Ruttinger & Sons Engineering

Designed by:
Taylor Kasperick
Jacob Wilson
Loren Ruttinger

Presented by: Loren Ruttinger

DALE CREEK STORAGE AUGMENTATION DAM
OUTLINE

- Purpose and Site Description
- Hydrology
- Geotechnical Information
- Hydraulics
- Construction
- Feasibility
Purpose and Site Description

- City of Cheyenne desires a water storage augmentation dam
- Purpose will be to contain water for long-term storage for City of Cheyenne West
- Existing pipeline from the Snowy Range runs north of the proposed dam location
- This pipeline will be the primary water supply for the dam
PURPOSE AND SITE DESCRIPTION

- Proposed Dam Location
PURPOSE AND SITE DESCRIPTION

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PURPOSE AND SITE DESCRIPTION

- Dam site Number One was chosen as the final location based on a rough estimate of capacity compared to dam size.
- This site provided the most storage with the smallest size of dam.
- Crest elevation was finalized at 8000 feet.
- Approximate maximum storage was determined to be 10,073 acre-feet with a surface area of 0.433 square miles.
HYDROLOGY

- Definition of watershed
- Creation of the Probable Maximum Flood hydrograph (PMF) based on the Probable Maximum Precipitation (PMP)
- Creation of frequency hydrographs
- Final decision of design hydrographs
HYDROLOGY

Definition of Watershed
HYDROLOGY

Definition of Watershed

- Area: 16.5 square miles
- Length of Watershed: 9.5 miles
- Length to Centroid: 4.5 miles
- Average Slope: 75 feet per mile
<table>
<thead>
<tr>
<th></th>
<th>24-HR PMP</th>
<th>24-HR 100 Year</th>
<th>6-HR 100 Year</th>
<th>6-HR 25 Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation (in)</td>
<td>26.46</td>
<td>3.23</td>
<td>2.55</td>
<td>2.06</td>
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<tr>
<td>Peak Flow (cfs)</td>
<td>50,610</td>
<td>6070</td>
<td>4760</td>
<td>3820</td>
</tr>
<tr>
<td>Volume (acre-ft)</td>
<td>22,619</td>
<td>2550</td>
<td>1960</td>
<td>1530</td>
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<tr>
<td>Intensity (in/hr)</td>
<td>36.3</td>
<td>4.4</td>
<td>7.5</td>
<td>6.0</td>
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<tr>
<td>Total Duration (hr)</td>
<td>43.9</td>
<td>43.9</td>
<td>11.0</td>
<td>11.0</td>
</tr>
<tr>
<td>Duration to 5% of Peak Flow (hr)</td>
<td>13.9</td>
<td>13.9</td>
<td>3.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>
24-HR Unit Hydrograph

Storm Flow, Q, (cfs)

Time (hrs)
HYDROLOGY

24-HR Probable Maximum Flood

Storm Flow, Q, (cfs)

Time (hrs)
HYDROLOGY

6-HR 100 Year Storm

Storm Flow, Qr (cts)

Time (hrs)
Design Hydrographs

Design storms and hydrographs are based upon the hazard level of the dam.

Wyoming has three dam classifications:

- Low Hazard: No significant economic loss
- Significant Hazard: Significant economic loss
- High Hazard: In case of failure, would likely cause loss of life and significant economic loss
**HYDROLOGY**

- **Design Hydrographs**
  - This dam has one farmstead 1.4 miles downstream, and another farmstead and the U.P. Railroad 2.5 miles downstream
  - Therefore, this is a “High Hazard” dam
  - The design hydrographs are the 24- HR PMF for the emergency spillway and the 24-HR 100 Year for the primary spillway
The measured base flow of Dale Creek is unknown.

USGS WaterWatch was visited to determine a value to represent Dale Creek.

Since Dale Creek is not monitored by USGS, a similar stream with a similar watershed was used for comparison.

Sand Creek (USGS 06659580) at the Wyoming/Colorado State Line:
- Mean Flow: 6.7 cfs
- Watershed Area: 29 square miles

A simple ratio was used to estimate the base flow of Dale Creek.

Dale Creek Estimated Base Flow: 4.0 cfs
All geotechnical site information was obtained from the USGS Web Soil Survey.

The surrounding area is almost strictly gravelly, sandy loam.

Bedrock is specified as being within 11 to 60 inches of the surface of the proposed dam site.

60 inches (5 feet) was assumed to be the uniform depth to bedrock for conservative construction costs calculations.
Due to a lack of clay and the vastly increased volume of a homogeneous dam, a zoned dam was chosen as the appropriate structure for this location.

Because the dam has a bedrock foundation, it is allowed the “minimum core A” with the base width of the core equal to the height (*Design of Small Dams*, 250).
A zoned dam with minimum core A is capable of upstream and downstream shell slopes of 2:1 (Design of Small Dams, 252)

To increase the factor of safety, but keep the volume of the dam minimal, the dam was designed with a 2.5:1 upstream slope and a 2:1 downstream slope

The crest was calculated to be 32 feet wide with the equation \( w = (z/5) + 10 \), where \( z \) is the height of the dam (Design of Small Dams, 253)
GEOTECHNICAL INFORMATION

- Maximum Dam Cross Section
GEOTECHNICAL INFORMATION

- Dam Profile
GEOTECHNICAL INFORMATION

- Dam Plan View
Seepage Analysis

- A model was constructed to show the flow of water through the core of the dam.
- Several methods were used to display a variety of solutions.
- Flows were calculated to range between 0.22 and 0.46 cubic feet per minute.
- These data were used to complete the slope stability and factor of safety analysis.
Slope Stability Analysis

Factor of Safety

- Long-Term
  - Specifications: 1.5
  - Dale Creek Dam: 1.601

- Maximum Pool
  - Specifications: 1.4
  - Dale Creek Dam: 1.500

- Rapid Drawdown
  - Specifications: 1.1
  - Dale Creek Dam: 1.661
GEOTECHNICAL INFORMATION

- Long-term
- Max Pool
- Rapid Drawdown

Specifications
Dale Creek
Reservoir Routing

Because this dam is classified as “High Hazard,” the emergency spillway was designed for the PMF, and the primary spillway was designed for the 24-HR 100 Year Storm.

After routing, the peak flows of both storms were reduced considerably:

- PMF: Reduced by 17,800 cfs
- 24-HR 100 Year: Reduced by 2180 cfs
Reservoir Routing: Probable Maximum Flood
HYDRAULICS

Reservoir Routing: 24-HR 100 Year Storm

Flow, $Q$, (cfs)

Time (hr)

Inflow
Outflow
Outlet Works

- Need to be large enough to drain dam at 0.5 to 1 foot per day
- This design considered draining the dam to one third its volume in 7 days in case of an emergency
- Assuming linear outflow, this resulted in a 6 foot diameter pipe with a 570 cfs capability
Primary Spillway

+ Peak flow from the outlet works was subtracted from the peak flow of the 24-HR 100 Year storm
+ The primary spillway was designed for 3 feet of water depth with a trapezoidal cross-section (for ease of construction)
+ Side slopes of the channel were set at 3:1
+ 2 feet of depth was added to avoid use of the emergency spillway as much as possible
+ Final dimensions:
  - Base Width: 125 feet
  - Top Width: 155 feet
Emergency Spillway

- Peak flow from the outlet works and peak flow from the 24-HR 100 Year Storm were subtracted from the peak flow of the PMF
- The emergency spillway was designed for 5 feet of water depth with a trapezoidal cross-section
- Side slopes of the channel were set at 3:1
- Final dimensions:
  - Base Width: 425 feet
  - Top Width: 455 feet
HYDRAULICS

- Spillway Placement
  - Depth was minimized to reduce excavation into bedrock
  - Several locations were considered
  - Ultimately, it was decided to construct one channel with both spillways rather than construct two separate channels through bedrock
  - The best location was determined to be next to the southwest abutment of the dam
Because the spillways were designed wide and deep, the Froud number was calculated to be less than 1.7

The flow from the outlet works also had a calculated Froud number of less than 1.7

Therefore, no special considerations for stilling basin design, baffled weirs, etcetera were required

The structures only required Type I stilling basins (design parameters are not specified in Design of Small Dams)
CONSTRUCTION

- **Borrow**
  - Clay Core Material: 2.55 miles away
  - Shell Material: 2.00 miles away
  - Filter Material: Purchased from gravel pit
  - Riprap: Plenty of bedrock on site to be excavated

- **Camber of 1.1 feet and crest cross-slope of 2% either direction for drainage**

- **Compaction 95% to 97%, wet of optimum**
CONSTRUCTION

- Foundation
  - Topsoil stripped down to bedrock
- Key Trench
  - Cut 5 feet into bedrock to form barrier for flow
  - Minimum base width of 91 feet equivalent to the average water height minus the depth of the trench (*Design of Small Dams*, 206)
- Grouting
  - All bedrock is to be treated with dental concrete to improve compaction against the rock, and to subsequently avoid piping
CONSTRUCTION

- Diversion of Dale Creek
  - During the initial stages of construction, Dale Creek is to be diverted to the northeast of the channel while half the base of the dam and the outlet works are installed. Once this is completed, Dale Creek is to be diverted through the outlet works while the other half of the base of the dam is constructed.
CONSTRUCTION

- Riprap is expensive to place
- Consideration of ArmorFlex® precast concrete blocks by CONTECH® Engineered Solutions
  + Decrease placement costs
  + Improve slope stability
  + Improve revegetation
- $125 per square yard
CONSTRUCTION

http://www.conteches.com/Products/Erosion-Control/Hard-Armor/ArmorFlex.aspx
Acceptable range of dam construction prices
+ $1000 to $3000 per acre-foot

Dale Creek Storage Dam estimated cost
+ $28.61 million
+ $2840.25 per acre-foot

Though on the high side, within the acceptable range of dam construction prices
QUESTIONS?
REFERENCES


