T-5 DREDGE MONITORING

HYDROACOUSTIC MONITORING REPORT

PREPARED FOR:

PORT OF SEATTLE

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MAY 2022

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INTRODUCTION

The Port of Seattle (Port) is conducting dredge operations as part of the berth deepening component of the Terminal 5 (T-5) Modernization Program. Grette Associates (Grette) was contracted to collect baseline data on underwater noise volume generated by clamshell dredging in the West Waterway (Figure 1).

Figure 1. Map of the Project Area.

METHODS

Vessel-based hydroacoustic monitoring was conducted during two days of dredging, on January 19 and January 21, 2022. Grette intermittently recorded background noise and dredging noise data on January 19 from approximately 12:30 to 14:45 and on January 21 from approximately 12:00 to 14:30. The hydrophone was recording during times of no operations (background only), during times when dredging was the only operation occurring, and during times when other operations were occurring (in addition to dredging and/or when dredging was not occurring). "Other operations" included pile driving, tugs and barges transiting up and down river, skiffs working, and ferries passing the mouth of the Waterway. Detailed topside observations (vessels passing by the hydrophone, nearby construction [in-water and upland, when applicable], T-5 operational activities, and a breakdown of the steps of the dredge process) were collected concurrently in order to allow changes in the sound profile to be linked to activities observed at the surface. Prior to and during dredge activities, environmental data were gathered such as water depth, predicted tide, and weather conditions. Start and stop time of each dredge cycle and each component within the cycle was recorded for several cycles each day.

The hydrophone was suspended from the vessel at mid-water depth as close to dredge operations as deemed safe by the contractor and Grette (167 yards on January 19 and 76 yards on January 21). The vessel was anchored and the batteries shut off to avoid possible voltage interference on the recordings. A hand-held depth sounder was used to determine the depth at the location of the hydrophone and a rangefinder was used to measure the horizontal distance to the dredge arm. The hydrophone cable was attached to a weighted nylon cord to reduce horizontal drift by keeping the line vertical. There was a direct acoustic "line of sight" between the dredging operations and the hydrophone in all cases. Table 2 details the equipment that was used to monitor underwater sound pressure levels.

Table 1. Equipment for underwater sound monitoring.

Item	Specifications	Minimum Quantity	Usage
CR-1 Hydrophone with 200 feet of cable	Receiving Sensitivity- 198dB ±3dB re 1V/μPa	1	Capture underwater sound pressures and convert to voltages that can be recorded/analyzed by other equipment.
SpectraDAQ-200 Data Acquisition Sound Card (2-channel)	Sampling Rate- 24K Hz to 192 kHz	1	Analyzes and transfers digital data to laptop hard drive via USB 3.0.
Laptop computer	Compatible with digital analyzer	1	Record digital data on hard drive and signal analysis.
Real Time and Post-analysis software (SpectraPlus)	-	1	Monitor real-time signal and post-analysis of sound signals.

Monitoring equipment was set to record 20 hertz (Hz) to 20 kilohertz (kHz) with a sampling rate of 96 kHz. To facilitate further analysis of data the underwater signal was recorded as a text file

(.txt) and a wave file (.wav). Recorded data did not use data compression algorithms or technologies (e.g. MP3, compressed .wav, etc.).

Dredge operations were conducted with a 4 cubic yard (CY) toothed clamshell dredge operated by a cable crane. The crane was stationed on a construction barge affixed to a transport barge (Figure 2). Material was collected from the bottom and deposited on the transport barge for disposal as approved in project permits. Material consisted of sediments dredged from the previous tideland area, predominantly sand and gravel and estuarine sediments.

Figure 2. Dredge crane and barge.

RESULTS

Data were collected for varying periods of time over approximately four-hour sessions on January 19 and January 21, 2022. Dredge operations occurred in approximately 60 and 67 feet of water, respectively, and the hydrophone was deployed at 30 and 34 feet. Weather was overcast to partly sunny, cold, and calm during both monitoring days.

Wave files were analyzed and divided into categories based on activity occurring during each noise profile, as illustrated in Figure 3. Categories were: Background (no construction, vessel movement, or other activities observed); Dredging only (no activities other than dredging observed); Dredge, tug (tug passing by up- or down-river during dredge operations); and Tug and barge (no dredging occurring, only tug and barge passing). Impact pile driving and cargo handling training were also occurring at the Terminal during dredging operations, but those data are not presented here.

Average (Avg), Maximum (Max), and Minimum (Min) decibel (dB) levels were calculated, both for all segments of each activity recorded combined, and broken down per segment. In order to standardize for comparison, average dB levels for "Dredging only" and "Dredge, tug" were run through the Practical Spreading Loss Model in order to standardize sound levels to 10 m from the source:

$$TL=15\log(R1/R2)$$

Where:

TL = transmission loss (measured sound level at the hydrophone – sound level @10 m)
R1 = distance at which transmission loss is estimated
R2 = distance of known or measured sound level (10 m in this case).

Results are presented in Tables 2, 3, 4, and 5 below. A snippet of a time series plot showing the underwater noise levels during dredge and other operations is shown in Figure 3. Table 6 shows average, maximum, and minimum decibel levels recorded per component of a dredge cycle over a subset of 5 cycles from Segment 2-1. This subset occurred over 10:31 and included the loudest and quietest recorded sounds during the Dredging Only periods. Similar subsets of the time series plots showing the components of the dredge cycle are presented in Figures 4, 5, and 6.

Table 2. Average, max, and min dB of all recorded activities combined.

	Total Duration of Recordings (H:MM:SS)	Avg dB	Max dB	Min dB
Background	1:10:27	113.1	130.9	101.1
Background-S end of Waterway	0:04:39	115.1	131.3	110.7
Dredging only	0:34:47	118.6	137.9	106.5
corrected to 10 m from dredge		*136.4*		
Dredge, tug	0:27:29	127.7	143.8	117.8
corrected to 10 m from dredge		*145.5*		
corrected to 10 m from one sample of tug @ closest point of approach		*148.4*		
Tug and barge	0:01:29	128.7	138.1	118.3
Small skiff	0:05:13	123.5	146.8	112.6
WSDOT ferry	0:05:08	121.0	135.1	109.1
corrected to 10 m from ferry		*156.0*		

Table 3. Average, max, and min of each segment of background recorded at the N end of T-5.

	Background - N end of T-5	Duration of Segment (H:MM:SS)	Avg dB	Max dB	Min dB
	Total	**1:10:27**	**113.1**	**130.9**	**101.1**
Recording Segments	1-1	30:49	111.3	129.4	101.1
	2-1	05:30	110.3	120.1	105.9
	2-2	04:01	112.0	117.5	104.8
	2-3	03:52	114.5	119.9	110.4
	2-4	02:45	115.1	119.5	111.3
	2-5	08:58	115.9	129.0	108.9
	2-6	05:50	112.1	120.7	105.7
	4-1	00:46	117.0	122.5	111.1
	4-2	07:00	118.2	125.4	112.1
	6-1	00:56	123.2	130.9	117.4

Table 4. Average, max, and min of each segment of background recorded at the south end of the West Waterway.

Background - S end of W Waterway	Duration of Segment (MM:SS)	Avg dB	Max dB	Min dB
Totals	**04:39**	**115.1**	**131.3**	**110.7**
10-1	01:25	114.7	118.3	111.9
10-2	01:32	119.1	131.3	115.7
10-3	01:42	111.8	116.7	110.7

Table 5. Average, max, and min dB levels of each segment of dredging recorded when no other activities were occurring.

Dredging	Duration of Segment (MM:SS)	Hydrophone Distance from Dredge	Avg dB @10 m	Avg dB	Max dB	Min dB
Totals	**34:47**		**136.4**	**118.6**	**137.9**	**106.5**
2-1	13:50	152.7 m	131.6	113.8	137.9	106.5
3-1	03:01	152.7 m	135.9	118.1	125.2	109.6
3-2	10:55	152.7 m	140.0	122.2	125.4	116.7
3-3	02:29	152.7 m	141.8	124.0	126.7	121.0
8-1	01:28	69.5 m	134.2	121.6	125.7	119.2
8-2	03:04	69.5 m	135.1	122.5	128.6	117.5

Table 6. Average, max, and min dB levels for each component of the dredge cycle over five cycles in segment 2-1. This 10-minute period included the Max dB (137.9) and Min dB (106.5) recorded during dredge operations, but was also the quietest overall period of dredging.

10 Minute Subset of Dredging (5 Cycles)	Avg dB	Max dB	Min dB
Subset Average	**113.5**	**137.9**	**106.5**
Bucket In the Water	113.3	137.9	106.7
Bucket on Bottom	112.7	115.8	109.7
Bucket Closing	113.4	123.3	106.8
Bucket Ascending	113.8	132.4	108.5
Bucket Out of the Water	114.2	127.6	108.2
Dumping on Barge	113.1	118.7	106.5

Figure 3. Example wave file showing breakdown by category correlating to changes in sound profile. Dredging was occurring during this whole 29 minute 40 second recording on January 21 from 14:04 to 14:33. Note the scale is -50.0 to 50.0 Pascals.

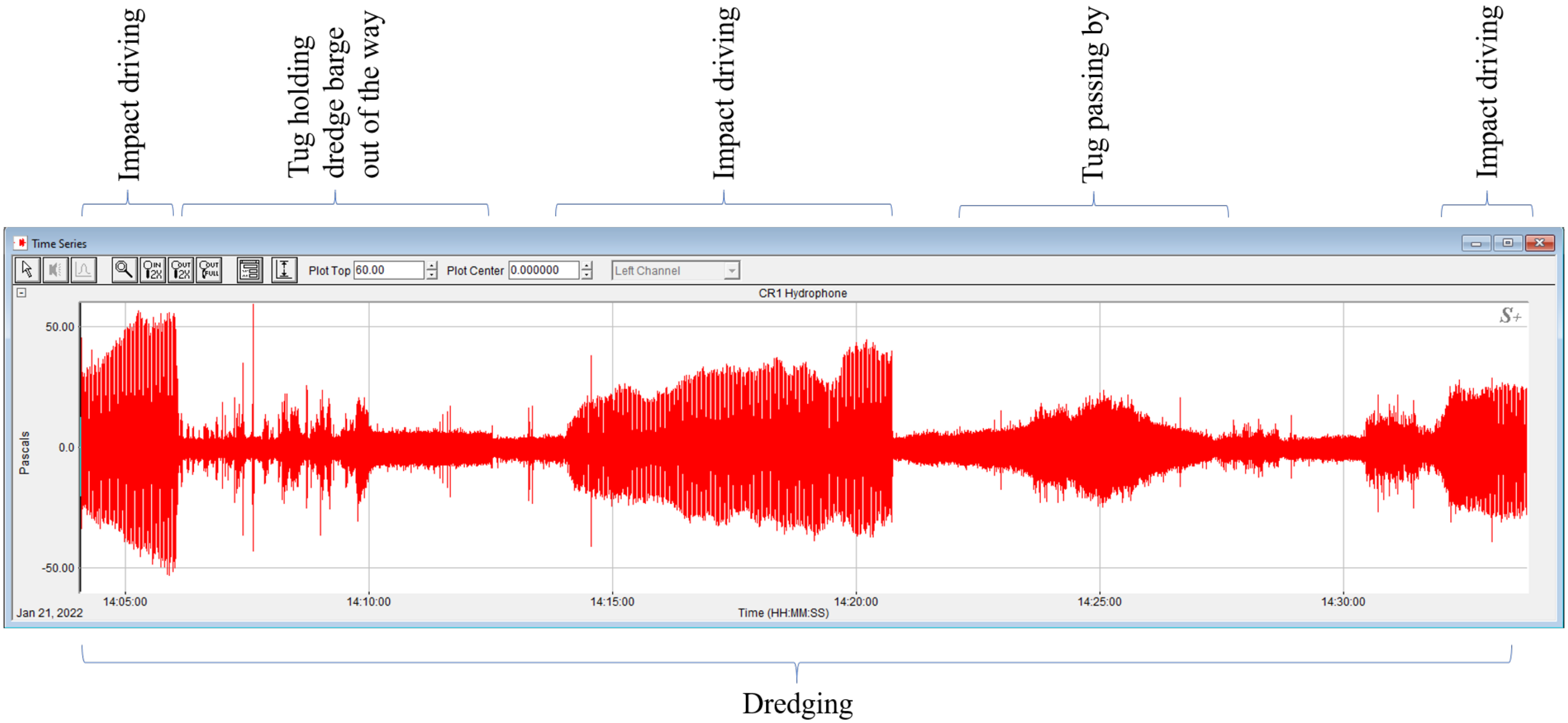


Figure 4. Example wave file showing breakdown of one dredge cycle. This time series represents approximately 90 seconds of dredging that occurred on January 21 from 14:12:30 to 14:14:00. Note the scale is -20.0 to 20.0 Pascals.

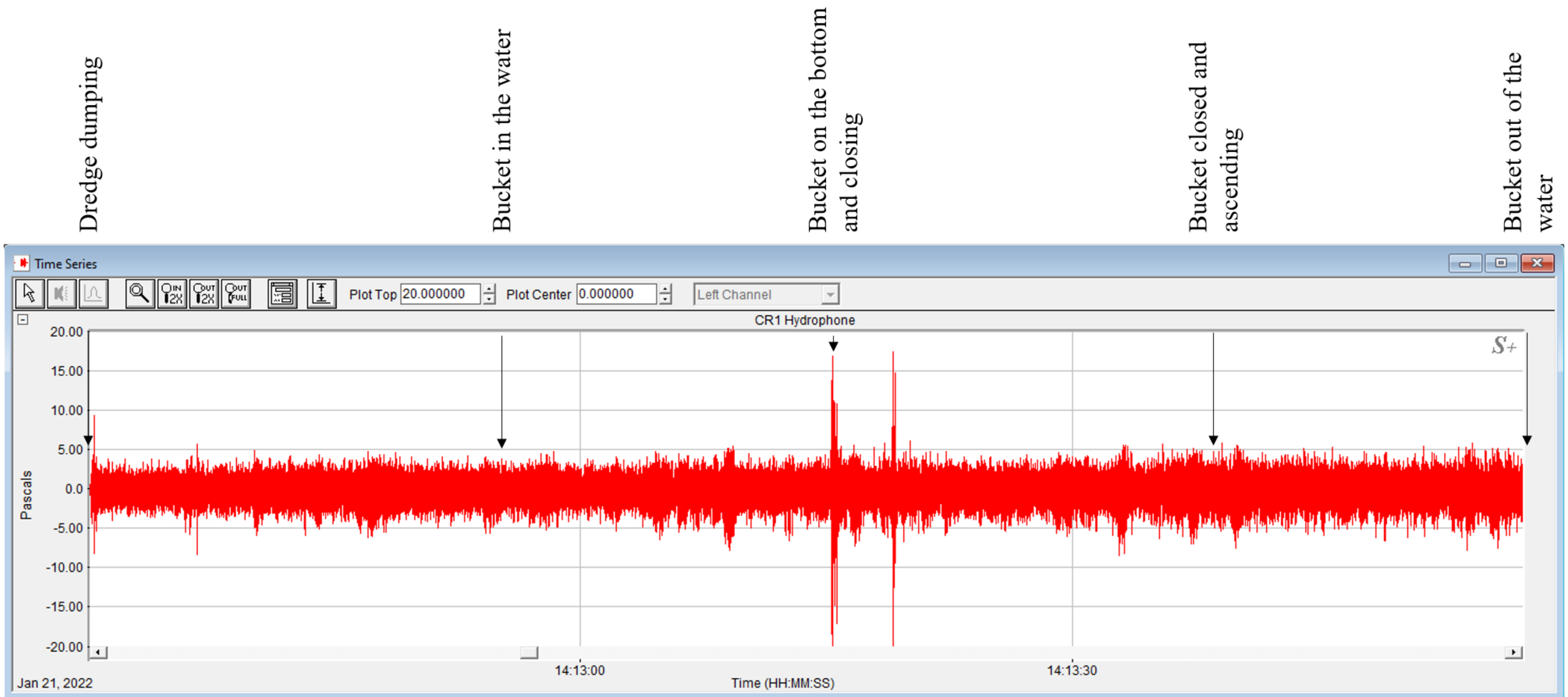


Figure 5. Example wave file showing background (no observed noise sources) followed by six dredge cycles. This time series represents approximately 16 minutes of dredging with no other observed sources of noise occurring simultaneously. Note the scale is -20.0 to 20.0 Pascals.

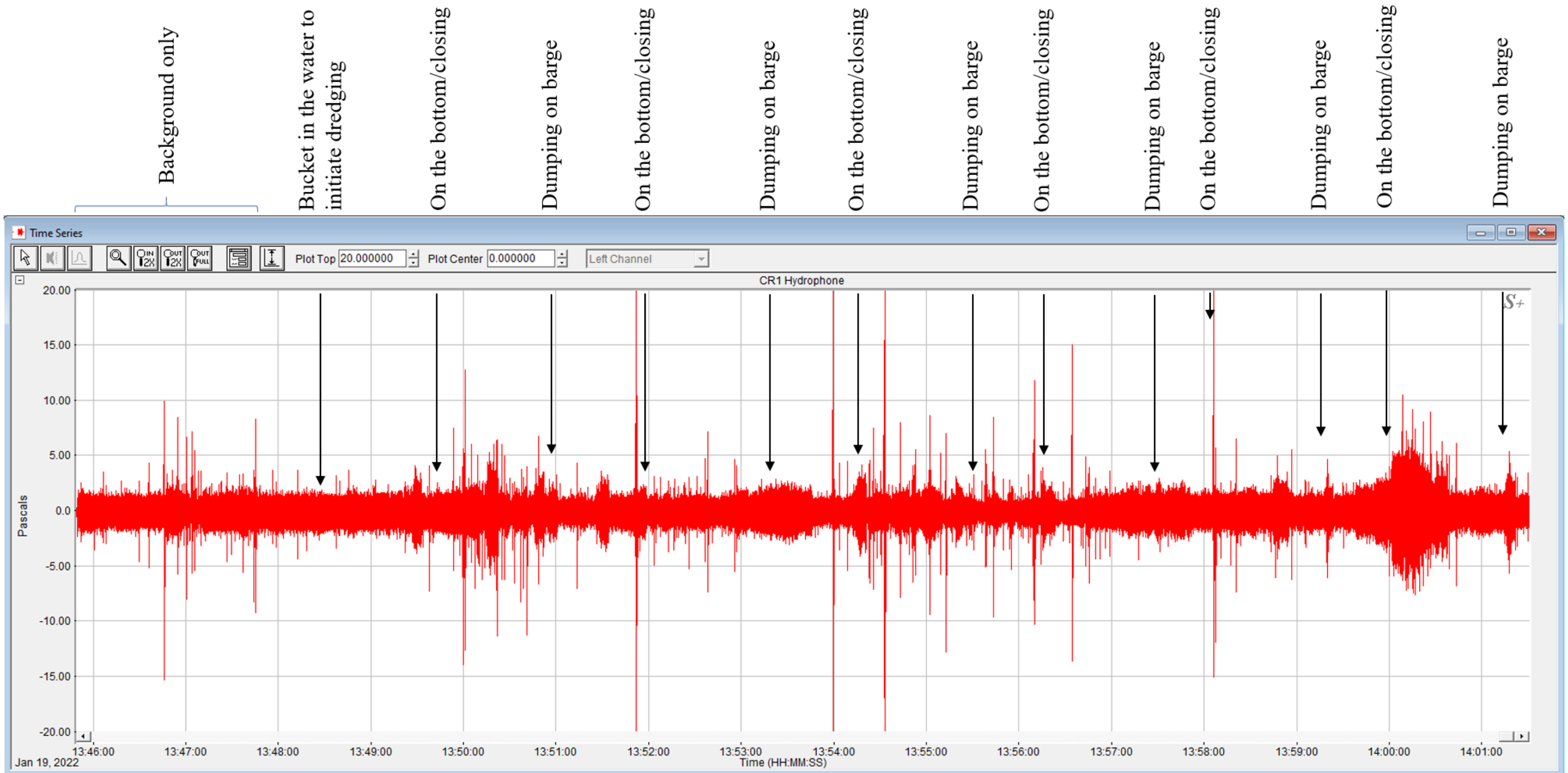
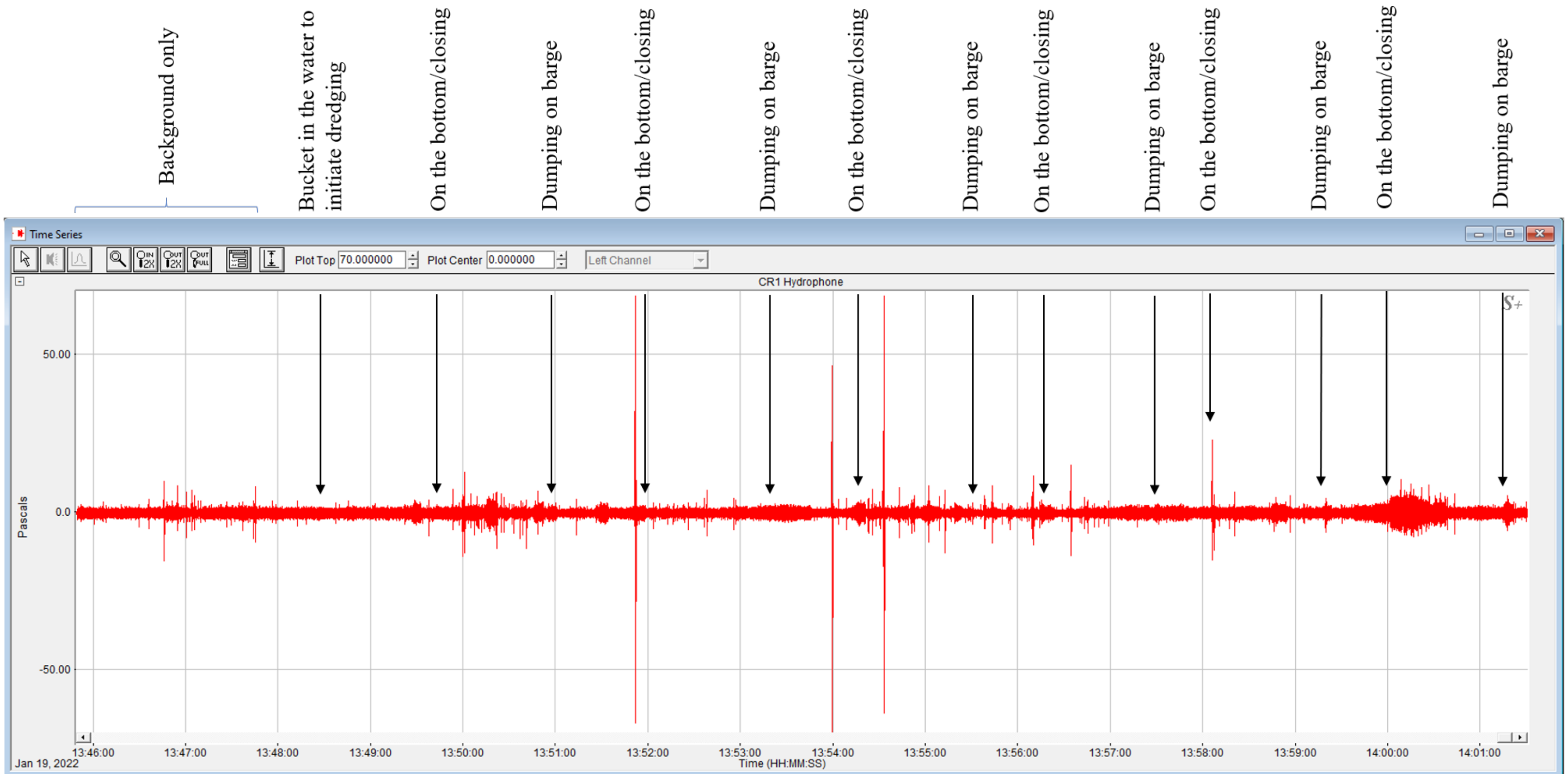


Figure 6. Same wave file as Figure 5 showing background (no observed noise sources) followed by six dredge cycles with the scale at -50.0 to 50 Pa.



DISCUSSION

Comparisons of noise levels among different sources of sound are qualitative in nature. Various factors affect how noise travels through water, including water temperature and pressure and bottom substrate and topography. Additionally, distance from the source of the noise to the hydrophone must be considered. Models are used to standardized noise levels at a specified distance from the hydrophone as a proxy for actual recorded levels at that distance.

Underwater noise levels during dredging operations at Terminal 5 were not measured to be considerably higher than background and were lower than all other observed noise sources. Average noise levels during background recordings were 113.1 dB and during dredging were 118.6 dB at an average distance of 125 m from the dredge. The estimated average dredging noise level when corrected to 10 m from the dredge was 136.4 dB.

The maximum noise level recorded during dredging only was 137.9 dB. The source of this elevated noise level is unknown, but the data show that levels went from 113.7 dB to 137.9 dB and back to 114.7 dB within 1.4 seconds; the period that sound was elevated above 120 dB (generally accepted "background" noise levels) was 0.7 seconds. This peak was a nearly instantaneous moment of elevated sound. The peak was recorded at 13:51:52. At this point in the dredge cycle, the bucket was descending from the surface to the bottom. The bucket reached the bottom at 13:51:56 (four seconds after the peak), and began to close at 13:52:15 (Table 6).

Other sources of noise that were documented during hydroacoustic monitoring included tugs and barges transiting up or down the Duwamish River via the West Waterway, small skiffs working in the waterway, and Washington State Department of Transportation (WSDOT)-operated ferries transiting to Pier 50 on the Seattle waterfront. The average noise level recorded for tug and barge operations coinciding with dredge operations was 127.7 dB. Closest point of approach was recorded for one tug passing upriver during dredge operations. When corrected for distance, the noise level @10 m from the tug was 148.4 dB. This distance-corrected result suggests that tug and barge operations are approximately 12 dB higher than dredging operations.

The average noise level recorded for small skiffs working nearby, both on the west side of the waterway as part of the Terminal 5 project and on the east side of the waterway separate from Terminal 5 operations was 123.5 dB. Closest point of approach was not recorded for skiffs, so there is not a corrected sound level @10 m. Uncorrected values indicate that skiff noise is approximately 5 dB higher than dredge noise.

Two WSDOT ferries were documented passing across Elliott Bay in acoustic line-of-sight from the mouth of the West Waterway. The average noise level recorded for the ferries was 121.0 dB, and when corrected for closest point of approach distance, average noise levels were 156.0 dB @10 m from the ferries. These results indicate that ferries are approximately 20 dB louder than dredging.

Models can be used to determine the distance at which vibratory pile driving noise attenuates to background levels. Although vibratory pile driving noise is acoustically different than dredging noise, they are both continuous sound rather than impulse sound. When dredge noise levels are input into the model for vibratory pile driving, results show that at 124 m, dredge noise (136.4 dB @10 m) will attenuate to 120 dB, the standard accepted level for background and the level at which marine mammals are considered to show a behavioral response. Injury or mortality of marine mammals occurs at 180 and 190 dB; underwater noise levels during dredging are considerably lower than these levels.

In 2 hours and 39 minutes of recording, less than 35 minutes of data were collected during periods of dredging only. Other sources of noise were recorded during almost 50 minutes of data collection, and all were elevated above dredge noise. Further, no detectable periods of elevated underwater noise were observed to coincide with any of the components of the dredge cycle (bucket entering the water, reaching the bottom, closing, exiting the water, or dumping on the barge; e.g., Table 6, Figure 4, Figure 5, and Figure 6). Based on the results of this effort, it appears marine mammals in these areas face larger impacts from underwater noise from general vessel traffic than from dredge operations. Neither vessel operations nor dredge operations approach underwater noise levels that are known to cause injury or death of marine mammals.