Dams in Cold Climates: Design Considerations and Challenges of Construction

Doug Johnson, P.E., FERC Division of Dam Safety and Inspections
Regional Engineer, Portland OR
FERC-regulated Dams in Alaska

Susitna-Watana
## Portland Region Dams > 5000 feet Elevation.

<table>
<thead>
<tr>
<th>Dam Name</th>
<th>Crest Elevation</th>
<th>State</th>
<th>Hazard Class</th>
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<tbody>
<tr>
<td>Mystic Dike</td>
<td>7675 MT</td>
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<td>Mystic Lake</td>
<td>7674 MT</td>
<td></td>
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<tr>
<td>Viva Naughton</td>
<td>7249 WY</td>
<td></td>
<td>H</td>
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<td>Hebgen Dam</td>
<td>6546 MT</td>
<td></td>
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<td>Georgetown Dam</td>
<td>6443 MT</td>
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<td>Soda</td>
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<tr>
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<td>Grace Main</td>
<td>5559 ID</td>
<td></td>
<td>S</td>
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<tr>
<td>Ashton</td>
<td>5147 ID</td>
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</table>
## Portland Region Dams at Highest Elevations In Alaska

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<th>Hazard Class</th>
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</thead>
<tbody>
<tr>
<td>Collection Pond (Goat Lake)</td>
<td>2885</td>
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<tr>
<td>Middle Fork Diversion (Bradley Lk.)</td>
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<td>Shotgun Creek Div</td>
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<td>Rolling Rock Creek Div</td>
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<td>Stetson Creek Diversion</td>
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<td>Terror Lake</td>
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<td>Allison Creek</td>
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<td>Crystal Lake</td>
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<td>Nuka River Div</td>
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<td>Cooper Lake</td>
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</table>
Allison Creek Dam

If we keep digging we may find where we stopped working last summer!
Challenges of Constructing FERC Projects In Cold Regions
Salmon Creek Dam
View looking up Valley at Dam

Height = 170 ft.
Crest Length = 650 ft.
Storage ≈ 12,000 ac-ft
Downstream Face of Dam

First Constant Angle Arch Dam in US. Completed 1914
Upstream Face showing severe freeze-thaw damage
Close-up view of eroded area of upstream face
Rubble at base of dam is remnant of shotcrete facing applied in 1960’s.
Cold Climate Design Considerations

- Dam built in 1914 – no air entrainment, poor consolidation, segregation of concrete
- Severe Freeze-thaw environment
- Tried to shotcrete faces of dam in 60s – most of that has fallen off.
- Dam has lost over 2 feet in thickness.
- As result dam is under reservoir restriction due to seismic instability – 32 foot drawdown
- However, even without the drawdown the dam still retains sufficient thickness to resist static loads
- Cost to rehab is prohibitive due to remote access – AEL&P has decided to live with restriction
Lake Dorothy Hydroelectric Project

- Alaska Electric Light and Power
- Juneau, Alaska
- 2006 - 2010
Lake Dorothy looking north toward outlet
Final Round - 12’ dia. By 12’ Thick 8/19/2008

Water then fills tunnel up to plug

Valve on pipe side of plug is opened or closed to control water out of Lake
Actual Tunneling Begins July 2007
Downstream face of tunnel plug
Lake Tap

- Lake tap was initiated from Lake Dorothy shoreline to allow observation of air pocket and energy from the blast emerge from below the water line.
- The final lake tap blast took place on August 19, 2008.
LAKE DOROTHY IS TAPPED!
Bifurcation of 60-inch penstock
Completed Road
Construction of concrete face panels
6.4 cfs

10-2-2009 at 1008.6'
The Lake Dorothy Project went into operation on Aug. 31, 2009.
Challenges Constructing the Lake Dorothy Project
Only Access to Site by Air
Seasonal Working Conditions
Initial landing areas were limited
All Tunneling Equipment Airlifted in Pieces
Fog and rain can move in very quickly.
Weather Impacts

- Good weather where crew could easily access tunnel - Rates of 40 feet per day
- Typical advance rates averaged 25 feet per day
- Changing weather conditions prevented mining crews from achieving steady advancement rates.
- Fog and wind could quickly show up and force an early exit from the portal
- 2007 – 35 weather related delay days
- 2008 – 33 weather related delay days
Main Project Features

• 16-foot-high, 95-foot-wide concrete gravity diversion dam with 50-foot-wide spillway
• 42-inch-diameter, 7,200-foot-long steel penstock
• 700-foot-long, 16-foot-diameter access tunnel through which a segment of the penstock would be routed
• 65 foot by 65 foot powerhouse with two turbine/generating units with a combined capacity of 6.5-MW
Powerhouse foundation construction with lower tunnel portal in background
Upper Portal August 2014 – Tunnel near completion
Pioneering Road from Upper Portal to Dam Site
August 2014
Diversion Dam Site July 2015
Twin 48-inch-diameter CMP diversion conduits carry Allison Creek through right abutment
View of Penstock Below Lower Tunnel Portal and Powerhouse Below July 2015
Concrete being placed for diversion dam intake structure. August 2015
Allison Creek diversion dam at spring break-up 2016 getting ready for final construction season to start.
Allison Creek Powerhouse at spring break-up 2016
Allison Creek Diversion Dam nearing completion
June 2016
Mass excavation of steep slope in reach 4 continues before penstock installation (dashed line) can resume.
Upstream face of completed diversion dam with reservoir full to the top of the spillway. August 2016
Downstream View of Completed Diversion Dam
Completed Powerhouse
Cold Climate Design Considerations

- Rugged terrain, no existing roads – the use of tunnels is common in Alaska. Construction can continue through winter.
- The Allison tunnel was designed to serve as both the penstock route and construction access road to site.
- Very Limited window for construction – June to September. Took 3 years to complete project.
- Frigid temps and deep snow necessitated burying penstock
- Project can only generate 6 months out of the year due to deep snow and frozen conditions at diversion dam.
Hebgen Lake Dam
Hebgen Lake Dam

Dam Height = 88ft
Crest Length = 721 ft
Normal Storage 386,000 af
Hebgen Lake Dam

- Underwent 2 major rehab projects in the 2008-2016 period.
- Failure of Outlet Tower Stoplogs in Aug 2008 + seismic inadequacy – necessitated rehab of tower 2008-14
- Spillway removal and replacement 2015-16
Outlet Tower Rehab

- Had to build cellular cofferdam first to dewater front of tower.
- Work could not proceed in winter, due to ice, snow, and reservoir lowering which required use of outlet instead of spillway.
- Cofferdam provided with a spillway gate to discharge wintertime flows.
- Scope of Project was to first stabilize tower, then improve seismic stability, replace the intake gates, and install a guard gate.
Winter comes early here
December 8, 2010
Work was able to continue despite cold and snow.
View inside Outlet Tower
Extreme danger posed by ice overhead from leaking stoplogs.
Rebar and concrete damaged from winter flows.
June 30 2013
Eventually, the structure was competed, in 2015!

Which leads us to the next phase.....
Spillway Removal and Replacement

- Once Intake was completed and functional, spillway removal could start
- Contractor reused sheetpiling from outlet cellular cofferdam to construct new cofferdam in front of spillway.
- Cofferdam installed in December 2015 so that it would be in place come spring, when reservoir was filled.
- New Outlet Tower acted as only spillway during construction.
Being December, it wasn’t the most hospitable condition for construction!
Sheet Piling being installed
View of ongoing removal of cofferdam from intake structure.
Not surprisingly, come the following spring, there was a lot of seepage through the cofferdam! 550 gpm.
Subsequently, a second cofferdam and sheetpile wall was constructed along with a sump to improve seepage control at the site.
View of cofferdam with spillway fully removed
Once again, construction extended into December
Placing embankment fill around core wall
Blankets were placed on fill surface at night to keep snow off and prevent freezing.
Snow was cleared off and blankets removed in morning prior to fill placement.
Finished Spillway and closure embankment in 2017
Finished Spillway Chute
Takeaway Points

- Short construction seasons mean that work must be done in multi-year stages. Detailed scheduling and planning ahead are critical.

- Severe weather conditions can damage recently completed work. Protecting partially completed work from damage can prevent delays in construction schedule.

- Tunneling work can be done year round. This makes building a combined power tunnel (or penstock) and construction access road attractive.
Takeaway Points

- Portable structures such as tents and canopies can help extend the construction seasons but may require dis/re-assembly for winter snow loading.

- In Alaska, lack of access is as much a problem as the cold climate. Equipment and supplies must be barged or helicoptered in, making construction costs much higher and advanced planning for deliveries critical.
QUESTIONS?