A11.4 Detailed Estuarine Ecology Impacts and Mitigation

This appendix provides supporting information for the assessments of potential significant impacts made in Chapter 11 (Estuarine Ecology), Section 11.5 of the ES. The supporting information is intended to provide additional reference material to that presented in the ES and should not be considered as a stand alone document.

The ES provides full descriptions of only those potential impacts assessed as being significant. An important part of the Ecological Impact Assessment (EcIA) process is to justify to stakeholders and consultees why some potential impacts are considered to be insignificant and do not require mitigation measures; these insignificant impacts are described in detail in this appendix following the supporting information for each potential impact.

Following the supporting information and assessments of insignificant impacts are descriptions of the mitigation measures for all significant potential impacts described in the ES. Summary tables are then provided of the significant potential impacts, mitigation and residual impacts identified from the Main Crossing on the relevant ecological receptors, as discussed in the ES (Chapter 11: Estuarine Ecology).

In summary, Appendix A11.4 includes:

- **Construction Impacts – supporting information, identification of significant impacts and justification for assessment of insignificant impacts.**
- **Operational Impacts – supporting information, identification of significant impacts and justification for assessment of insignificant impacts.**
- **Mitigation – generic and specific measures.**
- **Summary tables of significant impacts, mitigation and residual impacts.**

1 Potential Construction Impacts

1.1 Noise

General Description

1.1.1 The most likely construction impacts of the Main Crossing upon biota would be those associated with noise. Anthropogenic noise is a generic term referring to any man-made sound or vibration which intrudes into the natural environment. Noise can mask biologically useful sounds (‘signals’), disturb animals’ natural behaviour, impair hearing or cause injury. Anthropogenic noise sources include piling, shipping, dredging, drilling, and underwater explosives.

1.1.2 Noise is described in terms of two characteristics: sound, which is measured at the receptor as a sound pressure, and vibration, which is usually described in terms of particle velocity. A sound or vibration is defined in terms of its frequency (pitch) and amplitude (level or loudness). Frequency is measured in Hertz (Hz) where 1Hz = 1 cycle per second. The amplitude of sound pressure is measured in units of Pascals, whereas vibration is measured as a velocity, e.g. millimetres per second (mms^{-1}); in either case, amplitude is usually expressed in decibels (dB) in biological applications.

1.1.3 A pressure in decibels expresses a logarithmic ratio between the measured pressure and a reference pressure (typically one micro Pascal or 1µPa) and is often written as dBre1µPa, where the “re” means “referenced to” whichever reference value is then described. The equation for converting units of mms^{-1} (particle velocity) to dB (particle velocity) is [dB = 20log V/Vref] where V is the measured particle velocity and Vref is the reference particle velocity. For dB (pressure) this becomes [dB = 20log P/Pref], where P is pressure.

1.1.4 Nedwell and Turnpenny (1998) and Nedwell et al. (2007) proposed the $dB_{ht(Species)}$ as a metric for representing the audibility of noise to a given species. This is analogous to the dB(A) scale which is used as a measure of the perception of noise by humans, which weights the sensitivity according to an ’average’ human audiogram. The subscript “ht(Species)” refers to the hearing threshold for a given species, and in this case the audiogram of a marine fish or mammal can be used to provide the weighting. Thus, presenting noise data in terms of the $dB_{ht(Species)}$ metric indicates the loudness of the noise that will be perceived by individuals of the given species. Nedwell and Turnpenny (1998) and Nedwell et al. (2004) provide detailed data on the hearing thresholds of many marine mammals and can provide a useful reference when the precise nature of the noise pollution likely to occur at the Firth of Forth development is established.

Fish and Noise

1.1.5 In addition to the potential for physical injury arising from noise levels described in (Chapter 11: Estuarine Ecology) fish may also exhibit behavioural responses to noise in the form of avoidance responses; this can have significant impacts on migratory species. Research was conducted into the avoidance behaviour of fish to differing computer-generated sounds at 12 sound levels (Nedwell et al., 2007). Experiments were conducted in a choice chamber with sound being played from alternating sides; any avoidance behaviour was recorded. Some fish, such as flounder, were found to be unsuitable subjects for reaction experiments as their natural behavioural avoidance response to is to hide by remaining in one position. This consequently did not register as an avoidance response in the experiment, as it was not physical movement away from the sound. Pout and goldfish showed valid responses which differed between the species. Pout displayed a greater avoidance to noise and a greater increase in avoidance with increasing sound level.

Mammals and Noise

1.1.6 Other influences that interfere with detection of underwater sound by marine mammals relate to the Lloyd Mirror Effect and acoustic shadowing. The Lloyd Mirror Effect is a concept which has been described by Allman et al. (1993) as when “an interference pattern is formed by the superposition of light coming directly from a point source with that coming from the spectacularly reflected image of the same source in a mirror.” An analogous definition has been applied to sound by Gerstein et al. (2003) where the source (for example a ship’s propeller) emits sound and these are reflected off the seabed and the surface creating reflective waves that are 180˚ out of phase as well as producing the direct wave. The effect of this is that where both source and receptor are close to the water surface, the received level may be reduced by the partial cancellation of the direct sound wave and the inverted surface-reflected wave.

1.1.7 Acoustic shadow zones result from obstruction of the sound path by objects much larger than the wavelength of the sound. In water, a sound having a frequency of 100Hz, for example, has a wavelength of around 15m, while a 50Hz sound has a wavelength of around 30m. If the obstruction is larger than this, the received sound at a point beyond will depend on diffraction and interference of sound waves passing around the object. The confluence of the effects of spreading, shadowing and the Lloyd Mirror Effect make it very difficult for whales to hear large ships with propellers above keel level.

1.1.8 Background noise (often referred to as ambient noise) in an ocean can be caused by waves, wind, organisms, shipping, small craft and even ice; several of these sources are likely to contribute significantly to the overall sound in any location. Background levels vary according to the time of day, location and season. The total sound can be expressed using the following equation where x (dB) is a sound signal and y (dB) is the level:

Lx+y = 10 log (10x/10 + 10y/10)

1.1.9 For example where x = 100dB and y = 100dB the total ambient noise level is 103dB (Richardson et al. 1995).

1.1.10 Sound generated from many underwater sources has energy distributed over a wide range of frequencies. Some sounds, e.g. from SONAR equipment, may have a pure waveform with power concentrated in a narrow frequency band. In most other cases, for example shipping or construction noise, frequencies can extend over a very wide bandwidth from infrasound (<20Hz) to ultrasound (>20kHz, and often into the hundreds of kHz), generally with more complex and erratic waveforms (Richardson et al., 1995).

1.1.11 Noise emissions generated underwater can be most usefully presented as a source level (SL) and by convention, represented as the effective noise amplitude of sound estimated at one metre from the source. Since measuring in the near-field can be problematic (e.g. difficulties in determining the origin on a large ship's propeller), this is done by the calculating noise level at a larger distance away and back-calculating using a standard transmission loss (TL) equation (Turnpenny and Nedwell 1994). Transmission loss is the decay of noise levels with distance. Richardson et al. (1995) describes this in terms of spherical and cylindrical spreading. Spherical spreading is used most commonly in deep, open water applications and implies that intensity, or the mean square pressure, varies inversely with the square of the distance from the source (Inverse Square Law). This can be calculated using the following:

$$TL = 20 \log (R/R0)$$

1.1.12 Where R_0 is the reference range (usually taken at one metre). Here sound waves diminish by 6dB when the distance is doubled; when the distance increases by a factor of 10 the sound reduces by 20dB. The minimum depth at which a waveform propagates is calculated to be approximately $^1/_4$ of its wavelength, so 50Hz has a wavelength of 30m; therefore in order for the sound to propagate by spherical spreading, the water depth has to be at least 7.5m. However, where the water overlies water-saturated sediments, the effective propagation depth may be increased.

1.1.13 Cylindrical spreading generally occurs in shallow waters or non-homogenous waters where the surface and seabed reflects sound; this creates a complex sound field. Here the equation to calculate transmission loss is as follows:

$$TL = 10 \log R$$

1.1.14 Where R_1 is the range at which spherical spreading stops. Responses to sound are logarithmic and species specific, each has its own range of frequencies over which it can hear and its own hearing sensitivity.

1.1.15 In order to estimate the received level of sound at a particular range from source the following equation is used:

$$SPL = SL – TL$$

1.1.16 Where SPL is the Sound Pressure Level in dB, SL is the Source Level in dB and TL is the transmission loss in dB. In general the SL-TL model is appropriate for short ranges (up to a kilometre or so) but over larger distances, absorption needs to be taken into account. In seawater, absorption occurs owing to chemical components, particulates and plankton in the water column. Attenuation of sound is greater at higher frequencies; below 1kHz, absorption is negligible. The process is linear, so that for example at 15kHz, an additional 2dB loss per kilometre is incurred (UA 2008). Table 1.1 describes how sound at frequencies of <1kHz dissipates with spherical spreading, using different source levels. If the source level is at 160dB then assuming spherical spreading it takes 10km to reduce to 80dB. If sound levels are as high as 230dB then a distance of 60km only sees a reduction to 134dB.

Table 1.1: Calculating sound pressure levels at varying distances from the source and source noise levels

Assuming Spherical Spreading (m) *	Transmission Loss = 20 Log R dBre1μPa	100 dB	160 dB	170 dB	180 dB	190 dB	200 dB	225 dB	230 dB
1000	60	40	100	110	120	130	140	165	170
2000	66.02	33.98	93.98	103.98	113.98	123.98	133.98	158.98	163.98
3000	69.54	30.46	90.46	100.46	110.46	120.46	130.46	155.46	160.46
4000	72.04	27.96	87.96	97.96	107.96	117.96	127.96	152.96	157.96
5000	73.98	26.02	86.02	96.02	106.02	116.02	126.02	151.02	156.02
10000	80	20	80	90	100	110	120	145	150
15000	83.52	16.48	76.48	86.48	96.48	106.48	116.48	141.48	146.48
20000	86.02	13.98	73.98	83.98	93.98	103.98	113.98	138.98	143.98
30000	89.54	10.46	70.46	80.46	90.46	100.46	110.46	135.46	140.46
40000	92.04	7.96	67.96	77.96	87.96	97.96	107.96	132.96	137.96
50000	93.98	6.02	66.02	76.02	86.02	96.02	106.02	131.02	136.02
60000	95.56	4.44	64.44	74.44	84.44	94.44	104.44	129.44	134.44

* without absorption factor considered

1.1.17 Audiograms have been produced for a number of marine mammal species by Popov and Supin, (1990); Bibikov, (1992); Ridgeway and Joyce (1975) and Møhl (1968), both cited in Nedwell, et al. (2004) and illustrated in Plot 1.1 and Plot 1.2. It has not been possible to obtain audiograms for all the species that occur in the Firth of Forth and so minke whale and the long-finned pilot whale are not displayed. Plot 1.1 shows the harbour porpoise to be the most sensitive at frequencies around 30kHz and 125kHz with a hearing threshold of approximately 60dBre1μPa. The bottlenose dolphin has a hearing threshold of approximately 60dBre1μPa at around 80kHz and is more sensitive over a wide range of frequencies when compared to other species.

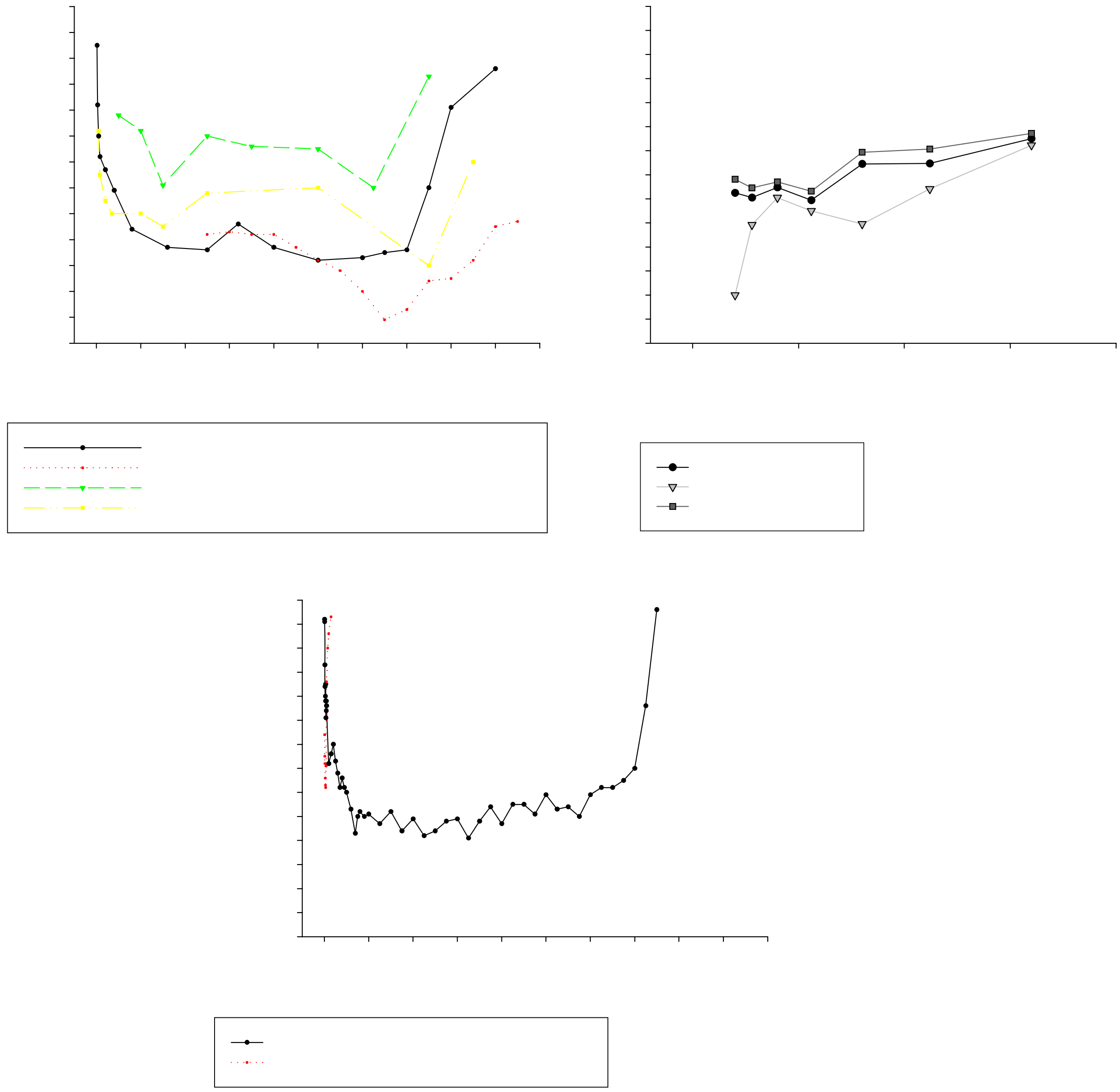
1.1.18 Studies undertaken by Schuldt et al. (2000, cited in DoC, (2008)) showed that using intense, non-pulse 1-s tomes at 3, 10 and 20kHz produced the onset of Temporary Threshold Shift (TTS) in beluga whales at a mean sound exposure level (SEL) of 195dB. Measured TTS in the beluga was 7 and 6dB at 0.4 and 30kHz respectively after exposure to intense single pulses. Behavioural responses of marine mammals to noise are highly variable and dependent on a suite of internal and external factors (Ocean-Studies-Board 2003).

1.1.19 Audiograms for the harbour porpoise are based on two different methods of analysis. The first method is through ABR (Auditory Brainstem Response) also known as the AEP method (Auditory Evoked Potential) and the second method is where the audiogram is derived from behavioural responses. ABR/AEP is a neurological test that typically uses a click stimulus that generates a response from the basilar region of the cochlea; it is not a substitute for evaluation of hearing and wherever possible behavioural responses should also be tested (Bhattacharyya, 2009).

1.1.20 Lucke et al. (2007) describes the studies carried out by Andersen (1970) and Kastelein et al. (2002) whereby one harbour porpoise subject was tested to obtain audiograms through behavioural responses to sound. Bibikov (1992 in Lucke et al. (2007)) gathered electrophysiological audiograms from three subjects by measuring AEP.

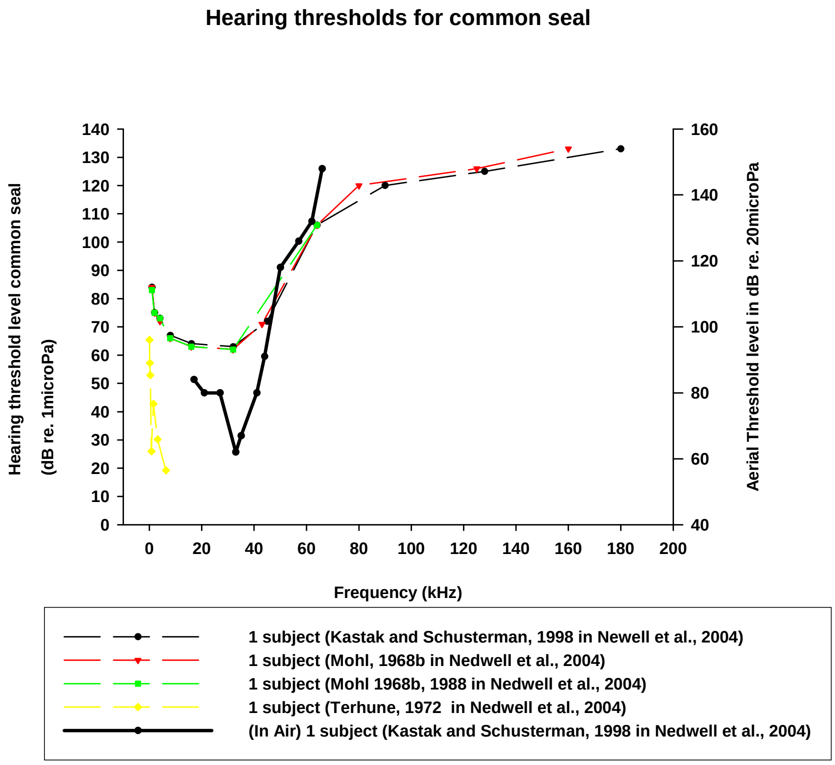
1.1.21 Lucke et al. (2007) obtained AEP results from the same experimental subject as used by Kastelein et al. (2002, cited in Lucke et al. (2007). Tests were carried out at various low level frequencies and upper and lower confidence intervals were calculated; their significance reflects the relationship between the received level of stimuli and the evoked neuronal response. The results observed in this study when comparing the low frequencies measured in the other four studies show similar hearing threshold levels.

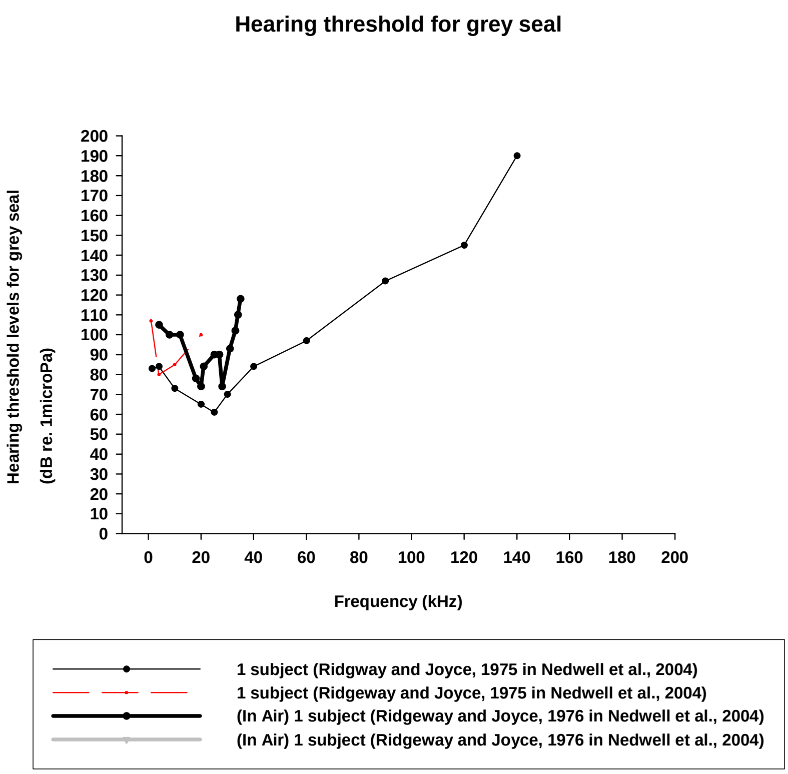
Plot 1.1: Audiograms for harbour porpoise and bottlenose dolphin. Data obtained from Lucke et al. (2007) and Nedwell et al. (2004)



1.1.22 In general there is wide variation in hearing threshold sensitivity over the entire range of frequencies measured for the harbour porpoise and bottlenose dolphin; the harbour porpoise being most sensitive at the higher frequencies. These discrepancies (illustrated on Plot 1.1) have been explained by Thomsen et al. (2006) and could be attributed simply to the natural intraspecific variation. Other reasons for the observed differences could include the differences in the methods employed in each study; behavioural studies could provide a more accurate response to auditory stimuli when compared to ABR/AEP that may provide a suprathreshold estimate from hearing at the low frequencies. The variations at the higher frequencies are thought to be either age related with the older specimens becoming less sensitive to auditory stimuli or simply owing to differences in background noise.

Plot 1.2: Audiograms for common and grey seals. Data obtained from Nedwell et al. (2004)





1.1.23 Plot 1.2 displays audiograms for the common seal and grey seal. They show common seals have a sensitivity between approximately 2kHz and 45kHz with an average hearing threshold of 69dBre1µPa over this range and the grey seal has an average hearing threshold of approximately 75dBre1µPa between frequencies of 5kHz and 50kHz. Data have been plotted showing hearing thresholds for grey seals in air and indicate hearing thresholds in this medium are higher within a frequency range of 0kHz to 40kHz.

1.1.24 Unlike cetaceans, pinnipeds spend a proportion of their time on land and as a result vocalise both in and out of the water. Sensitivity of the grey and common seal to airborne noise is thought to be similar to human sensitivity (Vella et al., 2001). As the frequency falls below 2kHz, the hearing-sensitivity of pinnipeds deteriorates (Richardson et al., 1995) however, it has been demonstrated by Kastak and Schusterman (1995 in Vella et al. (2001)) that common seals can sometimes perceive sound in air at frequencies as low as 100Hz with a source level of 96dB. Pinnipeds' hearing capabilities both in air and water have been reviewed by DoC (2008) who stated that the hearing range for this family is greatly reduced in air to 1kHz to 22kHz with sensitivity at 12kHz compared to 1kHz to 180kHz in water with peak sensitivity at around 32kHz.

1.1.25 Vella et al. (2001) research on common seals carried out at an on-shore wind farms found that airborne noise frequency ranged between 500Hz and 2kHz with source levels of 90-100dB and so, at the base of the turbine, the perceived noise would only be 10-20dB above their lowest audible threshold. Studies on common seals are less conclusive than harbour porpoises. Analysis of anecdotal evidence by Richardson et al. (1995) suggested a less negative impact of noise compared to harbour porpoises whereas Gordon et al. (2004, in Thomsen et al. (2006)) suggest they exhibit strong avoidance to noise from seismic air guns.

1.1.26 Vocalisations give a general idea of marine mammals' sensitivity to sound. It is expected that a species would have very sensitive hearing at the same frequencies as its communication clicks and echolocation calls.

1.1.27 Table 1.2 shows the frequencies used for communication and echolocation by cetaceans and the frequencies of communications used by grey and common seals that regularly occur in the Firth of Forth. All data have been cited in WDCS (2004) and Vella et al. (2001) and indicate a wide range of frequencies used, from ultrasonic frequencies in porpoises to the low frequencies used by baleen whales e.g. minke whales.

1.1.28 Table 1.2 and other studies on the harbour porpoise indicate that this species has a very wide range of hearing ability from <1kHz to 140kHz (Kastelein et al., 2002, in Thomsen et al., (2006)). Hearing thresholds are approximately 92 to 115dBrms (root-mean-square) re1µPa below 1kHz, 60 to 80dBrmsre1µPa from 1 to 8kHz and 32 to 46dBrmsre1µPa from 16 to 140kHz (Thomsen et al., 2006). The bottlenose dolphin would appear to be very similar.

1.1.29 The minke whale exists in good numbers in northwest European seas and is often observed in coastal regions including the Firth of Forth (Appendix A11.3: Detailed Estuarine Baseline Information) (Thomsen et al., 2006). Data on the hearing ability of the species is lacking, as with all other mysticetes. However, as with other whale species, minke whales produce sounds in the low frequency range (100 to 200Hz) and higher (up to 9kHz) (Richardson et al., 1995); (Gedamke et al., 2001, in Thomsen et al., 2006) and it is expected that their most efficient range of hearing is at low frequencies. Bowhead whales have exhibited avoidance when exposed to received sound levels between 122dB and 131dB; here they stopped feeding and moved to over 2km away from the sound source (Richardson et al., 1995).

Table 1.2: Summary of cetacean species found within the Firth of Forth and the frequencies used for communication (and echolocation in cetaceans). Data summarised by WDCS (2004) (cetaceans) and Vella et al. (2001) (pinnipeds)

Species and Communication	Frequency Range (kHz)
Harbour porpoise	
Clicks	2
Echolocation clicks	110-150
Bottlenose dolphin	
Whistles	0.8-24
Click	0.2-150
Bark	0.2-16
Low frequency calls	0.05-0.9
Echolocation clicks	110-130
Killer whale	
Whistles	1.5-1.8
Click	0.1-35
Scream	2
Pulsed calls	0.5-25
Echolocation clicks	12-25
White-beaked common dolphin	
Squeals	8-12
Whistles	3.4-16.4
Echolocation clicks	Up to 325
Short-beaked common dolphin	
Whistles	2-18
Chirps	8-14
Barks	< 0.5-3
Clicks	0.2-150
Minke whale	
Down sweeps	0.06-0.13
Moans, grunts	0.06-0.14
Ratchet	0.85-6
Sweeps and moans	0.06-0.14
Thump trains	0.1-2
Grey seal	
Clicks, hiss	0-30, 0-40
6 call types	0.1-5
Knocks	Up to 16
Common seal	
Social sounds	0.5- 3.5
Clicks	8-150
Roar	0.4-4
Bubbly growl	<1-4

Birds and Noise

1.1.30 The hearing range of birds is similar to that of humans, between 20 and 20,000Hz. There is no obvious consensus on the levels of sound which may cause disturbance to a range of bird species, with cited values ranging from 42dBA to 117dBA. Many studies quote dBA (A-weighted decibels) which are commonly used for the measurement of environmental and industrial noise as well as assessing potential hearing damage and other effects of noise. To provide some context, the levels in Table A1.3 can be compared with noise levels commonly encountered in daily life such as remote countryside on a still night (20dBA), a domestic fan heater at 1m (50dBA), an office or restaurant (60dBA) and a loud radio in a typical room (70dBA); sources of louder noise include heavy lorries at 5m (90dBA), a chain saw at 1m (110dBA) and a jet aircraft take-off at 110m (120dBA).

1.1.31 Disturbance responses of birds to noise are likely to vary between species and for a given species may depend on the levels of ambient noise in the environment they occupy and the extent to which noise levels are increased by a given activity. Species-specific thresholds of disturbance are likely to relate to differences in tolerance, spacing requirements and bioacoustic profiles. Activities which result in increases in noise levels above ambient noise may cause disturbance to birds. Overall, the evidence points to rapid and successful habituation to new noise sources but also to the fact that birds are more affected by startle than long-term, high noise levels. As well as mean ambient sound levels it is suggested that maximum sound levels are also a useful indicator of potential disturbance. Birds would be expected to respond to such disturbance by moving away from the noise source. If activities associated with the construction of the Main Crossing result in regular increases in ambient noise or more then there is the potential for adverse impacts.

1.1.32 The noise levels which potentially cause disturbance to birds are similar to thresholds set for people. In humans, hearing damage can begin with prolonged exposure of sounds of 85dBA (Bregman & Edell, 2001). Human noise limit targets are often based on recognised limits published many years ago in advisory documents such as DoE Advisory Leaflet (AL) 72 (1976). This recommends that daytime construction noise levels at the façades of noise sensitive receivers should not exceed 75dBLAeq,12h in urban areas near to main roads or in heavy industrial areas; or 70dBLAeq,12h in rural, suburban and urban areas away from road traffic and industrial noise; and noise limits should be 10dB(A) lower for the evening period.

1.1.33 Preliminary investigations of daytime ambient noise levels in the Firth of Forth found average levels of 69dBA on the north shore underneath the landfall of the Forth Road Bridge, approximately 250m north of Long Craig Island, and 58dBA at the western breakwater of Port Edgar Harbour, within about 200m of the tyre raft used by loafing and roosting terns. These exceed levels identified as potential sources of disturbance in some studies (Table 1.3). Ambient noise levels are likely to be lower at night.

Table 1.3: Summary of studies on the reactions of birds to noise disturbance

Bird Species	Disturbance noise level	Disturbance source/notes on impact	Reference
Waders	80dB	Sudden noise at around this level appears to elicit a flight response in waders up to 250m from source.	Environmental Agency stated for the Humber Estuary Tidal Defence Scheme (taken from the Poole Bridge AA (Anon, 2005)
	70dB	Noise at about this level causes flight or anxiety behaviour in some species.	
Black-tailed godwit Skylark Garganey	45dBA 42dBA 49dBA	Railway noise disturbance of meadow birds.	Waterman, et al. (2003)
Lapland longspur	6080dBA	This noise level at 620m from gas compressor station results in increased predation rates.	Gollop et al. (1974)
Waders	Lower abundance of breeding waders where noise levels that >56dB. This noise level apparently did not affect passerines.	Highway construction and traffic.	Hirvonen (2001)

Bird Species	Disturbance noise level	Disturbance source/notes on impact	Reference
Budgerigar Quail	112dB 70dB	Laboratory studies of noise impacts found that exposure to sounds at these levels resulted in temporary hearing loss for 12 hours.	Dooling (2005)
Brant geese	76dBA	Response of brant geese to aircraft disturbance , 51% of birds flew at noises exceeding this level.	Ward & Stehn (1989)
Canadian geese Tundra swans Spectacled eider Red throated diver	42-68dBA (Increase of 2.9dBA over baseline conditions)	Waterbird and noise monitoring programme. For all species these noise levels resulted in nest distribution further away from the source of noise.	Anderson et al. (1992)
Greater white-fronted geese	25 – 65dBA	Resulted in nest distribution further away from source.	Johnson et al. (2003)
Passerines	69 +/- 5dBA	No change in breeding density around high traffic density areas with these ambient noise levels.	Delaney et al. (2001)
Peregrines	85-117dBA	Low level jet resulted in alarm responses.	Ellis et al. (1991)
Northern goshawk	53.4dBA	Logging truck noise at this level within 500m resulted in no behavioural response.	Grubb et al. (1998)
Woodland species	50dBA	Noise at this level potentially deleterious to bird populations.	Reijnen et al (1997)

Noise Sources Relevant to the Main Crossing

1.1.34 A number of activities during the construction phase of the Main Crossing will result in increased noise levels in the surrounding waters of the Firth of Forth. The propagation of noise through the water will be dependent on the noise source whilst the detection of any particular noise will depend on the sensitivity of any given species and the audibility of the noise above background levels.

<u>Shipping and Dredging Noise</u>

1.1.35 Various sound levels have been documented for a number of shipping techniques and these are described in Table 1.4 below. Supertankers appear to produce the highest noise emissions reading between 185-190dBre1μPa at frequencies between 0.007 and 0.008kHz. Empty and loaded barges produce sound levels of between 145 and 170dBre1μPa within a frequency range of 1 to 5kHz.

Table 1.4: Noise levels of marine vessels (WDCS 2004)

Noise Source	dBre1μPa	kHz
Rigid inflatable	152	6.3
7m outboard motor boat	156	0.63
Fishing boat	151	0.25-1.0
Tug pulling empty barge	166	0.037
	164	1
	145	5
Tug pulling loaded barge	170	1
	161	5
34m (twin diesel engine) workboat	159	0.63
Tanker (135m)	159	0.43
Tanker (179m)	169	0.06
Supertanker (340m)	190	0.007

Noise Source	dBre1μPa	kHz
Supertanker (266m)	187	0.008
Supertanker (337m)	185	0.007
Containership (219m)	181	0.033
Containership (274m)	181	0.008
Freighter (135m)	172	0.041

1.1.36 Dredging can be a strong sound source with periods of continuous noise in near-shore regions emitting their highest levels at low frequencies. Although noise levels from dredges do not normally exceed ship noise, ships seldom produce strong noise in one area for a prolonged period of time (Richardson et al., 1995). The strongest underwater sounds from transfer dredges have been found to be at low frequencies; below approximately 300Hz (Green, 1985a and 1987b in Richardson et al. (1995). Sounds from clamshell dredges were variable; depending on status of operation it was found that winching the loaded clamshell onboard the barge produced levels from 150-162dBre1μPa and centred around 250Hz.

Piling Noise

1.1.37 Sound levels generated during piling operations are variable and depend on the method of piling, the frequency and duration. A report by Nedwell and Edwards (2002) summarised the sound levels produced during impact-piling and vibro-piling operations in the River Arun (Littlehampton) and Southampton Water (Southampton), England.

1.1.38 In the River Arun, vibro-piling produced underwater sound pressure levels of 132-152dBre1μPa at distances between 16m and 82m from the source (Nedwell and Edwards, 2002). The variation in sound pressure level could not be attributed to the distance from source, with readings of 151dBre1μPa being recorded at a distance of 80m. The variation in sound propagation was attributed to variations in soil/sediment density.

1.1.39 Underwater sound levels recorded during piling operations in Southampton Water (Nedwell et al., 2003a) ranged between 130-150dBre1μPa at a distance of 400m. Readings were taken when piling operations were in progress as well as when no works were taking place. It was evident from the measurements taken that the noise generated through piling operations was not discernible above background noise. Southampton Water is a busy shipping channel with constant ferry operations and therefore is subject to large background noise levels similar to those expected in the Firth of Forth.

1.1.40 Vagle (date unknown, in (David, 2006) investigated two drop hammer types used to drive 8” cedar and 20” steel piles into various underwater substrates. The 8” cedar pile driven with a one tonne drop hammer generated the highest sound levels. Table 1.5 below summarises the literature for noise levels generated through various types of piling. To date, no studies relating to TTS onset resulting from pile driving operations have been conducted for any cetacean species (DoC 2008).

Table 1.5: Examples of underwater sound level generated from various types of piling (Evans, 1999; Nedwell and Edwards, 2002; Nedwell et al., 2003a; Nedwell et al., 2003b; Vagle, 2003; Nedwell and Howell, 2004; Parvin and Nedwell, 2006)

	Type of piles	Diameter (inches)	dB re 1 µPa	Substrate	kHz (unless stated)	Additional information	Distance from hydrophone (m)	Transmission loss dB
Impact hammer	Cedar	8"	192	Mud and clay (layered)	1	Generate more low freq.		
	Steel	157"	262	Sand, gravel and clay		5m depth	1	
	Steel	157"	260	Sand, gravel and clay		10m depth	1	
	Steel	8"	192	Mud and clay (layered)	1	Generate higher freq.		
	Steel	12"	192	Gravel and sand				
	Steel	185"	252				1	
	Steel	157"	249				1	
	Steel	185"	249	Silt and sand banks			1	
Vibro drivers/ hammers			132-152		27Hz		1	
	Wind farm steel monopile foundations	157"	215				1	
Others/unknown drill type / pile			210-215			Source Emissions Level (SEL)		
			192-261			Linear peak Sound Pressure Level (SPL)		
			192				1	0.07
		20"	192	Clay and sand				
			125			Shallow water measurement s (6-7m)	130	
			86			Shallow water measurement s (6-7m)	480	
			115		10		5	
			118		20		5	
			128		15		5	
		3.5"	201				1	0.13
		2"	189				1	0.13
			145-191			Linear peak SPL		

1.1.41 Comparisons of two types of pile driving have produced estimates based on theoretical transmission loss within a homogenous environment. A six tonne diesel hammer is capable of masking weak 9kHz mammal vocalisations up to 40km away underwater and masking strong vocalisations within 10-15km. A 3.5t drop hammer only masks weak vocalisations within a 1.3km radius at 9kHz, 0.2km at 50kHz and 0km at 115kHz (David, 2006).

1.1.42 An investigation at a busy harbour port in Scotland produced background underwater noise levels of 118dB_{rms}re1µPa to 149dB_{rms}re1µPa over a bandwidth of 10Hz to 10 kHz. Percussive pile driving was used in this area and estimated source levels were 177-202dBre1µPa; this reduced to 162-168dBre1µPa more than 220m away from the pile driving activity (Hawkins, 2005).

1.1.43 Studies in Southampton Water were carried out on the impacts of noise generated from piling on caged brown trout (Nedwell et al., 2003a). Cages were placed at varying distances from piling operations and monitored for behavioural and physiological changes. At the end of the experiments trout were examined for gross physical injury resulting from pressure damage (swimbladder rupture, haemorrhaging) caused by the piling activity. Results showed no evidence of physical injury resulting from impact piling in any of the salmonids held in cages at distances between 20m to 400m (where the sound level would have been approximately 134dBre1µPa).

1.1.44 During the Southampton Water work, further analysis was undertaken to look at the possible impact on fisheries using the "dB_{ht}" metric. The dB_{ht} levels calculated indicated that the sound produced during impact piling was not greatly above the hearing threshold of salmon and trout within a few hundred metres of the operations, indicating that within Southampton Water the piling operations would have had no more than a small impact on the salmonids. The values in Table 1.6 show that the extinction point (when sound falls below the hearing threshold) would lie between 416 and 708m, depending on pile size and species with no background noise present. These can therefore be taken as a good indication of likely audible ranges for salmonids in the Firth of Forth, assuming the use of similar piling methods.

Table 1.6: Measured source levels in dBht(Species) and linear transmission loss from impact piling in Southampton Water (after Nedwell et al., 2003a)

Species	Pile diameter (mm)	Source level dBht (Species) @ 1m	Transmission loss dBht (Species) per 100 m	Extinction point (m)
Salmon (*Salmo salar*)	508	85.4	16	534
	914	85.0	12	708
Trout (*Salmo trutta*)	508	70.7	17	416
	914	62.0	9	688

1.1.45 In an assessment of an offshore windfarm construction, the ranges for audibility, responsiveness, 'masking' and TTS for pile-driving were estimated. It was argued that the effects of pile-driving would exceed any effects from increased shipping activity (Thomsen et al., 2006). It should be recognised that background noise at offshore sites will be far lower than that in a shipping port environment and therefore, effects of pile-driving noise will be relatively greater in comparison.

1.1.46 A review of the noise levels associated with the proposed scheme works was undertaken by Jacobs Arup noise team as part of the environmental impact assessment, this is summarised in Chapter 11 (Estuarine Ecology), paragraphs 11.4.13 to 11.4.16.

Blasting Noise

1.1.47 It has been well documented by Malme et al. (1989, in Richardson et al., 1995) that TNT explosions at a depth of 60m created source levels (in the broadband range of 45-7070Hz) ranging between 267-279dBre1µPa at one metre distance (amount of TNT ranging from 0.5kg to 20kg). Although, the proposed construction methods for the Main Crossing will not include the use of explosives at 60m depth, it gives an indication of the high source levels emitted for both small and large amounts of TNT.

1.1.48 Depending on blast approach and design, the noise generated from the excavation of Beamer Rock could pose a high risk of injury or mortality to marine life within a wide radius. This would be unacceptable and the design of an appropriate blast/ excavation method is considered in the mitigation section of this appendix.

Identification of Significant Potential Impacts Arising from Construction Noise

1.1.49 The following potential impacts from construction noise were identified as having a significant effect on the receptors mentioned. Full details of each assessment are provided in Chapter 11, Section 11.4 (Estuarine Ecology) of the ES:

- noise from the excavation of Beamer Rock on migratory and non-migratory fish, marine mammals and estuarine birds; and
- piling noise on migratory and non-migratory fish, marine mammals and estuarine birds.

Full Assessments of Insignificant Impacts Arising from Construction Noise

Benthic Habitats

1.1.50 Current knowledge suggests that decapod sensitivity to sound is poor compared to fishes (Popper et al., 2001). Despite this, it is possible that certain mobile, benthic fauna (e.g. crabs and lobsters) in the subtidal communities within the zone of responsiveness to piling and dredging, will migrate away from the noise source for the duration of construction operations. The distance of this movement will depend on the propagation of the sound from the construction site and the amount of disturbance caused to each species. The impact is predicted to be unlikely and therefore not significant and of negligible magnitude on species of local importance for the duration of construction. If any impact did occur, mobile benthic fauna would be expected to make a full recovery following cessation of construction activity.

1.1.51 The effects of underwater noise and vibration on the benthic intertidal infauna i.e. worms, bivalves and crustaceans (incapable of making long distance migrations), living in the zones that make up the Firth of Forth SPA are expected to be negligible and insignificant with any populations affected recovering soon after construction had ceased. Therefore the impact has been assessed as being of negligible magnitude on the intertidal areas of the Firth of Forth SPA of international importance.

Migratory and Non-Migratory Fish

1.1.52 The effects of underwater noise and vibration from dredging and shipping activities on migratory and non-migratory fish in the Firth of Forth SPA are expected to be negligible and insignificant. Impacts from this noise would be extremely unlikely to occur but if they should, they would cease immediately at the end of the construction period. Any impact has therefore been assessed as being of negligible magnitude on the fish populations of international and national importance.

Marine Mammals

1.1.53 Disturbance arising from general construction activity (e.g. increased vessel activity, workforce presence and associated construction machinery) will cause displacement of some pinnipeds. Owing to the high number of haul-out sites available in the Firth of Forth, this negative impact has been assessed as insignificant and of negligible magnitude on pinniped populations of international importance.

1.1.54 With respect to cetaceans, noise disturbance (from vessels, workforce and associated machinery) will also occur. Any cetaceans present around the construction area are expected to be displaced (i.e. move away from the area) or excluded during noisy periods but are expected to return following the cessation of noisy activities. This impact has been assessed as a negative but insignificant impact of negligible magnitude for cetacean populations occurring in the Firth of Forth.

1.1.55 The most likely impact of dredging activities on marine mammals will be through sound disturbance, local habitat modification and re-suspension of sediments and/or contaminants (the latter is dealt with under separate impacts of sedimentation and pollution). Dredging will be undertaken in the intertidal areas for the Main Crossing. It is expected to utilise heavy plant operating from a barge with an additional vessel moored alongside for carrying the extracted material. Utilisation of the heavy plant has yet to be confirmed and so noise sources from a variety of dredging vessels have been evaluated below.

1.1.56 Underwater noise from three dredging sources has been described by Richardson et al. (1995). Transfer dredges are moored or anchored ships that extend suction pipes to the seafloor and discharge onto a barge. A hopper dredge moves over the dredging site and once the hoppers are filled, moves to a discharge site to offload. Finally clamshell dredges pull up material and dispose of it onto a barge. According to Evans (2000) these dredging activities produce sounds varying from 172–185dBre1μPa at 1m over a range of 45Hz to 7kHz.

1.1.57 Maintenance dredging is a regular occurrence in the Firth of Forth and despite these activities marine mammals frequent all areas of the estuary. Pinnipeds exploit the Firth of Forth as a foraging ground and are known to become agitated by increased human activity and approaching vessels. It is anticipated that any pinnipeds present in the vicinity of dredging activity will alter their behavioural pattern and either avoid, or disperse from the immediate area.

1.1.58 Pinnipeds foraging in the water column within a few kilometres of dredging activity will be susceptible to noise and vibration emitted from the dredge. Although unlikely, occurrence of TTS/Permanent Threshold Shift (PTS) has been assessed as an insignificant, negative impact of low magnitude on pinniped populations of international importance. Should PTS occur in some individuals, the integrity of the Firth of Forth pinniped populations would not be affected.

1.1.59 Cetaceans are sighted frequently foraging in the Firth of Forth to within a few kilometres of the Forth Road Bridge and will be susceptible to the noise and vibration emitted from the dredge. Occurrence of TTS/PTS has been assessed as an insignificant, negative impact of low magnitude on cetaceans of international importance. Should PTS occur in some individuals, the integrity of the Firth of Forth cetacean populations would not be affected.

1.2 Vessel Movements

1.2.1 Table 1.7 describes the types of vessels that will be required in the Firth of Forth for the construction of the Main Crossing. Some vessels will be required for the duration of the development e.g. the crew boat and safety boat. Tugs, barges and cranes will be present for a several months, many of them carrying out several trips a day.

Table 1.7: Types of vessels and duration and frequency of use likely to be involved in the construction of the Main Crossing

Description of Vessel	Date of use		Duration of use (months)	Frequency of use
	Start	Finish		
Tug	04/12	06/12	2	4 trips per day
	01/12	06/12	6	4 trips per day
	07/12	08/12	1	1 trip
	08/12	10/12	2	2 trips
	05/12	08/13	15	52 return trips
	06/13	08/13	2	15 trips
	06/12	12/14	30	Assume 5 trips per day
	01/14	12/15	23	65 trips
	01/14	12/15	23	65 trips
	01/14	12/15	23	Assume 2 trips per day

Description of Vessel	Date of use		Duration of use (months)	Frequency of use
	Start	Finish		
Spilt hopper barge	04/12	06/12	2	4 trips per day
	06/13	08/13	2	15 trips
Clam shell dredger	01/12	06/12	6	Mob/demob
Crew boat	01/12	11/16	95	Continuous during working hours
Dump barges	01/12	06/12	6	4 trips per day
	01/12	06/12	6	4 trips per day
Safety boat	01/12	11/16	95	Continuous during working hours
Caisson	07/12	08/12	1	1 trips
	08/12	10/12	2	2 trips
Heavy lift crane (Rambiz)	06/12	06/13	12	Mob/demob +22 trips (20 days continuous working
Delivery barge (or tug and barge)	07/12	08/13	13	90 trips
	08/12	06/14	22	90 trips
Small floating crane	06/12	12/14	30	Attendance at site during working hours
	01/14	12/15	23	Attendance at site during working hours
Pontoon barge	01/14	12/15	23	65 trips
	01/14	12/15	23	65 trips
Large floating crane (Taklift 7)	TBA	TBA	TBA	2 visits for 3 weeks each visit
Small barge	06/12	12/14	30	Assume 5 trips per day
	01/14	12/15	23	Assume 2 trips per day

1.2.2 There are two prominent effects making marine mammals vulnerable to ship strike: the Lloyd Mirror Effect and acoustic shadowing (described in paragraph 1.1.6 above) that occur when a ship's propeller is above keel level (Gerstein et al., 2003). The combination of these effects together with attenuation by spherical spreading and masking can make it difficult for cetaceans to locate approaching ships.

1.2.3 A review of ship strikes on whales carried out by Jensen and Silber (2003) concluded that of the 134 cases reported in the USA, navy vessels and cargo/container vessels were the most likely vessels to be involved in marine mammal collisions. The mean speed of vessels when injury or mortality occurred was estimated at around 18.6 knots taken from 58 case studies. Large vessels often approach port at low speed and it has been suggested that this will reduce the risk of vessel strike. However, Gerstein et al. (2003) suggested that this mitigation is acoustically naïve as the reduction in audibility of approaching ships and the increase in transect time is likely to increase the risk of a marine mammal strike because of shadowing and masking. Injuries from collisions include lacerations, haemorrhaging and death (WDCS 2004).

1.2.4 The impacts of arising from increased vessel movements are not considered to be significant and are assessed in full below.

Full Assessments of Insignificant Impacts Arising from Increased Vessel Movements

1.2.5 The construction of the Main Crossing would result in a temporary increase in vessel traffic in the Firth of Forth and surrounding area owing to construction activities and the import/export of materials. The potential impacts of this increased activity on benthic habitats and marine mammals are assessed below.

Benthic Habitats

1.2.6 Increased vessel activity in the locality of the Main Crossing may displace benthic organisms through wash and/or anchor disturbance. Disturbance of this sort is likely to be limited to a small area surrounding the construction and is not expected to be significant. The impact from this disturbance has been assessed as being of negligible magnitude for subtidal benthic organisms. Consequently, the impact from vessel wash causing short periods of inundation on the Firth of Forth SPA intertidal habitats of international importance has also been assessed as being of negligible magnitude.

Marine Mammals

1.2.7 Other influences that interfere with a marine mammal's detection of underwater sound relate to the Lloyd Mirror Effect and acoustic shadowing (paragraph 1.1.6). Their overall effect is that where both source and receptor are close to the water surface the received sound level may be reduced, making it difficult for marine mammals to detect vessels and increasing the potential for vessel strike.

1.2.8 A survey commissioned by the Maritime and Coastguard Agency (MCA, 2003) in October 2003, estimated approximately 750 vessels per month passing by the Elie Ness Light both in and out bound from the Firth of Forth. Whilst this does not provide data on vessels travelling up to and beyond the location of the Main Crossing, it provides an indication of the volume of maritime traffic using the Firth of Forth.

1.2.9 The increase in construction and vessel activity in the vicinity of the Main Crossing is likely to deter marine mammals from the immediate area and thus reduce the risk of vessel strike. No data have been found on vessel strikes on marine mammals in the Firth of Forth and therefore the risk of strikes from the additional shipping in the outer Firth of Forth is considered low.

1.2.10 The increase in vessel traffic in the Firth of Forth (e.g. barges bringing material to and from site) will increase the collision risk to marine mammals, although the mammals are expected to avoid the area surrounding the construction of the Main Crossing.

1.2.11 An increase in shipping activity is certain to occur for the duration of the development and suggests an increased risk of vessel collision with marine mammals. The likelihood of vessels colliding with marine mammals depends on the size and how far/fast the vessel is travelling. However, most of the vessels involved with the construction operations will not be as large as many container/navy vessels (see information above), thus reducing the risk of vessel strike. Vessel strike has been assessed as being unlikely to occur. If vessel strike should occur, the negative impact on the integrity of the Firth of Forth cetacean population has been assessed as insignificant and of negligible magnitude.

1.2.12 For the internationally important pinniped populations of the Firth of Forth, the unlikely incidence of vessel strike has been assessed as an insignificant, negative impact of negligible magnitude that will have no lasting effects on the integrity of the populations. Owing to the uncertainty surrounding the amount of additional shipping in the Firth of Forth in terms of the Main Crossing, this impact may need to be reassessed at a later stage when the number of extra vessels per week is confirmed.

1.3 Severance to Juvenile Migration Routes

1.3.1 Certain activities associated with construction of the Main Crossing may affect migration of some juvenile fish species. The temporary intertidal causeway and the presence of bunds associated with piling and dredging will result in the fragmentation of juvenile migratory corridors. Species such as lamprey, plaice, eels and gobies utilise selective tidal stream transport (STST), riding favourable tides along high intertidal margins, and sitting out the reverse tide on the bottom or in the lea of structures. Any break in this system would impact on the recruitment success of these key species forcing individuals around the structures into deeper water, where there is an increased risk of predation and loss of orientation to the bed.

1.3.2 The impacts of this are not considered to be significant and are assessed in full below.

Full Assessments of Insignificant Impacts Arising from Severance to Juvenile Migration Routes

Migratory and Non-Migratory Fish

1.3.3 Potential for severance of juvenile fish migration routes would be concentrated around the proposed, temporary, intertidal causeway situated on the southern shore and will remain for the duration of the presence of the structure. Any obstruction across the upper intertidal zone would have a potentially negative effect on juvenile migrations although it is unlikely to cause outright prevention. Severance of fish migration routes has been assessed as an insignificant impact of negligible magnitude on species of international or national importance. Removal of the temporary causeways following construction will fully re-open the migration routes. Consequently, the impact of a temporary causeway on the Teith SAC (designated for its salmon and lamprey populations) of international importance has also been assessed as an insignificant impact of negligible magnitude. This is discussed further in the Teith SAC Appropriate Assessment.

1.4 Habitat Loss

1.4.1 During construction, an area in excess of 4000m^2 of intertidal habitat will be lost temporarily on the south shore under the footprints of the pile caps and the earthwork bund associated with pier S6.

1.4.2 Pier S6 will be located in the rocky upper shore and although the natural rock habitat will be removed the concrete pier structures will represent suitable hard substrate for recolonisation by flora and fauna. Consequently, the permanent habitat loss associated with the construction of pier S6 will be approximately 130m^2.

1.4.3 Piers S3–S5 will be located on the mudflats directly upstream of Port Edgar. Following construction tidal movements will aid the re-establishment of the mudflats around the base of the piers resulting in a probable permanent loss of mudflat habitat in the region of 400m^2.

1.4.4 Hydrodynamic modelling (Hydrodynamic Impacts, Initial Assessment Report) predicted only one hotspot of increased water movement between Abercorn Point and Society Bank on the south shore of the Firth of Forth. Here it was predicted that an increase of 0.2ms^{-1} would occur at the bed for only two hours per tidal cycle. The model concluded that effects of the Main Crossing would result in no discernible changes in water movement and therefore also no changes in sediment movement patterns within the model domain (the Firth of Forth); therefore no further modelling was conducted and any impacts on bed sediment stability and scour are likely to be minimal.

1.4.5 Further temporary loss of intertidal habitat will be associated with the re-location of the sewage outfall and construction of earth bunds, coffer dams and the temporary causeway, although this is not quantifiable at this stage.

1.4.6 Where temporary habitat loss occurs, re-colonisation by flora and fauna from surrounding areas is predicted to be relatively rapid. In mobile, sedimentary habitats recovery of benthic communities following dredging has been shown to be as rapid as four weeks, although a time scale of up to one year is more likely in the Firth of Forth owing to the lower level of sediment mobility and the timescale for migration and recruitment (UKMarineSAC, 2008).

1.4.7 Areas of rocky intertidal habitat temporarily lost during construction will also be re-colonised relatively rapidly, although the development of a climax community may take several years and follow a well understood pattern of succession (see Hawkins and Jones, 1992). The success and extent of any developing communities may be influenced by the effects of tidal scour around the piers.

Identification of Significant Potential Impacts Arising from Habitat Loss

1.4.8 The potential impacts from benthic habitat loss were identified as having a significant effect and full details of the assessment are provided in Chapter 11, Section 11.4 (Estuarine Ecology) of the ES.

Full Assessments of Insignificant Impacts Arising from Habitat Loss

Migratory and Non-Migratory Fish

1.4.9 The importance of intertidal areas for fish has only recently been documented and assigning a value to these areas is difficult using scientific literature. However, Elliott and Taylor (1989) reported intertidal habitats in the Firth of Forth were nearly twice as productive as their subtidal equivalents. Intertidal habitats are important for the juvenile life stages of many resident and migrating fish species, providing feeding grounds and migratory routes in relative safety from predation.

1.4.10 Habitat loss on the south bank will be concentrated on the intertidal mudflats close to Port Edgar. The temporary loss predicted during construction will be at least 2400m^2, owing to the width of the construction corridor, which includes the causeway, earth bund and pier structures discussed in Chapter 4 (The Proposed Scheme).

1.4.11 Fisheries data collected during baseline surveys (see Appendix A11.3: Detailed Estuarine Baseline Information) indicates that intertidal habitats on the north shore near St. Margaret's Marsh are potential nursery areas for plaice. Both the north and south shore are likely to be nursery areas for many species.

1.4.12 The total temporary loss of 0.0024km^2 that will occur as a result of construction activity represents less than 0.01% of available intertidal area of the Firth of Forth. Much of this intertidal habitat loss will be returned following construction. Therefore the impact of temporary habitat loss has been assessed as insignificant and of negligible magnitude on migratory and non-migratory fish species.

1.4.13 The construction of subtidal towers, intertidal piers and construction platforms/causeways will result in the temporary and permanent loss of subtidal habitat for marine fish. Any reduction in the available habitats could have negative effects on feeding, spawning and predator avoidance functions of juvenile, marine fish. Owing to the small proportion of subtidal habitat expected to be lost during the construction phase, the impacts on migratory and non-migratory fish utilising the subtidal zone have been assessed as insignificant and of negligible magnitude.

Mammals

1.4.14 Permanent intertidal and subtidal habitat loss that will occur as a result of the Main Crossing construction has been assessed as an insignificant impact of negligible magnitude on pinniped populations of international importance. The loss of habitat is not considered significant owing to the small areas involved relative to the entire estuary.

1.4.15 Temporary intertidal habitat loss that will occur during the construction phase has been assessed as an insignificant impact of negligible magnitude on the internationally important pinniped populations. The loss of habitat is not considered significant owing to the small areas involved that will be made available for use once again following the construction period.

1.4.16 Cetaceans occupy the subtidal area. Permanent habitat loss has been assessed as an insignificant impact of negligible magnitude on cetacean populations of international importance.

1.4.17 At present, pinnipeds utilise Beamer Rock as a haul-out site at low water. Both common and grey seals have been recorded hauled-out on Beamer Rock throughout the survey season.

1.4.18 The presence of workers, shipping vessels, construction machinery and subsequent material excavation is certain to cause displacement of pinnipeds that utilise Beamer Rock as a haul-out site; this is recurring and likely to continue for the duration of construction. Pinnipeds will therefore be required to find alternative habitats on which to haul-out to regulate their body temperature and rest (DoC, 2008).

1.4.19 Construction of the footings for the central tower will involve the loss of 700m² of intertidal rocky habitat on Beamer Rock. Although much of this habitat will be reconstructed following construction an area of 174m² of habitat available for haul-out of pinnipeds at low-tide will be permanently lost under the footprint of the tower.

1.4.20 The permanent and temporary habitat losses on Beamer Rock that will occur during construction of the Main Crossing have been assessed as an insignificant impact of low magnitude on the pinniped populations of international importance.

Estuarine Birds

1.4.21 Habitat loss resulting from clearance of suitable nesting habitat is unlikely to result in direct mortality of adults and/or fledged young since they are able to escape by moving into unaffected adjacent habitats. In addition to this, the proposed loss of intertidal habitat is less than 1% of available habitat within the intertidal zone of the Firth of Forth.

1.4.22 The total amount of intertidal estuarine land-take (which corresponds to permanent habitat loss) required in order to construct the Main Crossing is 950m^2.

1.4.23 The impact of habitat loss on estuarine birds has therefore been assessed as insignificant.

1.5 Habitat Gain

1.5.1 Although there will be a net loss in naturally occurring habitats it must be considered that the surfaces of the piers and towers will provide suitable substrate for colonisation by epilittoral flora and fauna. Such colonisation will be predominantly in the zone between the low and high water mark. Some colonisation will occur within the shallow infralittoral, although subtidally the development of communities will be limited by turbidity. The success of any colonization and the extent of any communities will also be limited by the effects of scour (paragraph 1.4.4) and associated abrasive action of suspended sediments.

1.5.2 With a tidal range varying between 2.5m on neap tides to 5m springs in this part of the Firth of Forth, the total available area of hard substrate represented by bridge structures would be in excess of 1500m^2.

1.5.3 The impacts of this are not considered to be significant and are assessed in full below.

Full Assessment of Insignificant Impacts Arising from Habitat Gain

1.5.4 Although the extent of created habitat is greater than that lost both from the intertidal and subtidal combined, the area is very small and insignificant in relation to natural hard substrate in the Firth of Forth. Therefore the net habitat gain that will occur has been assessed as insignificant and of negligible magnitude on all receptors.

1.6 Airborne Contamination

1.6.1 Activities that have the potential to cause airborne pollutants include blasting and onshore construction activities such as the use of heavy construction machinery and vehicles, close to habitats utilised by estuarine birds. In addition sandblasting of the bridge structure and spray painting of the structure will introduce toxic material into the air which may cause reproductive failure or mortality on estuarine birds.

Full Assessment of Insignificant Impacts Arising from Airborne Contamination

1.6.2 The release of airborne pollutants could result in a negative impacts however is considered insignificant. Any impact would be short-term and is considered of low magnitude.

1.7 Release of Sediment-Bound Contamination

1.7.1 The degree of impact of pollutants on the estuarine communities would be dependant on the frequency, duration, source and pollution type. Pollutant effects on the benthic habitats, fisheries, marine mammals and bird populations are discussed below.

1.7.2 Factors impacting on estuarine populations can be separated into two categories:

- disturbance i.e. where animals are physically destroyed (lethal effects) or removed/driven out from the area in response to a pollutant (sub-lethal); and
- stress i.e. where the productivity of an individual is reduced (sub-lethal effects) (Gray, 1979).

1.7.3 These two factors can be seen in the time-related sequence of effects listed by Blackstock (1984). Following detection of pollutants by its sensory receptors, the initial responses of an organism to the pollutants are behavioural and metabolic. Mobile fauna (e.g. crustaceans, fishes, mammals and birds) may simply migrate away from the affected area, while the response of sessile, sediment-bound animals unable to use the escape response (e.g. anemones or worms) will be hormone-controlled, metabolic changes designed to aid their survival.

1.7.4 In some instances, metabolic equilibrium might be restored, showing acclimatisation, or individuals might be genetically adapted to survive in the conditions, indicating adaptation (i.e. sub-lethal effects). Conversely, the impact may cause serious impairment of normal functions (e.g. feeding, reproduction) and subsequent death, leading to changes in populations and community structure (i.e. lethal effects).

1.7.5 Construction activities such as those from piling and dredging or the re-location of the sewage outfall will result in the re-suspension of sedimentary material. Depending on the quantity of sediment re-suspended, it could be carried over appreciable distances before depositing out. The additional vessels involved in construction and operating in shallow water might also disturb sediments.

1.7.6 Sediments act as sinks for many pollutants and the process of re-suspension and re-distribution of sediments will result in the re-distribution of their associated contaminants; this might have subsequent impacts for the receiving benthic environments. The distance over which material will be deposited will be related to current speed, water depth and the settling velocity of suspended particulates.

1.7.7 Historical studies have demonstrated that sediments in the Firth of Forth are contaminated by a wide range of materials, particularly metals and hydrocarbons; both originating from a wide range of current and historical sources. However, results of the baseline study (Appendix A11.3: Detailed Estuarine Baseline Information) indicate that the vast majority of the sediment-bound contaminant levels in the immediate vicinity of the Main Crossing are below the limits predicted as likely to impact sediment dwelling fauna. Similarly, contaminant concentrations are below the limits governing disposal of dredged material at sea.

1.7.8 Sediment chemical analysis has shown the contaminant concentrations around the Forth Road Bridge to be some of the lowest compared with other major UK estuaries (Chapter 11: Estuarine Ecology, Table 11.3). Only mercury exceeded the Probable Effects Limit (PEL) at six sites (two in the vicinity of the Main Crossing) and nickel at one site (away from the Main Crossing). The PEL represents the concentration threshold of a substance above which adverse impacts on aquatic organisms are expected to occur frequently.

1.7.9 Soil leachate tests on sediment samples collected as part of a ground investigation study within the vicinity of the Main Crossing found leachate concentrations to exceed the relevant saline waters Environmental Quality Standards (EQS) for ammoniacal nitrogen, copper, chromium and lead (Chapter 8: Geology, Contaminated Land and Groundwater). The resuspension of such sediments during construction of the Main Crossing could adversely affect the water quality of the Firth of Forth. The leachate analysis was based on a one stage test with a liquid to solid ratio of 2:1. Dredging will resuspend sediments into the water column at a much higher liquid (estuarine water) to solid ratio of those used in the leachate test resulting in substantial dilution. The contact time between the sediments and the liquid will be less than that used in the leachate tests, subsequently the partitioning of contaminants from the solid to aqueous phase will be significantly reduced compared to that of the leachate test. It should also be noted that the release of such contaminants would be of a transient nature, only occurring during each dredging activity with rapid deposition back to the bed; therefore it is highly unlikely that contaminant concentrations in estuarine waters would be elevated above baseline for appreciable periods. The relevant saline waters EQS are based on an annual average concentration and therefore estuarine waters within the vicinity of the Main Crossing are not expected to exceed the relevant EQS as a result of sediment resuspension.

1.7.10 Sediment transport was modelled (Chapter 9: Water Environment) and showed that the spread of sediments released from piling and dredging activities above background levels in the Firth of Forth would be restricted to within a few hundred metres of construction activities, therefore restricting the spread of any contaminants released. Tidal action will also disperse and dilute any contaminants, reducing any possible adverse effects.

Identification of Significant Potential Impacts Arising from Release of Sediment-Bound Contamination

1.7.11 Release of sediment-bound contamination has been assessed as potentially having a significant impact on estuarine birds and is detailed in full in Chapter 11 (Estuarine Ecology).

Full Assessment of Insignificant Impacts Arising from Release of Sediment-Bound Contamination

<u>Benthic Habitats</u>

1.7.12 Given the generally low sediment contaminant concentrations, the re-distribution of sediments and their associated contaminants is unlikely to impact significantly on the receiving intertidal and subtidal benthic environments. The impact of the probable release of sediment-bound contaminants on the estuarine benthic communities has been assessed as a negative impact of negligible magnitude.

1.7.13 The re-suspension of sediments has the potential to release nutrients into the water column. High levels of nutrients can lead to algal blooms and an associated drop in levels of dissolved oxygen. Such conditions may spread throughout the water column, affecting the benthos. In addition, benthic conditions may be worsened as dead algae fall through the water column and decompose on the sea floor.

1.7.14 The rapid dispersal of nutrients combined with dilution by tidal action and intermittent release will minimise the likelihood of algal blooms. Any potential impact would be short-lived and an ecological balance would return quickly. Therefore the impact from nutrient release with re-suspended sediments in both the intertidal and subtidal zones has been assessed as an insignificant, negative impact of negligible magnitude.

Fish

1.7.15 Given the current knowledge of the low contaminant concentrations in the surface sediments, the likelihood of significant degradation of water quality is low and therefore any impact on inter- and subtidal fish communities and marine mammals would also be low. In addition re-suspended material will disperse from the construction area through tidal action before re-settlement. The re-suspension of contaminants from sediments is probable although owing to the low concentrations present, the effects are not expected to be detectable or lasting. The negative impacts of the release of contaminants have been assessed as insignificant and of negligible magnitude on migratory and non-migratory fish.

Marine Mammals

1.7.16 Whilst the re-suspension of contaminants from sediments is probable, any negative impacts on marine mammals (pinnipeds and cetaceans) have been assessed as insignificant and of negligible magnitude.

1.8 Chemical Spills from Construction Activities

1.8.1 Should chemical spills occur during construction, the impacts have the potential to be significant for all receptors except cetaceans depending on the nature of the spill. The full assessment for benthic habitats, migratory and non-migratory fish, marine mammals and estuarine birds are detailed in Chapter 11 (Estuarine Ecology) of the ES.

Full Assessment of Insignificant Impacts Arising from Accidental Chemical Spills

Marine Mammals

1.8.2 Owing to the mobility of cetaceans and the vast foraging areas the predicted impacts from a chemical spills is predicted as unlikely, and of low magnitude on species of international importance.

1.9 Sediment Loading and Changes in Sedimentation

1.9.1 Increased turbidity will reduce the level of light penetration and affect the productivity of benthic algae. However, the waters of the Firth of Forth are naturally turbid which will limit the photosynthesis of submerged plants. Consequently, the majority of marine plants in the vicinity of the main crossing are limited to the intertidal areas.

1.9.2 Background turbidity levels in the estuary range between 0-500mgl^{-1} (SEPA, 2000; Appendix A9.1: Hydrodynamic Modelling) and are moderately high principally as a result of strong tidal currents (peak of 0.75ms^{-1} over the intertidal zones). The turbidity of the estuary is determined at any particular time on the tidal state, wind and freshwater input. Turbidity is highest on spring tides when water movement is greatest (SEPA, 2000). Turbidity measurements made in April 1999 demonstrated the area of highest turbidity to be between Alloa and Bo'ness immediately upstream of the freshwater/saltwater interface (SEPA, 2000). Increased fluvial input pushes the turbidity maximum downstream, reducing turbidity upstream. Despite the high concentrations further upstream, turbidity at the Forth Road Bridge was recorded up to 100mgl^{-1}; a concentration still recognised as being high.

1.9.3 A 3D hydrodynamic model was used to predict changes in flow hydrodynamics at the seabed within the area of the Main Crossing. Three scenarios were assessed, the first being existing conditions (baseline), the second being a temporary works condition (construction phase) where all temporary works activities were compressed into a single stage, and a permanent works condition (operational phase) where all bridge structures are in place as per the finalised project. Results from this modelling demonstrate that changes in sea bed current speed will change little during the construction or operational phases from that of baseline conditions with only slight increases and decreases (on average ± 0.05m/s) over very limited spatial and temporal scales (Appendix 9.1: Hydrodynamic Modelling). Based on these predictions it is concluded that effects would be negligible and there would be no discernable changes in sediment movement patterns within the Firth of Forth as a consequence of the Main Crossing.

1.9.4 Studies conducted in relation to dredging activities at Port Edgar indicate that related increases above background turbidity were not measurable six weeks after dredging ceased (Cefas, 2003). Such short-term rises in turbidity are unlikely to inhibit algal production significantly as the dominant algae present (i.e. fucoids and *Ascophyllum* sp.) are relatively tolerant of short term rises in turbidity and are able to photosynthesise during periods of emersion (MarLIN, 2001).

1.9.5 Piling and dredging activities will release particulate material into the water column which will increase the suspended sediment load and turbidity. Movements of vessels in shallow waters may also disturb sediments through wash effects and/or anchor drag. The main impacts from increased turbidity on benthic habitats will be reduced light penetration and smothering.

1.9.6 Material re-suspended by piling and dredging activities will ultimately sink back to the seafloor, although where this occurs will be related to water currents, depth and settling velocity. The amount of material likely to be released by construction activities has been modelled (Appendix A9.1: Hydrodynamic Modelling). Within approximately 200-400m (depending on the tidal state) of the piling activities on the south shore, re-suspended sediment concentrations are predicted to be highest; possibly as high as $1000mgl^{-1}$. Beyond this distance, the model predicts that elevated concentrations below $300mgl^{-1}$ will only be detectable on the south shore towards Society Bank in the west and crossing over Port Edgar to the SSSI/SPA/RAMSAR site on its east as far as the Forth Rail Bridge. These concentrations are not considered to be potentially damaging to the receiving environment and will be temporary and intermittent. Consequently, only small amounts of material are likely to be deposited in any given area. The modelling (Appendix A9.1: Hydrodynamic Modelling) assumes that the dredge pockets would be dredged one at a time. If the Contractor proposes to use more than one dredging vessel to dredge two or more pockets on or near the same shore at the same time, he would be required to demonstrate to SEPA, SNH and Marine Scotland that there would be no additional impacts that could result in an overall significant impact from the dredging activities.

Identification of Significant Potential Impacts Arising from Sediment Loading and Changes in Sedimentation

1.9.7 No significant impacts were identified from changes in sediment loading or increases in sedimentation.

Full Assessment of Insignificant Impacts Arising from Sediment Loading and Changes in Sedimentation

Benthic Habitats

1.9.8 Re-settling of sediments can smother benthic organisms, possibly clogging and damaging feeding and breathing structures; effects are likely to be greater in areas of naturally low turbidity. The effects of smothering can lead to re-structuring of benthic communities with sensitive filter feeding taxa disappearing and being replaced by more tolerant deposit feeding species.

1.9.9 The environment of the lower Firth of Forth is subject to natural fluctuations in turbidity, often reaching high levels ($0\text{-}500mgl^{-1}$ (SEPA, 2000)). Therefore, benthic communities are dominated by organisms adapted to high levels of suspended solids and associated deposition of sediments. For instance, 90% of individuals identified from intertidal sediment communities are characterised as deposit feeders such as cirratulid, spionid and capitellid polychaetes and oligochaetes (Appendix 11.3: Detailed Estuarine Baseline Information Section 2: Marine Fish). Therefore, a small increase in the level of deposition is unlikely to impact significantly on the benthic communities recorded within the area of influence of the Main Crossing construction.

1.9.10 Based on the discussion above, it is considered that the deposition of re-suspended sediments will have a negative insignificant impact of negligible magnitude on the intertidal and subtidal estuarine benthic communities owing to the natural, high turbidity of the Firth of Forth. Only temporary periods of re-suspension of solids will occur and any communities affected would be expected to recover quickly. This assessment includes the intertidal areas of the Firth of Forth SPA of international importance.

Fish

1.9.11 A reduced visual range caused by increased suspended solids may affect the feeding ability of fish. Physiological effects may also occur, such as reduced gill function and younger fish are expected to be more susceptible to increased suspended solids. As discussed previously, the associated works will seek to minimise re-suspension of sediments during the temporary construction period. Baseline data presented in Appendix A11.3 (Detailed Estuarine Baseline Information, Section 3: Marine Mammals) show that nursery areas exist in the Firth of Forth, although no designated areas are listed. There is unlikely to be any increased transport of sediment owing to the predicted lack of change in hydrodynamic regime, thus limiting the area affected by increased sediment loads. Typical engineering design mitigation, discussed in Section 3 will help further reduce the extent of any impact on the fish communities mentioned above.

1.9.12 The impact on the non-migratory subtidal and intertidal fish communities from the sediment release that will occur has been assessed as an insignificant, negative impact of negligible magnitude owing to the temporary nature of the disturbance, low contaminant concentrations, dispersal by tidal movements and the natural turbidity levels of the estuarine waters. The fish inhabiting the Firth of Forth are already adapted to living in a turbid environment. Slight, temporary increases in suspended solid or contaminant concentrations are unlikely to cause any major adverse affects on the subtidal fish populations.

1.9.13 Migratory species already negotiate turbid waters further up the Firth of Forth at the freshwater/saltwater interface. Re-suspended sediments and contaminants from the Main Crossing construction will be localised and dispersed rapidly by tidal action, minimising any negative impacts. Activities that might cause an increase in suspended solids could be timed to occur outside key migratory periods and are discussed in the following section on mitigation. The impact of re-suspended sediments on migratory fish such as salmon, eel, trout and lamprey have been assessed as being insignificant of negligible magnitude. Any impacts that do occur will not be lasting and the turbidity levels will return to normal following cessation of the construction activities.

Marine Mammals

1.9.14 Marine mammals are known to inhabit or frequent waters of high turbidity (e.g. the Thames, Humber and Forth estuaries). The short periods of increased turbidity that will occur from construction activities are not expected to impact significantly on the local populations of pinnipeds or cetaceans in the Firth of Forth. The impact of re-suspended sediments on marine mammals has been assessed as being of negligible magnitude.

1.10 Light Pollution

1.10.1 No potential impacts are predicted from light pollution during the construction phase on the benthic habitats, migratory and non-migratory fisheries and marine mammals.

2 Potential Operational Impacts

2.1 Noise and Vibration

2.1.1 No potential impacts are predicted on benthic habitats, migratory and non-migratory fish or marine mammals from noise and vibration during the operational phase.

Full Assessment of Insignificant Impacts Arising from Noise and Vibration

Estuarine Birds

2.1.2 Research undertaken by Reijnen et al., (1995) and Reijnen and Foppen (1994) has shown that operational noise is a primary factor in altering the density of bird populations adjacent to roads and highways. This is not the case with all species, for example wading species, such as the common ringed plover have also been reported to occur in greater numbers near towns and road networks (Burton et al., 2002).

2.1.3 The likelihood and effect of an impact given the presence of the existing Forth Road Bridge combined with the continuing presence of estuarine birds has been assessed as an insignificant impact of low magnitude.

2.2 Light Pollution

2.2.1 Hill (1992 in English Nature, 1996) observed that seabirds were disorientated by street lights on cloudy nights and observed that redshank and oystercatchers were observed feeding within 50m of artificial lighting at night. Flocks of dunlin were observed roosting near to a large, flood-lit roundabout.

2.2.2 No potential impacts are predicted from the lights on the Main Crossing during the operational phase on the benthic habitats, migratory and non-migratory fisheries and marine mammals.

Full Assessment of Insignificant Impacts Arising from Light Pollution

Estuarine Birds

2.2.3 There is the potential for the lights on the Main Crossing and the subsequent lights from traffic to affect birds in flight. However, the present bridges all are lit at night and therefore in the context of the Main Crossing any impacts on estuarine birds are predicted to be insignificant and of negligible magnitude.

2.3 Severance to Migration

2.3.1 A study on four bridges in Hong Kong and Macau (Ove Arup, 2002) recorded no bird collisions during a four month period and demonstrated that flying birds avoided collision by gaining altitude or flying under the bridge.

2.3.2 A 2006 study showed that there was little evidence that the M4 Severn Road Bridge affected the feeding, distribution or roosting behaviour of wading birds (Mersey Gateway Project, 2008). This is of particular interest since the Severn Estuary is a site of international importance for wading birds and wildfowl and is classed as a SSSI, a SPA, a Ramsar site and as an Important Bird Area by Birdlife International. The authors carried out a literature review regarding the site and the crossing and found no evidence that the crossing was a current or future threat to the wading bird interest.

2.3.3 There did appear to be a short-term impact of the M4 Severn Road Bridge on curlew, dunlin and lapwing, as their flight paths were altered and the birds appeared to prefer to fly over the bridge. However, this effect was short-lived and the birds returned to their normal flying height.

2.3.4 Assessments at smaller developments in the UK have also suggested that bridges are not likely to cause problems for bird behaviour in the longer term. A report on mute swans and a potential new road suspension bridge over the River Thames indicated that the bridge would have only a temporary effect (WWT Wetlands Advisory Service, 2004). The report pointed out that the less visible the bridge or cables were, the more likely it would be that swans would fly into them. The authors concluded that careful bridge design would minimise collision, including ensuring that the bridge and construction equipment are clearly visible both day and night and during poor daylight conditions.

2.3.5 No potential impacts are predicted on benthic habitats, migratory and non-migratory fish or marine mammals from severance to migration during the operational phase.

Full Assessment of Insignificant Impacts Arising from Severance to Migration

<u>Estuarine Birds</u>

2.3.6 Operation of the Main Crossing is unlikely to result in any increased fragmentation/severance effects owing to the presence of the proposed scheme and the Forth Road and Forth Rail Bridges. Therefore any negative impact on estuarine birds has been assessed as insignificant and of low magnitude.

2.4 Road Surface Run-Off

2.4.1 Road surface water run-off for the Main Crossing will consist of 'through deck drainage' over subtidal areas and will be piped back to sustainable drainage systems (SUDS) over intertidal areas. This is in contrast to the 'through deck drainage' over the full length of the present Forth Road Bridge and therefore the Main Crossing will have a reduced the quantity of road surface run-off entering the Firth of Forth compared to that of the Forth Road Bridge. As traffic will be diverted from the Forth Road Bridge to the Main Crossing there will be a net reduction in the quantity of pollutants entering the Firth of Forth.

2.4.2 Road surface run-off during routine operation is likely to contain suspended solids, petroleum hydrocarbons, hydrocarbons, heavy metals (copper, zinc, cadmium, iron, lead and chromium) from exhaust emissions and de-icing agents, lubricants and detergents. Such inputs will be frequent and will constitute chronic inputs into the estuarine ecosystem. In addition to the chromic pollution, infrequent and acute inputs of materials could arise from accidental spills, the nature of which could vary considerably. Over subtidal areas some level of dispersion will occur as material falls from the Main Crossing, the extent of dispersion will be influenced by flow rates, height above the water and wind speed.

2.4.3 Necessary maintenance activities on bridges can also adversely affect water and sediment quality in the receiving waters beneath. Maintenance activities may include bridge painting, surface treatments and surface cleaning, substructure repairs, joint repairs, drainage structure repairs and pavement repair or repaving (TRB, 2002).

2.4.4 The impacts arising from road surface run-off are not considered to be significant and are assessed in full below.

Full Assessment of Insignificant Impacts Arising from Road-Surface Run-Off

<u>Benthic Habitats, Fish and Marine Mammals</u>

2.4.5 Below the low water mark, run-off will enter the water column directly for the duration of the Main Crossing operation. Where materials enter the water column they are likely to be diluted rapidly and dispersed. Although bed sediments represent the ultimate sink for any contaminants, material originating from the bridge will be distributed over a wide area. Consequently, any negative impacts on the subtidal benthic habitats, migratory and non-migratory fish and marine mammals have been assessed as insignificant and of negligible magnitude. The insignificance of these impacts is due to the high dilution rates afforded by local tidal movement.

2.4.6 Road surface run-off will not directly contact the intertidal zone and would reach intertidal areas following dilution and dispersion within the subtidal zone. Any negative impacts from this exposure have been assessed as insignificant and of negligible magnitude on the benthic habitats, fish and marine mammals.

3 Mitigation Measures

3.1.1 A number of generic and specific mitigation measures are proposed to prevent, reduce or offset the significant impacts identified in Chapter 11, Section 11.4. Generic mitigation measures are presented in Table 3.1 and specific mitigation measures are detailed in Table 3.2; these measures are then cross-referenced in the subsequent impact summary tables (Table 4.1 to Table 4.8). Chapter 23 (Schedule of Environmental Commitments) provides a further summary of the mitigation measures proposed in the ES. Details of proposed mitigation measures are also provided in the following Reports to Inform an Appropriate Assessment: the River Teith SAC; Firth of Forth SPA; and Forth Islands and Imperial Dock Lock SPAs.

3.1.2 During any construction works, appropriate legislation must be complied with and best practice techniques should be followed. They are considered standard practices which should be implemented with any works regardless of impact. These measures are included in the scheme's generic mitigation.

3.1.3 Specific mitigation measures have principally been applied to noise and vibration impacts during the construction phase of the Main Crossing. Of particular note are the impacts from works associated with the excavation of Beamer Rock. It should be noted that measures in respect to the re-location of the sewage outfall at Port Edgar have also been included.

3.1.4 Techniques should be used that minimise noise propagation for the excavation of Beamer Rock to reduce the impacts of construction noise on the marine fishes present in the area. If explosive techniques are used then prior to any blasting activities acoustic deterrents should be used to discourage as many fish as possible from the area. Acoustic deterrents work by emitting sound at appropriate levels and frequencies to cause fish to disperse from an area. As different fish species hear sound at different frequencies and have different tolerance thresholds, the acoustic deterrents can be used to target species of conservation importance such as salmonids as well as other species of commercial importance. Such measures are not always completely effective as some families such as the flatfishes often response to stimuli by burying themselves in the seabed as opposed to swimming away. Despite this, acoustic deterrents will be able to reduce the number of individuals and species affected by blasting noise.

3.1.5 If appropriate, bubble curtain technology could be used to attenuate sound emitted from blasting activities on Beamer Rock and / or piling activities. Bubble curtains have been used with mixed results and it has not always been easy to prove their efficiency. One study by Keevin et al. (1997, cited in Hastings and Popper, 2005) demonstrated that use of bubble curtains could significantly reduce the mortality of caged fish during explosive demolition of a dam on the Mississippi River. Studies of bubble curtain efficiency with respect to reducing the impacts of noise from pile driving have been harder to prove owing to practical difficulties with the work (Hastings and Popper, 2005). In some cases, bubble curtains have produced reductions of between 8dB and 20dB over a frequency range of 400Hz to 6,400Hz from pile-driving operations (David, 2006).

3.1.6 Piling activity should aim to either minimise noise or ensure noise emitted is at a frequency that will not result in significant impacts for marine fauna. The use of vibratory pile driving (termed 'vibro-piling') is a low noise alternative to impact piling and should be considered for use if appropriate.

3.1.7 For piling activities it is recommended that a 'soft-start' approach to pilling should be undertaken enabling all receptors (fishes and mammals) to flee the area prior to full operation (specific mitigation measure EE8 in Table 3.2). JNCC have produced Best Practice guidelines for piling activities and these should be adhered to if appropriate for the construction activities involved.

3.1.8 If applicable, the dBht (salmon) from both piling and blasting activity should not exceed the maximum tolerance exposure for this species across 50% of the river, thus enabling migrating salmon to pass the construction area. The remaining 50% would be permitted to experience levels above this, provided all other mitigation listed here is implemented. The figure of 50% is not a statutory requirement but is based on recommendations by the Environment Agency to protect migrating salmonids from noise emitted by piling works in Southampton Water.

3.1.9 Excavation in the intertidal zone would be best carried out during periods of low water to restrict the emission of underwater noise and reduce impacts on the species occupying this zone.

3.1.10 Compton et al. (2007), JNCC (2004) and JNCC (2009) state that observations for the presence of marine mammals should take place using passive acoustic monitoring techniques (PAM) (operated by trained personnel) and/or trained marine mammal observers (MMO) at least 30 minutes before operations commence and any mammals observed in pre defined mitigation zone (no less than 500m radius) should prevent operations from going ahead until such time as the marine mammals vacate the zone and are not sighted / detected for a further 20 minutes. PAM usually takes the form of hydrophones towed in a linear array behind a survey vessel. The advantage that PAM has over the traditional MMO is the reliability in areas of poor visibility or hours of darkness. However, PAM is not always as accurate as visual observations and so a combination of both PAM and MMO is most reliable. Measure EE9 in Table 3.2 advises use of PAM as appropriate.

3.1.11 Additional mitigation measures for marine mammals include setting up mitigation zones of no less than 500m radius around the noise source, the size of each mitigation zone will depend on the techniques used (specific mitigation measure EE9 in Table 3.2). The distance must be determined to be far enough away from the sound source to prevent TTS or PTS to marine mammals although behavioural disturbance and masking are likely to still extend out of this zone (Compton et al., 2007).

3.1.12 As mentioned above in paragraph 3.1.5, some reduction of pile driving noise has been achieved by surrounding piles with air bubble curtains; these can be generated by placing manifolds around the pile at seven metre intervals (specific mitigation measure EE8 in Table 3.2). Such measures have the ability to produce significant reductions of the impacts of pile driving on cetacean and pinniped species.

Table 3.1: Generic mitigation measures

Mitigation Item. No.	Project phase	Mitigation Type	Impact	Description of Generic Mitigation
EE1	Pre- & post Construction	Prevent/reduce	General construction impacts	• Pre- and post construction ecological surveys to be undertaken as appropriate prior to commencement of project works and during works in order to identify sensitive sites, vulnerable species and changes in environment. • During construction ecological surveys to be undertaken in order to establish level of significant impacts on ecological receptors are as expected. • Surveys include benthic biotope mapping of the foreshore, estuarine birds surveys and water quality monitoring including turbidity monitoring.
EE2	Construction	Prevent/reduce	General construction impacts	• Plant and personnel to be constrained to a defined working corridor thereby minimising damage and disturbance to ecological receptors. Measures include the use of barriers, fences etc.
EE3	Construction	Prevent/reduce	General construction impacts	• Suitable constructed access roads/bridges to be created on intertidal zone to limit activities in direct contract with habitat.
EE4	Construction	Prevent/reduce	General construction impacts	• Ecological Clerk of Works (ECoW) on site to monitor construction activities to ensure the effective implementation of the construction methodology plan and appropriate environmental safeguards.
EE5	Construction	Prevent/reduce	General construction impacts	• Adherence to an Environmental Management Programme (EMP) and Code of Construction Practice (CoCP) incorporating Best Practice. • Method statements will detail full construction methodologies and specific rules in order to prevent environmental contamination. Contractors are legally required to minimise any impacts on the environment by following a CoCP; such techniques can include: i. making use of barriers, gutters and netting to avoid spillage of solids and liquids to watercourses; ii. dust should be suppressed; iii. in-water construction techniques should aim to reduce and control the disturbance of bed sediments; iv. airborne and underwater noise levels should be minimised where possible to avoid disturbance to aquatic life; and v. environmental consent may have to be obtained from the Marine Consents Environmental Unit, and the Inspector of Fisheries should be kept informed regarding activities.
EE6	Construction	Prevent/reduce	General construction impacts	• Strict adherence to SEPA pollution prevention guidelines PPG1, PPG2, PPG5, PPG7, PPG8, PPG13, PPG21,and PPG26. • Stockpiling of chemicals/fuel and other materials should be only conducted away from the river, using appropriate containers situated on a bunded waterproof surface. The area should also be covered to avoid washout from rain. • The use of approved pollution prevention schemes (e.g. oil separators) should be installed to prevent potentially polluted surface water from flowing into the Firth of Forth. • Specific site construction Method Statements and Environment Management Plans are to be in place during construction. • All activities are to comply with Water Environment (Controlled Activities) (Scotland) Regulations 2005. • Inspections, water quality monitoring and maintenance of all erosion / discharge controls to be undertaken weekly. • Positive rehabilitation of exposed areas throughout the construction period as soon as possible after work completed.

Table 3.2: Specific mitigation measures

Mitigation Ref. No.	Project phase	Mitigation Type	Impact	Description of Specific Mitigation
EE7	Construction	Prevent/reduce	Disturbance from blasting activities – noise and vibration	• Consider undertaking explosive excavation in intertidal zones during low water periods to restrict underwater noise (i.e. when area is exposed). • Consider undertaking explosive excavation within Beamer Rock so that edges of the Rock act as noise buffers reducing emissions to water. • Incorporation of non-explosive techniques for fracturing rock, where constructionally effective. • Use acoustic deterrents at appropriate frequency during key construction periods and bubble curtains if appropriate, to attenuate sound waves. An equipment maintenance programme will be required. • Use a string of explosions milliseconds apart to reduce the peak emission rather than one explosion that will reach a higher peak emission (JNCC, 2008). • The dBht (salmon) should not exceed the maximum tolerance exposure for this species across 50% of the river, thus enabling migrating salmon to pass the construction area. The remaining 50% would be permitted to experience levels above this, provided all other mitigation listed here is implemented.
EE8	Construction	Prevent/reduce	Disturbance from pilling activities – noise and vibration	• Use acoustic deterrents at appropriate frequency during key construction periods and bubble curtains if appropriate, to attenuate sound waves. An equipment maintenance programme will be required. • Soft-start approach or ramp-up approach to piling to allow any receptors in the vicinity to leave the area, procedure to follow JNCC guidelines (JNCC, 2009). • Piling methods should be used that produce either minimal noise or are of a suitable frequency. The use of vibratory pile driving (termed 'vibro-piling') is a low noise alternative to impact piling. Vibro-pile drivers apply a rapidly alternating force to the pile to drive it into the ground. • Best practice piling procedures to be followed with guidance taken from JNCC procedures (JNCC, 2009).
EE9	Construction	Prevent/reduce	Disturbance – noise and vibration	• A trained Marine Mammal Observer (MMO) to be incorporated into the role of ECoW and to be present during blasting/piling to enforce a marine mammal mitigation zone. The mitigation zone will be set dependant on the predicted/measured noise levels but be no smaller than 500m radius from the pile head/detonation site and the MMO should follow JNCC guidance on minimising the risk of disturbance and injury to marine mammals (JNCC, 2008 and JNCC, 2009). • Passive Acoustic Monitoring (PAM) to be used by a trained operative to identify mammals within the mitigation zone prior to piling. Piling should not commence if marine mammals are detected within the mitigation zone or until 20 minutes after the last visual or acoustic detection. The PAM operative should follow JNCC guidance (JNCC, 2008 and JNCC, 2009). • Should marine mammals be detected within the mitigation zone during the soft-start, then piling should cease or reduce power until the mammal exits mitigation zone and there is no further detection for 20 minutes (JNCC, 2009).
EE10	Construction	Prevent/reduce	Disturbance from blasting activities – noise and vibration	• There will be no explosive blasting on Beamer Rock between 01 May and 15 August to avoid the risk of impacts on breeding terns on Long Craig Island.

Mitigation Ref. No.	Project phase	Mitigation Type	Impact	Description of Specific Mitigation
EE11	Construction	Prevent/reduce	Disturbance – noise and vibration	• Avoid noisy activities at night (between 1 hour before dusk and dawn) during the post-breeding/ passage period for terns (between 15 August and 31 October in a given year). Noisy activities are defined as any activity which results in an increase of ≥3dB(A) in the ambient noise level (dBLAeq) at the receptor site (in this case the tern roosting site at Port Edgar). • If avoidance of 'noisy' activities is not possible, Port Edgar and Long Craig Island should not be simultaneously impacted as one can be used as an alternative roost site if the other is disturbed. • The Contractor will employ a 'soft-start' to all noisy activities (see definition above). Each time the activity is started up after a period of inactivity, the noise levels will be gradually increased over a period of 30 minutes to allow birds (and other animals) relocate. This will apply year round. For the first seven days after the commencement of each noisy activity, the soft-start must be applied each time the machinery is stopped, even if this is only for very short periods. The duration of periods of inactivity requiring a soft start will be increased incrementally over this seven day period. Subject to assessment of bird responses to the activity, after seven days a soft start will only be required overnight or after an extended period of inactivity.
EE12	Construction	Prevent/reduce	Disturbance – noise and vibration	• Best practicable means must be made to maintain noise levels below 75 dBLAeq day and night: at: (i) Long Craig Island at all times of day and night during the tern breeding season (1 May until 15 August in a given year) and (ii) Long Craig Island and the Port Edgar tern roost site at night (between 1 hour before dusk and dawn) during the post-breeding/ passage period for terns (between 15 August and 31 October in a given year).
EE13	Construction	Prevent/reduce	Disturbance – noise and vibration	• Monitoring of noise levels from construction activities to be undertaken at Long Craig Island during the breeding season for terns (May to mid-August) and at Long Craig Island and Port Edgar tyre raft from 60 minutes before sunset until sunrise between mid-August and October. The ECoW will identify and assess the significance of these levels on the tern population. • Monitoring of bird responses to construction activities to be undertaken. Assessment of the significance of these activities on estuarine birds will be undertaken.
EE14	Construction	Prevent/reduce	Disturbance – noise and vibration	• Visual screens to be installed along the perimeter of the temporary trestle bridges on both shores to reduce the impact of construction activities on birds using adjacent areas of the Firth of Forth.
EE15	Construction	Prevent/reduce	Disturbance – noise and vibration	• For boats/barges transporting personnel and supplying materials for construction, Jacobs Arup (in consultation with SNH and the Harbour Master) will identify where construction boat traffic is not permitted so that the constructor can stipulate routes in consultation with the Harbour Master. The compliance of boats/barges to defined routes will be determined by ECoW. • No construction boat traffic including small water vessels to go within 100m of Long Craig Island (except in the case of an emergency). The compliance of boats/barges to defined routes will be determined by ECoW. • If in exceptional circumstances, encroachment within 100m of Long Craig Island is unavoidable, prior approval by an ECoW will be required and the ECoW will over see the specified activity.
EE16	Construction	Prevent/reduce	Disturbance – noise and vibration	• Dredging footprint to be reduced as much as practicable.

Mitigation Ref. No.	Project phase	Mitigation Type	Impact	Description of Specific Mitigation
EE17	Construction	Prevent/reduce	Light pollution	• Design of lighting arrangements to ensure minimal light spillage out with the boundary of the construction the sites and associated site compounds: compliance to be determined by ECoW. • Monitoring of construction site lighting to be undertaken at night by ECoW to identify any potential adverse impacts on birds. • If identified by ECoW, preventative measures (e.g. installation of shields) to be taken if any adverse impacts are detected.
EE18	Pre-construction	Prevent/reduce	Disturbance – noise and vibration	• Between 15 August and 31 October, works for the relocation of the sewage outfall will not take place at night-time (between 1 hour before dusk and 1 hour after dawn) and within 200m and in direct view of the Port Edgar floating tyre raft at night-time.
EE19	Pre-construction	Prevent/reduce	Introduction of non-native marine species.	• Vessels involved in the construction activities for the FRC should adhere to the industry recommended guidelines for preventing the introduction of non-native marine species. UKMarineSAC (2009) recommends that vessels comply with International Maritime Organisation guidance wherever possible, seek guidance from the local port authority regarding areas where ballast water uptake should be avoided (e.g. near sewage outfalls), encourage the exchange of ballast water in the open ocean, and discourage/prohibit the unnecessary discharge of ballast water in port and harbour areas.

4 Summary of Significant Impacts, Mitigation Measures and Residual Impacts

Table 4.1: Summary of significant impacts, mitigation measures and residual impacts for benthic habitats - Construction Phase

Ecological Receptor	Potential Impact	Characterisation of Impact (pre-mitigation)	Impact Significance (pre-mitigation)	Proposed Mitigation	Significance of Residual Impact (post-mitigation)
Background Information: Conservation Status - Firth of Forth SPA, Firth of Forth SSSI, Hopetoun Road Park SINC. **Legal Framework:** EU Habitats Directive.					
Benthic Habitats Key Attributes: Highly productive infaunal and epifaunal communities representing important food resource for resident and migratory bird populations.	Habitat Loss	Scale/Extent: Permanent loss of habitat. Effect: Direct negative. Reversibility: Irreversible. Frequency: Single event. Duration: Permanent. Likelihood of occurrence: Certain.	Significance: Significant. Impact Magnitude: Low.	EE2 EE3	Significance: Insignificant. Impact Magnitude: Low.
		Scale/Extent: Temporary loss of habitat. Effect: Direct negative. Reversibility: Reversible. Frequency: Single event. Duration: Short term. Likelihood of occurrence: Certain.	Significance: Significant. Impact Magnitude: Low.	EE2 EE3	Significance: Insignificant. Impact Magnitude: Low.
	Chemical Spills	Scale/Extent: Spillage of chemicals from construction activity into the subtidal environment. Effect: Indirect negative. Reversibility: Potentially irreversible. Frequency: Single event. Duration: Short term. Likelihood of occurrence: Unlikely.	Significance: Significant. Impact Magnitude: Medium.	EE4 EE5 EE6	Significance: Significant. Impact Magnitude: Low.

Ecological Receptor	Potential Impact	Characterisation of Impact (pre-mitigation)	Impact Significance (pre-mitigation)	Proposed Mitigation	Significance of Residual Impact (post-mitigation)
		Scale/Extent: Spillage of chemicals from construction activity onto the intertidal environment. Effect: Direct negative. Reversibility: Irreversible. Frequency: Single Event. Duration: Short term. Likelihood of occurrence: Unlikely.	Significance: Significant. Impact Magnitude: Medium.	EE4 EE5 EE6	Significance: Significant. Impact Magnitude: Low.
	Increased vessel movements	Scale/Extent: Introduction of non-native marine species. Effect: Direct/indirect negative Reversibility: Irreversible. Frequency: Single event. Duration: Permanent. Likelihood of occurrence: Unlikely	Significance: Significant. Impact Magnitude: Low.	EE19	Significance: Insignificant. Impact Magnitude: Low.

KEY:
Effect: direct or indirect effect / positive or negative
Reversibility: irreversible or reversible
Frequency: single event, recurring (many events over the duration) or constant
Duration: short term (<1 year), medium term (1-3 years), long term (>3 years) or permanent
Likelihood of occurrence: certain, near certain, probable, unlikely or extremely unlikely
Significance: significant / negative or positive or insignificant (at pertinent geographical scale)

Table 4.2: Summary of significant impacts, mitigation measures and residual impacts for benthic habitats - Operation Phase

Ecological Receptor	Potential Impact	Characterisation of Impact (pre-mitigation)	Impact Significance (pre-mitigation)	Proposed Mitigation	Significance of Residual Impact (post-mitigation)
Background Information: Conservation Status - Firth of Forth SPA, Firth of Forth SSSI, Hopetoun Road Park SINC **Legal Framework:** EU Habitats Directive					
Benthic Habitats Key Attributes: Highly productive infaunal and epifaunal communities representing important food resource for resident and migratory bird populations.	Spillage event	Scale/Extent: The biggest risk is posed by an accident on the bridge where large quantities of liquid are discharged, such as fuel, chemicals, fire fighters foam, food substances (milk etc). These pollutants may then run-off into the marine environment. Effect: Direct negative. Reversibility: Potentially irreversible. Frequency: Single event. Duration: Dependant on scale of pollutant. Likelihood of occurrence: Extremely unlikely.	Significance: Significant. Impact Magnitude: High.	EE6	Significance: Significant. Impact Magnitude: Low.
KEY: Effect: direct or indirect effect / positive or negative Reversibility: irreversible or reversible Frequency: single event, recurring (many events over the duration) or constant Duration: short term (<1 year), medium term (1-3 years), long term (>3 years) or permanent Likelihood of occurrence: certain, near certain, probable, unlikely or extremely unlikely Significance: significant / negative or positive or insignificant (at pertinent geographical scale)					

Table 4.3: Summary of significant impacts, mitigation measures and residual impacts for fisheries - Construction Phase

Ecological Receptor	Potential Impact	Characterisation of Impact (pre-mitigation)	Impact Significance (pre-mitigation)	Proposed Mitigation	Significance of Residual Impact (post-mitigation)
Background Information: Conservation Status - Various **Legal Framework:** Under the Conservation Regulations 1994 the proposed scheme must demonstrate no significant affect on the integrity of the River Teith SAC, therefore there must be no significant impact on the integrity of SAC fish species. Migratory fishes - Habitats Directive (Annex II) (sea and river lamprey) and UKBAP species (lamprey species and salmonids). The intertidal zone is designated as a SSSI and Ramsar at Long Rib, St. Margaret's Marsh, North Queensferry and Port Laing.					
Feature: Migratory fish in inter- and subtidal zones. Key Attributes: Including species of conservation concern such as salmon, trout, eel and lamprey and UKBAP species. Level of importance: International.	Chemical Spill	Scale/Extent: Spillage of chemicals from construction activities. Effect: Direct negative. Reversibility: Potentially irreversible. Frequency: Single event. Duration: Short term. Likelihood of occurrence: Unlikely.	Significance: Significant. Impact Magnitude: Medium.	EE4 EE5 EE6	Significance: Significant. Impact Magnitude: Low.
	Noise and Vibration	Scale/Extent: Excavation of Beamer Rock. Effect: Direct negative. Reversibility: Reversible. Frequency: Recurring. Duration: Short term. Likelihood of occurrence: Certain.	Significance: Significant. Impact Magnitude: High.	EE7	Significance: Significant. Impact Magnitude: Low.
		Scale/Extent: Piling operations. Effect: Direct negative. Reversibility: Reversible. Frequency: Recurring. Duration: Short term. Likelihood of occurrence: Certain.	Significance: Significant. Impact Magnitude: Low.	EE8	Significance: Insignificant. Impact Magnitude: Low.
	Increased vessel movements	Scale/Extent: Introduction of non-native marine species. Effect: Direct/indirect negative Reversibility: Irreversible. Frequency: Single event. Duration: Permanent. Likelihood of occurrence: Unlikely	Significance: Significant. Impact Magnitude: Low.	EE19	Significance: Insignificant. Impact Magnitude: Low.

Ecological Receptor	Potential Impact	Characterisation of Impact (pre-mitigation)	Impact Significance (pre-mitigation)	Proposed Mitigation	Significance of Residual Impact (post-mitigation)
Feature: Non-migratory fish in inter- and subtidal zones. UKBAP species, species of conservation concern and commercially important species. Level of importance: National.	Chemical Spill	Scale/Extent: Spillage of chemicals from construction activities. Effect: Direct negative. Reversibility: Potentially irreversible. Frequency: Single event. Duration: Short term. Likelihood of occurrence: Unlikely.	Significance: Significant Impact Magnitude: Medium	EE4 EE5 EE6	Significance: Significant. Impact Magnitude: Low.
	Noise and Vibration	Scale/Extent: Excavation of Beamer Rock. Effect: Direct negative. Reversibility: Reversible. Frequency: Recurring. Duration: Short term. Likelihood of occurrence: Certain.	Significance: Significant. Impact Magnitude: High.	EE7	Significance: Significant. Impact Magnitude: Low.
		Scale/Extent: Piling operations. Effect: Direct negative. Reversibility: Reversible. Frequency: Recurring. Duration: Short term. Likelihood of occurrence: Certain.	Significance: Significant. Impact Magnitude: Low.	EE8	Significance: Insignificant. Impact Magnitude: Low.
	Increased vessel movements	Scale/Extent: Introduction of non-native marine species. Effect: Direct/indirect negative Reversibility: Irreversible. Frequency: Single event. Duration: Permanent. Likelihood of occurrence: Unlikely	Significance: Significant. Impact Magnitude: Low.	EE19	Significance: Insignificant. Impact Magnitude: Low.

KEY:
Effect: direct or indirect effect / positive or negative
Reversibility: irreversible or reversible
Frequency: single event, recurring (many events over the duration) or constant
Duration: short term (<1 year), medium term (1-3 years), long term (>3 years) or permanent
Likelihood of occurrence: certain, near certain, probable, unlikely or extremely unlikely
Significance: significant / negative or positive or insignificant (at pertinent geographical scale)

Table 4.4: Summary of significant impacts, mitigation measures and residual impacts for fisheries - Operational Phase

Ecological Receptor	Potential Impact	Characterisation of Impact (pre-mitigation)	Impact Significance (pre-mitigation)	Proposed Mitigation	Significance of Residual Impact (post-mitigation)
Background Information: Conservation Status - Various **Legal Framework:** The Firth of Forth must continue to meet the requirements of the Water Framework Directive despite chromic input of road run-off.					
Feature: Migratory fish and non-migratory in inter- and subtidal zones.	Spillage Event	Scale/Extent: The biggest risk is posed by an accident on the bridge where large quantities of liquid are discharged, such as fuel, chemicals, fire fighters foam, food substances (milk etc). These pollutants are then may then run-off into the marine environment. Effect: Direct negative. Reversibility: Potentially irreversible. Frequency: Single event. Duration: Dependant on scale of pollutant. Likelihood of occurrence: Extremely unlikely.	Significance: Significant. Impact Magnitude: High.	EE6	Significance: Significant. Impact Magnitude: Low.
KEY: Effect: direct or indirect effect / positive or negative Reversibility: irreversible or reversible Frequency: single event, recurring (many events over the duration) or constant Duration: short term (<1 year), medium term (1-3 years), long term (>3 years) or permanent Likelihood of occurrence: certain, near certain, probable, unlikely or extremely unlikely Significance: significant / negative or positive or insignificant (at pertinent geographical scale)					

Table 4.5: Summary of significant impacts, mitigation measures and residual impacts for marine mammals - Construction Phase

Ecological Receptor	Potential Impact	Characterisation of Impact (pre-mitigation)	Impact Significance (pre-mitigation)	Proposed Mitigation	Significance of Residual Impact (post-mitigation)
Background Information: Conservation Status - Harbour porpoise and bottlenose dolphin - International, Other cetaceans - Regional , Grey seal – International and Common seal - National **Legal Framework:** EC Habitats Directive, Wildlife and Countryside Act, 1981, Bonn and Bern Convention, ASCOBANS, UKBAP, Conservation of Seal Act (1970) and The Conservation of Seals (Scotland) Order 2007 - Legal Implications: All cetacean and pinniped species found here are protected through the EC Habitats Directive and Wildlife and Countryside Act, 1981. The cetacean species recorded in the Firth of Forth have protection through Appendix II of the Bonn and Bern Convention and (with the exception of the minke whale) are listed on ASCOBANS. Both the bottlenose dolphin and the harbour porpoise are Annex II species; the harbour porpoise is protected under species action plan of the UKBAP. All other cetacean species found here are protected under group action plans (UKBAP, 2007). Grey and common seals are protected under the Conservation of Seal Act (1970) with closed seasons in operation during the breeding seasons (occurring between 1st July to 31st August for common seals and 1st September and 31st December for the grey seal populations). The Conservation of Seals (Scotland) Order 2007 provides additional year round protection for eastern common seal populations (Wild-Scotland 2007).					
Cetacean populations (International Importance)	Noise and vibration	Scale/Extent: Excavation of Beamer Rock causing TTS or PTS. Effect: Direct negative. Reversibility: Reversible. Frequency: Single event. Duration: Short term. Likelihood of Occurrence: Unlikely.	Significance: Significant. Impact Magnitude: Medium.	EE7 EE9	Significance: Insignificant. Impact Magnitude: Low.
		Scale/Extent: Piling operations causing TTS or PTS. Effect: Direct negative. Reversibility: Reversible. Frequency: Recurring. Duration: Medium term. Likelihood of Occurrence: Unlikely.	Significance: Significant. Impact Magnitude: Low.	EE8 EE9	Significance: Insignificant. Impact Magnitude: Low.
Pinniped populations (International Importance)	Noise and vibration	Scale/Extent: Excavation of Beamer Rock causing TTS or PTS. Effect: Direct negative. Reversibility: Reversible. Frequency: Single event. Duration: Short term. Likelihood of Occurrence: Unlikely.	Significance: Significant. Impact Magnitude: Medium.	EE7 EE9	Significance: Insignificant. Impact Magnitude: Low.
		Scale/Extent: Piling operations causing TTS or PTS. Effect: Direct negative. Reversibility: Reversible.	Significance: Significant. Impact Magnitude: Low.	EE8 EE9	Significance: Insignificant. Impact Magnitude: Low.

Ecological Receptor	Potential Impact	Characterisation of Impact (pre-mitigation)	Impact Significance (pre-mitigation)	Proposed Mitigation	Significance of Residual Impact (post-mitigation)
		Frequency: Recurring. Duration: Medium term. Likelihood of Occurrence: Unlikely.			
	Chemical Spill	Scale/Extent: Spillage of chemicals from construction activities. Effect: Direct negative. Reversibility: Potentially irreversible. Frequency: Single event. Duration: Short term. Likelihood of occurrence: Unlikely.	Significance: Significant. Impact Magnitude: Medium.	EE4 EE5 EE6	Significance: Significant. Impact Magnitude: Low.

KEY:
Effect: direct or indirect effect/positive or negative
Reversibility: irreversible or reversible
Frequency: single event, recurring or constant
Duration: short term (<1 year), medium term (1-3 years), long term (>3 years) or permanent
Likelihood of occurrence: certain, near certain, probable, unlikely or extremely unlikely
Significance: significant / negative or positive or insignificant (at pertinent geographical scale)

Table 4.6: Summary of significant impacts, mitigation measures and residual impacts for marine mammals - Operational Phase

Ecological Receptor	Potential Impact	Characterisation of Impact (pre-mitigation)	Impact Significance (pre-mitigation)	Proposed Mitigation	Characterisation/Significance of Residual Impact (post-mitigation)
Background Information: Conservation Status - Harbour porpoise and bottlenose dolphin - International, Other cetaceans - Regional , Grey seal – International and Common seal - National **Legal Framework:** EC Habitats Directive, Wildlife and Countryside Act, 1981, Bonn and Bern Convention, ASCOBANS, UKBAP, Conservation of Seal Act (1970) and The Conservation of Seals (Scotland) Order 2007 - Legal Implications: All cetacean and pinniped species found here are protected through the EC Habitats Directive and Wildlife and Countryside Act, 1981. The cetacean species recorded in the Firth of Forth have protection through Appendix II of the Bonn and Bern Convention and (with the exception of the minke whale) are listed on ASCOBANS. Both the bottlenose dolphin and the harbour porpoise are Annex II species; the harbour porpoise is protected under species action plan of the UKBAP. All other cetacean species found here are protected under group action plans (UKBAP, 2007). Grey and common seals are protected under the Conservation of Seal Act (1970) with closed seasons in operation during the breeding seasons (occurring between 1st July to 31st August for common seals and 1st September and 31st December for the grey seal populations). The Conservation of Seals (Scotland) Order 2007 provides additional year round protection for eastern common seal populations (Wild-Scotland 2007).					
Cetacean and pinniped populations. (International importance).	Spillage Event	Scale/Extent: The biggest risk is posed by an accident on the bridge where large quantities of liquid are discharged, such as fuel, chemicals, fire fighters foam, food substances (milk etc). These pollutants are then may then run-off into the marine environment. Effect: Direct negative. Reversibility: Potentially irreversible. Frequency: Single event. Duration: Dependant on scale of pollutant. Likelihood of occurrence: Extremely unlikely.	Significance: Significant. Impact Magnitude: High.	EE6	Significance: Significant. Impact Magnitude: Low.
KEY: Effect: direct or indirect effect/positive or negative Reversibility: irreversible or reversible Frequency: single event, recurring or constant Duration: short term (<1 year), medium term (1-3 years), long term (>3 years) or permanent Likelihood of occurrence: certain, near certain, probable, unlikely or extremely unlikely Significance: significant/negative or positive or insignificant (at pertinent geographical scale)					

Table 4.7: Summary of significant impacts, mitigation measures and residual impacts for estuarine birds - Construction Phase

Ecological Receptor	Potential Impact	Characterisation of Impact (pre-mitigation)	Impact Significance (pre-mitigation)	Proposed Mitigation	Characterisation / Significance of Residual Impact (post-mitigation)
Background Information: Conservation Status: Coastal Birds Assemblage - International, Breeding Tern Assemblage - International, Passage Migrant Assemblage - National. **Legal Framework:** EC Directive 79/409 , Wildlife and Countryside Act 1981 (as amended) and Nature Conservation Scotland Act (2004) - Legal Implications Under EC Directive 79/409 conservation of wild birds (Birds Directive), the Wildlife and Countryside Act (1981) and Nature Conservation Scotland Act (2004) make it an offence to intentionally or recklessly kill, injure or take any wild bird; take, damage or destroy the nest of any wild bird while it is in use or being built; take or destroy the egg of any wild bird; disturb any wild bird listed on Schedule 1 while it is nest building or is at (or near) a nest with eggs or young or disturb the dependent young of such a bird. Under EC Directive 79/409 conservation of wild birds (Birds Directive) and the Wildlife and Countryside Act (1981), it is an offence to cause disturbance at an area where Annex 1 and Schedule 1 species are known to be present.					
Coastal Bird, Breeding Terns and Passage Migrants Assemblages.	Noise and vibration	Scale/Extent: Disturbance resulting from noise and vibration generated during construction activities including the re-location of the sewage outfall at Port Edgar. Effect: Direct negative. Reversibility: Reversible. Frequency: Recurring. Duration: Short term. Likelihood of Occurrence: Certain.	Significance: Significant. Impact Magnitude: Low.	EE4 EE10 EE11 EE12 EE13 EE14 EE15 EE18	Significance: Insignificant. Impact Magnitude: Low.
	Release of sediment bound contamination	Scale/Extent: Release of sediment bound contaminants from dredging and piling activities. Effect: Indirect negative. Reversibility: Reversible. Frequency: Recurring. Duration: Short term. Likelihood of Occurrence: Unlikely.	Significance: Significant. Impact Magnitude: Low.	EE16	Significance: Insignificant. Impact Magnitude: Low.

Ecological Receptor	Potential Impact	Characterisation of Impact (pre-mitigation)	Impact Significance (pre-mitigation)	Proposed Mitigation	Characterisation / Significance of Residual Impact (post-mitigation)
	Chemical Spill	Scale/Extent: Spillage of chemicals from construction activities. Effect: Indirect negative. Reversibility: Potentially irreversible. Frequency: Recurring. Duration: Short term. Likelihood of Occurrence: Unlikely.	Significance: Significant. Impact Magnitude: High.	EE4 EE5 EE6	Significance: Significant. Impact Magnitude: Low.
	Light pollution	Scale/Extent: Light pollution from areas of temporary works. Effect: Direct negative. Reversibility: Irreversible. Frequency: Recurring. Duration: Short term. Likelihood of Occurrence: Unlikely. Significance: Significant.	Significance: Significant. Impact Magnitude: Low.	EE17	Significance: Insignificant. Impact Magnitude: Low.
KEY: Effect: direct or indirect effect / positive or negative Reversibility: irreversible or reversible Frequency: single event, recurring or constant Duration: short term (<1 year), medium term (1-3 years), long term (>3 years) or permanent Likelihood of occurrence: certain, near certain, probable, unlikely or extremely unlikely Significance: significant / negative or positive or insignificant (at pertinent geographical scale)					

Table 4.8: Summary of significant impacts, mitigation measures and residual impacts for estuarine birds - Operational Phase

Ecological Receptor	**Potential Impact**	**Characterisation of Impact (pre-mitigation)**	**Impact Significance (pre-mitigation)**	**Proposed Mitigation**	**Characterisation / Significance of Residual Impact (post-mitigation)**
Background Information: Conservation Status: Coastal Birds Assemblage - International, Breeding Tern Assemblage - International, Passage Migrant Assemblage - National. **Legal Framework:** EC Directive 79/409 , Wildlife and Countryside Act 1981 (as amended) and Nature Conservation Scotland Act (2004) - Legal Implications Under EC Directive 79/409 conservation of wild birds (Birds Directive), the Wildlife and Countryside Act (1981) and Nature Conservation Scotland Act (2004) make it an offence to intentionally or recklessly kill, injure or take any wild bird; take, damage or destroy the nest of any wild bird while it is in use or being built; take or destroy the egg of any wild bird; disturb any wild bird listed on Schedule 1 while it is nest building or is at (or near) a nest with eggs or young or disturb the dependent young of such a bird. Under EC Directive 79/409 conservation of wild birds (Birds Directive) and the Wildlife and Countryside Act (1981), it is an offence to cause disturbance at an area where Annex 1 and Schedule 1 species are known to be present.					
Coastal Bird, Breeding Terns and Passage Migrants Assemblages.	Spillage Event	Scale/Extent: The biggest risk is posed by an accident on the bridge where large quantities of liquid are discharged, such as fuel, chemicals, fire fighters foam, food substances (milk etc). These pollutants are then may then run-off into the marine environment. Effect: Direct negative. Reversibility: Potentially irreversible. Frequency: Single event. Duration: Dependant on scale of pollutant. Likelihood of occurrence: Extremely unlikely.	Significance: Significant. Impact Magnitude: High.	EE6	Significance: Insignificant. Impact Magnitude: Low.
KEY: Effect: direct or indirect effect / positive or negative Reversibility: irreversible or reversible Frequency: single event, recurring or constant Duration: short term (<1 year), medium term (1-3 years), long term (>3 years) or permanent Likelihood of occurrence: certain, near certain, probable, unlikely or extremely unlikely Significance: significant / negative or positive or insignificant (at pertinent geographical scale)					

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