Technical Memorandum

Date	May 18, 2020
Project:	Chehalis River Basin Flood Damage Reduction Project
To:	Chehalis Basin Flood Control Zone District
From:	Lisa Danielski, PWS (HDR) Ed Zapel, PE (HDR)
Subject:	SEPA DEIS Review: FRE Facility Temporary Reservoir Inundation and Vegetation Analysis Clarification

1.0 Introduction and Purpose

The purpose of this technical memorandum (TM) is to provide refined spatial analysis of existing hydrologic data for operation of the Flood Retention Expandable (FRE) facility temporary reservoir and land cover within the temporary reservoir for the Proposed Chehalis River Basin Flood Damage Reduction project (project). This TM summarizes the results of detailed mapping of the duration and extent of inundation that would occur in the temporary reservoir when the FRE facility is activated during specific major flood events, as well as vegetation communities and land uses that occur within the temporary reservoir.

The primary purpose of this mapping is to assess the extent, duration, and severity of potential inundation and provide more granularity to land cover classifications in the temporary reservoir area in order to inform the detailed Vegetation Management Plan that is being prepared by the Chehalis Basin Flood Control Zone District (District) for the permitting phase of the project. This TM also serves to provide more targeted documentation of the effects of project operations over a range of flood flows as described in the *Proposed Chehalis River Basin Flood Damage Reduction Project Draft EIS* (Washington State Department of Ecology 2020), and anticipated effects to land cover within the temporary reservoir.

2.0 Hydrologic Events of Interest

For the purpose of this TM, existing hydrologic data were reviewed and available information for the following events were analyzed. No hydrographs for forecasted climate change conditions were available, so climate change events could not be analyzed. However, climate change events are expected to be similar in severity to the events considered here, but may occur more frequently and at different times of the year. Regardless, the FRE facility would be operated the same and therefore, the conclusions drawn here would likely be applicable to future events as well. The specific events considered included:

- 10-year recurrence interval event
- 100-year recurrence interval event
- 1996 flood event

- 2007 flood event (event of record to date)
- 2009 flood event

Anchor QEA confirmed with HDR Engineering, Inc. (HDR) that these flood events match what was evaluated in the draft Environmental Impact Statement (EIS) (Adam Hill, Anchor QEA personal communication, April 1, 2020) and the *Chehalis Basin Strategy Operations Plan for Flood Retention Facilities* (Anchor QEA 2017).

3.0 Assumptions and Given Information

The period of record used by Anchor QEA to generate the reservoir routing analyses was assumed to cover the United States Geological Survey (USGS) gage data available for the several gages included in the study. The hydrologic analysis conducted by Anchor QEA was concluded in September 2018. The period of record used in the study therefore terminated at study conclusion, though these gages continue in operation to collect continuous data since that date. The individual periods of record for these USGS gages vary, as follows:

- **Gage 12020000:** Chehalis River near Doty, Washington, 1939 to September 2018
- **Gage 12027500:** Chehalis River near Grand Mound, Washington, 1928 to September 2018
- **Gage 12031000:** Chehalis River at Porter, Washington, 1952 to September 2018

Topography data were obtained from public light detection and ranging (LiDAR) databases. A series of digital terrain models (DTMs) provided by the Washington State Department of Natural Resource's LiDAR program were used to generate contour lines (datum: North American Vertical Datum of 1988 [NAVD88]). The LiDAR data acquired were collected from 2012 to 2018 and have an average relative vertical accuracy of 0.167 foot (0.051 meter).

Flow hydrographs for the Hydrologic Engineering Center River Analysis System (HEC-RAS) river modeling conducted by Watershed Science and Engineering (WSE) to support the project characterization work were obtained from WSE via email attachment from Larry Karpack of WSE's staff, dated February 5, 2020, at 4:46 p.m. In addition to the HEC-RAS flow files, the reservoir routing analysis (i.e., inflows, outflows, reservoir elevation) data characterizing the proposed FRE operations were obtained from Anchor QEA via email attachment from Adam Hill of Anchor QEA's staff dated February 17, 2020, at 12:10 p.m. HDR did not conduct additional analyses using these data or any other topographic or hydrologic data to develop the maps and hydrograph representations illustrated in this TM.

4.0 Methods

4.1 Inundation Mapping

The project area considered encompasses the temporary reservoir pool from water surface elevation (WSEL) 425 up to WSEL 620 feet, the maximum WSEL for the 2007 event of record. The following methods were used to generate the temporary reservoir inundation limits anticipated for the regulation of flood events by the proposed FRE dam.

HDR used ArcGIS's "Mosaic to New Raster" tool to merge multiple DTM's into a single DTM that covers the entire project area. Once created, the new DTM was used to derive contours using ArcGIS's Contour tool. This tool was used to define the base contour, contour interval, and maximum vertices per contour. No unit conversion factor (Z factor) was used to generate the project contours. For the purpose of modeling we created contours at a 5-foot contour interval with a base contour of zero.

The contour files were imported to AutoCAD 2018 and used to generate the inundation contour lines and show the aerial extent of these inundation limits. We selected the following key WSEL contours to illustrate the aerial (i.e., planform) extent of inundation during each of the three stages of temporary reservoir drawdown that will be implemented to evacuate the reservoir after a major flood event when the FRE facility is activated:

1. **Initial Reservoir Evacuation (Max. Pool to WSEL 528 feet):** To evacuate the temporary reservoir after a major flood event, the partially closed reservoir outlet gates will open and increase outflow by 1,000 cfs per hour, from 300 cfs (minimum outflow during flood operations) to a maximum outflow of 5,000 to 6,500 cfs. This will cause drawdown of the temporary reservoir from its peak WSEL at the maximum pool, which will be limited to 10 feet per day (5 inches per hour) to reduce risk of landslides. The maximum WSEL for each major flood event will vary depending on the intensity of the flood event. During all major flood events, the 10 feet per day drawdown rate will continue until the storage pool elevation reaches 528 feet. Once the storage pool elevation reaches 528 feet, debris management operations will begin.

2. **Debris Management Evacuation (WSEL 528-500 feet):** During major flood events, debris from surrounding tributaries and hillsides will likely be swept into the reservoir. Debris management procedures will be used to ensure that large woody debris will not impact dam operations or cause damage to the FRE facility.

   During all major flood events, debris management will begin once the pool elevation reaches 528 feet. At this time, drawdown rates will be slowed to 2 feet per day (1 inch per hour) for a 14-day period. During this period, crews will use a boat to move large debris from the reservoir to an existing log sorting yard previously operated by Weyerhaeuser. The slowed drawdown rate will continue until the storage pool elevation reaches 500 feet. Once the storage pool elevation reaches 500 feet, debris management operations will conclude.

3. **Final Reservoir Evacuation (WSEL 500-425 feet):** During all major flood events, once the temporary reservoir reaches WSEL of 500 feet, drawdown rates will increase to 10 feet per day (5 inches per hour) once debris management operations are complete. Drawdown will continue at this rate until the storage pool has emptied and the pool elevation returns to 425 feet. At this time, the reservoir will no longer be impounding water and the Chehalis River will return to a free-flowing state.

To determine the maximum reservoir WSELs occurring with each of the flood events noted in the EIS (See Section 2.0 above), we obtained the regulated and unregulated flood hydrographs from the EIS, and added notations to the hydrograph plots to clarify key drawdown stages. Then we applied similar information to the inundation limit map created in AutoCAD 2018.

Additionally, we determined the total inundation time above each of the three key reservoir drawdown elevations - maximum WSEL, 528, and 500 - from the time steps obtained from the flood hydrographs provided in the EIS.

4.2 Land Cover Mapping

We have refined mapping of land cover in the study area using GIS data and aerial photography developed as part of the DEIS studies and available from public sources. A map exchange document (mxd) was set up in GIS with an empty feature class with defined domains for each of the land cover communities that would be digitized. The mxd was populated with the following GIS reference files from previous studies and publicly available information: digital surface models showing the height of tree canopy (Washington Department of Natural Resources [WDNR] 2020a), digital terrain models representing the ground elevation (WDNR 2020b), streams, wetlands and ditches mapped by Anchor QEA (2018), as well as logging road data (WDNR 2020c).

Using the reference data above as well as Google Earth aerial imagery from 1990 through 2018 (Google Inc. 2019), we characterized vegetation in the study area and digitized polygons into distinct land cover types using the vegetation communities identified in the *Proposed Flood Retention Facility Pre-construction Vegetation Management Plan* (Anchor QEA 2016), as amended with additional land use classifications such as open water, bare ground/roads and logged lands to accurately capture current conditions in the study area. Table 1 summarizes land cover classifications, typical vegetation composition, and distinct characteristics used to map land cover in the study area.

Table 1. Summary of Land Cover Classifications

Land Cover Classification	Typical Vegetation	Distinct Characteristics
Wetland	See Anchor QEA (2018)	Wetlands Delineated by Anchor 2018.
Open Water/Sand Bar	N/A	Mapped aquatic features (Anchor QEA 2018) and associated sand bars, rock features, etc.
Terrestrial Bare Ground/Roads	Unvegetated	Lack of vegetation over multiple growing seasons; often associated with logging roads and equipment staging areas.
Herbaceous/Grass	Reed canarygrass (*Phalaris arundinacea*), colonial bentgrass (*Agrostis capillaris*), sword fern (*Polystichum munitum*), western lady fern (*Athyrium angustum*), piggyback plant (*Tolmiea menziesii*), creeping buttercup (*Ranunculus repens*)	Grasses and forbs present during growing season; often found adjacent to wetlands, riparian corridors, and recently disturbed areas.
Deciduous Riparian Shrubland	Various willows (*Salix* spp.), young red alder (*Alnus rubra*), red-osier dogwood (*Cornus alba*), vine maple (*Acer circinatum*), Indian plum (*Oemleria cerasiformis*), thimbleberry (*Rubus parviflorus*), salmonberry (*Rubus spectabilis*)	Dominated by deciduous shrub/sapling species less than 6 meters (20 feet) tall (>75% cover)
Deciduous Riparian Forest with Some Conifers	Red alder, Western red cedar (*Thuja plicata*), Western hemlock (*Tsuga heterophylla*), black cottonwood (*Populus balsamifera*), cascara (*Frangula purshiana*), willows, big leaf maple (*Acer macrophyllum*), red elderberry (*Sambucus racemosa*), snowberry (*Symphoricarpos albus*)	Dominated by deciduous tree species 6 meters (20 feet) tall or taller (>75% cover).
Mixed Coniferous/Deciduous Transitional Forest	Douglas fir (*Pseudotsuga menziesii*), red alder, big leaf maple	Approximately even distribution of deciduous and coniferous species (not clearly dominated by one or the other).
Coniferous Forest	Douglas fir	Dominated by coniferous species (>75% cover).
Logged, replanted 0-5 years	Sun-tolerant grasses and forbs, Douglas fir seedlings	Evidence of logging (i.e. clearcutting) on historic aerial imagery; replanting visible within last 5 years (2015-2020) or not replanted.
Logged, replanted 5-15+ years	Douglas fir saplings	Evidence of logging on historic aerial imagery; replanting visible 5 or more years ago (prior to 2015).

4.2.1 Wetland and Open Water/Sand Bar

Wetlands and streams mapped in the *Wetland, Water, and Ordinary High Water Mark Delineation Report* (Anchor QEA 2018) were imported into GIS to create the Wetland and Open Water/Sand Bar land cover classifications, respectively.

The OHWM for Crim Creek, Roger Creek, and the Chehalis River were not delineated in their entirety during field visits conducted by Anchor QEA due to access limitations and the length of reaches within the project area. Instead, Anchor QEA conducted a desktop-based GIS analysis using LiDAR-generated topography to interpret the OHWM elevation between each point that

was gathered in the field. We made minor adjustments to GIS-based stream mapping to more accurately reflect the spatial extent of streams visible on aerial photography.

4.2.2 Terrestrial Bare Ground/Roads

This land cover class mainly includes wide logging roads and equipment staging areas. Historic aerial imagery was used to identify areas lacking vegetation for multiple growing seasons that were not associated with aquatic areas. To account for the surface area of logging roads obscured by dense vegetation and not visible on aerial imagery, a 7.5-foot buffer was applied to the centerline of mapped road features.

4.2.3 Herbaceous/Grass

The Herbaceous/Grass category accounts for upland areas dominated by grasses and forbs that are not wetlands. Herbaceous vegetation was distinguished from bare ground by comparing multiple years of aerial imagery to confirm the presence of vegetation during the growing season. Herbaceous vegetation was also commonly associated with areas recently disturbed by logging operations, and was found adjacent to areas categorized as Terrestrial Bare Ground. Species typically found in these areas include reed canarygrass (*Phalaris arundinacea*), colonial bentgrass (*Agrostis capillaris*), sword fern (*Polystichum munitum*), western lady fern (*Athyrium angustum*), piggyback plant (*Tolmiea menziesii*), and creeping buttercup (*Ranunculus repens*).

4.2.4 Deciduous Riparian Shrubland

The Deciduous Riparian Shrubland community was modeled after the Cowardin “Scrub-Shrub” class, which includes areas dominated by woody vegetation less than 6 meters (20 feet) tall, including true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions (Cowardin et al. 1979). This community was identified and mapped based on the prevalence of deciduous shrub species and proximity (generally within 200 feet) to mapped streams and aquatic areas. Species typically found in these areas include various willows (*Salix* spp.), red-osier dogwood (*Cornus alba*), vine maple (*Acer circinatum*), Indian plum (*Oemleria cerasiformis*), thimbleberry (*Rubus parviflorus*), salmonberry (*Rubus spectabilis*), and red alder (*Alnus rubra*).

4.2.5 Deciduous Riparian Forest with Some Conifers

The Deciduous Riparian Forest community was established based on the Cowardin “Forested” class, which includes forested areas characterized by woody vegetation that is 6 meters (20 feet) or taller (Cowardin et al. 1979). Deciduous forest stands were differentiated from scrub-shrub communities using the DHM (digital height model) GIS layer to determine approximate tree height. Although the community is dominated by deciduous tree species (approximately >75% deciduous cover), scattered conifer trees were also commonly observed in these areas. Deciduous species were distinguished from conifers using multiple years of aerial imagery to identify seasonal differences in canopy cover. Species typically found in the Deciduous Riparian Forest community includes red alder, Western red cedar (*Thuja plicata*), Western hemlock (*Tsuga heterophylla*), black cottonwood (*Populus balsamifera*), cascara (*Frangula purshiana*), willows, big leaf maple (*Acer macrophyllum*), red elderberry (*Sambucus racemosa*), and snowberry (*Symphoricarpos albus*).

4.2.6 Mixed Coniferous/Deciduous Transitional Forest

Mixed Coniferous/Deciduous Transitional Forest represents areas with an approximately equal distribution of coniferous and deciduous tree species. Tree heights were estimated using the DHM layer, and the distribution of coniferous and deciduous species was determined using seasonal differences in canopy cover from historic aerial imagery. Species typically found in these areas include Douglas fir (*Pseudotsuga menziesii*), red alder, and big leaf maple.

4.2.7 Coniferous Forest

Areas dominated by coniferous tree species (approximately >75% cover) were characterized as Coniferous Forest. The Coniferous Forest community is typically dominated by Douglas fir and often includes stands of various age classes produced for logging.

4.2.8 Recently Logged Areas

Areas with evidence of recent logging activity (i.e. clearcutting) were identified by comparing multiple years of aerial imagery. Recently logged areas with evidence of replanting within the last 5 years (2015 to present) or no evidence of replanting were characterized as “Logged, replanted 0-5 years.” Areas with evidence of replanting older than 5 years ago (prior to 2015) were characterized as “Logged, replanted 5-15+ years.” The five-year threshold represents an approximation of time required for logged lands in the Pacific Northwest to transition from an early seral stage where grasses and forbs are predominant to a shrub-sapling stage where Douglas-fir seedlings accelerate in growth (USDA Forest Service 2012, Lam and Maguire 2011, Burns and Honkala 1990).

5.0 Results and Conclusions

5.1 Inundation Mapping

Table 2 shows the acreage and duration of inundation expected during the three stages of temporary reservoir drawdown for each major flood event evaluated in the EIS. Inundation maps for historical and modeled flood events are presented in Attachment 1. The figures show the Initial Reservoir Evacuation, Debris Management, and Final Reservoir Evacuation areas in blue, yellow, and orange, respectively. Hydrographs for each major flood event are provided in Attachment 2.

The terms used in Table 2 are defined as follows:

- **Area of inundation** refers to the area (in acres) of reservoir inundated during each stage of temporary reservoir drawdown. As described above, the Debris Management and Final Reservoir Evacuation stages will have uniform operation during all major flood events; therefore, the acreage will be consistent during these operational milestones. The area inundated at the start of the Initial Reservoir Evacuation stage differs based on the severity of the flood event.
- **Duration of inundation** represents the maximum number of days of inundation during each stage of reservoir drawdown. The duration differs depending on the severity of the historical or modeled flood event. For the Debris Management Evacuation stage, this number includes 14 days for debris clearing activities.

Table 2. Acreage and Duration of Inundation for Historical/Modeled Flood Events during Temporary Reservoir Drawdown Stages

Historical/ Modeled Event	Initial Reservoir Evacuation (WSEL >528 feet)				Debris Management Evacuation (WSEL 528-500 feet)			Final Reservoir Evacuation (WSEL 500-425 feet)		
	Area of Inundation above WSEL 528 feet	Duration of Inundation above WSEL 528 feet	Total Reservoir Area[a]	Maximum WSEL[b]	Area of Inundation at WSEL 500–528 feet	Duration of Inundation at WSEL 528-500 feet[c]	Total Reservoir Area	Area of Inundation at WSEL 425–500 feet	Duration of Inundation at WSEL 500-425 feet[d]	Total Reservoir Area
10-year event	238 acres	Up to 5.9 days	519 acres	568 feet	122 acres	Up to 20.2 days	281 acres	159 acres	Up to 26.9 days	159 acres
100-year event	426 acres	Up to 10.7 days	707 acres	604 feet	122 acres	Up to 25.0 days	281 acres	159 acres	Up to 31.8 days	159 acres
1996 flood event	410 acres	Up to 9.8 days	691 acres	601 feet	122 acres	Up to 24.5 days	281 acres	159 acres	Up to 31.0 days	159 acres
2007 flood event	527 acres	Up to 11.1 days	808 acres	620 feet	122 acres	Up to 25.2 days	281 acres	159 acres	Up to 32.3 days	159 acres
2009 flood event	324 acres	Up to 7.8 days	605 acres	585 feet	122 acres	Up to 22.0 days	281 acres	159 acres	Up to 28.8 days	159 acres

[a] This value also represents the maximum area of inundation for the modelled flood event
[b] This value also represents the maximum WSEL for the modelled flood event
[c] Includes 14 days for debris clearing activities starting when drawdown following flood peak falls to elevation 528 feet.
[d] This value also represents the maximum number of days of flooding for the modelled flood event

- **Maximum WSEL** gives the peak temporary reservoir pool WSEL for each flood event prior to the start of the Initial Reservoir Evacuation stage.

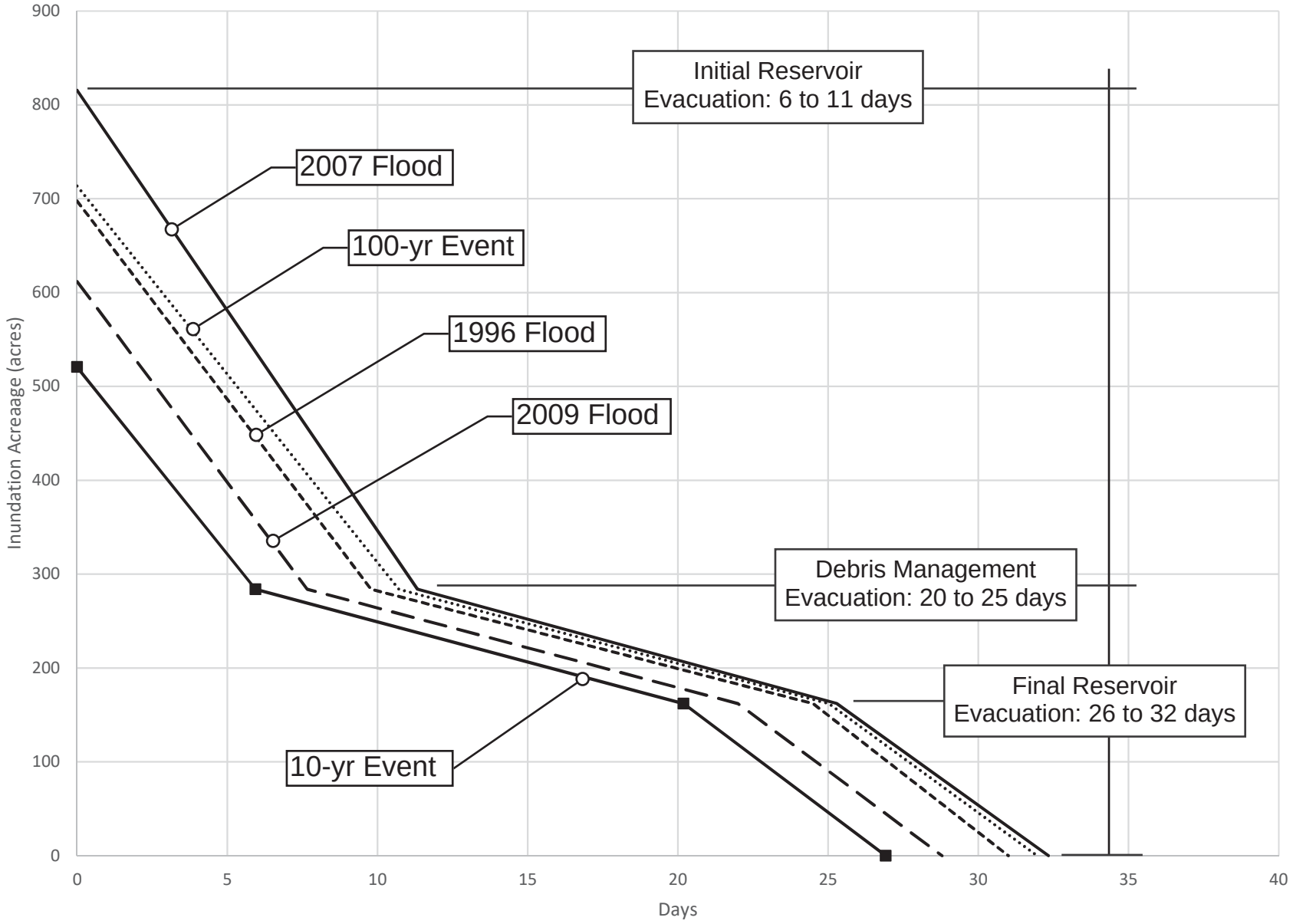
The results of the inundation mapping show that the Initial Reservoir Evacuation area at maximum WSEL will range between 568 and 620 feet. The acreage of inundation above 528 feet will range between 238 and 527 acres, and the duration of inundation will range between 5.9 and 11.1 days. The Debris Management Evacuation area will have 122 acres of inundation between WSEL 500 and 528 feet, and will be inundated between 20.2 and 25.2 days. The Final Reservoir Evacuation area will have 159 acres of inundation between WSEL 425 and 500 feet. This area will be inundated at least 26 days under each flood event, and up to 32 days under the event of record.

Table 3 summarizes the range of acreage, inundation extent and duration at each drawdown stage from the more frequent (10% chance) major flood event to the least frequent (<1% chance) major flood event. Figure 1 graphically depicts each drawdown stage for each flood event plotted as acreage of inundation over time. The standardized three-stage drawdown operations that will be implemented when the dam is activated during all major flood events provides a more accurate depiction of the duration and extent of inundation to evaluate impacts during operation of the dam. During any major flood event, nearly half of the reservoir or greater will only be inundated for 6 to 11 days. Longer periods of inundation that will have more potential effects on vegetation will commence at the Debris Management Evacuation stage.

Table 3. Inundation Zones Based on Temporary Reservoir Drawdown Stages

Temporary Reservoir Drawdown Stage	% Chance of being flooded in a year	Duration	WSEL Range	Total Reservoir Area
Initial Reservoir Evacuation	10%	Up to 5.9 days	568-528	238 acres
	<1%	Up to 11.1 days	620-528	527 acres
Debris Management Evacuation	10%	Up to 20.2 days	528-500	122 acres
	<1%	Up to 25.2 days	528-500	122 acres
Final Reservoir Evacuation	10%	Up to 26.9 days	500-425	159 acres
	<1%	Up to 32.3 days	500-425	159 acres

Figure 1. Inundation Acreage vs Inundation Time



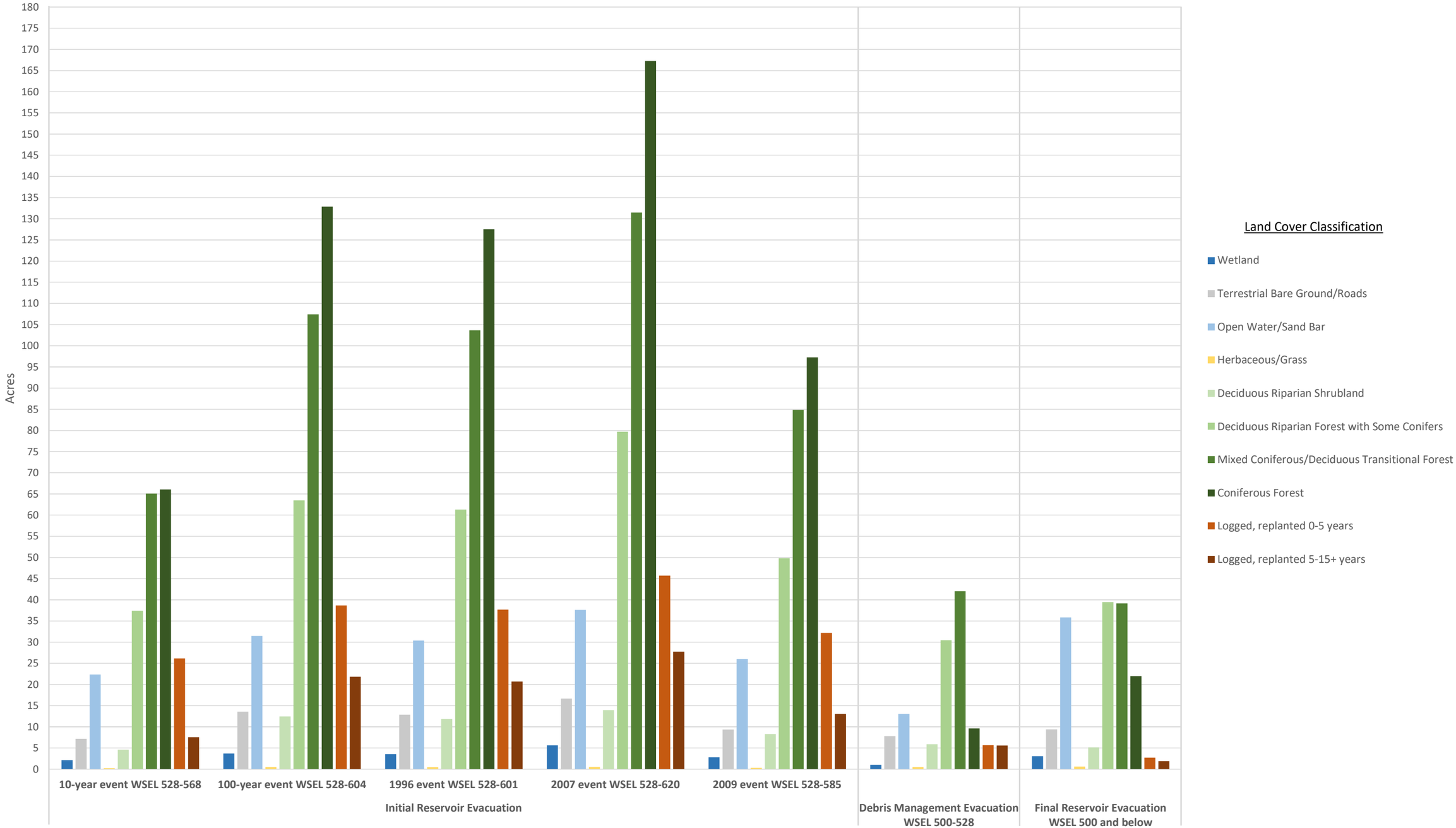
5.2 Land Cover Mapping and Inundation Effects

Figure 2 shows acreage of land cover communities mapped within the project area at each drawdown stage. Land cover acreages are also expressed as a percentage of total land cover for each major flood event and drawdown stage. An existing land cover map of the study area is presented in Attachment 3.

The Initial Reservoir Evacuation Area consists mainly of Coniferous Forest, followed by Mixed Coniferous/Deciduous Transitional Forest and Deciduous Riparian Forest with Some Conifers. Tree species in the Coniferous Forest community, particularly Douglas-Fir, are least tolerant of inundation, whereas the other forested communities consist of tree and shrub species that have higher tolerance for flooding (Anchor QEA 2016). Appendix 1 of the DEIS (Ecology 2020) states that "all non-flood-tolerant tree species would be removed from the zone where the inundation duration is expected to last 25 days or more when the reservoir is storing water." Lands in the Initial Reservoir Evacuation Area would only be inundated 6 to 11 days. Therefore, selective tree harvest of non-flood tolerant tree species is not expected be required throughout the Initial Reservoir Evacuation Area, although some individual trees that are exposed to longer inundation may die.

The Debris Management Evacuation and Final Reservoir Evacuation Areas mainly consist of Deciduous Riparian Forest with Some Conifers and Mixed Coniferous/Deciduous Transitional Forest; Coniferous Forest is the fourth most predominant land cover after Open Water. Although the Debris Management Evacuation Area would be inundated between 20 and 25.2 days, we are currently conservatively assuming that the duration of inundation throughout this area will likely require selective tree harvest of non-flood tolerant species as described in the project description of the DEIS. Selective tree harvest would be required throughout the Final Reservoir Evacuation Area. In total, up to 187 acres of forested vegetation communities would be subject to selective tree harvest in these two drawdown areas.

Figure 2. Land Cover Acreage by Drawdown Stage



6.0 Literature Cited

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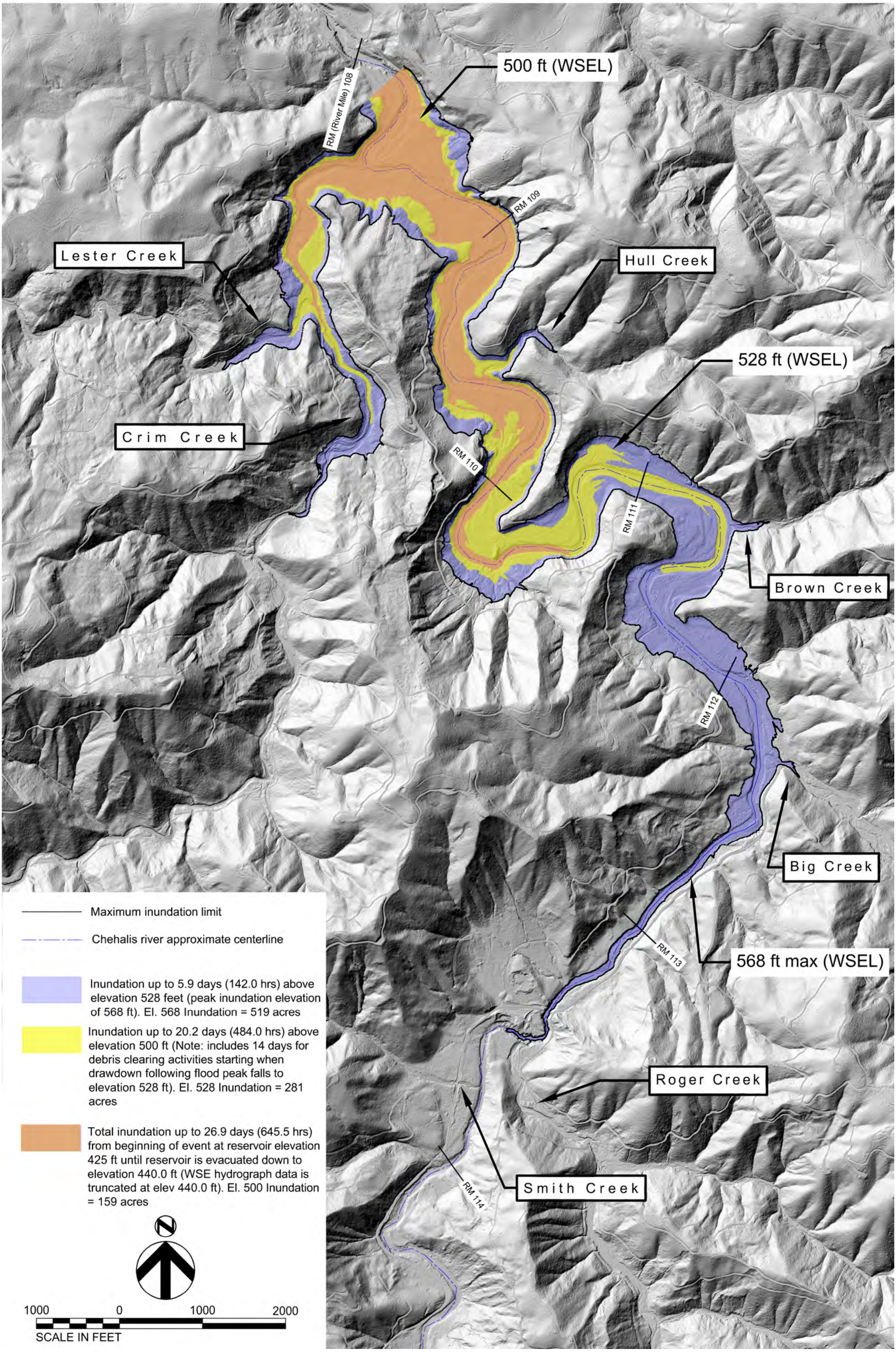
Attachment 1. Inundation Maps

10 Year Event Inundation Map for Proposed Dam (FRE)



Maximum inundation limit

Chehalis river approximate centerline

Inundation up to 5.9 days (142.0 hrs) above elevation 528 feet (peak inundation elevation of 568 ft). El. 568 Inundation = 519 acres

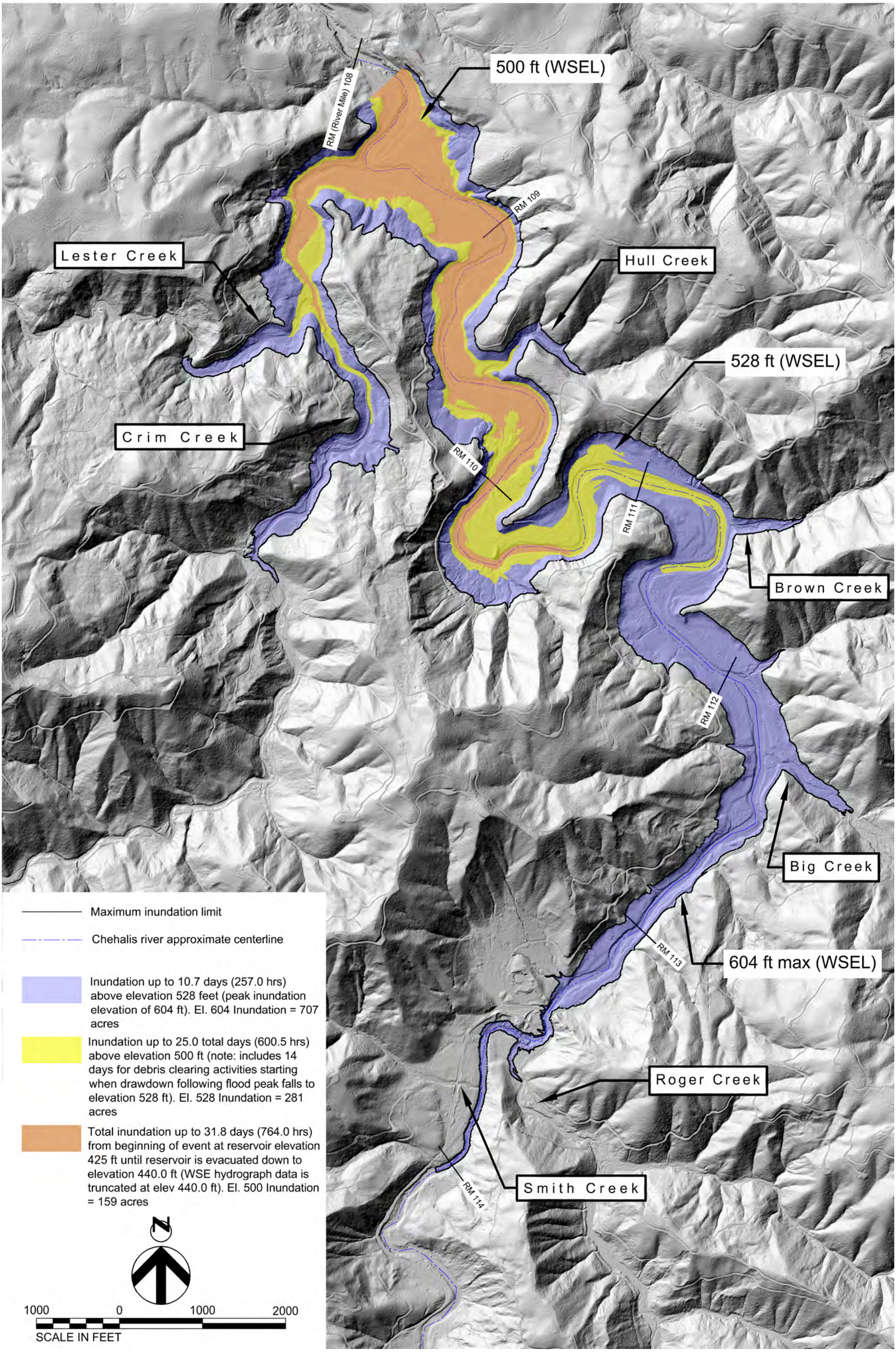
Inundation up to 20.2 days (484.0 hrs) above elevation 500 ft (Note: includes 14 days for debris clearing activities starting when drawdown following flood peak falls to elevation 528 ft). El. 528 Inundation = 281 acres

Total inundation up to 26.9 days (645.5 hrs) from beginning of event at reservoir elevation 425 ft until reservoir is evacuated down to elevation 440.0 ft (WSE hydrograph data is truncated at elev 440.0 ft). El. 500 Inundation = 159 acres

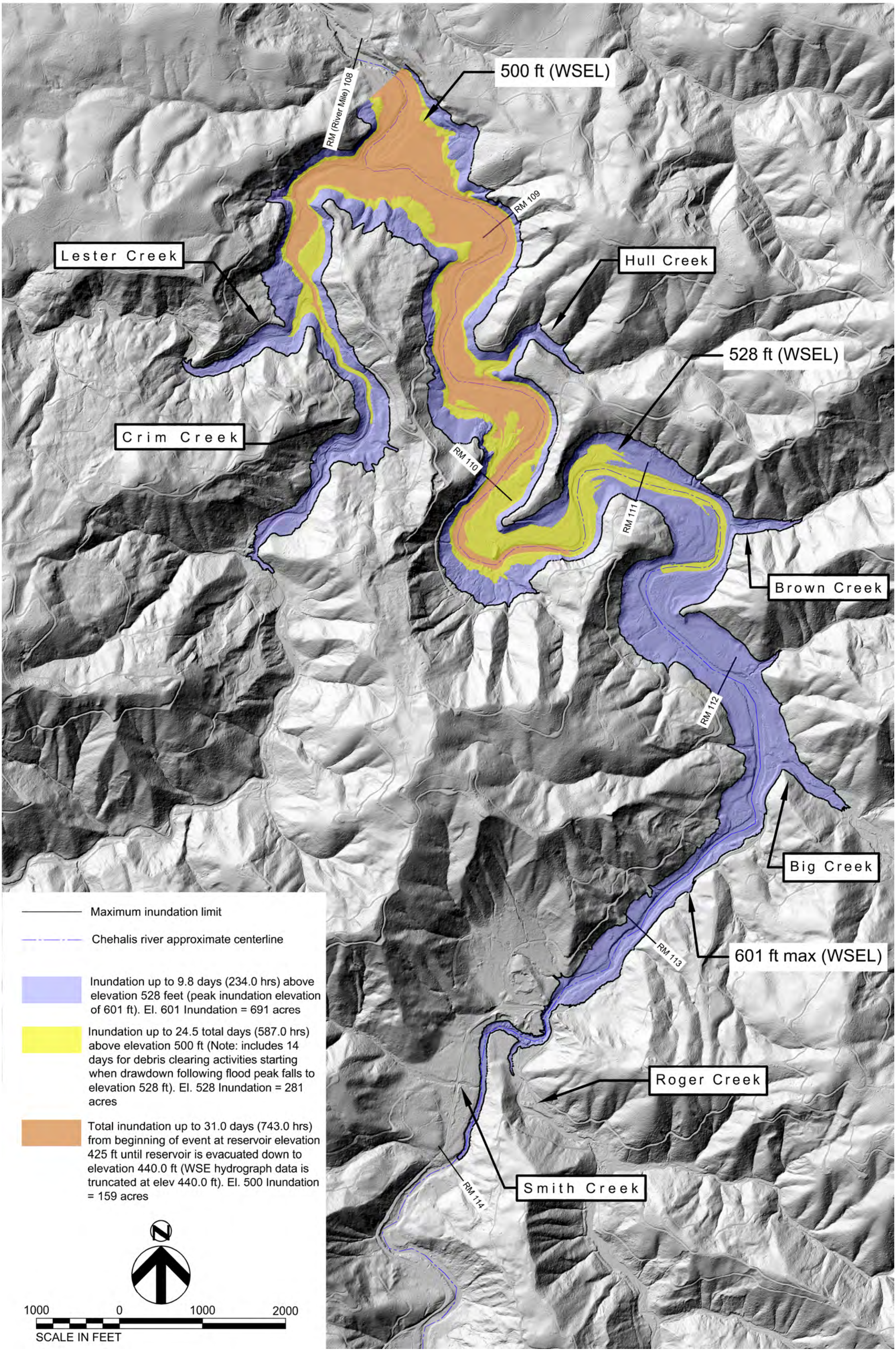
1000 0 1000 2000

SCALE IN FEET

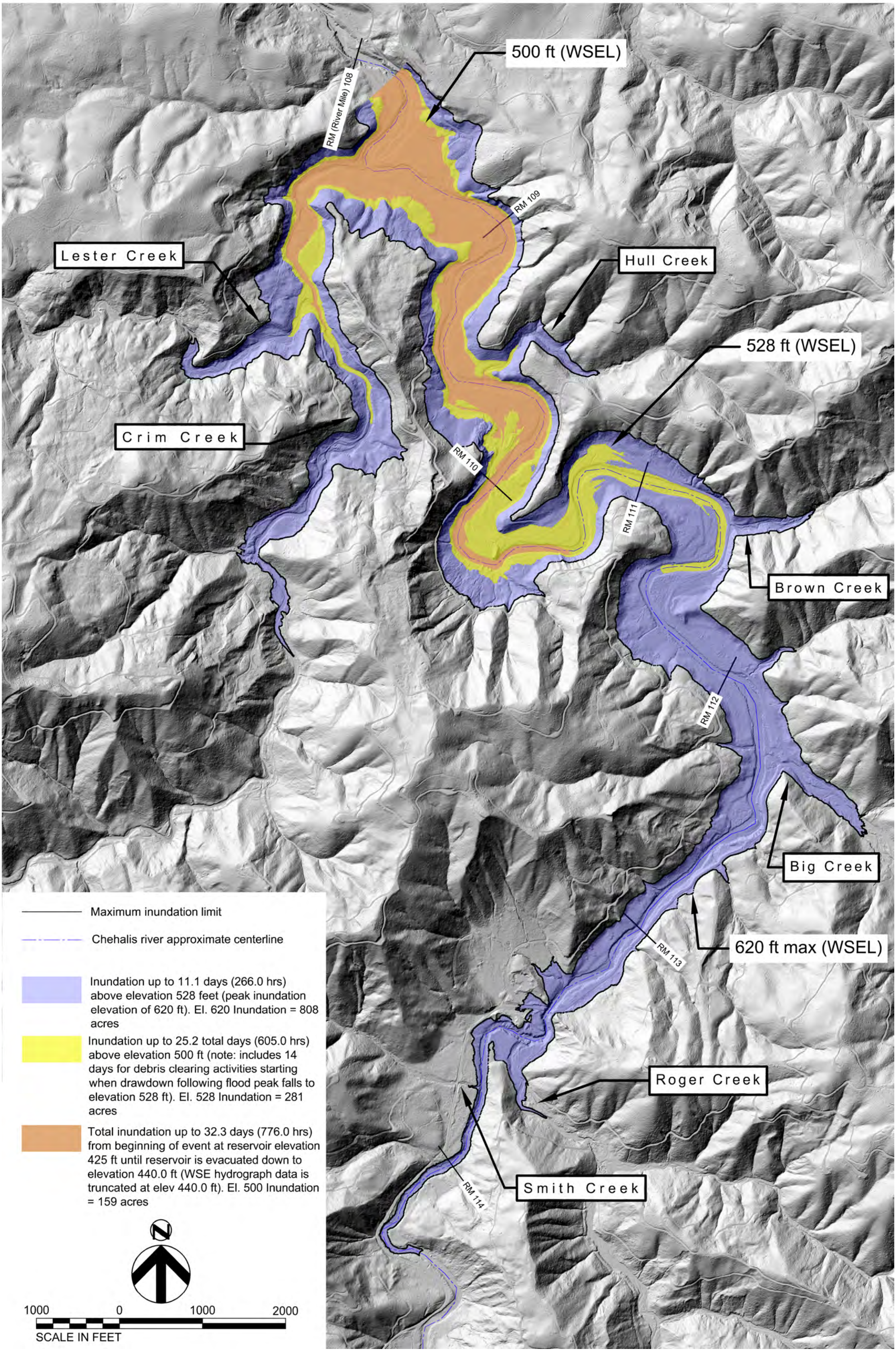
100 Year Event Inundation Map for Proposed Dam (FRE)



1996 Event Inundation Map for Proposed Dam (FRE)



2007 Event Inundation Map for Proposed Dam (FRE)



Maximum inundation limit

Chehalis river approximate centerline

Inundation up to 11.1 days (266.0 hrs) above elevation 528 feet (peak inundation elevation of 620 ft). El. 620 Inundation = 808 acres

Inundation up to 25.2 total days (605.0 hrs) above elevation 500 ft (note: includes 14 days for debris clearing activities starting when drawdown following flood peak falls to elevation 528 ft). El. 528 Inundation = 281 acres

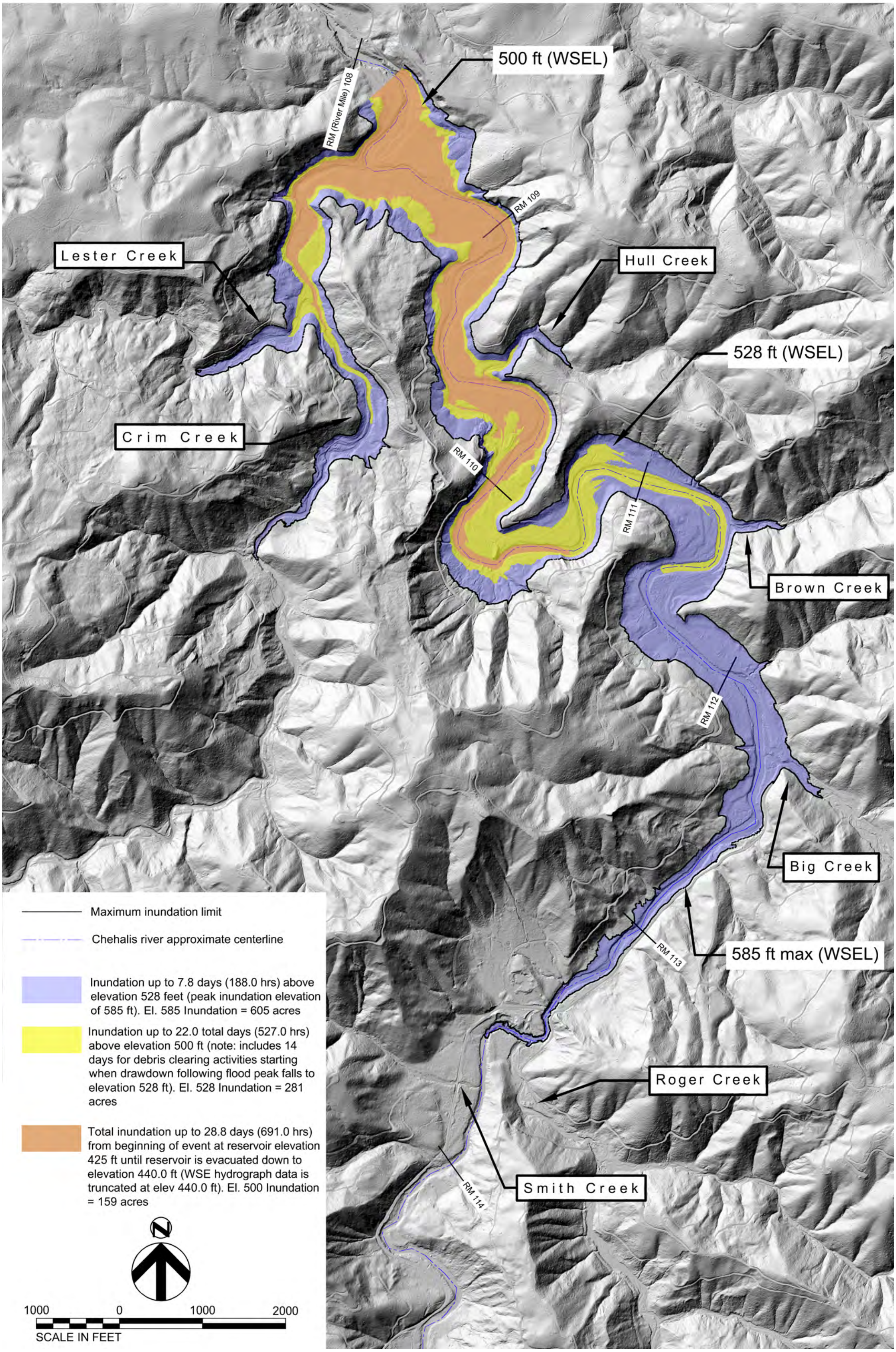
Total inundation up to 32.3 days (776.0 hrs) from beginning of event at reservoir elevation 425 ft until reservoir is evacuated down to elevation 440.0 ft (WSE hydrograph data is truncated at elev 440.0 ft). El. 500 Inundation = 159 acres

N

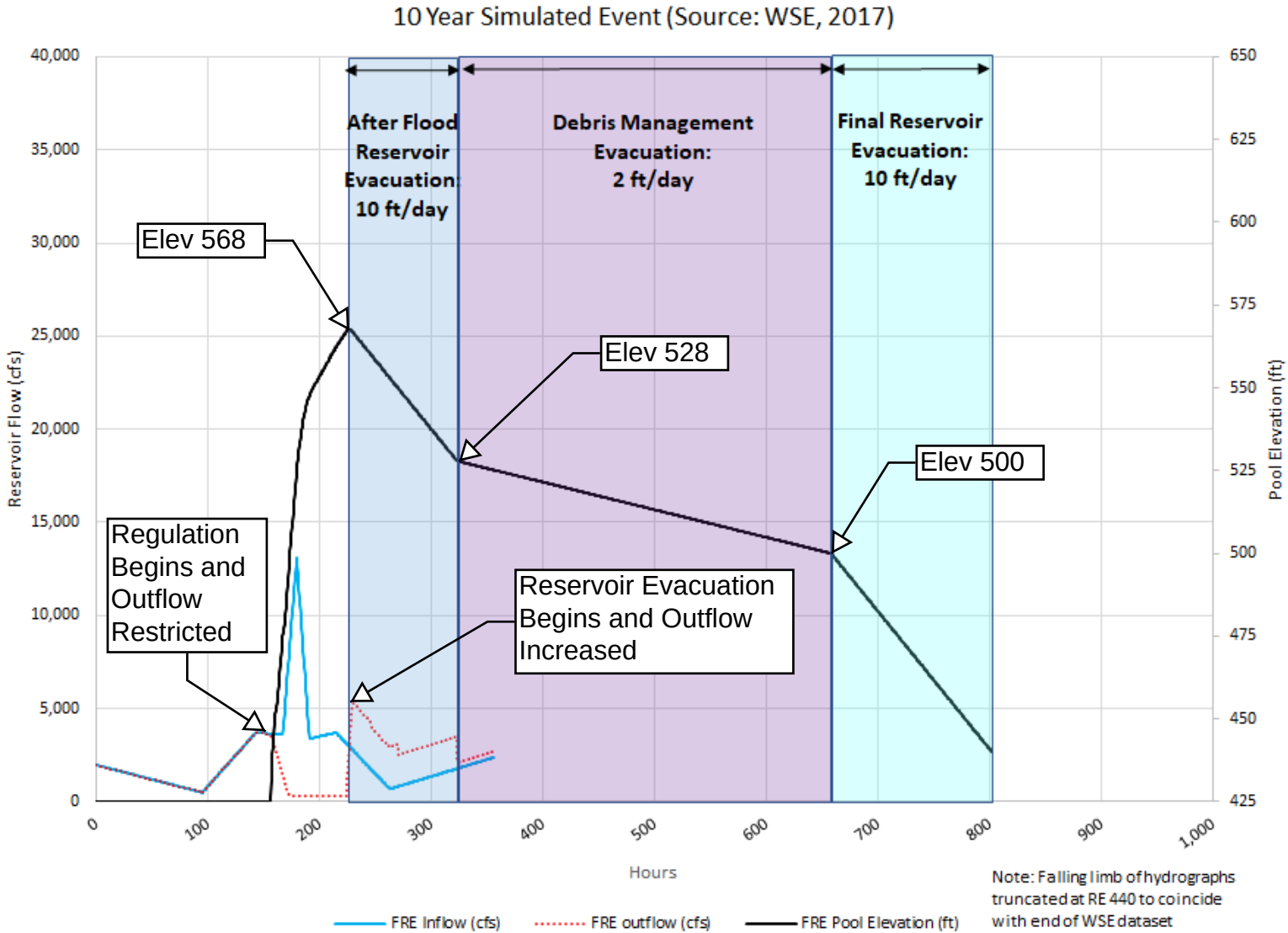
1000 0 1000 2000

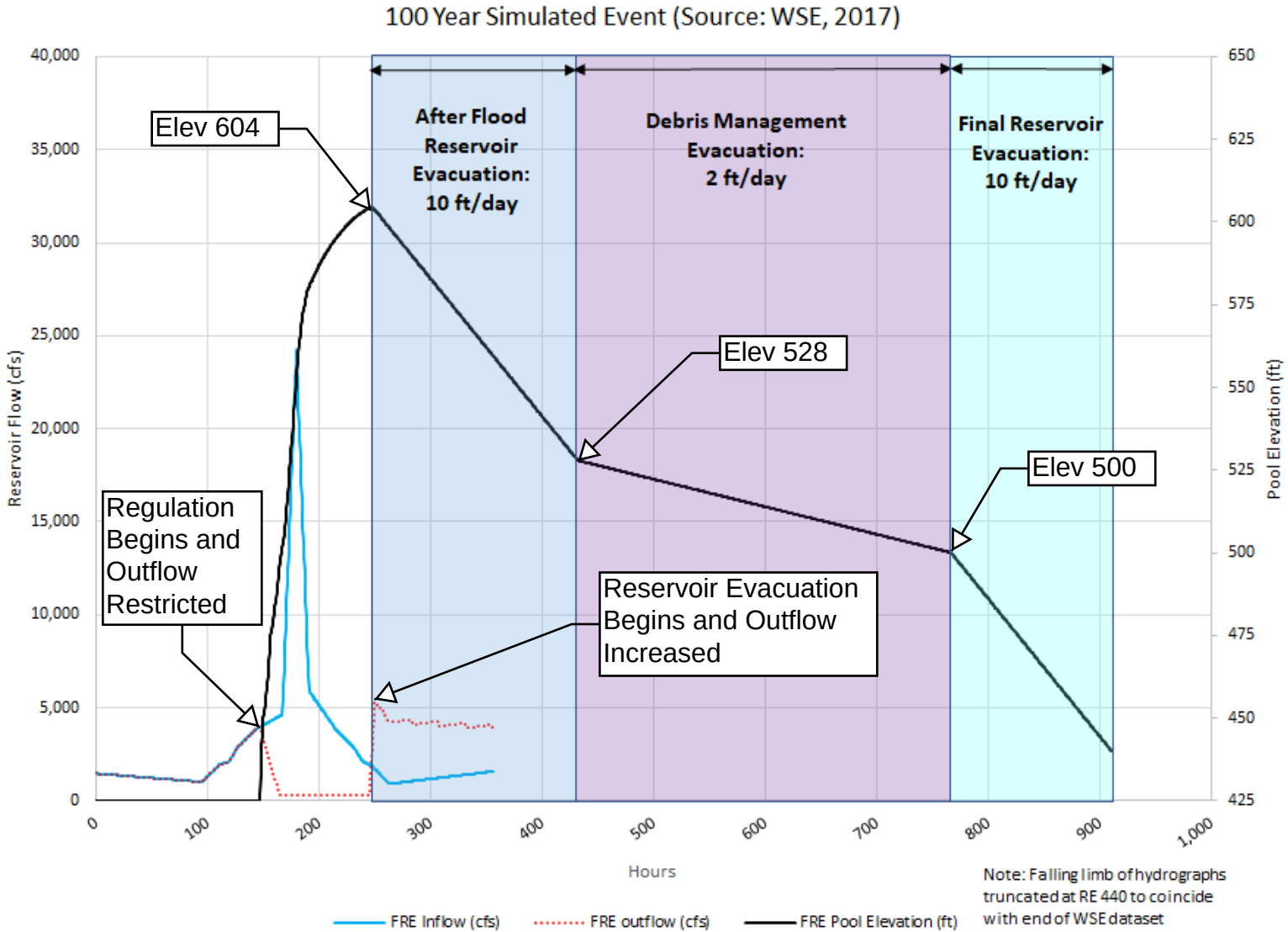
SCALE IN FEET

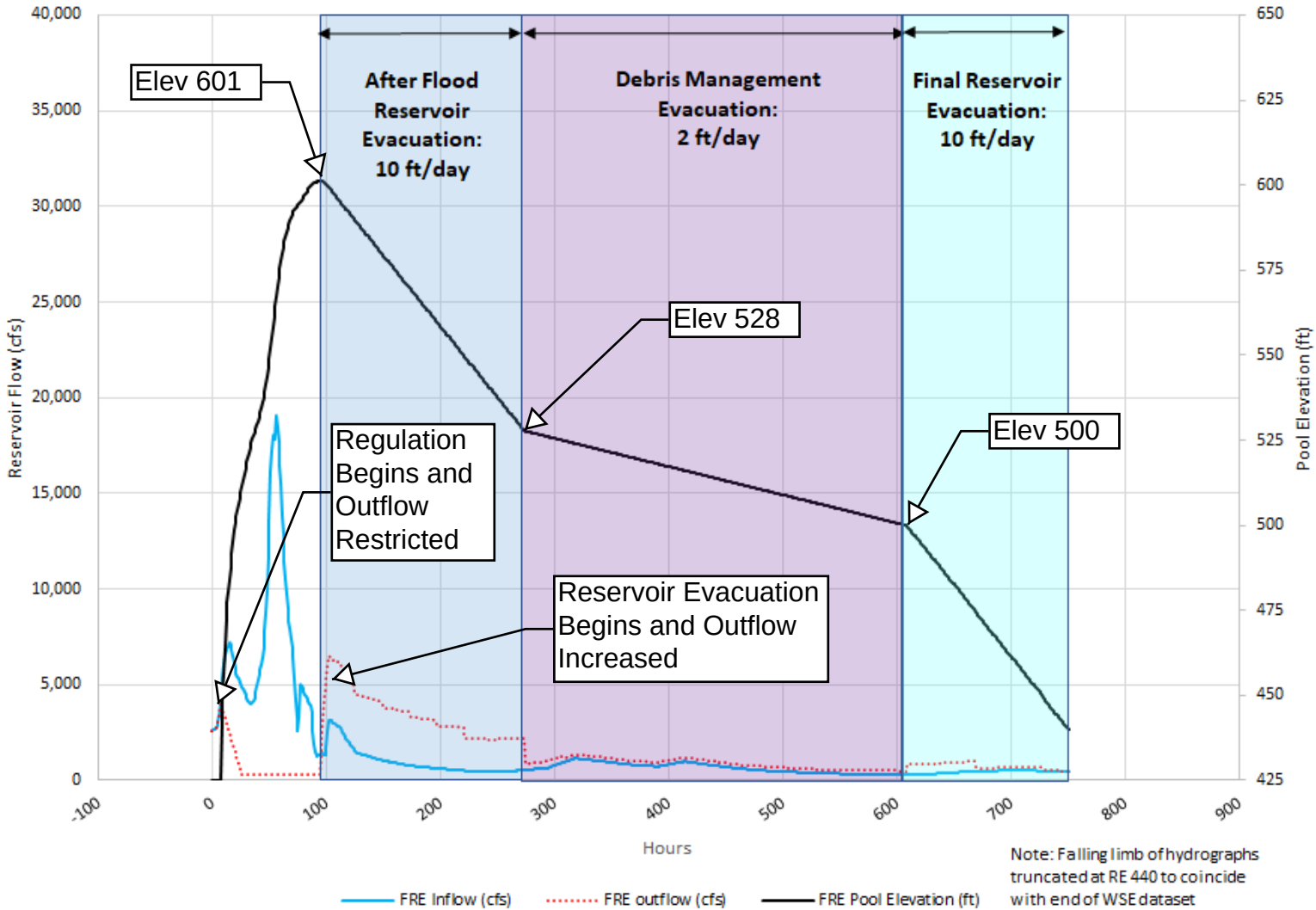
2009 Event Inundation Map for Proposed Dam (FRE)

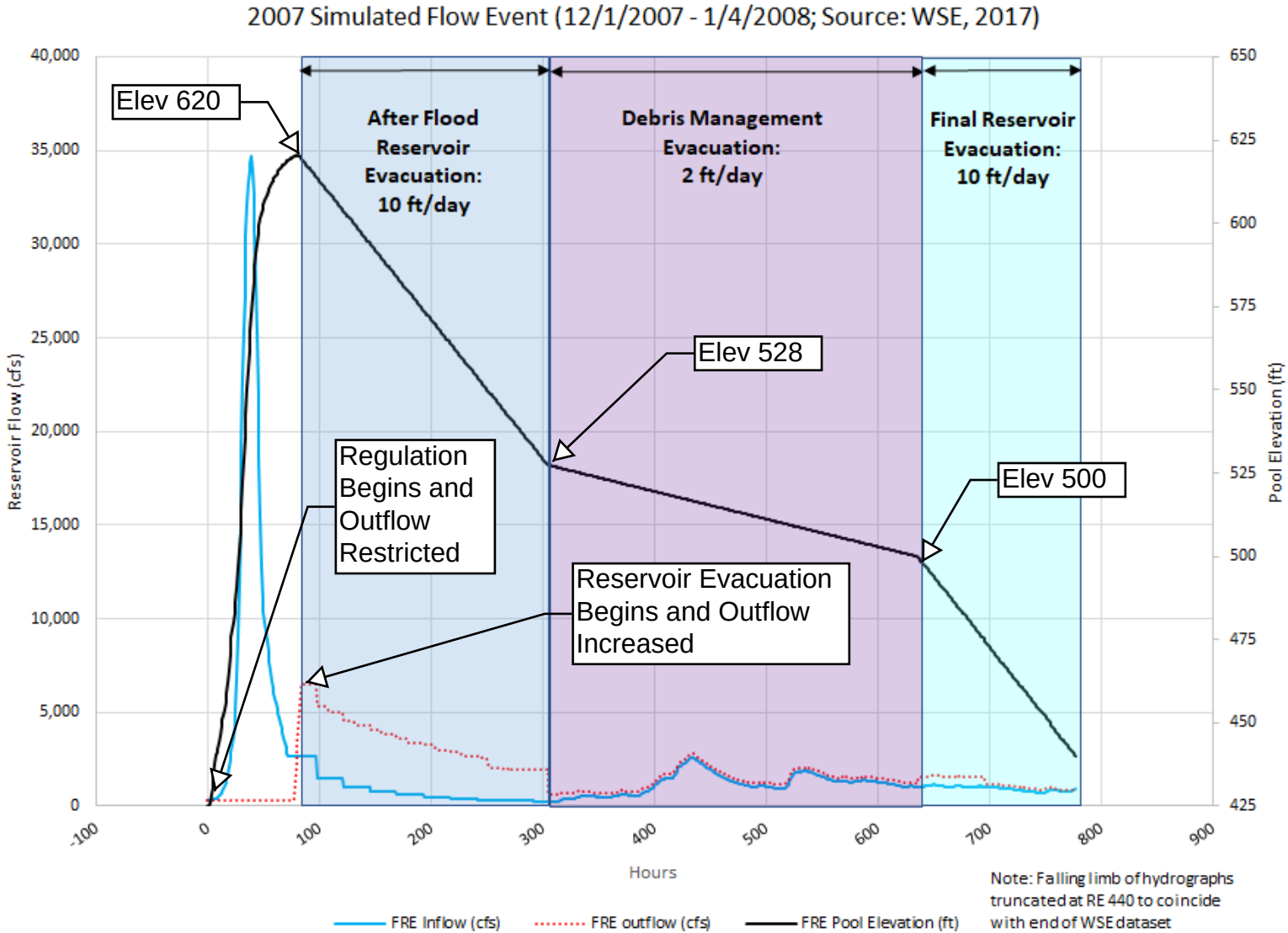


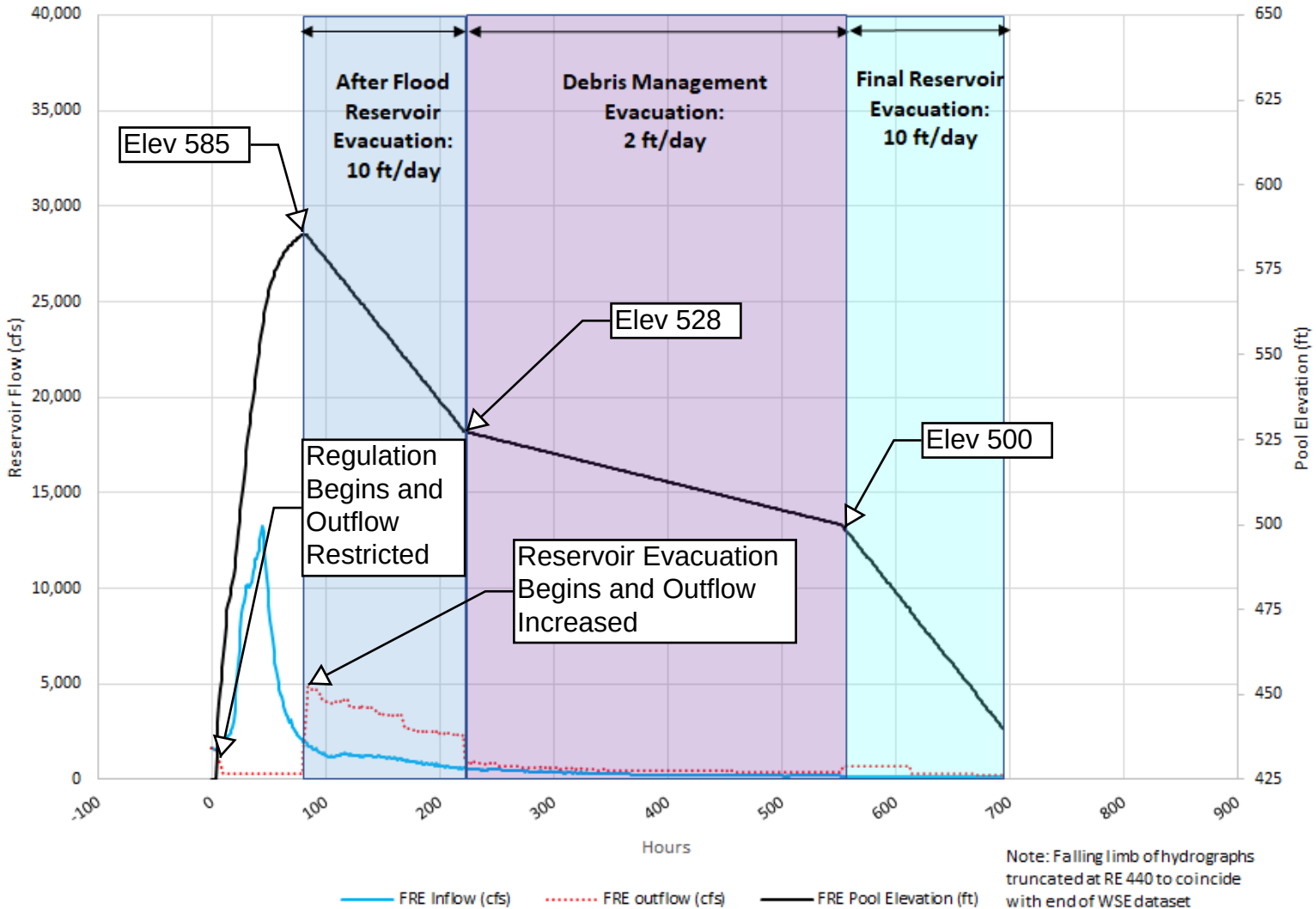
Attachment 2. Hydrographs


10 Year Simulated Event (Source: WSE, 2017)
After Flood Reservoir Evacuation: 10 ft/day
Debris Management Evacuation: 2 ft/day
Final Reservoir Evacuation: 10 ft/day
Elev 568
Elev 528
Elev 500
Regulation Begins and Outflow Restricted
Reservoir Evacuation Begins and Outflow Increased
Reservoir Flow (cfs)
Pool Elevation (ft)
Hours
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
650
625
600
575
550
525
500
475
450
425
0
100
200
300
400
500
600
700
800
900
1,000
FRE Inflow (cfs)
FRE outflow (cfs)
FRE Pool Elevation (ft)
Note: Falling limb of hydrographs truncated at RE 440 to coincide with end of WSE dataset

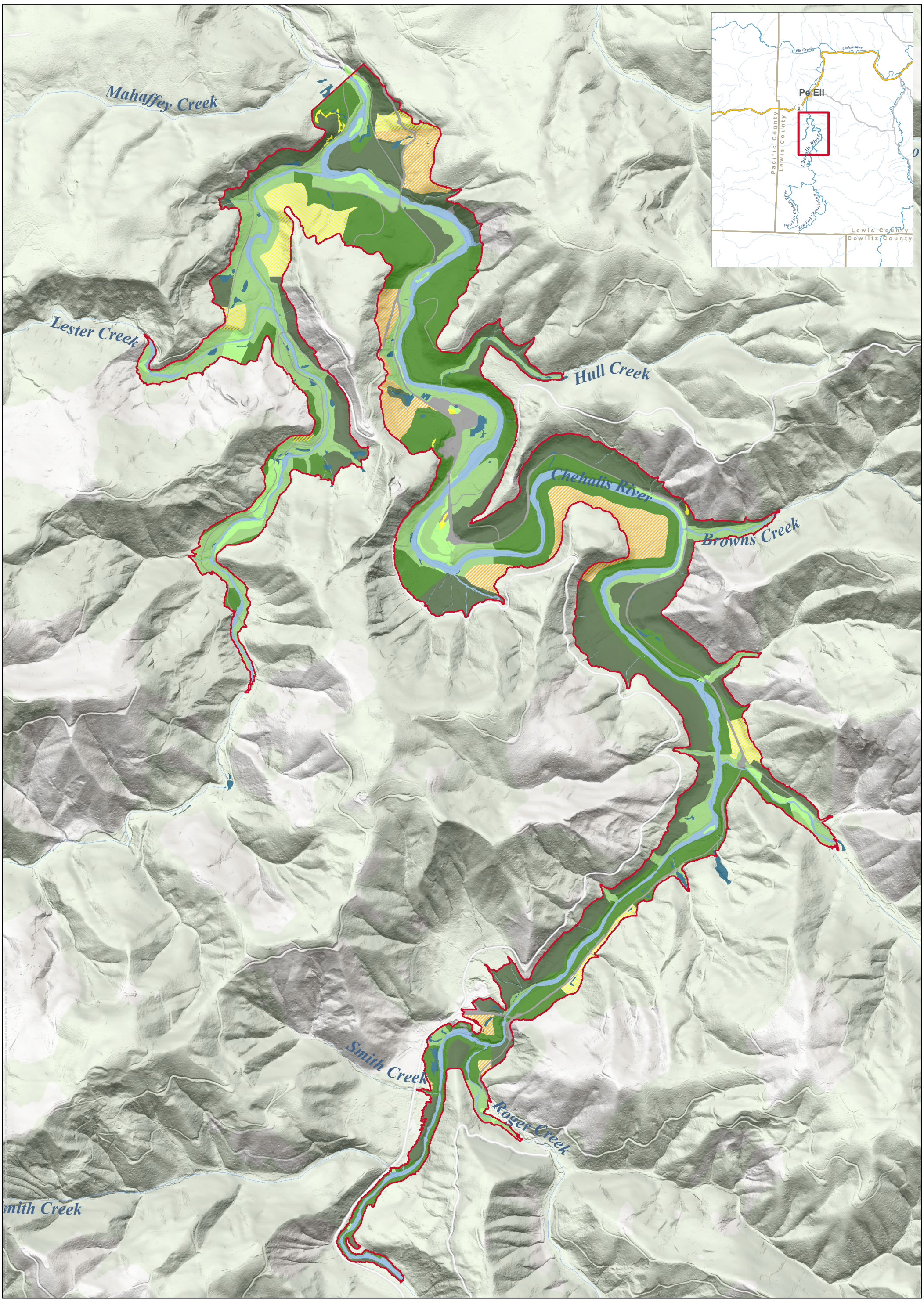

100 Year Simulated Event (Source: WSE, 2017)
Elev 604
After Flood Reservoir Evacuation: 10 ft/day
Debris Management Evacuation: 2 ft/day
Final Reservoir Evacuation: 10 ft/day
Elev 528
Elev 500
Regulation Begins and Outflow Restricted
Reservoir Evacuation Begins and Outflow Increased
Reservoir Flow (cfs)
Pool Elevation (ft)
Hours
FRE Inflow (cfs)
FRE outflow (cfs)
FRE Pool Elevation (ft)
Note: Falling limb of hydrographs truncated at RE 440 to coincide with end of WSE dataset


1996 Simulated Flow Event (2/6/1996 - 3/11/1996; Source: WSE, 2017)
Elev 601
After Flood Reservoir Evacuation: 10 ft/day
Debris Management Evacuation: 2 ft/day
Final Reservoir Evacuation: 10 ft/day
Elev 528
Elev 500
Regulation Begins and Outflow Restricted
Reservoir Evacuation Begins and Outflow Increased
Reservoir Flow (cfs)
Pool Elevation (ft)
Hours
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
650
625
600
575
550
525
500
475
450
425
-100
0
100
200
300
400
500
600
700
800
900
FRE Inflow (cfs)
FRE outflow (cfs)
FRE Pool Elevation (ft)
Note: Falling limb of hydrographs truncated at RE 440 to coincide with end of WSE dataset


2007 Simulated Flow Event (12/1/2007 - 1/4/2008; Source: WSE, 2017)
Elev 620
After Flood Reservoir Evacuation: 10 ft/day
Debris Management Evacuation: 2 ft/day
Final Reservoir Evacuation: 10 ft/day
Elev 528
Elev 500
Regulation Begins and Outflow Restricted
Reservoir Evacuation Begins and Outflow Increased
Reservoir Flow (cfs)
Pool Elevation (ft)
Hours
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
650
625
600
575
550
525
500
475
450
425
-100
0
100
200
300
400
500
600
700
800
900
FRE Inflow (cfs)
FRE outflow (cfs)
FRE Pool Elevation (ft)
Note: Falling limb of hydrographs truncated at RE 440 to coincide with end of WSE dataset


2009 Simulated Flow Event (1/6/2009 - 2/6/2009; Source; WSE, 2017)
After Flood Reservoir Evacuation: 10 ft/day
Debris Management Evacuation: 2 ft/day
Final Reservoir Evacuation: 10 ft/day
Elev 585
Elev 528
Elev 500
Regulation Begins and Outflow Restricted
Reservoir Evacuation Begins and Outflow Increased
Reservoir Flow (cfs)
Pool Elevation (ft)
Hours
FRE Inflow (cfs)
FRE outflow (cfs)
FRE Pool Elevation (ft)
Note: Falling limb of hydrographs truncated at RE 440 to coincide with end of WSE dataset

Attachment 3. Land Cover Map for Study Area



Source: Landcover, FRE Facility - HDR; Streams - DNR; Basemap - ESRI Online; Hillshade - DNR LiDAR Portal

Landcover

- Coniferous Forest
- Mixed Coniferous/Deciduous Transitional Forest
- Deciduous Riparian Forest w/some Conifers
- Deciduous Riparian Shrubland
- Herbaceous/Grass
- Wetland
- Logged, replanted 5-15+ years
- Logged, replanted 0-5 years
- Open Water/Sand Bar
- Terrestrial Bare Ground/Roads
- Streams
- Study Area (WSEL: 628ft)

0 1,000 2,000 Feet

LAND COVER CLASSIFICATION

Chehalis River Basin Flood Damage Reduction Project

Date: 5/6/2020