TECHNICAL NOTE

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AG	*JK*	*HB*	*HB*

1. Introduction

RSK / Binnies were commissioned by Aberdeenshire Council to carry out a flood study in Kemnay. This technical note forms part of the initial work to gather data and review the available hydraulic models in line with current SEPA guidance and industry best practise. The purpose of this document is to summarise the findings from the review of the model previously developed representing this area and to describe its main features.

At Kemnay, an existing model of the sewer network was available and was held by Scottish Water.

2. Existing Scottish Water Model

The Kemnay Drainage Operational Area (DOA000428) Infoworks ICM model was provided by Scottish Water for use in the Kemnay Flood Protection Study (FPS). This model was built in 2018 and was provided in ICM v.2025 format. *Figure 1* shows an overview of the network extents in Kemnay.

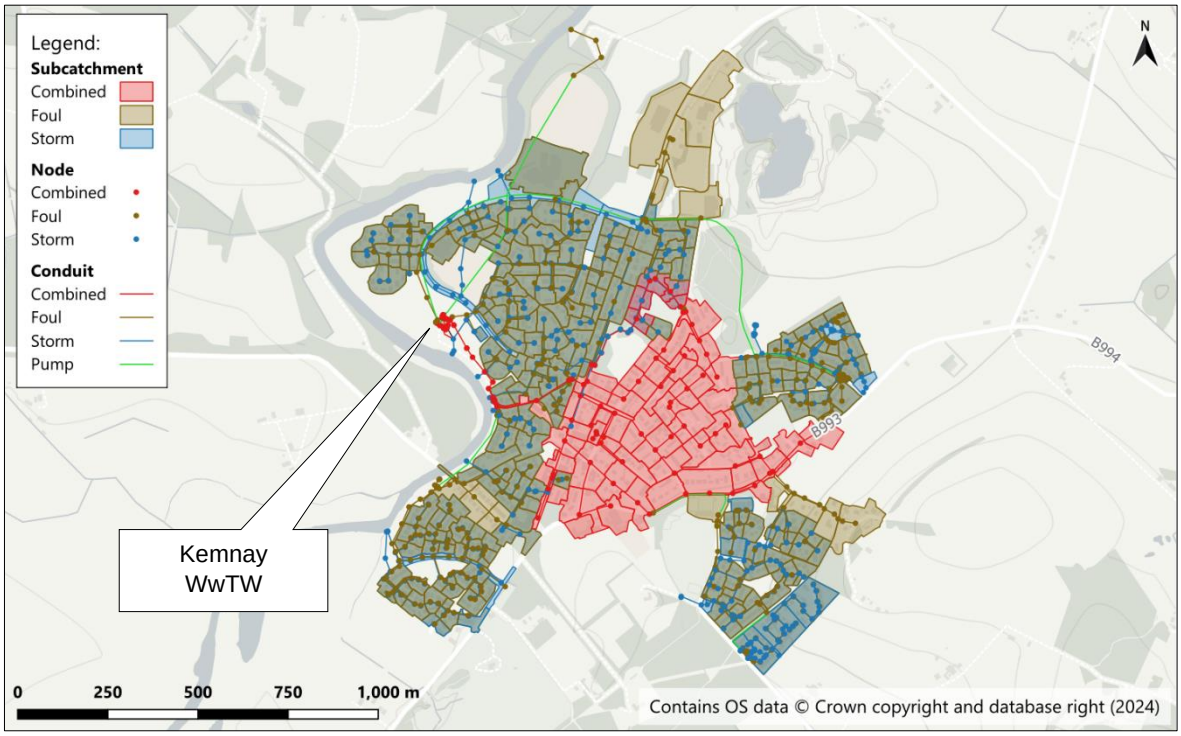

Figure 1 – DOA000427 Kemnay WwTW model network (InfoWorks ICM)

3. Review of Existing Sewer Network Model

The model provided by Scottish Water is a pure 1D network model that was built as part of the River Don Water Quality Study. The primary purpose of this was to develop a hydraulic model fulfilling Scottish Water specifications in order to ensure that the model was able to determine:

- Urban wastewater treatment continuous discharge.
- Intermittent discharges (CSOs).

This is not necessarily analogous to the current Kemnay FPS aims, and the model will therefore need to be integrated with the River Don geometry to enable a fully integrated catchment model suitable for the assessment of flood protection options.

3.1 Provenance of Model Input Data

An assessment of the provenance of model input data was carried out using the model build and verification (MBV) report provided by Scottish Water and commentary/flagging within the model itself. The flagging descriptions provided by Scottish Water were compared with the guidance set out in Section A4.3 of CIWEM's Integrated Urban Drainage Modelling Guide (v2.01, May 2021) to categorise these as 'Red', 'Amber' or 'Green' (RAG) for scoring. The CIWEM guidance specifies the following with regards to method of data collection:

- **Category A:** This is the best possible method with extensive use of surveys or good quality records.
- **Category B:** This method is based on a reasonable amount of good quality record data with a limited amount of assumed or estimated data based on interpolation or inferencing.
- **Category C:** This method makes use of extensive existing data with significant amounts of assumed or estimated data.
- **Category D:** This method uses limited amounts of existing data with extensive use of assumed or estimated data.

The CIWEM guidance specifies that these can be followed by a number (1 to 3) to signify the quality of the data, whereby a 1 would infer that quality control testing was in place, whilst a 3 would infer than there was little or no checking.

The CIWEM guidance specifies the following (RAG) table for data scoring, shown on Table 1.

Table 1 – CIWEM UDG RAG Table

Quality / Collection Categories	A	B	C	D
1	A1	B1	C1	D1
2	A2	B2	C2	D2
3	A3	B3	C3	D3

All Scottish Water models utilise a consistent flag system to identify the data sources used for all parameters defining the network. Based on this flag system, the origin of the data, and the CIWEM guidance, the flags within Scottish Water model have been categorised into the RAG system as shown in Table 2. Note that only the flags used in the model are shown and this list does not comprise Scottish Water's complete list of data flags.

Table 2 – Scottish Water data flag comparison with CIWEM RAG categories

Flag	Description	Method of Collection Category	Data Quality Category	RAG Category
#D	ICM default	N/A	2	N/A
A1	Assumed/estimated – Best estimated (calcs & surveys)	C	2	Amber
A2	Assumed/estimated – Estimated (incomplete surveys and plans)	C	2	Amber
A3	Assumed/estimated – Estimation (engineering judgement)	D	3	Red
F1	Flow Survey Data – Measured from site surveys	A	1	Green
L1	DTM/LiDAR - 1m or Less resolution	A	1	Green
N3	SW GIS – Archived records and drawings	B	2	Amber
R1	Record Plans – As-built drawings	A	1	Green
S1	Survey data – Survey as per SW specification	A	1	Green

Table 3 – RAG categories for various data types in existing Scottish Water model

RAG Categories	Manhole Ground Level	Manhole Floor Level	Pipe US Invert Level	Pipe DS Invert Level	Pipe Diameter	Pump Switch On	Pump Switch Off	Pump Rate	Subcatchment Area	Subcatchment Node
Green	24%	4%	12%	12%	20%	43%	43%	29%	0%	0%
Amber	67%	0%	82%	86%	77%	0%	0%	0%	0%	0%
Red	9%	1%	7%	2%	3%	57%	57%	71%	0%	100%
N/A	0%	95%	0%	0%	0%	0%	0%	0%	100%	0%

The following key features were assessed within the existing Scottish Water model as part of this model review, with the proportion of each of these features falling into the above noted RAG categories shown on Tabel 3:

- Manhole ground level – Mostly green or amber, overall acceptable quality.
- Manhole floor level – Mostly N/A; this is due to the selection of #D flag for this parameter. By selecting this flag InfoWorks assigns the manhole floor level to the lowest invert level of the connected conduits into that manhole. Pipe invert levels are mostly amber, and therefore, overall acceptable quality for manhole floor levels for feasibility stage.
- Pipe upstream invert level - Mostly amber, acceptable quality for feasibility stage.
- Pipe downstream invert level – Mostly amber, acceptable quality for feasibility stage.
- Pipe diameter - Mostly amber, acceptable quality for feasibility stage.
- Pump switch on/off levels – Half of the flags are green, and the remaining half are red. The green values correspond to the largest pumps and all pumping stations are foul only. Therefore, their impact on surface water and fluvial flooding estimation is deemed low and thus no update is required here, although it is recommended that it should be updated in the event that improved data becomes available.
- Pump rate – Most of the flags are red, and the remaining are green. Most of the pumps are foul only. Therefore, their impact on surface water and fluvial flooding estimation is deemed low and thus no update is required here, although it is recommended that it should be updated in the event that improved data become available.
- Subcatchment area – Set to the default drawn area on the map. When default flag is selected for subcatchment area, InfoWorks ICM calculates the area value based on the drawn georeferenced polygon representing the subcatchment. An improved representation of the generated runoff and overland flow paths could be achieved by removing subcatchments and applying direct rainfall on a 2D mesh (i.e., 2Di approach).
- Subcatchment allocated network node – Mostly red, based predominantly on engineering judgement. Similar to the subcatchment area, results could be improved by removing subcatchments, adding gullies into the model and applying direct rainfall on a 2D mesh (i.e., 2Di approach).

The Model Build and Verification Report (MBV) states that the Kemnay model was given an overall confidence of 64%. Flow volumes were overall comparable to observed during the short-term flow survey carried out for the MBV and the model flooding prediction for storms up to the 1 in 30 years return period (3.33% AEP) were considered generally reasonable.

The model has some further limitations on review:

- Several discharges for commercial and industrial areas in the model have been assumed. Some existing data may be available from SEPA or Aberdeenshire Council.
- At the time of preparation of the Kemnay MBV, no information regarding the SuDS located in the catchment was available and therefore most of the defining parameters have been

assumed. Detailed surveys or as-built drawings of these SuDS could reduce these model uncertainties.

- There are no historical records of combined sewer overflow (CSO) spill volumes, reducing confidence in model CSO performance. No event duration monitoring (EDM) data are available at the site, and this deficiency cannot be updated.

3.2 Model Schematisation

Kemnay's urban drainage network spans an area of 99.4 hectares (approximately 1km^2). This network comprises both combined and separated sewer systems. According to the model, the combined sewer network serves 27.4 hectares, which accounts for 28% of the total urban area. The remaining 72 hectares, or 72% of the area, is covered by a separated (i.e., foul and surface water) sewer network. As is typical across Scotland, the older parts of the town are served by the combined sewer network.

Within this model, there are two CSOs, five pumping stations, and one treatment works. Kemnay's treatment infrastructure includes both preliminary and secondary wastewater treatment works (WwTW).

The model schematisation was found to be acceptable for the purposes for which the model was built (estimation of continuous and intermittent discharges for posterior water quality study). The model makes use of subcatchments to estimate foul and surface water inflows to the 1D network. For runoff surfaces both 'Fixed' (roads, roofs, attenuated and slow runoff surface) and 'New UK' (permeable surfaces) runoff models were used in compliance with Scottish Water's Model Build & Verification specification. No greenfield or ReFH land uses are included in the model. A number of combinations of different runoff surfaces to define the roads, roofs and permeable areas conforming each one of the land uses indicated in Scottish Water's specification are include in the model. Within each of the surface and combine subcatchments an estimation of road, roof and pervious area extension is provided based on the available mastermap. These values determine the outflow hydrograph from each subcatchment.

Figure 2 shows a schematic representation of the model to show how generated flows are drained across Kemnay. Figure 3 shows the extents of the subcatchments across the town. The total area of subcatchments were found to always equal the contributing area – hence, no account was made for 'additional' inflows from areas outside the defined Subcatchments (i.e., overland flows from farmland, for example). While this was acceptable for the model build drivers, this situation is not considered suitable for an adequate representation to determine potential issues related with surface water. Therefore, some modifications are required to account for surface water flows from locations outside of the subcatchments areas represented in the provided model.

1. Apply storm, greenfield and ReFH subcatchments to remaining areas where they do not currently exist in the model and assign the appropriate parameters.

2. Represent the currently missing surface water networks and ditches not currently represented in the model.

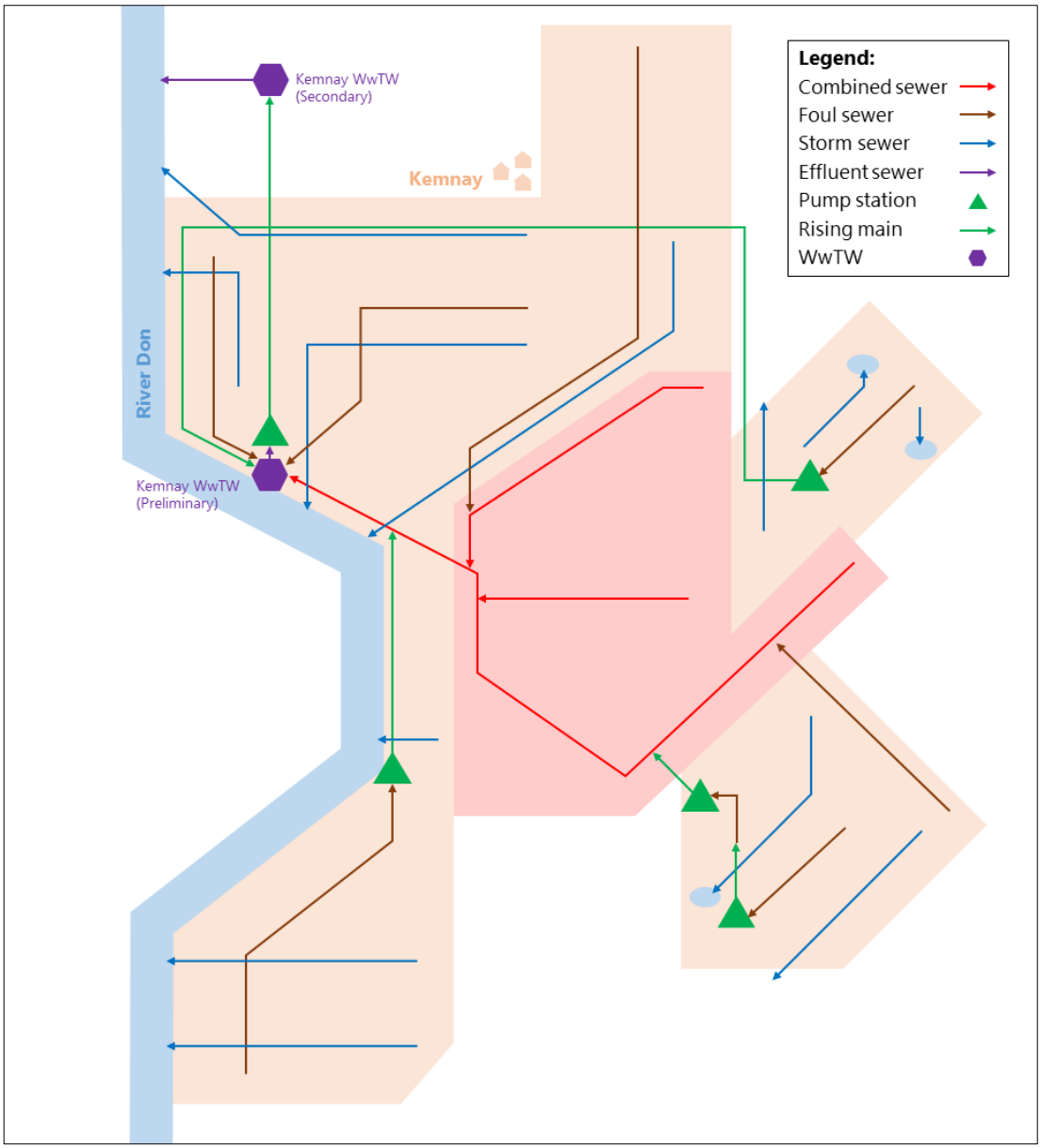

Figure 2 – DOA000427 Kemnay WwTW model network schematic representation

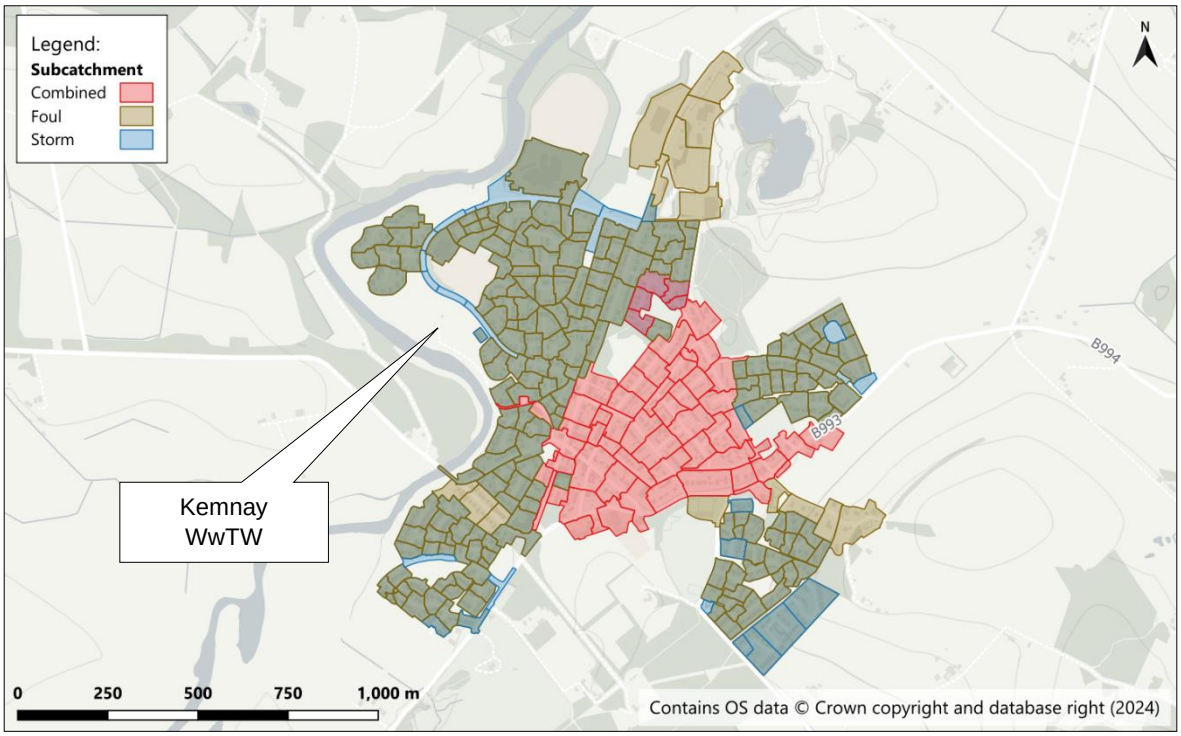

Figure 3 – Subcatchments within Scottish Water model

3.3 1D Network & Watercourses

As shown in Figure 4, the sewer network covers most of Kemnay, but there are some areas where storm water networks are not included in the model:

1. Industrial estate at Aquithie Road, north of Kemnay;
2. Residential area at Riverside Road;
3. Kemnay Bowling Club at Victoria Terrace; and
4. Some properties along Parkhill.

It is understood that information about these missing networks was not available during the model build process at the time of the original model build. Areas 1 and 2 are likely served by surface water networks draining into the River Don, while areas 3 and 4 likely drain into the ditch along Victoria Terrace. The exclusion of these networks did not affect the original purpose of the model, and their absence was deemed acceptable for the intended use of the model. These should be added to the model for the Kemnay Flood Protection Study.

A check on the applied roughness within the network was carried out. The Colebrook-White roughness coefficient was used to represent pipe roughness, with values ranging from 0.15 to 9mm. Higher values were associated with sediment depth in those pipes. Most pipes, however, were assigned roughness values of either 1.5mm for combined and foul networks or 0.6mm for surface water networks. These values complied with BS EN16933-2 standards and were found to be satisfactory.

No open watercourses are present in the provided model, and there are no interactions between watercourses and the sewer network in the model.

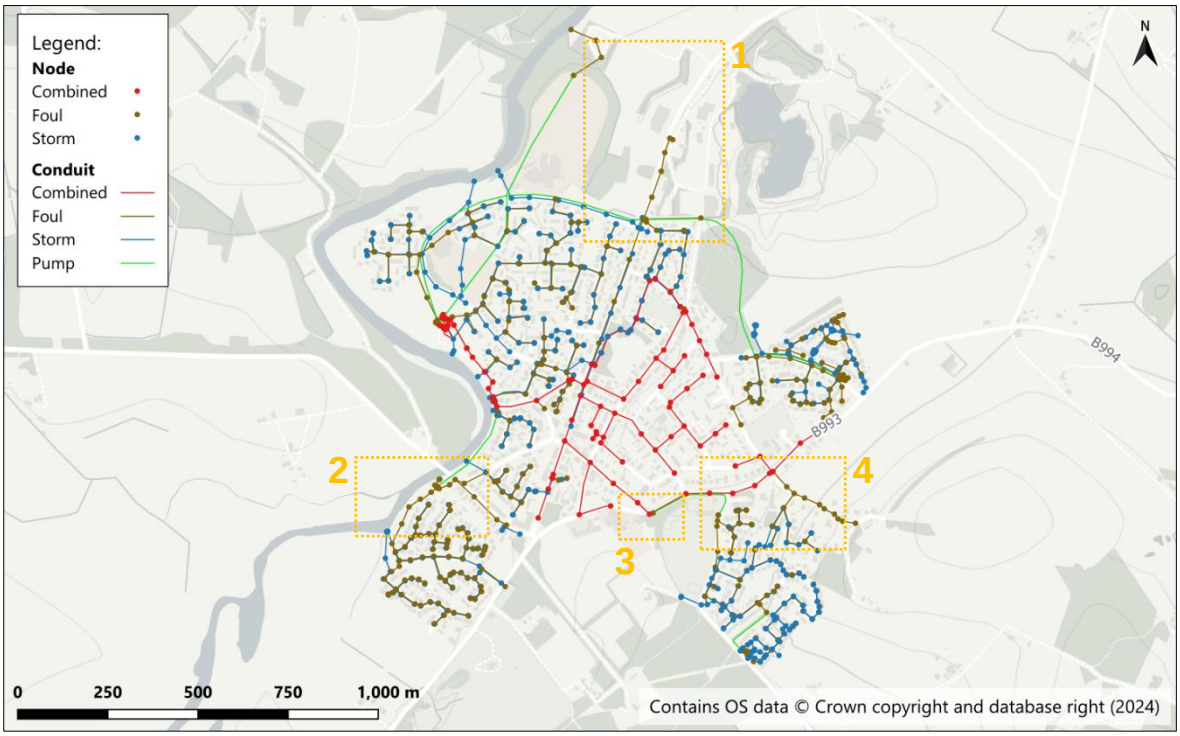

Figure 4 – Scottish Water network model extents

3.4 2D Domain Representation

The received DOA000428 Kemnay SW hydraulic model is purely 1D does not include any 2D areas. A 2D domain will be required for the Kemnay FPS.

3.5 1D/2D Linkage

There is no 2D area in the provided model. Therefore, no 1D/2D linkage is present.

3.6 Boundary Conditions

A total of 19 outfalls exists within the model. Two of these are CSOs, one is a pumping station emergency overflow, one represents the WwTW effluent discharge into the River Don and the remaining 15 are surface water outfalls. Eleven of these outfalls discharge into the River Don, the remaining eight discharge to different ditches in the Stuart Crescent area, Greystone Road area and Milton Meadows area. All of these were modelled as free discharge, although two level files are included in the model database representing constant watercourse water levels.

3.7 Numerical Convergency

Model simulations included in the database provided by Scottish Water were run at 60 seconds timestep, with the results timestep multiplier of 5 (i.e., detail results were output at 5-minute intervals). No initial conditions are provided in the runs. Wastewater and trade waste data were

included in the runs, as well as mean level file representing watercourse levels at the outfalls. This level file will not be required once the network model is integrated with the River Don geometry for the Kemnay FPS model update.

Mass balance error (MBE) and volume balance error (VBE) were typically of the values of 0% and 0.13% respectively. These values are well within acceptable tolerances.

3.8 Calibration & Validation

The model was built and verified in line with Scottish Water's specifications. The verification process was conducted in two distinct stages. The first stage aimed to achieve a reasonable match between the predicted hydraulic performance of the model and the observed data collected during the short-term flow survey, which included dry weather flow (DWF) and rainfall events. The second stage involved historical verification, where available flooding records from the SW Flood Register and Aberdeenshire Council's recorded flooding incidents were used to compare against the predicted flooding.

Despite some limitations, such as poor observed data at several flow monitor sites during dry weather flow (DWF) conditions due to low flows, the verification process was deemed acceptable and fit for purpose. A reasonable response was observed during storm conditions, which provided more reliable data. Historical verification followed the storm verification, involving the simulation of a range of design rainfall events through the model to compare with known historical flooding locations. This process demonstrated that the model reasonably replicated the overall low incidence of sewer flooding across the catchment. Note that this is distinct from fluvial and surface water flooding, which was not the focus of the original Kemnay sewer network model build.

4. Summary of Outcomes

The following are required updates to enable the hydraulic model to be updated such that it is suitable for use in the Kemnay Flood Study:

- The River Don will need to be integrated within the Infoworks ICM model to provide an integrated catchment model covering Kemnay.
- Drainage ditches and missing areas of sewer network should be added.
- A 2D domain covering Kemnay should be added.

The following are suggested updates which may enhance the model outputs in the Kemnay Flood Study:

- Pump rates and switch-on levels should be updated in the 1D network if this information becomes available; this would allow more accurate prediction of the movement of flows through the foul/combined network at low return period events.
- Discharges from commercial / industrial areas should be applied if SEPA / Aberdeenshire Council hold this data.
- Storm Subcatchments should be removed and direct rainfall applied to the mesh for entry into the network via the nearest road gully.

Existing SuDS should be represented within the model, if the information to do so is available.