

Risk of Internal Erosion Failure of West Pass Dike

Upper Baker Development, Baker River Project, P-2150

RIDM Level 2 Workshop – Spring 2013

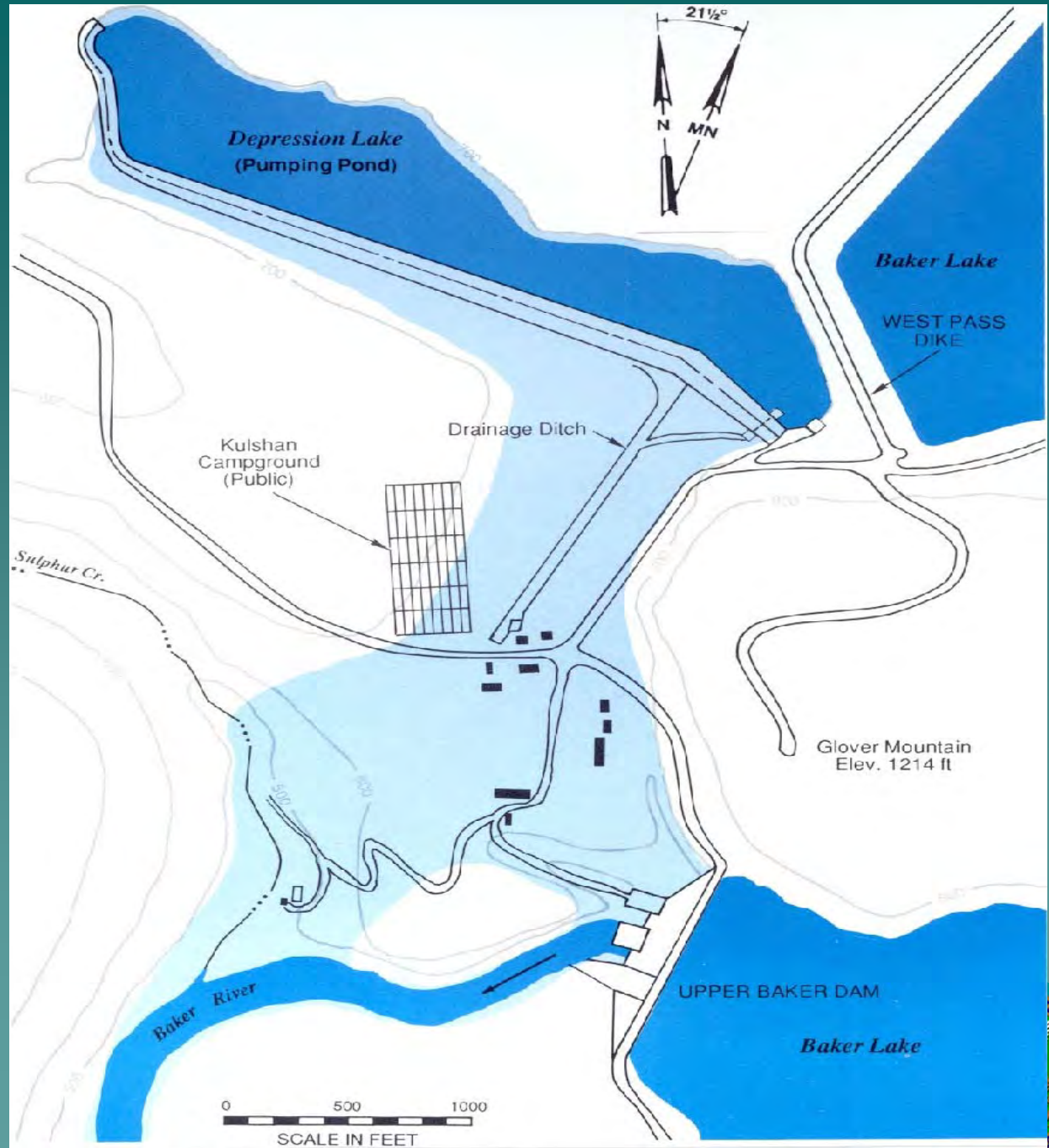


Baker River Project

- ◆ Upper Baker Dam is a 297-foot-high, “High” hazard concrete gravity dam, with a 285,500 acre-foot reservoir. Located in northwestern WA near Canada.
- ◆ West Pass Dike is a 115-foot-high earth and rockfill saddle dam located near the right abutment.
- ◆ Owned by Puget Sound Energy (PSE)



Upper Baker Development



Upper Baker Dam



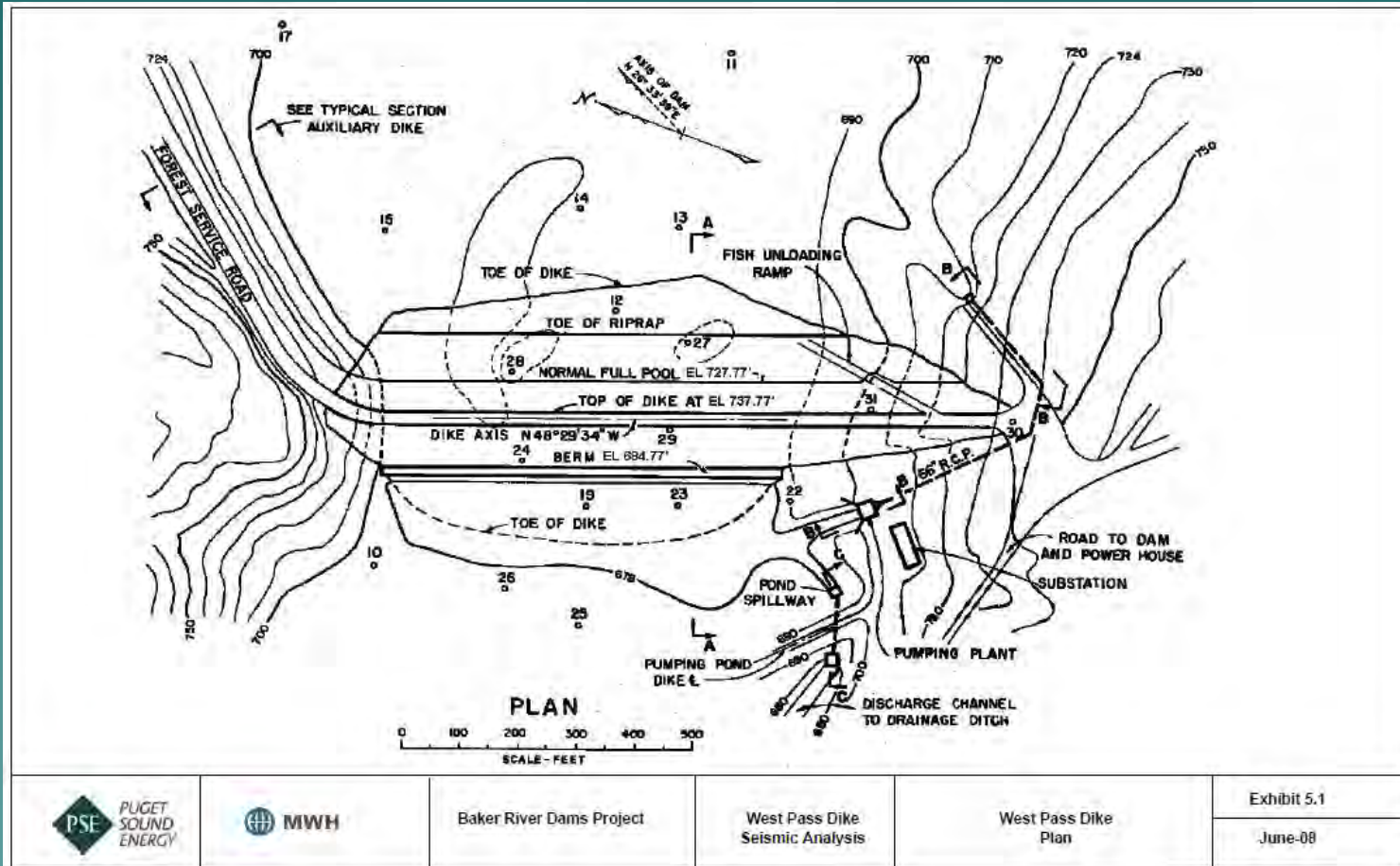
West Pass Dike



West Pass Dike



Plan View of WPD



Baker River Dams Project

West Pass Dike
Seismic Analysis

West Pass Dike
Plan

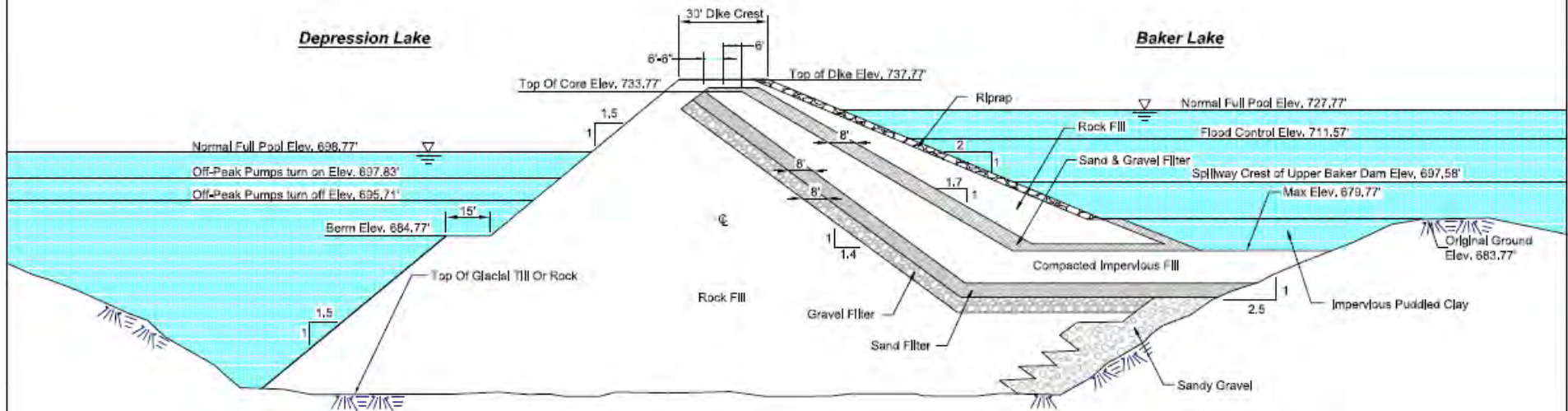
Exhibit 5.1

June-08



West Pass Dike

Typical Cross Section - Not to Scale
NAVD 68 Datum Elevations



Depression Lake

- Reservoir length = 0.7 miles
- Full pool surface area = 44 acres
- Full pool volume = 234 acre-ft

West Pass Dike

- NATDAM # WA00174
- Earth & Rock filled embankment
- Constructed from May 1957 to October 1959
- Length = 1200'
- Height = 115'
- West Pass Dike overtopping (PMF) = 1.42'
- Underground Koma Kulshan Transmission cable (34.5 kV Power Line) - average 3' below crest, runs along the dike crest on average 11' from NE slope (Baker Lake side)
- Cross-section adapted from original construction drawing, with crest width and side slope inclinations modified according to Leonard, Boudnot & Skoalje Dwg. No. 05133TOPO dated 12/27/2007.

Baker Lake

- Reservoir length = 9 miles
- Full pool surface area = 4,980 acres
- Full pool volume = 274,221 acre-ft.
- Storage above spillway gates at Upper Baker Dam = 124,950 acre-ft.
- FERC-required flood control volume = 16,000 acre-ft. (724.50', 10/15 - 03/01)
- USACE flood control volume = an additional 58,000 acre-ft. for a total of 74,000 acre-ft. (711.57', 11/15 - 03/01)
- Peak inflow (PMF) = 157,800 cfs
- Peak outflow (PMF) = 111,500 cfs (Inflow design flood)
- Max pool elevation (PMF) = 739.19'
- Dam overtopping (PMF) = 3.42'

Schematic is shown for illustrative purpose only.

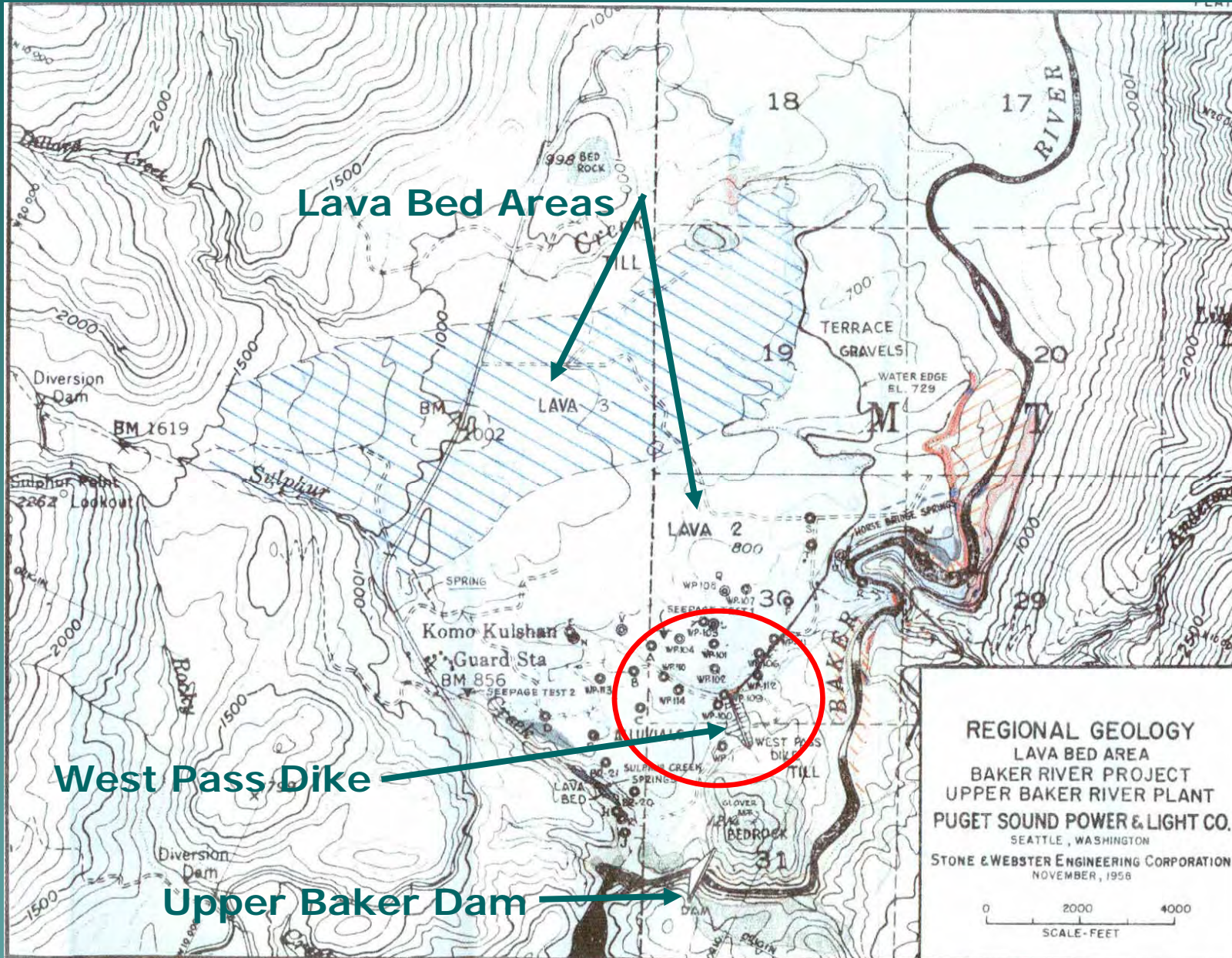


West Pass Dike - Rolled Rockfill

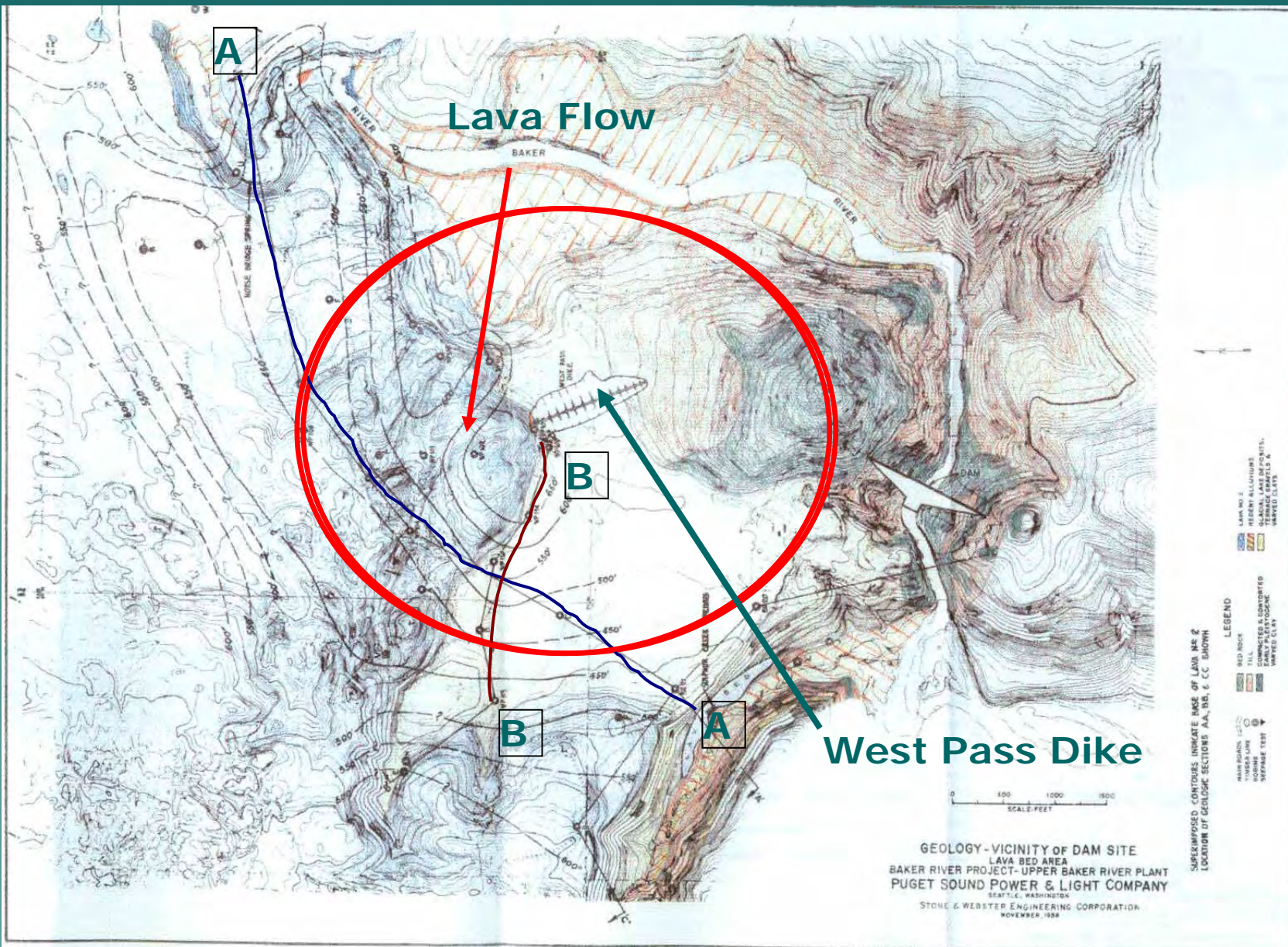
- ◆ There is no clear description or measured soil gradations of the rolled rockfill
- ◆ Based on visual observation it consists of sandy gravel with cobbles



West Pass Geology



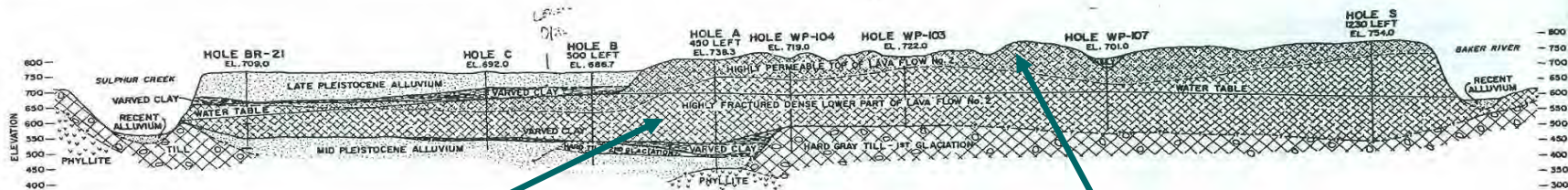
West Pass Geology



West Pass Geology

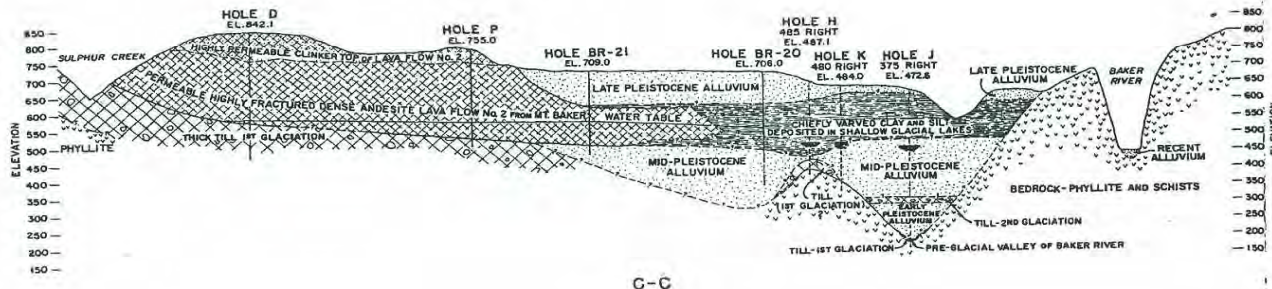
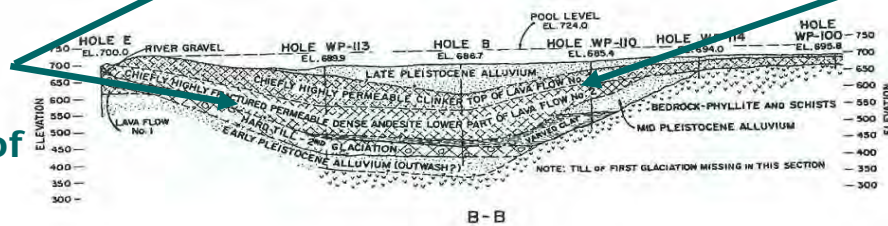


West Pass Geologic Cross-Section

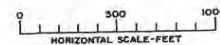


Highly Fractured Dense Andesite in Lower Part of Lava Flow

Highly Permeable Top of Lava Flow

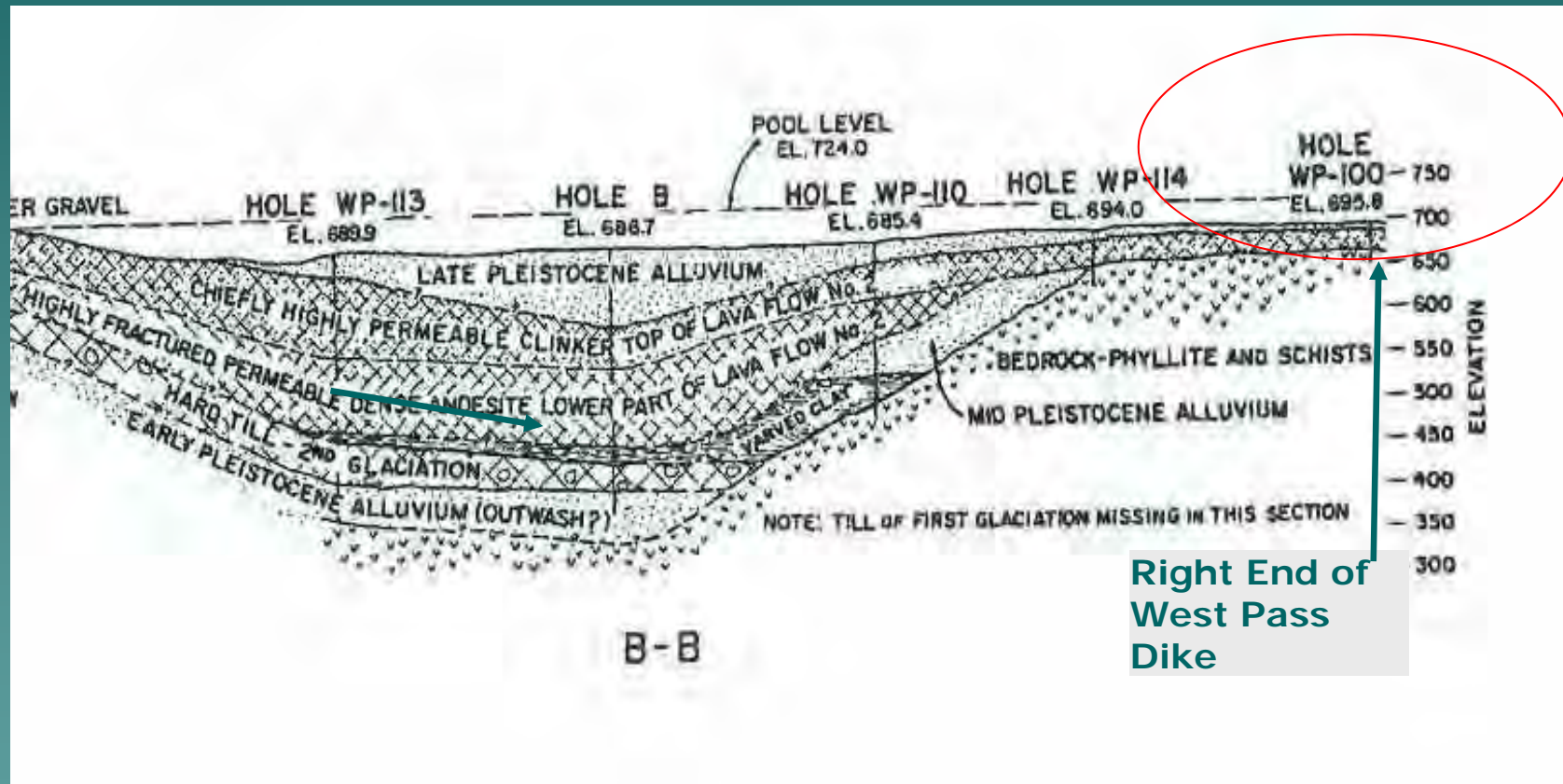


NOTE: FOR LOCATION OF SECTIONS SEE PLATE II.



GEOLOGIC SECTIONS
LAVA BED AREA
BAKER RIVER PROJECT-UPPER BAKER RIVER PLANT
PUGET SOUND POWER & LIGHT COMPANY
SEATTLE, WASHINGTON
STONE & WEBSTER ENGINEERING CORPORATION
NOVEMBER, 1958

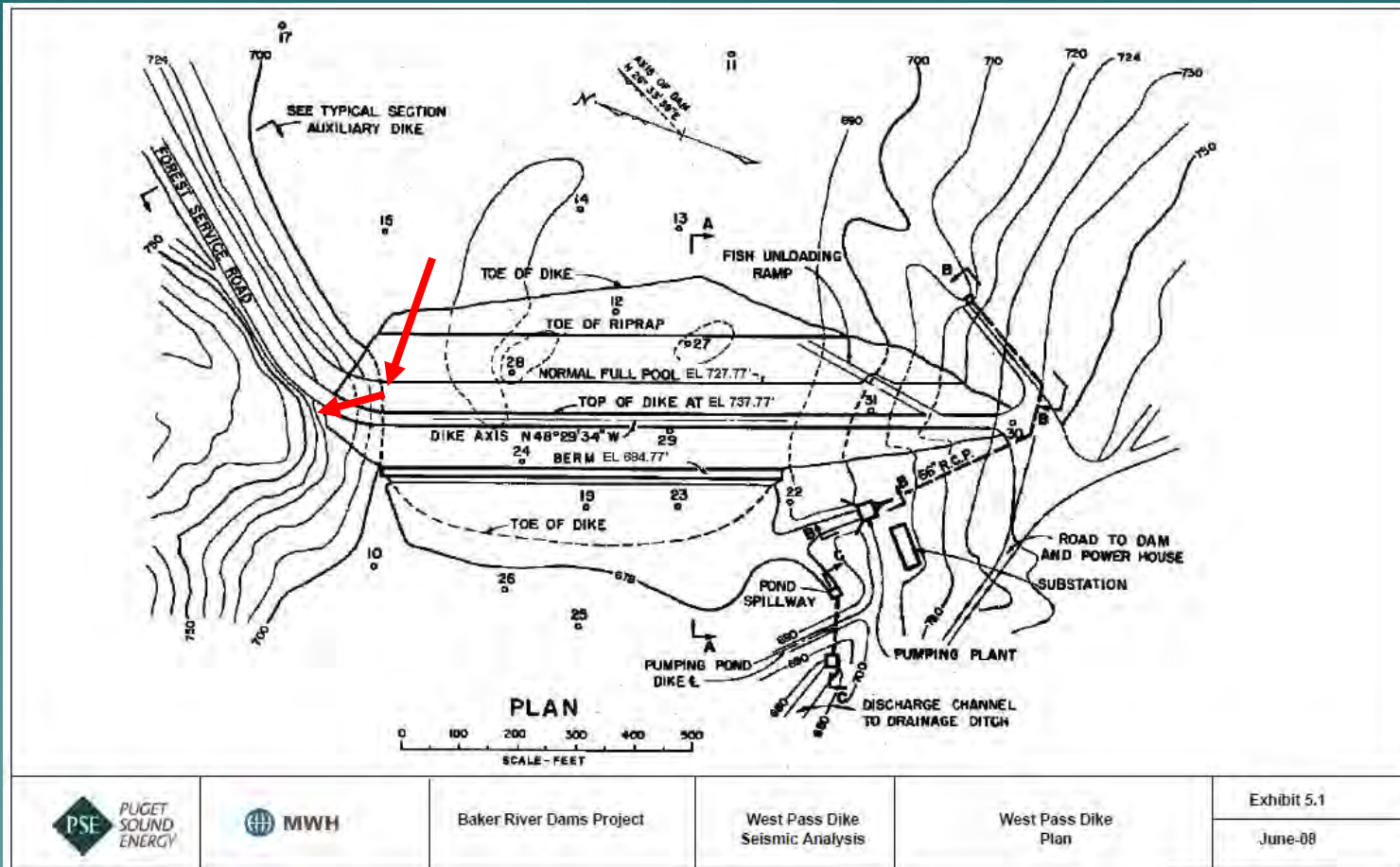
West Pass Geologic Cross-Section



Internal Erosion PFM Along Abutment Contact

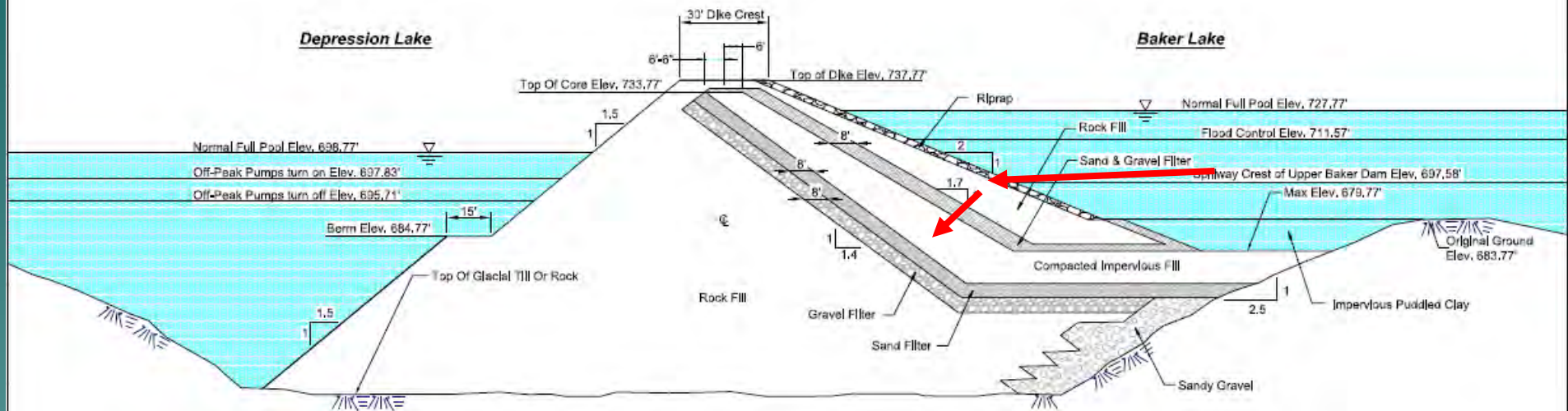
- ◆ Seepage through the embankment results in internal erosion of the embankment core into the fractured andesite lava flow of the right abutment.
- ◆ Sufficient core material flows into the fractured abutment creating a cavity at the abutment/embankment contact allowing the downstream filters to collapse into the cavity.
- ◆ The entire cavity collapses, creating a sinkhole in the upstream face of the embankment, compromising the downstream filter zones, and allowing additional flow along the bedrock/embankment contact.
- ◆ The flow along the abutment erodes the downstream shell material into Depression Lake until the embankment is breached.

Plan View of WPD



West Pass Dike

Typical Cross Section - Not to Scale
NAVD 88 Datum Elevations



Depression Lake

- Reservoir length = 0.7 miles
- Full pool surface area = 44 acres
- Full pool volume = 234 acre-ft

West Pass Dike

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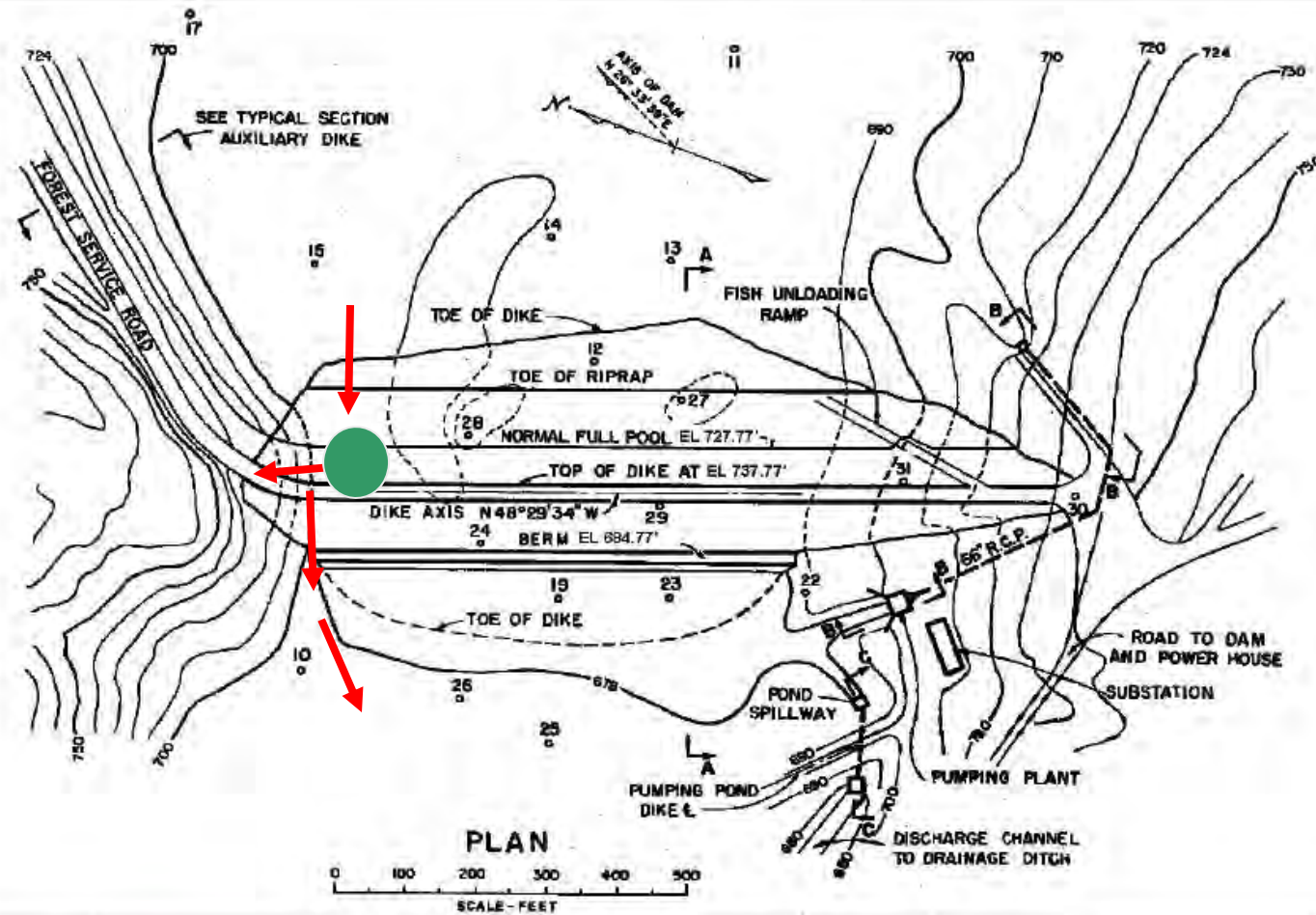
Baker Lake

- Reservoir length = 8 miles
- Full pool surface area = 4,980 acres
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Plan View of WPD



Baker River Dams Project

West Pass Dike
Seismic Analysis

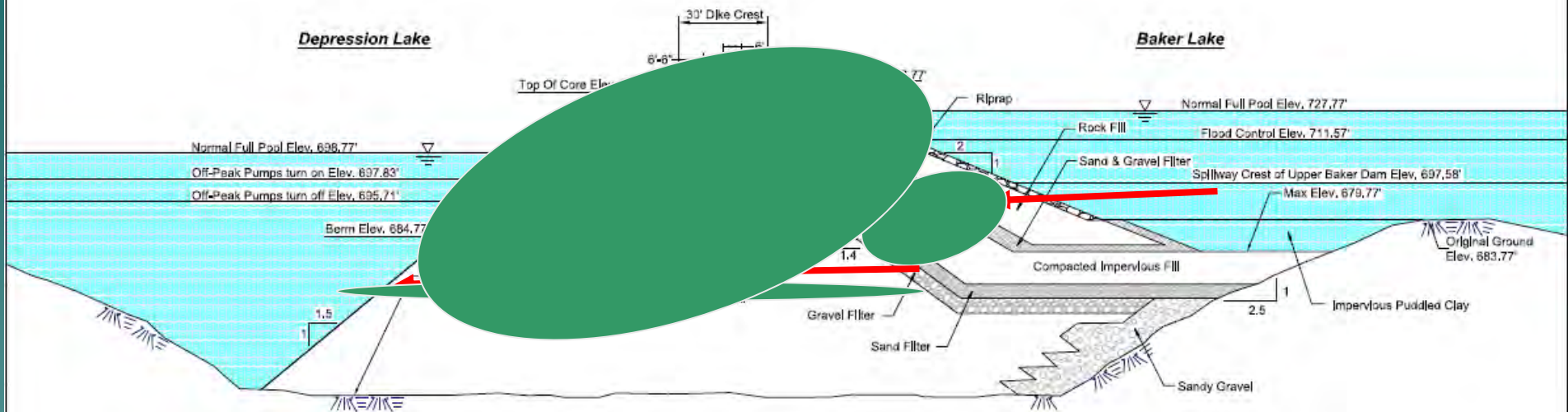
West Pass Dike
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June-08

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Potential Failure Mode

- ◆ ↪ Reservoir at or above threshold level
- ◆ ↪ Initiation – Erosion into right abutment starts
 - ↪ Continuation – Erosion cavity develops in core at abutment contact compromising downstream filter
 - ◆ ↪ Progression – Filter and core collapse into void
 - ◆ ↪ Progression – Unfiltered or inadequately filtered exit now exists
 - ◆ ↪ Progression – Erosion develops along abutment contact into downstream shell
 - ◆ ↪ Progression – Abutment rock forms a roof and a pipe develops to the downstream face under Depression Lake
 - ↪ Erosion is not observed so intervention fails to prevent “break-through”
- ◆ Dam breaches

PFM Likelihood

- ◆ Reclamation studies show rates of initiation of internal erosion at their embankments – 25%
- ◆ Annual probability of failure (APF) for this PFM uncertain without better information



Category	General Description	APF
Remote	The physical conditions do not exist for its development or the likelihood is so remote. Several events must occur concurrently or in series to trigger failure. Most, if not all of the events are very unlikely. Or, it would likely take a flood or earthquake with a return period of more than 1,000,000 years to trigger the potential failure mode.	$< 10^{-6}$
Very Low	The possibility cannot be ruled out, but there is <u>no compelling evidence</u> to suggest it <u>has occurred</u> or that a condition <u>or flaw exists</u> that could lead to its development. Or, a flood or earthquake with a return period of between 200,000 and 1,000,000 years would likely trigger the potential failure mode.	<u>10^{-6}</u> <u>to 10^{-5}</u>
Low	The fundamental condition or <u>defect is known to exist</u>, <u>indirect evidence</u> suggests it is <u>plausible</u>, but evidence is <u>weighted more heavily toward unlikely than likely</u>. Or, a flood or earthquake with a return period between 20,000 and 100,000 years would likely trigger the potential failure mode.	<u>10^{-5}</u> <u>to 10^{-4}</u>
Moderate	The fundamental condition or defect is known to exist, indirect evidence suggests it is plausible, but evidence is weighted more heavily toward likely than unlikely. Or, a flood or earthquake with a return period between 2,000 and 10,000 years would likely trigger the potential failure mode.	10^{-3}

PFM Likelihood

- ◆ Internal erosion PFM could range from APF = $1 \text{ E-}3$ to $1 \text{ E-}7$
- ◆ Likelihood could be between Very Low and Low
- ◆ Let's choose Low

Confidence

- ◆ High confidence in a likelihood estimate means we are unlikely to revise our estimate with more information.
- ◆ Low confidence means we are likely to revise our estimate with more information
- ◆ Moderate confidence means we are unsure about the potential to change the estimate

Confidence Estimate

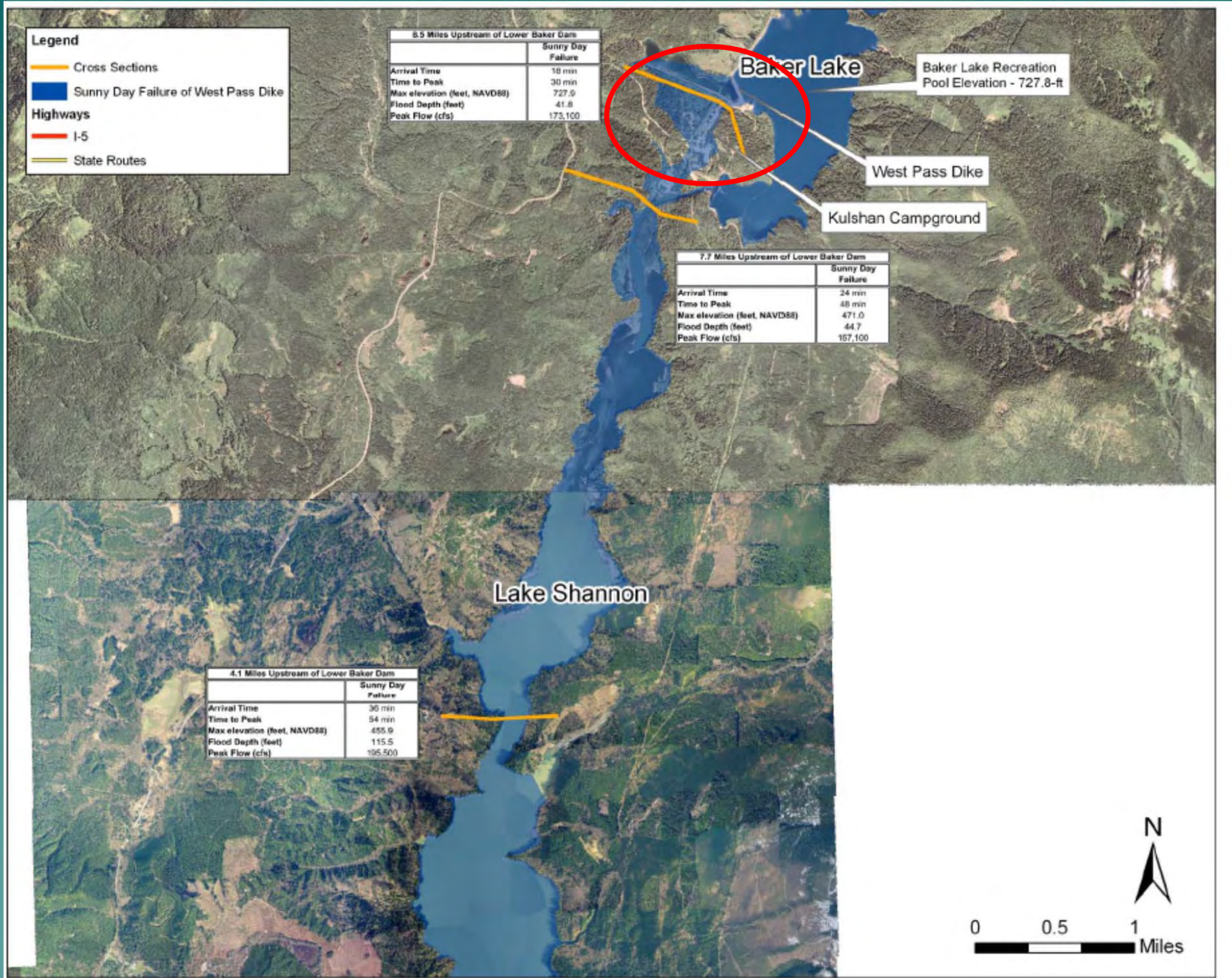
- ◆ Estimate of Likelihood would be improved with more information
- ◆ We have Low confidence in the category estimate.

Estimate Consequences

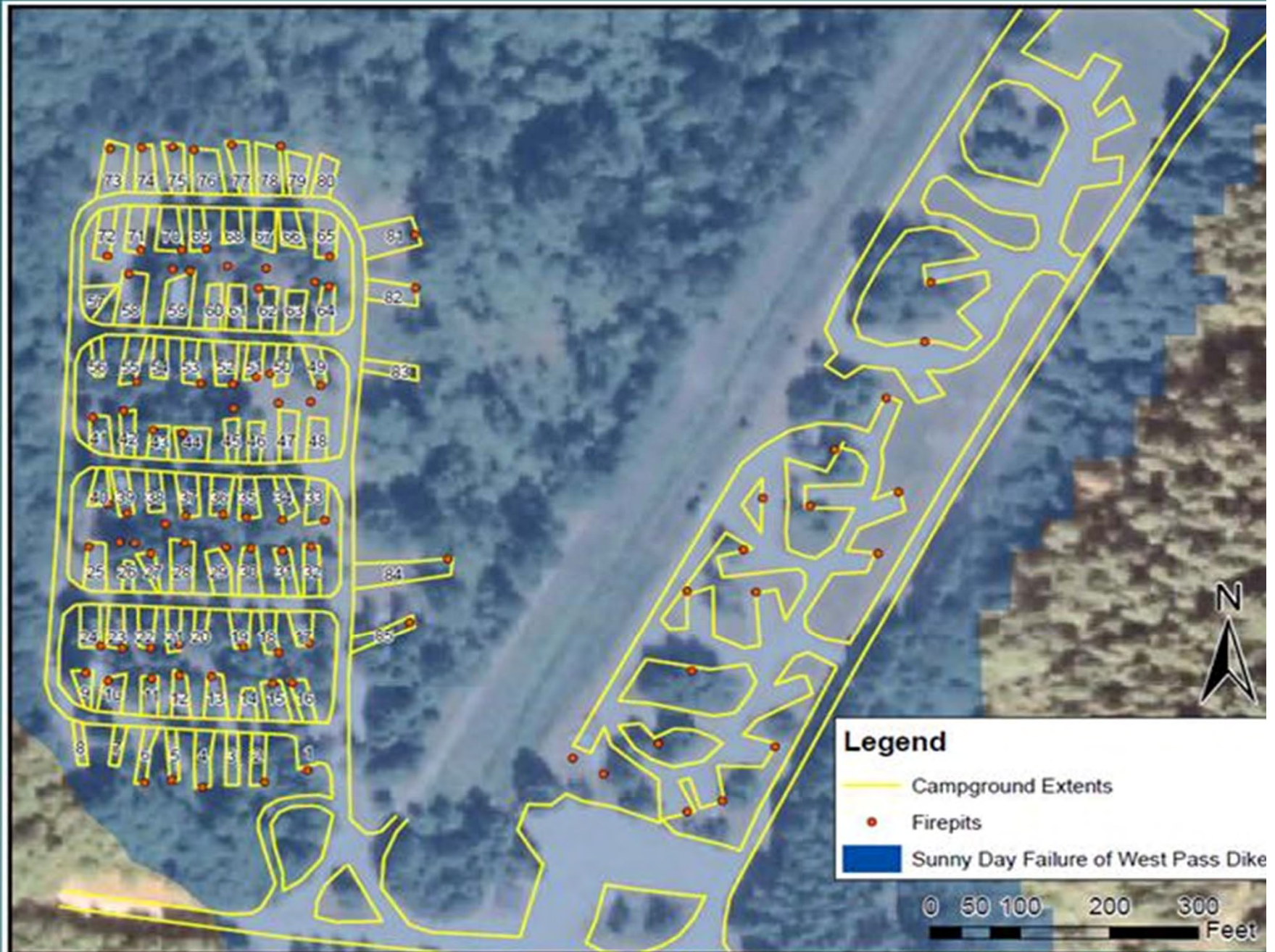
- ◆ Following slides show the inundation area from a sunny day failure of West Pass Dike



Population at Risk



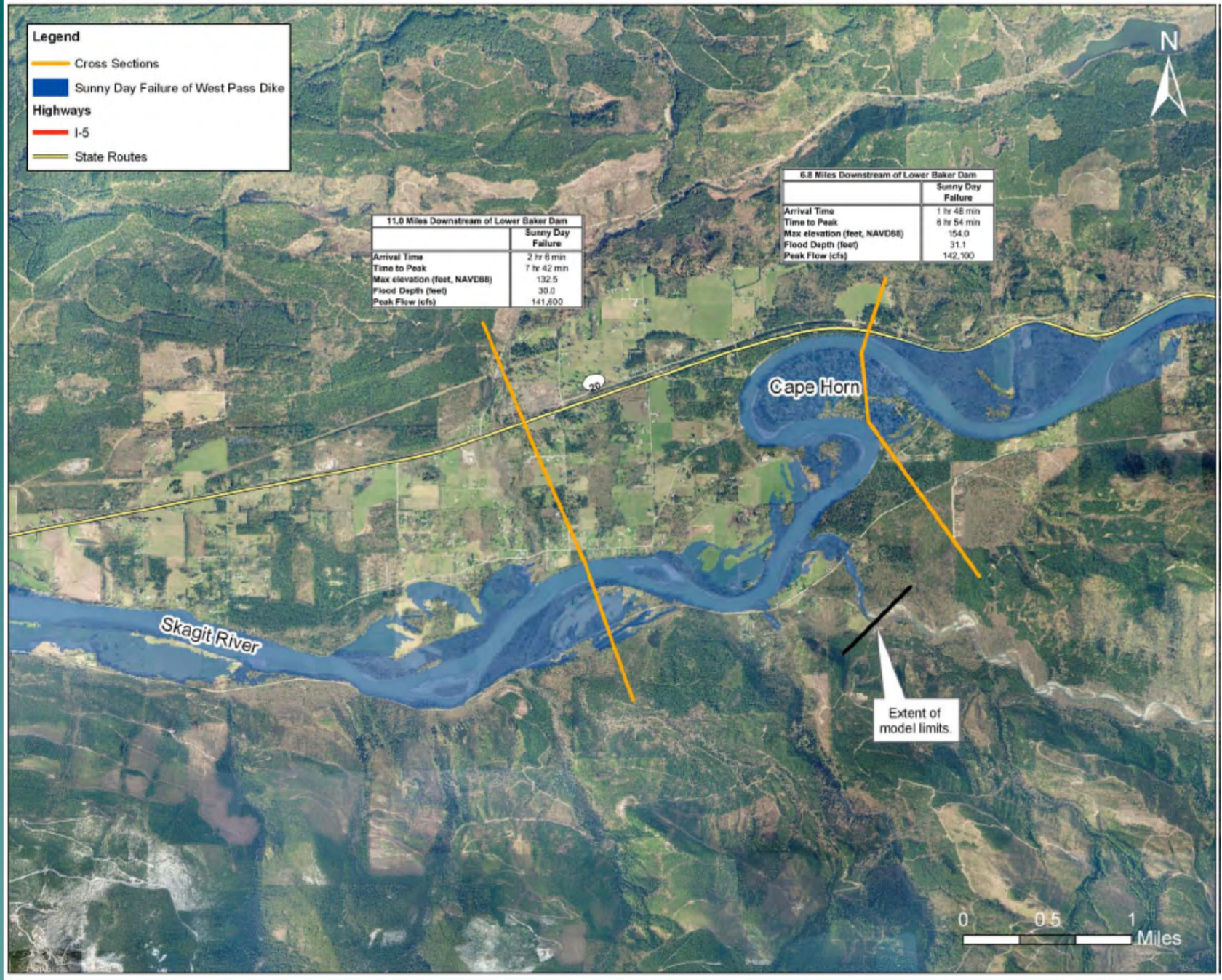
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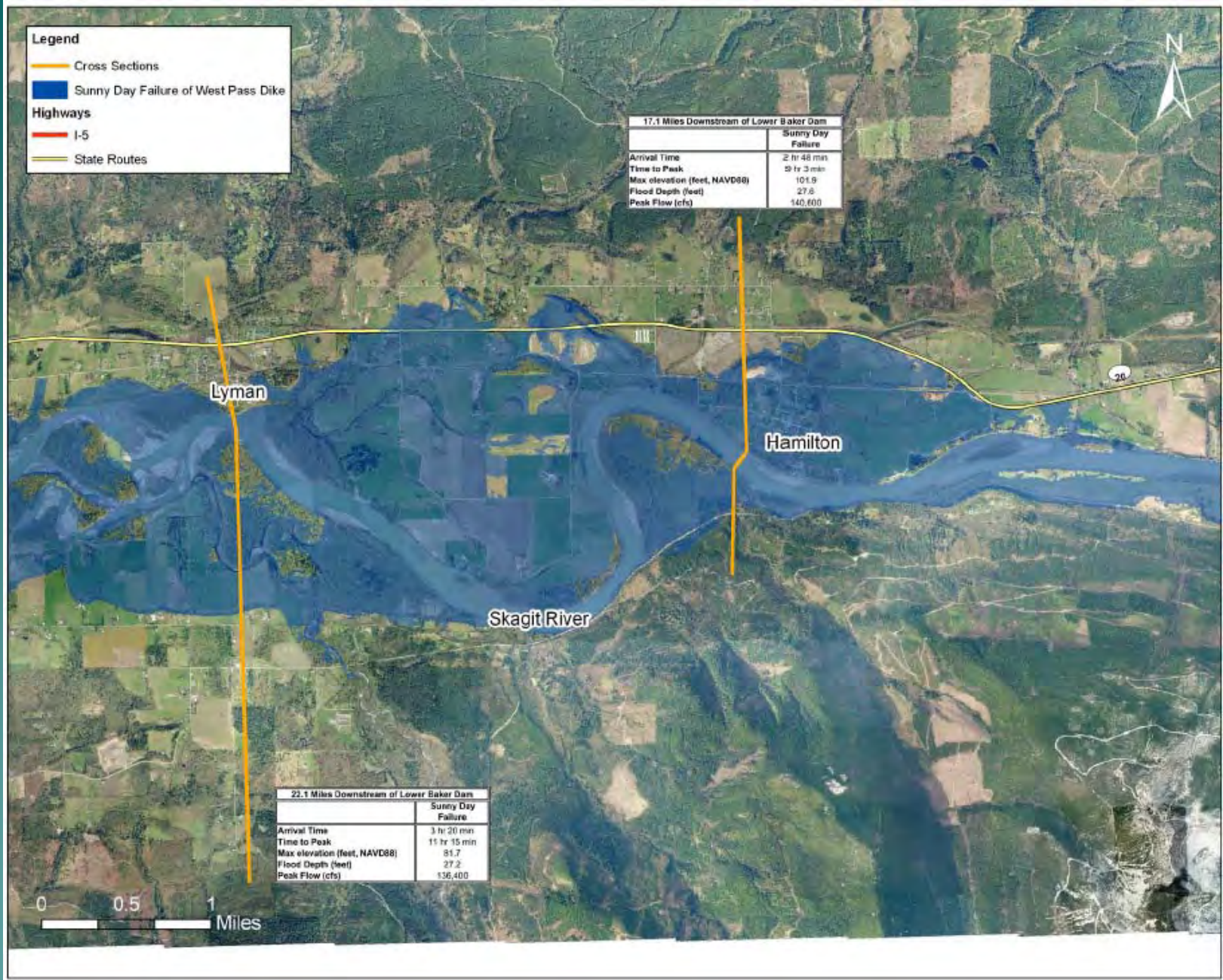
Population at Risk



Population at Risk



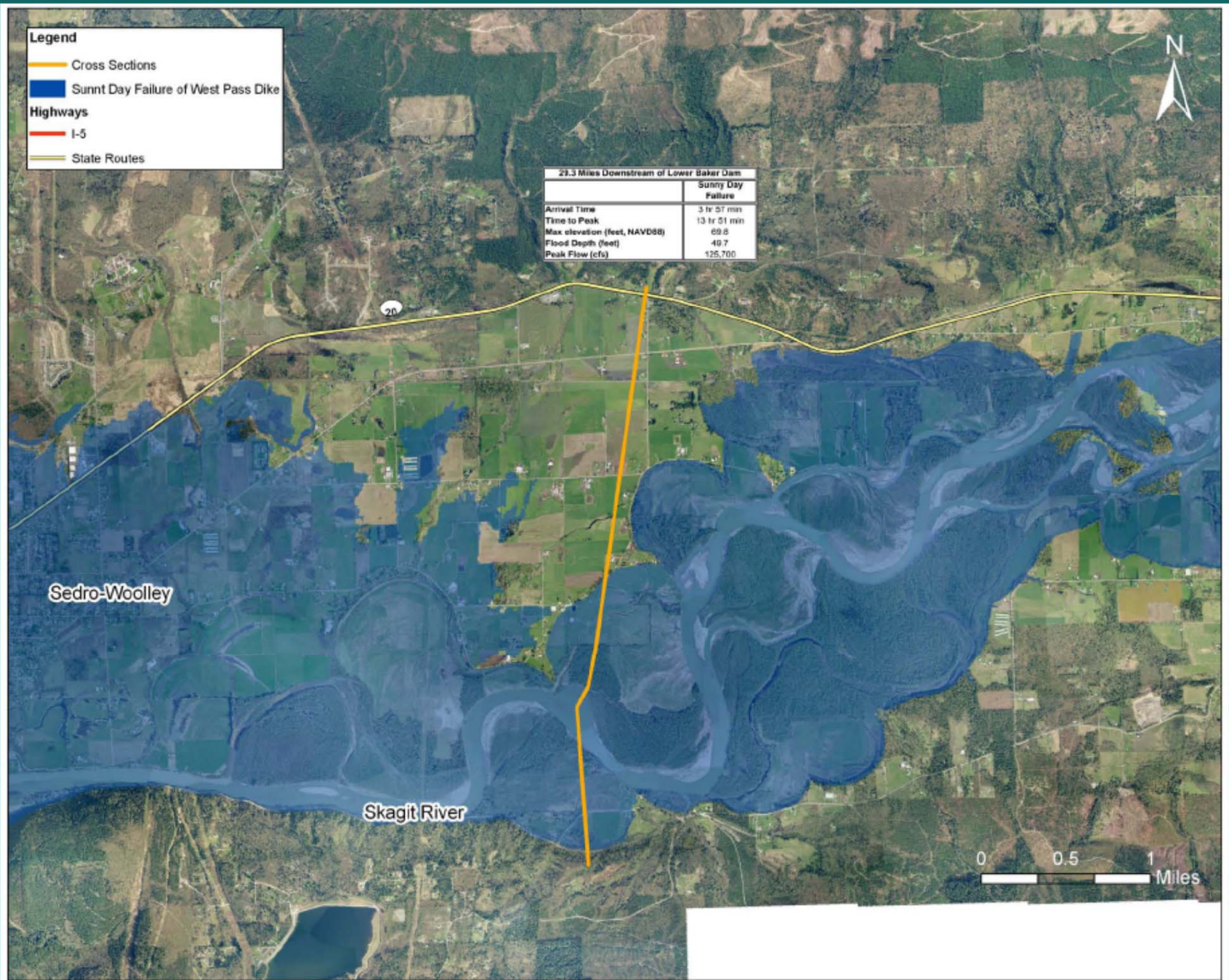
Population at Risk



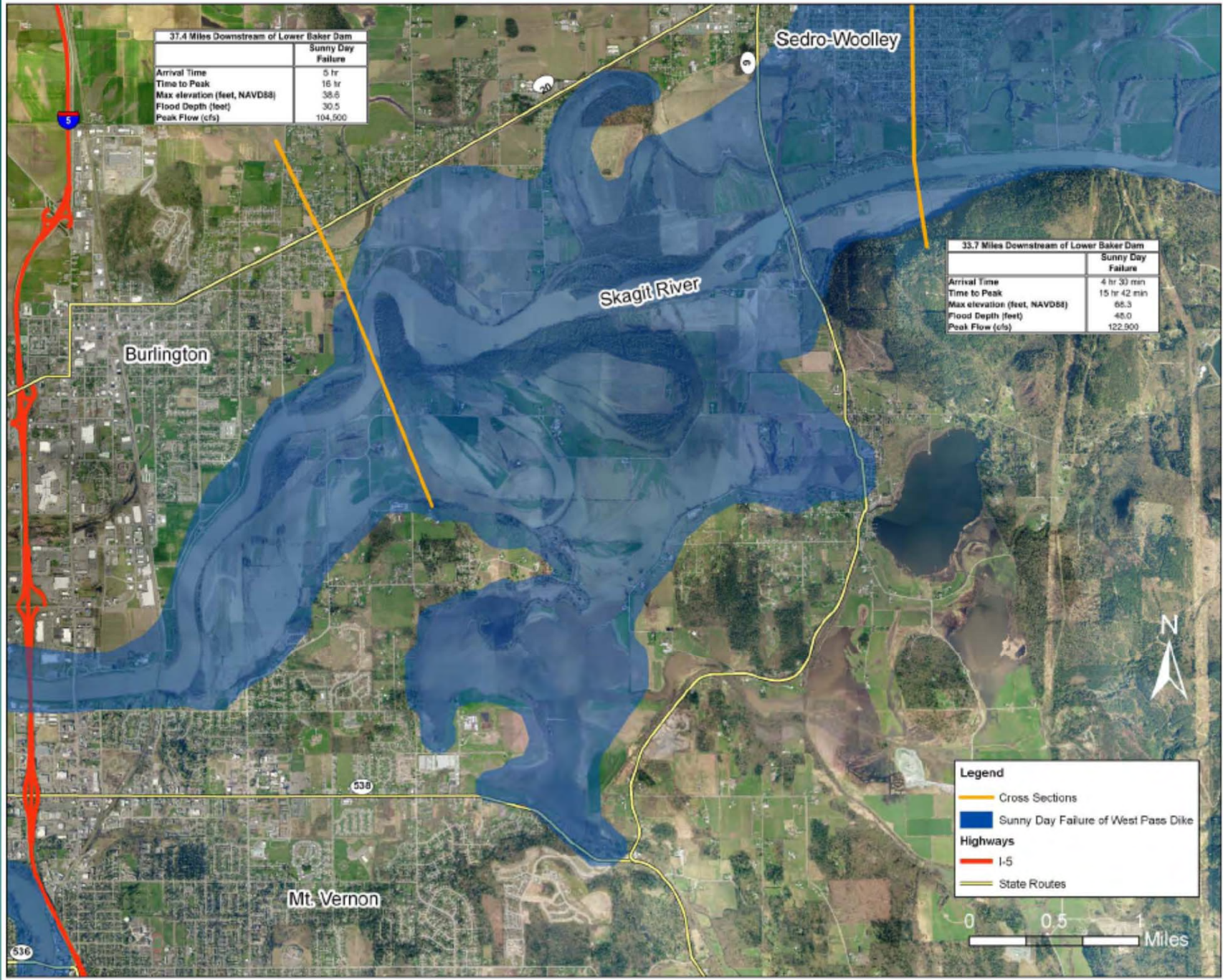
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Population at Risk



FERC Screening Level Consequence Tool*

	Low Flood Severity	Medium Flood Severity	High Flood Severity
	(No buildings washed off foundation, less than 10-foot depth of flooding) DV < 50	(Homes destroyed but trees or mangled homes remain, greater than 10-foot depth of flooding) DV > 50	(Instantaneous dam failure, inundation area swept clean of structures, deep flood depth reached very quickly)
No Warning (Excess response time less than 15 minutes)	0.01	0.15	0.75
Some Warning (Excess response time 15 to 60 minutes)	0.005	0.03	0.4
More Warning (Excess response time Greater than 60 minutes)	0.0003	0.02	0.2

* From Wayne Graham's Simplified Procedure for Estimating Loss of Life



PLL Parameters Discussion

PAR

- ◆ Campground 100 sites – 30% occupied per year

- ◆ PAR as follows

– Kulshan Campground -	30
– Concrete -	62
– Down through Hamilton, Mile 12 to 29 –	511
– Down through Sedro Woolley – Mile 29 to 42 -	3124
– Down past Mt Vernon – Mile 42 + -	4248
– Total -	7975

FERC Screening Level Consequence Tool*

Distance (miles)	Failure Notification Time (min)	PAR Description	PAR	Flood Severity	Adjustment Factor	PLL
0 to 3	0	Campground	30	High	0.75	22
3 to 9	0		0	Low	0.01	0
9 to 12	60	Concrete	62	Medium	0.02	1
12 to 29	100	Hamilton	511	Medium	0.02	10
29 to 42	195	Sedro Woolley	3124	Low	0.0003	20
42 to remainder	255	Mt. Vernon	4248	Medium	0.02	64

Total

117

* From Wayne Graham's Simplified Procedure for Estimating Loss of Life



PLL Parameters Discussion

PAR

- ◆ DamBreak - Based on WPD breach flood depths – conservative parameters
- ◆ Flood Severity - Based on Depth Velocity (DV) calculation – Flow/topwidth in feet
- ◆ Warning Time - Generally between little warning time at the Campground and 5 hours in Mt. Vernon



Economics

- Residents – 7945
- Homes affected likely about – 2500+
- Towns, Cities, and Communities
 - Camp Horn Community
 - Town of Hamilton
 - City of Sedro Woolley
 - Partial City of Burlington
 - Partial City of Mt. Vernon
- Damage estimate \$2 Billion without considering dam replacement and lost power



Consequence Category

<p>1-10</p>	<ul style="list-style-type: none"> • Direct loss of human life possible, related primarily to difficulties in warning and evacuating recreationists and few scattered individual houses close to the dam or downstream population centers with extensive warning time. • Minor to significant damage to permanently occupied structures, roadways and bridges throughout the inundation zone (~\$50 to \$100 M). • Local to regional disruption of essential facilities and access. • Medium environmental damage • Less than 1 year recovery. 	<p>7</p>
<p>10-100</p>	<ul style="list-style-type: none"> • Loss of human life is expected due to the severity of the flooding and nearby population centers (10-100 people). • Downstream discharges result in significant property damage (~\$100 M to \$500 M) • Regional disruption of essential facilities and access. • Significant environmental damage • 1 - 2 year recovery . 	<p>8</p>
<p>100-1000</p>	<ul style="list-style-type: none"> • Significant loss of human life is expected due to the severity of the flooding and moderate population affected within close proximity of the dam. • Significant property damage over a large area (~\$500 M to \$1 B)... • Multi-regional disruption of essential facilities and access. • Large environmental damage • Multi-year recovery 2-5 years. 	<p>9</p>

RISK

- **Likelihood for WPD Internal Erosion**
PFM = Low

- **Consequences - PLL > 100**

Consequence Category = 8 (PLL)

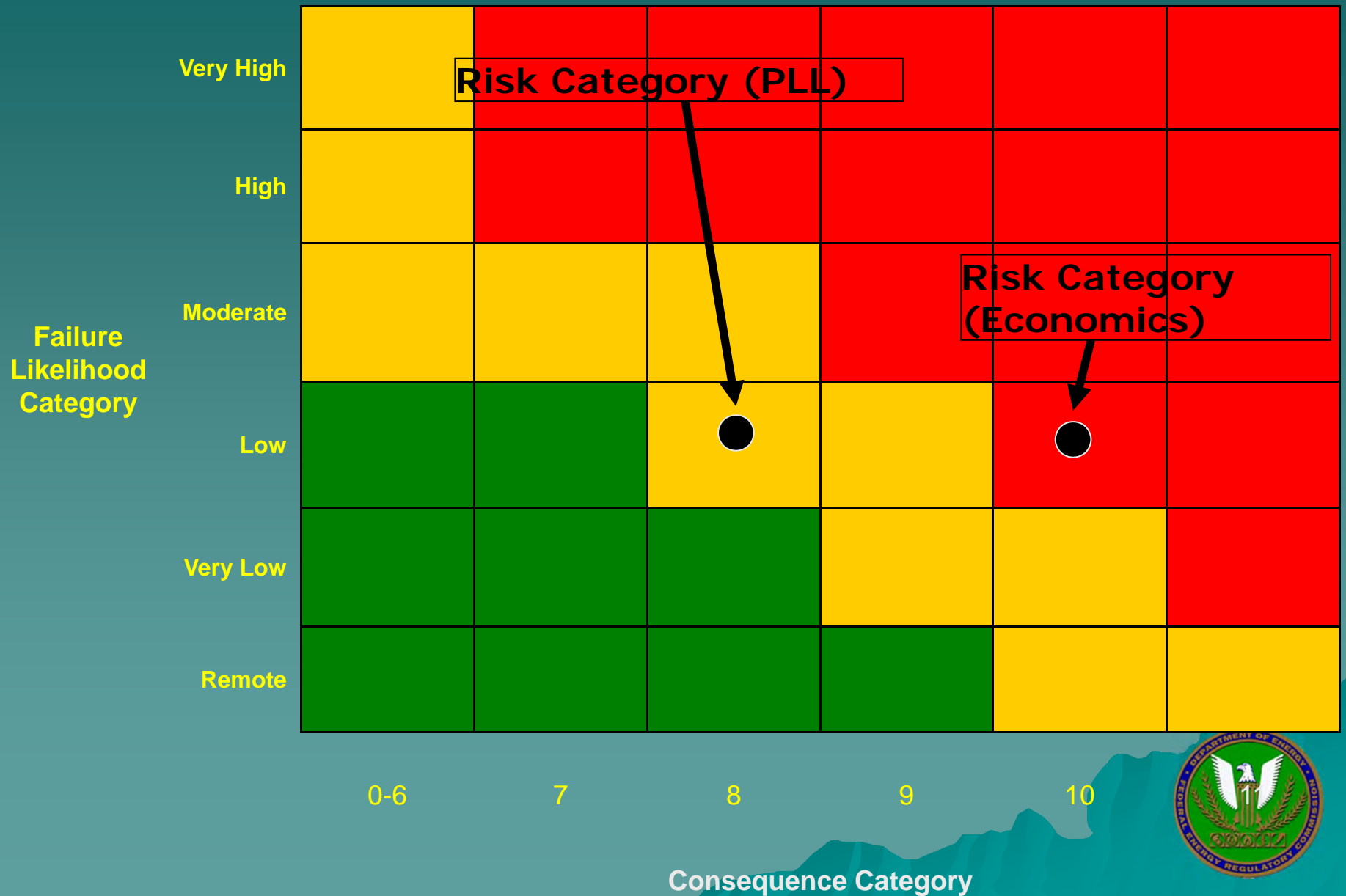
= 10 (Economics)



Confidence Estimate

- ◆ Estimate of Consequence would be improved with more information but might not change the category
- ◆ We have Medium to Low confidence in the category estimate.

Risk Matrix Estimate



Questions?

