23 February 2018

Note
Seagreen
Seagreen EIA Coordination
Underwater Noise Modelling Plan

Introduction

This Note describes the approach to underwater noise modelling for The Seagreen Project. The work is being undertaken to support impact assessments for marine mammals and fish in relation to the proposed use of monopile foundations for wind turbines, and updated assessment of jacket foundations pin pile installation previously considered in the 2012 Offshore Environmental Statement).

Marine Scotland[1] have previously agreed that modelled parameters for monopile foundations were appropriate and SNH[2] have approved positions for modelling monopile foundations. This Note also incorporates proposed updated modelling of jacket foundation installation to allow a coherent assessment to be completed for scenarios which could see a combination of jacket and monopile foundations used, or a jacket only solution to allow a re-assessment of the 2012 design envelope. For completeness, the Note summarises key assumptions for modelling including animal fleeing and injury/disturbance thresholds which have been discussed with stakeholders at meetings (marine mammal baseline update meeting, 5 February 2018).

Jacket foundations were the only piled option included in the previous assessment and remain a consented option for Seagreen. In order to comprehensively assess the potential impacts of wind farm construction on key receptors in the event that both monopiles and jackets are utilised it is necessary to remodel jacket pin pile installation to generate outputs that are comparable to modelling of monopile foundations. This will allow the overall effect of construction piling on marine mammal populations and fish as a result of jacket installation before or after mopile installation (Scenarios 5 & 6) or simultaneous monopile and jacket piling (Scenarios 7 & 8) to be evaluated. Modelling of jacket only piling will also support a re-assessment using latest best practice guidelines for marine mammals (NMFS, 2016) and fish (Popper *et al*., 2014).

The four scenarios (numbered 1-4) originally planned and consulted upon are set out below. Scenarios 5 and 6 assume that jackets are installed individually at Alpha and Bravo; 7 and 8 are for simultaneous piling of a monopile and jacket pin piles at Alpha and Bravo respectively. Scenario 9 was added to allow simultaneous jacket piling at Alpha and Bravo to be assessed. NB these noise modelling scenarios are different from wind farm 'Build Scenarios' listed in the marine mammal impact assessment (Chapter 10) of the ES.

[1] Email from Sophie Humphries, dated 1 February 2018. MS-LOT supported the submitted approach (Scenarios 1-4 in this Note) with the comments that outputs would be required before the sensitivity to alternative hammer energies could be evaluated and that an absolute worst case should be modelled.
[2] Email from Erica Knott, dated 21 December 2017. SNH agreed with the proposed pile locations for modelling (Scenarios 1-4 in this Note). Opinion on proposed engineering ramp up assumptions and outputs is awaited.

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Key output metrics of modelling for all scenarios are summarised in Table 1.

Table 1. Key output metrics for underwater noise modelling.

impact/metric	species/ threshold	notes
SELcum PTS range (NMFS weighted)	HF cet	Fleeing assumptions (m/s): harbour porpoise 1.4; bottlenose/white-beaked dolphin, 1.52; harbour/grey seal, 1.8; minke whale, 2.1
SELcum PTS range (NMFS weighted)	MF cet	
SELcum PTS range (NMFS weighted)	LF cet	
SELcum PTS range (NMFS weighted)	Seals	
SELcum TTS range (NMFS weighted)	HF cet	
SELcum TTS range (NMFS weighted)	MF cet	
SELcum TTS range (NMFS weighted)	LF cet	
SELcum TTS range (NMFS weighted)	Seals	
unweighted SPLpk PTS range at max hammer energy	HF cet	
unweighted SPLpk PTS range at max hammer energy	MF cet	
unweighted SPLpk PTS range at max hammer energy	LF cet	
unweighted SPLpk PTS range at max hammer energy	Seals	
unweighted SPLpk PTS range at starting hammer energy	HF cet	To demonstrate no risk of 'instantaneous' PTS at start of ramp up
unweighted SPLpk PTS range at starting hammer energy	MF cet	
unweighted SPLpk PTS range at starting hammer energy	LF cet	
unweighted SPLpk PTS range at starting hammer energy	Seals	
unweighted SPLpk TTS range at max hammer energy	HF cet	as above for SELcum TTS ranges
unweighted SPLpk TTS range at max hammer energy	MF cet	
unweighted SPLpk TTS range at max hammer energy	LF cet	
unweighted SPLpk TTS range at max hammer energy	Seals	
unweighted SELss isopleths at 5dB increments at max hammer energy	NA	
SELcum mortality	herring	Popper *et al.* (2014) criteria
SELcum injury	herring	
SELcum TTS	herring	
Range to 240dB (unweighted)	NA	For comparison with 2012 Offshore ES modelling
Range to 220dB (unweighted)	NA	

NMFS, NMFS (2016); HF, high frequency; MF, mid frequency; LF, low frequency.

All scenarios assume that animals flee to a distance of 25km then stop. Flee response is assumed to start with the deployment of an acoustic deterrent device (ADD) 15 minutes before commencement of piling.

During pauses between installaiton of consecutive jacket pin piles the modelling assumes that animals stop fleeing and remain stationary until the next piling event, wherupon they continue to flee until a distance of 25km is achieved.

Scenarios 1-4 (single event piling of 10m diameter monopiles)

These scenarios relate to installation of monopile foundations, of up to 10m diameter. There is no prospect of simultaneous piling of monopile foundations in Seagreen Alpha, Seagreen Bravo or Seagreen Alpha and Bravo, and so noise modelling has been undertaken for discrete piling events.

Piling locations match those of the 2012 Offshore ES which positioned the sources for noise modelling towards the west of Seagreen Alpha which was considered relatively sensitive, particularly for bottlenose dolphin occuring around the coast, and in relation to coastally distributed seals. The Seagreen Bravo location is also towards the western boundary of this area but is more offshore in nature and relevant for more offshore distributed species.

Outputs for scenarios 1 and 3 (worst case, 3,000kJ hammer energy) were reviewed and as no significant adverse impacts for marine mammals are expected it was concluded not to be necessary to proceed with scanarios 2 and 4 (most likely, 2,300kJ hammer energy).

Modelling assumed that there would be a single piling event in any given 24 hour period. Key parameters are identified in Table 2. These values should be considered indicative; for example, final piling energy is not expected to be 3,000kJ in all cases as ramp up will cease when adequate pile penetration is achieved.

Some information on ground conditions for pile driving is available from completed geotechnical surveys. Further surveys are planned; for present purposes, assumptions summarised in Table 2 presume that ground conditions at Seagreen are relatively hard, but driveable. If underlying rock is 'softer' lower energy levels will be needed and piling is expected to be quicker. If ground conditions are harder some drilling may be required but this is not expected to result in incresed energy levels being required.

★ 10m diameter monopiles

1. Single at Alpha (worst case, 3,000kJ) **PRIORITY**
2. Single at Alpha (most likely, 2,300kJ) not modelled
3. Single at Bravo (worst case, 3,000kJ) **PRIORITY**
4. Single at Bravo (most likely, 2,300kJ) not modelled

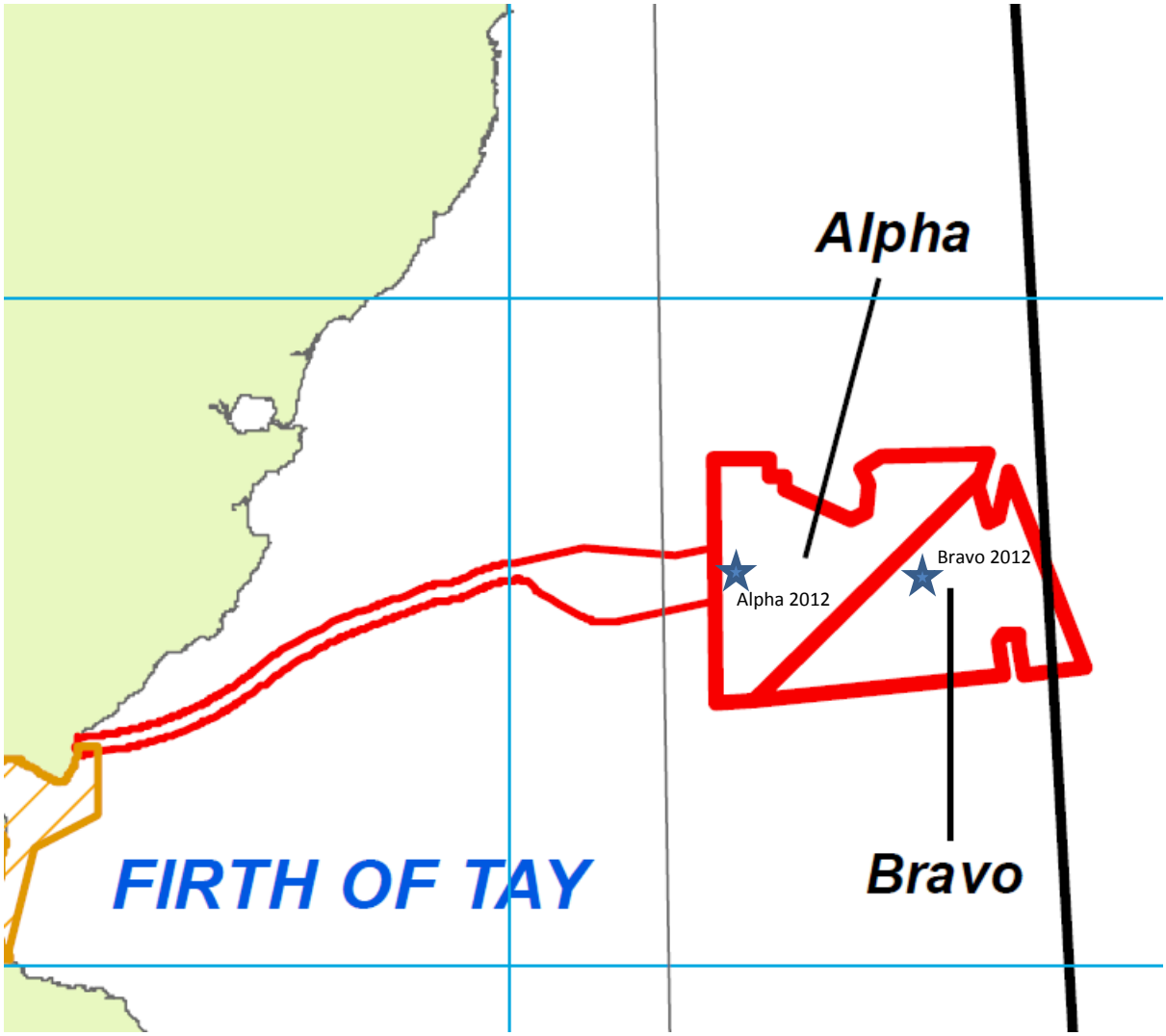

Figure 1 2012 & 2018 scenario 1-4 Noise modelling locations (Decimal degrees, WGS84: Alpha 2012: -1.9301, 56.5929; Bravo 2012: -1.7328, 56.5897).

Table 2. Key parameters for modelling of underwater noise from piling of monopiles.

Piling Phase	Parameter	Most Likely	Worst Case
	noise modelling scenarios:	**2 & 4**	**1,3,7 & 8**
Pre-piling Acoustic Deterrent Device (ADD) deployment (min) and assumed start of marine mammal flee response		15	15
A. Soft start initiation	Starting energy (kJ)	300	400
	Energy ramp up	none	none
	Duration (min)	1	1
	Blows/min	7	7
	Number of blows	7	7
	End energy (kJ)	300	400
B. Soft start	Starting energy (kJ)	300	400
	Energy ramp up	even	even
	Duration (min)	19	19
	Blows/min	31	31
	Number of blows	589	589
	End energy (kJ)	500	600
C. Progression to Full Power	Starting energy (kJ)	500	600
	Energy ramp up	even	even
	Duration (min)	100	120
	Blows/min	35	35
	Number of blows	3500	4200
	End energy (kJ)	2300	3000
D. Full Power Piling	Starting energy (kJ)	2300	3000
	Energy ramp up	none	none
	Duration (min)	60	100
	Blows/min	35	35
	Number of blows	2100	3500
	End energy (kJ)	2300	3000
Total estimated active piling duration (min)		180	240
Total blows (approx.)		6196	8296

Scenarios 5 and 6 (single event piling of 2m jacket foundations)

These scenarios model piling noise from installation of jacket pin piles at Seagreen Alpha and Bravo respectively. They are based on the 2012 modelled worst case scenario of fully driven 2m diameter pin piles utilising up to 1,800kJ hammer energy (previously named 'GM1'). 3m diameter pin piles were also modelled previously but are expected to be driven more quickly as they would be shorter in length with lower resultant cumulative sound exposure.

Previous (2012) parameters for jacket pile installation have been used where possible but in keeping with the approach of updating the assessment with best available information and practices it is proposed to assume 135min for each pin pile installation (previously 55min), based on current understanding of available ground conditions data and experience at the Beatrice Offshore Wind farm site where jacket foundations were utilised. This represents a more precautionary approach in terms of injury (PTS) but initial modelling of underwater noise suggests that the resultant range to PTS should not be problematic. This will be confirmed through full testing of the scenarios described.

It is also assumed that up to four pin piles (one jacket foundation) could be installed in one 24 hour period (previously two days), based on pile installation experience at the Beatrice wind farm site in the Moray Firth. This has no implication for the disturbance assessment where it will be assumed that installation of one jacket will constitute two 'disturbance days', in line with the 2012 approach.

The locations used for noise modelling to support the 2012 Offshore ES were retained as they represent appropriate worst case locations balancing marine mammal and fish receptors and for consistency with Scenarios 1-4, as already agreed with MS-LOT and SNH.

It is assumed that four piles (one jacket) could be installed in a 24 hour period for the injury (PTS) assessment, and that installation would take place over two days for the disturbance assessment.

Other assumptions, including ramp up of hammer energy, are as detailed in Table 3.

Jackets

5. Single at Alpha (worst case, 1800kJ for 135min x4)
6. Single at Bravo (worst case, 1800kJ for 135min x4)

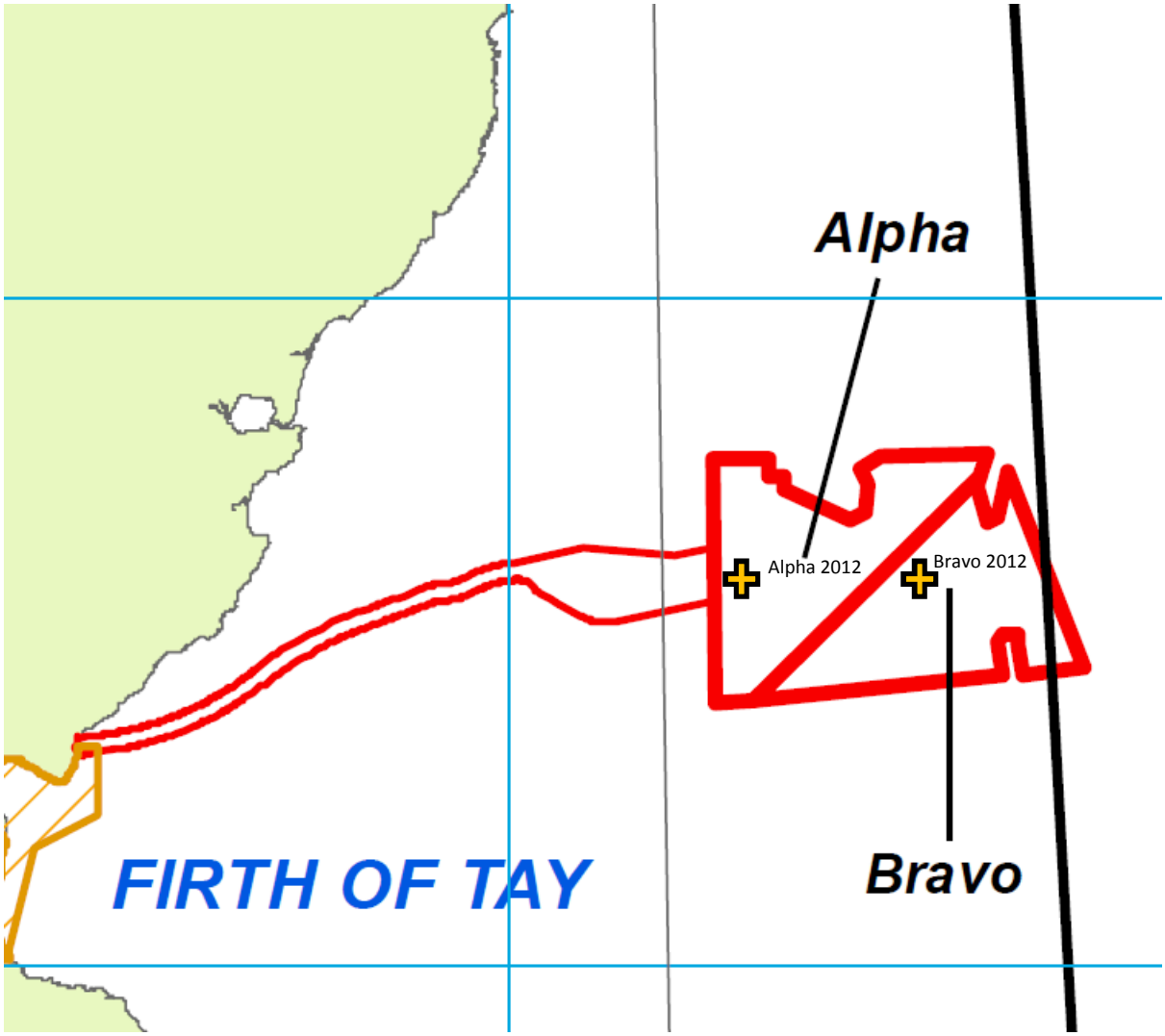

Figure 2 2012 & 2018 scenario 1-4 Noise modelling locations (Dec Degrees, WGS84: Alpha 2012: -1.9301, 56.5929. Bravo 2012: -1.7328, 56.5897).

Table 3. Key parameters for modelling of underwater noise from piling of jacket pin piles.

Piling Phase	Parameter	Values
	noise modelling scenarios:	**5, 6, 7 & 8**
Pre-piling Acoustic Deterrent Device (ADD) deployment (min) and assumed start of marine mammal flee response (first pin pile of each jacket foundation only)		15
1	Starting energy (kJ) 15%	270
	Energy ramp up	none
	Duration (min)	6
	Blows/min	45
	Number of blows	270
	End energy (kJ)	270
2	Starting energy (kJ) 35%	630
	Energy ramp up	Even
	Duration (min)	4
	Blows/min	45
	Number of blows	180
	End energy (kJ)	630
3	Starting energy (kJ) 55%	990
	Energy ramp up	even
	Duration (min)	5
	Blows/min	45
	Number of blows	225
	End energy (kJ)	990
4	Starting energy (kJ)	1350
	Energy ramp up	none
	Duration (min)	30
	Blows/min	45
	Number of blows	1350
	End energy (kJ)	1350
5	Starting energy (kJ)	1710
	Energy ramp up	none
	Duration (min)	90
	Blows/min	45
	Number of blows	4050
	End energy (kJ)	1710
Total estimated active piling duration per pin pile (min)		135
Total blows per pin pile (approx.)		6075

Scenarios 7 and 8 (simultaneous jacket and monopile piling)

Potential for simultaneous piling of monopile and jacket pile foundations at either Alpha or Bravo exists (i.e. a maximum of two installation vessels across the whole project at any time). The worst case scenario has been identified by assuming the maximum separation of simultaneous installation operations, balanced with the generally increased sensitivity of inshore compared to offshore locations for both marine mammals (especially bottlenose dolphin) and fish (herring spawning). For herring, the selection of a monopile location in area Alpha represents the closest location to the known area for herring spawning to the north.

Key parameters are as dentified in Table 2 for monopiles and Table 3 for jacket piles.

Monopiles and Jackets

7. Together at Alpha (monopile 3,000kJ, jacket 1,800kJ for 135min x4)
8. Together at Bravo (monopile 3,000kJ, jacket 1,800kJ for 135min x4)

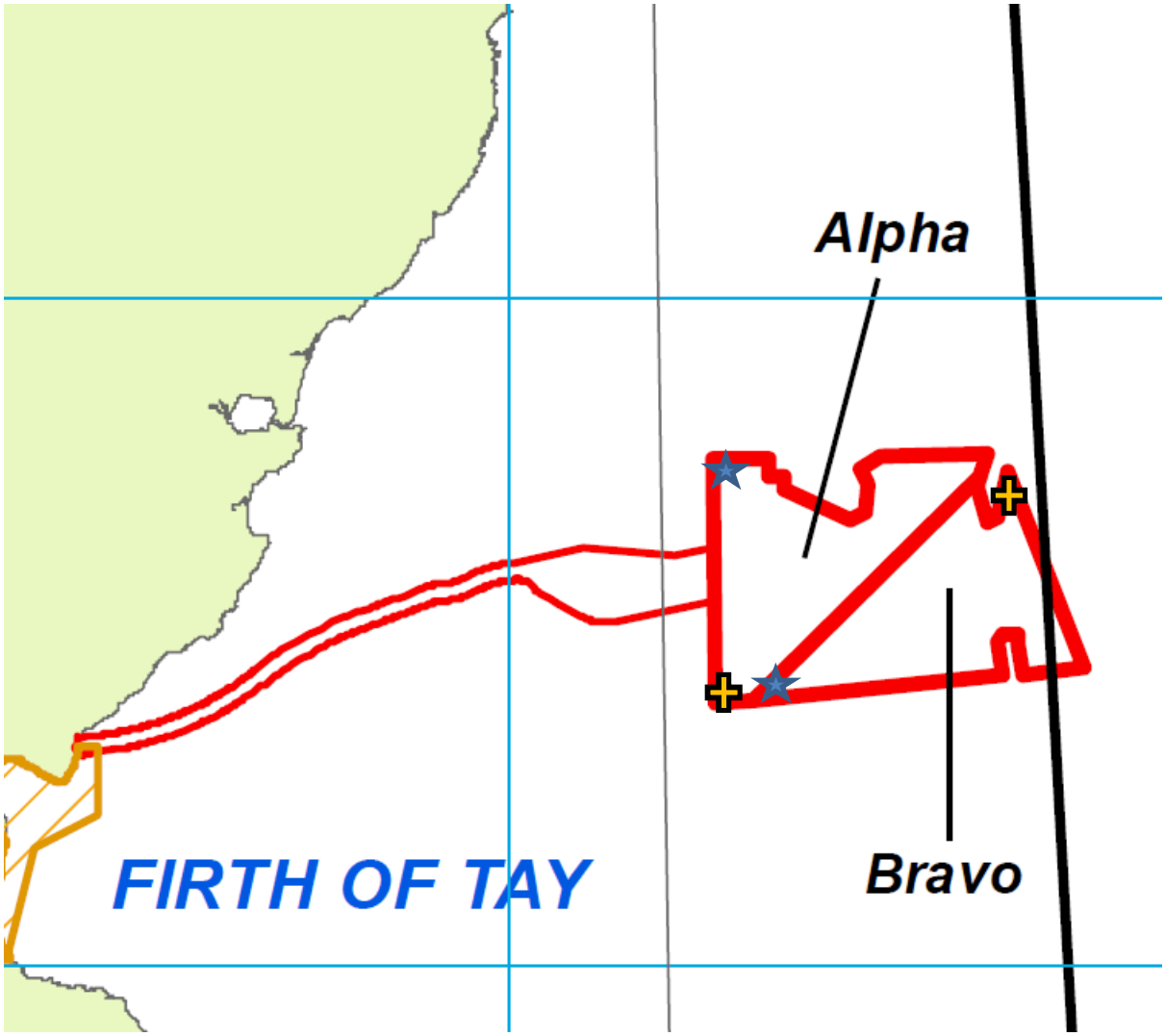

Figure 3. Scenario 7 & 8 noise modelling locations.

Scenario 7&8 Locations	Latitude	Longitude
Monopile NW	-1.937101	56.677553
Monopile SW	-1.892356	56.515385
Jacket SW	-1.939632	56.513386
Jacket NE	-1.577116	56.665388

Decimal Degrees, WGS84

Additional notes re Scenarios 7 and 8:

monopiles

- One monopile in a 24 hour period
- parameters match scenarios 1 and 3

Jacket pin piles

- Four piles (one jacket) in a 24 hour period for PTS assessment, installation over two days for disturbance assessment
- parameters match scenarios 5 and 6

Monopile and jacket pin piling operations assumed to start together.

Scenario 9 (simultaneous (concurrent) jacket piling at Alpha and Bravo)

This scenario considers potential simultaneous installation of jacket foundations in Seagreen Alpha and Bravo. The positions previously used for monopile installation in Scenarios 7 and 8 have been selected as represent ative of the worst case for concurrent jacket piling, in terms of the overall largest area over which disturbance might occur for bottlenose dolphin.

Key parameters are identified in Table 3.

Jackets

9. Together at Alpha and Bravo (1,800kJ for 135min x4)

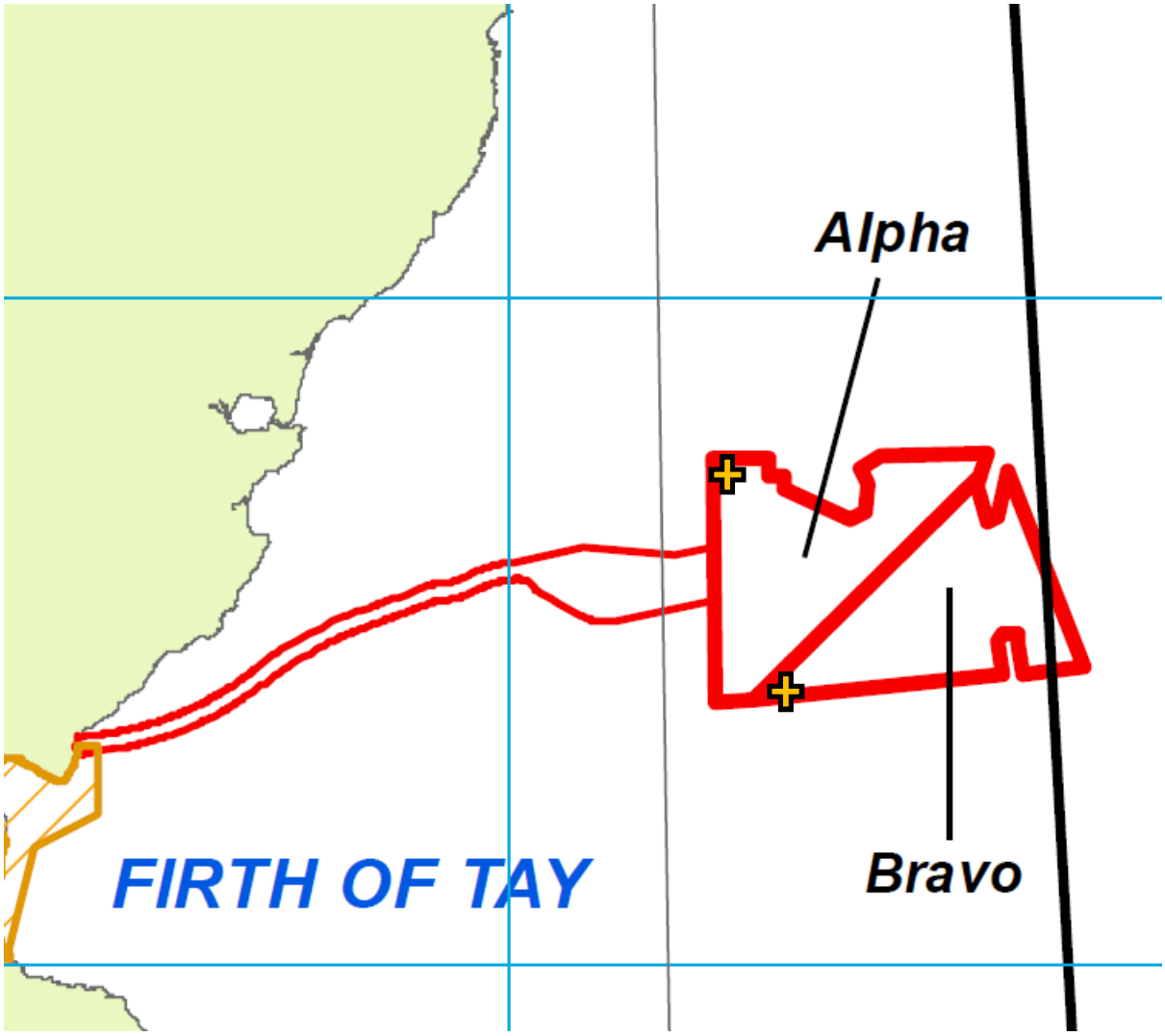

Figure 4. Scenario 9 noise modelling locations.

References

National Marine Fisheries Service (NMFS) (2016) Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-55, 178 p.

Popper *et al*., (2014) Sound Exposure Guidelines for fishes and sea turtles: A technical report prepared by ANSI-Accredited Standards Committee S3/SC1 and registererd with ANSI.