Boundary Hydroelectric Project (FERC No. 2144)

Study No. 2

Analysis of Peak Flood Flow Conditions above Metaline Falls

Interim Report

Prepared for
Seattle City Light

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1 INTRODUCTION

Study No. 2 (Analysis of Peak Flood Flow Conditions above Metaline Falls) is being conducted in support of the relicensing of the Boundary Hydroelectric Project (Project), Federal Energy Regulatory Commission (FERC) No. 2144, as identified in the Revised Study Plan (RSP; SCL 2007) submitted by Seattle City Light (SCL) on February 14, 2007, and approved by FERC in its Study Plan Determination letter dated March 15, 2007. This interim report describes the 2007 study efforts of the Analysis of Peak Flood Flow Conditions above Metaline Falls.

During the July 19, 2006, FERC scoping meeting, Mr. Karl McKenzie, owner of Riverview Trailer Court & RV Park in Metaline, Washington, indicated that Project operations might exacerbate flooding in the Upper Reservoir Reach of the Boundary Reservoir (above Metaline Falls), thereby potentially contributing to the flooding of his and other improved properties within the reservoir floodplain. However, FERC notes in its study request (FERC 2006) that information in the Pre-Application Document (PAD) (SCL 2006) suggests that the natural constriction formed by the Canyon Reach and Metaline Falls prevents the Project from significantly affecting flood water surface elevations in the Upper Reservoir Reach. After FERC reviewed the information presented in the PAD and the comments provided during the scoping meeting, FERC identified a gap between existing information and the information needed to evaluate whether Project operations are influencing the duration and water surface elevation of floods upstream of Metaline Falls (FERC 2006).

This study evaluates how Project operations influence the duration and water surface elevation of flood conditions on the McKenzie property in the town of Metaline and on any other improved properties above Metaline Falls within the reservoir floodplain when flow exceeds 50,000 cubic feet per second (cfs) based on recent water surface elevation calibration using pressure transducer data. If Project operations are influencing the duration and water surface elevation of flood conditions, this study will identify opportunities for and costs of implementing procedures that may attenuate flooding above Metaline Falls.

The study uses recent topography and bathymetry to develop a hydraulic routing model to characterize reservoir conditions upstream of Metaline Falls relative to Project operations during periods of high flows in 1972, 1974, and 1997—the years Mr. McKenzie indicated in the FERC scoping meeting that flooding had occurred.

2 STUDY OBJECTIVES

The goals of the Analysis of Peak Flood Flow Conditions above Metaline Falls Study are to evaluate how Project operations may influence the duration and water surface elevation of flood conditions on the McKenzie property and on any other improved properties above Metaline Falls within the reservoir floodplain and to identify any procedures that may attenuate the potential conditions and the cost of implementing such measures. The objectives of the study are as follows:

- Select transects (number and location) to measure and utilize in a hydraulic routing model for the Upper Reservoir Reach adjacent to and in the vicinity of the town of Metaline.
- Develop an unsteady-flow hydraulic routing model that estimates water surface elevations and storage along modeled transects on an hourly basis for historical 1972, 1974, and 1997 high flows and Project operational conditions.
- Document the flow conditions when flooding of the Metaline area occurred in 1972, 1974, and 1997, and document the reservoir water surface elevations and surrounding land elevations in the Metaline area during these floods, if applicable.
- Determine the Project operational feasibility, effects on generation, and cost of implementing any procedures that might attenuate flooding conditions attributable to Project operations in the area of Metaline.

3 STUDY AREA

The overall study area for this effort encompasses the Pend Oreille River from Box Canyon Dam at Project river mile (PRM) 34.5 to Boundary Dam at PRM 17.0, as presented in Figure 3.0-1 (SCL 2007). The area of focus for this study is within the Upper Reservoir Reach, which extends from Box Canyon Dam to Metaline Falls (PRM 34.5 to PRM 26.8). The study area encompasses land adjacent to the reservoir sufficient to address the issue of the potential relationship of Project operations to flood conditions on the McKenzie property in the town of Metaline (PRM 29.0 to PRM 27.8). It further encompasses other improved properties that are determined to be within the reservoir floodplain in the Upper Reservoir Reach based on the results of the peak flood flow hydraulic routing modeling.

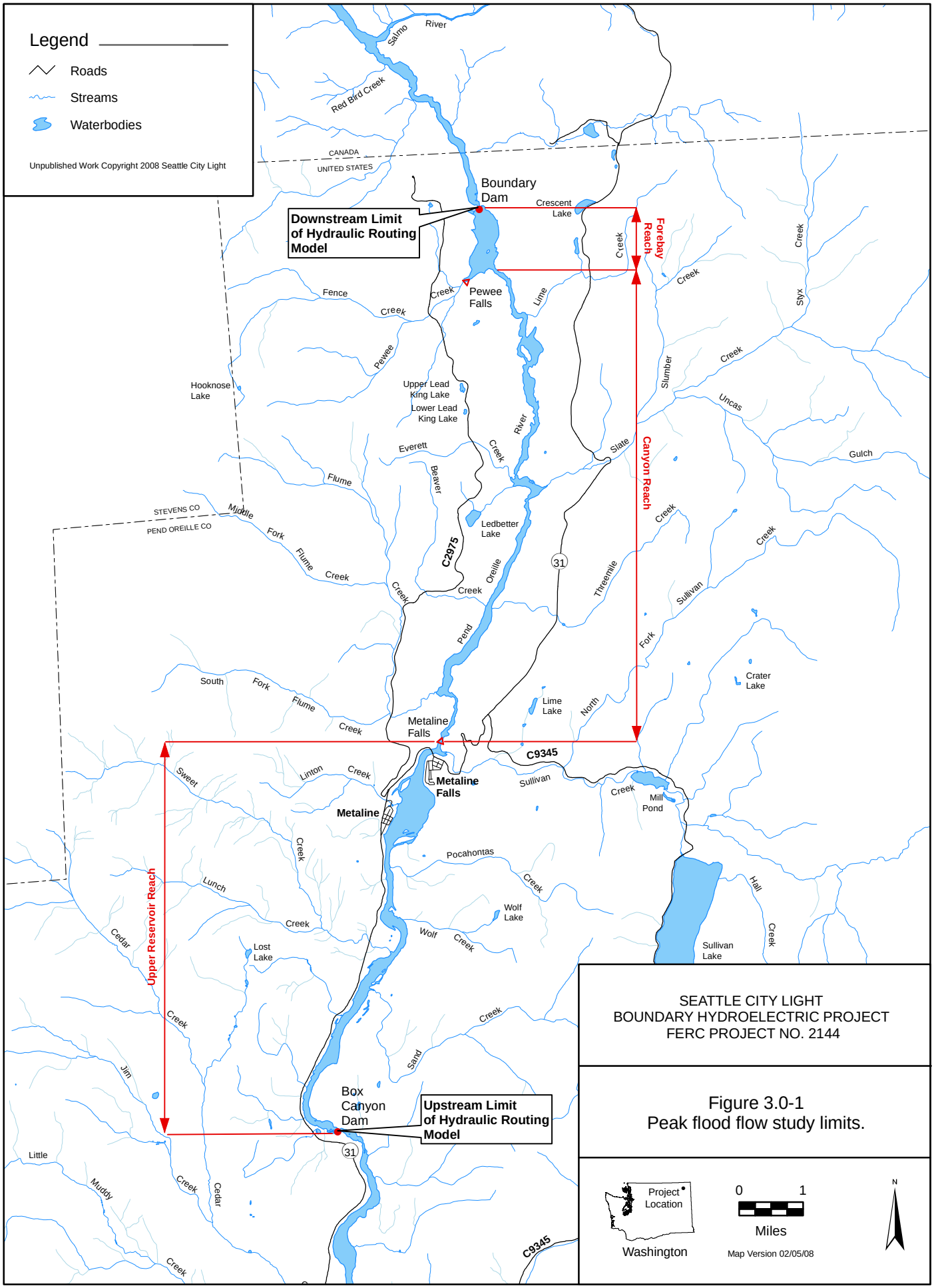

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Figure 3.0-1
Peak flood flow study limits.

4 METHODS

A one-dimensional, unsteady-flow hydraulic routing model is being constructed in support of Study 7 (Mainstem Aquatic Habitat Modeling) (SCL 2008a). It will be used as a starting point for Study 2 to analyze the influence of Project operations on the Upper Reservoir Reach near the town of Metaline during the high-flow periods of 1972, 1974, and 1997. The hydraulic routing model is being developed using the U.S. Army Corps of Engineers (USACE) HEC-RAS software (USACE 2002a, 2002b, 2006). The hydraulic routing model will be used to understand the influence of Project operations on water surface elevations during flooding conditions above Metaline Falls in areas of improved properties. If the flood inundation analysis indicates that the Project contributes to flooding conditions, the hydraulic routing model will also be used to specifically evaluate the potential for implementing procedures to reduce or eliminate flooding of the improved properties identified within the reservoir floodplain. The specific tasks involved in this study are described below.

4.1. Task 1 — Hydraulic Routing Model Construction

A one-dimensional, unsteady-flow hydraulic routing model will be used to simulate the hydraulic conditions above and below Metaline Falls. The hydraulic routing model developed for Study 7 (Mainstem Aquatic Habitat Modeling Study) will be used as the starting point for the development of the hydraulic routing model used for this study. The need for a one-dimensional, unsteady-flow hydraulic routing model was substantiated in Study 7 to analyze the translation and attenuation of flood waves generated by Project operations or by variation in upstream hydrologic conditions. Building on previous work, the peak flow study will use the Study 7 hydraulic routing model as the initial framework to derive a model capable of reproducing hydraulic conditions observed during high flow events.

As summarized in Study 7, Version 4.0 (Beta) of the USACE HEC-RAS model, along with Version 4.1.1 of the USACE HEC-GeoRAS software, were chosen for use in the study. The HEC-RAS executable code and documentation are public domain software for river analysis system (RAS) that was developed by the Hydrologic Engineering Center (HEC) for USACE. HEC-RAS is designed to perform one-dimensional hydraulic calculations for a dendritic network of natural and constructed channels. HEC-RAS computes the propagation of a floodwave with respect to the distance along the channel. The hydraulic routing model computes water surface elevations for a given time-step using the complex one-dimensional Saint-Venant equations of unsteady flow. The principles of conservation of mass and conservation of momentum form the basis of these equations. User input to HEC-RAS is composed of a series of cross sections spaced at intervals along the channel, along with definitions of the upstream and downstream boundary conditions.

Current topographic and bathymetric data were used as the basis for the cross section geometry of the study area for the Study 7 hydraulic routing model. The bathymetric and light detection and ranging (LiDAR) data were distinct products that were subsequently merged to form a continuous digital terrain model (DTM) in the form of a triangulated irregular network (TIN). The process used to collect the bathymetric data is described in the report titled “Boundary Dam/Seven Mile Dam Bathymetry Survey” (SCL 2008b). The LiDAR data was used to develop

the above-water portion of the cross section geometry. The LiDAR data set was derived from aerial flights conducted in August 2005 (Terrapoint 2005).

Cross section input geometry data were developed for the Study 7 hydraulic routing model using HEC-GeoRAS. HEC-GeoRAS is an ArcGIS extension that provides the user with a set of procedures, tools, and utilities to prepare geographic information system (GIS) data for import into HEC-RAS and subsequent generation of GIS data from HEC-RAS output (USACE 2005).

Supplemental cross sections required for the Study 2 peak flow hydraulic routing model will also be developed using HEC-GeoRAS. Supplemental cross sections will be located at specific points where hydraulic information will be required for calibration and for post-processing. Supplemental cross sections will be identified after Mr. McKenzie and surrounding residents are interviewed in spring 2008. The supplemental cross sections will then be imported into the existing hydraulic routing model developed as part of Study 7.

Downstream boundary conditions will be hourly water surface elevations measured at Boundary Forebay. Upstream boundary conditions will be synthesized flow hydrographs from mean daily data provided at USGS Gage No. 12396500 for the Pend Oreille River below Box Canyon Dam during the 1972, 1974, and 1997 events. Supplemental calibration events will use actual 15-minute data recorded at USGS Gage No. 12396500.

4.2. Task 2 — Hydraulic Routing Model Calibration

Calibration of the Study 2 hydraulic routing model will be based on observed high-water marks as recollected by Mr. McKenzie where his property and surrounding areas within the town of Metaline were inundated during the three flood events in 1972, 1974, and 1997. Other high-water marks observed by neighboring residents will also be used as appropriate. Historical photo documentation, newspaper articles, and official reports spanning the timeframe of the flood events will be sought and used to supplement the observed high-water marks. The Study 2 hydraulic routing model will also be calibrated to hourly stage data obtained from USGS Gage No. 12396500 for these same three flood events. Peak mean daily flow rates during each of these three events were in excess of 130,000 cfs. The available data that will be used to calibrate the hydraulic routing model include the following:

- High-water marks as observed by Mr. McKenzie and other property owners near the town of Metaline.
- Hourly stage data from the USGS for the Pend Oreille River below Box Canyon Dam (Gage No. 12396500).
- Hourly flow and stage data from Seattle City Light for total flow release from Boundary Reservoir (energy generation plus spill). Four (4) turbines were operating in 1972 and 1974, and six (6) turbines were operating in 1997.[1]
- Water surface elevation data (15-minute readings) during high flow conditions (flows in excess of 50,000 cfs) that occurred from 2006 through 2008. Water surface

[1] The Project began commercial operation in 1967, with turbine-generator Units 51 through 54. In accordance with a 1982 license amendment approving expansion of the Project, Units 55 and 56 were constructed in two previously excavated bays in the machine hall and came on line in 1986.

elevation data are available at pressure transducers deployed in the Pend Oreille River at the following locations:

- Just downstream of Box Canyon Dam, in the Upper Reservoir Reach.
- Just upstream from Metaline Falls, in the Upper Reservoir Reach.
- Just downstream from Metaline Falls, in the Canyon Reach.
- At the downstream end of the Canyon Reach.
- In the Boundary Project forebay, in the Forebay Reach.

Calibration to observed stage records, high-water marks, and any pertinent anecdotal information will be accomplished for each flood event. Mr. McKenzie will be interviewed to identify any observed high-water marks or other pertinent hydraulic conditions during the three flood events. Additionally, other stakeholders will be interviewed to obtain any additional anecdotal information for each of these events. These interviews are scheduled to be completed in spring 2008.

Additionally, post-processed water surface elevation data from the pressure transducer sites and water surface elevation data reported at the USGS Gage No. 12396500 between September 2006 and September 2008 will be used to supplement the calibration. These data will be used to calibrate the Study 2 hydraulic routing model to high flows on the order of 50,000 cfs. The locations of the pressure transducer sites and the USGS gaging station can be found Figure 4.2-1. These data will provide the lower bound of the peak flow calibration. Table 4.1-1 summarizes the two supplemental time periods that will be used to provide the lower bound of the peak flow calibration.

Table 4.1-1. Supplemental time periods for hydraulic routing model calibration for peak flow study.

Time Period[1]	**Flow Rate Range[2] (cfs)**	**Forebay Water Surface Elevation Range (ft NAVD 88)[3]**	**Forebay Water Surface Elevation Range (ft NGVD 29)**
5/11/07 – 5/23/07	37,800 – 50,100	1,975.71 – 1,993.32	1,971.68 – 1989.29
5/22/07 – 5/29/07	33,700 – 50,100	1,984.27 – 1,993.01	1,980.24 – 1988.98

Notes:

1 All simulations start and end at 12 noon on the specified days of the calibration time period

2 Flow rates as recorded at USGS gaging station 12396500

3 SCL is in the process of converting all Project information from an older elevation datum (National Geodetic Vertical Datum of 1929 [NGVD 29]) to a more recent elevation datum (North American Vertical Datum of 1988 [NAVD 88]). As such, elevations are provided relative to both data throughout this document. The conversion factor between the old and new data is approximately 4 feet (e.g., the crest of the dam is 2,000 feet NGVD 29 and 2,004 feet NAVD 88). Although some other relicensing studies may round the conversion to 4 feet, the Project forebay elevations are monitored with precision of 0.01 foot and the hydraulic routing model provides output to the same level of precision — rounding of output, if appropriate, will be performed after application of the actual conversion factor of 4.03 feet.

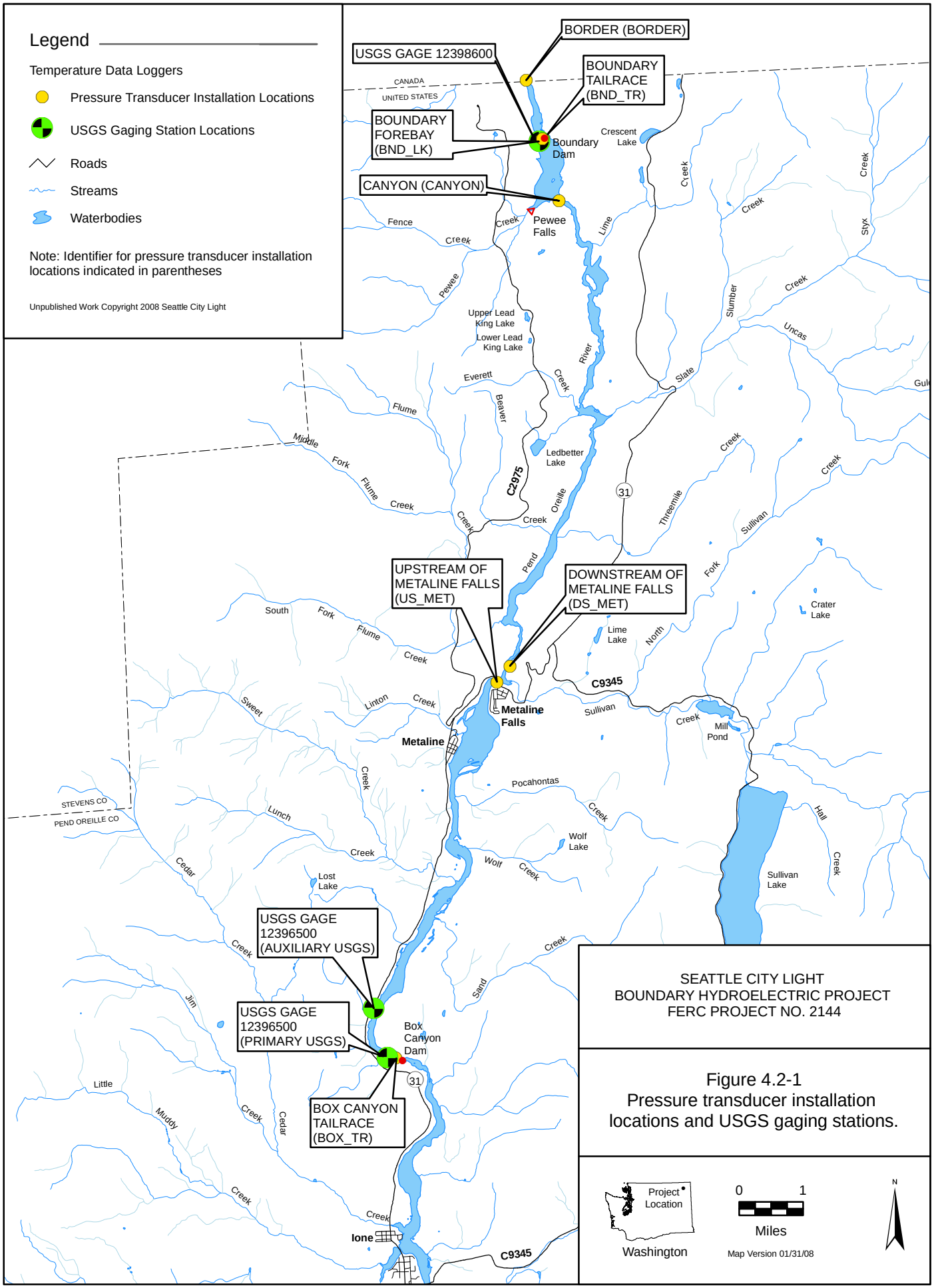

Figure 4.2-1
Pressure transducer installation locations and USGS gaging stations.

The Study 2 hydraulic routing model will use the following parameters to calibrate the model to the observed stage data:

- Main channel hydraulic resistance (Manning's roughness) coefficient
- Overbank Manning's roughness coefficient
- Expansion and contraction loss coefficients
- Ineffective flow boundary definition

Manning's roughness coefficients are spatially variable empirical parameters; the values are based on local substrate conditions, channel and overbank vegetation, cross section geometry, and other localized conditions that affect the hydraulics of the system. Initial selection of the magnitudes of the main channel and left overbank and right overbank Manning's roughness coefficients will be based on the calibrated values derived in Study 7.

Expansion and contraction loss coefficients are used to evaluate the energy loss that occurs due to flow expansion or contraction from one cross section to another. The coefficients are multiplied by the change in velocity head at each cross section. Similar to the Manning's roughness coefficients, initial selection of the expansion and contraction coefficients will be based on the calibrated values derived in Study 7.

The ineffective flow boundary definitions are not parameters but instead are locally defined portions of specific cross sections that do not "effectively" convey discharge. Ineffective flow areas are portions of the cross section where the downstream velocity is near zero. Eddy areas upstream and downstream of natural constrictions or constructed constrictions such as bridges can create ineffective flow areas in a cross section. Ineffective overbank areas that were not previously identified in Study 7 will be addressed for Study 2.

Iterative calibration of the peak flow hydraulic routing model will be evaluated through several statistical means using Microsoft Excel®. The observed stage hydrographs or high-water marks for each event will be compared to the simulated stage hydrographs or high-water marks. Similar to the calibration efforts in Study 7, the maximum absolute error will be computed at each calibration location for each comparison. The root mean square error (RMSE) will be evaluated as follows to provide a quantitative measure of the deviation from observed conditions at each calibration location for which stage hydrograph data are available:

$$\text{Root Mean Square Error (RMSE)} = \left[\sqrt{\frac{\sum_{i=1}^{n} \left(WSEL_{OBSi} - WSEL_{SIMi} \right)^2}{n}} \right]$$

where:

$WSEL_{OBSi}$ = observed water surface elevation at time interval i
$WSEL_{SIMi}$ = simulated water surface elevation at time interval i
n = number of time intervals in simulation

The magnitudes of each calibration parameter will be iteratively varied within physically acceptable ranges until hydraulic routing model calibration is attained within a pre-defined acceptable error range.

The calibrated parameters will be verified using the 1997 flood event. The incorporation of an independent verification event provides validation that the hydraulic routing model represents the hydraulic conditions experienced during peak flow conditions. The verification will be deemed unsuccessful if the hydraulic routing model results are outside of the pre-defined error ranges defined originally for the calibration step. In this case, the 1997 stage hydrograph will be used as additional hydraulic routing model calibration event and the model parameters will be adjusted until the model-simulated results are within the pre-defined error ranges for all calibration and verification periods.

4.3. Task 3 — Hydraulic Routing Model Documentation and Executable

An executable hydraulic routing model and supporting documentation will be prepared for Study 2. The model will be used to develop hydraulic conditions for the 1972, 1974 and 1997 high flow events based on historic project conditions and Project operations. The modeled water surface elevations, will be exported from the hydraulic routing model using HEC-GeoRAS into GIS maps. Maps will be generated to illustrate areas inundated for the 1972, 1974, and 1997 events in the vicinity of the McKenzie property in the town of Metaline. These maps will also identify inundation on other improved properties in the Upper Reservoir Reach that are determined to be within the reservoir floodplain. Each of the three historical events will be reanalyzed with the potential hydraulic influence of the Project operations removed. The resulting modeled water surface elevations and inundation areas will be compared with those developed from the historical conditions run to determine if any of the flood inundation occurred due to Project operations. If these results show that Project operations contributed to flooding during thee historical events, Task 4 will be undertaken to identify potential procedures to attenuate flooding in the future.

4.4. Task 4 — Flood Analysis Documentation

If it is found that Project operations contributed to flooding of the McKenzie property or other improved property above Metaline Falls during 1972, 1974, and 1997, the calibrated hydraulic routing model will be used to evaluate SCL's ability to implement procedures to attenuate the flooding. This task will also evaluate the Project operational feasibility, the effects on energy generation, and the cost of implementation of these procedures. An example of such a procedure would be changing the flows at which the spillway gates are opened during the rising limb of the flood event. Another possibility, if deemed feasible, may be to temporarily adjust Project operations during specified flood conditions to maintain lower forebay water surface elevations to reduce any identified Project related backwater influence above Metaline Falls.

5 PRELIMINARY RESULTS

This section presents the results of work for Study 2 from January 2007 through December 2007. Study 2 builds on the hydraulic routing model developed for Study 7. However, development of the hydraulic routing model for Study 7 was held up by delays in the receipt of the bathymetric data. Once the hydraulic routing model for Study 7 is adequately calibrated, the model's response during peak flow conditions will be examined for Study 2.

Additionally, information necessary to supplement the peak flow calibration effort is needed. As noted above, interviews with stakeholders and review of historical documentation are required to establish any high-water marks or hydraulic conditions experienced during the historical events. The following sections detail the work that has been completed thus far.

5.1. Hydraulic Routing Model Input Development

The following subsections describe the specific input parameters being developed for the hydraulic routing model.

5.1.1. Cross-Section Locations

Initial cross section locations for the peak flow model will be based on the cross section locations included in the Study 7 hydraulic routing model. At this time, no supplemental cross sections have been identified for the Study 2 peak flow hydraulic routing model. Identification of the supplemental cross section locations is pending until the high-water marks on the McKenzie property are surveyed.

Cross sections currently included in the Study 7 hydraulic routing model are shown in Figure A.1-1 in Appendix 1. An example of the figures presented in Appendix 1 is shown in Figure 5.1-1.

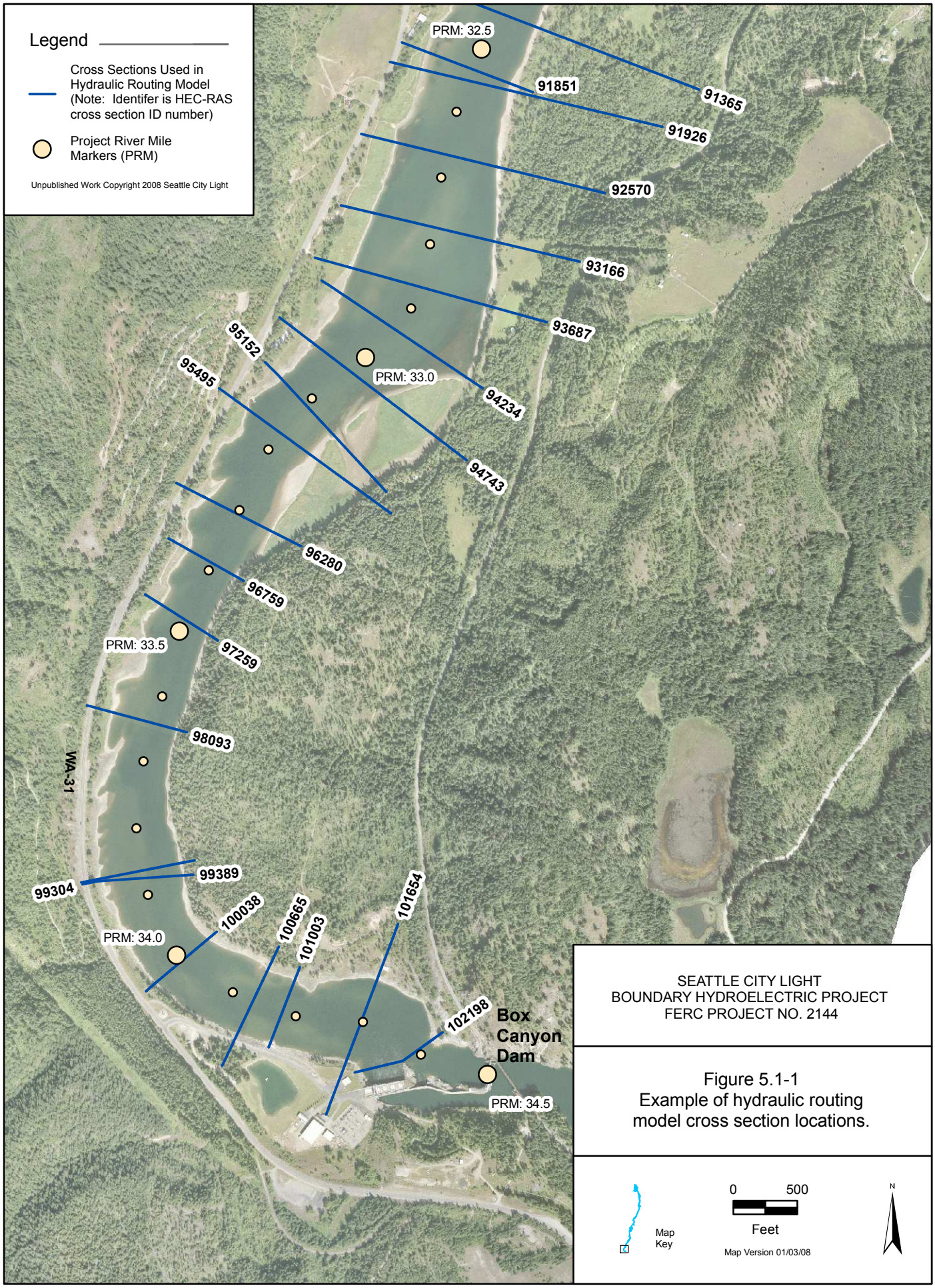

Figure 5.1-1
Example of hydraulic routing model cross section locations.

5.1.2. Initial n-Value and Loss Coefficient Estimates

Initial estimates of the Manning's roughness coefficients and the expansion and contraction loss coefficients for the Study 2 peak flow model will be based on the final calibrated values obtained for the Study 7 hydraulic routing model. Table 5.1-1 summarizes the estimated initial values obtained from the January 2008 Study 7 Interim Report. Photographic examples of roughness characteristics at selected locations within the study area and the corresponding Study 7 final calibrated Manning's roughness coefficients are presented in Figures 5.1-2 through 5.1-3. Initial estimates of the main channel and overbank Manning's roughness coefficients and the expansion and contraction loss coefficients for Study 7 were based on observations made during the September 2007 site visit and guidance presented in USACE (2006), Barnes (1967), and Arcement and Schneider (1989). In the case of Figure 5.1-2, the river is a smooth glide with unobstructed flow. Vegetation along the shoreline is composed of deciduous and conifer trees with medium density undergrowth providing some reduction in flow conveyance during significant flood events. A resultant Manning's roughness coefficient of 0.032 and 0.050 representing main channel and overbank roughness was selected, respectively. In the case of Figure 5.1-3, both the channel and overbank areas contain significant obstructions and irregularities causing the turbulent flow along the channel perimeter. As flow irregularities increase and flow efficiency decreases, the equivalent channel roughness is increased to account for the loss of flow conveyance. As a result, the channel and overbank roughness coefficient at PRM 26.1 was increased to 0.089. Additional details on identification of appropriate roughness coefficients can be found in the Study 7 Interim Report (SCL 2008).

Table 5.1-1. Initial estimates of hydraulic routing model calibration parameters for peak flow study.

U/S HEC-RAS Cross Section	D/S HEC-RAS Cross Section	U/S Project River Mile	D/S Project River Mile	Manning's Roughness			Contraction Coefficient	Expansion Coefficient
				Left Overbank	Channel	Right Overbank		
102198	98093	34.39	33.64	0.060	0.037	0.050	0.1	0.3
98093	94743	33.64	33.03	0.060	0.036	0.050	0.1	0.3
94743	90344	33.03	32.24	0.050	0.032	0.050	0.1	0.3
90344	83995	32.24	31.08	0.040	0.028	0.040	0.1	0.3
83995	81030	31.08	30.54	0.050	0.032	0.050	0.1	0.3
81030	76404	30.54	29.75	0.050	0.032	0.075	0.1	0.3
76404	72815	29.75	29.08	0.050	0.032	0.050	0.1	0.3
72815	60555	29.08	26.90	0.050	0.032	0.050	0.3	0.5
60555	60143	26.90	26.83	0.089	0.089	0.089	0.5	0.7
60143	59729	26.83	26.75	0.123	0.123	0.123	0.5	0.7
59729	59451	26.75	26.69	0.123	0.123	0.123	0.9	0.9
59451	57424	26.69	26.31	0.089	0.089	0.089	0.9	0.9
57424	12044	26.31	17.99	0.089	0.089	0.089	0.3	0.5
12044	5428	17.99	17.02	0.028	0.028	0.028	0.1	0.3

Notes:
1 Refer to Figure A.1-1 for HEC-RAS cross section locations.
2 River mile assignments were based on linear interpolation between river mile identifiers at 0.1-mile increments.
3 Initial estimates of the calibration parameter values are based on the results of the Study 7 hydraulic routing model calibration presented in the Study 7 Interim Report (SCL 2008).

Figure 5.1-2. Photograph of Pend Oreille River at PRM 32.5, representing main channel n-value of 0.032 and overbank n-value of 0.050.

Figure 5.1-3. Pend Oreille River at PRM 26.1, representing a channel and overbank n-value of 0.089.

5.1.3. Boundary Conditions to Calibrate Hydraulic Routing Model

Boundary conditions are used to establish starting and coincidental water surface elevations to calibrate the peak flow hydraulic routing model. A time-series of the Boundary forebay water surface elevations and a time-series of flow measured at the USGS Gage No. 12396500 (USGS 2006) will be used as the downstream and upstream boundary conditions. The downstream and upstream boundary condition time-series that will be used for the 1997 calibration event are shown as Figures 5.1-4 and 5.1-5. Figures that show the boundary conditions for the other two historical flood events (1972 and 1974) and the supplemental calibration time periods are included in Appendix 2.

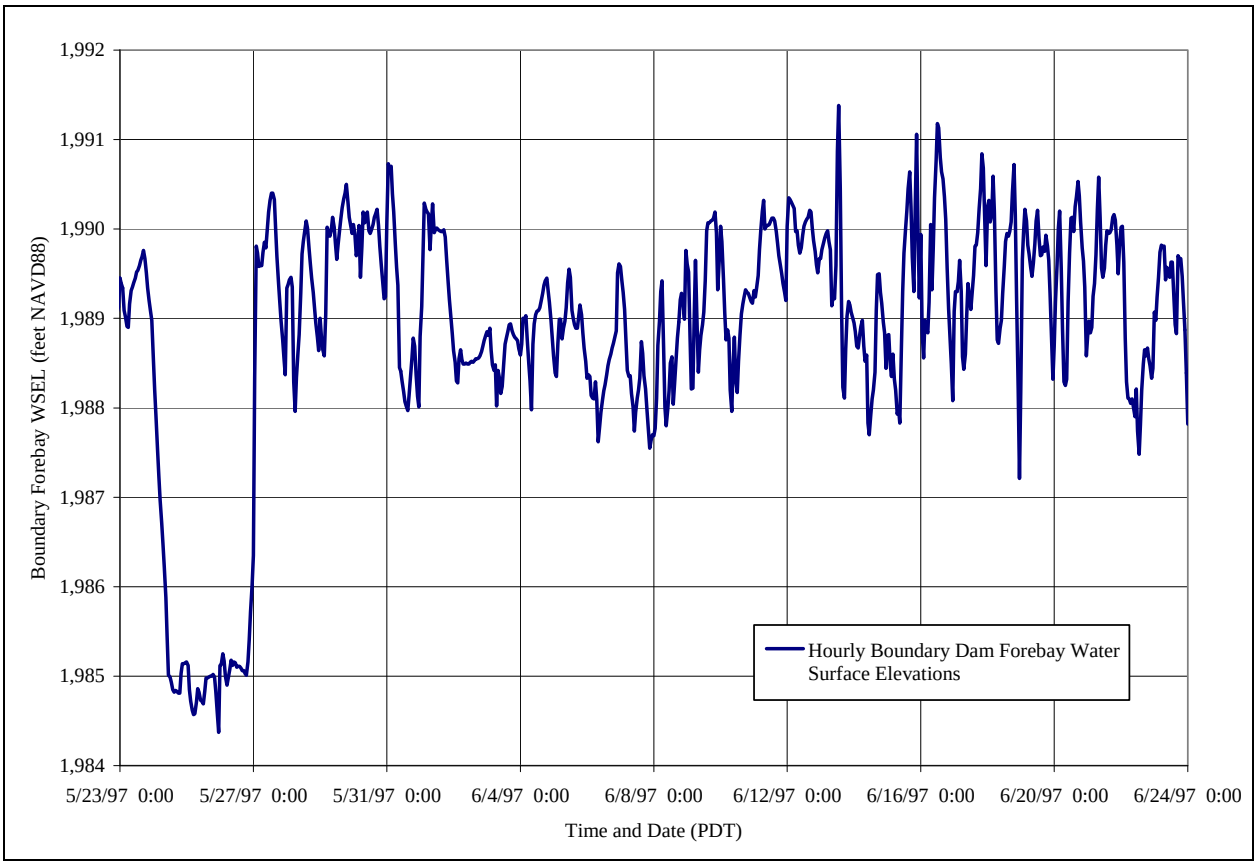

Figure 5.1-4. Boundary forebay hourly stage hydrograph for the 1997 event.

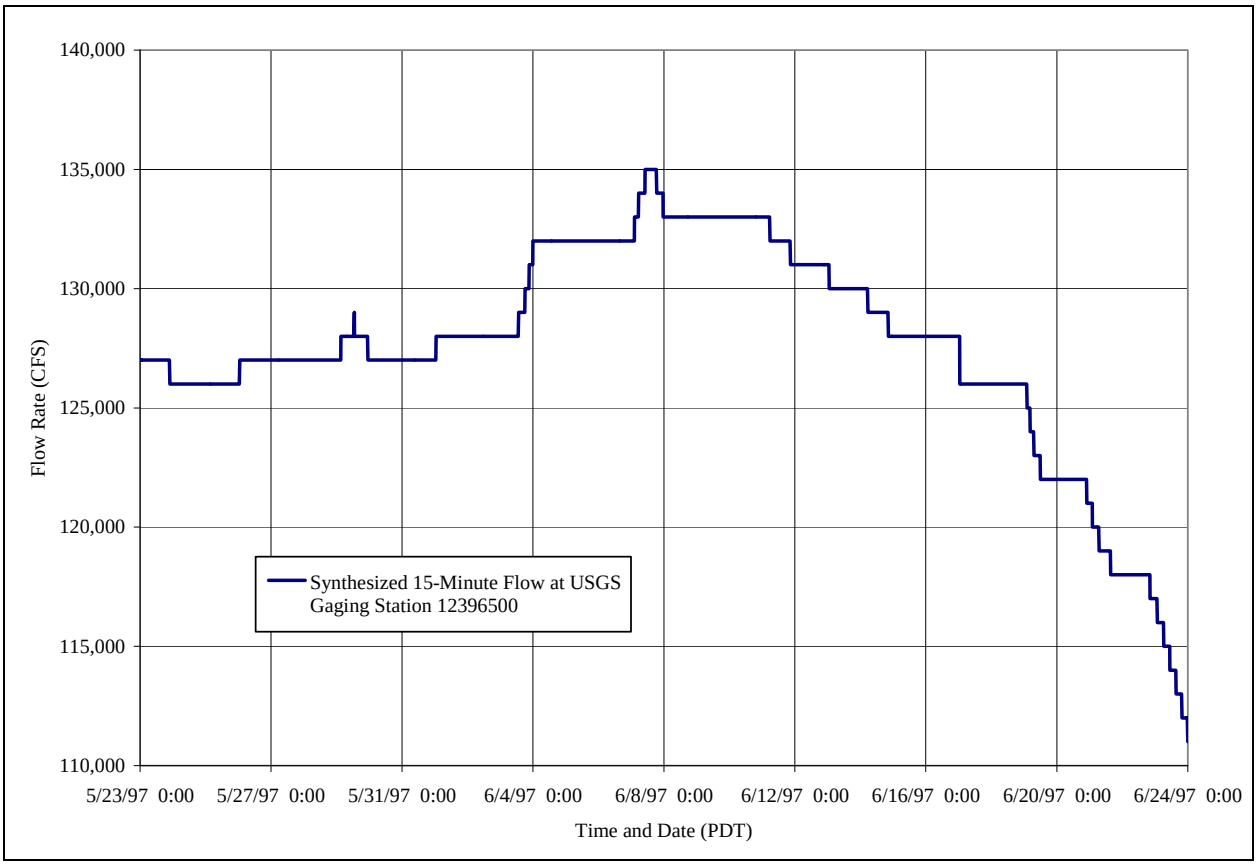

Figure 5.1-5. USGS Synthesized 15-minute flow hydrograph at USGS Gage No. 12396500 for the 1997 event.

5.2. Initial Hydraulic Routing Model Calibration

At this point, no calibration has been conducted specifically for the Study 2 peak flow hydraulic routing model.

5.2.1. Initial Calibrated n-Values and Loss Coefficients

This subsection will present the calibrated n-values and loss coefficients that result from the initial calibration. At this time, the hydraulic routing model has not been calibrated for peak flow conditions.

5.2.2. Stage and Discharge Comparisons

At this point, no calibration has been conducted specifically for the Study 2 peak flow model. However, preliminary calibration of the hydraulic routing model for Study 7—which will be used as the basis for the Study 2 peak flow model—has been completed for several high-flow periods that occurred in 2007.

As described in Section 4.2 of this report, two separate time periods from the 2007 high-flow conditions will be used to calibrate the Study 2 peak flow hydraulic routing model. The preliminary results of the Study 7 calibration are included in this section to illustrate the status of the hydraulic routing model calibration as of the time of this writing. Figures 5.2-1 and 5.2-2 show the Study 7 calibration results for the pressure transducer location upstream of Metaline Falls for the two supplemental calibration periods described in Section 4.2. Additional information regarding the calibration of the Study 7 hydraulic routing model for the two periods mentioned is presented in Figure A.3-1 through A.3-12 located within Appendix 3.

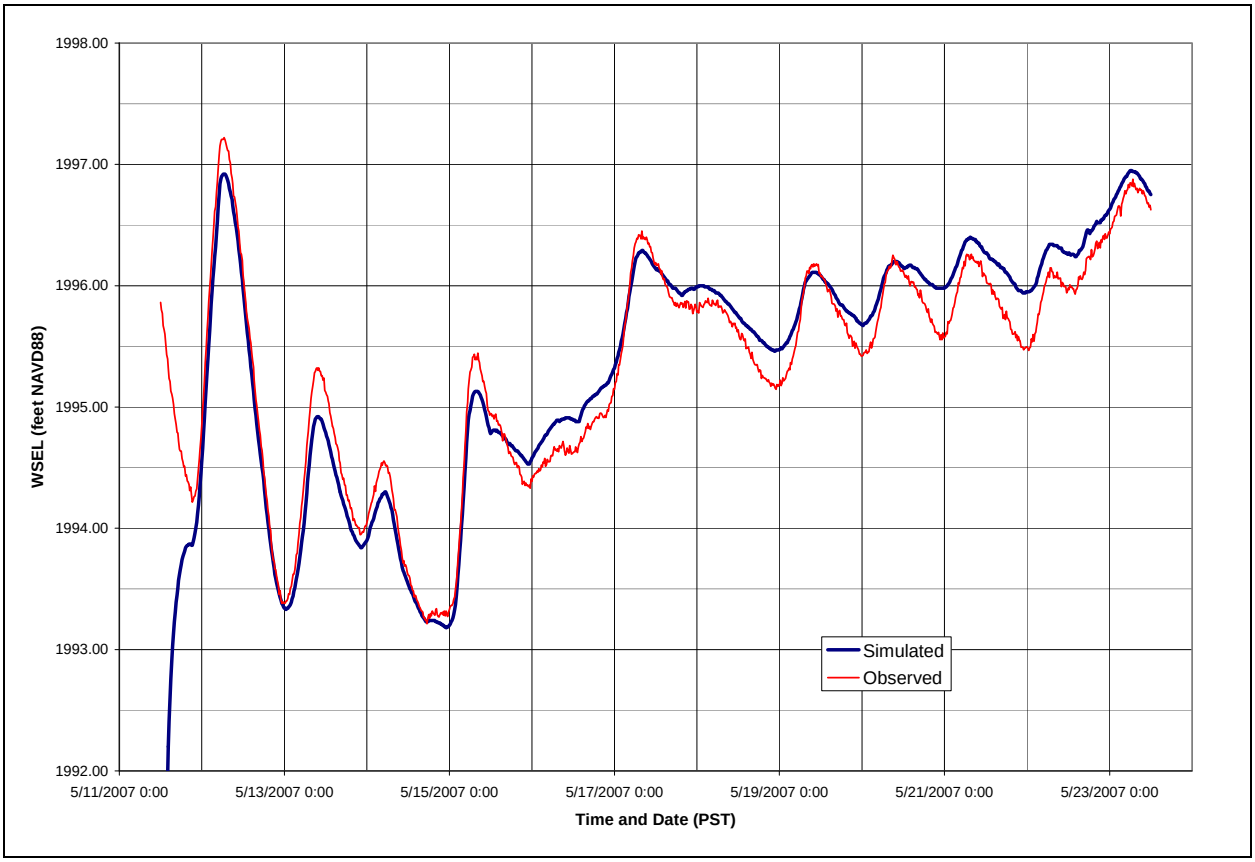

Figure 5.2-1. Study 7 hydraulic routing model calibration results upstream of Metaline Falls for May 11, 2007, through May 23, 2007, high-flow time period.

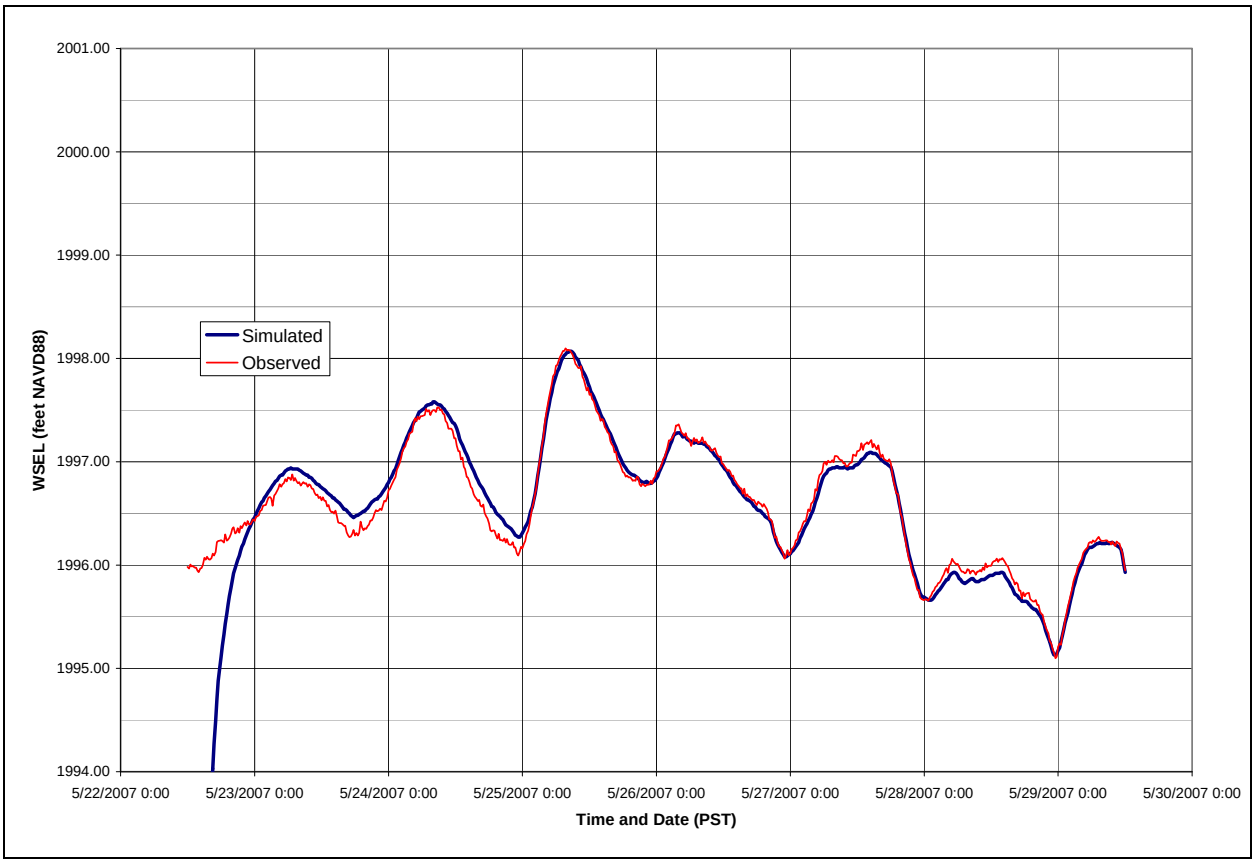

Figure 5.2-2. Study 7 hydraulic routing model calibration results upstream of Metaline Falls for May 22, 2007, through May 29, 2007, high-flow time period.

6 SUMMARY

Additional work remains on the tasks associated with Study 2 due to delay in the development of the final reservoir bathymetry. The peak flow hydraulic routing model, which will be based on modeling efforts from Study 7, will evaluate hydraulic conditions and the extent of flooding upstream of Metaline Falls for flood events that occurred in 1972, 1974, and 1997 and for several supplemental high-flow events recorded between 2006 through June 2008. Work associated with Study 2 will be performed during 2008. In general, items to be executed include:

- Acquire and assess calibration data points such as high water marks, historical photo documentation, and pertinent anecdotal information.
- Calibrate the hydraulic routing model to historical peak flood flow conditions.
- Prepare hydraulic routing model documentation and subsequent inundation mapping of the historical peak flood events.
- Assess the relationship between Project operations and the duration and location of flooding above Metaline Falls.

This section summarizes work that has been completed in 2007 and lists the work that remains to be competed in 2008. The crossover elements for each study component are also identified.

6.1. Study Status

A summary of the efforts completed through December 2007 and the work remaining through 2008 is provided in Table 6.1-1. The initial framework of the hydraulic routing model has been completed as part of Study 7. The majority of the analysis and hydraulic routing modeling effort remains to be completed. Calibration will occur into mid-2008 and subsequent reporting will be completed by the end of 2008.

Table 6.1-1. Summary of work status for Study 2.

RSP Task / Interim Study Report Section	Task Name	Status of Work Effort (Completed / *Remaining*)
1/4.1	Hydraulic Routing Model Construction	Model construction completed as part of Study 7 / *Supplemental cross sections will be included at calibration locations*
2/4.2	Hydraulic Routing Model Calibration	Model has not been calibrated to peak flood flows / *Calibration of model will occur in early to mid-2008*
3/4.3	Hydraulic Routing Model Documentation and Executable	No work for this task has been completed / *Documentation of the calibration and modeling effort will commence post calibration; development of inundation map will occur at that time*
4/4.4	Flood Analysis Documentation	No work for this task has been completed / *This work is scheduled to be completed by the end of 2008*

6.2. Crossover Studies

The following crossover studies were identified for Study 2, as listed and discussed below:

- Study 3 – Study 2 will be coordinated with Study 3 (Evaluation of Total Dissolved Gas and Potential Abatement Measures) to assess the potential benefit of temporary, Project operation adjustments.
- Study 7 – The hydraulic routing model developed for the Mainstem Aquatic Habitat Modeling Study will be used as the initial framework for development of the peak flood flow hydraulic routing model. Initial channel properties such as roughness coefficients, loss coefficients, and ineffective flow areas defined within Study 7 will be used as the starting point during the calibration effort. Continued coordination between the two studies will be necessary as final calibration of the Study 7 hydraulic routing model is completed. Spring high-flow data collected by the pressure transducers in 2008 will be used in both the Study 2 and Study 7 calibration efforts. Hydraulic output generated from the Study 2 peak flow hydraulic routing model may be used as supplementary information in fulfilling information requests during execution of Study 7. Close coordination between the two studies will be facilitated because the consultant lead on these studies is the same, and several individuals are participating in both efforts.

7 VARIANCES FROM FERC-APPROVED STUDY PLAN AND PROPOSED MODIFICATIONS

No variances in the study plan have been identified. However, some changes in schedule are necessary because of the delay in receiving final bathymetry. The revised schedule still meets all critical needs of the effort. The performance periods for tasks related to the calibration and documentation tasks were shifted into early and mid-2008. This change requires shifting the hydraulic routing model development and calibration task completion from the fourth quarter of 2007 to early third quarter of 2008. The determination of peak flood inundation conditions will be conducted in the third quarter of 2008. If Project operations contribute to flooding conditions above Metaline Falls in areas of improved property, the feasibility and costs of mitigating the flooding conditions will be analyzed in the fourth quarter of 2008. The documentation of Study 2 will be completed by the end of 2008.

8 REFERENCES

Arcement G.J., and V. Schneider. 1989. Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains. United States Geological Survey Water-Supply Paper 2339. United States Government Printing Office, Washington.

Barnes, H.H., Jr. 1967. Roughness of Characteristics of Natural Channels. United States Geological Survey Water-Supply Paper 1849. United States Government Printing Office, Washington.

Federal Energy Regulatory Commission (FERC). 2006. Analysis of Peak Flood Flow Conditions above Metaline Falls. Study request dated August 31, 2006, for Project No. 2144-035-Washington, Boundary Hydroelectric Project, City of Seattle.

Seattle City Light (SCL). 2006. Pre-Application Document for the Boundary Hydroelectric Project (FERC No. 2144). Seattle, Washington. May 2006. Available online at: http://www.seattle.gov/light/news/issues/bndryRelic/br_document.asp.

SCL. 2007. Revised Study Plan Boundary Hydroelectric Project (FERC No. 2144). Seattle, Washington. February 2007. Also available online at: http://www.seattle.gov/light/news/issues/bndryRelic/br_document.asp

SCL. 2008a. Study 7 – Mainstem Aquatic Habitat Modeling Study Interim Report for the Boundary Hydroelectric Project (FERC No. 2144). Prepared by Tetra Tech and TRPA. March 2008.

SCL. 2008b. Study 25 – Bathymetry Survey – Boundary Reservoir and Tailwater to Seven Mile Dam Interim Report for the Boundary Hydroelectric Project (FERC No. 2144). Prepared by Tetra Tech. March 2008.

Skone, R.L. 1975. Memorandum to R.K. Walker regarding Boundary Reservoir backwater effects at Metaline Falls. Seattle City Light, Seattle Washington, August 20, 1975.

Terrapoint. 2005. Project Report, Metaline Falls (Contract #2354-H). Report presented to DeGross Aerial Mapping Inc.

U.S. Army Corps of Engineers (USACE). 2002a. HEC-RAS River Analysis System Hydraulic Reference Manual, Version 3.1, CPD-69, November 2002.

USACE. 2002b. HEC-RAS River Analysis System Applications Guide, Version 3.1, CPD-70, November 2002.

USACE. 2005. HEC-GeoRAS GIS Tools for support of HEC-RAS using ArcGIS User's Manual. Version 4.0, CPD-83, September 2005.

USACE. 2006. HEC-RAS River Analysis System User's Manual. Version 4.0, CPD-68, November 2006.

U.S. Geological Survey (USGS). 2006. On-line NWIS web data for the nation. Available at: http://waterdata.usgs.gov/nwis/qw.

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Appendix 1. Cross Section Locations

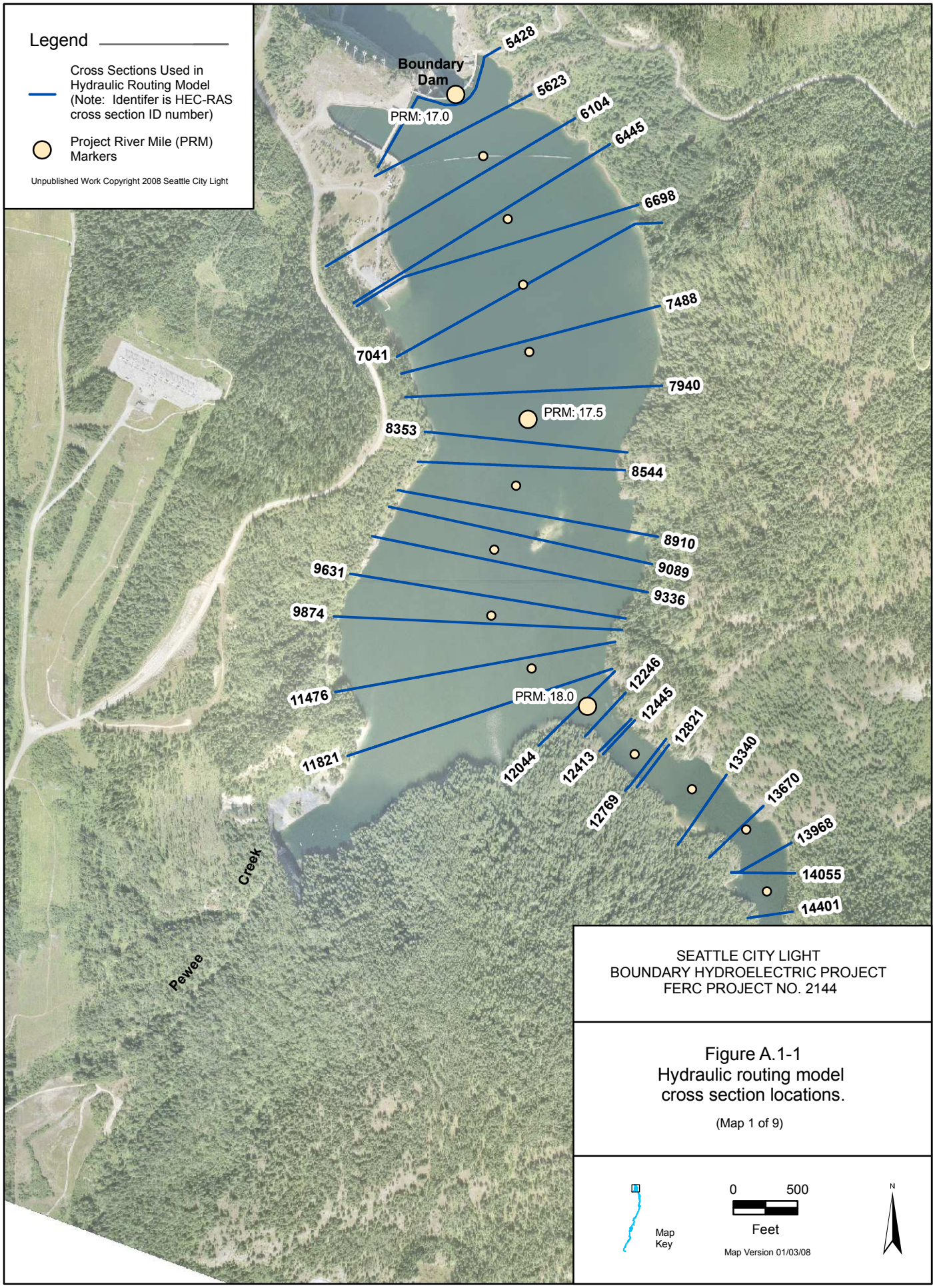
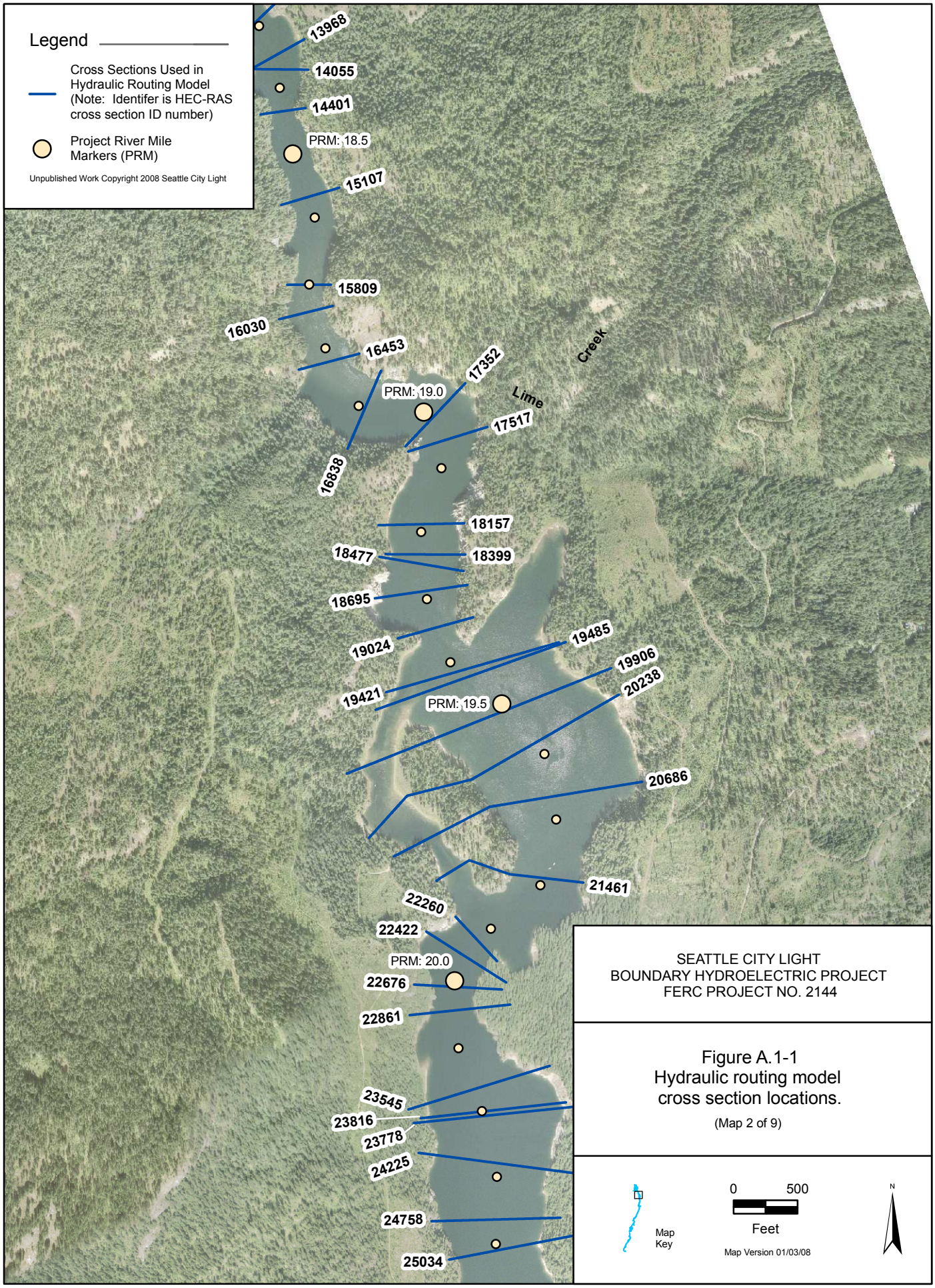


Figure A.1-1
Hydraulic routing model cross section locations.

(Map 1 of 9)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Cross Sections Used in Hydraulic Routing Model (Note: Identifer is HEC-RAS cross section ID number)
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Unpublished Work Copyright 2008 Seattle City Light
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14401
PRM: 18.5
15107
15809
16030
16453
17352
PRM: 19.0
Lime
Creek
17517
16838
18157
18477
18399
18695
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19421
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20686
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22422
PRM: 20.0
22676
22861
23545
23816
23778
24225
24758
25034
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure A.1-1
Hydraulic routing model
cross section locations.
(Map 2 of 9)
Map Key
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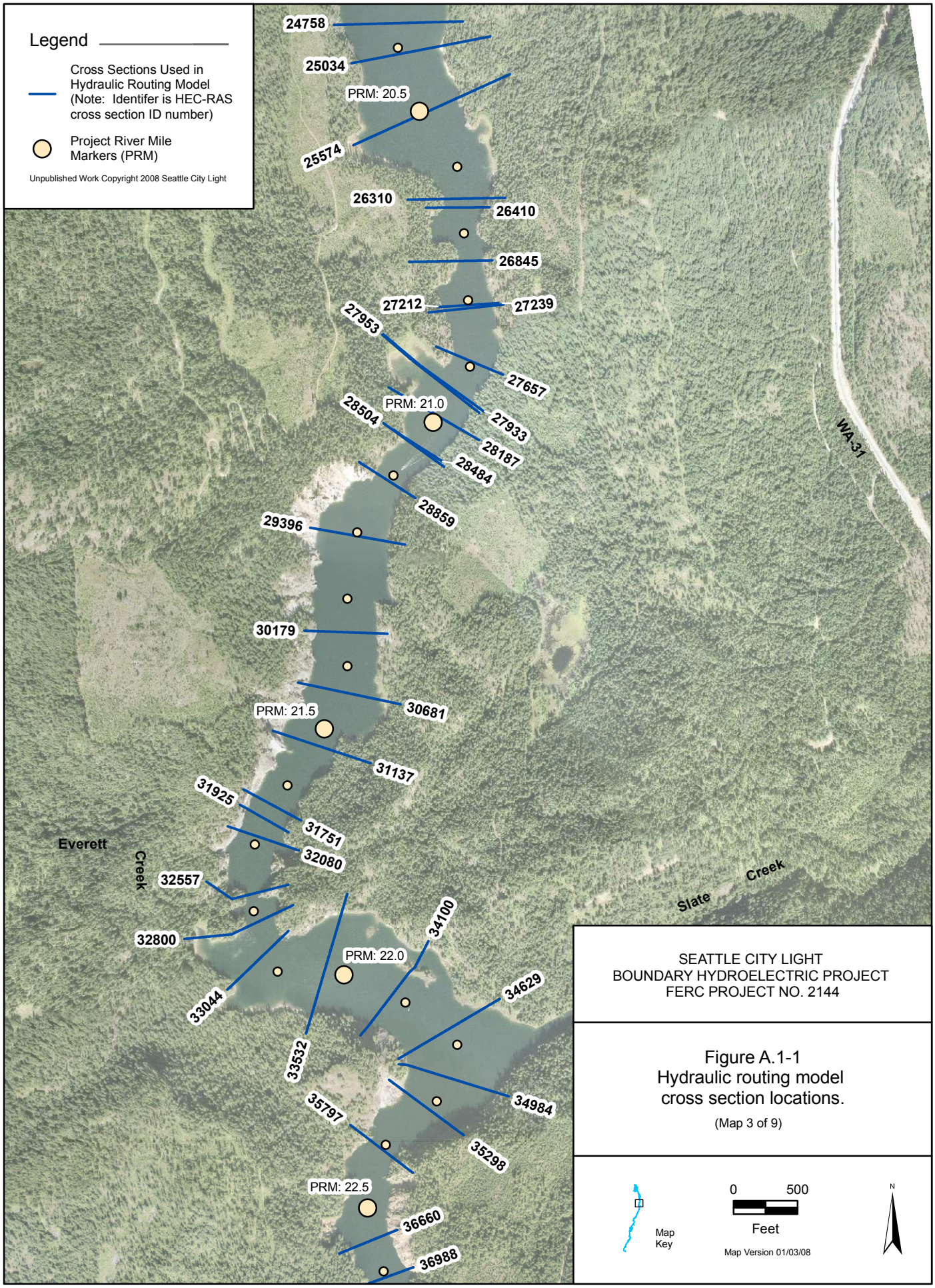
Feet
Map Version 01/03/08
N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Unpublished Work Copyright 2008 Seattle City Light
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26310
26410
26845
27212
27239
27953
27657
PRM: 21.0
28504
27933
28187
28484
28859
29396
30179
30681
PRM: 21.5
31137
31925
31751
32080
32557
32800
33044
33532
34100
PRM: 22.0
34629
34984
35797
35298
PRM: 22.5
36660
36988
Everett
Creek
Slate
Creek
WA-31
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
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Hydraulic routing model
cross section locations.
(Map 3 of 9)
Map Key
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Feet
Map Version 01/03/08
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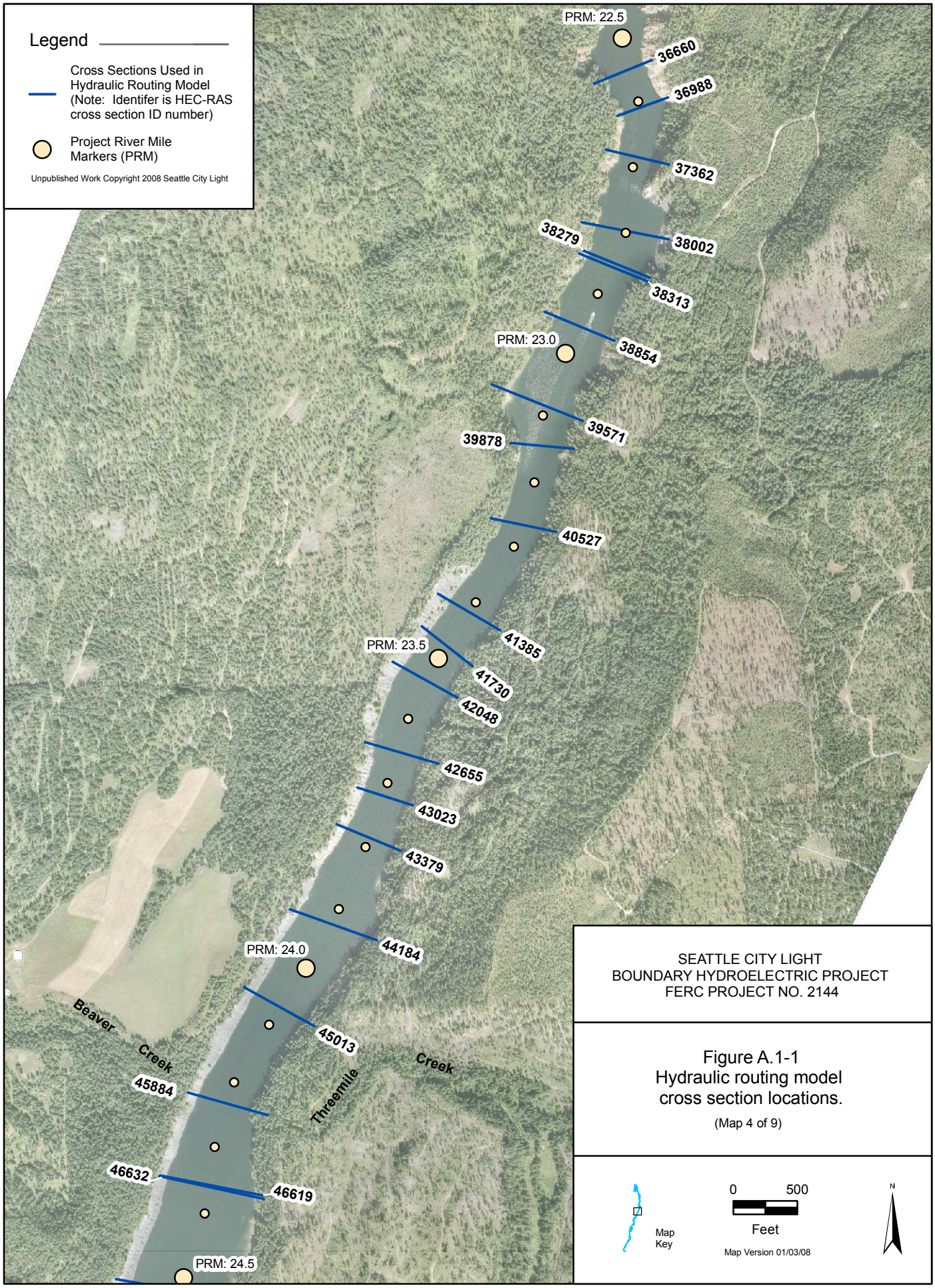
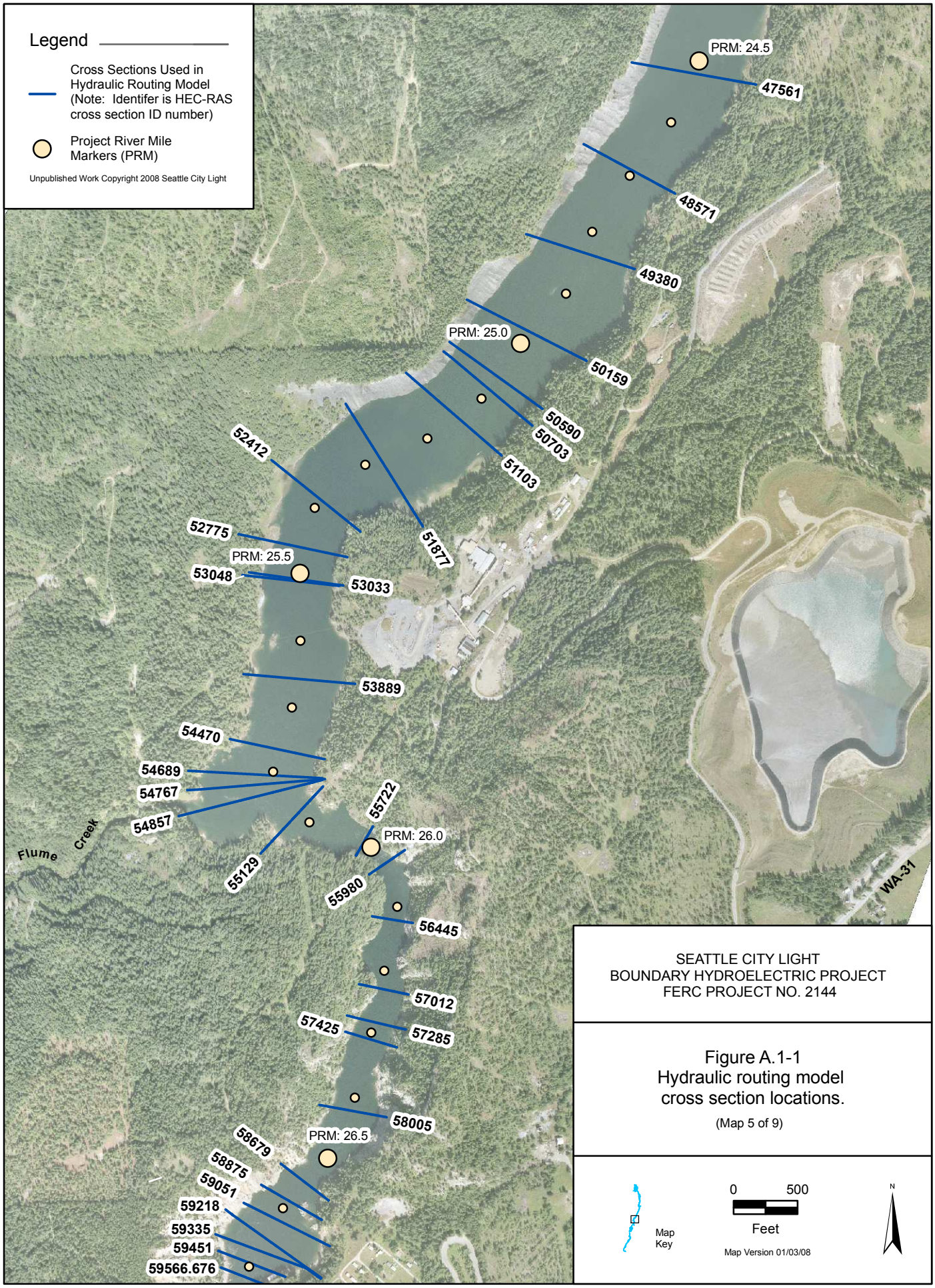


SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144

Figure A.1-1
Hydraulic routing model cross section locations.

(Map 4 of 9)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Unpublished Work Copyright 2008 Seattle City Light
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48571
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PRM: 25.0
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50590
50703
51103
51877
52412
52775
PRM: 25.5
53048
53033
53889
54470
54689
54767
54857
55722
PRM: 26.0
55129
55980
56445
57012
57425
57285
58005
PRM: 26.5
58679
58875
59051
59218
59335
59451
59566.676
Flume Creek
WA-31
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure A.1-1
Hydraulic routing model
cross section locations.
(Map 5 of 9)
Map Key
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Feet
Map Version 01/03/08
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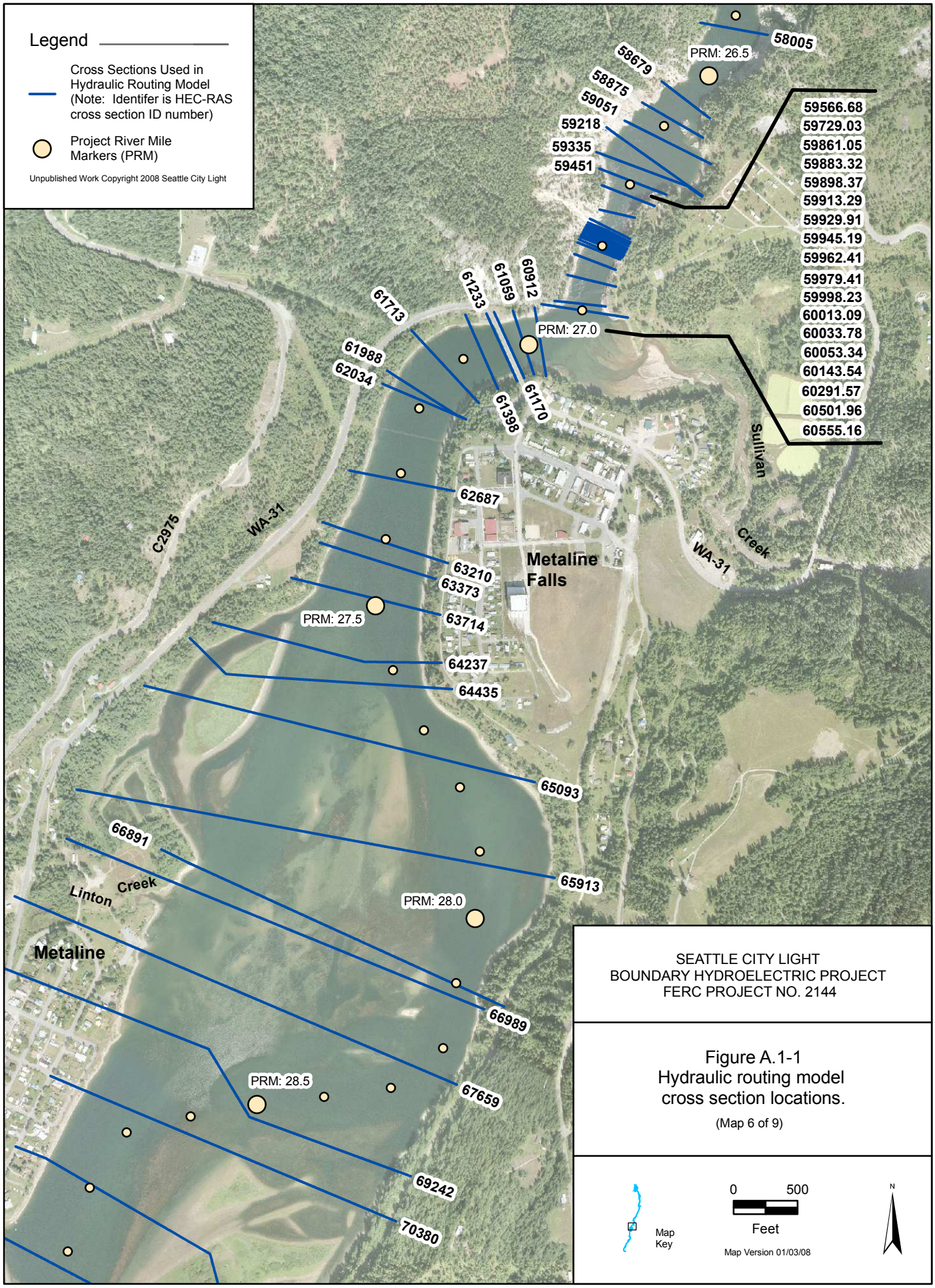
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Unpublished Work Copyright 2008 Seattle City Light
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59451
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59729.03
59861.05
59883.32
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59913.29
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59962.41
59979.41
59998.23
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Sullivan
Creek
62687
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WA-31
Metaline Falls
WA-31
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Creek
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Metaline
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SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure A.1-1
Hydraulic routing model
cross section locations.
(Map 6 of 9)
Map Key
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Feet
Map Version 01/03/08
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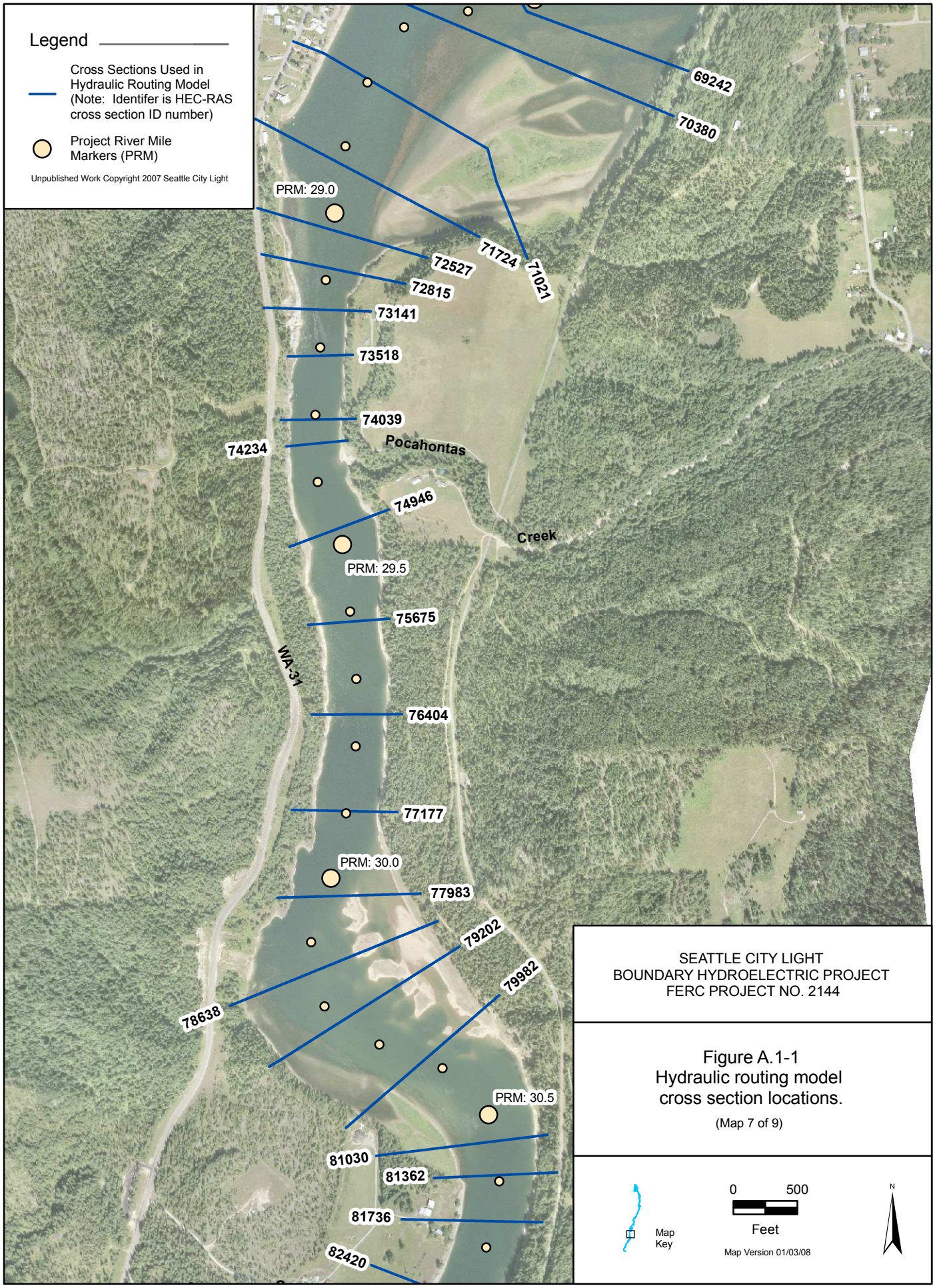
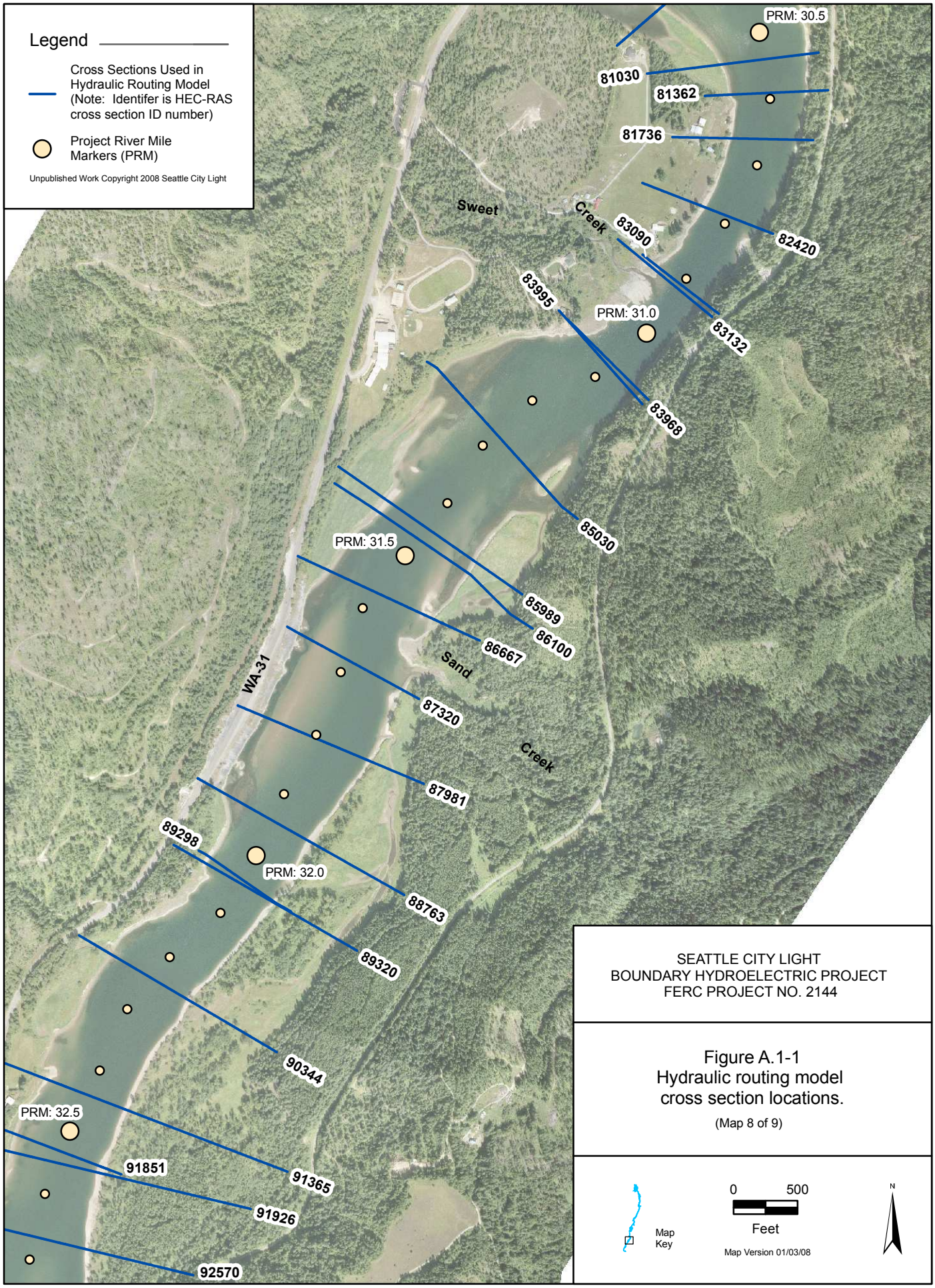


SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144

Figure A.1-1
Hydraulic routing model cross section locations.

(Map 7 of 9)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Unpublished Work Copyright 2008 Seattle City Light
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82420
Sweet
Creek
83090
83132
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PRM: 31.0
83968
85030
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85989
86100
86667
Sand
Creek
WA-31
87320
87981
89298
PRM: 32.0
88763
89320
90344
PRM: 32.5
91851
91365
91926
92570
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure A.1-1
Hydraulic routing model
cross section locations.
(Map 8 of 9)
Map Key
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Feet
Map Version 01/03/08
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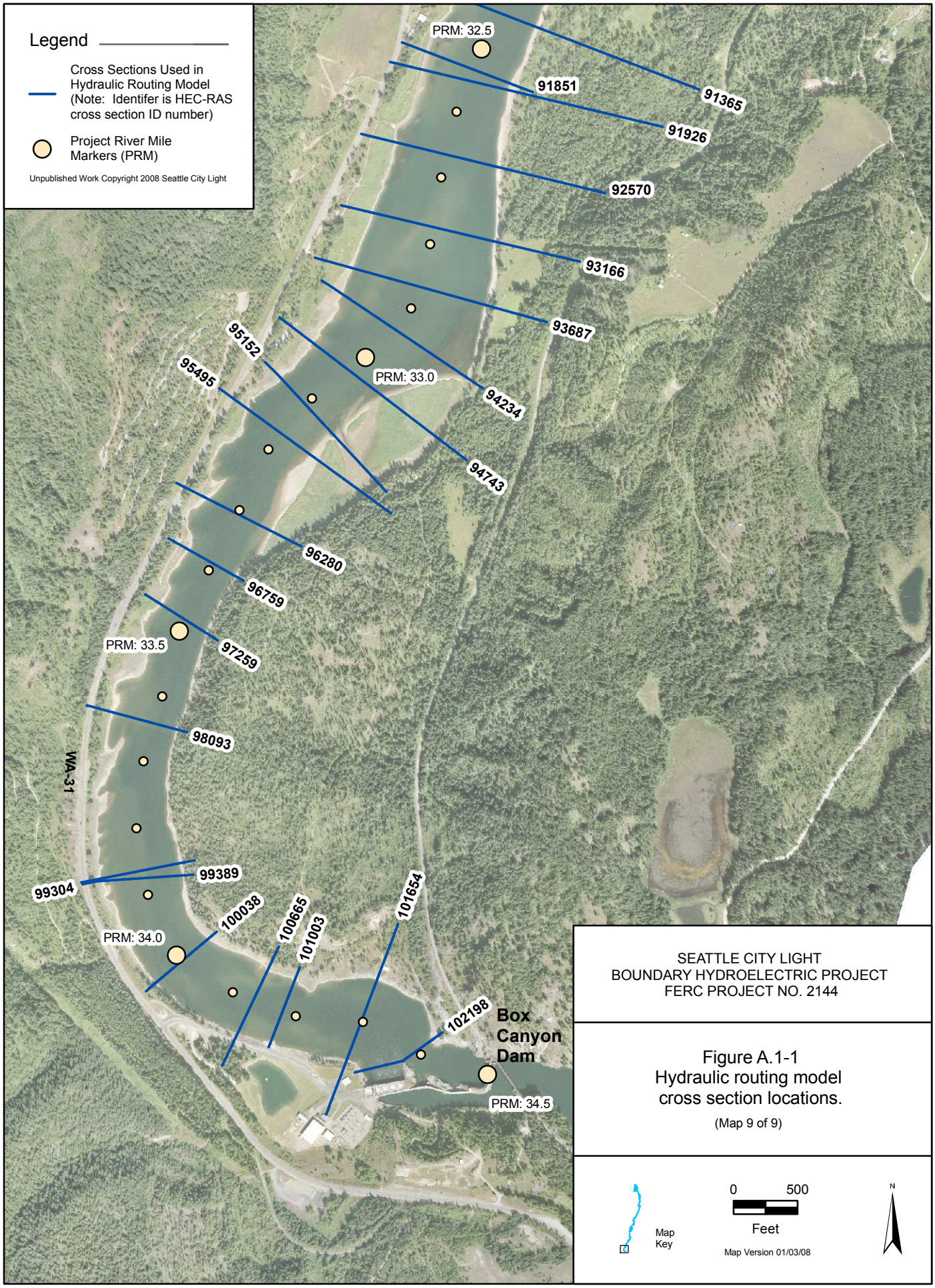
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Cross Sections Used in Hydraulic Routing Model (Note: Identifer is HEC-RAS cross section ID number)
Project River Mile Markers (PRM)
Unpublished Work Copyright 2008 Seattle City Light
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91926
92570
93166
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95495
PRM: 33.0
94234
94743
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96759
PRM: 33.5
97259
98093
WA-31
99389
99304
100038
100665
101003
101654
PRM: 34.0
102198
Box Canyon Dam
PRM: 34.5
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure A.1-1
Hydraulic routing model cross section locations.
(Map 9 of 9)
Map Key
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Feet
Map Version 01/03/08
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Appendix 2. Stage and Discharge Boundary Conditions for the 1972, 1974, and 1997 Flood Event Periods to Calibrate Hydraulic Routing Model

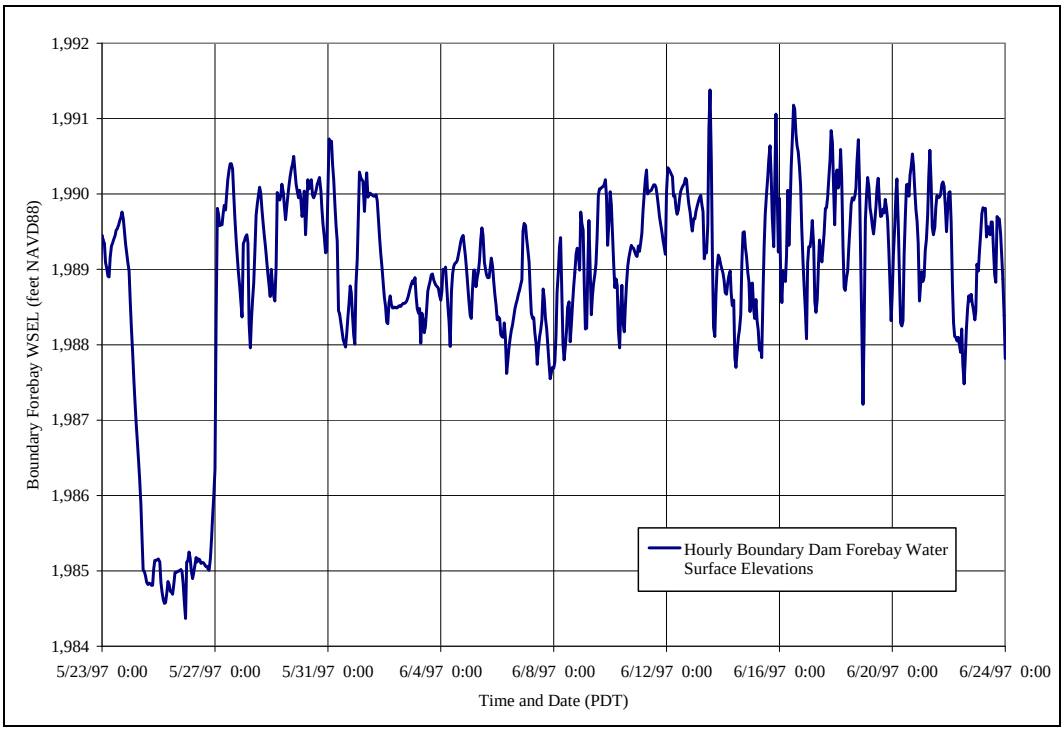

Figure A.2-1. Boundary forebay hourly stage hydrograph for the 1997 event.

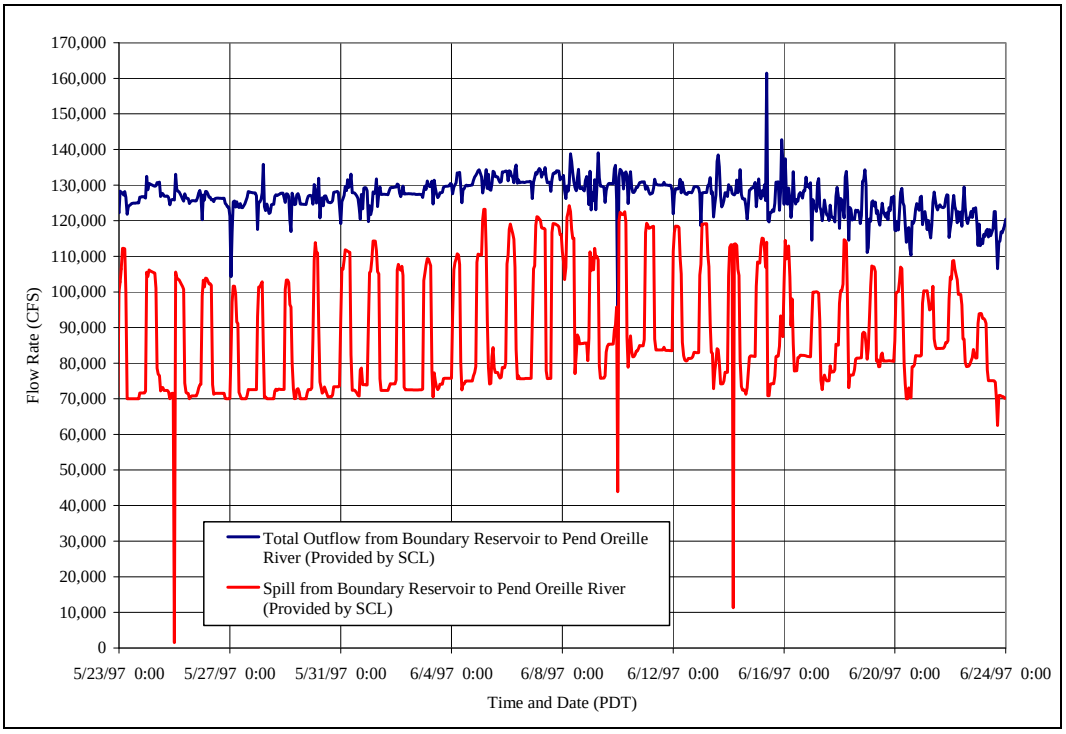

Figure A.2-2. Boundary Dam outflow hourly flow hydrograph for the 1997 event.

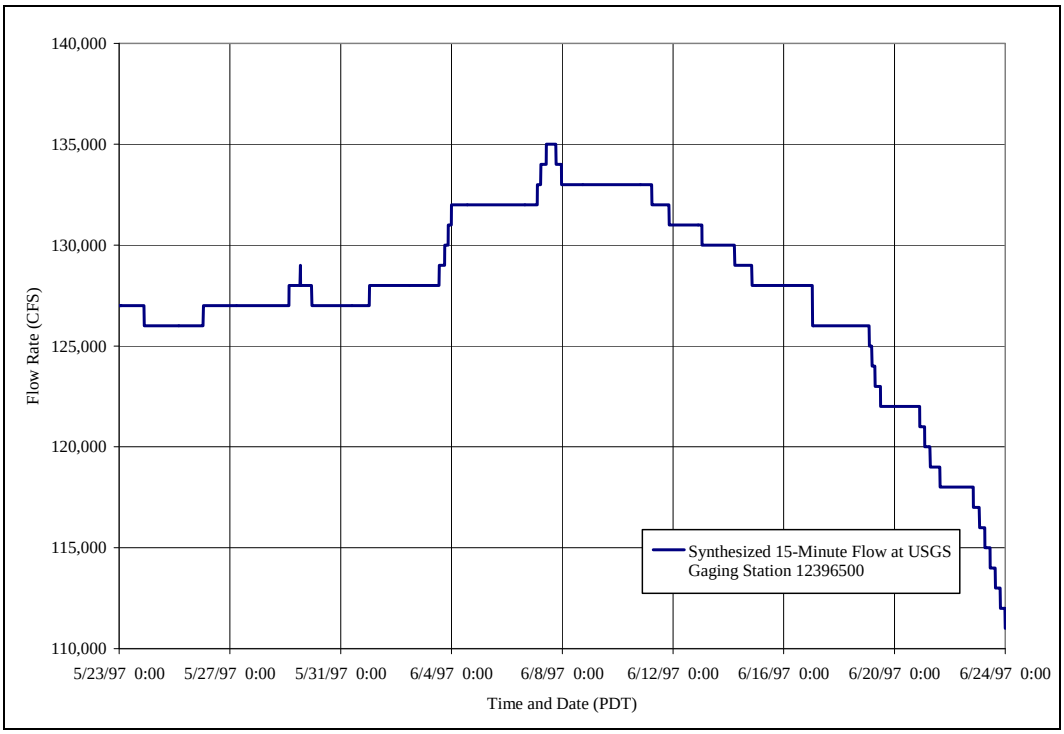

Figure A.2-3. USGS synthesized 15-minute flow hydrograph at USGS Gage No. 12396500 for the 1997 event.

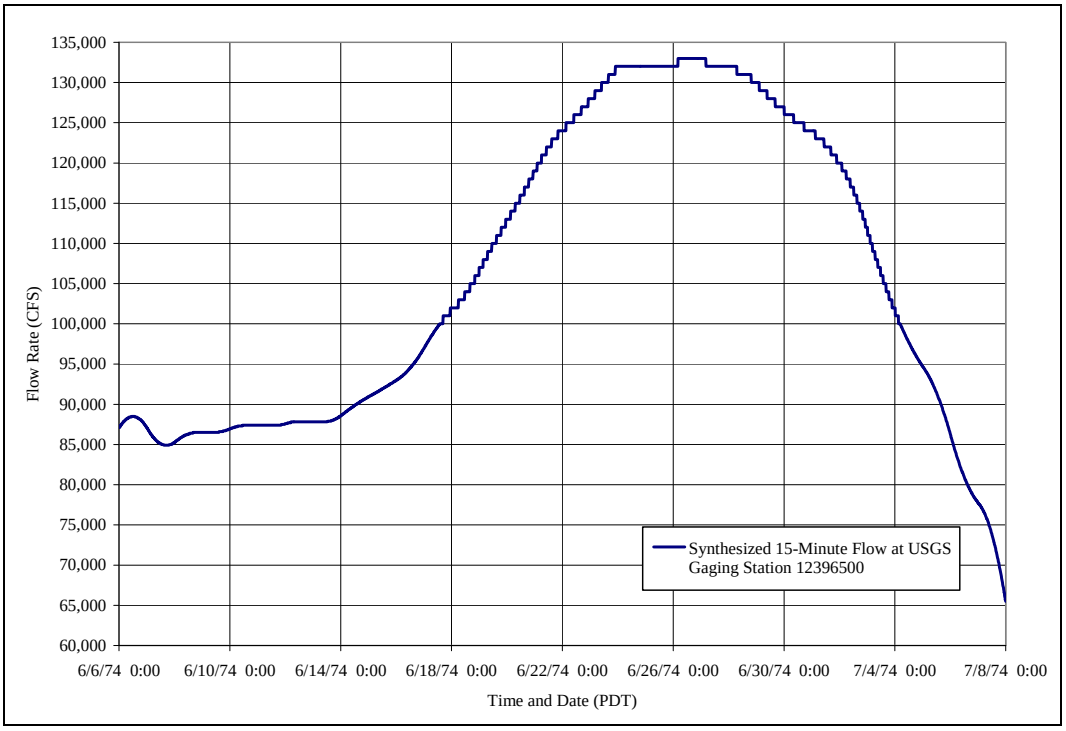

Figure A.2-4. USGS synthesized 15-minute flow hydrograph at USGS Gage No. 12396500 for the 1974 event.

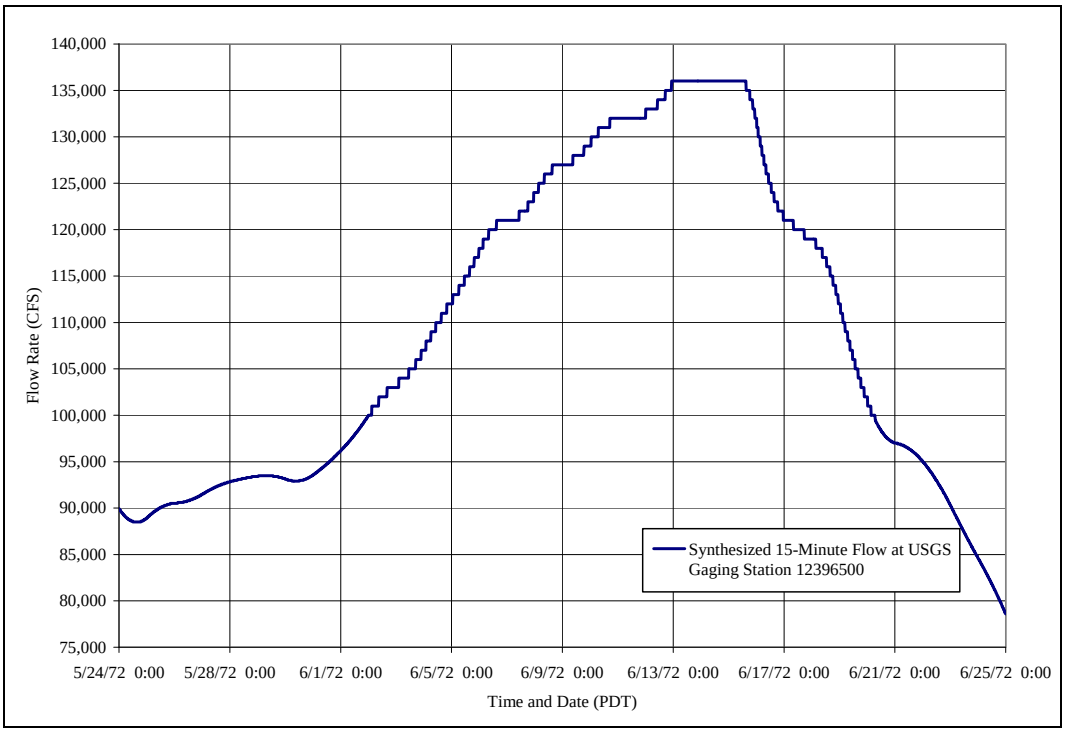

Figure A.2-5. USGS synthesized 15-minute flow hydrograph at USGS Gage No. 12396500 for the 1972 event.

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Appendix 3. Preliminary Study 7 Model Calibration Results Graphs

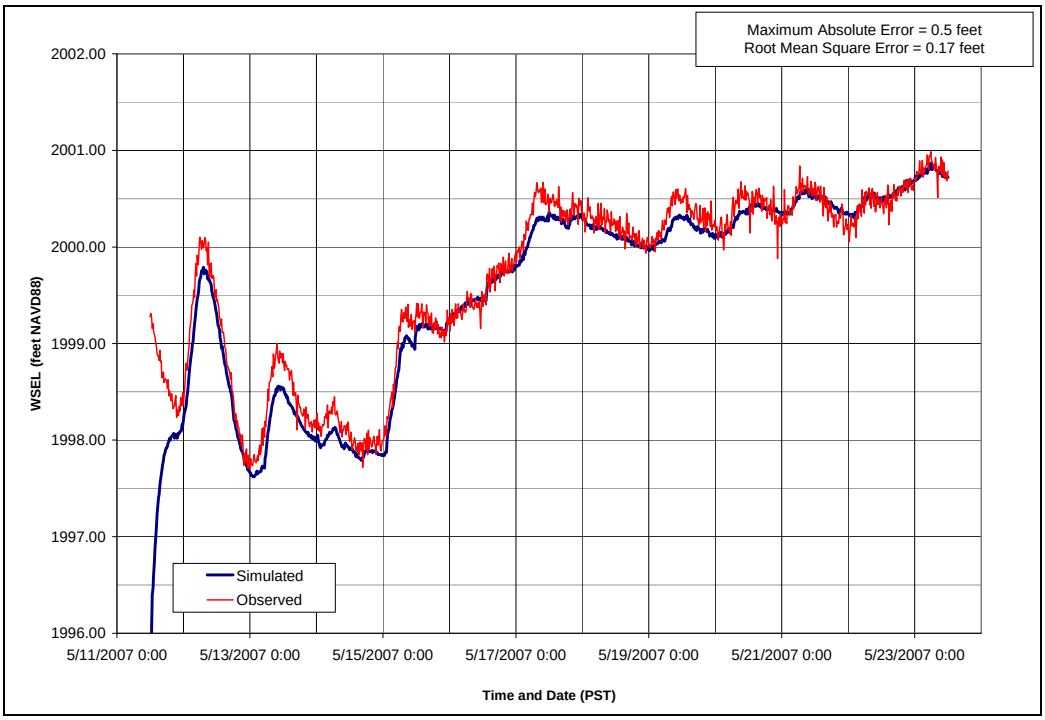

Figure A.3-1. Model calibration results for Lo_Hi Calibration Period at BOX_TR Pressure Transducer Location.

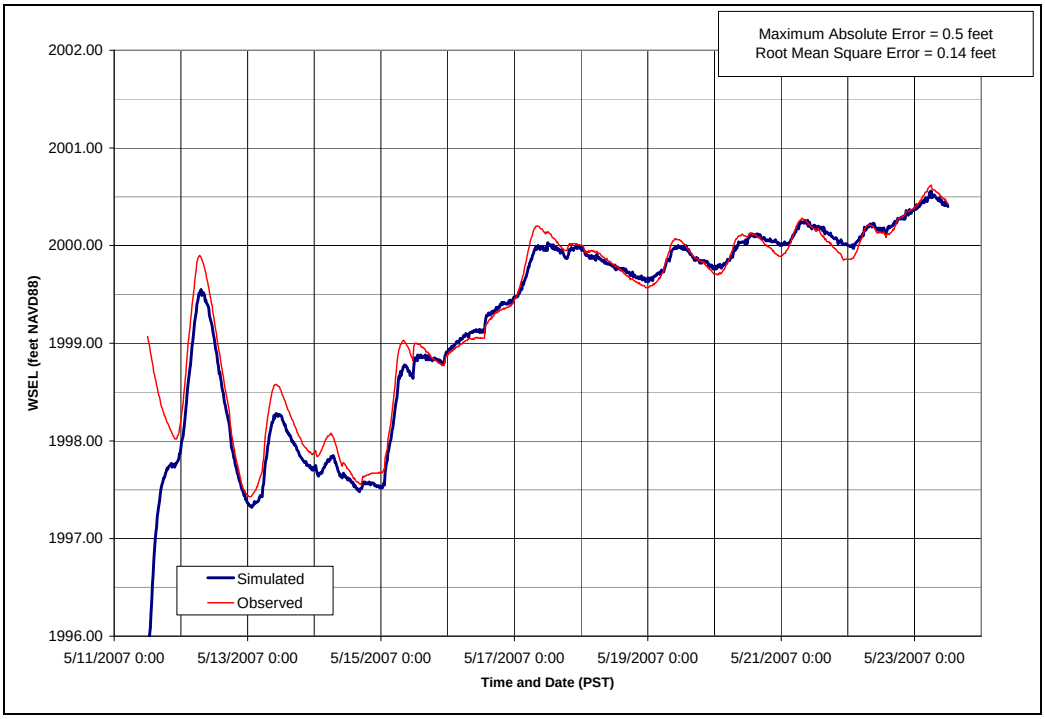

Figure A.3-2. Model calibration results for Lo_Hi Calibration Period at USGS Station 12396500 (Primary) Location.

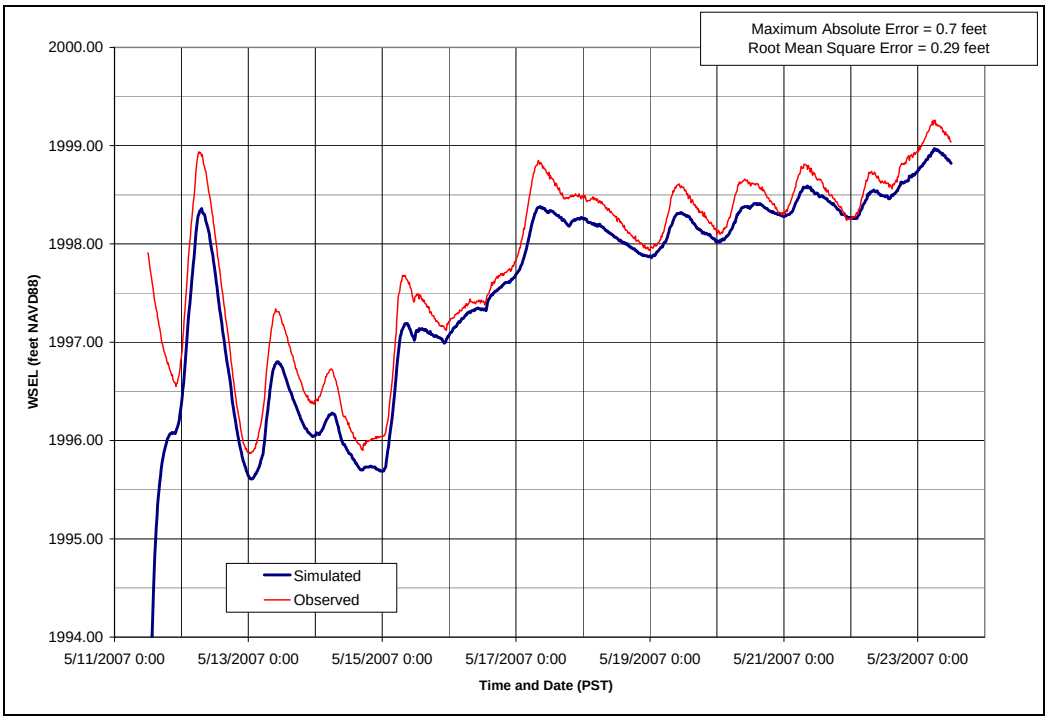

Figure A.3-3. Model calibration results for Lo_Hi Calibration Period at USGS Station 12396500 (Auxiliary) Location.

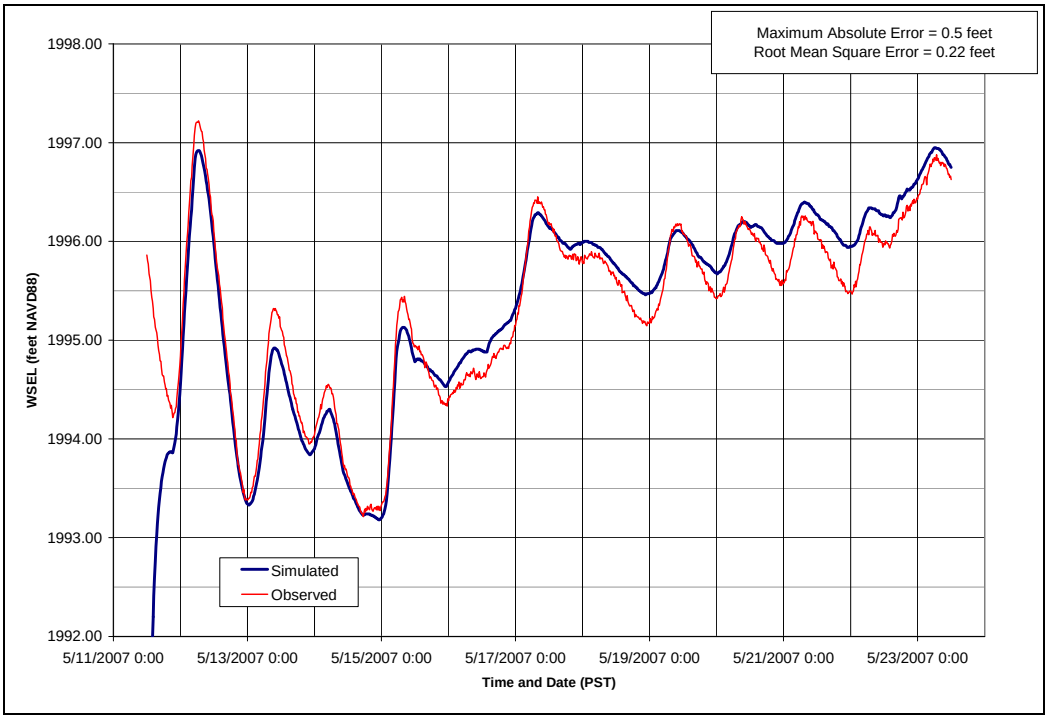

Figure A.3-4. Model calibration results for Lo_Hi Calibration Period at US_MET Pressure Transducer Location.

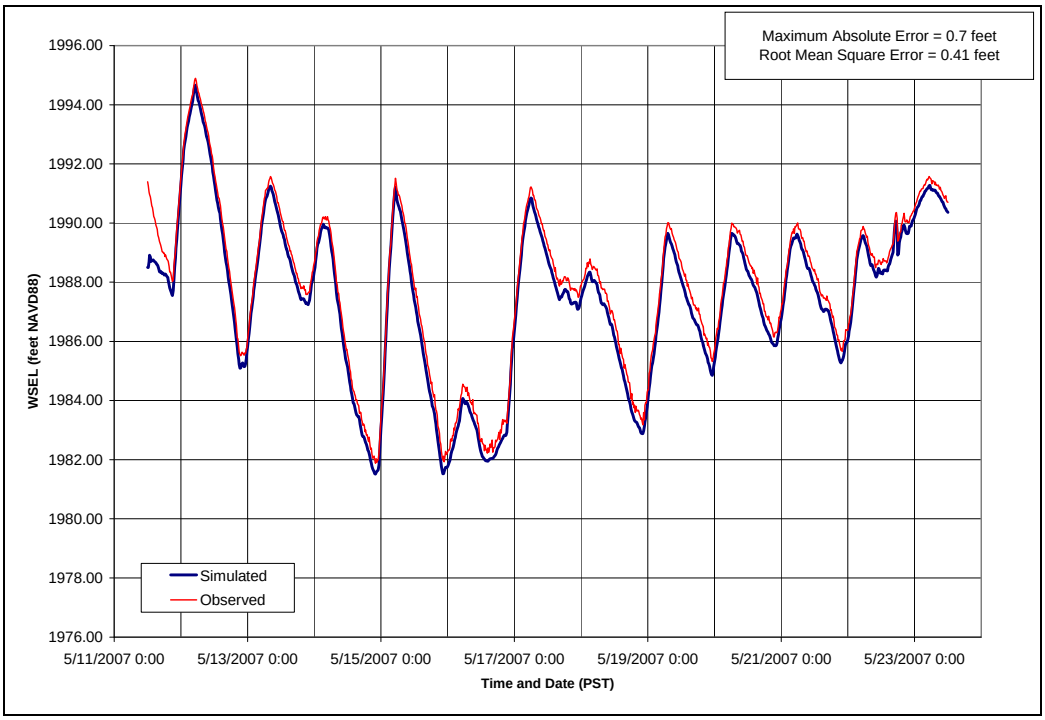

Figure A.3-5. Model calibration results for Lo_Hi Calibration Period at DS_MET Pressure Transducer Location.

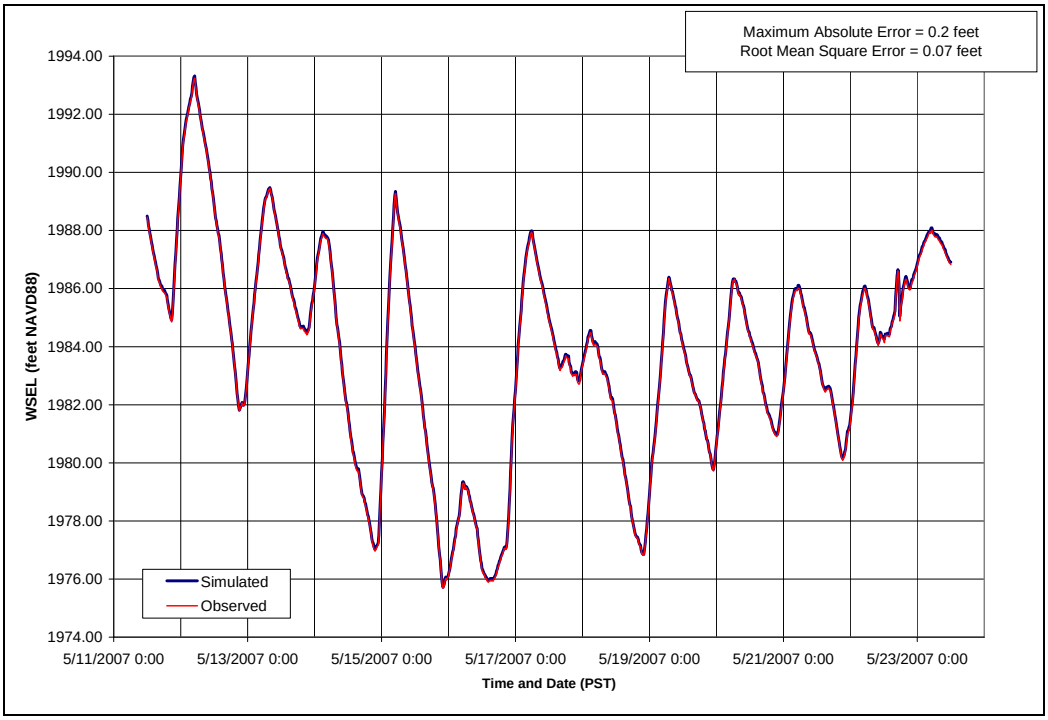

Figure A.3-6. Model calibration results for Lo_Hi Calibration Period at CANYON Pressure Transducer Location.

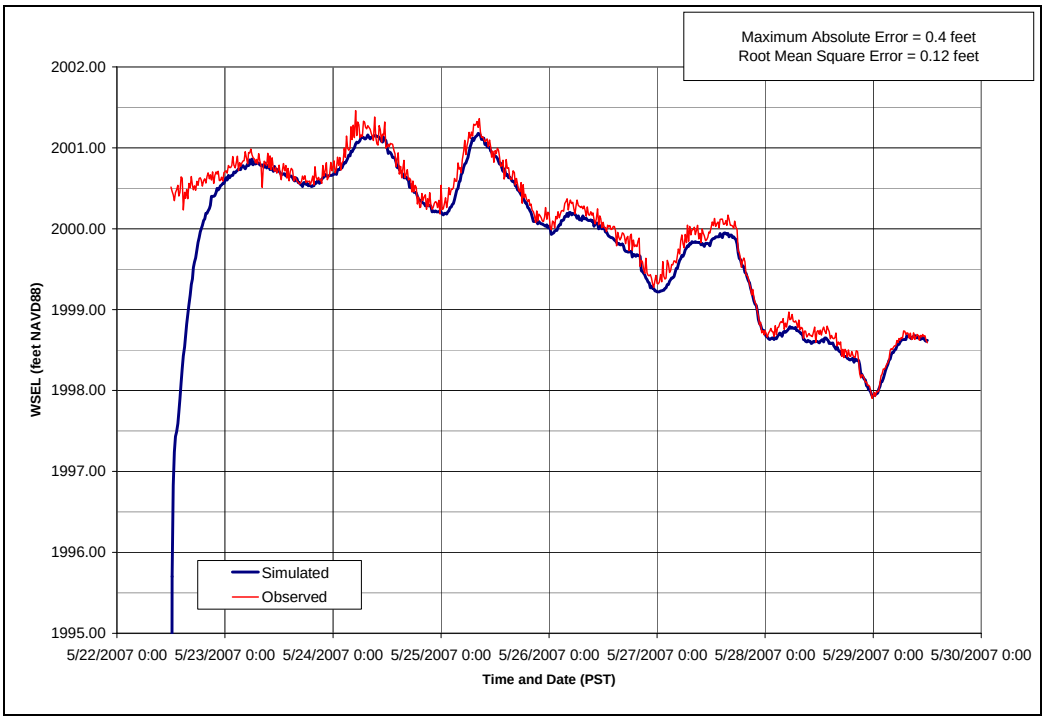

Figure A.3-7. Model calibration results for Hi_Hi Verification Period at BOX_TR Pressure Transducer Location.

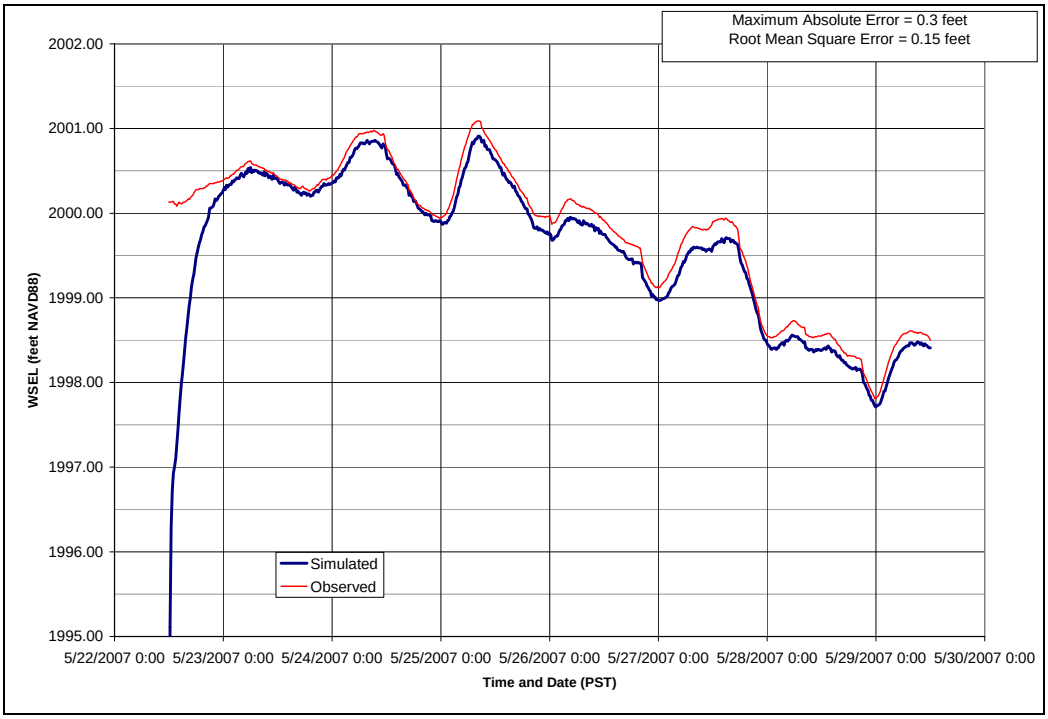

Figure A.3-8. Model calibration results for Hi_Hi Verification Period at USGS Station 12396500 (Primary) Location.

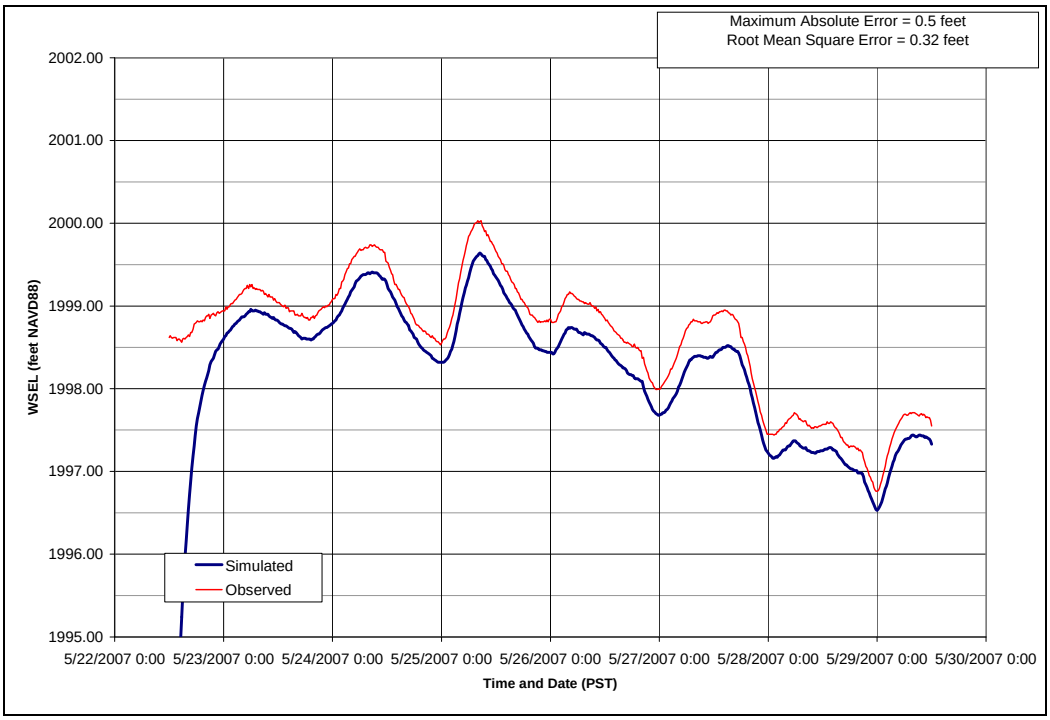

Figure A.3-9. Model calibration results for Hi_Hi Verification Period at USGS Station 12396500 (Auxiliary) Location.

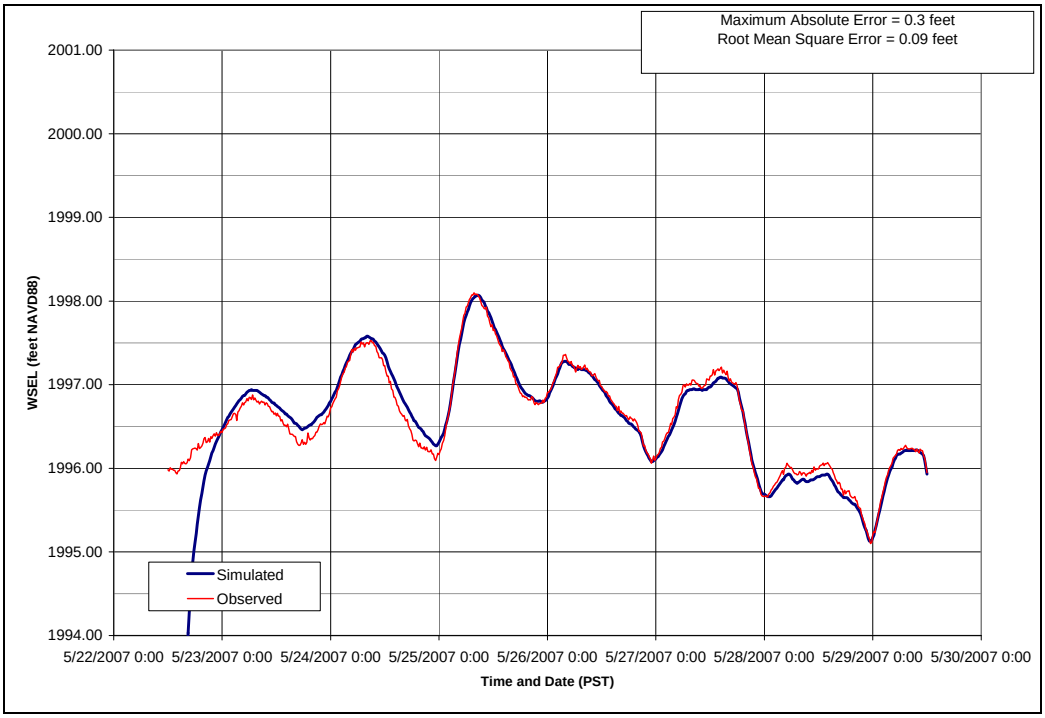

Figure A.3-10. Model calibration results for Hi_Hi Verification Period at US_MET Pressure Transducer Location.

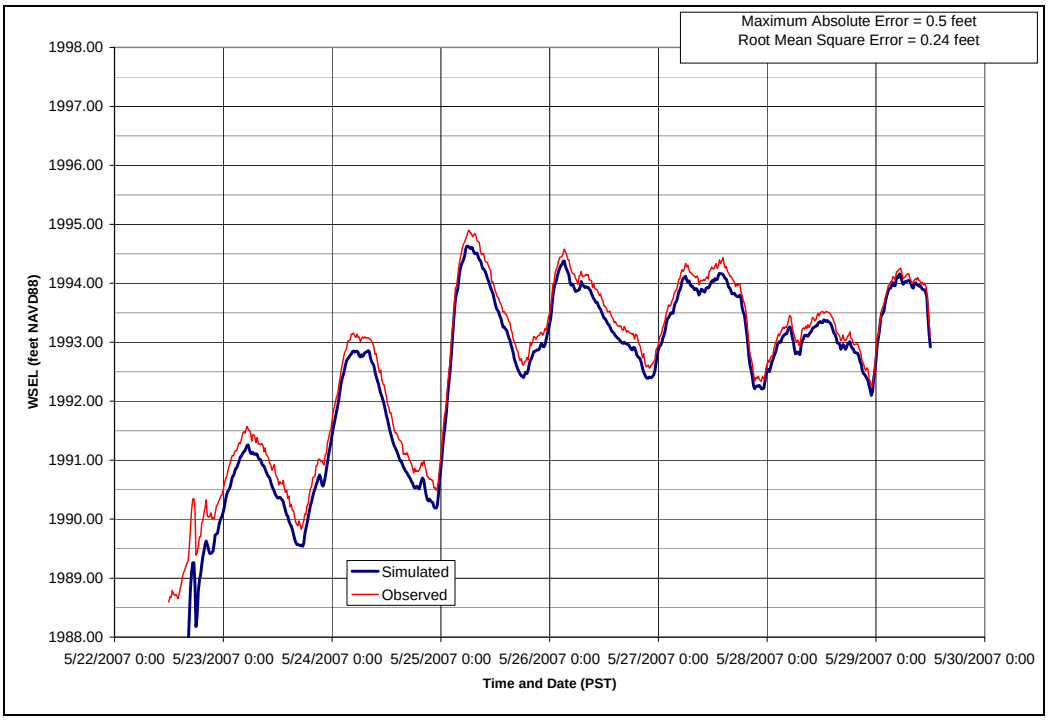

Figure A.3-11. Model calibration results for Hi_Hi Verification Period at DS_MET Pressure Transducer Location.

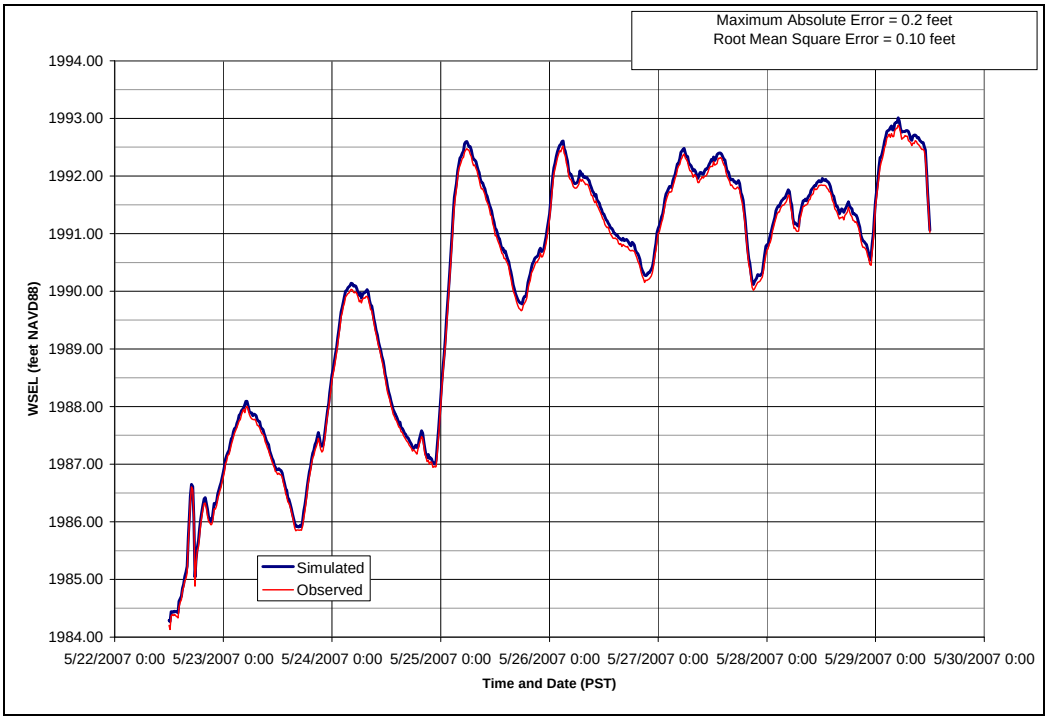

Figure A.3-12. Model calibration results for Hi_Hi Verification Period at CANYON Pressure Transducer Location.