Chena River Lakes Flood Control Project/Moose Creek Dam, North Pole, Alaska - USACE Design, Cost, And Constructability Considerations For CSM Barrier Walls In The Far North

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Coleman Chalup, P.E.
Lead Engineer
USACE Alaska District

Derek Maxey P.E.
Cost Engineer
USACE DSMMCX

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PROJECT BACKGROUND
Authorization, Project Purposes and Current Uses

- Authority: Flood Control Act of August 13, 1968, Public Law 90-483, Section 203, 90th Congress
  - Maximum flow objective of 12,000 cubic feet per second in downtown Fairbanks

- Project Purpose & Warranted
- Continued Federal Interest are the same:
  - Flood Control
  - Recreation
  - Environmental Stewardship

- Total Damages Prevented since 1981
  - $397.6 Million
Project Location & History

- Chena River Floods Fairbanks: 1967
- Congressional Authorization: 1968
- Construction Begins: 1973
- Project Operational: 1979
- Test Fill Operation: 1981
- Operating History: 37 years
- Dam operations to date: 25
- Last Operation: 2016
- Largest operational flood: 1992
Floodway and Dam
Recreational Uses/Benefits

- **Over 165,000 visitors annually**

- **16,000 acres of public land** for dispersed low impact recreational activities and a variety of indigenous wildlife, migratory birds, and waterfowl

- **~25 special use/event permits issued annually** including retriever dog trials, civil war reenactments, triathlons, cross country meets, trail riding, scouting events, and youth conservation camps.

- Almost annually the Project is proud to host a **paralyzed veteran moose hunt** for hunters selected from across the country.

- The **Project partners** with the Fairbanks North Star Borough, Alaska Department of Fish and Game, Bureau of Land Management/Alaska Fire Service, and the U.S Fish and Wildlife on a number of ongoing cooperative projects.
PROJECT FEATURES
Geologic Overview

- Foundation is gravelly sand/sandy gravel that likely exceeds 1000 ft thickness with a surficial blanket of silt.
- The transition from sand and gravel to silt includes layers of sand and silty sand, including fine sand with Cu<3.
- The sand and gravel includes gap graded and open work gravel lenses.
- Sloughs from meanders and braids, as well as permafrost, complicate the near surface geology.
Sand And Gravel

- S&G is very heterogeneous across site
- The foundation materials are “sandy gravel to gravelly sand”
- About 1/4 of S&G samples are gap graded
- Open work gravel is present but rare
- Zones of erodible fine sand are present (Cu ≤ 7)
Permafrost

• Permafrost is soil or bedrock that has been continuously frozen ($0^\circ$C or less) for at least two years, with or without the presence of ice or water.

• An area of known discontinuous permafrost is present under the central portion of the dam.

• Permafrost excavation similar to rock excavation
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Dam Features - General Layout

- Weir
- Embankment and Stability Berm
- Low Point Drain and South Seepage Collector Channel
- Sill
- Floodway
- Control Works
- Low Point Drain
- Relief Wells
Relief Wells

- Six relief wells were installed during original construction
- Current count is 158 Relief Wells
- Relief Wells are a continuing O&M issue
1. Moose Creek is a sand and gravel dam.
2. A high-capacity seepage collection and drainage channel system with a drainage ditch and lateral conduits to convey collected seepage through the stability berm.
3. A downstream stability berm to protect the embankment against heave.
4. A downstream toe drain, consisting of free-draining material.
5. Test relief wells, and greatly increasing the number of relief wells after 1981 test fill.
6. Extensive upstream impervious blanket (enlarged after the 1981 test fill).
# Typical Centerline Boring

<table>
<thead>
<tr>
<th>Depth to Groundwater</th>
<th>Depth to Centerline</th>
<th>Depth to Cut-off Wall</th>
<th>Water Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I Fill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi-Permous Fill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type II Fill</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Depth of Cutoff Wall at 465.5 feet NAVD88**
DAM SAFETY CONCERNS
Reaches
Dam Safety Issues: Actionable Potential Failure Modes

- Backward Erosion and Piping with Vertical Exit (BEPv)
- Backward Erosion and Piping with Horizontal Exit (BEPh)
- Contact Erosion

**Contributing Factors**
- Flaw is a continuous fine sand layer
- Roof is a continuous silt layer
- Unfiltered exit is a pre-existing defect or is created during the flood event by blowout of the downstream silt blanket
- Average horizontal gradients are sufficient to initiate BEP
- No upstream flow limiter exists
2014 – 2016 Floods - Sand Boils

Majority of boils found from Station 285+00 to 294+00 (Reach 4) and Station 306+75 to 307+75 (Reach 5)

<table>
<thead>
<tr>
<th>Boil classification</th>
<th>Silt Cone Size Range (Feet)</th>
<th>Typical Throat Size (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small/Pin</td>
<td>0.0 to 0.5</td>
<td>0.25 to 1.0</td>
</tr>
<tr>
<td>Medium</td>
<td>0.5 to 2.0</td>
<td>1.0 to 2.0</td>
</tr>
<tr>
<td>Large</td>
<td>2.0 to 4.0</td>
<td>1.0 to 9.0</td>
</tr>
<tr>
<td>Extra Large</td>
<td>4.0 to 10.0 or larger</td>
<td>4.0 to 12.0</td>
</tr>
</tbody>
</table>

Height of boils ranged from an inch to one foot and typically equalized with tail water level.
PLAN FORMULATION PROCESS
- Found a critical flaw in assumptions made to create a single stage filter material that would work with materials ranging from silt to openwork gravels.
• Mix in Place Cutoff Wall
• New phase took what was learned in Phase I and focused on development of a cutoff wall to address continuous flaw in foundation.
Tentatively Selected Plan
Tentatively Selected Plan

Plan F9:

► Centerline Cutoff Wall: Reaches 4, 5, 6, 8, 9
► Addresses Flaw (biggest risk driver). The Cutoff Wall will interrupt and discontinue the flaw.
► Minimal environmental impacts.
► Less uncertainty with untested embankment performance.
► Meets Planning Objectives (TRG) with High Level of certainty.
► Reduces risk around 1 order of magnitude below Tolerable Risk Guidelines.
Centerline Cutoff Wall (F9)

- Centerline Cutoff Wall in Reaches 4, 5, 6, 8 and 9.
- Extending crest at Low Point Drain.
- Cutoff Wall will not impact expected permafrost under dam.
- Working Platform at crest of dam.
  - Deform Crest to no more than PMF elevation of 525.4 feet NAVD88.
- New instrumentation
  - Piezometers
  - Weir/Flumes

**Expected Permafrost**

Maximum Deformation of Crest (525.4 NAVD88)
Control Structure and Low Point Drain – Tie-ins

- Cutoff wall will require tie-in with Control Structure located within Reach 7 and Low Point Drain in Reach 5
  - Sheet Pile
  - CSM Wall
Geophysical Investigation

- Ground Penetrating Radar (GPR)
- Capacitively Coupled Resistivity (CCR)
- Electrical Resistivity Tomography (ERT)
- 3 Longitudinal Lines
  - Upstream Dam Toe
  - Centerline
  - Downstream Stability Berm Toe
- 9 Transects

<table>
<thead>
<tr>
<th>9 Transects of Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>250+00 (Reach 3-4)</td>
</tr>
<tr>
<td>290+00 (Boils/Permafrost)</td>
</tr>
<tr>
<td>320+00 (Reach 4-5)</td>
</tr>
<tr>
<td>338+00 (3-4 feet of silty fine sand)</td>
</tr>
<tr>
<td>380+00 (Reach 5-6)</td>
</tr>
<tr>
<td>399+00 (Old Chena River Slough)</td>
</tr>
<tr>
<td>411+50 (Old Chena River Slough)</td>
</tr>
<tr>
<td>440+00 (Reach 8-9)</td>
</tr>
<tr>
<td>480+00 (Near North Abutment)</td>
</tr>
</tbody>
</table>
Geophysical Results
Geophysical Results

GPR

CCR

ERT

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Geotechnical Investigation

Sonic Drilling

- Savannah District sonic rig with Alaska District Engineers.
- Ground truth for geophysics.
- Obtain material for mix design.
- Installation of 3 piezometers.
- Look for aquitard around 90-110 feet below ground surface.
- Test borings are on ~1200 foot intervals. Subject to be adjusted based on findings of geophysical investigation.

Drilling Methods

- Sonic drilling with minimal water through embankment and foundation.
- Continuous sampling to depth of interest.

<table>
<thead>
<tr>
<th>Boring Location</th>
<th>Depth (ft)</th>
<th>Number of Borings</th>
<th>Total Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centerline Dam</td>
<td>90</td>
<td>24</td>
<td>2,160</td>
</tr>
<tr>
<td>Centerline Dam</td>
<td>50</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td>Centerline Dam</td>
<td>130</td>
<td>1</td>
<td>130</td>
</tr>
<tr>
<td>Centerline Dam</td>
<td>100</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Upstream Dam</td>
<td>60</td>
<td>2</td>
<td>120</td>
</tr>
<tr>
<td>Downstream Dam</td>
<td>130</td>
<td>14</td>
<td>1,820</td>
</tr>
<tr>
<td>Downstream Dam</td>
<td>60</td>
<td>8</td>
<td>480</td>
</tr>
<tr>
<td></td>
<td>Total:</td>
<td>51</td>
<td>4,860 feet</td>
</tr>
</tbody>
</table>

Additional Borings

<table>
<thead>
<tr>
<th>Boring Location</th>
<th>Depth (ft)</th>
<th>Number of Borings</th>
<th>Total Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downstream Dam</td>
<td>130</td>
<td>2</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>New Total:</td>
<td>72</td>
<td>5120 feet</td>
</tr>
</tbody>
</table>
Unique Site and Climate Conditions
Remote Location

- Fairbanks, AK is modern, modest sized city
  - Big-box stores, chain hotels/restaurants, etc.

- Serves as the northern-most major outpost for equipment, materials, and supplies to oil/gas and mining industries
  - Several large equipment dealers including Caterpillar, etc.

- Shipments from out of state (lower 48, etc.) routed, either:
  - MARINE FERRY -> Alaska State Ferry from Seattle to Alaska -> Highway or Alaska Rail to Fairbanks
  - TRUCK -> ALCAN Highway (difficult, time-intensive)
  - RAIL -> Alaska Rail for in-state transport
Limited Commercial Aggregate Sources

- Generally, transportation of aggregate materials throughout the state is costly and seasonally restricted
- Most large projects are sourced from on-site borrow pits
- Even commercially available aggregates are generally quarried locally, and produced to order
Varied Duration of Daylight Hours

Source: https://www.timeanddate.com/sun/usa/fairbanks
Varied Duration of Daylight Hours

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### Fairbanks, Alaska

#### Monthly Averages & Records - °F | °C

<table>
<thead>
<tr>
<th>Date</th>
<th>Average Low</th>
<th>Average High</th>
<th>Record Low</th>
<th>Record High</th>
<th>Average Precipitation</th>
<th>Average Snow</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>-13°</td>
<td>2°</td>
<td>-60° (1969)</td>
<td>47° (1981)</td>
<td>0.61°</td>
<td>7.9°</td>
</tr>
<tr>
<td>February</td>
<td>-10°</td>
<td>10°</td>
<td>-52° (1999)</td>
<td>49° (1980)</td>
<td>0.44°</td>
<td>7.3°</td>
</tr>
<tr>
<td>March</td>
<td>1°</td>
<td>26°</td>
<td>-41° (1971)</td>
<td>57° (1998)</td>
<td>0.34°</td>
<td>6.4°</td>
</tr>
<tr>
<td>April</td>
<td>19°</td>
<td>44°</td>
<td>-24° (1986)</td>
<td>71° (2005)</td>
<td>0.2°</td>
<td>3.5°</td>
</tr>
<tr>
<td>May</td>
<td>35°</td>
<td>61°</td>
<td>3° (1964)</td>
<td>88° (1960)</td>
<td>0.6°</td>
<td>0.4°</td>
</tr>
<tr>
<td>July</td>
<td>50°</td>
<td>73°</td>
<td>32° (1957)</td>
<td>92° (1993)</td>
<td>1.96°</td>
<td>0°</td>
</tr>
<tr>
<td>August</td>
<td>45°</td>
<td>67°</td>
<td>24° (1987)</td>
<td>93° (1994)</td>
<td>1.95°</td>
<td>0°</td>
</tr>
<tr>
<td>September</td>
<td>34°</td>
<td>55°</td>
<td>5° (1992)</td>
<td>82° (1957)</td>
<td>1.32°</td>
<td>0.9°</td>
</tr>
<tr>
<td>October</td>
<td>16°</td>
<td>32°</td>
<td>-27° (1975)</td>
<td>71° (2003)</td>
<td>1.01°</td>
<td>11.5°</td>
</tr>
<tr>
<td>November</td>
<td>-2°</td>
<td>12°</td>
<td>-45° (1990)</td>
<td>49° (1976)</td>
<td>0.78°</td>
<td>15.2°</td>
</tr>
<tr>
<td>December</td>
<td>-9°</td>
<td>5°</td>
<td>-66° (1961)</td>
<td>44° (2001)</td>
<td>0.82°</td>
<td>13°</td>
</tr>
</tbody>
</table>

Source: [http://www.intellicast.com](http://www.intellicast.com)
Heave/Frost Jacking

- Relief wells/other feature extending through the frost zone experience significant loading due seasonal frost heave/jacking.
CSM Barrier Wall Construction Methods
Barrier Wall Technologies

- Slurry Trench
  - Clamshell
  - Continuous Chain Trenching
  - Hydraulic Excavator
  - Jet-Grouting
- Cutter Soil Mixing
  - Continuous Chain Trenching
  - Hydromill
  - Secant Pile
  - Multiple auger
- Many more…
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- Many more…
Design & Budgeting Considerations

- Several state-of-the-art technologies exist for CSM wall construction
  - Most are proprietary, custom-built machines unique to specific construction firms
  - Some technologies are more competitive than others depending on the wall design and site arrangement.

- Equipment access & hauling materials often drive production
  - Work platform (25'-50' wide) required to accommodate construction traffic around CSM machines
  - Size/arrangement of work platform varies by specific technology employed
  - Accommodations for work platform can be significant $
    - Degrade dam crest
    - Rock fill
    - Paved work surfaces

- Therefore, it is difficult to budget to specific technology AND foster competitive bid market

Herbert Hover Dike - Florida
Far North/Remote Location Considerations

- Availability of machines within industry to mobilize
- Mobilization related costs for specialty equipment
- Winterization/standby related costs for specialty equipment
- Availability within local/regional labor market
- Availability of local/regional construction equipment
  - Haul trucks & teamsters
- Seasonal on-highway load restrictions
- Commercial availability of large quantities of anything… especially aggregates
Cold Weather Considerations for CSM

- Typical civil/earthwork construction season is 7 of 12 months, due to cold temps, snow, and reduced daylight, and DOT highway load restrictions
- CSM work in far north has been successfully demonstrated by industry, including work through winter months.
- Freezing weather reduces production, machines do better in 24/7 operation
- Maintenance of haul routes
For More…

- **USACE Alaska District – Moose Creek Project Website**

- **Chena Google Virtual Project Tour**
  [https://www.youtube.com/watch?v=IUwReK5FEfE](https://www.youtube.com/watch?v=IUwReK5FEfE)

- **USACE “AlaskaCorps” YouTube® Channel**
  [https://www.youtube.com/user/AlaskaCorps](https://www.youtube.com/user/AlaskaCorps)
Chena River Lakes Flood Control Project/Moose Creek Dam, North Pole, Alaska - USACE Design, Cost, And Constructability Considerations For CSM Barrier Walls In The Far North

Questions, Comment, or Discussion?