Re: SR 411, Lexington Bridge Underwater Noise Monitoring Results

Dear Mr. Widener,

This memo summarizes the preliminary results from the pile driving monitoring activities associated with the construction of the Lexington Bridge on SR 411. These measurements were obtained side-by-side with your biologist monitoring the affected environment.

This technical memorandum describes the data collected during pile driving efforts at the construction site for the new Lexington Bridge on SR411 during the months of July and August 2006. Ambient underwater sound levels in the river were measured with and without the nearby train traffic on the nearby Burlington Northern Railroad tracks. The ambient sound level results were an RMS of 160 dB with peaks between 170 and 175 dB (see Attachment 1).

Eight 24-inch diameter steel piles were monitored at various water depths. Piles were driven with an ICE Model 60 diesel Pile Hammer (see Attachment 2). The pile hammer energy to drive a pile can be estimated by the stroke length used to drive the pile. Most piles for this structure were driven using 5 to 7 foot hammer strokes with an occasional 9 foot stroke. This equates to 35 to 49 K foot pounds with an occasional drive in excess of 60K ft-lbs. Table 1 summarizes the results for each pile monitored.

Table 1: Summary Table of Monitoring Results.

<table>
<thead>
<tr>
<th>Pile #</th>
<th>Midwater Hydrophone Depth</th>
<th>Bubble Curtain</th>
<th>Absolute Peak (dB)</th>
<th>Rise Time (Sec.)</th>
<th>Number of Pile Strikes</th>
<th>Average Peak for all Pile Strikes (Pa)</th>
<th>+/- Standard Deviation</th>
<th>RMS Average for all Pile Strikes (Pa)</th>
<th>+/- Standard Deviation</th>
<th>Average Decibel Reduction (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4 feet</td>
<td>YES</td>
<td>188</td>
<td>.0011</td>
<td>3</td>
<td>2157</td>
<td>418</td>
<td>370</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4 feet</td>
<td>NO</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>*8</td>
</tr>
<tr>
<td>3</td>
<td>1.5 feet</td>
<td>YES</td>
<td>194</td>
<td>.0066</td>
<td>12</td>
<td>2063</td>
<td>1315</td>
<td>258</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.5 feet</td>
<td>NO</td>
<td>202</td>
<td>.0074</td>
<td>180</td>
<td>4864</td>
<td>1702</td>
<td>576</td>
<td>166</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2 feet</td>
<td>YES</td>
<td>188</td>
<td>.0083</td>
<td>82</td>
<td>2015</td>
<td>234</td>
<td>339</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2 feet</td>
<td>NO</td>
<td>198</td>
<td>.0049</td>
<td>17</td>
<td>5428</td>
<td>1369</td>
<td>533</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1.5 feet</td>
<td>YES</td>
<td>187</td>
<td>.0010</td>
<td>64</td>
<td>1918</td>
<td>107</td>
<td>200</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1.5 feet</td>
<td>NO</td>
<td>193</td>
<td>.0058</td>
<td>261</td>
<td>3056</td>
<td>283</td>
<td>384</td>
<td>47</td>
<td></td>
</tr>
</tbody>
</table>

*Pile 2 required only one strike to seat pile and the monitoring equipment failed to record the data. Pile 8 was used for comparison purposes.

A bubble curtain was tested on alternate piles. The bubble curtain was used to minimize effects of underwater sound for piles 1, 3, 5 and 6. Peak underwater sound levels ranged from 187 to
202 dB$_{\text{peak}}$ during the pile driving activity with an effective average reduction of 4 to 9 dB from the use of bubble curtains. The average sound reduction achieved with the bubble curtain on pile 6 was 4 dB, which was approximately half of the reduction seen with the other piles. This could possibly be because the bubble curtain sitting on a small rock and was not seated properly on the bottom of the river allowing sound to escape through the opening.

Other notes and observations made during the monitoring of the pile driving activity include; piles 1 through 3 and the last pile, pile 8, required few strikes before attaining the bearing required for this temporary work structure. Small fish appeared to be feeding along the west bank of the Cowlitz River. No harm to fish was apparent during the pile driving operation from observations made near the piles. Post analysis of the unweighted frequency distribution of the peak pile strikes in the underwater environment can be seen in Figures 1 through 5 below. Figure 1 is the ambient level frequency distribution in the river before driving piles, and it likely includes sound from the project propagating through the piles already in the river as well as sound propagating from the project itself. It does provide a base line for comparing the effect the pile driving activity has on the existing river sound environment. It does not, however, take into consideration the sensitivity organisms may have to any particular range of frequencies by any form of weighting that is likely important in considering its effect on the species effected.

Figure 1: Unweighted Ambient Underwater Sound

In Figure 2 it was not possible to analyze the sound level from pile driving and compare it with the sound level mitigated by the use of a bubble curtain. Pile 2 was not measured because of equipment malfunction during the single pile strike to set pile 2 so only the pile with the bubble curtain on it was measured and analyzed. I have left the ambient sound levels frequency distribution recorded in Figure 1 to show a relationship to the current ambient level.

Figures 3 through 5 demonstrate the effect on the frequency distribution of sound from the peak pile strike on the underwater environment with and without the use of a bubble curtain.
This information may be useful in the future when it is determined at what frequencies beings living in that environment are sensitive to sound.

Figure 2: Pile 1 Unweighted Frequency Distribution Compared with Ambient

Figure 3: Pile 3 & 4 Unweighted Frequency Distribution
Figure 4: Pile 8 & 5 Unweighted Frequency Distribution Compared with Ambient

Figure 5: Pile 6 & 7 Unweighted Frequency Distribution Compared with Ambient

Appended to this technical memorandum are the post processed data sheets for the peak pile strike for each of the piles monitored. This is the form we typically use to report the data that is acquire in our pile monitoring programs. We still have the raw data on file and may be able to further process this into useable information. If you would like to do something different or would like to get the raw data please contact me, Larry Magnoni at (206) 440-4544 or Jim Laughlin at (206) 440-4643.
Sincerely,

Larry J. Magnoni  
Acoustical, Air Quality and Energy Engineer  
LM/ljm  
Attachments  
- Ambient Sound Level Analysis Sheet  
- Pile Driver Data Sheet  
- Unweighted Peak Sound Waveform Analysis Sheets for each Pile  
cc: Jim Laughlin  MS NB82-138  
    John C. Heinley  MS 47390  
    day file  
    file
**Ambient With & Without Train**

**Figure a. Waveform**

- Graph showing sound pressure level over time with different colors for 'With Train' and 'Without Train'.

**Figure b. Narrow Band Frequency Spectra**

- Graph showing frequency spectra with different colors for 'With Train' and 'Without Train'.

**Figure c. Accumulation of Sound Energy**

- Graph showing accumulation of sound energy with SEL (Sound Exposure Level).

**Figure d. Sound Pressure and Sound Energy Levels**

<table>
<thead>
<tr>
<th>Signal Analysis Sound Pressure / Energy Levels</th>
<th>2-feet - 00:00:00</th>
<th>Peak</th>
<th>RMS90%*</th>
<th>SEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>With Train</td>
<td>170</td>
<td>160</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>Without Train</td>
<td>175</td>
<td>160</td>
<td>160</td>
<td>160</td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%)*
Clean • Efficient • Reliable

Designed and engineered for lightweight driven pile applications.

- High-pressure fuel injection provides easy start, even in extreme weather.
- Dual injectors dual-size fuel atomization and delivery for clean, efficient operation.
- Remote variable fuel pump.
- Operates on vegetable-based fuel & lubricants without modification, contributing to a clean and tox-free job site.
- Hydraulically operated remote throttle permits precise control of stroke to match hammer energy to any job or pile condition.
- Upper & lower polymers: rain bearings minimize wear and maximize energy transfer.
- Lower cylinder and other critical components are chemically treated for superior surface hardness and fatigue resistance.
- Ferro-chromium alloy forged ram & anvil exceed strength of cast rams & anvils for durability and long life.
- Weighs less than competitive hammers to move more easily from pile to pile.
- Swinging, fixed and sliding lead setups available in 16 and 3 ft sections.
- Four models of light-to-heavy-duty weld sections for precise pile positioning.

Working Specifications

- Maximum energy
  - 7,000 lb (3175 kg)
  - 72,900 ft-lbs (98.5 kNm)
  - 60,000 ft-lbs (81.4 kNm)
- Minimum energy
  - 26,000 ft-lbs (35.2 kNm)
  - 41-59

- Speed (strokes per minute)

Weights

- Bare hammer
  - 3,600 lbs (1635 kg)
  - 5,300 lbs (2400 kg)

- Typical weight (with pipe cap & 26” leads)

Capacities (adequate for average day of operation)

- Diesel fuel tank
  - 18 gal (70 l)
- Lube oil tank
  - 8 gal (30 l)

Dimensions of Hammer

- Width (side to side)
  - 26” (660 mm)
- Depth
  - 37.5” (950 mm)
- Centerline to front
  - 17” (430 mm)
- Centerline to rear
  - 20.5” (520 mm)
- Length (hammer only)
  - 17'-3" (508 mm)
- Operating length (top of ram to top of pile)
  - 26'-9" (815 mm)
# Model 605

Fuel-Injected Diesel Pile Hammers

## ICE 605 Diesel Pile Hammer Bearing Chart

This chart is based on the Data beiden give and is presented as a replacement only for those supplied when this form is ordered.

According to Federal Highway Administration, 123 1/2 in. (0.65) minimum depth is desired.

The truck you are buying is subject to 123 1/2 in. 123 1/2 in. The truck is designed to be for a large range of sizes.

The ICE 605 diesel hammer is subject to 123 1/2 in. The ICE 605 diesel hammer is subject to 123 1/2 in.

<table>
<thead>
<tr>
<th>Size</th>
<th>Bearing No.</th>
<th>Load</th>
<th>RPM</th>
<th>Motor</th>
<th>123 1/2 in. 123 1/2 in.</th>
<th>123 1/2 in. 123 1/2 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
</tr>
<tr>
<td>12.5</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
</tr>
<tr>
<td>13</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
</tr>
<tr>
<td>13.5</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
</tr>
<tr>
<td>14</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
</tr>
<tr>
<td>14.5</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
</tr>
<tr>
<td>15</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
</tr>
<tr>
<td>15.5</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
</tr>
<tr>
<td>16</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
</tr>
<tr>
<td>17</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
<td>123 1/2 in.</td>
</tr>
</tbody>
</table>

**CAUTION:** When using this chart, consult the manufacturer's recommendations. The chart in this manual is subject to change without notice. Driving in excess of the above limit of 123 1/2 in. or more than an hour

Driving or driving 123 1/2 in. of 123 1/2 in. per minute is recommended and will not exceed 123 1/2 in.

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## LEADS/SPOTTERS

ICE manufactured leads with a 20", 26", 32", and 36" guide rails for all ICE and other pile hammers. Standard components are available in 8 positions for swinging, fixed and sliding lead setups. Two designs are available to provide the most cost-effective configuration for every job. Four models of spotters and three spotter power units sizes are available.

## DRIVE CAPS

ICE offers a drive cap or pin system for all ICE pile sizes as well as for pile leads. Drive caps or pins are available for practically any pile type and size. The ICE drive cap system maintains pile top position under the hammer, protects the hammer from peak stresses, minimizes pile top deformation, and transmits maximum force to pile.

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**INTERNATIONAL CONSTRUCTION EQUIPMENT INC.**

Corporate offices:
301 Warehouse Drive, Matthews, NC 28104
Phone: 704-823-8858 FAX: 704-823-8970

Fax: 704-823-8970
Figure a. Waveform

Figure b. Narrow Band Frequency Spectra

Figure c. Accumulation of Sound Energy

Figure d. Sound Pressure and Sound Energy Levels

<table>
<thead>
<tr>
<th>Signal Analysis Sound Pressure / Energy Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>37-feet - 11:15:16 Peak RMS90%* SEL</td>
</tr>
<tr>
<td>4-feet</td>
</tr>
<tr>
<td>188</td>
</tr>
<tr>
<td>175</td>
</tr>
<tr>
<td>162</td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%)}
Unweighted Peak Sound Waveform Analysis Sheets for each Pile

Pile 3 w BC

**Figure a. Waveform**

**Figure b. Narrow Band Frequency Spectra**

**Figure c. Accumulation of Sound Energy**

**Figure d. Sound Pressure and Sound Energy Levels**

<table>
<thead>
<tr>
<th>Signal Analysis Sound Pressure / Energy Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>37-feet - 11:01:07 Peak RMS&lt;sup&gt;90%*&lt;/sup&gt; SEL</td>
</tr>
<tr>
<td>1.5-feet 194 181 165</td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%)*
Unweighted Peak Sound Waveform Analysis Sheets for each Pile

### Pile 4 w/o BC

**Figure a. Waveform**

![Waveform Graph]

**Figure b. Narrow Band Frequency Spectra**

![Frequency Spectra Graph]

**Figure c. Accumulation of Sound Energy**

![Energy Accumulation Graph]

**Figure d. Sound Pressure and Sound Energy Levels**

<table>
<thead>
<tr>
<th>Signal Analysis Sound Pressure / Energy Levels</th>
<th>37-feet - 11:52:15</th>
<th>Peak</th>
<th>RMS&lt;sub&gt;90%*&lt;/sub&gt;</th>
<th>SEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5-feet</td>
<td>202</td>
<td>191</td>
<td>175</td>
<td></td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%)*
Unweighted Peak Sound Waveform Analysis Sheets for each Pile

**Pile 5 w/ BC**

**Figure a. Waveform**

**Figure b. Narrow Band Frequency Spectra**

**Figure c. Accumulation of Sound Energy**

**Figure d. Sound Pressure and Sound Energy Levels**

<table>
<thead>
<tr>
<th>Signal Analysis Sound Pressure / Energy Levels</th>
<th>32.8-feet - 15:34:04</th>
<th>Peak</th>
<th>RMSs0%*</th>
<th>SEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-feet</td>
<td>188</td>
<td>174</td>
<td>162</td>
<td></td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%).*
Unweighted Peak Sound Waveform Analysis Sheets for each Pile

### Pile 6 w BC

#### Figure a. Waveform

#### Figure b. Narrow Band Frequency Spectra

#### Figure c. Accumulation of Sound Energy

#### Figure d. Sound Pressure and Sound Energy Levels

<table>
<thead>
<tr>
<th>Signal Analysis Sound Pressure / Energy Levels</th>
<th>33-feet - 16:03:35</th>
<th>Peak</th>
<th>RMS&lt;sub&gt;90&lt;/sub&gt;%&lt;sup&gt;*&lt;/sup&gt;</th>
<th>SEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5-feet</td>
<td>187</td>
<td>173</td>
<td>157</td>
<td></td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%)*
Unweighted Peak Sound Waveform Analysis Sheets for each Pile

**Pile 7 w/o BC**

**Figure a. Waveform**

![Waveform Graph]

**Figure b. Narrow Band Frequency Spectra**

![Frequency Spectra Graph]

**Figure c. Accumulation of Sound Energy**

![Energy Accumulation Graph]

**Figure d. Sound Pressure and Sound Energy Levels**

<table>
<thead>
<tr>
<th>Signal Analysis Sound Pressure / Energy Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>32.8-feet - 16:18:52</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>1.5-feet</td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%)
Unweighted Peak Sound Waveform Analysis Sheets for each Pile

### Pile 8 w/o BC

#### Figure a. Waveform

#### Figure b. Narrow Band Frequency Spectra

#### Figure c. Accumulation of Sound Energy

#### Figure d. Sound Pressure and Sound Energy Levels

<table>
<thead>
<tr>
<th>32.8-feet</th>
<th>Peak</th>
<th>RMS90%*</th>
<th>SEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:35:43</td>
<td>198</td>
<td>184</td>
<td>166</td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%)