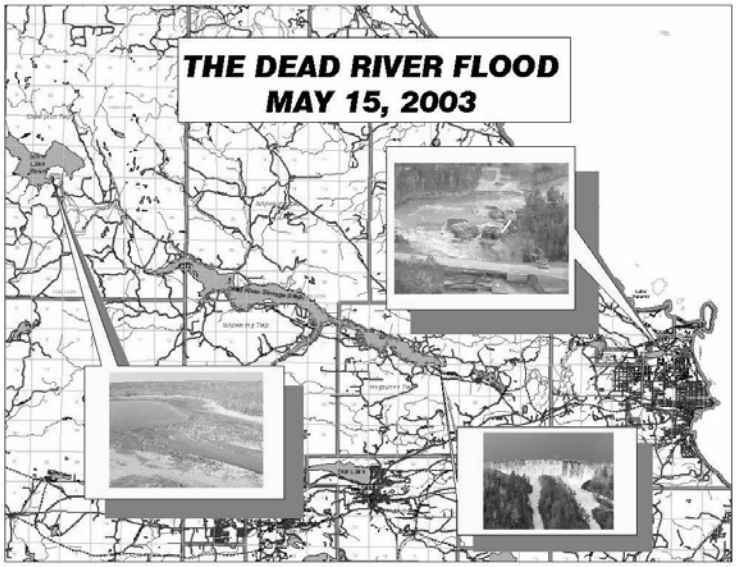
A DAM MYSTERY:

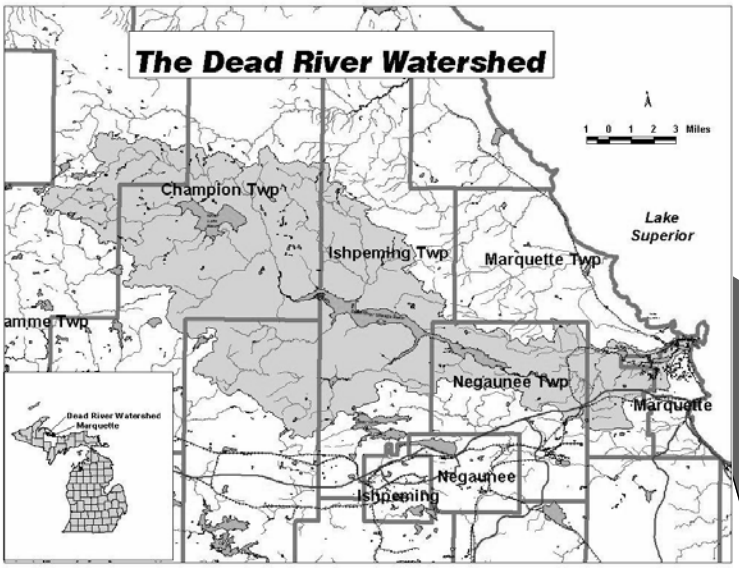
DEAD RIVER FLOOD

Marquette County, MI

May 14-16, 2003

Information contained herein is from the "Root Cause Report," submitted to UPPCO by the Washington Group, Inc., June 2003.





Dead River Flood

Silver Lake Basin Breach

- May 14, 2003
- Silver Lake Basin earthen dike bursts – approx. 5:00 p.m.
- 8:44 p.m. Flash Flood Warning Issued

Dead River Flood

Downriver from Silver Lake

- Break unleashes an estimated 8 billion gallons of water downriver.
- Mqt. County Board Chair Gerald Corkin declares State of Emergency at 1:30 a.m., May 15.

Dead River Flood

Dead River Basin

- Floodwaters reach Dead River Basin – damaging camps and homes

Dead River Flood

Dead River Basin

- The torrent of water also destroys roads along the way

Dead River Flood

Hoist Dam

- Floodwaters crest the Hoist Dam and flow further downriver

Dead River Flood

CR 510 Steel Bridge

- Water continues downstream – crossing CR 510 (Steel Bridge)

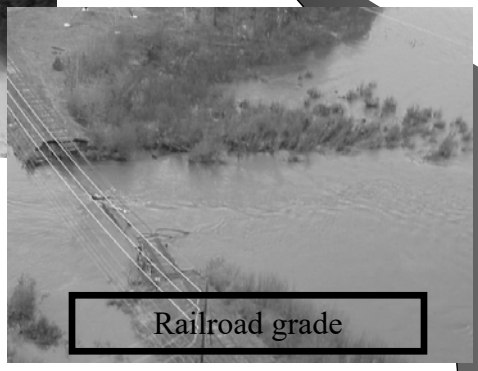
Dead River Flood

McClure Dam

- Downriver, the floodwaters crest the McClure Dam

Dead River Flood

- Floodwaters reach Forestville Dam, destroy railroad grade.



Dead River Flood

- Flood reaches Tourist Park and destroys the Dam

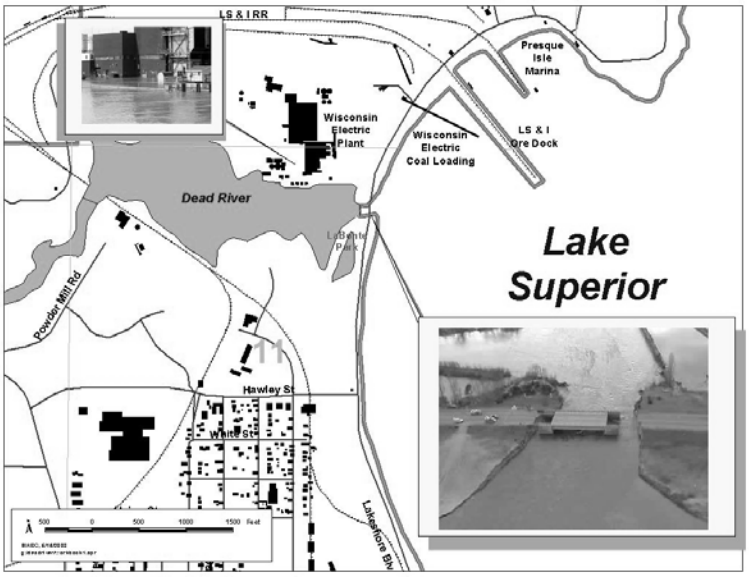
Dead River Flood

Tourist Park Damage

Dead River Flooding

CR 550

- Flood damages bridges on CR 550
- Utility service interrupted to Big Bay



Dead River Flood

- Considerable damage to Presque Isle Power Plant

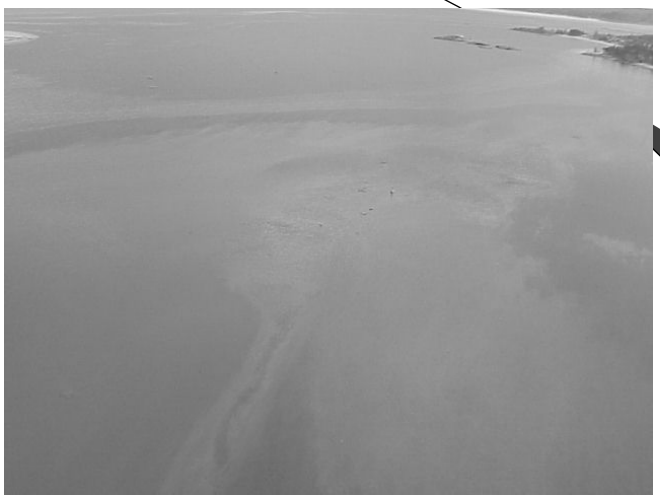
Presque Isle Power Plant

Dead River Flood

Lakeshore Blvd.

- Flood destroys bridge on Lakeshore Blvd
- Cuts power, gas, and telephone service to residences

Dead River Flood



Lake Superior

- Silt and debris flow into Lake Superior

Dead River Flood

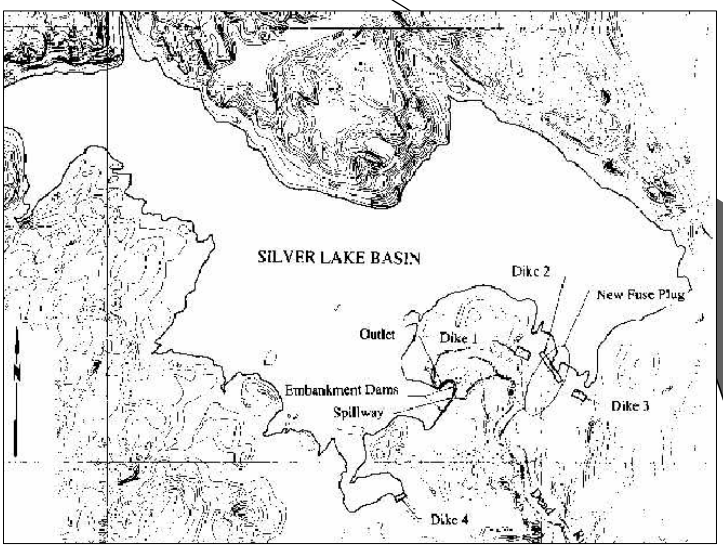
- City of Marquette, Marquette County, 4 townships affected
- Evacuation of 2300 residents
- Major employers impacted:
  - WE Energy
  - Cleveland-Cliffs Iron Company
  - LS&I Railroad
  - Northern Michigan University
  - Marquette Board of Light and Power
  - Argonics
  - Pioneer Labs
- At least 8 small to medium employers affected
- Estimated total damage of $100 million

Dead River Flood

- Three dams or dikes damaged
- Two dams or dikes destroyed
- Nine bridges damaged or destroyed
- Damage to two parks and three public access sites
- Major river channel realignments
- Major soil and stream bank vegetation loss
- Significant sediment deposition, debris field, and undetermined sheen discharged to Upper Harbor

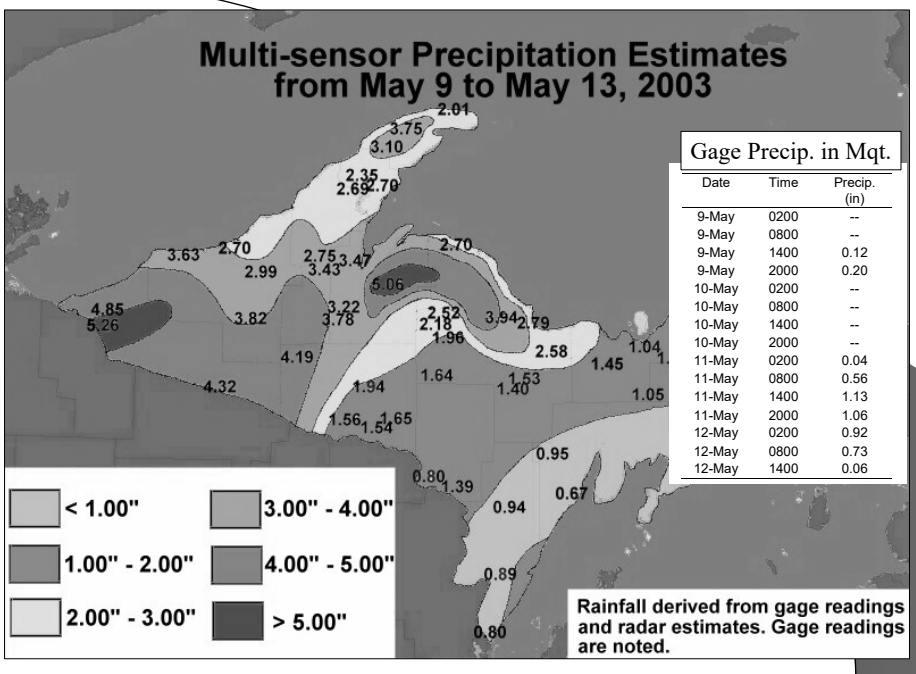
Failure of Fuse Plug Dam

Silver Lake Dam



Fuse Plug Dam

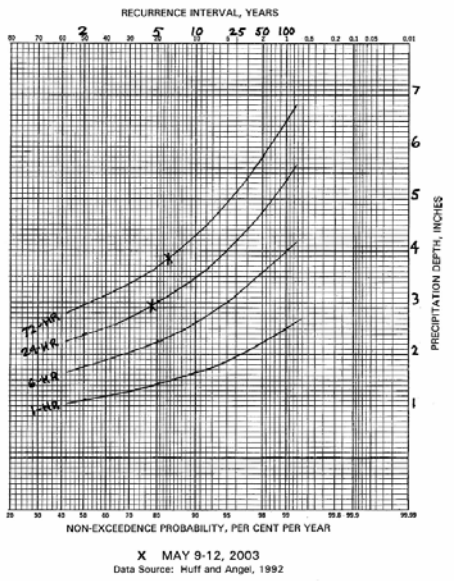
- Constructed in Fall 2002.
- Earth dam, about 5 feet high.
- Designed to overtop and serve as an emergency spillway in the event of a very severe flood (approx. 500-yr flood).
- Required operational change – keeping lake level lower to maintain storage capacity for flood control.



Whodunnit?

- What was the cause of failure of the dam (i.e., who is to blame)?
  - What happened between 2:00 pm on May 12th (rainfall ends) and 5:00 pm on May 14th (dam bursts)?
  - What data are needed for this analysis?
  - What data are available?

Frequency Analysis



Hydrologic Analysis

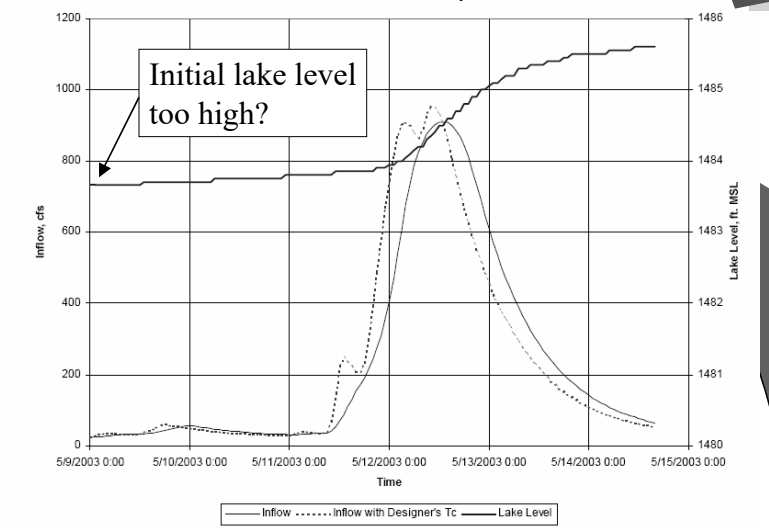
- Watershed delineation
  - Area = 23.6 mi^2
  - Tc ~ 12 hrs
- Soils (loss model) analysis

% of Area	Initial loss (in)	Constant loss rate (in/hr)
31.6	0.0	0.0
15.7	0.9	0.01
12.2	0.9	0.06
6.7	0.9	0.10
33.8	0.9	1.0

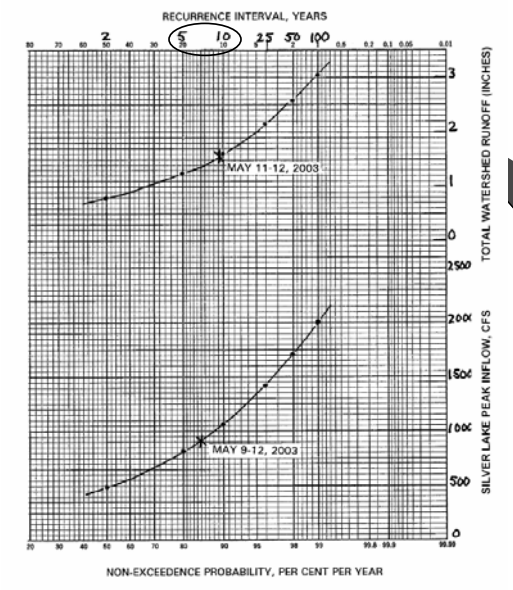
Hydraulic Analysis

- Dam outlets include:
  - 4-ft discharge pipe with gate valve
    - Gate open just 4 in., allowing only 10 cfs outflow
  - Overflow spillway
    - Stop logs in place to shut off outflow
- Storage-area-elevation relationships for lake were developed.

HEC-HMS Model

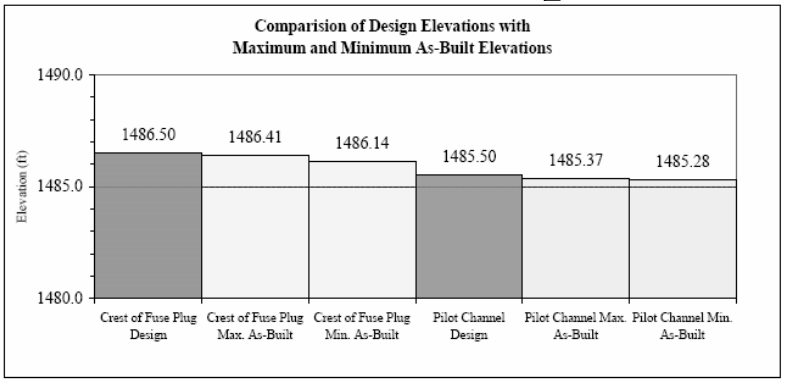


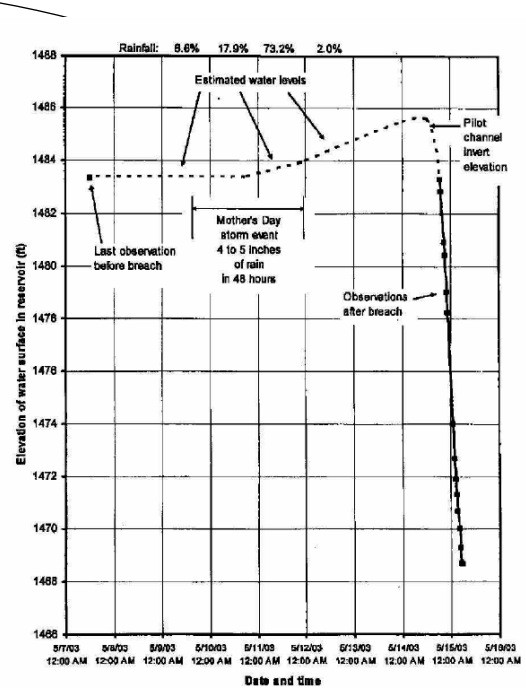
Frequency Analysis



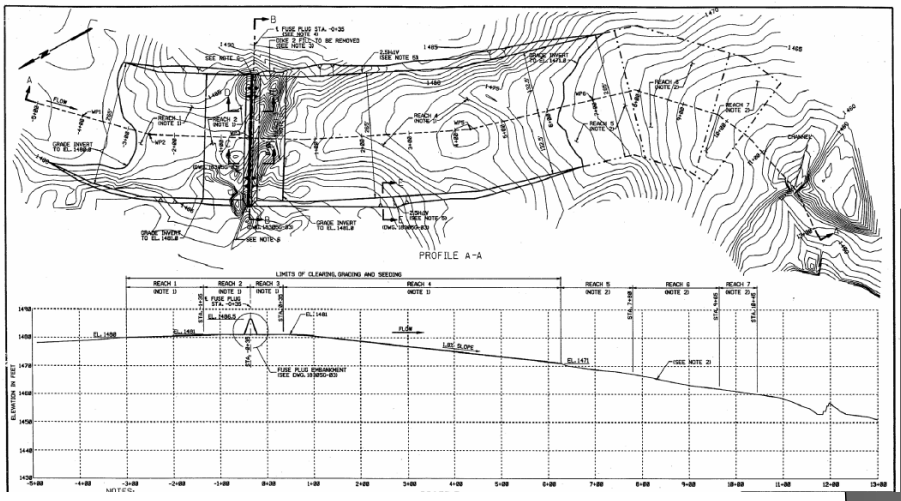
Not a 500-yr flood

Structure Elevations





Spillway Discharge Velocities



HEC-RAS Model

Calculated Maximum Velocity in Fuse Plug Channel

Discharge (cfs)	Maximum Velocity (ft/sec)	Section of Maximum Velocity	Lake Elevation (ft)
1,000	4.95	1900	1482.98
2,000	6.22	1900	1483.84
3,000	7.14	1900	1484.54
4,000	7.85	1900	1485.13
4,900[1]	8.38	2328, 2100, 1900	1485.61
6,000	9.20	2100	1486.14
7,000	9.85	2100	1486.59
10,000	11.56	2100	1487.80
15,000	14.32	1772	1489.49
19,230	15.82	1772	1490.74

[1] A discharge of 4,900 cfs is comparable to the estimated May 14, 2003 discharge from Silver Lake immediately after the breach and washout of the fuse plug embankment.

Maximum Channel Velocities
(US Army Corps of Engineers, EM 1110-2-1601, 1991)

Channel Material	Mean Channel Velocity (ft/sec)
Fine Sand	2.0
Coarse Sand	4.0
Fine Gravel	6.0
Earth - Sandy Silt	2.0
Grass-lined Earth (slopes less than 5%)	
Bermuda Grass on Sandy Silt	6.0
Kentucky Blue Grass on Sandy Silt	5.0

Headcutting

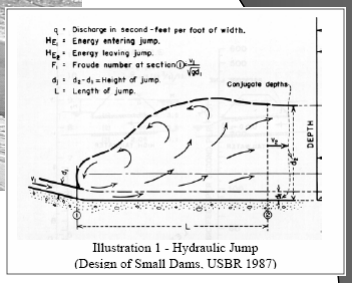


Illustration 1 - Hydraulic Jump
(Design of Small Dams, USBR 1987)

So Who is to Blame?

- Design firm?
  - Did not account for erosive soils?
  - Improper design of fuse plug foundation?
- Contractor?
  - As-built elevations below design elevations?
  - Was the spillway really grass-lined?
- Operator?
  - Holding lake too high?
  - Set release rate too low?