Aberdeen Western Peripheral Route

Appendix A24.2 – Hydrodynamic Modelling (River Dee)

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Contents

1 Introduction

1.1 General Background

1.1.1 This report is a supporting technical appendix to Chapter 24 (Water Environment) of the Environmental Statement (ES) for the Aberdeen Western Peripheral Route (AWPR). The Southern Leg of the proposed scheme would cross the River Dee, which is one of the major watercourses in the Aberdeenshire area, shown in Figure 24.3a. The approximate road crossing coordinates on River Dee are 388111E, 814595N.

1.1.2 As part of the Environmental Impact Assessment of the proposed scheme, the potential risk of direct flooding from the proposed road crossing structure over the River Dee has been assessed. Different design options for the crossing structure have been investigated and discussed with Scottish Environment Protection Agency (SEPA). The results of modelling two options: the 3-span viaduct and the bow-string arch were presented in the AWPR December 2006 ES.

1.1.3 This report presents the summary findings of the flood risk assessment conducted for the preferred option: the 3-span viaduct. Further information regarding this structure is provided in Chapter 26 (Landscape).

1.1.4 The proposed scheme would also cross numerous other smaller watercourses along its length. The flood risk assessment of smaller watercourses is considered in the in Appendix 24.1 (Surface Water Hydrology).

1.2 Assessment Aims

1.2.1 To determine the potential flood risk associated with the new River Dee crossing for the proposed scheme, an assessment of flooding characteristic has been completed. This required a hydrological analysis of the contributing catchments and the development of a one-dimensional numerical hydraulic model of River Dee.

1.2.2 The aim of hydrological analysis was primarily to provide the calibration and design event flow inputs to the river model. The hydraulic study aimed to predict peak water levels in the river in the vicinity of the proposed crossings using a mathematical river model. The hydraulic analysis assesses the change in the flood risk in the vicinity brought about by the proposed bridge structure.

2 Approach and Methods

2.1 General Approach

2.1.1 The indicative criteria used for the purposes of this assessment to assess the sensitivity to flood risk are presented in Table 1 with the magnitude of potential impacts defined in Table 2. The resulting significance of impact is defined by reference to both the sensitivity of the feature and the magnitude of impact, according to the matrix presented in Table 3.

Table 1 − Criteria to Assess the Flood Risk Sensitivity

Sensitivity	Criteria
High	A watercourse with direct flood risk to the adjacent populated areas and/or presence of critical social infrastructure units such as hospitals, schools, safe shelters, etc. In this scenario, the watercourse with any new development is highly sensitive to increase in the flood risk by the possible increase in the water levels.
Medium	A watercourse with possibility of direct flood risk to the less populated areas without any critical social infrastructure units such as hospitals, schools, safe shelters, etc., and/or utilisable agricultural lands. In this scenario, the watercourse with any new development is moderately sensitive to increase in the flood risk by the possible increase in the water levels.
Low	A watercourse passing through uncultivated agricultural land and/or critical infrastructure in the immediate vicinity of the proposed crossings. In this scenario, the watercourse with new developments would be less sensitive to increase in the flood risk by the possible increase in the water levels.

Table 2 − Criteria to Assess the Magnitude of the Flood Risk

Magnitude	Criteria
High	Major shift away from baseline conditions. Increase in the predicted peak water levels in the watercourse is greater than 100mm at locations immediately upstream of the area.
Medium	Moderate shift away from the baseline conditions. Increase in the predicted peak water levels in the watercourse varies between 50mm and 100mm at locations immediately upstream of the area.
Low	Minor shift away from the baseline conditions Increase in the predicted peak water levels in the watercourse varies between 10mm and 50mm at locations immediately upstream of the area.
Negligible	Very slight change to the baseline conditions. Increase in the predicted peak water levels in the watercourse is less than 10mm at locations immediately upstream of the area.

Table 3 − Impact Significance Matrix

Sensitivity	Magnitude			
	High	**Medium**	**Low**	**Negligible**
High	Substantial	Moderate/Substantial	Moderate	Slight / Negligible
Medium	Moderate/Substantial	Moderate	Slight	Negligible
Low	Moderate	Slight	Negligible	Negligible

2.2 Impact Assessment Method

2.2.1 The flood risk assessment study required the collation and review of the historic information available, relevant to the modelled reaches, including the hydrological information relating to River Dee catchment and the channel cross-section information.

2.2.2 The hydrological analysis of the annual maxima series flow data at the Park Gauging Station on the River Dee established a flood frequency curve for a range of % Annual Exceedance Probability (AEP) flood events (2 year to 200 year return period). This was based on the methodology set up by the Flood Estimation Handbook (IH, 1999).

2.2.3 To assess the risk of flooding, a one-dimensional unsteady state mathematical model of the River Dee was developed using ISIS river modelling software. Data from channel cross-section surveys carried out in 2004 and 2006 were used to construct the model. Low flow calibration of the mathematical model was undertaken using water levels measured during channel cross-section survey.

2.2.4 Design event simulations for a range of % AEP flood events periods were carried out and consequent flood risk was determined in the vicinity of the proposed river crossing for both the existing situation and several river crossing options.

Limitations to Assessment

2.2.5 It should be noted that water levels are predictions from a one–dimensional mathematical model of the River Dee. The model does not include effects such as variation of water surface across the channel cross-section, local effects and fluctuations or elevation of water surface due to wind induced turbulence during flood events. The reaches of the River Dee used for the assessment have been calibrated to low flows measured during channel cross-section surveys and may not be entirely representative of the conditions during high flow events.

3 Baseline

3.1 Hydrological Assessment

3.1.1 Calibration event flow values were extracted from the Park Gauging Station flow records held by the SEPA for the days when water level data were collected.

3.1.2 Design peak flows were estimated using the methodology set up by the Flood Estimation Handbook (FEH). Both single-site analyses of the limited annual maxima series flow records at Park and Woodend Gauging Stations and FEH pooling-group analyses were undertaken. In a departure from standard FEH practice, following discussion with SEPA, greater weighting was given to the single-site growth rate in view of the presence of larger historical flow events at Woodend Gauging Station that were observed prior to establishment of Park Gauging Station.

3.1.3 The FEH Unit Hydrograph Rainfall-Runoff model was used to estimate design hydrograph inflow shapes at the upstream end of the model. In terms of design peak flow, the flood frequency curve determined from the statistical analysis (see above) was viewed as providing the better estimate. Consequently, the hydrographs obtained from the rainfall-runoff model were scaled to agree with peak flows of the statistical approach. The hydrographs were further scaled as the adopted gauging stations were not located at exactly the upstream boundary of the hydraulic model. The scaling accounts for the additional flow contributions between Park Gauging Station and the upstream boundary near Peterculter Golf Club. The flow adjustment factor of 1.02 is based on the Q_{med} flow relationship between Park Gauging Station on River Dee and the upstream boundary location. Flows for various % AEP flood events are summarised in Table 5.

3.1.4 As mentioned previously, flow data for the low-flow calibration events were extracted from the flow records at Park Gauging Station (refer to Table 4). These flows were also scaled with Q_{med} factor adjustment (1.02) for use in the mathematical model.

Table 4 − River Dee at Park Gauging Station

Return Period (year)	Growth factors	Design flows (m^3/s)
2	1.00	571
5	1.25	713
10	1.41	803
25	1.61	921
50	1.77	1013
100	1.94	1110
200	2.12	1212

3.2 Hydraulic Modelling

3.2.1 Further to the hydrological assessments, a baseline mathematical model for the River Dee representing the existing situation was constructed to establish baseline water levels in the watercourse for various % AEP flood events. The model extends from approximately 1.5km upstream of the Culter Burn confluence down to the Bridge of Dee (refer to Figure 24.3a).

3.2.2 Following the limited calibration, the mathematical model was used to carry out design event simulation to assess the flood risk for the existing situation. Model simulations were carried out using flood flows and the methodology described in Section 2 of this report to predict peak water levels in both watercourses for 50%, 20%, 10%, 4%, 2%, 1% and 0.5% AEP (2, 5, 10, 25, 50, 100 and 200 year return periods) flood events.

3.2.3 The predicted peak water levels in the main river channel in the vicinity of the proposed road crossing of the River Dee are presented in Table 6. Figure 24.3bi-ii shows the location of the model nodes used for the comparison.

3.2.4 The sensitivity of predicted peak water levels to increases in flow and channel roughness were assessed for a 0.5% AEP flood event. Mathematical model predictions indicate that the peak water levels in the River Dee in the area of interest could be increased by up to 420mm due to 20% increase in the channel roughness coefficient (Manning's n). A 20% increase in flows led to model predictions of an increase in water levels in the area of interest by up to 560mm.

3.2.5 The mathematical model representing the existing situation in the watercourse was used to establish the baseline conditions for a 0.5% AEP (200 year return period) flood event.

3.2.6 The large floodplain area along the southern bank of the River Dee immediately upstream of Maryculter Bridge is the only floodplain area with existing residential and commercial properties in the vicinity of the proposed crossing. Model predictions indicate that the properties located within the floodplain are likely to be affected by flooding for flood events with % AEP greater than 2% (50 year return period).

3.3 River Dee Sensitivity Assessment

3.3.1 From the results of the baseline simulations of the flood model and following the criteria set out in Table 1, the sensitivity of the River Dee is considered to be medium. The watercourse currently poses a potential direct flood risk to less populated areas without any critical social infrastructure units such as hospitals, schools, and/or utilisable agricultural lands. Figure 24.3bi-ii shows the indicative extent of inundation in the vicinity of the proposed river crossing for 0.5% AEP flood event. Comparison of the indicative extent of inundation with the SEPA's Indicative River and Coastal Flood Map (Scotland) shows a close agreement of the extents in the vicinity of the proposed river crossing. Table 5 shows the peak water level predictions for the existing situation.

Table 5 − Design Flood Events Peak Water Level Predictions

Location	Predicted Peak Water Level (mAOD)						
	50% AEP	20% AEP	10 % AEP	4% AEP	2% AEP	1% AEP	0.5% AEP
River Dee							
DEE_2 (US of Maryculter Bridge)	13.58	13.89	14.09	14.33	14.51	14.69	14.85
DEE_2D (DS of Maryculter Bridge)	13.53	13.81	13.99	14.20	14.35	14.49	14.63
DEE_BR (Proposed Bridge)	13.37	13.64	11.24	14.02	14.17	14.32	14.46
MCULTER (US floodplain on the northern side of Maryculter Bridge)	12.00	12.35	12.56	12.78	12.93	13.09	13.25
ICULTER (Southern floodplain US of Maryculter Bridge)	13.63	14.00	14.29	14.67	14.98	15.29	15.75
UPPER (Northern floodplain at the proposed bridge)	12.00	12.35	12.56	12.78	12.93	13.09	13.25

4 Potential Impacts

4.1 Modelled Option

4.1.1 In order to assess the effect of the proposed bridge crossing on peak water levels, the mathematical model of the River Dee, representing the existing situation, was amended to represent the proposed river crossing structure.

Three Span Viaduct Bridge

4.1.2 This structure comprises a three span viaduct bridge, with main central span extending 120m over the main channel and 75m side spans on the left and right floodplains respectively. The bridge contains two central piers, with piers aligned in the flow direction. The proposed bridge structure was represented in the mathematical model using a USBPR flat soffit bridge unit. The proposed route would pass over the left and right floodplain areas of the River Dee in the vicinity of existing Maryculter Bridge. The left floodplain is represented using flood storage reservoir unit within the model. In order to represent the effect of the road embankment on the water levels in the floodplain downstream of Maryculter Bridge, the storage volume likely to be occupied by the embankment was incorporated into the level - area relationship of the relevant storage reservoir unit.

4.2 Modelling Results

4.2.1 The effect of the bridge crossing option over the River Dee on the peak water levels for 0.5% AEP flood event in comparison with the baseline case is shown in Table 6. Figure 24.3bi-ii shows the location of each cross-section or floodplain storage reservoirs detailed.

Table 6 − Comparison of the Effect of Bridge Options on the Peak Water Levels

	Channel Cross-sections			Floodplain Storage Reservoirs			Magnitude of Impact
	DEE_2	DEE_ 2D	DEE_BR	MCULTER	ICULTER	UPPER	
Base case peak water level (mAOD)	14.85	14.63	14.46	13.25	15.75	13.25	-----
OPTION	**Difference with Base Case (mm)**						
Option 1 (Afflux, mm)	0	0	0	0	0	0	Negligible

4.2.2 ICULTER is the only floodplain area with existing residential and commercial properties in the vicinity of the proposed river crossing. Model predictions indicate that currently the properties located within the floodplain would be likely to be affected by flooding for flood events with % AEP greater than 2% (50 year return period). The proposed bridge structure is located at model node DEE_BR on the River Dee. UPPER, MCULTER and ICULTER are all reservoir units representing flood storage areas in floodplains in the vicinity of the proposed river crossing.

4.2.3 The structure has been designed to span the active flood width for the 0.5% AEP at the point of crossing. It should be noted, however, that the approach roads over the north side of the River Dee are located within the floodplain. The marginal storage volume lost to road embankment has been removed from the floodplain storage reservoir (UPPER).

4.2.4 The results indicate that with the bridge in place, there is likely to be no appreciable impact upon water levels during the 0.5% AEP flood event (200 year return period), which is a result of spanning the active flow width at this flow. No appreciable change to water levels is predicted as a result of the proposed embankment located within the northern floodplain. This is due to the insignificant area of storage lost in comparison to the overall available storage. As no change is observed in predicted water levels, there is not likely to be any associated change in the predicted flood extents from the baseline case.

4.3 Summary of Potential Impacts

4.3.1 As changes to the water levels upstream and in the vicinity of the bridge are considered unlikely, the overall impact upon flood risk is considered to be of negligible magnitude and negligible significance.

5 Mitigation and Recommendations

5.1.1 In part of an iterative process, the design of the bridge structure has taken hydrodynamic effects into account and therefore no further mitigation measures are proposed.

5.1.2 It is recommended, however, that periodic maintenance of the riverbanks and floodplains is undertaken in order to reduce changes in roughness coefficient due to vegetation growth in the riverbanks and the floodplains.

6 Residual Impacts

6.1.1 The residual impacts of the river crossing are as described in Section 4. No change to predicted water levels on the River Dee is anticipated as a result of the proposed bridge crossing.

Table 7 − Watercourse Predicted Impact Evaluation for River Dee

Watercourse	Factors Considered	Sensitivity	Magnitude	Significance of Impact
Flood Risk	Impact of crossing (Viaduct)	Medium	Negligible	Negligible