Susitna-Watana Hydroelectric Project Document
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Title: Fluvial geomorphology modeling below Watana Dam study (Study 6.6), decision point on fluvial geomorphology modeling of the Susitna River below PRM 29.9, technical memorandum	**SuWa 242**
Author(s) – Personal:	
Author(s) – Corporate: Tetra Tech, Inc.	
AEA-identified category, if specified: September 26, 2014 technical memorandum filings	
AEA-identified series, if specified:	
Series (ARLIS-assigned report number): Susitna-Watana Hydroelectric Project document number 242	**Existing numbers on document:**
Published by: [Anchorage, Alaska : Alaska Energy Authority, 2014]	**Date published:** September 2014
Published for: Alaska Energy Authority	**Date or date range of report:**
Volume and/or Part numbers: Attachment C	**Final or Draft status, as indicated:**
Document type: Technical memorandum	**Pagination:** vi, 66 p.
Related work(s): Cover letter to this report: Susitna-Watana Hydroelectric Project, FERC Project no. 14241-000; Second set of 2014 technical memoranda for Initial Study Plan meetings. (SuWa 239) Attachments A-B (SuWa 240-241) and D-G (SuWa 243-246)	**Pages added/changed by ARLIS:** Added cover letter
Notes:	

September 26, 2014

Ms. Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, D.C. 20426

Re: Susitna-Watana Hydroelectric Project, Project No. 14241-000

Second Set of 2014 Technical Memoranda for Initial Study Plan Meetings

Dear Secretary Bose:

As the Alaska Energy Authority (AEA) explained in its September 17, 2014 filing with the Federal Energy Regulatory Commission (Commission or FERC) for the proposed Susitna-Watana Hydroelectric Project, FERC Project No. 14241 (Project), the June 3, 2014 Initial Study Report (ISR) provided for AEA to prepare certain technical memoranda and other information based on 2014 work. In accordance with Commission Staff direction, on September 17, 2014, AEA filed and distributed the first set of technical memoranda and other information generated during the 2014 study season.

With this letter, AEA is filing and distributing the second set of technical memoranda generated during the 2014 study season, as described below. As part of its continued implementation of the study plan, AEA expects to file a third set of technical memoranda prior to October 1, 2014.

This second set of technical memoranda includes:

- Attachment A: *Geomorphology Study (Study 6.5) - Updated Mapping of Aquatic Macrohabitat Types in the Middle Susitna River Segment from 1980s and Current Aerials Technical Memorandum.* This technical memorandum updates the Middle Susitna River Segment portion of the aquatic macrohabitat mapping results previously provided in the technical memorandum titled *Mapping of Aquatic Macrohabitat Types at Selected Sites in the Middle and Lower Susitna River Segments from 1980s and 2012 Aerials* (Tetra Tech 2013a).

- Attachment B: *Geomorphology Study (Study 6.5) - Mapping of Geomorphic Features and Turnover within the Middle and Lower Susitna River Segments from 1950s, 1980s, and Current Aerials Technical Memorandum*. This technical memorandum updates the geomorphic mapping and assessment of channel change that were initially provided in *Mapping of Geomorphic*

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Features and Assessment of Channel Change in the Middle and Lower Susitna River Segments from 1980s and 2012 Aerials (Tetra Tech 2013a). The initial technical memorandum provided the results from tasks identified in Revised Study Plan Study 6.5 Section 6.5.4.4. This update extends the previous 30 year analysis between the 1980s and 2012 by an additional 30 years with aerial photography from the 1950s, and also provides a short term analysis of geomorphic changes by comparing 2012 with 2013 aerial photography.

- Attachment C: *Fluvial Geomorphology Modeling below Watana Dam Study (Study 6.6) - Decision Point on Fluvial Geomorphology Modeling of the Susitna River below PRM 29.9 Technical Memorandum*. This technical memorandum describes the decision of whether to extend the downstream limit of the 1-D bed evolution model below Susitna Station at PRM 29.9.

- Attachment D: *Fluvial Geomorphology Modeling Below Watana Dam (Study 6.6) - Winter Sampling of Main Channel Bed Material Technical Memorandum*. The overall purpose of this technical memorandum is to quantify main channel bed material gradations at selected sites in the Upper, Middle, and Lower Susitna River Segments. The data obtained from this study serves as input for the 1-D and 2-D bed evolution modeling efforts being conducted under the Fluvial Geomorphology Modeling Study (Study 6.6).

- Attachment E: *Cook Inlet Beluga Whale Study (Study 9.17) - 2014 Cook Inlet Beluga Whale Prey Study Implementation Technical Memorandum.* This technical memorandum summarizes activities implementing the Cook Inlet Beluga Whale Study (Study 9.17) conducted in 2014 that tested methods to document Cook Inlet Beluga Whale prey and prey habitat in the Susitna River delta.

- Attachment F: *River Productivity Study (Study 9.8) - 2013 Initial River Productivity Results Technical Memorandum*. This technical memorandum provides a preliminary review and summary of 2013 river productivity sample results based on laboratory data received after the ISR submittal in June 2014.

- Attachment G: *River Productivity Study (Study 9.8) - 2014 Field Season River Productivity Progress Report Technical Memorandum*. This technical memorandum presents an update on activities conducted during the Spring field sampling event in June 2014, which was focused on data collection to support the needs of the trophic modeling and stable isotope analysis objectives of the River Productivity Study.

AEA appreciates the opportunity to provide this additional information to the Commission and licensing participants, which it believes will be helpful in determining the appropriate development of the 2015 study plan as set forth in the ISR. If you have questions concerning this submission please contact me at wdyok@aidea.org or (907) 771-3955.

Sincerely,

Wayne Dyok
Project Manager
Alaska Energy Authority

Attachments

cc: Distribution List (w/o Attachments)

Attachment C

Fluvial Geomorphology Modeling below Watana Dam Study (Study 6.6) - Decision Point on Fluvial Geomorphology Modeling of the Susitna River below PRM 29.9 Technical Memorandum

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Fluvial Geomorphology Modeling below Watana Dam Study (Study 6.6)

Decision Point on Fluvial Geomorphology Modeling of the Susitna River below PRM 29.9 Technical Memorandum

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

Tetra Tech, Inc.

September 2014

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LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
1-D	One-dimensional
2-D	Two-dimensional
AEA	Alaska Energy Authority
cfs	cubic feet per second
CIBW	Cook Inlet Beluga Whale
FERC	Federal Energy Regulatory Commission
ft	foot
ft/s	feet per second
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center River Analysis System
HEC-ResSim	Hydrologic Engineering Center Reservoir Simulation System
ISR	Initial Study Report
LiDAR	Light Detection and Ranging
LR	Lower River
Max LF OS-1b	Maximum Load Following Operation Scenario 1B
MVUE	Minimum Variance Unbiased Estimator
OWFP	Open-Water Flow Period
OS	Operation Scenario
PRM	Project River Mile
RSP	Revised Study Plan
USGS	U.S. Geological Survey

SUMMARY

This technical memorandum describes the decision of whether to extend the downstream limit of the 1-D bed evolution model below Susitna Station at PRM 29.9. An earlier decision to extend the modeling from PRM 87.9 (Sunshine) to PRM 29.9 was made based on appreciable changes occurring at Sunshine and the potential for appreciable change below that location.

As presented in Initial Study Report (ISR) 6.6 Section 7.1.1.1.2, the primary reason to consider extending the fluvial geomorphology modeling below PRM 29.9 is to assist in describing the relationship between river flows, water surface elevation and Cook Inlet Beluga Whale (CIBW) foraging habitat in the Susitna River. Without actually modeling the area below Susitna Station, the changes occurring upstream of that location are used to evaluate potential downstream change.

The metrics that were evaluated included hydrology (peak flows and flow duration curves), sediment transport (volumes of bed materials comprised of sands and larger sizes), channel morphology (bed elevation changes and channel width adjustments), and hydraulic conditions (changes in channel flow velocity and depths). The changes in these variables between existing conditions (pre-Project) and the Maximum Load Following Operational Scenario 1B (Max LF OS-1b) were characterized within the context of the natural variability under existing conditions. If the expected changes due to Project operations are small relative to the range of natural variability then potential impacts are considered as minor and extension of the 1-D fluvial geomorphology modeling downstream is not warranted.

The Project-induced changes during the open water flow period are generally reduced flows, sediment transport, water surface elevations, flow depth, and velocities. The Lower Susitna River Segment was determined to be generally aggradational for existing conditions. The reduced flows and sediment transport combined to maintain the aggradational trends of the Lower River, but at a slightly reduced rate. The Susitna River channel is also expected to narrow slightly due to changes in channel forming flows.

Although there are consistent reductions in the variables, they are predominantly within the range of natural variability, both spatially and temporally. Values fall outside (below) the range of natural variability infrequently and by small amounts. The ranges of variability for Max LF OS-1b are also similar to the ranges of natural variability based on pre-Project conditions. Based on the results regarding change and variability, combined with the finding that the Middle River will continue the aggradational trends, AEA does not recommend extending the fluvial geomorphic modeling or associated 1-D hydraulic modeling below PRM 29.9.

Because the tide range in Cook Inlet is extreme and highly variable, the expected relative changes in hydrology, hydraulics, sediment transport, and channel morphology will be reduced further when the tidal zone is reached. The large range in tides combined with continually varying river flows means that the location of significant tidal influence varies greatly under existing conditions. Because expected changes resulting from Project operations will be very small compared to the large range of natural variability in the tidal zone, AEA recommends that no tidal hydrodynamic modeling be conducted in the lowest portions of the Susitna River.

1. INTRODUCTION

The Alaska Energy Authority (AEA) is preparing a License Application that will be submitted to the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project using the Integrated Licensing Process. The Project is located on the Susitna River, an approximately 320-mile-long river in the Southcentral region of Alaska. The Project's dam site will be located at Project River Mile (PRM) 187.1. The results of this study will provide information needed to support the FERC's National Environmental Policy Act analysis for the Project license.

On December 14, 2012, AEA filed its Revised Study Plan (RSP) with the FERC for the Susitna-Watana Hydroelectric Project (FERC Project No. 14241), which included 58 individual study plans (AEA 2012). Included with the RSP is the Fluvial Geomorphology Modeling below Watana Dam Study (RSP Study 6.6). RSP Study 6.6 focuses on the modeling planned for assessing the effects of the proposed Project and its operations on the fluvial geomorphology of the Susitna River. There are three study components to the Fluvial Geomorphology Modeling Study below Watana Dam (Fluvial Geomorphology Modeling Study):

1. Bed Evolution Model Development, Coordination, and Calibration
2. Model Existing and with-Project Conditions
3. Coordination and Interpretation of Model Results

Several decision points have been reached in the Bed Evolution and Model Development, Coordination, and Calibration study component, and one significant decision point remains. The past decision points include:

- Selection of Focus Areas for the 2-D Bed Evolution Model
- Extension of the 1-D Bed Evolution Model downstream from PRM 79 to PRM 29.9
- Selection of Middle River tributaries to complete the tributary delta modeling
- Selection of Lower River tributaries to support investigation of potential changes in geomorphology that might influence adult salmon habitat at their mouths, in particular, holding and ability to access the tributaries (Study 9.12)
- Selection of 1-D and 2-D Bed Evolution Modeling software

As presented in the Initial Study Report (ISR) Section 7.1.1.1.2, the last decision point remaining in RSP Study 6.6 Section 6.6.3.2 for this study component is the potential need to extend the downstream limit of the 1-D Bed Evolution Model below Susitna Station (PRM 29.9). This decision will be based on characterizing geomorphic and hydraulic effects of the Project using specific numerical criteria. The geomorphic criteria represent the potential for long-term channel change related to alteration of flows and sediment supply due to Project operations that could result in changes to habitat. The hydraulic criteria represent the potential for immediate changes in habitat related to alteration in flows due to Project operations. The magnitudes of change in the criteria, reflecting differences between pre-Project (existing) conditions and the maximum load-following operation scenario (Max LF OS-1b) during the open-water period, were compared to the range of natural variability, which is largely driven by hydrology. The range of natural variability was characterized by considering spatial and temporal changes in the existing conditions.

The four decision point criteria are:

1. Changes in flow at Susitna Station (PRM 29.9) and associated potential for channel width adjustment
2. Change in sediment transport mass (sand and larger materials) over the open-water period
3. Difference in modeled bed elevations represented by channel aggradation or degradation
4. Estimated change in flow depth and velocity

Since the current downstream limit of the 1-D Bed Evolution Model is PRM 29.9, the model could not be used directly to evaluate Project effects downstream of PRM 29.9. Instead, the results of the model in Geomorphic Reach LR-4 (PRM 44.6 to PRM 32.3) and the portion of LR-5 (PRM 32.3 to PRM 23.9) upstream of PRM 29.9 were compared to estimate the potential for changes to the geomorphology and hydraulics downstream of PRM 29.9. The lower portion of LR-6 is of particular interest in estimating the potential for change because this is the area of most interest in terms of Cook Inlet Beluga Whale (CIBW) foraging habitat.

2. OBJECTIVE

The objective of the analyses documented in this technical memorandum is to provide a rational basis for deciding whether to extend the 1-D Bed Evolution Model downstream of PRM 29.9 to assist in describing the relationship between river flows, water-surface elevations, and CIBW foraging habitat in the Susitna River.

3. STUDY AREA

As shown in Figure 3.0-1, the Susitna River, located in Southcentral Alaska, drains an area of approximately 20,010 square miles and flows about 320 miles from its headwaters at the Susitna, West Fork Susitna and East Fork Susitna glaciers to the Cook Inlet (Curran 2012). The Susitna River basin is bounded on the west and north by the Alaska Range, on the east by the Talkeetna Mountains and Copper River Lowlands and on the south by Cook Inlet. The highest elevations in the basin are at Mt. McKinley at 20,320 feet while its lowest elevations are at sea level where the river discharges into Cook Inlet. Major tributaries to the Susitna River between the headwaters and Cook Inlet include the Chulitna, Talkeetna and Yentna Rivers that are also glacially fed in their respective headwaters. The basin receives, on average, 35 inches of precipitation annually with average annual air temperatures of approximately 29^{o}F.

The overall study area extends from Cook Inlet to the Maclaren River confluence at PRM 261.3. Within the geomorphology study area, the Susitna River has been subdivided into three segments whose general characteristics are governed by the basin geology as described by Wilson et al. (2009). The segments are referred to as the Upper, Middle, and Lower Susitna River Segments and are identified in Figure 3.0-1 with the associated extents:

- Upper Susitna River Segment: Maclaren River confluence (PRM 261.3 / RM 260) downstream to the proposed Watana Dam site (PRM 187.1 / RM 184).[1]
- Middle Susitna River Segment: Proposed Watana Dam site (PRM 187.1 / RM 184) downstream to the Three Rivers Confluence (PRM 102.4 / RM 98.5).
- Lower Susitna River Segment: Three Rivers Confluence (PRM 102.4 / RM 98.5) downstream to Cook Inlet (PRM 3.3 / RM 0).

The study area for this technical memorandum encompasses the Lower and Middle Susitna River Segments.

4. METHODS

This section describes the methods used to analyze criteria to decide whether to extend the 1-D Bed Evolution Model downstream of PRM 29.9.

4.1. Overview

The methods section begins with a summary of existing information, then describes how metrics for each criterion were quantified, and how natural variability was characterized. The existing information uses the most current information available including information in recently submitted (2014) Technical Memorandums. The memorandum describing the development and calibration of the 1-D bed evolution models of the Middle and Lower Susitna River Segments (from Watana Dam site to PRM 29.9) and 2-D bed evolution model in the Middle River Focus Areas will be submitted in Q4 2014 (Study 6.6 ISR Sections 7.2.1.2.1 and 7.2.1.2.2). Therefore, a brief summary of the development, calibration and results of this model are included in this section.

4.2. Existing Information

The analyses of the decision point criteria were related to multiple previous and ongoing efforts. A summary of the existing information related to the analyses is presented below.

4.2.1. Study Area Extents

In March 2013, R2 Resource Consultants, Inc. (R2) prepared a Technical Memorandum documenting *Selection of Focus Areas and Study Sites in the Middle and Lower Susitna River for Instream Flow and Joint Resource Studies- 2013 and 2014* (R2 2013). One objective of this technical memorandum was to discuss the rationale and criteria considered for extending the IFS related studies into the Lower River Segment. The Revised Study Plan described the downstream boundary of the Study Area as RM 75 (PRM 79) because information indicated that

[1] Note: Project River Miles (PRMs) are the river mile system used for the current Susitna-Watana Project. River Miles (RMs) were the river mile system used in the 1980s project. The PRM delineation starts about 3 miles farther into Cook Inlet than the RMs and has a slightly different thalweg than that of the 1980s. Thus, PRM values are generally 3 to 4 miles higher than the RM values. Because this analysis is a temporal comparison, both systems are referenced.

the hydraulic effects of the Project below the Three Rivers Confluence are attenuated (See RSP Study 8.5 Section 8.5.3). As noted in RSP Study 8.5 Section 8.5.3, the extent of the studies conducted in the Lower River Segment was based upon consideration of the following six criteria.

1. Magnitude of daily stage change due to load-following operations relative to the range of variability for a given location and time under existing conditions (i.e., unregulated flows)
2. Magnitude of monthly and seasonal stage change under Project operations relative to the range of variability under unregulated flow conditions
3. Changes in surface area (as estimated from relationships derived from LiDAR and comparative evaluations of habitat unit area depicted in aerial digital imagery under different flow conditions) due to Project operations
4. Anticipated changes in flow and stage to Lower River off-channel habitats
5. Anticipated Project effects resulting from changes in flow, stage and surface area on habitat use and function, and fish distribution (based on historical and current information concerning fish distribution and use) by geomorphic reaches in the Lower River Segment
6. Initial assessment of potential changes in channel morphology of the Lower River based on Project-related changes to hydrology and sediment supply in the Lower River.

As a result of analyses of these six criteria, AEA confirmed that studies should be expanded in the Lower River Segment. During the February 14, 2013 TWG meeting, this decision was noted and an initial plan presented for commencing such studies in 2013 and completing the studies in 2014 (R2 2013).

The sixth criterion considered in defining the downstream extent of the study area in the Lower River Segment was based on the *Reconnaissance Level Assessment of Potential Channel Change in the Lower Susitna River Sediment* (Tetra Tech 2013a). This technical memorandum evaluated potential Project-related changes in morphology of the Lower River to determine whether portions of the Fluvial Geomorphology Modeling Study and other studies need to be extended downstream in the Lower River. Results from the evaluation served as the basis for the conclusion that the 1-D Bed Evolution Modeling should be extended approximately 50 miles farther downstream to Susitna Station (PRM 29.9). This conclusion was based largely on initial results suggesting the portion of the Lower River Segment below Sunshine could tend toward degradation and channel narrowing, which warranted more detailed analyses to further investigate potential Project effects below Sunshine (PRM 88). Subsequent to these analyses, the sediment rating curves, post-Project hydrology, and bed material gradations used in the analyses were updated, and results of more detailed analyses are presented and discussed in Section 5 and Section 6.

4.2.2. Sediment Transport

Preliminary estimates of the overall sediment balance in the Middle and Lower River segments under pre-Project conditions and the potential magnitude of the changes that could occur under Maximum Load Following Operation Scenario (OS)-1 hydrologic conditions are presented in

Development of Sediment-Transport Relationships and an Initial Sediment Balance for the Middle and Lower Susitna River Segments (Tetra Tech 2013b). The sediment load rating curves and preliminary estimates of the overall sediment balance under pre-Project conditions were updated in *2014 Update of Sediment-Transport Relationship and a Revised Sediment Balance for the Middle and Lower Susitna River Segments Technical Memorandum* (Tetra Tech 2014a). The updated sediment load rating curves reflect additional measurements collected by the U.S. Geological Survey (USGS) in 2012 and 2013; while the USGS will collect additional measurements in 2014 that will be reviewed, AEA does not anticipate further revision of the sediment rating curves. Linear regressions of sediment transport and discharge were calculated at five USGS gaging stations along the mainstem Susitna River: Denali, Cantwell (Vee Canyon), Gold Creek, Sunshine, and Susitna Station, and on the three largest tributaries: the Chulitna, Talkeetna, and Yentna Rivers. The minimum variance unbiased estimator (MVUE) technique was used to convert the sediment load regression lines into unbiased sediment load rating curves. The sediment rating curves were applied to develop the sediment balance along the Susitna River mainstem, and to quantify sediment inflows to the 1-D Fluvial Geomorphology Modeling. Unlike the 2013 analyses, operational conditions were not considered as part of the 2014 analyses because the effect of these operational conditions will be based on results of simulations carried out using the 1-D Bed Evolution Model.

4.2.3. Pre-Project and Post-Project Hydrology

The pre-Project and Maximum Load Following OS-1b hydrology for the mainstem Susitna River and tributaries was prepared within the Fish and Aquatics Instream Flow Study (Study 8.5) as described in ISR Study 8.5 Part C Appendix K. Project operations will cause hourly, daily, and seasonal changes in the Susitna River flows because releases from the Project are driven by power generation requirements and constrained by flow requirements to protect non-power resources such as fish and aquatic habitat. A HEC-ResSim model was developed to simulate the releases from the Project and to simulate flow and stage hydrographs downstream from the Project under pre-Project and post-Project conditions (MWH 2012). A 61-year period extending from Water Years 1950 through 2010 was established as the period of record for the Project; daily flow records were developed along the mainstem and major tributaries over this period (Curran 2012). The extended flow series data were used to estimate pre-Project daily average flows at the dam site by drainage-area-scaling the flows at Gold Creek and Cantwell. The extended flow series were also input to the HEC-ResSim model, and the post-Project releases were based on Max LF OS-1b. The pre-Project and post-Project daily flows were converted to hourly flows to preserve the daily average flow and provide smooth and continuous flow hydrographs. Lateral inflow hydrographs were calculated first on a daily basis, and then on an hourly basis. Potential diurnal flow fluctuations were not synthesized in version 1 of the flow records; version 2 accounts for potential diurnal flow fluctuations; version 3 will incorporate measurements collected in 2013 and 2014.

Initially the HEC-ResSim model (MWH 2012) was used to simulate flow and stage hydrographs downstream from the Project under pre-Project and post-Project conditions. These simulations were subsequently replaced by the development and application of an unsteady-flow HEC-RAS Open-water Flow Routing Model. The Open-water Flow Routing Model simulates the translation and attenuation of changes in flow during the open-water period (defined as May 23 through October 27) associated with Project operations to locations downstream of the dam site.

Version 1 of the Open-water Flow Routing Model extended from the dam site at PRM 187.1 downstream to PRM 80.0. Version 2 of the Open-water Flow Routing Model extends downstream to Susitna Station (PRM 29.9). Results from Version 1 of the model showed that Project effects were still apparent at the PRM 80.0; consequently, Version 2 of the model was extended downstream. Version 3 of the Open-water Flow Routing Model will be completed in 2015; this will be the final version of the model and it will include (1) surveys and calibration data collected in 2014, (2) revisions to tributary lateral inflows (i.e., Version 3), (3) LiDAR data collected in 2014, and (4) incorporation of potential diurnal flow fluctuations.

While the Open-water Flow Routing Model assumed a constant duration open-water period each year (May 23 through October 27), it is known that the spring break-up and fall freeze-up occur at different times each year in response to climatic conditions. Study 7.6 Ice Processes in the Susitna River provided specific dates of break-up and freeze-up for the selected 50 years of open-water periods for use in the 1-D Bed Evolution Modeling.

4.2.4. Changes in Channel Width

In the *Mapping of Geomorphic Features and Turnover within the Middle and Lower Susitna River Segments from 1950s, 1980s and Current Aerials Technical Memorandum* (Tetra Tech 2014b), measurements of non-vegetated channel width were calculated by geomorphic reach. The total non-vegetated channel area per geomorphic reach was divided by the reach length to calculate the average non-vegetated channel width. Changes in average width of Lower River geomorphic reaches are apparent between the 1950s aerials and the 1980s aerials, as well as between the 1980s aerials and the current aerials (Table 4.2-1). This analysis shows fluctuations in channel width over the two successive three-decade periods between the 1950s and current.

4.2.5. 1-D Bed Evolution Model

As described in the *Fluvial Geomorphology Modeling Approach Technical Memorandum* (Tetra Tech 2013c), a numerical 1-D Bed Evolution Model was developed to simulate reach-scale sediment transport and morphologic change in the Susitna River and tributaries associated with Project operations over the 50-year term of a FERC license. The development, calibration, and application of this model will be documented in a technical memorandum submitted at the end of 2014; a brief summary is presented below since the model results are a key component of the analyses carried out to support the determination of whether to extend the 1-D Bed Evolution Model downstream of PRM 29.9.

4.2.5.1. Model Development

The 1-D Bed Evolution Model was developed using the U.S. Army Corps of Engineers Hydrologic Engineering Center River Analysis System (HEC-RAS) version 5.0.0 Beta (August 2014 computational engines). This software was made available by U.S. Army Corps of Engineers Hydraulic Engineering Center (HEC) because of the new unsteady-flow sediment routing routines, which are ideally suited to the Susitna River and tributaries. The 1-D Bed Evolution Model is comprised of four main reaches: (1) Middle Susitna River (PRM 187.1 to PRM 107.1); (2) Lower Susitna River (PRM 107.1 to PRM 29.9); (3) the lower extent of the Chulitna River (PRM 18.1 to PRM 0.0); and, (4) the lower extent of the Talkeetna River (PRM 4.7 to PRM 0.0). Each reach is defined by cross-sections perpendicular to the primary flow path and located to capture key hydraulic controls of each system. Three secondary flow paths (flow splits) are included in key locations in the Middle River and two in the Lower River. The Middle River is defined by 166 cross-sections with an average spacing of about 3,000 feet. The Lower River is defined by 93 cross-sections with an average spacing of about 4,000 feet. The Talkeetna River is defined by 14 cross-sections with an average spacing of about 1,800 feet. The Chulitna River is defined by 34 cross-sections with an average spacing of about 2,800 feet.

Overbank topography for the Middle and Lower River was available from LiDAR mapping collected between May 2011 and October 2011 (ISR Study 6.6, Part A, Section 5.1.9.5). LiDAR for the Talkeetna and Chulitna overbank topography was collected in September 2013 (ISR Study 6.6, Part A, Section 5.1.9.5). Bathymetric data for each reach were surveyed at each cross-section by Geovera (ISR Study 8.5, Part A, Section 5.3.1). Survey efforts for the Talkeetna and Chulitna reaches were conducted in August 2013. The Middle and Lower River reaches were surveyed between June 2012 and August 2013. Between PRM 165.9 and PRM 154.6 (Devils Canyon), the Middle River is inaccessible to surveyors so a simplified trapezoidal geometry developed as part of ISR Study 7.6 Ice Processes in the Susitna River was used for bathymetry in this area. Throughout all of the model reaches, at each cross-section the bathymetric surveys were merged with the LiDAR topography to create continuous geometry.

Following guidance provided by staff at HEC for using the mobile-bed capabilities within HEC-RAS, the number of points that define each cross-section was filtered to reduce the potential for bed adjustment issues while still preserving the essential geometry. In areas with dramatic topographic changes between cross-sections, additional sections were included to keep conveyance ratios within reasonable limits. Geometry for these new cross-sections was estimated using a feature within HEC-RAS to linearly interpolate geometry between bounding surveys. Ineffective flow areas were used in the Middle River along the tops of islands to simulate the high roughness and low conveyance over these features. A simplified scheme of overbank and channel roughness values was initially based on field observations and refined during the calibration of each model.

The hydraulic model is the foundation of the sediment routing model; additional functionality and associated inputs were specified to develop the sediment routing model. Sediment supplies at model boundaries, bed material gradations and layering, the bed sorting method, the sediment transport function, and the fall velocity method are the main components of the sediment routing model that need to be specified. The bias-corrected sediment rating curves developed as part of the *2014 Update of Sediment-Transport Relationship and a Revised Sediment Balance for the Middle and Lower Susitna River Segments Technical Memorandum* (Tetra Tech 2014a) were specified as the bed material rating curves at major inflows (i.e., the dam site, the Chulitna River, the Talkeetna River, and the Yentna River). Bed material gradations for surface and subsurface materials were based on field measurements documented in both ISR Study 6.6 Part A and the *Winter Sampling of Main Channel Bed Material Technical Memorandum* (Tetra Tech 2014c). Due to the armored channel bed throughout the Middle River the Exner 5 bed sorting method was selected and it was coupled with a user-defined sediment transport function based on the Ackers-White function. Given the sand- and gravel-dominated bed material in the Lower River Segment, the Exner 7 bed sorting method was selected and it was coupled with the Ackers-White transport function (Ackers and White 1973; Ackers 1993).

4.2.5.2. Hydraulic Calibration and Validation

After development and initial testing of the 1-D Bed Evolution Model, the simulated hydraulics were calibrated and validated. Since flood flows have the greatest potential to mobilize bed material and transport sediment, it was important to focus the calibration and validation efforts on flood hydrographs. Calibration was carried out using measured flow and water-surface elevations during periods of high flow conditions (Table 4.2-2). Calibration periods were selected based on availability of measured data and the magnitude of the flood event. Since calibration data in the Middle River and Lower River were available for different periods, these two reaches of the model were calibrated independently. The hydraulic calibration was then validated using flow data collected at the USGS stations between July 1981 and September 1981 (Table 4.2-2), which is the representative wet year. Calibration of the Talkeetna River reach and Chulitna River reach was not conducted because data for the calibration and validation time periods is only available for these rivers at the USGS gaging stations, which are used as boundary conditions. The Chulitna and Talkeetna River reaches will be calibrated using surveyed water surfaces when these tributaries are included in the final 1-D model.

The required boundary conditions for the calibration and validation events came from a variety of sources. The mainstem Susitna River inflow at the dam site (PRM 187.1) came from the USGS gage above Tsusena Creek (Gage No. 15291700) for the calibration event and from results of Study 8.5 for the validation event. Ungaged tributary flows along the Middle and Lower River were calculated for the calibration events following the method described previously in ISR Study 8.5, Part C, Appendix K; tributary inflows for the validation event were based on results from Study 8.5. USGS gages on the Talkeetna River (Gage No. 15292700) and Chulitna River (Gage No. 15292410) provided additional input hydrographs for these two model reaches, respectively, for the calibration event; for the validation event the inflows were provided by Study 8.5. The downstream boundary condition was created by extending the model below PRM 29.2 along a normal depth slope of 0.0003492 (ft/ft). Roughness for these extended cross-sections was then varied with discharge so the modeled water-surface elevation at PRM 29.9 matched the current rating curve published by the USGS for Susitna Station (Gage No. 15294350).

Calibration of the simulated hydraulics to the observed data was achieved primarily through adjustments to the base channel roughness coefficient. In the Middle River reach, where it was supported by observed data, further refinement was achieved by allowing the channel roughness to decrease with increasing discharge, reflecting the reduction in grain resistance due to the greater submergence of the bed material. Overbank roughness values were not varied during calibration and ranged between 0.13 and 0.15. Consistent with the Open-water Flow Routing Model (ISR Study 8.5, Part C, Appendix K) the final calibrated main channel roughness values varied between 0.032 and 0.035 in the Middle River, except through Devils Canyon where higher roughness values (0.035 to 0.050) were necessary to maintain model stability. In the Lower River, the calibrated main channel roughness values varied between 0.025 and 0.032. Results indicate good correlation between observed and simulated flow and stage hydrographs (Figure 4.2-1 and Figure 4.2-2). Additionally, point-in-time water-surface elevation measurements from the ground surveys were also compared with model results. In the Middle River simulated water-surface elevations were within one foot of the observed value at 33 of the 36 (92%) locations (Figure 4.2-3). The average difference for all 36 observed points was -0.13 ft with an RMS of 0.65 ft. In the Lower River, 91 of the 119 (76%) modeled water-surface elevations were within one foot of the observed value (Figure 4.2-4), with a total average difference of -0.08 ft and RMS of 0.95 ft. The calibrated model was validated, and the results compare favorably with observations; an example of the validation at Gold Creek is provided in Figure 4.2-5. Based on the agreement between the simulated and observed hydraulics, the hydraulic calibration and validation were judged successful. The model provided a solid foundation for incorporating the sediment routing capabilities.

4.2.5.3. Sediment Routing Calibration

The sediment routing was calibrated separately for the Middle River and Lower River reaches. In the Middle River reach, the sediment rating curve simulated at the USGS gaging station at Gold Creek was compared to measured sediment transport rates as described in the *2014 Update of Sediment-Transport Relationship and a Revised Sediment Balance for the Middle and Lower Susitna River Segments Technical Memorandum* (Tetra Tech 2014a); the gradation of the simulated bed material load was also compared to the measured gradations. Additionally, simulated changes in bed profile were compared to observed changes in profile documented in the *Susitna River Historical Cross Section Comparison, 1980s to Current Technical Memorandum* (Tetra Tech 2014d). In the Lower River reach, the simulated sediment rating curve and transported gradations at the USGS gaging stations at Sunshine and Susitna Station were compared to measured sediment transport rates and gradations presented in Tetra Tech (2014a).

The observed changes in bed profile along the Middle River between the early 1980s surveys and the current surveys are described in Tetra Tech (2014d). Most of the profile changes are less than about 2 feet with many portions of the profile showing only minor changes of less than one foot. Spatially consistent patterns of degradation or aggradation are not apparent, indicating that the thalweg profile has generally been dynamically stable over the past three decades.

For the simulation of the selected 50 open-water flow periods in the Middle River, the bed material rating curve simulated at Gold Creek closely matches measured transport rates (Figure 4.2-6) and the average transported gradation over the entire simulation is similar to measured gradations over a range of flows (Figure 4.2-7). The simulated changes in bed elevation ranged from 1.8 to -2.0 feet, with 90 percent of the cross sections exhibiting changes between 0.9 and -1.1 feet; these changes compare favorably with the trends presented in Tetra Tech (2014d) comparing the 1980s surveys to current surveys. In the Lower River, the bed material rating curve simulated at Sunshine also closely matches measured transport rates (Figure 4.2-8) and the average transported gradation over the entire simulation is similar to the measured gradations over a range of flows (Figure 4.2-9). The same patterns are evident at Susitna Station (Figure 4.2-10 and Figure 4.2-11). Based on the model similarities to the measured transport rates and gradations, and the similarity in the simulated and observed changes in bed profile in the Middle River, the sediment routing models were successfully calibrated and thus judged suitable for simulating changes in the sediment balance and geomorphology of the Susitna River associated with proposed Project operations.

4.3. Decision Point Criteria

As presented in the Initial Study Report (ISR) Section 7.1.1.1.2 the four decision point criteria for evaluating whether to extend the 1-D Bed Evolution Model below PRM 29.9 are:

1. Changes in flow at Susitna Station (PRM 29.9) and associated potential for channel width adjustment
2. Change in sediment transport mass (sand and larger materials) over the open-water period
3. Difference in modeled bed elevations represented by channel aggradation or degradation
4. Estimated change in flow depth and velocity

The decision point criteria were selected to assist in describing the relationship between river flows, water surface elevation and Cook Inlet Beluga Whale (CIBW) foraging habitat in the Susitna River. The evaluation of these criteria includes determining the magnitude and natural variability of metrics associated with each of the criteria. The magnitude of the change in each of the metrics due to the Maximum Load Following OS-1b scenario, as well as variability, is determined using consistent methods. Each of the metrics and the methods for their determination are described in the following sections.

4.3.1. Approach for Changes in Flow at Susitna Station and Associated Potential for Channel Width Adjustment

Hydraulic geometry relationships (Leopold and Wolman 1953; Langbein 1964; Emmett 1972; Parker 1979; Andrews 1984; Hey and Thorne 1986; Julien and Wargadalam 1995) correlate channel width to dominant discharge, which is often considered to be approximated by flows in the range of 1.5- to 5-year average annual recurrence interval. Flow frequency analysis was used with simulated annual peak flows at Susitna Station (PRM 29.9) under existing conditions and Max LF OS-1b hydrology. The annual peak flows area based on the hourly maximum discharges simulated over the 61-year period of record using the version of the 1-D Bed Evolution Model with calibrated hydraulics but without sediment routing. Based on the changes in 1.5-, 2- and 5-year recurrence interval flows, and the typical hydraulic geometry relationship that channel width is proportional to approximately the square-root of the dominant discharge, channel width changes were computed using Equation 4.1, where Q_i denotes the i-year peak flow:

$$\frac{Channel\ Width_{with-Project}}{Channel\ Width_{Existing}} = \sqrt{\frac{Q_{i(with-Project)}}{Q_{i(Existing)}}}$$

The natural variability of existing channel width was evaluated in several ways. Because the decision is whether to extend below PRM 29.9, the non-vegetated channel width was measured from PRM 29 down to PRM 2.5 at 0.5 mile intervals. This provides information on spatial trends in channel width, but also the variability in the area of interest. Temporal trends in channel width were based on measurements of active channel width throughout the Lower Susitna River for the 1950s, 1980s, and 2012 (Tetra Tech, Inc. 2014b). Another method for evaluating temporal variability in channel width is to review temporal variability in discharge. For this method the Q_2 was computed at 10-year intervals throughout the 61-year period of record. Periods of higher discharge would tend to cause channel widening and lower flows would produce channel narrowing.

Open-water flow period (OWFP) flow duration curves at Susitna Station were developed to understand the temporal change in flow distribution. Monthly and OWFP curves were developed using simulated instantaneous hourly flows for Existing conditions and Max LF OS-1b for each of the 50 years used in the 1-D Bed Evolution Model. These 50 curves were summarized using the maximum, minimum and quartiles of the flows over the range of flow exceedance values. The curves are used not only to compare with-Project conditions to Max LF OS-1b, but also to evaluate the range of variability in both conditions.

The method for developing each flow duration curve followed the standard practice of determined the amount of time any level of flow was exceeded. Although flow duration curves are typically developed for long-term periods, annual curves were developed to evaluate the range of flow conditions that would occur under operational versus pre-Project (existing) conditions. Flow duration curves were developed for monthly as well as the full open-water flow period. Each curve represents the amount of time flows are exceeded for each year in the 50 open-water flow periods over the period of interest (month or total). This process not only allows for comparisons between existing conditions and Max LF OS-1b, but also provides information on the range of temporal variability within each of the operational scenarios.

4.3.2. Approach for Change in Sediment Transport Mass Over the Open-Water Flow Period

The sediment load transported past Susitna Station (PRM 29.9) under existing conditions and Max LF OS-1b during the open-water flow period of the representative wet, average, and dry years was simulated using the 1-D Bed Evolution Model. The model was run for the 50 selected open-water flow periods, which allowed the results for the representative years to be extracted along with the average over all 50 years.

To provide a means for interpreting the effect of Project operations under Max LF OS-1b on transported sediment mass over the open-water flow periods, the expected range of natural variability in this parameter was quantified. There is no spatial component to the variability; the analysis is restricted to the location of Susitna Station because (1) this is the most downstream location, (2) measured data are available at the USGS gaging station, and (3) this location captures the hydrologic and sediment influences of the Yentna River. To capture temporal variability, the masses transported over the 50 open-water flow periods were compared.

4.3.3. Approach for Difference in Modeled Bed Elevations Represented by Channel Aggradation or Degradation

The 1-D Bed Evolution Model was run for 50 years of open-water flow periods to simulate changes in bed elevations throughout the Lower River. Daily output was generated that includes both instantaneous (final hour of each day) and cumulative results for each cross section in the model. These results are used to evaluate the spatial and temporal trends in sediment loads and channel aggradation and degradation. Aggradation and degradation are evaluated in terms of mean bed elevation (i.e., mean elevation of all points within the bank stations) change at individual cross sections, geomorphic reach-averaged bed elevation change, and the volume (mass) storage along the river.

The 1-D Bed Evolution Model was used to simulate existing and Max LF OS-1b conditions over the selected 50-year period of record. For the Max LF OS-1b conditions no sand or gravel load was included with these flow releases at the Watana Dam site.

4.3.4. Approach for Estimated Change in Flow Depth and Velocity in the Lower Portion of Geomorphic Reach LR-6 Inferred from Changes Modeled in the Upper Portion of LR-5

Flow depth was quantified using the simulated channel hydraulic depth; velocity was quantified using the simulated channel average velocity. Only the upper portion of LR-5 between PRM 29.9 and the Yentna River confluence was considered. The Yentna River on an average annual basis contributes approximately 40 percent of the flow and approximately 55 percent of the bed material load passing Susitna Station (Tetra Tech 2014a). Estimates of the potential for changes to depth and velocity in LR-6, which includes inflow and sediment loading from the Yentna River, are most similar to the modeled conditions downstream of the Yentna River confluence. Therefore, the changes in depth and velocity were characterized using all model results between PRM 29.9 and the Yentna River confluence. Four surveyed cross sections within this reach were included in the 1-D Bed Evolution Model: PRM 29.9, PRM 30.8, PRM 31.6, and PRM 32.4.

While it was assumed that hydrologic effects of Project operations would be the primary factor that contributes to flow depth and velocity changes, the 1-D Bed Evolution Model was used to simulate the effects of Project operations. Flow depth and velocity were compared under existing conditions and Max LF OS-1b for the representative wet, average, and dry years. The detailed hydraulic results, at 2-hour intervals, were extracted during the representative years from the 50-year simulation of open-water flow periods. This allowed for geomorphic effects to be combined with the hydrologic effects of Project operations when making comparisons.

To provide a means for interpreting the effect of Project operations under Max LF OS-1b on flow depth and velocity, the expected range of natural variability in these parameters was quantified. By considering four cross sections (i.e., PRM 29.9, 30.8, 31.6, and 32.4), which reflect substantial variability in channel morphology, spatial variability in flow depth and velocity was inherent in this analysis. To capture temporal variability, the flow depth and velocity were compared over the open-water flow period during the representative wet, average, and dry years. Because the duration of the open-water flow period varies, the temporal variability was considered relative to days from the start of the open-water flow period.

4.4. Variances

There are no variances from the planned methods presented in ISR Study 6.6 Section 7.1.1.1.2 (AEA 2014).

5. RESULTS

This section presents the results of the analyses of the metrics associated with the four decision point criteria.

5.1. Changes in Flow at Susitna Station and Associated Potential for Channel Width Adjustment

Table 5.1-1 includes 1.01- through 100-year recurrence interval flows for Sunshine and Susitna Station for Existing and Max LF OS-1b scenarios. Over this range of recurrence intervals in response to Project operations, flows decrease by 21 percent to 15 percent at Sunshine and by 13 percent to 5 percent at Susitna Station. The largest changes are for more frequent flows (1.01- to 5-year). The percent changes are smaller at Susitna Station due to the influence of tributary flows between Sunshine and Susitna Station, with the Yentna River providing the largest contributions. The expected reduction in width at Sunshine is approximately 10 percent and at Susitna Station is less than 6 percent (Table 5.1-1, 1.5- to 5-year recurrence interval flows). These width changes would likely require decades to occur, so these should be viewed as trends that would be established by a new flow regime.

Temporal variability in width can result from changes in flow when higher flows would tend to cause widening and lower flows would tend to cause channel narrowing. Table 5.1-2 shows decadal variations in the 2-year flow (as a surrogate for the dominant discharge) at Susitna Station. This table shows that channel would tend to widen and narrow over the 61-year period as the 2-year discharge varies. Changes in the decadal 2-year discharges range from -8 to +11 percent of the long-term average resulting in width changes ranging from -3 to +5 percent. The values are also shown for Max LF OS-1b conditions, which are also based on comparisons with the long-term Existing conditions value. These show 2-year discharge ranging from -19 to +6 percent and corresponding width change ranging from -10 to +3 percent. Table 5.1-2 is intended to show that channel widths are likely to adjust (widen or narrow) over time. Widening can occur progressively or in single, extreme events. Narrowing may require longer time periods for vegetation growth and sediment accumulation to occur.

Spatial variability of existing channel width below PRM 29.9 was evaluated by measuring the non-vegetated width from 2012 aerial photographs at 0.5 mile intervals. The locations of the measurements are shown on LiDAR base maps in Figures 5.1-1 and 5.1-2. Where there are multiple channels the total width is based on the sum of the individual channel widths: vegetated islands are excluded. These measurements and a power-fit trend line are shown in Figure 5.1-3. Width generally increases with distance downstream of Susitna Station but varies considerably between adjacent locations. Width increases rapidly below PRM 10, doubling between PRM 10 and PRM 5 and more than doubling again from PRM 5 to PRM 2.5.

Although channel width increases with increasing channel-forming discharge, other factors influence channel width along a river. These include bed and bank materials, vegetation, geologic controls, aggradation/degradation, and channel gradient. Below PRM 30, the width increases are probably due to decreasing gradient, sediment deposition and tidal backwater. The rapid increase below PRM 10 in channel width in the downstream direction is probably related to these factors plus increasing channel forming discharge due to combined river flows and tidal currents.

In Figure 5.1-3, a downward shift of 6 percent in the trend line is shown to represent the tendency to narrow under Max LF OS-1b. The 6 percent value is a conservative, long-term average and would only apply to the river-dominated areas. Where tidal flows (flood and ebb currents) add to the river discharge the relative changes in flow and channel width would be reduced.

Flow duration curves were developed in order to understand the temporal change in flow distribution, as well as the variability (pre- and post-Project) in flow conditions. Individual flow duration curves for each of the 50 years were developed for monthly and open-water flow periods. The model results used to develop the flow duration curves were hourly instantaneous flows at Susitna Station (PRM 29.9). Figure 5.1-4 shows all 50 annual (full open-water flow period) flow duration curves for pre- and Max LF OS-1b conditions. Below 50,000 cfs, the curves for the two conditions are nearly coincident and for flows greater than 50,000 cfs Max LF OS-1b results in generally lower flow for a specific exceedance percentage.

For better visualization, 50 individual flow duration curves were not plotted; rather, the maximum, minimum and quartiles of the flows were computed from the 50 curves. The quartiles for the full open-water flow period are shown in Figure 5.1-5. Solid lines are used for existing conditions and dashed lines with the same color are shown for Max LF OS-1b. The maximum and minimum curves are generated from maximum and minimum values at each exceedance percentage from each of the 50 individual curves, so the enveloping curves are not the result from a single year. Similarly, the inner quartiles are developed from the 50 flow values for each exceedance percentage. Two other curves are included in Figure 5.1-5 as dotted lines. These curves show the approximate percentage of time one conditions falls outside the range of the other condition. For example, Max LF OS-1b flows are within the range of existing conditions 96 percent of the time (i.e. lower flow approximately 2 out of every 50 years). The dotted line at the high range shows that existing conditions flows are higher than would occur approximately 4 percent of the time compared to Max LF OS-1b. The dotted lines were determined by selecting the value from flow duration curves that best matched the minimum or maximum lines for other condition. Figures (5.1-6 through 5.1-11) for individual months of the OWFP were developed and discussed below. Each figure uses the same line types and colors and dotted lines are when flows for one condition occur outside the range of the other condition.

Figure 5.1-6 shows the flow duration curves for May. The curves for May include earlier portions of the open-water flow period when it starts in April. All of the individual flow duration curves would plot between the computed minimum and maximum curves and 25 percent of the values plot between successive quartiles. There is generally more than a 100,000 cfs range of flows for the majority of exceedance values under Existing conditions. Flows between 25,000 and 50,000 cfs occur fairly often in May and the majority of flows are less than 150,000 cfs. The flows are lower for Max LF OS-1b conditions and the range is slightly compressed.

The primary difference between May and both June and July (Figures 5.1-7 and 5.1-8) is that flows are greater in the later months. June and July flows always exceed 50,000 cfs and often exceed 150,000 cfs. Under Existing conditions June also has a slightly greater range. As with May, Max LF OS-1b conditions are consistently lower and the range is smaller than Existing conditions. For Existing conditions, August (Figure 5.1-9) shows greater extremes, but with narrower interquartiles than the earlier months. Similar to June and July, flows greater than 150,000 cfs are relatively common, but unlike June and July flows less than 50,000 cfs also occur. For Max LF OS-1b, the extremes are nearly the same as Existing conditions, but the interquartiles are shifted lower.

August appears to be a transitional month between the characteristics of July and the latter part of the OWFP. As shown in Figures 5.1-10 and 5.1-11, September and October show generally reduced flows. Note that October includes flows through the end of the OWFP. In September and October, flows greater than 150,000 cfs are uncommon and flows below 50,000 cfs occur frequently. October is unusual in that it has predominantly low flow (<40,000 cfs) but also includes the highest flows in the record (approximately 280,000 cfs, which occurred in 1986).

5.2. Change in Sediment Transport Mass Over the Open-Water Flow Period

The change in transported sediment mass (sand and larger materials) over the open-water flow period due to Project operations under Max LF OS-1b is presented in Figure 5.2-1. This figure plots the sediment mass transported past Susitna Station under Max LF-OS1B as a function of the sediment mass transported past Susitna Station under existing conditions. There are 50 points on the figure to represent each of the 50 open-water flow periods. Symbols identify the representative wet, average, and dry years, as well as the 50-year-average (i.e., the average over the 50 open-water flow periods). A 1:1 reference line is shown along with reference lines showing +/- 10 percent and -15 percent from the 1:1 reference.

In general, Figure 5.2-1 shows Project operations under Max LF OS-1b produce a 10 to 15 percent reduction in the sediment load (sand and larger materials) transported past Susitna Station. Table 5.2-1 summarizes the effects of Max LF OS-1b on the representative wet, average, and dry years, as well as on the 50-year-average. The average reduction in load is 12.6 percent, with a maximum reduction of 21.5 percent and a minimum reduction of 8.9 percent. These reductions in transported mass are consistent with expectations because under existing conditions on an average annual basis the Middle Susitna River delivers approximately 11 percent of the bed material load passing Susitna Station (Tetra Tech 2014a) and the proposed Watana Dam is expected to trap 100 percent of incoming bed material load.

The expected natural variability in transported sediment mass (sand and larger materials) over the open-water flow period during the representative wet (1981), average (1985), and dry (1976) years is shown in Figure 5.2-2. This figure shows the time series of simulated sediment mass (sand and larger materials) transported over the open-water flow period past Susitna Station. The median values and the bounding quartile values are included. Figure 5.2-2 shows the influence of Projection operations under Max LF OS-1b is to reduce the sediment mass transported past Susitna Station. The reduction is consistently about 13 percent between the interquartile thresholds. The range of sediment transport is from 0.61E7 to 1.62E7 tons/year for existing conditions and from 0.56E7 to 1.39E7 tons/year for Max LF OS-1b. These extremes are approximately +/- 40 to 50 percent of the long-term averages for the two conditions.

5.3. Difference in Modeled Bed Elevations Represented by Channel Aggradation or Degradation

The differences in bed elevations represented by channel aggradation or degradation simulated using the 1-D Bed Evolution Model for the 50 years of existing conditions are shown in Figures 5.3-1 through 5.3-3.

Figure 5.3-1 shows the channel bed profile at the beginning (dark blue) and end of the (red) of the simulation. The initial bed profile is mostly obscured by final bed profile, except in areas of greater change, which occur in LR-4 at and above the Yentna River confluence. The profiles show gradually decreasing gradients in the downstream direction with a significant upward convexity between profile low-points at PRMs 30 and 45. This convexity indicates historical aggradation between these two locations of lateral channel constriction.

The individual cross section changes are shown along the river in light blue. Where there are two lines (around PRMs 50 and 70) the model includes split flow reaches, so one line represents the main channel and the other the secondary channel. The model indicates that the bed is generally aggradational with 50-year bed elevation changes between approximately -0.3 and +5 ft with the largest values occurring in LR-4 and LR-5. Channel aggradation is slightly higher from approximately PRM 100 to PRM 85 (up to 2 ft in 50 years), reducing downstream between PRMs 85 and 45 (generally less than 1 ft in 50 years), and dramatically increasing below PRM 45 (ranging from 1 to 5 ft in 50 years). These trends are expected based on the shape of the profile and the form of the river. The frequent areas of braiding, multiple channels, islands and bars are all indicative of an aggrading channel. The lower 2 miles of the Yentna River also include multiple channels, islands, and active bars indicating sediment accumulation similar to the Susitna River LR-4 and upper LR-5 geomorphic reaches. The rates of sediment accumulation are very reasonable, though in the vicinity of the Yentna River confluence are probably slightly high because aggradation in the lower portion of the Yentna River is not accounted for in the loads input to the 1-D Bed Evolution Model.

Figure 5.3-2 shows reach-average bed change (all aggradation) and the amounts of sediment stored in the bed on an average annual basis. The average bed elevation change in LR-5 of 0.071 ft/yr is probably slightly exaggerated because it includes some sediment that would likely have deposited in the lower two miles of the Yentna River. The bed change in LR-4 (0.038 ft/yr) and upstream reaches ranging from 0.013 to 0.023 ft/yr are not unreasonable considering the river form.

Sediment transport along geomorphic reaches MR-8 and LR-1 through LR-5 (representing PRM 107.1 to PRM 29.9) are presented on Figure 5.3-3. This figure shows the sediment storage and the total bed material (sand and gravel) transport. The bed profiles are also shown for reference. The sediment transport line (green) shows split flow reaches where flow and sediment are conveyed in the primary and secondary channels. The large vertical changes in sediment transport reflect major tributary inputs from the Chulitna (PRM 102), Talkeetna (PRM 100) and Yentna (PRM 32) Rivers. The gradual drop in the sediment transport along the channel is due to sediment stored in the bed.

Figures 5.3-4 through 5.3-6 are equivalent figures to Figures 5.3-1 through 5.3-3, except they represent the Max LF OS-1b simulation. The rates and ranges are all slightly less than for Existing conditions. Individual cross section bed elevation changes range from -0.7 ft to +4.5 ft in 50 years (Figure 5.3-4). The reach average rates of bed elevation change (Figure 5.3-5) are 0.064 ft/yr for LR-5, 0.028 ft/yr for LR-4, and upstream Lower River reaches range from 0.009 ft/yr to 0.022 ft/yr. The Lower Susitna River remains aggradational for Max LF OS-1b conditions, but at a slightly slower rate. Figure 5.3-6 shows that sediment transport for Max LF OS-1b is generally reduced over the Lower River, but the trends of sediment accumulation are very similar to Existing Conditions. Although there is bed material being transported out of the Middle River in this operational condition, the amount is insignificant.

Tables 5.3-1 and 5.3-2 show the reach-average bed elevation change for the 50-years and individual decades. The decadal amounts are generally consistent between Max LF OS-1b and Existing conditions with only LR-1 showing slightly more aggradation for the with-Project condition in two decades (second and fifth). These results indicate that the aggradational character of the Lower Susitna River would be maintained throughout the extent of the Lower River, through the entire 50-year licensing period, and through individual decades. This is illustrated in Figure 5.3-7 where sediment storage is shown at each cross section and cumulatively along the Lower River for Existing and Max LF OS-1b conditions. The primary difference is that less sediment is stored (approximately 23 percent less) along the Lower River for Max LF OS-1b conditions. Although the reduction in bed material sediment supply (zero at Watana Dam site and minimal from the Middle River) is clearly evident, the reduction is not enough to change the long-term aggradation trend of the Lower River. The change in supply at Watana Dam site due to Max LF OS-1b appears to be sufficient to change MR-8 from slightly aggradational (0.3 ft in 50 years) to very slightly degradational (-0.11 feet in 50 years), though these amounts are likely undiscernible and within the limitations of the model.

5.4. Estimated Change in Flow Depth and Velocity in the Lower Portion of Geomorphic Reach LR-6 Inferred from Changes Modeled in the Upper Portion of LR-5

The changes in flow depth and velocity due to Project operations under Max LF OS-1b are presented in a series of figures. The series of figures progresses through channel hydraulic depth from PRM 29.9 to PRM 32.4 (Figure 5.4-1 through Figure 5.4-4), and then channel average velocity following the same order (Figure 5.4-5 through Figure 5.4-8). Each figure plots the parameter using instantaneous results at 2-hour intervals. The 2-hour interval was required due to limitations in HEC-RAS file output size. The values under Max LF OS-1b conditions are plotted as a function of the parameter under existing conditions. A 1:1 reference line is shown along with reference lines showing +/- 10 percent from the 1:1 reference. The three representative years are differentiated by symbol shape and color.

In general, the channel hydraulic depth and channel average velocity under Max LF OS-1b during the representative wet, average, and dry years are within 10 percent of the values under existing conditions. However, a bias is apparent corresponding to a reduction in both flow depth and velocity under Project operations. Across all four locations over the open-water flow periods, the median flow depth decreases approximately 4 percent and the median velocity decreases nearly 2 percent. As was expected, the narrower sections (PRM 29.9 and PRM 30.8) exhibit channel hydraulic depths approximately twice as great as the wider sections (PRM 31.6 and PRM 32.4). PRM 31.6 shows a narrow range of channel velocities, which is attributed to the backwater caused by the downstream constriction to the narrow cross section at PRM 30.8.

The expected natural variability in flow depth and velocity over the open-water flow period during the representative wet, average, and dry years is also illustrated in a series of figures. Each figure shows the 2-hr instantaneous time series of simulated channel hydraulic depth or channel average velocity with the solid lines reflecting existing conditions and the dashed lines showing Project operations under Max LF OS-1b. The three representative years are differentiated by color. Figure 5.4-9 through Figure 5.4-12 provide the channel hydraulic depth for each of the four locations; Figure 5.4-13 through 5.4-16 show the channel average velocity. These sets of figures show the changes resulting from Max LF OS-1b and the range of conditions for both scenarios.

6. DISCUSSION

This section presents the interpretation of the results of the analyses of the metrics associated with the four decision point criteria.

6.1. Changes in Flow at Susitna Station and Associated Potential for Channel Width Adjustment

The Susitna-Watana Hydroelectric Project would modify flows and sediment transport downstream of the Watana Dam site. Changes relative to existing conditions would be greatest in the Middle River and decrease as tributaries add flow and sediment. In the Lower River, three major tributaries, the Chulitna, Talkeetna, and Yentna Rivers, are the major sources of flow and sediment below Watana Dam. Therefore, flow frequency and flow duration relationships are strongly influenced by these tributaries.

Below Susitna Station (PRM 29.9) channel forming discharges are reduced approximately 11 percent (Table 5.1-1). This results in an expected change in channel width of 5 to 6 percent. As shown in Figure 5.1-3, a relative change in channel width of 6 percent is small in comparison with the variability in channel width along the LR-5 and LR-6 geomorphic reaches.

Another way to consider the natural variability of channel width is to evaluate change over time for historic conditions. Table 4.2-1 includes channels widths measured throughout the Lower Susitna River from 1950s, 1980s, and current (2012) aerial photography. Also included in the table are percent changes in width between the time periods. Along the Lower Susitna River, width changes range from -15 to +12 percent for the intermediate time periods and between -20 and +12 percent for the total time period. The variability in LR-5 is between 0 and +12 percent and for LR-6 is between -8 and +5 percent. The expected narrowing of up to 6 percent is within the range of natural temporal variability in the Lower River in general and the geomorphic reaches of interest.

As demonstrated in Table 4.2-1, channel width shows substantial variability over time. Periods of high flow tend to increase hydraulic stress and increase channel widths; periods of lower flows can result in channel narrowing. Short periods of high flows can cause significant change. For both Existing and Max LF OS-1b conditions, 2-year recurrence flows computed on a decadal interval vary appreciably (Table 5.1-2). Existing Q_2 varies +11 to -8 percent from the long-term value, and Q_2 for Max LF OS-1b varies from +6 to -19 percent from the long-term pre-Project value. Although the values for Max LF OS-1b indicate a long-term narrowing, the temporal variability of flow and width would be maintained.

The results from the flow duration curves show similar trends. In general, flows during the open water flow period (OWFP) are reduced, but the reductions are small compared to the wide range of variability. Table 6.1-1 shows a comparative summary of the flow duration curves. The values shown in the table are averages over the range of curves. Over the OWFP, the curves are on average about 4 percent lower for Max LF OS-1b than for Existing conditions.

The OWFP range of variability for Max LF OS-1b is 95 percent of the range for Existing conditions. The range of variability was calculated by determining the ratio of the range (maximum minus minimum) for the two conditions at each exceedance percent and averaging the ratios over the exceedance percentages. May has the greatest change in range of variability, with Max LF OS-1b maintaining 82 percent of the range for existing conditions.

Because there is a small downward shift in flows, Max LF OS-1b operations result in periods of flow that are outside (less than) the existing range of variability. Other periods occur when Existing conditions would have higher flows than with Max LF OS-1b operations. In each case this occurs about 4 percent of the time (or 2 years out of 50). These percentages are shown in Figure 5.1-5 as the “Max LF OS-1b 96 Percent” and “Existing 4 Percent” curves, which were visually fit to approximate the extremes of the other condition. The monthly comparisons (Figures 5.1-6 through 5.1-9) include similar comparisons when the range of one condition is outside the range of the other condition. None of these results indicate a significant change over the open-water flow period.

The flow duration curves were also compared on a monthly basis because CIBW and eulachon activity vary by month. Primary use is in the May through July timeframe. As shown in Table 6.1-1, these three months have greater change than the total open-water flow period. June shows the largest differences with a 12 percent downward shift in the flow duration curves, 82 percent of the range of variability for Max LF OS-1b compared to pre-Project conditions, and 4 to 5 percent of the flows for one condition outside the range of flows of the other condition. In the May through July period, flows for one condition fall outside the range of flows for the other condition up to 6 percent of the time. When flows for Max LF OS-1b are less than the minimum flow duration curves for Existing conditions, they average 3 percent lower during the full open water flow period and 8 percent lower in June and July. When flows for Existing conditions are higher than the maximum flow durations curves for Max LF OS-1b conditions, they average 5 percent higher for the entire open water flow season and 17 percent higher in June.

Given the infrequent occurrence of operational flows outside the natural range of natural variability and the low magnitude of the differences when these excursions do occur, the flow changes are not expected to noticeably affect the existing relationship between river flows, water-surface elevations, and CIBW foraging habitat in the Lower Susitna River. Potential reductions in channel width are also small and within the range of natural variability.

6.2. Changes in Sediment Transport Mass over the Open-Water Flow Period

The simulated transported sediment mass (sand and larger materials) past Susitna Station during the open-water flow period was considered to represent the potential for changes to transported mass downstream of PRM 29.9. The simulated transported masses corresponding to wet, average, and dry years (Table 5.2-1) illustrate the effects of Project operations under Max LF OS-1b relative to existing conditions; however, of key importance is evaluating these effects in the context of expected natural variability. Based on the consistently reduced sediment loads transported past Susitna Station under Max LF OS-1b it is expected that the sediment masses transported downstream of PRM 29.9 would similarly decrease. However, the range in sediment masses (sand and larger materials) transported during the open-water flow periods over 50 years under Max LF OS-1b is 83 percent of the range over the 50 years under existing conditions. In 2 years out of the 50, the sediment loads under Max LF-OS 1b are less than the minimum under existing conditions, with differences of approximately 2 and 9 percent. In 5 years out of the 50, the sediment loads under existing conditions are greater than the maximum load under Max LF

OS-1b, with difference between approximately 1 and 17 percent. Since the effect of Project operations under OS-1b is to decrease the sediment mass (sand and larger materials) transported past Susitna Station, but (1) the range of annual variability relative to existing conditions is largely preserved, (2) the occurrence of excursions outside the natural range of variability under existing conditions is infrequent, and (3) the magnitude of the excursions is relatively small, it is not expected that Project operations will appreciably affect the relationship between river flows, water-surface elevations, and CIBW foraging habitat in the Lower Susitna River.

6.3. Difference in Modeled Bed Elevations Represented by Channel Aggradation or Degradation

The results of the 50-year simulations using the 1-D Bed Evolution Model indicate that the Lower River tends to be aggradational for both existing and Max LF OS-1b conditions, but less so under the operational condition. In the Lower River, reach-average bed elevation change over 50-years ranges from 0.65 to 3.5 ft for existing conditions and from 0.43 to 3.2 ft for Max LF OS-1b conditions. The reach-scale bed evolution model integrates the effects of hydrology, sediment supply, hydraulics, and channel response throughout the Susitna River from the Watana Dam site to Susitna Station. The aggradational character of the Lower River predicted by the model is consistent with observations of the planform of the river as well as the trends in the channel profile. These factors indicate that the Lower Susitna River is not strictly an equilibrium channel, but the rates of change are so low that long-term change is not significant. The model results differ from the initial assessment of potential channel change presented in Tetra Tech (2013a), which indicates the potential for degradation and narrowing as a potential response in the Lower River below Sunshine Station. The initial assessment was based on the assumption that the channel is in equilibrium prior to the Project. Because the existing channel is aggradational the combined influence of reduced flow and sediment under Max LF OS-1b does not cause degradation, but instead continues aggradation at a slightly lower rate.

6.4. Estimated Change in Flow Depth and Velocity in the Lower Portion of Geomorphic Reach LR-6 Inferred from Changes Modeled in the Upper Portion of LR-5

The simulated channel hydraulic depth and channel average flow velocity in the upper portion of LR-5 were considered to infer the potential for changes in flow depth and velocity in the lower portion of LR-6. The simulated hydraulics for the representative wet, average, and dry years (Section 5.4) illustrate the effects of Project operations under Max LF OS-1b relative to existing conditions; however, of key importance is evaluating these effects in the context of expected natural variability. What is apparent from Figures5.4-9 through 5.4-16 is that the influence of Project operations under Max LF OS-1b is generally within and less than the natural variability between wet, average, and dry hydrologic conditions. The results at PRM 32.4 may be the most representative of conditions downstream of PRM 29.9 because the cross section morphology and hydrology are most similar to the downstream conditions. At this cross section, the operation of the Project tends to decrease channel hydraulic depth and decrease channel average velocity; however, increases approaching 25 percent for channel hydraulic depth and 10 percent for channel average velocity occur within the overall trend of decreases. When evaluated in context of the temporal variability throughout the representative wet, average, and dry open-water flow periods, and across the representative years, it is obvious that despite there being an effect of

Project operations on both flow depth and velocity, the effect is less than the natural variability within a single open-water flow period, and much less than the natural variability across hydrologic conditions. While the geomorphic conditions at PRM 29.9 and PRM 30.8 are substantially different than any locations downstream of PRM 29.9, comparing the simulated hydraulics at these sections to PRM 32.6 and PRM 32.4 further expands the natural variability through a spatial component.

Since the simulated effect of Project operations under Max LF OS-1b on flow depth and velocity is approximately one order of magnitude less than the natural variability in these parameters, it is not expected that Project operations will have a noticeable long-term effect on the relationship between river flows, water-surface elevations, and CIBW foraging habitat in the Lower Susitna River.

6.5. Decision Point Recommendation

Each of the decision point criteria were evaluated based on the amount of change relative to the natural variability of the existing river. There are reductions in flows, sediment supply and transport, channel width, aggradation, velocities and depths in the Lower River in general and in the geomorphic reaches of primary concern related to this decision point (LR-4 and LR-5). The changes predominantly occur within the range of natural variability and generally have a similar range of variability as the existing river.

The changes in the Lower River provide the basis for making the decision whether to extend the fluvial geomorphology modeling below PRM 29.9. The small amount of relative change between Existing conditions and Max LF OS-1b indicates that the 1-D Bed Evolution Model does not warrant extension. The changes are also small in comparison to the natural variability. It is also important to note that the range of variability with operational conditions is very similar to existing conditions.

Bed elevation change is the integration of many factors, including hydrology, sediment supply, bed material composition, channel geometry, flow depths and velocities. Because the Lower River is currently aggradational and remains aggradational under Max LF OS-1b conditions, the character of the river will be unchanged. Minor channel narrowing is also expected below PRM 29.9, but the amounts are within natural spatial and temporal variability.

Depth and velocity were analyzed because they are indicative of both sediment transport conditions and habitat availability. Although there are periods of reduced depths and velocities, the representative years show far greater variability between years than occur within years. This is also true over monthly and shorter periods within the representative years. Further, the effect of the expected channel narrowing under the Max LF OS-1b conditions would somewhat offset the reduced depths and velocities simulated without accounting for the narrowing; whether the narrowing would fully offset the hydraulic effects is unknown, but will be addressed in future 1-D Bed Evolution Modeling efforts.

Since the Max LF OS-1b represents the greatest potential hydrologic effects of Project operations, it is likely that alternate operation scenarios would produce less pronounced effects on the relationship between river flows, water-surface elevations, and CIBW foraging habitat in the Lower Susitna River.

Based on the results of these analyses, AEA recommends that bed morphology modeling not be extended below PRM 29.9. AEA further recommends that associated 1-D hydraulic modeling not be extended below PRM 29.9 as the range of hydraulic conditions is not appreciably changed.

One area that is not addressed by the decision point criteria is tidally affected flow areas. Based on the measured channel widths and observable channel form, it appears that tides begin to dominate river flows downstream of about PRM 10. Figures 6.5-1 and 6.5-2 show tides levels measured at Anchorage, and include stage records from pressure transducers located between PRMs 10.5 and 20.5. These figures show that at PRM 10.5 tides or river flows can control the water levels, but that only a small tidal influence reaches PRMs 15.6 and above. During spring tides (new and full moon) the higher tides are more likely going to dominate water levels below PRM 10.5. During neap tides (during the half moon periods) water levels are more likely to be river-flow dominated.

The large range in tidal conditions combined with continually varying river flows means that the location of significant tidal influence will vary greatly. The phases of the moon also mean that periods of spring and neap tides do not occur during the same periods from year to year. The large range in tide levels result in a highly variable zone of tidal influence over the range of river flows. Because river flows are only slightly lower for Max LF OS-1b conditions (Section 5.1), the changes in tidally influenced areas will be even less in comparison to the natural range of variability. This conclusion is in agreement with the CIBW study (ISR Section 9.17.4.3) stating "The degree of Project effects on instream flow and geomorphology in the Susitna River Delta is likely insignificant or discountable compared to the high tidal flux in the delta." Therefore, AEA recommends that no tidal hydrodynamic modeling be conducted in the lowest portions of the Susitna River.

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8. TABLES

Table 4.2-1. Average non-vegetated widths by Geomorphic Reach in the Lower River.

Reach	Reach Bounds (PRM)		Average non-Vegetated Width (ft)			Width Change (%)		
	U/S	D/S	1950s	1980s	Current	1980s from 1950s	Current from 1980s	Current from 1950s
LR-1	102.4	87.9	3,495	3,488	3,340	-0.2	-4.2	-4.4
LR-2	87.9	65.6	3,890	3,671	3,120	-5.6	-15.0	-19.8
LR-3	65.6	44.6	4,290	4,395	4,040	2.4	-8.1	-5.8
LR-4	44.6	32.3	2,979	2,778	2,750	-6.7	-1.0	-7.7
LR-5	32.3	23.5	2,909	3,244	3,250	11.5	0.2	11.7
LR-6	23.5	3.3	5,443	5,722	5,280	5.1	-7.7	-3.0

Table 4.2-2. Calibration and validation data for the 1-D Bed Evolution Model.

Reach	Period	Available Data
Middle River	Calibration: 9/12/2012 – 10/15/2012	1. Water-surface elevation hydrographs from 7 ESS locations and 2 USGS gages 2. Flow hydrographs from 2 USGS gages 3. Point-in-time water-surface elevations
Middle River	Validation: 7/5/1981 – 9/4/1981	Flow hydrographs from 2 USGS gages
Lower River	Calibration: 5/24/2013 – 8/31/2013	1. Water-surface elevation and flow hydrographs from 2 USGS gages 2. Point-in-time water-surface elevations
Lower River	Validation: 7/5/1981 – 9/4/1981	Flow hydrographs from 2 USGS gages

Table 5.1-1. Flow frequency and width comparisons for the Lower Susitna River.

Recurrence Interval (yrs)	Sunshine				Susitna Station			
	Pre-Project Q (cfs)	Max LF-OS1B Q (cfs)	Q Diff. (%)	Width Diff. (%)[1]	Pre-Project Q (cfs)	Max LF-OS1B Q (cfs)	Q Diff. (%)	Width Diff. (%)[1]
1.01	66,100	52,300	-21	n/a	128,400	112,200	-13	n/a
1.5	91,200	73,800	-19	-10.0	171,600	152,500	-11	-5.7
2	99,700	81,300	-18	-9.7	185,500	166,000	-11	-5.4
5	121,100	100,200	-17	-9.0	219,400	199,800	-9	-4.6
10	135,500	113,100	-17	n/a	241,400	222,300	-8	n/a
20	149,500	125,800	-16	n/a	262,300	244,000	-7	n/a
50	168,000	142,600	-15	n/a	289,400	272,600	-6	n/a
100	182,200	155,700	-15	n/a	309,800	294,600	-5	n/a

Notes:
1 Width difference is based on the square-root of change in discharge.

Table 5.1-2. Variability of 2-Year discharge (Q2) and associated potential for width adjustment at Susitna Station.

Period	2-Year Discharge, (cfs)		Q_2 Difference from Existing 61-yr Average (%)		Width Difference from Existing 61-yr Average (%)[1]	
	Existing	Max LF OS-1b	Existing	Max LF OS-1b	Existing	Max LF OS-1b
60-yr Average	185,500	166,000	0.0	-10.5	0.0	-5.4
1950-1959	186,100	165,100	0.3	-11.0	0.2	-5.7
1960-1969	200,800	178,100	8.2	-4.0	4.0	-2.0
1970-1979	174,000	150,200	-6.2	-19.0	-3.1	-10.0
1980-1989	205,700	197,400	10.9	6.4	5.3	3.2
1990-1999	170,700	151,500	-8.0	-18.3	-4.1	-9.6
2000-2009	175,900	157,600	-5.2	-15.0	-2.6	-7.8

Notes:

1 Width difference based on the square-root of difference in decadal discharge and long-term Existing conditions discharge.

Table 5.2-1. Comparison of sediment masses (sand and larger materials) transported past Susitna Station.

Year	Existing Conditions (tons)	OS-1b (tons)	Percent Change
Wet (1981)	1.444E+07	1.243E+07	-13.9
Average (1985)	1.130E+07	9.768E+06	-13.6
Dry (1976)	9.225E+06	8.104E+06	-12.1
50-year-average	1.100E+07	9.615E+06	-12.6

Table 5.3-1. Reach average bed elevation change for existing conditions.

Reach	Reach average aggradation(+) and degradation (-) (ft)								
	Years 0-10	Years 10-20	Years 20-30	Years 30-40	Years 40-50	Max.	Avg.	Min.	50-yr total
MR-8	0.11	0.08	0.03	0.02	0.06	0.11	0.06	0.02	0.30
LR-1	0.31	0.27	0.24	0.23	0.13	0.31	0.23	0.13	1.17
LR-2	0.12	0.14	0.17	0.14	0.14	0.17	0.14	0.12	0.70
LR-3	0.07	0.11	0.14	0.16	0.17	0.17	0.13	0.07	0.65
LR-4	0.78	0.33	0.31	0.30	0.18	0.78	0.38	0.18	1.90
LR-5	1.60	0.72	0.49	0.30	0.43	1.60	0.71	0.30	3.53

Table 5.3-2. Reach average bed elevation change for Max LF OS-1b conditions.

Reach	Reach average aggradation(+) and degradation (-) (ft)								
	Years 0-10	Years 10-20	Years 20-30	Years 30-40	Years 40-50	Max.	Avg.	Min.	50-yr total
MR-8	-0.04	-0.03	-0.02	-0.01	-0.01	-0.01	-0.02	-0.04	-0.11
LR-1	0.29	0.29	0.14	0.23	0.18	0.29	0.22	0.14	1.12
LR-2	0.08	0.10	0.12	0.10	0.13	0.13	0.11	0.08	0.53
LR-3	0.04	0.07	0.08	0.12	0.12	0.12	0.09	0.04	0.43
LR-4	0.59	0.28	0.22	0.21	0.11	0.59	0.28	0.11	1.41
LR-5	1.53	0.70	0.40	0.20	0.37	1.53	0.64	0.20	3.21

Table 6.1-1. Summary comparison of flow duration curves.

	Open Water Period	Start-May	June	July	Aug.	Sept.	Oct.-End
Percent difference in Max LF OS-1b compared to Existing Conditions	-4%	-7%	-12%	-9%	-3%	0%	2%
Relative variability (Range of Max LF OS-1b/ Range of Existing Conditions)	0.95	0.85	0.82	0.91	1.00	1.00	1.01
Approximate Percent time Max LF OS-1b within range of Existing Conditions	96%	96%	96%	94%	99%	100%	100%
Approximate Percent time Existing Conditions would exceed maximum flow duration curve of Max LF OS-1b	4%	6%	5%	2%	2%	0%	0%

9. FIGURES

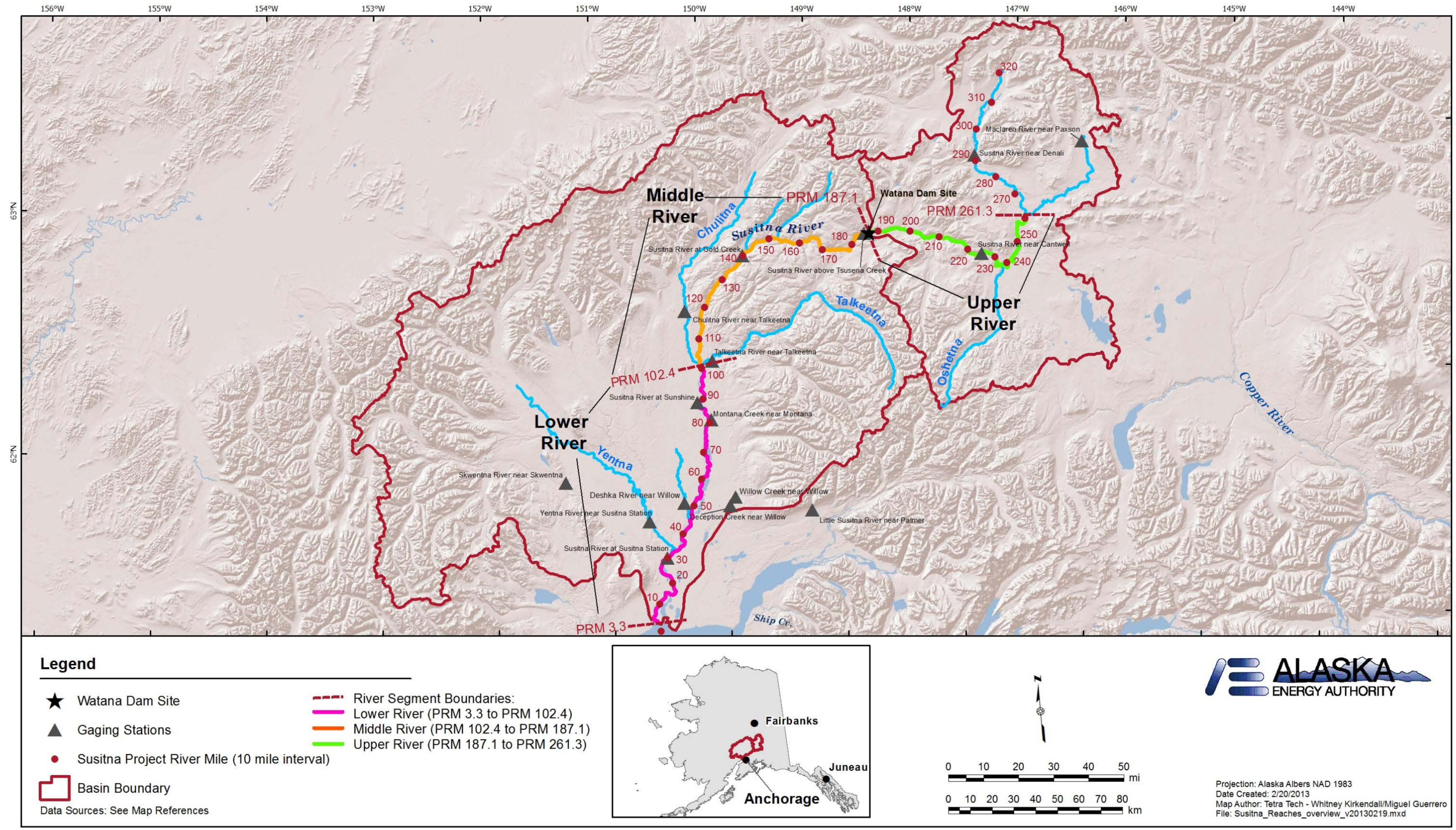

Figure 3.0-1. Study area.

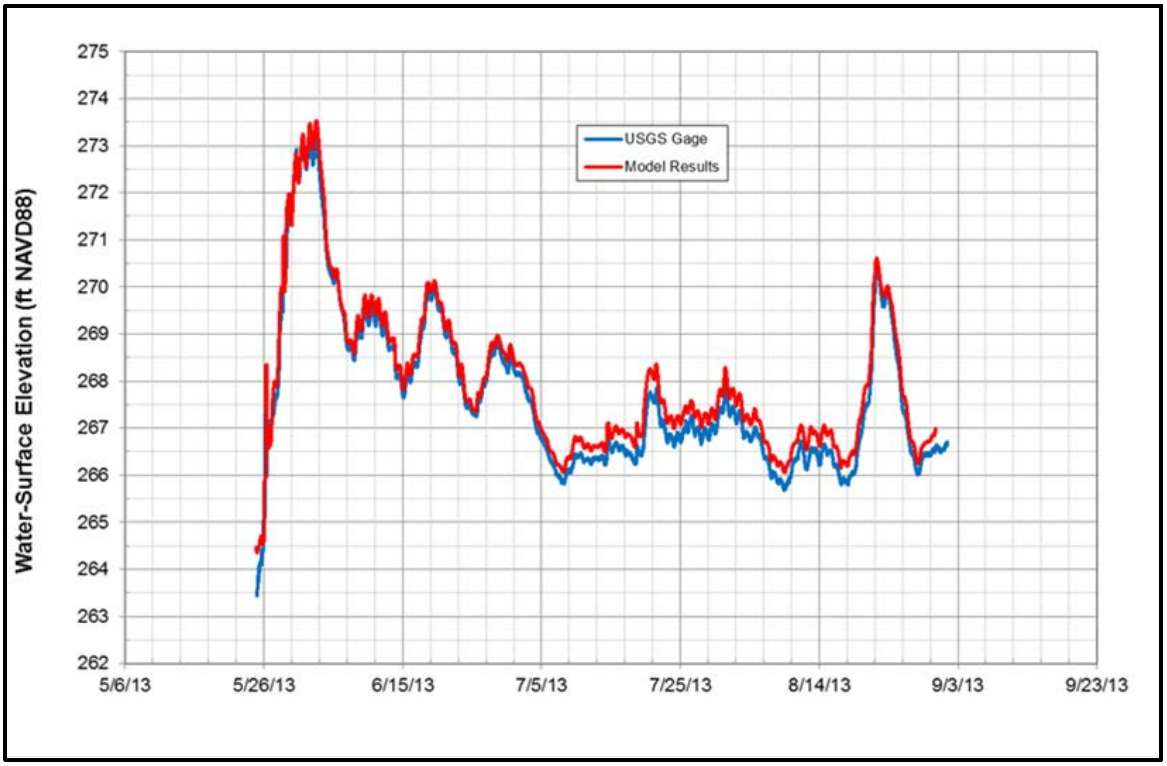

Figure 4.2-1. Comparison of observed and simulated water-surface elevations at Sunshine for the calibration event.

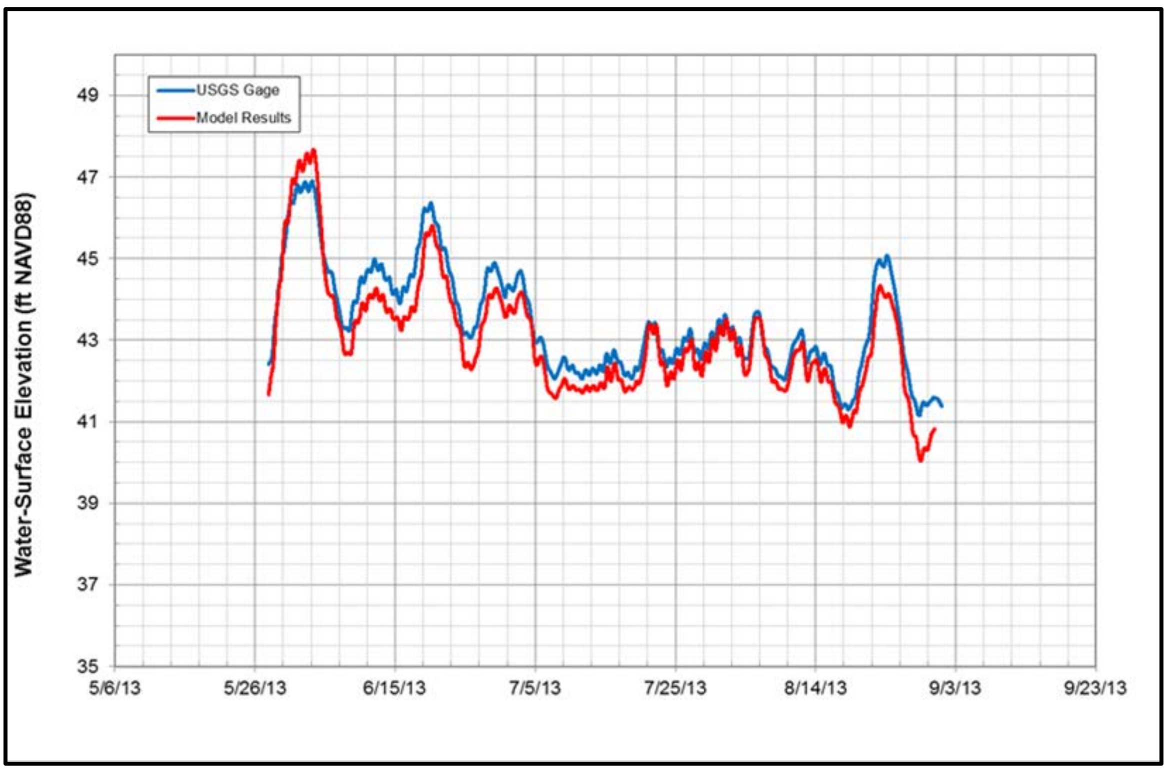

Figure 4.2-2. Comparison of observed and simulated water-surface elevation at Susitna Station for the calibration event.

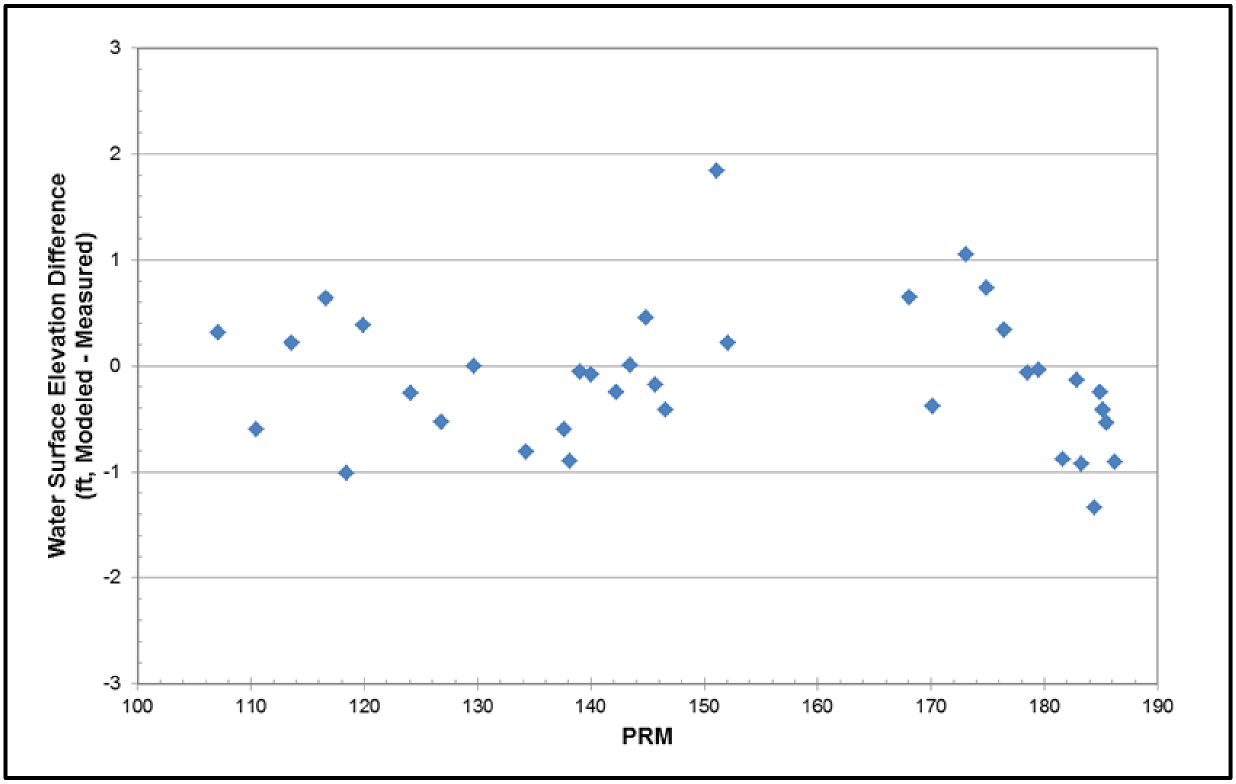

Figure 4.2-3. Middle River comparison of observed point-in-time water-surface elevations to simulated elevations for the calibration event.

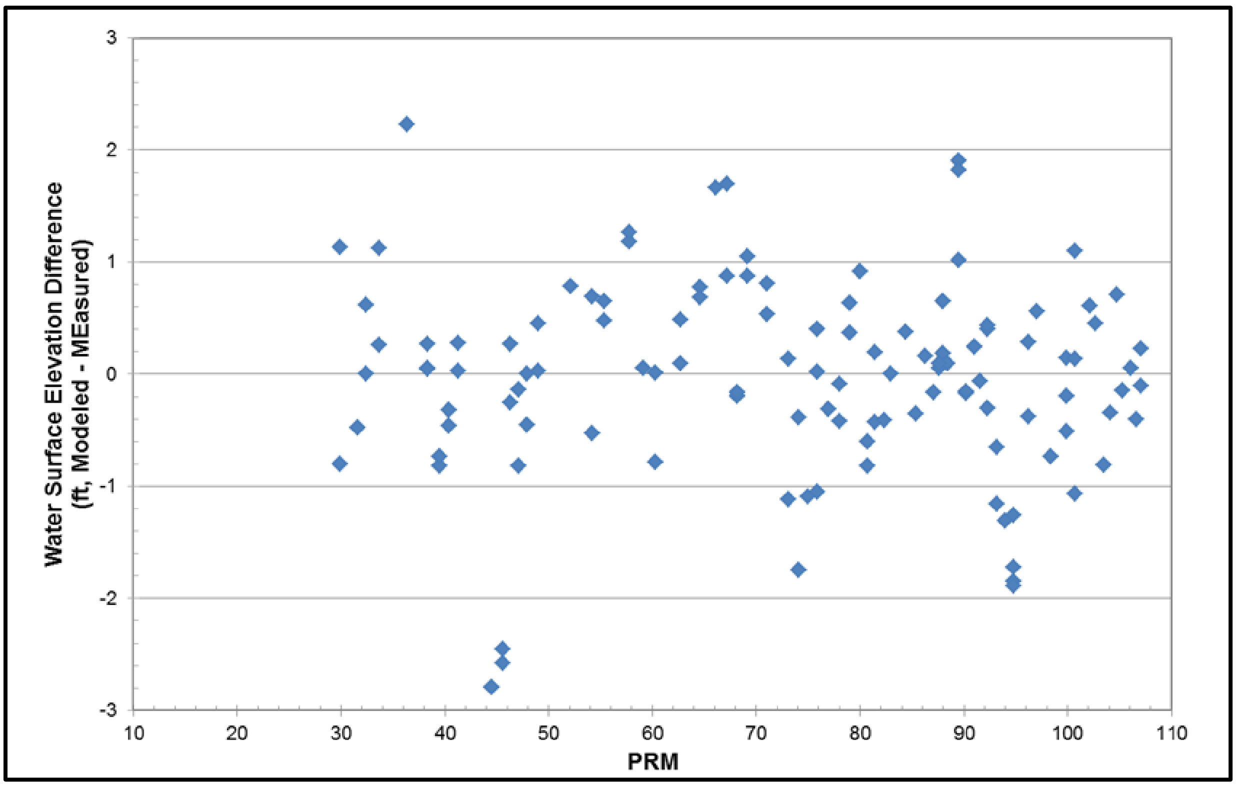

Figure 4.2-4. Lower River comparison of observed point-in-time water-surface elevations to simulated elevations for the calibration event.

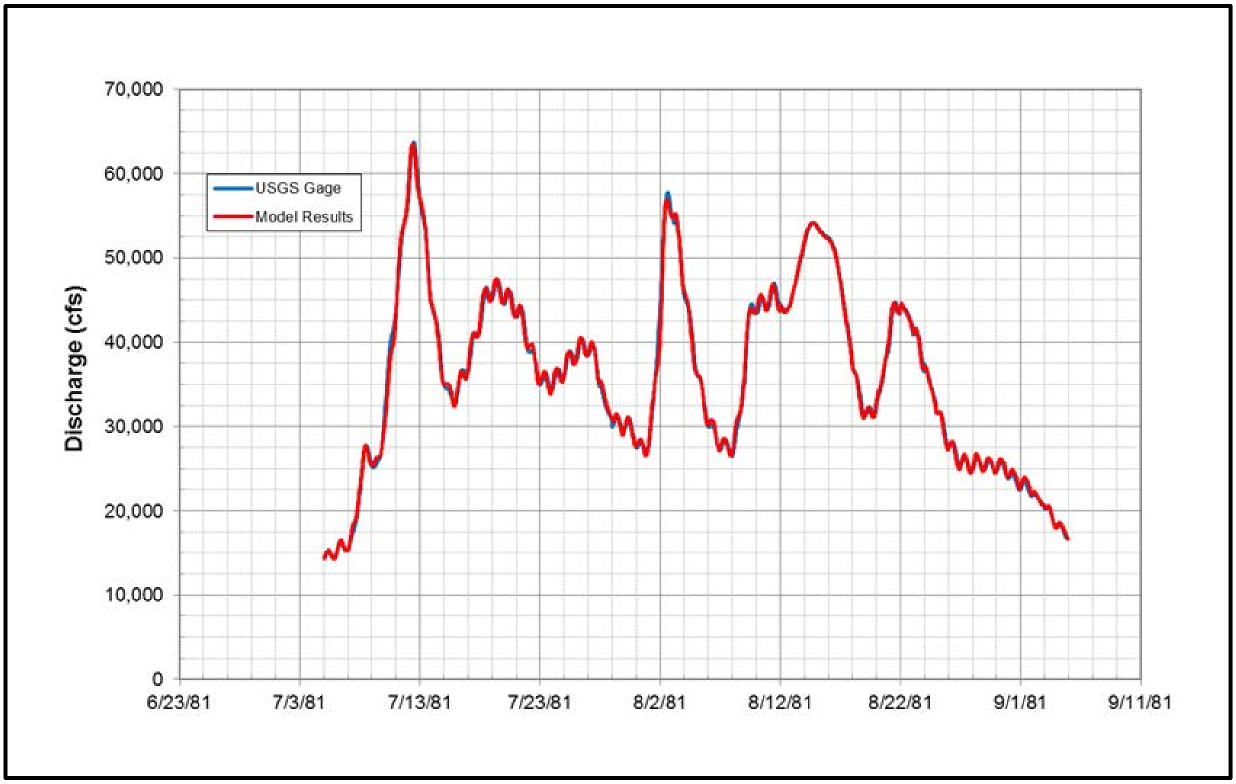

Figure 4.2-5. Comparison of observed and simulated flows at Gold Creek for the validation event.

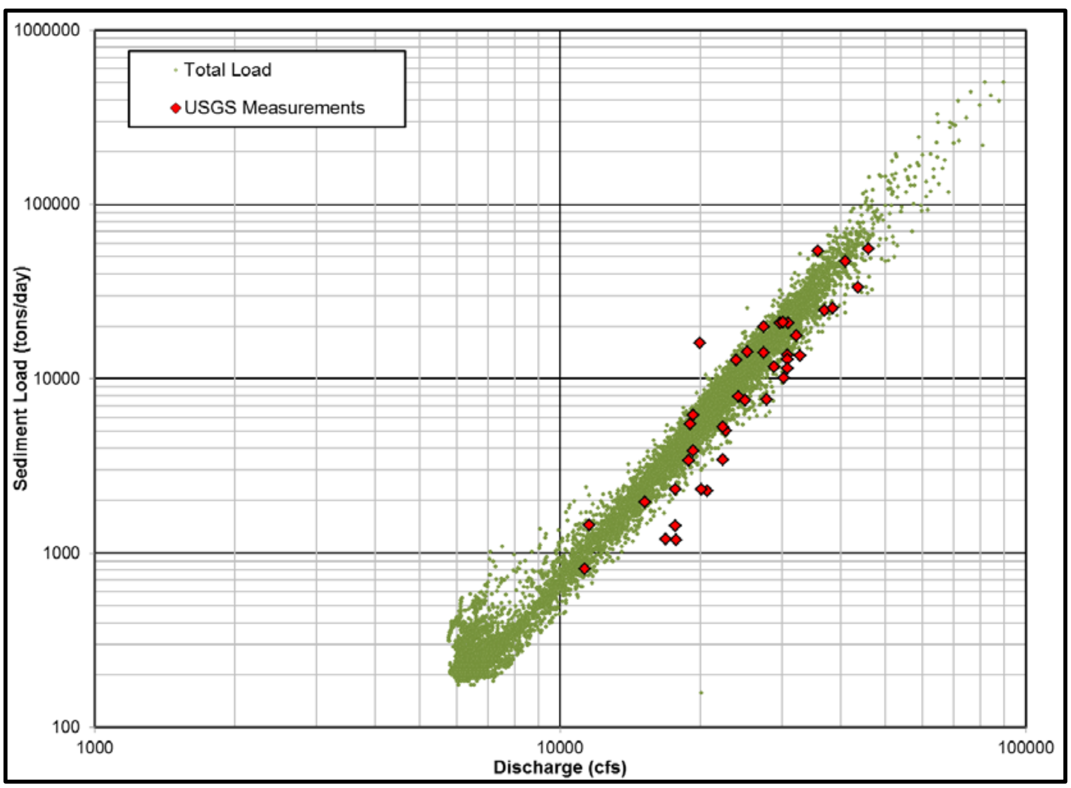

Figure 4.2-6. Susitna River near Talkeetna comparison of measured and modeled total bed material loads.

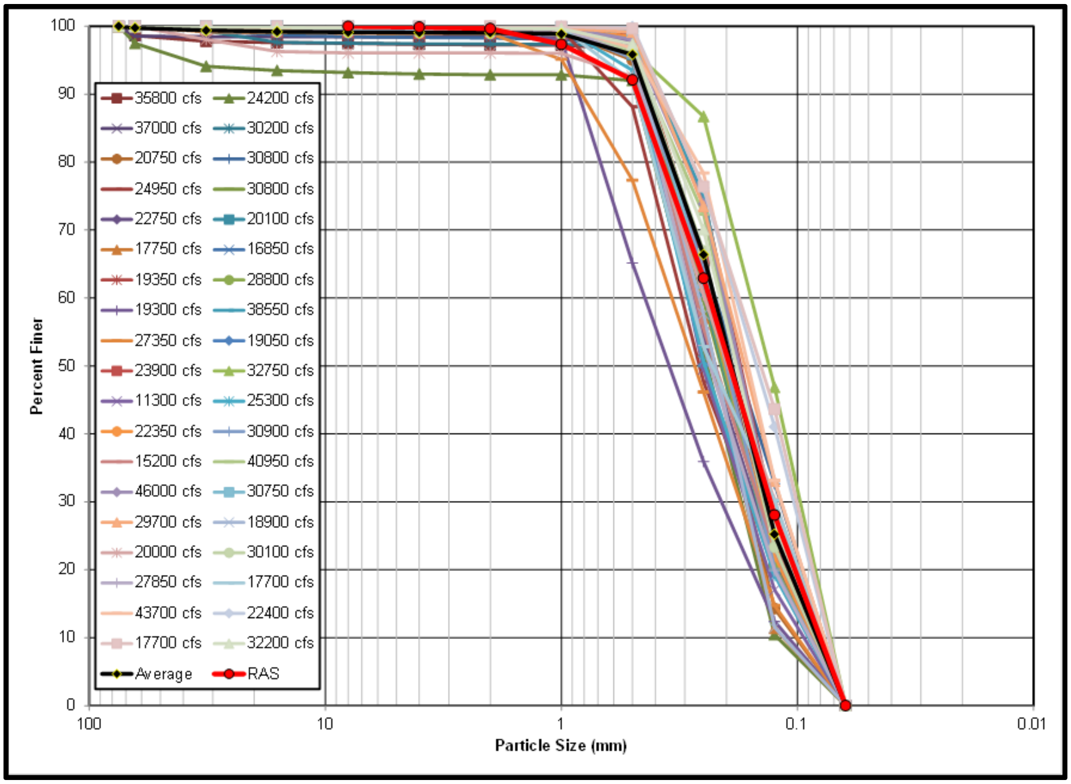

Figure 4.2-7. Susitna River near Talkeetna comparison of measured and modeled transported bed material gradations.

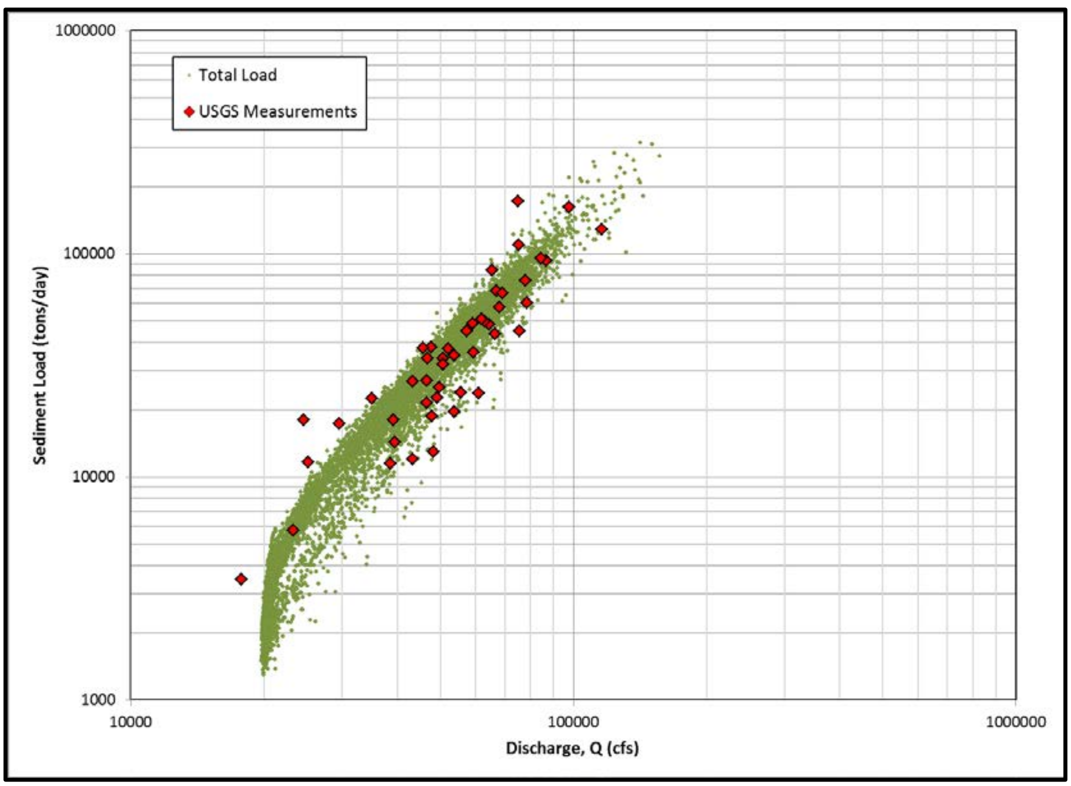

Figure 4.2-8. Susitna River at Sunshine comparison of measured and model total bed material loads.

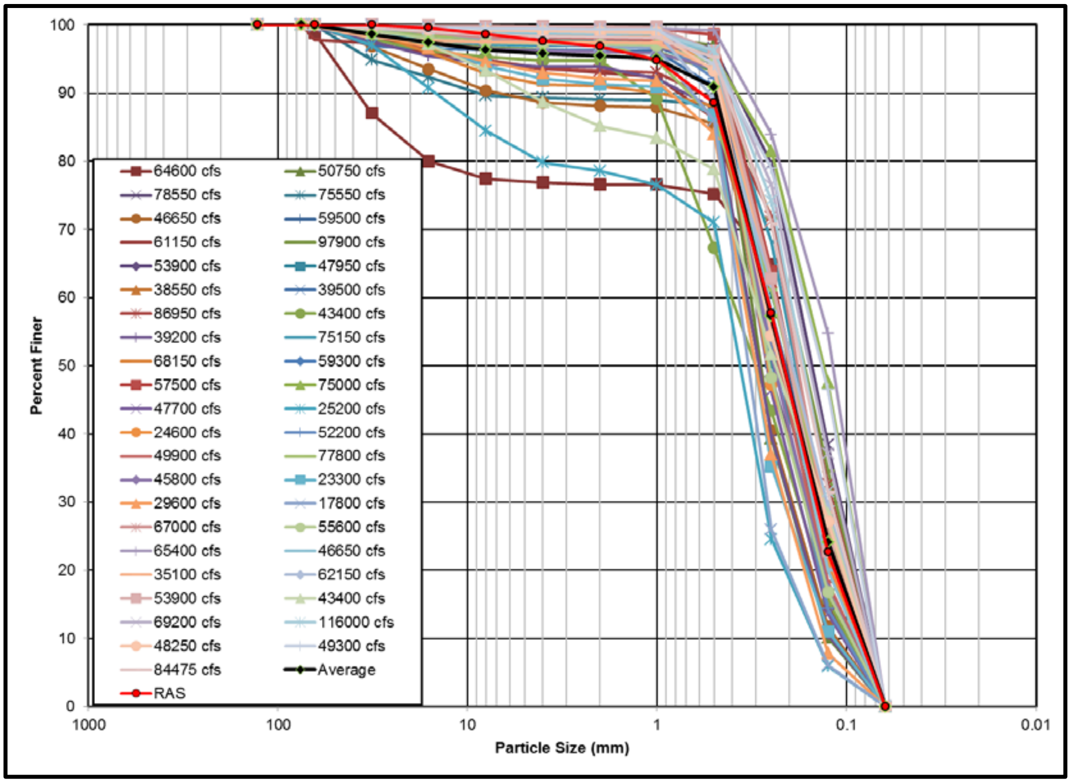

Figure 4.2-9. Susitna River at Sunshine comparison of measured and model transported bed material gradations.

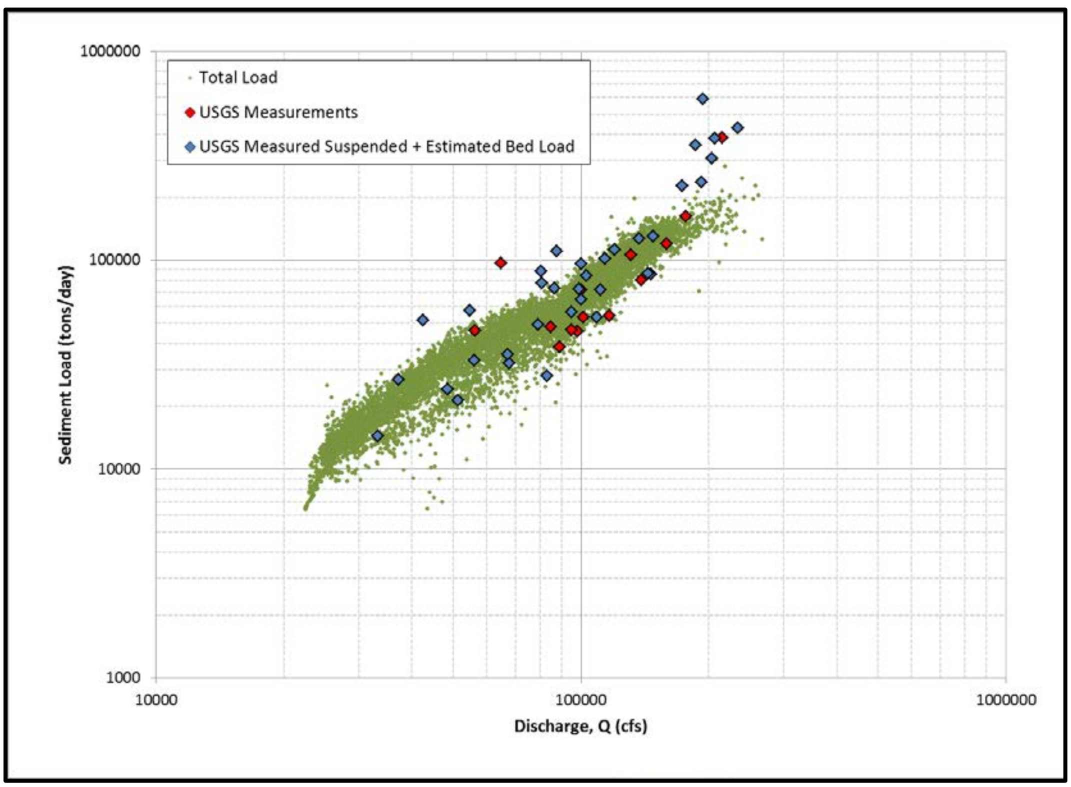

Figure 4.2-10. Susitna River at Susitna Station comparison of measured and model total bed material loads.

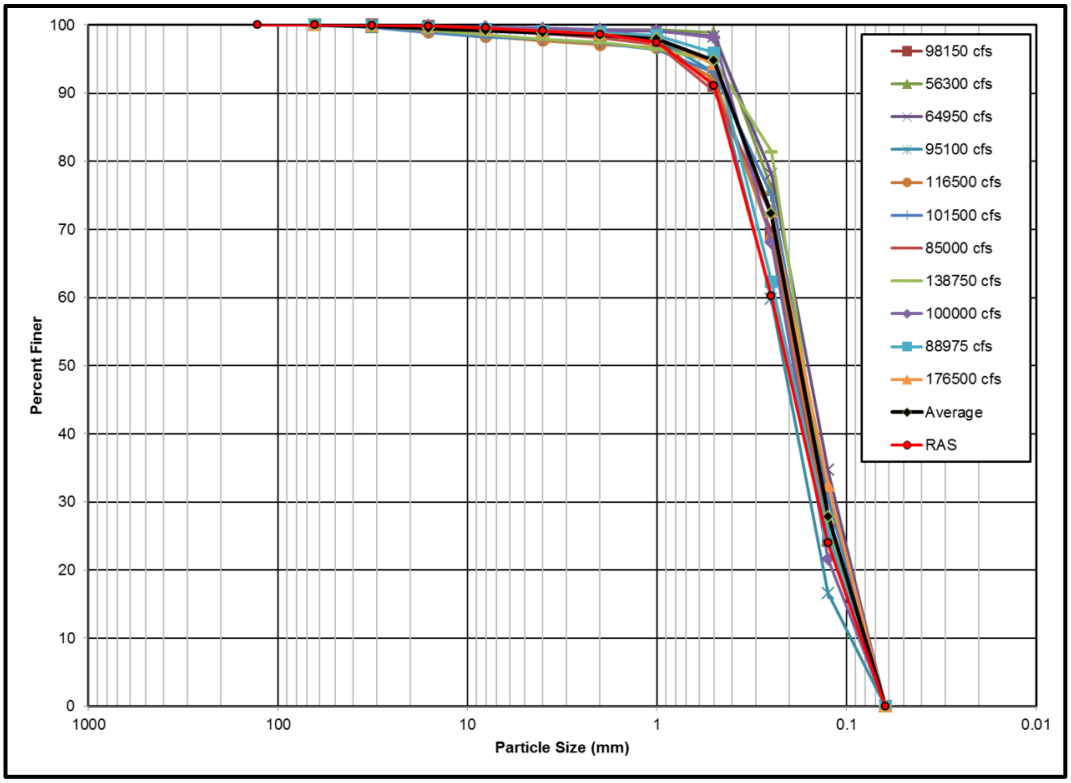

Figure 4.2-11. Susitna River at Susitna Station comparison of measured and model transported bed material gradations.

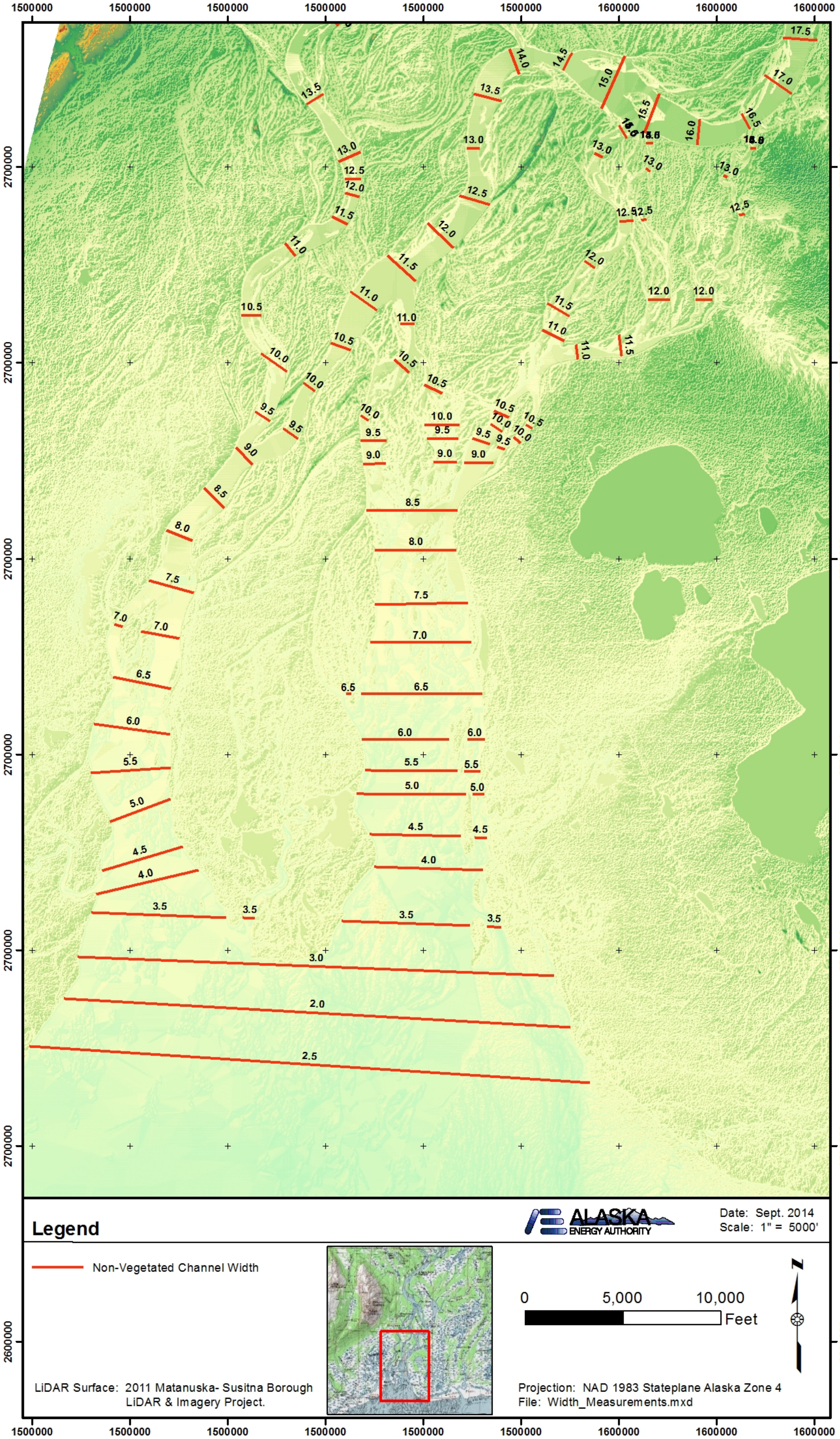

Figure 5.1-1. Susitna River active channel width measurements from PRM 29.5 to 13.0.

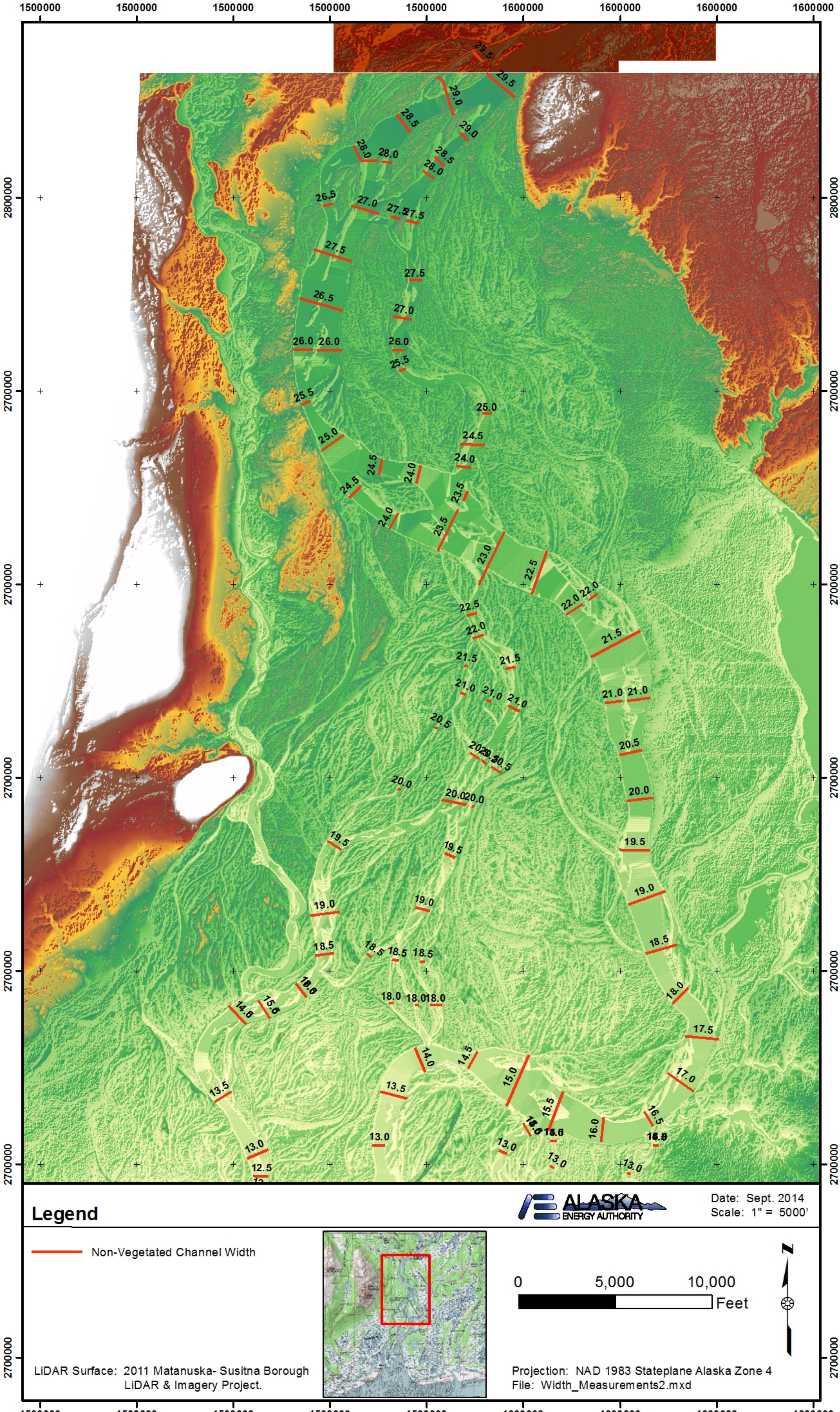

Figure 5.1-2. Susitna River active channel width measurements from PRM 16.0 to 2.5.

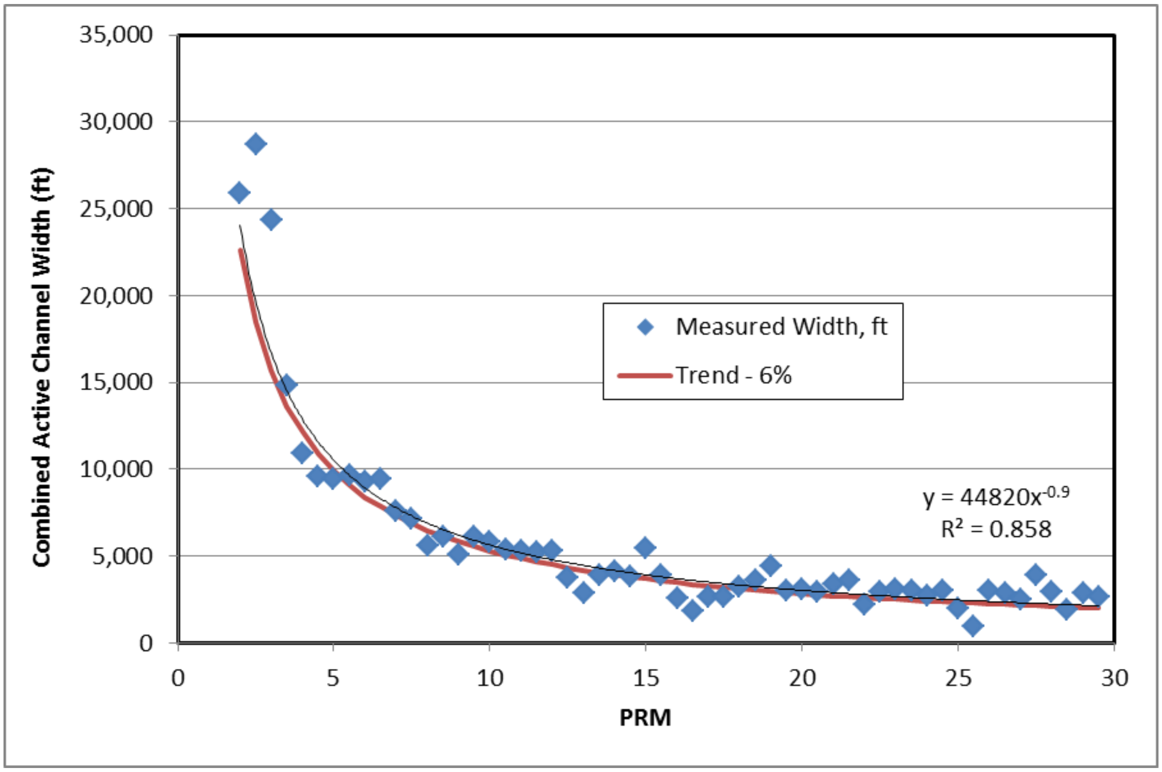

Figure 5.1-3. Susitna River non-vegetated channel width below PRM 29.5.

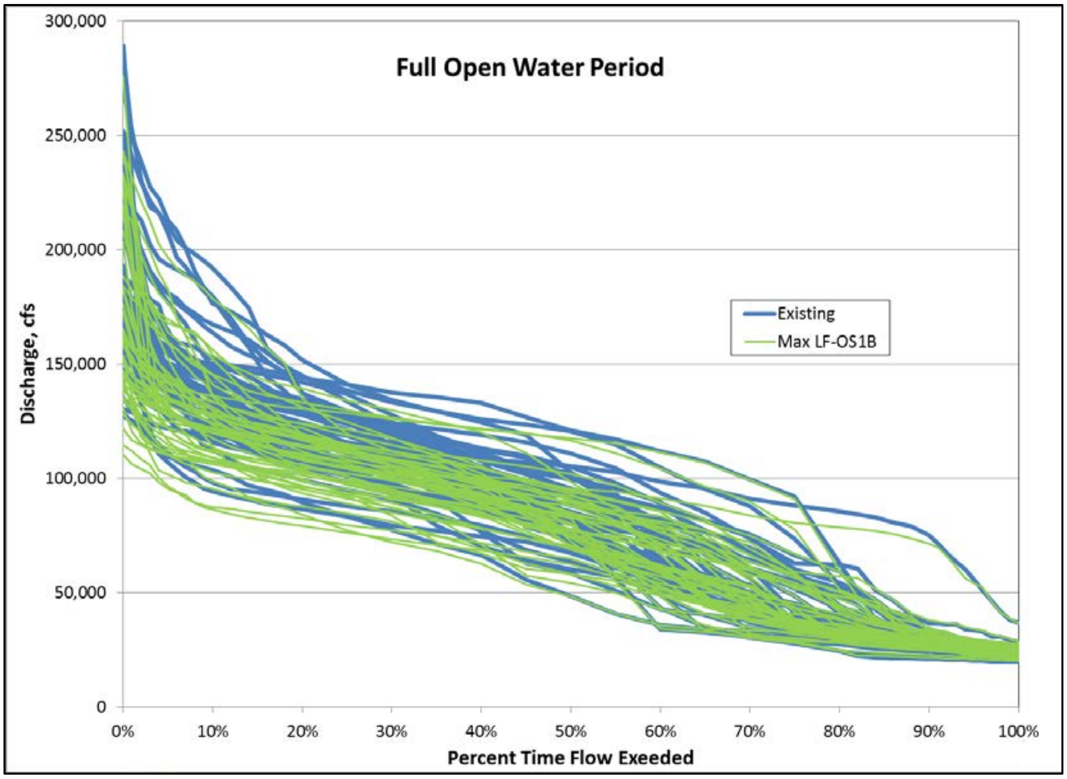

Figure 5.1-4 Comparison of annual flow duration curves for full open-water flow period.

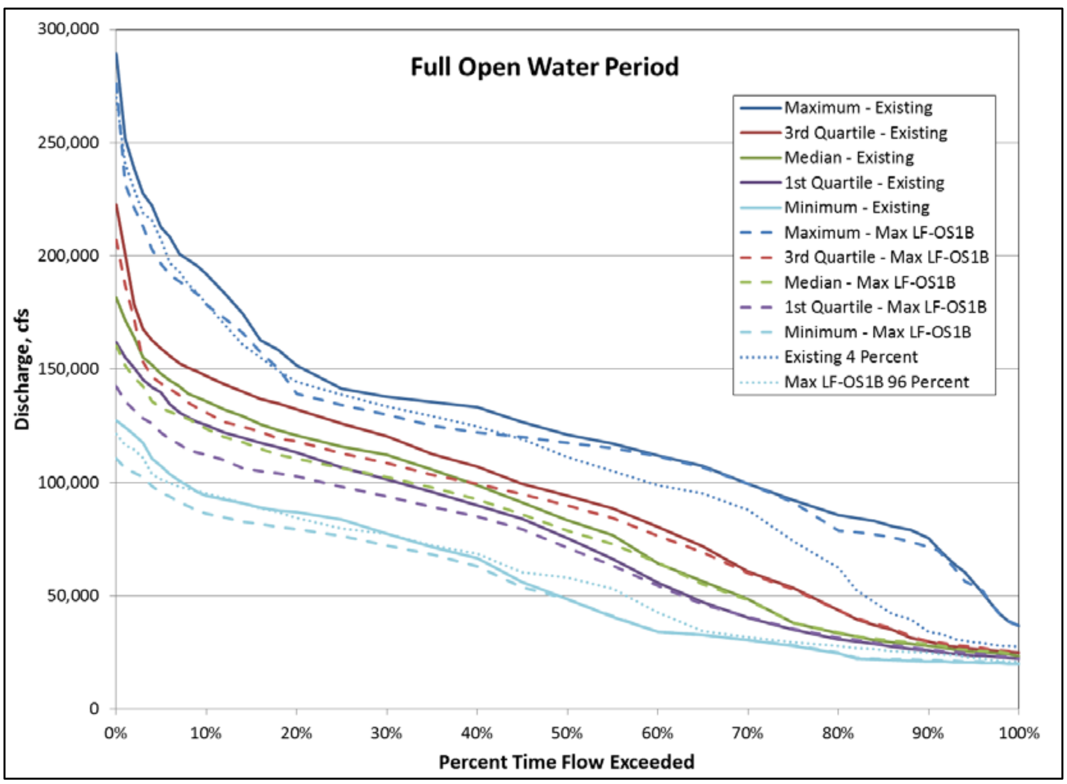

Figure 5.1-5. Range of flow duration curves for the full open water flow period.

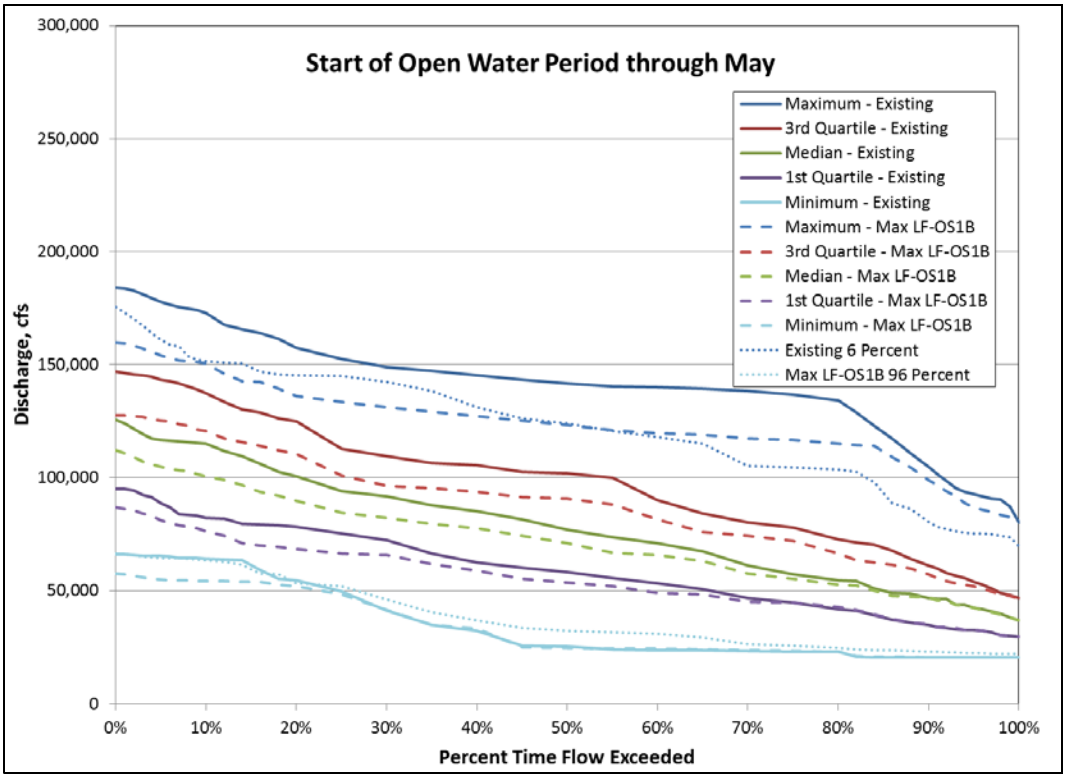

Figure 5.1-6. Range of flow duration curves from start of open water flow period to end of May.

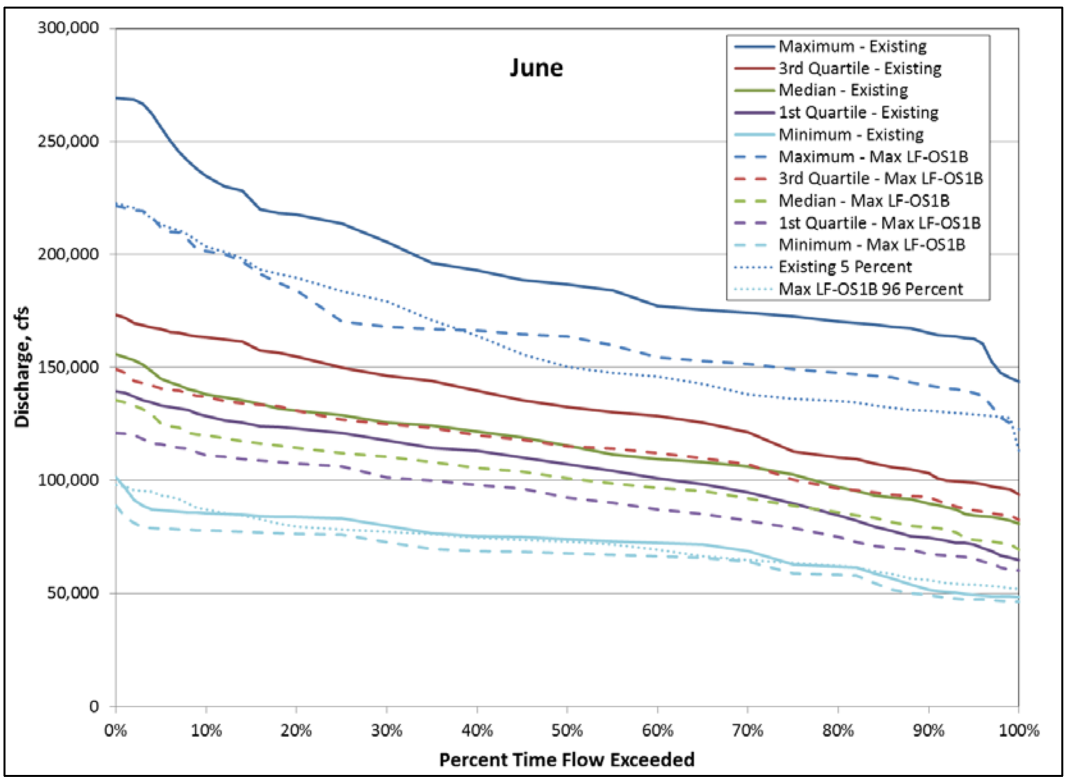

Figure 5.1-7. Range of flow duration curves for June.

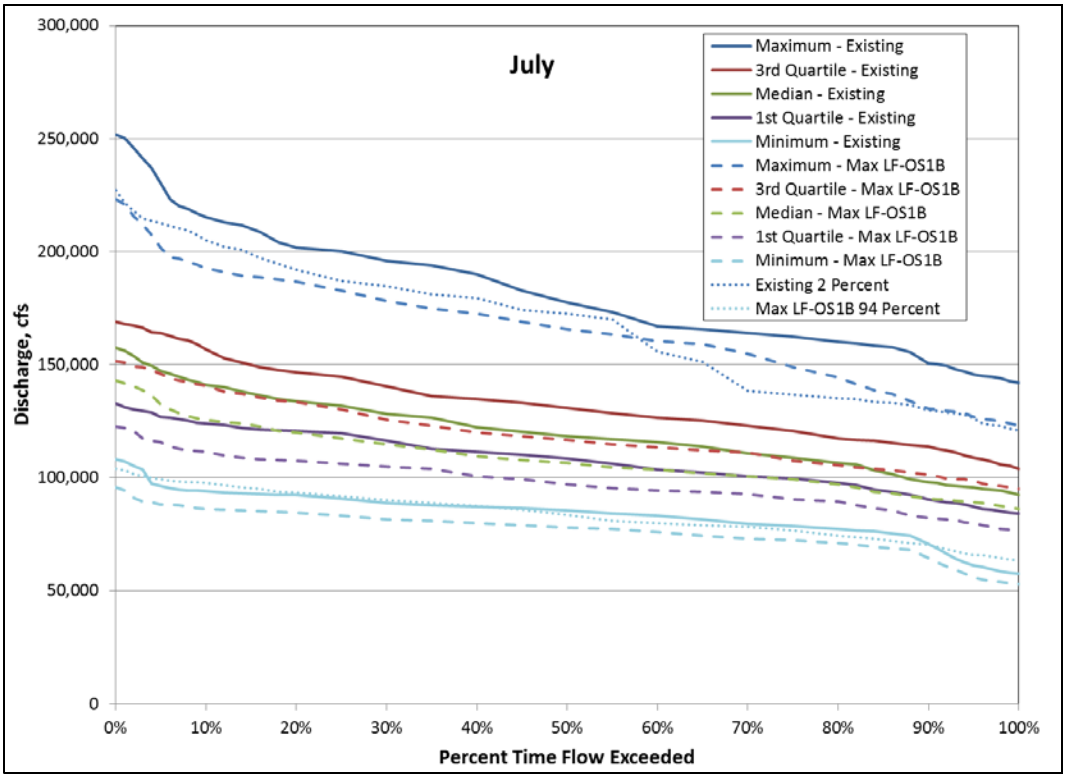

Figure 5.1-8. Range of flow duration curves for July.

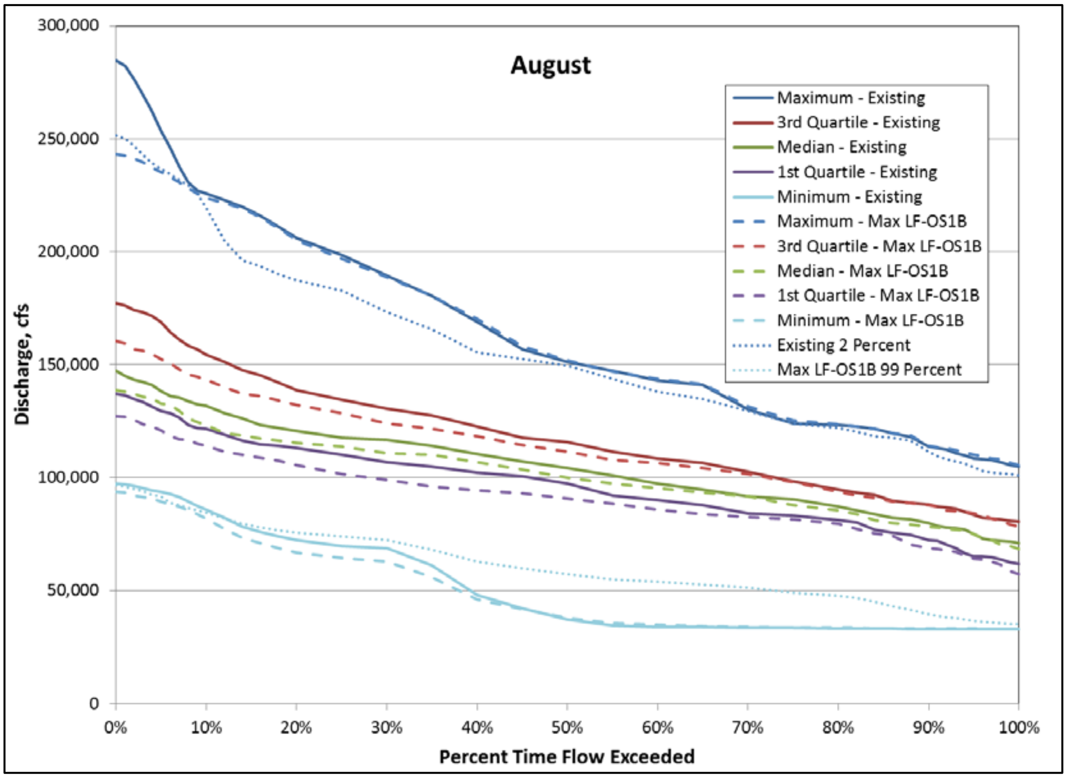

Figure 5.1-9. Range of flow duration curves for August.

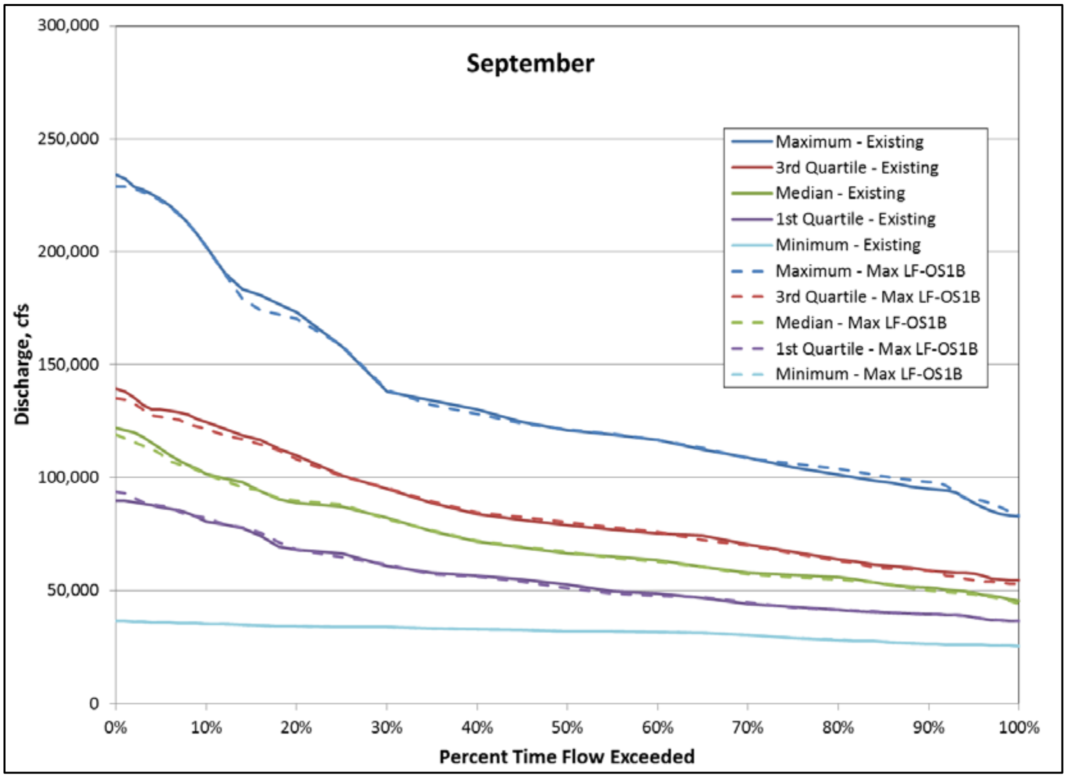

Figure 5.1-10. Range of flow duration curves for September.

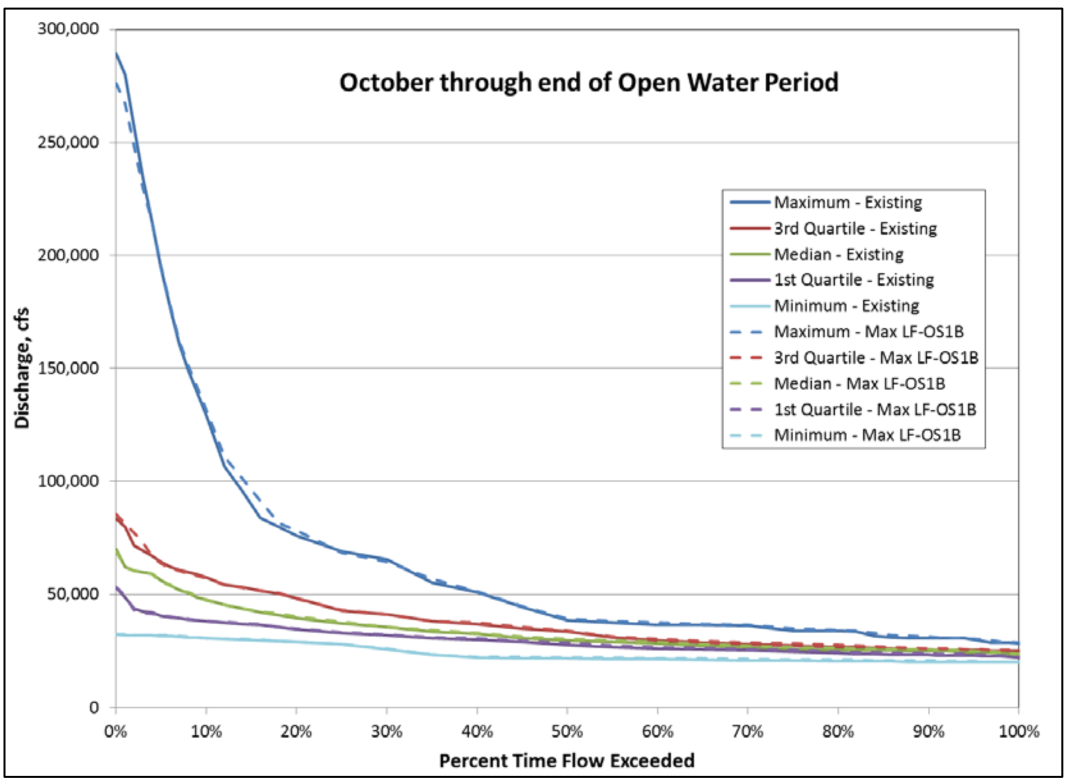

Figure 5.1-11. Range of flow duration curves for October to end of open water flow period.

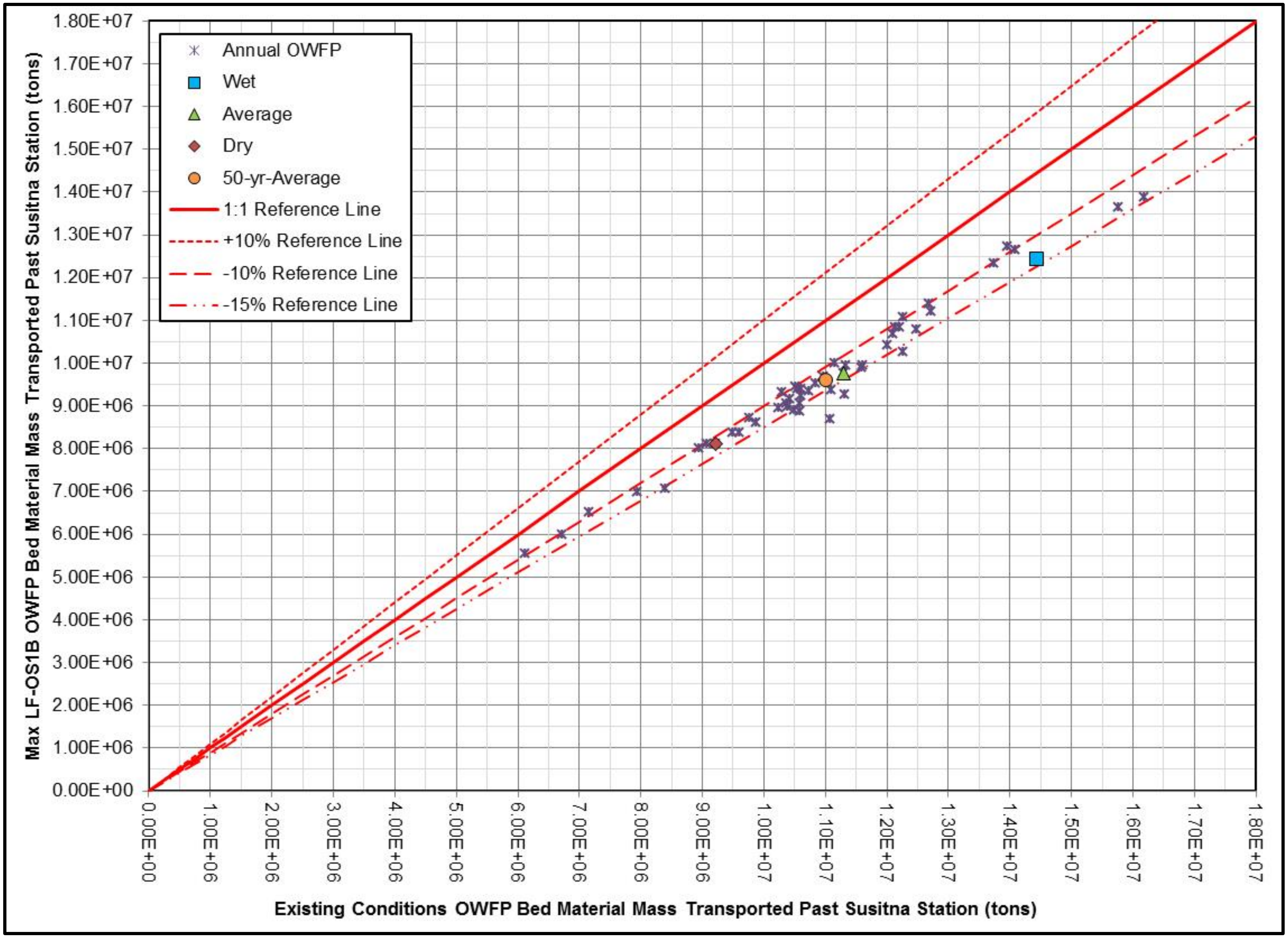

Figure 5.2-1. Comparison of sediment mass (sand and larger materials) transported past Susitna Station by OWFP under existing conditions and Max LF OS-1b.

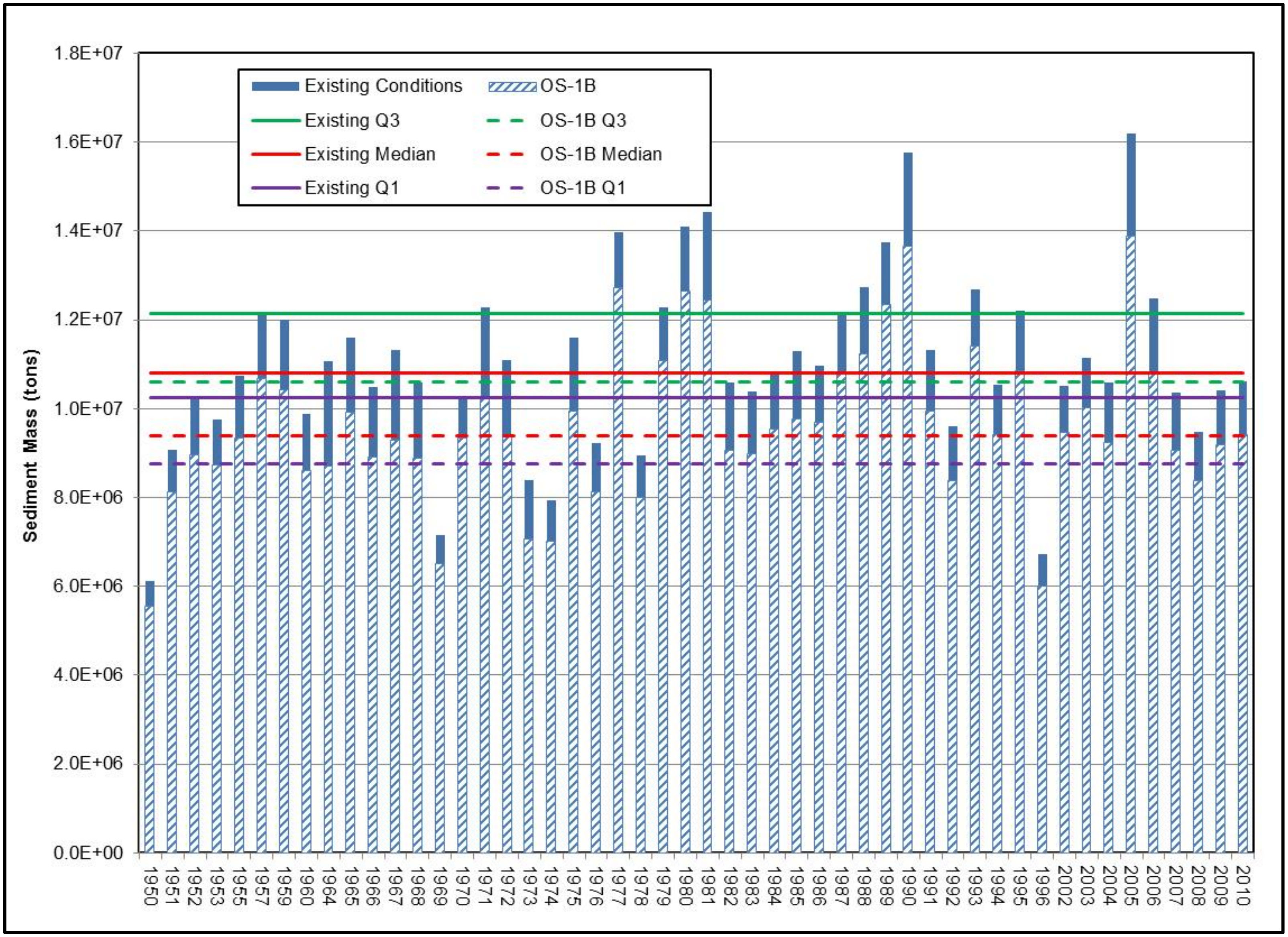

Figure 5.2-2. Time series of sediment mass (sand and larger materials) transported past Susitna Station under existing conditions and Max LF OS-1b.

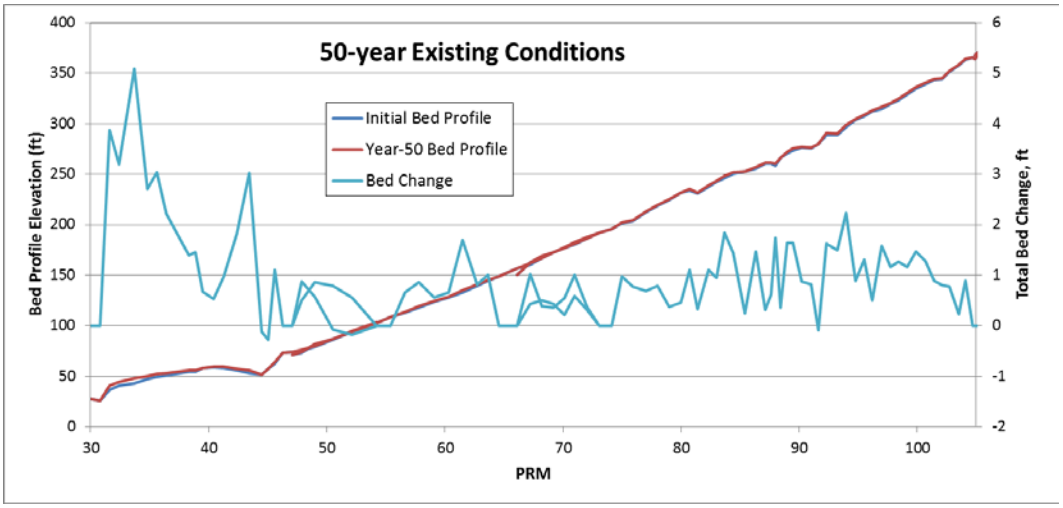

Figure 5.3-1. Bed elevation and change in 50-years for existing conditions.

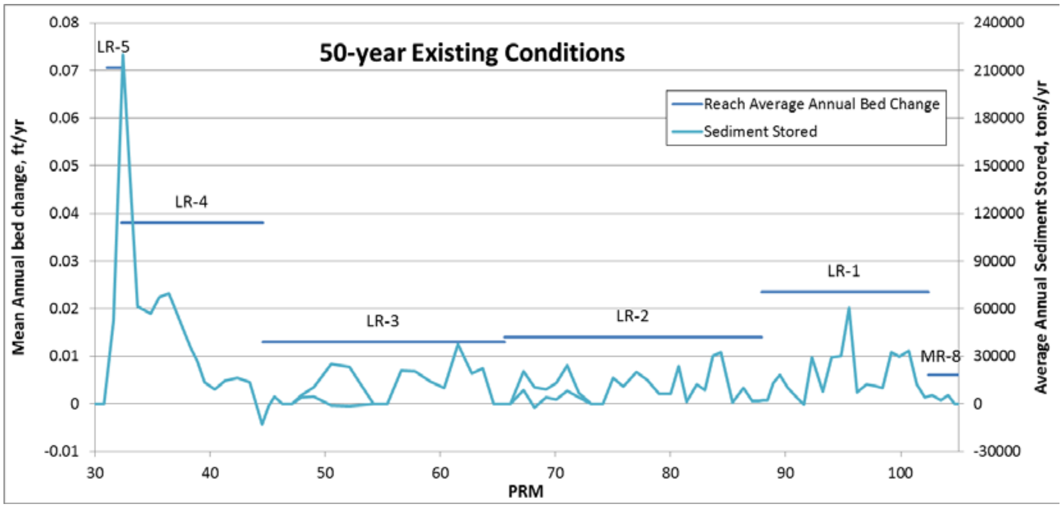

Figure 5.3-2. Sediment stored in the bed and reach averaged bed change for existing conditions.

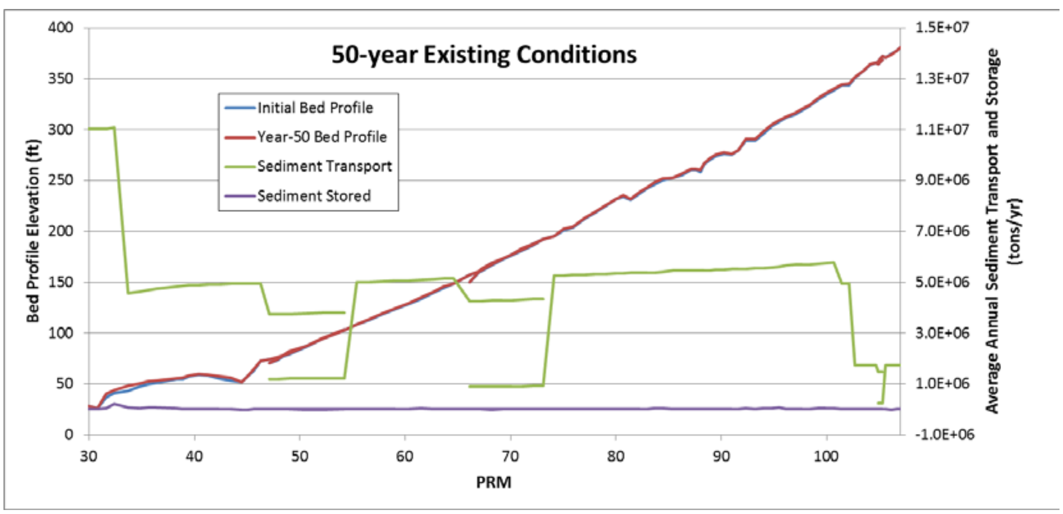

Figure 5.3-3. Bed material transport and bed storage for existing conditions.

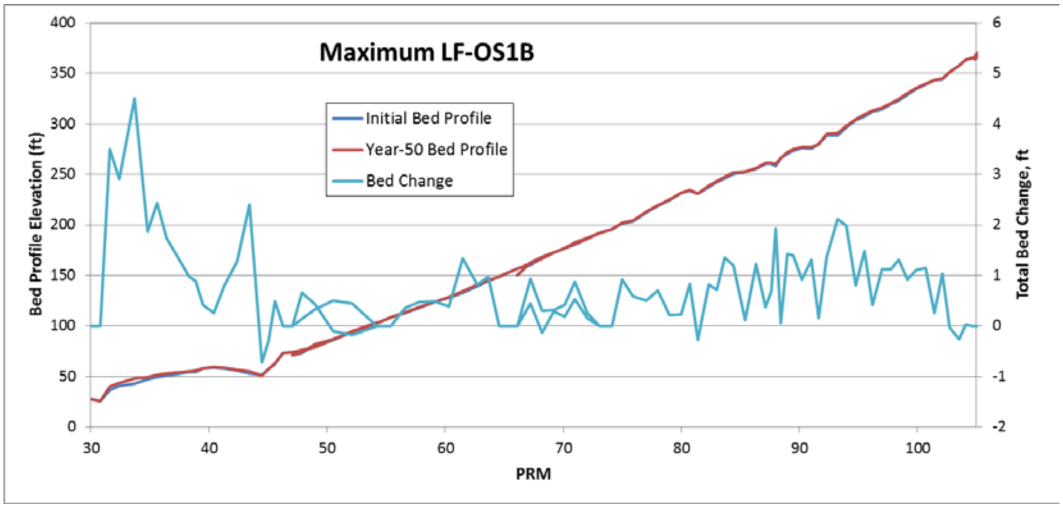

Figure 5.3-4. Bed elevation and change in 50-years for Maximum LF-OS1B conditions.

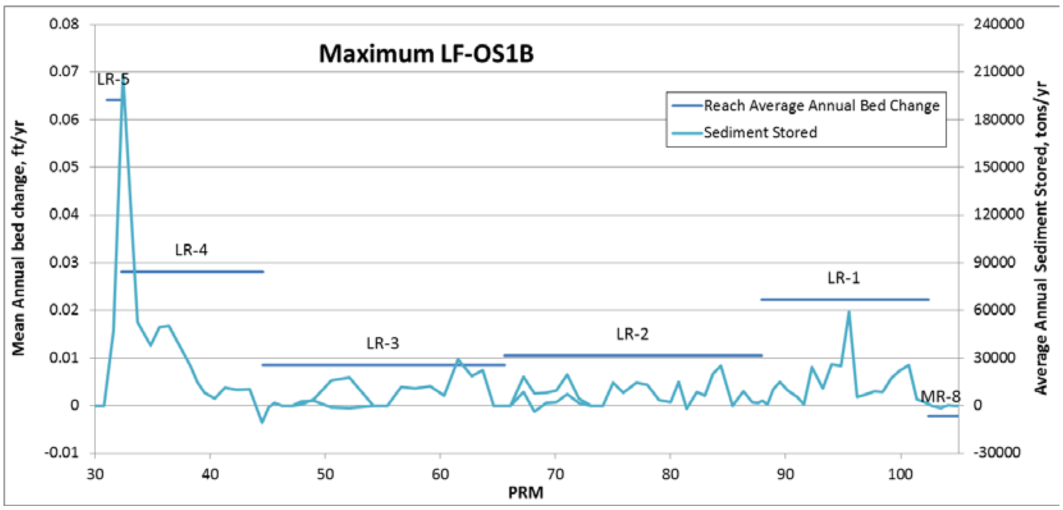

Figure 5.3-5. Sediment stored in the bed and reach averaged bed change for Maximum LF-OS1B conditions.

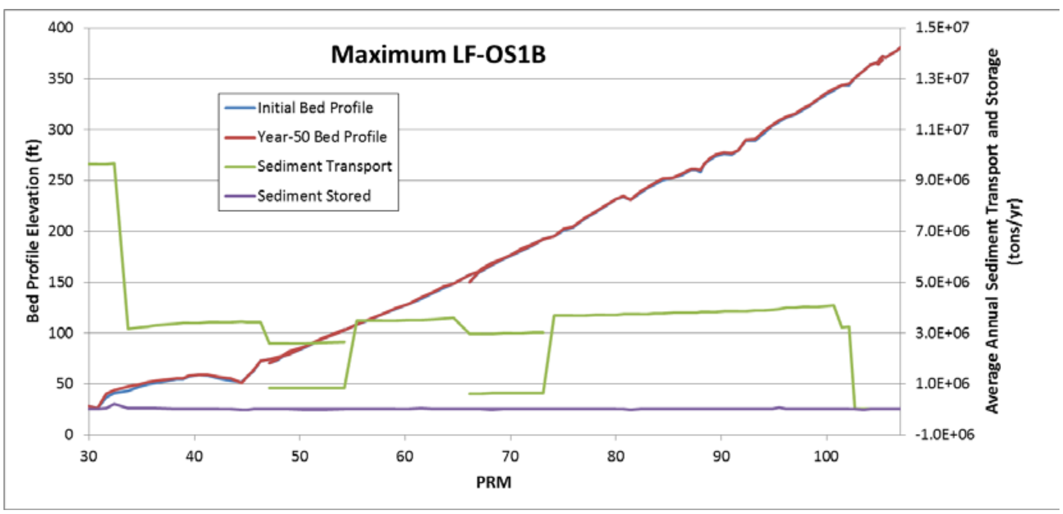

Figure 5.3-6. Bed material transport and bed storage for Maximum LF-OS1B conditions.

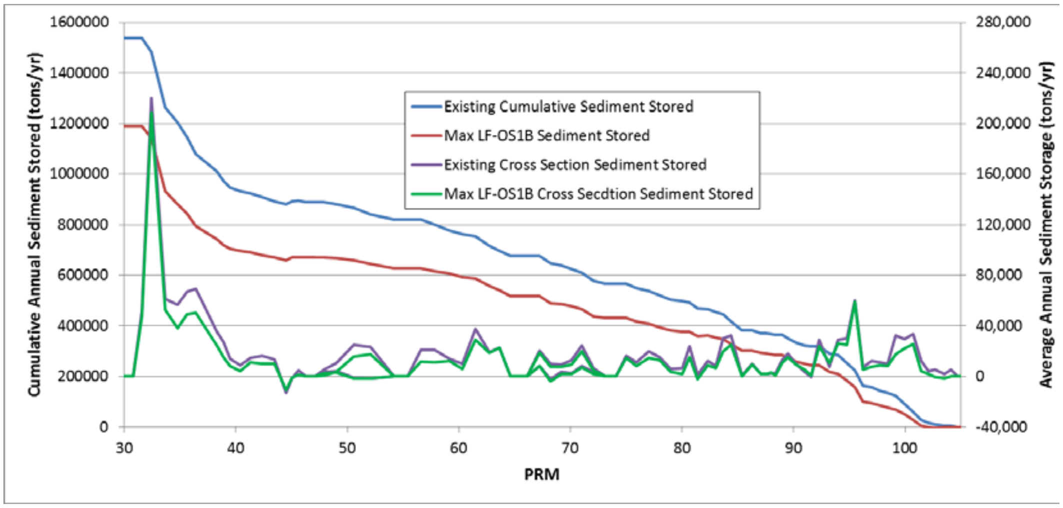

Figure 5.3-7. Comparison between existing and Max LF OS-1b conditions incremental (at a cross section) and cumulative sediment stored in the bed of the Lower River.

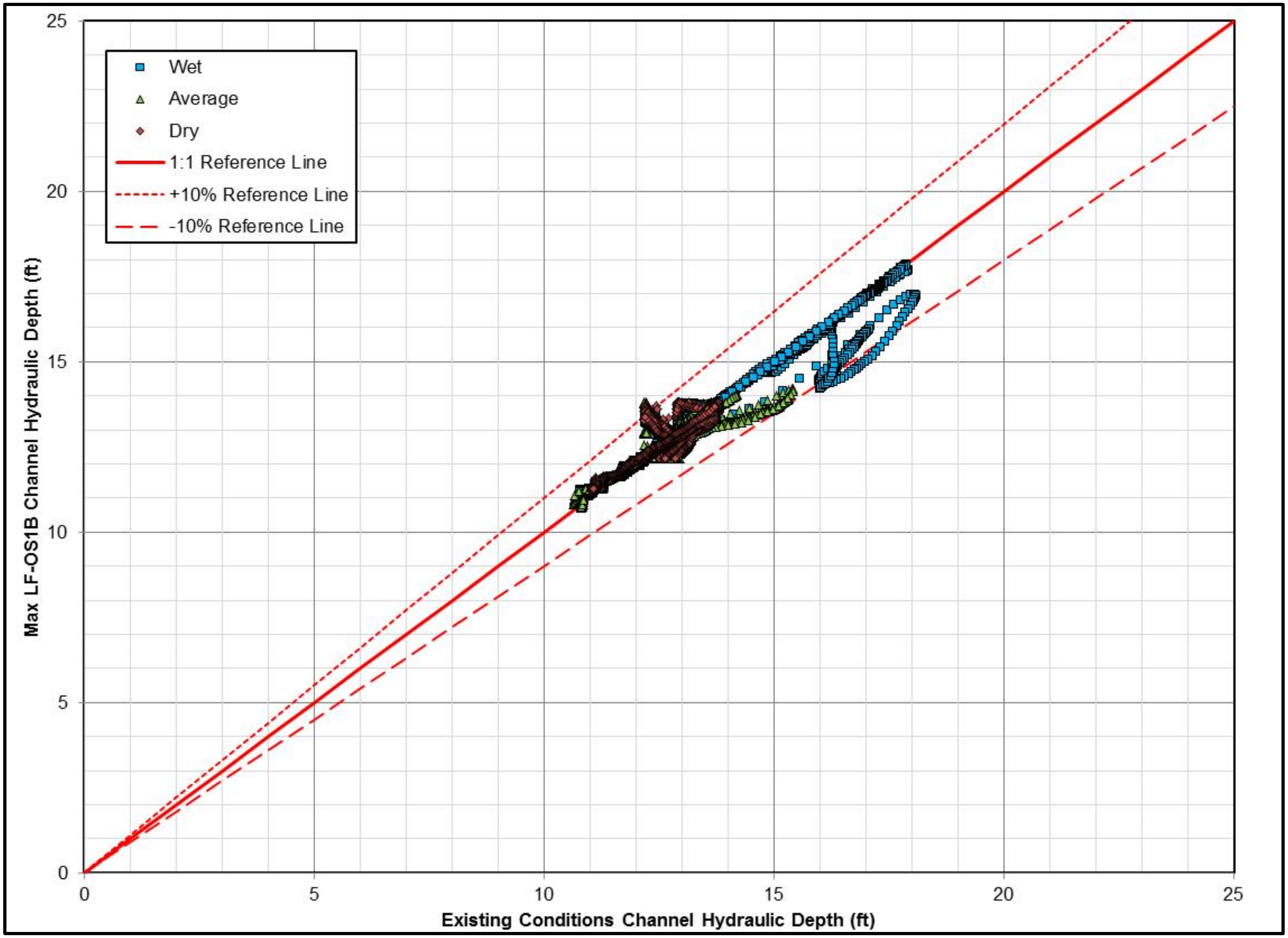

Figure 5.4-1. Comparison of channel hydraulic depth at PRM 29.9 under existing conditions and Max LF OS-1b.

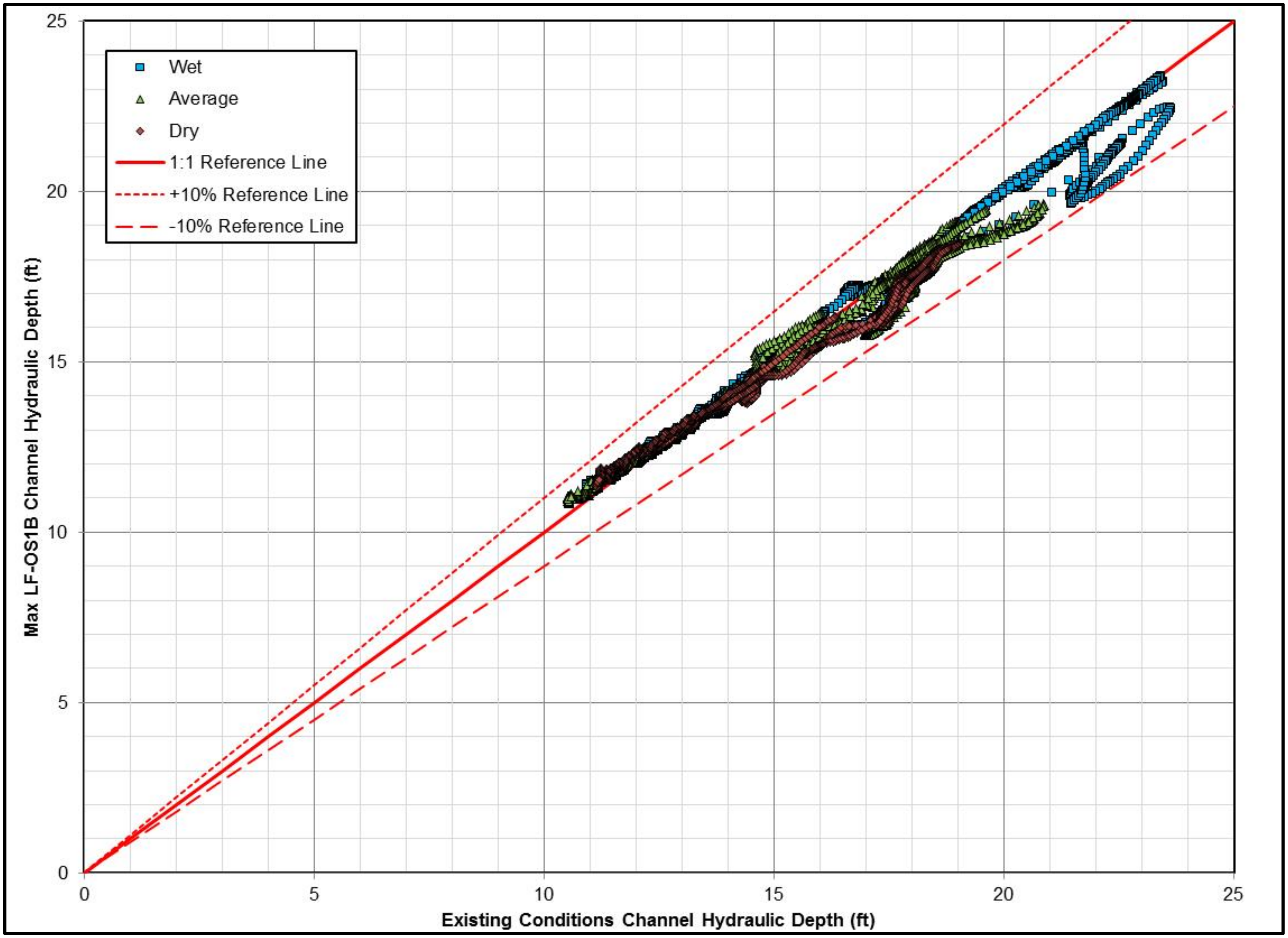

Figure 5.4-2. Comparison of channel hydraulic depth at PRM 30.8 under existing conditions and Max LF OS-1b.

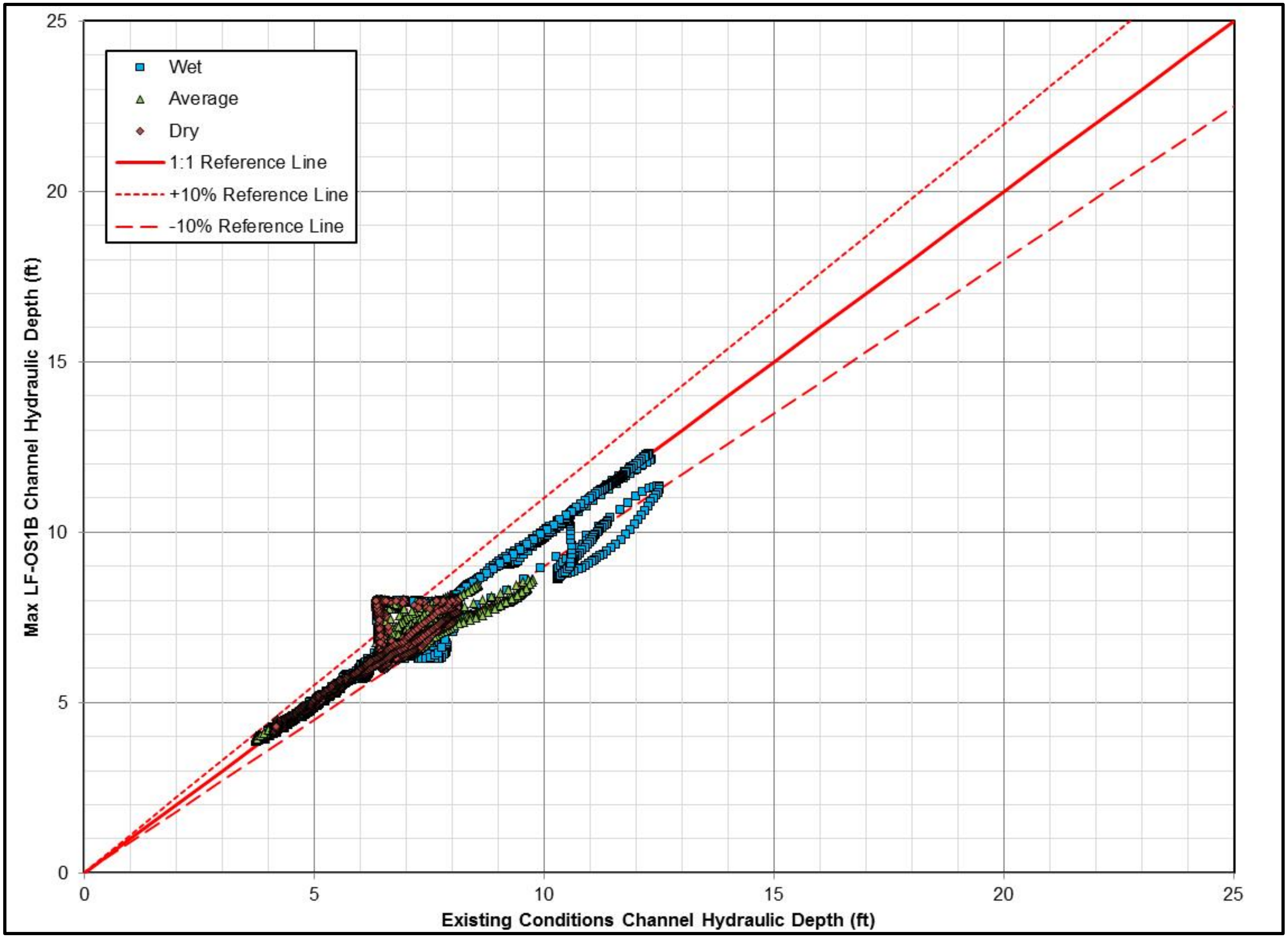

Figure 5.4-3. Comparison of channel hydraulic depth at PRM 31.6 under existing conditions and Max LF OS-1b.

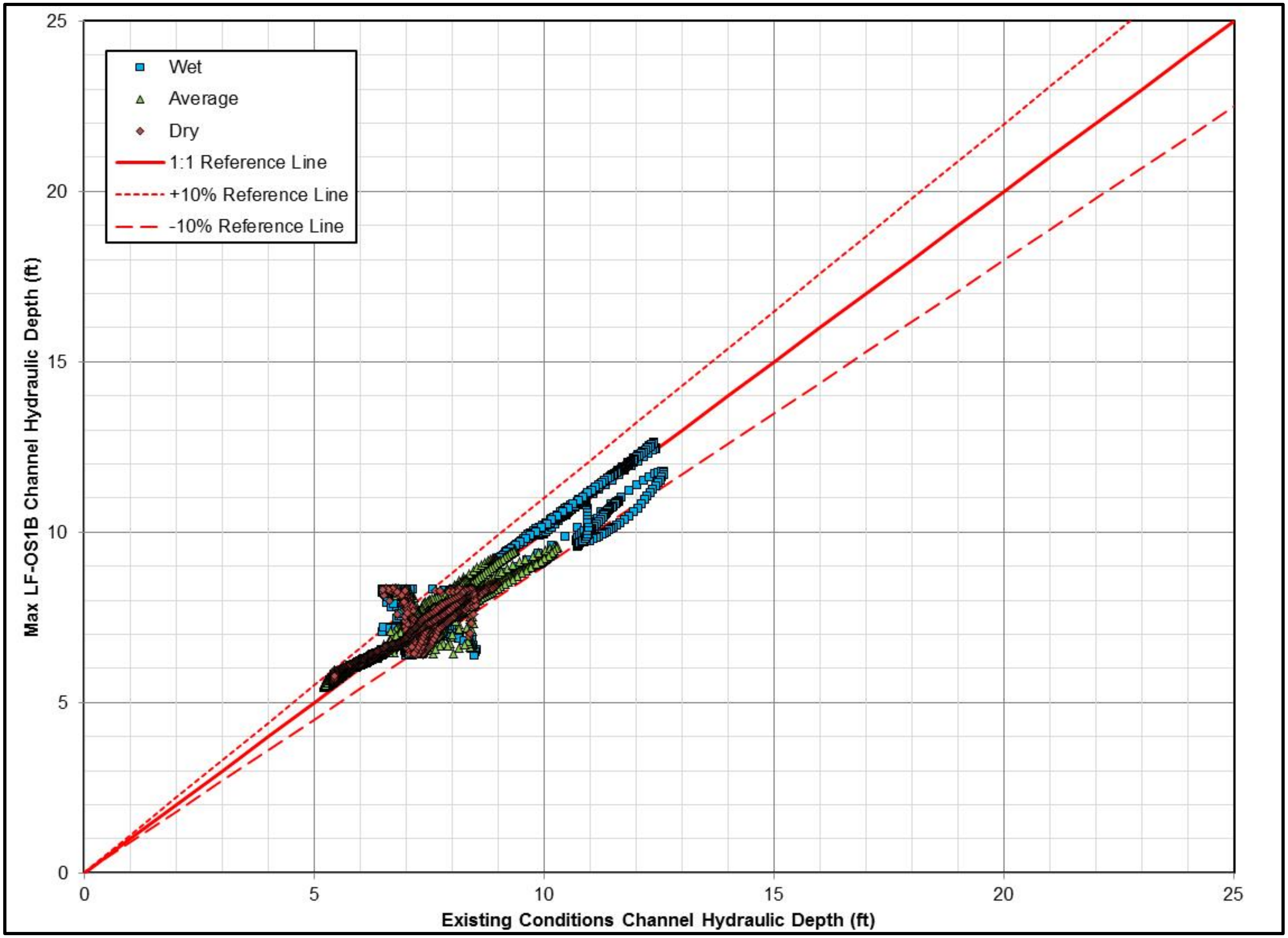

Figure 5.4-4. Comparison of channel hydraulic depth at PRM 32.4 under existing conditions and Max LF OS-1b.

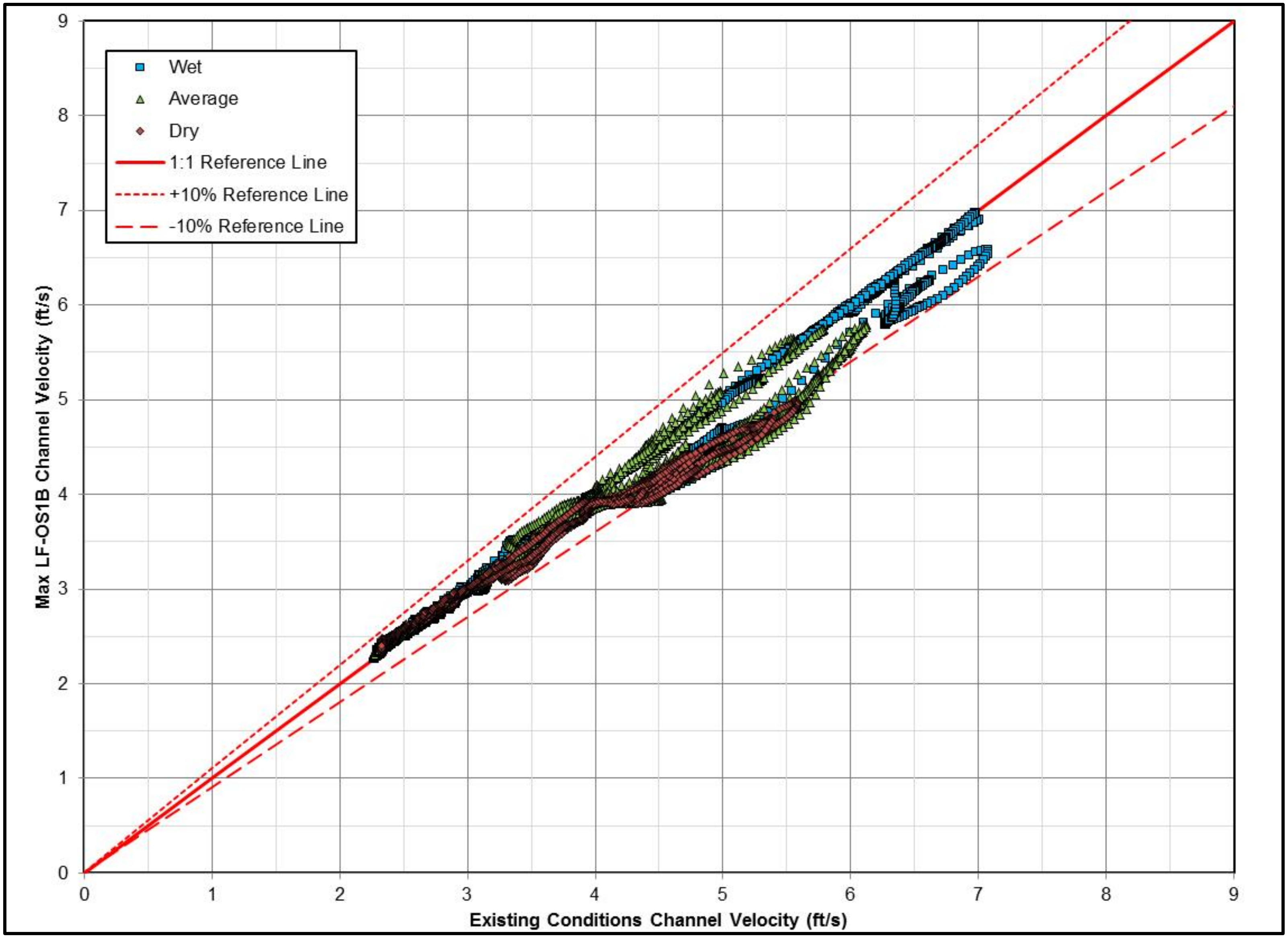

Figure 5.4-5. Comparison of channel average velocity at PRM 29.9 under existing conditions and Max LF OS-1b.

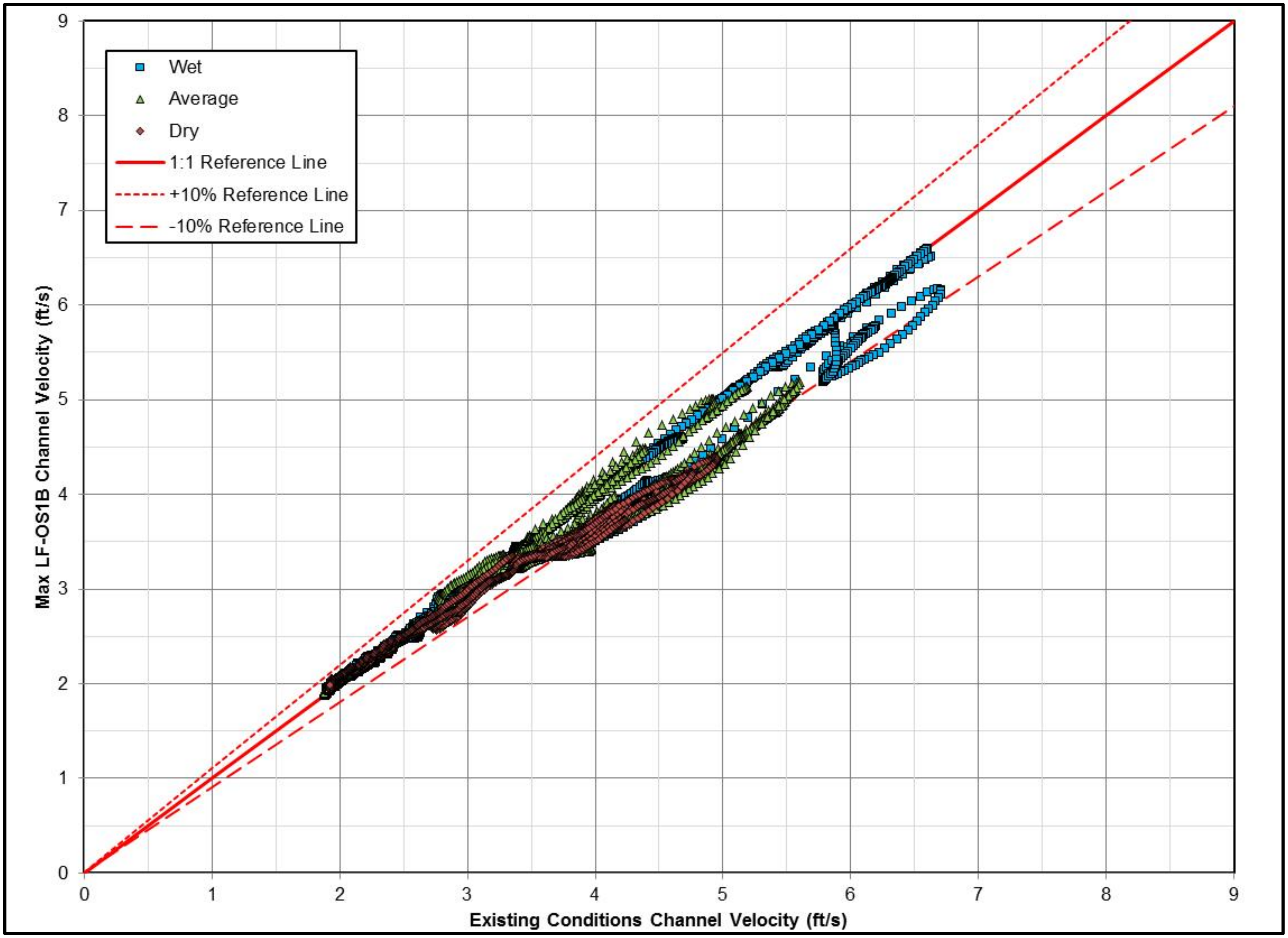

Figure 5.4-6. Comparison of channel average velocity at PRM 30.8 under existing conditions and Max LF OS-1b.

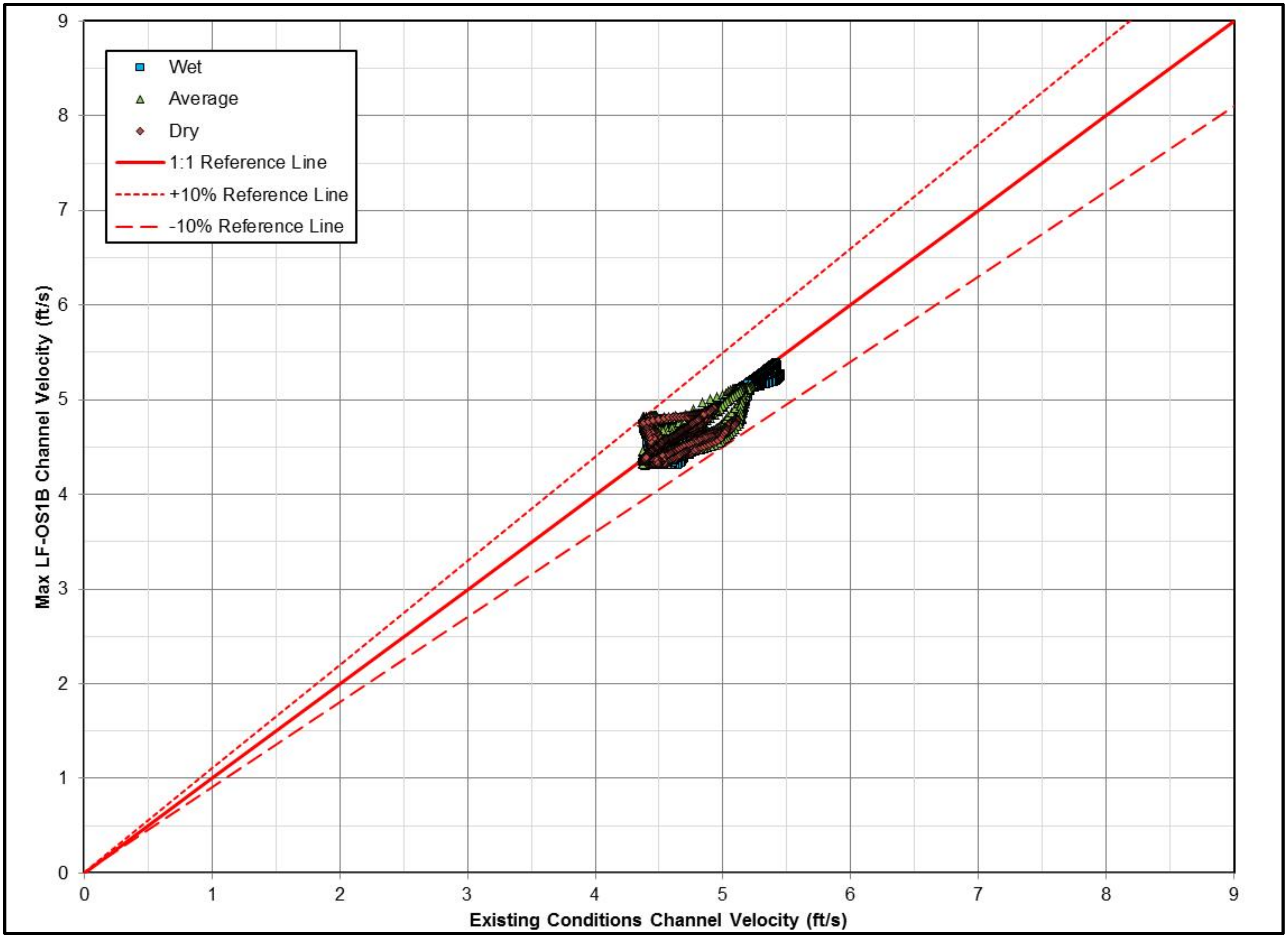

Figure 5.4-7. Comparison of channel average velocity at PRM 31.6 under existing conditions and Max LF OS-1b.

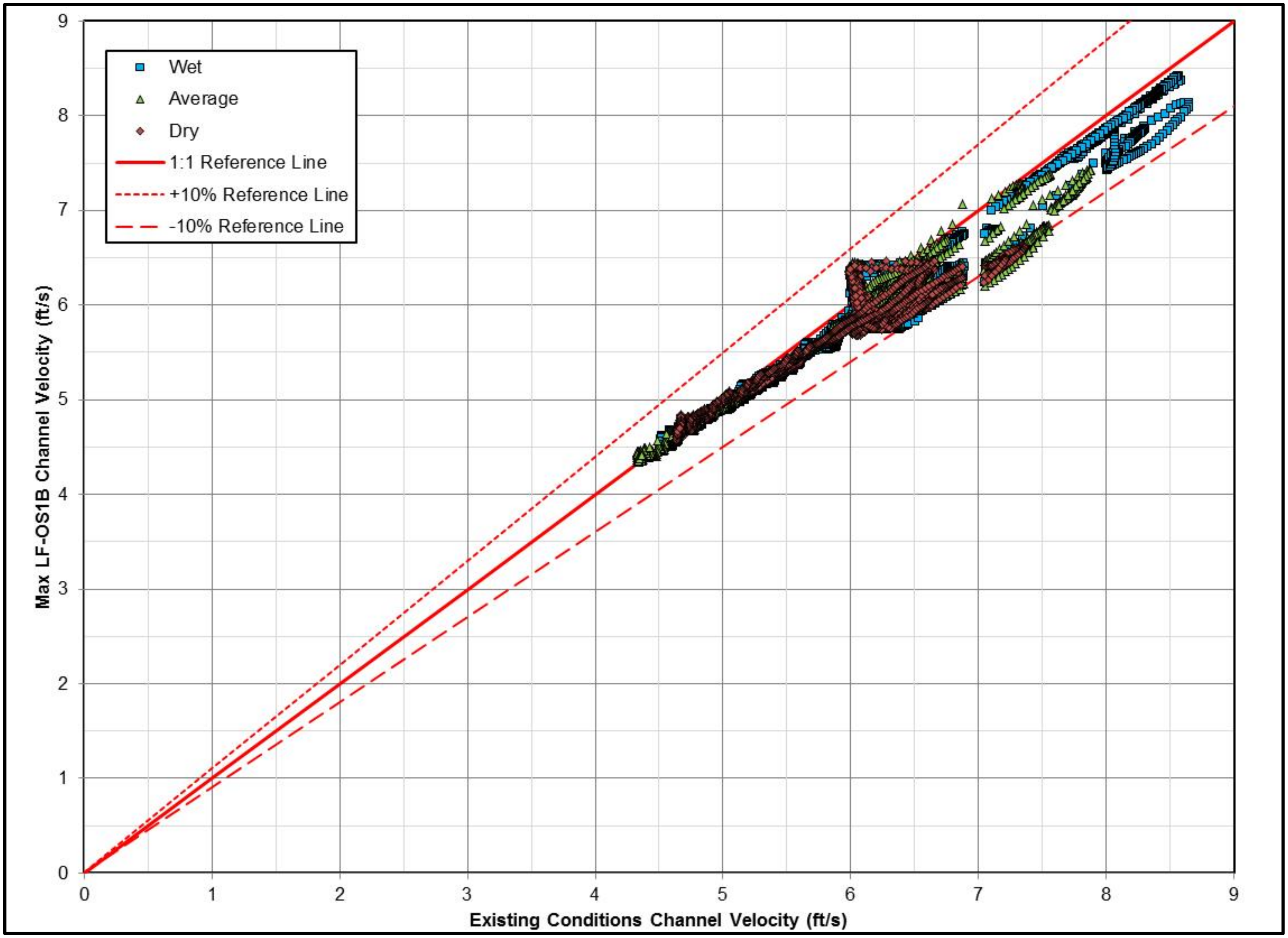

Figure 5.4-8. Comparison of channel average velocity at PRM 32.4 under existing conditions and Max LF OS-1b.

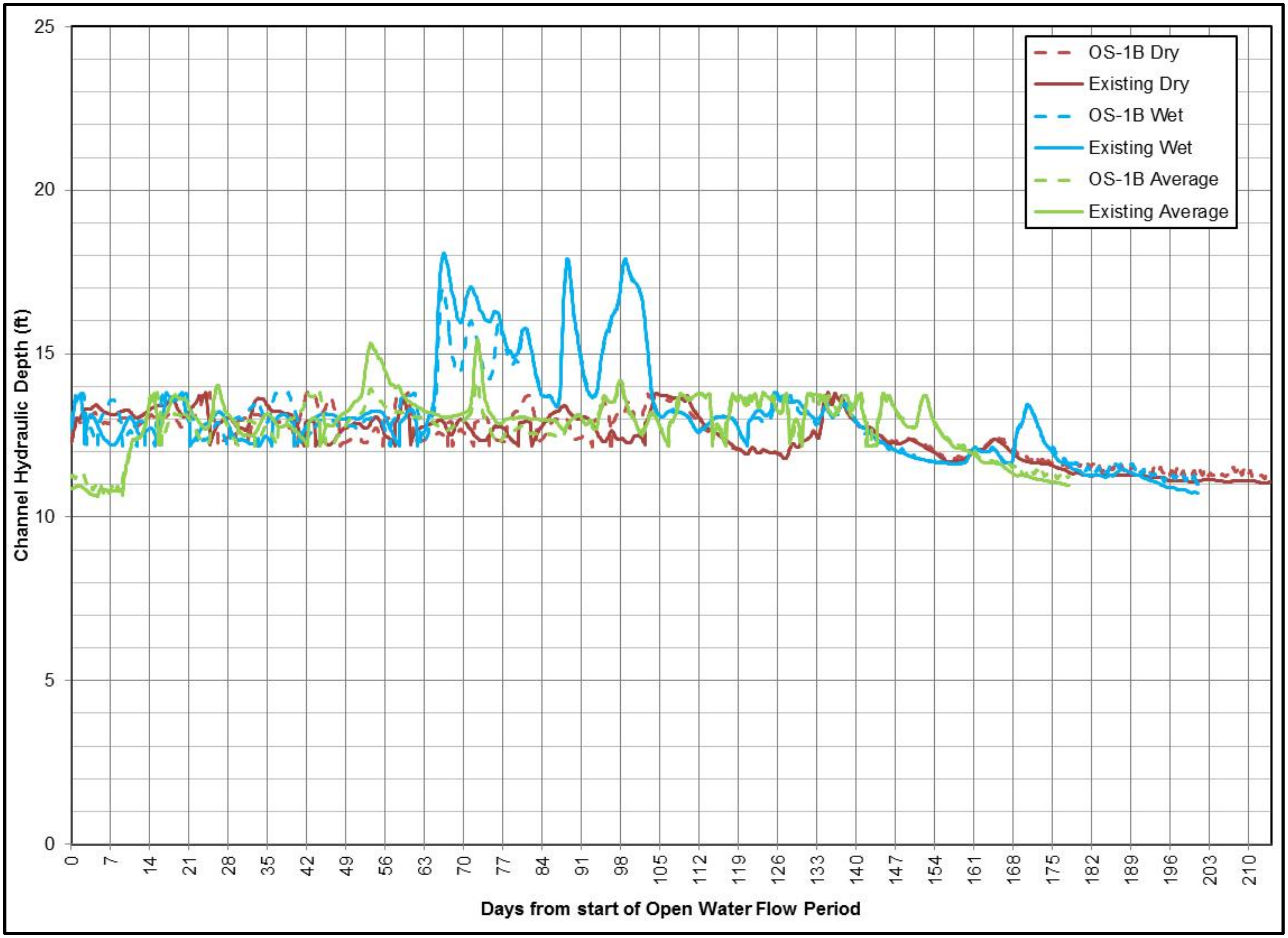

Figure 5.4-9. Time series of channel hydraulic depth at PRM 29.9 under existing conditions and Max LF OS-1b.

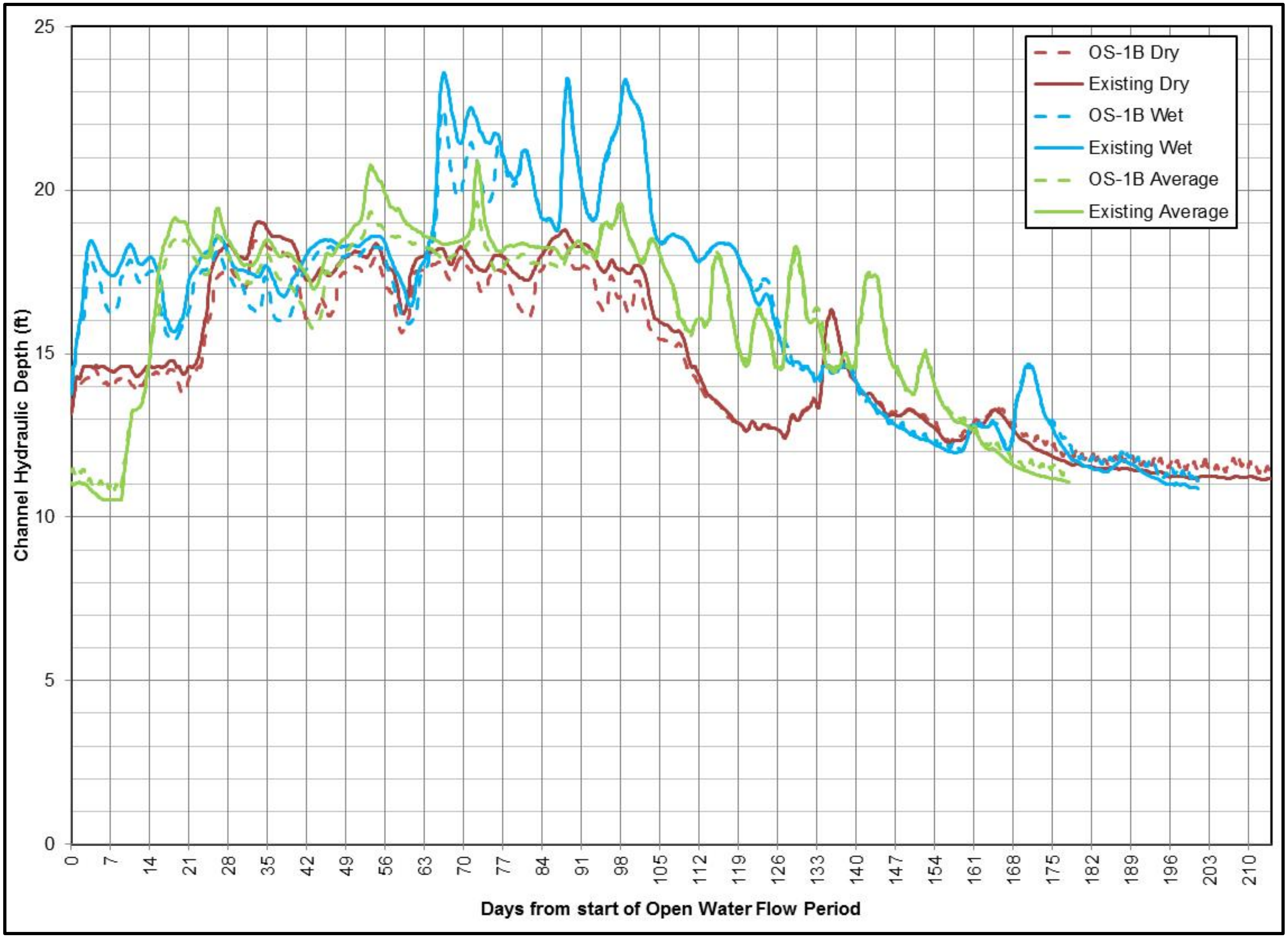

Figure 5.4-10. Time series of channel hydraulic depth at PRM 30.8 under existing conditions and Max LF OS-1b.

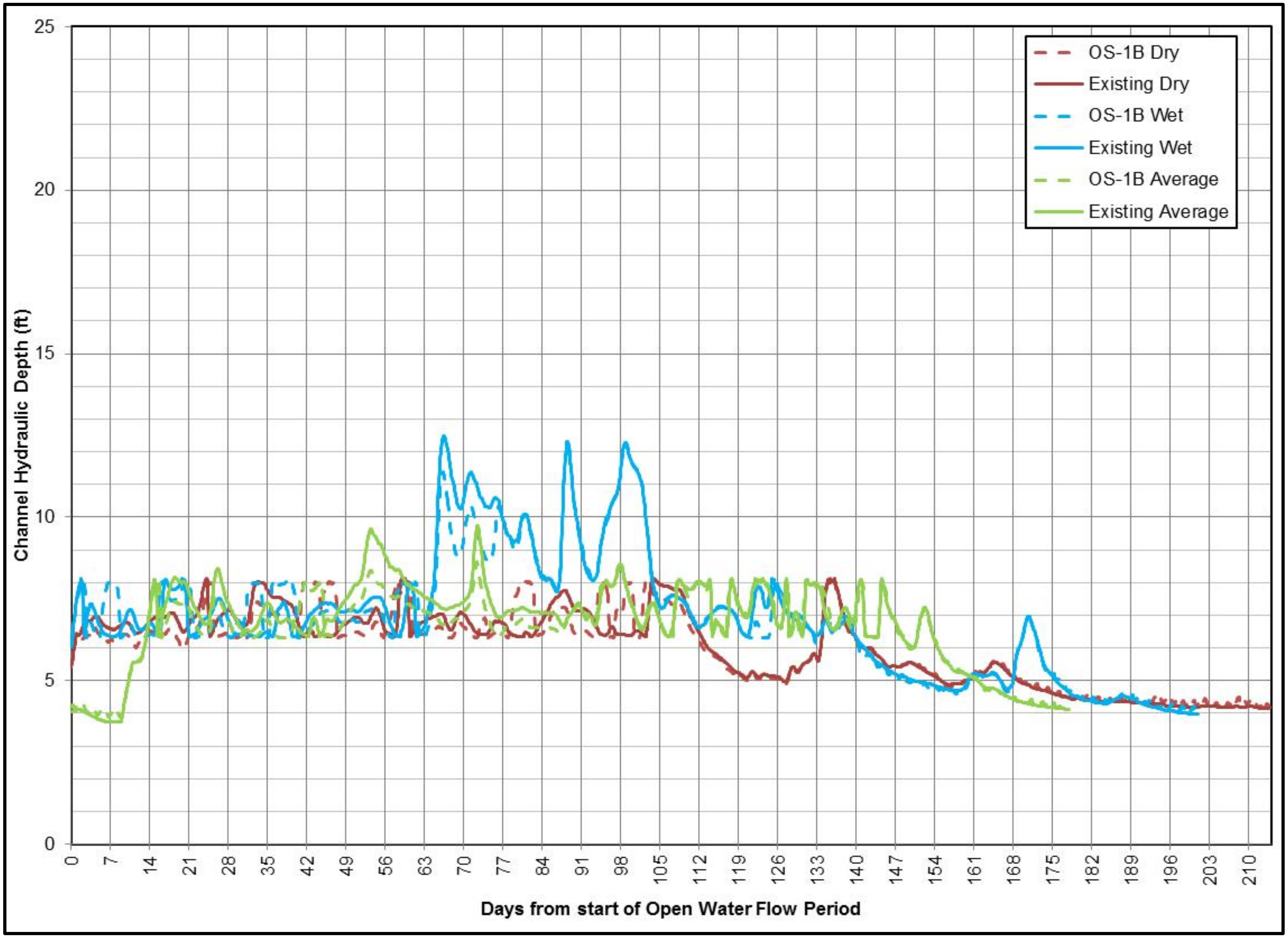

Figure 5.4-11. Time series of channel hydraulic depth at PRM 31.6 under existing conditions and Max LF OS-1b.

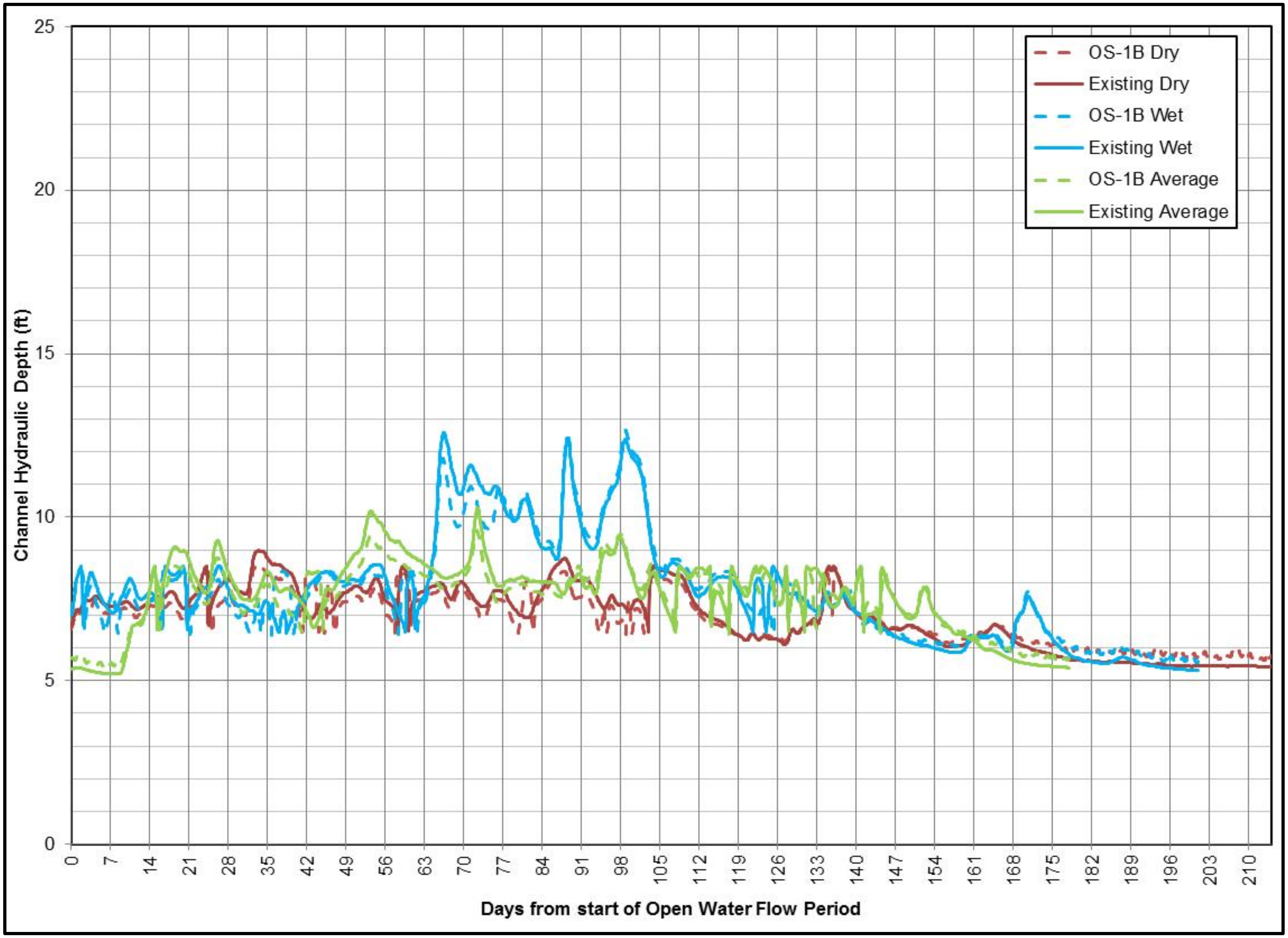

Figure 5.4-12. Time series of channel hydraulic depth at PRM 32.4 under existing conditions and Max LF OS-1b.

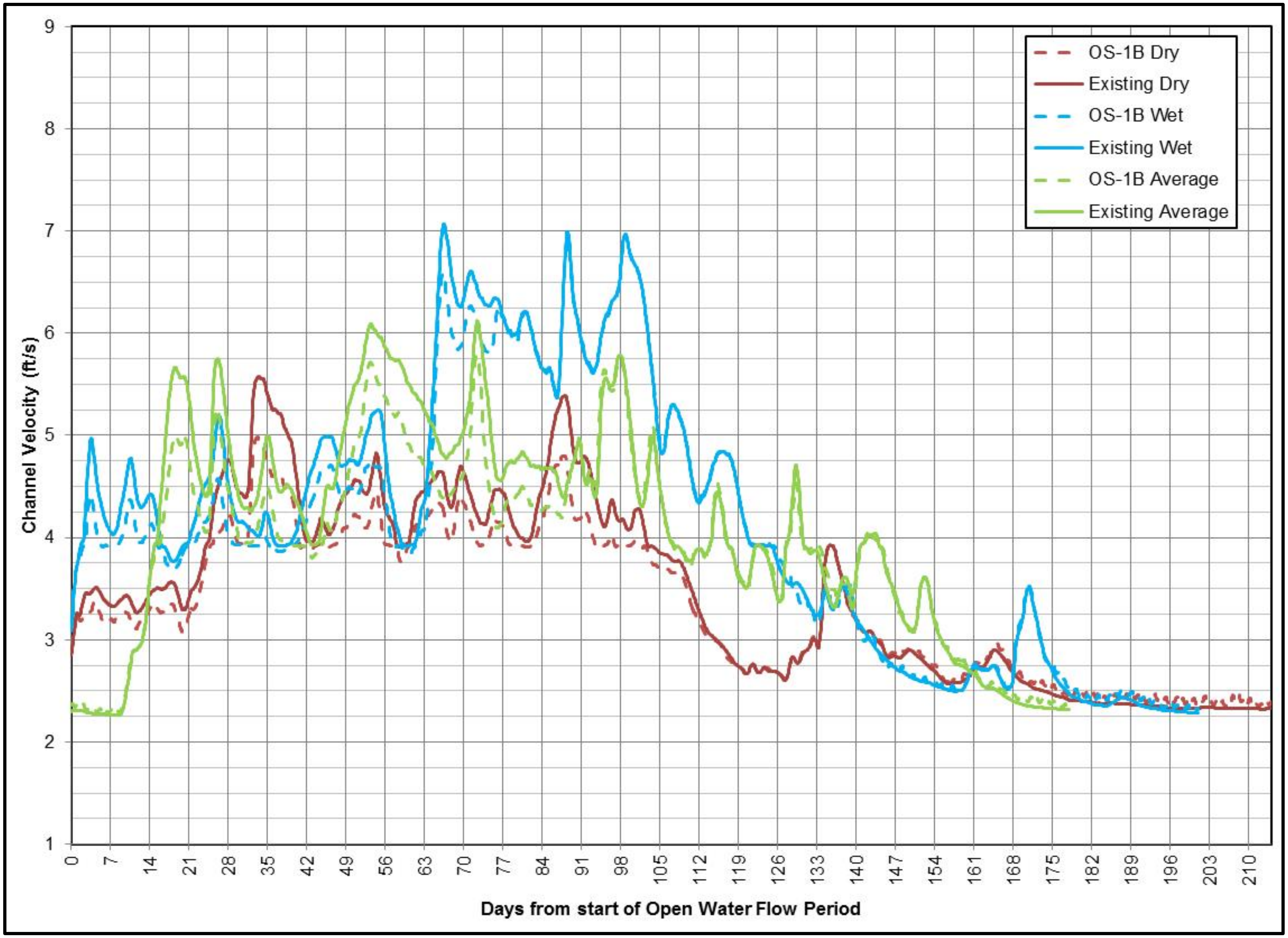

Figure 5.4-13. Time series of channel average velocity at PRM 29.9 under existing conditions and Max LF OS-1b.

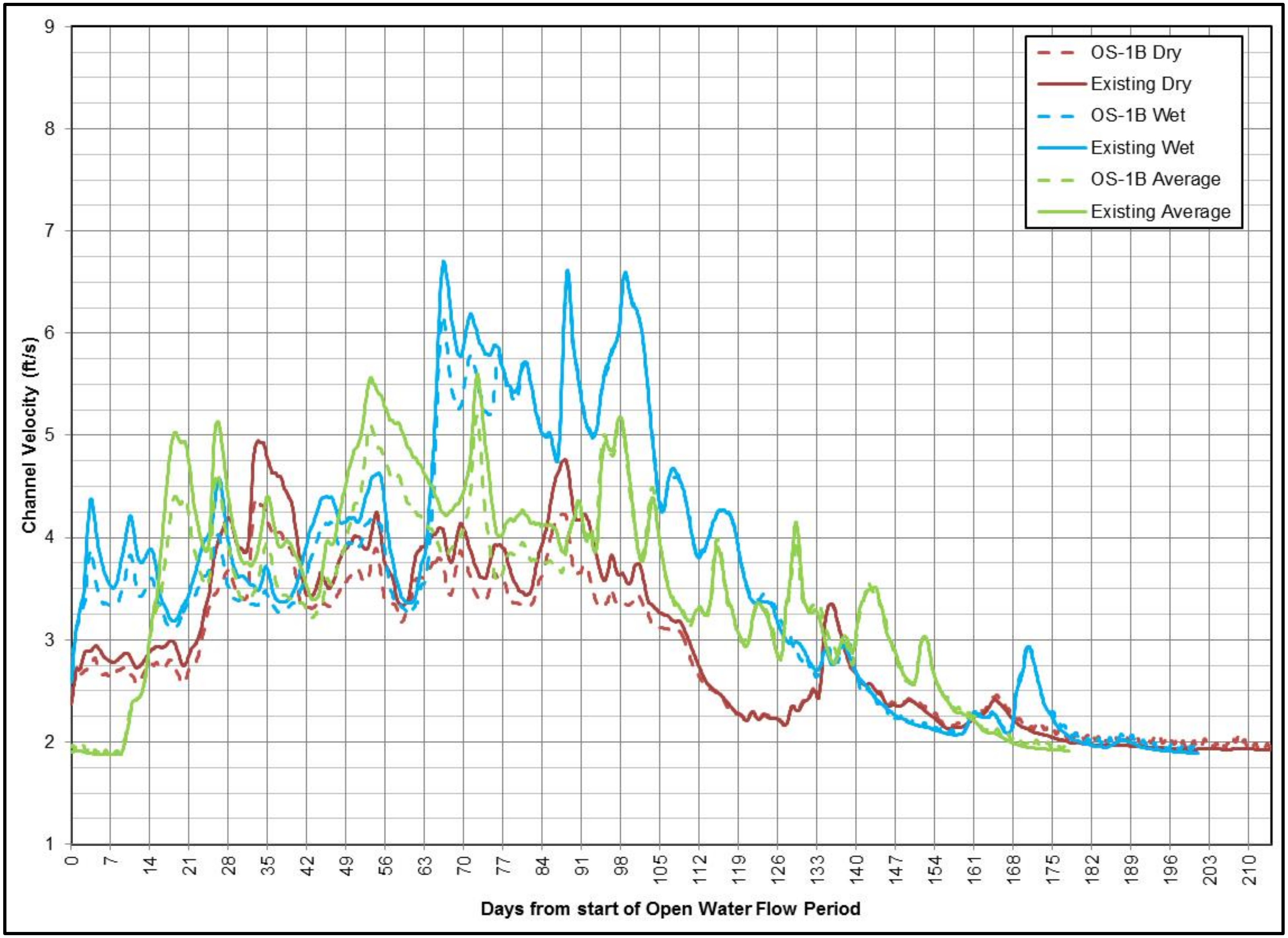

Figure 5.4-14. Time series of channel average velocity at PRM 30.8 under existing conditions and Max LF OS-1b.

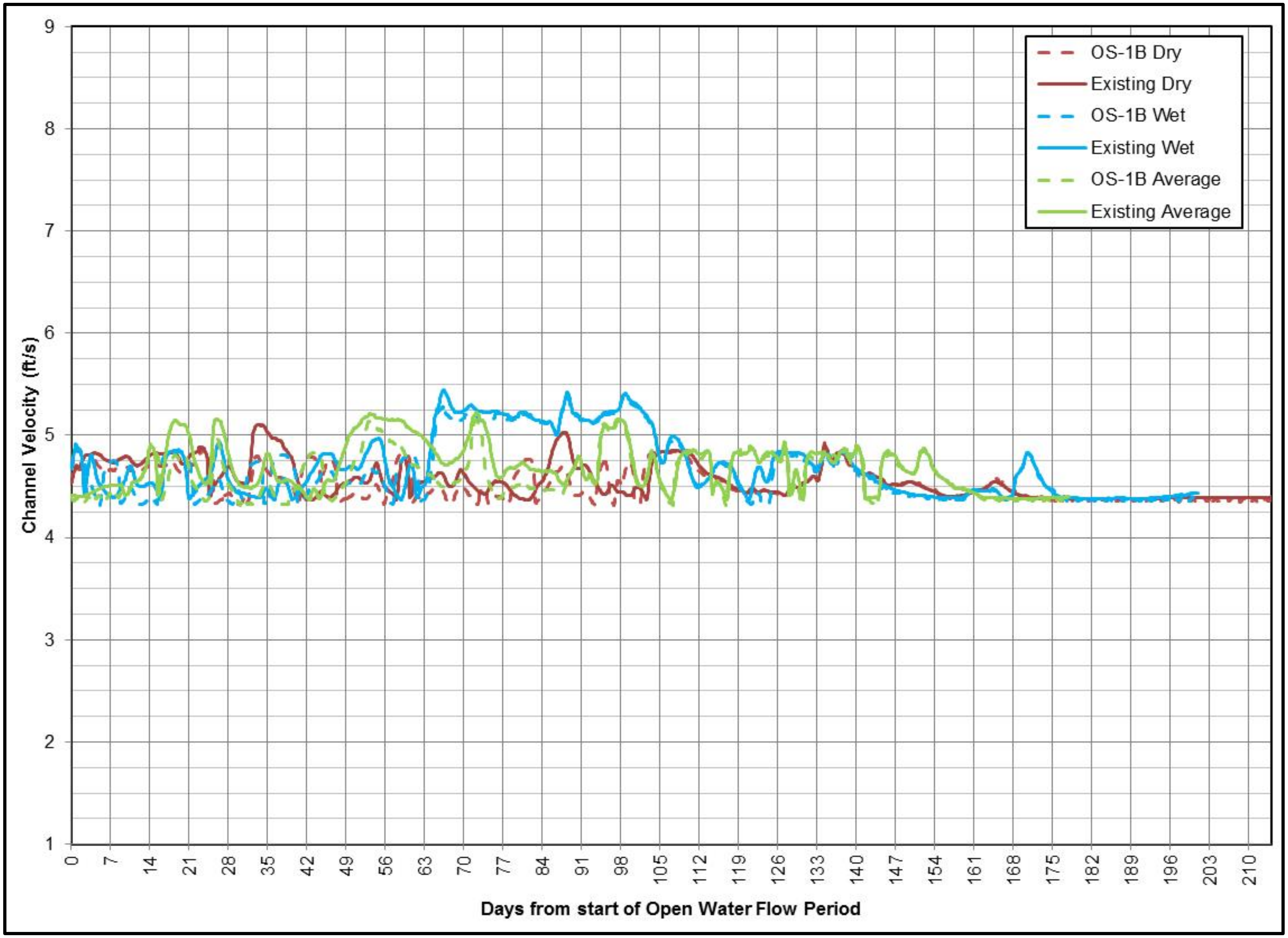

Figure 5.4-15. Time series of channel average velocity at PRM 31.6 under existing conditions and Max LF OS-1b.

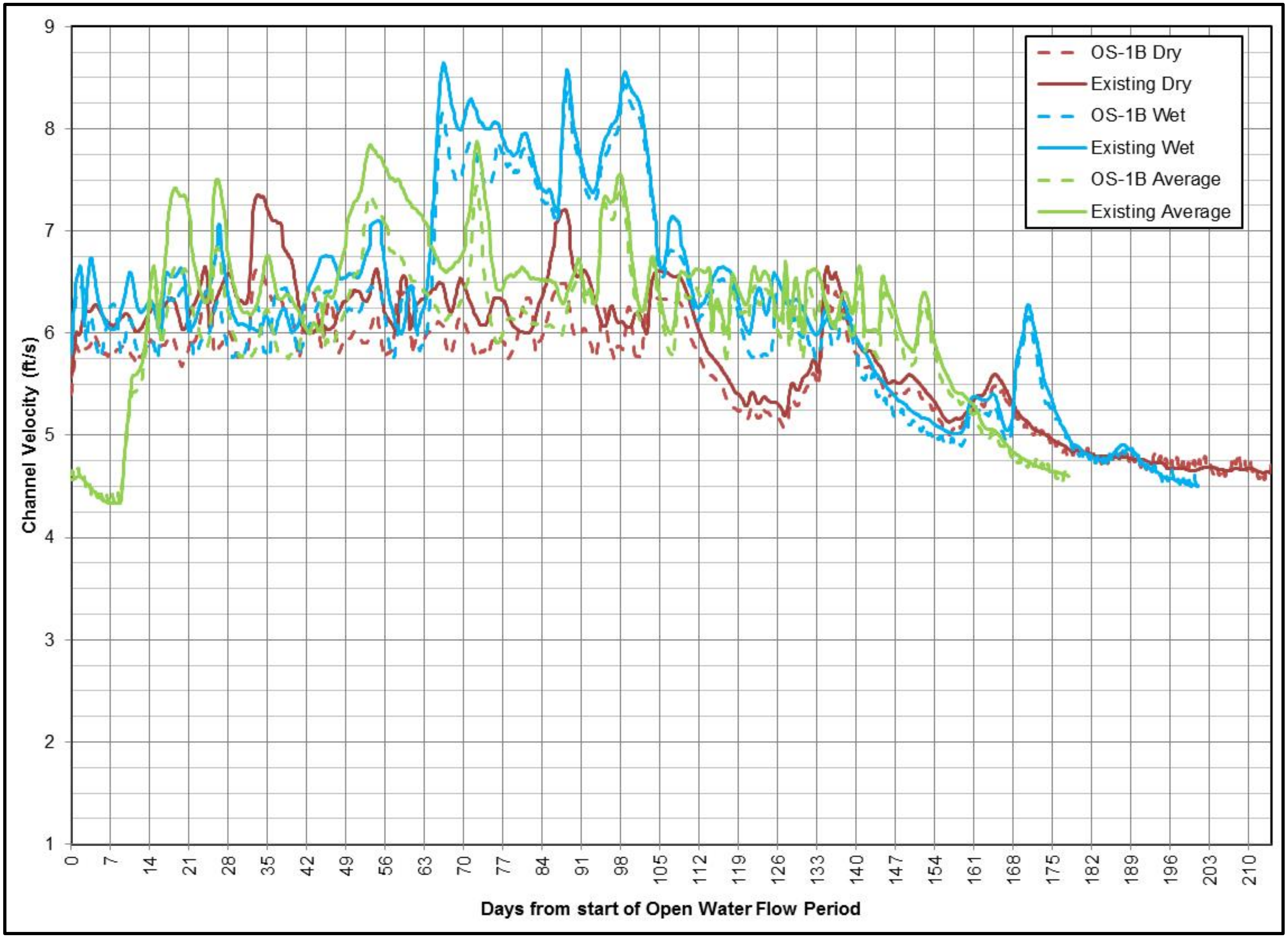

Figure 5.4-16. Time series of channel average velocity at PRM 32.4 under existing conditions and Max LF OS-1b.

Figure 6.5-1. Tide levels at Anchorage and stage data from PRMs 10.5 to 20.5.

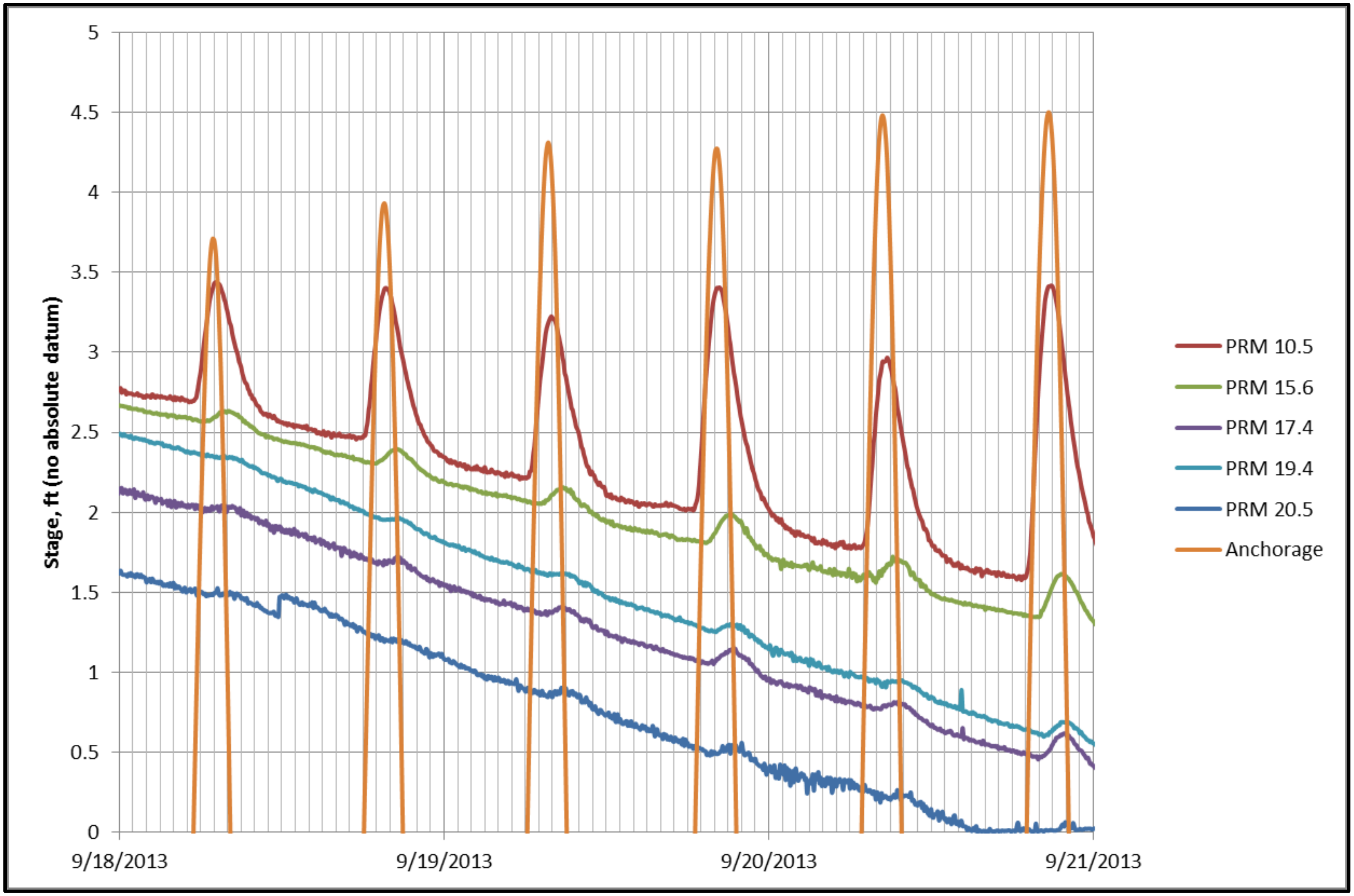

Figure 6.5-2. Detailed plot of tide levels at Anchorage and stage data from PRMs 10.5 to 20.5.