Attachment 5

Technical Analysis: Crescent City Harbor Proposed Monitoring Measures

Klamath River Dam Removal

Crescent City Harbor

Proposed Monitoring Measures

Final
Revision No. 6

February 19, 2021

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Distribution

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Revision Log

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1.0 Introduction

1.1 Purpose

The purpose of this conceptual-level analysis is to develop a recommended approach and specific measures for quantifying the potential impacts of sediment releases from the Klamath River Dam Removal (Project) on Crescent City Harbor.

1.2 Scope

The scope of this report includes measures for monitoring and determining the effect of sediment releases from the Project during the drawdown period on Crescent City Harbor. The report presents existing data and information to frame the issue, then outlines monitoring measures. The information presented in this report is intended to inform the discussions between the Klamath River Renewal Corporation (KRRC) and the County of Del Norte, California (County), with the agreed-upon approach and measures incorporated into a workplan that will be implemented by KRRC.

1.3 Background

The dam removal and reservoir drawdown planned with the Project will release sediment from the reservoirs into the Klamath River below Iron Gate Dam. The reservoir sediment is primarily fine-grained silts and clays and is expected to be carried by Klamath River flows from Iron Gate Dam to the Pacific Ocean, with minimal deposition in the river itself. Depending on whether wet, dry, or average river flow conditions occur during the drawdown period, the amount of sediment released from the reservoir is estimated to vary from 1.4 to 3.2 million tons. This sediment load represents an approximate increase of 24 to 55 percent over the current average annual Klamath River sediment discharge of 5.83 million tons. The County has raised concerns about potential increased sediment deposition in Crescent City Harbor due to the increased river sediment loads from the reservoir drawdown. Measures to evaluate and monitor sediment deposition within the harbor have been requested.

2.0 Crescent City Harbor

2.1 Project Authorization

The existing federal project for the improvement of the Crescent City Harbor was authorized by the Rivers and Harbors Act of 1918. It was based on a report printed in House Document 434 of the 64th Congress, First Session, and provided for construction of a rubble mound outer breakwater. The Crescent City Harbor District is the non-federal sponsor for the project. The U.S. Army Corps of Engineers (USACE) Environmental Assessment (USACE 2019) provides a full history of the documents authorizing improvements that make up the existing federal project.

2.2 Project Area

Crescent City Harbor is a small commercial harbor located on the northern California coast, approximately 280 miles north of San Francisco and 17 miles south of the Oregon border (USACE 2019). The south-facing harbor occupies a natural indentation in the coastline and is protected by a 4,700-foot-long rubble mound outer breakwater to the west; a 2,400-foot sand barrier to the east; a 1,600-foot inner breakwater to the south; and the topography of the coastline to the north (USACE 2019).

As shown on Figure 1, the Inner Harbor contains two boat basins that are maintained by the Crescent City Harbor District (USACE 2019). The Commercial Small Boat Basin (outer boat basin) has temporary moorage space for approximately 20 vessels. The outer basin also contains two fish processing plants with docks, a main dock (Citizens Dock), a marine repair facility equipped with a syncrolift, a dock for the U.S. Coast Guard, and other auxiliary commercial and recreational facilities. Citizens Dock is a publicly owned, Y-shaped, wooden dock originally constructed in 1950 and operated by the Crescent City Harbor District. It is primarily used for refueling, loading ice, and unloading commercial fish catch. The depths maintained in the outer basin range from -10 feet mean lower low water (MLLW) in the southern half adjacent to Whaler Island to -15 feet MLLW.

The Recreational Small Boat Basin (inner boat basin) was damaged by a tsunami in 2006 and destroyed by the March 11, 2011, tsunami. The rebuilding process took 3 years, and the inner boat basin was re-opened in March 2014. The new inner boat basin was designed to resist the 50-year tsunami event, has 291 slips ranging in length from 30 feet to 70 feet, and is maintained to a depth of -15 MLLW.

To remain a viable option for commercial fishing activities, the Harbor must maintain accessibility of its navigation channels for a variety of vessels, especially larger commercial vessels. Dredging of the Entrance Channel and Inner Harbor Basin Channel has been conducted under the USACE Operations and Maintenance (O&M) program since 1936. The Marina Access Channel was deepened in 2000, at which time it also became part of the federal channel system (USACE 2019). Crescent City Harbor Basin and Channel areas and dredge maintenance depths are shown in Figure 2.

2.3 Historical Maintenance Dredging

The dredging history of the Harbor is well documented (USACE 2019). The Crescent City Harbor Entrance and Inner Harbor Basin Channels were first dredged under the USACE O&M Program in 1936. Maintenance dredging of the two channels was subsequently conducted in 1937, 1938, 1939, 1956, 1964, 1965, 1976, 1982, 1983, 1988, 1993, and 1998, with the dredging intervals ranging from 1 to 17 years. In 1999, only the Entrance Channel was dredged, and in 2000, the Marina Access Channel was deepened and became a federal channel. The Marina Access Channel and Entrance Channel were dredged in 2009 and the Inner Harbor Basin was dredged in 2011. The Harbor was dredged in 2019, as well. Table 1 shows the years and volumes of the historical dredging. Much of the data related to the existing Harbor presented in this report were sourced from the 2019 Crescent City Harbor Federal Channels Maintenance Dredging Environmental Assessment (USACE 2019).

Table 1. Crescent City Harbor Federal Channels Historical Dredged Volumes

Year	Channels	Volume (cubic yards)
1936	Inner Harbor Basin and Entrance Channels	48,449
1937	Inner Harbor Basin and Entrance Channels	27,756
1938	Inner Harbor Basin and Entrance Channels	16,353
1939	Inner Harbor Basin and Entrance Channels	58,396
1956/1957	Inner Harbor Basin and Entrance Channels	120,466
1964/1965	Inner Harbor Basin and Entrance Channels	187,372 [b]
1976	Inner Harbor Basin and Entrance Channels	61,013
1982	Inner Harbor Basin and Entrance Channels	125,319
1983	Inner Harbor Basin and Entrance Channels	40,221
1988	Inner Harbor Basin and Entrance Channels	62,192
1993	Inner Harbor Basin and Entrance Channels	37,487
1999/2000	Entrance Channel and Marina Access Channel	35,000
2009	Marina Access Channel	34,947
2011 [a]	Inner Harbor Basin and Entrance Channels	41,630
	Total	896,601
2019 [c]	Inner Harbor Basin and Entrance Channels	118,000

(Source: USACE 2019)

Note:

a) Due to funding, the Entrance Channel and Marina Access Channel were only dredged to -14 feet MLLW (with 1 foot of over-depth) in 2009.

b) The 1964 tsunami may have contributed to the larger-than-usual volume.

c) The most recent dredging occurred in 2019, with estimated volume as noted.

2.4 Project Maintenance Dredging Volumes

The estimated average shoaling and dredging rate for the Entrance and Inner Harbor Basin Channels was estimated from the historic dredged volumes from 1936 to 2000 (USACE 2019). The dredged volumes after 2000 were not included in the analysis because the 2011 dredge event was limited and did not dredge to the maintained project depth or include over-depth. Similarly, due to tsunamis in 2006 and 2011, more recent shoaling estimates and dredged volumes are not likely indicative of typical shoaling in Crescent City Harbor or the federal channels. Consequently, the historical pre-tsunami estimates were used to conservatively estimate the shoaling for planning purposes by the USACE to determine the estimated dredging volumes proposed for 2019.

Based on the USACE analysis, the average shoaling and dredging rate for the Entrance and Inner Harbor Basin Channels was approximately 12,000 cubic yards of material per year. Based on a 2005 hydrographic survey, the Marina Access Channel was estimated to shoal at an average rate of approximately 8,000 cubic yards per year since it was deepened in 2000. The combined average shoaling and dredging rate for the Entrance, Inner Harbor Basin, and the Marina Access Channels (Areas 4, 5 and

6 in Figure 2) is approximately 20,000 cubic yards per year, which equates to approximately 100,000 cubic yards every 5 years (HydroPlan and Anchor QEA 2015). These values will be assumed to represent the baseline condition within the channels for the purposes of the analysis presented within this report.

2.5 Sediment Testing and Characterization

The majority of deposited sediments in the Crescent City Harbor are sourced from littoral transport of sediments into the harbor from north to south (USACE 2019). Composition of the sediment sources from north to south are similar, with approximately equal (30 to 45 percent) proportions of rock fragments and quartz. Mean grain sizes range from fine to medium sands with large range of sediment size distribution, from very well sorted (i.e., very poorly graded) to very poorly sorted (i.e., very well graded) (USACE 2006).

Sediment samples from the Crescent City Harbor federal channels have been subjected to a comprehensive suite of physical, conventional, and chemical analyses and biological tests based on applicable guidelines established in the Inland Testing Manual (USEPA/USACE 1998), the Ocean Testing Manual (USEPA/USACE 1991), and the Upland Testing Manual (USACE 2003).

Previous sampling events indicate that the dredged material from the Entrance Channel predominantly has consisted of sand with little organic matter, while dredged material from the Marina Access Channel has predominately consisted of sand with moderate organic material, and dredged material from the Inner Harbor Basin Channel has predominately consisted of fine-grain material (silt) with high amounts of organic material. The percent sand and total organic carbon (TOC) of sediment dredged from the Crescent City Harbor federal channels in the past are presented in Table 2.

Table 2. Dredged Material Grain Size and TOC Composition

Date	Entrance Channel		Inner Harbor Basin Channel		Inner Harbor Basin and Access Channels		Marina Access Channel	
	% Sand	% TOC	% Sand	% TOC	% Sand	% TOC	% Sand	% TOC
1993	94	0.1	49	5.6	--	--	--	--
1998	72	1.2	34	8.7	--	--	--	--
1999	--	--	--	--	88.9	6.04	--	--
2003	--	--	--	--	76	1.81	--	--
2009	87.4	0.8	46.4	10.8	--	--	80.0	6.1

(Source: USACE 2019)

Note: Samples from the Inner Harbor Basin and Marina Access Channels were composited and analyzed.

As part of the development of the proposed Crescent City 2019 maintenance dredging program Environmental Assessment, the USACE (2019) submitted a consistency determination to the California Coastal Commission, which included the results of sediment testing used to characterize the existing material. A brief summary of the results indicated:

- Entrance Channel: greater than or equal to 80 percent sand with little or no organic matter content.
- Marina Access Channel: 75 to 80 percent sand with low organic matter content.

- Inner Harbor Basin Channel: much less than 80 percent sand plus high organic matter content

The analysis was completed to support selection of the appropriate dredging method and equipment, as well as impact of material placement on the alternative disposal sites.

As part of the overall Klamath Dam Removal Project, characterization of the sediment within the existing reservoirs was completed. The existing sediment was found to be composed of primarily small-grain material with a high organic material content. The material was found to have a very high water content, as well. A more detailed description of the existing reservoir sediment characterization is presented in a subsequent section.

3.0 Estimated Sediment Releases from the Klamath River

3.1 Klamath Dam Removal and Reservoir Drawdown

The reservoir drawdown and dam removal processes are proposed to occur in 2022. The drawdown is scheduled to be initiated in January 2022, with all reservoir drawdowns and dam removal completed to support volitional fish passage on the mainstem Klamath River in October 2022. The rate of drawdown and associated sediment evacuation is dependent on the hydrologic conditions within the basin and final reservoir operation guidelines implemented by KRRC and the design-build team.

Extensive hydraulic and sediment transport modeling has been completed for the Project. The initial modeling work was initiated by the U.S. Bureau of Reclamation (USBR) to support their alternatives analysis and environmental impact statement (EIS) development (USBR 2011). Multiple updates and model run scenarios were completed to support the regulatory analysis, as well as the current dam removal and restoration detailed design. In general, the modeling work to date and the associated sediment evacuation and transport volume estimates are based on the 2011 USBR work effort with updates to reflect 2019 hydrologic flow conditions and system operation.

In general, it is important to consider the following:

- The sediment found within the existing reservoirs at J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate is fine-grained with a high organic material content. The sediment has little sand content and has a high water content. More than 84 percent of the total reservoir sediment volume is silt or finer.
- The rate and total volume of sediment evacuation are highly dependent on watershed hydrology during the drawdown year and associated river flow conditions available to flush accumulated sediment out of the reservoirs. During dry years, less sediment will be evacuated and transported downstream; during wet years, more sediment will leave the reservoirs.
- The maximum rate of flow and associated sediment concentration released below Iron Gate Dam will be determined by the hydraulic capacity of the existing diversion tunnel. The tunnel is the primary flow release structure once the spillway and powerhouse facilities are no longer operational.
- The total suspended solids of the flow released below Iron Gate during the drawdown period is expected to vary from as low as 100 mg/l to more than 10,000 mg/l.
- The total maximum volume of sediment expected to be released during the dam removal is a fraction of the total sediment load that currently discharges at the Klamath River mouth. Post-dam-removal volumes are be expected to decrease significantly because the Upper Klamath Project lakes will continue to trap sediment inputs from the upper watershed, and the primary tributaries feeding the Klamath River above Iron Gate Dam are not expected to contribute large quantities of sediment. The Trinity River watershed would continue to represent the largest sediment source within the Klamath River Basin.

A brief summary of the estimated sediment volumes and characteristics is presented in the following sections.

3.1.1 Project Reservoir Estimated Sediment Volume

Drawdown of the reservoirs is expected to release approximately 1.4 to 3.2 million tons of sediment, which represents 1/3 to 2/3 of the approximately 15 million cubic yards of sediment stored in the reservoirs. In a wet year, more material will be eroded, and if there is a dry year, less material will be eroded from the reservoirs. More than 80 percent of the reservoir sediment is fine sediment (silt, clays, organics). Most of the material will be transported to the ocean during the drawdown period. The maximum sediment concentrations during this period may be more than 10,000 mg/l downstream from Iron Gate Dam. The tributaries entering the Klamath River will significantly reduce the concentrations to less than 2,000 mg/l at the mouth of the Klamath River during the drawdown period. The majority of this material is expected to be released from January through March 2022, with continued lower sediment releases through June 2022.

3.1.2 Klamath River Annual Sediment Loads

The estimated annual sediment delivery to the Klamath River from Keno Dam to the Pacific Ocean under existing conditions was estimated at 5.8 million tons (Stillwater 2010). The three tributaries that contribute the largest amount of sediment to the lower Klamath are the Scott River (814 mi^2 source area), Salmon River (751 mi^2 source area), and the Trinity River (2,274 mi^2 source area). The Scott River supplies approximately 607,300 tons per year (10.4 percent of the total basin delivery downstream of Keno Dam), more than doubling the supply to the Klamath River at its confluence. The Salmon River supplies 320,600 tons per year (5.5 percent of the total basin delivery downstream of Keno Dam), increasing supply to the Klamath River by 22 percent at its confluence. Tributaries in the Lower-Middle Klamath River collectively increase the delivery by 4.7 percent. The Trinity River supplies 3,317,300 tons (56.9 percent of the total delivery downstream of Keno Dam), more than doubling the supply to the Klamath River at its confluence. The existing sediment discharging into the Pacific Ocean has a larger grain-size distribution with limited fine-grained silts and clays compared to the expected drawdown period sediment profile to be released to the river below Iron Gate Dam.

3.1.3 Estimated Sediment Load at Klamath River Mouth during Drawdown

During the drawdown period, sediment releases from the reservoirs will contribute from 1.4 to 3.2 million tons of additional material to the annual sediment loads of approximately 5.8 million tons to the Klamath River. The reservoir sediment material is predominately fine-grained and would be expected to remain suspended in the water column with minimal deposition in the Klamath River. The majority of this material would be expected to reach the Pacific Ocean. The annual sediment loading discharging from the Klamath River would be expected to increase by 24 to 54 percent during the drawdown period, depending on the amount of sediment that is evacuated from the reservoirs based on hydrology during the drawdown period. The maximum sediment release and potential impact will occur in the first year of the drawdown. Once the drawdown is completed, the sediment loads from upstream of Iron Gate Dam are expected to be a fraction of the total existing sediment load in the Klamath River.

3.1.4 Littoral Drift

The movement of the sediment as it leaves the Klamath River is an important factor in determining the potential impact of the increased sediment load on Crescent City Harbor during the drawdown period. Analysis of the movement of sand along the coastline under the influence of waves has been observed for many years. The concept of littoral cells or beach compartments is used as a key element in understanding these flow patterns and their impact on sand movement (Griggs 1987). The existence of littoral cells or beach compartments was first recognized in 1966 by Inman and Frautschy (1966). These cells are distinct segments of the coastline and include three elements: (1) a source or sources of sediment, (2) littoral transport, and (3) a sink or depositional site for sediment. Along the California coast, input from coastal streams and rivers is the dominant source of sediment, with cliff or bluff erosion, dredging of harbors, marinas, and offshore sands of the inner shelf serving as locally important sources, as well (Griggs 1987). Littoral transport mechanisms and direction vary along the coast, and in some locations, appear to seasonally reverse direction.

Crescent City Harbor lies in the lee of Point St. George, which is a rocky headland. To the north, littoral drift appears to move both north and south. To the south of the harbor, a few streams discharge, and farther south, the Klamath River enters the ocean. Sand produced from these sources appears to move downcoast away from the harbor (Griggs 1987).

In order to determine the impact to Crescent City Harbor during the dam removal and reservoir drawdown period, it will be important to confirm the sand movement patterns. If the predominant movement is to the south, then sediment deposition rates within the harbor would be expected to follow historic patterns. If the flow patterns are to the north, then delivery of the fine-grained material released from the reservoirs to the harbor will have to be evaluated.

KRRC will continue to research and evaluate currents and sediment transport in the vicinity of the mouth of the Klamath River. We will consult with (1) USGS (https://woodshole.er.usgs.gov/project-pages/sediment-transport), (2) USACE and USEPA per HOODS, and (3) the Yurok Tribe, as part of our due diligence associated with workplan implementation.

3.1.5 Annual Sediment Accumulation

In order to determine potential impacts of sediment deposition within the harbor, it is important to establish the monitoring period upon which the impact analysis will be based. As discussed previously, the dam removal and reservoir removal process will occur during one calendar year. The reservoir drawdown will be initiated in January 2023, with full dam removal achieved by November 2023. The reservoir drawdown will occur in two periods; the initial drawdown will occur between January 2023 and March 2023, and the final drawdown will occur between May 2023 and July 2023. The majority of sediment evacuation from the reservoirs is anticipated to occur during the initial drawdown period. The reservoirs will partially refill during the spring freshet, with the remaining sediment evacuation occurring during the second drawdown period between May and July. Following the spring freshet, the minimum flow release of 1,000 cfs from Iron Gate Dam during the final dam removal process will result in minimal sediment mobilization. The sediment transport analysis indicates that suspended sediment released from the reservoirs during the drawdown period would reach the ocean in approximately 14 to 21 days. Once the river flows decrease, the sediment movement will reduce as the riverbank floor and sides reach a stable condition.

Post-dam removal (post-drawdown period), sediment movement through the Project reach will occur with the spring freshet when the river flows and associated channel velocities are high enough to affect normal sediment transport mechanisms and drop off with the corresponding decrease in river flows. Similar sediment movement timing would occur in the Klamath River tributaries.

Considering both the drawdown and post-drawdown periods, sediment monitoring surveys at the harbor would be timed to follow the completion of the reservoir drawdown and subsequent spring freshet flow conditions. These surveys would be conducted in the fall. Annual surveys are anticipated in 2023, 2024 and 2025 to capture the drawdown and post-drawdown periods and subsequent spring freshet period and average annual deposition volumes.

4.0 Proposed Monitoring Program

4.1 General Approach

As outlined in the previous sections, KRRC's objective is to determine if the Project would result in an incremental increase in sediment deposition within Crescent City Harbor. The previous sections of this report presented data that can be used to establish the baseline condition upon which an evaluation of incremental impacts can be estimated. In order to determine the potential impact to Crescent City Harbor, the analysis would be focused on addressing the following questions.

1) What are the existing average shoaling and dredging sediment volumes and characteristics at the harbor?
2) What is the prevailing sediment movement pattern seen at along the coastline at Crescent City Harbor?
3) What are the estimated existing baseline sediment volumes and characteristics being discharged from the Klamath River under current conditions?
4) What are the estimated existing sediment volumes and characteristics being discharged from the Klamath River during the dam removal and drawdown period?
5) Does the discharged sediment move north from the mouth of the Klamath River to Crescent City Harbor and deposit within the harbor channels, and if so, what is the incremental impact over baseline conditions?
6) What monitoring measures are required to determine if sediment transport into the harbor is occurring, and to quantify the amount?
7) What mitigation measures are required to address potential increased sediment deposition within Crescent City Harbor during the reservoir dam removal and drawdown period?

An initial review of Questions 1, 2, 3, and 4 was presented in the previous sections. The baseline conditions for the channels can be established based on actual dredging data collected at Crescent City Harbor, as well as sediment modeling work completed for the Klamath River Dam Removal Project. The sediment characteristics were developed through active sediment sampling and testing at both the harbor and dam reservoirs. These data and information provide an adequate baseline upon which to address Questions 5, 6, and 7. Additional literature review on coastal flow patterns and field data collection and analysis is proposed to fully address the potential impact to Crescent City Harbor. The measures proposed to assist in the impact analysis are presented in the following section.

4.2 Proposed Measures

In order to quantify the potential impacts to Crescent City Harbor from the Project, KRRC is proposing to implement a series of measures designed to monitor the movement of sediment from the mouth of the Klamath River north toward Crescent City. Three measures are proposed to evaluate whether the sediment released from the reservoirs is (1) moving north from the mouth of the Klamath River to the harbor, (2) depositing in the harbor, and (3) if sediment deposition occurs, what percentage of the total sediment accumulation is from the dam reservoir drawdown sediment versus normal annual accumulation of sediment, which occurs independent of dam removal. The proposed measures would include the following:

- Measure 1: Establish Baseline Bathymetric and Topographic Survey Areas
- Measure 2: Conduct Current Monitoring during Drawdown
- Measure 3: Monitor Bathymetric and Topographic Survey Areas

A brief description of each of these proposed measures is presented in the following sections. KRRC and the County have agreed on an adaptive management approach for implementation of the monitoring measures. Adaptive management is a structured, iterative process of decision-making that considers new data as they become available. The objective of the adaptive management process is to implement the optimum program considering all factors, including drawdown period, hydrologic year, available resources, and cost. Final design and implementation of the monitoring plan measures will be determined by KRRC in close coordination with the County.

4.2.1 Measure 1: Establish Baseline Bathymetric and Topographic Survey Areas

The focus of Measure 1 is to establish baseline conditions for Crescent City Harbor. Baseline conditions will then be used to evaluate sediment accumulation, as detailed in Measure 3. Within Measure 1, multi-beam bathymetric surveys will be established at the locations listed below and depicted in Figure 2:

- Harbor (Area 1 in Figure 2)
- Inner Basin (Area 2 in Figure 2)
- Outer Basin (Area 3 in Figure 2)
- Marina Access Channel (Area 4 in Figure 2)
- Inner Harbor Basin Channel (Area 5 in Figure 2)
- Entrance Channel (Area 6 in Figure 2)

The bathymetric and topographic baseline surveys will be established in late summer or early fall of 2022. Survey data for each monitoring area will be used to develop a digital elevation model (DEM), which is a three-dimensional representation of a terrain's surface. The collected dataset for each area will be compared on a cell-by-cell basis using a GIS spatial analyst program to set the baseline condition for monitoring of the sediment deposition during the dam removal period.

Bathymetric and topographic survey data will be provided to the County for review within 2 weeks of completion of quality assurance and preparation of draft maps. Determination of baseline surfaces will be made in coordination with the County and associated reports, memos, and calculations will be provided to the County for review and comment prior to finalizing documents.

4.2.2 Measure 2: Conduct Current Monitoring During Drawdown

The primary focus of this measure is to assist in determining the sediment flow patterns exiting the Klamath River and to answer whether the sediment moves north, south, or directly out into the ocean upon discharging from the river. This measure consists of using acoustic doppler current profilers (ADCPs) mounted to buoys to determine current patterns during initial, peak, and terminal sediment deposition periods. An ADCP measures current speed at specified intervals over a water column up to 70 meters in depth. The instrument can be anchored to the seafloor or mounted to a vessel, such as a buoy.

At this time, we anticipate ADCP instruments will be attached to buoys and secured in an array, as depicted in Figure 3. The ADCP units should be placed in three rows between the mouth of the Klamath River and Crescent City Harbor. Approximate locations are summarized in the table below. Current monitoring locations are subject to change prior to implementation. All changes to monitoring station locations will be completed in coordination with the County.

Table 3. Proposed ADCP Equipped Buoy Locations

Station No.	Approximate Latitude (deg)	Approximate Longitude (deg)
1	41.524707	-124.160322
2	41.533235	-124.128613
3	41.539675	-124.102637
4	41.617272	-124.194723
5	41.626333	-124.160585
6	41.632653	-124.133581
7	41.704088	-124.210586
8	41.712113	-124.180159
9	41.716628	-124.160064

Data collected during the monitoring program can be stored within the ADCP unit and downloaded manually or set up for real-time monitoring, with data uploaded to a cloud database. Additional functionality can be added to the current monitoring, including echo sounding and turbidity monitoring. Detailed layout and design of the current monitoring and data acquisition system will be completed prior to implementation in coordination with the County. An example of the proposed technology used for this analysis can be found at https://www.whoi.edu/what-we-do/explore/instruments/instruments-sensors-samplers/acoustic-doppler-current-profiler-adcp/.

Upon completion of Measure 2, KRRC will transfer the buoys and associated equipment to the County of Del Norte for continued use in monitoring ocean currents.

4.2.3 Measure 3: Monitor Bathymetric and Topographic Survey Areas

If current monitoring under Measure 2 indicates sediment transport to Crescent City Harbor, survey areas established under Measure 1 will be monitored to evaluate net sediment deposition volumes. In order to effectively capture sediment deposition, an estimate of the travel time from Iron Gate Dam to the mouth of the river will be required to determine the appropriate time to initiate and complete survey monitoring. The sediment movement through the river will be heavily influenced by the hydrologic conditions during the drawdown year, river flow, the drawdown timing, and the level of sediment evacuation from the reservoir. Review of the reservoir drawdown hydraulic modeling and associated sediment modeling will provide an initial indication of the anticipated sediment movement and timing. This analysis was completed for a range of hydrologic years, so the estimated timeline can be tied to the anticipated hydrologic year during the drawdown period. Monitoring of the active water quality and flow measurement stations along the Klamath River will provide an assessment of real-time sediment movement from Iron Gate Dam to the mouth of the Klamath River. Water quality and flow measurement stations along the Klamath River are shown in Figure 4.

As discussed previously, it is anticipated that the reservoir sediment will be evacuated primarily in the 2023 drawdown year. The fine-grained material is expected to stay in solution and remain suspended as it moves down the Klamath River and out to the ocean. Sediment transport from the project reach during the post-drawdown period in 2024 is expected to be limited and will occur during the spring freshet period. Any impacts to the harbor would be expected to occur by the late fall of 2024. The sediment transport characteristics and remaining sediment in the reservoirs will be monitored during reservoir drawdown and for 1-year and 2-year post-drawdown to confirm the sediment transport assumptions and associated monitoring periods.

Four sets of data will be collected at each monitoring area; the first dataset will be collected approximately 1 month after peak discharge from the mouth of the Klamath River, the second dataset will be collected after completion of drawdown, the third dataset will be collected approximately 1 year post-drawdown, and the fourth data set will be collected approximately 2 years post-drawdown. Anticipated timing of data collection is provided in the Workplan (Appendix A).

The bathymetric and topographic survey data will be used to generate post-drawdown DEM surfaces and compared to baseline DEM surfaces to clearly indicate the change in sediment deposition. This information will provide both a graphical representation of the sediment deposition changes from the baseline through post-drawdown conditions and the net total sediment volume observed from the baseline through post-drawdown conditions for each monitoring area.

In order to assess impact to Crescent City Harbor, a threshold volume must be established. Based on discussions between the County and the KRRC team, an incremental increase of 25 percent will be used to define the threshold volume of sediment deposit. Threshold volume calculations for each monitoring area are described in the following sections. Example calculations for determination of impact within Crescent City Harbor channels and basin areas are provided in Appendix B.

4.2.3.1 Threshold Volume Calculation for Areas with Historic Dredging Data

The Entrance Channel, Inner Harbor Basin Channel, and Marina Access Channel have established historic dredge volumes, as discussed in Section 2.4. For the Entrance and Inner Harbor Basin Channels (Areas 5 and 6 in Figure 2), the estimated average annual dredged volume is 12,000 cubic yards. For the Marina Access Channel (Area 4 in Figure 2), the average dredged volume is 8,000 cubic yards. For purposes of impact determination, the total combined dredged volume of 20,000 cubic yards for the Entrance Channel, Inner Harbor Basin Channel, and Marina Access Channel will be used. The threshold volume for this area will be calculated as follows:

$$V_{Th} = V_{AA} + 0.25 * V_{AA}$$

where V_{Th} = Threshold Volume of Sediment, and
V_{AA} = Average Annual Dredged Volume

The threshold volume of sediment for the Entrance Channel, Inner Harbor Basin Channel, and Marina Access Channel is therefore 25,000 cubic yards.

Bathymetric and topographic survey data collected to support Measure 3 will be provided to the County for review within 2 weeks of completion of quality assurance and preparation of draft maps. Threshold volume calculations and associated reports or memos will be provided to the County for review and comment prior to finalizing.

4.2.3.2 Threshold Volume Calculation for Areas without Historic Dredging Data

The Harbor, Inner Basin, and Outer Basin (Areas 1, 2 and 3 in Figure 2) do not have established historic dredge volumes. Anticipated dredge volumes for these areas will be determined from the baseline survey completed in 2022. These surveys will be staggered by 12 months and completed prior to drawdown activities to provide an estimate of the anticipated annual sediment deposition. Threshold volume for these areas will be calculated as follows:

$$V_{Th} = V_A + 0.25 * V_A$$

where V_{Th} = Threshold Volume of Sediment, and
V_A = Annual Sediment Deposition Volume Measured during Baseline Monitoring Period

Bathymetric and topographic survey data collected to support Measure 3 will be provided to the County for review within 2 weeks of completion of quality assurance and preparation of draft maps. Threshold volume calculations and associated reports or memos will be provided to the County for review and comment prior to finalizing.

4.3 Workplan

A draft workplan that outlines the specific work activities, equipment, logistics, and protocols associated with implementation of each monitoring measure is presented in Appendix A. The workplan was developed assuming that the reservoir drawdown will occur in January 2023, with pre-drawdown work activities occurring in 2021 and 2022. This schedule assumes that KRRC will receive a FERC license transfer in 2021 and a license surrender by April 2022.

4.4 Documentation and Reporting

The recommended monitoring measures as presented within this report will be implemented as outlined in the draft workplan (see Appendix A). As discussed, measures may be fine-tuned prior to implementation as part of our adaptive management approach. Documentation of each measure will be completed by KRRC for the pre-drawdown, drawdown, and post-drawdown activities. Data collected for each measure will be provided to the County for review within 2 weeks of completion of quality assurance. If real-time monitoring of currents is determined to be the best approach, the County will be given access to the database. Documents summarizing work activities and/or the results of each measure will be provided to the County for review and comment prior to finalizing. The assessment of potential impacts will be prepared in draft form, reviewed with the County, and final impacts determined.

4.5 Impact Analysis

The monitoring measures outlined within this report will provide the required data collection and analysis to evaluate the impact to Crescent City Harbor. An impact to the harbor is defined as a threshold volume of sediment released from the dam reservoirs being transported to and deposited in the harbor. Threshold volumes are defined under Measure 3 (see Section 4.2.3). Impact to the harbor will be estimated as follows:

- **Step 1:** Determine if sediment released from the reservoirs is transported to Crescent City Harbor. This will be accomplished through a buoy array equipped with current meters (Measure 2). If current monitoring indicates transport to the harbor, proceed to Step 2. Otherwise, the impact analysis is complete, and a determination of No Impact is declared.
- **Step 2:** Compare the harbor baseline bathymetry to the post-drawdown bathymetry to determine the total volume of sediment deposited during the monitoring period. Bathymetric survey data will be used to develop a three-dimensional representation of the terrain's surface. A GIS spatial analyst program is then used to complete a cell-by-cell comparison of the two surfaces and calculate the net volume difference.
- **Step 3:** Compare the net volume of sediment deposited during the monitoring period to the established threshold volume for each monitoring area. If the net volume of sediment deposited during the monitoring period is greater than the threshold volume, proceed to Step 4. If the net volume of sediment deposited during the monitoring period is less than the threshold volume, the impact analysis is complete, and a determination of No Impact is declared.
- **Step 4:** Determine the mitigation requirements to address the sediment deposition directly attributed to the reservoir drawdown and associated sediment evacuation. Mitigation requirements are stipulated in the fully executed Memorandum of Understanding between the County and KRRC.

5.0 Conclusions and Recommendations

5.1 Conclusions

Review of the historical dredging data and analysis developed to support the Environmental Assessment for the 2019 dredging of the Crescent City Harbor was used to generate a baseline estimate of the anticipated annual shoaling and dredging quantities that could be expected at the harbor (USACE 2019). As a first step, active monitoring of the physical sediment plume exiting the mouth of the Klamath River, coupled with installation of current monitoring stations (see Figure 3), will indicate whether flow patterns are moving the sediment to the north or south. If sediment is moving toward the north, bathymetric surveys within the harbor itself will allow for estimating whether the rate of accumulation exceeds the threshold sediment volumes.

Table 4. Summary of Measure Application

Question No.	Description	Approach to Address
1	What is the existing average shoaling and dredging sediment volumes and characteristics at the harbor?	Existing data review and analysis
2	What is the prevailing sediment movement pattern seen along the coastline at Crescent City Harbor?	Review of existing data - Measure 2
3	What are the estimated existing average annual sediment volumes and characteristics being discharged from the Klamath River under current conditions?	Existing data review and analysis
4	What are the estimated existing sediment volumes and characteristics being discharged from the Klamath River during the dam removal and drawdown period?	Existing data review and Measures 1 and 2
5	Does the discharged sediment move north from the mouth of the Klamath River to Crescent City Harbor and deposit within the harbor channels, and if so, what is the incremental impact over baseline conditions?	Existing data review and Measures 1, 2, and 3
6	What monitoring measures are required, if any, to determine if sediment transport into the harbor is occurring, and if so, to quantify the amount?	Existing data review and Measures 1, 2, and 3
7	What mitigation measures are required, if any, to address potential increased sediment deposition within Crescent City Harbor during the reservoir dam removal and drawdown period?	Review and analysis of all measures and implementation of identified mitigation measures outlined in the MOU[a].

[a] Memorandum of Understanding Between the County of Del Norte, the Crescent City Harbor District and the Klamath River Renewal Corporation

5.2 Recommendations

This report provides a conceptual-level analysis of the baseline conditions at Crescent City Harbor and sediment loads currently discharging from the mouth of the Klamath River. An approach to confirming the baseline conditions prior to reservoir drawdown period and dam removal is presented. Additional measures are presented that would provide the ability to determine the flow patterns either north or south of the Klamath River during the drawdown period, and if moving north, the incremental impact, if any, of sediment deposition within Crescent City Harbor. Mitigation measures are developed and presented within the MOU based on the estimated incremental impact. A draft workplan was developed and is included in this report as Appendix A. The workplan clearly outlines the planning activities, pre-drawdown and drawdown work activities, and analysis procedures required to determine potential impacts to Crescent City Harbor. If it is determined that sediment is migrating from the reservoir downstream north to the harbor and has an incremental impact on sediment deposition in the Harbor, measures agreed upon by KRRC and the County in the MOU will be implemented to efficiently mitigate the issue.

6.0 References

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Figures

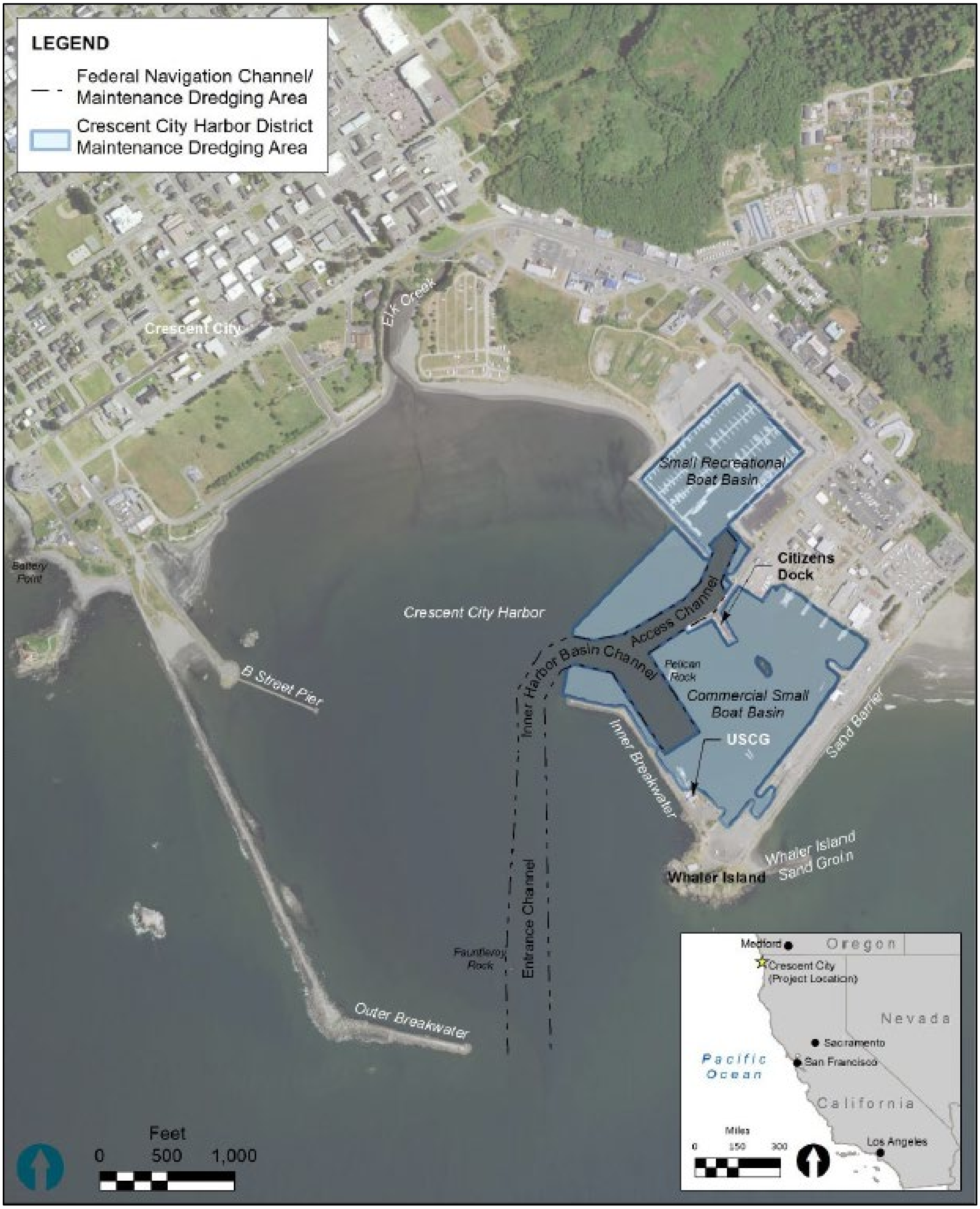

Figure 1. Crescent City Inner Harbor (after USACE 2019)

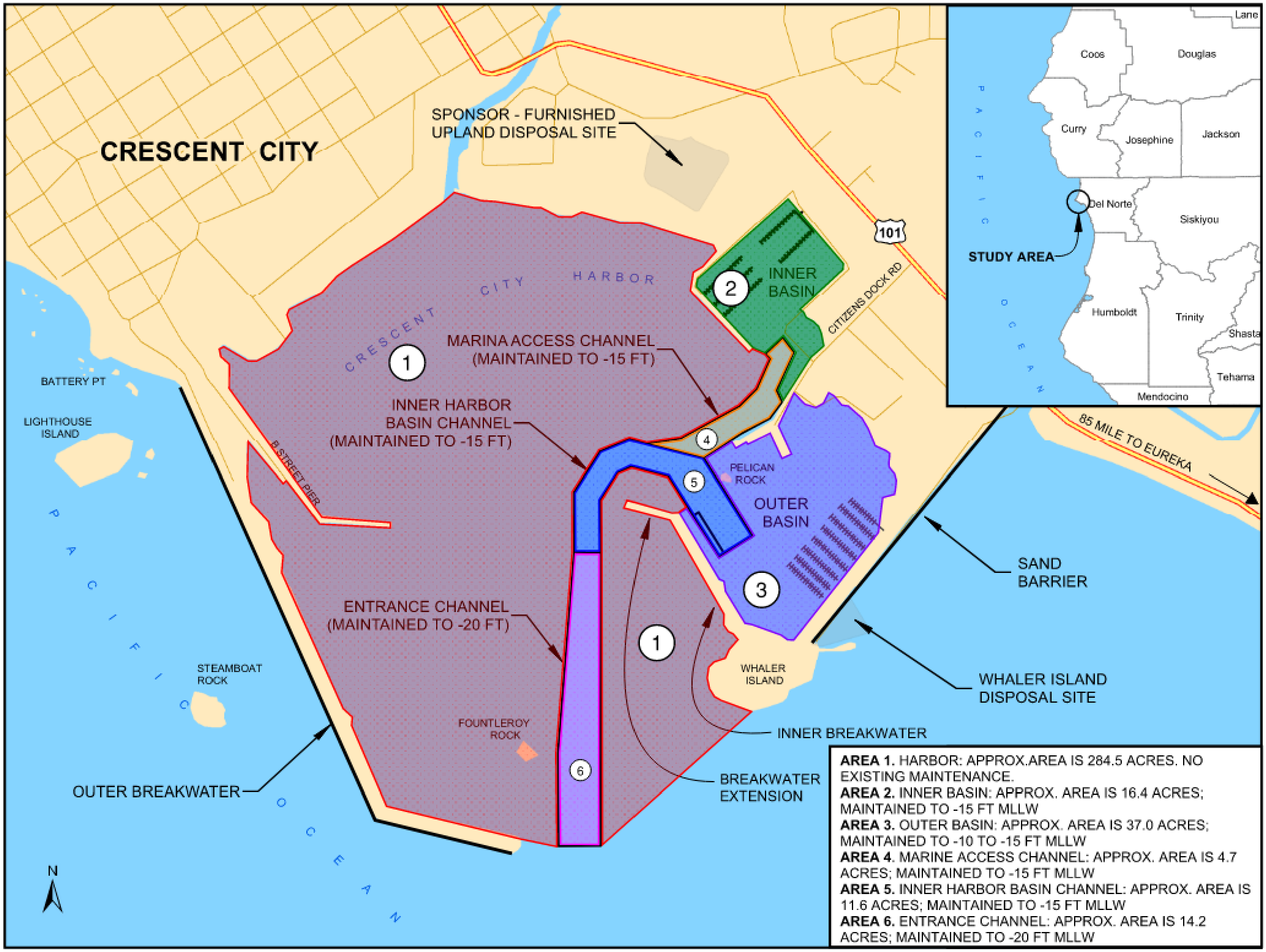

Figure 2. Bathymetric Survey Areas: Crescent City Harbor (after USACE 2019)

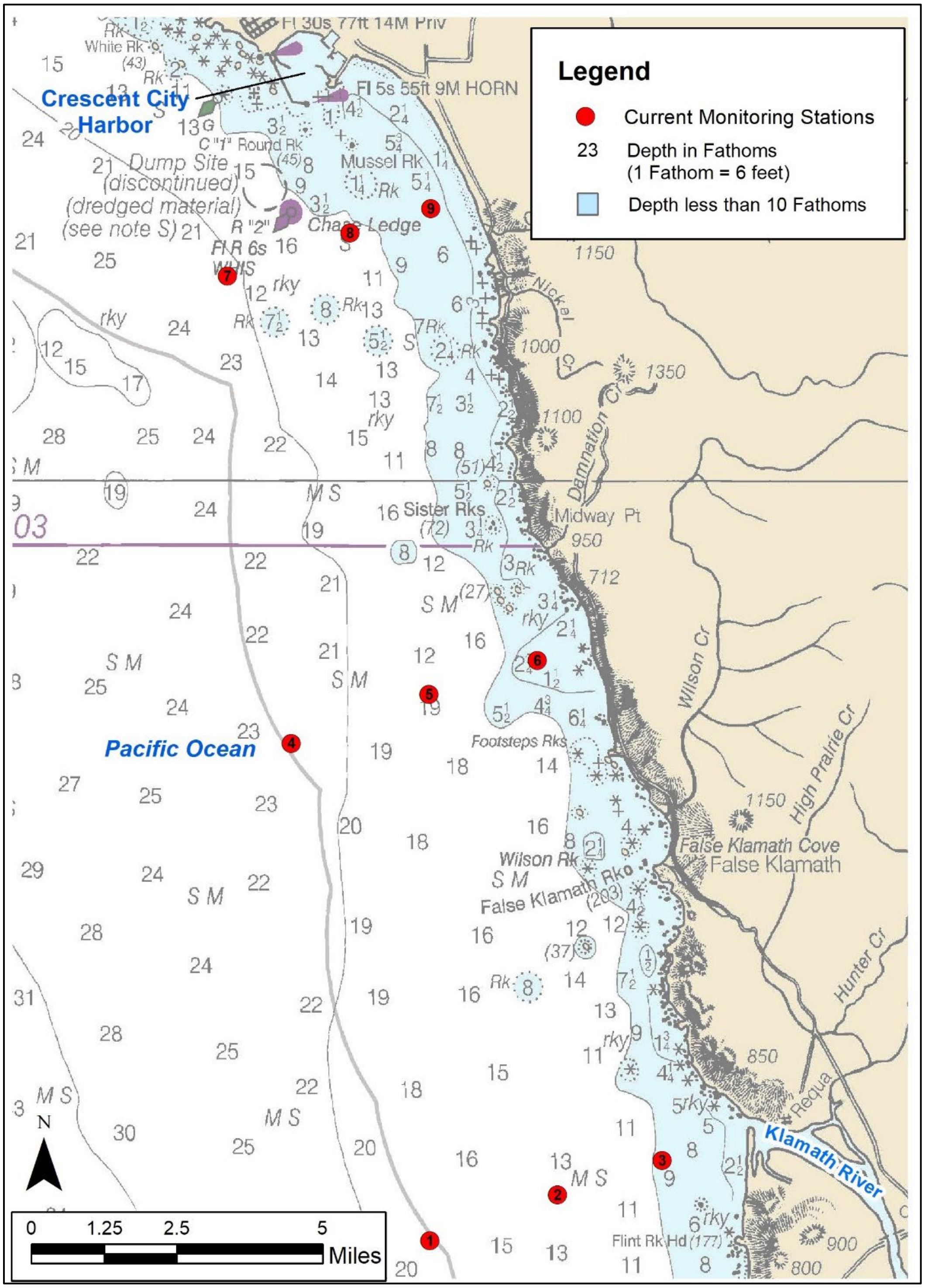

Figure 3. Current Monitoring Station Configuration (after NOAA Chart 18602)

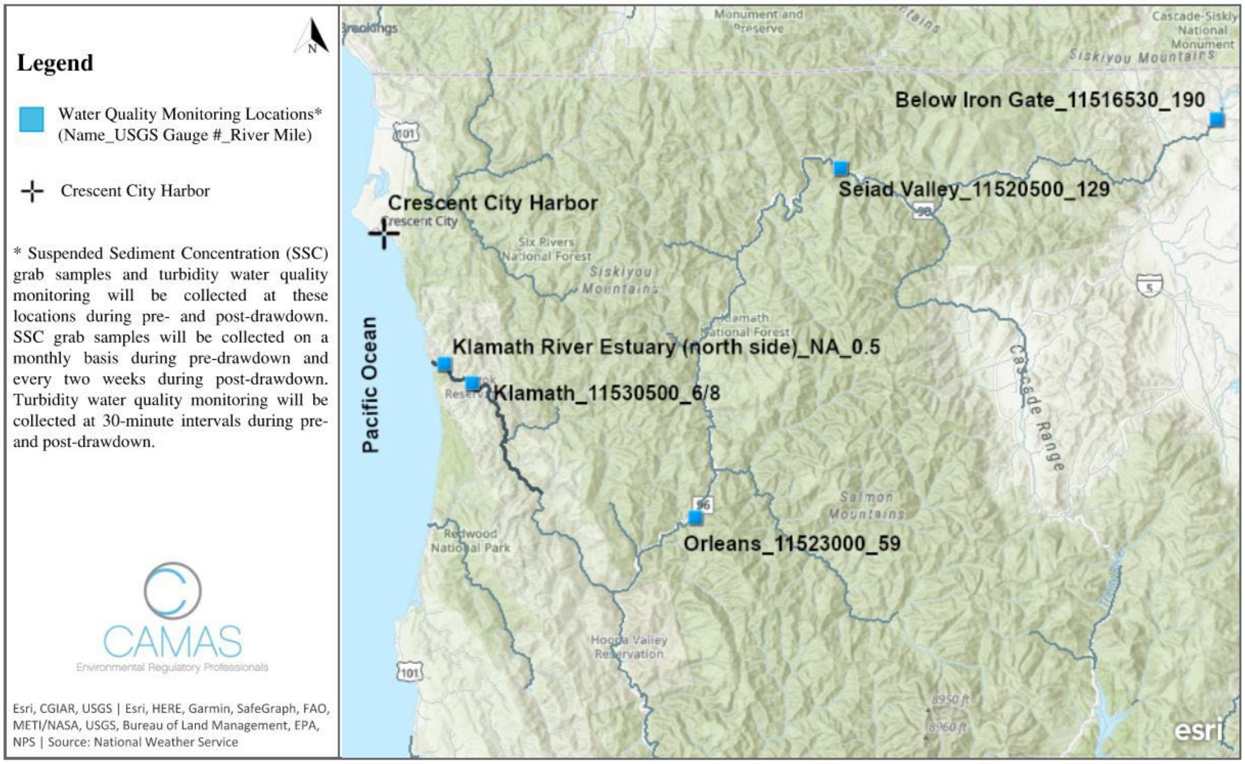

Figure 4. Monitoring Stations: Klamath River

APPENDIX A

Appendix A

Crescent City Harbor Monitoring Measures Workplan

Technical Memorandum

To:	Klamath River Renewal Corporation	Project:	Klamath River Renewal Project
From:	McMillen Jacobs Associates	cc:	File
Prepared by:	Mort McMillen Whitney Ciani	Job No.:	19-128
Date:	February 19, 2021		
Subject:	Crescent City Harbor Monitoring Measures Workplan		

Revision Log

Revision No.	Date	Revision Description
0	May 28, 2020	Draft document for client review
1	June 17, 2020	Draft document for client review
2	July 1, 2020	Internal Review Draft. Subject to change, not binding on KRRC
3	July 10, 2020	Final
4	December 2020	Final Rev 1
5	February 19, 2021	Final Rev 2

1.0 Introduction

1.1 Purpose

The purpose of this memorandum is to present the draft workplan for implementing the sediment monitoring measures designed to quantify the potential impacts of sediment releases from the Klamath River Dam Removal Project (Project) on Crescent City Harbor.

1.2 Scope

The draft workplan provides the general approach, work activities, and requirements for implementing measures for monitoring and determining the effect of sediment releases from the Project during the drawdown period on Crescent City Harbor. The draft workplan outlines the work activities, milestone schedule, and preliminary logistics associated with each monitoring measure, as well as the basic process for determining if Crescent City Harbor is impacted by sediment releases from the Project.

1.3 Background

The dam removal and reservoir drawdown planned with the Project will release sediment from the reservoirs into the Klamath River below Iron Gate Dam. The reservoir sediment is primarily fine-grained silts and clays and is expected to be carried by the Klamath River flows from Iron Gate Dam to the

Pacific Ocean, with minimal deposition in the river itself. Depending on whether wet, dry, or average river flow conditions occur during the drawdown period, the amount of sediment released from the reservoir is estimated to vary from 1.4 to 3.2 million tons. This additional sediment load represents an approximate increase of 24 to 55 percent over the average annual Klamath River sediment discharge of 5.83 million tons. The County of Del Norte (County) has raised concerns about potential increased sediment deposition in Crescent City Harbor due to the increased river sediment loads during the reservoir drawdown. Measures to evaluate and monitor sediment deposition within the harbor have been requested.

1.4 Reference Document

A more detailed description of the monitoring measures and background is presented in the document titled "Crescent City Harbor Sediment Monitoring Measures" prepared by McMillen Jacobs Associates for the Klamath River Renewal Corporation, July 9, 2020.

2.0 General Approach

2.1 Approach

The monitoring measures were developed as individual components of an overall sediment monitoring workplan. The measures are intended to provide a systematic approach to determining the sediment transport flow patterns from the mouth of the Klamath River, either north, south, or west to the ocean. If the sediment is determined to be moving north, the amount of sediment that may be transported and deposited in Crescent City Harbor will be estimated. The monitoring measures and corresponding analysis are designed to quantify the impact of sediment released as part of the Project. The workplan presents the specific implementation activities associated with each measure during the pre-drawdown, drawdown, and post-drawdown periods. The data collected from the monitoring measures will then be used to estimate the sediment impact on the harbor. The procedure for determining the impact is presented at the end of this workplan.

2.2 FERC Timeline

The draft workplan implementation activities, requirements, and timelines are based on an assumed Project FERC license transfer to KRRC in 2020 and a subsequent FERC license surrender by KRRC in April 2021. The Project reservoir drawdown and dam removal would then be initiated in January 2022. All project permits are required to be in place by June 2021 to support the Project execution. If the FERC license transfer and surrender process is delayed, then an adjustment to this workplan will be required to reflect the modified schedule.

2.3 Monitoring Measures

In order to quantify the potential impacts to Crescent City Harbor from the Project, KRRC is proposing to implement a series of measures designed to monitor the movement of sediment from the mouth of the Klamath River north toward Crescent City. Several measures are proposed to evaluate whether the sediment released from the reservoirs is (1) moving north from the mouth of the Klamath River to the harbor, (2) depositing in the harbor, and (3) if sediment deposition occurs, what percentage of the total sediment accumulation is from the dam reservoir drawdown sediment versus normal annual accumulation of sediment that occurs independent of dam removal. The proposed measures include the following:

- Measure 1: Establish Baseline Bathymetric and Topographic Survey Areas
- Measure 2: Conduct Current Monitoring during Drawdown
- Measure 3: Monitor Bathymetric and Topographic Survey Areas

These measures will be implemented to provide a systematic method for evaluating the potential impact of the Project on sediment transport and deposition at Crescent City Harbor. Implementation of the measures will be during one or all of three monitoring periods, as noted in Table 1.

Table 1. Crescent City Harbor Sediment Monitoring Periods

Period No.	Description	Anticipated Schedule
1	Pre-drawdown	1/2022 to 12/2022
2	Drawdown	1/2023 to 12/2024
3	Post-drawdown	1/2025 to 12/2026

Note: The schedule is dependent on the FERC license transfer and surrender schedule. A delay in the FERC schedule will result in a delay in the implementation of the monitoring measures schedule.

These three work periods are incorporated into the workplan presented in the next section. In general terms, activities that will occur in the pre-drawdown work period are intended to provide an estimate of the baseline conditions that exist at the monitoring locations. Baseline conditions will be informed by long-term trends in coastal erosion and accretion and by seasonal fluctuations in shoreline position, with the understanding that surveyed conditions represent a snapshot in time of an otherwise dynamic system and that surveyed data may need adjustment, as appropriate. Activities associated with this work effort include estimating existing levels of sediment deposition at Crescent City Harbor, the volume of sediment transport and deposition prior to Project implementation, and the volume of sediment transport and deposition resulting from Project implementation. The drawdown period refers to the period when the reservoir water level will be lowered, with a corresponding sediment evacuation from the reservoirs. The work activities during the drawdown period are intended to monitor the sediment transport from the Klamath River at the mouth of the Klamath River and deposition of sediment at the Crescent City Harbor. At the end of this work period, the dams will be fully removed, with free-flowing river and volitional fish passage conditions within the river reach from J.C. Boyle Dam downstream to Iron Gate Dam. The post-drawdown period consists of the period immediately following dam removal. Monitoring measures proposed for this period would only be implemented if required to provide additional data for determining impacts to Crescent City Harbor.

3.0 Workplan

3.1 General Organization

The workplan was developed to provide a logical, sequenced organization of the proposed work activities. A specific workplan is presented for each monitoring measure using a tabular format that identifies the specific work task, the timeline, and anticipated review process with the County. The work activities are presented in the three proposed work periods, as previously described. A summary of the anticipated logistics required to implement the monitoring measure is also presented in Table 2. Additional details related to specialized subcontractor information, proposed equipment, KRRC staff and subconsultants, and identified County staff will be included in the final workplan, developed with full review from the County in the months prior to actual implementation.

3.1.1 Measure 1: Establish Bathymetric and Topographic Survey Areas

The focus of Measure 1 is to establish baseline conditions for Crescent City Harbor. Baseline conditions will then be used to evaluate sediment accumulation, as detailed in Measure 3. Within Measure 1, multi-beam bathymetric surveys will be established at the locations listed below and depicted in Figure 2:

- Harbor (Area 1 in Figure 2)
- Inner Basin (Area 2 in Figure 2)
- Outer Basin (Area 3 in Figure 2)
- Marina Access Channel (Area 4 in Figure 2)
- Inner Harbor Basin Channel (Area 5 in Figure 2)
- Entrance Channel (Area 6 in Figure 2)

The bathymetric and topographic surveys will be established in late summer or early fall of 2022. Survey data for each monitoring area will be used to develop a digital elevation model (DEM), which is a three-dimensional representation of a terrain's surface. The collected dataset for each area will be compared on a cell-by-cell basis using a GIS spatial analyst program to set the baseline condition for monitoring of the sediment deposition during the dam removal period.

Measure 1 will be completed within the pre-drawdown period, as outlined below.

Table 2. Measure 1 Pre-Drawdown Period Work Activities and Schedule

Task	Description	Schedule[a]	
		Start	Finish
1	Update Workplan	7/6/2020	7/20/2020
2	County Review	7/21/2020	7/31/2020
3	Issue Final Workplan	8/3/2020	8/7/2020
4	Issue Bathymetry/Topographic Survey Subcontract	8/3/2020	8/7/2020
5	Complete Baseline Field Survey	8/10/2020	10/2/2020
6	Office Data Analysis	10/5/2020	10/16/2020
9	Prepare Draft Baseline Memo	10/25/2021	10/29/2021
10	County Review	11/1/2021	11/12/2021
11	Prepare Final Baseline Memo	11/15/2021	11/19/2021

[a] The pre-drawdown measurements will occur in 2022 to support establishing the baseline sediment transport and deposition levels.

Table 3. Measure 1 Equipment and Logistics

Period	Pre-drawdown, Drawdown, Post-Drawdown
KRRC Key Staff	To be determined
Subcontractors	Bathymetric survey contractor - TBD
	Topographic survey contractor - TBD
Specialized Equipment	Multi-beam bathymetric survey equipment
- Multi-beam bathymetric survey	TBD
Field Access Required	
- Crescent City Harbor	Boat access for bathymetric survey
Health and Safety Planning	McMillen Jacobs Health and Safety Plan
- Bathymetric Survey	Boat and Marine Work

3.1.2 Measure 2: Conduct Current Monitoring During Drawdown

The primary focus of this measure is to assist in assessing the sediment flow patterns exiting the Klamath River and to determine whether the sediment moves north, south, or directly west into the ocean upon discharging from the river. This measure consists of using acoustic doppler current profilers (ADCPs) mounted to buoys to determine current patterns during initial, peak, and terminal sediment deposition periods. An ADCP measures current speed at specified intervals over a water column up to 70 meters in depth. The instrument can be anchored to the seafloor or mounted to a vessel, such as a buoy.

At this time, we anticipate ADCP instruments will be attached to buoys and secured in an array as depicted in Figure 3. The ADCP units should be placed in three rows between the mouth of the Klamath River and Crescent City Harbor. Approximate locations are summarized in the table below. All buoys would be placed within 0.75 miles of the shoreline between the mouth of the Klamath River and Crescent

City Harbor. The final location of the monitoring buoys will be determined based on research and discussion with industry experts, USGS representatives familiar with the Klamath River and coastal flow conditions, and County technical representatives.

Table 4. Proposed ADCP Equipped Buoy Locations

Station No.	Approximate Latitude (deg)	Approximate Longitude (deg)
1	41.524707	-124.160322
2	41.533235	-124.128613
3	41.539675	-124.102637
4	41.617272	-124.194723
5	41.626333	-124.160585
6	41.632653	-124.133581
7	41.704088	-124.210586
8	41.712113	-124.180159
9	41.716628	-124.160064

Data collected during the monitoring program can be stored within the ADCP unit and downloaded manually or set up for real-time monitoring, with data uploaded to a cloud database. Additional functionality can be added to the current monitoring, including an echo sounding and turbidity monitoring. Detailed layout and design of the current monitoring and data acquisition system will be completed prior to implementation in coordination with the County. An example of the proposed technology used for this analysis can be found at https://www.whoi.edu/what-we-do/explore/instruments/instruments-sensors-samplers/acoustic-doppler-current-profiler-adcp/.

Upon completion of Measure 2, KRRC will transfer the buoys and associated equipment to the County of Del Norte for continued use in monitoring ocean currents.

Table 5. Measure 2 Drawdown Period Work Activities and Schedule

Task	Description	Schedule	
		Start	Finish
1	Update Workplan	10/11/2021	11/5/2021
2	County Review	11/8/2021	11/19/2021
3	Issue Final Workplan	11/22/2021	12/3/2021
4	Mobilize ADCP Monitoring Equipment	12/27/2021	12/31/2021
5	Monitor River Monitoring Stations and Drawdown	1/3/2022	7/8/2022
6	Complete Current Monitoring with Bi-Monthly Data Collection	1/3/2022	7/29/2022
7	Bi-Monthly Current Monitoring Data Analysis	1/17/2022	7/29/2022
8	Final Data Analysis and Map Preparation	8/1/2022	9/9/2022
9	Prepare Draft Memo	9/12/2022	9/23/2022
10	County Review	9/26/2022	10/7/2022
11	Prepare Final Memo	10/10/2022	10/21/2022

Table 6. Measure 2 Equipment and Logistics

Period	Drawdown
KRRC Key Staff	TBD
Subcontractors	ADCP Current Monitoring Equipment - TBD
Specialized Equipment	
- ADCP Instruments	TBD
- Buoys	TBD
Field Access Required	
- Mouth of Klamath River	Boat access for placement and monitoring of buoys
Health and Safety Planning	McMillen Jacobs Health and Safety Plan
- Current Monitoring	Boat and Marine work

3.1.3 Measure 3: Monitor Bathymetric and Topographic Survey Areas

If current monitoring under Measure 2 indicates sediment transport to Crescent City Harbor, survey areas established under Measure 1 will be monitored to evaluate net sediment deposition volumes. Four sets of data will be collected at each monitoring area; the first dataset will be collected approximately 1 month after peak discharge from the mouth of the Klamath River, the second dataset will be collected after completion of the drawdown period, the third dataset will be collected approximately 1 year post-drawdown, and the fourth data set will be collected approximately 2 years post-drawdown.

The bathymetric and topographic survey data will be used to generate post-drawdown DEM surfaces and compared to baseline DEM surfaces to clearly indicate the change in sediment deposition. This information will provide both a graphical representation of the sediment deposition changes from the baseline through post-drawdown conditions and the net total sediment volume observed from the baseline through post-drawdown conditions for each monitoring area.

In order to assess impact to Crescent City Harbor, a threshold volume must be established for each monitoring location. Based on discussions between the County and the KRRC team, an incremental increase of 25 percent will be used to define the threshold volume of sediment deposit. Threshold volume calculations for each monitoring area are described in the following sections.

Bathymetric and topographic survey data collected to support Measure 3 will be provided to the County for review within 2 weeks of completion of the quality assurance and preparation of draft maps. Threshold volume calculations and associated reports or memos will be provided to the County for review and comment prior to finalizing.

Table 7. Measure 3 Post-Drawdown Year 1 Work Activities and Schedule

Task	Description	Schedule	
		Start	Finish
1	Office Data Analysis	10/5/2023	10/30/2023
2	Update Memo to Include Year 1 Drawdown Period Data	11/2/2023	11/6/2023
3	County Review	11/9/2023	11/20/2023

Table 8. Measure 3 Post-Drawdown Year 2 Work Activities and Schedule

Task	Description	Schedule	
		Start	Finish
1	Office Data Analysis		
2	Update Memo to Include Year 2 Drawdown Period Data		
3	County Review		
4	Prepare Final Memo		

3.1.3.1 Threshold Volume Calculation for Areas with Historic Dredging Data

The Entrance Channel, Inner Harbor Basin Channel, and Marina Access Channel have established historic dredge volumes, as discussed in Section 2.4 of the Proposed Monitoring Measures Memorandum. For the Entrance and Inner Harbor Basin Channels (Areas 5 and 6 in Figure 2), the estimated average annual dredged volume is 12,000 cubic yards. For the Marina Access Channel (Area 4 in Figure 2), the average dredged volume is 8,000. For purposes of impact determination, the total combined dredged volume of 20,000 cubic yards for the Entrance Channel, Inner Harbor Basin Channel, and Marina Access Channel will be used. The threshold volume for this area will be calculated as follows:

$$V_{Th} = V_{AA} + 0.25 * V_{AA}$$

where V_{Th} = Threshold Volume of Sediment, and
V_{AA} = Average Annual Dredged Volume

The threshold volume of sediment for the Entrance and Inner Harbor Basin Channels is therefore 25,000 cubic yards.

3.1.3.2 Threshold Volume Calculation for Areas without Historic Dredging Data

The Harbor, Inner Basin, and Outer Basin (Areas 1, 2, and 3 in Figure 2) do not have established historic dredge volumes. Anticipated dredge volumes for these areas will be determined from the baseline surveys completed in 2022. These surveys will be staggered by 12 months and completed prior to drawdown activities to provide an estimate of the anticipated annual sediment deposition. Threshold volume for these areas will be calculated as follows:

$$V_{Th} = V_A + 0.25 * V_A$$

where V_{Th} = Threshold Volume of Sediment, and
V_A = Annual Sediment Deposition Volume over Baseline Monitoring Period

4.0 Documentation

A database will be developed at the initiation of the sediment monitoring plan implementation. The database will be organized by monitoring measure, with sub-directories set up for each monitoring phase (pre-drawdown, drawdown, and post-drawdown). At the completion of each reservoir drawdown phase, the data will be analyzed and presented in memorandums prepared for each monitoring measure. The pre-drawdown work will be used to develop the baseline conditions for the sediment transport and deposition, upon which sedimentation during the drawdown and post-drawdown periods will be compared.

5.0 Impact Analysis

5.1 Monitoring Measure Analysis

The sediment monitoring measures are designed to collect data that will be used to establish the baseline conditions present prior to the Project drawdown and post-drawdown conditions. The pre-drawdown measures use bathymetric and topographic survey and review of existing data to determine the baseline conditions. The primary focus of these initial measures is to establish the anticipated sediment transport flow patterns at the mouth of the Klamath River, the existing sediment deposition levels at the harbor, and the sediment characteristics in terms of sediment gradation, geologic source, and chemical composition.

During drawdown, current monitoring and turbidity monitoring will be used to characterize the flow patterns and associated sediment transport exiting the mouth of the Klamath River. Table 8 presents a summary of the measures, providing a sequenced impact evaluation.

Review of the historical dredging data and analysis developed to support the Environmental Assessment for the 2019 dredging of Crescent City Harbor provides a baseline estimate of the anticipated annual shoaling and dredging quantities that could be expected at the harbor (USACE 2019). As a first step, active monitoring of the physical sediment plume exiting the mouth of the Klamath River, coupled with installation of current monitoring stations (See Figure 3), will indicate whether flow patterns are moving the sediment to the north or south. If sediment is moving toward the north, bathymetric surveys within the harbor itself will allow for estimating whether the rate of accumulation exceeds the threshold sediment volumes.

Table 9. Summary of Measure Application

Question No.	Description	Approach to Address
1	What is the existing average shoaling and dredging sediment volumes and characteristics at the harbor?	Existing data review and analysis
2	What is the prevailing sediment movement pattern seen along the coastline at Crescent City Harbor?	Review of existing data - Measure 2
3	What are the estimated existing average annual sediment volumes and characteristics being discharged from the Klamath River under current conditions?	Existing data review and analysis
4	What are the estimated existing sediment volumes and characteristics being discharged from the Klamath River during the dam removal and drawdown period?	Existing data review and Measures 1 and 2
5	Does the discharged sediment move north from the mouth of the Klamath River to Crescent City Harbor and deposit within the harbor channels, and if so, what is the incremental impact over baseline conditions?	Existing data review and Measures 1, 2, and 3
6	What monitoring measures are required, if any, to determine if sediment transport into the harbor is occurring, and if so, to quantify the amount?	Existing data review and Measures 1, 2, and 3
7	What mitigation measures are required, if any, to address potential increased sediment deposition within Crescent City Harbor during the reservoir dam removal and drawdown period?	Review and analysis of all measures and implementation of identified mitigation measures outlined in the MOU[a].

[a] Memorandum of Understanding Between the County of Del Norte, the Crescent City Harbor District and the Klamath River Renewal Corporation

5.2 Impact Determination

The monitoring measures outlined within this memorandum will provide the required data collection and analysis to evaluate the impact to Crescent City Harbor. An impact to the harbor is defined as a threshold volume of sediment released from the dam reservoirs being transported to and deposited in the harbor. Threshold volumes are defined under Measure 3. Impact to the harbor will be estimated as follows:

- **Step 1:** Determine if sediment released from the reservoirs is transported to Crescent City Harbor. This will be accomplished through a buoy array equipped with current meters (Measure

2). If current monitoring indicates transport to the harbor, proceed to Step 2. Otherwise, the impact analysis is complete, and a determination of No Impact is declared.

- **Step 2:** Compare the harbor baseline bathymetry to the post-drawdown bathymetry to determine the total volume of sediment deposited during the monitoring period. Bathymetric survey data will be used to develop a three-dimensional representation of the terrain's surface. A GIS spatial analyst program is then used to complete a cell-by-cell comparison of the two surfaces and calculate the net volume difference.
- **Step 3:** Compare net volume of sediment deposited during the monitoring period to the established threshold volume for each monitoring area. If the net volume of sediment deposited during the monitoring period is greater than the threshold volume, proceed to Step 4. If the net volume of sediment deposited during the monitoring period less than the threshold volume, the impact analysis is complete, and a determination of No Impact is declared.
- **Step 4:** Determine the mitigation requirements to address the sediment deposition directly attributed to the reservoir drawdown and associated sediment evacuation. Mitigation requirements are stipulated in the fully executed Memorandum of Understanding between the County and KRRC.

The review process presented in Table 9, along with the sediment deposition analysis, will be summarized in a technical report, including support data, calculations, and maps.

APPENDIX B

Appendix B

Example Calculation for Impact Analysis

CRESCENT CITY HARBOR IMPACT DETERMINATION SAMPLE CALCULATION

EXAMPLE 1: MONITORING AREA: ENTRANCE CHANNEL, INNER HARBOR BASIN CHANNEL, AND MARINA ACCESS CHANNEL

1. Collect baseline survey data and generate baseline DEM surface
2. Collect post-drawdown survey data and generate post-drawdown DEM surface
3. Overlay baseline and post-drawdown DEM surface to calculate total sediment accumulation volume.
4. Calculated sediment volume (VPD) is 30,000 cubic yards

$$\mathrm{VPD} := 30000$$

5. Calculate Percent Accumulation (PAcc) over Threshold Volume (VTh)

$$\mathrm{VTh} := 25000$$

$$\mathrm{PAcc} := \frac{(\mathrm{VPD} - \mathrm{VTh})}{\mathrm{VTh}}$$

$$\mathrm{PAcc} = 0.2$$

= 20%

6. Percent Accumulation used to define the percent contribution KRRC pays for dredging costs, as detailed in the MOU.