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SUSITNA-WATANA HYDRO

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Water Quality Modeling Study
Study Plan Section 5.6

Initial Study Report
Part A: Sections 1-6, 8-10

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

URS/Tetra Tech, Inc.

June 2014

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LIST OF ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

Abbreviation	Definition
1-D	one-dimensional
2-D	two-dimensional
3-D	three-dimensional
AEA	Alaska Energy Authority
AEIDC	Arctic Environmental Information and Data Center
EFDC	Environmental Fluid Dynamics Code
FA	Focus Area
FERC	Federal Energy Regulatory Commission
Hg	mercury
ILP	Integrated Licensing Process
ISR	Initial Study Report
PRM	Project River Mile
Project	Susitna-Watana Hydroelectric Project
RM	River Mile(s) referencing those of the 1980s Alaska Power Authority Project.
RSP	Revised Study Plan
SPD	study plan determination
TSS	total suspended solids
WOE	weight of evidence

1. INTRODUCTION

On December 14, 2012, Alaska Energy Authority (AEA) filed its Revised Study Plan (RSP) with the Federal Energy Regulatory Commission (FERC or Commission) for the Susitna-Watana Hydroelectric Project, FERC Project No. 14241, which included 58 individual study plans (AEA 2012). Included within the RSP was the Water Quality Modeling Study, Section 5.6. RSP Section 5.6 focuses on the modeling planned for assessing the effects of the proposed Susitna-Watana Project (Project) and its operations on water quality in the Susitna River basin.

On February 1, 2013, FERC staff issued its study determination (February 1 SPD) for 44 of the 58 studies, approving 31 studies as filed and 13 with modifications. On April 1, 2013 FERC issued its study determination (April 1 SPD) for the remaining 14 studies; approving 1 study as filed and 13 with modifications. RSP Section 5.6 was one of the 13 approved with modifications. In its April 1 SPD, FERC recommended the following:

> *Calibration of the Hydrodynamic Model Component of EFDC [Environmental Fluid Dynamics Code]*
>
> > *- We recommend that AEA incorporate water-surface elevations and flow velocities when calibrating the hydrodynamic model and that the hydrodynamic model be calibrated prior to the calibration of the water quality model component of the EFDC model.*

AEA included FERC's requested modification in the Final Study Plan.

Following the first study season, FERC's regulations for the Integrated Licensing Process (ILP) require AEA to "prepare and file with the Commission an initial study report describing its overall progress in implementing the study plan and schedule and the data collected, including an explanation of any variance from the study plan and schedule" (18 CFR 5.15(c)(1)). This Initial Study Report (ISR) on Water Quality Modeling Study has been prepared in accordance with FERC's ILP regulations and details AEA's status in implementing the study, as set forth in the FERC-approved RSP and as modified by FERC's April 1 SPD, as appropriate (collectively referred to herein as the "Study Plan").

2. STUDY OBJECTIVES

The collective goal of the water quality studies (Baseline Water Quality Study, Water Quality Modeling Study, and the Mercury Assessment and Potential for Bioaccumulation Study) is to assess the impacts of the proposed Project operations on water quality in the Susitna River basin with particular reference to state water quality standards. Predicting the potential impacts of the dam and its proposed operations on water quality requires the development of a water quality model. The goal of the Water Quality Modeling Study is to utilize the extensive information collected from the Baseline Water Quality Study to develop a model(s) that evaluates the potential impacts of the proposed Project and operations on various physical parameters within the Susitna River watershed.

The objectives of the Water Quality Modeling Study are as follows:

- Implement (with input from licensing participants) an appropriate reservoir and river water temperature model for use with past and current monitoring data.
- Using the data developed as part of the Baseline Water Quality Study, model water quality conditions in the proposed Watana Reservoir, including (but not necessarily limited to) temperature, DO, fine suspended sediment and turbidity, chlorophyll-a, nutrients, ice, and metals.
- Model water quality conditions in the Susitna River from the proposed site of the Watana Dam downstream, including (but not necessarily limited to) temperature, DO, fine suspended sediment and turbidity, chlorophyll-a, and nutrients. Ice processes effects are accounted for using output from the River 1D Ice Processes Model (in coordination with the Ice Processes Study).

3. STUDY AREA

As established in RSP Section 5.6.3, the study area begins at RM 15.1 (PRM 19.9) and extends past the proposed dam site to RM 233.4 (PRM 235.2) as described in Table 3-1. The distribution of sites for the Susitna Basin is also shown in Figure 3-1.

4. METHODS

4.1. Model Description

During 2013, AEA selected a (3-D) Reservoir Water Quality Model, a (2-D) River Water Quality Model, and a (2-D) River Water Quality Model with Enhanced Resolution Focus Areas for this Project. The rationale for selection of the (3-D and 2-D) Reservoir and River Water Quality Models is set forth in the Technical Memorandum: Water Quality Modeling Study: Model Selection (May 18, 2012).

The models are capable of simulating both river and reservoir environments. It is a multi-dimensional dynamic model that includes hydrodynamics, water temperature, water quality, and sediment transport modules and considers ice formation and break-up.

Ice formation and break-up can impact hydrodynamics and water quality conditions in the reservoir and riverine sections of the basin. Ice cover affects transfer of oxygen to and from the atmosphere and this directly affects the DO concentration in the water column. Ice dynamics evaluated in the Ice Processes Study were used to inform the water quality model of ice cover and thickness and the output.

The model was configured for the reservoir and downstream river under pre-and post-Project conditions. The upstream boundary conditions for the pre-Project river model were provided by observational data at or near the dam. The reservoir model provided upstream boundary conditions of the post-Project version of the river model. This approach forms a holistic modeling framework that can accurately simulate changes in the hydrodynamic, temperature, and water quality regime within the reservoir and downstream river. The modesl for use in this study features an advanced turbulence closure scheme to represent vertical mixing in reservoirs, necessary to predict future conditions. Thus, it is capable of representing the temperature regime within the reservoir without resorting to arbitrary assumptions about vertical mixing coefficients.

The models selected for this proposed Project have the ability to simulate an entire suite of water quality parameters, and is internally coupled with the hydrodynamic and temperature modeling processes. The model was configured to simulate the impact of the proposed Project on temperature as well as DO, nutrients, algae, turbidity, total suspended solids (TSS), and other key water quality features both within the reservoir and for the downstream river (Table 4.1-1). This avoids the added complexity associated with transferring information among multiple models and increases the efficiency of model application.

4.2. Reservoir and Downstream River Modeling Approaches

The reservoir model represents the river from the proposed dam location to the upstream extent of inundation. The model will represent the proposed reservoir condition when the dam is in place. The reservoir representation is being developed based on the local bathymetry and dimensions of the proposed dam. A three-dimensional model (3-D) Reservoir Water Quality Model is being developed for the proposed reservoir to represent the spatial variability in hydrodynamics and water quality in longitudinal, vertical, and lateral directions. The model will simulate flow or circulation in the reservoir, turbulence mixing, temperature dynamics, nutrient fate and transport, interaction between nutrients and algae, sediment transport, and metals transport. The key feature to be captured is water column stratification during the warm season and the de-stratification when air temperatures cool down. The capability of predictively representing the stratification/de-stratification period is of critical importance for evaluating the impact of the dam because this is the critical period for primary production and nutrient cycling in the reservoir.

With the dam in place, the original river will be converted into a slow flowing reservoir; therefore, any sediment previously mobilized will likely settle in the reservoir, disrupting the natural sediment transport processes. Before the construction of the dam, primary production is likely driven by periphyton. After construction of the dam, periphyton will be largely driven out of existence due to deep water conditions typical of a reservoir environment. In lieu of periphyton, phytoplankton will likely be the dominant source of primary production of the ecological system with the dam in place. Nutrients from upstream will have longer retention in the reservoir, providing nutrient sources to fuel phytoplankton growth. All processes are to be predictively simulated by the reservoir model.

Because the dam is not in place when the model is constructed, proper calibration of the model using actual reservoir data is not possible. To achieve reasonable predictions of water quality conditions in the proposed reservoir, a literature survey was conducted to acquire parameterization schemes of the model. An uncertainty analysis approach will also be developed to account for the lack of data for calibration, therefore enhancing the reliability of reservoir model predictions.

Downstream of the proposed dam location, a river model is being developed to evaluate the effects of the proposed Project. The same model platform used for the reservoir model is being implemented for the river model maintaining consistency of state variables and process representations. The (2-D) River Water Quality Model will be capable of representing conditions in both the pre-Project absence and post-Project presence of the dam. The river model will extend downstream from the dam site to the lowermost monitoring site on the Susitna River mainstem (PRM 19.9) downstream of the Susitna-Talkeetna-Chulitna confluence. The (2-D) River Water Quality Model uses channel topography and flow data at select locations will be used for model configuration and calibration necessary for predicting water quality conditions under various Project operational scenarios.

Flow, temperature, TSS, DO, nutrients, turbidity (continuous at USGS sites and bi-weekly at additional locations required for calibrating the model), and chlorophyll-a output from the (3D) Reservoir Water Quality Model is being directly input into the downstream post-Project version of the (2-D) River Water Quality Model. This will enable downstream evaluation of potential impacts of the proposed Project on hydrodynamic, temperature, and water quality conditions. Observational data will provide the upstream boundary conditions for the pre-Project version of the river model.

The (2-D) River Water Quality Model will be calibrated and validated using available data concurrently with the initial reservoir condition model (representing absence of the dam). Output from the models will be used directly in other studies (e.g., Ice Processes, Productivity, and Instream Flow studies).

To meet the Study Plan objectives, the pre-project river upstream of the dam site will be modeled using imagery shorelines, estimated bed elevations, and rectangular cross-sections. Resolution of the pre-project model is determined by uniformity in water quality conditions from the uppermost site to the site immediately below the dam. AEA reported existing water quality as well-mixed surface water conditions (ISR Section 5.5; Sections 5.2 and 5.4.2) and a single river channel that has little to no braiding in the Upper River pre-project conditions. RSP Section 5.6.4.8.2 described the type of model output under conditions when water quality uniformity was high at depth and laterally within the non-braided channel.

The (2-D) River Water Quality Model will be calibrated in order to simulate water quality conditions for load-following analysis. When calibrating the (2-D) River Water Quality Model, water-surface elevations and flow velocities are incorporated. The hydrodynamic module in the (2-D) River Water Quality Model is being calibrated prior to calibration of the water quality module. Organic carbon content from inflow sources will be correlated with mercury concentrations determined from the Baseline Water Quality Study discussed in Section 5.5 of the RSP. Predicted water quality conditions established by Project operations and that promote methylation of mercury in the bioaccumulative form will be identified by location and intensity in both riverine and reservoir habitats. Water temperature modeling and routing of fluctuating flows immediately prior to and during ice cover development may be conducted with a separate thermodynamics-based River 1-D ice-processes model: the Susitna Hydraulic and Thermal Processes Model (Section 7.6.3.2).

Modeling of mercury concentrations in dissolved and in methylated form will be done by updating the (3-D) Reservoir Water Quality Model to simulate three sorptive toxic variables representing mercury (Hg) states. Algorithms have been successfully used with the (3-D) Reservoir Water Quality Model in other studies and will be modified to account for potential sources of Hg as the reservoir is filled (e.g., soils, vegetation, air deposition). Other metals parameters will be modeled if significant concentrations are identified from surface water and sediment. However, cumulative impacts of multiple metals on aquatic life are difficult to predict using the proposed modeling strategy because there are associated uncertainties. Measuring additivity or synergism of toxics effects is possible using laboratory bioassays, but may not be adequately predicted by a model. The level of uncertainty in extrapolating results from laboratory to field conditions is large and potentially unreliable. A suggested approach for estimating toxicity mixtures would be to develop a weight of evidence (WOE) algorithm that produces a weighting factor for re-calculating the potential chronic and acute toxic effects of a mixture (Mumtaz et al. 1998).

4.3. Focus Area Modeling

The (2-D) River Water Quality Model with Enhanced Resolution Focus Areas will be used to predict water quality conditions at a finer scale of resolution for river Focus Areas. The increased intensity of sampling at transects 100 m apart and at three locations across each transect will improve resolution for predictions at approximately 100 m longitudinally and a smaller distance laterally. These models are embedded within the larger-scale (2-D) River Water Quality Model used for the entire riverine component of the Project area. An embedded model can also be used for predicting conditions in sloughs and selected braided areas of the mainstem Susitna River.

Some of the water quality parameters listed in Section 5.5.4.4 of the RSP will be used to predict conditions within the Focus Areas to determine if suitability of habitat for life stages of select fish species is maintained or changes under each of the operational scenarios. The resolution of the (2-D) River Water Quality Model with Enhanced Resolution Focus Areas will be dynamic, allowing both the temporal and areal extent of the water quality parameter variations associated with various load-following scenarios to be determined.

4.4. Scales for Modeling and Resolution of the Output

The large-scale (2-D) River Water Quality Model calibrated using the mainstem water quality monitoring data will have a longitudinal predictive resolution between 250 m and 1 kilometer (km) depending on channel complexity, lateral variability of conditions, and required run-time performance. Single channel areas of the mainstem Susitna River and sloughs may not require higher resolution predictions if water quality conditions are uniform. The uniformity of conditions will be evaluated by measuring across transects at a few locations in the drainage to determine if lateral variability is low.

Model grid size determines spatial resolution of predicted water quality conditions. The reservoir and riverine areas of the Project are represented by model grid cells and model predicted water quality conditions represent averages over the cells. The grid size is dependent on a number of characteristics of the Project area. These characteristics include elevation changes throughout the model domain, surrounding terrain, and length of time the model is run for predicting temporal changes. Each of the factors ultimately determines the resolution of the predictive capability of the EFDC model.

4.5. Variances

No variances from the methods occurred during the implementation of this study in 2013.

5. RESULTS

5.1. Selection of Model State Variables and Options

State variables for the hydrodynamic components of the reservoir and river models include water surface elevation, horizontal velocity, and vertical velocity for the reservoir model. The three-dimension reservoir model uses a curvilinear horizontal grid and the (3-D) Reservoir Water Quality Model's generalized vertical coordinate formulation, which is appropriate for deep and narrow reservoirs. The two-dimension river model uses a curvilinear horizontal grid. Both the reservoir and river models operate in drying and wetting mode to accommodate large pool fluctuations in the reservoir and floodplain inundation in the river under high flow conditions.

The full (3D and 2D) Reservoir and River Water Quality Model thermal formulation is being used for temperature simulation, which includes incoming short wave radiation, long-wave radiated, and sensible and latent surface heat exchange. A bed thermal model is also coupled to the reservoir water column thermal formulation. Horizontally variable ice cover and thickness will be simulated by the reservoir temperature model. Ice cover and thickness will not be directly simulated in the river but will be provided by the River Ice Processes model (RSP Section 7.6). The provided information will be used to account for ice effects on surface re-aeration and light penetration.

The reservoir and river models will simulate fine inorganic sediment having particle diameters less than 125 microns. This serves a number of purposes including incorporation of inorganic suspended sediment, concentration on light attenuation, and estimating the trapping of fine sediment by the reservoir. Sediment loadings at the dam site and at the upstream extent of the reservoir will be provided by the Geomorphology Modeling Study (RSP Section 6.6). Existing fine sediment processes formulations for settling, deposition and mobilization in the (3-D) Reservoir Water Quality Model are being used.

The water quality models will use a reduced set of the full set of state variables. The current set under consideration includes:

- Two phytoplankton species
- Periphyton
- Dissolved oxygen
- Dissolved and particulate organic carbon

- Dissolved and particulate organic nitrogen
- Nitrite plus Nitrate
- Ammonia Nitrogen
- Dissolved and particulate organic phosphorous
- Dissolved and particulate inorganic phosphorous

These categories of parameters represent 14 state variables. The standard set of sediment organic and nutrient variables in the diagenesis module will be used. Reaction rates and particulate settling velocity will be based on analysis of observational data and literature values for high latitude reservoirs and rivers.

The (3-D) Reservoir Water Quality Model toxic contaminant sub-model will be used to simulate mercury cycling and possibly other metal and organic contaminants if analysis of observational data suggests a need to address potential toxicity. The mercury model will simulate elemental, ionic, and methyl mercury in the water column and sediment bed. Free dissolved, dissolved organic carbon, complexated and particulate phases, are simulated. Dissolved and particulate organic carbon concentrations will be provided by the water quality model and fine inorganic sediment concentrations will be provided by the sediment transport model component.

5.2. Reservoir Model Configuration and Preliminary Results

The reservoir model has been spatially configured with approximately 1400 horizontal grid cells and 20 vertical layers. Longitudinal horizontal resolution along the drowned river valley ranges from 400 to 800 meters with lateral resolution ranging from 75 to 150 meters. The reservoir model horizontal grid is shown in Figure 5.2-1. Vertical resolution with 20 layers ranges from 2.5 meters layer thickness near the surface to 25 meter thickness near bottom of the deepest area. The number of layers varies horizontally to account for topographic variations. A higher resolution 40 layer vertical grid is also being used to investigate the sensitivity of predicted temperature stratification to vertical resolution. Topographic layer used to configure the model is based on the MatSu Lidar DEM. Figure 5.2-1 shows the horizontal reservoir grid and bathymetry.

The reservoir hydrodynamic model has been tested using the 1984 historical inflow and a corresponding load following outflow. The model successfully simulated the one year period which has an approximately 45 meter variation in pool level. Scaling of computational performance for this simulation indicated that approximately four years can be simulated in one day. Preliminary temperature simulation for ice-free conditions indicated that the 20 layer configuration adequately represents vertical stratification. Annual time scale temperature simulations are being conducted to evaluate a number of ice processes representations ranging from semi-empirical freezing degree day to thermodynamic cover and thickness without and with transport of ice cover. Inclusion of frazil ice remains a possible option.

5.3. River Model Configuration and Preliminary Results

The river model was initially configured spatially between PRM 80 and PRM 187.2 with approximately 1000 horizontal grid cells. Longitudinal resolution is approximately 500 meter and lateral resolution uses three cells laterally in the main channel and one cell laterally in smaller side channels. Channel bathymetry is based on 88 cross sections surveyed in 2012. Figures 5.3-1 and 5.3-2 show model grids below the dam site and upstream of PRM 80. This configuration is being extended downstream to PRM 30 using additional cross sections surveyed during 2013 and higher resolution surveys in a number of Focus Areas. Lateral resolution is being refined to better represent side channels and sloughs.

The river hydrodynamic model has been tested using the 1984 historical flow and the 1984 load following flow from the reservoir without accounting for ice cover. Scaling of computational performance for this simulation indicated that approximately six years can be simulated in one day. The hydrodynamic model has also simulated the June through August 2012 period for preliminary calibration. Preliminary temperature simulation of ice free conditions is in progress for calibration. Ice covered hydrodynamic and temperature simulation will require information from the ice processes model and proceed when those data become available.

5.4. Focus Area Modeling

The (2-D) River Water Quality Model with Enhanced Resolution Focus Areas is being locally enhanced with finer spatial resolution to simulate water quality processes in the riverine focus areas. Anticipated spatial resolution in the focus areas is approximately 100 m longitudinally and 30 m laterally. Higher resolution bathymetric data are presently available for Focus Areas FA-104 (Whiskers Slough), FA-113 (Oxbow 1), and FA-115 (Slough 6A). Figure 5.4-1 shows the preliminary refined grid in Focus Area FA-115 (Slough 6A). The Focus Area grid enhancements are being embedded in a version of the full river model to eliminate the need for inefficient, limited area modeling. Additional Focus Areas are being added as corresponding bathymetric data become available.

6. DISCUSSION

The reservoir and river EFDC models have been configured for hydrodynamics, temperature, and fine suspended sediment. The models have been tested with annual time-scale historical and proposed Project flow scenarios to demonstrate stability and acceptable run-time performance. Test data sets for water temperature generated in 2012 have been used in both the reservoir and riverine models and capable of decade time scale simulations. The same data set has been extended into 2013 and used to verify and further refine calibration of the model. Development of the model and calibration with water quality data is on schedule and will meet study objectives.

The river model hydrodynamics are being calibrated to 2012 water surface elevation and velocity observations. Model parameterization has been completed for both the large-scale riverine model and the enhancement for the internally-coupled Focus Area riverine model. The riverine model has been configured with horizontal grid cells and tested using the 1984 load following flow from the reservoir without accounting for ice cover.

Reservoir temperature simulations are being conducted to investigate seasonal thermal structure including thermocline formation, fall overturn and ice cover formation to determine vertical resolution sensitivity and refine the resolution for optimum model performance. The reservoir model has been configured with both vertical and horizontal grid cells and the hydrodynamic model tested using the 1984 historical inflow and a corresponding load following outflow.

River temperature simulations are being conducted for temperature calibration to ice-free post-Project observational data. Output from the reservoir model will be provided for development of the River1D Ice Processes Model (Study 7.6). Water quality monitoring data and watershed characteristics are being analyzed to develop organic matter and nutrient loads necessary for water quality model configuration.

Preliminary simulations of the transport of fine inorganic sediment (less than 125 microns) through the reservoir and in the downstream river under pre- and post-Project conditions are underway.

7. COMPLETING THE STUDY

[Section 7 appears in the Part C section of this ISR.]

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9. TABLES

Table 3-1. Susitna River Basin Temperature and Water Quality Monitoring Sites

Susitna Project River Mile (PRM)	Description	Susitna River Slough ID	Latitude (decimal degrees)	Longitude (decimal degrees)
19.9	Susitna above Alexander Creek	NA	61.4014	-150.519
29.9[3]	**Susitna Station**	NA	61.5454	-150.516
32.5	**Yentna River**	NA	61.589	-150.468
33.6	**Susitna above Yentna**	NA	61.5752	-150.248
45.1[3]	**Deshka River**	NA	61.7098	-150.324
59.9[1]	**Susitna**	NA	61.8589	-150.18
87.8[3]	**Susitna at Parks Highway East**	NA	62.175	-150.174
88.3[3]	Susitna at Parks Highway West	NA	62.1765	-150.177
99.2	LRX 1	NA	62.3223	-150.127
102.8	**Talkeetna River**	NA	62.3418	-150.106
118.6	**Chulitna River**	NA	62.5574	-150.236
107[2,3]	**Talkeetna**	NA	62.3943	-150.134
116.69[2]	LRX 18	NA	62.5243	-150.112
124.2[2,3]	**Curry Fishwheel Camp**	NA	62.6178	-150.012
129.6	--	8A	62.6707	-149.903
129.9[2]	LRX 29	NA	62.6718	-149.902
132.7[3]	--	9	62.7022	-149.843
134.1[2]	LRX 35	NA	62.714	-149.81
	--	11	62.7555	-149.7111
140.0	Susitna near Gold Creek	NA	62.7672	-149.694
140.1[3]	**Gold Creek**	NA	62.7676	-149.691
140.0[1]	--	16B	62.7812	-149.674
142.2[3]	**Indian River**	NA	62.8009	-149.664
142.3[2]	**Susitna above Indian River**	NA	62.7857	-149.651
143.6	--	19	62.7929	-149.615
143.6[2]	LRX 53	NA	62.7948	-149.613
145.6	--	21	62.8163	-149.576
152.2	Susitna below Portage Creek	NA	62.8316	-149.406
153.0[2]	**Susitna above Portage Creek**	NA	62.8286	-149.379

Susitna Project River Mile (PRM)	Description	Susitna River Slough ID	Latitude (decimal degrees)	Longitude (decimal degrees)
152.7	**Portage Creek**	NA	62.8317	-149.379
168.1[1]	Susitna	NA	62.7899	-148.997
183.1[1]	Susitna below Tsusena Creek	NA	62.8157	-148.652
184.8[3]	Tsusena Creek	NA	62.8224	-148.613
187.2[1]	**Susitna at Watana Dam site**	NA	62.8226	-148.533
196.8	Watana Creek	NA	62.8296	-148.259
209.2	Kosina Creek	NA	62.7822	-147.94
225.5[3]	**Susitna near Cantwell**	NA	62.7052	147.538
235.2	Oshetna Creek	NA	62.6402	-147.383

1. Site not sampled for water quality or temperature in the 1980s or location moved slightly from original location.
2. Proposed mainstem Susitna River temperature monitoring sites for purposes of 1980s SNTEMP model evaluation.
3. Locations with overlap of water quality temperature monitoring sites with other studies.

Locations in **bold** font represent that both temperature and water quality samples are collected from a site.

Table 4.1-1. Evaluation of Models based on Technical, Regulatory, and Management Criteria

●High Suitability◐Medium Suitability○Low Suitability

Considerations	Relative Importance	H2OBAL/SNTEMP/DYRESM	CE QUAL W2	EFDC
Technical Criteria				
Physical Processes:				
• advection, dispersion	High	◐	●	●
• momentum	High	○	●	●
• compatible with external ice simulation models	High	○	●	●
• reservoir operations	High	◐	●	●
• predictive temperature simulation (high latitude shading)	High	◐	●	●
Water Quality:				
• total nutrient concentrations	High	○	●	●
• dissolved/particulate partitioning	Medium	○	●	●
• predictive sediment diagenesis	Medium	○	○	●
• sediment transport	High	○	◐	●
• algae	High	○	●	●
• dissolved oxygen	High	○	●	●
• metals	High	○	◐	●
Temporal Scale and Representation:				
• long term trends and averages	Medium	◐	◐	●
• continuous – ability to predict small time-step variability	High	○	●	●
Spatial Scale and Representation:				
• multi-dimensional representation	High	○	◐	●
• grid complexity - allows predictions at numerous locations throughout model domain	High	○	◐	●
• suitability for local scale analyses, including local discharge evaluation	Medium	○	◐	●
Regulatory Criteria				
Enables comparison to AK criteria	High	○	●	●
Flexibility for analysis of scenarios, including climate change	High	◐	●	●

●High Suitability◐Medium Suitability○Low Suitability				
Considerations	**Relative Importance**	**H2OBAL/SNTEMP/DYRESM**	**CE QUAL W2**	**EFDC**
Technically defensible (previous use/validation, thoroughly tested, results in peer-reviewed literature, TMDL studies)	High	◐	●	●
Management Criteria				
Existing model availability	High	●	●	●
Data needs	High	●	●	●
Public domain (non-proprietary)	High	●	●	●
Cost	Medium	●	◐	◐
Time needed for application	Medium	N/A	◐	◐
Licensing participant community familiarity	Low	●	◐	◐
Level of expertise required	Low	●	●	●
User interface	Low	◐	◐	◐
Model documentation	Medium	◐	●	●

10. FIGURES

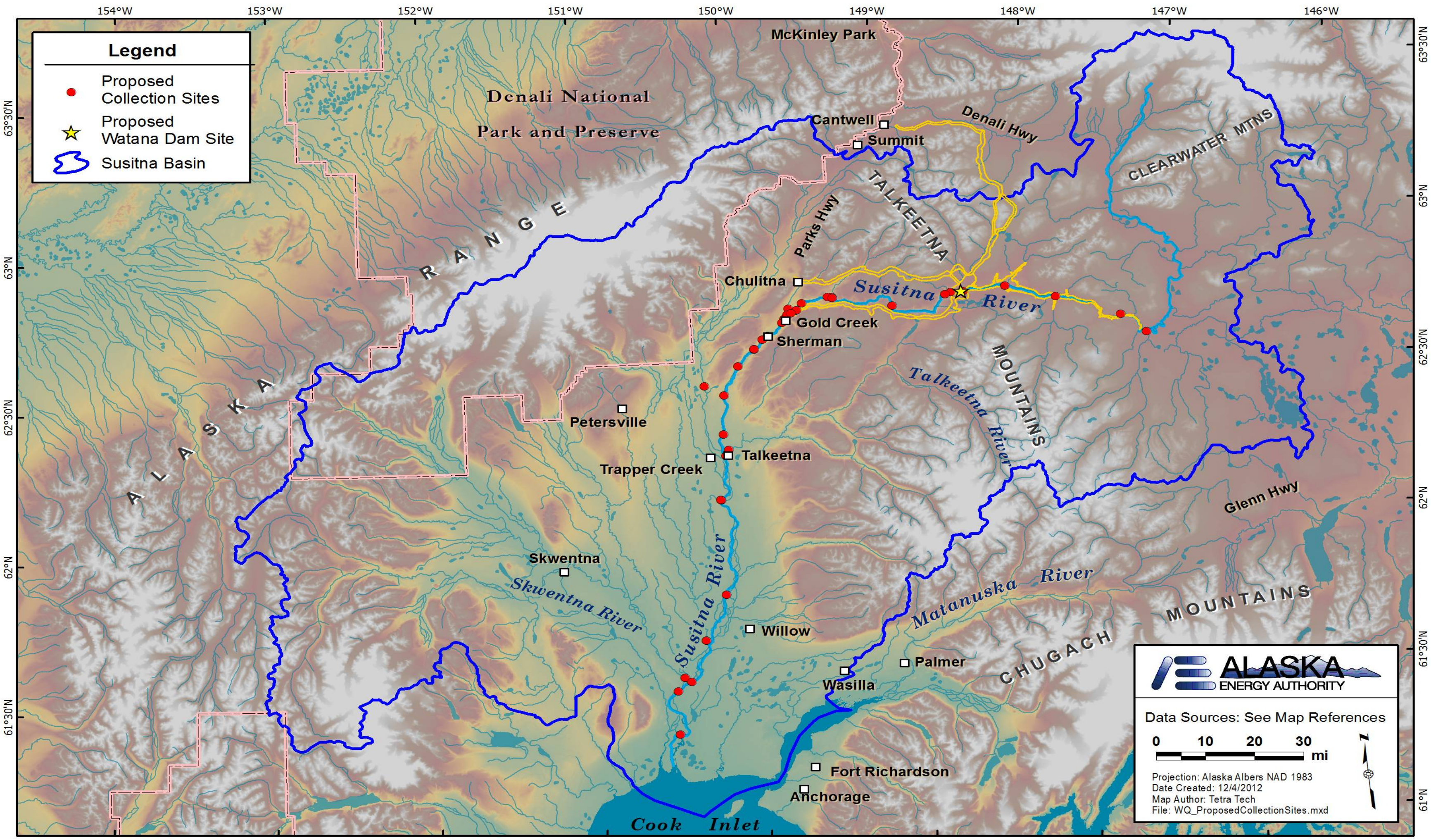

Figure 3-1. Stream Water Quality and Temperature Data Collection Sites for the Susitna-Watana Hydroelectric Project

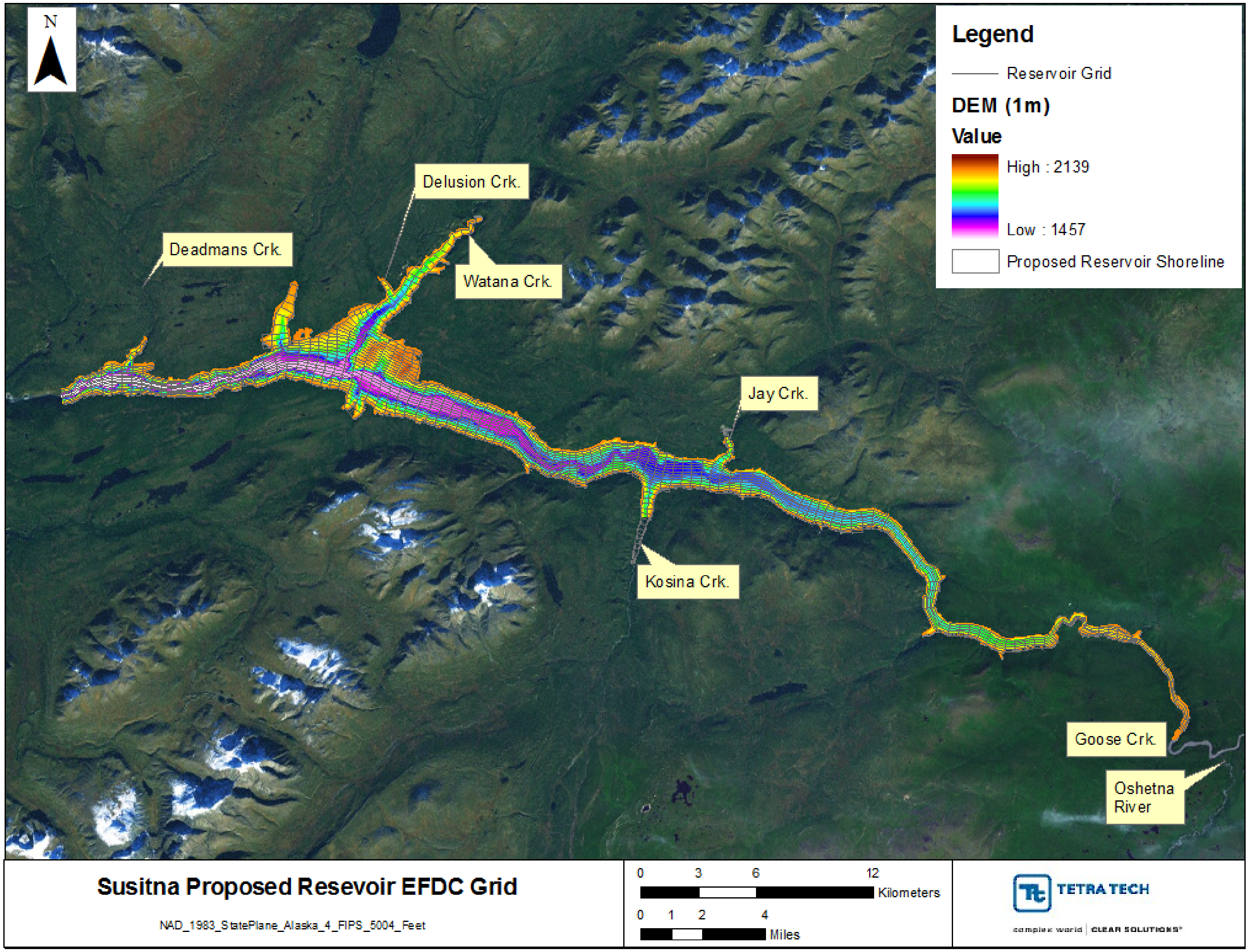

Figure 5.2-1. Reservoir Model Grid with Bathymetry

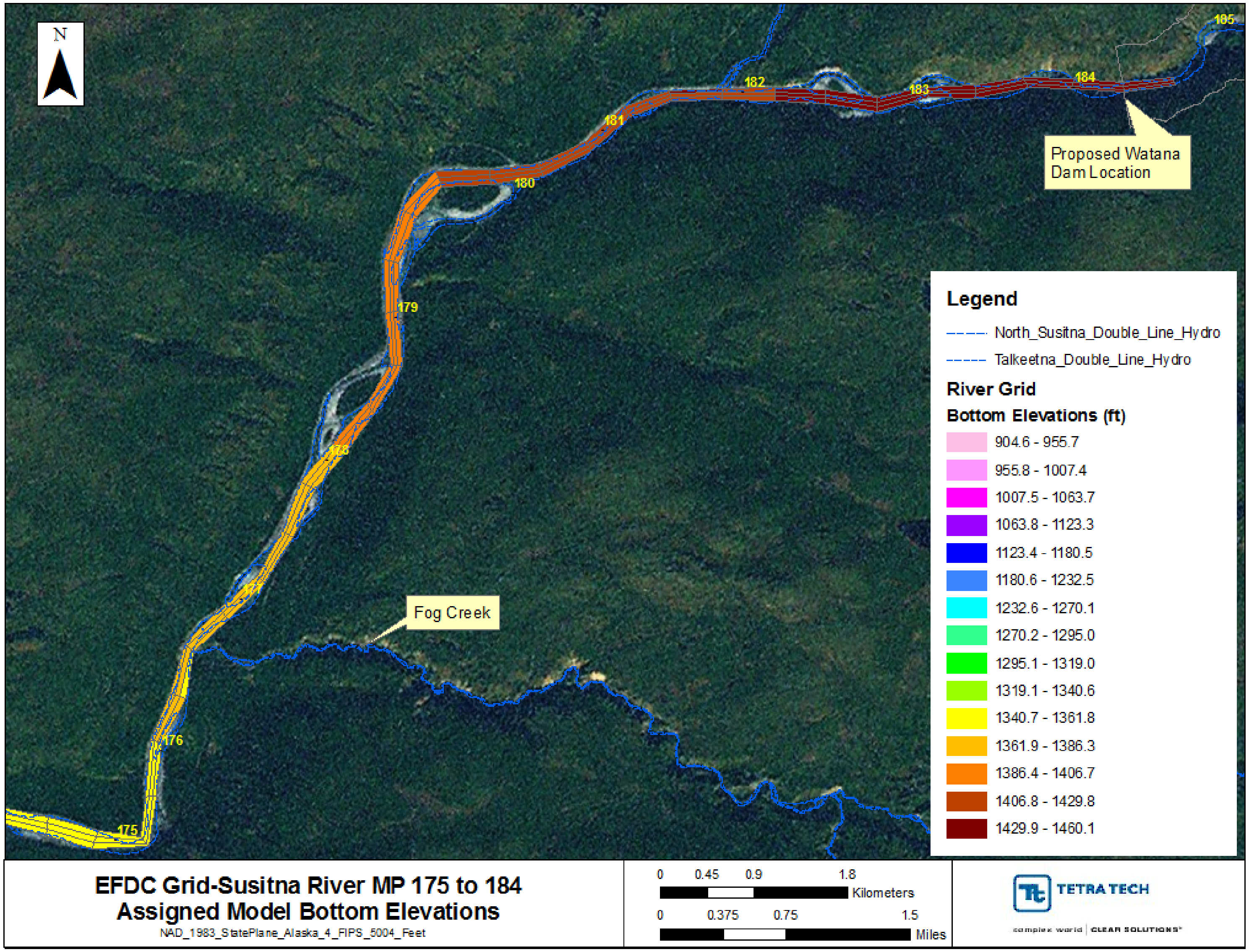

Figure 5.3-1. River Model Grid Below Dam Site (PRM 187.2)

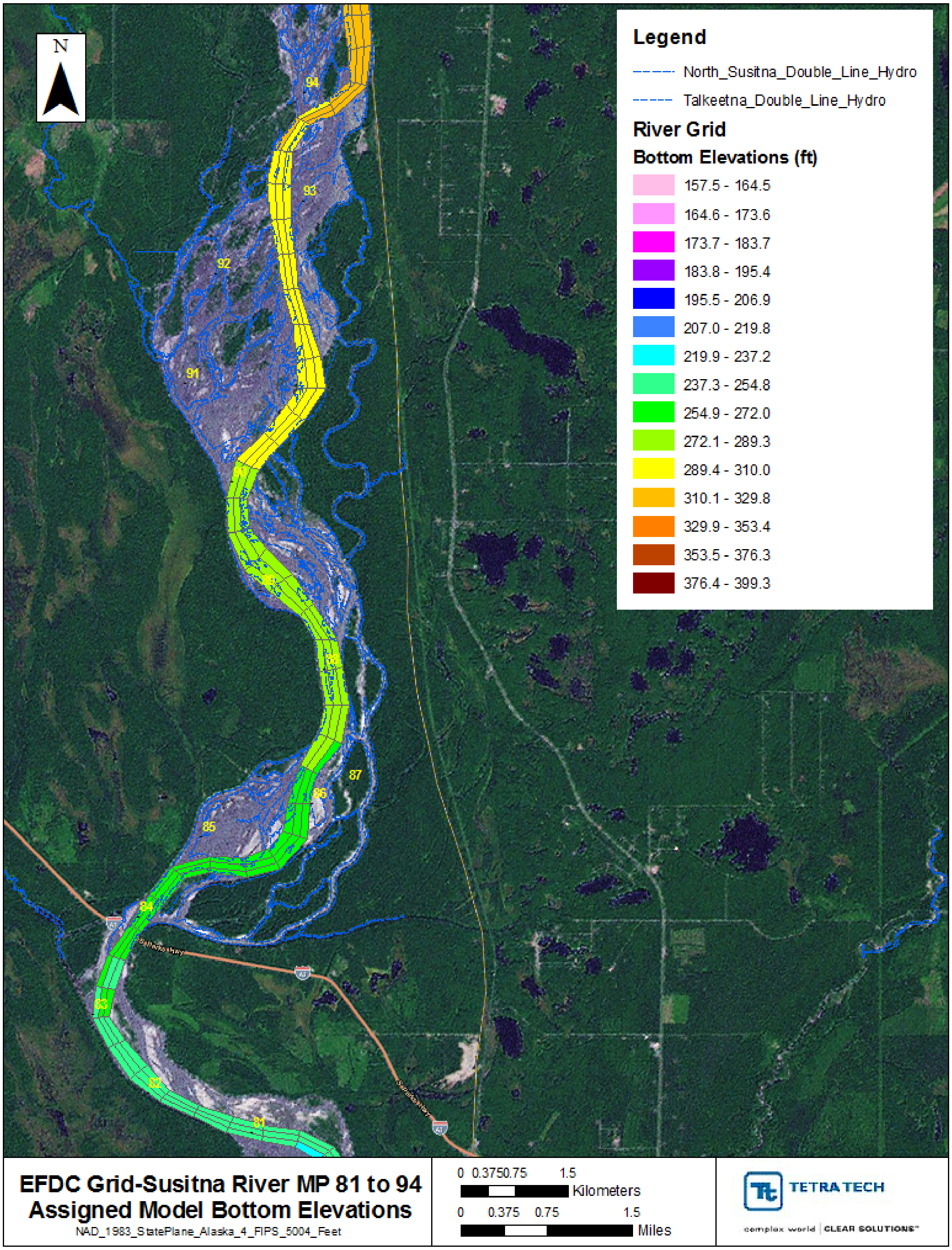

Figure 5.3-2. River Model Grid Upstream of PRM 80.

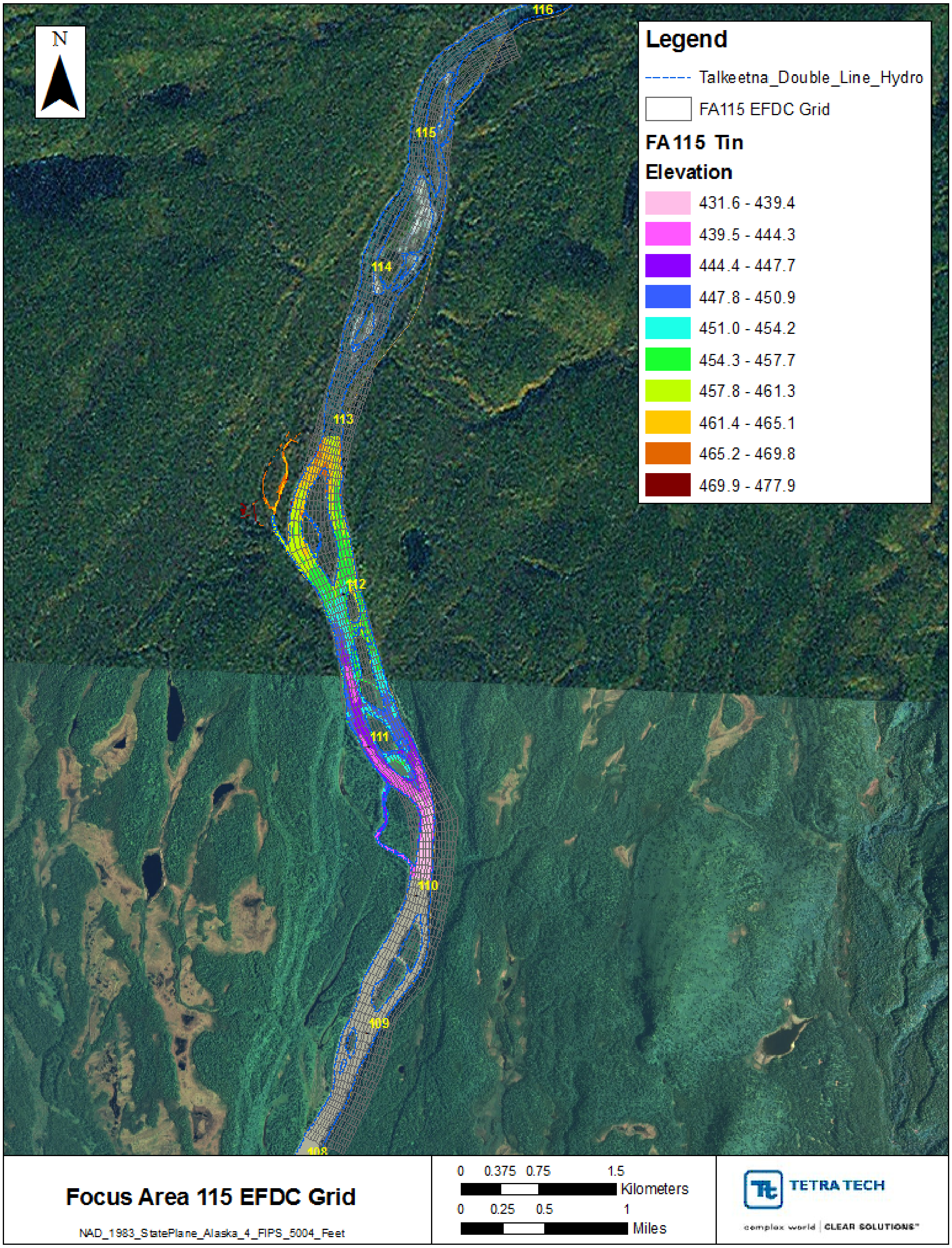

Figure 5.4-1. Enhanced River Model Grid for Focus Area FA-115