Underwater Noise Measurements at the WestShore Coal Terminal, Roberts Bank, British Columbia, September 2006

Prepared for

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Introduction

Development of coal deposits on the west side of Cook Inlet in south-central Alaska would require construction of a marine terminal on the shore of Upper Cook Inlet. The west side of Upper Cook Inlet is relatively shallow near shore, preventing ships from docking along shore to receive cargo. Regular dredging of the nearshore area to increase the depth for ship passage would be costly and would permanently alter sea floor habitat potentially affecting fish, invertebrates, and marine mammals. A lower-impact solution is to construct and operate a pile-supported trestle and conveyor that would extend far enough out from shore to deliver coal to ships docked in deep water. Such a solution is proposed in the area known as Ladd, approximately 2.5 km (1.5 mi) north of the Village of Tyonek on the west side of Upper Cook Inlet, Alaska.

The proposed Ladd deepwater marine coal terminal would generate underwater noise that could potentially affect marine mammals and other marine wildlife near the terminal. The Ladd terminal would include a pile-supported trestle to carry conveyor systems that transport coal from the onshore coal yard to the vessel berths, approximately 3 km (2 miles) offshore, where water depths reach 20 m (65 feet). The primary sources of underwater noise will include the self-noise of large coal carrier vessels, the noise of coal being loaded into the holds of these vessels, and also noise from the conveyor and its drive systems that is conducted through the supporting piles into the water.

Little information concerning underwater noise generation and emission by marine terminals is available for the type of terminal planned for this project. To quantify the expected sound levels, JASCO Research Ltd carried out a sound measurement study at a similar marine coal terminal in a similar shallow-slope environment under a contract with DRven Corporation (through LGL Alaska Research Associates, Inc.). The noise measurements at this surrogate terminal are representative of noise levels that can be expected at the Ladd terminal. The study was performed at the WestShore terminal in Delta, British Columbia, Canada. The WestShore terminal is located at Roberts Bank in a delta environment, with water depths reaching 20 m at approximately 4.5 km (2.5 miles) from shore. The final 600 m (2000 feet) of the WestShore terminal consists of a pile-supported trestle that carries the coal conveyor system leading to the outer berth.

Underwater noise measurements were performed on 15 and 16 September, 2006 at the WestShore terminal using two bottom-moored autonomous sound recording systems, deployed for a 22-hour period. The recordings captured sounds produced by loading of a large coal carrier and the sounds produced by the pile-supported conveyor system. The noise measurements were used to compute 1/3-octave band source levels for the composite loading operation. These source levels were input to a noise model that computed sound level isopleths (presented as contour maps of sound levels) for the respective operations. These maps can be used to determine sound levels at any distance and direction from the terminal.

The results from this study are summarized in a Summary section, and a following Preliminary Recommendations section suggests methods that could be used to reduce underwater noise levels.

Study Location

The WestShore Coal terminal is located in Delta, British Columbia, Canada, approximately 25 km (16 miles) south of Vancouver. The main terminal is situated on an artificial island connected to the mainland by a 4 km constructed causeway with roadway and railway access (Figure 1). The island accommodates both the WestShore marine coal terminal and the Deltaport container shipping terminal. The WestShore terminal occupies the outer (southwest) section of the island, which can be identified by the darker area in Figure 1. Coal is delivered to the terminal by rail on a railway that is routed along the perimeter of the coal stockpile yard. Rail cars are dumped at a dumping station near the southwest corner of the yard and the coal is moved to the stockpiles using conveyor systems.

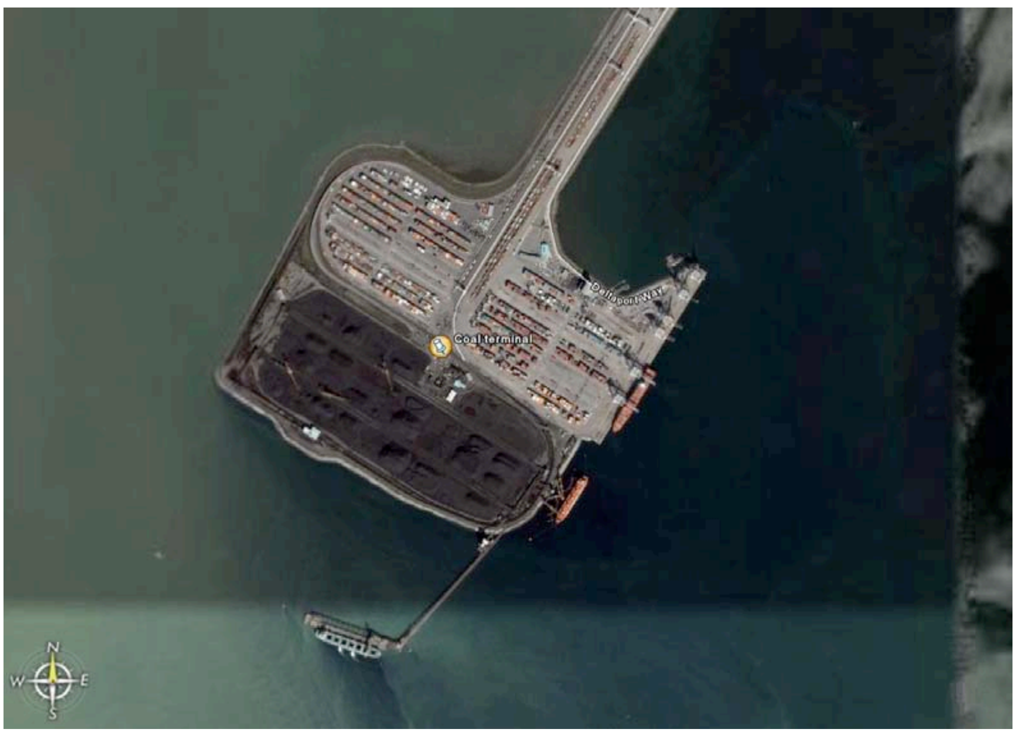

Figure 1: Aerial photograph of Westshore marine coal terminal in Delta, BC, Canada.

WestShore terminal has two main berths; the east berth is adjacent to the coal stockpile yard and the south berth is located at the end of a 600 m pile-supported trestle off the south corner of the yard. Coal is loaded from the stockpiles onto conveyor systems using wheel-diggers on large stacker-reclaimer equipment. The conveyors transport the coal to the berths where it is loaded through a hopper loader directly into the carrier holds.

The noise measurements made for the present study were made off the south berth. This berth is most closely representative of the proposed Ladd terminal berth in terms of water depth and its pile-supported conveyor belt system.

The WestShore terminal is adjacent to the British Columbia Ferry Corporation's Tsawwassen ferry terminal. That ferry terminal is in fact similar to the Roberts Bank terminal as it is situated on an artificial island with outer berths approximately 3 km (2 miles) from shore and it is connected to shore by a constructed causeway with highway. The proximity of this ferry terminal is important for this noise study because the large amount of ferry traffic causes substantial underwater noise.

Methods

Equipment

Two Ocean Bottom Hydrophone (OBH) systems were utilized for this project (Figure 2). The systems were anchored to the seafloor by expendable weights attached to the OBHs' acoustic releases. Each OBH system recorded 22 hours of single-channel continuous high-resolution digital acoustic data at 48 kHz sample rate with 24-bit samples. These systems incorporate calibrated Reson TC4032 hydrophones (nominal sensitivity -170 dB re V/μPa) that were factory-calibrated in October and November 2005 (standard recalibration schedule is 2 years). The calibration accuracy is formally ±2.5 dB from 10 Hz to 40 kHz, but these hydrophones have flattest response (and better stability) in the sub-5 kHz range, which was most relevant for this study.

The OBHs have an internal Sound Devices Model 722 hard-drive digital acoustic recorders housed in water-tight pressure canisters. The manufacturer's stated digital conversion accuracy of the recorders is ±0.2 dB and this was confirmed through laboratory calibration tests just prior to this field study. For recovery, an integral acoustic release was acoustically pinged from the surface to cause it to disengage the weight. The OBH's floats then floated the systems back to the surface for recovery and data download.

Figure 2: JASCO Ocean Bottom Hydrophone system

Field Study Location

The OBH systems were deployed in Georgia Strait off the south berth from a 23-foot workboat on 15 September at 13:00 and 13:17 PDT, at approximate locations 49° 0.542’ N, 123° 10.042’ W and 49° 0.417’ N, 123° 10.135’ W. The deployment locations were 400 m and 100 m respectively off the starboard (offshore side) of the carrier *Pierre LD* that was loading at the south berth (Figure 4). Water depths measured by the echosounder of the work boat were respectively 63 m and 43.5 m. The corresponding depths from a bathymetric map were 54 m and 37 m, but these were derived from a coarse dataset and are believed less accurate than the echosounder’s measurements.

The OBH deployments were made directly at right angles to mid-ship of the carrier, and distances from the vessel were measured using a laser rangefinder. For deployment, the OBHs were balanced on the stern of the work boat as distance from the *Pierre LD* was monitored using a laser rangefinder. The OBHs were dropped off as the measured range was within 5m of the nominal 400 m and 100 m deployment distances. There may have been some additional drift of the OBHs as they descended to the seabed that could affect the final deployment positions by up to 10 m. The systems were left in place on the seabed through the remainder of 15 September and overnight. They were recovered in the morning of 16 September at 10:55 (OBH-A) and 11:00 (OBH-B). The data were copied to external hard drives and backed-up to data DVD.

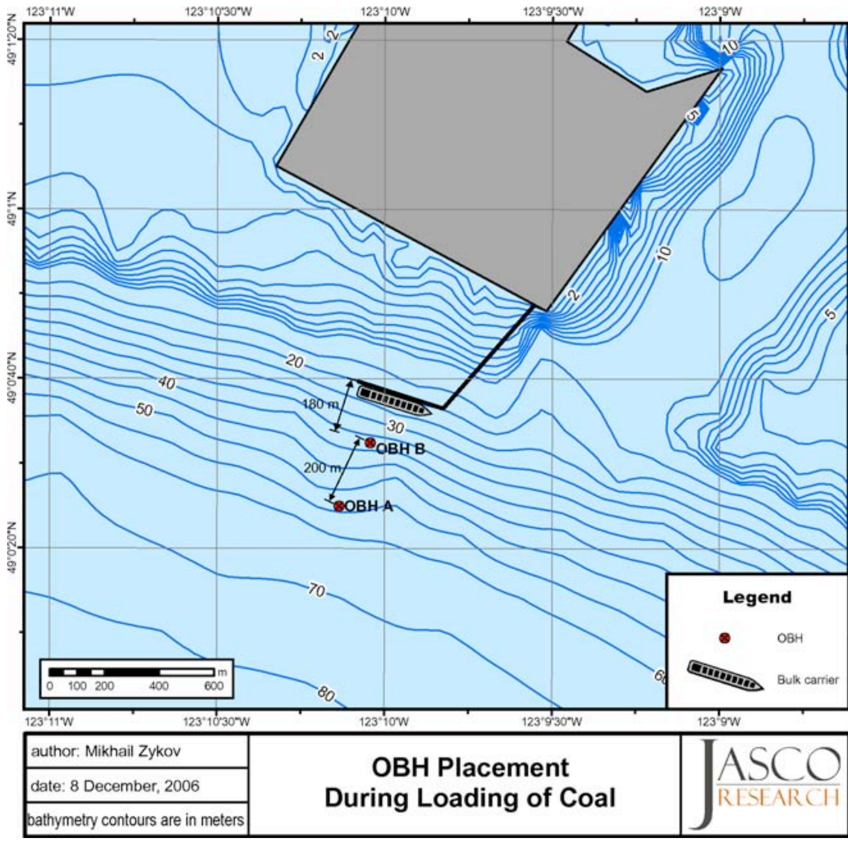

Figure 3: OBH deployment locations near the WestShore terminal, September 2006.

Figure 4: Photograph of Coal Carrier *Pierre LD* while it was loading at the south berth, September 15, 2006.

Data Analyses

The 24-bit acoustic recordings from the OBH systems provided high resolution capture of acoustic signals between 1 Hz and 24 kHz. These data were processed to obtain broadband sound levels, spectral levels, and several decade-band levels. The broadband frequency range reported here is 1 Hz to 24 kHz. The four decade frequency bands computed were: 1 Hz – 10 Hz, 10 Hz – 100 Hz, 100 Hz – 1 kHz, and 1 kHz – 24 kHz. We note the last band is not a decade band, but since most of its energy occurred below 10 kHz, and for brevity, we will refer to it as such. Spectral levels were calculated in 1 Hz frequency bins computed from 60 second fast Fourier transforms (FFTs) stepped in 30 second increments. Results are presented in data plots showing the spectrograms and decade band levels over the full 22-hour recording time period for the two OBH systems. The data plots contain two panels; the lower panel shows the spectrogram (spectral amplitude versus time and frequency), and the upper panel shows broadband and decade band sound levels versus time for the same period. The broadband levels were analyzed to compute percentile histograms.

A higher-resolution analysis was performed of two 10-minute time periods during which coal loading was occurring and noise from other sources (mainly ferry traffic) was low. The first 10-minute period includes the start of the loading into an empty hold and therefore contains loud sounds corresponding with coal striking the steel base of the hold. The second 10-minute period contains the sounds of loading after the hold was partially full (so the falling coal did not directly strike the bottom of the hold). This recording is more representative of the normal loading situation. Data from both 10-minute periods were processed using a 1 second FFT time windows computed in 0.5 second steps. The results from the first type (loading into empty hold) are plotted and discussed in the Results section. Data from the second period were processed to compute representative 1/3-octave band source levels for the normal loading operation. Those source levels were then used in a brief noise modeling study to compute sound levels at many locations surrounding the terminal. These results were used to generate sound level isopleths maps.

Results

General Noise Characteristics

Spectrograms and decade band levels for the two OBH systems are presented in Figure 5 and Figure 6. The large spikes in sound levels in all frequency bands above 10 Hz are due to passes by ferries and other vessel traffic. These vessel sounds are significant and dominate the noise field when present, but there are several time periods between passes and at night that contain primarily noise produced by coal terminal operations. Ferry traffic ended at 11 PM and did not restart until 6 AM, but two unknown vessel passes were observed in the recordings between at 00:45 and 02:00 on 16 September.

Conveyor System Noise

Broadband noise levels for sounds other than passing vessel traffic were dominated by acoustic energy in the 100 Hz to 1 kHz band. Noise levels in this band were 112-114 dB re µPa on OBH-A and 118-120 dB re µPa on OBH-B. The difference in levels on the two OBHs indicates that the origin of these sounds was near or at the loading location. This background underwater noise spectrum comprises a series of tonals that are clearly visible in all spectrogram plots, and they are attributed to the electric drive motors of the conveyor system and to self-noise from the *Pierre LD*. The specific conveyor drive motor responsible for most of this noise is at the base of the hopper located at the east end of the south berth, approximately 500 m and 300 m respectively from OBHs A and B. This hopper is at the far right side of the photograph in Figure 4. These measured levels correspond with an effective source level of approximately 174.5 dB re µPa at 1m. Airborne noise from this motor system was clearly audible from the workboat on the water at 1 km range, and in one instance as far away as 2 km.

Coal Carrier Self Noise

Underwater noise in the 10 Hz to 1 kHz band increased by almost 7 dB at 03:00 on 16 September to 121 dB re µPa on OBH-A and 126 dB re µPa on OBH-B. This noise is attributed to use of the *Pierre LD's* propulsion system to assist with maintaining position at the berth as wind speed reached 15 kt at 03:00. Weather information including wind speed and direction for the full recording time period is given in Appendix A. Wind speed increased gradually from near 5 kt at 20:00 on 15 September to 20 kt at 09:00 on 16 September. Wind direction remained fairly constant from the northeast, which was broadside of the vessel, and pushing it directly off the berth. The source level of this propulsion noise was 166-173 dB re µPa at 1m.

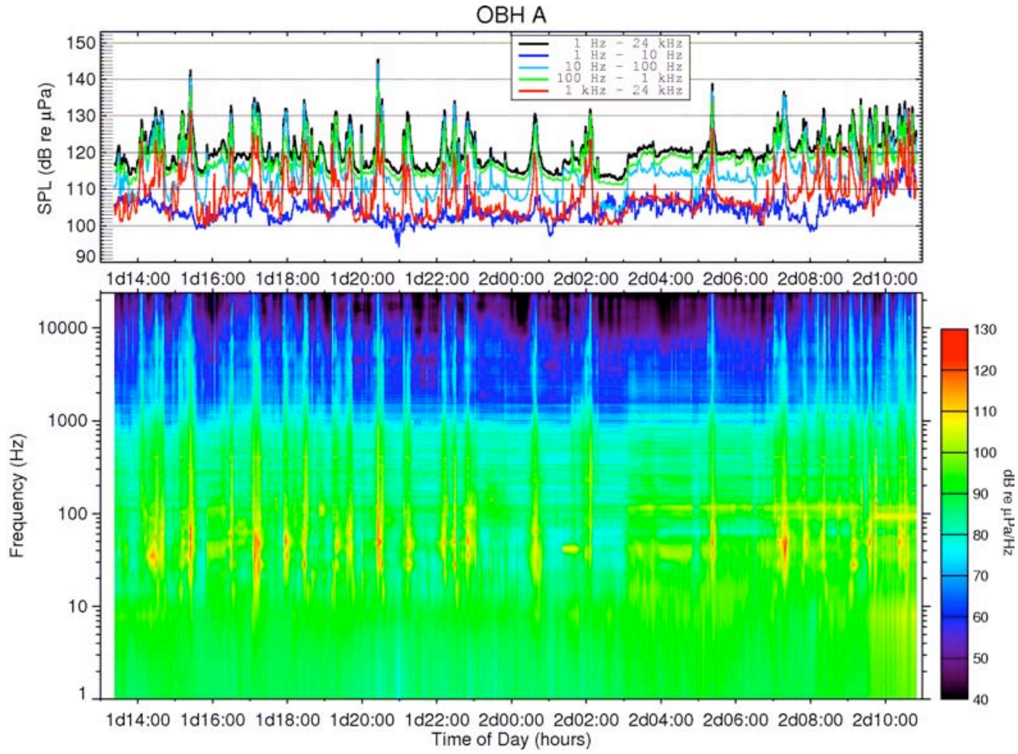

Figure 5: Spectrogram and band levels from OBH-A for a 22-hour monitoring period, September 15-16, 2006.

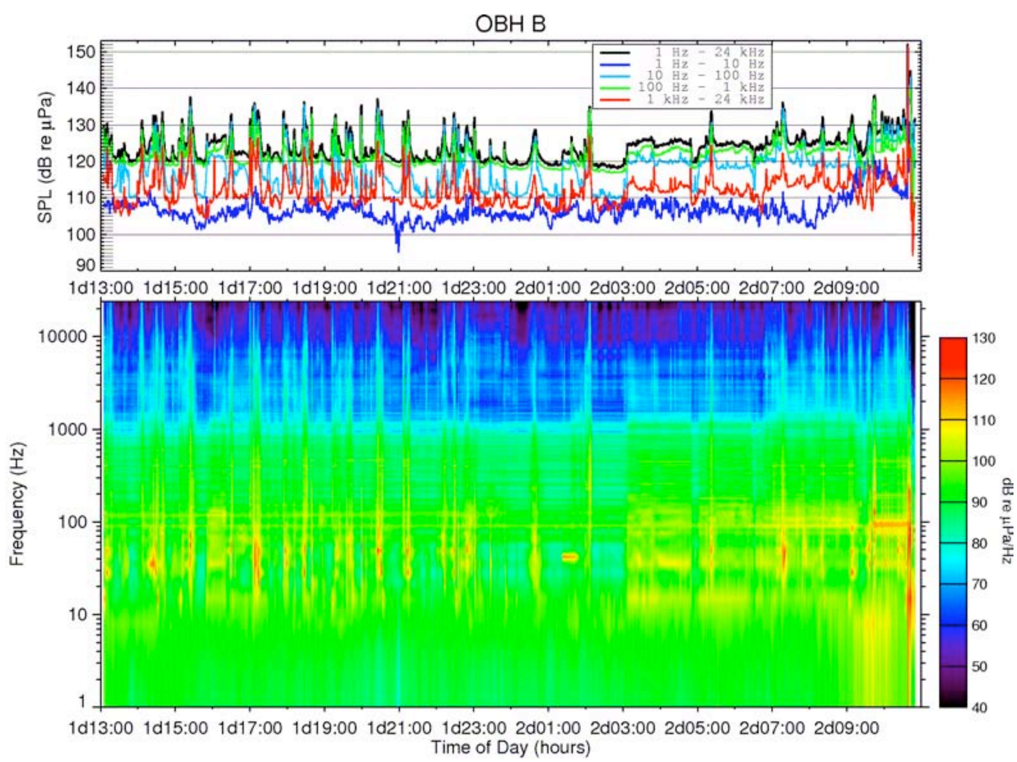

Figure 6: Spectrogram and band levels from OBH-B for a 22-hour monitoring period, September 15-16, 2006.

Coal Loading Noise

Loading of coal into the holds of *Pierre LD* continued throughout the time period of this acoustic study. The actual loading process produced relatively less noise than the carrier itself and the conveyor drive system except during the first two minutes of loading into an empty hold. The characteristics of loading noise are evident in Figure 7, which shows the spectrogram and band levels through a 10-minute period during which loading into an empty hold began. Underwater noise levels increased abruptly by more than 20 dB to over 140 dB re μPa on OBH-B as the coal fell into the empty hold. The noise level then dropped by about 10 dB within 30 seconds, and by a further 10 dB back to background levels within 2 minutes. The background levels were due primarily to carrier self-noise and to conveyor drive noise. Interestingly the initial loading noise includes a high frequency (above 1 kHz) component for the first few seconds. This noise is probably from the actual striking of coal against the metal of the hold. This high frequency noise quickly dropped in level as the bottom of the hold became covered with coal. Sound levels in the dominant 100 Hz – 1 kHz band dropped to background (120 dB) within 2 minutes. Sound levels in the 10 Hz – 100 Hz band remained 2 to 5 dB above the corresponding background level (110 dB re μPa) through the remainder of loading.

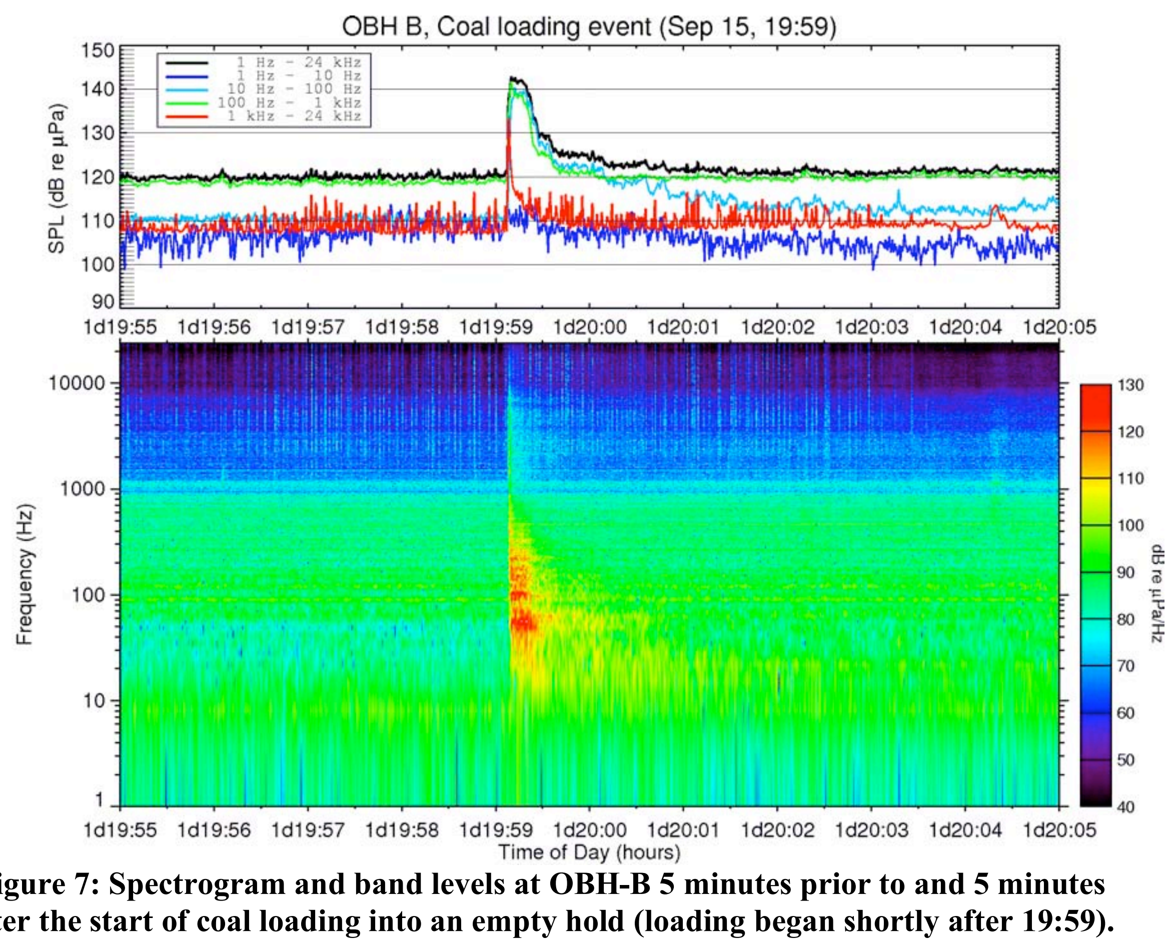

Figure 7: Spectrogram and band levels at OBH-B 5 minutes prior to and 5 minutes after the start of coal loading into an empty hold (loading began shortly after 19:59).

Noise level statistics

Sound level data were analyzed to compute percentile sound levels for representative daytime (14:00-20:00, 15 September), nighttime (0:00-06:00, 16 September), and full-day (13:30, 15 September – 10:30, 16 September) time periods. Percentiles represent the thresholds in decibels that sound levels were below for the given percentile percent of the time. For example, the 70th percentile sound level on OBH-A between 0:00 and 06:00 on 16 September was 120.4 dB re μPa. This means that sound levels were below 120.4 dB re μPa for 70% of the time, and above this level for the remaining 30% of the time. The use of percentile levels allows us to assess the general noise conditions by excluding short-duration events, such as vessel passes. A good measure of the representative normal terminal levels is given by the percentile levels below the 70th percentile because other (not related to terminal operations) noise sources were present for less than 30% of the time.

Sound level percentile histograms, showing percent of 1-minute samples versus sound levels in 1 dB bins, are presented in Figure 8. The most noticeable difference of the histogram characteristics between daytime and nighttime is the spread of sound levels to higher values during the daytime. This is a direct result of the presence of ferry and other vessel transit noise during the day. The nighttime histograms are most representative of the noise level distribution caused by the WestShore terminal and therefore also of the noise levels that will be present near the Ladd terminal. The nighttime 70th percentile levels were 124.9 dB re μPa on OBH-B and 120.4 dB re μPa on OBH-A. All of the sound contributing to these levels is attributed to coal terminal operations.

If it is assumed that all noise originated at the conveyor drive motor location, then the equivalent 70th percentile source level for all terminal noise would be 174.5 dB re μPa at 1m. The above assumption is consistent with the observed difference in levels measured on the two OBH systems; the difference of 4.5 dB is expected if the source was located 300 m and 500 m from the respective systems. It would have been much larger (about 12 dB) if the source was near the berth at 100 m and 400 m respectively from the OBH positions.

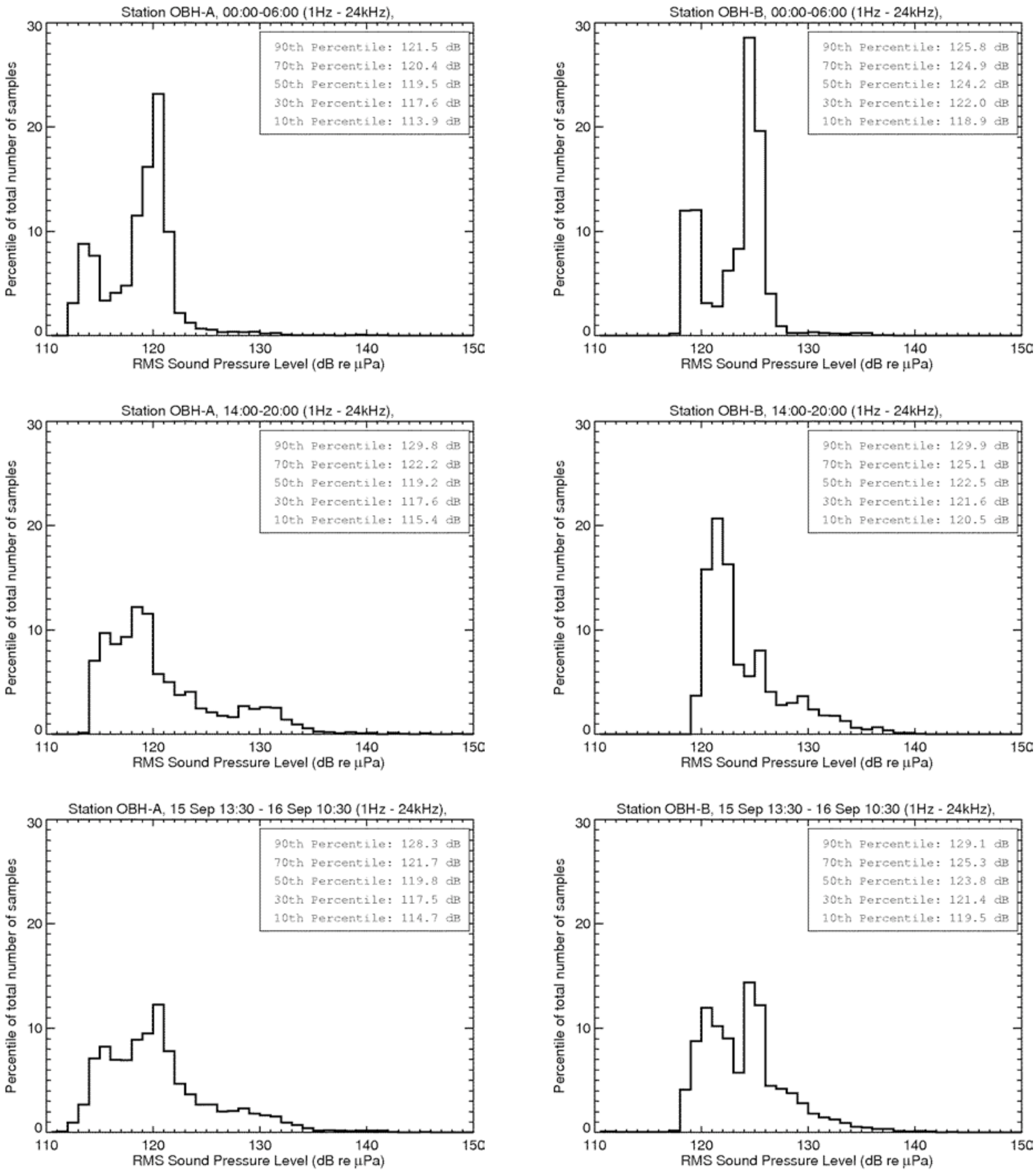

Figure 8: Sound level percentile histograms for daytime and nighttime periods, WestShore terminal, September 15-16, 2006.

Sound Modeling

Sound propagation models are useful for predicting the spatial variation of noise levels from sounds produced at known locations. A modeling approach was applied to predict spatial variation of noise levels in vicinity of the WestShore terminal based on the measured levels at the OBH locations. JASCO Research Ltd's Marine Operations Noise Model (MONM) was used for this purpose. MONM is a parabolic equation finite difference model that accounts for spectral characteristics of the source and the geoacoustic parameters of the ocean environment. It specifically treats bathymetric effects, ocean sound speed profile, compressional and shear wave speed and attenuation profiles of the seabed, and density profile of the seabed. The model uses a 2-D computational engine that is run along many radials to compute the three dimensional field. This approach is commonly referred to as Nx2D modeling.

MONM requires the sound source levels in 1/3-octave bands. These levels were derived from the measurements from the OBH systems during normal coal loading operations into partially-full holds as described in the previous sections. Back-propagation of the 1/3-octave measured levels from OBH-B to a source at the conveyor drive location was performed using point-to-point runs of the propagation model for each band center frequency. Back-propagation assumed the source was at 7 m depth, which was approximately mid-water depth at the conveyor drive location, and the receiver was on the bottom. The resulting 1/3-octave band source levels are given in Table 1.

Table 1: 1/3-octave band source levels for typical terminal operations, including coal conveyor drive systems, loading noise, and vessel noise from its propulsion system assisting with holding berth position.

Frequency (Hz)	Source Level (dB re μPa // 1m)	Frequency (Hz)	Source Level (dB re μPa // 1m)
0010	146.3	0315	159.2
0013	148.4	0400	161.3
0016	153.8	0500	160.6
0020	151.8	0630	159.2
0025	154.8	0800	158.6
0032	155.6	1000	157.0
0040	159.1	1250	153.4
0050	156.3	1600	148.2
0063	156.6	2000	146.7
0080	157.3	2510	148.3
0100	161.5	3160	147.3
0125	160.0	3980	145.1
0160	159.7	5010	145.4
0200	158.7	6310	147.0
0250	159.4	7950	145.2

The source levels given in Table 1 were input to MONM and the model was run to generate sound level isopleths for an 8 km by 8 km square area surrounding the terminal. The model results are representative of a receiver at 10 m depth. The source depth was specified at 7 m. Water sound speed profile was based on a principal component analysis of CTD casts by Canadian Department of Fisheries and Oceans (unpublished) for the Fraser river delta region of Georgia Strait. The seabed geoacoustic profile was obtained from sediment core data obtained on the Fraser River Delta. Modeling results are presented in the sound level isopleth map in Figure 9. The approximate distance to 120 dB re μPa is 1.2 km in the offshore and alongshore directions, and approximately 500 m in the inshore direction. The lower sound levels in the inshore direction are a result of low frequency sound propagation being preferentially better supported in deeper water. This is also the reason that the isopleths extend farther in the dredged channel northeast of the berth than the not-dredged area in the northwest direction.

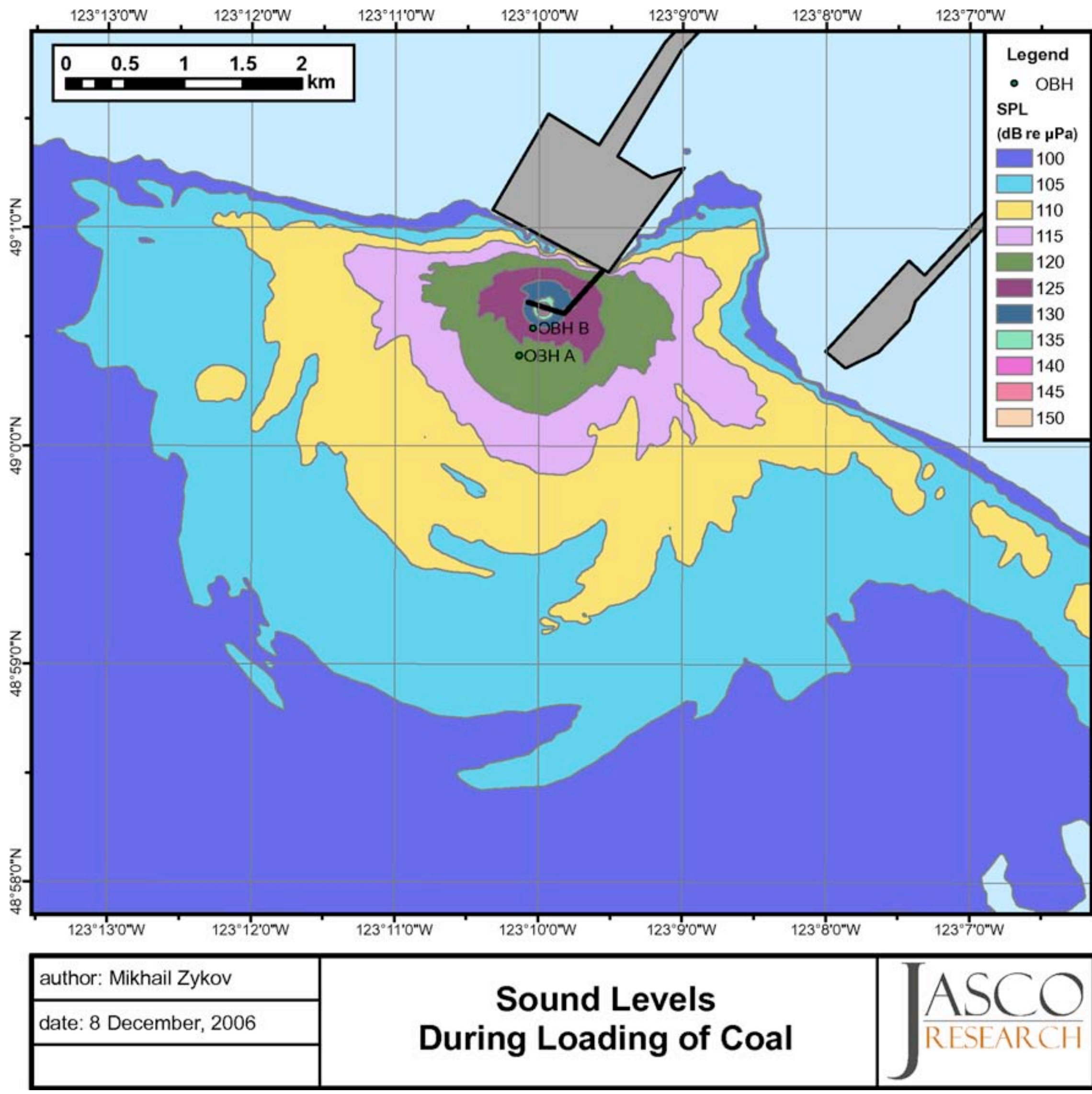

Figure 9: Noise model results for terminal operations showing sound pressure isopleths in the vicinity of the WestShore terminal.

Summary

Sound level measurements were made 100 m and 400 m from the south berth of WestShore terminals Ltd Roberts Bank marine coal terminal in Delta, British Columbia, Canada, for the purpose of quantifying expected sound levels that will be present near DRven's Ladd terminal in upper Cook Inlet, Alaska. The measurements were made using two autonomous Ocean Bottom Hydrophone (OBH) systems deployed on the seabed over a 22-hour period starting 13:00 on 15 September 2006 while loading of the coal carrier *Pierre LD* was in progress. The measurements captured noise produced by coal falling into the carrier's holds during the loading process as well as noise produced by the carrier's propulsion system and noise produced by the terminal's conveyor drive system. Conveyor drive motor noise was conducted into the water by the pilings that supported the conveyor trestle.

The coal loading process itself was relatively quiet except for brief periods, lasting a few seconds, when the coal was loaded into empty holds. This noise was produced by the coal striking the metal bottom of the hold and it decreased quickly as the bottom of the hold became covered in coal. The initial broadband noise level increased abruptly from background level of 121 dB re μPa to 143 dB re μPa at 400 m range as coal loading started. The "background" noise was due primarily to carrier self-noise and to conveyor drive noise. After one minute the level at 400 m dropped to 125 dB re μPa, and after 3 minutes it reached the steady-state loading level near 122 dB re μPa.

The most significant source of underwater noise at the WestShore terminal was a pile-supported drive motor that drove the conveyor belt systems that deliver coal to the berth and loader. The noise from this motor, as received underwater, is characterized by a series of tonals between 100 Hz and 1 kHz. The effective acoustic source level[1] for this motor was calculated by back-propagating the measured sound levels from the two OBH deployment positions to the motor location. This was approximately 174.5 dB re μPa at 1m.

The source level of underwater noise produced by the carrier's propulsion system approached that of the conveyor drive motor, approximately 166 to 173 dB re μPa at 1 m, when the carrier had to use its propulsion system to assist in maintaining position at the berth as wind speeds became strong. However, this sound was emitted more directly into the water as compared to the drive motor sound.

JASCO's Marine Operations Noise Model (MONM) was applied to compute the spatial variability of noise levels in vicinity of the WestShore terminal using the

[1] Source level here refers to the sound pressure level near a point-like sound source that would produce the actual sound levels measured at the OBH locations. The source level is referenced specifically to the pressure at 1 meter from the point source. At the WestShore terminal, noise from the conveyor drive system was emitted into the water by several of its supporting piles in about 14 m of water. Although this source configuration differs from the point source representation, the point source level is still very useful for predicting sound levels at other locations. It is important to note, however, that nowhere in the water does the actual received sound reach as high as the calculated source level of 174.5 dB.

measured 1/3-octave band source levels (including both the vessel noise and the conveyor drive noise). The model results are presented as a map of sound level isopleths. The model results show that, at the WestShore terminal, sound levels are higher in the offshore direction and in one direction towards shore that was dredged deeper than surrounding inshore areas. The model results predict that the 120 dB re μPa isopleth occurs approximately 1.2 km in the offshore and alongshore directions, and approximately 500 m in the inshore direction, from the berth.

Discussion

Ambient sound levels measured in six areas of upper Cook Inlet and away from industrial activity averaged 95 dB re 1 μPa, and up to a maximum of 124 dB at Point Possession during an incoming tide (Blackwell and Greene 2002). At Port Mackenzie, across the inlet from the Port of Anchorage and an area frequented by beluga whales, "ambient" sound levels (presumably not completely devoid of some industrial sounds) ranged from 115 to 133 dB during low tidal currents and 125 to 132 dB during incoming and outgoing tides (Blackwell 2005). It seems likely that, during some parts of the tide, broadband sound levels produced from the operation of a coal loading facility at Ladd would be similar to those during periods of high tidal flux within as little as 100m. At quieter stages of the tide, unmitigated broadband sounds from the terminal would be above broadband ambient levels (95 dB) for up to 10 km. It is reasonable to assume that design engineering to dampen or attenuate sounds produced from the conveyor motor could reduce its effective source level by 10 dB; such a reduction would decrease the distance to where broadband would reach 95 dB down to about 3.3 km.

The National Marine Fisheries Service (NMFS) currently uses 160 dB re 1 μPa SPL as a threshold for *pulsed* sounds that would constitute "disturbance" to marine mammals. Noise produced from pile driving is considered a pulsed sound. However, for continuous or extended-duration sounds, like those that would be produced from coal loading, it is commonly assumed by NMFS that disturbance is possible at received levels > 120 dB re 1 μPa. This criterion is based mainly on early studies of gray and bowhead whale reactions to industrial sounds. The 120 dB value has also been used as a disturbance criterion for impact assessments for pipeline construction noise on gray whales offshore of Sakhalin Island. The criterion may be overly conservative for belugas, which have significantly lower hearing sensitivity to the low sound frequencies that dominate the terminal noise emissions as compared with the baleen whales for which the 120 dB criterion was developed. Beluga responsiveness has been shown to be highly variable in different situations; there are documented cases when belugas have shown strong avoidance to continuous sounds with received levels <120 dB, but there are other documented cases where they tolerated considerably stronger sounds.

The presence of broadband industrial sounds above ambient levels does not necessarily mean that they will have an effect or that they will even be heard by marine mammals found in the area. The broadband sounds measured at WestShore terminal were made up predominantly of low frequency components at frequencies well below 1 kHz. Seals and especially beluga whales (and other toothed whales) are considerably less sensitive to these low frequency sounds as compared to higher frequencies (Richardson et al. 1995). In assessing potential impact to whales and seals in the area, a more appropriate measure than broadband sound levels relative to broadband ambient noise levels would be the distance to which the industrial sound would be above the animal's hearing threshold in one or more frequency bands. These species-specific distances at which the industrial sound would fall below the hearing threshold can be estimated based on the frequency composition of the industrial sound, its rate of attenuation with distance (which usually depends on frequency), and the audiogram for each species. Audiograms of belugas, harbor porpoises and harbor seals are known and could be used for such calculations. For those marine mammals that frequent upper Cook Inlet, the distances at which the animals could actually hear or detect the stronger components of the industrial sound could be either more or less than the distance at which broadband sound levels attenuate to broadband ambient.

Recommendations

Our study found that the two primary underwater noise sources at the WestShore terminal were the drive motor of the pile-supported coal conveyor system, and the coal carrier vessel itself. The carrier noise was produced by its propulsion system as it was used to maintain berth position in moderate winds. Noise from the coal loading operation was also detected, but this noise generally was lower in amplitude. However, high level transient noise, lasting up to two minutes, was generated when coal was loaded into empty holds. Most of the energy in the industrial sound was below 1 kHz. Based on these observations we provide the following preliminary recommendations for assessing potential impacts and reducing and mitigating underwater noise effects from the Ladd terminal:

1.) Use audiograms from marine mammal species in the area, along with available data on frequency-composition of the industrial sounds, to calculate the distance by which sound levels in all 1/3rd octave bands drop below the hearing thresholds at those frequencies.

2.) Consider sound dampening technology in the design of the conveyor and its drive system.

3.) Consider designs for the berth orientation and anchoring system that minimize the need for vessel propulsion to maintain the ships position.

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Appendix A: Hourly Weather

Location: Vancouver International Airport (20 km North of Roberts Bank).

Hourly Data Report for September 15, 2006										
Time	Temp °C	Dew Point Temp °C	Rel Hum %	Wind Dir 10's deg	Wind Spd km/h	Visibility km	Stn Press kPa	Hmdx	Wind Chill	Weather
00:00	10.8	9.3	90		0	32.2	100.61			Mostly Cloudy
01:00	10.9	9.1	89	9	4	24.1	100.64			Mostly Cloudy
02:00	10.8	9.2	90	9	6	24.1	100.65			Rain Showers
03:00	11.0	9.2	89	10	6	24.1	100.66			Rain Showers
04:00	10.7	9.3	91	10	4	24.1	100.65			Rain Showers
05:00	10.8	9.6	92	9	6	24.1	100.69			Cloudy
06:00	11.0	9.5	90		0	24.1	100.72			Rain Showers
07:00	11.5	9.8	89	11	7	24.1	100.75			Rain Showers
08:00	12.4	10.1	86	11	6	24.1	100.75			Rain Showers
09:00	12.8	10.1	84	20	7	24.1	100.82			Cloudy
10:00	14.0	10.5	79	23	9	24.1	100.85			Mostly Cloudy
11:00	15.3	10.5	73	25	15	24.1	100.89			Mostly Cloudy
12:00	14.2	10.2	77	27	15	24.1	100.92			Cloudy
13:00	13.8	11.3	85	29	15	24.1	100.95			Rain Showers
14:00	14.5	9.9	74	28	15	32.2	100.96			Rain Showers
15:00	16.4	9.1	62	30	9	32.2	100.97			Mostly Cloudy
16:00	16.4	8.4	59	25	9	32.2	100.99			Mainly Clear
17:00	16.0	6.8	54	30	13	32.2	101.03			Mainly Clear
18:00	13.7	6.9	63	29	7	48.3	101.07			Mainly Clear
19:00	12.4	6.9	69	35	4	48.3	101.11			Mainly Clear
20:00	12.4	8.1	75		0	48.3	101.17			Mainly Clear
21:00	11.3	7.5	77	8	7	48.3	101.21			Mainly Clear
22:00	12.7	7.7	72	10	6	48.3	101.27			Mainly Clear
23:00	11.2	7.8	80	8	9	32.2	101.34			Mostly Cloudy

Hourly Data Report for September 16, 2006											
Time	Temp °C	Dew Point Temp °C	Rel Hum %	Wind Dir 10's deg	Wind Spd km/h	Visibility km	Stn Press kPa	Hmdx	Wind Chill	Weather
00:00	10.0	7.6	85	9	9	32.2	101.42			Mainly Clear
01:00	10.2	7.7	84	11	11	32.2	101.46			Mainly Clear
02:00	10.4	8.5	88	11	17	32.2	101.52			Mainly Clear
03:00	10.1	8.4	89	10	15	32.2	101.57			Mostly Cloudy
04:00	10.1	8.2	88	9	15	32.2	101.62			Mostly Cloudy
05:00	9.9	7.6	86	10	15	32.2	101.70			Mostly Cloudy
06:00	10.0	7.2	83	10	15	32.2	101.76			Mostly Cloudy
07:00	10.0	6.5	79	11	13	32.2	101.83			Mostly Cloudy
08:00	12.7	6.7	67	13	22	32.2	101.88			Mostly Cloudy
09:00	14.2	7.9	66	11	17	32.2	101.94			Mostly Cloudy
10:00	15.2	8.0	62	14	20	32.2	102.00			Mainly Clear
11:00	15.8	8.5	62	16	17	32.2	102.02			Mainly Clear
12:00	16.9	8.5	58	16	20	32.2	102.03			Mainly Clear
13:00	17.2	3.9	41	15	17	32.2	102.02			Mainly Clear
14:00	17.4	9.0	58	21	19	32.2	102.03			Mainly Clear
15:00	17.9	8.0	52	19	15	32.2	102.04			Mainly Clear
16:00	17.5	6.6	49	21	17	32.2	102.05			Mainly Clear
17:00	17.3	7.4	52	17	17	32.2	102.07			Mainly Clear
18:00	16.5	7.1	54	15	11	48.3	102.10			Mainly Clear
19:00	12.9	8.0	72	10	15	32.2	102.12			Mainly Clear
20:00	12.4	8.1	75	9	11	32.2	102.18			Mainly Clear
21:00	12.8	8.3	74	9	13	32.2	102.18			Mainly Clear
22:00	12.3	8.5	78	8	11	32.2	102.20			Mostly Cloudy
23:00	11.5	8.3	81	10	13	32.2	102.19			Mostly Cloudy

Hourly Wind Speed for September 15, 2006	**Hourly Wind Speed for September 16, 2006**