BAKER RIVER PROJECT – FERC 2150

Stochastic PMP/ PMF/ IDF Experience & Thoughts

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NHA Hot Topics Session
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The take away from this presentation:

“How often would that there PMF happen?”

And “is that a reasonable criteria?”

UPPER BAKER DAM

Gravity Dam:
On-line in 1959   312’ High
1,200’ Long
103 MW Output

Reservoir: 9-Miles, 215 Square Mile Drainage Basin; 184,796 Acre-feet; 4,985 Acres Coverage, Elevation 724-feet.

Mt Baker to West 10, 878 ft, Mt Shuksan to North is 9,131-feet.

[118,640 cfs PMF inflow 1969]

LOWER BAKER DAM

Gravity Arch:
On-line 1927
285' High
550' Long
80 MW Output

Reservoir:
7 miles long
82 Square Miles Drainage Area
2,278 Acre Surface
146,279 Acre-feet

438.6' Full Pool Elevation

[108,250 cfs PMF inflow, 1969

DEPRESSION LAKE ("pumping pond")

WEST PASS DIKE

DEPRESSION LAKE DIKE

TWO EARTHEN DIKES

West Pass Dike: 'wing dam', 64 Feet High, 1200 Feet long;

Depression Lake Dam: 22 Feet High 3000 Feet long.

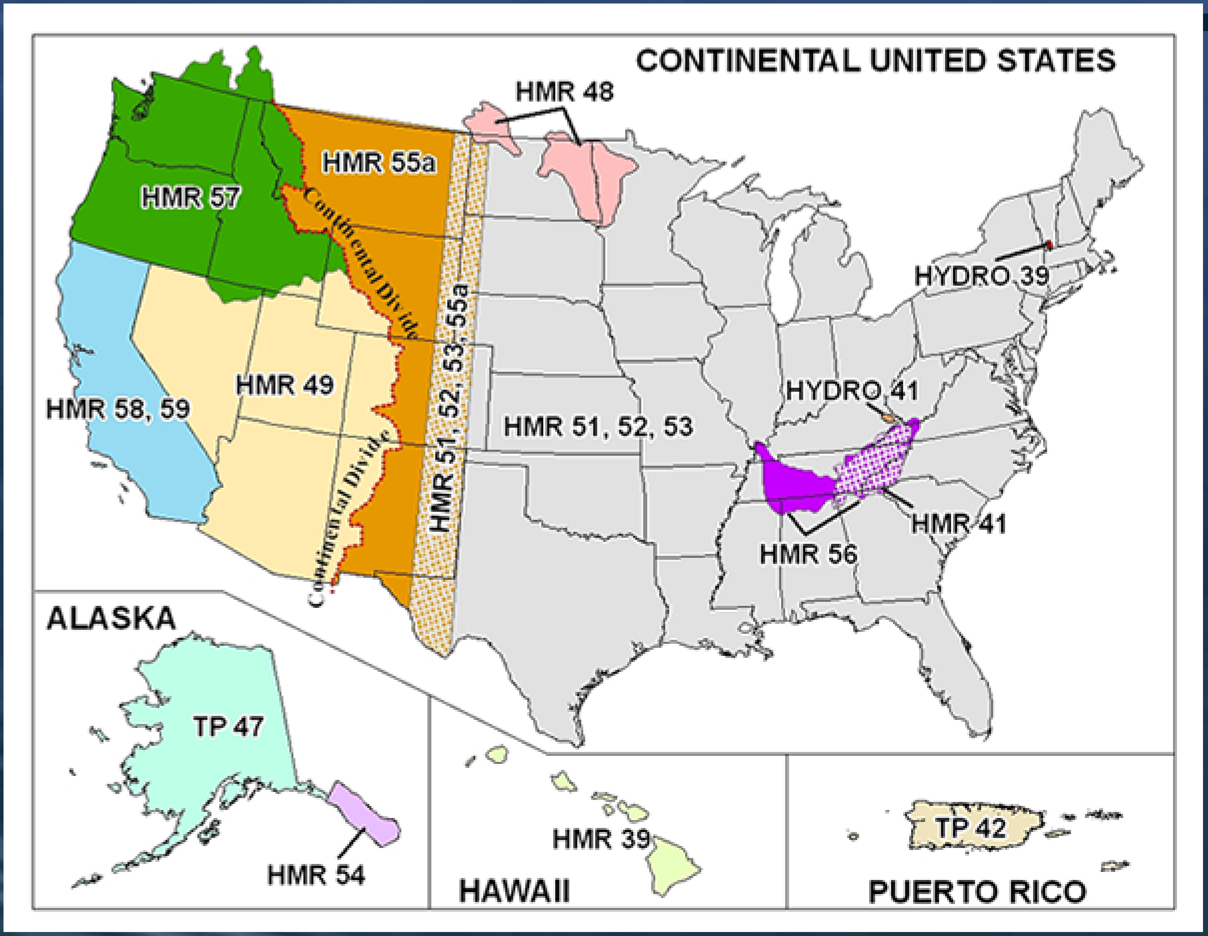
Depression Lake: 200 Acre Ft.

As FERC licensees we are being asked to
determine our Probable Maximum Flood for our projects
(FERC Guidelines Chapter 8 affirmed 2001)

Typical mandate is to use the latest hydrometeorlogical precipitation report
These reports are by region and numbered, e.g. HMR 57 and
published by the National Weather Service.

The deterministic FERC Chapter 8 guidelines coupled with latest HMR’s,
may result in higher flows than a project design - requiring capital investment.

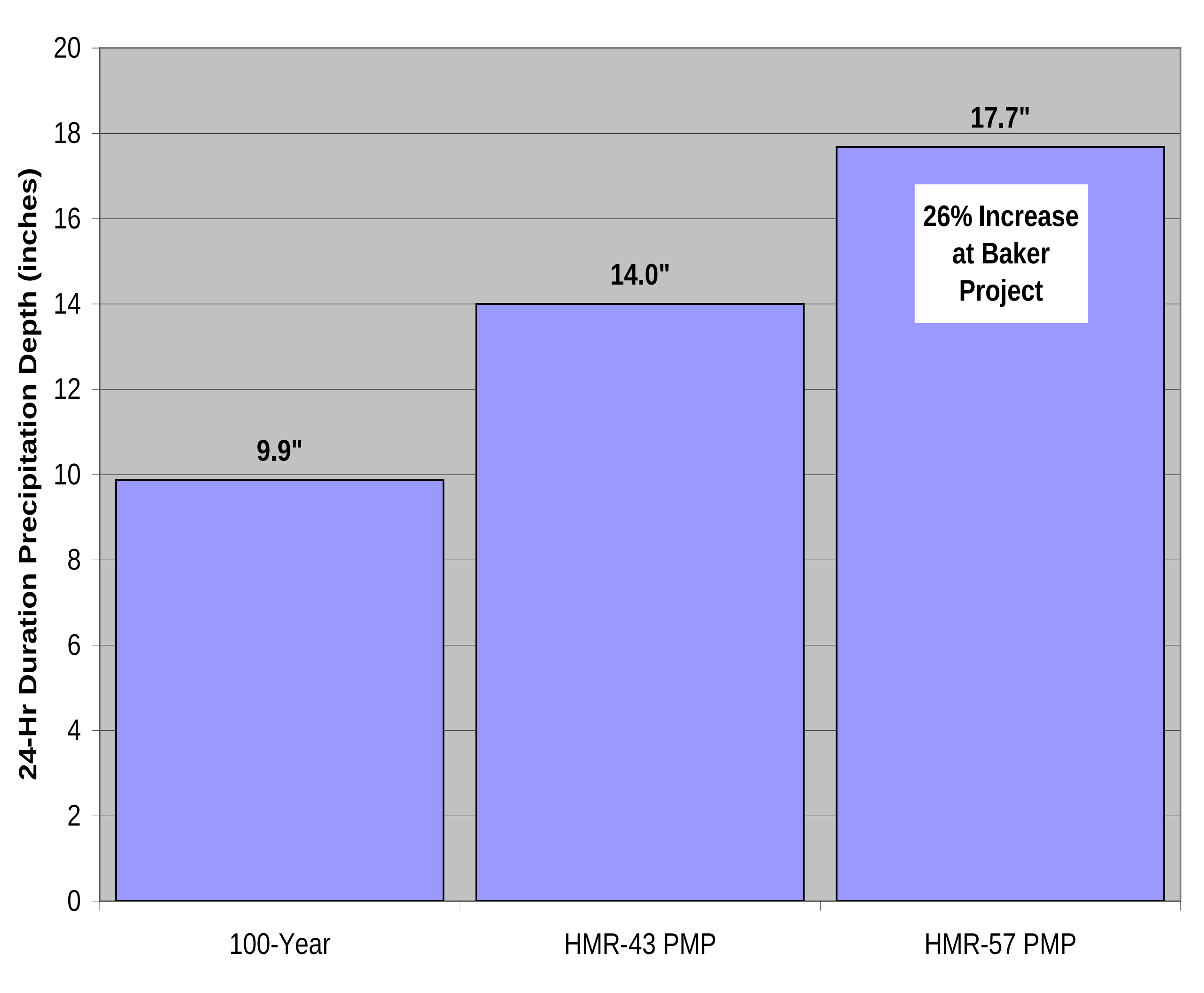
With current databases, GIS geographic information systems, new computer
technology and modeling capabilities,
we are now able to investigate the probabilities or likelihood of an event.
We can now ask what is the annual exceedance probability
of a prescriptive PMF and other flows.



HMR 57 (1994) SUPPLEMENTS HMR 43 (1966)

Deterministic PMF Study

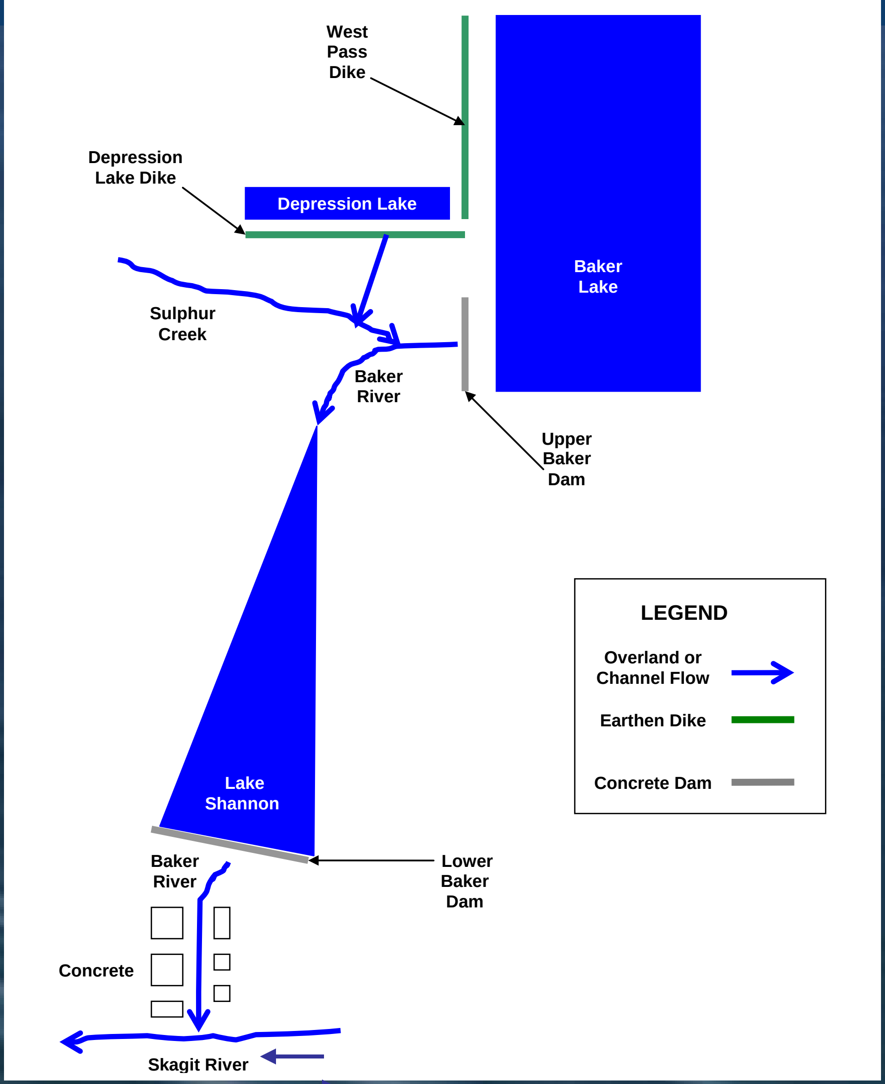
- PSE was required to update the Baker PMF from HMR 43 (1966) to HMR-57 (1994)



Consultants

- TetraTech, Inc.
- MGS Engineering Consultants
- Applied Weather Associates, Inc

Baker Project Modeling



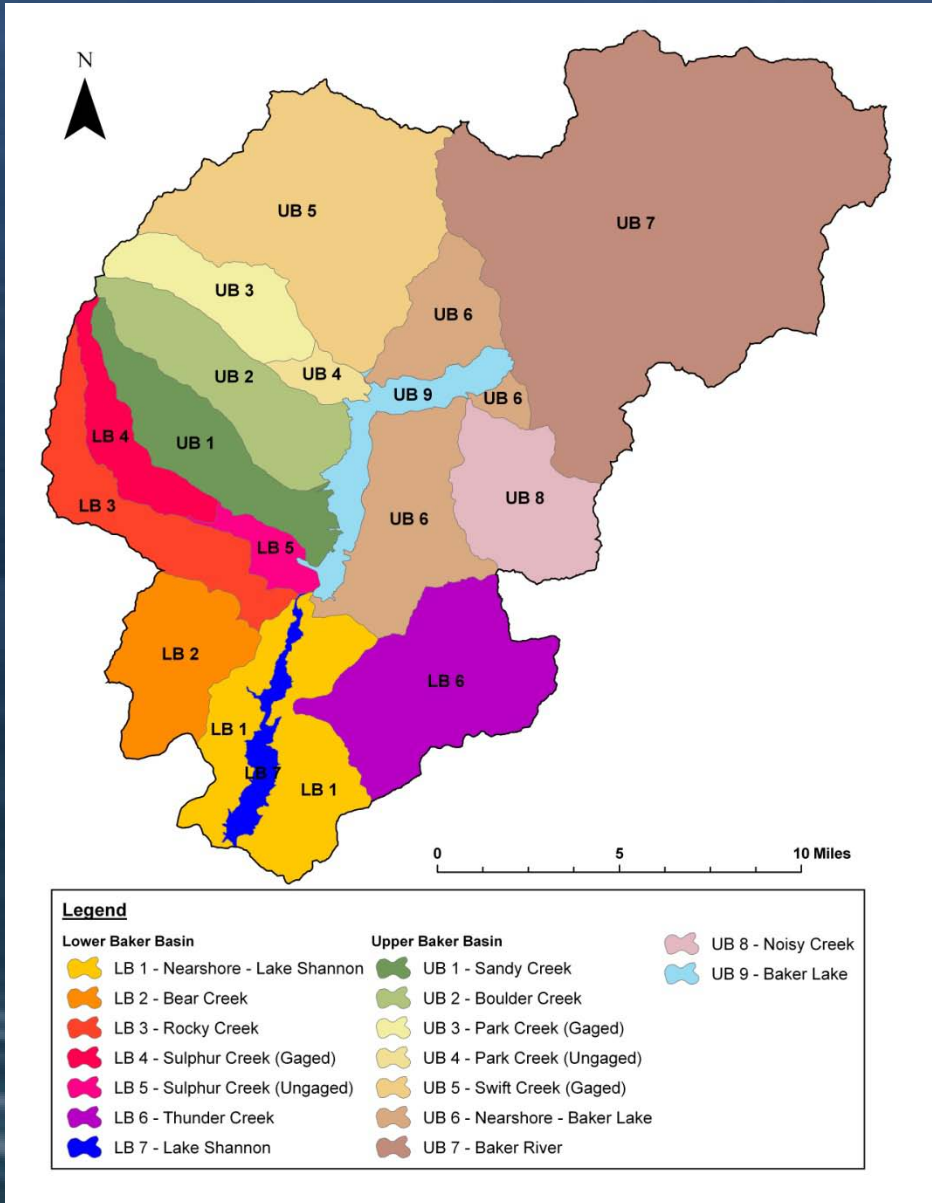
Distributed Hydrologic Modeling Approach

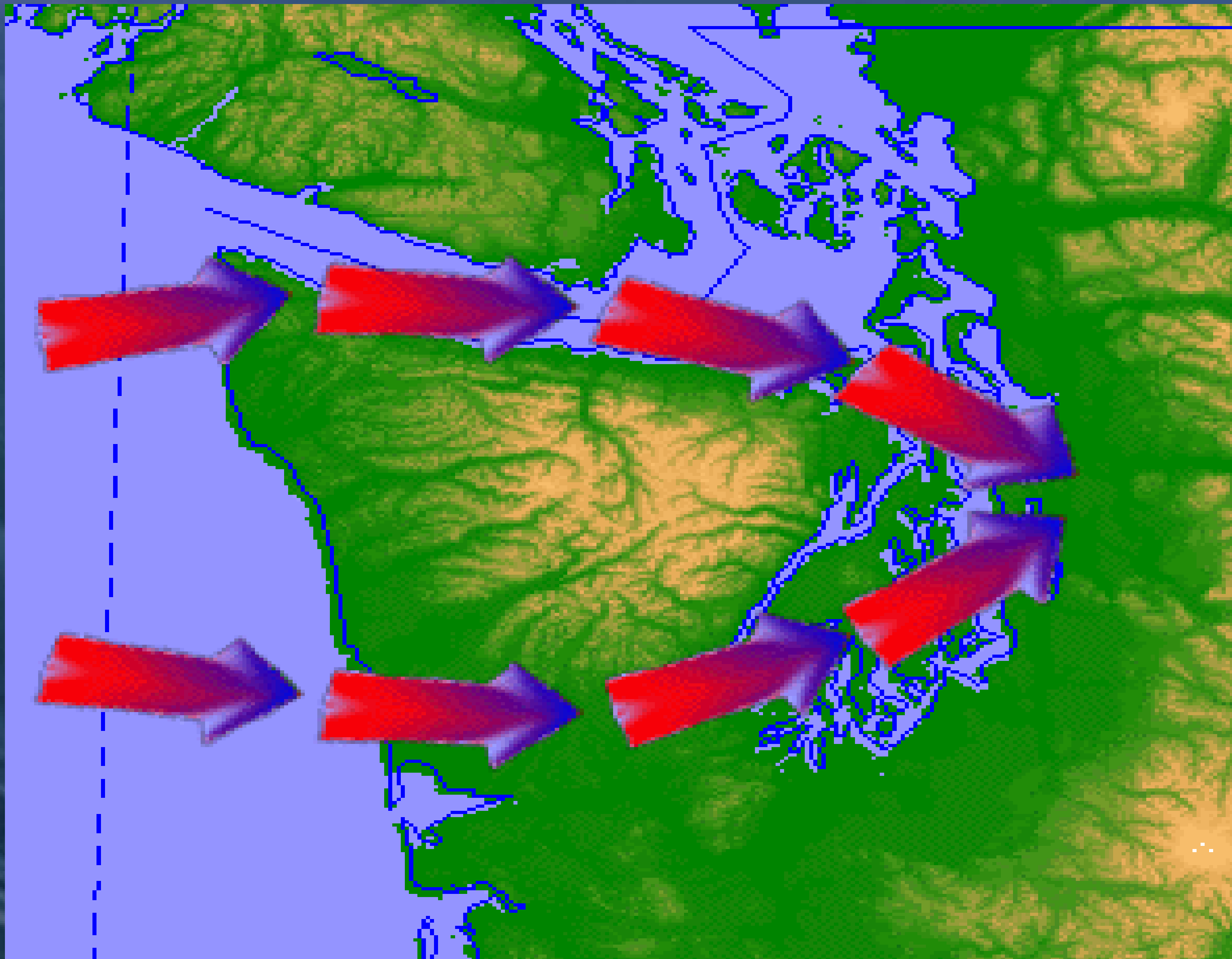
- Precipitation : rain, snow, glaciation, snow-water.

•Soils, surface & bedrock 70% is evergreen forest

- Elevation Zones Mt. Baker is at 10,778 feet.

•Over 5000 zones.



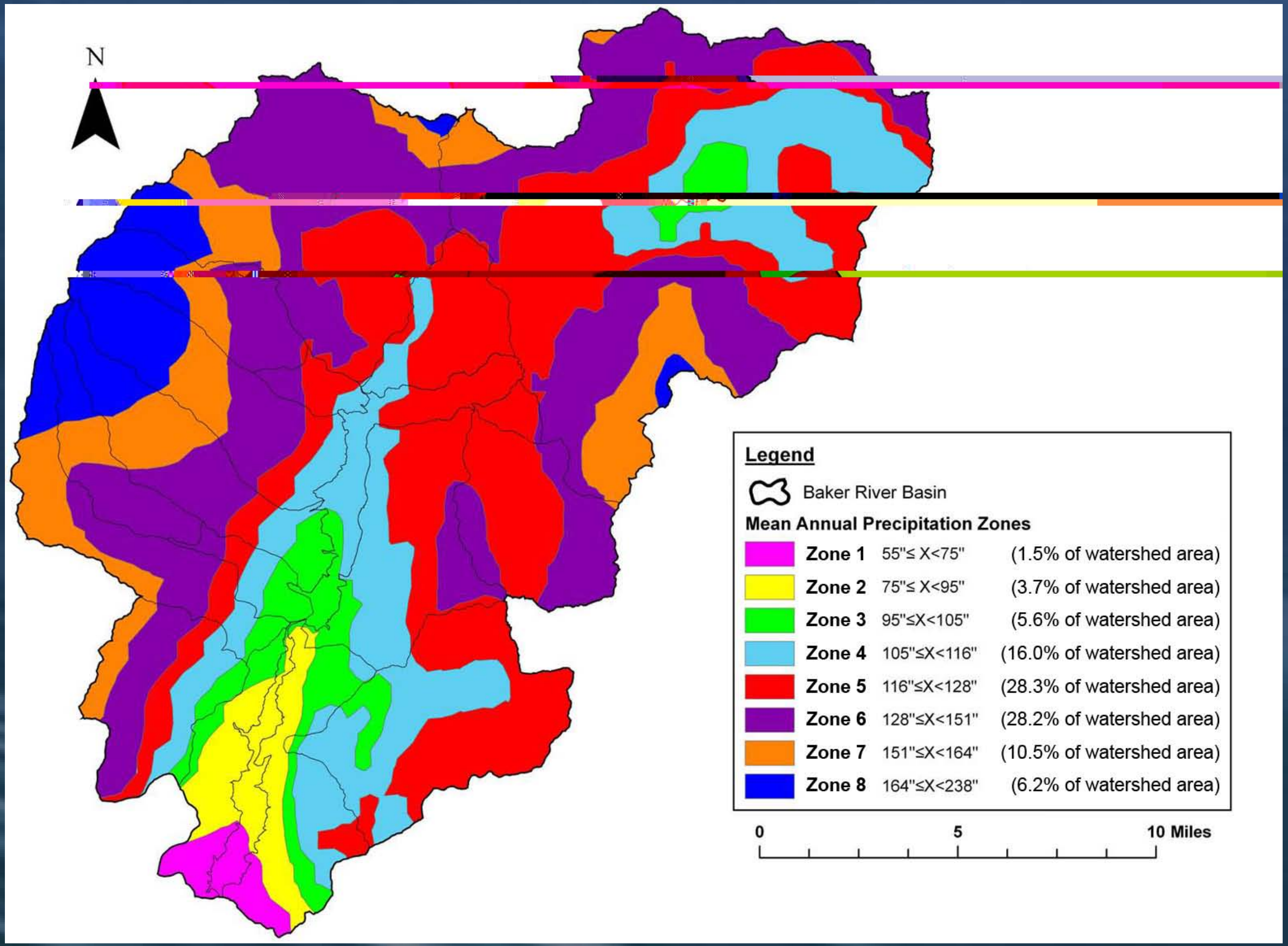


Baker Basin

At Mt. Baker, the temperature decreases approximately 3° F with each 1,000 feet increase in elevation.

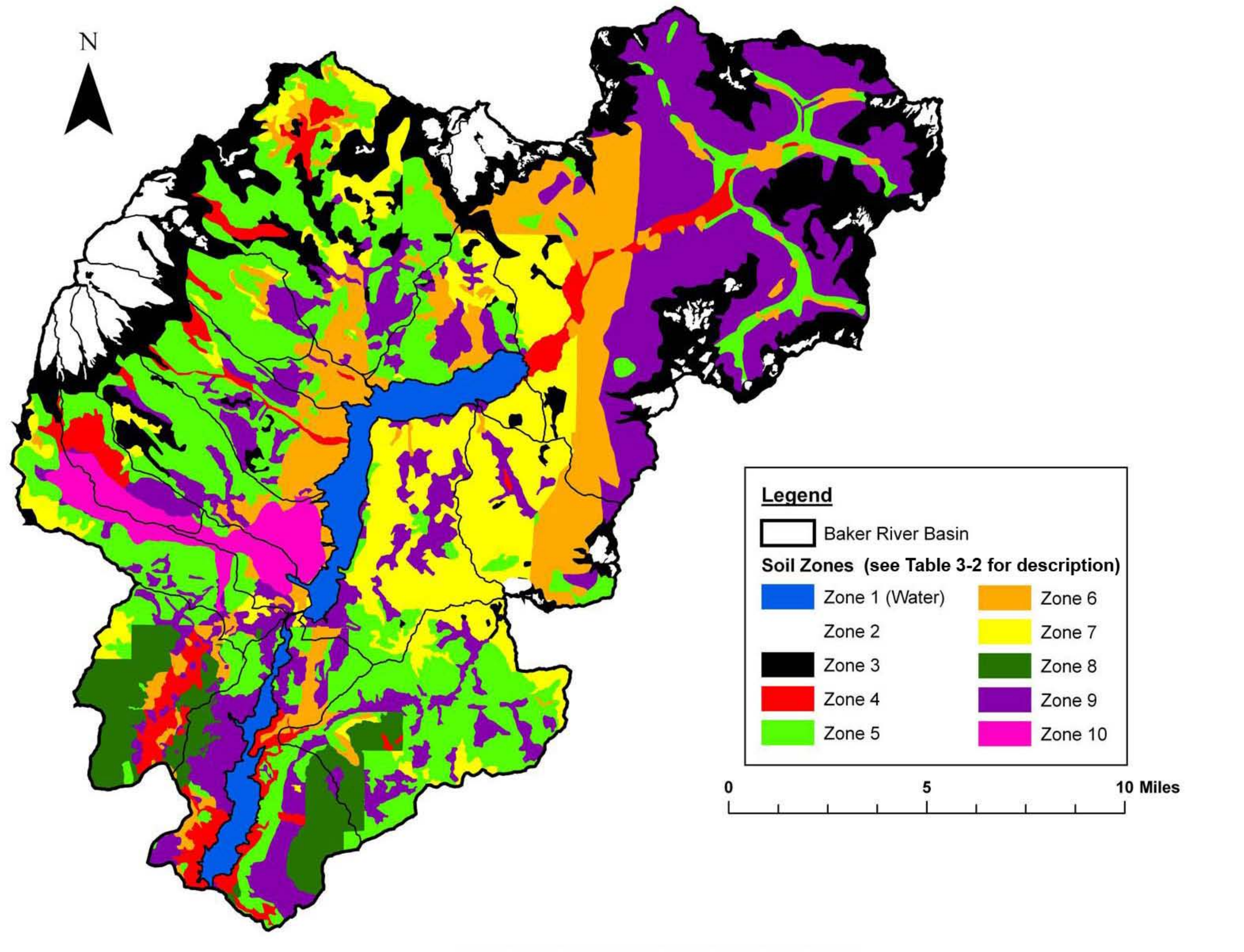
Watershed Characterization

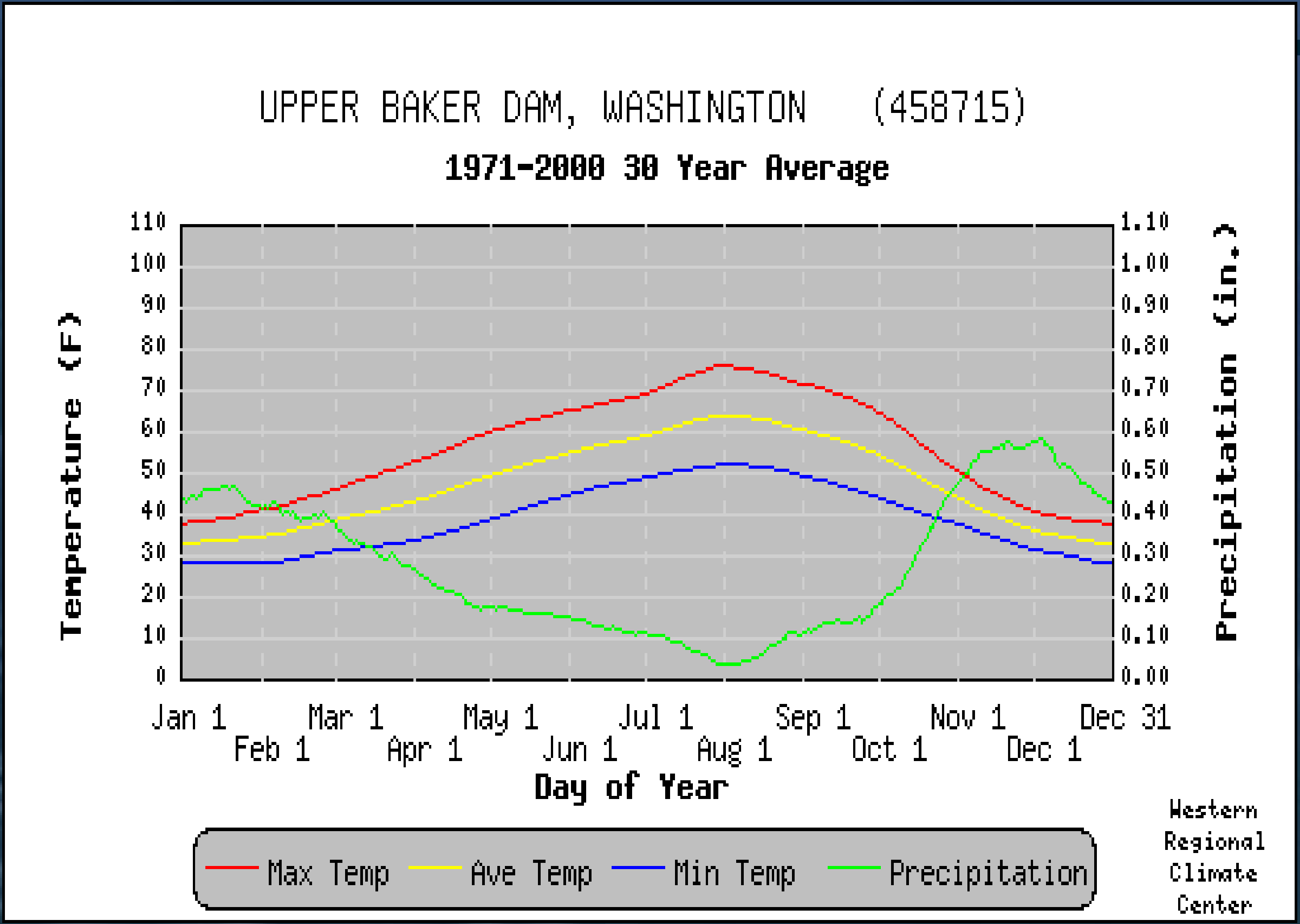
Zones of Mean Annual Precipitation



Watershed Characterization

Soil Zones

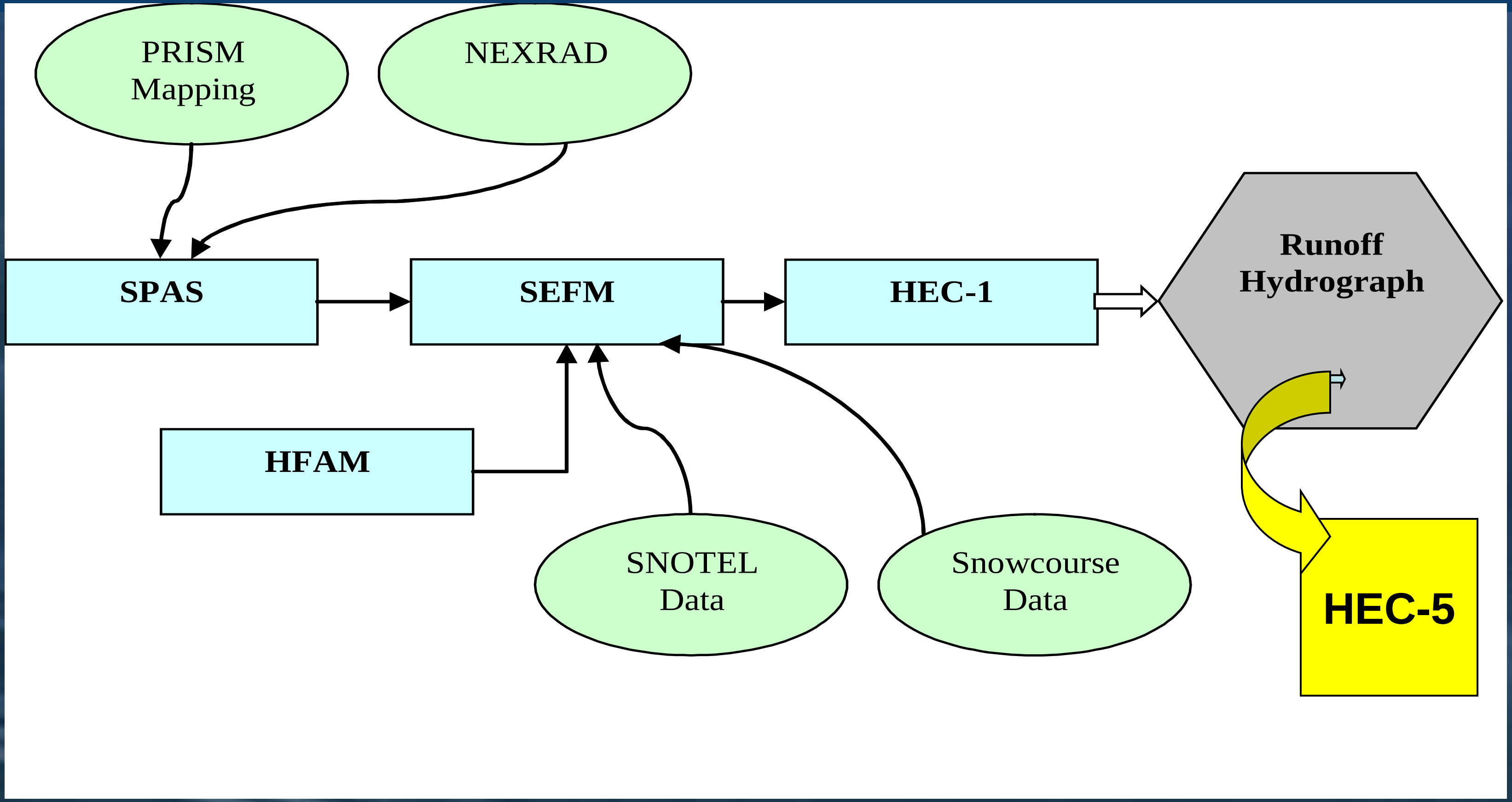



UPPER BAKER DAM, WASHINGTON (458715)
1971-2000 30 Year Average
Temperature (F)
Precipitation (in.)
110
100
90
80
70
60
50
40
30
20
10
0
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Dec 31
Day of Year
Max Temp
Ave Temp
Min Temp
Precipitation
Western Regional Climate Center

PMF Deterministic Hydrograph Modeling

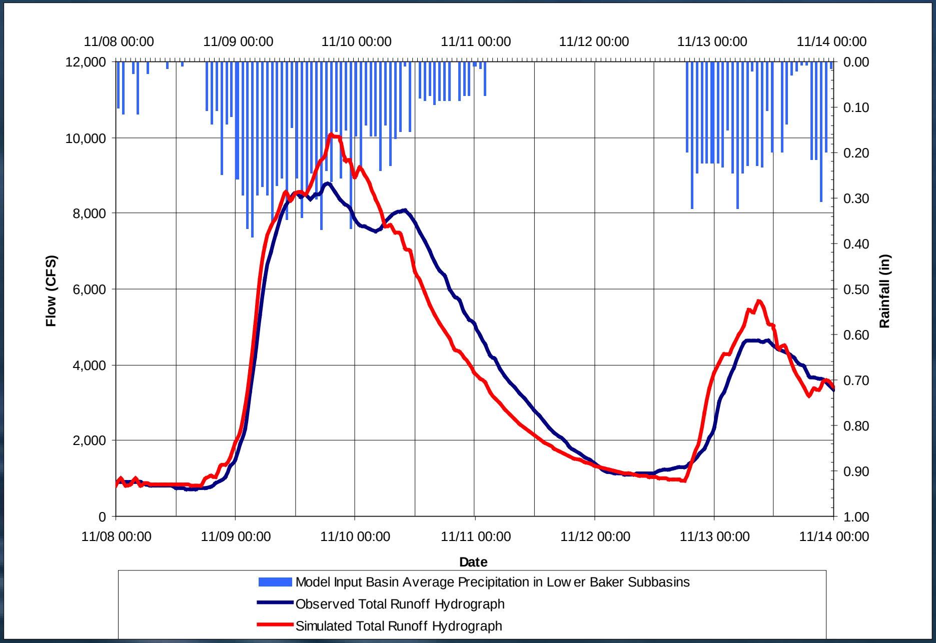
Input Parameters	
Seasonality	All months/seasons
Storm Centering	Three scenarios
Storm Temporal Pattern	Three patterns
Antecedent Precipitation	Average cumulative end of month value for each month
Antecedent Snow Water Equivalent	Iteratively determine return period resulting in maximum runoff volume
Antecedent Snowpack Density	Average end of month
Antecedent UB Reservoir Elevation	ACOE flood control rule curve UBK
Antecedent LB Reservoir Elevation	Normal pool
Basin In-Flow	Average monthly flow
Air Temperature	HMR-57 methodology
Wind Speed	HMR-57 methodology

Model Development

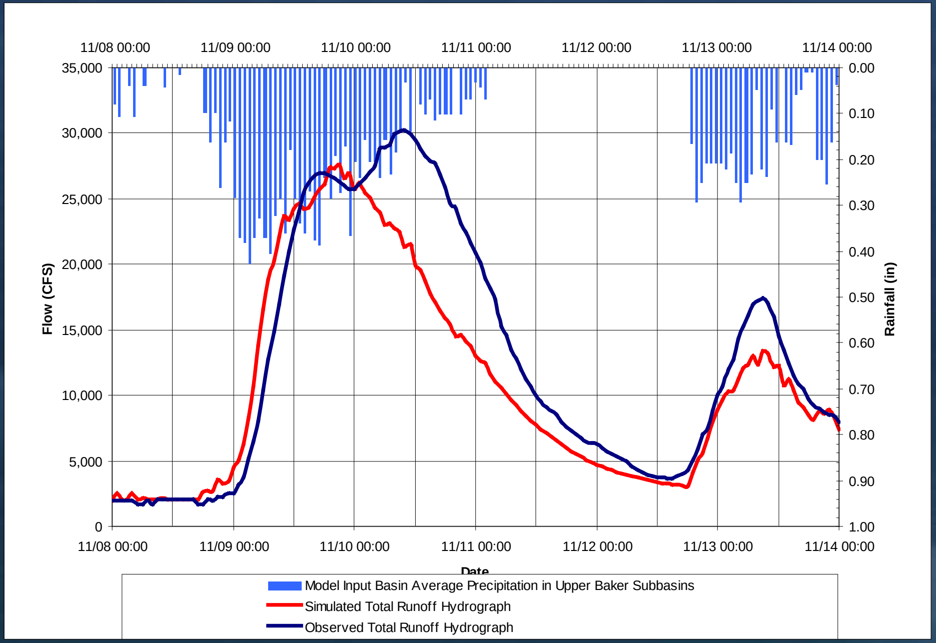


Flow Diagram of Hydrograph Models Used. HEC-5 was used for routing the runoffs through the project.

Hydrologic Model Calibration



Lower Baker Tributary Hydrograph



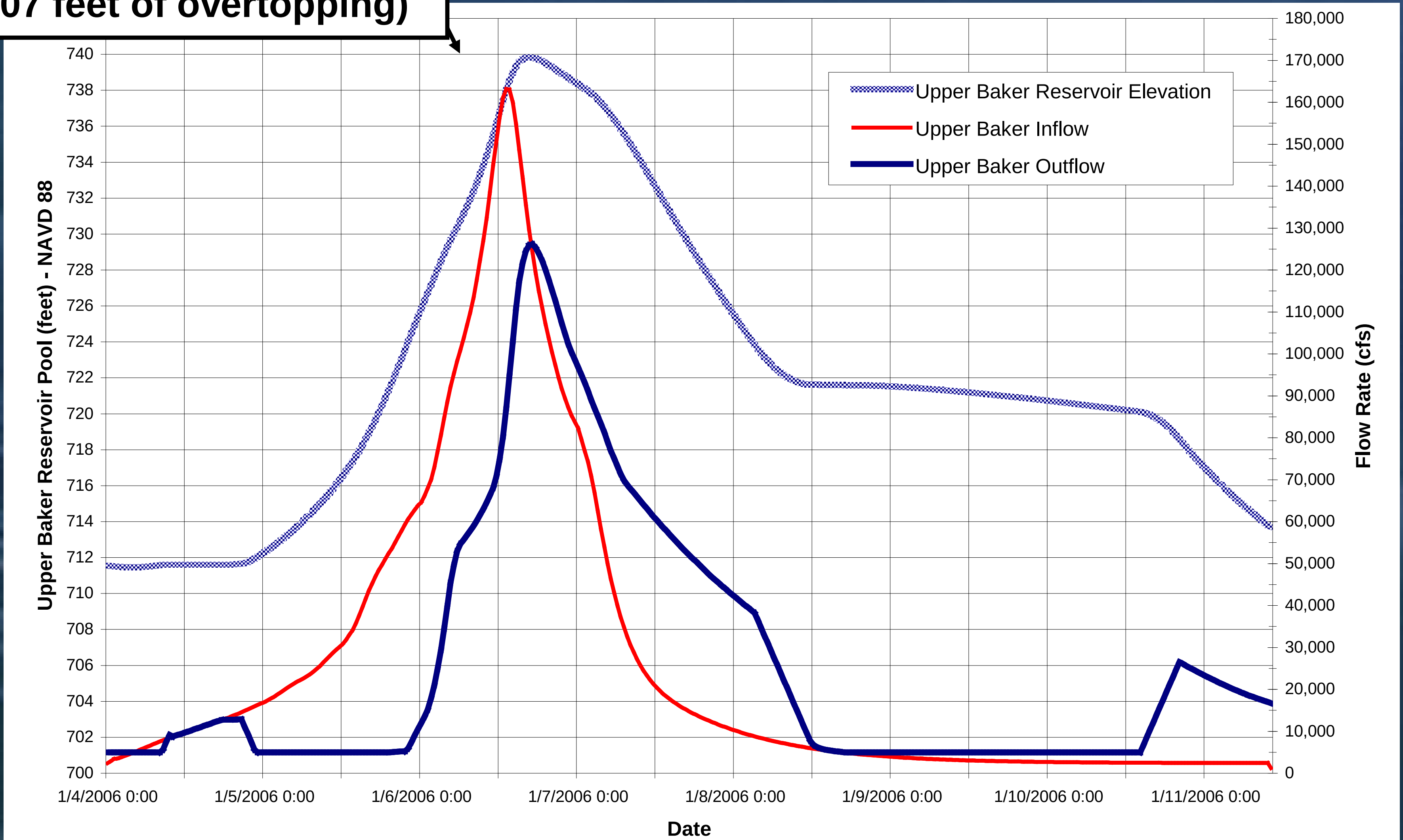
Upper Baker Tributary Hydrograph

November 1990 (1) Hydrographs

Upper Baker PMF Hydrographs

Deterministic – Pre Global Sensitivity Analysis

Max Res. Elev. = 739.84 ft (4.07 feet of overtopping)



Global Sensitivity Analysis

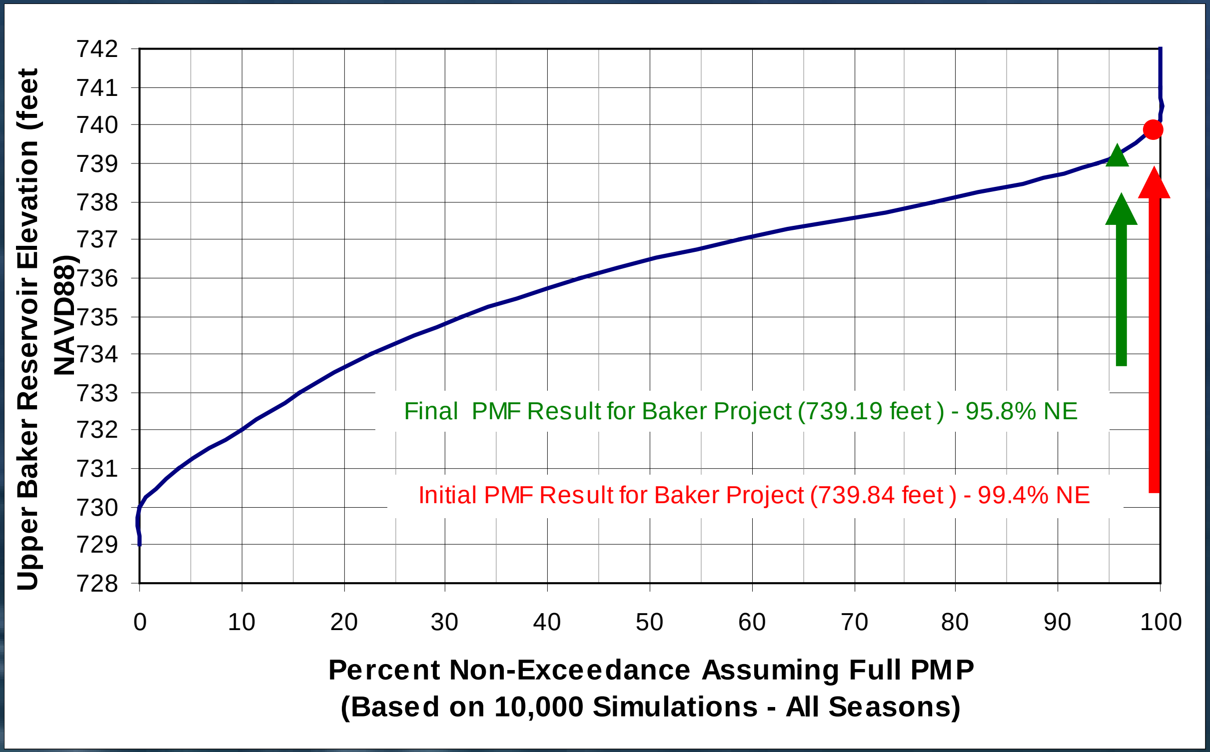
Per FERC Guidelines.

Table 8-10. Flood and Reservoir Response Sensitivity to Input Parameters, and Input Parameter Uncertainty

Input Parameter	Flood Response Sensitivity	Reservoir Response Sensitivity	Parameter Uncertainty
Seasonality of Occurrence	Moderate	Moderate	Low
Centering of Storm	Low	Low	Moderate
Storm Temporal Pattern	Moderate	**High**	Low
Antecedent Precipitation	Moderate	Moderate	Low
Antecedent Snow Water Equivalent	**High**	**High**	Moderate
Antecedent Snowpack Density	Low	Low	High
Antecedent Reservoir Elevation Lower Baker	n/a	Low	Moderate
Antecedent Reservoir Elevation Upper Baker	n/a	Moderate	Moderate

PMF Hydrographs - Sensitivity

Global Sensitivity Analysis – Frequency Analysis



PMF Hydrographs - Final

	Scenario	Peak inflow CFS	Peak outflow CFS	Max Pool Elev. NAVD 88	Depth of overtopping
Upper Baker Reservoir	2 year snow pack	157,800	111,500	739.19	3.42
Lower Baker Reservoir	2 year snow pack	136,800	120,300	458.43	13.86

Stochastic Approach …

1) *Use Deterministic Rainfall-Runoff Model (HEC-1)*

2) *Treat Hydrometeorological Inputs as Variables*

3) *Stochastically Generate Multi-Thousand Years of Storms and Dates of Storm Occurrence – Use Monte Carlo techniques*

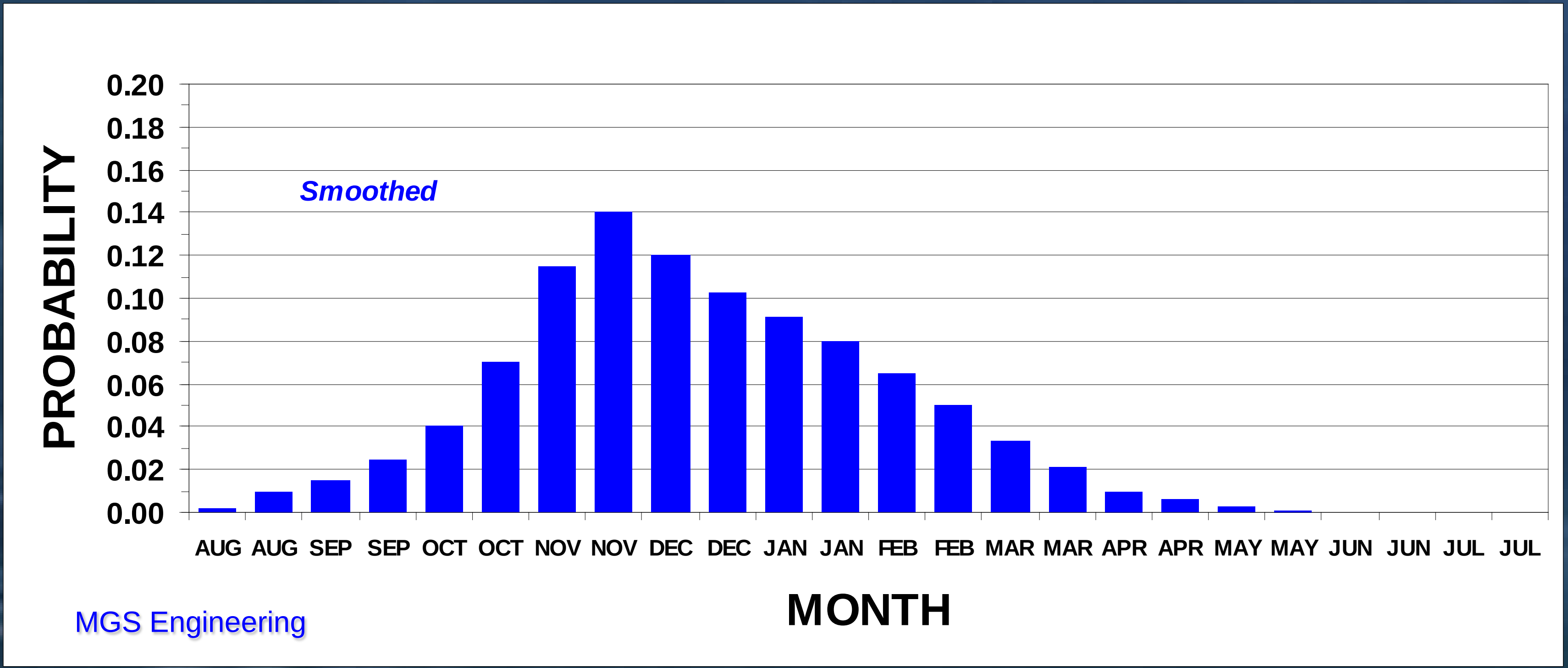
4) *Select Hydrometeorological Inputs to Accompany Storms and Maintain Seasonal Characteristics and Dependencies Where They Exist*

5) *Compute Multi-Thousand Flood Annual Maxima using Hydrologic Model and Input Datasets*

6) *Conduct Frequency Analysis of Model Outputs for: Flood Peak, Runoff Volume, Maximum Reservoir Level*

Storm Seasonality

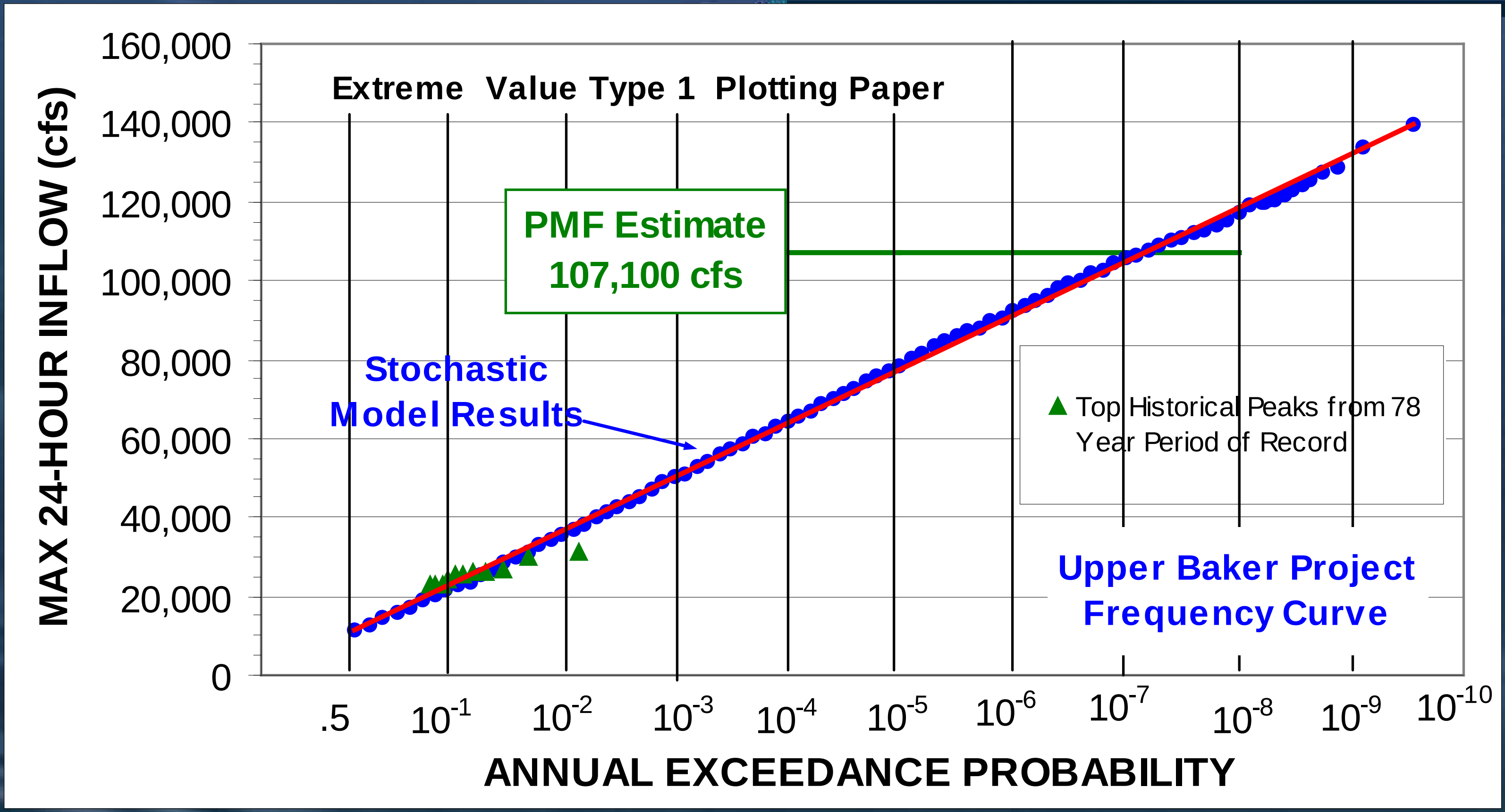
- *Database of 132 extreme storms (rarer than 20-yr event)*
- *Windward Puget Sound Lowlands and West Slope of Cascades*



Uses:

- ***Effectiveness of current flood control rule curve***

Flood Frequency Curves



- *Stochastic model verified using historical record*
- *Stochastic results are therefore extension of historical record*

PMF ANNUAL EXCEEDANCE PROBABILITIES

Table ES-1. Estimated Annual Exceedance Probabilities Associated with PMF Hydrograph for Upper Baker Dam

Flood Characteristic	Magnitude	Annual Exceedance Probability
Peak Inflow	**157,800 cfs**	**5.1×10^{-9}**
Maximum 24-Hour Inflow	107,100 cfs	7.2×10^{-8}
Maximum 72-Hour Inflow	59,200 cfs	4.5×10^{-7}
Maximum Reservoir Elevation	739.19 feet [a]	1.0×10^{-8}

Notes:
a.Elevation referenced to North American Vertical Datum of 1988 (NAVD 88)

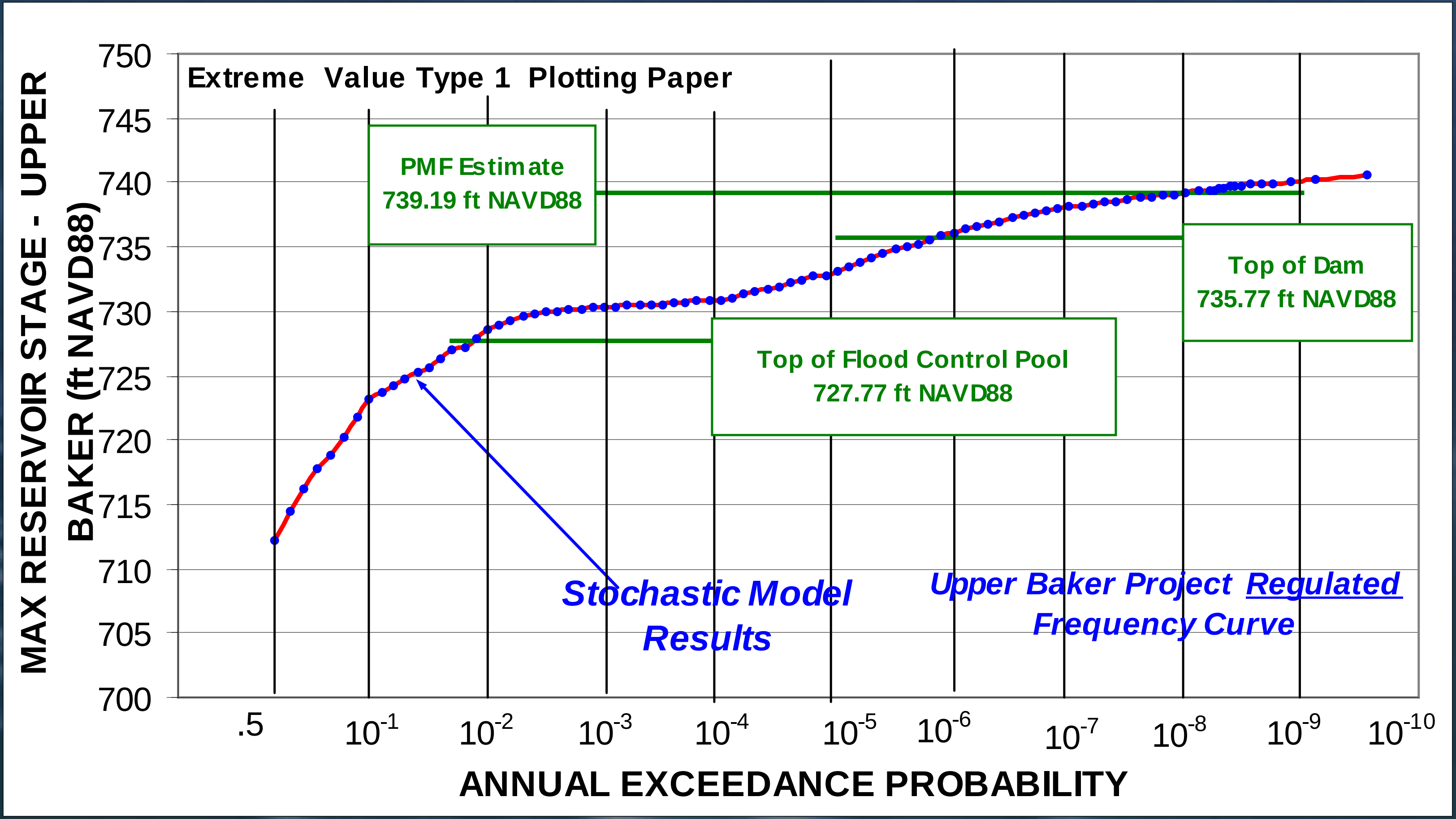
Table ES-2. Estimated Annual Exceedance Probabilities Associated with PMF Hydrograph for Lower Baker Dam

Flood Characteristic	Magnitude	Annual Exceedance Probability
Peak Inflow	**136,800 cfs**	**2.8×10^{-8}**
Maximum 24-Hour Inflow	113,200 cfs	5.4×10^{-8}
Maximum 72-Hour Inflow	67,000 cfs	9.5×10^{-7}
Maximum Reservoir Elevation	458.43 feet [a]	5.3×10^{-8}

Notes:
a.Elevation referenced to North American Vertical Datum of 1988 (NAVD 88)

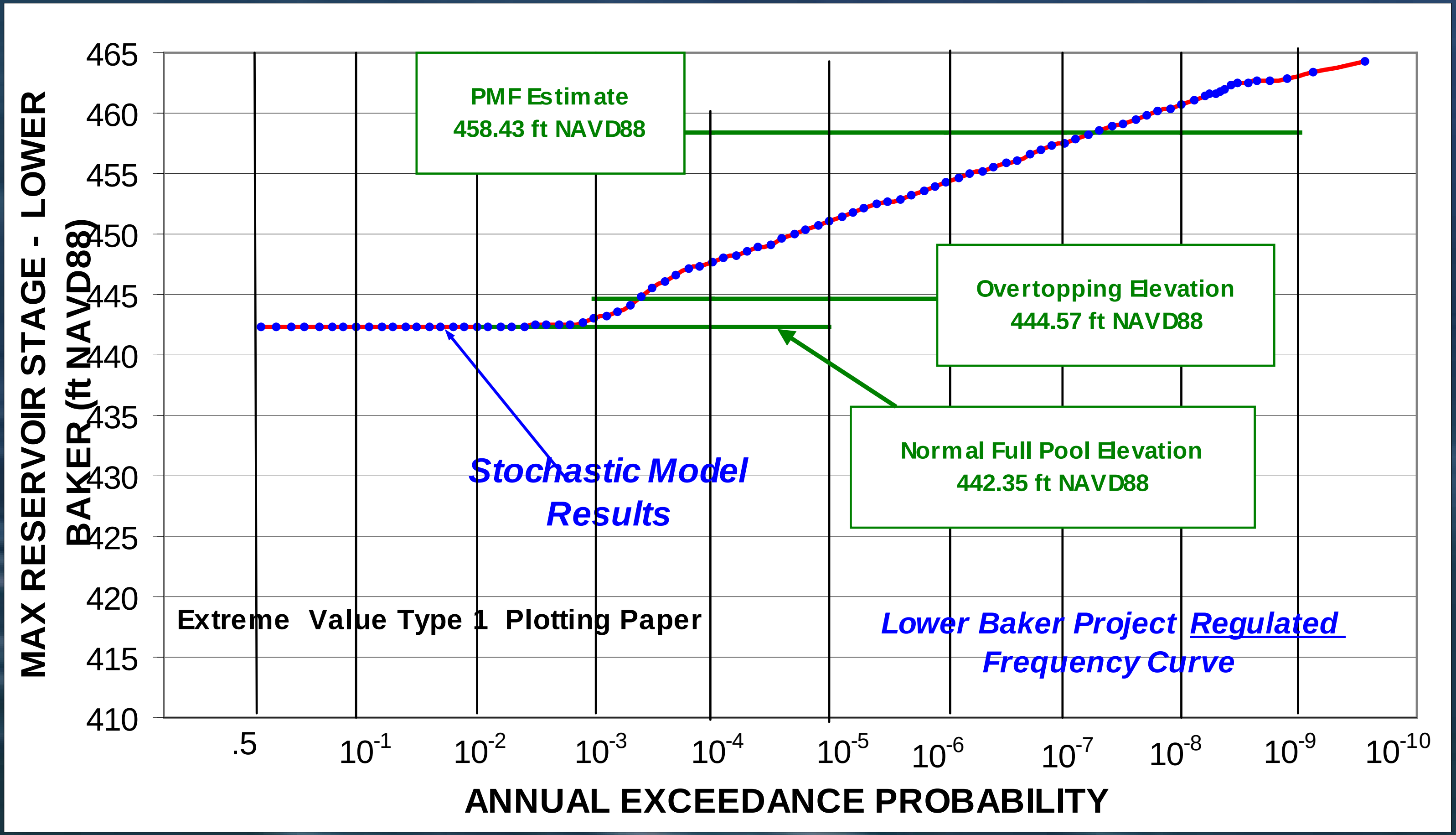
Flood Frequency Curves

Upper Baker Max Elevation



Flood Frequency Curves

- Lower Baker Max Elevation



History of Stochastic Event Flow Model

Development started in 1996 for USBR

Initial Public Domain Model Completed in 1998

Used by USBR for Hydrologic Risk Assessments since 1998

Bumping Lake Dam – Bumping River, WA

A.R. Bowman Dam – Crooked River, OR

Cle Elum Dam – Cle Elum River, WA

Keechelus Dam – Yakima River, WA

Minidoka Dam – Snake River, ID

Whiskeytown Dam – Clear Creek, CA

Trinity Dam – Trinity River, CA

History of SEFM …

BChydro

Mica Dam, Upper Columbia River, BC

Received International Peer Review 2001

US Corps of Engineers

Folsom Dam, American River, CA

SEFM Accepted by USCOE

for Analysis of Extreme Floods and PMF

Puget Sound Energy

Baker River Project, Baker River, WA

FERC Licensed Project

Summary

- FERC guidelines require a deterministic solution to define PMF.
- PSE has showed both Lower and Upper Baker Dams are stable under the PMF loading.
- FERC guidelines require that a project must safely pass the PMF. 1:190,000,000 likelihood for PSE.
- What is appropriate FERC AEP?
- What is appropriate PMF approach deterministic vs. stochastic? Or weighted?
- Consider using stochastic criteria as in FERC anticipated Maximum Credible Earthquake likelihood for an Maximum Credible Flood?
- **“How often would that there PMF happen?”**
- **And “is that a reasonable criteria?”**