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 Kintore. This technical note forms part of the initial work to gather data and review the available hydrology 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 models previously developed representing this area and to describe their main aspect

At Kintore, an existing model of the sewer network was available and was held by Scottish Water; and an existing model of the River Don was available and was held by Aberdeenshire Council. The River Don model was originally commissioned to JBA in October 2017 and completed in December 2019.

2. Existing Scottish Water Model

The Inverurie Drainage Operational Area (DOA000426) Infoworks ICM model was requested from Scottish Water, which covers Kintore. This model was updated in 2023 and was provided in ICM v.2025 format. Figure 1 shows an overview of the network extents in Kintore.

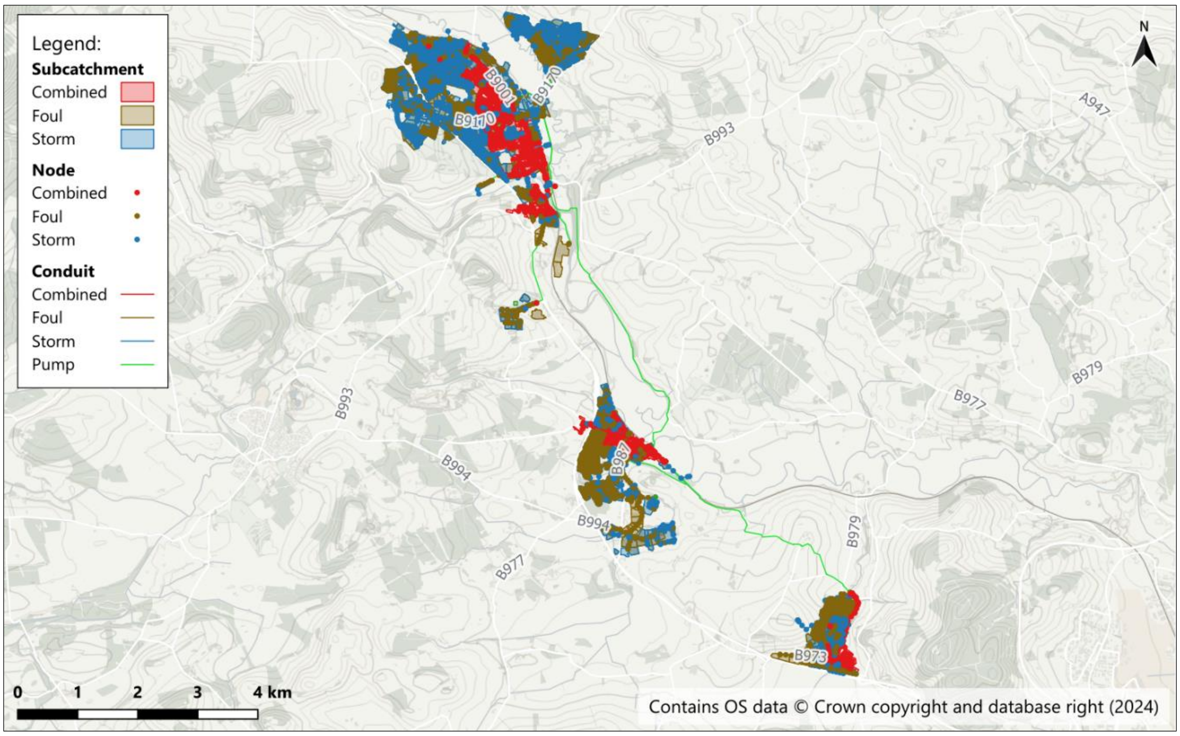

Figure 1 – DOA000426 Inverurie WwTW model network (InfoWorks ICM)

3. Review of Existing Sewer Network Model

The baseline model for the Inverurie sewer catchment was built in 2011. In 2017, Atkins & RPS Consultancy (ARC) was commissioned by Scottish Water (SW) to undertake a Model Build and Verification (MBV) Study for the Inverurie Drainage Operational Area (DOA) as part of the River Don Water Quality Study. It was last updated and verified by M^2 consultancy in 2021. The Scottish Water Hydraulic Modelling Team were commissioned to carry out the model maintenance on the Inverurie catchment in 2023.

The latest model update was carried out in InfoWorks ICM version 2024.2. The model is a pure 1D network model.

The primary purpose of the study was to develop a hydraulic model fulfilling Scottish Water specifications to improve model confidence at reported and unreported flooding locations.

3.1 Provenance of Model Input Data

An assessment of the provenance of model input data was carried out using the Model Maintenance (MM) report provided by Scottish Water and commentary/flagging within the model itself. This 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	System Default	0	0	N/A
A2	Assumed/Estimated - estimated (incomplete surveys and plans)	C	2	Amber
A3	Assumed/Estimated - estimation (engineering judgement)	D	3	Red
CC	CCTV Data - measured survey data	A	1	Green
F1	Flow Survey Data - measured from site surveys	A	1	Green
F3	Flow Survey Data - assumptions from observed data	A	3	Amber
L1	DTM/LiDAR - 1m or Less resolution	A	1	Green

N1	SW GIS - As Builts and Surveys	A	1	Green
N2	SW GIS - Cert Drawings and Surveys Outside SW Spec	A	2	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
S3	Survey Data - archived survey information	A	3	Amber

Table 3 – Scottish Water data flag comparison with CIWEM RAG categories

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	32%	6%	11%	11%	17%	80%	80%	30%	0%	0%
Amber	63%	0%	75%	80%	77%	10%	10%	10%	0%	10%
Red	5%	7%	14%	8%	5%	10%	10%	60%	10%	0%
N/A	0%	87%	0%	0%	0%	0%	0%	0%	90%	90%

The following key features were assessed within Kintore in the existing Scottish Water model – ignoring Inverurie and Blackburn as they are not relevant for the current flood study. The assessment provided a summary of the proportion of each of the key features falling into the above noted RAG categories shown on Table 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 – Mostly green; therefore, the quality is considered acceptable for feasibility stage.
- Pump rate – A slightly more than half of the flags are red, and the remaining are green and amber. Low overall quality for feasibility. Most of the 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 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 should be improved by removing subcatchments, adding gullies into the model, and applying direct rainfall on a 2D mesh (i.e., 2Di approach).

The MM Report (DOA000426 Inverurie) does not include an overall confidence assessment. The model main reservations and limitations relevant to the present flood study are the following:

- The primary limitation of the model is its tendency to overpredict flood volumes. Specifically, 15 of the predicted flooding clusters were not supported by historical flooding records. This should be reviewed once again with the flood history data curated for the Kintore FPS to understand if the model can be re-validated or if it requires further calibration.

- The model predictions were compared with 2022 flow data from the Kintore Sunnyside Sewerage Pumping Station (SPS) Capital Maintenance Project, showing reasonable fits. However, no WaPUG compliant rainfall events were identified, and the flow survey was brief, reducing confidence in the flow survey checks.

3.2 Model Schematisation

The model coverage includes the towns of Inverurie, Kintore, and Blackburn. The WwTW that serves this area is located south of Inverurie, specifically in Port Elphinstone, on the left bank of the River Urie. The model shows that the urban drainage is made up of a combination of combined and separate sewer systems, with a significant presence of separate sewer networks across the three towns that make up the DOA. The urban wastewater generated in both Kintore and Blackburn is transported to the WwTW in Inverurie via pumping.

Kintore has a modelled surface of 138 hectares, representing a 20% of the whole model surface. The division between different sewer network typologies is 18% combined and 82% surface water network, being in line with the rest of the model. As is typical across Scotland, the older parts of Kintore are served by the combined sewer network.

Within Kintore, there is one Combined Sewer Overflow (CSO) and six pumping stations.

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 SW'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 combined 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 understand how generated flows are drained across Inverurie DOA. Figure 3 shows the extents of the subcatchments across Kintore. 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. 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.

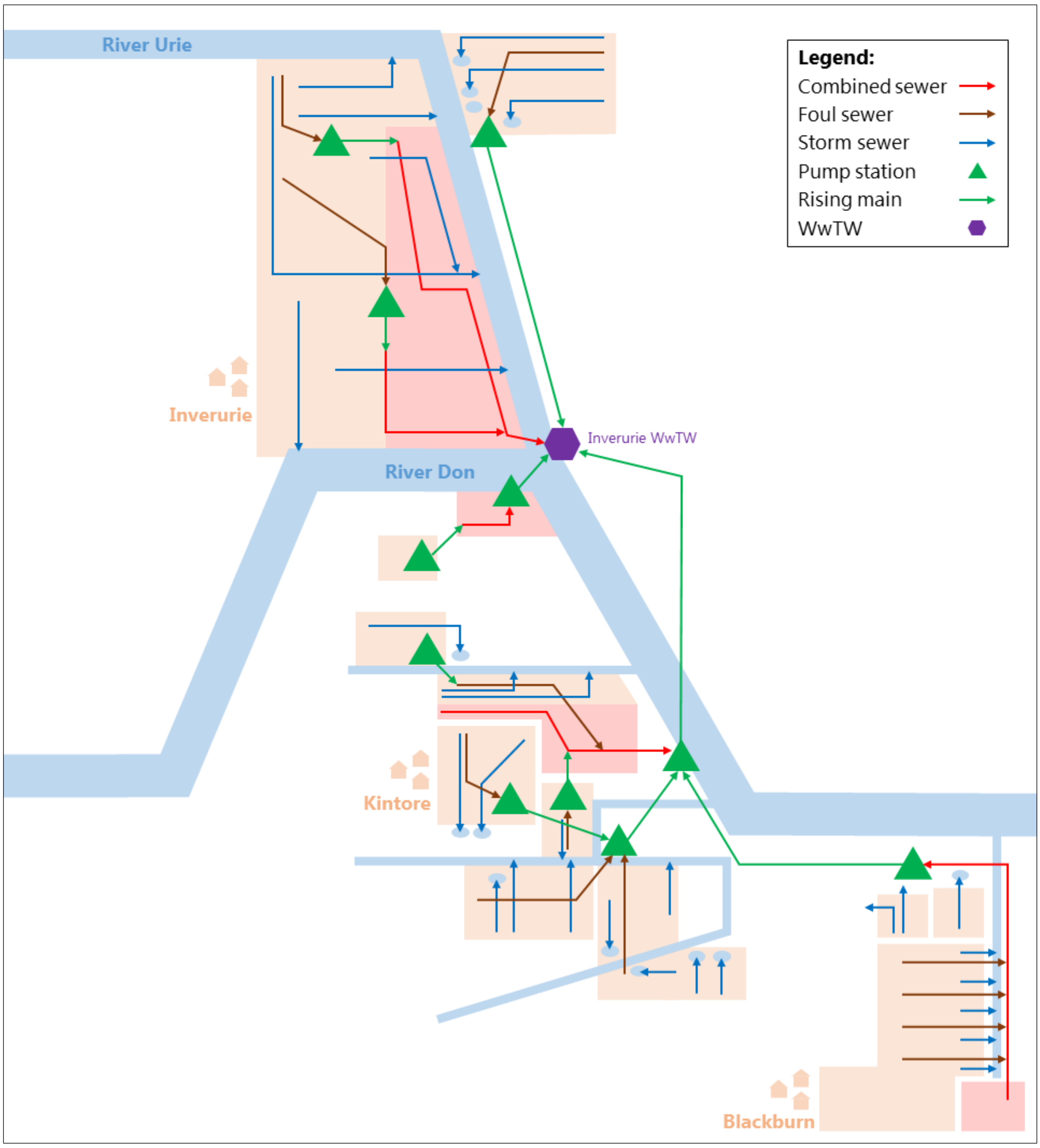

Figure 2 – DOA000426 Inverurie WwTW model network schematic representation

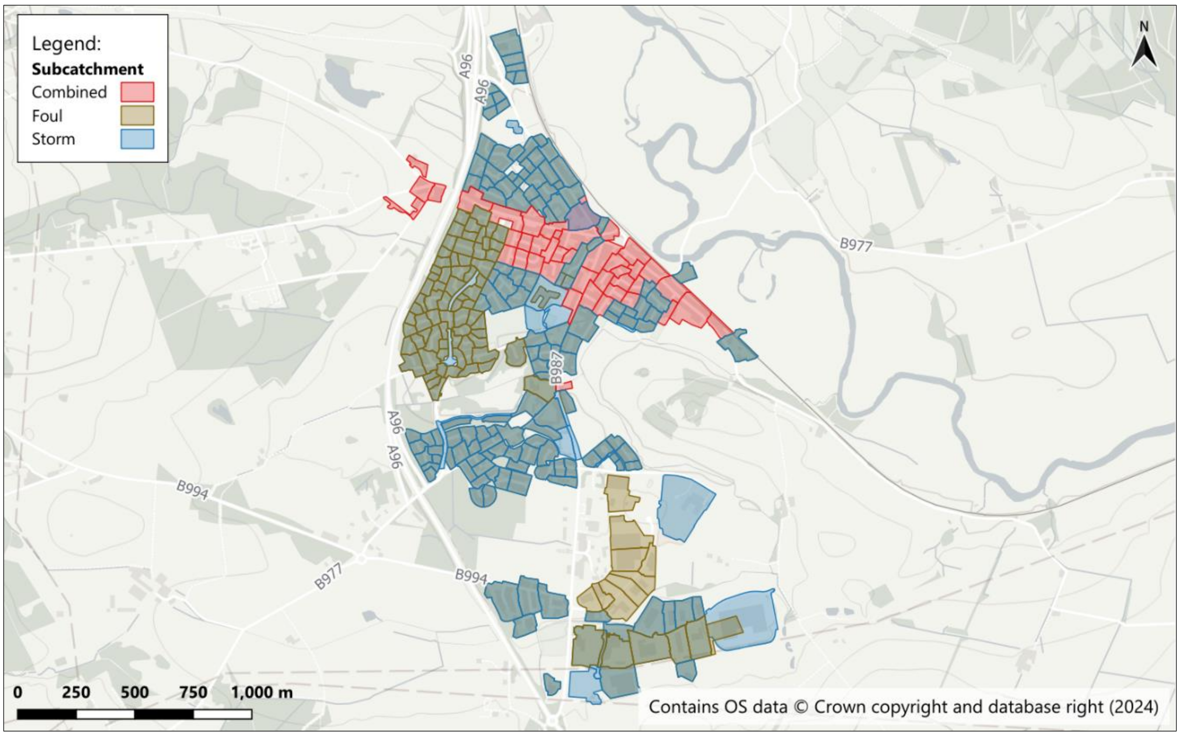

Figure 3 – Subcatchments within Scottish Water model (at Kintore)

3.3 1D Network & Watercourses

The 1D network primarily consists of a separate sewer system, with the older parts of the town being served by a combined sewer network. As shown in Figure 4, the network covers most of Kintore, but there are some areas where foul and storm water networks are not included in the model:

1. Missing foul and surface water along School Road (B987);
2. Surface water network Tumulus Way;
3. Foul network at Midmill Primary School;
4. Foul network at Tofthills Avenue; and
5. Missing surface water network section at Tofthills Avenue.

It is understood that information about these missing networks was not available during the model build process at the time of most recent model maintenance. Areas 1 and 2 are likely served by surface water networks draining into the drain crossing underneath these flowing from the west. Areas 3 and 4 are missing the foul subcatchments defining the generated wastewater flows; however, the foul sewer networks themselves are included in the model. In Area 5, a surface water network section ends abruptly at Tofthills Avenue with Newmill View. The exclusion of the foul subcatchments networks does not affect the purpose of the model for the flood study, although the lack of surface water networks reduces its accuracy. This information should be added if it is available.

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. The model should be updated to be integrated with the River Don, Loch Burn, Torry Burn and Tauch Burn for the Kintore FPS to provide a single integrated catchment model for use in option development.

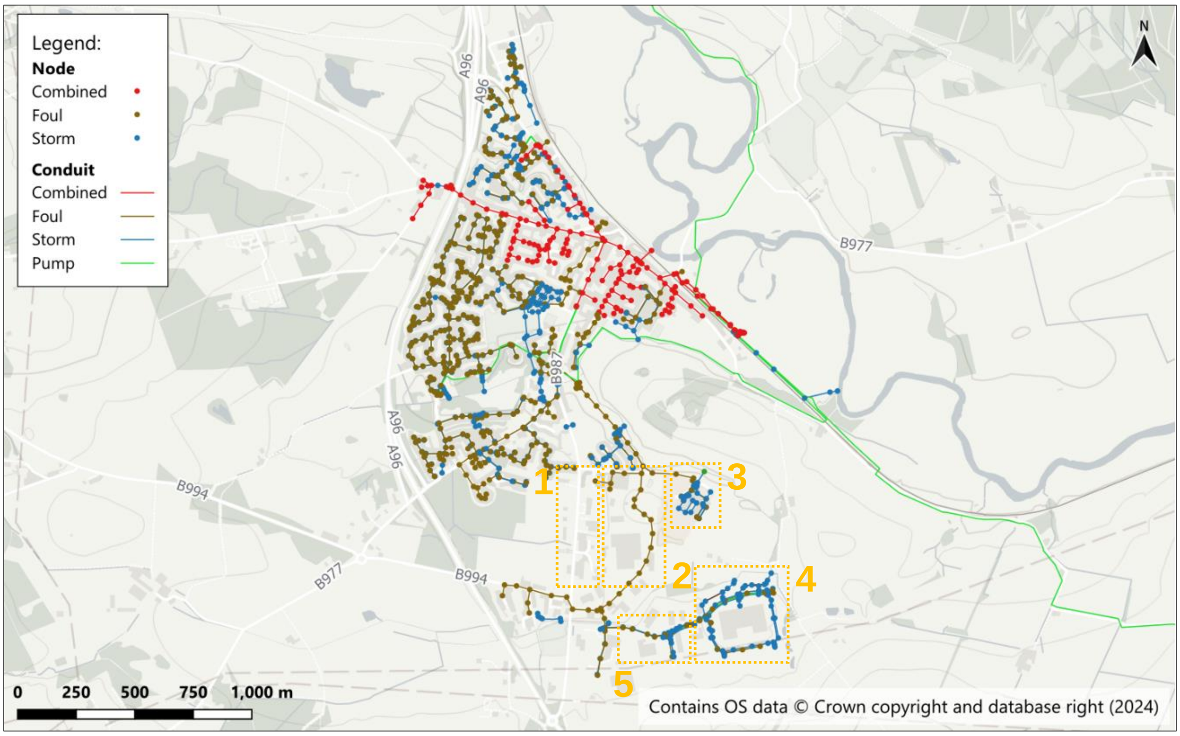

Figure 4 – Scottish Water network model extents (at Kintore)

3.4 2D Domain Representation

The received DOA000426 Inverurie SW hydraulic model is purely 1D does not include any 2D areas. A 2D domain will be required for the Kintore FPS.

3.5 1D/2D Linkage

There is no 2D areas in the provided model. Therefore, not 1D/2D linkage is present.

3.6 Boundary Conditions

A total of 27 outfalls exists within the Kintore. One of these is a CSO, two are pumping station emergency overflows, and the remaining 24 are surface water outfalls. Eight of these outfalls discharge into the Torry Burn, nine outfalls discharge into the Tuach Burn, seven outfalls discharge into the Loch Burn, one outfall discharges into a pond at Tofthills Avenue, one discharges at Tofthills Avenue with Newmill View, and one discharges into the River Don. All of these were modelled as free discharge.

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. Waste water and trade waste data are included in the runs, as well as mean level file representing watercourse levels at the outfalls.

Mass balance error (MBE) and volume balance error (VBE) were typically of the values of 0% and 0.1% respectively. These values are well within acceptable tolerances.

3.8 Calibration & Validation

Inverurie DOA 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 Scottish Water Flood Register were used to compare against the predicted flooding.

Overall, the final predicted vs recorded verification plots showed reasonable fits for the full period short-term flow survey data. This increased the confidence in the model predictions. Verification plots assess the flows within the 1D network, note that these are distinct from the validation of flood volumes on the surface which recall from Section 3.1 are considered a potential overestimate.

4. Review of Existing River Model

The hydraulic model covering the Rivers Don and Urie is a 1D/2D linked model, utilising Flood Modeller Pro (FMP) v4.3 for the 1D components and TUFLOW for the 2D components. The River Don and Urie were modelled in 1D up to top of bank. The out-of-bank region has been represented in 1D from North of the Shevock until North of Inverurie. The out of bank extent is then represented in 2D from North of Inverurie until South of Parkhill Gauging Station.

4.1 Provenance of Model Input Data

The following table summarises the provenance of the available data used in the existing Rivers Don and Urie fluvial model.

Table 4 – River Don & Urie fluvial model (JBA) input data

Item	Comments
Cross-section survey	Two surveys were carried out as shown in Figure 5. The upstream extent of the River Urie, the River Don upstream of Haughton gauging station and around Parkhill gauging station were provided by SEPA and carried out by Six West, dated December 2016. The sections in between were carried out by Malcolm Hughes Loys Surveys on behalf of JBA Consulting and dated 2018.
Other survey	-
LiDAR and other topographic data	LiDAR in 1m DTM format supplied by SEPA. Further LiDAR in 0.25m DTM format for Aberdeenshire also supplied by SEPA. 5m resolution NEXTmap as shown in Figure 6.
Map data	Obtained under OSMA license.
Gauging station flows and levels	Urie @ Pitcaple gauging station (ID: 11004) flow and level series. Don @ Haughton gauging station (ID: 11002) flow and level series. Don @ Parkhill gauging station (ID: 11001) flow and level series.
Rainfall data	Esslemont House recording rainfall, 15-minute data. Rothienorman recording rainfall, 15-minute data. Milton of Noth recording rainfall, 15-minute data. Westhill recording rainfall, 15-minute data.
Historical data	Observed flood event data. Photographs and post survey levels from January 2016 flood event.

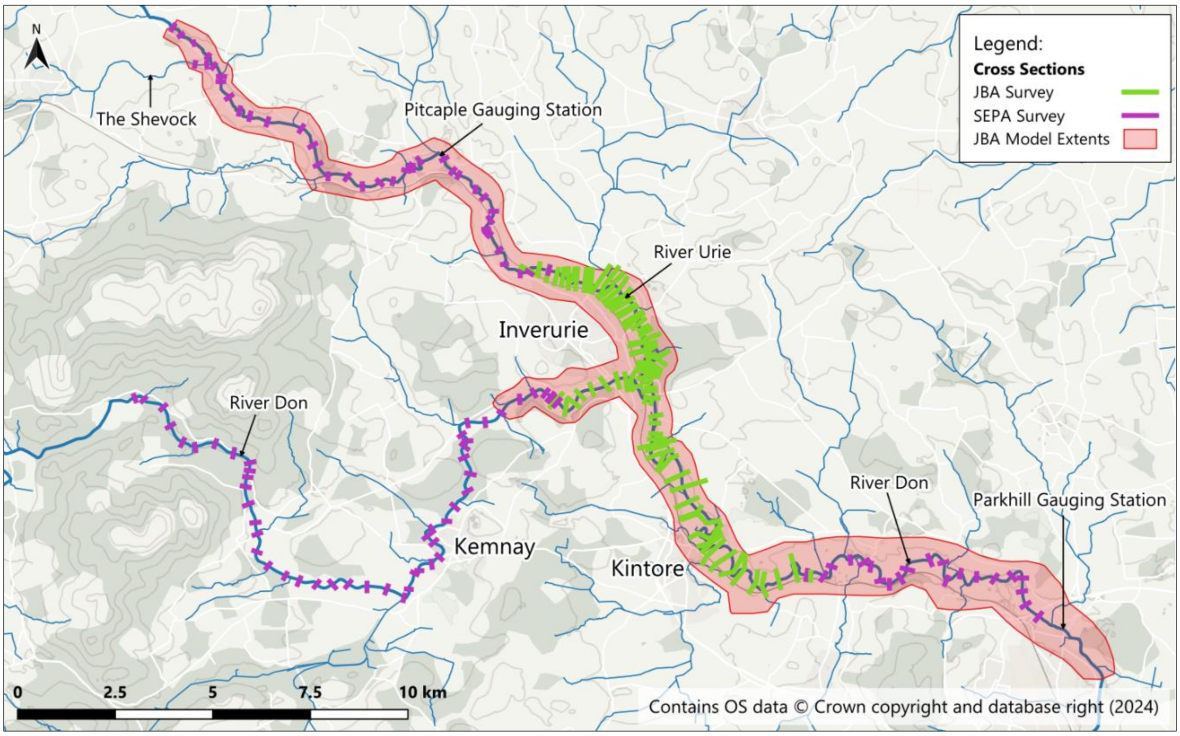

Figure 5 – Surveyed cross sections

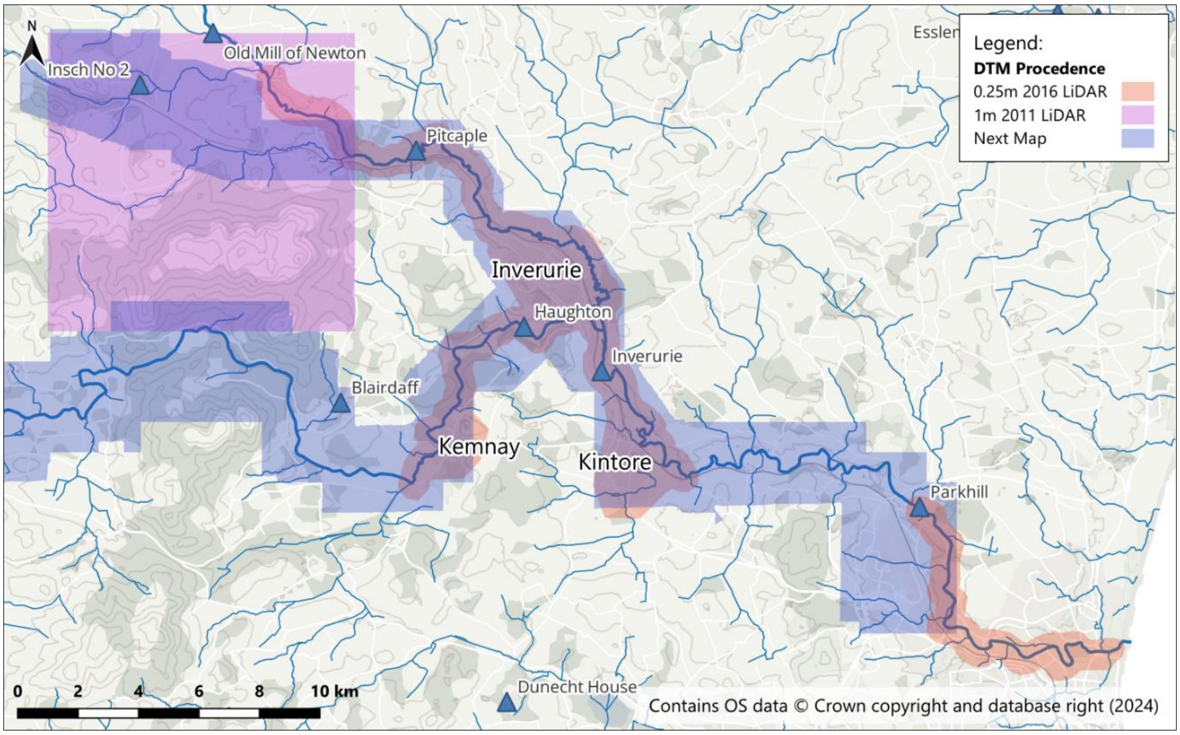

Figure 6 – DTM source

4.2 Model Schematisation

The main channel and structures are represented in the 1D domain, while the floodplain is represented in both the 1D and 2D domains (depending on location). 2D modelling of the floodplain allows for identification of flow paths, and mapping of flood extent, depths, velocities, and hazard.

Three domains are used in this model. A 1D extended cross section domain is used upstream of the study area from upstream of Old Rayne on the River Urie to the rail bridge at Inveramsay to allow for less detailed (but faster) modelling outside of the area of study. Furthermore, a second 1D extended cross section domain is used downstream of Kintore B997 road bridge to downstream of Parkhill gauging station at Dyce for the same purpose as above. A 2D domain is used for the rest of the modelled floodplain to allow for more detailed modelling of flow paths within the area of study. The representation is shown in Figure 7 below:

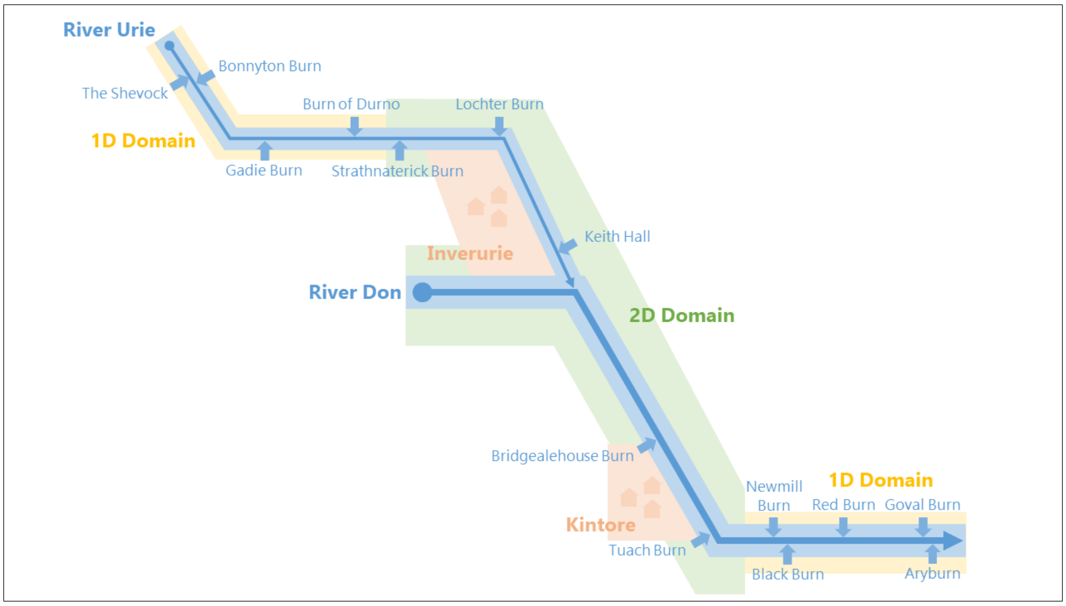

Figure 7 – Rivers Urie and Don fluvial model (JBA) schematisation

The model contains 16 ReFH2 hydrographs, two associated to the inflows upstream from Rivers Urie and Don, and the remaining 14 associated to the tributaries merging with these main rivers. The connection of these hydrographs is made via lateral inflow connections.

4.3 1D Cross-Section Representation

The model contains the following 1D network elements, with a schematic from Flood Modeller Pro (FMP) shown on Figure 8:

- 217 River Sections
- 82 Interpolated sections
- 27 Bridges
- 28 Spills
- 47 Junctions

The cross sections were incorporated into the model using survey data provided by JBA Consulting and SEPA (refer to Figure 5 for locations). After reviewing the cross sections within the fluvial model, it was noted that some sections were extended using Digital Terrain Model (DTM) data. This approach was used to represent the floodplain in the areas of the model outside urban areas that have detailed 2D domains. Additional interpolated cross sections were included using Flood Modeller Pro, thereby increasing the frequency of cross sections in the hydraulic model, enhancing simulation stability and improving model convergence. All spill points and most of the junctions are associated with bridge setups within the model. These setups accurately represent the bridge decks and allow for the simulation of water overtopping the structures during flood events.

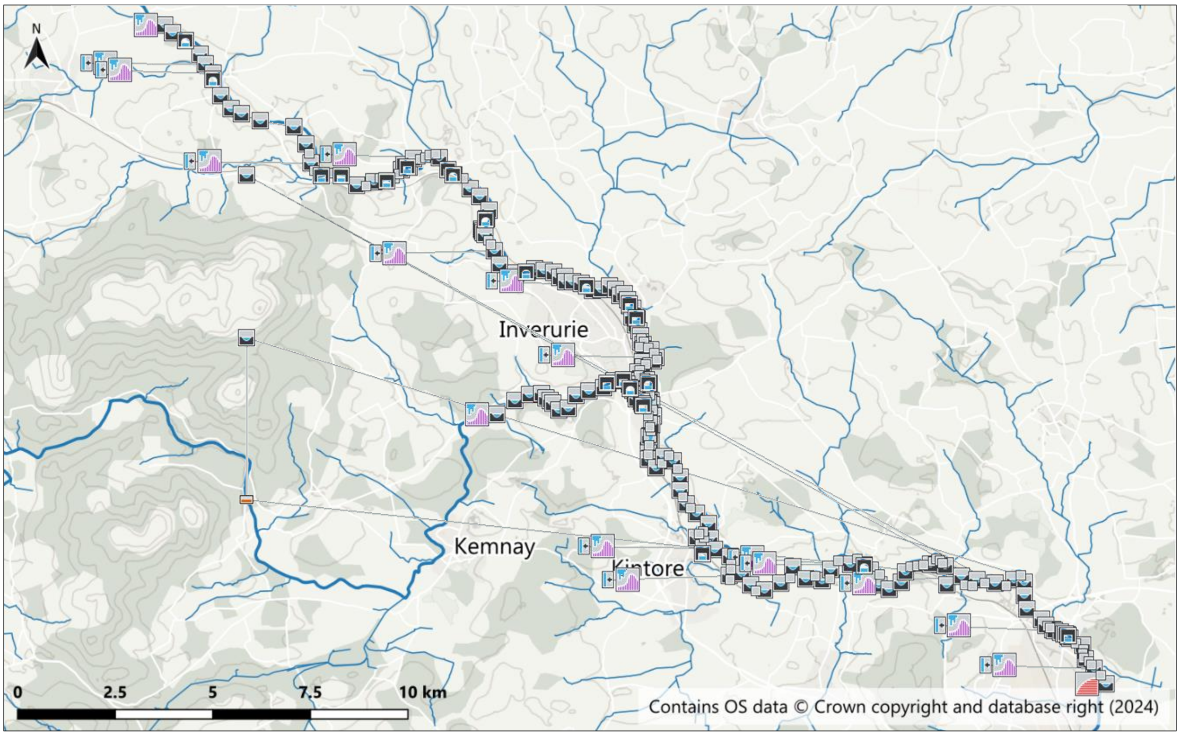

Figure 8 – Flood Modeller Pro 1D network

4.4 2D Domain Representation

The 2D TUFLOW components are as follows:

- A 4m cell size was used for the entire 2D domain with an orientation northwest-southeast. This should be reduced to 1m in urban areas for the Kintore FPS to improve the accuracy of overland flow routes – particularly from minor watercourses.
- The total area of the active grid is 22.5 km^2 for the full defended model.
- Spatially varying Manning's n roughness values were used in the 2D domain. Typical values used were 0.1 for buildings & structures; 0.06 for rough grassland; and 0.035 as a general surface out-of-bank.

- The main source for the DTM was a combination of the 1m LiDAR and 25cm LiDAR shown in Figure 6 resampled by TUFLOW at the mentioned 4m grid resolution.

- The model includes urban areas, the buildings have been represented individually raising the DTM levels by 0.3m across the building footprint and are given a roughness value of 0.1. The buildings were defined using OS Master Map data. Doorstep threshold levels will be used to apply more accurate building upstands in the Kintore FPS modelling.

4.5 1D/2D Linkage

HX boundaries are used to link the 1D model of the channel to the 2D TUFLOW model of the floodplain. This boundary condition allows for the exchange of water levels between the 1D and 2D domains, enabling flow to either enter or leave the 2D cells based on the water levels in the surrounding areas. These are set along the left and right banks. The channel area in between is inactive in the 2D grid. HX boundaries are linked to Flood Modeller nodes using CN connection lines. HX lines are discontinued at structures.

4.6 Boundary Conditions

The fluvial model has the following hydraulic boundaries:

- 16 inflows
    - 2 upstream inflows at Rivers Urie and Don
    - 14 lateral inflows
- 1 downstream boundary at River Don

The River Urie upstream boundary exists at Mill of Newton (2.3km northwest from Old Rayne) and for the River Don at Haughton (to match the SEPA gauge location). At these sections, inflow hydrographs into the River Urie and River Don have been used to represent the flows into the modelled watercourses.

Minor tributaries into River Urie and River Don between the upstream and downstream model extent are represented via 14 lateral inflows capturing the rest of the catchment. The selected ReFH inflow locations are: The Shevock, Bonnyton Burn, Gadie Burn, Burn of Durno, Strathnaterick Burn, Lochter Burn, Keith Hall, Bridgealehouse Burn, Tuach Burn, Newmill Burn, Black Burn, Red Burn, Goval Burn and Ayrburn.

The downstream boundary condition is controlled by a normal depth boundary condition with a user defined slope of 1:685 which has been calculated from the surveyed river sections on the River Don.

4.7 Numerical Convergency

The model runs are stable in both the Flood Modeller and TUFLOW domains. The Flood Modeller domain shows slight fluctuation that remains within an acceptable limit where there is no increase in the number of iterations required for the model to converge around the peak. Mass balance errors are low, with slight fluctuations around 0.1%, the highest discontinuity occurs during initialisation where the model briefly struggles for stability on commencement of the initial wetting of a large number of 2D cells. This will be mitigated in the Kintore FPS by running a short period of baseflow prior to the application of flood flows.

4.8 Calibration & Validation

The following calibration and validation exercises were completed:

- A comparison of the peak water levels from the model and observed SEPA gauge data at Pitcaple, Haughton and Parkhill gauging stations during different events.

- A comparison of the modelled flood extents to different observed information, including post event outlines and photographs.

- A comparison of the modelled stage hydrograph with the observed event stage hydrograph at Pitcaple, Haughton and Parkhill gauging stations.

The calibration process was carried out to meet the following criteria:

- ±0.15m difference between modelled and observed peaks.
- Within a 15 minutes lag for hydrograph peaks.

The calibration results indicated that model peaks were accurately predicted at Pitcaple and Haughton gauging stations, and generally at Parkhill, despite limited rainfall data. The model sensitivity to rainfall is evident, particularly due to ungauged tributaries, but estimates from available rain gauges helped mitigate this. Most events were within ±0.15m accuracy, except for two at Parkhill. The model effectively predicted out-of-bank extents, confirmed by aerial imagery, especially at Inverurie and Port Elphinstone. Model stability was considered strong with minimal convergence issues, and the TUFLOW component shows low mass errors and smooth volume changes between 1D and 2D domains. Sensitivity to rainfall is likely to be improved once the model is converted to Infoworks ICM and integrated within the Scottish Water network model.

5. 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 Kintore Flood Study:

- The River Don will need to be integrated within the Infoworks ICM model to provide an integrated catchment model covering Kintore.
- Drainage ditches and missing areas of sewer network should be added.
- A 2D domain covering Kintore should be added.
- Prediction of surface water flooding should be re-reviewed with the most recent availability of flood history data and following model update to include 2Di modelling on a 2D domain.
- The 2D domain should aim to have a mesh triangle area of $1m^2$ in specific locations where high predictive accuracy is required.
- Surveyed doorstep threshold levels should be applied to the model once available.
- A short period of baseflow should be applied prior to increasing the rate of discharge to flood flows to promote high model stability throughout the simulations.

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

- Pump rates and switch-on levels should be updated in the 1D network, if this information becomes available, to more accurately predict 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.
- Existing SuDS should be represented within the model, if the information to do so is available.
- Storm Subcatchments should be removed and direct rainfall applied to the mesh for entry into the network via the nearest road gully.