Appendix P

Delfin LNG Revised Acoustic Modeling Analysis

P-1 Revised Underwater Acoustic Modeling Analysis – June 28, 2016

P-2 Revised Underwater Acoustic Modeling Analysis – October 3, 2016

P-3 Revised Underwater Acoustic Modeling Analysis – October 4, 2016

P-4 Cumulative In-Air Acoustic Analysis – April 7, 2016

Appendix P-1

Revised Underwater Acoustic Modeling Analysis – June 28, 2016

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Date: 28 June 2016

To: William Daughdrill, Director, Health, Safety and Environment, Fairwood Peninsula Energy Corporation

From: Jeffrey Martin, Senior Technologies Manager, Ocean Sound and Marine Life Services, CSA Ocean Sciences Inc.

Re: Impact Calculations

Injury and behavior zones of influence (ZOI) were calculated based on unmitigated source levels for impact-driven 78-inch steel pipe pilings. Affected area radii representing potential behavioral disruption to fish and marine mammals were calculated using the root mean square (rms) of the anticipated sound pressure level (SPL) at the source.

SPL_{rms} is primarily used in the assessment of the effects of underwater sound on marine mammals and fish. The SPL_{rms} is the square root of the sum of the squares of the pressure contained within a defined period from the initial time to a final time (**Equation 1**). (Caltrans 2009, Robinson et al., 2014).

Equation 1:

$$SPL_{rms} = \left[\frac{1}{t_f - t_i} \int_{t_f}^{t_i} p^2\,(t)dt \right]^{1/2}$$

Where:

p^2 = pressure;
d = difference;
t_i = initial time; and
t_f = final time.

Further, Sound Exposure Level (SEL) is the constant sound level in one second, which has the same amount of acoustic energy as the original time-varying sound (i.e., the total energy of an event). SEL is calculated by summing the cumulative pressure squared over the time of the event. The accumulation of exposure over a designated period of time or number of instances of a sound is termed Cumulative SEL (cSEL). cSEL is used for injury metrics in fish (GARFO, 2016) and in newer impact metrics for marine mammals (NOAA 2016). cSEL can be estimated from a representative single-strike SEL value and the number of strikes that likely would be required to place the pile at its final depth by using the following equation:

$$cSEL = SEL + 10 \log (\# \text{ of pile strikes})$$

It was estimated in the original application that 3600 pile strikes would occur per day.

To determine the affected area, the transmission loss (TL) of the sound was computed across varying ranges from the source. The practical spreading equation (**Equation 2**) was used to determine the amount of sound loss.

Equation 2:

$$TL = 15 \log_{10} r$$

Where: r = range (m).

In order to determine propagation distances, the source SPL must be determined. No directly comparable SPL measurement references were found for the proposed 78-inch steel pile. Therefore, measurements from piling of 96-inch Cast-in-Steel-Shell (CISS) piles for the Benicia-Martinez Bridge were used as proxies for the impact analysis (ICF Jones & Stokes and Illingworth and Rodkin Inc. 2009; Caltrans 2015). In order to account for the smaller pile diameter considered in this analysis, the 96-inch proxy measurements were reduced by 5dB to estimate the source level of the 78-inch piles. This modified source level was then carried through the propagation calculations to determine impact radii (**Table 1**). This follows the guidance set forth in the NMFS pile driving impact calculation guidance (GARFO, 2016). No other modifications in the calculations were made

Table 1. Estimated sound pressure levels produced by a 78-inch steel pile calculated for seven propagation distances

Propagation distance for 78-inch steel pile	$SPL_{0\text{-}p}$ (dB re 1μ Pa)	SPL_{RMS} (dB re 1μ Pa)	SEL (1-sec dB re 1μ Pa)
5 meters	220	205	194
10 meters	215	200	189
20 meters	210	195	184
50 meters	205	190	179
100 meters	200	185	174
500 meters	190	175	164
1000 meters	185	170	159

The SPLs selected for the ZOI radii calculations are based on accepted threshold criteria described in **Table 2**.

Table 2. Threshold levels used to determine ZOI radii.

Criterion	Definition	Metric	Threshold
Cetaceans[1]			
Behavior	Impulsive source	SPL_{rms}	160 dB re 1 μPa
Injury	Impulsive source	SPL_{rms}	180 dB re 1 μPa
Fish[2]			
Behavior	Impulsive or continuous source	SPL_{rms}	150 dB re 1 μPa
Injury	Peak sound pressure level (SPL_{peak})	SPL_{peak}	206 dB re 1 μPa
Injury	Injury >2 g fish size for cumulative sound exposure level over 12 hours	SEL_{cum}	187 dB re 1 μPa²·s
Injury	Injury <2 g fish size for cumulative sound exposure level over 12 hours	SEL_{cum}	183 dB re 1 μPa²·s

1. Based on current regulatory criteria (NOAA, 2005). Newer threshold criteria is currently proposed by NMFS (NOAA 2016) but have not yet been accepted for regulatory purposes.
2. Based on GARFO 2016, available at: http://www.greateratlantic.fisheries.noaa.gov/protected/section7/guidance/consultation/index.html

The calculated propagation radii for an unmitigated 78-inch steel pile are listed in **Table 3** and graphically displayed in **Figures 1** through **5.** The figures are shown to visually represent the calculations described above. Other parameters that influence the propagation and attenuation of sound underwater such as water depth, sediment type, sound speed profile, etc. were not accounted for in this exercise.

Table 3. Estimated distances to species threshold levels for an unmitigated 78-inch pile

	Onset of physical injury			**Onset of behavioral effects**
FISH	**Distance to 206 dB (SPL_{peak})**	**Distance to cSEL of 187 dB (injury for fish >2g)**	**Distance to cSEL of 183 dB (injury for fish <2g)**	**150 dB_{rms}**
Distance from source (78" Steel Pile)	40 m	3193 m	3,981 m	21,544 m
CETACEANS	**180 dB_{rms}**			**160 dB_{rms}**
Distance from source (78" Steel Pile)	215 m			4,642 m

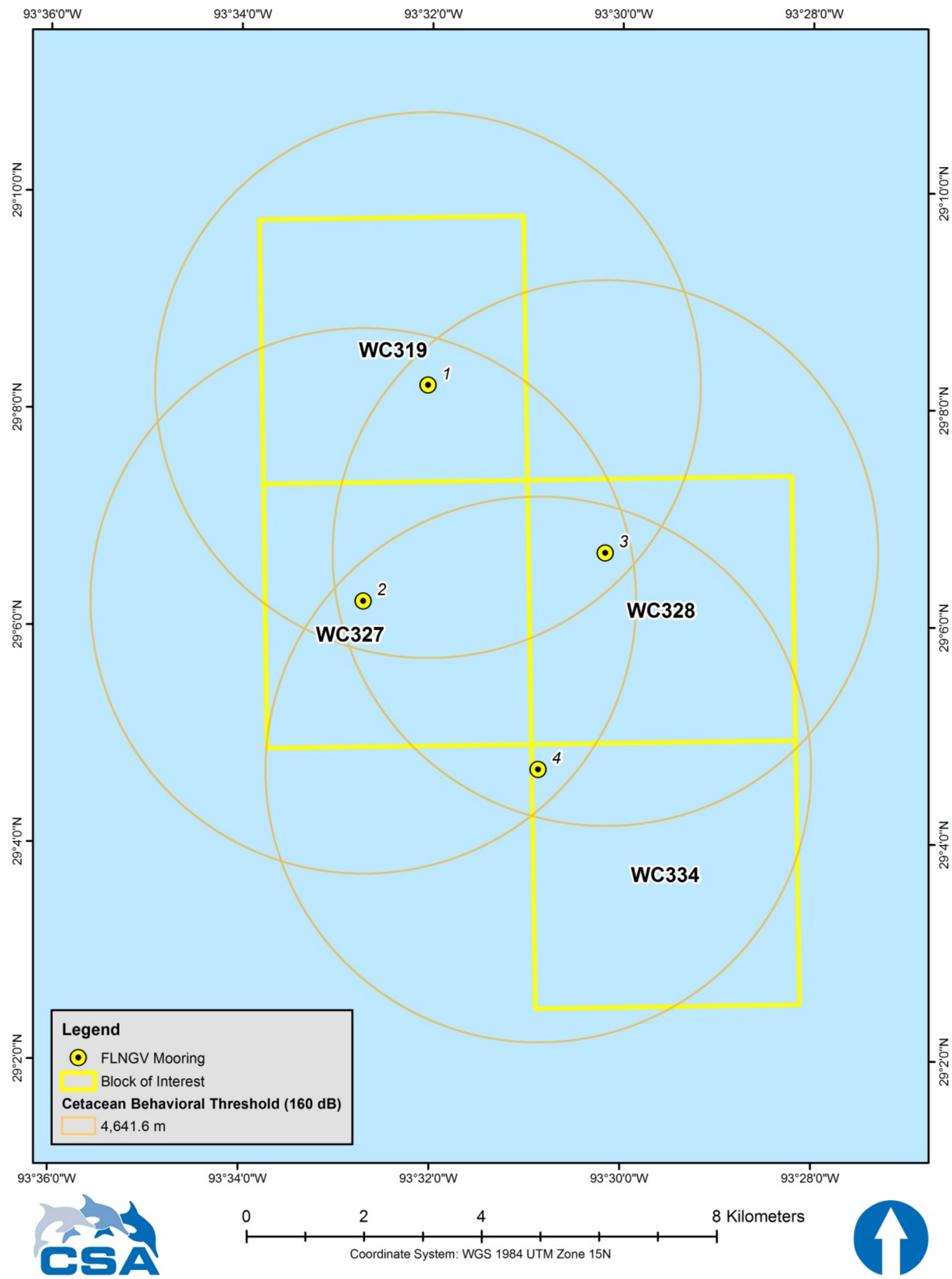

Figure 1. Cetacean behavioral threshold radii for the160dB_{rms} isopleths surrounding the pile locations. The noise propagation distances depicted are based on a non-mitigated impulsive source.

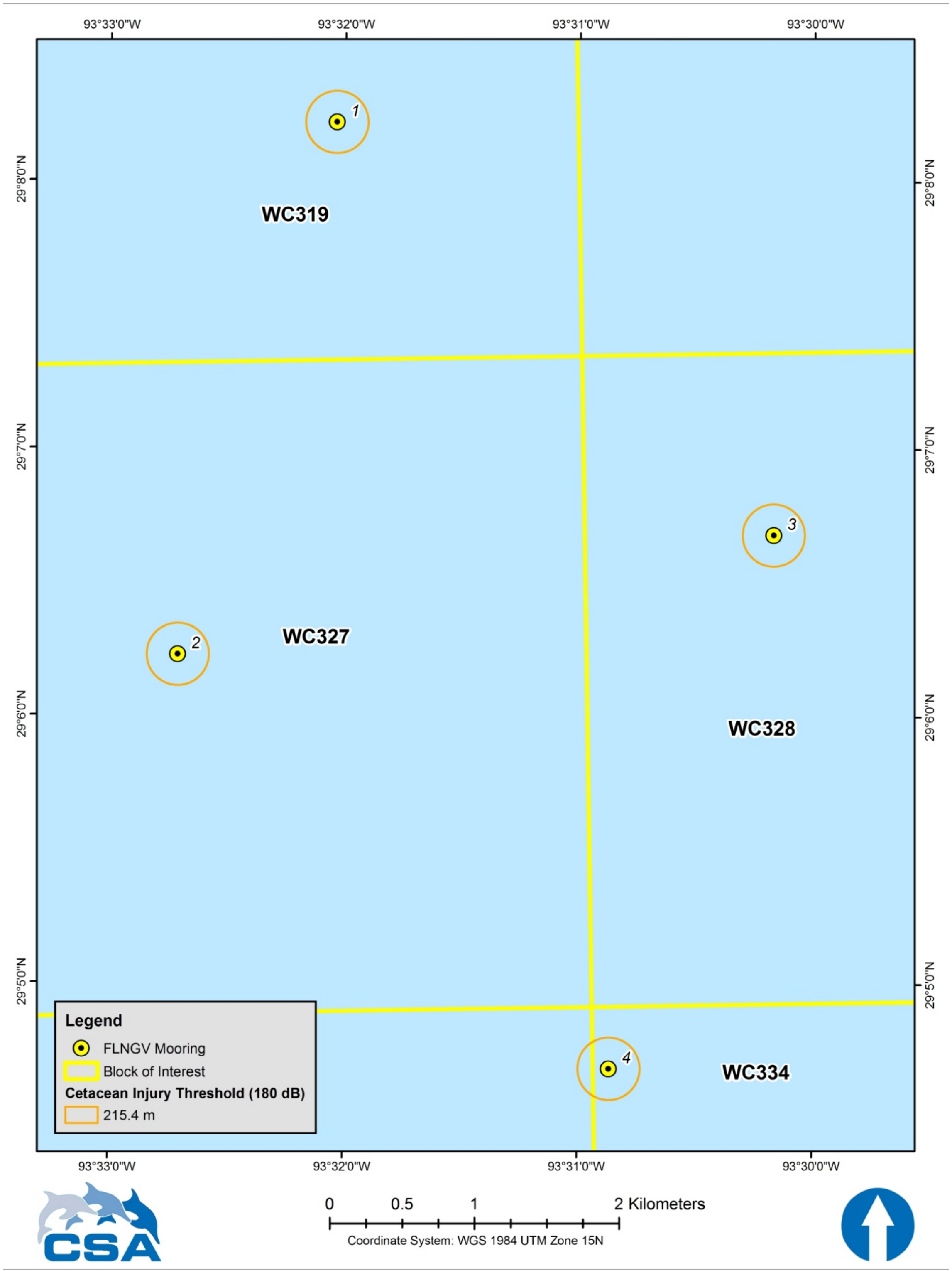

Figure 2. Cetacean injury threshold radii for the180dB$_{rms}$ isopleths surrounding the pile locations. The noise propagation distances depicted are based on a non-mitigated impulsive source.

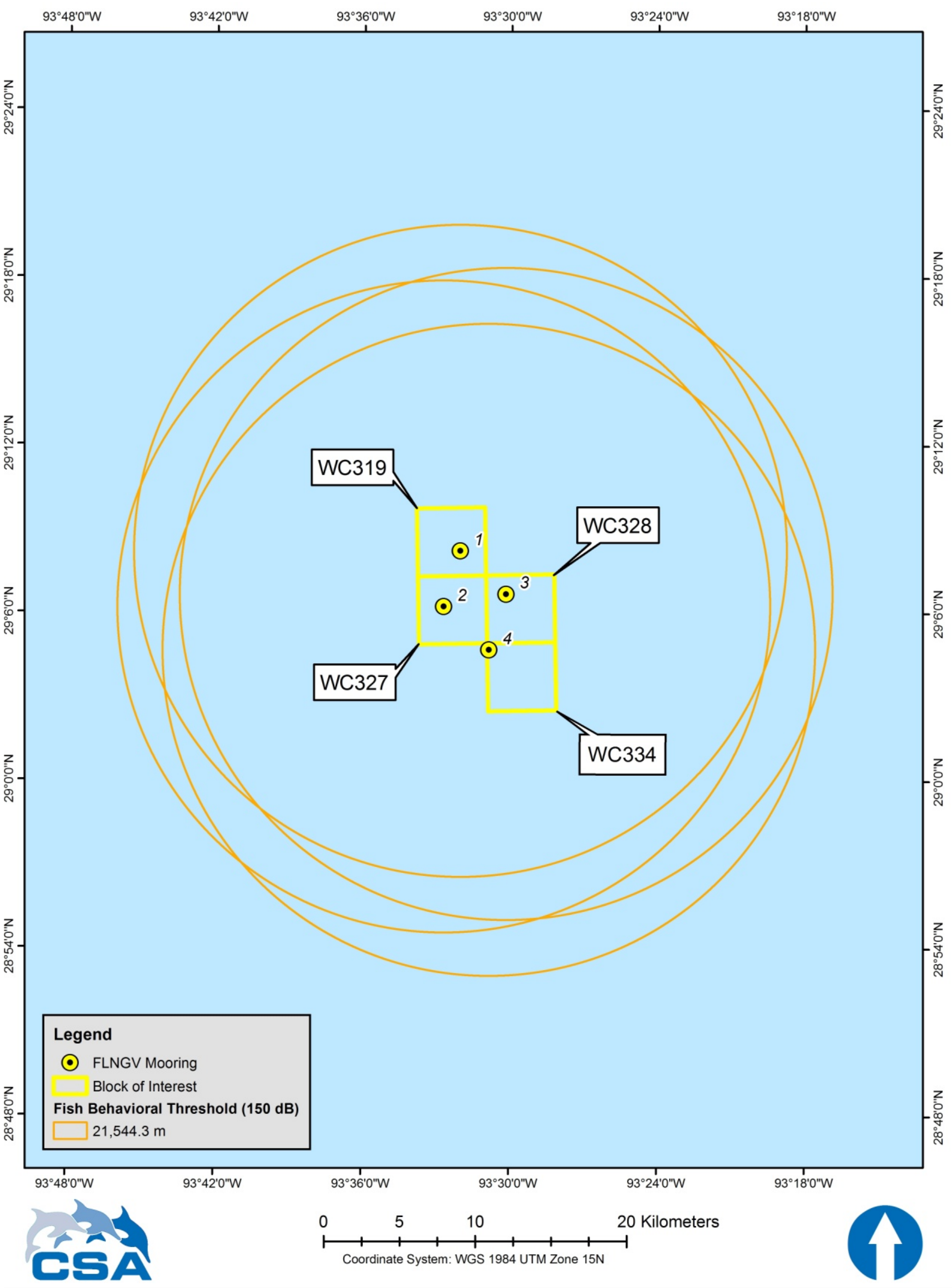

Figure 3. Fish (based on calculations for salmonids and sturgeon) behavioral threshold radii for the150dB$_{rms}$ isopleths surrounding the pile locations. The noise propagation distances depicted are based on a non-mitigated impulsive source.

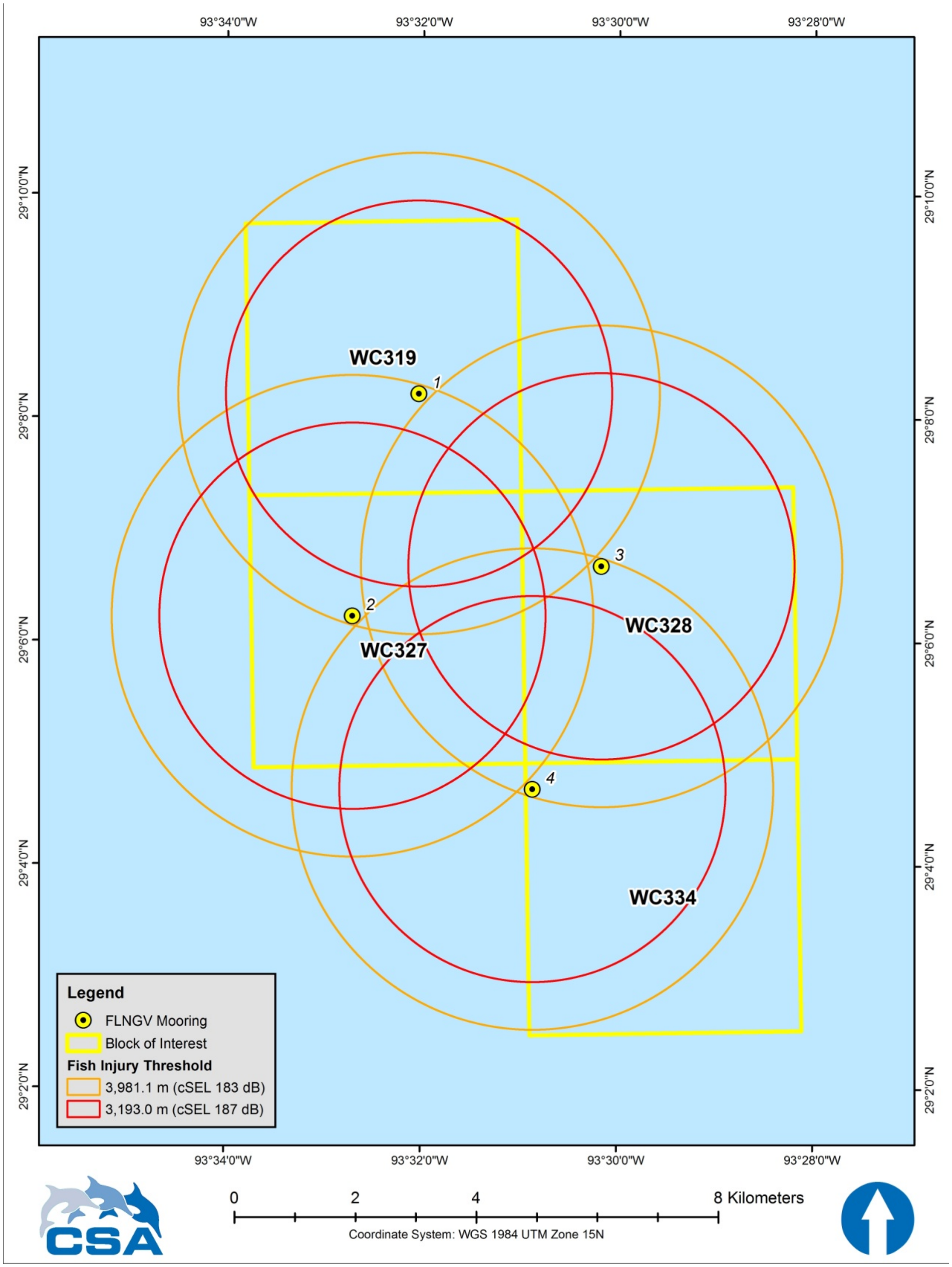

Figure 4. Fish injury threshold (based on calculations for salmonids and sturgeon) radii for cumulative sound exposures. The 187 dB and 183 dB isopleths surrounding the pile locations relate to injury thresholds for fish weighing greater than 2g and fish weighing less than or equal to 2 g. respectively. The noise propagation distances depicted are based on a non-mitigated impulsive source.

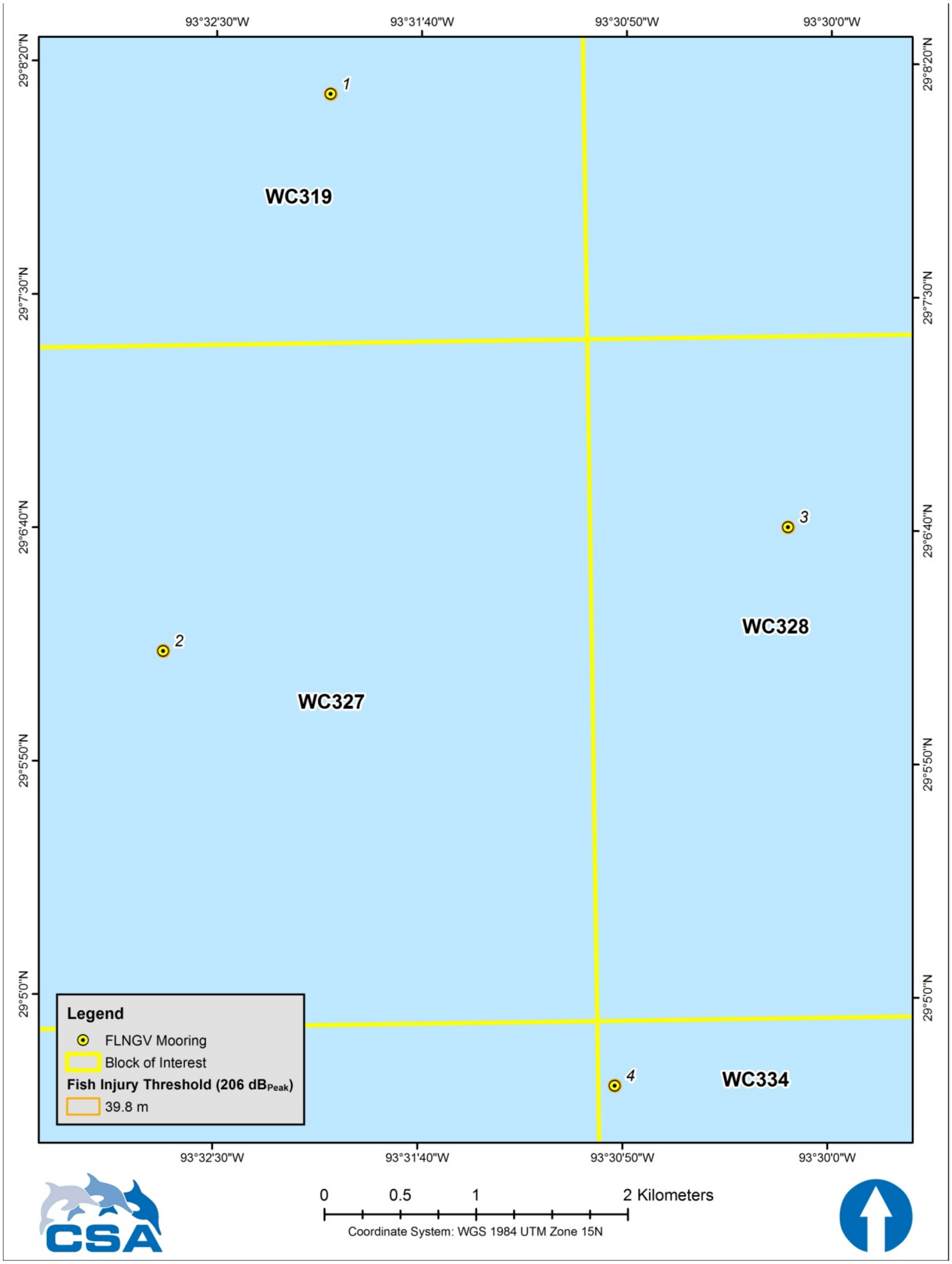

Figure 5. Fish injury threshold (based on calculations for salmonids and sturgeon) radii for the 206dB$_{peak}$ isopleths surrounding the pile locations. The noise propagation distances depicted are based on a non-mitigated impulsive source.

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Appendix P-2

Revised Underwater Acoustic Modeling Analysis – October 3, 2016

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Date: 03 October 2016

To: William Daughdrill, Director, Health, Safety and Environment, Fairwood Peninsula Energy Corporation

From: Jeffrey Martin, Senior Technologies Manager, Ocean Sound and Marine Life Services, CSA Ocean Sciences Inc.

Re: New Impact Radii Figures – Amended

Acoustic zones of influence (ZOIs) for potential injury and behavioral disturbance thresholds were calculated based on mitigated source levels for impact-driven, 78-inch steel pipe piling within an air bubble-infused coffer dam. Affected area radii representing potential behavioral and injurious effects to fish and marine mammals were calculated based on the 2016 National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS, 2016) acoustic criteria for marine mammals and the 2016 NOAA Greater Atlantic Regional Fisheries Office (GARFO) criteria for fish (GARFO, 2016). It is important to note that the 2016 NMFS acoustic criteria for marine mammals provide updated acoustic thresholds for the onset of permanent threshold shift (PTS), which is considered an auditory injury, and temporary threshold shift (TTS), which is not considered an auditory injury but is considered an adverse effect and "harassment" under the Marine Mammal Protection Act (MMPA). Acoustic thresholds for the onset of behavioral effects have not been updated by NMFS, and so the acoustic threshold for TTS onset is used here as a proxy for behavioral disturbance threshold and ZOI.

Both 2016 NMFS and GARFO criteria rely on the acoustic metrics of peak (pk) and root mean square (rms) of the anticipated sound pressure level (SPL) and sound exposure level (SEL) to define thresholds. The SPL_{pk} is a measure of the maximum instantaneous sound pressure from a specified source. It is used as a metric for the criteria for effects of underwater sound on fish and marine mammals. SPL_{rms} is primarily used in the assessment of the behavioral effects on fish. The SPL_{rms} is the square root of the sum of the squares of the pressure contained within a defined period from the initial time to a final time (**Equation 1**) (California Department of Transportation, 2009).

Equation 1:

$$SPL_{rms} = 20log_{10}(\left[\frac{1}{t_f - t_i}\int_{t_f}^{t_i} p^2\,(t)dt\right]^{1/2} / \, p_{ref})$$

Where:

p = pressure;
p_{ref} = reference pressure for water (1µPa);
t_i = initial time; and
t_f = final time.

Further, SEL is the constant sound level in one second, which has the same amount of acoustic energy as the original time-varying sound (i.e., the total energy of an event). SEL is calculated by summing the cumulative pressure squared over the time of the event. The accumulation of exposure over a designated period of time or number of instances of a sound is termed cumulative SEL (cSEL). cSEL can be estimated from a representative single-strike SEL value and the number of strikes that likely would be required to place the pile at its final depth by using the following equation:

$$\text{cSEL} = \text{SEL} + 10 \log (\text{\# of pile strikes}).$$

It was estimated in the original application that 3,600 pile strikes would occur per day. cSEL is used for injury metrics in fish (GARFO, 2016) for impulsive sources and in revised impact metrics for marine mammals (NMFS, 2016). SPL_{rms} measurements are used for sea turtle criteria.

To determine the affected area, the transmission loss (TL) of the sound was computed across varying ranges from the source. The practical spreading equation (**Equation 2**) was used to determine the amount of sound loss.

Equation 2:

$$TL = 15 \log_{10} r$$

Where: r = range (m).

In order to determine propagation distances, the source SPL must be determined. No directly comparable SPL measurement references were found for the proposed 78-inch steel pile. Therefore, measurements from piling of 96-inch Cast-in-Steel-Shell (CISS) piles for the Benicia-Martinez Bridge were used as proxies for the impact analysis (ICF Jones & Stokes and Illingworth and Rodkin Inc., 2009; California Department of Transportation, 2015). In order to account for the smaller pile diameter considered in this analysis, the 96-inch proxy measurements were reduced by 5 dB to estimate the source level of the 78-inch piles. As directed by the client, this modified source level was then reduced by 11 dB to account for the mitigative effects of an air bubble-infused coffer dam surrounding each pile and carried through the propagation calculations to determine impact radii (**Table 1**). This follows the protocols set forth in the NMFS pile driving impact calculation guidance (GARFO, 2016). No other modifications in the calculations were made.

Table 1. Estimated sound pressure levels produced by a 78-inch steel pile calculated for 7 propagation distances. The source level used for the propagation calculations was reduced by 11 dB to account for the mitigative effects of an air bubble-infused coffer dam surrounding each pile.

Sound propagation distance for 78-inch steel pile (m)	SPL_{0-p} (dB re 1 µPa)	SPL_{rms} (dB re 1 µPa)	SEL (dB re 1 $\mu Pa^2 \cdot s$)
5	209	194	183
10	204	189	178
20	199	184	173
50	194	179	168
100	189	174	163
500	179	164	153
1,000	174	159	148

dB re 1 µPa = decibels relative to one micropascal; SPL_{rms} = root mean square sound pressure level; SEL = sound exposure level; SPL_{0-p} = zero to peak sound pressure level.

The threshold levels for the marine mammal ZOI radii calculations are based on NMFS (2016) noise criteria for impulsive sources (**Table 2**). These are dual-criteria, meaning thresholds can be reached either through cSEL or SPL_{pk}; therefore, both criteria should be used in establishing ZOIs or impact radii. Additionally, different criteria apply to each marine mammal functional hearing group (low-, mid-, and high-frequency), reflecting the fact that each marine mammal group will have different hearing sensitivities to the sound spectra produced by the source. The criteria are based on sound levels that equate to the onset of marine mammal auditory threshold shifts. Currently, PTS and TTS are the only two criteria applicable for noise impact analyses. Acoustic thresholds for the onset of behavioral effects have not been updated by NMFS, and therefore the interim thresholds (NMFS 2005), using SPL_{rms} received sound levels for an impulsive source are used for determining the behavioral threshold. The 2005 NMFS interim criteria do not consider functional hearing groups and the criteria are applied equally across the groups.

Table 2. Threshold levels used to determine the zone of influence radii for cetaceans (From: National Marine Fisheries Service, 2016).

Threshold Criteria		Low-Frequency Cetacean Thresholds	Mid-Frequency Cetacean Thresholds	High-Frequency Cetacean Thresholds
Permanent Threshold Shift	cSEL (dB re 1 µPa^2•s)	183	185	155
	SPL_{pk} (dB re 1 µPa)	219	230	202
Temporary Threshold Shift	cSEL (dB re 1 µPa^2•s)	168	170	140
	SPL_{pk} (dB re 1 µPa)	213	224	196
Behavioral Onset	SPL_{rms} (dB re 1 µPa)	160		

cSEL = cumulative sound exposure level; SPL_{pk} = peak sound pressure level.

The criteria used for the fish ZOI radii calculations are based on 2016 guidance from NOAA's GARFO noise threshold criteria for impulsive sources (**Table 3**). Fish noise thresholds are based on sound levels that have the potential to produce injury or illicit a behavioral response.

Table 3. Threshold levels used to determine the zone of influence radii for fish.

Criterion	Definition	Metric	Threshold
Fish[1]			
Behavior	Impulsive or continuous source	SPL_{rms}	150 dB re 1 µPa
Injury	Peak sound pressure level (SPL_{peak})	SPL_{pk}	206 dB re 1 µPa
Injury	Injury >2 g fish size for cumulative sound exposure level over 12 hours	cSEL	187 dB re 1 µPa^2·s
Injury	Injury <2 g fish size for cumulative sound exposure level over 12 hours	cSEL	183 dB re 1 µPa^2·s

dB re 1 µPa = decibels relative to one micropascal; cSEL = cumulative sound exposure level; SPL_{pk} = peak sound pressure level; SPL_{rms} = root mean square sound pressure level.
[1] Based on National Oceanic and Atmospheric Administration Greater Atlantic Regional Fisheries Office (2016); available at: http://www.greateratlantic.fisheries.noaa.gov/protected/section7/guidance/consultation/index.html

There is scarce information regarding hearing and acoustic thresholds for marine turtles. The most recent criteria from Popper et al. (2014), do not provide numerical TTS or behavioral threshold criteria for sea turtles but rather provide subjective standards of "low, medium, and high" risk for turtles that are "near, intermediate, or far" from a continuous noise source. However, for impulsive sources, Popper et al (2014) estimates injury threshold levels of 210 dB re 1 µPa (cSEL) and 207 dB re 1 µPa (SPL_{pk}). Sea turtle hearing thresholds in water have not been established by NMFS. Avoidance reactions to seismic sources have been documented in caged turtles at levels between 166 and 179 dB re 1 µPa (Moein et al., 1995; McCauley et al., 2000). Popper et al. (2014) estimates that the potential for TTS, masking, and behavioral alterations are high for exposures occurring near (within tens of meters from) the source; and low for exposures occurring at intermediate (hundreds of meters) and far (thousands of meters) from the source. Sea turtle underwater acoustic injury and behavioral thresholds of 207 dB re 1 µPa and 166 dB re 1 µPa, respectively (**Table 4**) have been used in NMFS Biological Opinions (NMFS 2015) and are applied in these analyses. No distinction is made between impulsive and continuous sources for these thresholds.

Table 4. Threshold levels used to determine the zone of influence radii for sea turtles

Sea Turtle Threshold Criteria (SPL_{rms})	Injury Onset	Behavioral Reaction Onset
	207 dB re 1 µPa	166 dB re 1 µPa

dB re 1 µPa = decibels relative to one micropascal; SPL_{rms} = root mean square sound pressure level.

The calculated impact threshold radii for a 78-inch steel pile encompassed in the coffer dam are listed in **Table 5** for fish, **Table 6** for cetaceans, and **Table 7** for sea turtles. To calculate the cSEL threshold isopleths, both weighting function and sound accumulation period must be incorporated. NMFS (2016) provides alternative methods for incorporating these parameters into calculations of the cetacean PTS and TTS cSEL isopleths. Weighting functions can be calculated for a specific source or default weighting factor adjustments (WFAs) can be uniformly applied. Accumulation periods can be incorporated using the SPL_{rms} source method or the single strike equivalent method. The radii in these analyses were determined by applying NMFS's default WFAs and the single strike equivalent alternative. Using default WFAs rather than modeling weighting functions will result in slightly larger (more conservative) isopleths. The SPL_{rms} method produces unrealistically large isopleths because it assumes that animals at the edge of the isopleth will remain there for the entire activity (accumulation) period. For that reason the single strike alternative was selected. These topics are highly complex and their full explanations are not within the scope of this document. Please refer to the NMFS guidance document (NMFS, 2016) for a full discussion of the entire 2016 noise criteria component.

Table 5. Estimated distances to fish species threshold levels for a mitigated 78-inch pile.

Fish	Onset of physical injury			Onset of behavioral effects
	Isopleth to SPL_{pk} threshold (meters)	Isopleth to cSEL threshold (meters) (injury for fish >2 g)	Isopleth to cSEL threshold (meters) (injury for fish <2 g)	Isopleth to SPL_{rms} threshold (meters)
Distance from source (78-inch steel pile)	7 m	590 m	736 m	3,981 m

cSEL = cumulative sound exposure level; SPL_{pk} = peak sound pressure level; SPL_{rms} = root mean square sound pressure level.

Table 6. Estimated distances to cetacean species threshold levels for a mitigated 78-inch pile.

Threshold Criteria		Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans
Permanent Threshold Shift	Isopleth to cSEL threshold (meters)	1,088.8	38.7	1,296.9
	Isopleth to SPL_{pk} threshold (meters)	0.0	0.0	0.3
Temporary Threshold Shift	Isopleth to cSEL threshold (meters)	10,887.8	387.2	12,969.0
	Isopleth to SPL_{pk} threshold (meters)	0.0	0.0	0.6
Behavior	Isopleth to SPL_{rms} threshold (meters)	858		

cSEL = cumulative sound exposure level; SPL_{pk} = peak sound pressure level; SPL_{rms} = root mean square sound pressure level.

Table 7. Estimated distances to sea turtle threshold levels for a mitigated 78-inch pile.

Sea Turtle Threshold Criteria	Injury Onset Isopleth to SPL_{rms} threshold (meters)	Behavioral Reaction Onset Isopleth to SPL_{rms} threshold (meters)
	0	341

SPL_{rms} = root mean square sound pressure level.

The threshold isopleths for fish, sea turtles and cetaceans are graphically displayed in **Figures 1** through **5.** The figures are shown to visually represent the calculations described above. Other parameters that influence the propagation and attenuation of sound underwater such as water depth, sediment type, sound speed profile, etc. were not accounted for in this exercise.

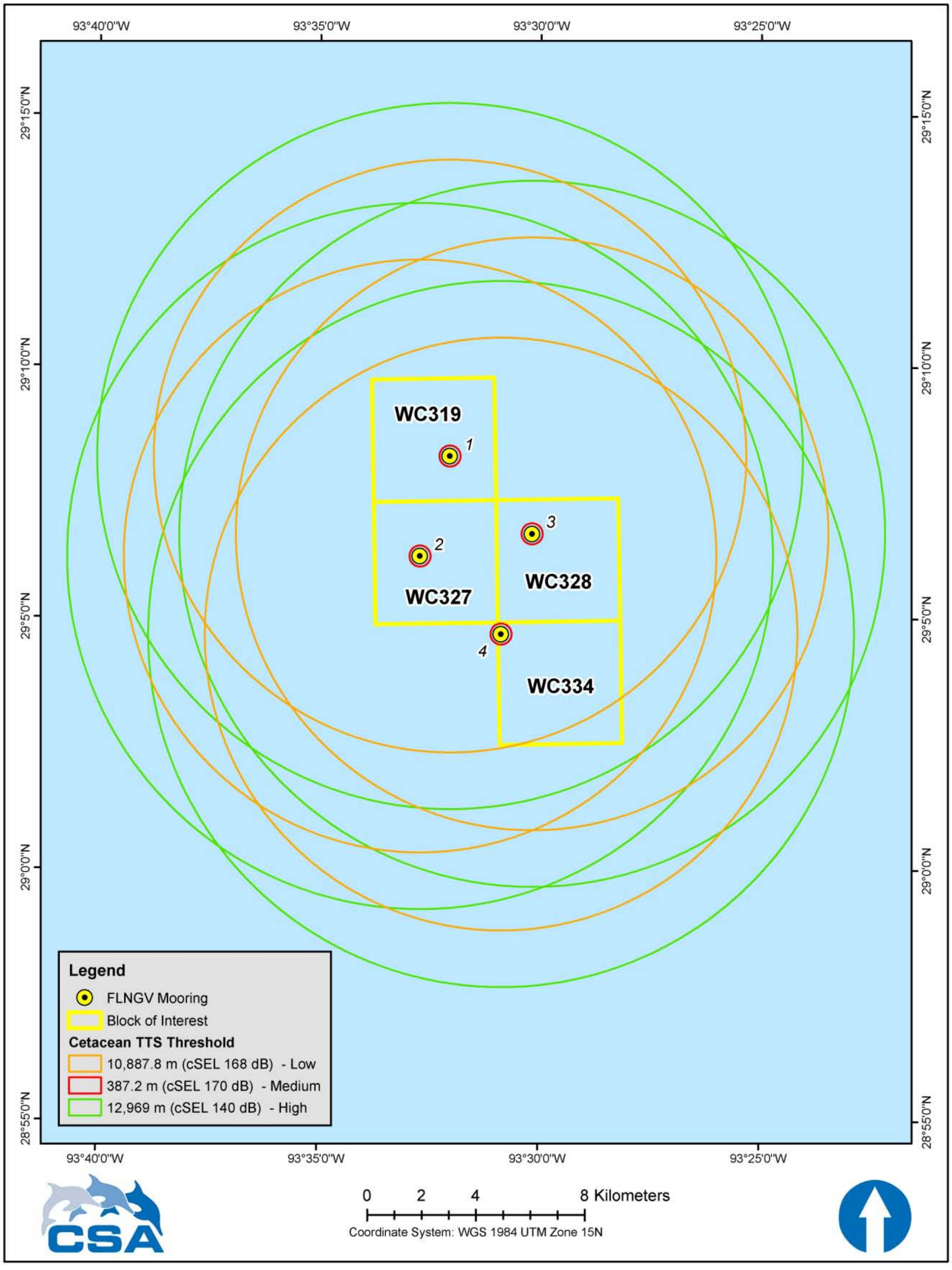

Figure 1. Radii for cetacean TTS threshold isopleths surrounding the pile locations. The noise propagation distances depicted are based on a mitigated impulsive source.

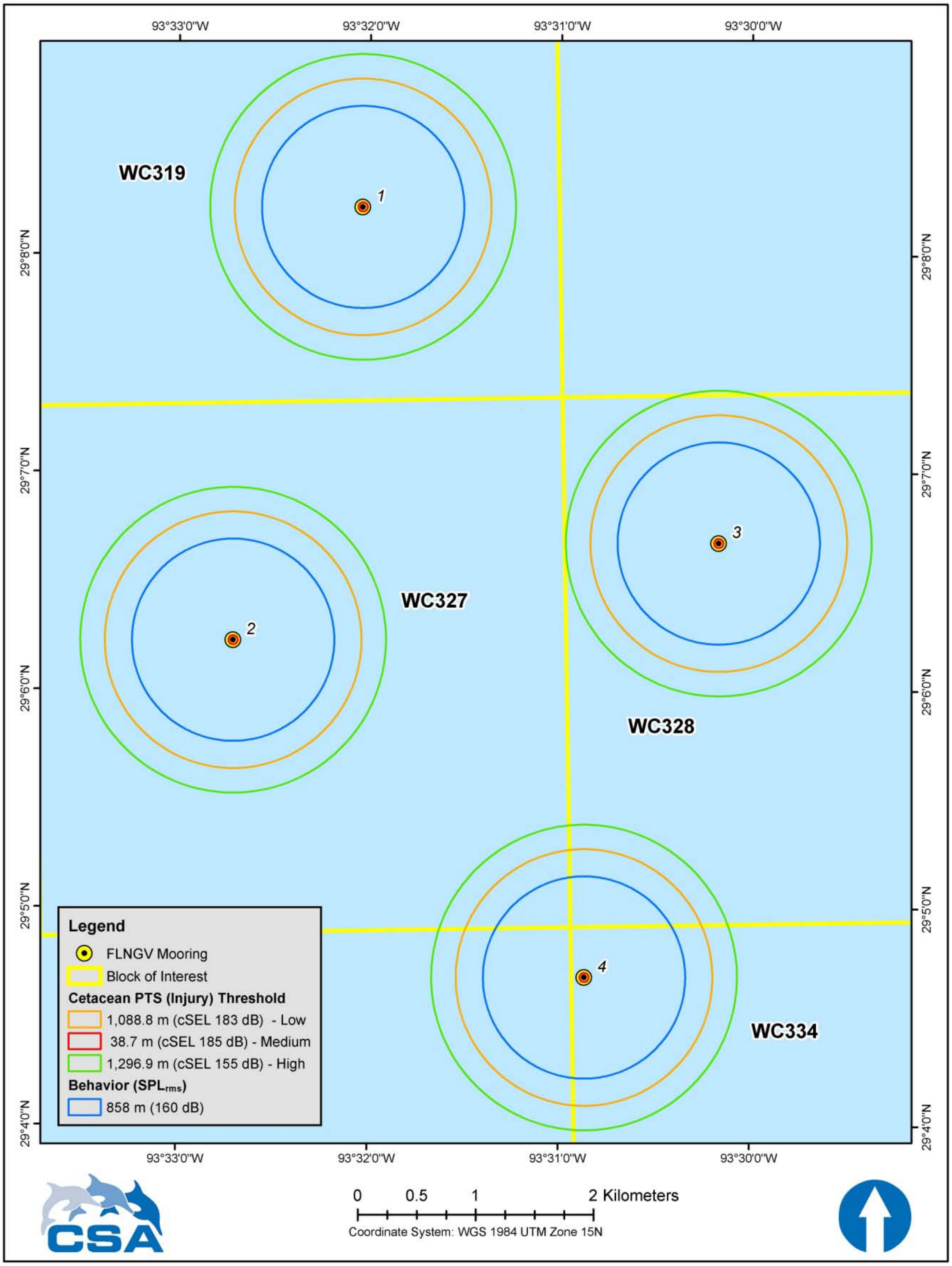

Figure 2. Radii for cetacean PTS and behavior threshold isopleths surrounding the pile locations. The noise propagation distances depicted are based on a mitigated impulsive source.

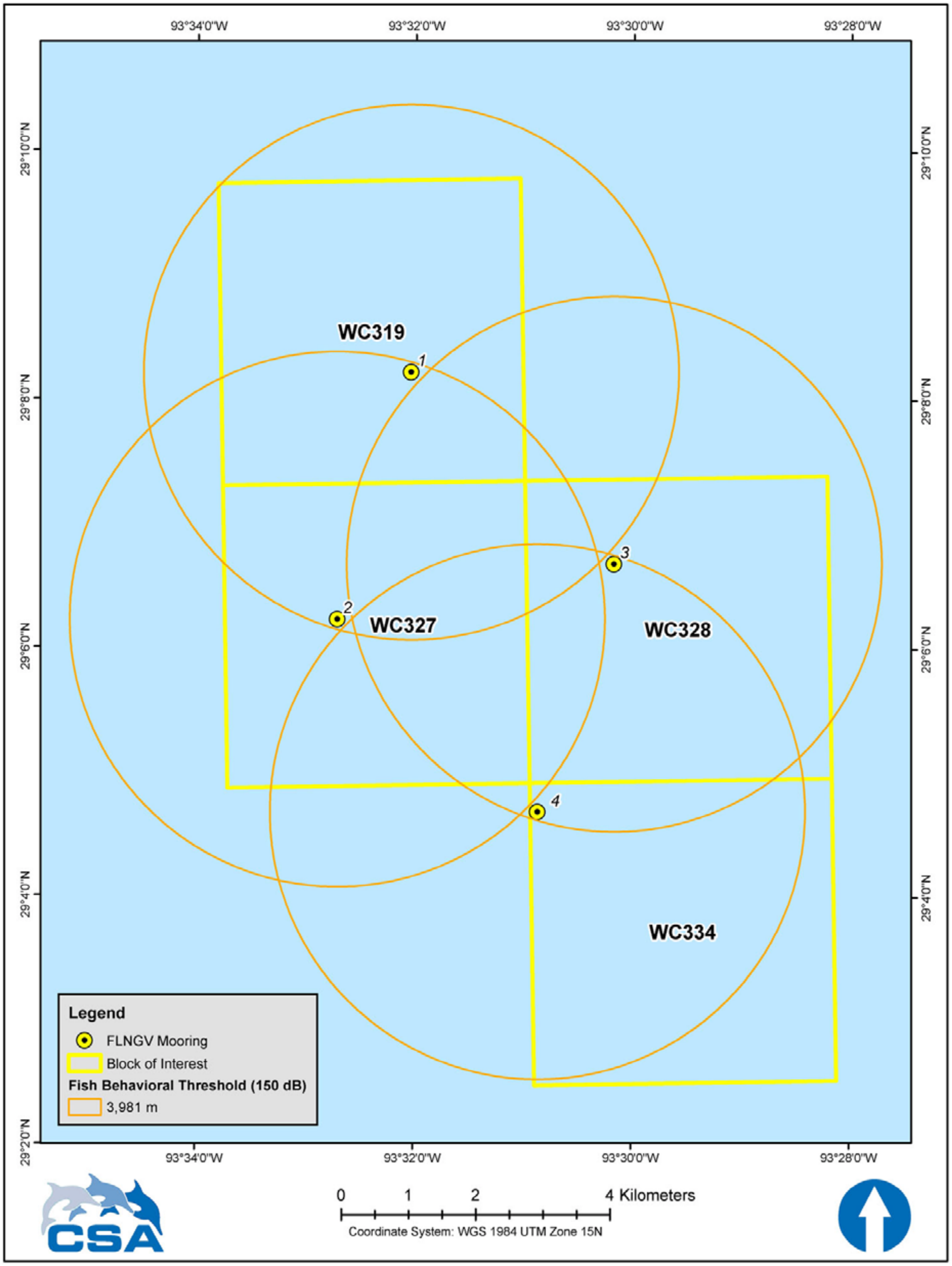

Figure 3. Fish (based on calculations for salmonids and sturgeon) behavioral threshold radii for the SPL_{rms} of 150 dB re 1µ Pa isopleths surrounding the pile locations. The noise propagation distances depicted are based on a mitigated impulsive source.

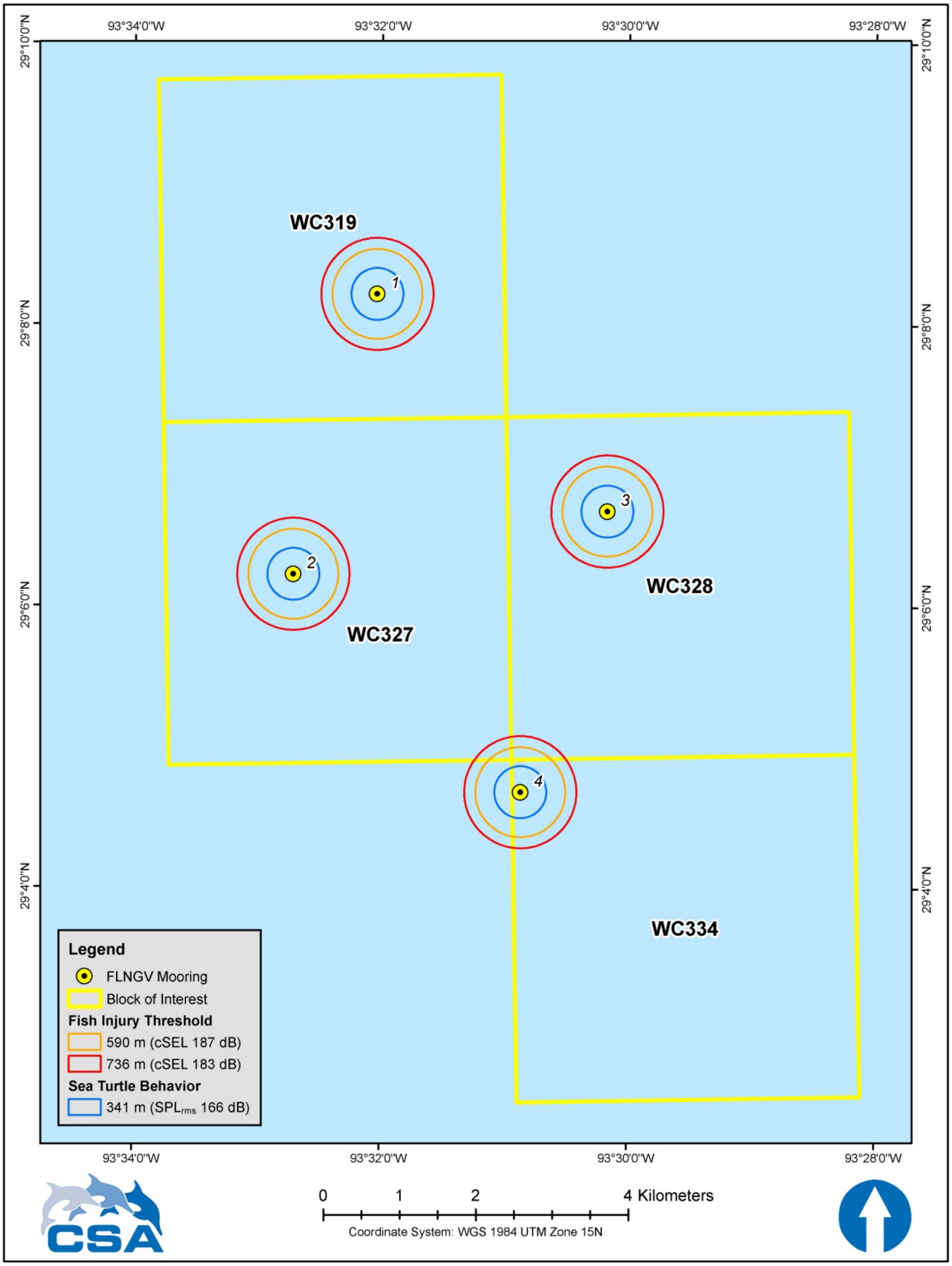

Figure 4. Fish injury threshold (based on calculations for salmonids and sturgeon) radii for cumulative sound exposures and sea turtle behavior threshold. The 187- and 183-dB isopleths surrounding the pile locations relate to injury thresholds for fish weighing >2 g and fish weighing less than or equal to 2 g, respectively. The noise propagation distances depicted are based on a mitigated impulsive source.

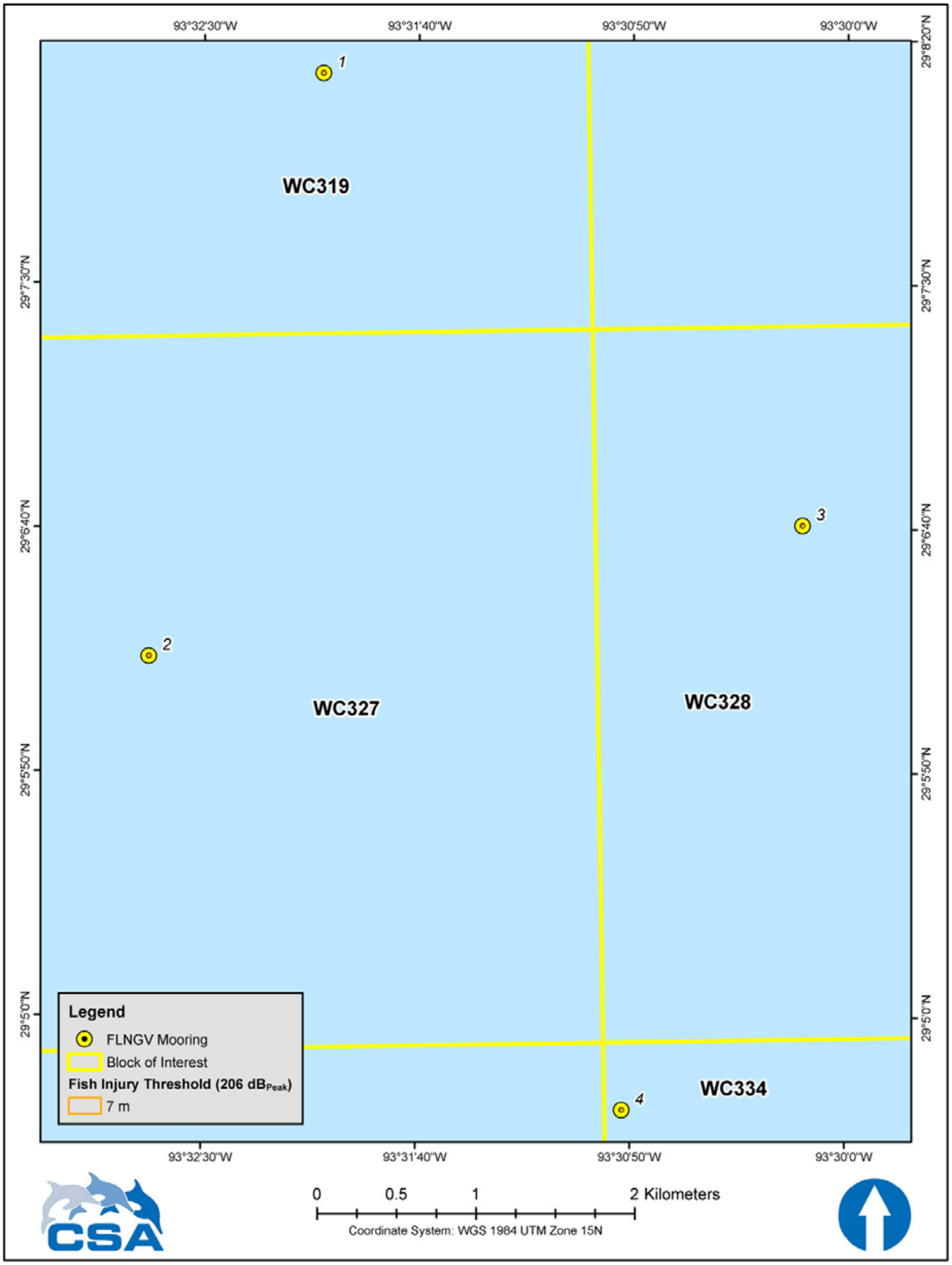

Figure 5. Fish injury threshold (based on calculations for salmonids and sturgeon) radii for the 206-dB_{peak} isopleths surrounding the pile locations. The noise propagation distances depicted are based on a mitigated impulsive source.

REFERENCES

California Department of Transportation. 2015. Technical guidance for assessment and mitigation of the hydroacoustic effects of pile driving on fish. Report No. CTHWANP-RT-15-306.01.01.

ICF Jones & Stokes and Illingworth and Rodkin Inc. 2009. Final technical guidance for assessment and mitigation of the hydroacoustic effects of pile driving on fish. Prepared for the California Department of Transportation.

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National Marine Fisheries Service. 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 Commerce NOAA. NOAA Technical Memorandum NMFS-OPR-55, 178 pp.

Popper, A.N., Hawkins, A.D., Fay, R., Mann, D., Bartol, S., Carlson, T., Coombs, S., Ellison, W.T., Gentry, R., Halvorsen, M.B. and Lokkeborg, S., 2014. *ASA S3/SC1. 4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report Prepared by ANSI-Accredited Standards Committee S3/SC1 and Registered with ANSI*. Springer.

New impact radii figures - Amended

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02	09/07/2016	Revised draft	J. Martin	S. Viada	J. Martin
03	09/07/2016	Draft for client review	J. Martin	L Weekes	J. Martin
REV02	10/03/2016	Revised Final	J. Martin	M.J. Barkaszi	J. Martin

Appendix P-3

Revised Underwater Acoustic Modeling Analysis – October 4, 2016

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Date: 04 October 2016

To: William Daughdrill, Director, Health, Safety and Environment, Fairwood Peninsula Energy Corporation

From: Jeffrey Martin, Senior Technologies Manager, Ocean Sound and Marine Life Services, CSA Ocean Sciences Inc.

Re: Delfin LNG Vessel Noise Modeling

Activities associated with construction and operation of the Delfin Liquefied Natural Gas (LNG) port facility will require vessels which use thrusters for primary propulsion as well as for dynamic positioning (DP) during station keeping and maneuvering. Individual DP vessels may use a variety of thrusters and adjustable propellers for propulsion and steering. The cavitation noise generated by engagement of these thrusters and propellers can produce noise levels well above that of other machinery operations or vessel propulsion noise. (Erbe et al. 2013; Roth et al. 2013; Fisher 2000; Lee et al. 2010). While general vessel noise may affect the acoustic environment, the noise levels produced during thruster engagement present the greatest potential for acoustic impacts exceeding regulatory thresholds to marine mammals and fish (Erbe et al. 2013; Roth et al. 2013; Fisher 2000; Lee et al. 2010).

Because of the need for regulatory compliance, as part of the environmental assessment process, Fairwood Peninsula Energy Corporation (Fairwood), parent company of Delfin LNG LLC, contracted CSA Ocean Sciences (CSA) to conduct acoustic modeling for one construction and one operational scenario for the proposed Delfin LNG offshore facility. A full acoustic impact assessment or marine mammal take calculations will require further modeling development of the potential activity scenarios. The two scenarios that were modeled represent the most likely and potentially longest duration source of DP vessel noise, and therefore provide a good overview for calculating the most likely extent of impact areas. The modeling provides Delfin LNG with a predicted range of distances from a sound source, or group of sources, to the boundaries of regulatory acoustic thresholds for cetaceans and fish.

Noise produced by a non-impulsive (continuous) sources such as ship engines, thrusters, and propellers, unlike an impulsive source (pile driving, seismic surveys with air guns), is characterized by gradual intensity variations over time. DP vessel operation, even though thruster engagement may be varied and intermittent, is considered a continuous noise source.

Affected area radii represent the distance at which regulatory acoustic thresholds (see specific metrics in the following paragraphs) are predicted to be met or exceeded, resulting in potentially detrimental auditory or physical effects to fish and marine mammals. Acoustic thresholds for continuous sources rely on two sound pressure level (SPL) metrics for establishing the thresholds at which a fish or marine mammal, exposed to acoustic energy, would reach the "dosage" necessary to elicit a regulatory impact. These regulatory thresholds are measured in either root mean square sound pressure level (SPL_{rms}) (Popper et al. 2014; GARFO 2016; NMFS, 2016; NMFS 2005) or cumulative sound exposure level (cSEL) (NMFS, 2016). The SPL_{rms} is a measure of the root-mean square, or "effective" sound pressure, converted to dB and used to quantify noise of a continuous nature. The time period over which measurements are taken is not relevant as the measurement will give the same result regardless of the period over which the measurements are averaged. This is contrasted with cSEL which is calculated by summing the accumulated SPL_{rms}, squared, over the time of the event. It effectively takes account of both the level of the sound, and the duration over which the sound is present in the acoustic environment.

MARINE MAMMAL ACOUSTIC THRESHOLD CRITERIA

For this document, impact radii were calculated based on the 2016 National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS, 2016) acoustic criteria for marine mammals. It is important to note that the 2016 NMFS acoustic criteria for marine mammals provide updated acoustic thresholds for the onset of permanent threshold shifts (PTS), which is considered an auditory injury, and temporary threshold shifts (TTS). A TTS is not considered an auditory injury but is considered adverse "harassment", and therefore a regulated take, under the Marine Mammal Protection Act (MMPA). Acoustic thresholds for the onset of behavioral effects have not been updated by NMFS, and therefore the interim thresholds (NMFS 2005), using SPL_{rms} received sound levels, are used for determining the behavioral onset threshold criteria.

The NMFS 2016 criteria apply different threshold to marine mammal functional hearing groups (low-, mid-, and high-frequency), reflecting the fact that each marine mammal group has different hearing sensitivities to the sound spectra produced by the source. For cetaceans, the criteria are based on sound levels that equate to the onset of marine mammal auditory threshold shifts (PTS or TTS) for each functional hearing group (**Table 1)**. The NMFS criteria use a default accumulation period of 24 hours for cetacean cSEL calculations. The 2005 NMFS interim criteria used to determine behavioral disturbance do not consider functional hearing groups and the criteria are applied equally across the groups.

Table 1. Threshold levels used to determine the zone of influence radii for cetaceans (From: National Marine Fisheries Service, 2016, 2005) from a non-impulsive source.

Cetacean Threshold Criteria[1]		Low-Frequency Cetacean Thresholds[1]	Mid-Frequency Cetacean Thresholds[1]	High-Frequency Cetacean Thresholds[1]
Permanent Threshold Shift	cSEL (dB re 1 $\mu Pa^2 s$)	199	198	173
Temporary Threshold Shift	cSEL (dB re 1 $\mu Pa^2 s$)	179	178	153
Behavioral Disturbance Onset	SPL_{rms} (dB re 1µPa)	120	120	120

[1] Frequency Weighted (NMFS 2016)
dB re 1 $\mu Pa^2 s$ = decibels relative to one micropascal for 1 second; cSEL = cumulative sound exposure level over 24 hours; SPL_{rms} root mean square sound pressure level; dB re 1 µPa = decibels relative to one micropascal.

FISH ACOUSTIC THRESHOLD CRITERIA

Standard acoustic criteria used for establishing acoustic impacts to fish are the 2016 NOAA Greater Atlantic Regional Fisheries Office (GARFO) guidelines (GARFO, 2016). However, these criteria are only applicable to pile driving activities and do not address continuous noise sources addressed in this assessment. Therefore, we used the best available information and recommended guidelines from Popper et al. (2014) to establish impact radii for fish. Because of the limited exposure and response data available for fish, Popper et al. (2014) did not assign specific threshold levels for impacts. For most fish groups, Popper et al. (2014) only provide subjective impact criteria such as "low, medium, and high" for injury risk potential of fish in zones defined as "near, intermediate and far" from the sound source. These subjective criteria, therefore, are impossible to apply in the current acoustic assessment. The only defined threshold levels for continuous noise given by Popper et al. (2014) are for fish with swim bladders that provide some hearing (pressure detection) function for the fish. Threshold levels are given for acoustic impacts resulting in recoverable injury and acoustic impacts resulting in TTS (**Table 2**). Popper et al. (2014) uses a 48 hour accumulation period for recoverable injury and 12 hour accumulation period for TTS. Additionally, NMFS and US Fish and Wildlife Service (USFWS) have used a SPL_{rms} of 150 dB re 1 µPa as a threshold for behavioral responses in fish (Hawkins and Popper 2014). This 150 dB re 1 µPa threshold level has subsequently been used in the acoustic impact literature for fish although the scientific origin of this value is not known (Hasting 2008). As this threshold level has been used by regulatory entities, we have included the 150 dB re 1 µPa threshold for potential behavioral impacts.

Table 2. Threshold levels used to determine the zone of influence radii for fish.

Fish Category	Criteria Definition	Exposure assessment period	Metric	Threshold
Fish (non-descriptive)	Onset of behavioral reaction[1]	12 hours	SPL_{rms}	150 dB re 1 µPa
Fish: swim bladder involved in hearing (primarily pressure detection)	Temporary Threshold Shift (TTS)[2]	12 hours	SPL_{rms}	158 dB re 1 µPa
	Recoverable injury[2]	48 hours	SPL_{rms}	170 dB re 1 µPa

1-No documented scientific basis for criteria (Hastings 2008).
2-From Popper et al. (2014) Table 7.7.
dB re 1 µPa = decibels relative to one micropascal; SPLrms = root mean square sound pressure level.

SEA TURTLE THRESHOLD CRITERIA

There is scarce information regarding hearing and acoustic thresholds for marine turtles. The currently accepted hearing and response estimates are derived from fish hearing data rather than from marine mammal hearing data in combination with the limited experimental data available (Popper et al. 2014). The most recent criteria from Popper et al. (2014), do not provide numerical threshold criteria for sea turtles but rather, like the fish criteria described above, provide subjective standards of “low, medium, and high” risk for turtles that are “near, intermediate, or far” from a continuous noise source. However, for impulsive sources, Popper et al (2014) estimates injury threshold levels of 210 dB re 1 µPa (cSEL) and 207 dB re 1 µPa (SPL_{peak}). Sea turtle hearing thresholds in water have not been established by NMFS. Avoidance reactions to seismic sources have been documented in caged turtles at levels between 166 and 179 dB re 1 µPa (Moein et al., 1995; McCauley et al., 2000). Popper et al. (2014) estimates that the potential for TTS, masking, and behavioral alterations are high for exposures occurring near (within tens of meters from) the source; and low for exposures occurring at intermediate (hundreds of meters) and far (thousands of meters) from the source. Based on this information and documented in NMFS Biological Opinions (NMFS 2015) sea turtle underwater acoustic injury and behavioral thresholds are believed to occur at SPL_{rms} 207 dB re 1 µPa and 166 dB re 1 µPa, respectively (**Table 3**). No distinction is made between impulsive and continuous sources for these thresholds.

Table 3. Threshold levels used to determine the zone of influence radii for sea turtles

Sea Turtle Threshold Criteria (SPL_{rms})	Injury Onset	Behavioral Reaction Onset
	207 dB re 1 µPa	166 dB re 1 µPa

dB re 1 µPa = decibels relative to one micropascal; SPLrms = root mean square sound pressure level.

Sound Propagation Modeling

The modeling software, *dBsea* (©Marshall-Day) was used to forecast the underwater acoustic fields resulting from the construction and operation of a floating liquefied natural gas vessel (FLNGV) export terminals at the Delfin LNG site. The model makes use of several types of user-defined environmental data, including bathymetry, speed of sound through the water column (sound speed profiles), and geoacoustic properties of the seabed. Frequency dependence of sound propagation characteristics is treated by computing acoustic transmission loss at the center frequencies of 1/3-octave bands. The SELs received along the radius in each band are computed by applying the frequency-dependent transmission losses to the corresponding 1/3-octave band source levels.

Ambient Noise

Ambient noise is considered as the composite sound from both natural and anthropogenic sources within an area of interest that excludes the contributions of the sources being measured or assessed. Ambient conditions are important to consider in impact assessment as it affects the zone of audibility that an animal will have for perceiving any added sound sources. If the propagated sound level from the noise source is lower than ambient noise levels, then for this exercise it is considered that noise is not within the perceptibility of the selected animal (Kyhn et al. 2014, Wang et al. 2014)

During preliminary baseline surveys conducted by Fairwood in 2015, ambient noise measurements were recorded using a Loggerhead Instruments DSG underwater acoustic recorder with a calibrated HTI hydrophone (CSA, 2016). Results from these measurements indicate that maximum third-octave band spectral noise levels in the vicinity of the site were generally between around 115 and 150 dB re $1\mu Pa^2\ Hz^{-1}$ with these peak band levels occurring in frequencies of a few hundred hertz, depending on time. This is fairly typical of coastal underwater noise, having higher noise levels at frequencies around a few hundred hertz and falling off at higher frequencies. The overall sampling average for the site was 123 dB re $1\mu Pa^2\ Hz^{-1}$; which was the ambient level used in our analyses. The primary anthropogenic contributors to the ambient noise level in and around the proposed LNG facility are from nearby commercial shipping lanes which pass within 50 km of the site and nearby vessels supporting existing oil and gas facilities.

MODELING SCENARIOS

Two activity scenarios, one for construction and one for LNG vessel mooring operations, were modeled to determine the expected acoustic isopleths. The propagation distances for the two scenarios were calculated based on the combined source levels (SL) of the DP vessels and the environmental parameters. The specific vessels to be used on the project are not known and therefore, no direct measurements of the sources were available. The modeled scenarios, therefore, used proxy vessel measurements that were comparable to the vessels that are expected to be used during the associated project phases. The vessels modeled for the activity scenarios are described in **Table 4**.

Scenario 1 (Construction) Model

Construction will require the use of DP vessels for delivery of supplies and construction materials and potentially for positioning of construction vessels as they prepare for anchoring at the construction site. All of the constructions vessels in this scenario (pipelay barge, crane barge, and dive support vessel) are assumed to be already in place and anchored and will not operate in a dynamic positioning mode within the modeled 24 hour assessment period. The anchored vessels will require servicing from an offshore supply vessel (OSV) for crew changes, maintenance, and delivery of construction materials. The servicing OSV will remain relatively stationary while operating in DP mode as it makes the service calls to each anchored platform. The OSV will not be on site for longer than 3 hours every 24 hour period. Additionally, all DP activity is assumed to occur within a 1km range over the entire 3 hour period.

Because there is only 1 OSV vessel operating in DP mode in the scenario, the SPL_{rms} source level for the scenario is 186 dB re 1 µPa, equal to that of the OSV alone.

Scenario 2 (Operations) Model

Under normal operational procedures, an empty LNG carrier will berth at the FLNGV (liquefaction vessel). LNG Carriers are escorted into the Delfin LNG facility area by tugs. Four tugs are attached and provide assistance within approximately 1 km of the FLNGV mooring. The tugs are connected by line to the LNG Carrier and use their engines/thrusters to control and arrest the LNG Carrier as it positions alongside the FLNGV. The FLNGV is moored to a tower yoke mooring system (moored by the bow in a weather vanning arrangement) but can use any of its three installed propulsion thrusters to position the FLNGV in relation to the wind/waves. The propulsion thruster on the FLNGV is an azimuthing directional thruster (one of three propulsion thrusters). During normal operations, the propulsion thrusters are engaged only when the FLNGV is receiving an LNG carrier. For this scenario, we assumed that when an LNG carrier is arriving or departing, there will be four tugs with thrusters operating at very slow speed (1 to 2 knots) and the FLNGV is using one of its thrusters for positioning to receive or release the LNG carrier with tugs attached. While the tugs are moving very slowly during mooring (three hours) and departure (1 hour) they could be using their thrusters under significant power to arrest the incoming ship or move the FLNGV into position (or away from the FLNGV during un-mooring). The scenario assumes that while there are a total of 4 moorings proposed for the facility, only one mooring operation will be conducted within a single 24 hour period. The tugs are used for 3 hours within the vicinity of the mooring during arrival and 1 hour during departure. Thus, the combination of tug thrusters and FLNGV thrusters (for positioning) are only expected to last for a maximum of 4 hours to complete a cycle within any single 24 hour period. During this time, the LNG carrier is expected to be at or near idle and will not contribute appreciable to the source levels. All DP activity is assumed to occur within a 1km range over the entire 4 hour period. The activity of the 4 tugs plus the FLNGV positioning produces a combined SPL_{rms} source level of 193 dB re 1 µPa.

Table 4. Description of vessel activity parameters used for modeling two activity scenarios, at one location within the Delfin LNG project area, over one 24-hour time period. The modeled activity location is at planned FLNG mooring #1, located in OCS Lease Block WC 319, Latitude: 29°8'13.100"N; Longitude 93°32'2.200"W.

	Noise Source	Activity	Proxy Source	Proxy Source Description	Number in use	Modeled Broadband per Vessel SL (dB re 1 µPa·@1m)	Hours of operation within a 24 hour period
Construction Scenario	Offshore Support Vessel	Servicing anchored vessels	Setouchi Surveyor[1]	Length: 64m Draft: 5m Source Depth:4.8m	1	186.1	3
	Pipe Lay Vessel	Anchored	N/A	Idle	1	N/A	N/A
	Crane Barge	Anchored	N/A	Idle	1	N/A	N/A
	Dive Support Vessel	Anchored	N/A	Idle	1	N/A	N/A
Operations Scenario	LNG Escort Tug	Positioning LNG Carrier	Pacific Ariki[2]	Length: 64m Draft:6.6m Source Depth: 6m 6,437 HP	4	185.7	4
	LNG Carrier	Positioning to FLNG	N/A	Idle	1	N/A	N/A
	FLNGV	Weather vanning on mooring to stabilize with LNG Carrier	FPSO[2] with thrusters operating	(2) 8000 HP azimuth thrusters operating at full power	1	188.9	4

[1]-Hannay et al 2004.
[2]-Duncan 2014 & McCauley 1998.

MODELING RESULTS

The predicted sound field for the non-impulsive noise sources was modeled for the construction and operations scenarios at FLNGV site 1. It is assumed, based on the environmental parameters, that the propagation distances will be the same for each FLNGV location. **Figures 1** through **6** depict the distances to threshold isopleths for each scenario and regulatory metric.

The Cetacean TTS (cSEL) and Cetacean Behavior ($SPL_{rms)}$ thresholds for the construction scenario are depicted in **Figure 1**. The Cetacean PTS (cSEL) threshold for the construction scenario is depicted in **Figure 2**. The Fish Injury (SPL_{rms}), Fish TTS (SPL_{rms}), Fish Behavior (SPL_{rms}), and Sea Turtle Behavior (SPL_{rms}) are depicted in **Figure 3**. The Cetacean TTS (cSEL) and Cetacean Behavior ($SPL_{rms)}$ thresholds for the operations scenario are depicted in **Figure 4**. The Cetacean PTS (cSEL) threshold for the operations scenario is depicted in **Figure 5**. The Fish Injury (SPL_{rms}), Fish TTS (SPL_{rms}), Fish Behavior (SPL_{rms}), and Sea Turtle Behavior (SPL_{rms}) threshold for the operations scenario are depicted in **Figure 6**.

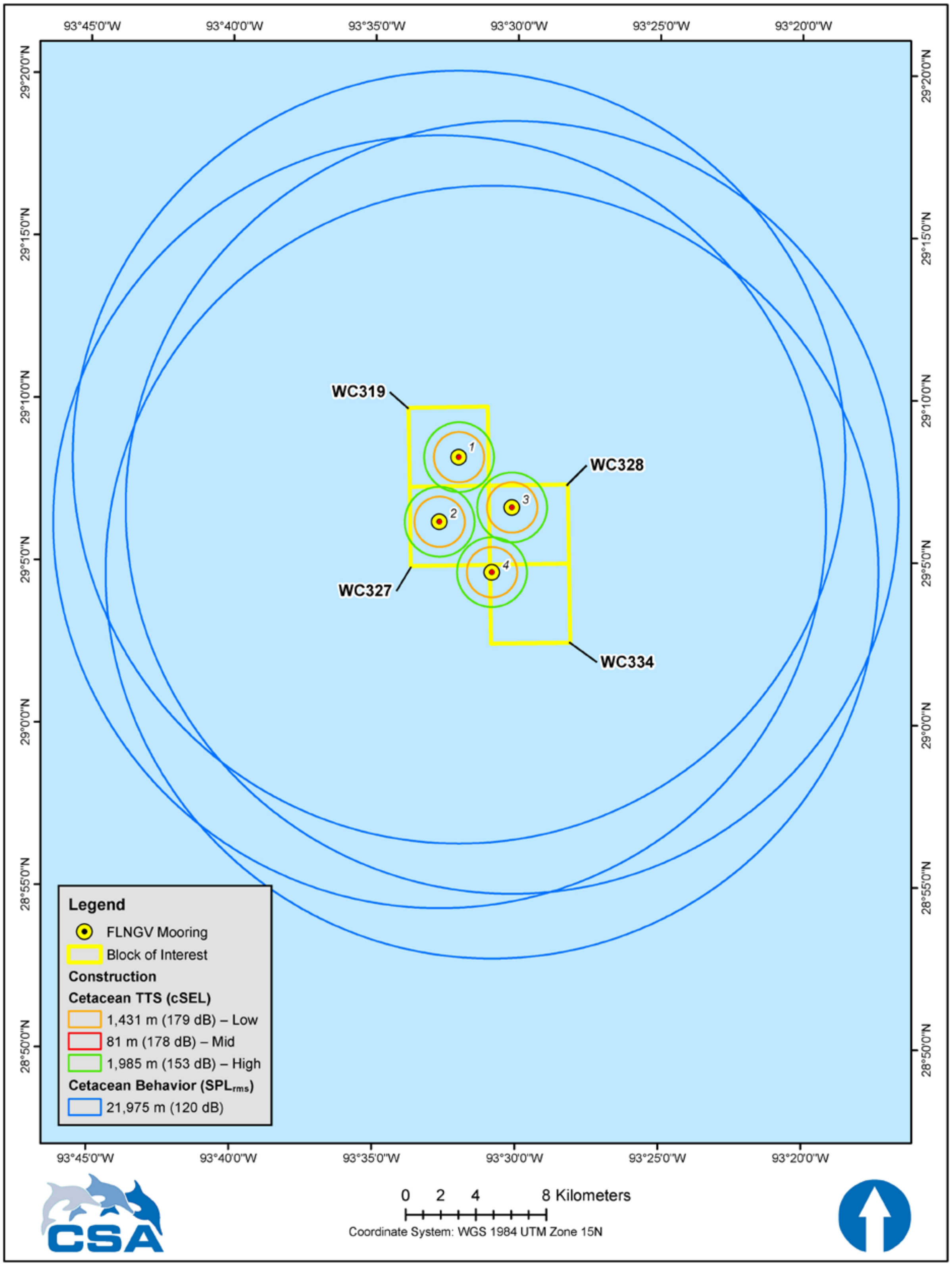

Figure 1. Cetacean TTS (cSEL) and Cetacean Behavior (SPL_{rms}) thresholds for the construction scenario.

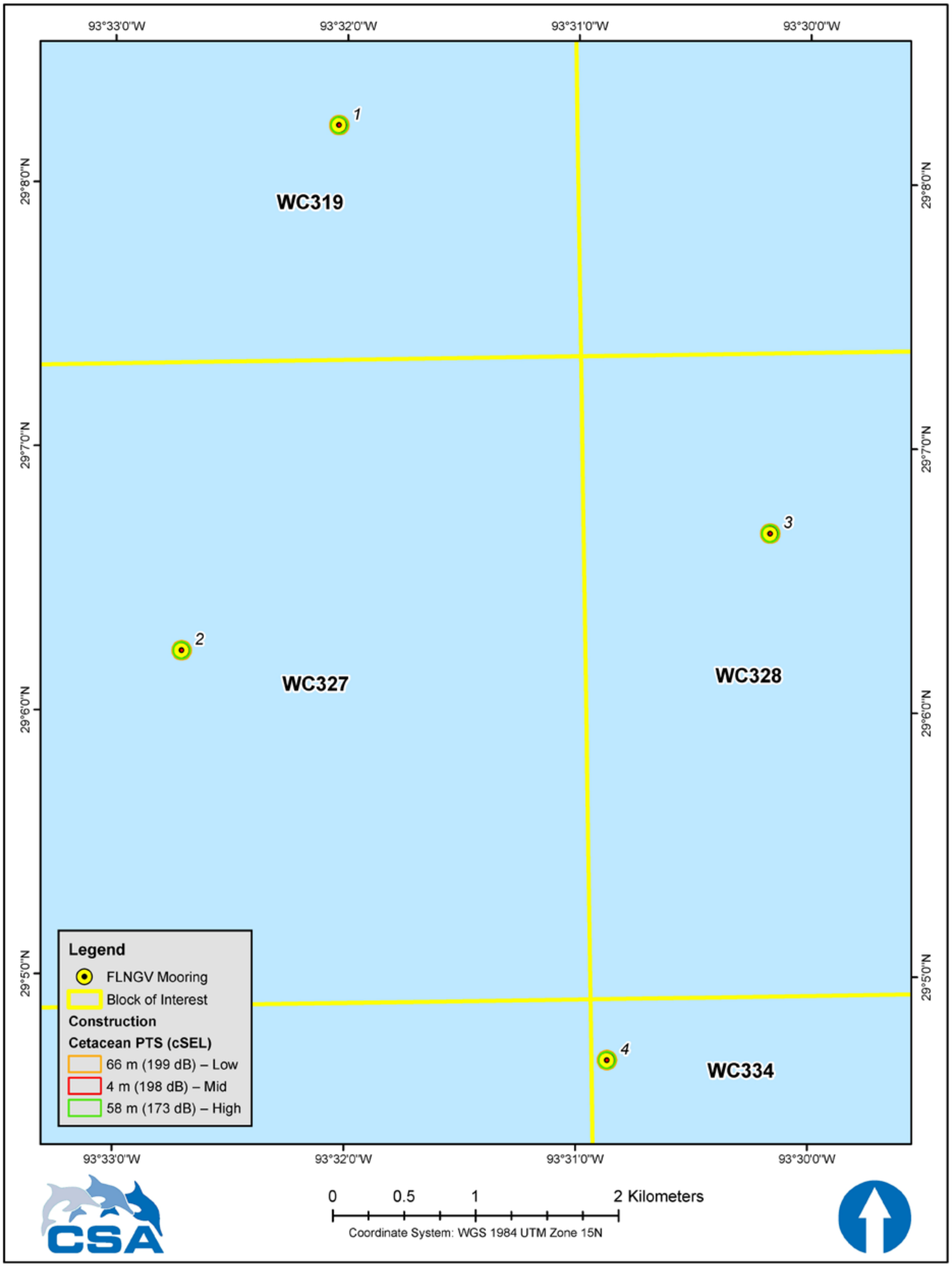

Figure 2. Threshold isopleths for cetacean PTS (cSEL) at each mooring location for the construction scenario.

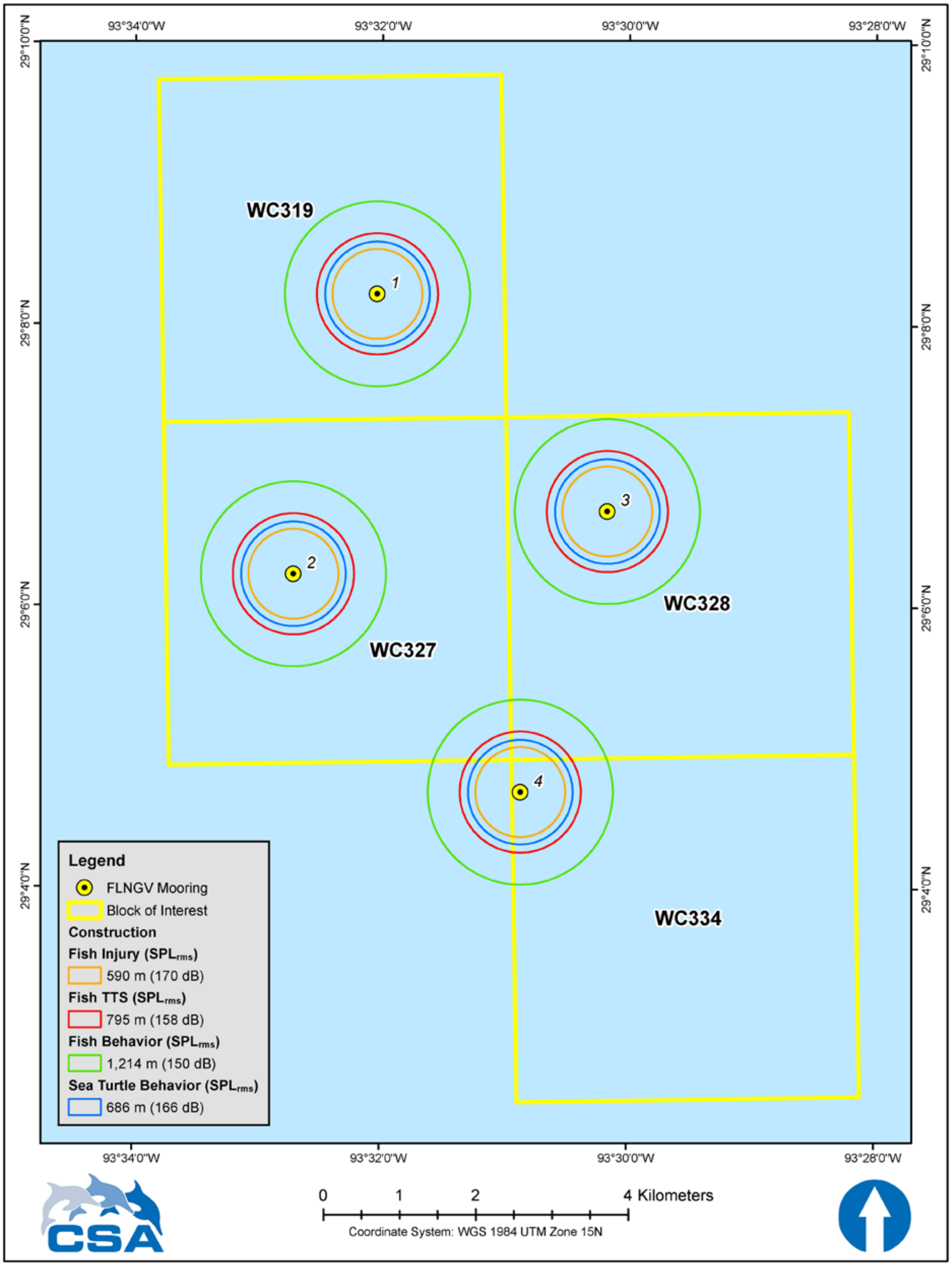

Figure 3. Threshold isopleths around each mooring location for Fish Injury (SPL_{rms}), Fish TTS (SPL_{rms}), Fish Behavior (SPL_{rms}), and Sea Turtle Behavior (SPL_{rms}) during the construction scenario.

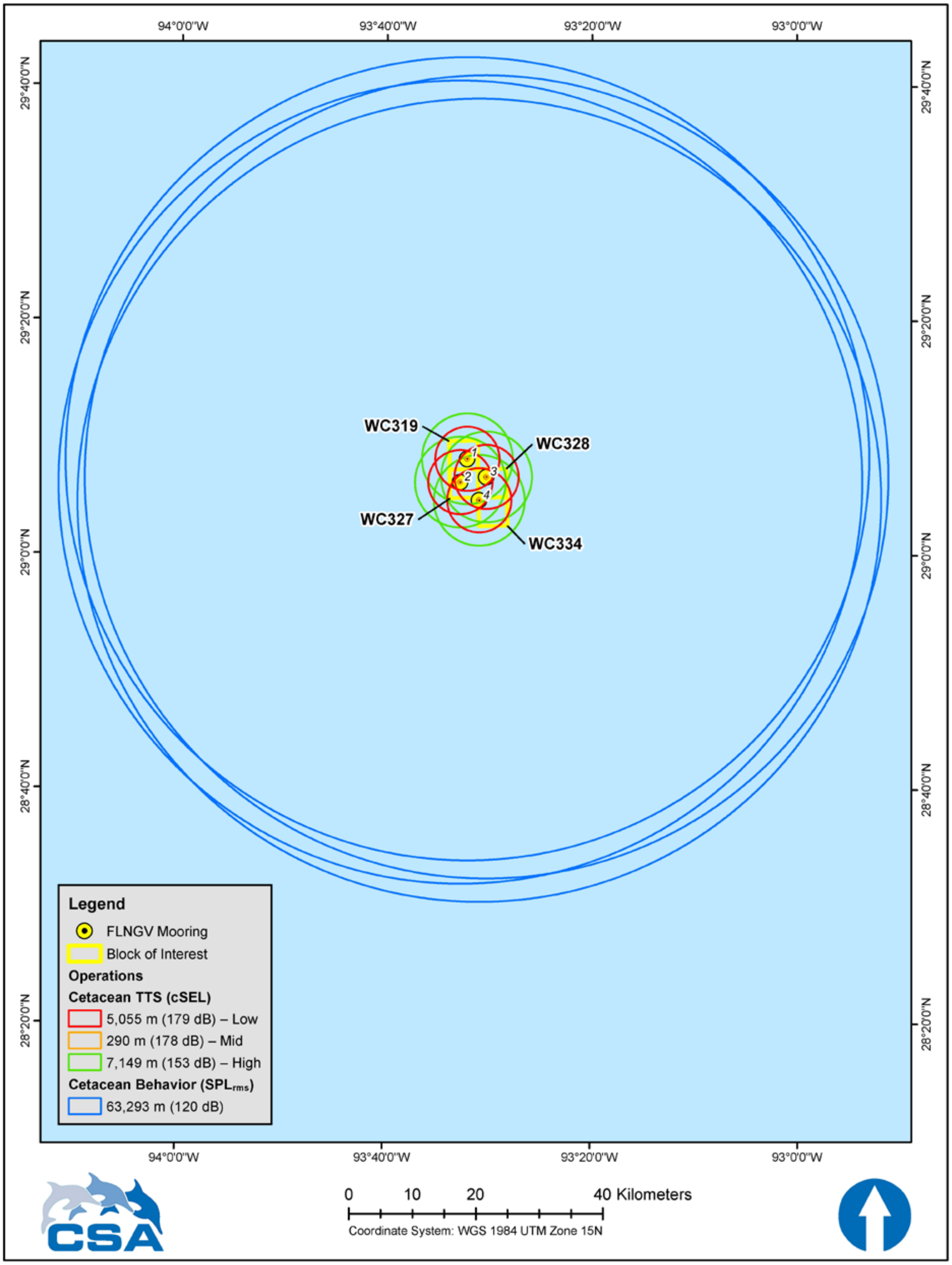

Figure 4. Threshold isopleths for cetacean TTS (cSEL) and Cetacean Behavior ($SPL_{rms)}$ during the operations scenario.

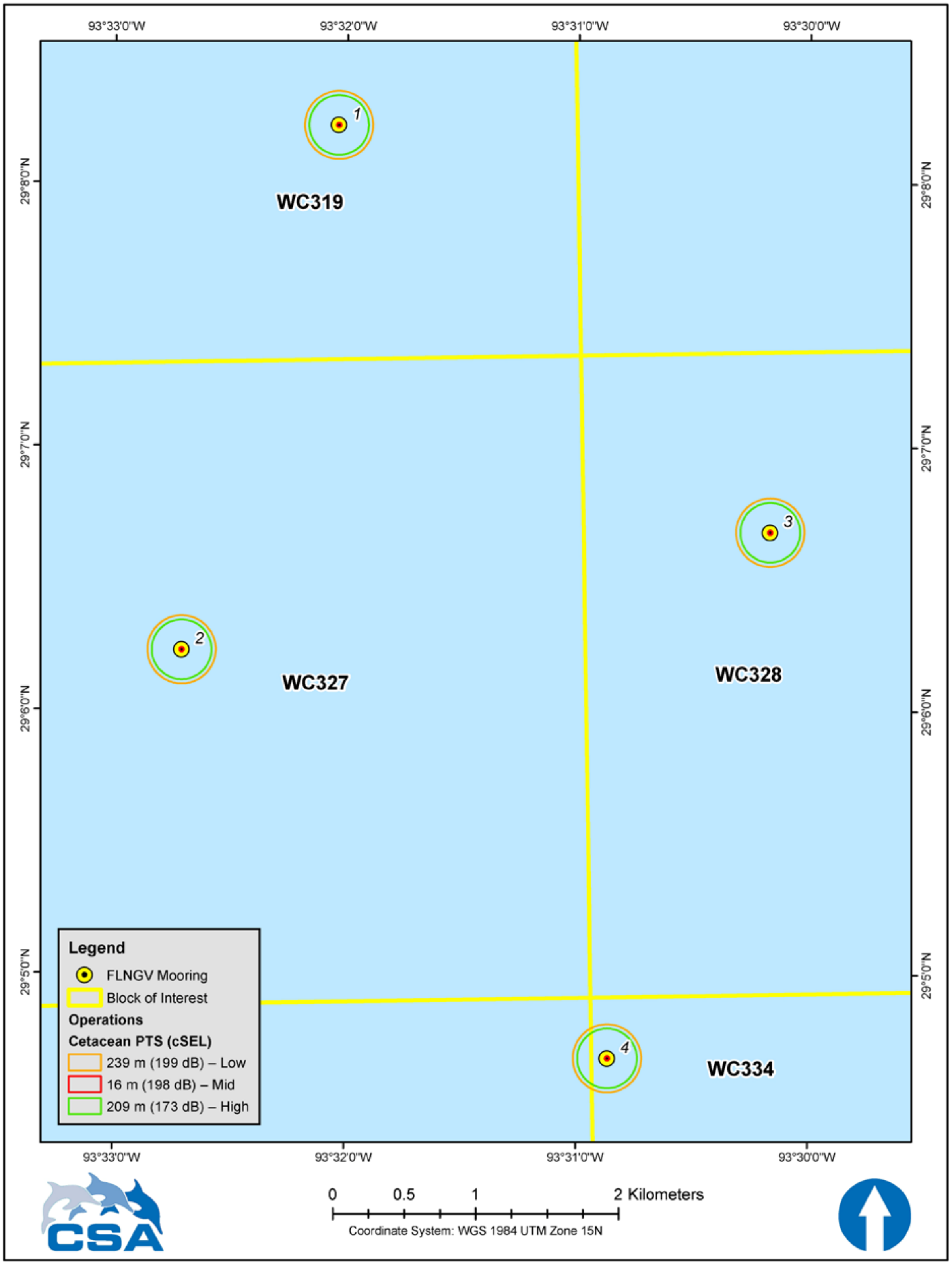

Figure 5. Threshold isopleths for cetacean PTS (cSEL) during the operations scenario.

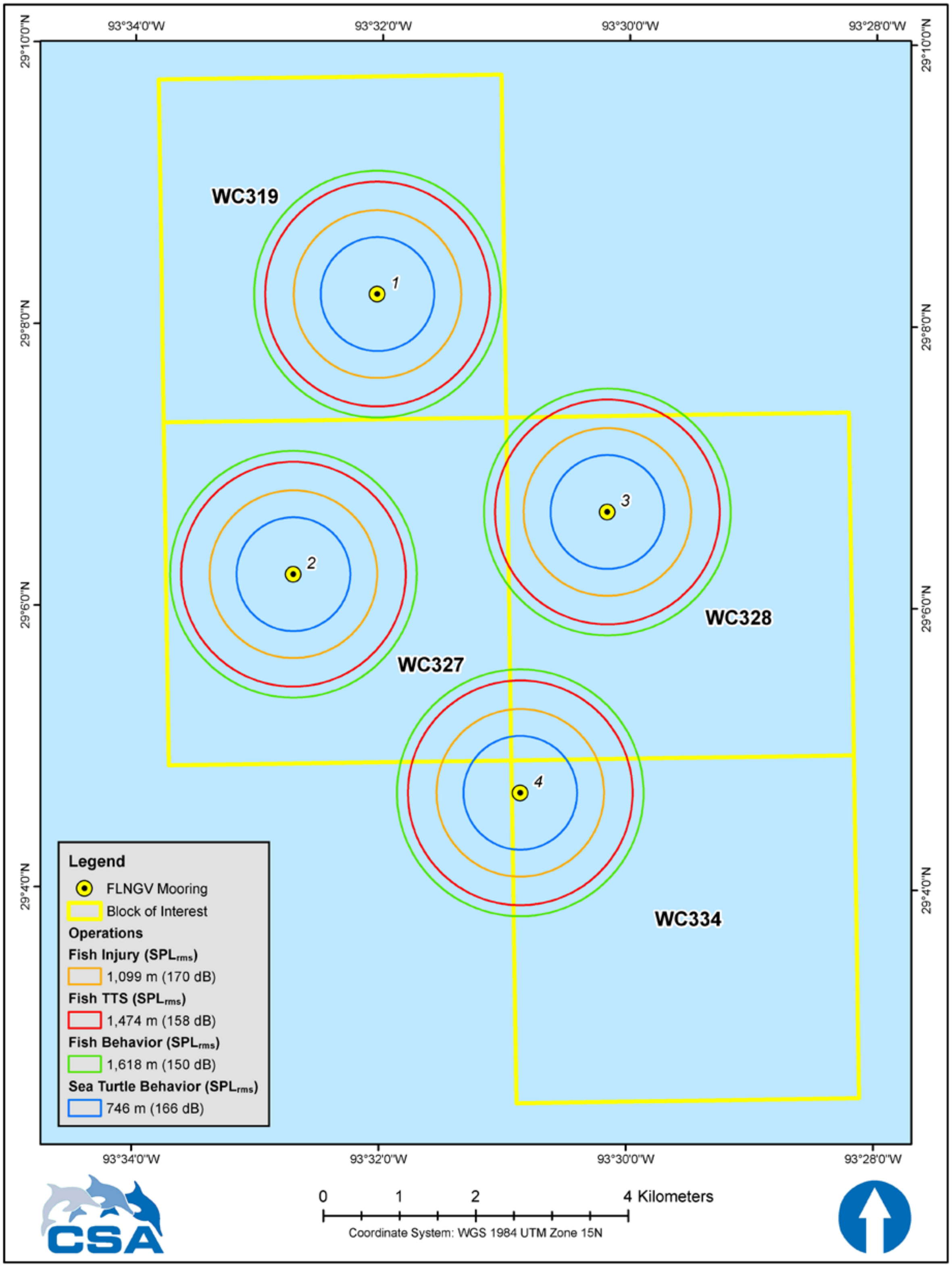

Figure 6. Threshold isopleths around each mooring location for Fish Injury (SPL_{rms}), Fish TTS (SPL_{rms}), Fish Behavior (SPL_{rms}), and Sea Turtle Behavior (SPL_{rms}) during the operations scenario.

Threshold Isopleths and Zone of Influence Determination

MARINE MAMMALS

The isopleths corresponding to the regulatory threshold levels for marine mammals were calculated using the NMFS (2016) User Spreadsheet Calculator for non-impulsive stationary sources. These results are listed in **Table 5**. The threshold metric (cSEL) accounts for the exposure time during which DP operations are active within the 24 hour assessment period. Exposure times of 3 hours and 4 hours for construction and operational scenarios, respectively, were used in these calculations. Additionally, NMFS (2016) requires that auditory weighting functions be applied for calculating the threshold isopleths for marine mammals in order to account for the differences in audible bandwidths amongst cetacean groups (NMFS 2016, Southall et al. 2007, Finneran and Jenkins 2012). We used the default weighting function adjustment (WFA) of 2 kHz as described in the NMFS guidance document (NMFS, 2016). NMFS concedes that using the default WFAs will result in larger impact distances than modeling (NMFS 2016).

CSA conducted acoustic threshold modeling using calculated weighting functions (Finneran et al. 2012, NMFS 2016) to compute cSEL rather than the default WFAs as described above. By using these more precise weightings rather than default WFAs, the impact areas were significantly reduced. The modeled cSEL resulted in no PTS exposure thresholds met for any cetaceans, and TTS thresholds met only for low frequency cetaceans during the operations scenario (403 m); no TTS thresholds were met for any cetaceans during the construction scenario. However, for the purposes of this document, the more conservative NMFS spreadsheet calculator estimates were used to predict the largest zone of influence, or maximum areal extent, of potential impact zones around a single mooring, for low, medium, and high frequency cetaceans.

The behavioral threshold distances were based upon NMFS interim criteria (2005) calculated from modeled sound propagation. The criteria do not incorporate any exposure duration for meeting the threshold, are unweighted, and are applied equally for all functional hearing groups. Therefore, it is assumed that any marine mammal exposed to the SPL_{rms} 120dB re 1 µPa has met the threshold criteria for behavioral disturbance.

Table 5. Estimated distances from source to cetacean species threshold onset levels for each activity scenario.

Scenario	Cetacean Threshold Criteria	Radial threshold distance in meters for the propagated acoustic energy		
		Low-Frequency	Mid-Frequency	High-Frequency
Construction SL=186 EP = 3 hours	PTS	66	4	58
	TTS	1,431	81	1,985
	Behavior	21,975		
Operation SL= 193.1 EP = 4 hours	PTS	239	16	209
	TTS	5,055	290	7,149
	Behavior	63,293		

SL = Source Level
EP = Exposure Period

FISH

The isopleths corresponding to the recommended threshold levels for the fish (derived from Popper et al. 2014) were calculated using the unweighted sound field estimations modeled using dBsea acoustic modeling software (© Marshall Day). These results are listed in **Table 6**. The threshold metric (SPL_{rms})

does not directly account for the exposure time during which DP operations are active in the same way the cSEL metric accounts for exposure time. However, to meet the threshold criteria it is assumed that a fish would need to be exposed to the DP source levels at the distances listed in **Table 6** for 48 hours in the case of recoverable injury, or 12 hours in the case of TTS.

Table 6. Estimated average radial distances from source to potential fish threshold levels for each activity scenario. Note that to reach the impact thresholds, fish would need to be at these distances for prescribed amount of time established in each threshold level.

Scenario	Average radial distance in meters to SPL_{rms} thresholds for fish		
	Recoverable Injury (170 dB re 1 µPa for 48 hours)	TTS (158 dB re 1 µPa for 12 hours)	Onset of behavioral reaction (150 dB re 1 µPa for 12 hours)
Construction	590	795	1,214
Operations	1,099	1,474	1,618

SEA TURTLES

The isopleths corresponding to the currently-used threshold level for the onset of behavioral reaction in sea turtles were calculated using the unweighted sound field estimations modeled using dBsea acoustic modeling software (© Marshall Day). These results are listed in **Table 7**. The source levels do not reach any injury thresholds for sea turtles; therefore, only behavioral thresholds are considered for the threshold radii and subsequent zones of influence.

Table 7. Estimated average radial distances from source to potential behavioral threshold levels in sea turtles for each activity scenario.

Scenario	Average radial distance in meters to SPL_{rms} behavior thresholds for sea turtles
Construction	686
Operations	746

The ZOIs (km^2) are the areal extent encompassing cetacean, sea turtle and fish threshold sound levels expressed for construction and operation scenarios and are listed in **Table 8**. It is assumed here that the isopleths are circular and therefore, the ZOI is the calculated area of the circle based on the distance from the source to the selected threshold isopleths. In reality, this area is likely not a true circle and variations in propagation, particularly in the shallow water environment, will result in unequal propagation. However, the areal calculation provides a reasonable, albeit highly conservative, predicted ZOI for each of the species groups.

Table 8. Zones of influence in square kilometers for regulatory threshold levels established by NMFS for fish, sea turtles, and cetaceans (NMFS 2016, NMFS 2015, Popper et al 2014, NMFS 2005), based on the radial distances and exposure times described within each activity scenario.

Scenario	Threshold Criteria	Zone of Influence (km^2)		
		Behavior Onset	TTS Onset	PTS/Injury Onset
Construction SL=186 EP = 3 hours	LF Cetacean	1,506	6.4	< 0.1
	MF Cetacean		< 0.1	< 0.1
	HF Cetacean		12.3	< 0.1
	Sea Turtle	0.1	0	0
	Fish	0[a]	0[a]	0[a]
Operation SL= 193 EP = 4 hours	LF Cetacean	12,548	80.2	0.2
	MF Cetacean		0.2	< 0.1
	HF Cetacean		160.5	0.1
	Sea Turtle	0.2	0	0
	Fish	0[a]	0[a]	0[a]

a – threshold criteria not met because exposure time requirements are not met in the scenario.

The behavioral threshold criteria used for cetaceans do not take into consideration frequency weighting or exposure periods, resulting in large ZOIs. Additionally, ambient noise levels can reach SPL_{rms}150 dB re 1 µPa at the project site with average ambient levels (123 dB re 1 µPa) exceeding the 120 dB re 1 µPa SPL_{rms} threshold criteria. Therefore, any impact assessment should take into consideration the ambient conditions. The largest cSEL calculated ZOI was TTS onset for high frequency cetaceans (160.5 km^2). The only high frequency cetacean groups in the Gulf of Mexico (GOM) are the *Kogia* species which are rare in shelf waters and typically found in slope habitat greater than 200m depth. Similarly, maximum TTS ZOIs for low frequency cetaceans (80.2 km^2) may encompass only a very small portion of the actual distribution of low frequency species in that area of the GOM. Impact thresholds for mid frequency cetaceans are most applicable to the location. However, as noted in the document, modeling results produce much smaller impact threshold isopleths than the NMFS User Spreadsheet; therefore, the ZOIs listed here should be considered a highly conservative, maximum estimate of threshold distances. Fish thresholds were not met due to the short time period (3 to 4 hours) of exposure which falls below the 12-48 hour exposure period necessary to meet the guidelines for onset of impacts.

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Delfin Vessel Noise Modeling

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01	09/16/2016	Initial draft for review	M.J. Barkaszi	M. Fonseca	J. Martin
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FIN	09/27/2016	Final	M.J. Barkaszi	J. Martin	J. Martin
FIN5	10/04/2016	Revised figures	J. Martin	M.J. Barkaszi	J. Martin

Appendix P-4

Cumulative In-Air Acoustic Analysis – April 7, 2016

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April 7, 2016

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, NW
Room 1A, East
Washington, DC 20426

Re: Delfin LNG LLC, Docket No. CP15-490-000, 001
Delfin Onshore Facilities
Supplement to February 12, 2016 Environmental Information Request Response

Dear Secretary Bose:

On March 3, 2016, Delfin LNG LLC (Delfin LNG) submitted its responses to the Commission Staff's February 12, 2016 Environmental Information Requests (March 3 Filing). In the March 3 Filing, Delfin LNG stated in its response to Environmental Information Request No.10 (Resource Report 9) that it would provide a response at a later date.

Delfin LNG's response to Environmental Information Request No.10 (Resource Report 9) is attached. Hard copies and CDs of this filing are being provided directly to Commission Staff and the agency contacts identified in the February 12, 2016 request.

This response is filed under oath pursuant to 18 C.F.R. § 385.2005 and includes the name, position, and telephone number of the respondent. The signer represents that she has read the filing and knows its contents, that the contents are true as stated to the best of her knowledge and belief, and that she possesses full power and authority to sign and submit this filing.

Any questions may be directed to the undersigned.

Respectfully submitted,

/s/ Janna R. Chesno

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Enclosures
cc: Douglas Cotton, OEP, 61-41, Gas Branch 4
Roddy Bachman, USCG
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Service List

Delfin LNG LLC
Docket No. CP15-490-000, -001
Delfin Onshore Facilities
Response to FERC Staff Environmental Information Request
Issued February 12, 2016

Environmental Information Request No. 10 (Resource Report 9)

10. Perform a cumulative noise impact analysis for the day-night sound level (L_{dn}) noise contribution of the proposed DOF Compressor Station, proposed meter station, and Transco Compressor Station 44 facilities at nearby noise-sensitive areas (NSAs) during combined full load operation. Provide any available information concerning the full load L_{dn} noise contribution of the Stingray Gas Plants and Cameron Meadows Gas Processing Plant (within one mile of the project site) at nearby NSAs in common with the DOF Compressor Station and Transco Compressor Station 44.

Response:

PSI Cameron Meadows Gas Processing Plant

On January 13, 2015 during the baseline noise survey, the Cameron Meadows Gas Processing Plant was operating with (2) Centaur Turbines, Expander compressor, and (1) generator Processing 90 mmcf/d. The sound contribution from this operation was captured in the baseline noise measurements. PSI has discontinued operations at the Cameron Meadows Gas Processing Plant (with no intention to resume operations as the facility has been shut down, de-staffed, and the equipment and land are being offered for sale by PSI) since the original baseline noise survey was conducted and the current baseline noise conditions at the NSAs would be expected to be lower than those presented in Resource Report 9, Tables 9.3-1 and 9.3-6 and in Table 1 below.

Stingray Gas Plant

The distance from the Stingray Gas Plant to NSA 1 (the nearest NSA to DOF Compressor Station and Stingray gas plant) is 5,617 feet or 1.06 miles. Given this distance and the type of operation at the plant (Centaur Turbines), it is unlikely that there would be any noise contribution from the Stingray Gas Plant at any of the NSAs. In addition, according to FERC guidance, operational noise cumulative impacts should include other projects where noise from the other long-term projects/facilities would affect NSAs within 1 mile of the proposed facility.

Meter Station

Delfin proposes to install a new meter station for the DOF located on the Transco Station 44 property. The location of the meter station would be approximately 2,450 feet north of the DOF site center, and 4,232 feet from the nearest NSA. The noise contribution at the nearest NSA resulting from the operation of the meter station was calculated using the following equation for noise attenuation over distance:

$$L_2 = L_1 - 20\log\left(\frac{d_2}{d_1}\right)$$

Where:

L2 = sound level at distance d_2

L1 = sound level at distance d_1

Based on this calculation, due to the distance between the meter station and the NSAs, and accounting for the meter station sound level design (not to exceed 85 dBA at 3 feet), no additional noise contribution would be expected at the NSAs due to the operation of the meter station.

Compressor Station 44

The existing Compressor Station 44 in Cameron Parish is being upgraded with the addition of two Mars 100S turbine driven compression units rated at 16,000 horsepower (hp) each (for a total of 32,000 hp) and four bays of cooling and related auxiliary equipment installed on an elevated platform with new station suction and discharge piping with a target in-service date of January 1, 2017. The noise level for Compressor Station 44 was taken from FERC filing August 2015 entitled "Gulf Trace Expansion Project and East Meter Pipe Project" Docket No. CP15-29, Table 2.7.7-1. The noise contribution at the NSAs resulting from the operation of Compressor Station 44 was calculated based on this level using the following equation for noise attenuation over distance:

$$L_2 = L_1 - 20\log\left(\frac{d_2}{d_1}\right)$$

Where:

L2 = sound level at distance d_2

L1 = sound level at distance d_1

The noise level contribution at the NSAs resulting from the operation of the DOF was estimated using Acoustic noise modeling of the major DOF sources was conducted using the Computer Aided Noise Abatement (CadnaA) acoustic model version 3.7.124 developed by Datakustik GmbH. Primary noise-producing equipment at the proposed DOF, along with corresponding estimated noise-emission data and noise-control equipment-reduction values, were derived from equipment manufacturer's data sheets. The model simulates the outdoor three-dimensional propagation of sound from each noise source and accounts for sound wave divergence, atmospheric and ground sound absorption, and sound attenuation due to interceding barriers and topography based on the International Standard ISO9613-2 (ISO 1996). Standard conditions of 50°F and 70% relative humidity were assumed. Ground absorption was set to 0.5. A database was developed that specified the location and sound power levels of each noise source. A receptor grid was specified that covered the entire area of interest. The model calculated the overall A-weighted sound pressure levels (SPLs) within the receptor grid based on the sound level contribution of each noise source.

The noise levels for the DOF and Compressor Station 44 were combined using the following equation:

$$Leq_{total} = 10\log\left(10^{\frac{Leq_1}{10}} + 10^{\frac{Leq_2}{10}} + 10^{\frac{Leq_3}{10}} \ldots etc.\right)$$

Table 1 presents the combined estimated L_{dn} noise level contribution at the NSAs with the full potential operation of the DOF and the two additional Mars 100S turbine driven compression units to be operating at Compressor Station 44 in year 2017. The table also presents the expected increase in the Ldn noise level for both operations and for the DOF operation only.

Table 1 Summary of Cumulative Noise Levels at NSAs and Expected Increase in Ldn Above Existing Ldn

NSA	Existing Ambient L_{dn} (dBA)	DOF Contribution L_{dn} (dBA)	Compressor Station 44 Contribution L_{dn} (dBA)	Combined L_{dn} DOF, Station 44, and Existing Ambient (dBA)	Cumulative Expected Increase (dB)	DOF Only Expected Increase (dB)
#1	52.2	46.4	38.8	53.4	1.2	1.0
#2	65.3	50.6	41.5	65.5	0.2	0.1
#3	55.8	45.3	36.5	56.2	0.4	0.4

Considering the above, Delfin is confident that it will be able to meet the FERC's requirements for minimizing project-related noise at the three nearby NSAs discussed above.

Response prepared by:

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Document Content(s)