Table 3-5. Distances at Which Underwater Noise Exceeds SEL Injury Thresholds for Fish in the Columbia River Based on Fish Speed and Transit Rate

Pile Size	Number of Pile Drivers	Strikes per Day		Strike Interval (sec)	Distance (m) 187 dB Over 2 g at 0.1 m/s		Distance (m) 187 dB Over 2 g at 0.8 m/s		Distance (m) 183 dB Under 2 g at 0.6 m/s	
		Without Attenuation Device	With Attenuation Device		Without Attenuation Device	With Attenuation Device	Without Attenuation Device	With Attenuation Device	Without Attenuation Device	With Attenuation Device
18- to 24-inch pile	1	150	400	1.5	113	50	102	9	200	50
36- to 48-inch pile	1	150	800	1.5	243	156	237	67	446	235
Two 18- to 24-inch piles	2	N/A	200	0.75	N/A	59[a]	N/A	48[a]	N/A	79[a]
Two 36- to 48-inch piles OR one 18- to 24-inch and one 36- to 48-inch pile	2	N/A	400	0.75	N/A	130[a]	N/A	111[a]	N/A	209[a]

Note: Includes adult salmon, steelhead, and eulachon.
a Applies to Columbia River only.

Table 3-6. Distances at Which Underwater Noise Exceeds SEL Injury Thresholds for Fish in North Portland Harbor Based on Fish Speed and Transit Rate

Pile Size	Number of Pile Drivers	Strikes per Day		Strike Interval (sec)	Distance (m) 187 dB Over 2 g at 0.1 m/s		Distance (m) 187 dB Over 2 g at 0.8 m/s		Distance (m) 183 dB Under 2 g at 0.6 m/s	
		Without Attenuation Device	With Attenuation Device		Without Attenuation Device	With Attenuation Device	Without Attenuation Device	With Attenuation Device	Without Attenuation Device	With Attenuation Device
18- to 24-inch pile	1	75	900	1.5	71	72	67	9	69	15
36- to 48-inch pile	1	75	900	1.5	153	169	153	66	153	90

Note: Includes adult salmon, steelhead, and eulachon.

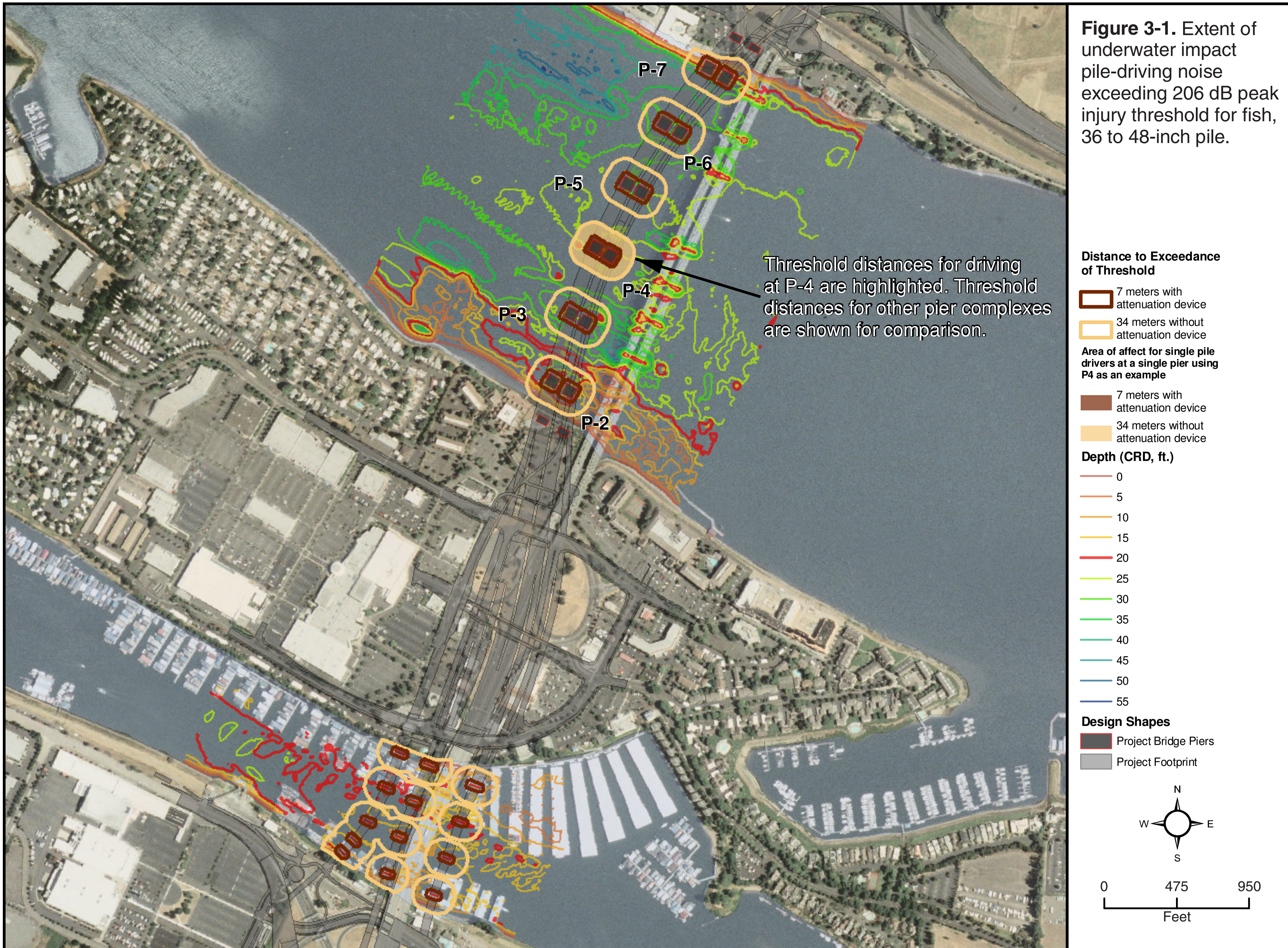
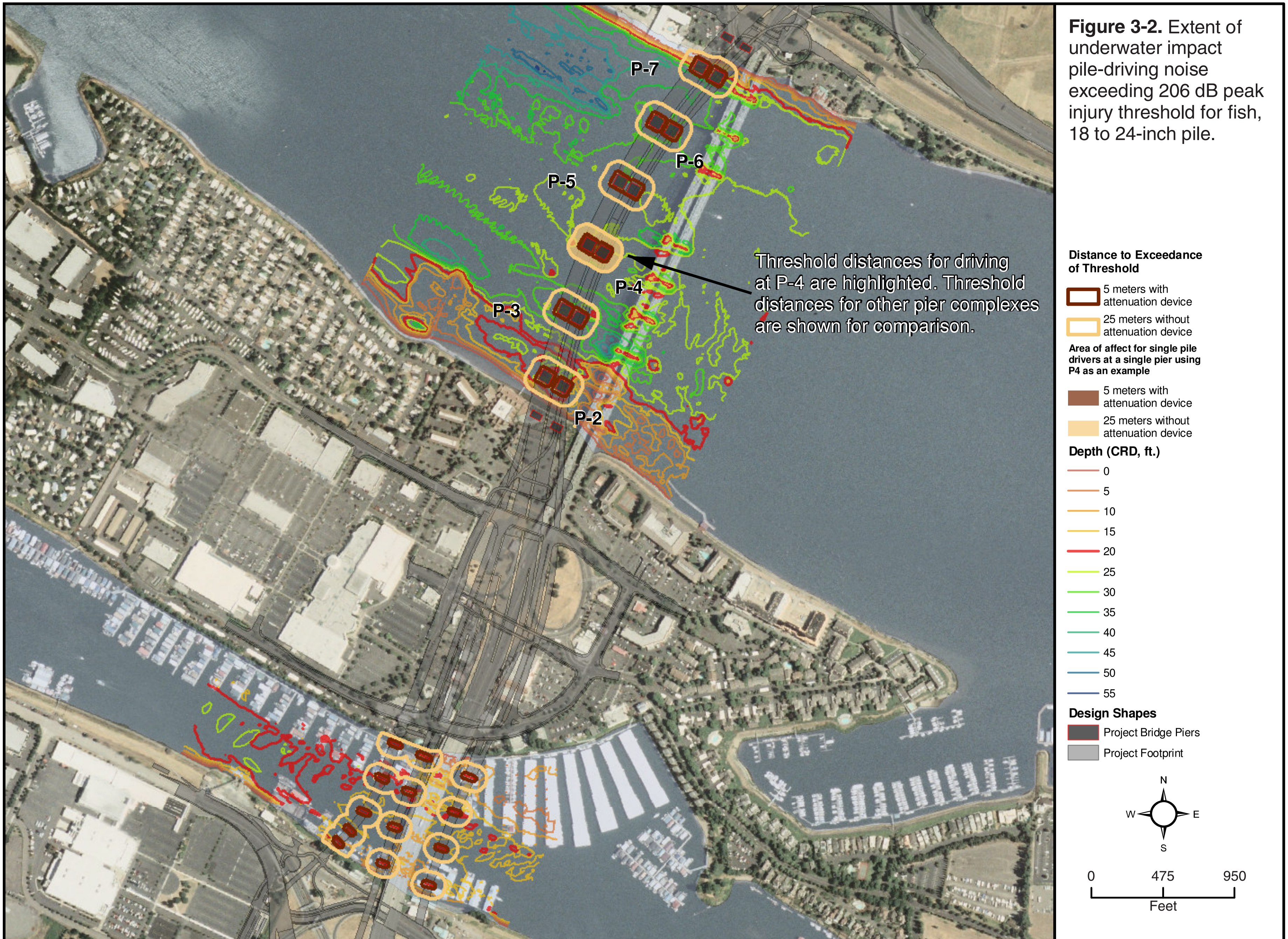


Figure 3-1. Extent of underwater impact pile-driving noise exceeding 206 dB peak injury threshold for fish, 36 to 48-inch pile.

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Analysis by J. Koloszar; Analysis Date: Feb. 11, 2010: File Name: HydroSound_MG246_2.mxd

Figure 3-2. Extent of underwater impact pile-driving noise exceeding 206 dB peak injury threshold for fish, 18 to 24-inch pile.



This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: Feb. 11, 2010: File Name: HydroSound_MG246_2.mxd

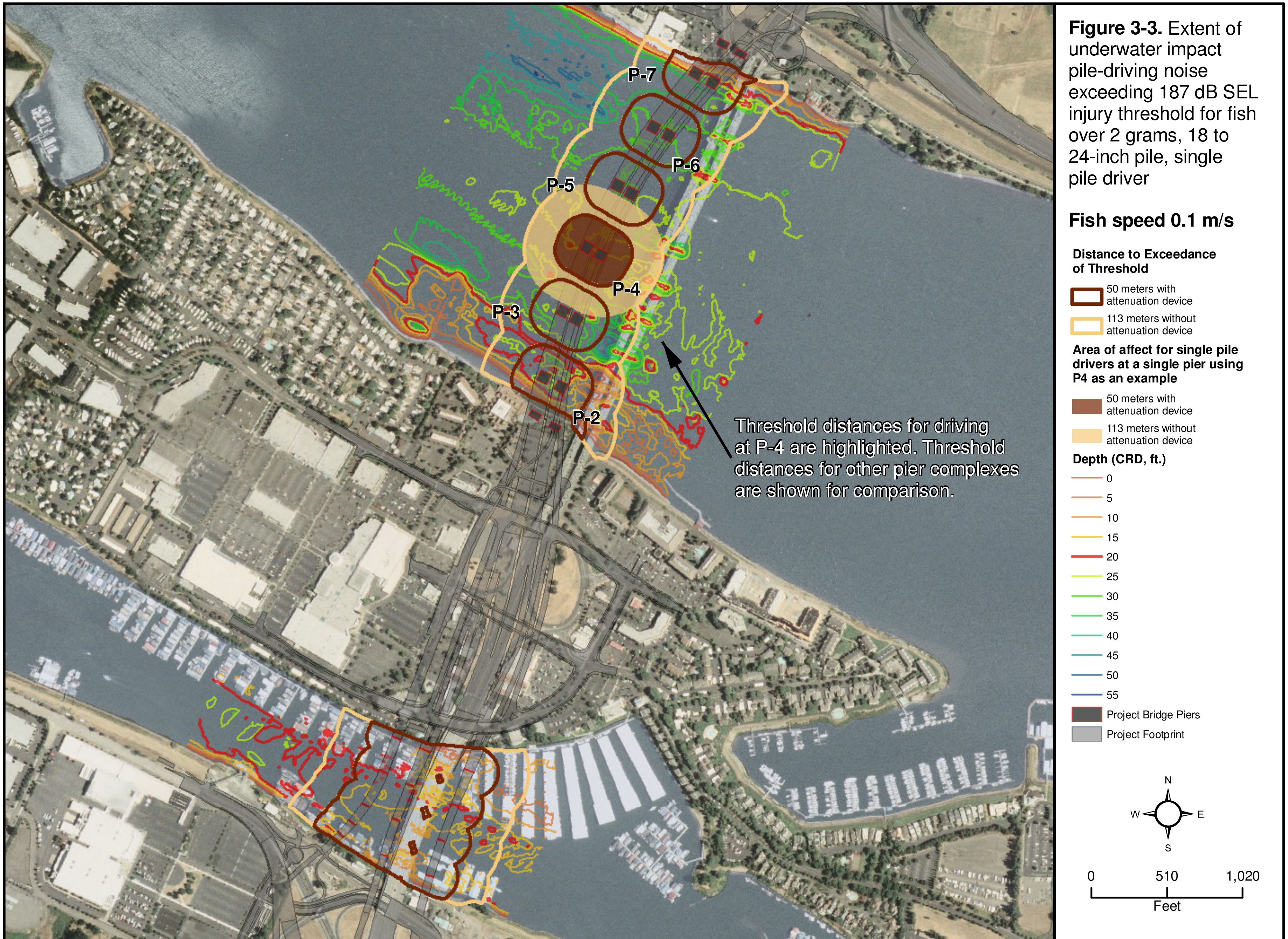


Figure 3-3. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, 18 to 24-inch pile, single pile driver

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Analysis by J. Koloszar; Analysis Date: June 2, 2010: File Name: HydroSound_MG246_2.mxd

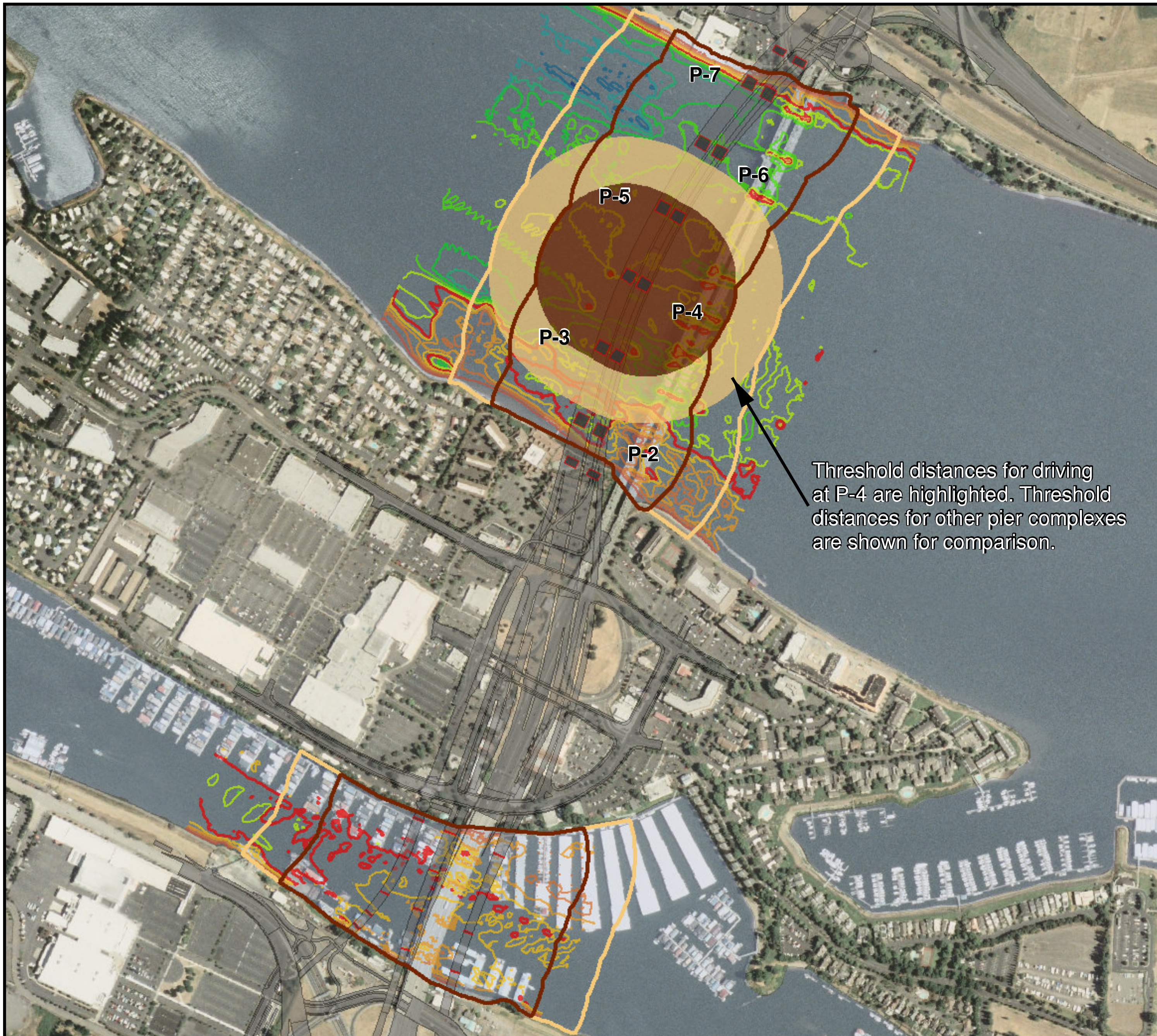


Figure 3-4. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, 36 to 48-inch pile, single pile driver

Fish speed 0.1 m/s

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: June 2, 2010: File Name: HydroSound_MG246_2.mxd

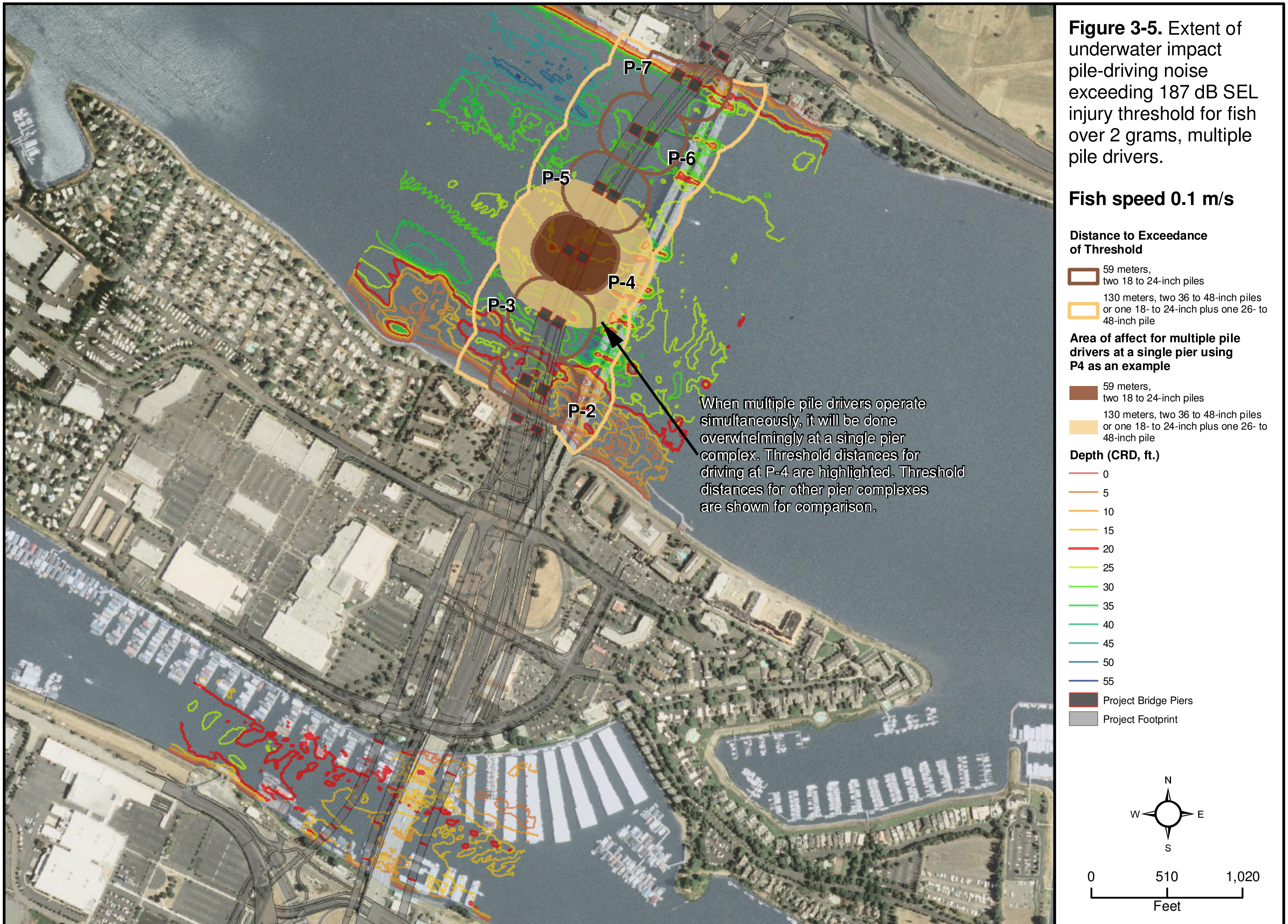


Figure 3-5. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, multiple pile drivers.

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Multiple pile drivers will operate simultaneously at a single pier complex for a large majority of impact pile driving. Only rarely (about one day out of every 142 in-water work days) will multiple pile drivers operate at separate pier complexes.

Columbia River CROSSING

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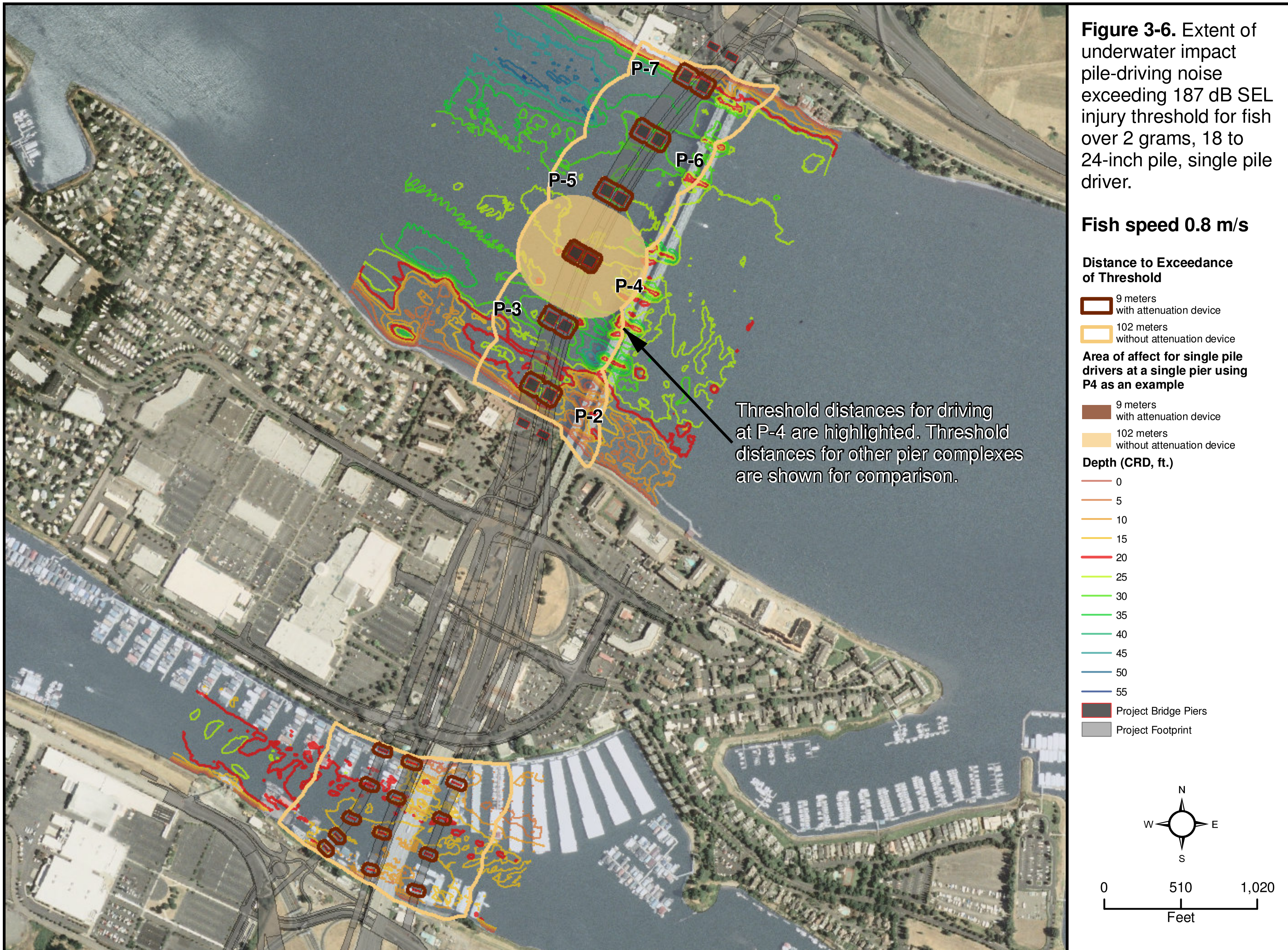


Figure 3-6. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, 18 to 24-inch pile, single pile driver.

Fish speed 0.8 m/s

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: June 2, 2010: File Name: HydroSound_MG246_2.mxd

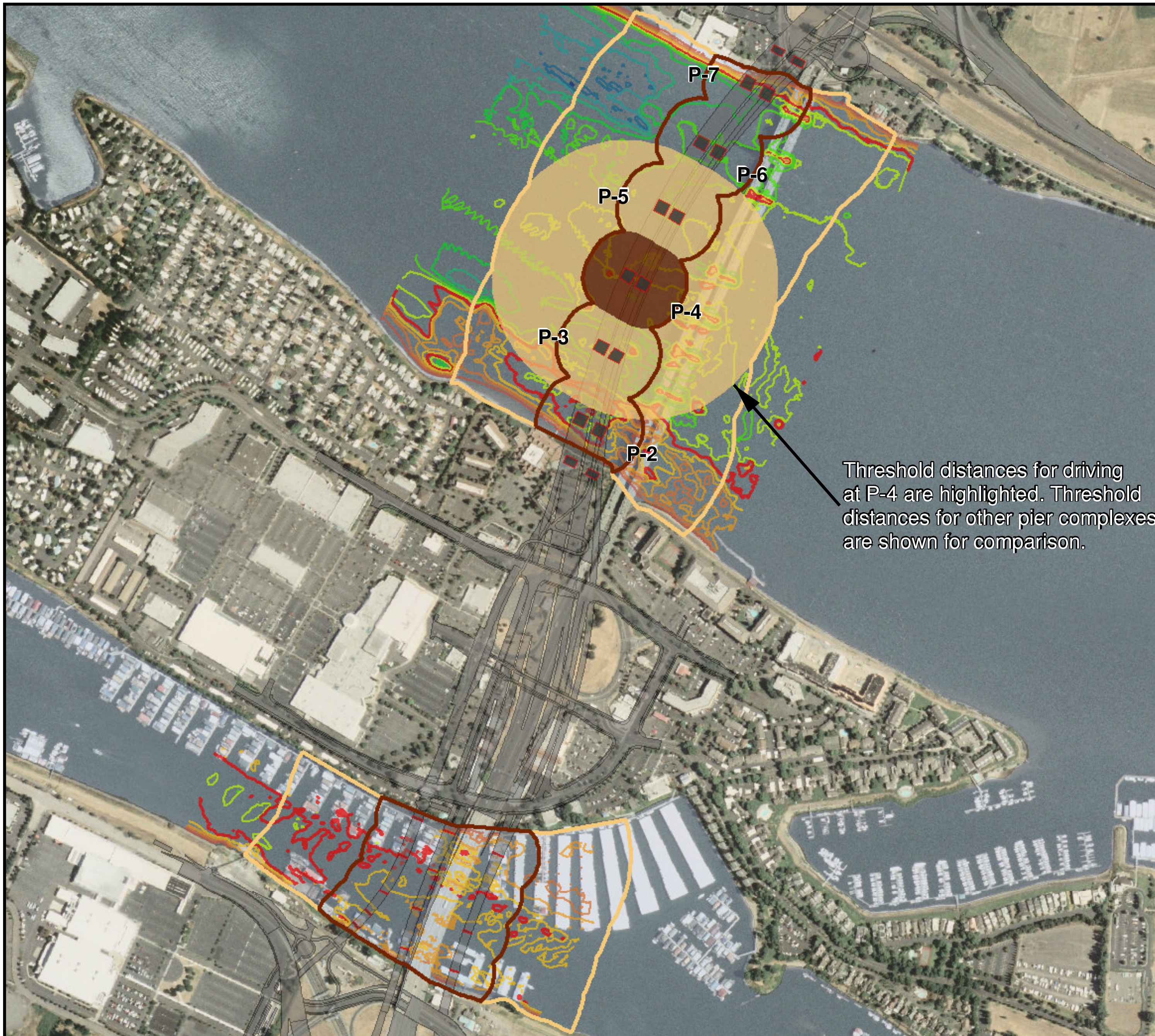


Figure 3-7. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, 36 to 48-inch pile, single pile driver.

Fish speed 0.8 m/s

Distance to Exceedance of Threshold

- 67 meters, with attenuation device
- 237 meters, without attenuation device; 237

Area of affect for single pile drivers at a single pier using P4 as an example

- 67 meters, with attenuation device
- 237 meters, without attenuation device

Depth (CRD, ft.)

0
5
10
15
20
25
30
35
40
45
50
55

Project Bridge Piers
Project Footprint

N W E S

0 520 1,040
Feet

Columbia River CROSSING

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Analysis by J. Koloszar; Analysis Date: June 2, 2010: File Name: HydroSound_MG246_2.mxd

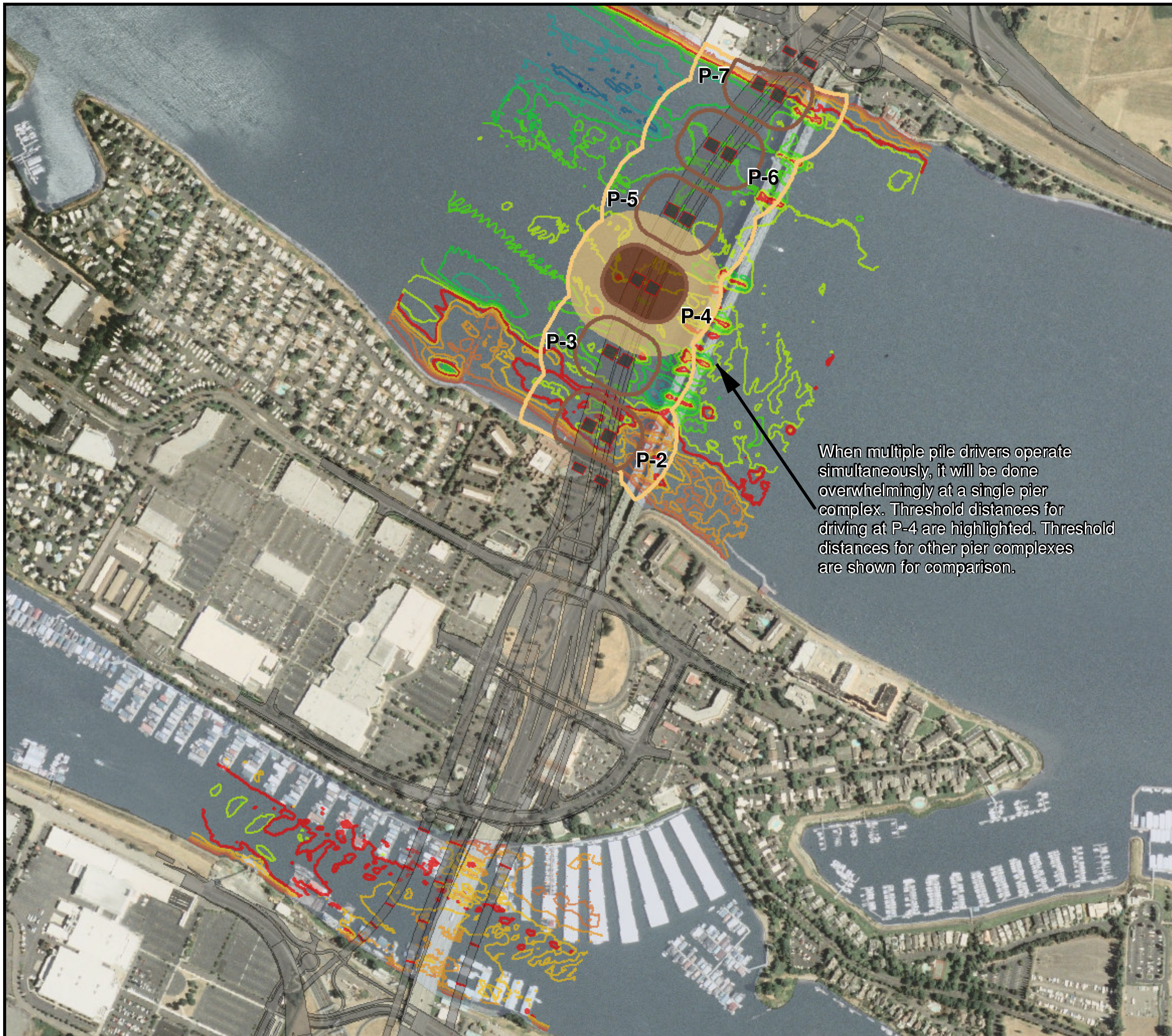
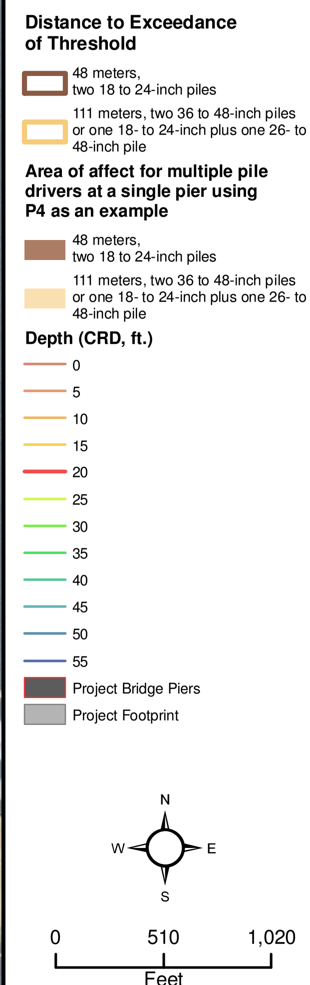


Figure 3-8. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, multiple drivers.

Fish speed 0.8 m/s



Columbia River CROSSING

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Multiple pile drivers will operate simultaneously at a single pier complex for a large majority of impact pile driving. Only rarely (about one day out of every 142 in-water work days) will multiple pile drivers operate at separate pier complexes.

Analysis by J. Koloszar; Analysis Date: June 2, 2010: File Name: HydroSound_MG246_2.mxd

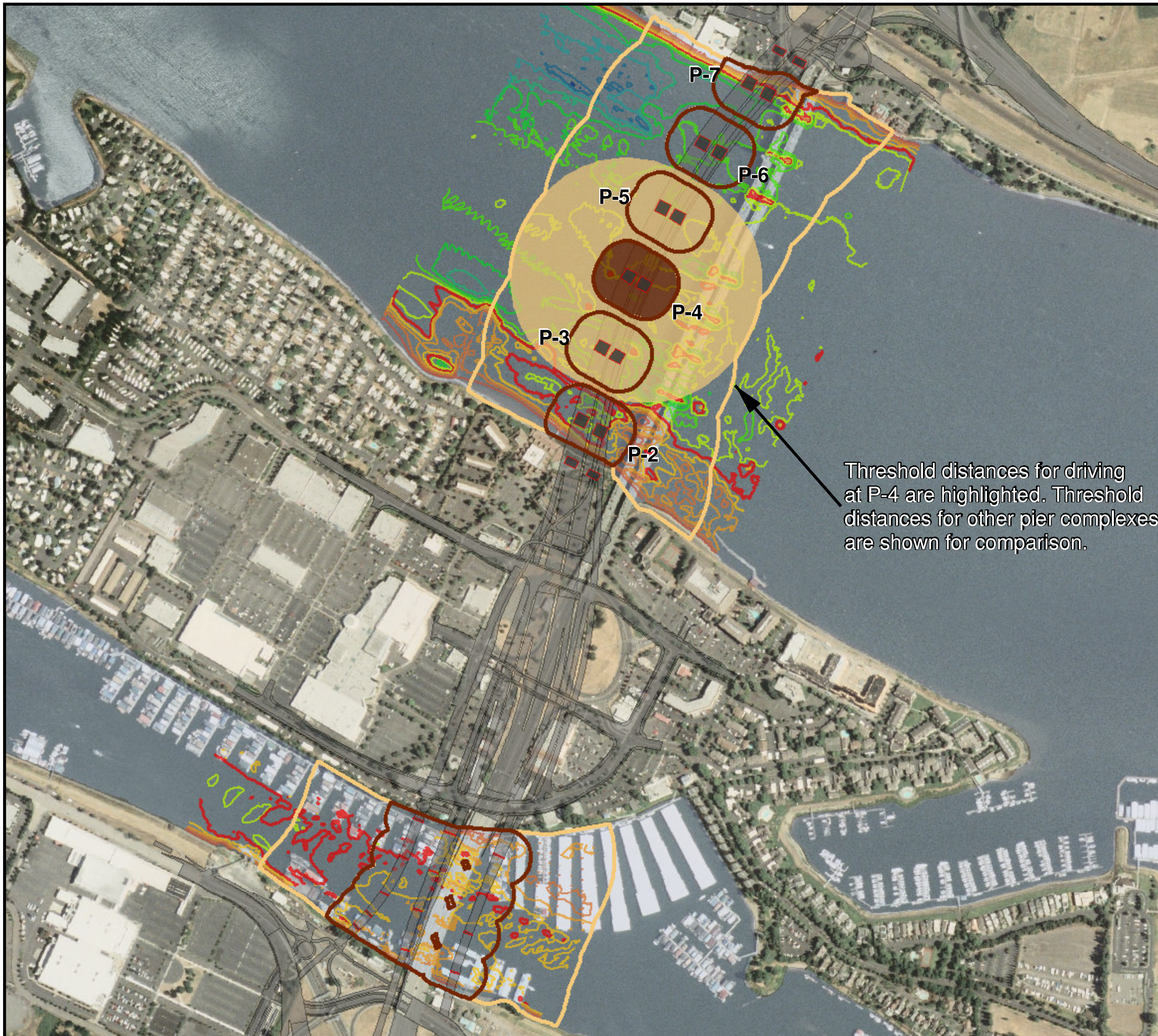


Figure 3-9. Extent of underwater impact pile-driving noise exceeding 183 dB SEL injury threshold for fish under 2 grams, 18 to 24-inch pile, single pile driver.

Fish speed 0.6 m/s

Distance to Exceedance of Threshold

- 50 meters with attenuation device
- 205 meters without attenuation device

Area of affect for single pile drivers at a single pier using P4 as an example

- 50 meters with attenuation device
- 205 meters without attenuation device

Depth (CRD, ft.)

0
5
10
15
20
25
30
35
40
45
50
55

Project Bridge Piers
Project Footprint

N W E S

0 520 1,040
Feet

Columbia River CROSSING

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Analysis by J. Koloszar; Analysis Date: June 2, 2010: File Name: HydroSound_MG246_2.mxd

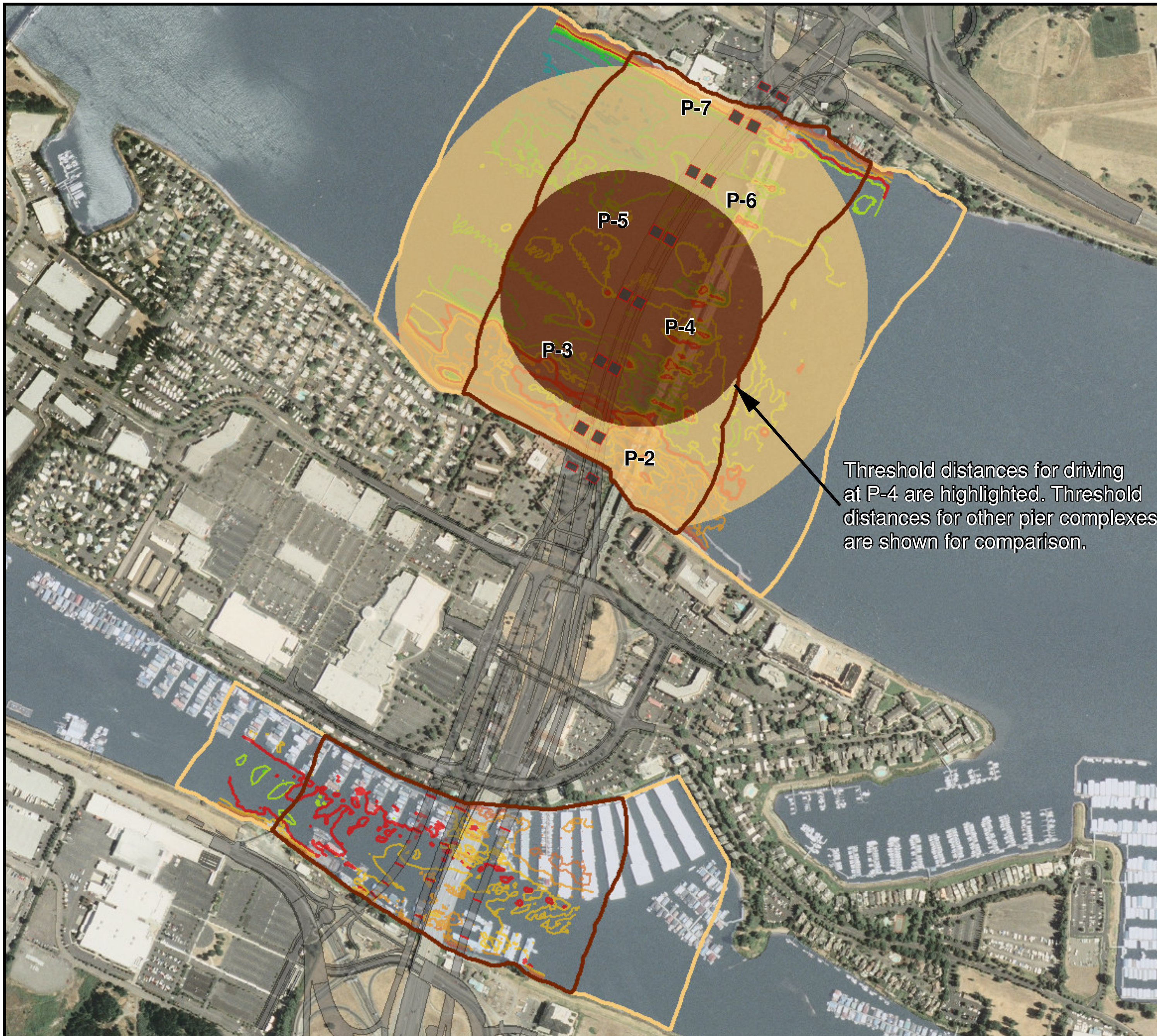


Figure 3-10. Extent of underwater impact pile-driving noise exceeding 183 dB SEL injury threshold for fish under 2 grams, 36 to 48-inch pile, single pile driver.

Fish speed 0.6 m/s

Distance to Exceedance of Threshold

- 235 meters with attenuation device
- 446 meters without attenuation

Area of affect for single pile drivers at a single pier using P4 as an example

- 235 meters with attenuation device
- 446 meters without attenuation device

Depth (CRD, ft.)

0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55

- Project Bridge Piers
- Project Footprint

N E S W

0 560 1,120
Feet

Columbia River CROSSING

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Analysis by J. Koloszar; Analysis Date: June 2, 2010: File Name: HydroSound_MG246_2.mxd

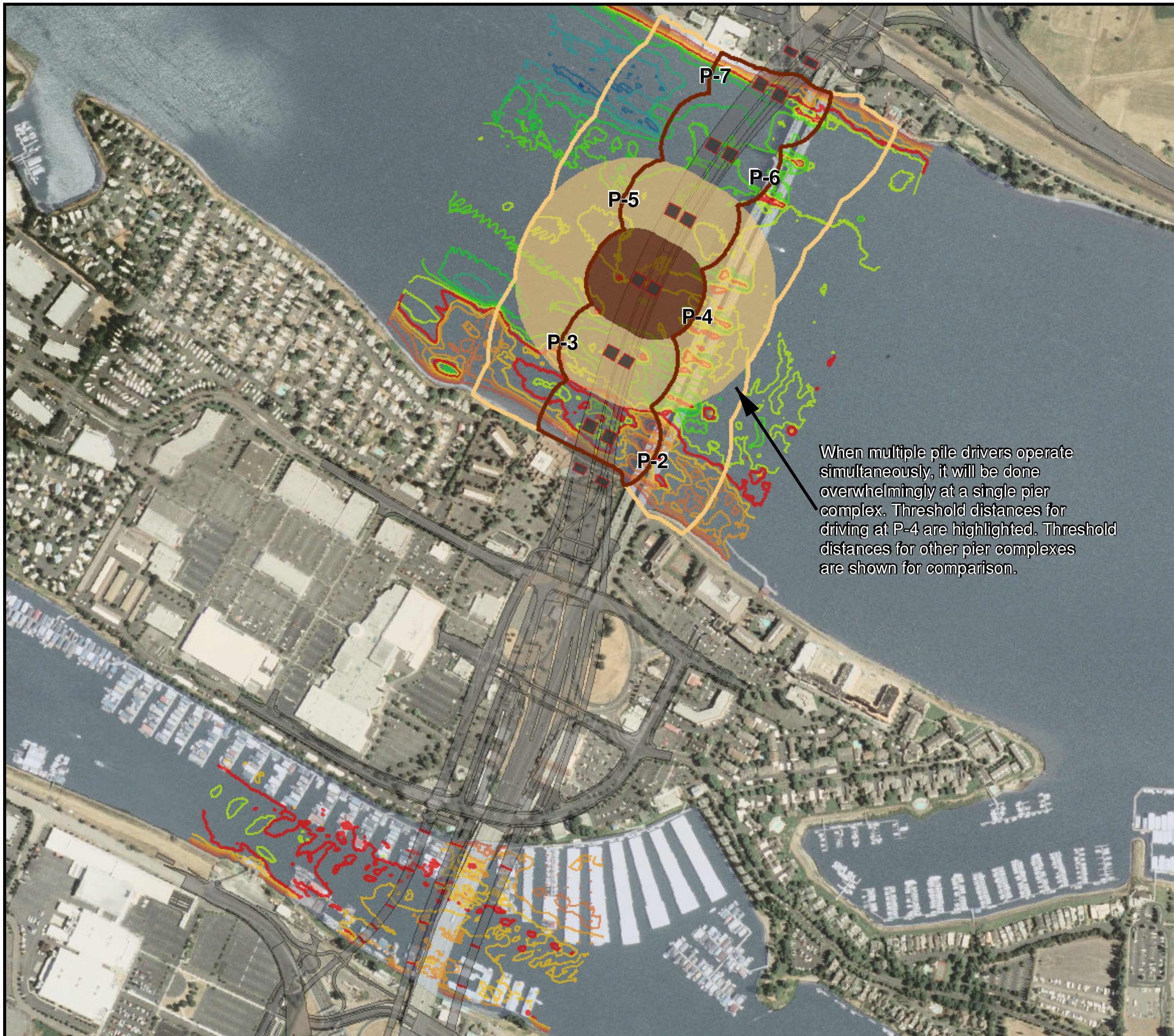


Figure 3-11. Extent of underwater impact pile-driving noise exceeding 183 dB SEL injury threshold for fish under 2 grams, multiple drivers.

Fish speed 0.6 m/s

Distance to Exceedance of Threshold

- 79 meters, two 18 to 24-inch piles
- 209 meters, two 36 to 48-inch piles or one 18- to 24-inch plus one 26- to 48-inch pile

Area of affect for multiple pile drivers at a single pier using P4 as an example

- 79 meters, two 18 to 24-inch piles
- 209 meters, two 36 to 48-inch piles or one 18- to 24-inch plus one 26- to 48-inch pile

Depth (CRD, ft.)

0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55

- Project Bridge Piers
- Project Footprint

N, W, E, S

0 510 1,020
Feet

Columbia River CROSSING

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Multiple pile drivers will operate simultaneously at a single pier complex for a large majority of impact pile driving. Only rarely (about one day out of every 142 in-water work days) will multiple pile drivers operate at separate pier complexes.

Analysis by J. Koloszar; Analysis Date: June 2, 2010: File Name: HydroSound_MG246_2.mxd

Table 3-7, Figure 3-12, and Figure 3-13 present the results of calculations showing distances to the 150 dB RMS disturbance boundary for impact pile driving of 18- to 24-inch piles and 36- to 48-inch piles. Note that, the use of multiple pile drivers and different strike intervals do not affect how attenuation of RMS sound is calculated. Single and multiple drivers will show the same distances. In describing distances related to disturbance thresholds, upstream distances may differ from downstream distances. These values indicate the distance at which noise encounters a landform (such as an island or streambank), which are assumed to block the spread of in-water noise. In all instances, noise levels above 150 dB RMS will extend across the Columbia River or North Portland Harbor when active impact pile driving is occurring in a given waterbody.

Table 3-7. Distances at Which Underwater Noise Exceeds 150 dB RMS Disturbance Guidance in the Columbia River and North Portland Harbor

	Columbia River		North Portland Harbor	
Impact Pile Driving	**Distance Upstream (m)**	**Distance Downstream (m)**	**Distance Upstream (m)**	**Distance Downstream (m)**
Without Attenuation Device				
18 to 24-inch pile	3,981	3,981	3,058	3,981
36 to 48-inch pile	20,166	8,851	3,058	5,632
With Attenuation Device				
18 to 24-inch pile	858	858	858	858
36 to 48-inch pile	5,412	5,412	3,058	5,412

Note that in most instances, use of an attenuation device that achieves a 10 dB reduction across RMS, SEL, and peak noise levels and decreases the area of effect appreciably. For example, when comparing scenarios in which a single pile driver is operating:

- The onset of injury distance decreases by about 80 percent for peak levels.
- In the Columbia River, the disturbance distance shrinks by about 80 percent for smaller piles and by 40 to 70 percent for larger piles, depending on the direction of sound travel (upstream or downstream).
- In North Portland Harbor, the disturbance distance shrinks for smaller piles by about 75 percent. For the larger piles, use of a noise attenuation device does not shrink the disturbance distance because noise encounters landforms at short distances from the source (3,058 m upstream and 5,412 m downstream).
- Similar reductions for accumulated SEL distances occur when all other factors remain constant (from approximately 70 to more than 90 percent depending on the number of strikes, the strike interval, fish speed, and fish size).

Figure 3-12. Extent of underwater impact pile-driving noise exceeding 150 dB RMS disturbance guidance for fish, 36 to 48-inch pile.

Distance to Exceedance of Guidance

- 5,412 meters with attenuation device
- 20,166 meters without attenuation device

Design Shapes

- Project Bridge Piers
- Project Footprint

N
W
E
S

0
6,600
13,200
Feet

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: Feb. 11, 2010: File Name: HydroSound_MG246_2.mxd

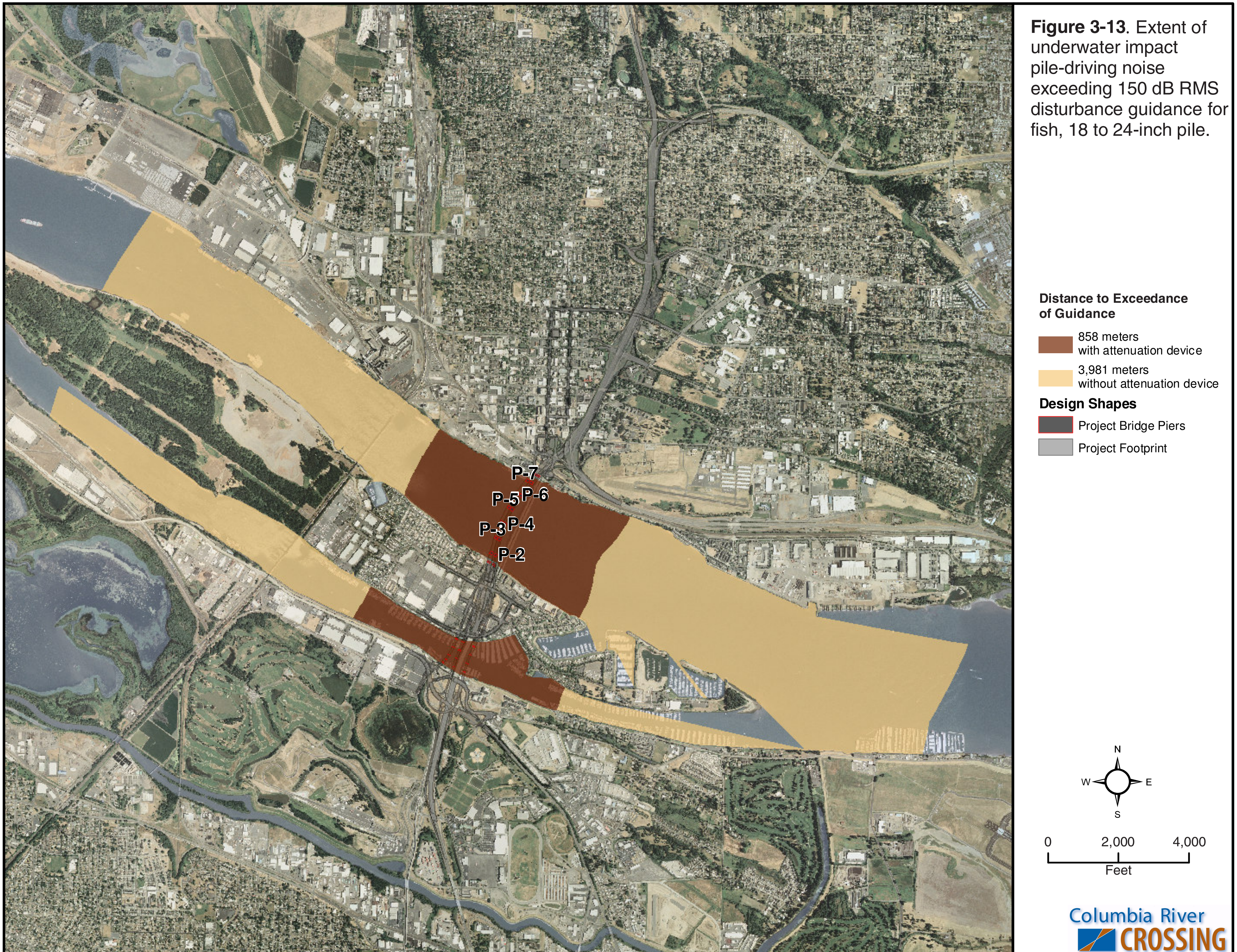


Figure 3-13. Extent of underwater impact pile-driving noise exceeding 150 dB RMS disturbance guidance for fish, 18 to 24-inch pile.

Analysis by J. Koloszar; Analysis Date: Feb. 11, 2010: File Name: HydroSound_MG246_2.mxd

3.3.2.1 Modeling Impact Pile Driving (Weekly/Yearly/Project)

Areas of effect, as described above, are based on daily driving scenarios. The CRC project is also estimating exposure over the weekly, yearly, and project-wide time scale to better assess impacts to listed fish from project activities.

For construction of the Columbia River bridges, the CRC engineering team developed probable construction sequences that included timing at each pier location for installing structures that require load bearing piles and the number and sizes of piles needed per structure. Because impact pile driving will only occur during a 31-week work window, the amount of in-water impact pile driving that could occur in the first year of construction and in subsequent years depends on when the contractor could start in-water impact driving. Because the project start date is unknown at this time, to account for all possible sequences of in-water work, CRC modeled impact pile driving sequencing for hypothetical contract award dates every month from January 2013 through January 2014. The analysis assumes that in-water impact pile driving in the Columbia River begins 6 months after a contract award. Table 3-8 presents three of the 13 scenarios for the Columbia River bridge based on contract award dates of February 5, July 1, and October 1, 2013.

The analysis also includes one construction sequence for the North Portland Harbor bridge activities. Because the North Portland Harbor bridge construction schedule has a more flexible timeline and is less complex than the Columbia River bridge construction schedule, the design team was able to readily select a single construction schedule for the North Portland Harbor bridges. Thus, only one construction sequence was deemed necessary for construction work in North Portland Harbor.

All 13 sequences for the Columbia River bridge construction and the one North Portland Harbor are included the Excel spreadsheet on the accompanying CD.

3.3.2.2 Impact Pile Driving Model Assumptions

This section lists the weekly and yearly schedule assumptions used to model impact pile driving. The variables discussed below are important in determining weekly and yearly exposure factors.

- **In-water work window:** The model assumes a 31-week in-water work window for impact pile driving from September 15 through April 15 of the following year (Week 38 to Week 16 of the following year) of each construction year.
- **Construction sequencing:** Contract award dates are assumed to start consecutively at 1-month intervals between February 5, 2013, and February 1, 2014, for a total of 13 modeled sequences. The analysis assumes that in-water impact driving starts six months after the award date. If the contract award is earlier or later than the specific monthly date, driving scenarios and impacts will likely not change substantially.

  Each sequence contains the following activities and durations:

  - Each of the six Columbia River work bridges/platforms will require 100, 18- to 24-inch piles and 32, 36- to 48-inch piles. Work bridges/platforms will have a ratio of 3, 24-inch piles per one 48-inch pile.

Table 3-8. Select Pile Driving Schedule Scenarios Showing Potential Impact Driving for Weeks 1–18 and 38–52

Pile Driving Schedule - February 5, 2013

	Week		2013	2014	2015	2016
jan	1	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane			6 / 3 / 1 / P	
jan	2	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
jan	3	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
jan	4	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
feb	5	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
feb	6	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
feb	7	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
feb	8	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
mar	9	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane			2 / 1 / 1 / C	
mar	10	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				7 / 1 / 1 / C
mar	11	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
mar	12	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane			4 / 1 / 1 / C	
apr	13	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				5 / 1 / 1 / C
apr	14	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
apr	15	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
apr	16	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				6 / 1 / 1 / C

Blue cells represent pier construction
Pink cells represents crane support construction

Pile Driving Schedule - July 1, 2013

	Week		2013	2014	2015	2016
jan	1	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		2 / 5 / 1 / P		
jan	2	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		2 / 4 / 1 / P; 4 / 1 / 1 / P		
jan	3	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		4 / 5 / 1 / P		
jan	4	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		4 / 5 / 1 / P		
feb	5	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		4 / 5 / 1 / P		
feb	6	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		4 / 5 / 1 / P		
feb	7	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		4 / 1 / 1 / P		
feb	8	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
mar	9	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane			6 / 4 / 1 / P	
mar	10	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane			6 / 5 / 1 / P; 2 / 1 / 1 / C	7 / 1 / 1 / C
mar	11	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane			6 / 5 / 1 / P	
mar	12	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane			6 / 5 / 1 / P	
apr	13	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane			6 / 3 / 1 / P; 4 / 1 / 1 / C	5 / 1 / 1 / C
apr	14	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
apr	15	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
apr	16	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				6 / 1 / 1 / C

Blue cells represent pier construction
Pink cells represents crane support construction

Pile Driving Schedule - October 1, 2013

	Week		2013	2014	2015	2016
jan	1	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
jan	2	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
jan	3	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane				
jan	4	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane			5 / 5 / 1 / P	
feb	5	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane			5 / 5 / 1 / P	
feb	6	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		3 / 1 / 1 / P	5 / 5 / 1 / P	
feb	7	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		3 / 5 / 1 / P	5 / 5 / 1 / P	
feb	8	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		3 / 5 / 1 / P	5 / 2 / 1 / P	
mar	9	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		3 / 5 / 1 / P		
mar	10	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		3 / 5 / 1 / P		7 / 1 / 1 / C
mar	11	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		2 / 4 / 1 / P; 3 / 1 / 1 / P		
mar	12	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		2 / 5 / 1 / P		
apr	13	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		2 / 5 / 1 / P		5 / 1 / 1 / C
apr	14	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		2 / 5 / 1 / P		
apr	15	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		2 / 3 / 1 / P; 4 / 2 / 1 / P		
apr	16	Pier Number / Full Days of Driving / Days of Monitoring / Pier or Crane		4 / 5 / 1 / P		

Blue cells represent pier construction
Pink cells represents crane support construction

Pile Driving Schedule

	Week		2013	2014	2015	2016
jan	1	Bridge/Bent / Full Days of Driving / Days of Monitoring		19 / 5 / 1 / B		
jan	2	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator		19 / 5 / 1 / B	45 / 2 / 1 / O	34 / 2 / 1 / O
jan	3	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator		19 / 5 / 1 / B		
jan	4	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator		19 / 2 / 1 / O	45 / 2 / 1 / O	35 / 5 / 1 / B
feb	5	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator				35 / 5 / 1 / B
feb	6	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator			46 / 5 / 1 / B	
feb	7	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator			46 / 5 / 1 / B	35 / 2 / 1 / O
feb	8	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator				
mar	9	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator			46 / 2 / 1 / O	
mar	10	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator				
mar	11	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator			46 / 2 / 1 / O	
mar	12	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator				
apr	13	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator				
apr	14	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator				
apr	15	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator				
apr	16	Bridge/Bent / Full Days of Driving / Days of Monitoring / Bridge or Oscillator				

Blue cells represent work bridge construction
Pink cells represents oscillator support construction

The first digit in the "Bridge/Bent" designator denotes which bridge is being analyzed; the second digit denotes which bent is being analyzed (e.g., Bridge/Bent #18 is used to describe the 8th bent on Bridge #1).

Table 3-8. Continued

Pile Driving Schedule - February 5, 2013

	Week		2013			2014			2015			2016		
sep	38	Pier Number Full Days of Driving Days of Monitoring Pier or Crane		3 5 1 P										
sep	39	Pier Number Full Days of Driving Days of Monitoring Pier or Crane		3 5 1 P										
oct	40	Pier Number Full Days of Driving Days of Monitoring Pier or Crane		3 5 1 P		3 1 1 C	7 5 1 P							
oct	41	Pier Number Full Days of Driving Days of Monitoring Pier or Crane		3 5 1 P			7 5 1 P							
oct	42	Pier Number Full Days of Driving Days of Monitoring Pier or Crane	2 3 1 P	3 2 1 P			7 5 1 P							
oct	43	Pier Number Full Days of Driving Days of Monitoring Pier or Crane	2 5 1 P				7 5 1 P							
nov	44	Pier Number Full Days of Driving Days of Monitoring Pier or Crane	2 5 1 P			5 3 1 P	7 2 1 P							
nov	45	Pier Number Full Days of Driving Days of Monitoring Pier or Crane	2 5 1 P			5 5 1 P								
nov	46	Pier Number Full Days of Driving Days of Monitoring Pier or Crane	2 4 1 P	4 1 1 P		5 5 1 P								
nov	47	Pier Number Full Days of Driving Days of Monitoring Pier or Crane		4 5 1 P		5 5 1 P								
dec	48	Pier Number Full Days of Driving Days of Monitoring Pier or Crane		4 5 1 P		5 5 1 P								
dec	49	Pier Number Full Days of Driving Days of Monitoring Pier or Crane		4 5 1 P			6 5 1 P							
dec	50	Pier Number Full Days of Driving Days of Monitoring Pier or Crane		4 5 1 P			6 5 1 P							
dec	51	Pier Number Full Days of Driving Days of Monitoring Pier or Crane		4 2 1 P			6 5 1 P							
dec	52	Pier Number Full Days of Driving Days of Monitoring Pier or Crane					6 5 1 P							

Blue cells represent pier construction
Pink cells represents crane support construction

Pile Driving Schedule - July 1, 2013

	Week		2013			2014			2015			2016		
sep	38	Pier Number Full Days of Driving Days of Monitoring Pier or Crane												
sep	39	Pier Number Full Days of Driving Days of Monitoring Pier or Crane												
oct	40	Pier Number Full Days of Driving Days of Monitoring Pier or Crane												
oct	41	Pier Number Full Days of Driving Days of Monitoring Pier or Crane												
oct	42	Pier Number Full Days of Driving Days of Monitoring Pier or Crane												
oct	43	Pier Number Full Days of Driving Days of Monitoring Pier or Crane												
nov	44	Pier Number Full Days of Driving Days of Monitoring Pier or Crane					7 4 1 P	3 1 1 C						
nov	45	Pier Number Full Days of Driving Days of Monitoring Pier or Crane	3 3 1 P				7 5 1 P							
nov	46	Pier Number Full Days of Driving Days of Monitoring Pier or Crane	3 5 1 P				7 5 1 P							
nov	47	Pier Number Full Days of Driving Days of Monitoring Pier or Crane	3 5 1 P				7 5 1 P							
dec	48	Pier Number Full Days of Driving Days of Monitoring Pier or Crane	3 5 1 P			5 1 1 P	7 3 1 P							
dec	49	Pier Number Full Days of Driving Days of Monitoring Pier or Crane	3 5 1 P			5 5 1 P								
dec	50	Pier Number Full Days of Driving Days of Monitoring Pier or Crane	2 5 1 P			5 5 1 P								
dec	51	Pier Number Full Days of Driving Days of Monitoring Pier or Crane	2 5 1 P			5 5 1 P								
dec	52	Pier Number Full Days of Driving Days of Monitoring Pier or Crane	2 5 1 P			5 6 1 P								

Blue cells represent pier construction
Pink cells represents crane support construction

Pile Driving Schedule - October 1, 2013

	Week		2013			2014			2015			2016		
sep	38	Pier Number Full Days of Driving Days of Monitoring Pier or Crane					4 5 1 P		2 1 1 C					
sep	39	Pier Number Full Days of Driving Days of Monitoring Pier or Crane					4 5 1 P							
oct	40	Pier Number Full Days of Driving Days of Monitoring Pier or Crane					4 5 1 P							
oct	41	Pier Number Full Days of Driving Days of Monitoring Pier or Crane												
oct	42	Pier Number Full Days of Driving Days of Monitoring Pier or Crane												
oct	43	Pier Number Full Days of Driving Days of Monitoring Pier or Crane							6 5 1 P	4 1 1 C				
nov	44	Pier Number Full Days of Driving Days of Monitoring Pier or Crane							6 5 1 P			6 1 1 C		
nov	45	Pier Number Full Days of Driving Days of Monitoring Pier or Crane				7 3 1 P	3 1 1 C		6 5 1 P					
nov	46	Pier Number Full Days of Driving Days of Monitoring Pier or Crane				7 5 1 P			6 5 1 P					
nov	47	Pier Number Full Days of Driving Days of Monitoring Pier or Crane				7 5 1 P			6 2 1 P					
dec	48	Pier Number Full Days of Driving Days of Monitoring Pier or Crane				7 5 1 P								
dec	49	Pier Number Full Days of Driving Days of Monitoring Pier or Crane				7 5 1 P								
dec	50	Pier Number Full Days of Driving Days of Monitoring Pier or Crane												
dec	51	Pier Number Full Days of Driving Days of Monitoring Pier or Crane												
dec	52	Pier Number Full Days of Driving Days of Monitoring Pier or Crane												

Blue cells represent pier construction
Pink cells represents crane support construction

Pile Driving Schedule

	Week		2013			2014			2015			2016		
sep	38	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator		14 5 1 B			42 5 1 B			26 5 1 B				
sep	39	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator		14 5 1 B			42 5 1 B			26 5 1 B				
oct	40	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator												
oct	41	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator		15 2 1 O			42 2 1 O							
oct	42	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator								27 2 1 O				
oct	43	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator												
nov	44	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator		16 2 1 O			43 2 1 O			28 2 1 O				
nov	45	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator												
nov	46	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator		17 2 1 O			43 2 1 O			29 5 1 B				
nov	47	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator								29 5 1 B				
dec	48	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator		18 2 1 O			44 2 1 O							
dec	49	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator								29 2 1 O				
dec	50	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator		18 2 1 O			44 2 1 O			32 5 1 B				
dec	51	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator								32 5 1 B				
dec	52	Bridge/Bent Full Days of Driving Days of Monitoring Bridge or Oscillator		19 5 1 B			45 2 1 O			33 2 1 O				

Blue cells represent work bridge construction
Pink cells represents oscillator support construction

The first digit in the "Bridge/Bent" designator denotes which bridge is being analyzed, the second digit denotes which bent is being analyzed (e.g., Bridge/Bent #18 is used to describe the 8th bent on Bridge #1).

- Each of the six Columbia River tower crane platforms will require 1 day of pile driving with one pile driver. Driving for crane piles requires the same number of pile strikes for driving and monitoring purposes.
- In North Portland Harbor at the eight bents closest to shore, nine temporary work bridges, each consisting of 25, 18- to 24-inch piles, will be constructed to support equipment for drilled shafts.
- At each of the 31 North Portland Harbor bent locations, one oscillator support platform will be constructed, each consisting of four, 36- to 48-inch piles.
- Daily pile driving assumptions were used as described in Table 3-2 and Table 3-3.

The 13 individual impact-driving scenarios sometimes required minor adjustments to project element timing to fit into the hydroacoustic analysis spreadsheet. For example, impact driving for each Columbia River bridge pier platform requires 22 days with two pile drivers, while each Columbia River bridge tower crane requires 1 day of driving by one pile driver. However, the timeline to complete that 1 day of driving could occur over a 15-day period. For the purposes of calculating exposure, the CRC project assumed that impact driving will occur on the first day of the 15-day period. The project also assumed no more than two impact pile drivers working at any given time in the Columbia River and only one working pile driver at any given time in North Portland Harbor. In rare instances (fewer than 2 days out of 138 to 142 days of driving in most scenarios and never more than 6 days), the driving of piles for work platforms and tower cranes at different pier complex locations overlap. Instead of refining the timing of the driving those weeks to account for one driver being at one pier complex all week and one driver being at a tower crane location for just 1 day, it was assumed that the pile driving will occur at the same rate for both platforms and cranes. This combination of impacts results in a slightly more impactful analysis by analyzing essentially 6 days of pile driving when only 5 would occur. See Week 40 of Year 2 on the February 5, 2013 scenario in Table 3-8 for an example of how this situation was entered into the analysis spreadsheets.

Similarly, because the estimated schedule for construction of work platforms in the Columbia River was based on 22 workdays, several iterations of the project overlapped with holiday periods, particularly in November, December, and January. In such cases, the analysis of timing was not refined enough to account for specific non-working days within an assumed work period. Within the analysis, the start and end dates were kept consistent with the dates provided by engineering staff, but did not limit workdays to just 22 days. In those instances, some work periods would consist of more than 22 workdays. By following the assumed project schedule, there would be exactly 138 workdays for work platforms (six pier complexes multiplied by 23 days each = 138 workdays or 22 days for two pile drivers plus 1 day per pier complex for each tower crane).

After integrating the schedule into the analysis, the number of driving days for platforms for all the scenarios varied between 138 and 142 days. The inclusion of holidays often resulted in work completed in the 53rd week of a calendar year, with a 52-week analysis period for a calendar year consisting of 52 weeks plus one day (for 365-day years) and not always starting on January 1. With the combination of holidays and the 52-week limitation of the analyses, there are times where the 52nd week of the year will have 6 days of driving. Adjustments to all scenarios affected are made to be consistent and without regard to potential effects on impact analysis. See Week 52 of the July 1, 2013 scenario in Table 3-8 for an example of how this situation was entered into the analysis spreadsheets.

For North Portland Harbor, it was assumed that installation of each work bridge at near shore bents will require approximately 8 days. Each oscillator platform will require 2 days. After a work bridge is built, installation of an oscillator platform near the work bridge will occur over the next 2 days (for a total of 10 days at each bent). For oscillator platforms that are not near shore and are not serviced by a work bridge, installation at a bent site will require only 2 days.

Table 3-8 presents a sample of three pile-driving scenarios for the Columbia River and the one driving scenario for North Portland Harbor for Weeks 1–16 and Weeks 38–52 in the format used in the analysis spreadsheet. The entire Excel spreadsheet is on the CD included with this report.

- **Incorporation of unattenuated strikes:** It was assumed that unattenuated impact pile driving occurs at a rate of 300 strikes on 1 day per week for any week in which attenuated impact pile driving occurs in the Columbia River. This was assumed even for weeks with only 1 or 2 days of impact driving and for any single day of crane construction. This likely overestimates the amount of unattenuated impact pile driving that will occur for the following reasons. First, 300 pile strikes for hydroacoustic monitoring are anticipated to be more than needed.[13] Second, equipment malfunctions that result in no or little attenuation will likely be rare and observed within the first few dozen strikes. In conclusion, 37 or 38 days of unattenuated impact pile driving is expected to occur over the course of the project in the Columbia River and the rate of 300 strikes per day is unlikely to be reached.

  Due to the smaller size of North Portland Harbor, the use of only one impact driver, and the generally shorter construction timelines for each project element, the CRC project assumed that only 150 unattenuated strikes will occur 1 day per week for any week in which attenuated impact pile driving occurs in North Portland Harbor. The CRC project assumes that approximately 40 days of unattenuated impact pile driving will occur over the course of the project in North Portland Harbor.

3.4 Method for Calculating Exposure to Fish in the CRC Project Area

Previous subsections showed how areas of effects were determined from daily driving scenarios, and how potential construction dates were incorporated into the analysis. This section will present the steps taken to incorporate areas of effect and impact driving schedules into the daily, weekly, yearly, and total exposure factors that can be used to analyze effects from the CRC project.

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[13] If this total were spread out over three workdays with 100 unattenuated pile strikes each, the impacts from unattenuated pile driving would decrease by approximately 50 percent (from an aggregate exposure factor of 0.00033 to 0.00016) and would lower the total exposure factor by approximately 4 percent (from 0.00581 to 0.00564) (values based on a fish weighing more than 2 g and moving at .0.1 m/s).

3.4.1 Overview of Exposure Calculations

The cumulative SEL threshold for the onset of injury was identified to have the greatest spatial extent even when an attenuation device achieving a reduction of 10 dB is used. In contrast, the distance to the threshold for the onset of injury from peak sound levels extends no more than 10 m when a single pile driver with an attenuation device achieving a reduction of 10 dB is used. Therefore, potential fish exposure to sound levels above the onset of injury threshold was modeled using the cumulative SEL thresholds. Section 6 of the BA discusses potential impacts to fish from exposure to sound levels above the behavioral disturbance guidance (150 dB RMS) in detail that is not presented in this report.

The CRC project team considered modeling exposure to individual fish migrating through the project corridor on an individual basis. However, forecasting impacts on an individual level was determined not to be possible due the numerous complexities involved in individual fish behavior, individual fish location, and variability in pile driving timing, strike numbers, locations, etc. For example, one method of determining potential impacts is to simulate thousands of scenarios with various fish locations, fish trajectories, pile driving strike numbers, and pile driving locations. However, there is insufficient published information about the factors involved in these calculations to be able to provide valid results. Also, this simulation would not be easily replicated by others or flexible enough to determine potential impacts based on different driving scenarios, start dates, and driving efforts.

The CRC project team discussed the proposed project and modeling exposure to fish within the project site with Dr. John Stadler in the August 2009 meeting. Dr. Stadler concurred that a feasible approach would be to start with the estimated proportion of a listed-fish run passing through an area of effect during a 24-hour day. The analogy for the analysis was that of fish moving through the area of effect on a conveyor belt running at a certain speed (fish transit rate). The proportion of a listed fish run moving through the area of effect for a specific duration (calculated using total number of impact strikes per day and strike interval) was considered defensible. This model was presented to other NMFS, WDFW, and ODFW representatives in September 2009 and January 2010; those representatives agreed with the approach.

3.4.2 Elements of Exposure Calculations

To determine exposure to each fish run throughout the in-water work window for impact pile driving, the timing of each fish run through the project area was determined. Detailed daily data on many fish runs are available from fish count studies at Bonneville Dam. However, data on runs that are based in the lower Columbia River are not as detailed. In order to provide comparable data for each species analyzed, and account for inherent annual variability in fish run timing and annual abundance, we estimated fish run timing and relative abundances by week of the year. Week 1 started generally on January 1 and continued through Week 52. One benefit of the CRC project's analytical approach is that it can calculate potential injury based on proportion of a run index, regardless of size, as long as the run timing remains generally the same. Section 4 of this document provides detailed information on the analysis of fish run timing and relative abundance by week for each listed DPS/ESU.

Therefore, fish exposure is modeled by the proportion of each species at each life stage that will be in the affected proportion of channel (area of effect) when impact pile driving will occur. Exposure was calculated separately for the Columbia River and North Portland Harbor activities.

The equation for determining exposure is:

Weekly Fish Exposure = Weekly Proportion of Fish Run x Proportion of Channel Affected x Proportion of Day Affected x Proportion of Week Affected

The **proportion of the fish run** is the estimate of fish presence and relative abundance by week of the year within the project area based on the material presented in Section 4 of this document. To account for errant fish outside of estimated times of presence, the analysis assumes that one fish is present every week, even if a fish from a particular ESU/DPS and life stage is not anticipated to be present.

Abundance data were not available from published sources or communications with fisheries experts for numerous juvenile fish. In the absence of reliable data, a value of 1,000 individuals was assumed for analysis purposes. This value is likely lower than actual abundance for most of the juvenile populations.[14]

The **proportion of the channel affected** is the cross-channel diameter of the area of effect divided by the width of the river (800 m for the Columbia River at the bridge site or 300 m for North Portland Harbor). Because of the different channel widths and separate waterbodies, Columbia River and North Portland Harbor proportions are calculated separately. Cross-channel threshold diameters entered into the calculation are adjusted to any exclude area extending into land (e.g., when piers are close to land). These are termed by CRC to be *effective* threshold diameters.

As an example, assume a single 36- to 48-inch pile struck 400 times at Columbia River pier complex 4 and an adult cumulative SEL threshold (187 dB SEL). The threshold diameter is 198 m. This distance does not extend onto land at this location. Thus, the proportion of the channel affected is 198 divided by 800, or 0.24750. If the effective threshold diameter is above 800 m (the width of the channel), this portion of the exposure factor equation is 1.

The **proportion of the day affected** is the number of hours of impact strikes per day with strikes for a specific impact-driving scenario and site based on a contract award date divided by 24 hours. Continuing with the example above, the proportion of the day affected is 400 strikes divided by 40 strikes per minute (a 1.5-second strike interval), is equal to 10 minutes per day or 0.16667 hours of strikes. Dividing 0.16667 hours by 24 hours is 0.00694.

[14] Use of this value was presented to federal and state biologists as an assumption for those juvenile fish runs with no site-specific abundance values. Although fact-based data is preferable, it does not appear to exist. Its use in the analysis does not tend to influence results more than a negligible amount. The analysis will slightly overestimate potential impacts for ESUs/DPSs and life stages that do not occur in the area during impact pile driving periods. Conversely, the analysis will slightly underestimate potential impacts for runs that do occur in the project area during impact pile driving periods. A larger value would provide only negligibly more realistic analyses when discussing percentages of runs affected. Because this report focuses on percentages of runs affected, rather than individuals affected, the authors of this report determined that its use was valid in this context. Overestimates and underestimates of impacts could result in approximately 0.1 percent differences in relative abundance per week of modeled presence, which when multiplied by relatively low exposure factors, should be considered negligible.

The **proportion of the week affected** is the number of days of driving in the Columbia River or North Portland Harbor divided by 7 days. For this example, assume impact driving would occur for 5 days each week, so the proportion of the week affected is 5 days divided by 7 days or 0.71428. For the impact analysis discussed in Section 5 of this report, the number of workdays within a week will vary from 0 to 6 days.

The above example uses just one pile driving activity (a single driver installing a 36- to 48-inch pile) as an example. During construction and for the analysis, all pile driving activities occurring in one week are calculated (Table 3-9 through Table 3-14). CRC defines the proportion of the channel affected multiplied by the proportion of the day affected multiplied by the number days in a week affected as a **weekly exposure factor**. The weekly exposure factor consists of all pile driving conducted during the week.

In the preceding example, the weekly exposure factor for the single pile driver is:

$$0.24750 \text{ x } 0.00694 \text{ x } 0.71428 = 0.00123$$

A weekly exposure factor would be calculated for each pile-driving scenario within a week. When added together, these become the weekly exposure factor. Because all factors in the equation are proportions, exposure factors are unitless. Therefore, the equation for fish exposure used in our analysis is simplified to:

$$\text{Weekly Fish Exposure} = \text{Weekly Proportion of Run x Weekly Exposure Factor}$$

A weekly exposure factor was calculated for each week of construction for all of the 13 construction sequences. These exposure factors are applied to all the ESUs/DPSs analyzed.

The benefits of this analytical approach are relatively easy replication, transparent calculations, and readily available desktop computer software for the computations. One of the drawbacks is the lack of precise impacts to individuals, although determining potential impacts to individuals in a highly variable environment is difficult regardless of model sophistication.

3.4.3 Site-Specific Exposure Factors

Site-specific exposure factors are calculated for each pier/bent each week of every construction year based on 13 probable project construction scenarios for the Columbia River, one construction scenario for North Portland Harbor, and an IWWW of 31 weeks, from September 15 to April 15 (Week 38–52) for impact pile driving. When the Columbia River and North Portland Harbor scenarios were combined, a total of 13 scenarios were evaluated.

Table 3-9 shows site-specific weekly exposure factors calculated for typical impact pile driving activities at each of the 6 pier complexes in the Columbia River for a fish speed of 0.1 m/s; Table 3-10 and Table 3-11 show these same factors for fish speeds of 0.8 and 0.6 m/s, respectively. Table 3-12 through Table 3-14 present the daily and weekly exposure factors for North Portland Harbor. Typical activities on the Columbia River include five days of driving per week of active driving, while typical driving activities in North Portland Harbor involved two days of impact pile per week of active driving.

In practice, weekly exposure factors varied based on the factors inherent within the exposure factor calculation, such as pier location (e.g., how much of the channel will be impacted), the type and size of pile being driven (initial sound level), the number of pile drivers (one or two for the Columbia River), and the length of the work week. Pile strikes per day were kept constant relative to the work location (Columbia River versus North Portland Harbor), but days of pile driving per week were dependent on the schedules provided. For example, days of pile driving varied; one pier complex with 2 days of driving followed by 3 days of driving at a different pier, driving for platforms in combination with driving for crane placement; etc.

Variations in each of the 13 driving scenarios used for modeling impacts produced variations in the exposure factors. Exposure factors are most influenced by pile driving location and fish speed. For example, as shown in Table 3-9, when using cumulative SEL threshold distances for adult fish (over 2 grams and traveling 0.1 m/s), 5 days of driving at Columbia River pier complex 4 or 5 result in a weekly exposure factor of 0.00436. The same variables at pier complex 2 result in a weekly exposure factor of 0.00349. The difference is due to pier complex 2 being nearer to land, which blocks in-water noise and reduces the effective threshold diameter.

Table 3-15 shows the weekly exposure factors for adult fish (over 2 g, speed of 0.1 m/s) calculated from the in-water impact pile-driving scenario based on a construction contract awarded on February 5, 2013. Weekly exposure factors are presented for both Columbia River and North Portland, in addition to the total weekly exposure factor. When no pile driving is anticipated to occur, the weekly exposure factor is zero. Different weekly exposure factors shown in the tables generally result from variations in pile driving locations, due to different effective threshold diameters, and in the number of days of driving.

3.4.4 Integration of Columbia River and North Portland Harbor Activities

Because impact pile driving is proposed to occur in both the Columbia River and North Portland Harbor, impacts to fish runs for both water bodies were calculated. As noted previously, it is not possible to determine with certainty when or how many fish will use the project area. Likewise, it is not possible to accurately determine whether fish use the Columbia River preferentially over North Portland Harbor. Through conversations with fish biologists, it was determined that the project team could assume that fish are evenly distributed across the channels. The mainstem Columbia River channel is approximately 800 m in width, and the North Portland Harbor channel is approximately 300 m in width, for a combined width of 1,100 m. Taking each channel as a portion of the whole, the Columbia River is therefore 72.7 percent of the overall channel, and North Portland Harbor is 27.3 percent of the channel.

Using the assumption that adult and juvenile fish pass through the project area in proportion to the channel width available, it was determined that impacts would also be in proportion to the width available. That is, when impact pile driving occurs in the Columbia River, those impacts could be experienced by approximately 72.7 percent of the fish present in the project area.[15] The

[15] Two ways to address this apportioning of fish in the channel was to: 1) multiply the total weekly run proportion (or its weekly estimated size) by the channel proportions for each channel's scenario, or 2) to calculate the channel scenario effects and then apportion the run percentages. Either method provides the same results, but the latter method allows for more flexibility when ranking scenarios. It also allows for more expedient comparisons if future research confirms that fish usage of the channels is not in proportion to their widths. The reason for proportioning the impacts based on channel usage afterward is that the potential impacts to fish populations are based on the exposure factor within each channel multiplied by the run proportion during a given week. The exposure factor is determined by impact pile driving elements (number of consecutive piles strikes, initial sound levels, days of driving per week, etc.). The run proportion is based on the estimated abundance for a given week divided by the total abundance in a calendar year.

27.3 percent of fish that occur in North Portland Harbor would not be affected because in-water noise will not extend the several miles to the eastern or western tips of the island and then curve around to the North Portland Harbor channel area.

3.4.5 Calculation of Fish Exposure

For each of the 13 impact pile driving schedules, the analysis calculates the following for juveniles and adults of each listed ESU/DPS:

1. The daily and weekly exposure factor from impact pile driving.
2. The range and maximum potential species exposure from impact pile driving for each construction year.

After calculation of the daily and weekly exposure factors, the results were integrated Section 5 of this document presents the results of the analysis for each driving scenario's estimated impacts on the listed salmonids and eulachon in the project area, as well as a summary of potential impacts for all 13 scenarios. The following example, Table 3-15, illustrates the fish exposure calculations for adult Columbia River chum.