2023 Geomorphology Observations

Amendment to Bradley Lake Hydroelectric Project
(FERC No. 8221)

Proposed Dixon Diversion

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February 2024

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1.0 INTRODUCTION

The Alaska Energy Authority (AEA) is pursuing a Federal Energy Regulatory Commission (FERC) license amendment associated with the existing 120-megawatt (MW) Bradley Lake Hydroelectric Project (Bradley Lake Project, FERC No. P-8221). The Bradley Lake Project is located on the Bradley River in the Kenai Peninsula Borough northeast of the town of Homer in Southcentral Alaska. The purpose of the proposed amendment is to gain authorization to divert seasonal meltwater coming from Dixon Glacier, located in the Martin River basin, to Bradley Lake and to increase the maximum pool elevation of the Bradley Lake impoundment to increase power production at the Bradley Lake Project (Figure 1-1).

On April 27, 2022, AEA initiated the amendment process by filing its Initial Consultation Document (ICD) with FERC (18 Code of Federal Regulations [CFR] § 4.38). The ICD described existing facilities and current Bradley Lake Project operation; characterized the affected environment; and described the proposed Dixon Diversion project alternatives. AEA conducted consultation during 2022 and on November 2, 2022, submitted a Draft Study Plan (DSP) describing the studies to be conducted to collect relevant resource data associated with the proposed amendment. On March 2023, AEA filed a letter with FERC pausing the amendment process while the agency conducted additional feasibility analyses, collected Martin River hydrology data, and refined the selected Dixon to Bradley Lake alternative. During 2023, AEA conducted field reconnaissance and collected data related to geomorphology and DSP Section 4.5 Hydraulic Modeling, Geomorphology, and Aquatic Habitat Connectivity Evaluation study. This 2023 Geomorphology Observations report describes the 2023 data collection and analysis associated with the geomorphology and sediment transport study for the proposed Dixon Diversion Amendment.

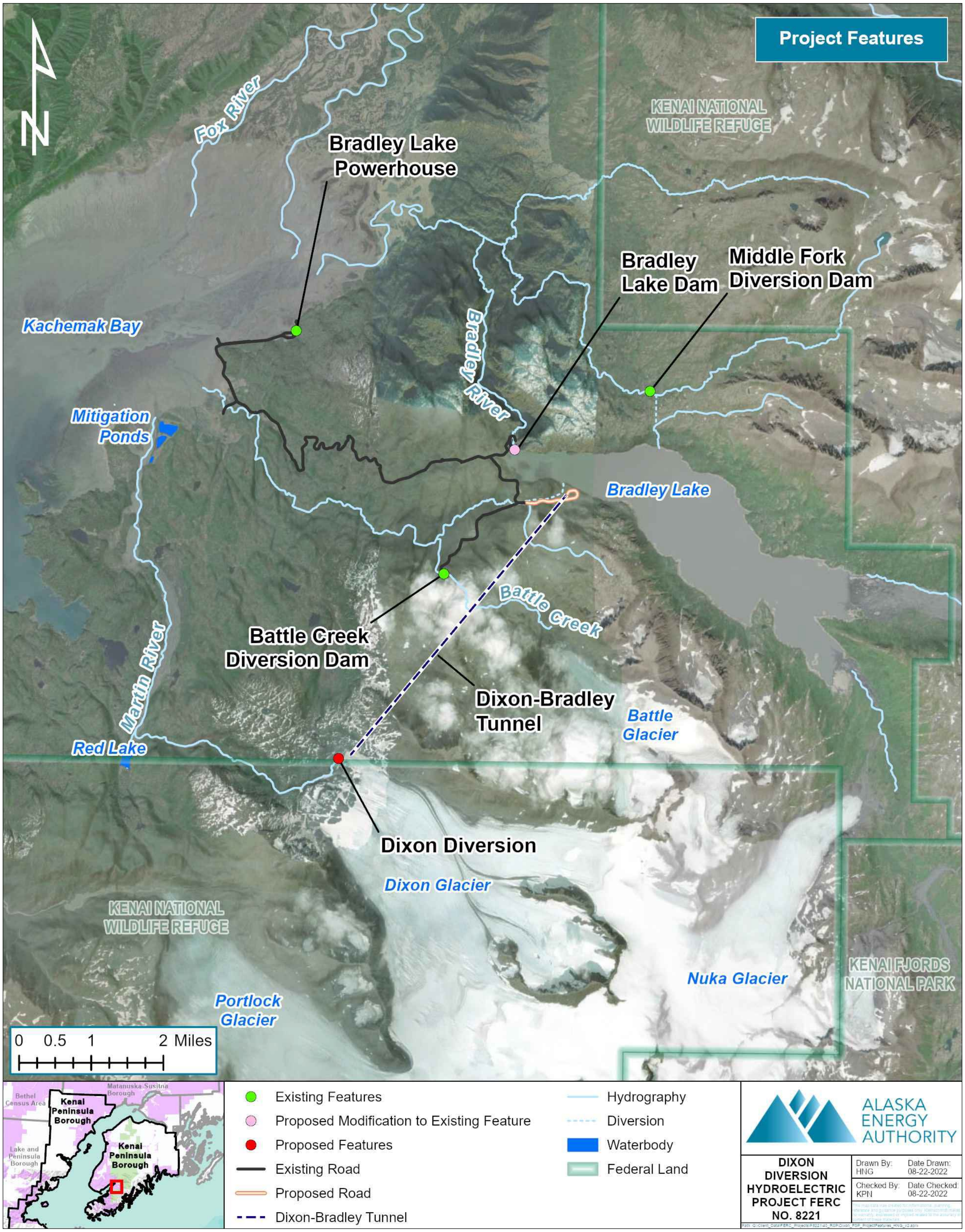

Figure 1-1 Location of Proposed Dixon Diversion Project near Kachemak Bay, Alaska

1.1 Geomorphology Study Goals and Objectives

The East Fork Martin River (EFMR) flows from the Dixon Glacier through a high-gradient canyon to the confluence with the West Fork Martin River (WFMR), where it forms the Martin River which flows through a lower-gradient, very dynamic glacial outwash plain to Kachemak Bay. The Dixon Glacier supplies a large amount of sediment to the river and includes material from boulder to clay size. This material is transported through the EFMR canyon reach and then deposited in the Martin River outwash plain as the valley widens and water velocity drops, forming a braided river pattern. Initial observations of the outwash plain show several distinct geomorphic reaches where the adjacent bedrock valley walls provide for a wide valley or narrower pinch points. Substrate generally fines in a downstream direction, and vegetation patterns in the wider valley areas suggest long-term aggradation consistent with a pro-glacial stream environment.

The geomorphology and sediment transport analysis outlined in DSP Section 4.5 will analyze available historic aerial photograph and LiDAR data as well as collect current information on substrate size and analyze potential future sediment transport and accumulation trends based on output from the 2D hydraulic model that will be completed as part of DSP Section 4.5 (Kleinschmidt 2022). The DSP lists eight geomorphology and sediment transport tasks. This 2023 Geomorphology Observations Report includes information obtained to date on four of the tasks, listed below.

1. Segment the Martin River into geomorphic analysis reaches based on confinement, degree of braiding, and gradient.
2. Delineate past changes to Martin River, adjacent forest community growth/destruction patterns (resulting from channel migration), and stream/pond connectivity through time using historic aerial photographs (1984 through present are available, possibly older series as well).
3. Map degree of channel braiding in each reach of Martin River through time to determine past changes to braiding patterns in each geomorphic reach. This step will help to determine expected future variability in braiding patterns.
4. Collect pebble count data and sub-surface samples during low flow conditions in each geomorphic reach.

In addition, the report includes the analysis of timelapse camera footage that documents changes in braided channel reaches and geomorphic observations made during and following the August 2023 breach of the right bank levee near the mouth of the river which diverted the river into the right bank mitigation ponds. Data collection and analysis to complete DSP Section 4.5 will take place in 2024-2025.

2.0 METHODS

2.1 Geomorphic Reach Mapping and Historic Aerial Photograph Observations

The Martin River valley was delineated into geomorphic reaches and map units based on confinement, channel/off-channel connectivity, and vegetation characteristics visible using the 2022 LiDAR and aerial photography (Table 2-1; NV5 2023). The valley was defined as the relatively flat valley bottom areas within the steeper side slopes. Mapping extended from the mouth of the Martin River to approximately 0.5 miles upstream of the EF Martin River canyon (approximately EFMR River Mile (RM) 0.5) and from the mouth of the WFMR upstream of Red Lake. The initial mapping was field checked during the May 2023 field visits (see Section 2.2) and adjusted as needed based on field observations. Observations of channel conditions shown in 1950 through 2023 historic aerial and satellite imagery were made to help determine the aggradation and channel mobility characteristics of the Martin River. More detailed mapping of channel characteristics on historic imagery will continue in 2024.

Table 2-1 Available LiDAR and Aerial Photography

Product	Acquisition Date
NIR-LiDAR[1]	10/13/2022
4 band Digital Imagery[1]	7/28/2022
Sentinel 2 satellite imagery (various dates) [2]	2017-2023
Aerial imagery (05915 series)[3]	9/3/1996
Aerial imagery (58200 series) [3]	8/2/1982
Aerial imagery (63640 series) [3]	7/16/1977
Aerial imagery (4KACH series) [3]	9/6/1964
Aerial imagery (BM064 series) [3]	5/25/1951
Aerial imagery (BM 0375 series) [3]	8/9/1950

1 NVE 2023

2 Satellite Imagery obtained from Copernicus Brower https://dataspace.copernicus.eu/

3 Imagery obtained from USG Earth Explorer website https://earthexplorer.usgs.gov/

2.2 Field Visits

Field visits to the Martin River were conducted on May 16, May 22-24, and November 2, 2023. The following tasks were completed during the visits:

May 16, 2023

- Installed three timelapse cameras set to photograph braided areas of the Martin River valley (see Section 2.4 for details).

May 22-24, 2023

- Video footage of Martin River and EFMR from tidewater to Dixon Glacier.
- Surficial Wolman pebble count data (100 clasts each) collected at 15 locations along Martin River from Geomorphic Reach 2 through 9.
- General geomorphic observations, field checking of mapped Geomorphic Unit breaks and off-channel connectivity corridors.

November 2, 2023

- Photographs of new delta forming in the mitigation ponds and the new river mouth from helicopter.
- Surveyed elevations along new delta and took GPS points to outline extent of delta deposits in mitigation ponds.
- Took GPS points to preliminarily outline the lateral extent of the erosion/headcutting in the Martin River valley upstream from the levee breach point (this task will be completed using the 2024 LiDAR data and additional field work).
- Pebble count at representative bar in river at levee breach location.
- Video of Martin River and EFMR from new mouth to Dixon Glacier to compare with May 2023 video.

2.3 Pebble Counts

Wolman pebble counts (100 clasts) were collected at 15 locations along the Martin River and WFMR to characterize substrate size in Geomorphic Reaches along the river on May 22-24, 2023 and at one location on the new delta fan on November 2, 2023. The Martin River is a braided river downstream from Geomorphic Reach 9; pebble count locations were selected at the head of river bars in non-braided reaches and at the head of anabranch bars in braided reaches (after Guerit et. al 2014). A mid-channel bar just downstream of the levee breach was sampled during the November site visit. At each location 100 clasts were selected using a random-walk method in an area covering approximately 100 square feet (the random walk covered the representative geomorphic facies at each location). Each clast was passed through a gravelometer and the size range was recorded (e.g., 2-4 millimeter (mm), 4-8mm, 8-16mm, etc.) Particles smaller than 2 mm were not counted in any of the locations due to the abundance of interstitial fine material, a lag deposit of fines in many locations, and the desire to capture variations in the coarser bedload-sized material along the river.

2.4 Timelapse Cameras

Timelapse cameras were deployed at three locations with a view of braided areas along the Martin River to record braid/sediment transport timing during 2023 (Figure 2-1, Photo 2-1, Photo 2-2 and Photo 2-3). Movement of braided river channels occurs when bedload transport takes place (Middleton et al. 2019).

The three cameras were Brinno TLC 202 timelapse cameras in waterproof housing (with 1 gm desiccant pack) with mounting bracket. Each bracket was screwed to a 12-inch-long piece of 1-inch by 6-inch wooden board. The boards were attached to an appropriately sized tree by two tie-down straps. Cameras were set to take one photo per day at approximately noon. Cameras were installed on May 16, 2023, serviced (fresh batteries and micro-SD cards) on August 24, 2023 and removed on October 19, 2023.

The footage from each camera was viewed to determine dates when channel change occurred.

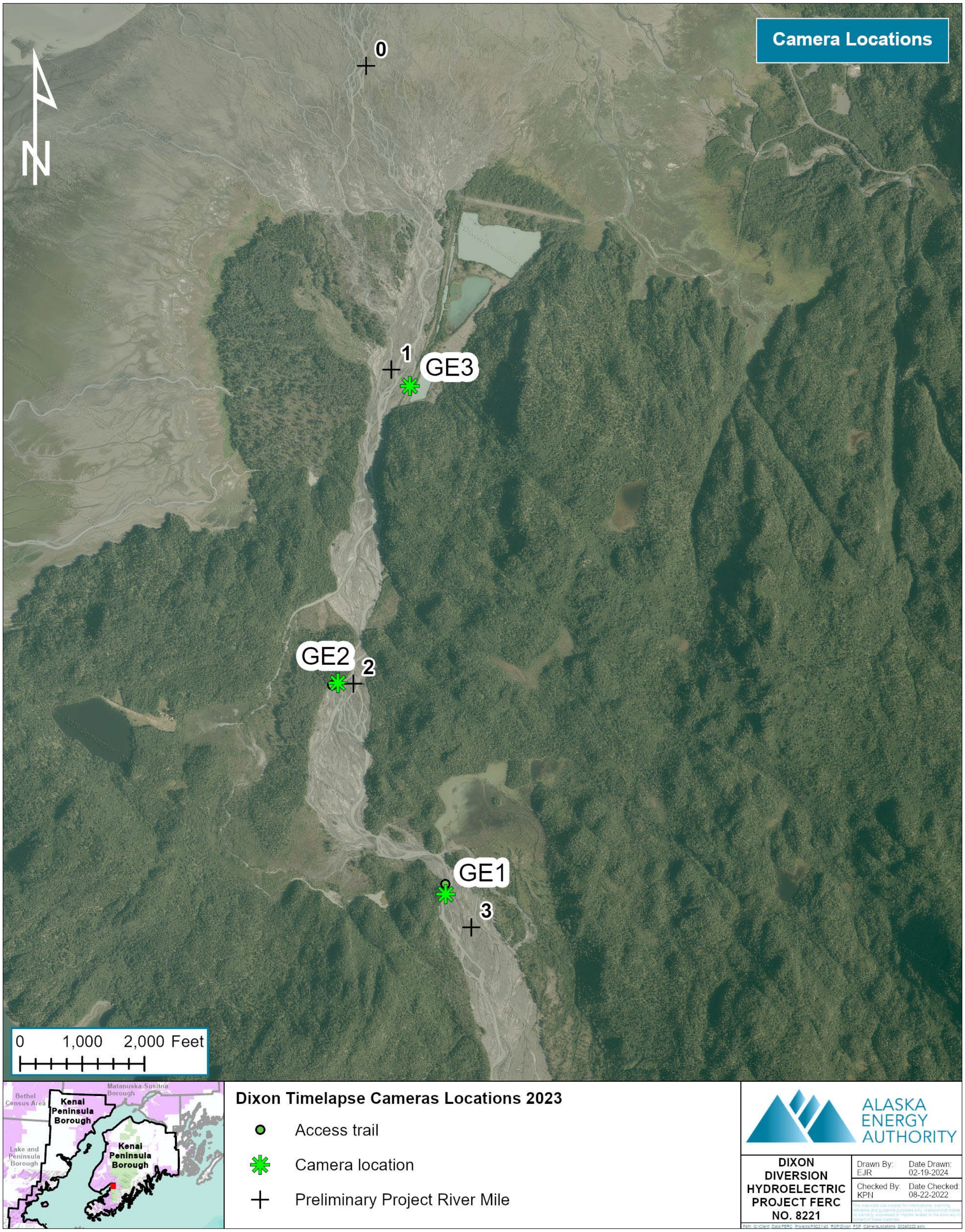

Figure 2-1 Martin River 2023 Timelapse Camera Locations.

Photo 2-1 Martin River Timelapse Camera GE1 view looking upstream May 16, 2023

Photo 2-2 Martin River Timelapse Camera GE2 view looking upstream May 16, 2023

Photo 2-3 Martin River Timelapse Camera GE3 view looking downstream May 16, 2023

3.0 RESULTS

3.1 Geomorphic Reach Mapping and Historic Aerial Photograph Observations

Delineation of geomorphic reaches along the Martin River is helpful to differentiate parts of the river with different gradient and confinement characteristics that are often correlated with varying responses of the channel to changes in water or sediment supply. Geomorphic mapping units are similar, but instead of linear features the map units are areas of the river valley that have had similar past geomorphic activity. For example, unvegetated alluvial areas indicate recent fluvial reworking while areas with vegetation of a similar height or age indicate the length of time since the river was active in those areas. The following sections describe geomorphic reaches and geomorphic map units based on the 2022 aerial photographs, LiDAR, and field observations. The levee breach in August 2023 resulted in changes to the mouth of the river that will require re-mapping of these areas when updated remote sensing data are available (see Section 3.5 for a description of channel changes).

3.1.1 Geomorphic Reaches of the Martin River

Twelve different geomorphic reaches were delineated along the Martin River and EF Martin River from tidewater to the Dixon Glacier (Table 3-1 and Figure 3-1). Reaches that are constricted/confined by bedrock or steep valley walls generally have one or two channels; unconfined areas generally have multiple channels. The number of wetted channels in each unconfined reach varies depending on flow conditions; at higher flows, more channels are wetted while at lower flows only one or two channels may be wetted. Note that Geomorphic Reach 8, while unconfined by valley walls, was subdivided into two distinct sub-reaches; a downstream unconfined sub-reach with multiple channels and an upstream sub-reach that is currently confined by a high terrace. The upstream reach (8b) is currently incising into past deposits to create the confining terrace; this section of the river was not confined to a single channel on historical aerial photographs (see discussion in Section 3.1.3).

Average channel gradients in the geomorphic reaches are relatively consistent (0.6 to 0.8 percent) between the delta (Geomorphic Reach 1) and Geomorphic Reach 7 except for the slightly steeper Geomorphic Reach 5 constriction. Channel gradients gradually increase in the upstream direction from Geomorphic Reach 7 (0.8 percent) through Geomorphic Reach 9 (1.5 percent). The EF Martin River canyon (Geomorphic Reach 10) has an average gradient of 6.7 percent, with gradient increasing closer to the Dixon Glacier.

Table 3-1 2022 Geomorphic Reach Characteristics

Geomorphic Reach No.	Reach Characteristics	Length (ft)	Average Gradient
0	Tidewater	n/a	n/a
1	Delta	2,530	0.7%
2	Levee	3,458	0.7%
3	Constriction	1,365	0.6%
4	Unconfined, left bank off-channel enters	2,114	0.8%
5	Constriction	283	1.1%
6	Unconfined; left bank off-channel area at upstream end	3,400	0.8%
7	Moderately confined; right bank side channel enters	1,537	0.8%
8a	Unconfined, multiple channels	5,536	1.2%
8b	Unconfined single channel (constrained by high terrace)	3,820	1.2%
9	Moderately confined single thread Red Lake outflow (WFMR) near upper end of reach	4,238	1.5%
10	EF Martin River Canyon	19,671	6.7%
11	Glacier	33,256	9.8%

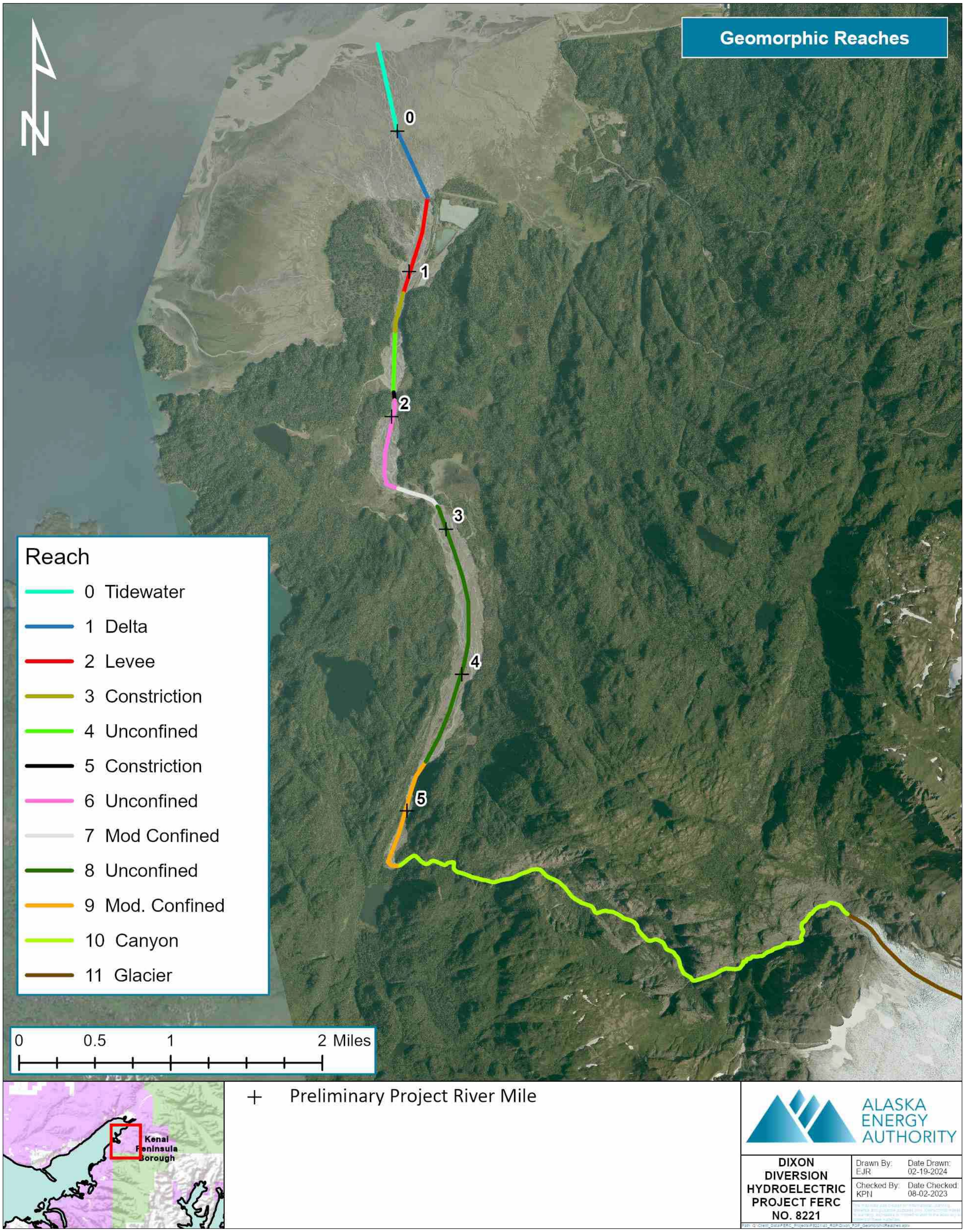

Figure 3-1 Martin River 2022 Geomorphic Reaches.

3.1.2 Geomorphic Units in the Martin River Valley

The Martin River valley is relatively flat bottomed with steep bedrock sidewalls as a result of the braided glacial river that has filled the valley with alluvial material. As the river fills one area of the valley bottom, the active channel moves into a different location in the valley bottom and the previously active area re-vegetates. The valley bottom was delineated into geomorphic units based on current (2022) dominant geomorphic process or, in the case of forested valley bottom areas, vegetation height that is indicative of the length of time since the area was part of the active channel (Table 3-2 and Figure 3-2).

The active channel Geomorphic Unit dominates the Martin River valley, with unvegetated alluvial deposits and an active braid plain up to 1,000 feet wide in unconfined areas of the valley.

At least five off-channel areas or tributaries and connecting channels (corridors) occur between RM 1.5 and the WFMR confluence. All of the off-channel/tributary areas except the left bank lakes at RM 3.4 show evidence of current or recent (past 50 years) activity from the mainstem river channel in the form of alluvial deposits or turbid water during high flow conditions.

There are three large, forested areas that have small active mainstem channels, primarily high flow channels: the left bank area at the mouth of the river that is part of the Martin River delta, and large areas on the right and left bank between RM 2 and RM 3 that connect to off-channel areas. Based on field observations, the river valley has recently been actively aggrading in the active channel adjacent to these locations which has resulted in fresh alluvium and small high flow channels through the forested areas.

Much of the remaining valley is in various stages of revegetation following past fluvial activity. Tree height and species are indicators of how recently these areas have been active and can provide insights into how frequently the Martin River re-occupies portions of the valley. Revegetation generally starts with forbs, alder, and cottonwood. Spruce regeneration follows. Cottonwood grows tall quickly; spruce grows more slowly. Additional work on vegetation age/height and age of deposits will occur using recent and historical aerial photographs and LiDAR data (canopy height) in 2024-2025.

Table 3-2 2022 Geomorphic Units in the Martin River Valley

Geomorphic Unit Name	Characteristics	Area (acres)
Tidelands	Areas that are primarily tidal in nature.	33
Active channel (2022)	Unvegetated (or very sparsely vegetated) alluvial areas indicative of relatively recent fluvial action.	605
Off-channel habitat or tributaries	Ponds or wetlands that are connected to the active channel area but do not currently show signs of recent mainstem re-working (some off-channel areas receive high flows from the Martin River, some areas are only connected by channels flowing out of the off-channel habitat and maintain relatively low turbidity water). Includes WFMR/Red Lake	80
Off-channel/tributary connectivity corridor	Small channels that connect off-channel/tributary habitat with the main channel.	4
Forested with small active high flow channels	Primarily forested area that contains one or multiple Dixon River channels; these channels are wetted primarily under high flow conditions.	395
Vegetated (to 5 ft high)	Vegetated valley bottom with shrubs/trees up to 5 feet high.	33
Vegetated (to 10 ft high)	Vegetated valley bottom with shrubs/trees up to 10 feet high.	4
Vegetated (to 15 ft high)	Vegetated valley bottom with shrubs/trees up to 15 feet high.	16
Vegetated (to 20 ft high)	Vegetated valley bottom with shrubs/trees up to 20 feet high.	18
Vegetated (to 30 ft high)	Vegetated valley bottom with shrubs/trees up to 30 feet high.	2
Vegetated (to 40 ft high)	Vegetated valley bottom with shrubs/trees up to 40 feet high.	37
Vegetated (to 50 ft high)	Vegetated valley bottom with shrubs/trees up to 50 feet high.	55

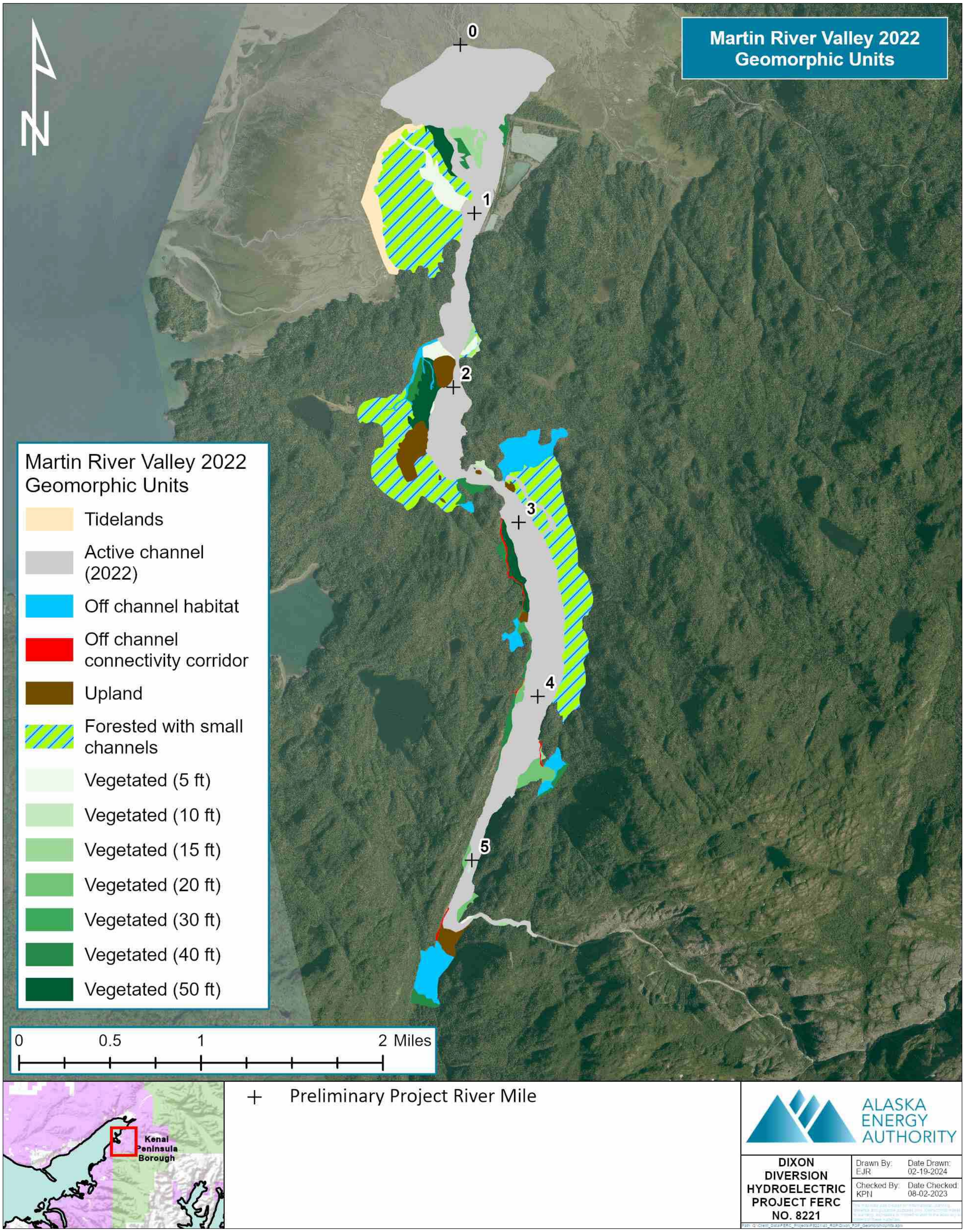

Figure 3-2 2022 Martin River Valley Geomorphic Units.

3.1.3 Historical Aerial Photograph Observations

An overview of historical aerial photographs from 1950 through present (Table 2-1, above) yielded the following observations:

- The Dixon Glacier has been progressively retreating since 1950.
- The Martin River downstream from the EF Martin River canyon has been active across much of the valley, with the active channel occupying different parts of the valley, off-channel areas, and river delta through the years.
- The Martin River has been aggrading differently in the various reaches of the channel through time (e.g., aggradation rates are not necessarily constant throughout the river in space or time).
- The general characteristics of geomorphic reaches (e.g., single or multi-channel) have been relatively constant since 1950 except for Geomorphic Reach 8b which was a multi-channel reach prior to at least 1996. This suggests downcutting in Geomorphic Reach 8b that created the constraining terrace occurred after 1996.

A more comprehensive analysis of channel changes through time utilizing the historic aerial photographs will be made in 2024-2025.

3.2 Field Visit Observations

May 16, 2023

- Water was low/clear. Substrate in most of main channel (from tidewater to EF Martin River canyon) was cobble/gravel dominated and generally coarsened upstream. Substrate suitable for spawning fish was observed in most main channel areas.
- Changes to channel locations (braids) have occurred since aerial photographs (7/28/2022) and LiDAR (10/13/2022) were flown in some areas indicating river flows in the time between aerials/LiDAR and LiDAR/freeze-up were high enough to transport bedload material.

May 22-24, 2023

- Evidence of very high sediment loading from Dixon Glacier (or glacial deposits) to the Martin River. The entire Martin River valley mapped as “active channel 2022” in Geomorphic Reach 2 through 8a is aggrading as evidenced by sediment deposition along all active channel Geomorphic Unit margins covering tree trunks resulting in dying vegetation. Old, buried trees (in grown position) observed throughout valley. Fresh gravel/cobble deposition into vegetated areas on left bank in Geomorphic Reach 6 and 2 (likely last fall, has only a few scattered leaves on surface from last autumn's leaf fall).

- Past deposition in Geomorphic Reach 8b (lightly vegetated bars) is currently incising; 5- to 6-foot incision depths to top of banks, uncovering buried cottonwood stumps in middle of channel.
- Outlet of left bank off-channel open water area in Geomorphic Reach 8a was checked via helicopter – will be adjusted in GIS/map.
- Main channel flow has shifted to right bank side channel at downstream end of Geomorphic Reach 8a, deposition of small to medium gravel in channel is controlling water level in large off-channel open water area on right bank.
- Deposition in the Martin River valley/fan has blocked the outlet to the former spawning channel/mitigation pond drainage near the mouth of the river. The ponds currently drain to the east toward the Battle Creek estuary over a shallow lip. This likely affects fish passage into/out of ponds.
- Gravel deposition in Martin River fan extends out to tidewater and the boundary between river and tidewater can be delineated based on color change on aerials (light gray gravel to organic sand).

November 2, 2023

- Water was low/fairly clear.
- The Martin River eroded an approximately 100-foot-wide section of the existing levee; likely mechanism was aggradation on the river side of the levee, overtopping of levee during high flows, and erosion of the pond-side (unprotected) portions of the levee which then undercut rip rap protection on river side of levee. Depth of erosion from top of dike to bottom of channel on November 2, 2023 approximately 10-12 feet (based on estimated water depth in channel). Observations of levee cut showed rip rap blanket on river side, smaller fill material on pond side.
- Extensive gravel, sand, cobble deposits in middle and lower pond areas (deposits cover 19.5 acres).
- Extensive headcut upstream from dike breach (total extent of headcut not delineated). Width of headcut up to 350 feet.

3.3 Pebble Counts

River substrate provides habitat for fish and aquatic organisms and channel roughness that influences hydraulic conditions. Sixteen pebble counts were taken along the Martin River in 2023 to help characterize substrate (Figure 3-3). Grain size distribution data are shown in Table 3-3, Figure 3-4, and Figure 3-5. Grain size generally decreased in a downstream direction, with the median (D_{50}) grain size ranging from 231 mm at the outlet of the EF Martin River canyon to 17 mm in the delta near sea level. Substrate is primarily gravel and cobble downstream from RM 4 with cobble, gravel and boulder upstream from RM 4 and in the moderately confined Reach 7. Sub-surface material was visually observed and had a fine gravel/sandy matrix at most locations. Sub-surface sampling is anticipated to take place in 2024 to characterize sub-surface grain size.

A pebble count was also made on the mid-channel bar at the levee breach location (Sample 2023-16); this sample is representative of bedload transported through the breach location under high flow conditions in late 2023. The material was primarily gravel with some cobble and sand. Median (D_{50}) grain size was 33 mm. Sub-surface material had a fine gravel/sand matrix.

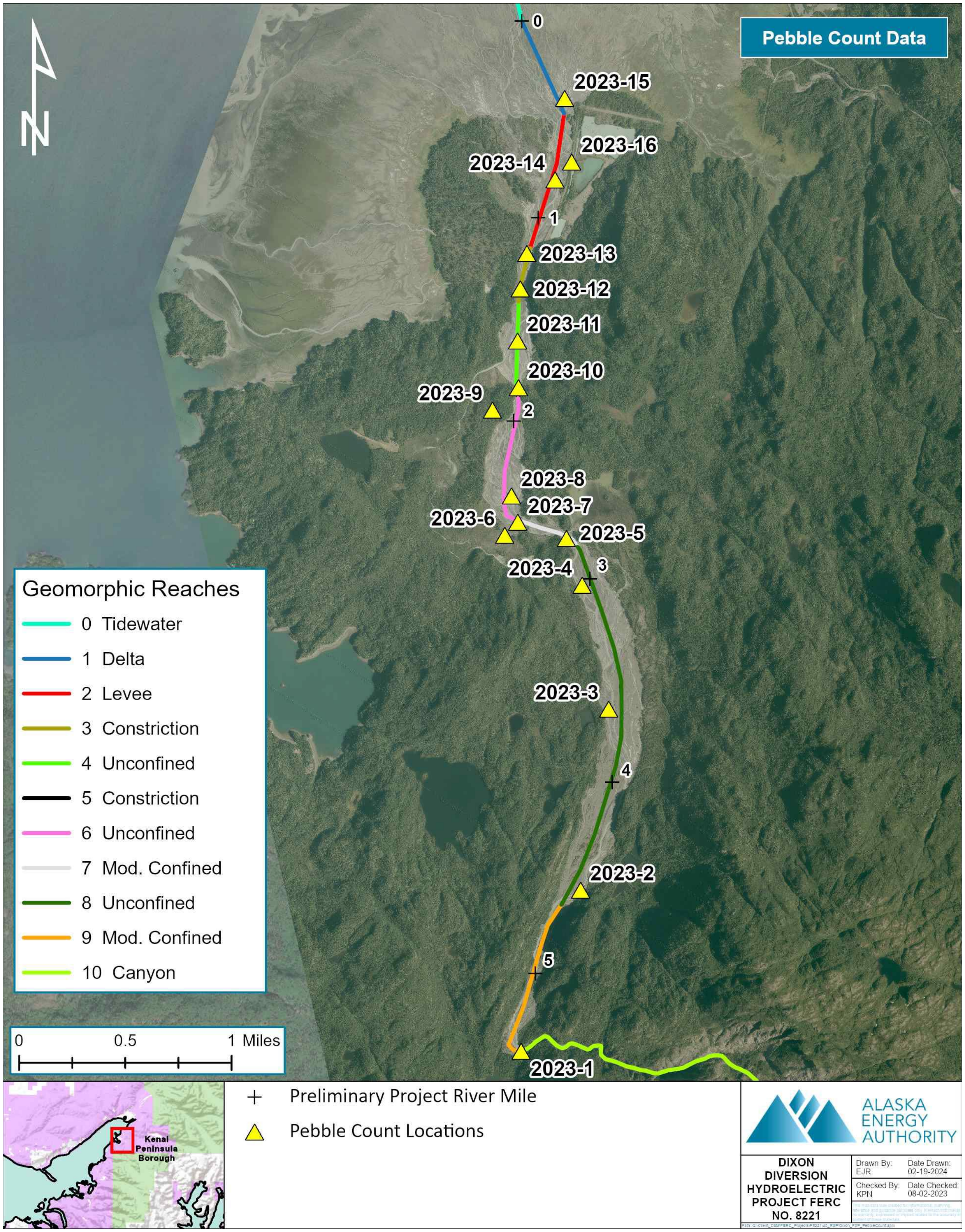

Figure 3-3 Martin River 2023 Pebble Count Locations.

Table 3-3 Martin River 2023 Pebble Count Summary Statistics

Sample No.	2023-1	2023-2	2023-3	2023-4	2023-5	2023-6	2023-7	2023-8	2023-9	2023-10	2023-11	2023-12	2023-13	2023-14	2023-15	2023-16
River Mile	5.62	4.72	3.79	3.13	2.86	2.61	2.61	2.49	2.07	1.95	1.71	1.47	1.29	0.91	0.46	0.8
Geomorphic Reach	9/10	8b	8a	8a	7	Side Channel	6/7	6	Side Channel	5	4	3	3	2	1	New Delta at Levee Breach
Grain Size (mm)																
D_{16}	86	64	34	31	50	13	25	17	13	23	9	14	8	11	8	11
Median - D_{50}	231	119	68	55	84	27	49	30	23	43	18	25	16	20	17	33
D_{84}	481	250	132	87	143	50	83	47	51	75	40	51	43	36	31	64
D_{90}	542	299	156	100	160	56	90	54	64	84	47	67	55	43	40	74
Percent in Grain Size Category																
Sand	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Gravel	17%	3%	13%	17%	3%	57%	26%	54%	71%	37%	75%	70%	75%	79%	86%	49%
Cobble	52%	53%	70%	82%	75%	43%	74%	46%	29%	62%	25%	30%	25%	21%	14%	51%
Boulder	31%	44%	17%	1%	22%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%

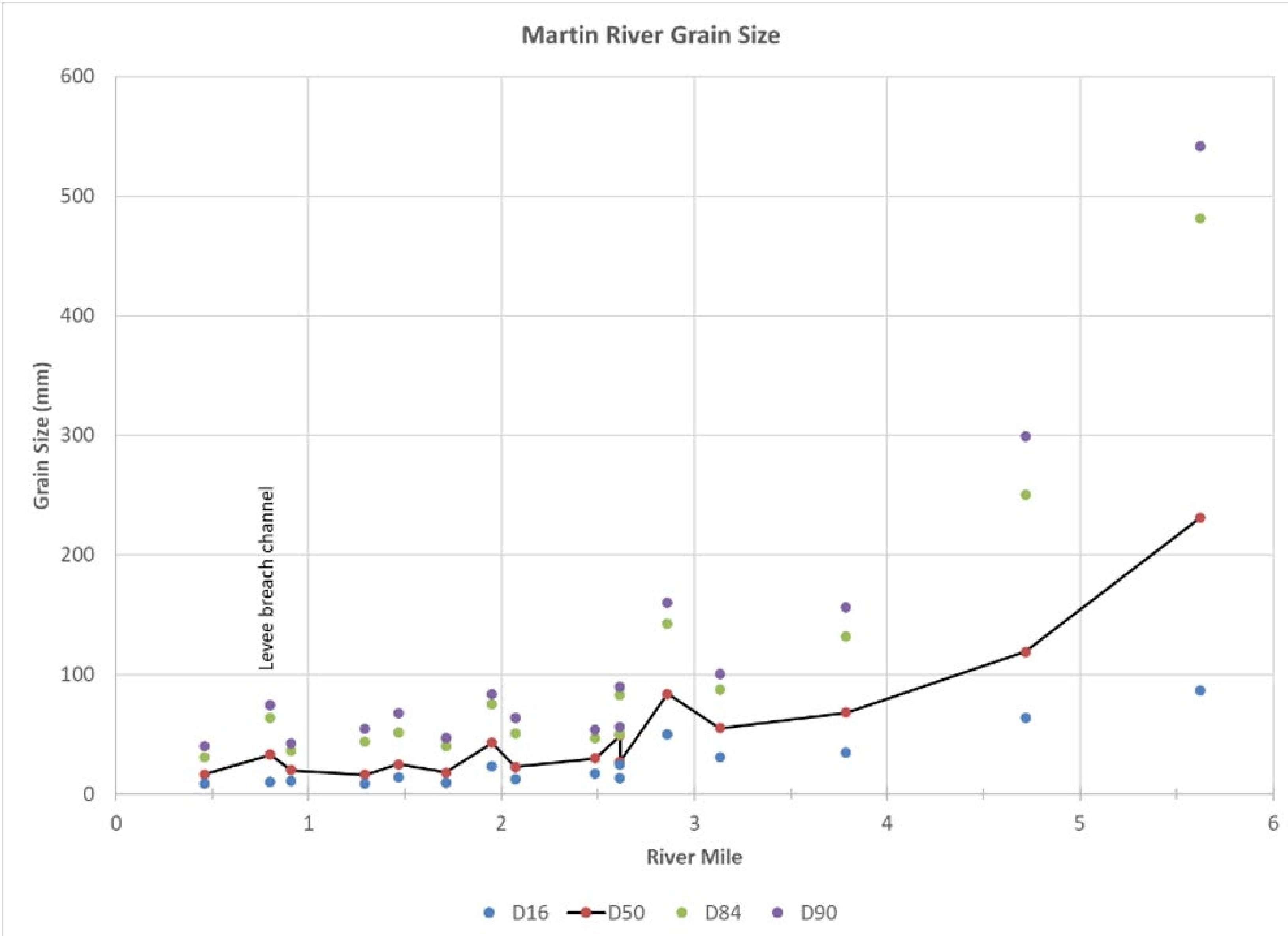

Figure 3-4 Martin River Longitudinal Variations in Grain Size.

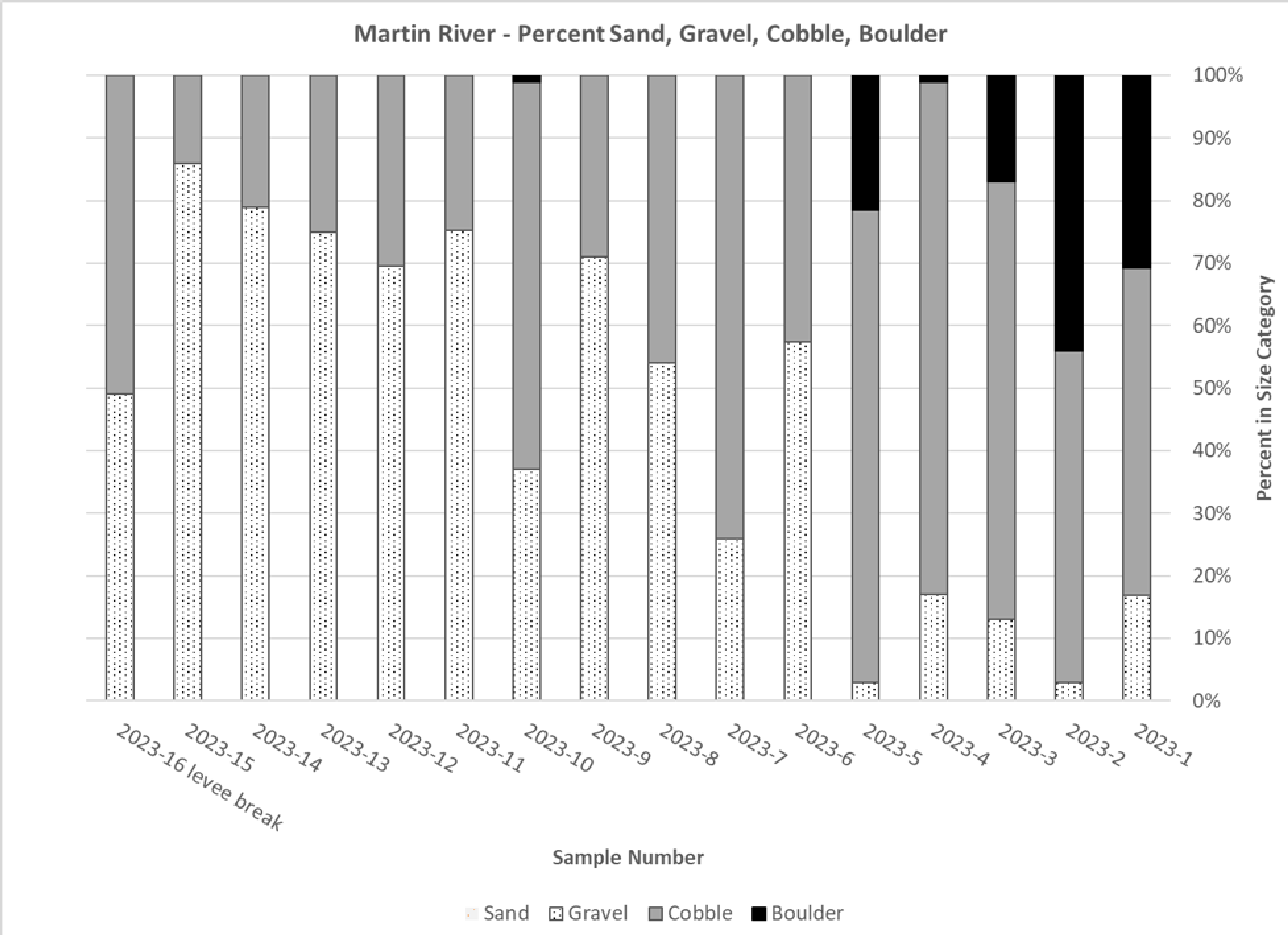

Figure 3-5 Martin River Percent Sand, Gravel, Cobble Boulder.

3.4 Timelapse Camera Analysis

Timelapse camera images from the three cameras that were deployed along braided sections of the Martin River showed change on numerous days between May 16 through October 19, 2023 (Table 3-4, Figure 3-6). Channel changes (e.g., shifts in channel locations) in braided river systems occur when flows are high enough to transport bedload (Middleton et al. 2019).

Table 3-4 Dates with Channel Change on Timelapse Camera Footage

Date	USGS 15238951 Stage (ft) PROVISIONAL	Camera Designation		
		GE 1	GE 2	GE 3
6/24/2023	6.30	X	X	
6/25/2023	6.44	X	X	
6/26/2023	6.27		X	X
6/27/2023	6.28		X	
6/28/2023	6.20		X	
7/3/2023	6.34			X
7/6/2023	6.3		X	X
7/7/2023	6.36		X	
7/16/2023	6.64			X
7/17/2023	6.45			X
7/22/2023	6.22		X	
7/28/2023	6.44			X
7/29/2023	6.49	X	X	
7/30/2023	6.18		X	
8/6/2023	6.52		X	X (downcutting after this date)
8/7/2023	6.7	X	X	
8/12/2023	6.61			X
8/14/2023	6.39	X		
8/21/2023	5.91			X
8/25/2023	6.62	X	X	
8/27/2023	6.72			X
8/29/2023	6.86		X	X
8/31/2023	6.7		X	X
9/16/2023	6.27		X	X

The upstream-most camera (GE 1) showed the least amount of channel change; this may have been due to the camera location that primarily showed a secondary, left bank channel that had less flow than the main channel (Photo 2-1 above). The GE 2 and GE 3 cameras both showed frequent channel changes (during at least eight different high flow events) during the 2023 flow season, consistent with braided glacial river dynamics. In addition, images from the GE 3 camera (Photo 2-3 above). showed channel incision, bank erosion, and resulting base level changes on August through October images following the downstream right bank levee breach.

The provisional USGS gage heights (USGS Gage No. 15238951) were compared for each date that had channel change and showed that in general, flow events corresponding to gage heights above about 6.1 to 6.2 feet resulted in channel change (Figure 3-6). This analysis will be updated to help determine flow levels that result in bedload transport and channel change when an approved rating curve is developed for the USGS gage. It is anticipated that additional timelapse cameras will be deployed in 2024 to augment the 2023 data.

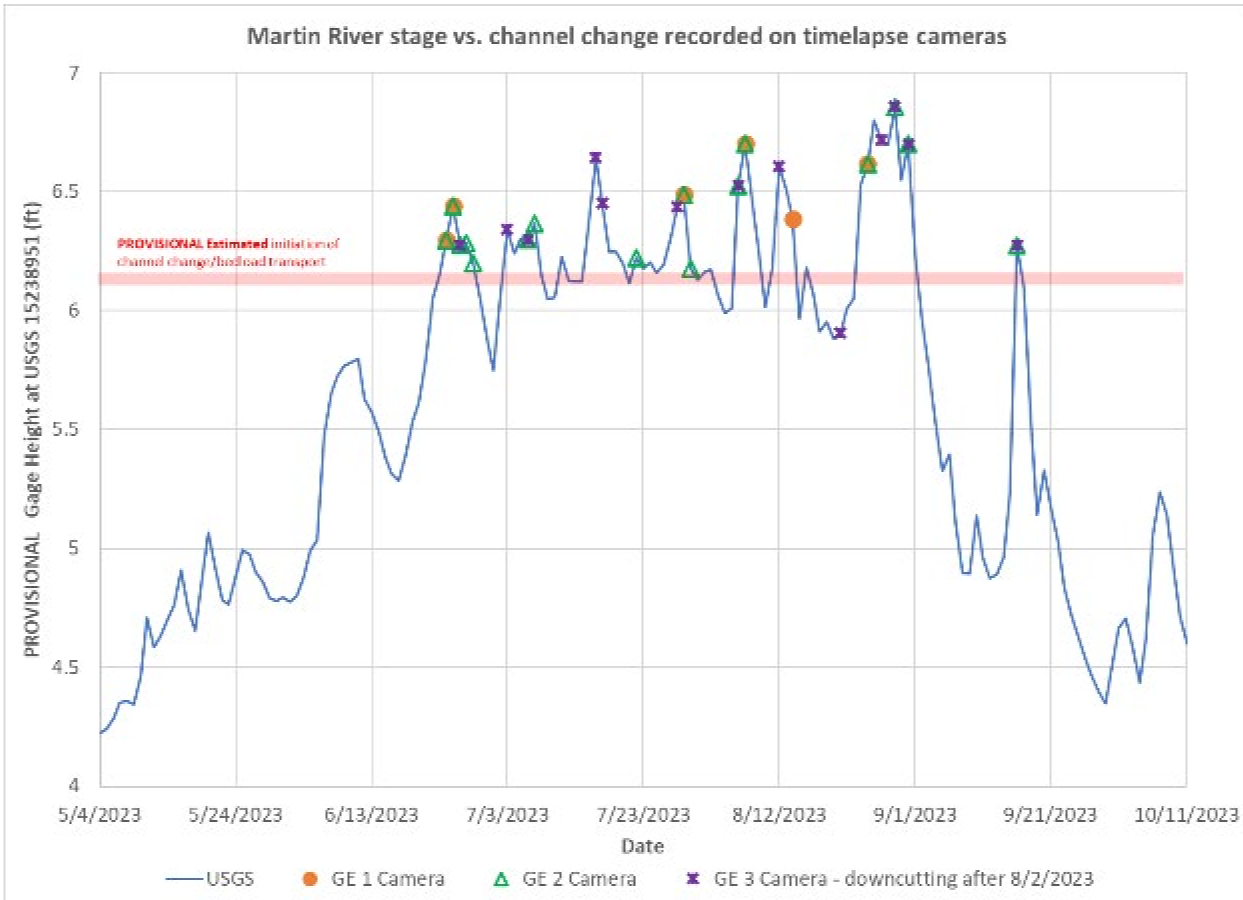

Figure 3-6 Martin River Stage vs. Channel Change; cameras deployed from May 16 to October 19, 2023

3.5 2023 Levee Breach

The right bank levee near the mouth of the Martin River (approximately RM 0.2) was overtopped and breached by the river at the beginning of August 2023 (Figure 3-7). A field visit on November 2, 2023 was conducted to delineate the new delta that is aggrading into the mitigation ponds on the east side of the levee, survey relative elevations of the breach and levee surface, and make observations of the headcut in the Martin River upstream from the levee breach.

The levee was constructed to separate the river from borrow pits that were dug to supply material used during construction of the Bradley Lake Hydroelectric Project in the 1980s. The borrow pits were rehabilitated for fish spawning and rearing ponds in 1991 by the Alaska Energy Authority (AEA). Prior to levee construction, the Martin River delta spread across the area that was used for the borrow pits/ponds. As-built drawings of the borrow pits/levee (dated March 12, 1992) show the levee was approximately five feet higher than the river at the breach location at time of construction, and borrow pits were dug 15 to 35 feet deep (Figure 3-8 and Figure 3-9). The levee was constructed with rip rap armoring on the river side but filled and topped with native material. It was anticipated that the Martin River would aggrade and eventually breach the levee based on assessments at the time (Parry and Seaman 1994).

As anticipated, the Martin River has been aggrading since construction of the levee. During reconnaissance site visits at high flow levels in 2022, a minor amount of flow from the river was overtopping the levee in the vicinity of the middle of the three ponds, the location where levee breaching occurred in 2023. Assuming 5 feet of aggradation in the 32 years between construction and overtopping yields an average aggradation rate of 0.16 feet/year.

Based on satellite imagery from July and August 2023, the breach occurred between July 31 and August 2, 2023. It is hypothesized that the levee overtopped with flow over the top and back side of the levee high enough to erode the fill on the back side of the levee, leading to eventual undercutting of the protective rip rap and breaching of the levee. Pieces of rip rap were observed in the newly cut channel downstream from the breach location. In November 2023, the bottom of the channel was approximately 10-12 feet below the top of the levee at the breach location.

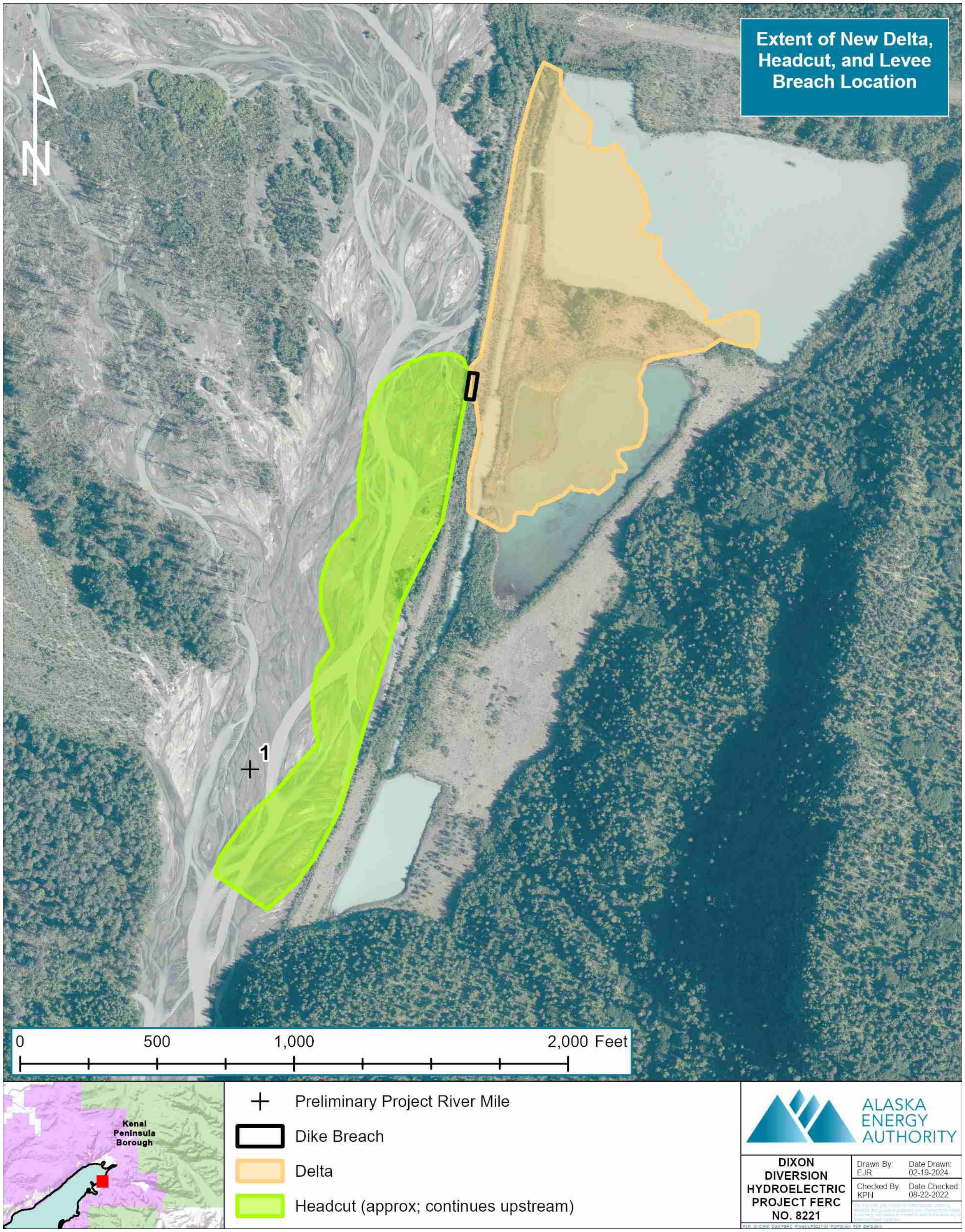

Figure 3-7 Extent of New Delta, Headcut, and Levee Breach Location near the Mouth of the Martin River, November 2023.

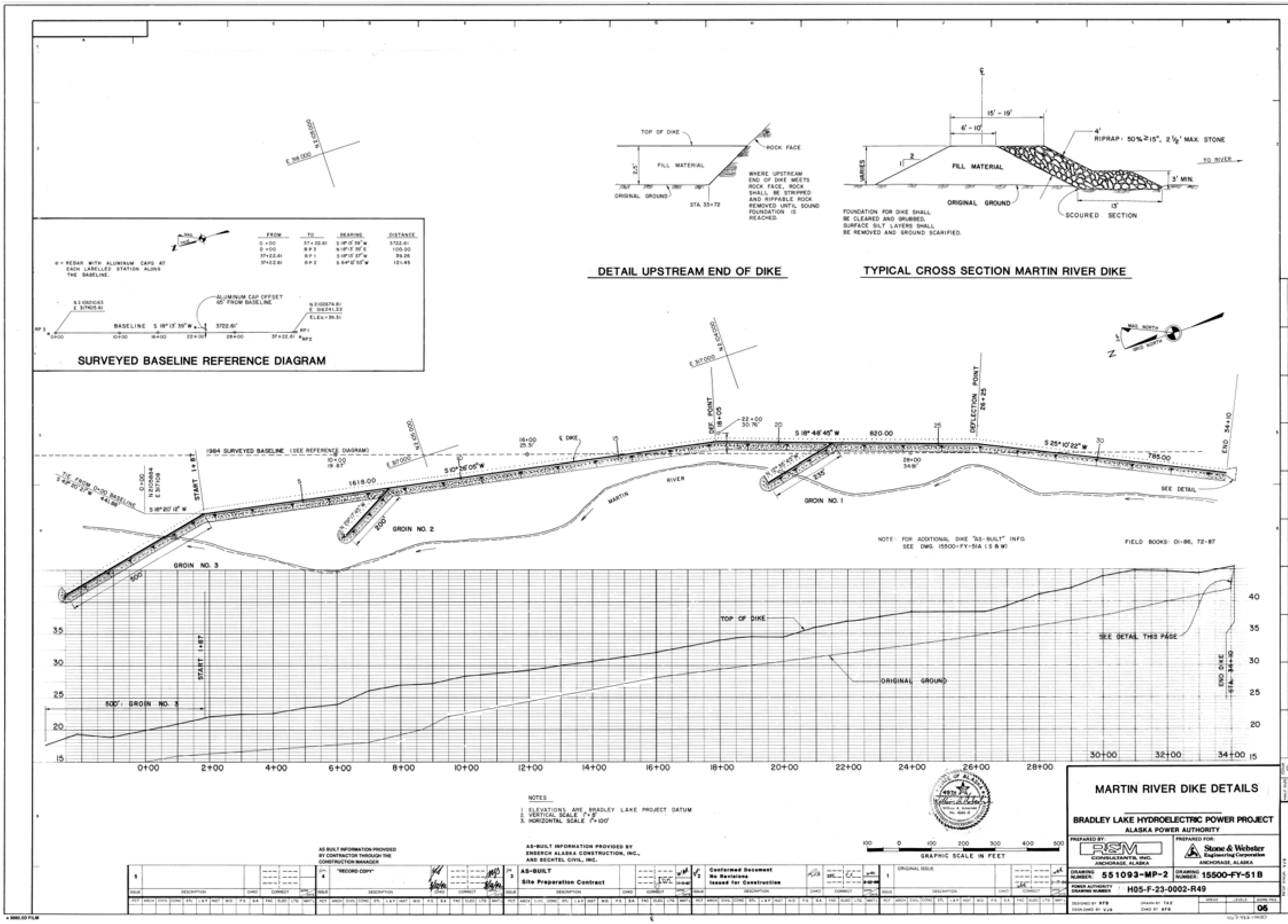

Figure 3-8 As-built Drawing of Martin River Levee.

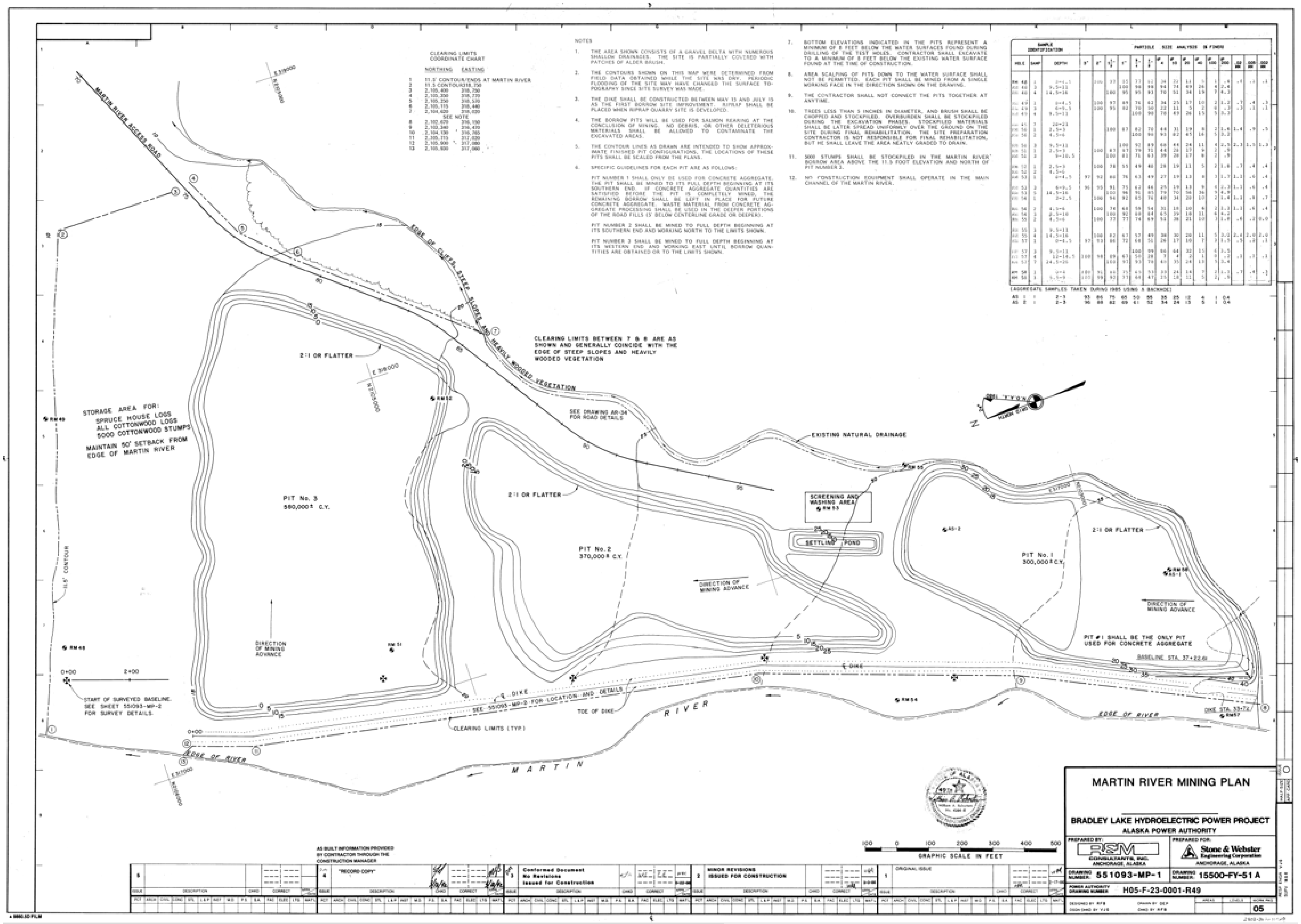

Figure 3-9 As-built Drawing of Martin River Mining Plan (ponds).

Photo 3-1 Cross-section of Levee at Breach Location November 2, 2023.

Since August 2, 2023, all flow from the Martin River flows through the levee breach, into the mitigation ponds, and out a low point at the northeast corner of the largest (northern) pond into Kachemak Bay (Photo 3-2 and Photo 3-3). The river has been building a delta into the ponds, with up to 15- to 35-foot-deep accumulations in some areas assuming the northern-most ponds were originally dug 15 to 35 feet below grade as shown on the as-built drawings. As of November 2023, the delta covered approximately 19.5 acres. Coho Salmon adults were observed in the ponds and just upstream of the levee breach during the November site visit, indicating that they were able to utilize and traverse the new river channel.

As the river breached the levee, it eroded a new channel through the levee resulting in a new base level at the ponds (Photo 3-4). This resulted in continued downcutting of the river bed at the levee location and headcutting upstream of the levee. As of November 2023, the headcut proceeded at least half a mile upstream; there was not sufficient time during the November site visit to document the upstream extent of headcutting.

Photo 3-2 Extent of Deposition in Mitigation Ponds; New Martin River Outlet to Tidewater (top right) November 2, 2023.

Photo 3-3 New Outlet of Martin River Looking Upstream from Tidewater to the Northeast Corner of the Lowermost Mitigation Pond November 2, 2023.

Photo 3-4 Mid-channel Bar just Downstream from Levee Breach (pebble count 2023-16 location), Looking downstream November 2, 2023.

4.0 SUMMARY AND IMPLICATIONS FOR STUDY PLANNING

The Martin River is a braided glacial river with a very high sediment load. Channel gradient is fairly consistent from the mouth to the EF Martin River canyon, with a slight increase in gradient upstream from RM 2.5. Substrate is primarily gravel and cobble downstream from RM 4 with cobble, gravel and boulder upstream from RM 4 and in the moderately confined Geomorphic Reach 7. The river is actively aggrading. The braided channels migrate and bedload transport occurs multiple times per flow season (June through August in 2023), particularly in unconfined reaches. Current off-channel habitat areas were part of the active channel in the past and will likely be part of the active channel in the future as the river aggrades and migrates across the valley bottom. The levee breach near the mouth of the river has resulted in aggradation in the mitigation ponds as a delta builds into the ponds, and headcutting upstream of the breach location as the river adjusts to the new base level. Channel adjustment to the breach will continue for years to decades until a new, more stable base level is reached.

4.1 Implications for Study Planning

- Due to the extremely active channel conditions (channel changes multiple times/year), study results, particularly hydraulic and sediment transport modeling, will be representative of the types of processes active in different reaches of the river rather than exact conditions in the future.
- It would be most advantageous to have all LiDAR/topographic surveys, aerial photography, and substrate sampling occur simultaneously so that a “snapshot in time” of river conditions can be used for hydraulic and geomorphic studies.
- Geomorphic reaches and map units should be revised at the mouth of the river to reflect the changes due to the levee overtopping.
- Active headcutting and channel/base level changes should be considered when interpreting results from the AEA stream gage in the constriction (Geomorphic Reach 5).

5.0 REFERENCES

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