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Dear Karen

Insh Marshes National Nature Reserve
River Restoration Feasibility Study: Additional Hydraulic Model Validation

Based on feedback received from community consultation events, noting that model validation presented in the 2016 report focussed on smaller flow events, additional modelling analysis has been undertaken to assess the ability of the model to replicate observed flooding from two historical flooding events:

- January 1993
- December 2015 (i.e. Storm Frank)

The model is demonstrated to replicate observations of flooding at Kincraig Bridge, Invereshie and Loch Insh reasonably well, such that modification or calibration of the model is not required. This letter report provides further detail of the context, methodology and outcomes of this analysis.

Yours sincerely
for EnviroCentre Ltd

(issued electronically)

Dr Iain Struthers
Associate Director

Dr Kenneth A. MacDougall
Projects Director

Enc: Additional Hydraulic Model Validation
Addendum – Discussion and responses to selected queries raised by respondents

CC: Neil Cowie, RSPB

Additional Hydraulic Model Validation

Scope

1. RSPB In November 2020, RSPB Insh Marshes and Cairngorms Connect began a conversation with communities surrounding Insh Marshes to look at possible options for the future of the floodplain. This involved sharing the findings of a feasibility study conducted in 2016 to gain an understanding of views towards different options that were looked at in the study.

2. Written feedback from several respondents raised concerns regarding the predictive performance of the hydraulic model of the local reach of the River Spey that underpins option assessment.

3. While some element of the feedback may be due to misunderstanding (noting that the area at and downstream of Loch Insh is only represented in 1D, such that while high water levels and flooding are predicted at these locations, this flooding is not represented in 2D flood mapping), it is nonetheless noted that model validation undertaken in the original study did not consider extreme flood events.

4. Observed flooding in response to Storm Frank during 2015 in the area of Invereshie was extensive and comparable to flooding in the same area in 1993. Additional validation was therefore undertaken to assess/confirm the ability of the hydraulic model to replicate observations from these events.

Methodology

5. The analysis has used previously obtained data from SEPA for the 1993 and 2015 events as SEPA are not currently providing hydrometry services. The following data was retained from previous phases of the project and a post 2015 event review for each of the three gauged locations (i.e. Spey @ Invertruim, Feshie @ Feshie Bridge and Tromie @ Tromie Bridge):

    - 15-minute stage-time data for the month of December 2015, covering the Storm Frank event, combined with rating curve information obtained from the National River Flow Archive (NRFA).
    - 15-minute flow-time data for an extended period pre-2015, including the January 1993 flood event. However, the current annual maximum flow (AMAX) data series for each gauge makes clear that all 3 gauges have been re-rated since this data was obtained. Hydrographs were uniformly scaled to ensure event flow peaks matched revised peak estimates in the AMAX series.

6. Flow hydrographs obtained from gauge data were applied directly as inflows for the River Feshie and River Tromie. The upstream boundary of the modelled reach of the River Spey is located downstream of the Invertruim gauge, and therefore inflows at this location must be inferred; this was done using two alternative methodologies:

- A "low" estimate, based on Median Annual Maximum Flood (Qmed) transfer from the Invertruim gauge and Flood Estimation Handbook) FEH catchment descriptors at the gauge and upstream boundary locations (as per the 2016 EnviroCentre report). This implicitly assumes that flow contributions in the intervening reach – which includes two watercourses – are hydrologically and hydraulically similar to those from the catchment upstream of Invertruim.
- A "high" estimate, based on adding the flow peak estimate at Invertruim to those estimated using the FEH Rainfall Runoff (FEH-RR) method for the River Calder and Milton Burn (with the latter upscaled to ensure that the summed catchment area accounted for in inflows equals the catchment area at the model's upstream boundary).

7. Inflows from ungauged smaller watercourses (the Gynack Burn, Ruthven Burn, Raitts Burn and Allt Baile Mhuillin) were assumed to scale with Feshie flows, noting that (as per the 2016 methodology) the Tromie was considered an unsuitable donor catchment due to the impact of impoundment and abstraction upon flows in this watercourse. Inflow hydrographs for these watercourses were therefore based on the Feshie @ Feshie Bridge gauged flows for the event of interest, scaled to maintain the same ratio of peaks determined for the 1 in 200 year return period event; in effect, these watercourses were assumed to be subject to an identical storm (in terms of temporal pattern and the rainfall depth duration and frequency (DDF)) to that impacting the catchment of the Feshie.

2015 (Storm Frank) Event Validation

8. The 176.7 m^3/s flow peak at Invertruim for this event has an estimated return period of approximately 13 years, whereas the 260 m^3/s peak at Feshie Bridge has an estimated return period of 100 years, and the 80.6 m^3/s peak at Tromie Bridge has an estimated return period of 10 years. The flow peak at each of these three gauges occurred within 2.5 hours of one another, with the Tromie leading the Feshie, and the Spey @ Invetruim reaching a peak slightly after the Feshie @ Feshie Bridge.

9. Observed flooding occurred in the Invereshie area to the north-east of Loch Insh, including:

- The road between Kincraig Bridge and the B970 flooded over a significant length to the east of the church, where the estimated road levels are between 212.4 and 212.7 metres above Ordnance Datum (mAOD). Invereshie Steading and the Kincraig shinty pitch both flooded (estimate ground levels from just below 211 mAOD to just above 212 mAOD). Modelling predicts peak water levels of between 221.83 – 222.24 mAOD around the perimeter of Loch Insh, including these areas, and is therefore consistent with observations.

- The bridge itself was not surcharged, although levels exceeded the springing height of the arched underside of the bridge (i.e. peak water levels between 221.66 and 221.94 mAOD). This compares to predicted peak water levels at the bridge of between 221.76 and 222.14 mAOD. The gauge at Kincraig Bridge, which is located downstream of the bridge, recorded a peak water level of 221.631 mAOD in response to Storm Frank, which compares well with predictions.

10. A comparison between the gauged water level at Kincraig and the predicted water level from the model in the vicinity of Kincraig Bridge for the Storm Frank event is provided in Figure 1.

11. The model performs reasonably well in replicating observed flooding in response to Storm Frank, with the lower estimate method (based on Qmed transfer) providing more realistic predictions and the alternative estimate (based on additive peaks) being too pessimistic.

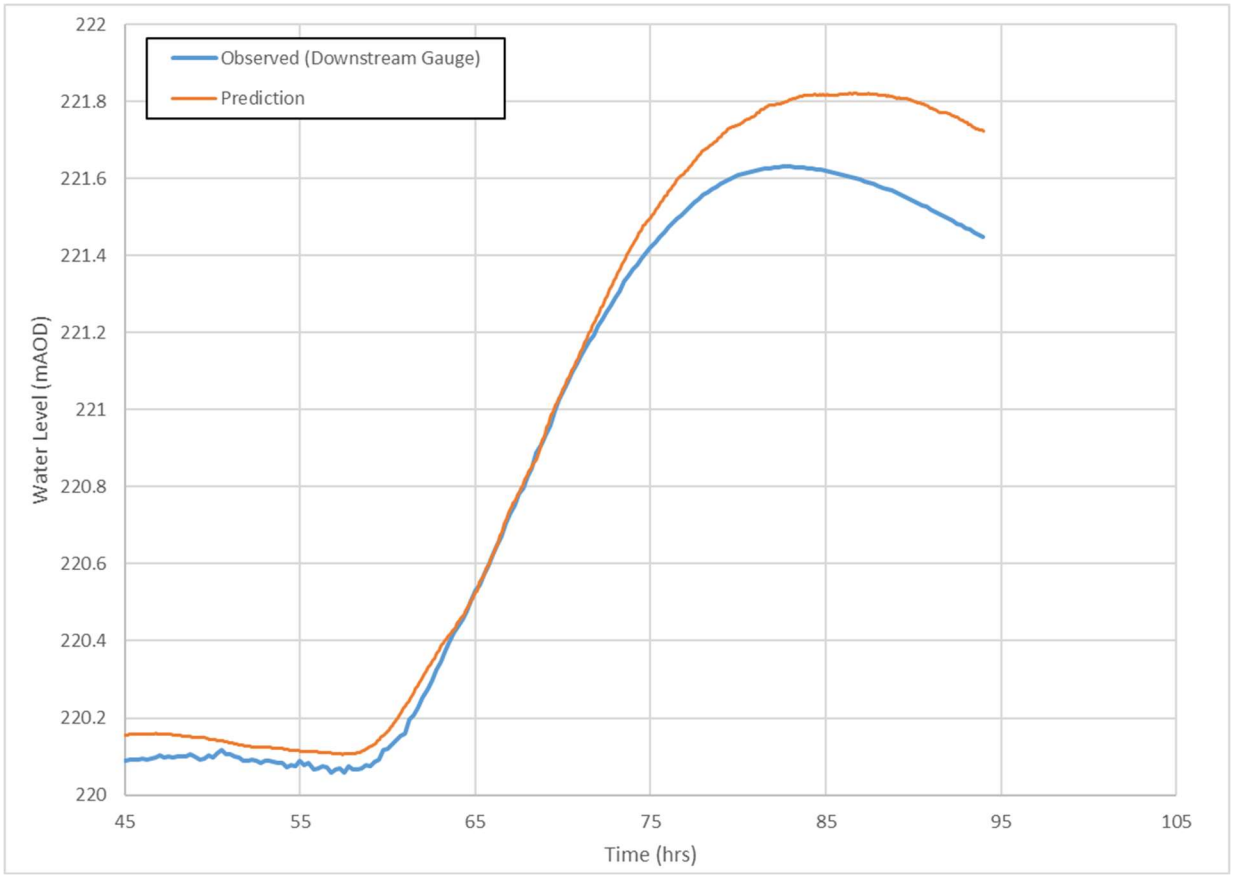

Figure 1: Comparison between predicted and gauged water level in the vicinity of Kincraig Bridge for the Storm Frank event

1993 Event Validation

12. The 188.6 m^3/s flow peak at Invertruim for this event has an estimated return period of approximately 18 years, whereas the 144.9 m^3/s peak at Feshie Bridge has an estimated return period of 5 years, and the 58.6 m^3/s peak at Tromie Bridge has an estimated return period of just under 5 years. The flow peak at the Invertruim gauge occurred 4 hours before the peak at Feshie Bridge and 4.5 hours before the peak at Tromie Bridge.

13. The 1993 event caused flooding of the road between Kincraig Bridge and the B970, including flooding of the Loch Insh Watersports facility. Based on photographs provided in written responses, flood levels reached the road junction at the site entrance into the watersports facility, with ground levels at the junction estimated (from the available LiDAR ground model) at 221.9 mAOD. By comparison, peak water level predictions at Loch Insh were between 221.88 and 222.24 mAOD for the event. The Kincraig Bridge gauge recorded a peak water level of 222.12 mAOD for this event. Observed flooding therefore falls between the two inflow estimation methods used in modelling.

Validation Outcomes

14. A summary of observed and predicted flood levels is shown in the table below. The model is found to perform reasonably well in its ability to replicate observed flooding from the 1993 and Storm Frank events in the area around Kincraig. While it is noted that this validation is spatially limited, given the lack of reported observed flood extents/depths elsewhere in the modelled domain, and still has inherent uncertainty associated with significant flow contributions from ungauged watercourses, there is equally no basis for amending or calibrating the model stemming from this analysis.

Event	Peak Flow (m^3/s)			Peak Water Level (mAOD)		
	Spey @ Invertruim	Feshie	Tromie	Observed at Kincraig Bridge gauge	Predicted at Kincraig Bridge	Predicted at Loch Insh
1993	188.6	144.9	58.6	222.12	221.85 - 222.23	221.88 - 222.24
2015	176.8	260.0	80.6	221.63	221.76 - 222.14	221.84 - 222.26

Additional Outcomes

15. A hydrological update was undertaken as a component of this assessment, using the latest NRFA peak flows database (Version 10; 2021). With exception of a minor reduction in design 1 in 200 year flow estimates at Invertruim (and hence the upper model boundary), revision to design flow estimates for all other gauged and ungauged inflows to the model are negligible, such that 1 in 200 year design event peaks used in the original 2016 study remain valid, erring on being slightly conservative.

16. Anecdotal evidence referred to in written responses variously describes the lag between flooding from the Feshie and from the Spey reaching Kincraig. One respondent claims the Feshie typically floods 24-48 hours before the Spey for the same storm event, whereas another says the Feshie floods about 6 hours before the Spey at their confluence. By comparison, for the Storm Frank event, the model predicts a 12-14 hour lag between the Feshie inflow peak and peak water levels occurring at the downstream end of the loch, increasing a short distance further downstream to 15-18 hours at mid-distance between Kincraig Bridge and the Feshie confluence. The possibility is that both pieces of anecdotal evidence are correct, but relate to different events with different rainfall spatio-temporal patterns resulting in different lags. Nonetheless, the model qualitatively replicates the existence of a lag between Feshie flood peaks and corresponding peaks on the Spey at Kincraig.

17. Modelling also replicates anecdotal evidence of backflow at Kincraig Bridge, with transient backflows of up to 9 m^3/s predicted at the time of the Feshie inflow peak for the Storm Frank event and much higher backflows of the order of 100 m^3/s predicted for the 1 in 200 year plus climate change event. For the 1993 event, where Feshie flows were lower and Spey flows higher, backflow is not predicted.