**UNITED STATES OF AMERICA**
**BEFORE THE**
**FEDERAL ENERGY REGULATORY COMMISSION**

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|---|---|
| **Klamath River Renewal Corporation** | **Project Nos. 14803-001;** |
| **PacifiCorp** | **2082-063** |

**<u>AMENDED APPLICATION FOR SURRENDER OF LICENSE FOR MAJOR PROJECT AND REMOVAL OF PROJECT WORKS</u>**

**Attachment A-10**

# Lower Klamath Project Biological Assessment

## Appendix I
## (Reservoir Drawdown Hydraulic Model and SRH-1D Suspended Sediment Concentration Model Update Documentation)

# Biological Assessment

## Appendix I - Reservoir Drawdown Hydraulic Model and SRH-1D Suspended Sediment Concentration Model Update Documentation

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# I. RESERVOIR DRAWDOWN HYDRAULIC MODEL AND SRH-1D SUSPENDED SEDIMENT CONCENTRATION MODEL UPDATE DOCUMENTATION

The purpose of this memorandum is to document and present an overview of the supplemental hydraulic and sediment transport modeling update completed in 2020 for the Lower Klamath Project (Project or LKP). This effort utilizes and builds off of previous modeling efforts (see USBR 2011a), with refinement of reservoir hydraulics through the advancement of the Project design, to simulate dam removal suspended sediment concentrations (SSCs) on the downstream river environment. The United States Bureau of Reclamation (USBR) conducted updated modeling to support the effects analyses of reservoir drawdown and associated dam removal processes for the Project, as presented in this Biological Assessment.

This memorandum is intended to summarize the updated 2020 hydraulic modeling based upon the previous USBR analysis performed in 2011 and reported in “Hydrology, Hydraulics and Sediment Transport Studies for the Secretary’s Determination on Klamath River Dam Removal and Basin Restoration,” Technical Report No. SRH-2011-02 (USBR 2011a). The updated hydraulic modelling represented the advanced dam removal engineering (60%-90% design) by the Project design builder, Kiewit with engineering support from Knight Piésold (Kiewit/KP). USBR updated the one-dimensional sediment transport model (Sedimentation and River Hydraulics - One Dimension, or SRH-1D) used for the 2011 analysis and described in USBR 2011a, using the Kiewit/KP hydraulic results. This memorandum presents a summary of the modeling work purpose, background, and approach.

References cited in this appendix are listed in Chapter 8 of the BA.

# I.1 Introduction

## I.1.1 Background

The 2018 Definite Plan Report presented a proposed drawdown sequence and schedule for the removal of the four Lower Klamath River Dams (Renewal Corporation 2018). This drawdown schedule focused on achieving the drawdown during the period of January 1 through March 15 of the drawdown year, which the Renewal Corporation identified as the period of least impact to aquatic species in the Klamath River downstream of Iron Gate Dam. The Renewal Corporation developed the dam removal process, sequencing, and schedule in the 2018 Definite Plan Report to maximize the reservoir drawdown and corresponding sediment evacuation during this period. The Renewal Corporation based the 2018 Definite Plan Report proposed drawdown schedule upon assumptions and the schedule outlined in the USBR analysis (USBR 2011a).

Kiewit/KP, as part of the 60% design development, determined that the safe operating capacity of the existing Iron Gate tunnel is 4000 cubic feet per second (cfs), which corresponds to a full opening of the upper gate at full reservoir water level (Kiewit 2020). The 4000 cfs capacity represented a significantly lower capacity than the 8500 cfs assumed and presented in the 2018 Definite Plan Report. The limitation of 4000 cfs for the tunnel is necessary to ensure the tunnel velocities are sustained below 20 feet per second (fps) to prevent damage and caving of the tunnel liner throughout the drawdown period.

With the identified reduced tunnel discharge, Kiewit/KP updated the hydraulic modeling for the reservoir drawdown. The hydraulic modeling indicated that the drawdown rates could extend into the summer months. The 2018 Definite Plan Report or the 2011 USBR analysis presumed a drawdown to be completed earlier. Kiewit/KP determined in the updated drawdown model that the initial drawdown period would extend from January 1 through March 15 followed by a partial or full refill of the reservoirs during the spring freshet. The rate and duration of refill during the spring freshet period is subject to the water year that occurs during the drawdown period. The Renewal Corporation would then accomplish final drawdown by late July and subsequently remove the dams. Based on the results of the reservoir hydraulic modeling, the Renewal Corporation determined that updated sediment modeling should be completed to reflect the advanced modified drawdown schedule. The Renewal Corporation would then use SSCs determined from the model to evaluate the potential effects on aquatic species, particularly for coho salmon.

## I.1.2 Modeling Approach

The modeling approach focused on two separate modeling efforts of the modified drawdown sequence: (1) hydraulic modeling of the reservoir drawdown, and (2) sediment transport modeling which used the information developed as part of the hydraulic modeling work effort. The hydraulic modeling work was completed by Kiewit/KP to reflect their proposed drawdown sequence, the maximum safe velocities in the Iron Gate tunnel, and advanced engineering analysis of the dam removal process. Kiewit/KP provided this information to USBR as input files for updating the SRH-1D sediment transport model. The sediment model then provided the updated SSCs in the Klamath River at various locations from the Iron Gate Dam to the

Klamath River estuary. USBR provided the sediment modeling output files to the Renewal Corporation to evaluate effects on aquatic species as part of the development of this BA. A brief summary of the modeling approach is presented in the following paragraphs.

### I.1.3 Technical Work Group

In 2020 the Renewal Corporation formed a Technical Work Group (TWG) comprised of members of National Marine Fisheries Service (NMFS), US Fish and Wildlife Service (USFWS), California Department of Fish and Wildlife (CDFW), Oregon Department of Fish and Wildlife (ODFW), USBR, the Yurok Tribe, and the Karuk Tribe to participate in the BA development and analysis of the modified reservoir drawdown and dam removal plan. The TWG members brought specific knowledge of the existing Klamath River Project operation, hydrologic and hydraulic conditions, and previous studies and analysis specific to the proposed dam removal. The Renewal Corporation conducted coordination calls with the TWG to discuss the proposed workplan, initial model results, and to solicit input on the work execution. The TWG held nine meetings. Each meeting further refined the need for additional modeling, model inputs and assumptions, the SWRCB analysis for the issuance of the Clean Water Act 401 certificate, and the level of impact analysis for the BA.

### I.1.4 Workplan Development

As a first step in the revised modeling work effort, the Renewal Corporation developed a workplan which outlined the basic approach to updating the hydraulic and sediment modeling for the LKP. The workplan identified the basic steps anticipated for completing the reservoir drawdown methodology and the related reservoir hydraulic operation required to achieve the drawdown. Table I-1 presents a summary of the sequential work tasks followed in the workplan for the overall development process for the proposed modified drawdown. The hydraulic and sediment modeling workplan summary is presented in Table I-2. The Renewal Corporation worked collaboratively with the TWG throughout the workplan implementation, providing updated technical analysis and data to the TWG throughout the coordination meetings. The Renewal Corporation presented interim work products and data to the TWG, and discussed and incorporated member comments, where appropriate, to enhance the technical analysis.

**Table I-1: Proposed Modified Drawdown – Overall Development Process**

| Work Task | Description |
|---|---|
| 1 | Iron Gate Tunnel Evaluation |
| 2 | Computational Fluid Dynamics (CFD) Rating Curves |
| 3 | Modified Drawdown |
| 4 | Outlet Tunnel Modifications Concept Design |
| 5 | Final Breach Design |
| 6 | Technical Summary Documentation |
| 7 | Peer Review of Concept Design |
| 8 | Hydraulic and Sediment Modeling Updated Analysis |
| 9 | Integration with Science Team Analysis |

**Table I-2: Hydraulic and Sediment Modeling Workplan.**

| Work Task | Description |
|---|---|
| 1 | USBR to Provide Klamath Basin Restoration Agreement (KBRA) Flows (daily average) to Knight Piesold (KP) |
| 2 | KP Runs Hydraulic HEC-RAS Model with KBRA Flows |
| 3 | KP to provide HEC-RAS Water Surface Elevations (WSE) as the new hydraulic model runs to USBR |
| 4 | USBR to run SRH-1D Sediment Model update with new KP HEC-RAS WSE to determine Suspended Sediment Concentration (SSCs) |
| 5 | Renewal Corporation to evaluate SRH-1D Model update output for input to Biological Assessment effects analysis |
| 6 | Final Updated SSCs Technical Presentation |

## I.1.5 Model Development History

As illustrated in Table I-3, various entities have completed hydraulic and sediment modeling for the Project over the past 10 years. USBR completed initial modeling work for the Project in 2011 (reported in USBR 2011a) and AECOM subsequently reviewed and analyzed USBR's work (Renewal Corporation 2018). USBR developed their modeling work to simulate potential dam removal scenarios and related reservoir drawdown operation for the Lower Klamath River Dams. USBR completed sediment modeling to estimate the anticipated sediment transport and estimated suspended sediment concentration in the Klamath River below the Iron Gate Dam. This included simulations of the modeled scenarios for USGS gage locations at Iron Gate (11516530), Seiad Valley (11520500), Orleans (11523000), and Klamath (11530500) to evaluate SSC attenuation and timing in the lower reaches of the Klamath River.

USBR used the SRH-1D model, a one-dimensional mobile boundary hydraulic and sediment transport simulator for rivers and manmade canals. This model can estimate sediment concentrations throughout a waterway given the sediment inflows, bed material, hydrology, and hydraulics of that waterway. The necessary information to make predictions of dam removal impacts include:

1. Reservoir sediment characterization including its volume, distribution and gradations
2. Geometry and hydraulic characteristics of the channel
3. Sediment model parameters
4. Reservoir drawdown and hydrologic scenarios

The model used historical measured inflows into Upper Klamath Lake and then treated Link River Dam (impounding Upper Klamath Lake) releases according to assumed operational rules.

USBR developed the hydraulic model with assumptions related to the method of flow release at each dam and the related reservoir rating curves for the proposed hydraulic structures used to achieve the drawdown (USBR 2011a). The USBR analysis focused on a primary drawdown period of January 1 through March 15, the period of time representing the least impact to aquatic species, particularly coho salmon, in the Klamath River.

The Renewal Corporation revisited the USBR work as part of the Definite Plan Report development (Renewal Corporation 2018). In general, the previous USBR model and parameters were maintained with specific revisions to reflect modifications to the hydraulic structures at each dam used to implement the drawdown. The Renewal Corporation maintained the reservoir drawdown period of January 1 through March 15 for that analysis (Renewal Corporation 2018).

Kiewit/KP assumed the role as the design builder responsible for the Project implementation in 2018. Kiewit/KP developed a new hydraulic model as part of their work effort, reflecting updated survey data and design approaches for the drawdown flow releases at each dam. Kiewit/KP's analysis reflected the 60%-90% design advancement and the reduced releases through the Iron Gate Dam tunnel. A comparison of the updated Kiewit/KP hydraulic model assumptions and the USBR 2011 model assumptions for the LKP are summarized in Table I-4.

**Table I-3: Klamath River Dam Removal Project Modeling History**

| Year | Modeling Entity | Model Purpose/Type | Reference Document |
|---|---|---|---|
| 2011 | USBR | EIS/Hydraulic and Sediment Models | USBR 2011a |
| 2018 | AECOM | Definite Plan/Hydraulic – use USBR sediment results | The Renewal Corporation 2018 |
| 2019 | Kiewit/KP | Project Design Development/Hydraulic – use USBR sediment model results | Kiewit 2020 |
| 2020 | Kiewit/KP<br>USBR | Project Design Development/Hydraulic – update USBR sediment model | Kiewit 2020 |

**Table I-4: Comparison of USBR and KRRP Model Assumptions**

| Site | Parameter | USBR 2011 Model (1) | Renewal Corporation (KP) Model |
|---|---|---|---|
| Project Wide | Representative Water Year | 1961 - 2008 | 2019 USBR BO Flows (1980 to 2016) |
| | Upper Klamath Lake Flows | 90% Exceedance (Dry) = 2001; 50 % Exceedance (Median) = 1976; 10%; Exceedance (Wet) = 1984<br><br>Methods: Evaluated with cumulative volume March to June (Keno) | Driest on record = 2015 25th P (dry) = 1990 Median/Avg = 2005 Wet (5yr) = 2011<br>Very Wet (20 yr) = 1983<br>Extreme Wet (100 yr) = 1998<br><br>Methods: Evaluated based on cumulation of flow volume from April 1 to June 15 (2019 USBR BO Flows at Keno) |
| | Upper Klamath Basin WY | Reclamation 2011/2012 Operations (Keno) | 2019 BO Flows (1980 to 2016) at Keno |

| Site | Parameter | USBR 2011 Model (1) | Renewal Corporation (KP) Model |
|---|---|---|---|
| | Upper Klamath Lake Flows | Reclamation Operations 2011/2012 (Keno) | 2019 BO Flows 1980 to 2016 (Keno) |
| | Channel Geometry Used | 2010 LiDAR plus bathymetric data | 2018 bathymetry and LiDAR (GMA 2018)<br><br>Bathymetry is complete and continuous |
| | Reservoir Geometry used | 2001 survey. Combining the LiDAR with the bathymetric data.<br>Cross sections every 500 ft, Mile 0-8 d.s. Iron Gate; 1000 ft d.s. +8mi | |
| | Channel Roughness Used | Channel=0.03 to 0.05<br>overbanks = 0.06 | Channel = 0.04 to 0.1 (average 0.04)<br>overbanks = 0.06 to 0.1 |
| Iron Gate | Drawdown start date | 1-Jan | 1-Jan |
| | Target drawdown elevation | Not presented. | 2208 ft.: Top of historic coffer dam |
| | Max. tunnel capacity | 8,500 cfs<br>39.5 ft/s (avg velocity)<br><br>12,000 cfs (1984, wet year)<br>56.2 ft/s | 4000 cfs<br>18.75 ft/s (avg velocity). Criteria < 20 ft/s<br>Subject to ROV tunnel inspection |
| | Drawdown method | Diversion tunnel: new gate<br>Spillway: Some flood flow<br>Drawdown: 1 to 3 ft/day. | Diversion tunnel: open upper gate, removal of lower gate, by 9 ft orifice.<br><br>Spillway: Some flood flow<br>Power tunnel intake (powerhouse)<br><br>Drawdown: approx. 3ft/day |
| Copco No. 1 | Drawdown start date | Nov 1: 1 feet/day to 2590 WSE<br>Jan 1: 1.75 ft/day - 2.25 ft/dy until it reaches the pre-dam river elevation. | 1-Jan |
| | Target drawdown elevation | Not presented. | 2,532 WSE<br>(historic coffer dam hydraulic control) |
| | Hydraulic capacity (cfs discharge) | Diversion Tunnel: 5,000 cfs. 2597.1 WSE | New Low-level outlet: 4,000 cfs. 2597 WSE spillway invert (ft) |
| | Drawdown method | Pre drawdown method not specified, Drawdown by diversion tunnel.<br>If diversion tunnel capacity exceeded,<br>overtop notched dam. | New low-level outlet (10-ft orifice). No overtopping proposed. |
| J.C. Boyle | Drawdown start date | 1-Jan | 1-Jan |
| | Target drawdown elevation | Not presented. | 3767 WSE,<br>3ft below crest of historic coffer dam |
| | Assumed capacity to release water downstream (cfs discharge) | 5,500 cfs (2750 cfs each culvert)<br>3781.5 (3.7ft datum adjustment required). Spillway crest | 4,000 cfs (2,000 cfs each culvert)<br>3785 WSE at spillway invert (ft) |
| | Drawdown method | Spillway, power intake,<br>diversion culverts | Spillway, power intake, diversion culverts |

# I.2 60% Design Hydraulic Modeling

Kiewit/KP developed a one-dimensional (1D) Hydraulic Engineering Center River Analysis System (HEC-RAS) hydraulic model and applied it to assess the reservoir hydraulics during the drawdown of J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate reservoirs (NHC 2019). Kiewit/KP developed the model using 2018 LiDAR and bathymetric surveys and a newly created Digital Elevation Model (DEM) of the Klamath River (GMA 2018). The model development included updating the input flows to represent the 2019 Biological Opinion (BO) flows (NHC 2019).

Kiewit/KP used daily average 2019 BO flows, from October 1980 through September 2016, at Keno, Oregon, and at the USGS station below Iron Gate Dam, California (NHC 2019), for the simulation developed for the 60% design development. The Keno flow was specified as the hydraulic model inflow into the riverine reach upstream of the J.C. Boyle reservoir. The Renewal Corporation determined local inflow based on the difference between the Keno and Iron Gate BO flows. Kiewit/KP summed the BO flow volumes for each year to help identify representative “wet” and “dry” years to be used in the model. For evaluating the drawdown conditions, the Renewal Corporation summed water volume from January 1, when drawdown was assumed to begin, through March 15. The hydrologic scenarios evaluated in the drawdown hydraulic modeling were defined as follows for the 60% design phase (BO flow years shown in parentheses):

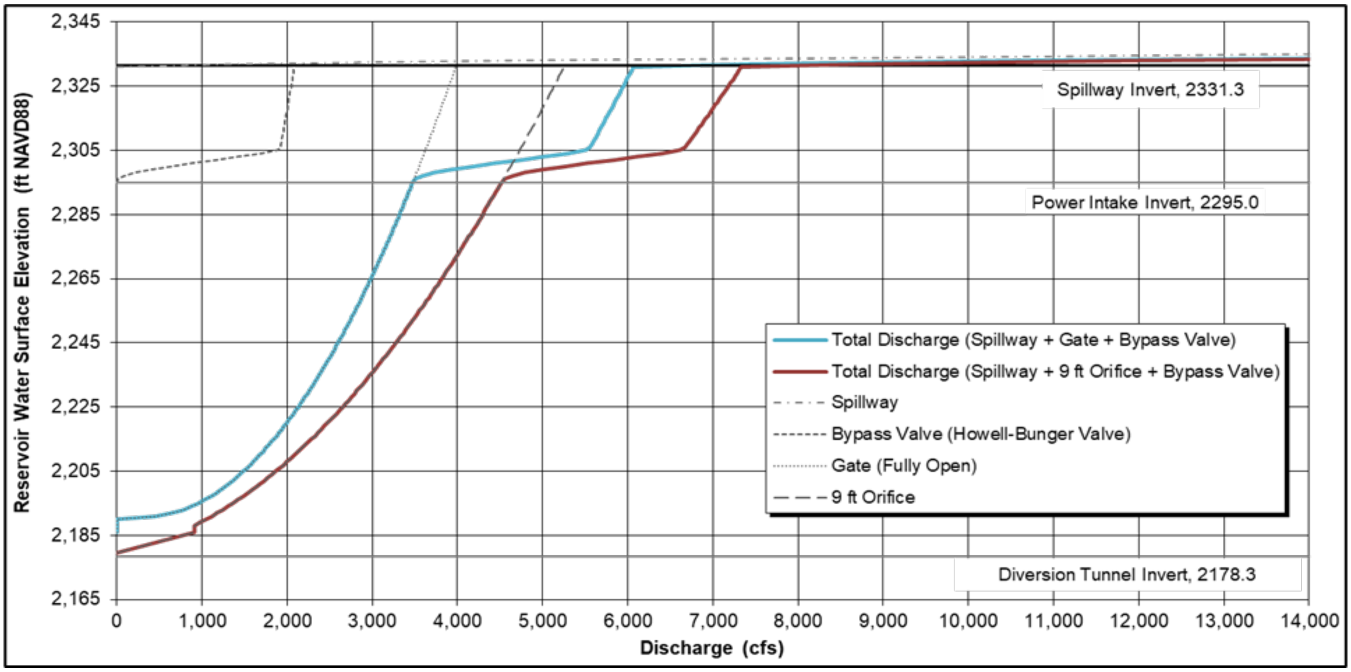
- “Extremely dry year” = year with lowest BO flow volume (2005)
- “Moderately dry year” = year closet to the 25$^{th}$ percentile of the BO flow volumes (1991)
- “Typical year” = year closest to the average of the BO flow volumes (1987)
- “Moderately wet year” = year closet to 75$^{th}$ percentile of the BO flow volumes (1999)
- “Extremely wet year” = year with the highest BO flow volume (1997)

Kiewit/KP used computational fluid dynamic (CFD) methods to determine rating curves for each outlet structure at all four dams. Kiewit/KP used these rules in the drawdown hydraulic modeling to specify outflow from the Klamath River dams through diversion tunnels, power plant intakes, spillways, and diversion conduits. The HEC-RAS model utilizes these rules to dictate when a specific outlet structure is active based on elevation, flow, date, time, duration and associated parameters.

# I.3 2020 Modified Drawdown Hydraulic Modeling

As part of the advanced design development following the 60% design, Kiewit/KP conducted continuing evaluation and risk management analysis for the Iron Gate tunnel. From this analysis, Kiewit/KP determined that the existing Iron Gate tunnel had a functional and safe discharge capacity of 4000 cfs. Kiewit/KP based this evaluation on the condition of the existing concrete liner system and a limiting maximum velocity of 20 fps within this tunnel section. The revised maximum design flow represented a significant reduction from the prior modeling assumptions which utilized a maximum hydraulic capacity of 8500 cfs.

Incorporation of the reduced tunnel design flow required reevaluation of the reservoir drawdown schedule. Kiewit/KP completed updated hydraulic modeling to reflect modified rule curves at all four dams, but specifically at Iron Gate and Copco No. 1. At Iron Gate, Kiewit/KP reduced the tunnel discharge capacity to 4000 cfs by keeping the upper gate fully open at 57 inches throughout the drawdown period and updated the modifications to the existing outlet tunnel to reflect this lower design flow (Figure I-1). At Copco No. 1, Kiewit/KP modified the design such that the historic diversion tunnel opens after June 15 of the drawdown year and once the reservoir water surface elevation is below 2,530 feet, which is approximately 20 feet above the top of the existing intake structure. The model assumed that the diversion tunnel is opened instantaneously.




*Klamath River Renewal Corporation, Klamath River Renewal Project*

**Figure I-1: Iron Gate Dam reservoir rating curve, which provided hydraulic conditions input to the updated reservoir drawdown schedule and suspended sediment concentration modeling.**

Kiewit/KP simulated the proposed modified drawdown methodology using the Klamath Basin Restoration Agreement (KBRA) flows, which were used earlier by the USBR for the drawdown assessment and sediment mobility assessment (USBR 2011a). The KBRA flows for the mainstem of the Klamath River, and associated flow accretions were provided to Kiewit/KP by the USBR. Kiewit/KP used these inflows as inputs to the hydrodynamic drawdown model, then provided the results to USBR for J.C. Boyle, Copco No. 1, and Iron Gate facilities as follows:

- Daily average reservoir water surface levels
- Daily average outflows.

Copco No. 2 was not included in this assessment as it does not have substantial active storage. The Renewal Corporation presented the results of the model to the TWG in summary figures comparing the updated hydrologic scenario compared with the USBR 2011a modeled scenarios for three representative years (Figures I-2, I-3, and I-4). The Renewal Corporation provided the full model output data to the USBR on May 11, 2020 for the incorporation into the SRH-1D model update.

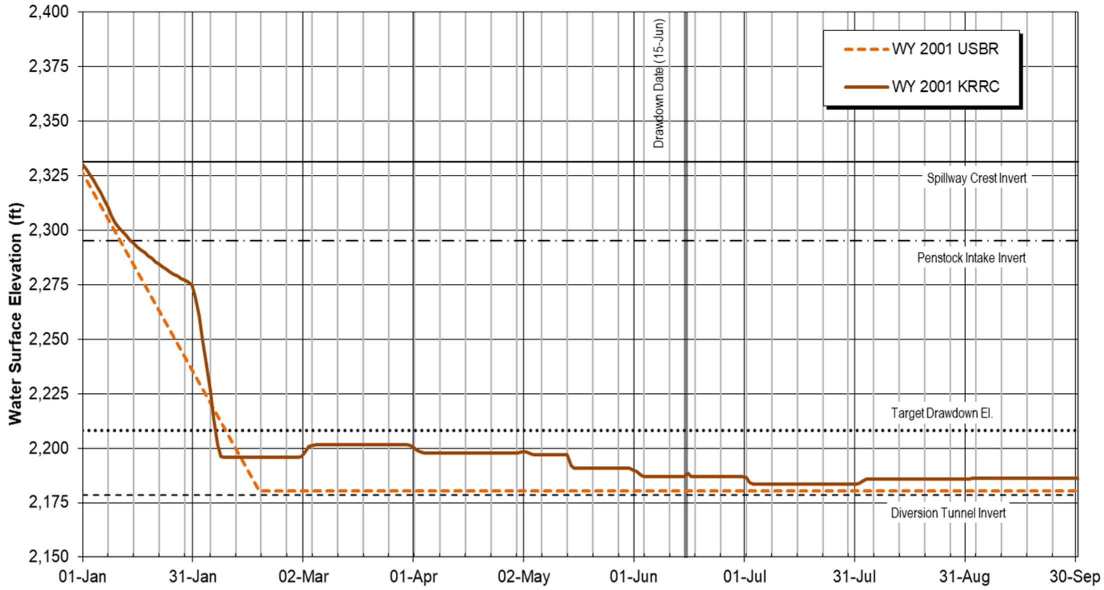



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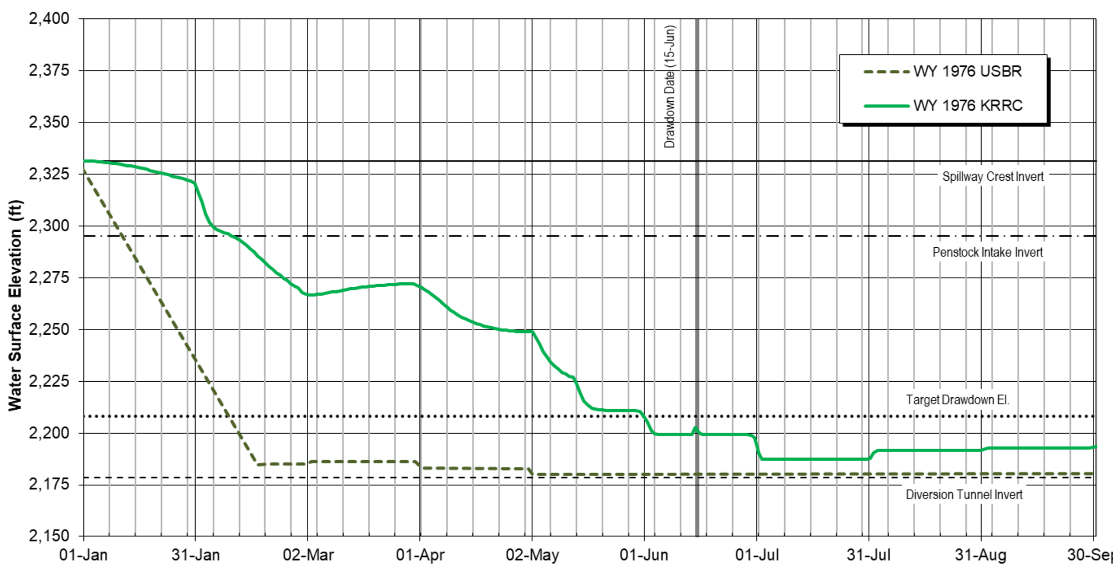
**Figure I-2: Drawdown schedule using Klamath Basin Restoration Agreement (KBRA) hydrologic flows at Iron Gate as modeled for a dry water year (based on water year 2001) by USBR (2011a; dashed line) and updated KRRC schedule (solid line).**




*Klamath River Renewal Corporation, Klamath River Renewal Project*

**Figure I-3: Drawdown schedule using KBRA hydrologic flows at Iron Gate as modeled for an average water year (based on water year 1976) by USBR (2011a; dashed line) and updated KRRC schedule (solid line).**

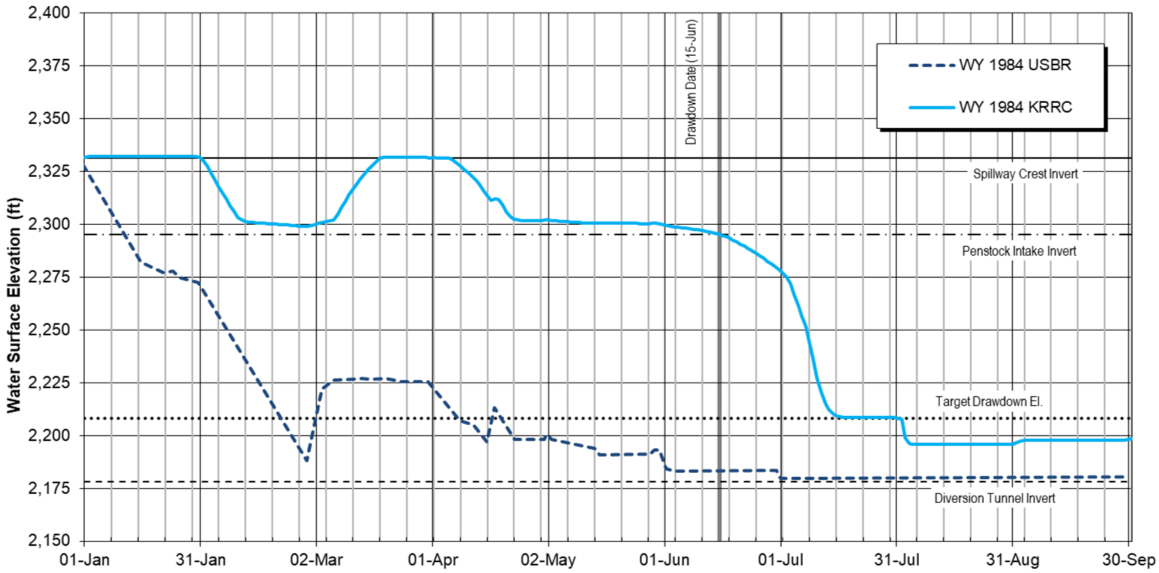



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**Figure I-4: Drawdown schedule using KBRA hydrologic flows at Iron Gate Dam as modeled for a wet water year (based on water year 1984) by USBR (2011a; dashed line) and updated KRRC schedule (solid line).**

# I.4 2020 Sediment Modeling

With the updated hydraulic modeling, the Renewal Corporation determined the sediment modeling (USBR 2011a) needed to be updated to reflect the modified drawdown schedule. The objective of the updated modeling was to allow a direct comparison of the suspended sediment concentrations developed under the original modelling work and the modified drawdown schedule. The process to complete this analysis was:

1. The Renewal Corporation provided hydraulic model output developed by Kiewit/KP to USBR as the input hydraulic conditions and reservoir rule curves for the sediment modeling.
2. Kiewit/KP ran the hydraulic model with the KBRA hydrologic flows to match the previous USBR model.
3. USBR staff ran the existing SRH-1D model with the updated hydraulic input files and provided updated output suspended sediment concentrations in a spreadsheet format.
4. The Renewal Corporation used the updated sediment analysis results to update the aquatic impact analysis in the Klamath River downstream of Iron Gate Dam.

USBR completed the updated modeling work in June 2020. The results of the hydraulic model and sediment model for three representative years used are presented in Figures I-5, I-6, and I-7. The Renewal Corporation presented the following primary observations from this modeling work to the TWG:

- Hydraulic modeling illustrated that two distinct drawdown periods occurred under all hydrologic year conditions. The initial drawdown occurred from January 1 to March 15 in all reservoirs. The normal spring freshet resulted in partial to full refilling of the reservoirs depending on the hydrologic year. Final drawdown to allow initiation of dam removal occurred between May and July (depending on the hydrologic year).

- The Renewal Corporation expects that the sediment evacuation could be focused on the initial drawdown period of January 1 through March 15. Subsequent sediment evacuation in the final drawdown period would be smaller in total sediment volume but would produce high concentrations of suspended sediment downstream of the Iron Gate Dam.
- Opening of the existing diversion tunnel at Copco No. 1 will result in a spike in sediment concentrations during the short period when the diversion is accomplished. This is due to an approximately 20-ft drawdown of the reservoir upstream from the existing cofferdam when the diversion tunnel is re-opened.
- Final removal of the existing cofferdams at J.C. Boyle, Copco No. 1, and Iron Gate Dams will produce a short-term spike in suspended sediment concentrations during the actual breaching work activity.

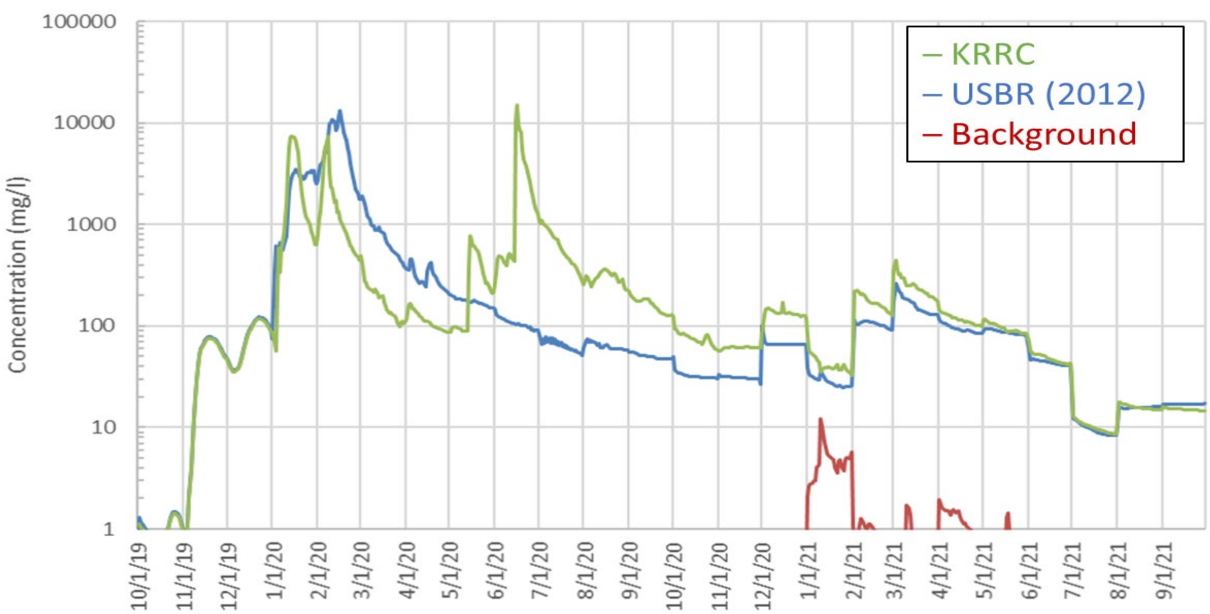


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**Figure I-5: Suspended sediment concentrations (SSC) at the Iron Gate USGS gage, as modeled for an anticipated dry water year (based on water year 2001). Background SSCs are represented by the red line, blue line represents the USBR model (2011a) and the green line represents the updated KRRC model. Years noted on horizontal axis are relative.**

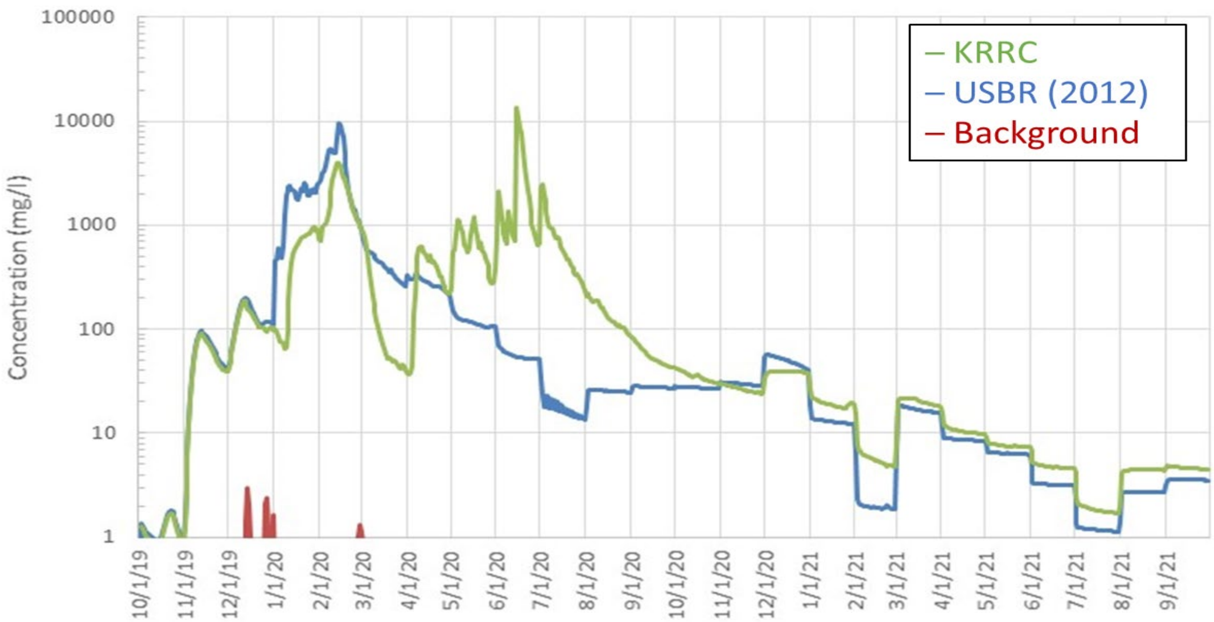


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**Figure I-6: SSC at the Iron Gate USGS gage, as modeled for an anticipated average water year (1976). Background SSCs are represented by the red line, blue line represents the USBR model (2011a) and the green line represents the updated KRRC model. Years noted on horizontal axis are relative.**

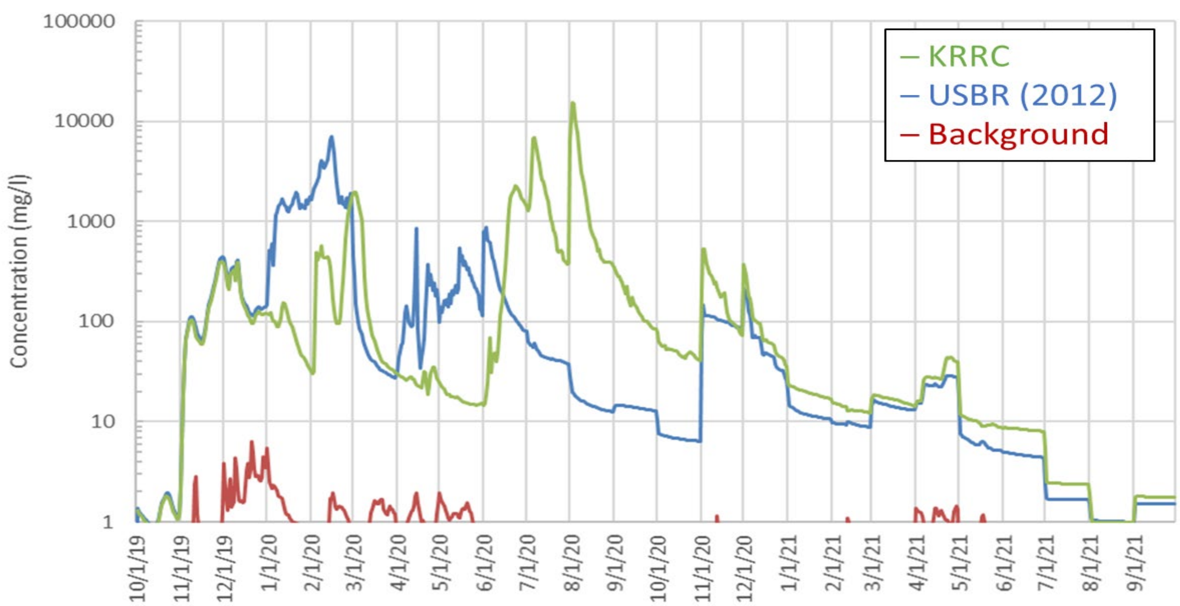


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**Figure I-7: SSC at the Iron Gate USGS gage, as modeled for an anticipated wet water year (based on water year 1984). Background SSCs are represented by the red line, blue line represents the USBR model (2011a) and the green line represents the updated KRRC model. Years noted on horizontal axis are relative.**