2013Google, Imagery Mar 29, 2009

February 16, 2016

Middle Chase River Dam
Dam Safety Assessment

Agenda

1. Overview of approach
2. Background and current status
   - Overview of rationale for prior remediation decisions
   - Lower Dam remediation implementation
3. Middle Dam – Overview of current condition and previous studies
4. Risk Assessment
   - Context and background
   - Approach and modelling
5. Mitigation Options
   - Approach
   - Development
6. Further work
   - Steps 1 through 5
7. Discussion

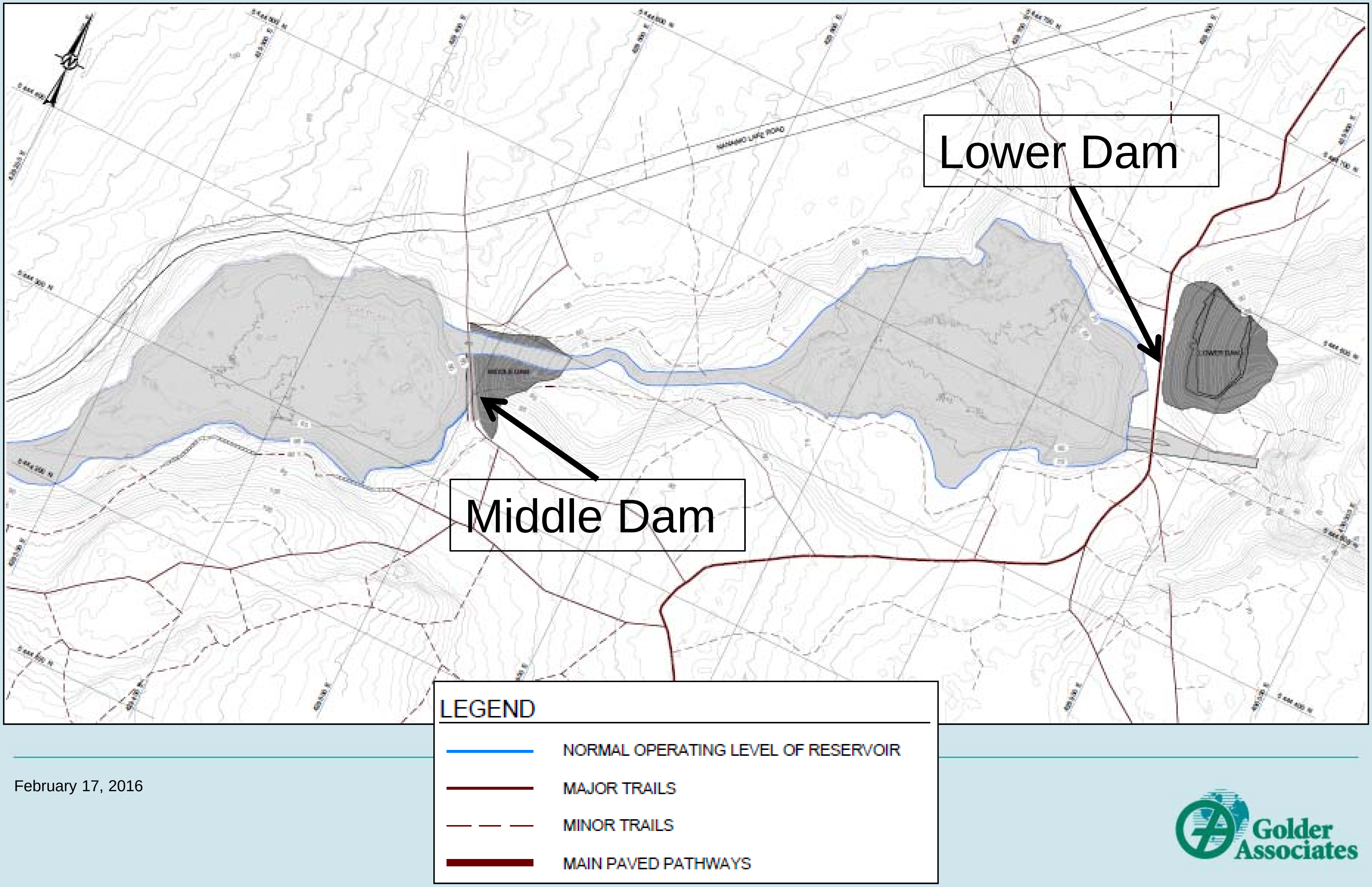
Overview of Approach

This presentation will outline the work that will be undertaken to assess the potential remediation requirements for the Middle Colliery Dam.

The work will revolve around a risk-informed approach to dam safety analysis, which offers the following benefits for this project.

- Since the risk assessment requires a more complete understanding of the relationship between hazards (and failure modes), likelihood and consequences, a more complete understanding of the critical risks for each dam is developed (in comparison to traditional forms of analysis which tend to look at these factors in isolation).
- The CDA Guidelines (2013) provide a framework for use of the risk-informed approach in dam safety analysis, as an supplement to the traditional “standards-based” approach.
- This approach has been discussed with the City and the DSS and has been generally accepted and applied for the Lower Dam.
- The DSS has provided guidance on how the risk-informed approach would be interpreted by DSS as the Regulator and in the context of the BC Dam Safety Regulation (May 8 e-mail).

Background and Current Status



Review - Dam as a System

- The two dams act as a system.
  - Middle Dam or Lower Dam could fail.
  - Middle Dam failure could lead to Lower Dam failure (cascade), which is worst case
- Focused effort on evaluating the options related to remediating the Lower Dam only - reasons for this were as follows,
  - The dams operate as a system, with the stability of the Lower Dam controlling the downstream consequences. Under any dam remediation scenario, remediation of the Lower Dam will be required (ie it is not enough to remediate the Middle Dam alone).
  - If the Lower Dam can sustain the release associated with the failure of the Middle Dam (either due to seismic, a storm event, or other initiating event) – cascading event removed.
  - The Lower dam is larger and of higher consequence.

Mitigation Conceptual Design Options

- 4 Mitigation conceptual designs and relative costs developed for the Lower Dam
- Increase spillway capacity and/ or strengthen dam to allow overtopping (reinforce downstream face of dam)
  - Option 1: Enlarge Existing Spillway
  - Option 2: Swale (Auxiliary Spillway)
    - **Option 2B – Auxiliary Labyrinth Spillway**
  - Option 3: Labyrinth Spillway
  - Option 4: Overtopping Protection for the Dam

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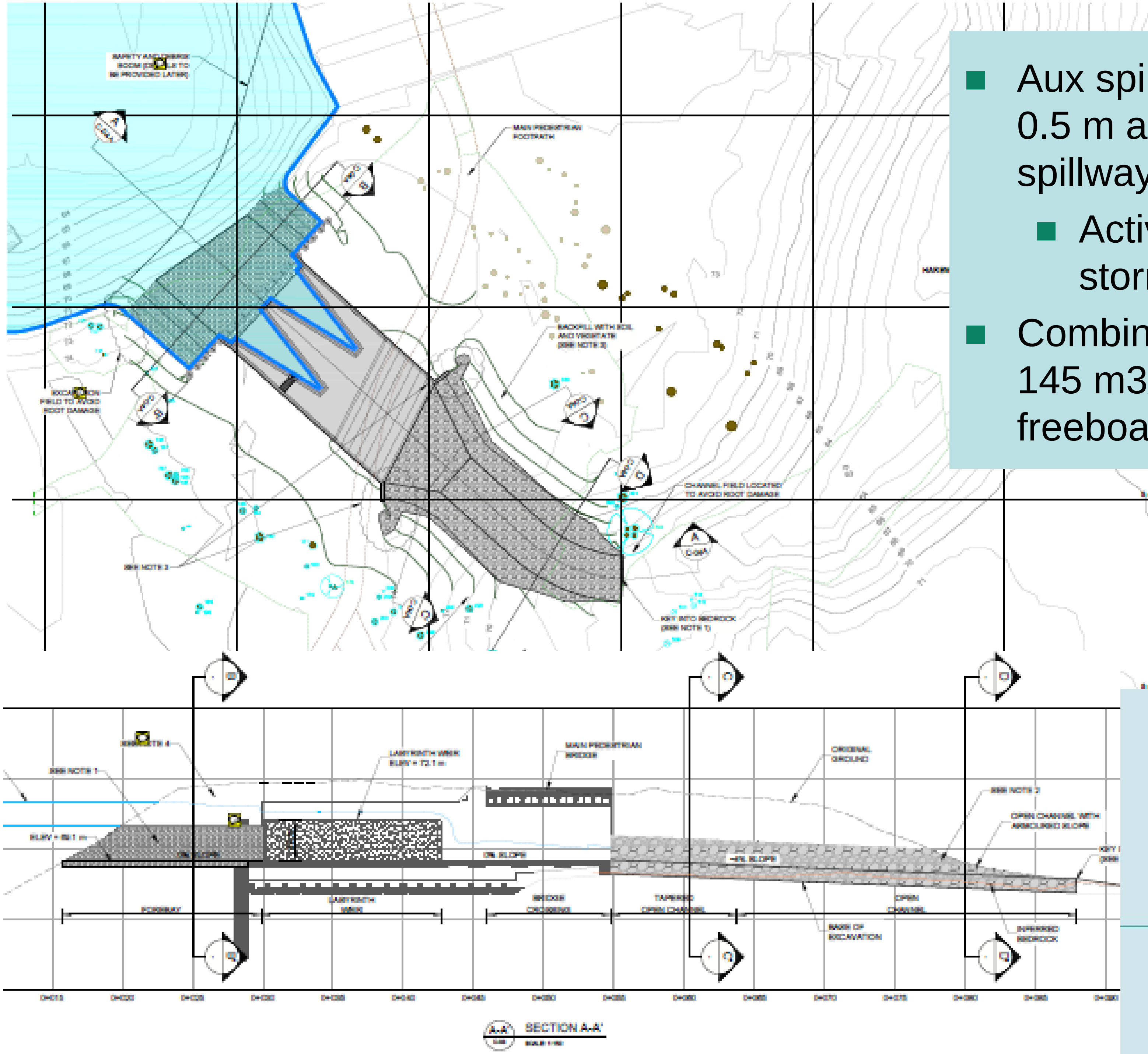
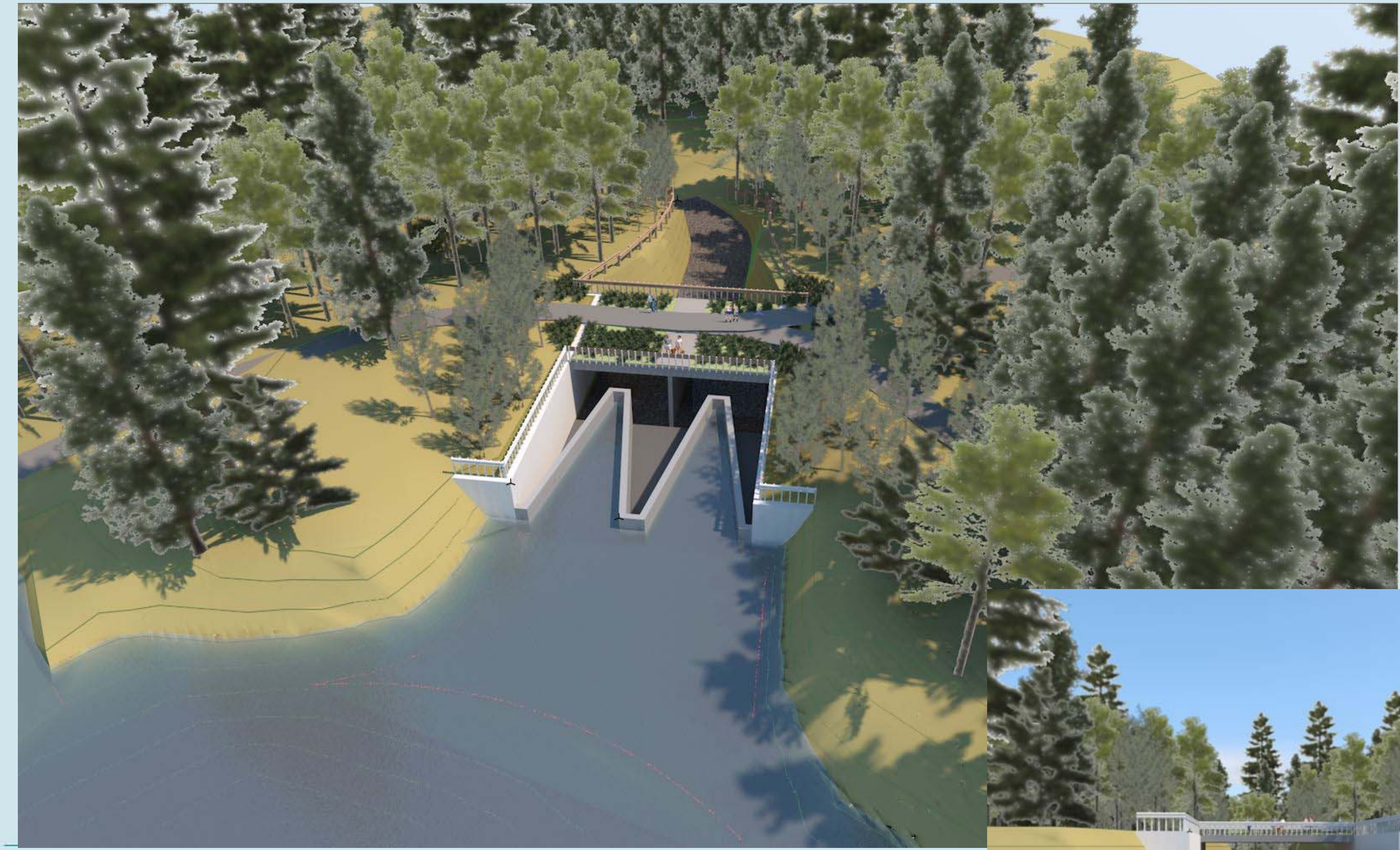


- Aux spillway – crest 0.5 m above primary spillway crest
  - Activated only in storms
- Combined capacity = 145 m3/sec (incl freeboard)

Lower Dam Remediation – Auxiliary Spillway

Lower Dam Remediation – Auxiliary Spillway



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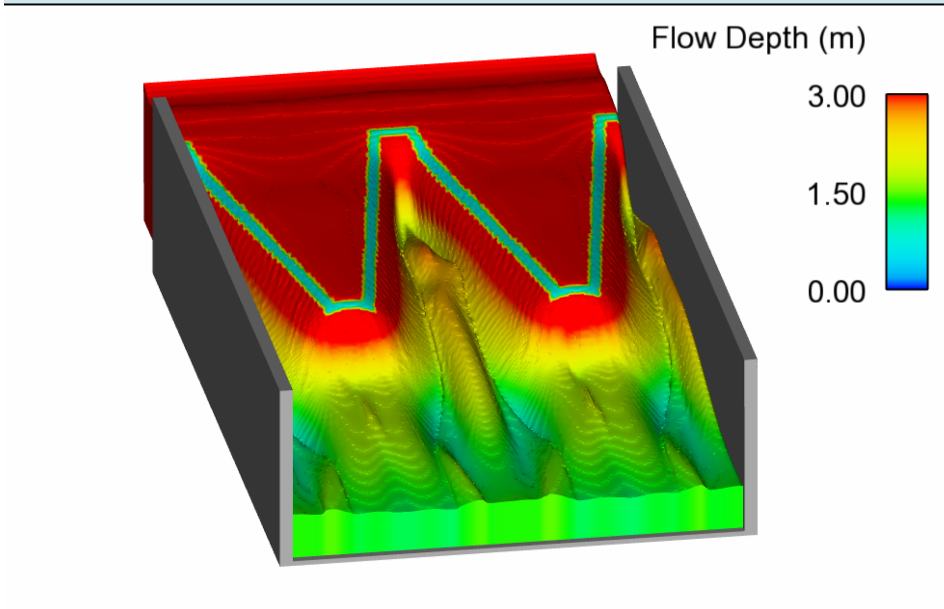
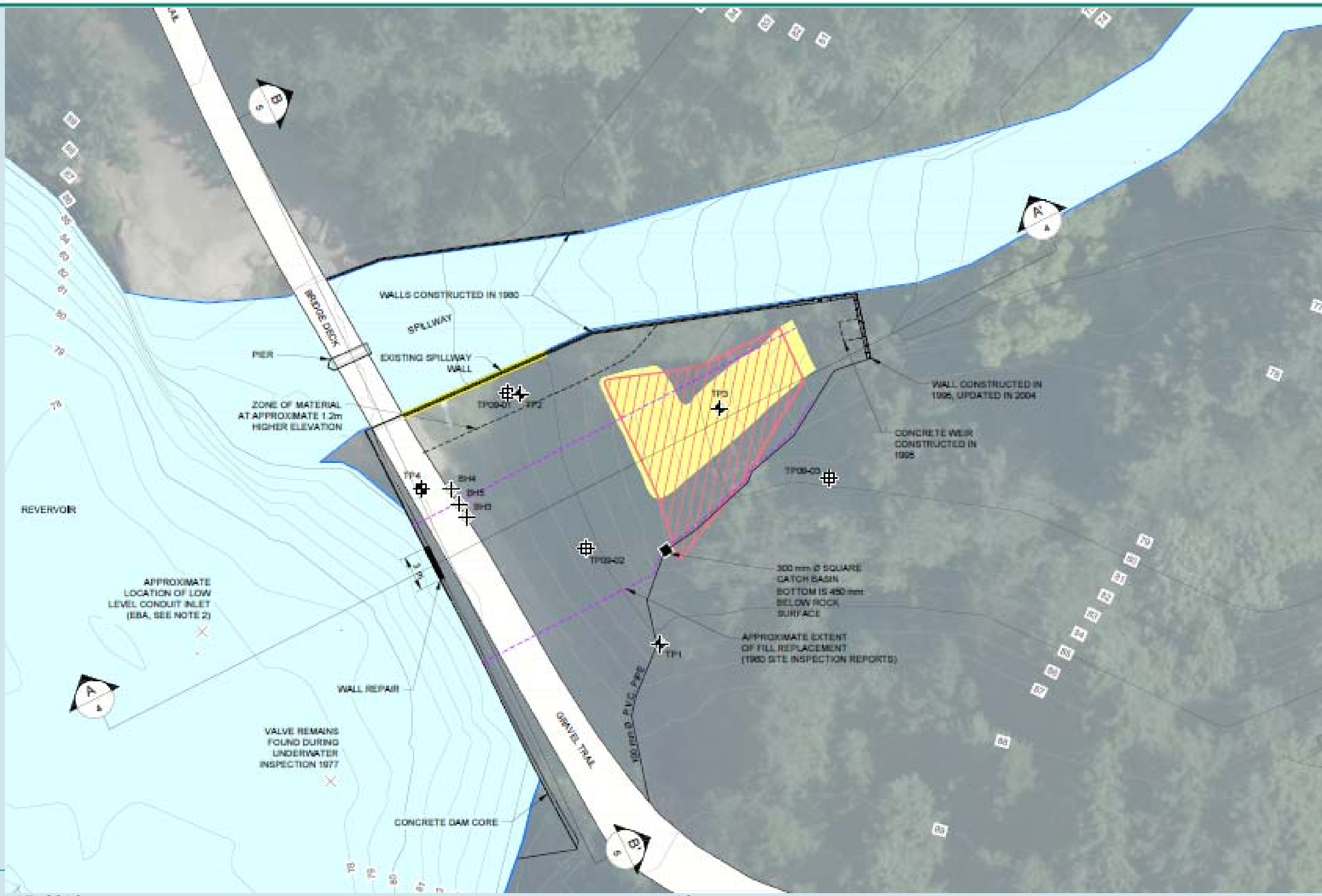

Flow Depth (m)
3.00
1.50
0.00


Date & Time: Wed Nov 18 08:28:34 PST 2015
Position: 10 N 429852 5444515
Altitude: 73m
Azimuth/Bearing: 177° S03E 3147mils (True)
Elevation Grade: +016%
Horizon Grade: -001%
Zoom: 1X


Date & Time: Thu Nov 12 10:35:50 PST 2015
Position: 10 N 429849 5444471
Altitude: 62m
Azimuth/Bearing: 026° N26E 0462mils (True)
Elevation Grade: -011%
Horizon Grade: +001%
Zoom: 1X


DEERE

Middle Dam

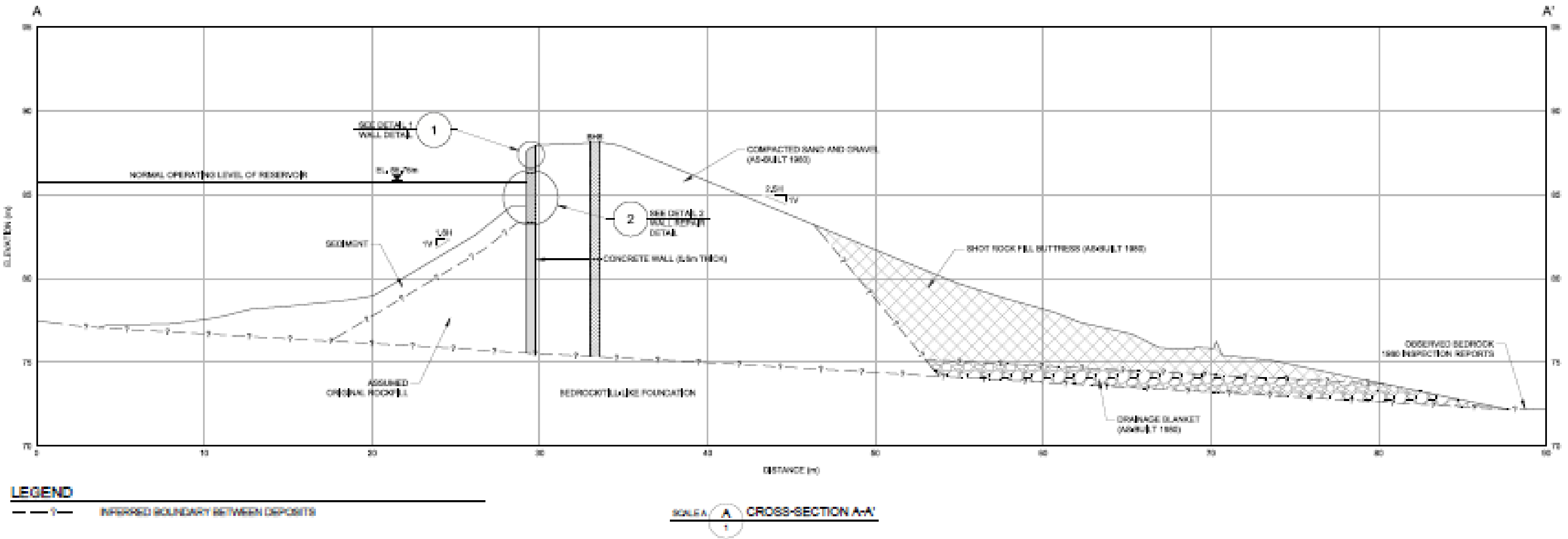


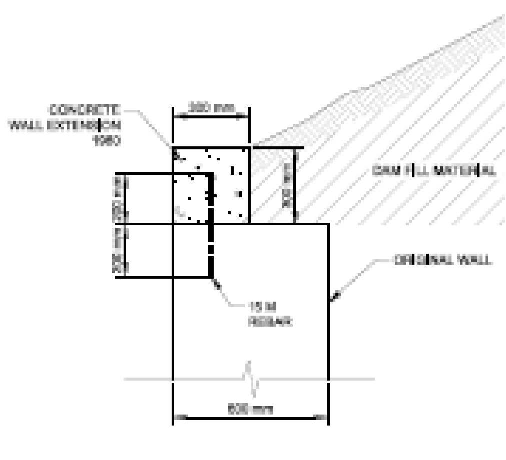
WALLS CONSTRUCTED IN 1980
SPILLWAY
BRIDGE DECK
PIER
EXISTING SPILLWAY WALL
ZONE OF MATERIAL AT APPROXIMATE 1.2m HIGHER ELEVATION
TP09-01
TP2
TP3
WALL CONSTRUCTED IN 1995, UPDATED IN 2004
CONCRETE WEIR CONSTRUCTED IN 1995
TP09-03
TP4
BH4
BH5
BH3
REVERVOIR
TP09-02
300 mm Ø SQUARE CATCH BASIN BOTTOM IS 450 mm BELOW ROCK SURFACE
APPROXIMATE LOCATION OF LOW LEVEL CONDUIT INLET (EBA, SEE NOTE 2)
APPROXIMATE EXTENT OF FILL REPLACEMENT (1980 SITE INSPECTION REPORTS)
TP1
WALL REPAIR
VALVE REMAINS FOUND DURING UNDERWATER INSPECTION 1977
GRAVEL TRAIL
100 mm Ø P.V.C. PIPE
CONCRETE DAM CORE

Middle Dam – History

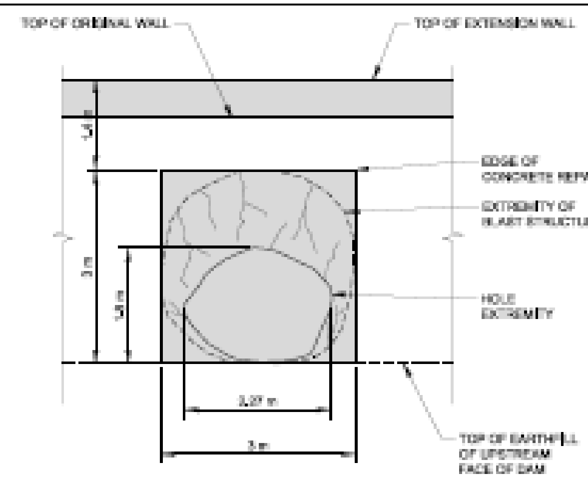
- ~1910: concrete dam constructed by Western Fuel Company/ Wellington Colliery/ Harewood Colliery
- Nov 1955: Flooding (heavy rain) problems on Chase River likely occasion that prompted hole made in dam to increase discharge capacity of reservoir.
- 1978 (Dam Investigation)
- 1980 (Dam Remediation)
  - 300mm high concrete addition placed on upstream face concrete wall
  - Hole in concrete core (from 1955) patched
  - Digging continued until an intact log crib was exposed. LLO not located.
  - 3’ thick drainage blanket was placed, compacted sand and gravel placed in d/s shell, shot rock buttress placed

Middle Dam – Cross Section



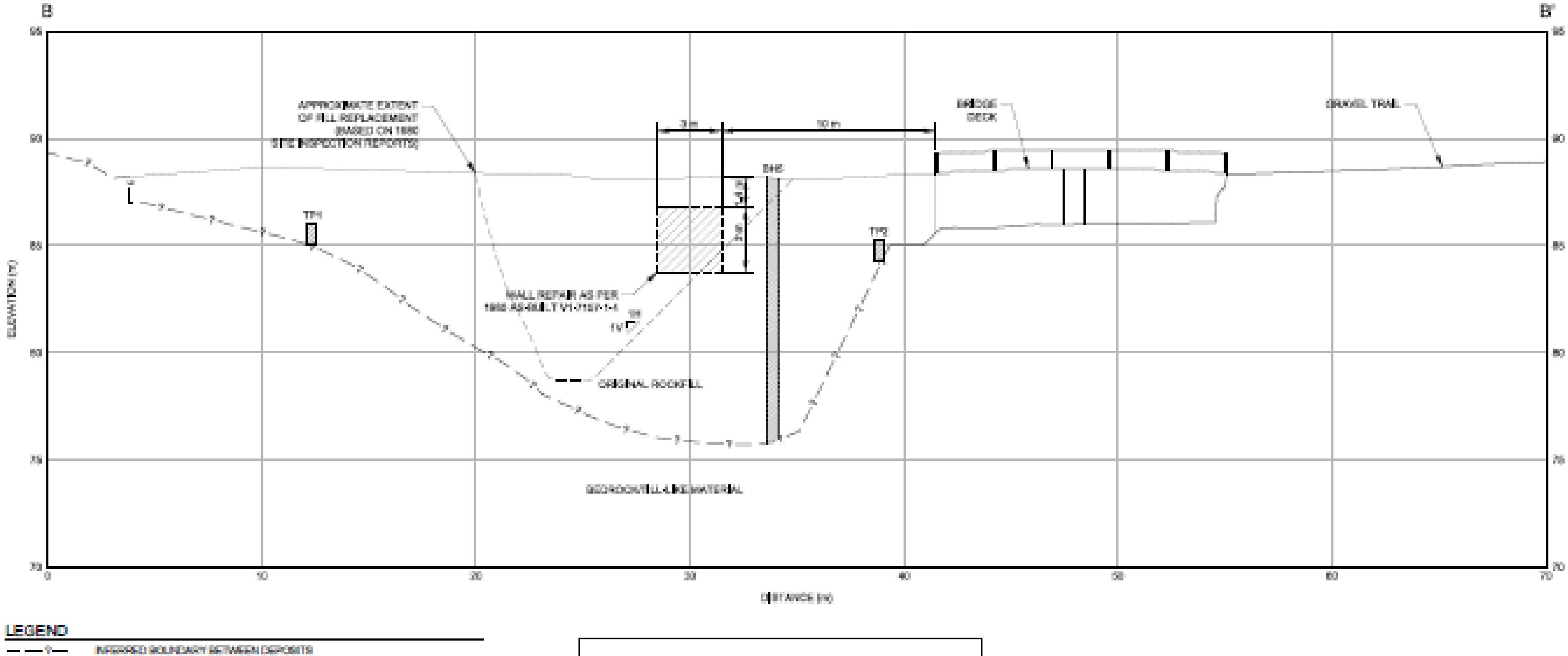


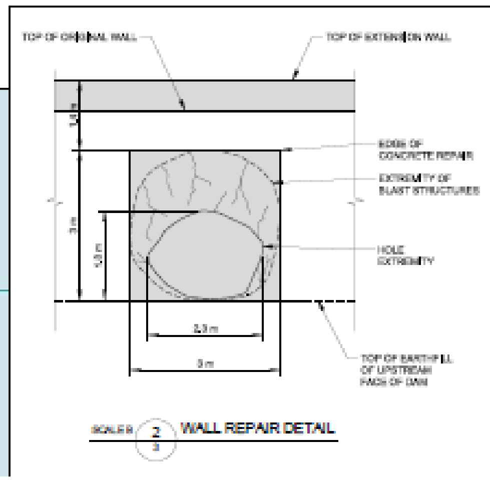
WALL DETAIL



WALL REPAIR DETAIL

Middle Dam – Transverse Section





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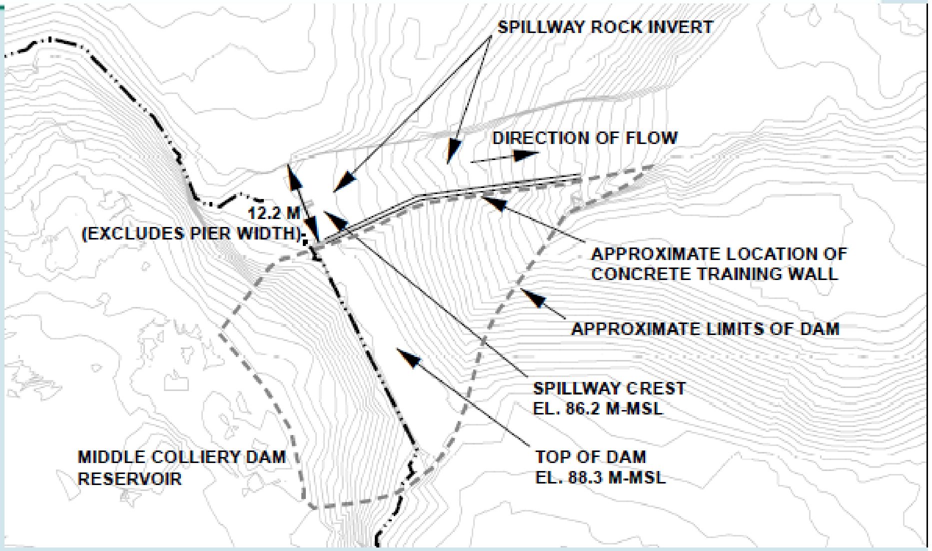
Middle Dam - Spillway

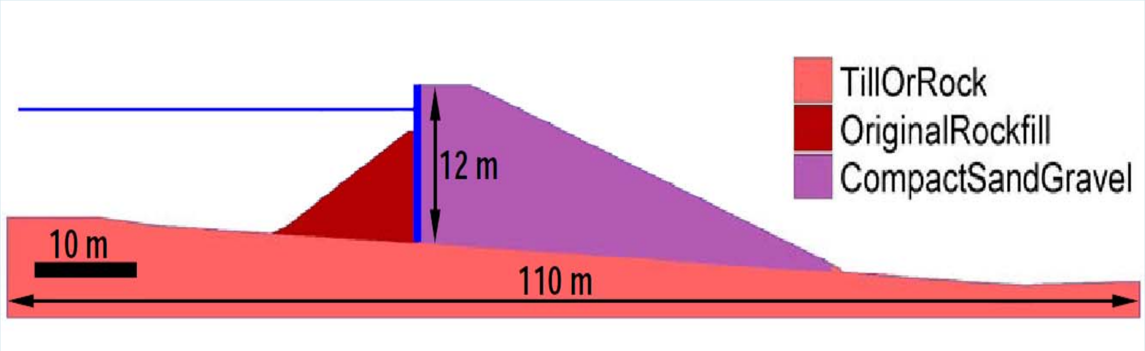
- Traditional Standards-Based Requirement (HIGH)
  - Flood (capacity = 1000 year + 1/3(PMF-1000year))
  - Current capacity 62 m3/sec

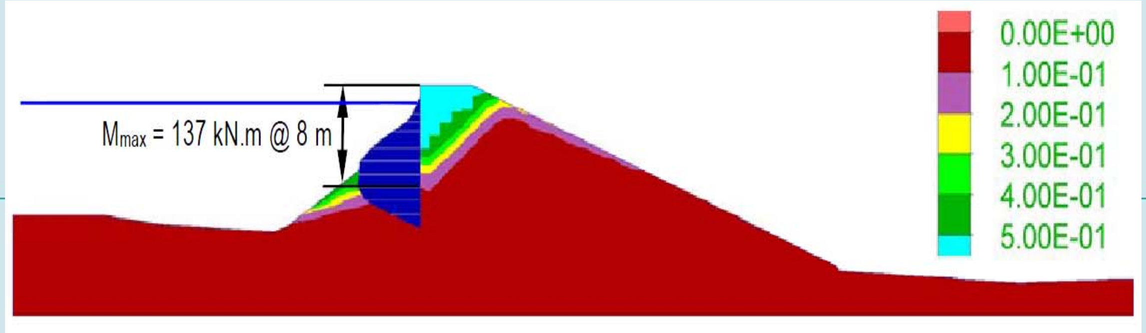


Middle Dam – Seismic Stability

EBA Report (2010)

“The concrete wall exposed on the upstream face of Middle Chase Dam is expected to topple during the design seismic event with development of an overtopping failure and uncontrolled discharge of the Middle Chase reservoir.”





Middle Dam – Seismic Stability

In 2014, the structural assessment of Lower Dam was extended to the Middle Dam. Using results form 2010 (EBA) modelling, and based on characteristics of concrete from 2014 investigation (of Lower Dam)

- Assumed a minimum one bar within a meter length of the Middle Chase Dam core wall to evaluate the wall capacity
- Based on our sectional analysis of the Middle Chase Dam core wall, the wall has just started to yield at a moment demand of 112 kN.m assuming one single twisted bar within a meter length
- The crack width are quite small for the demand above; however, it is noted that, as demand increases, so does the crack width, but the possibility of the wall toppling over is extremely low.

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Seismic Stability

- The risk assessment and the supporting technical studies has led to an increased understanding of the key dam safety risks:
  - Reservoir Size. Given the relatively small size of the reservoir, the dam breach development duration (i.e., the time it takes for the dam to fail completely) is of importance in determining the extent of flooding and thus of consequences/risk.
    - For seismic failure, since there is a low likelihood of overtopping, the failure mechanism is cracking and internal erosion – relatively slow failure development.
    - If the dam failure is relatively slow, it was found that there was insufficient storage in the reservoirs to cause significant downstream flooding.
  - Implications on Seismic Risk:
    - Very unlikely to fail in a rapid manner that will cause significant downstream flooding.
  - In addition, it is noted that the seismic risk due to the cascading effect of a Middle Dam failure has been mitigated by remediation of the Lower Dam (to increase flood routing capacity).

Seismic Stability

- Therefore the seismic risk of the dam is considered to be low in comparison to the risk to the dams due to a large storm event.
- However, the dams would likely be badly damaged by a large earthquake and may be susceptible to more severe damage and possibly rapid failure in the event of large earthquake aftershocks.
  - Following an earthquake, an assessment of the dam would need to be promptly made (assess instrumentation) and a decision to evacuate downstream residents and remediate or remove the dams.

Dam Safety Analysis – Risk Informed Approach

Dam Safety Analysis Framework

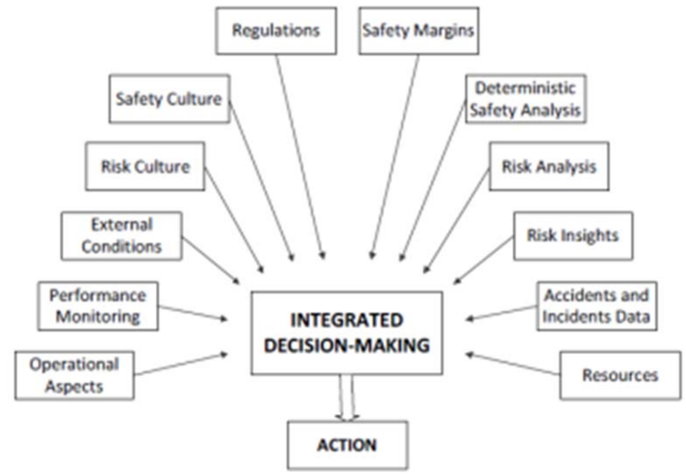
- CDA Guidelines (2013):
- *"Safety Management is ultimately concerned with management of risk and should provide answers to the following questions,*
  - *What can go wrong?*
  - *What is the likelihood (probability) of it happening?*
  - *If it occurs, what are the possible consequences?"*
- Two approaches considered
  - Risk-Informed Approach
  - Traditional Standards-Based Approach

Dam Safety Analysis

Dam Safety Analysis Framework

- Risk Informed Approach
  - CDA Guidelines : *“In view of the large uncertainties involved, a risk-informed approach is encouraged. Such an approach includes traditional deterministic standards-based analysis as one of many considerations, as shown in Figure 6-1”.*
    - Such an approach has been adopted in the dam safety analysis for Colliery Dams – e.g. seismic analysis (numerical (FLAC) modelling), H and H analyses.
  - Established, performance-based criteria (e.g. F-N curves)
  - This approach, with the performance based criteria, forms the basis for determination of dam safety conformance.

Figure 6-1: Integrated (Risk-Informed) Decision-Making [Source: Bulletin 154, ICOLD 2011]



Dam Safety Analysis

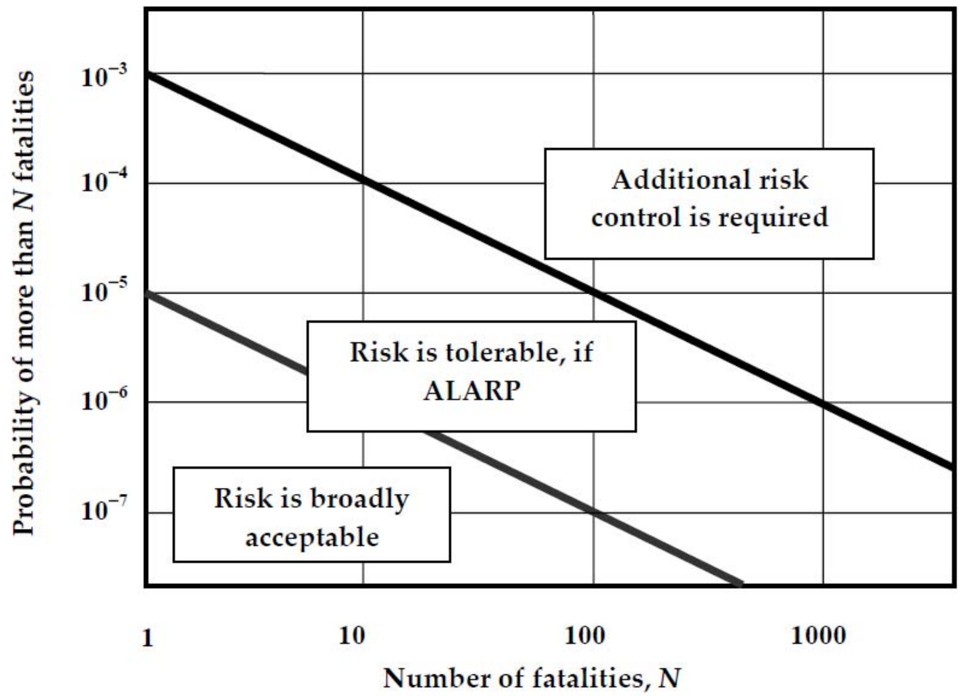
ALARP

- Risk Informed Approach, CDA Guidelines. Figure 6-2

DSS E-mail (May 8, 2014)

- Initial target frequency levels for flood and earthquake hazards (CDA Guidelines (Table 6-1A))
- Basis for consideration and discussion between the Owner and Regulator.
- It may be appropriate to adjust some of these target levels up or down based on the principle of decreasing the risk to "As Low as Reasonably Practicable" (ALARP).

Figure 6-2: Example Societal Risk Levels for Dam Safety



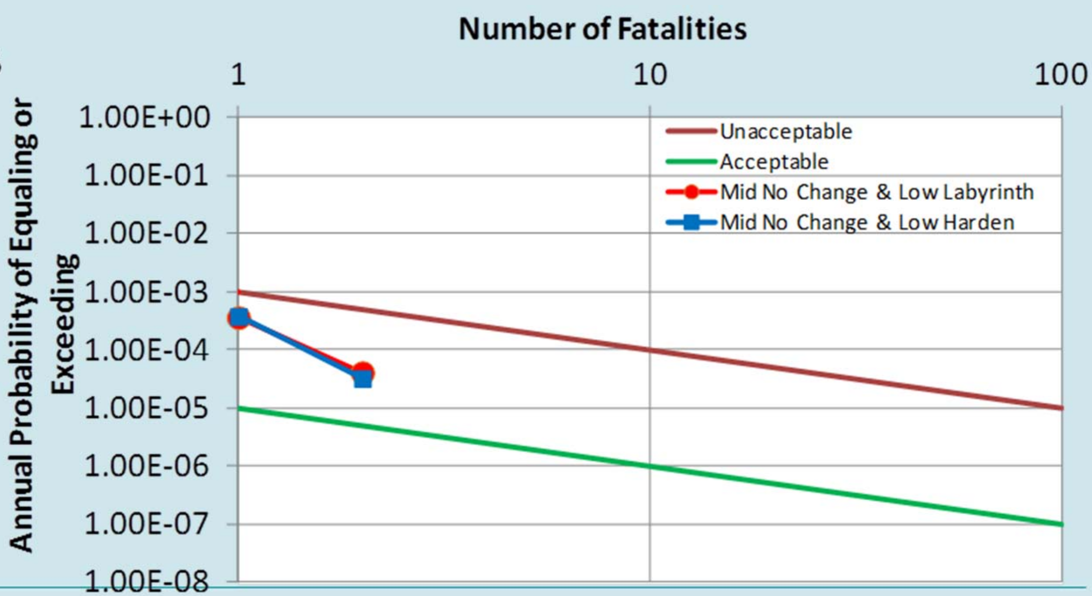
Risk Assessment

- See Separate Presentation

Development of Mitigation Options

Approach

1. Risk findings –
   - With the Lower Dam remediation completed, ALARP applies
2. ALARP to consider cost-benefit of Middle Dam alternatives, ie
   - Risk reduction (risk modelling assessment and analysis)
   - Cost
   - Environmental Impacts
   - Public Impacts of the option



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Development of Mitigation Options

Option Development

A. Focus will be on options to address key risk (flood routing risk)

B. Potential Middle Dam Options

   1. Monitor and data collection, including,
      - Additional data collection
        - Hydrology - calibrate run-off model
        - Dam condition (coring, if required)
      - Monitoring (for storm events)
        - Spillway/reservoir instrumentation
        - EPP amendments
   2. Spillway improvements
   3. Overtopping protection

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Next Steps

Step 1. Identify Conceptual Middle Dam Remediation Options

- Identify potential options (as above)
- If necessary, carry out screening (3 or 4 options).

Step 2. Risk Assessment

- Review/update of previous (2014) findings/risk inputs
  - Seismic analysis
  - Storm modelling (HEC HMS model)
- Collect additional site data (if required)

Step 3. Conceptual Development of Middle Dam Options

- Develop conceptual design of remediation options
- Compare options based on ALARP (cost-benefit)
  - Risk reduction (risk model analysis, and insights based on risk assessment)
  - Cost
  - Environmental Impacts
  - Public Impacts of the Option

Next Steps

Step 4. Further discussion/meetings

- Update on additional analyses
- Overview of options
- Risk assessment findings
- Cost-benefit analysis (ALARP)

Step 5. Selection of remediation approach