Appendix A13.5: Watercourse Crossing Report

1 Introduction

1.1 This appendix provides additional information relating to watercourse crossings to be constructed or modified as part of the proposed scheme:

- Section 2 provides a general description of the design approach being adopted.
- Section 3 considers each watercourse crossing in turn identifying the preferred approach that has been adopted at this stage in the proposed scheme development.
- Section 4 provides photographs of the existing watercourse at the location of the proposed crossings.

1.2 This report considers the watercourse crossings associated with the proposed scheme at Design Manual for Roads and Bridges (DMRB) Stage 3. After the completion of DMRB Stage 3, the design of watercourse crossings will be developed further (i.e. Specimen and Detailed designs) in consultation with SEPA to form part of the licence applications under The Water Environment (Controlled Activities) Regulations (CAR) 2011 (as amended).

1.3 This appendix is to be read in conjunction with Chapter 13 (Road Drainage and the Water Environment) of the Environmental Impact Assessment Report (EIAR).

1.4 The location of the 10 watercourse crossings are shown on Figure 13.1 which accompanies Chapter 13 (Road Drainage and the Water Environment).

1.5 A summary of the proposed watercourse crossings is provided in Table 1. Reference is made to the approximate chainage of the watercourse crossing in relation to the 'links' of the proposed scheme. Further detail on these 'links' are provided in Chapter 4 (The Proposed Scheme) and they are shown on Figure 4.1 which accompanies Chapter 4.

Table 1: Proposed Watercourse Crossings

Structure No.	Watercourse	Approximate Chainage (m)
C01	Scretan Burn (SWF04)	ch150 of Link 2
C02	Tributary of Scretan Burn (SWF05)	ch550 of Link 2
C03	Tributary of Scretan Burn (SWF05)	ch550 of Link 3
C04	Scretan Burn (SWF04)	ch300 of Link 3
C05	Beechwood Burn (SWF03)	ch050 of Link 3
C06	Cairnlaw Burn (SWF08)	ch075 of Link 4
C07	Cairnlaw Burn (SWF08)	ch850 of Link 4
C08	Scretan Burn (SWF04)	ch025 of non-motorised users (NMU) Link Eastfield Way Roundabout to Drumrosach Bridge
C09	Beechwood Burn (SWF03)	ch010 of Link 1
C10	Beechwood Burn (SWF03)	ch650 of A9 southbound lane gain/lane drop

2 Design Approach

2.1 At each proposed watercourse crossing, consideration has been given to the nature and size of the crossing, fluvial scour and environmental requirements. This appendix summarises the adopted design at each crossing location and considers the various factors which have influenced the design process.

2.2 At each watercourse crossing, consideration has been given to the 'opening size' of the structure required to pass the design flood event incorporating appropriate freeboard. The 'design flood event' is

used to define the fluvial event used in the design of watercourse crossings and in the consideration of the impact of the proposed watercourse crossing on flood risk. The 'design flood event' is the estimated peak flow associated with the 0.5% Annual Exceedance Probability (AEP) (200-year) plus a 20% allowance for climate change (plus CC) flood event. Flood risk impacts associated with the proposed watercourse crossings are reported in greater detail in Appendix A13.1 (Flood Risk Assessment).

2.3 The design approach being adopted for each of the watercourse crossings is provided below.

2.4 As per Scottish Environment Protection Agency (SEPA) Good Practice guidelines (SEPA 2008, 2010a and 2010b), a clear span bridge option is generally a preferable option to that of a culvert. Whilst lessening the environmental impact with regards to the river corridor environment, it is noted that the clear span bridge option often represents a disproportionate cost to environmental benefit when compared with the culvert option. Where the culvert solution is adopted, a range of mitigation measures will be considered.

2.5 Following consideration of crossing options at each location, the proposed scheme generally adopts the approach of conveying the watercourses by means of a culvert. This will be carried out in accordance with the requirements of the DMRB HA107/04 (The Highways Agency; Scottish Executive; Welsh Assembly Government; The Department for Regional Development Northern Ireland 2004) and in conjunction with SEPA Good Practice guidelines (SEPA 2008, 2010a and 2010b).

2.6 Watercourse crossings have been assessed against the design flood event i.e. 0.5% AEP (200-year) plus an allowance for long term sustainability and resilience (e.g. an allowance for climate change and a minimum of 600mm flood freeboard to road level) such that the proposed scheme remains operational and safe for users during times of flood and flood risk is not compromised elsewhere. Additionally, all new replacement watercourse crossings have been sized as a minimum to freely pass the design flood event with appropriate freeboard within the culvert barrel, meeting the requirements of DMRB HA107/04 (The Highways Agency et al. 2004), as reported in Appendix A13.1 (Flood Risk Assessment).

2.7 Culvert C05 has been designed with a reduced standard of freeboard due the requirement to tie-in with the existing road within the Inverness Retail and Business Park, whilst also conveying flood flows. Culvert C05 is associated with the Eastfield Way Roundabout to Inverness Retail and Business Park link (Link 3), which is not a trunk road.

Scour Protection Measures

2.8 It is critical that attention is given to the design of new watercourse crossings to prevent failure of the highway structure due to fluvial scour.

2.9 Where highways structures are founded directly onto sound bedrock and/or the watercourse local to the structure is formed by a bedrock channel with little or no alluvium mantling, the risk of scour is considered to be 'low' and hence no additional scour protection measures are considered necessary.

2.10 Where highway structures are not founded directly onto sound bedrock and/or the channel local to the structure is not formed of bedrock, consideration will be given to estimating the maximum depth of scour such that structure foundations are set below this level and/or scour protection measures will be provided to offer protection against scour and possible undermining of the structure foundations.

2.11 The nature of any scour protection measure will be determined at the Specimen and Detailed design stages, taking into account hydraulic requirements, channel morphology and nature of the underlying strata (if known). However, this may include appropriately designed structural foundations and / or stone (rip-rap) aprons and revetments forming the river bed and banks to limit the extent to which scour can occur.

2.12 The design of any scour protection measure will be in accordance with SEPA good practice guidance (SEPA 2008, 2010a and 2010b) and the relevant provisions of the DMRB HA97/12 (The Highways Agency; Scottish Executive; Welsh Assembly Government; The Department for Regional Development Northern Ireland 2012).

Environmental Design

2.13 In so far as practicable, all river engineering works associated with the scheme will be in accordance with SEPA good practice guidance, particularly with respect to river crossings (SEPA 2010a), sediment management (SEPA 2010b) and bank protection (SEPA 2008).

2.14 Particular consideration has been given in this report to the provision of mammal and fish passage; and burying the culvert invert with natural riparian river deposits.

Mammal Passage

2.15 The provision of mammal passage within watercourse crossings has been considered alongside geometric constraints, hydraulic performance requirements and other aspects of scheme design in developing the watercourse crossing proposals outlined in this appendix.

2.16 Where existing watercourse crossing culverts are being replaced with a new culvert, consideration has been given to providing integral mammal passage where an ecological need has been identified (refer to Chapter 11: Ecology and Nature Conservation). Mammal ledges have been designed in accordance with the DMRB HA81/99 (The Highways Agency; The Scottish Executive Development Department; The National Assembly For Wales; The Department for Regional Development 2001).

2.17 Where applicable, details relating to the provision of mammal passage within culvert structures are provided in Section 3. Dry mammal underpasses are not detailed within this report.

Fish Passage

2.18 The current accessibility of each watercourse for migratory fish, where known, is provided in Chapter 11 (Ecology and Nature Conservation).

2.19 In line with good practice guidance (SEPA 2010a), measures to provide fish passage would be developed for each watercourse crossing, where required through consultation with SEPA and the Ness and Beauly Fisheries Trust. This would be part of further design development (i.e. post DMRB Stage 3) of the Specimen design to inform applications made under CAR and at the Detailed design phase to be undertaken by the contractor.

2.20 Culverts would be designed so that they are passable to all fish species where practical, even if some fish species are not present as the culvert could affect future measures to improve passage in the catchment. Adequate fish resting places (pools or slower water) would be provided above and/or below the structures as required. The culverts may also require resting places within the structure with the introduction of baffles to aide fish passage (for more detail on baffles see Scottish Government's River Crossings and Migratory Fish: Design Guidance (Scottish Government 2012).

Buried Culvert Invert

2.21 Where possible, consideration has been given to burying the culvert invert below the natural river bed level to allow for a naturalised culvert bed. This approach has been taken where a new culvert is proposed of moderate gradient and generally where the natural river bed level and bed slope is maintained through the culvert. Burying the culvert invert below the natural bed level reduces the likelihood of bed discontinuities which form a barrier to fish passage such as 'perching', where there is a drop at the culvert outlet to the river bed (i.e. at the downstream end).

2.22 The depth of natural river bed material to be provided above the culvert invert would vary depending on the size of culvert and also hydraulic requirements. Typically, the depth of natural material would meet the following criteria, as suggested in 'River Crossings (Engineering in the water environment: a good practice guide)', published by SEPA (2010a):

- for culverts less than 1.2m diameter, the invert should be buried at least 150mm below natural bed level;

- for culverts between 1.2 and 1.8m diameter, the invert should be buried at least 200mm below natural bed level; and
- for culverts greater than 1.8m diameter, the invert should be buried at least 300mm below natural bed level.

2.23 In addition, and where possible, to further aim to maintain the existing hydraulic regime for normal flows, all new proposed scheme culverts have been designed to maintain the existing channel width at least up to the predicted QMED water level. QMED is defined as the Median Annual Maximum Flood, further detail on the derivation of QMED is provided in Appendix A13.2 (Surface Water Hydrology).

3 Watercourse Crossing Information

3.1 Table 2 provides information for each watercourse crossing which could be affected by the proposed scheme. This includes identification of the water body affected (together with predicted flood flows at the point of interest), details of the proposed works and broad justification for the engineering solution.

3.2 When reviewing this table, cross-reference should be made to Table 3 as this provides photographs of the existing watercourse at each proposed crossing location.

Table 2: Proposed Watercourse Crossings - Additional Information

Water body	Culvert number and Location	Construction Detail	Justifications for Engineering Solution
SWF 04 **Scretan Burn** Flow Data: 50% AEP: 1.7 m^3/s 1% AEP: 5.2 m^3/s 0.5% AEP + CC: 7.4 m^3/s	C01 Grid Reference: E: 269736 N: 844792	Precast concrete closed box culvert with embedded invert: 4.5m wide by 2.1m high by approximately 48m long.	Scretan Burn (SWF04) crosses the proposed scheme at three separate locations. The location of proposed culvert C01 is between the proposed Eastfield Way Roundabout and Cradlehall Roundabout (Link 2). There is no existing road structure at this location. **Selected Option:** The preferred solution for this crossing, taking account of engineering and environmental design criteria, is to convey the watercourse via a closed box culvert. The natural bed is proposed to be reinstated through the new structure, placed to a minimum thickness of 300mm to provide continuity of the river bed and associated sediment transport. The proposed channel bed profile replicates the existing channel shape up to the predicted QMED water level. Where practical to do so, the reinstatement of riverbed deposits would use material recovered from the existing channel. The culvert barrel has been hydraulically designed in accordance with DMRB requirements to be free-flowing with appropriate freeboard during the 0.5% AEP (200-year) event including allowance for climate change. It is not possible to include the provision of mammal ledges at this location due to insufficient clearance between culvert soffit level and the maximum water level under the appropriate design flow. Adjacent flood relief culverts provide alternative crossing locations with sufficient headroom to install ledges above the floodwater. **Alternative Options Considered:** The alternative of a single span bridge at this location would comprise a 12m span and be approx. 48m in length to fully span the flood envelope associated with the design flood event. The capital cost associated with a single span bridge in this location is estimated to be in the region of £2.8 million, whereas the capital cost associated with the closed culvert is estimated to be in the region of £337,000[i]. Whilst recognised to be the preferable environmental solution, the adoption of a single span bridge would represent approximately a 730% increase in capital cost which is considered disproportionate to the environmental benefits of this option, when taking into account the range of mitigation measures that are incorporated into the design of the culvert option. It is therefore recommended that the 'closed culvert' option is adopted, designed in accordance with DMRB and SEPA's good practice guide.
SWF 05 **Tributary of Scretan Burn** Flow data: 50% AEP: 0.1 m^3/s 1% AEP: 0.4 m^3/s 0.5% AEP + CC: 0.6 m^3/s	C02 Grid Reference: E: 270026 N: 845063	Precast concrete closed box culvert with embedded invert: 3.0m wide by 1.7m high by approximately 54m long.	Tributary of Scretan Burn (SWF05) crosses the proposed scheme at two separate locations. The location of proposed culvert C02 is on Link 2, close to the proposed Eastfield Way Roundabout and to the north of the existing Highland Main Line Railway Line. There is no existing road structure at this location. **Selected Option:** The preferred solution for this crossing, taking account of engineering and environmental design criteria, is to convey the watercourse via a closed box culvert. The natural bed is proposed to be reinstated through the new structure, providing continuity of the river bed and associated sediment transport. The proposed channel bed profile replicates the existing channel shape up to the predicted QMED water level. Where practical to do so, the reinstatement of riverbed deposits would use material recovered from the existing channel. The culvert barrel has been hydraulically designed in accordance with DMRB requirements to be free-flowing with appropriate freeboard during the 0.5% AEP (200-year) event including allowance for climate change.

Water body	Culvert number and Location	Construction Detail	Justifications for Engineering Solution
			To improve permeability of the culvert to riparian mammals, appropriately sized ledges are proposed to be provided to both the left and right side of the culvert barrel, set at a level 175mm above the predicted 3.33% AEP (30-year) water level and with at least 600mm headroom. Ledges tie into the proposed ground level at the culvert entrance and exit. **Alternative Options Considered:** The alternative option of a single span bridge at this location would comprise a 12m span and be approximately 54m in length to fully span the flood envelope associated with the design flood event. The capital cost associated with a single span bridge in this location is estimated to be in the region of £3.1 million, whereas the capital cost associated with the closed culvert is estimated to be in the region of £370,000[i]. The adoption of a single span bridge in this location would represent approximately a 740% increase in capital cost which is considered disproportionate to the environmental benefits offered by this option, when taking into account the range of mitigation measures are incorporated into the design of the culvert option. It is therefore recommended that the 'closed culvert' option is adopted, designed in accordance with DMRB and SEPA's good practice guide.
SWF 05 **Tributary of Scretan Burn** Flow data: 50% AEP: 0.2 m^3/s 1% AEP: 0.5 m^3/s 0.5% AEP + CC: 0.7 m^3/s	C03 Grid Reference: E :269917 N: 845174	Precast concrete closed box culvert with embedded invert 2.5m wide by 1.6m high by approximately 35m long.	Tributary of Scretan Burn (SWF05) crosses the proposed scheme at two separate locations. The location of proposed culvert C03 is on Link 3 between the proposed Eastfield Way Roundabout and Inverness Retail and Business Park. There is no existing road structure at this location. **Selected Option:** The preferred solution for this crossing, taking account of engineering and environmental design criteria, is to convey the watercourse via a closed box culvert. The natural bed is proposed to be reinstated through the new structure, placed to a minimum thickness of 300mm to provide continuity of the river bed and associated sediment transport. The proposed channel bed profile replicates the existing channel shape up to the predicted QMED water level. Where practical to do so, the reinstatement of riverbed deposits would use material recovered from the existing channel. The culvert barrel has been hydraulically designed in accordance with DMRB requirements to be free-flowing with appropriate freeboard during the 0.5% AEP (200-year) event including allowance for climate change. To improve permeability of the culvert to riparian mammals, appropriately sized ledges are proposed to be provided to both the left and right side of the culvert barrel, set at a level 175mm above the predicted 3.33% AEP (30-year) water level and with at least 600mm headroom. Ledges tie into the proposed ground level at the culvert entrance and exit. **Alternative Options Considered:** The alternative of a single span bridge at this location would comprise a 12m span and be approximately 35m in length to fully span the flood envelope associated with the design flood event. The capital cost associated with a single span bridge at this location is estimated to be in the region of £2.0 million, whereas the capital cost associated with the closed culvert is estimated to be in the region of £266,000[i]. The adoption of a single span bridge option would approximately represent a 650% increase in capital cost which is considered disproportionate to the environmental benefits of this option, when taking into account the range of mitigation measures are incorporated into the design of the culvert option. It is therefore recommended that the 'closed culvert' option is adopted, designed in accordance with DMRB and SEPA's good practice guide.

Water body	Culvert number and Location	Construction Detail	Justifications for Engineering Solution
SWF 04 **Scretan Burn** Flow data: 50% AEP: 1.8 m^3/s 1% AEP: 5.4 m^3/s 0.5% AEP + CC: 7.7 m^3/s	C04 Grid Reference: E: 269687 N: 845221	Precast concrete closed box culvert with embedded invert: 5.5m wide by 1.8m high by approximately 28m long.	Scretan Burn (SWF04) crosses the proposed scheme at three separate locations. The location of proposed culvert C04 is on Link 3 between the proposed Eastfield Way Roundabout and Inverness Retail and Business Park. There is no existing road structure at this location. **Selected Option:** The preferred solution for this crossing, taking account of engineering and environmental design criteria, is to convey the watercourse via a closed box culvert. The natural bed is proposed to be reinstated through the new structure, placed to a minimum thickness of 300mm to provide continuity of the river bed and associated sediment transport. The proposed channel bed profile replicates the existing channel shape up to the predicted QMED water level. Where practical to do so, the reinstatement of riverbed deposits would use material recovered from the existing channel. The culvert barrel has been hydraulically designed in accordance with DMRB requirements to be free-flowing with appropriate freeboard during the 0.5% AEP (200-year) event including allowance for climate change. To improve permeability of the culvert to riparian mammals, appropriately sized ledges are proposed to be provided to both the left and right side of the culvert barrel, set at a level 175mm above the predicted 3.33% AEP (30-year) water level and with at least 600mm headroom. Ledges tie into the proposed ground level at the culvert entrance and exit. **Alternative Options Considered:** The alternative of a single span bridge at this location would comprise a 12m span and be approximately 28m in length to fully span the flood envelope associated with the design flood event. The capital cost associated with such a bridge is estimated to be in the region of £1.6 million, whereas the capital cost associated with the 'closed culvert' is estimated to be in the region of £227,000[i]. The adoption of a bridge in this location would represent approximately a 600% increase in capital cost and this is considered disproportionate to the environmental benefits offered of this option, when taking into account the range of mitigation measures that are incorporated into the design of the culvert option. It is therefore recommended that the closed culvert option is adopted, designed in accordance with DMRB and SEPA's good practice guide.
SWF 03 **Beechwood Burn** Flow data: 50% AEP: 0.5 m^3/s 1% AEP: 1.6 m^3/s 0.5% AEP + CC: 2.3 m^3/s	C05 Grid Reference: E: 269465 N: 845349	Precast concrete closed twin barrel box culvert with embedded invert: 2 x 4.0m wide by 1.5m high by approximately 16m long.	Beechwood Burn (SWF03) crosses the proposed scheme at three separate locations. The watercourse is currently crossed by a small footbridge as part of a pedestrian access track directly south of Inverness Retail and Business Park. The proposed scheme crosses Beechwood Burn at the same approximate location as the existing footbridge before tying in to an existing road within the retail park. **Selected Option:** The preferred solution for this crossing, taking account of engineering and environmental design criteria, is to convey the watercourse via a closed box culvert. Numerical modelling has identified that a twin barrel box culvert comprising of two, 4m wide by 1.5m high culvert barrels is the optimum practical solution to provide acceptable control of flood risk associated with this crossing. The natural bed is proposed to be reinstated through the new structure, placed to a minimum thickness of 300mm to provide continuity of the river bed and associated sediment transport. The proposed channel bed profile requires a widening of the existing channel profile to distribute flood flows between the two barrels of the proposed structure. Consideration will be given at the Specimen and Detailed design phases to the practicalities of maintaining the existing channel shape for 'normal'

Water body	Culvert number and Location	Construction Detail	Justifications for Engineering Solution
			flows, i.e. up to and including QMED flow. Where practical to do so, the reinstatement of riverbed deposits would use material recovered from the existing channel. The culvert barrel has been hydraulically designed in accordance with DMRB requirements to be free-flowing with appropriate freeboard during the 0.5% AEP (200-year) event including allowance for climate change. It is not possible to include the provision of mammal ledges at this location due to insufficient clearance between culvert soffit level and the maximum water level under the appropriate design flow. **Alternative Options Considered:** The alternative of a single span bridge at this location would comprise a 12m span and be approximately 16m in length to fully span the flood envelope associated with the design flood event. The capital cost associated with a single span bridge at this location is estimated to be in the region of £0.9 million, whereas the capital cost associated with the closed culvert is estimated to be in the region of £161,000[i]. The adoption of a single span bridge would represent approximately a 460% increase in capital cost which is considered disproportionate to the environmental benefits of this option, when taking into account the range of mitigation measures are incorporated into the design of the culvert option. It is therefore recommended that the 'closed culvert' option is adopted, designed in accordance with DMRB and SEPA's good practice guide.
SWF 08 **Cairnlaw Burn** Flow data: 50% AEP: 0.9 m^3/s 1% AEP: 2.9 m^3/s 0.5% AEP + CC: 4.0 m^3/s	C06 Grid Reference: E: 270186 N: 845208	Precast concrete closed box culvert with embedded invert: 3.5m wide by 1.7m high by approximately 27m long.	Cairnlaw Burn (SWF08) crosses the proposed scheme at two separate locations. The location of proposed culvert C06 is to the north of the proposed Eastfield Way Roundabout. There is no existing road structure at this location. **Selected Option:** The preferred solution for this crossing, taking account of engineering and environmental design criteria, is to convey the watercourse via a closed box culvert. The natural bed is proposed to be reinstated through the new structure, placed to a minimum thickness of 300mm to provide continuity of the river bed and associated sediment transport. The proposed channel bed profile replicates the existing channel shape up to the predicted QMED water level. Where practical to do so, the reinstatement of riverbed deposits would use material recovered from the existing channel. The culvert barrel has been hydraulically designed in accordance with DMRB requirements to be free-flowing with appropriate freeboard during the 0.5% AEP (200-year) event including allowance for climate change. To improve permeability of the culvert to riparian mammals, appropriately sized ledges are proposed to be provided to both the left and right side of the culvert barrel, set at a level 175mm above the predicted 3.33% AEP (30-year) water level and with at least 600mm headroom. Ledges tie into the proposed ground level at the culvert entrance and exit. **Alternative Options Considered:** The alternative of a single span bridge at this location would comprise a 12m span and be approximately 27m in length to fully span the flood envelope associated with the design flood event. The capital cost associated with a single span bridge in this location is estimated to be in the region of £1.6 million, whereas the capital cost associated with the closed culvert is estimated to be in the region of £222,000[i]. The adoption of a single span bridge option would represent approximately a 620% increase in capital cost which is considered disproportionate to the environmental benefits offered by this option, when taking into account the range of

Water body	Culvert number and Location	Construction Detail	Justifications for Engineering Solution
			mitigation measures are incorporated into the design of the culvert option. It is therefore recommended that the 'closed culvert' option is adopted, designed in accordance with DMRB and SEPA's good practice guide.
SWF 08 **Cairnlaw Burn** Flow data: 50% AEP: 1.0 m^3/s 1% AEP: 2.9 m^3/s 0.5% AEP + CC: 4.2 m^3/s	C07 Grid Reference: E: 270237 N: 845944	Precast concrete closed box culvert with embedded invert: 3.0m wide by 1.7m high by approximately 39m long.	Cairnlaw Burn (SWF08) crosses the proposed scheme at two separate locations. The location of proposed culvert C07 is to the north-east of the proposed Scheme on Link 4 to the north of the existing Highland Main Line Railway Line. There is no existing road structure at this location. **Selected Option:** The preferred solution for this crossing, taking account of engineering and environmental design criteria, is to convey the watercourse via a closed box culvert. The natural bed is proposed to be reinstated through the new structure, placed to a minimum thickness of 300mm to provide continuity of the river bed and associated sediment transport. The proposed channel bed profile replicates the existing channel shape up to the predicted QMED water level. Where practical to do so, the reinstatement of riverbed deposits would use material recovered from the existing channel. The culvert barrel has been hydraulically designed in accordance with DMRB requirements to be free-flowing with appropriate freeboard during the 0.5% AEP (200-year) event including allowance for climate change. To improve permeability of the culvert to riparian mammals, appropriately sized ledges are proposed to be provided to both the left and right side of the culvert barrel, set at a level 175mm above the predicted 3.33% AEP (30-year) water level and with at least 600mm headroom. Ledges tie into the proposed ground level at the culvert entrance and exit. **Alternative Options Considered:** The alternative of a 'single span bridge' at this location would comprise a 12m span and be approximately 39m in length to fully span the flood envelope associated with the design flood event. The capital cost associated with a single span bridge in this location is estimated to be in the region of £2.2 million, whereas the capital cost associated with the closed culvert is estimated to be in the region of £288,000[i]. The adoption of a single span bridge option would represent approximately a 660% increase in capital cost which is considered disproportionate to the environmental benefits of this option, when taking into account the range of mitigation measures are incorporated into the design of the culvert option. It is therefore recommended that the closed culvert option is adopted, designed in accordance with DMRB and SEPA's good practice guide.
SWF 04 **Scretan Burn** Flow data: 50% AEP: 1.76m^3/s 1% AEP: 5.37m^3/s 0.5% AEP + CC: 7.63m^3/s	C08 Grid Reference: E: 269723 N: 845060	Precast concrete closed box culvert with embedded invert: 4.0m wide by 2.2m high by approximately 6m long.	Scretan Burn (SWF04) crosses the proposed scheme at three separate locations. The location of proposed crossing C08 is to the west of the proposed bridge crossing of the existing Highland Main Line Railway line, on the NMU link, which runs from the Eastfield Way Roundabout and connects into an existing NMU path leading to the to the Inverness Retail and Business Park. There is no existing road structure at this location. **Selected Option:** The preferred solution for this crossing, taking account of engineering and environmental design criteria, is to convey the watercourse via a closed box culvert. The natural bed is proposed to be reinstated through the new structure, placed to a minimum thickness of 300mm to provide continuity of the river bed and associated sediment transport. The proposed channel bed profile replicates the existing channel shape up to the predicted

Water body	Culvert number and Location	Construction Detail	Justifications for Engineering Solution
			QMED water level. Where practical to do so, the reinstatement of riverbed deposits would use material recovered from the existing channel. The culvert barrel has been hydraulically designed in accordance with DMRB requirements to be free-flowing with appropriate freeboard during the 0.5% AEP (200-year) event including allowance for climate change. To improve permeability of the culvert to riparian mammals, appropriately sized ledges are proposed to be provided to both the left and right side of the culvert barrel, set at a level 175mm above the predicted 3.33% AEP (30-year) water level and with at least 600mm headroom. Ledges tie into the proposed ground level at the culvert entrance and exit. **Alternative Options Considered:** The alternative of a 'single span bridge' at this location would comprise a 12m span and be approximately 6m in length to fully span the flood envelope associated with the design flood event. The capital cost associated with such a bridge is estimated to be in the region of £346,000, whereas the capital cost associated with the 'closed culvert' is estimated to be in the region of £107,000[i]. The adoption of a bridge at this location would represent approximately a 230% increase in capital cost and this is considered disproportionate to the environmental benefit offered by this option, when taking into account the range of mitigation measures are incorporated into the design of the culvert option. It is therefore recommended that the 'closed culvert' option is adopted, designed in accordance with DMRB and SEPA's good practice guide.
SWF 03 **Beechwood Burn** Flow data: 50% AEP: 0.3 m^3/s 1% AEP: 1.0 m^3/s 0.5% AEP + CC: 1.4 m^3/s	C09 Grid Reference: E: 269402 N: 844403	Replacement of existing culvert with new, 0.8m diameter pipe culvert, approximately 35m long.	Beechwood Burn (SWF 03) crosses the proposed scheme at three separate locations. The location of proposed culvert C09 is at the junction of the B9006 Culloden Road and U1058 Caulfield Road North. At present, the B9006 Culloden Road runs parallel to the watercourse with the U1058 Caulfield Road North road crossing the watercourse by means of a circular culvert. The cross-section of the culvert varies from upstream to downstream locations, with a diameter of 0.8m upstream to 0.5m downstream. It is unclear at which point through the length of the culvert that this change in cross-section occurs. **Selected Option:** The preferred solution for this crossing, taking account of engineering and environmental design criteria, is to convey the watercourse by replacing the existing circular culvert with a culvert of continuous cross-section. The culvert invert is proposed to be buried beneath natural bed materials to maintain sediment transport through the culvert. However, it is considered impractical to provide continuity with the profile of the surrounding reach within the circular pipe culvert. The culvert barrel has been hydraulically designed in accordance with DMRB requirements to be free-flowing with appropriate freeboard during the 0.5% AEP (200-year) event including allowance for climate change. It is impractical to include the provision of mammal ledges at this location due to the size and circular shape of both the existing culvert and the proposed extension. **Alternative Options Considered:** The alternative of a single span bridge at this location would comprise a 12m span and be approximately 35m in length to fully span the flood envelope associated with the design flood event. The capital cost associated with a single span bridge at this location is estimated to be in the region of £2.0 million, whereas the capital cost associated with the closed culvert is estimated to be in the region of £266,000[i]. The adoption of a single span bridge option would represent approximately a 650% increase in capital cost which is considered

Water body	Culvert number and Location	Construction Detail	Justifications for Engineering Solution
			disproportionate to the environmental benefit of this option, when taking into account the range of mitigation measures are incorporated into the design of the culvert option. Additional costs would also be associated with the raising of the road level at this location both in the proposed scheme and adjoining existing roads to accommodate the single span bridge option. It is therefore recommended that the closed culvert option is adopted, designed in accordance with DMRB and SEPA's good practice guide.
SWF 03 **Beechwood Burn** Flow data: 50% AEP: N/A 1% AEP: N/A 0.5% AEP + CC: N/A	C10 Grid Reference: E: 269029 N: 844691	Downstream extension of existing A9 culvert by approximately 5m.	Culvert C10 is south-west of Inverness Campus. At present, there is an existing culvert at this location which is anticipated to be affected by the proposed widening of the southbound A9 and associated earthworks. Culvert C10 is understood to no longer convey the watercourse beneath the A9 since the watercourse was diverted upstream of the A9. The current function of the culvert is thought to be to convey road drainage from the northbound carriageway to outfall into SWF03. **Selected Option:** It is proposed to extend the existing culvert downstream to accommodate the widening of the A9. As this culvert no longer conveys a watercourse, mitigation measures associated with a culverted watercourse are not applicable. **Alternative Options Considered:** As the culvert no longer conveys a watercourse and functions as part of a road drainage network, the use of alternative forms of conveyance (for example replacing the structure with a larger culvert or bridge) were considered to offer minimal or no environmental benefit.

[i] *The capital cost estimate associated with the closed culvert option is based on identification of the principal quantities associated with the proposed works and applying a unit cost rate for each principal quantity as presented in Spon's 'Civil Engineering and Highway Works Price Book 2018' (AECOM). Similarly, the capital cost estimate associated with the single span bridge option has been based on a unit cost rate for the proposed bridge deck area, which has been developed using principal quantities and unit cost rates from comparable scope/ projects. In addition, the capital cost estimates incorporate 'optimism bias' in accordance with 'Green Book Supplementary Guidance: Optimism Bias', published by the UK Government HM Treasury (2013).*[i]

Table 3: Proposed Watercourse Crossings – Photographs of Existing Channel

Water body	Culvert ID	Photographs at proposed crossing locations	
SWF 03 Beechwood Burn	C05	 View of Beechwood Burn at position of crossing C05, looking upstream at NMU bridge crossing watercourse.	 View of Beechwood Burn at position of crossing C05, looking downstream of NMU bridge crossing of watercourse.

Water body	Culvert ID	Photographs at proposed crossing locations	
	C09	 Downstream view of existing and replacement C09 crossing of Beechwood Burn .	 Downstream view of open channel section of Beechwood Burn towards existing C09 crossing and location of replacement crossing.
	C10	No photo available	No photo available

Water body	Culvert ID	Photographs at proposed crossing locations	
SWF 04 Scretan Burn	**C01**	 **View of Scretan Burn at position of crossing C01, looking downstream**	 **View of Scretan Burn at position of crossing C01, looking upstream**

Water body	Culvert ID	Photographs at proposed crossing locations	
	C04	 View of Scretan Burn at position of crossing C04, looking downstream	 View of Scretan Burn downstream of crossing C04, looking downstream

Water body	Culvert ID	Photographs at proposed crossing locations	
	C08	 View of Scretan Burn at position of crossing C08, looking upstream of Highland Main Line Railway and NMU crossing.	 View of Scretan Burn at position of crossing C08, looking downstream towards Highland Main Line Railway and NMU crossing.

Water body	Culvert ID	Photographs at proposed crossing locations	
SWF 05 Tributary of Scretan Burn	**C02**	 **View of Tributary of Scretan Burn at position of crossing C02, looking upstream.**	 **View of Tributary of Scretan Burn at position of crossing C03, looking downstream.**

Water body	Culvert ID	Photographs at proposed crossing locations	
	C03	 View of Tributary of Scretan Burn at position of crossing C03, looking downstream from existing field access crossing.	 View of Tributary of Scretan Burn at position of crossing C03, looking upstream at existing field access crossing.

Water body	Culvert ID	Photographs at proposed crossing locations	
SWF 08 Cairnlaw Burn	**C06**	 **View of Cairnlaw Burn at position of crossing C06, looking downstream**	 **View of Cairnlaw Burn at position of crossing C06, looking upstream**

Water body	Culvert ID	Photographs at proposed crossing locations	
	C07	 View of Cairnlaw Burn at position of crossing C07, looking downstream towards C1032 Barn Church Road.	 View of Cairnlaw Burn at position of crossing C07, looking upstream

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