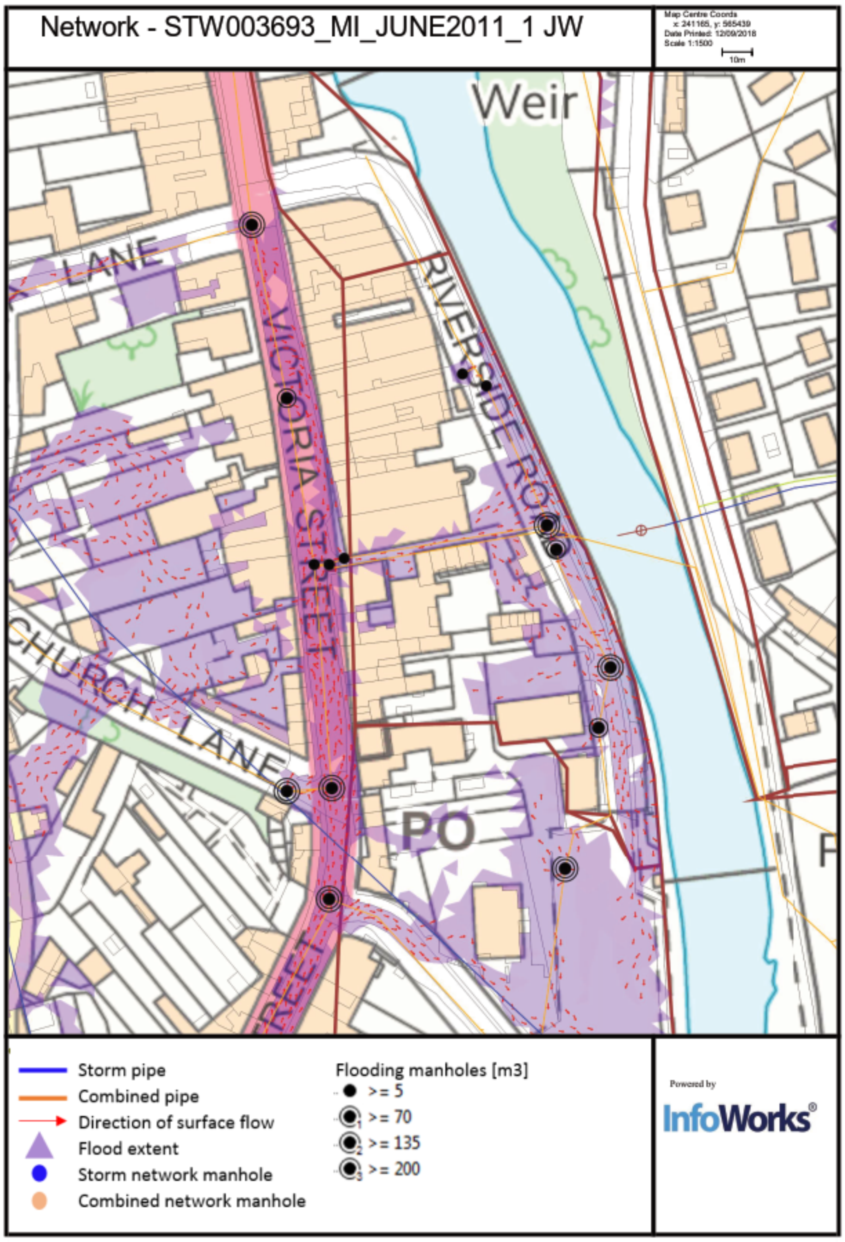


Figure 3.12 Surface water ponding at the Area 15 in the post-development situation without mitigation measures.

3.4.2 Preferred option: new drainage system with a pumping station

Provision of the following items has been proposed, with Appendix F illustrating the proposed site layout:

- 10m long heavy duty double drainage channel (Aco, Charcon type or similar) in Mortons Entry to capture surface water runoff to Riverside Road;
- 450mm diameter, 26m long pipe with a tide flap valve to be installed in the new defence wall at Riverside Road to bypass the pumping station during low river water level;
- 450mm diameter, 10m long inlet PS pipe;

- 5m diameter Pumping Station, 3.5m deep chamber with 3 no. 225 l/s duty/assist/standby pumps to activate during high river water levels. This can be either Precast manhole rings or utilise a proprietary Caisson type;
- 3m diameter valve chamber, 2m deep;
- 450/600mm diameter, 40m long rising main;
- Control panel with ducting and electric supply;
- Flow meter chamber;
- 2no. PC rings manholes; and
- 2no. ultrasonic flow meters.

The proposed outline layout of Area 15 is presented in Appendix F. Examples of the structures proposed have been given in Figure 3.13 through to Figure 3.15. The benefits of this design are as follows:

- effective in significantly reducing the secondary flooding detriment from 1107 m^3 to 14 m^3; and
- no overpumping is required.

Construction considerations for this option include :

- construction needs to be undertaken in parallel with the construction of the defence walls / embankments;
- utility crossings;
- traffic management required;
- Aco drain to be suitably designed to contain the runoff flows;
- possible extensive dewatering of trenches;
- cofferdam required;
- land ownership; and
- potential to reuse the excavated soil by increasing the ground level in the car park area as part of the solution at Area 16.

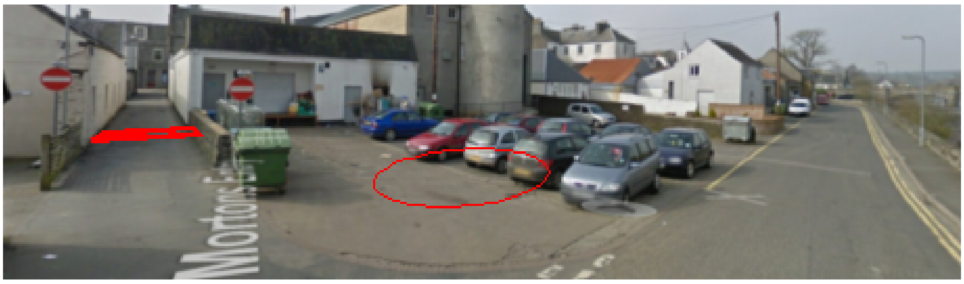


Figure 3.13 Photograph showing location of proposed drainage channel and the pumping station at Area 15

Figure 3.14 Typical Caisson manhole (reference: http://deltace.com/pages/caisson-shaft-construction.html)

Figure 3.15 Typical large PC rings manhole (reference: http://www.cpm-group.com/products/drainage/sealed-manholes/)

3.4.3 Discarded options

Other options were considered during the optioneering stage but were not progressed as they either did not reduce the detriment in secondary surface water flooding to a satisfactory level or significant constraints were identified during the buildability review (i.e. insufficient space). Some of the options also pushed the flood risk to the surrounding areas. The following options were considered and discarded:

- increase in the combined pipe diameter in Victoria Street;
- construction of a gravity drainage system only;
- construction of a storage tank and a pumping station; and
- construction of a CSO in Victoria Street.

3.5 Area 16

3.5.1 Predicted flooding

There are four major surface water flowpaths in this area (Appendix C):

1. From the undersized combined water network located to the west of the area. This system overtops its manholes at Victoria Street. A small portion of flood water runs down between buildings through the car park in Area 16 to discharge into the River Cree, whilst the remainder flows down Victoria Street and Mortons Entry to cross Riverside Road and discharge into the River Cree at Area 15.
2. From the undersized combined water network located in Princess Terrace, Dashwood Square and Albert Street. The floodwater flows down Albert Street, turns right onto Goods Lane to overtop the kerbline, follow the car park to exit into the river.

3. From the undersized surface water network located in Goods Lane. Surface water from this system flows down Good Lane and discharges into the river.
4. From the undersized combined water network located in the car park. Flood water follows the car park to the south-east direction and discharges into the river.

Construction of the proposed flood defence would stop water spilling to the river and cause an increase in the water depths within the car park. The carpark would also receive additional flood volumes due to overflowing of Riverside Road from Area 15. The model predicts flooding in this area would increase by 1305 m³ during the 1 in 200 year plus climate change rainfall event (with a 1 in 2 year river level on outfalls). Indicative flood extents are shown in Figure 3.16.

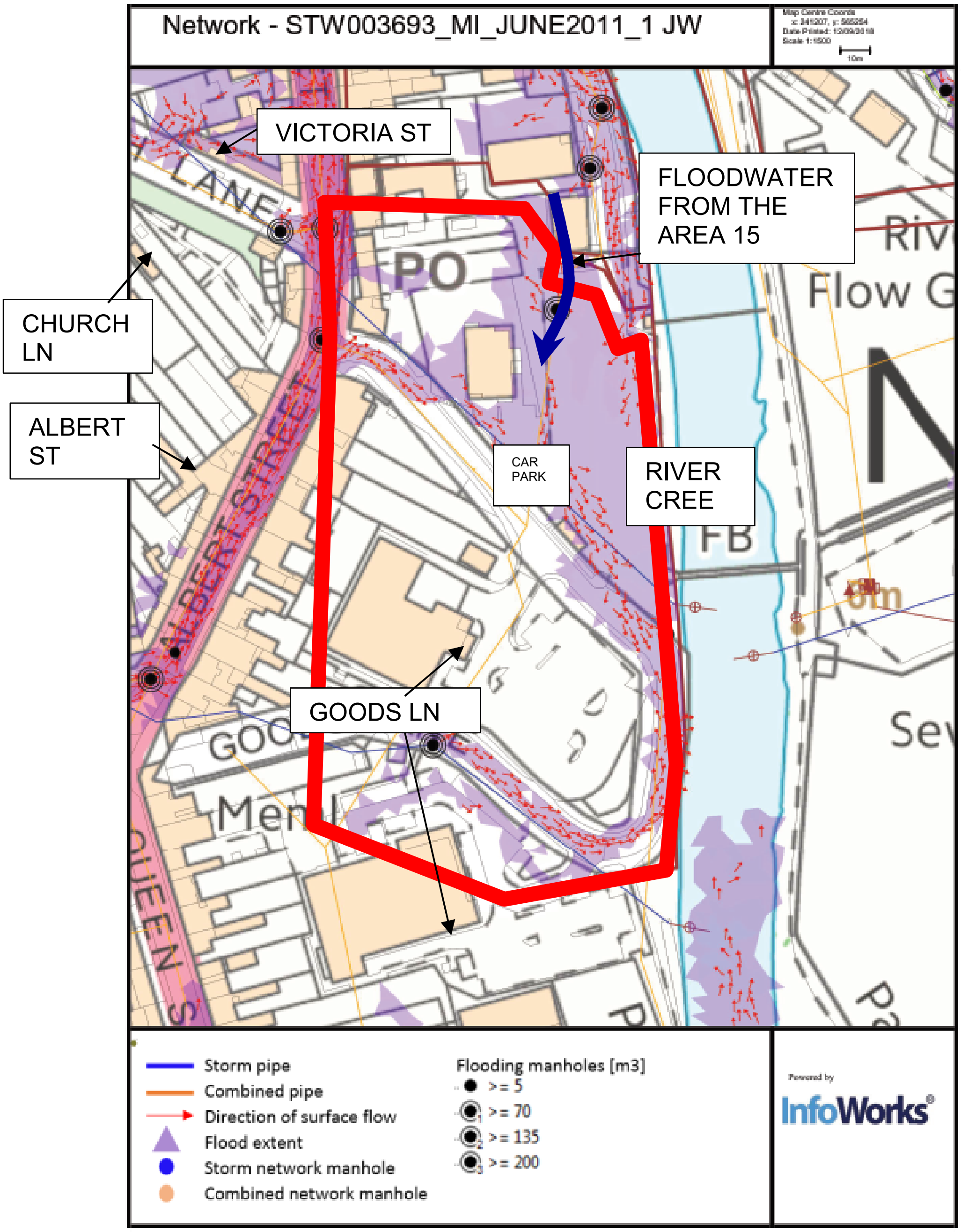


Figure 3.16 Surface water ponding at the Area 16 in the post-development situation without mitigation measures.

3.5.2 Preferred option: two new drainage systems with a storage tank and a pumping station

Provision of the following items has been proposed, with Appendix H illustrating the proposed site layout:

Drainage system no 1:

- 13m long heavy-duty drainage channel (Aco, Charcon type or similar) in Goods Lane kerbline to capture surface water runoff flowing down from Albert Street to the car park.
- Requires a 300mm diameter, 100m long pipe.

Drainage system no 2:

- 14m long heavy-duty drainage channel (Aco, Charcon type or similar) in the car park to capture surface water runoff flowing down from Victoria Street as well as flooding from manholes located at the car park; and
- Requires a 300mm diameter, 7m long pipe.

Provision of a storage:

- 700 m^3 underground storage tank. This can be either in-situ reinforced concrete tank or a proprietary modular system.
- Requires a 300mm diameter, 15m long pipe with a tide flap valve to be installed in the new defence wall at Riverside Road/ Goods Lane, to bypass the pumping station at low river water level.

Provision of a pumping station:

- 1.8m diameter pumping station, 3.0m deep chamber with 2 no. 10l/s duty-assist pumps to activate during high river water levels.
- 1.8m diameter valve chamber, 1.5m deep.
- 100/150mm diameter, 23m long rising main.
- Flow meter chamber.
- 3no. manholes.
- 2no. ultrasonic flow meters.

The benefits of this design are as follows::

- effective in eliminating secondary flooding; and
- no overpumping is required.

Construction considerations for this option include:

- construction needs to be progressed in parallel with the construction of the defence walls / embankments;
- utility crossings;
- possibly diversion of the existing drainage system in the car park.
- traffic management required;
- Aco drain to be suitably designed to contain the runoff flows;

- possible extensive dewatering of trenches;
- excavated soil could be reused by rising ground level at the car park area;
- extensive reinstatement of the road surface;
- cofferdam required; and
- land ownership.

Figure 3.17 Photograph showing the location of the proposed Aco drain at the Area 16 at Goods Lane

Figure 3.18 Photograph showing the location of the proposed Aco drain at the Area 16

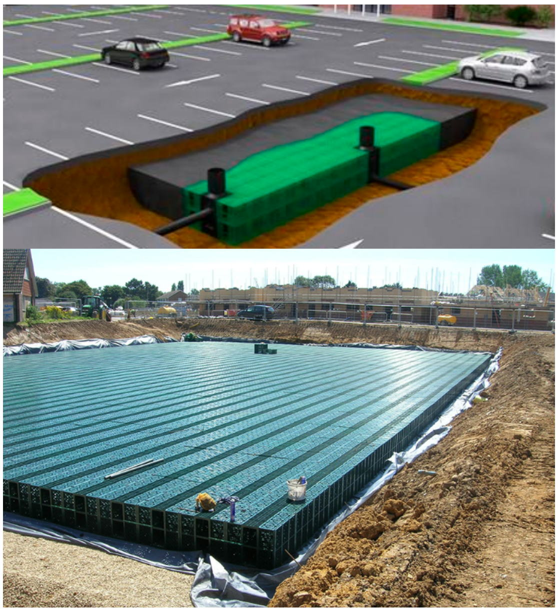


Figure 3.19 Typical modular system attenuation tank (reference: https://www.hydro-int.com/en/products/stormbloc?gclid=EAIaIQobChMI3cWgkve33QIVwueaCh1ddwjTEAAYASAAEgKz-_D_BwE)

Figure 3.20 Typical in-situ reinforced attenuation tank (reference: http://trueformltd.co.uk/storm-water-attenuation-tanks/)

Figure 3.21 Typical precast concrete attenuation tank (reference: http://www.carlowprecast.co.uk/house-builder/stormcast-attenuation-system/)

3.5.3 Discarded options

Other options were considered during the optioneering stage but were not progressed further as they either did not reduce the detriment in secondary surface water flooding to a satisfactory level or significant constraints were identified during the buildability review (i.e. insufficient space). Some of the options also pushed the flood risk to the surrounding areas. The following options were considered and discarded:

- Increase in the combined pipe diameter in Victoria Street, Albert Street and the car park;
- Construction of a gravity drainage system alone, without the support of the pumping station;
- Construction of a storage tank with a gravity outfall, without the support of the pumping station;
- Construction of a new CSO chamber at the car park; and
- Utilisation of Weholite storage pipes under the car park.

4 Additional analysis

To assess the resilience of the proposed mitigation measures, including the impact upon all twelve of the previously identified flooding areas, two scenarios were considered.

4.1 Scenario 1

In this scenario it has been assumed all proposed flap valves are efficiently working and the river water level is low enough to accept gravity flows from the Areas 15 and 16 with omission of the pumping stations. The analysis showed no detriment in the secondary surface water flooding. All areas indicated a significant improvement in flood volumes (Table 4.1).Table 4.1 Scenario 1 predictions

Node ID	M200-15 Flood Volume (m^3)	M200-30 Flood Volume (m^3)	M200-60 Flood Volume (m^3)	M200-90 Flood Volume (m^3)	M200-120 Flood Volume (m^3)	M200-180 Flood Volume (m^3)	M200-240 Flood Volume (m^3)	M200-360 Flood Volume (m^3)	M200-420 Flood Volume (m^3)	M200-540 Flood Volume (m^3)	M200-720 Flood Volume (m^3)	M200-900 Flood Volume (m^3)	M200-1440 Flood Volume (m^3)
Area 1	-16	-21	-24	-28	-29	-29	-29	-30	-29	-29	-28	-27	-14
Area 2	0	0	0	0	0	0	0	0	0	0	0	0	0
Area 3	-142	-231	-333	-366	-376	-387	-391	-386	-380	-372	-360	-345	-282
Area 4	-47	-68	-88	-96	-98	-100	-100	-101	-100	-98	-93	-81	-54
Area 5	-244	-250	-237	-223	-214	-202	-191	-175	-169	-162	-154	-145	-127
Area 6	-39	-40	-40	-40	-40	-39	-38	-37	-36	-35	-32	-16	-7
Area 7	-2	-2	-2	-2	-2	-2	-2	-1	-1	-1	0	0	0
Area 8	-8	-7	-7	-6	-6	-5	-5	-4	-4	-4	-3	-2	-1
Area 9	-7	-9	-18	-21	-22	-24	-24	-23	-21	-21	-20	-19	-16
Area 10	-2	-2	-2	-2	-1	-1	-1	-1	-1	-1	0	0	0
Area 11	-2	-2	-2	-2	-2	-1	-1	-1	-1	-1	-1	0	0
Area 12	-15	-16	-16	-15	-14	-13	-12	-10	-10	-9	-8	-8	-8
Area 13	-1	-1	0	0	0	0	0	0	0	0	0	0	0
Area 14	-5	-5	-3	-2	-1	0	0	0	0	0	0	0	0
Area 15	-102	-130	-139	-149	-156	-165	-164	-159	-153	-142	-128	-109	-70
Area 16	-271	-382	-456	-478	-480	-477	-465	-445	-439	-420	-396	-376	-335
Area 17	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	-903	-1166	-1366	-1428	-1439	-1445	-1424	-1374	-1344	-1293	-1223	-1129	-913

4.2 Scenario 2

In this scenario it has been assumed all proposed flap valves and gravity outfall pipes in the Areas 15 and 16 do not preform efficiently due to high river water levels and the support of pumping stations is required.

Although, the analysis showed slight increase in predicted secondary surface water flooding in individual areas (to a maximum of 68 m^3 in Area 4), the overall volume of flooding is predicted to reduce (Table 4.2).Table 4.2 Scenario 2 predictions

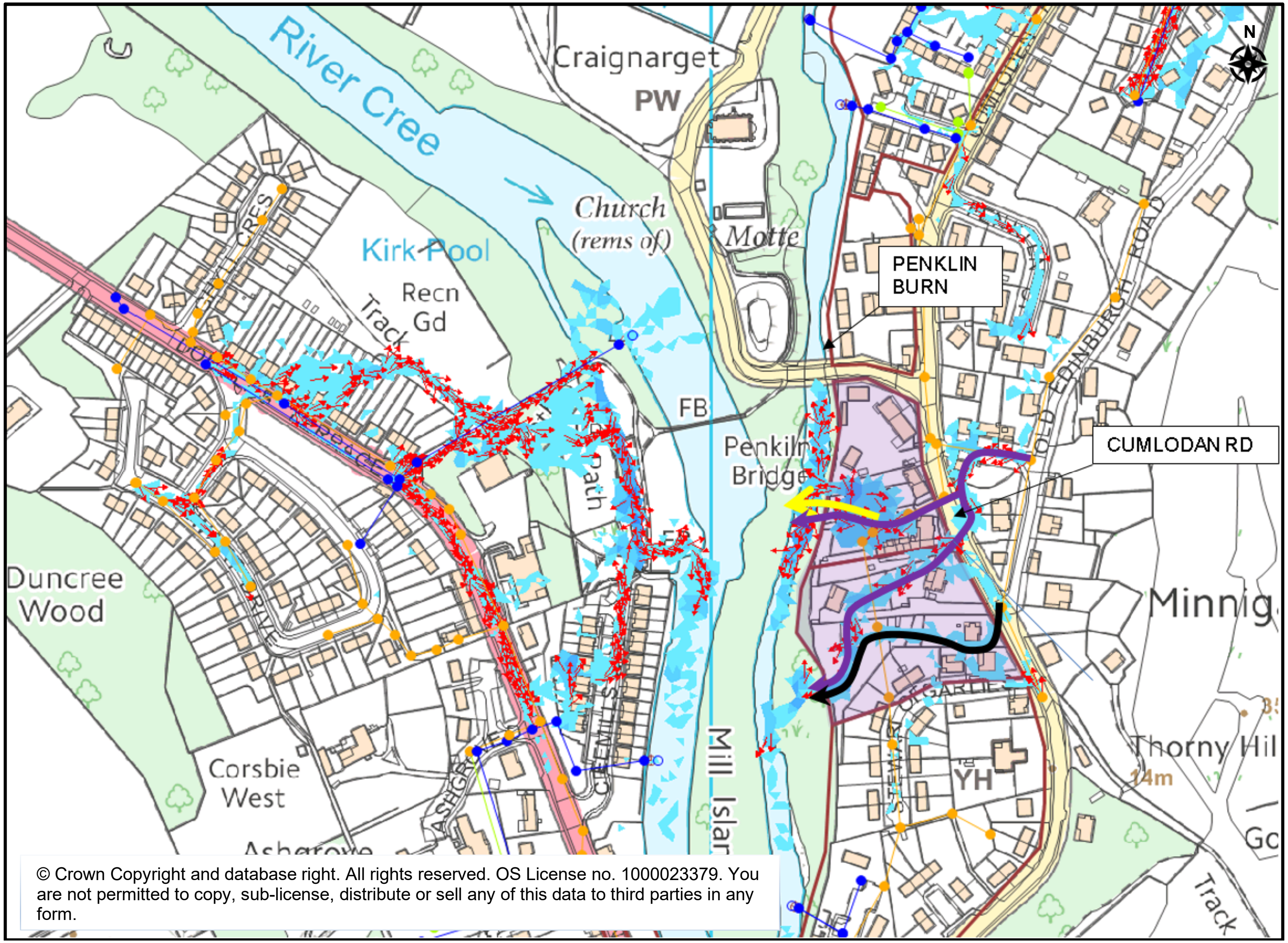
Node ID	M200-15 Flood Volume (m^3)	M200-30 Flood Volume (m^3)	M200-60 Flood Volume (m^3)	M200-90 Flood Volume (m^3)	M200-120 Flood Volume (m^3)	M200-180 Flood Volume (m^3)	M200-240 Flood Volume (m^3)	M200-360 Flood Volume (m^3)	M200-420 Flood Volume (m^3)	M200-540 Flood Volume (m^3)	M200-720 Flood Volume (m^3)	M200-900 Flood Volume (m^3)	M200-1440 Flood Volume (m^3)
Area 1	0	0	1	1	1	1	1	1	1	1	1	1	4
Area 2	0	0	0	0	0	0	0	0	0	0	0	0	0
Area 3	-41	-69	-103	-87	-69	-43	-33	-23	-31	-62	-123	-193	-206
Area 4	1	0	-2	12	68	20	27	25	20	22	19	12	11
Area 5	-49	-51	-47	-53	-54	-52	-51	-49	-47	-46	-43	-38	-28
Area 6	2	11	22	29	33	37	37	33	28	19	5	4	3
Area 7	2	4	5	5	5	5	4	4	3	2	1	0	0
Area 8	11	20	29	36	40	46	48	49	49	45	38	28	0
Area 9	12	14	9	8	6	3	0	-4	-5	-5	-7	-9	-15
Area 10	-1	-1	-1	-1	-1	-1	0	0	0	0	0	0	0
Area 11	3	4	1	-1	-2	-1	-1	-1	-1	-1	0	0	0
Area 12	-1	38	37	24	13	3	-5	-9	-9	-8	-7	46	92
Area 13	1	1	0	0	0	0	0	0	0	0	0	0	0
Area 14	11	10	3	0	0	0	0	0	0	0	0	0	0
Area 15	-34	-44	-21	-5	-1	38	45	14	25	39	49	21	-42
Area 16	-104	-134	-156	-163	-159	-157	-151	-140	-136	-128	-116	-109	-92
Area 17	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	-187	-197	-223	-195	-120	-100	-80	-101	-103	-123	-185	-237	-274

5 Recommendations

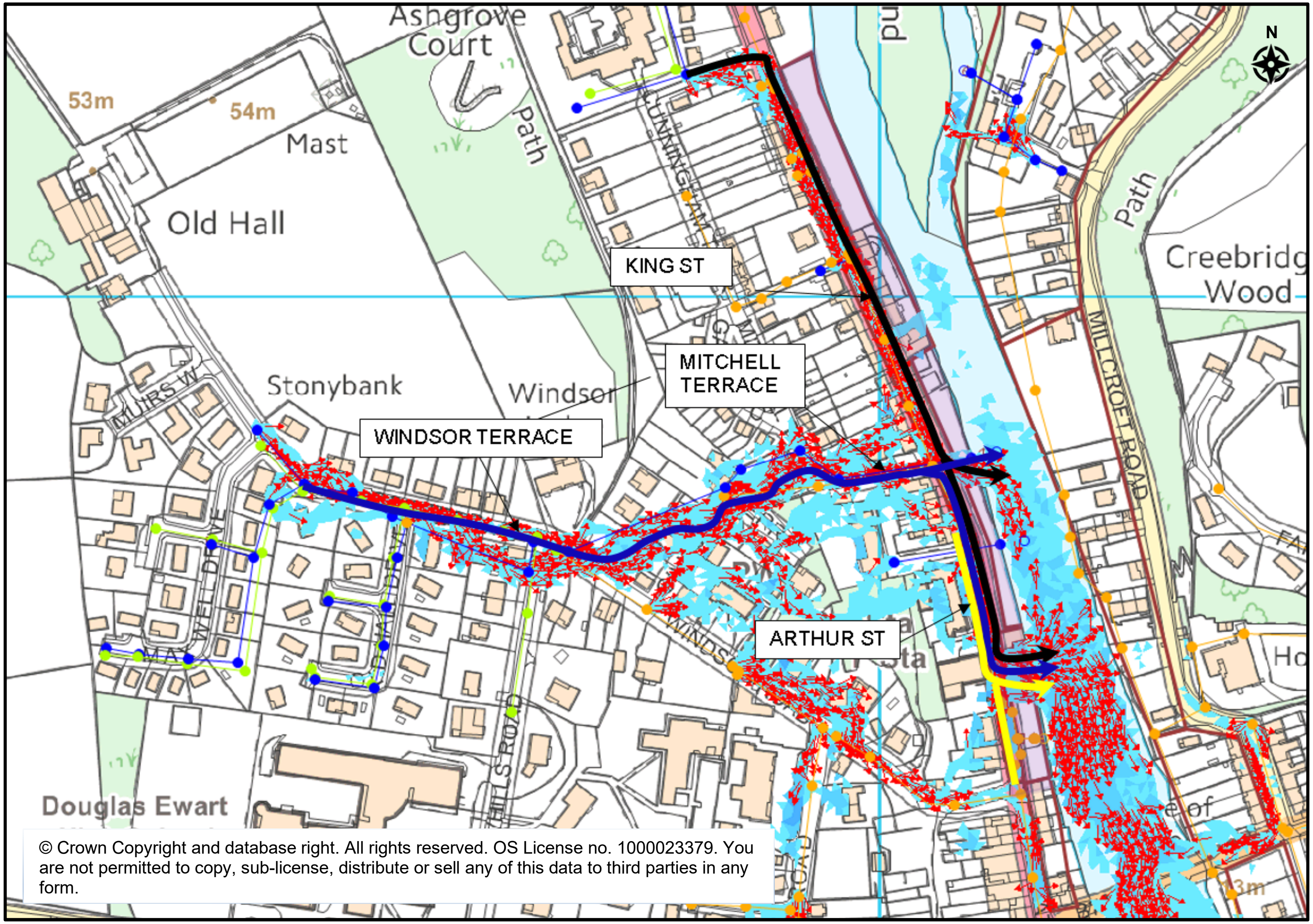
The recommended solutions for secondary flooding are as follows:

- combined outfall and flap valve system at the new defence walls/ embankment between the Penklin Burn and Cumloden Road;
- combined kerb, drainage and outfall system at King Street;
- combined kerb, drainage and outfall system at Michelle Terrance and King Street;
- combined kerb, drainage and outfall system at Arthur Street;
- surface water pumping station at Mortons Entry and Riverside Street; and
- combined drainage system, underground surface water storage tank and pumping station at car park area at Riverside Road.

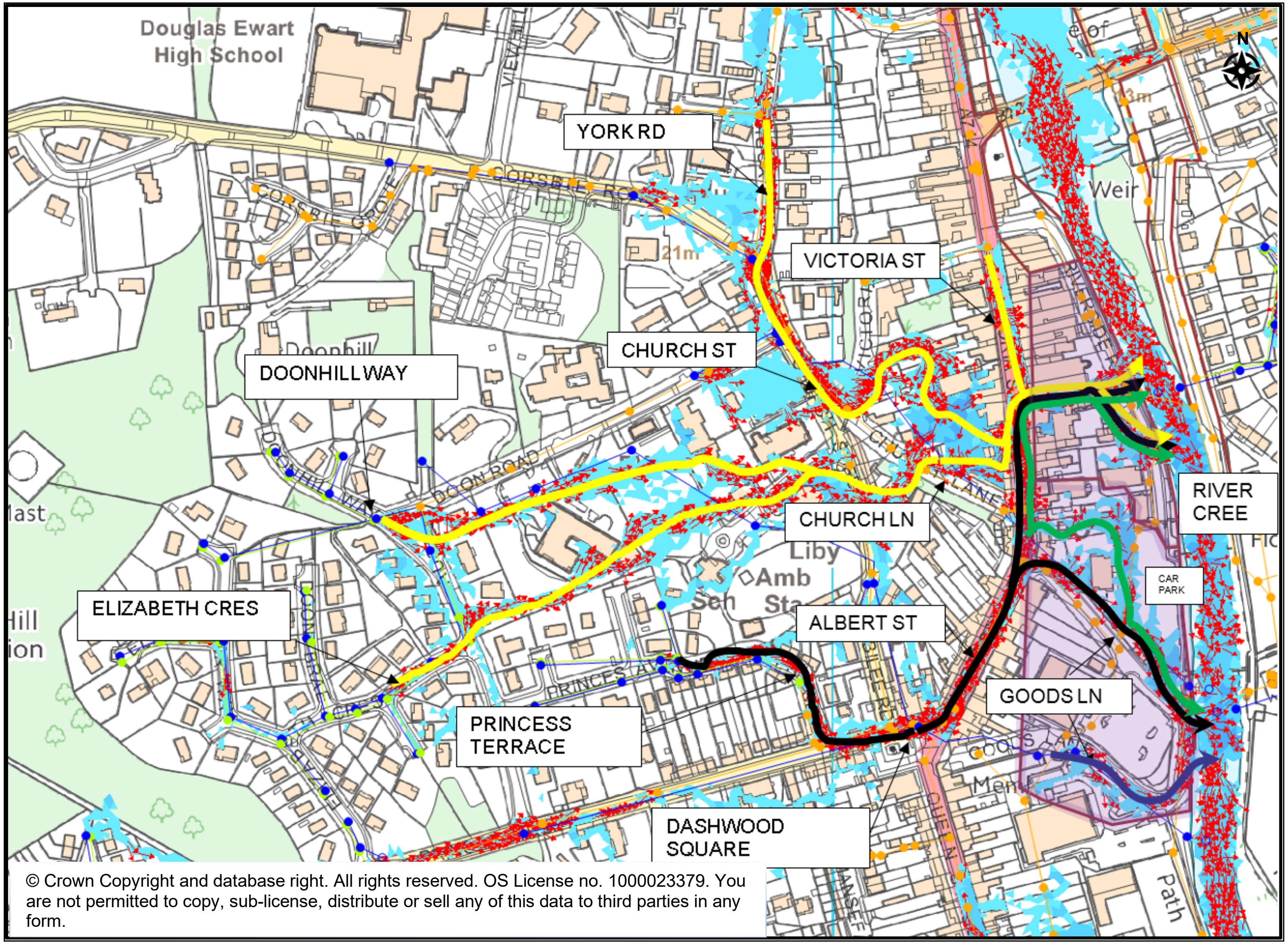
Appendix A Existing Floodpaths in Areas 3 and 4



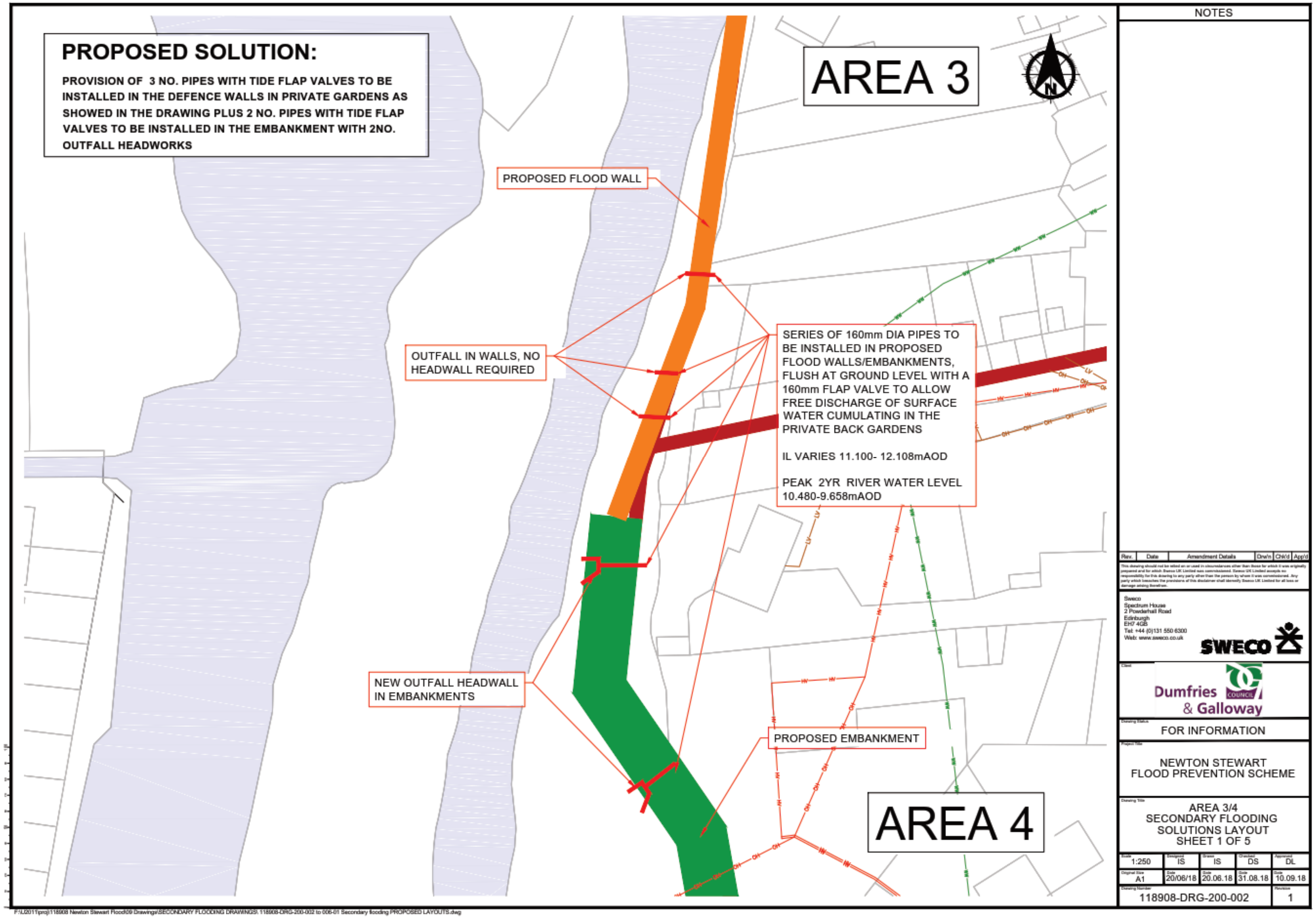
Appendix B Existing Floodpaths in Areas 10, 11 and 12



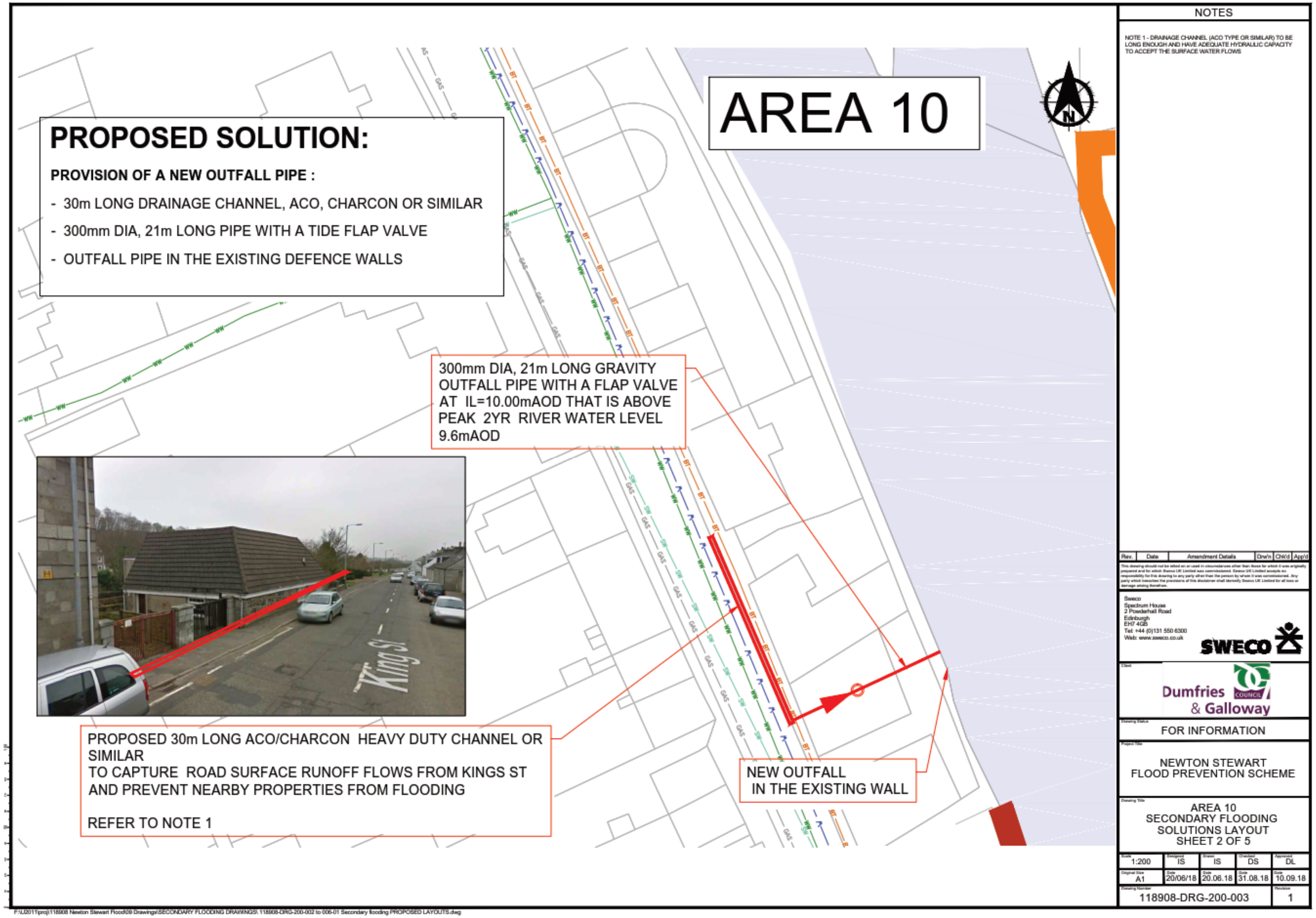
Appendix C Existing Floodpaths in Areas 15 and 16



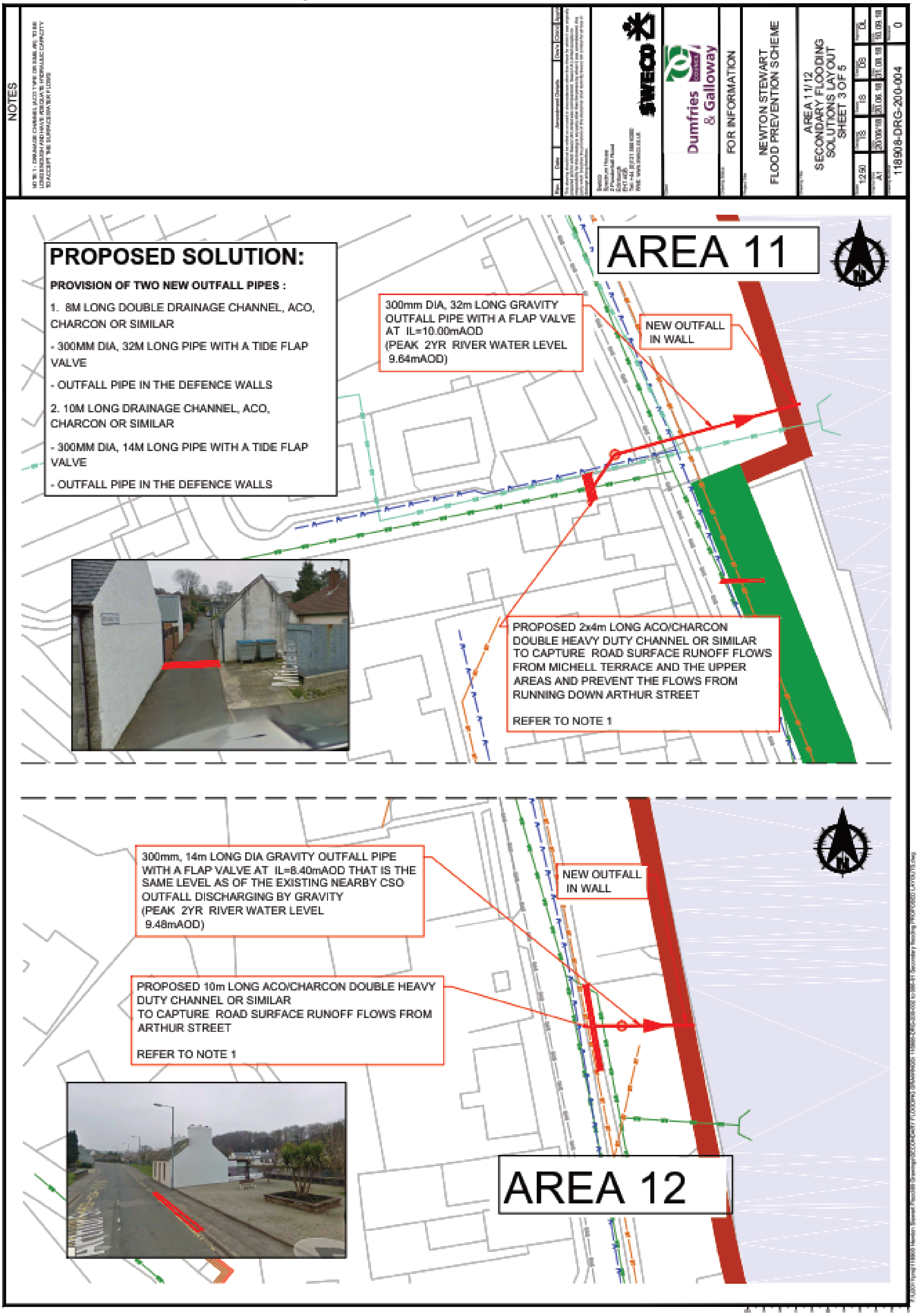
Appendix D Solutions layout for Area 3/4



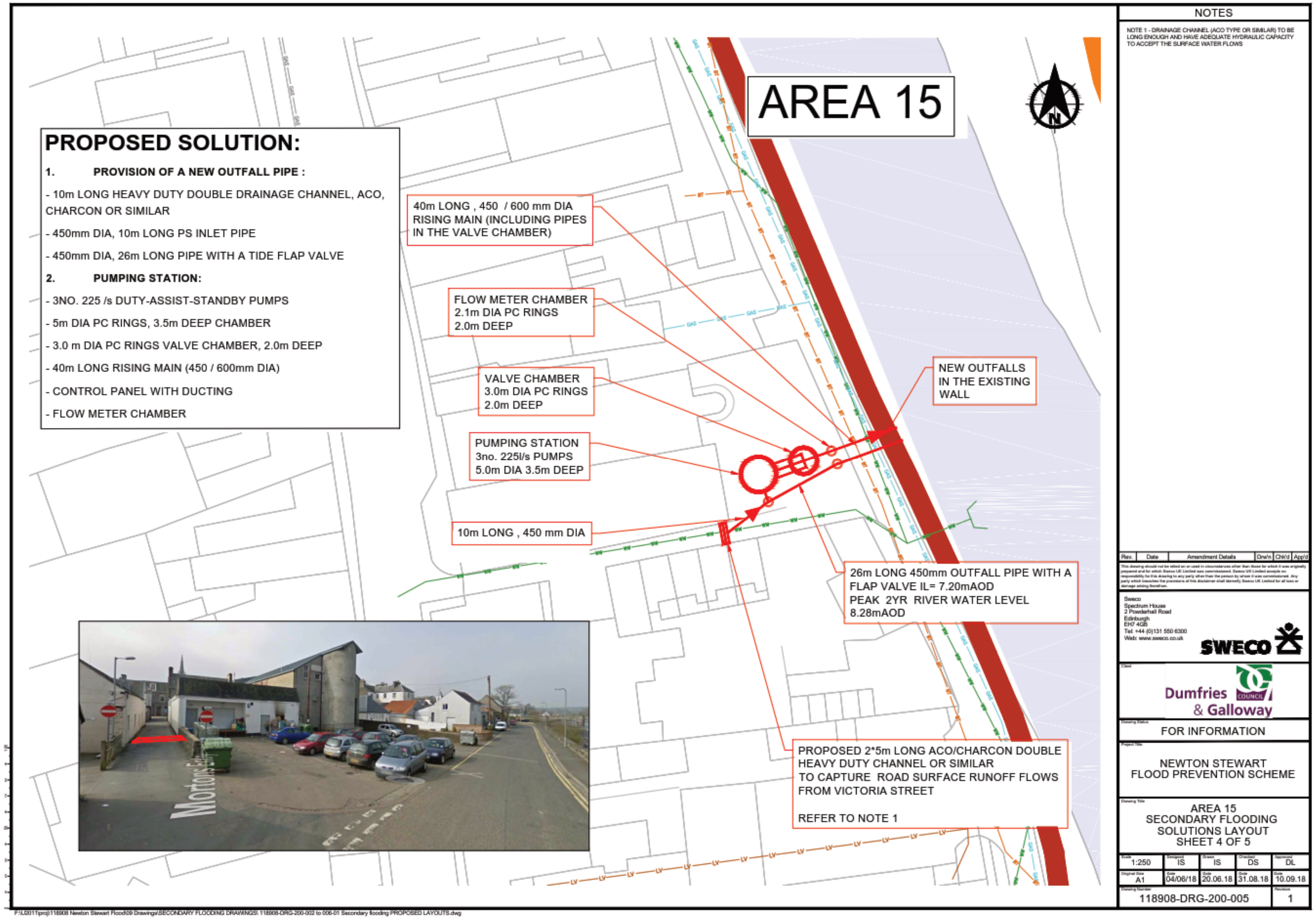
Appendix E Solutions layout for Area 10



Appendix F Solutions layout for Area 11/12



Appendix G Solutions layout for Area 15



Appendix H Solutions layout for Area 16