DOWL ALASKA

HYDROLOGY REPORT

Dixon Diversion Conceptual Study

Prepared for:

ALASKA ENERGY AUTHORITY

Prepared by:

DOWL ALASKA

November 2023

DIXON DIVERSION CONCEPTUAL STUDY HYDROLOGY REPORT

PREPARED FOR:

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EXECUTIVE SUMMARY

DOWL performed the hydrologic analyses documented in this report for the Dixon Diversion Conceptual Study. To support the analysis, DOWL collected streamflow data for Martin River in 2023 and considered available data from the USGS gage at Dixon Creek (USGS 15238951). Figure 2 shows the location of the Dixon Creek and Martin River streamgages. Dixon Creek is the major tributary of the Martin River, and the Martin River begins just downstream of the Dixon Creek streamgage (i.e., downstream of the Red Lake Basin Outlet). Dixon Creek at the Mouth (A.K.A. "East Fork Canyon Outlet") is a good place to evaluate streamflow for the potential Dixon Diversion given its proximity to the potential diversion location.

DOWL previously investigated the hydrology of the Dixon Diversion Basin based on area relationships between the USGS streamgage for the Upper Bradley River (A.K.A. "Nuka Glacier") and documented the initial findings in a technical memorandum in March 2022. This report builds upon the methodologies presented in the March 2022 memorandum and includes the following:

- A synthetic discharge record for Dixon Creek at the Mouth, based on Upper Bradley River near Nuka Glacier discharge measurements and discharge measurements collected in the in 2023 for the Martin River
- Flow-duration statistics for Dixon Creek at the Mouth
- A flood-frequency analysis for Dixon Creek at the Mouth
- A mass balance analysis of Dixon Creek at the Mouth, adjusted to known values for Upper Bradley River near Nuka Glacier
- A diversion operations model was used to estimate the average annual runoff volume and potential diversion volumes for different diversion tunnel sizes

The diversion operations model is ultimately the culmination of this report. Table 1 presents the summarized model results. Based on the 2023 analysis performed, a tunnel size achieving between 1,000 and 1,400 cfs appears to achieve a reasonable balance between size and cost.

Table 1. Summarized Diversion Operational Model Results*

Average Annual Runoff Volume (acre-ft)	Tunnel Capacity	Average Annual Diverted Volume (acre-ft)
212,200	1,000 cfs	147,900
	1,200 cfs	158,400
	1,400 cfs	165,500
*Based on the most recent 20-years of measured streamflow at the Upper Bradley River nr Nuka USGS Streamgage.		

DOWL anticipates continuing to measure Martin River streamflow in 2024. As other relevant data become available, such as an "approved" USGS streamflow record for Dixon Creek at the Mouth or precipitation/temperature data for Dixon Glacier, DOWL will update, enhance, and expand the hydrologic analyses to account for the new data. The estimated diversion volumes presented in this report are of the same order of magnitude as the estimates presented in the March 2022 analysis.

1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

Alaska Energy Authority (AEA) is evaluating the potential expansion of hydroelectric power generation at the Bradley Lake Hydroelectric Project (BLHP). The Dixon Diversion Project would expand BLHP by capturing outflow from the Dixon Glacier, a tributary of the Martin River. Conceptual designs and power-generation methods are the subject of separate reports, and the information presented in this report is specifically related to the amount and timing of water expected to flow past the potential Dixon Diversion location.

Figure 1 shows the potential Dixon Diversion location, which is on lands owned by the State of Alaska. The Dixon Diversion Basin is a 19.1-mi^2 basin predominantly covered by the Dixon Glacier. The basin is located on the west side of the Kenai Mountains and ultimately drains to Kachemak Bay via the Martin River.

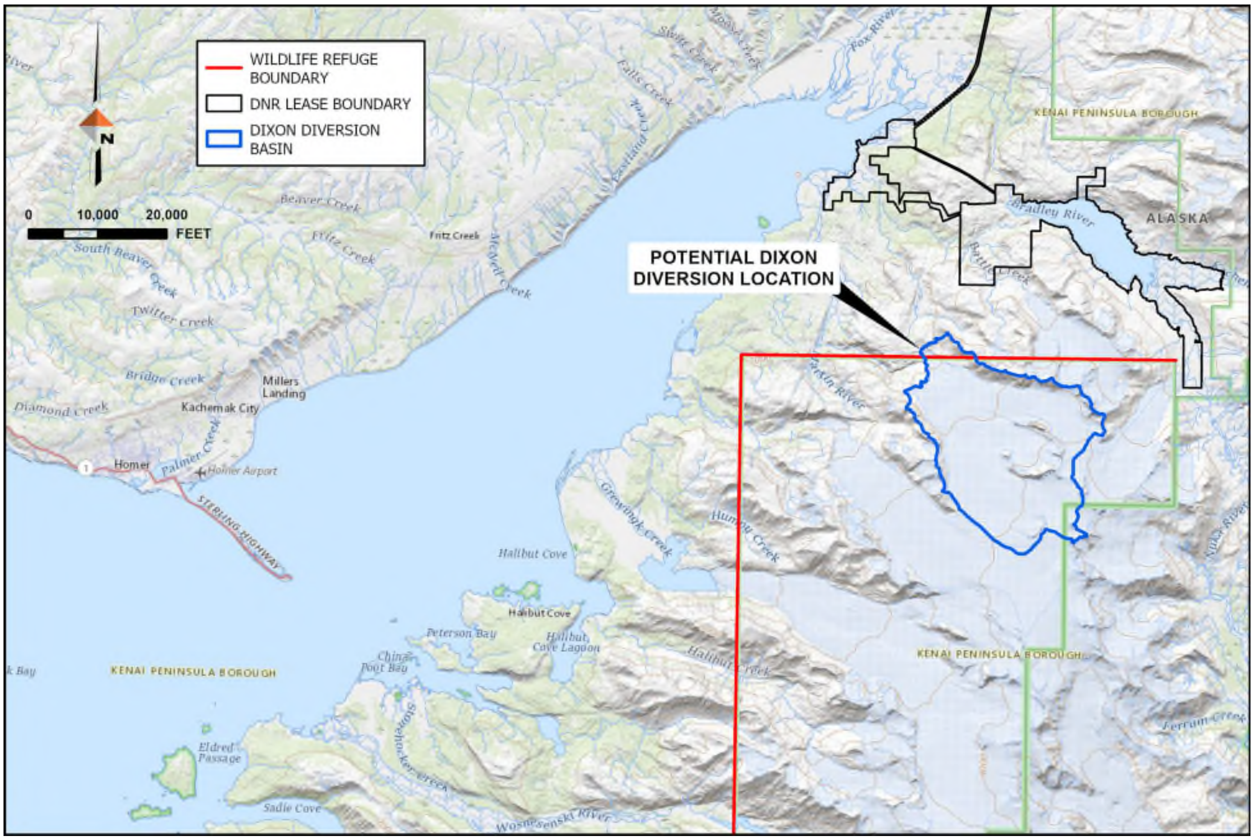


Figure 1. Potential Dixon Diversion Location

1.2 PREVIOUS HYDROLOGY STUDIES

In March 2022, DOWL submitted a technical memorandum regarding Dixon Diversion hydrology based on the limited data available at the time of document submission [1]. At that time, virtually no data were available for the Dixon/Martin River basins. Estimates of streamflow at the Dixon Diversion were based on (1) streamflow data for the Upper Bradley River near Nuka Glacier Basin (an adjacent basin with hydrologically similar characteristics) and (2) mass balance (i.e., water balance) methodology centered on precipitation (snow and rain) data.

DOWL submitted another technical memorandum to AEA in October 2022 that documented a brief analysis of precipitation trends in the area [2]. Statistically relevant year-over-year precipitation trends are not apparent in the available data, and there does not appear to be a trending increase or decrease in annual precipitation volume over time.

1.3 REPORT PURPOSE

Since submitting the above-described memoranda, significantly more data are available for the Dixon/Martin River basins, including streamgage data and glacier melt volume estimates. This report presents DOWL's revised/expanded hydrologic analyses and results for the Dixon Diversion Basin, including:

- Revised estimates of natural streamflow at the potential Dixon Diversion location
  - Average monthly natural streamflow and volume
  - Statistically-expected natural streamflow timing and magnitude (i.e., flow durations)
  - Annual peak flood magnitudes and probabilities of exceedance (i.e., flood frequency)
- Revised estimates of Dixon Diversion operational parameters
  - Minimum instream flow (MIF) rates
  - Diversion flow rates and volumes
  - Maintenance flow events

2.0 RELEVANT BASINS & STREAMFLOW DATA

Figure 2 presents a map of the basins in the Bradley Lake area. Basin drainage areas are reported in the figure, and Table 2 repeats the drainage areas for basins important to this study.

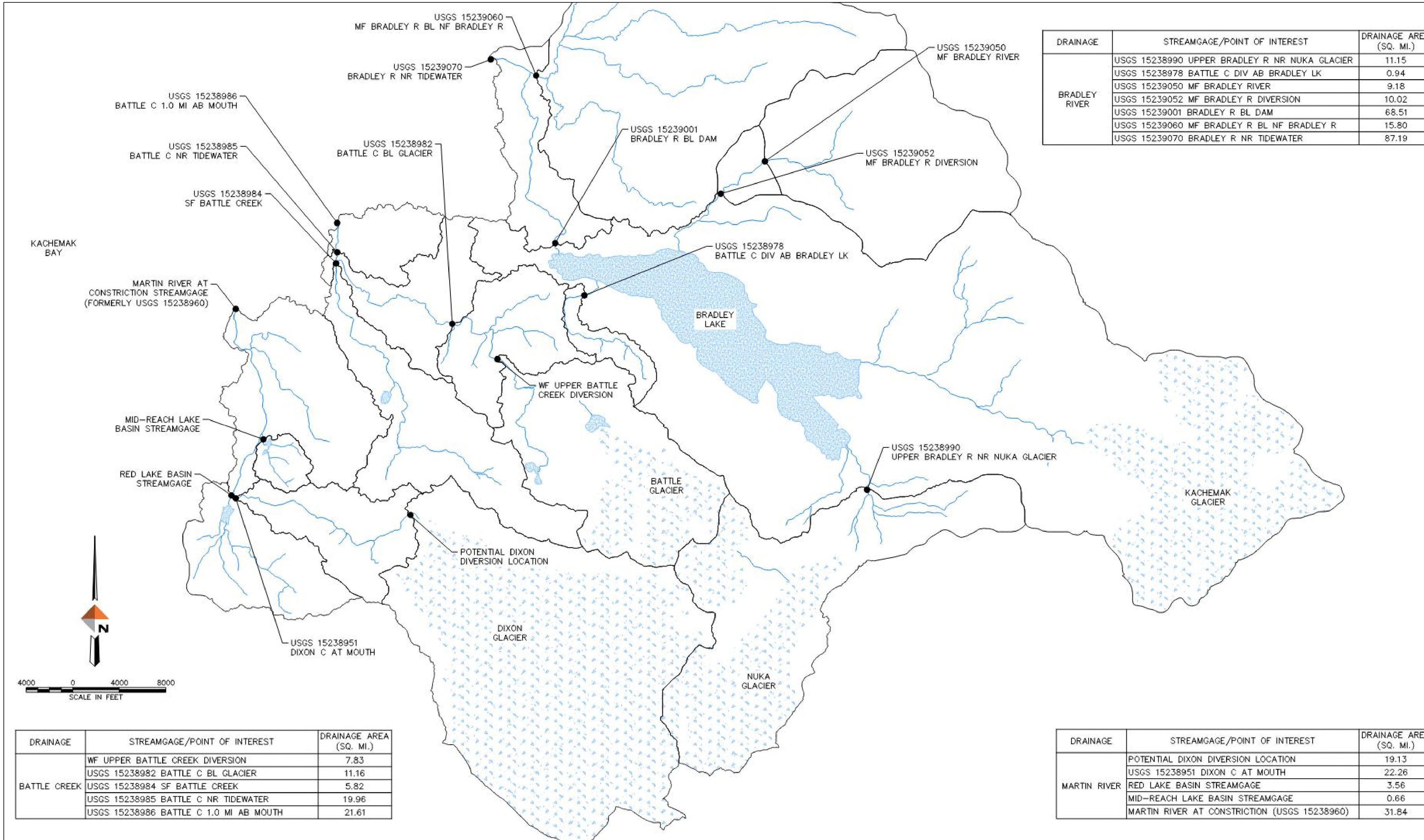
Table 2. Key Basin Drainage Areas

Drainage	Streamgage/Point of Interest	Drainage Area (mi^2)
Martin River	Potential Dixon Diversion Location	19.13
	Dixon Creek at Mouth (USGS 15238951)	22.26
	Red Lake Basin Streamgage	3.56
	Mid-Reach Lake Basin Streamgage	0.66
	Martin River at Constriction (USGS 15238960)	31.84
Bradley River	Upper Bradley River near Nuka Glacier (USGS 15238990)	11.15

Appendix A includes a technical memorandum documenting the streamgaging performed by DOWL in 2023. DOWL measured streamflow at the following locations:

- Martin River at the Constriction
- Red Lake Basin Outlet
- Mid-Reach Lake Basin Outlet

The USGS is currently establishing a streamgage at Dixon Creek at the Mouth. Although preliminary stage data are available for the Mouth, continuous streamflow data are not currently available for this site. Dixon Creek at the Mouth has proven to be a difficult site to establish a gage at, particularly a difficult site to measure discharge. The USGS has measured streamflow at this site a handful of times and anticipates collecting more measurements to support the development of a USGS-approved rating curve for the site.



DRAINAGE	STREAMGAGE/POINT OF INTEREST	DRAINAGE AREA (SQ. MI.)
BRADLEY RIVER	USGS 15238990 UPPER BRADLEY R NR NUKA GLACIER	11.15
	USGS 15238978 BATTLE C DIV AB BRADLEY LK	0.94
	USGS 15239050 MF BRADLEY RIVER	9.18
	USGS 15239052 MF BRADLEY R DIVERSION	10.02
	USGS 15239001 BRADLEY R BL DAM	68.51
	USGS 15239060 MF BRADLEY R BL NF BRADLEY R	15.80
	USGS 15239070 BRADLEY R NR TIDEWATER	87.19

DRAINAGE	STREAMGAGE/POINT OF INTEREST	DRAINAGE AREA (SQ. MI.)
BATTLE CREEK	WF UPPER BATTLE CREEK DIVERSION	7.83
	USGS 15238982 BATTLE C BL GLACIER	11.16
	USGS 15238984 SF BATTLE CREEK	5.82
	USGS 15238985 BATTLE C NR TIDEWATER	19.96
	USGS 15238986 BATTLE C 1.0 MI AB MOUTH	21.61

DRAINAGE	STREAMGAGE/POINT OF INTEREST	DRAINAGE AREA (SQ. MI.)
MARTIN RIVER	POTENTIAL DIXON DIVERSION LOCATION	19.13
	USGS 15238951 DIXON C AT MOUTH	22.26
	RED LAKE BASIN STREAMGAGE	3.56
	MID-REACH LAKE BASIN STREAMGAGE	0.66
	MARTIN RIVER AT CONSTRICTION (USGS 15238960)	31.84

Figure 2. Basins in the Bradley Lake Area

2.1 STREAMFLOW DATA

Figure 3 presents the 2023 daily average flow hydrograph for Dixon Creek at the Mouth, which was used as the basis for estimating discharge at the proposed Dixon Diversion location. The technical memorandum in Appendix A details the development of the hydrograph, and Attachment 1 of the memorandum includes tabulated daily average discharges for Dixon Creek at the Mouth, the Martin River at the Constriction, the Red Lake Basin Outlet, and the Mid-Reach Lake Basin Outlet.

Based on data limitations described in the attached memorandum (e.g., data gaps in the DOWL constriction gage record and geomorphologic factors influencing where accurate streamgages can be installed), DOWL developed the hydrograph shown in Figure 3 based on the following assumptions:

- The Dixon Creek at Mouth discharge was estimated by subtracting Red Lake and Mid-Reach Lake Basin discharge from Martin River at Constriction discharge. Inherent in this assumption is that the purple drainage shown in Figure 4 contributes negligibly to Martin River discharge. For comparison purposes, purple area in Figure 4 is a 5.36 mi^2 area, the Red Lake Basin is a 3.56 mi^2 area, and the Red Lake Basin does not contribute significantly to Martin River Discharge. Both the purple drainage area and the Red Lake Basin share relatively similar, non-glaciated, hydrologic characteristics, although Red Lake itself is expected to attenuate discharge in a way that the purple basin does not.
- The Martin River at Constriction streamgage rating curve is based on more measured datapoints than the Dixon Creek at Mouth streamgage rating curve (based on provisional USGS streamflow measurements). Therefore, DOWL assumed that when Martin River at Constriction stage data are available, a more accurate estimate of Dixon Creek at Mouth discharge is provided using the Constriction dataset as the estimate basis.
- For times when Martin River at Constriction discharge data are unavailable, DOWL filled the gaps in the dataset using provisional USGS Dixon Creek at Mouth stage data.

As more data become available (e.g., a USGS-published rating curve for Dixon Creek at the Mouth), DOWL will review and update the discharge record and stage-discharge relationships accordingly.

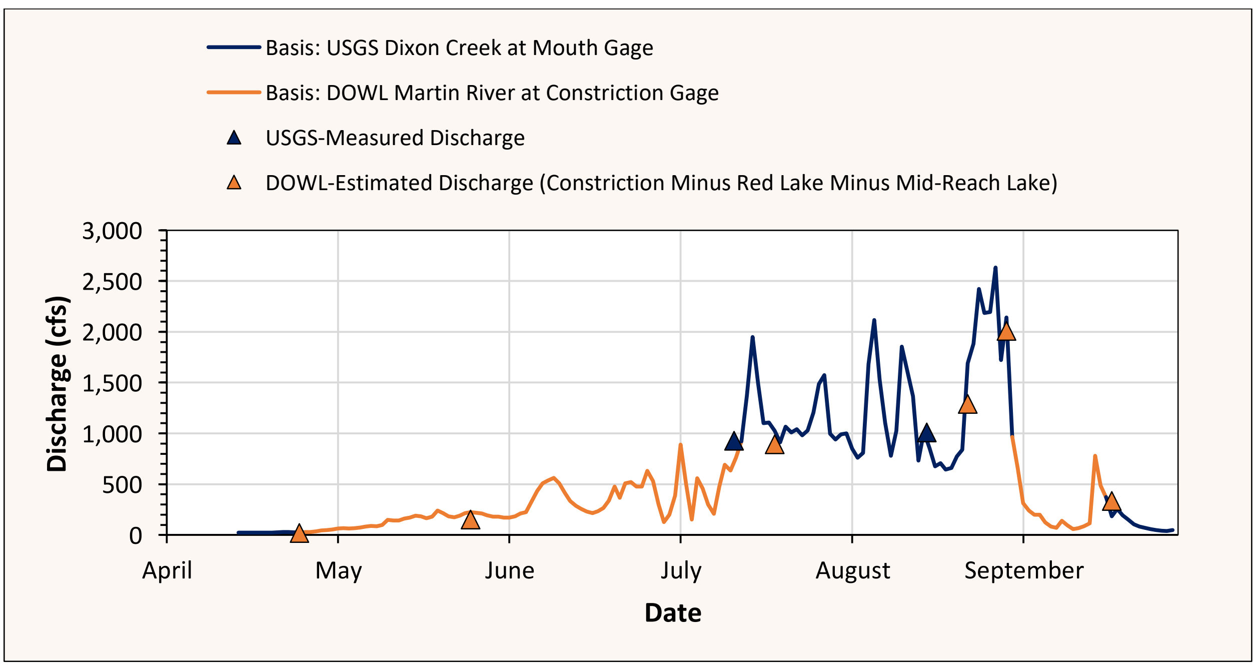


Figure 3. Dixon Creek at Mouth Best-Estimate 2023 Streamflow Record

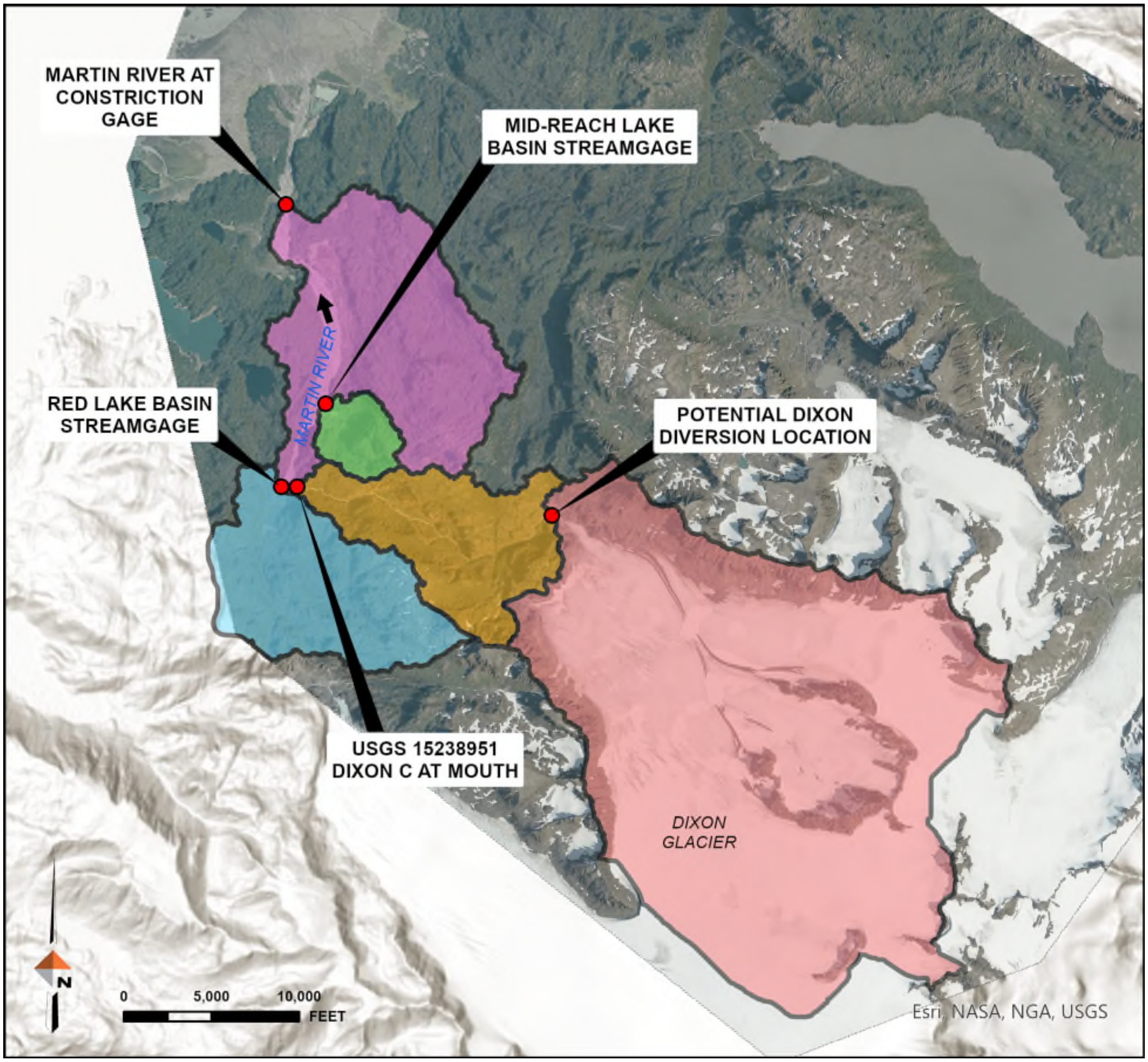


Figure 4. Martin River/Dixon Creek Drainage Basins

3.0 HYDROLOGIC ANALYSIS

The following subsections describe the hydrologic analyses performed by DOWL for the Dixon Diversion Conceptual Study.

3.1 SYNTHETIC DISCHARGE RECORD

3.1.1 METHODOLOGY & BACKGROUND

In 2022, DOWL established the following relationship to estimate discharge at proposed Dixon Diversion location based on discharge measured at the Upper Bradley River near Nuka Glacier (USGS 15238990):

$$Q_{Dixon} = Q_{Bradley}\left(\frac{A_{Dixon}}{A_{Bradley}}\right)^{\alpha}$$

In the above equation, Q = discharge, A = area, and α = an area exponent. The discharge estimated using this equation is termed "synthetic discharge.". When the relationship was initially developed in 2022, no discharge data were available for Dixon Creek at the Mouth, and a constant area exponent was assumed based on "normal" meteorological conditions [3]. Discharge data are now available for Dixon Creek at the Mouth (Figure 3), and DOWL has revised the relationship as described in the following subsections.

3.1.2 AREA COEFFICIENT REGRESSION

Figure 5 compares the Dixon Creek at Mouth and Upper Bradley River streamflow measured from May through October 2023. The Upper Bradley River streamgage was not functioning this year until late May, and Dixon Creek streamflow data were unavailable for October when this report was written. Upon inspection of Figure 5, it is apparent that the Dixon Creek/Upper Bradley River relationship is distinctly different during July and August than the rest of the year. Based on this observation, DOWL assumed that the Dixon Creek/Upper Bradley River relationship can be represented using three different area exponents:

1. An area exponent for May 1 through June 30 ($\alpha_{May-Jun}$)
2. An area exponent for July 1 through August 31 ($\alpha_{Jul-Aug}$)
3. An area exponent for September 1 through October 31 ($\alpha_{Sep-Oct}$)

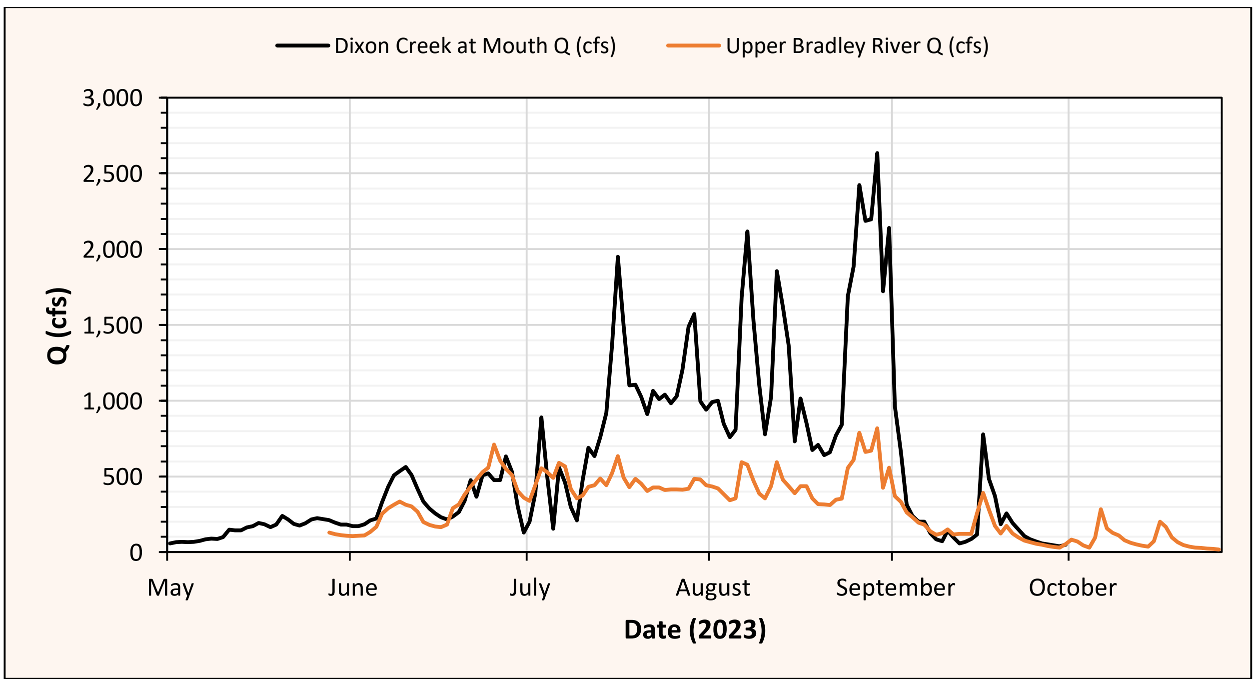


Figure 5. Dixon Creek at Mouth & Upper Bradley River 2023 Flow Comparison

Figure 6 presents the regressions performed for each period and the corresponding best-fit area coefficients for each. Table 3 summarizes the revised Dixon Creek/Upper Bradley River relationship. For comparison purposes, the cursory relationship DOWL developed in 2022 was that Dixon Creek discharge equaled 1.6 times the Upper Bradley River discharge.

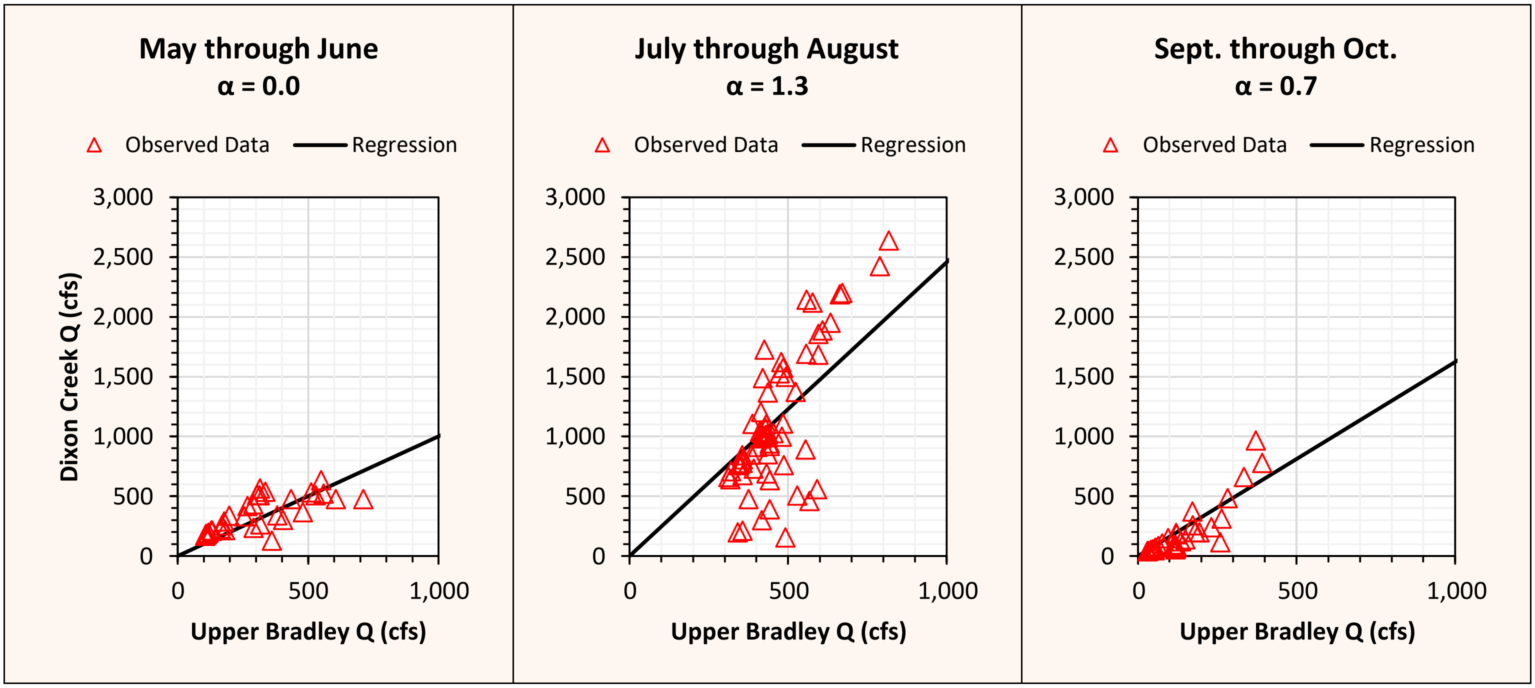


Figure 6. Regressions for Area Exponents

Table 3. Revised Dixon Creek/Upper Bradley River Relationship

Period	Area Exponent (α)	Relationship
July 1 through August 31	0.0	$Q_{Dixon} = Q_{Bradley}\left(\frac{22.26}{11.15}\right)^{0.0} = 1.0 \times Q_{Bradley}$
July 1 through August 31	1.3	$Q_{Dixon} = Q_{Bradley}\left(\frac{22.26}{11.15}\right)^{1.3} = 2.5 \times Q_{Bradley}$
September 1 through October 31	0.7	$Q_{Dixon} = Q_{Bradley}\left(\frac{22.26}{11.15}\right)^{0.7} = 1.6 \times Q_{Bradley}$

3.1.3 SYNTHETIC DISCHARGE RECORD

Figure 7 compares the 2023 synthetic discharge to the measured Dixon Creek at Mouth discharge, and Table 4 compares the streamflow volumes estimated from the synthetic discharge record to those calculated using the measured data. The estimated Dixon Creek/Upper Bradley River relationship reasonably agrees with the measured data. DOWL used the revised relationship to develop a synthetic discharge record for Dixon Creek at the Mouth for all years where Upper Bradley River streamflow data are available (i.e., from 1979 to 2023). To reduce file size, the tabulated record is not included with this report, but it is available upon request.

Table 4. Synthetic vs. Measured Dixon Creek at Mouth Streamflow Volume (2023)

Period	Streamflow Volume[1] (acre-ft)		Percent Difference
	Measured	Synthetic	
May 1 through June 30	23,040	21,253	8% (-)
July 1 through August 31	136,222	139,703	2% (+)
September 1 through October 31	12,556	14,778	15% (+)
May 1 through October 31	171,818	175,734	2% (+)

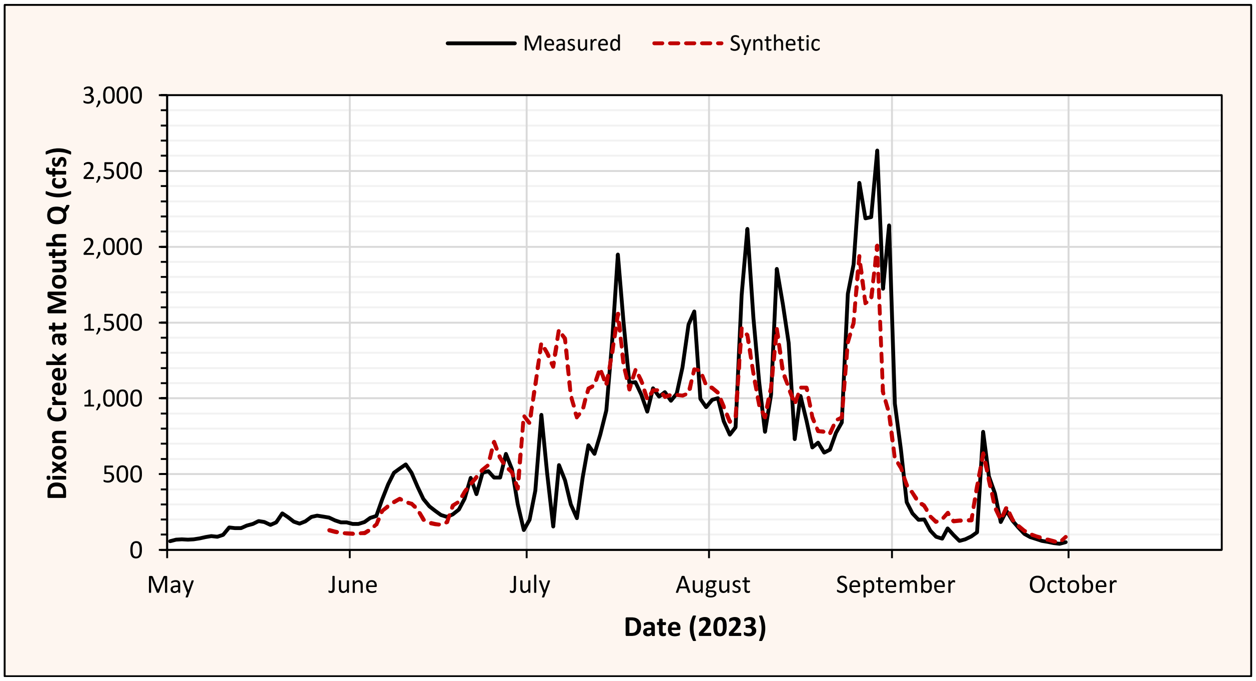


Figure 7. Dixon Creek at Mouth Synthetic/Measured Discharge Comparison (2023)

By estimating Dixon Creek streamflow using the above-described correlation, it is inherently assumed that the two watersheds experience similar meteorological and antecedent conditions at the same time, year after year. Sufficient data are not yet available to validate this assumption (e.g., precipitation and temperature data for the Dixon Creek basin/Dixon Glacier). Alaska Pacific University recently installed a meteorological station on Dixon Glacier, and when the data from the station become available, DOWL will incorporate the data in analysis.

Related to the above assumption, DOWL evaluated the potential for an anomalously low or high 2023 water year to skew the synthetic flow record for the Dixon Creek at Mouth. As shown in Figure 8, the Upper Bradley River discharge measured in 2023 is relatively near the historical mean (especially during the higher-flow months of July and August), which suggests that 2023 is a good year to use as the basis of correlation between Dixon Creek and the Upper Bradley River (assuming Dixon Creek and the Martin River also experienced normal water years). As more Dixon Creek streamflow data become available, the margin for error in the correlation between the Upper Bradley River discharge and the Dixon Creek discharge will decrease, and our confidence in the analysis will increase.

[1] The streamflow volume amount shown in this table only includes volume for days where both synthetic and measured discharge are available (i.e., excluding May 1 through May 27 and October 1 through October 31).

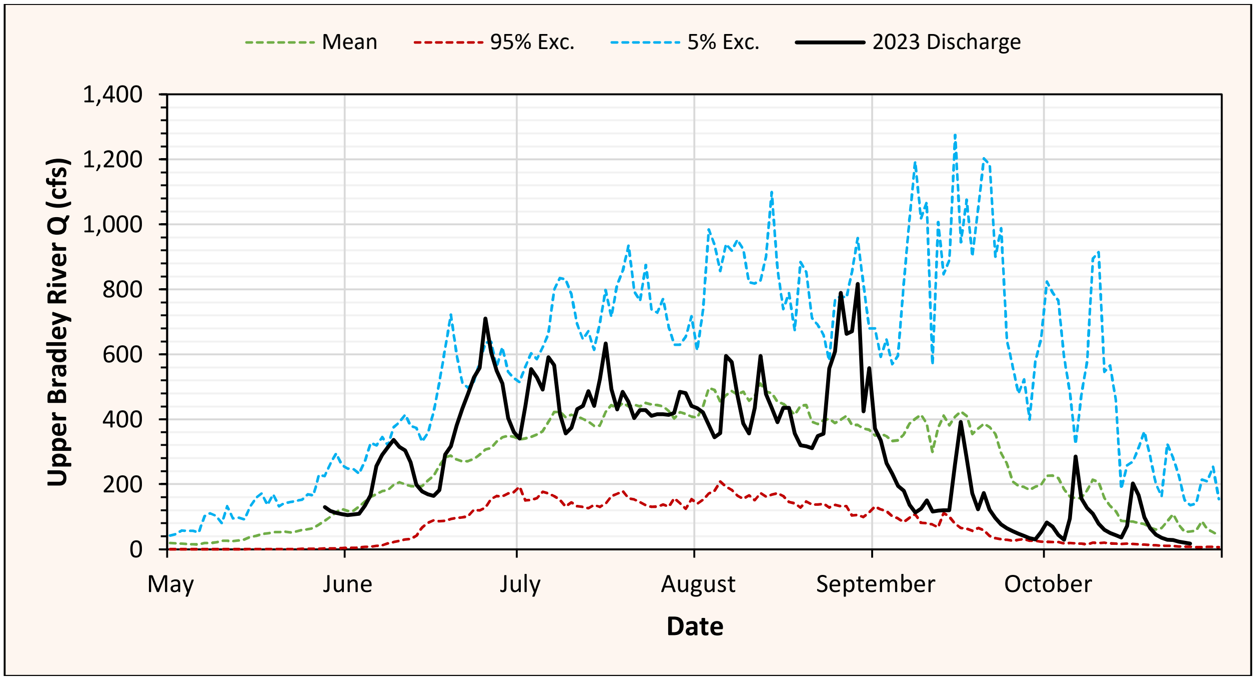


Figure 8. Upper Bradley River Streamflow Statistics and 2023 Measured Discharge

3.2 FLOW DURATION

Table 5 presents flow-duration statistics calculated using the Dixon Creek at Mouth synthetic record (from 1979 to 2023). Flow-duration statistics are generally useful for agencies to establish instream flows and make fisheries decisions.

Table 5. Dixon Creek at Mouth Flow-Duration Statistics from Synthetic Record

Month	Dixon Creek at Mouth Discharge (cfs)			
	Mean	95% Exceedance	50% Exceedance (Median)	5% Exceedance
May	56	1	32	180
June	235	44	210	517
July	1,005	341	943	1,862
August	1,072	341	983	2,164
September	538	70	408	1,424
October	191	16	78	765

3.3 FLOOD FREQUENCY

DOWL estimated the flood frequency (i.e., the probability of instantaneous-occurring streamflow magnitudes to be exceeded annually) for the Dixon Diversion Basin. The following independent methods were applied to estimate the flood frequency for the basin:

1. USGS regression equations for ungaged streams in Alaska

2. USGS Bulletin 17C and the synthetic record for Dixon Creek at the Mouth

3.3.1 USGS METHODS FOR UNGAGED STREAMS

The USGS provides regional regression equations for estimating peak streamflow magnitude and frequency for ungaged sites in Alaska [3]. As defined by the USGS for Alaska, the Dixon Diversion Basin lies within Region 3 and, thus, the applicable peak flow regression equations are a function of drainage area, area of lakes and ponds, mean annual precipitation, and mean minimum January temperature; Table 6 lists the relevant basin characteristics for the USGS regression equations. Table 7 presents the Dixon Diversion Basin flood frequency estimated using the USGS regression methods for ungaged streams.

Table 6. Dixon Diversion Basin Characteristics for USGS Peak Flow Regression

Basin Characteristic	Variable	Value
Drainage Area	A	19.13 mi^2
Area of Lakes & Ponds	ST	0%
Mean Annual Precipitation[2]	P	104 in.
Mean Minimum January Temperature[3]	J	17.3 °F

Table 7. Dixon Diversion Flood Frequency Using USGS Regression [3]

Recurrence Interval (years)	Annual Exceedance Probability	Estimated Inst. Annual Maximum Flow (cfs)	95% to 5% Confidence Interval (cfs)
2	50%	1,960	Between 1,090 and 3,580
5	20%	2,740	Between 1,540 and 4,960
10	10%	3,280	Between 1,830 and 5,960
25	4%	3,960	Between 2,180 and 7,300
50	2%	4,480	Between 2,430 and 8,410
100	1%	4,990	Between 2,640 and 9,560
200	0.5%	5,540	Between 2,860 and 10,900
500	0.2%	6,240	Between 3,110 and 12,700

3.3.2 USGS BULLETIN 17C

DOWL developed a synthetic instantaneous annual peak discharge record for Dixon Creek at the Mouth using the Upper Bradley River/Dixon Creek relationship described in Section 3.1. Individual Upper Bradley River annual maximum discharges were translated to Dixon Creek using the relationship in Table 3 corresponding to the month the annual peak occurred. Figure 9 compares the measured Upper Bradley River peak discharges to the synthetic Dixon Creek at Mouth peak discharges.

[2] The mean annual precipitation used for USGS regression is obtained from the area-average of 2010 normal PRISM data (1981-2010).
the 2010 normal PRISM area-averaged value for Dixon Diversion Basin (1981-2010).
[3] The mean minimum January temperature used for USGS regression is obtained from the area-average of 2010 normal PRISM data (1981-2010).

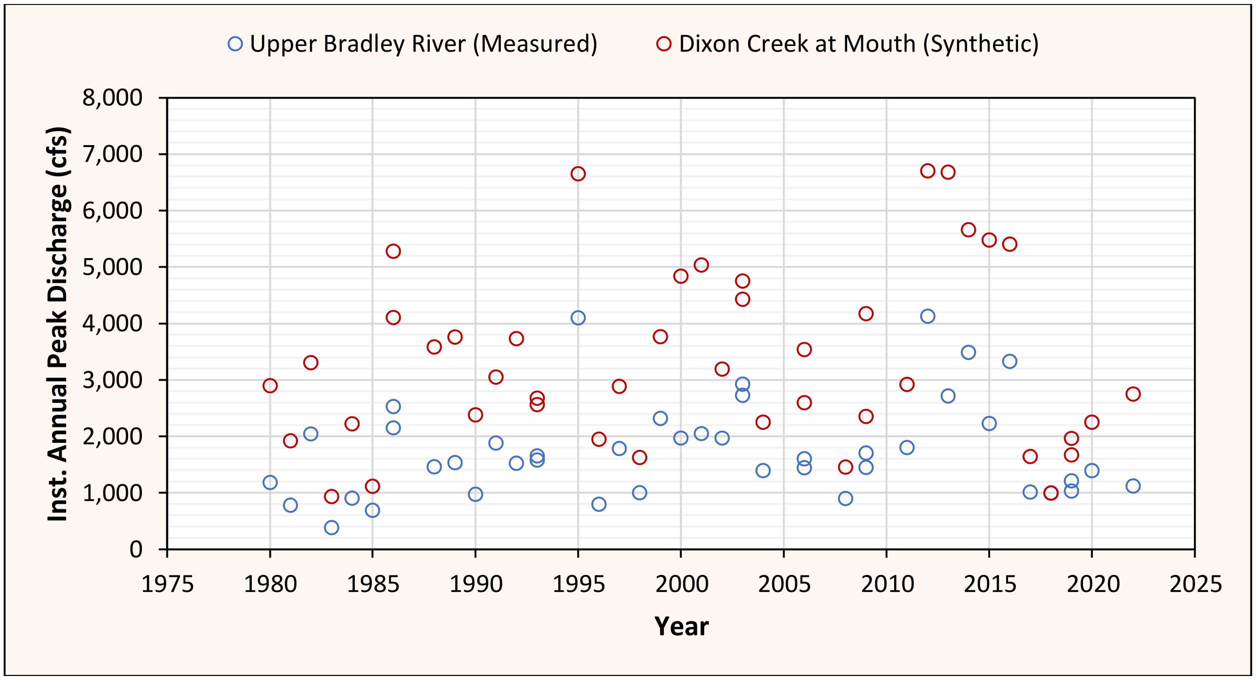


Figure 9. Instantaneous Annual Peak Discharge

Table 8 presents the results of the Bulletin 17C analysis for Dixon Creek at the Mouth using the synthetic discharge record.

Table 8. Bulletin 17C Analysis Results (Dixon Creek at Mouth)

Recurrence Interval (years)	Annual Exceedance Probability	Estimated Inst. Annual Maximum Flow (cfs)
2	50%	3,100
5	20%	4,600
10	10%	5,500
20	4%	6,400
50	2%	7,600
100	1%	8,400
200	0.5%	9,100
500	0.2%	10,000

3.3.3 FLOOD FREQUENCY SUMMARY

Figure 10 compares the (1) USGS Methods for Ungaged Streams results and (2) Bulletin 17C results. The Bulletin 17C analysis provides significantly larger peak flow magnitudes, especially at less-frequent recurrence intervals, but are within the 5% and 95% confidence intervals of the Ungaged Method results. Table 9 presents the maximum instantaneous discharges measured at Dixon Creek at the Mouth and the Upper Bradley River in 2023 and their corresponding recurrence interval. The peak flow measured in the Upper Bradley River in 2023 corresponds to a frequent recurrence interval (< 2-yr flood magnitude). Assuming Dixon Creek at the Mouth basin experienced hydrological and meteorological conditions similar to the Upper Bradley River basin, the peak flow occurring at Dixon Creek at the Mouth would also correspond to a relatively frequent recurrence interval. Therefore, it appears the Bulletin 17C results (Table 8) are more appropriate for Dixon Creek at the Mouth.

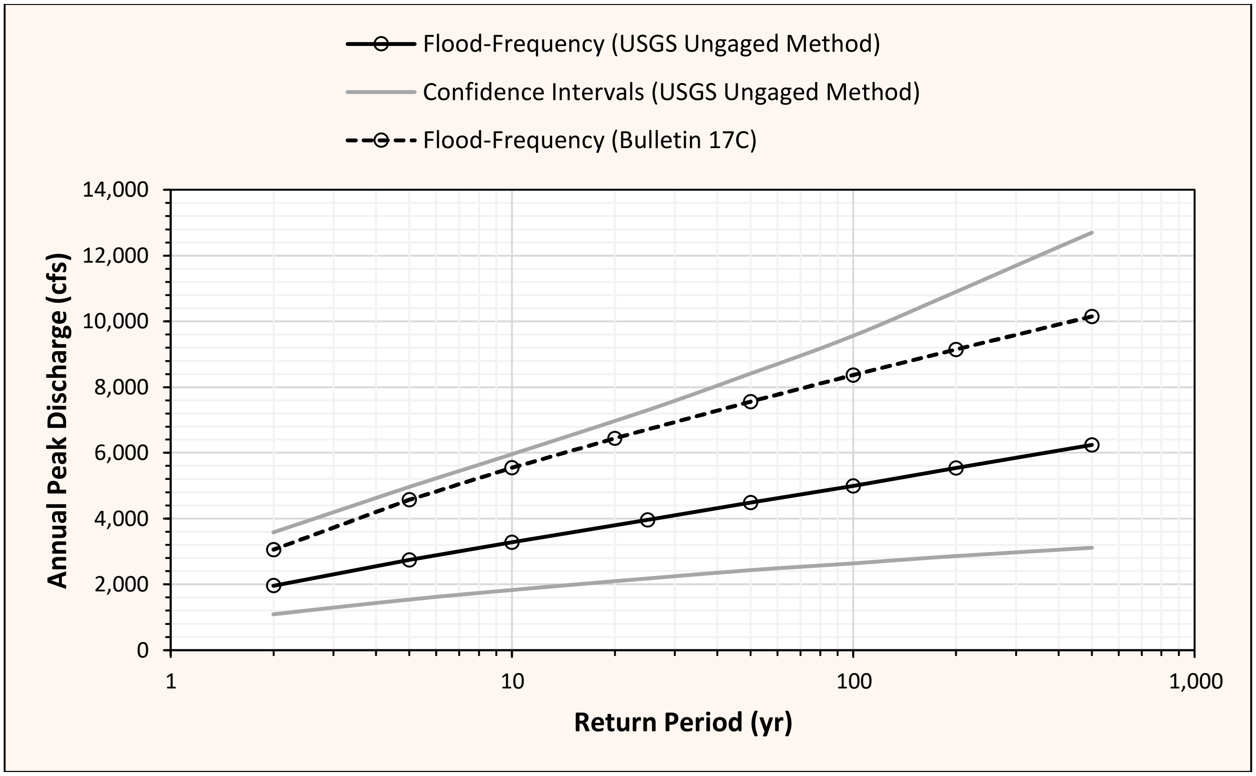


Figure 10. Flood-Frequency Results Comparison

Table 9. 2023 Peak Flows

Location	Instantaneous Maximum Q in 2023 (cfs)	Corresponding Recurrence Interval	
		Bulletin 17C Basis	USGS Ungaged Stream Basis
Dixon Creek at Mouth	3,590	3.0-yr	17-yr
Upper Bradley River near Nuka Glacier	1,090	1.3-yr	N/A

3.4 MASS BALANCE COMPARISON

By applying the principle of conservation of mass, runoff volume at the Upper Bradley River or Dixon Creek can be theoretically described using the following equation:

$$V_{runoff} = V_{precip} + V_{glacial} + V_{baseflow}$$

Precipitation, glacial melt, and streamflow (i.e., runoff) data are available for the Upper Bradley River. However, the baseflow component of streamflow is challenging to define accurately, and even if defined accurately, the equation's left and right sides will inevitably not be equal in a real-world scenario. The theoretical equation can be modified as follows to be used with available data:

$$V_{runoff} = C\left(V_{precip} + V_{glacial}\right)$$

In the above equation, C is a dimensionless coefficient to account for all other factors influencing the mass balance, including baseflow.

3.4.1 UPPER BRADLEY RIVER MASS BALANCE

3.4.1.1 PRECIPITATION DATA

Precipitation data from snowpack telemetry (SNOTEL) Site 1037 (Nuka Glacier) are available for the Upper Bradley River Basin. Figure 11 shows the cumulative annual precipitation recorded at the site. Table 10 compares the SNOTEL site data with parameter-elevation regressions on independent slope model (PRISM) 1981-2010 precipitation normals—the PRISM normals correlate well with the measured values at the SNOTEL site.

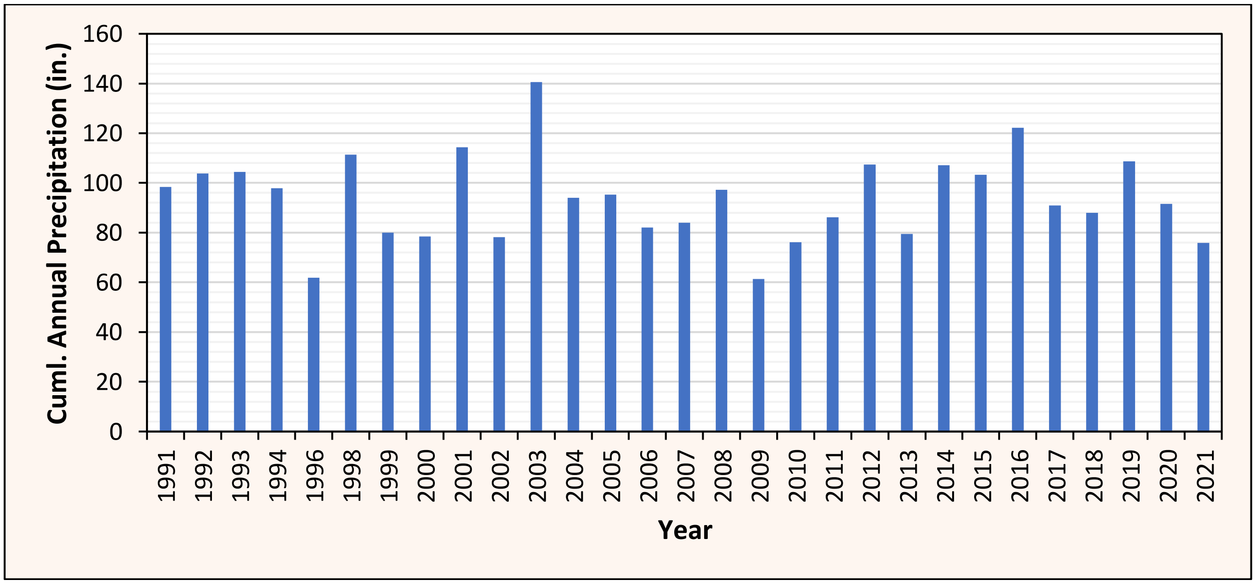


Figure 11. SNOTEL Site 1037 – Cumulative Annual Precipitation

Table 10. SNOTEL Site 1037 Comparison to PRISM Precipitation Normals

Month	Precipitation (in.)			
	1981-2010 PRISM Normals (Basin Average)	1981-2010 PRISM Normals (Min.-Max.)	SNOTEL Site 1037 Average 1991-2010	SNOTEL Site 1037 Average 2011-2021
January	8	7-10	6	10
February	8	7-9	7	6
March	6	5-9	6	5
April	8	6-10	7	5
May	5	5-6	5	5
June	4	4-5	4	4
July	5	4-7	5	5
August	7	6-8	6	8
September	12	11-16	11	15
October	13	10-18	13	15
November	10	7-13	11	9
December	12	9-15	11	10
Annual	98	80-126	92	97

3.4.1.2 GLACIAL MELT DATA

Two terrain mapping datasets are available for the glaciated area of the Upper Bradley River basin (i.e., Nuka Glacier), collected in two different years: 2014 and 2022. The 2014 terrain is derived from five-meter resolution interferometric synthetic aperture radar (IfSAR) mapping, and the 2022 terrain is derived from one-foot resolution light ranging and detection and ranging (LiDAR) mapping. By subtracting the 2022 terrain from the 2014 terrain, an estimate of glacial melt volume and spatial distribution is obtained, as shown in Figure 12. Table 11 presents the estimated glacial melt volume in the Upper Bradley River basin from 2014 to 2022 and an estimated annual melt volume assuming meteorological and hydrological stationarity between the years.

Table 11. Nuka Glacier Melt Volume (2014 to 2022)

Estimated Glacial Melt Volume	285,000 acre-ft
Estimated Average Annualized Melt Volume	34,800 acre-ft/yr

3.4.1.3 MASS BALANCE

Table 12 summarizes the mass balance for the Upper Bradley River basin from 2014 to 2022 (i.e., between the terrain mapping events). For documentation purposes, the total precipitation depth between the terrain mapping events was 792.5 inches, as measured at SNOTEL Site 1037. Approximately 302,000 more acre-ft of water ran off from 2014 to 2022 than was estimated from precipitation and glacial melt. To account for the discrepancy, a correction coefficient C of 1.40 is calculated.

Table 12. Upper Bradley River Mass Balance (2014 to 2022)

$V_{precip} =$	471,270 acre-ft
$V_{glacial} =$	285,000 acre-ft
$V_{in} =$	**756,270 acre-ft**
$V_{runoff} =$	1,058,320 acre-ft
$V_{out} =$	**1,058,320 acre-ft**
$V_{out} - V_{in} =$	302,050 acre-ft
$\boldsymbol{C = \frac{V_{out}}{V_{in}}} =$	**1.40**

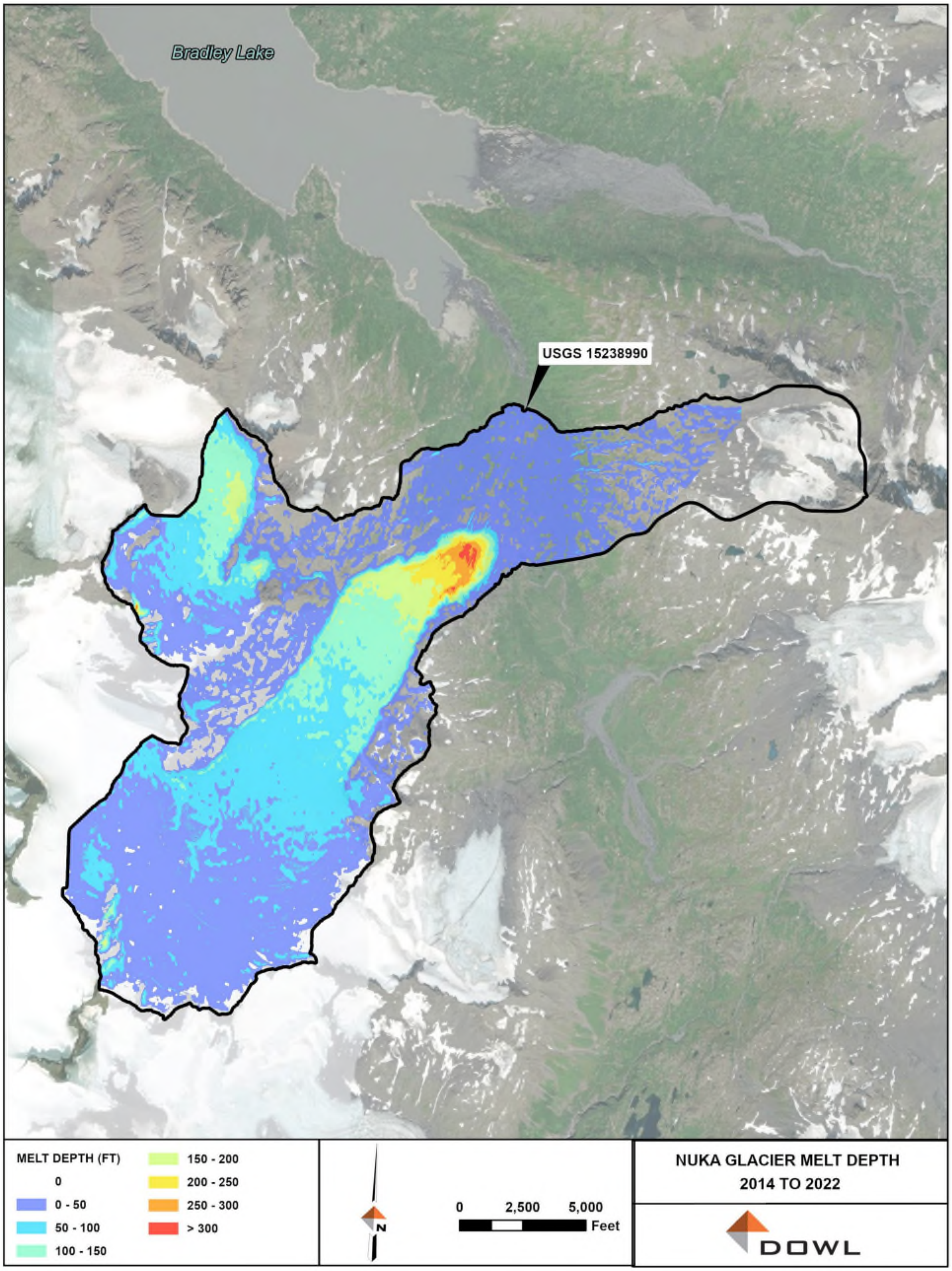


Figure 12. Nuka Glacier Melt Depth Map (2014 to 2022)

3.4.2 DIXON CREEK AT MOUTH MASS BALANCE

3.4.2.1 PRECIPITATION DATA

DOWL estimated cumulative annual precipitation depths occurring in the Dixon Creek at Mouth Basin using the following relationship:

$$P_{Dixon} = P_{SNOTEL\ 1037}\left(\frac{P_{Dixon\ PRISM}}{P_{Bradley\ PRISM}}\right)$$

The above relationship is based upon the assumption that precipitation depths in the Dixon Creek at Mouth basin can be estimated using measured precipitation in the Upper Bradley River Basin (i.e., SNOTEL Site 1037). DOWL adjusted the SNOTEL Site 1037 precipitation to the Dixon Creek at Mouth basin using a ratio of the PRISM normal between the basins. Based on the agreeance of PRISM normals and SNOTEL data shown in Table 10, the normals are likely a good indicator of precipitation for the Dixon Creek at Mouth basin. The cumulative precipitation depth between the terrain data collection times is estimated to be 841 inches.

3.4.2.2 GLACIAL MELT DATA

The Dixon Glacier melt volume from 2014 to 2022 can be estimated using the methodology described in Section 3.4.1.2. Figure 13 presents a melt depth map for the Dixon Glacier, and Table 13 summarizes the estimated glacial melt volume in the Dixon Creek at Mouth basin from 2014 to 2022.

Table 13. Dixon Glacier Melt Volume (2014 to 2022)

Estimated Glacial Melt Volume	755,000 acre-ft
Estimated Average Annualized Melt Volume	94,500 acre-ft/yr

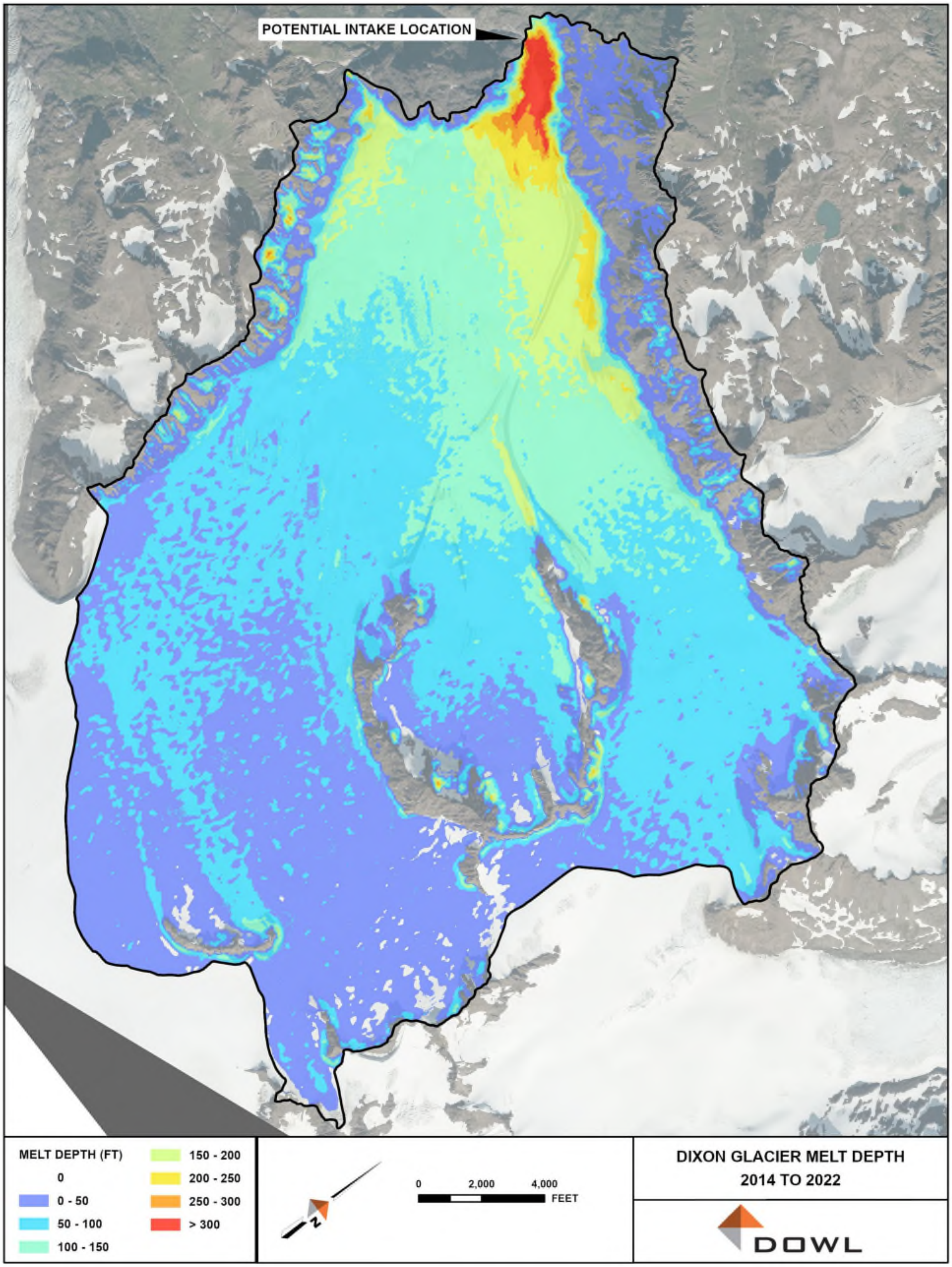


Figure 13. Dixon Glacier Melt Depth Map (2014 to 2022)

3.4.2.3 MASS BALANCE

Assuming the correction coefficient C solved for in Table 12 applies to the Dixon Creek at Mouth basin, the cumulative Dixon Creek runoff volume occurring between 2014 and 2022 can be estimated using the following mass balance approach:

$$V_{runoff} = C\left(V_{precip} + V_{glacial}\right)$$

$$= 1.40 \times \left((998{,}460\ acre \cdot ft) + (775{,}000\ acre \cdot ft)\right)$$

$$= 2{,}483{,}000\ acre \cdot ft$$

3.5 HYDROLOGIC ANALYSIS SUMMARY

Figure 14 presents the Dixon Creek at Mouth cumulative May through October runoff volumes estimated using the synthetic discharge record described in Section 3.1. Note that these are not potential diversion volumes and do not account for minimum instream flow and other diversion operations parameters. Estimated diversion amounts were investigated using the diversion operations model described in Section 4.0.

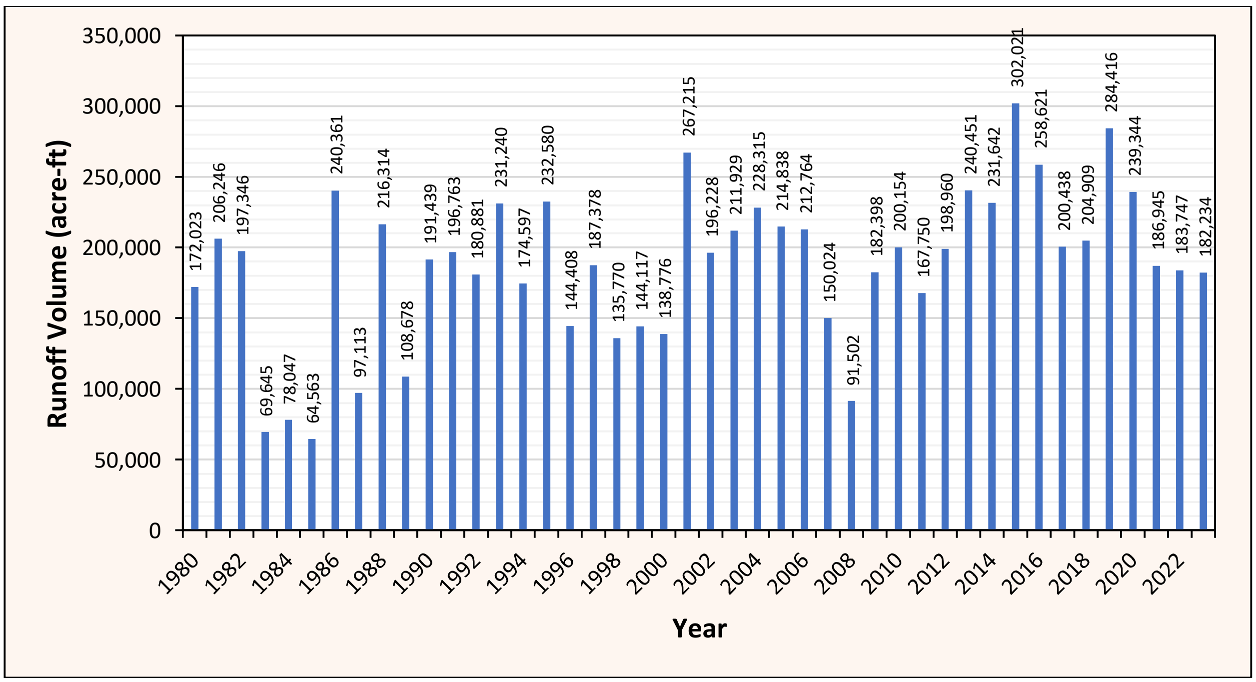


Figure 14. Dixon Creek at Mouth Runoff Volumes Estimated from Synthetic Discharge Record

Table 14 compares the Dixon Creek at Mouth 2014-2022 runoff volume estimated using the synthetic discharge record and the runoff volume estimated using the mass-balance methodology. The synthetic discharge methodology provides a runoff volume of 478,000 acre-ft less than the mass balance methodology. However, the synthetic discharge record volume estimate only accounts for streamflow from May through October. The comparison of the independent methodologies validates the order of magnitude of the synthetic discharge volume estimate, and the synthetic discharge record is used in the diversion operations model described in the following section.

Table 14. Comparison of Dixon Creek Runoff Volume Estimated Using Different Methodologies

Basis of Estimate	Estimated Runoff Volume (acre-ft)	Period
Synthetic Discharge Record	2,005,000	2014 to 2022
Mass Balance	2,483,000	2014 to 2022

4.0 DIVERSION OPERATIONS MODEL

The objective of the diversion operations model described in the following subsections is to quantify the amount of water that could be diverted using different assumed diversion tunnel capacities and minimum instream flow requirements. Appendix B includes results printouts from the model.

4.1 ASSUMPTIONS & METHODOLOGY

The operations model is based on the following instream flow assumption for all months the diversion would be operating:

- When Dixon Creek streamflow is less than or equal to 100 cfs, all flow would be passed downstream (i.e., diversion would not occur).
- When Dixon Creek streamflow exceeds 100 cfs, at least 100 cfs would be passed downstream (i.e., Q_{MIF} = 100 cfs).

Minimum Instream Flow (MIF) requirements will evolve as more hydrological and biological information becomes available for the watershed. Agency-determined MIFs will likely be different for different months/periods.

The operations model uses the following logic to estimate diverted streamflows from the synthetic Dixon Creek discharge record:

- Streamflows up to 100 cfs are bypassed. The “first water” in the creek goes to the MIF.
- Streamflows exceeding 100 cfs and less than the assumed tunnel capacity for the particular scenario are diverted.
- Streamflows exceeding the tunnel capacity are bypassed (i.e., wasted).

For this report, DOWL examined three different tunnel capacities: 1,000 cfs, 1,200 cfs, and 1,400 cfs. DOWL also investigated the sensitivity of different periods of record (e.g., the last 20 years vs. the entire period of record) to consider the potential of non-stationarity in Dixon Glacier melt rates and precipitation trends.

4.2 RESULTS SUMMARY

Table 15 presents the results of the diversion operations model. More extensive results are included in Appendix B. The diverted amounts listed in Table 15 are average annual amounts for the specified period of record. Table 16 presents results from the operations model based on only the measured 2023 data. Note that October data were not available for the measured dataset, and thus, the diverted volume in Table 16 is lower than the expected diverted volumes listed in Table 15.

It appears that the average runoff volume in Dixon Creek is increasing over time. For example, the average annual runoff volume estimated using only 2003-2022 data, a sample size of reasonable statistical relevance, is about 12% larger than when considering the entire period of record.

Table 15. Diversion Operational Model Results (Using Synthetic Record)

Period of Record	Average Annual Runoff (acre-ft)	Average Annual Diverted Volume (acre-ft)		
		Tunnel Capacity: 1,000 cfs	Tunnel Capacity: 1,200 cfs	Tunnel Capacity: 1,400 cfs
1980-2022 (All Data)	189,300	133,200 (70% diverted)	141,900 (75% diverted)	147,400 (78% diverted)
1993-2022 (30-yr Record)	203,700	143,200 (70% diverted)	152,800 (75% diverted)	159,000 (78% diverted)
2003-2022 (20-yr Record)	212,200	147,900 (70% diverted)	158,400 (75% diverted)	165,500 (78% diverted)
2013-2022 (10-yr Record)	238,500	160,400 (67% diverted)	173,600 (73% diverted)	182,800 (77% diverted)

Table 16. Diversion Operational Model Results (Using Measured 2023 Data)

Period of Record	Runoff (acre-ft)	Average Annual Diversion Volume (acre-ft)		
		Tunnel Capacity: 1,000 cfs	Tunnel Capacity: 1,200 cfs	Tunnel Capacity: 1,400 cfs
5/1/2023 – 9/30/2023	179,559	122,573 (68% diverted)	130,339 (73% diverted)	137,315 (76% diverted)

Table 17 compares tunnel size (i.e., capacity) to the incremental increase in diverted volume. The table shows that the incremental benefit of increasing tunnel size decreases as tunnel capacity increases. Based on this analysis, it appears that a tunnel size that achieves a capacity between 1,000 and 1,400 cfs will achieve a reasonable balance between size and cost.

Table 17. Incremental Increase in Diverted Volume with Increased Tunnel Capacity

Tunnel Capacity	Average Annual Diverted Volume (acre-ft)	Incremental Increase in Diverted Volume (acre-ft)	Incremental Increase in Diverted Volume (%)
1,000 cfs	133,200 to 160,400	-	-
1,200 cfs	141,900 to 173,600	8,700 to 13,200	7% to 8%
1,400 cfs	147,400 to 182,800	5,500 to 9,200	4% to 5%

5.0 REFERENCES

[1] DOWL, "Dixon Glacier Basin Hydrologic Analysis," 2022.

[2] DOWL, "Dixon Glacier Precipitation Trends," 2022.

[3] J. H. Curran, D. F. Meyer and G. D. Tasker, "Estimating the Magnitude and Frequency of Peak Streamflows for Ungaged Sites on Streams in Alaska and Conterminus Basins in Canada," US Geological Survey, Anchorage, AK, 2003.

Appendix A:
Streamflow Data Collection Memorandum

TO: Bryan Carey, PE
FROM: Jack Krusemark, EI; Euan-Angus MacLeod, PE, CFM; Cameron Brailey, EIT
DATE: 10/27/2023
PROJECT: Dixon Diversion Conceptual Study
SUBJECT: Streamflow Data Collection
\\dowl.com\j\Projects\36\90090-01\91Rpts\HydrologyReportsAndMemos\202310_DixonDiversionHydrologyReport\Appendices\A_StreamflowDataMemo\Dixon_StreamflowDataCollectionMemo.docx

DOWL collected stage and discharge data at three locations along the Martin River/Dixon Creek watercourse to support the hydrologic analyses performed for the Dixon Diversion Conceptual Study, listed below:

1. At a constriction in the Martin River near river mile (RM) 1.5 (a.k.a. Martin River at Constriction)
2. Near the outlet of Red Lake (a.k.a. Red Lake Basin Outlet)
3. Near the outlet of Mid-Reach Lake (a.k.a. Mid-Reach Lake Basin Outlet)

DOWL also analyzed the preliminary USGS data for a gage at Dixon Creek at Mouth near RM 4.2 (USGS 15238951). Figure 1 presents an excerpt of a schematic map showing the general locations of the gage locations. The Dixon Diversion Conceptual Study Hydrology Report includes the full schematic map.

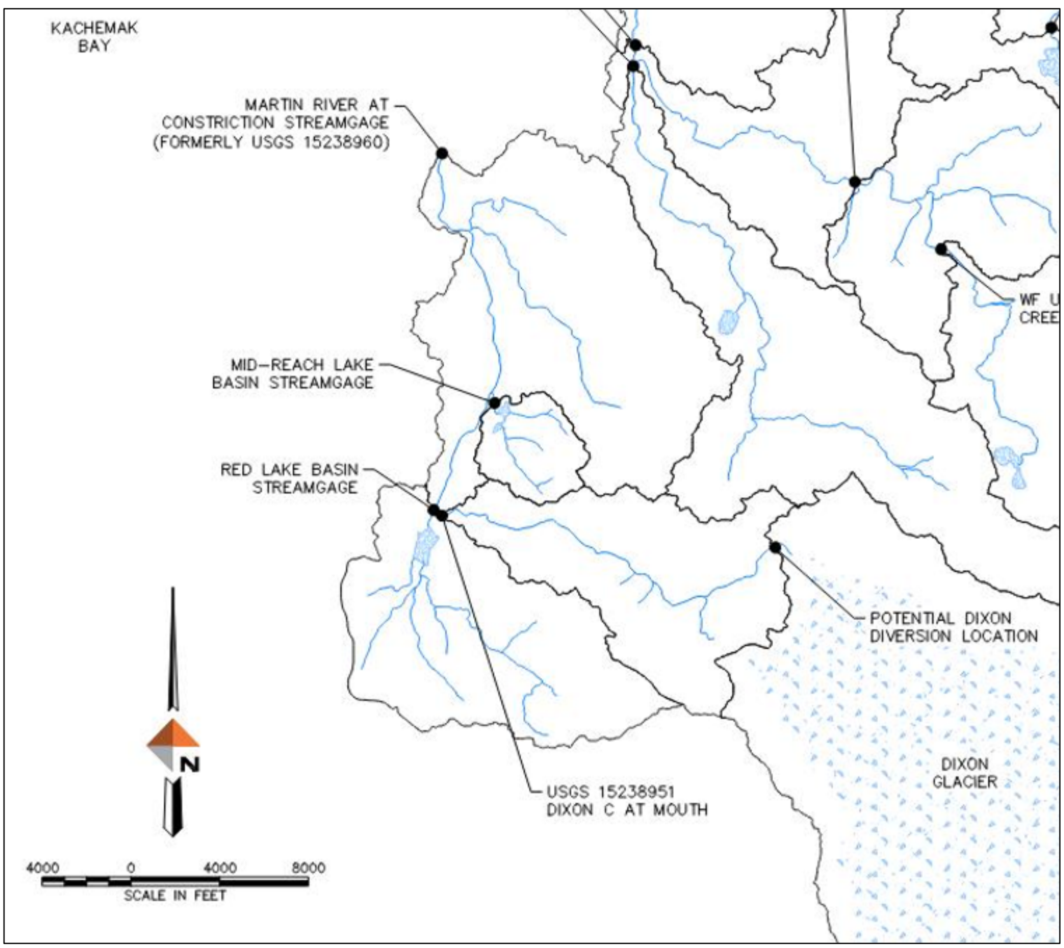


Figure 1. Streamgages along the Martin River/Dixon Creek Watercourse

MEASUREMENT METHODOLOGY

To measure stage, DOWL used HOBO MX2001 water level data loggers. Once installed, the loggers captured data at a 15-minute interval. The loggers were secured to a protective casing, either a 1.25-inch stainless steel pipe or a 2-inch aluminum stilling well. In low-velocity locations, the protective casings were attached to dowels driven into the channel bed, and in high-velocity locations, the stilling well was fastened to bedrock using self-tapping rock bolts.

DOWL deployed the stage data loggers during open-water conditions (approximately April to November) and retrieved the data from the loggers monthly. While retrieving data, DOWL assessed each logger for damage and movement. Stage measurements performed by DOWL used guidance from the USGS methodology Techniques and Methods 3-A7: Stage Measurement at Gaging Stations.

Depending on flow conditions, DOWL used either a Sontek RS5 Acoustic Doppler Current Profiler (ADCP) or a FlowTracker 2 to measure discharge. Discharge measurements were performed as close to the stage data logger as possible. Discharge measurements were collected monthly (at a minimum) to capture the seasonal discharge variations of the watershed. Discharge measurements performed by DOWL used guidance from the following USGS methodologies:

- Techniques and Methods 3-A8: Discharge Measurements at Gaging Stations
- Techniques and Methods 3-A22: Measuring Discharge with Acoustic Doppler Current Profilers from a Moving Boat

Each ADCP discharge measurement consisted of four to sixteen individual ADCP measurements (i.e., transects). The individual measurements were averaged to provide a single flow measurement for that date and time. DOWL reviewed all ADCP measurements for consistent bottom tracking, estimated flows near banks, percent of flow measured, average water velocity, total flow, and the coefficient of variation. Transects with significant errors or missing data were removed. Low-flow discharge measurements were collected with the FlowTracker 2 ADCP using at least twenty discrete sampling stations along a transect, velocities, depths, and percent discharge uncertainty values.

SITE DESCRIPTIONS

MARTIN RIVER AT CONSTRICTION

DOWL collected stage data for the Martin River at the Constriction using two stage data loggers, one installed on each side of the constriction for redundancy. The streambed within the bedrock constriction is an alluvial braid plain. The high-velocity environment appears to induce varying channel properties such as cross-sectional area, channel orientation, velocity distribution, and bed elevation. Moving beds induced by sediment transport may impact hydroacoustic discharge measurements at this site.

Figure 2 shows the Martin River at Constriction gage location, Figure 3 shows an aerial photograph of the site, and Figure 4 shows photos of the two stage gages installed. The river-right gage was damaged on July 3 during a high flow event, and DOWL was unable to replace this sensor. Three relatively low-flow discharge measurements were collected while this sensor was operable. The river-left sensor operated from April 25 to July 16, 2023, and from August 31, 2023 to present day. The river-left sensor malfunctioned from July 16 to August 31 and could not be replaced until DOWL had the proper safety equipment and resources to access the gage. Check gage heights were not collected at the constriction due to safety concerns in reaching the established gage height reference points.

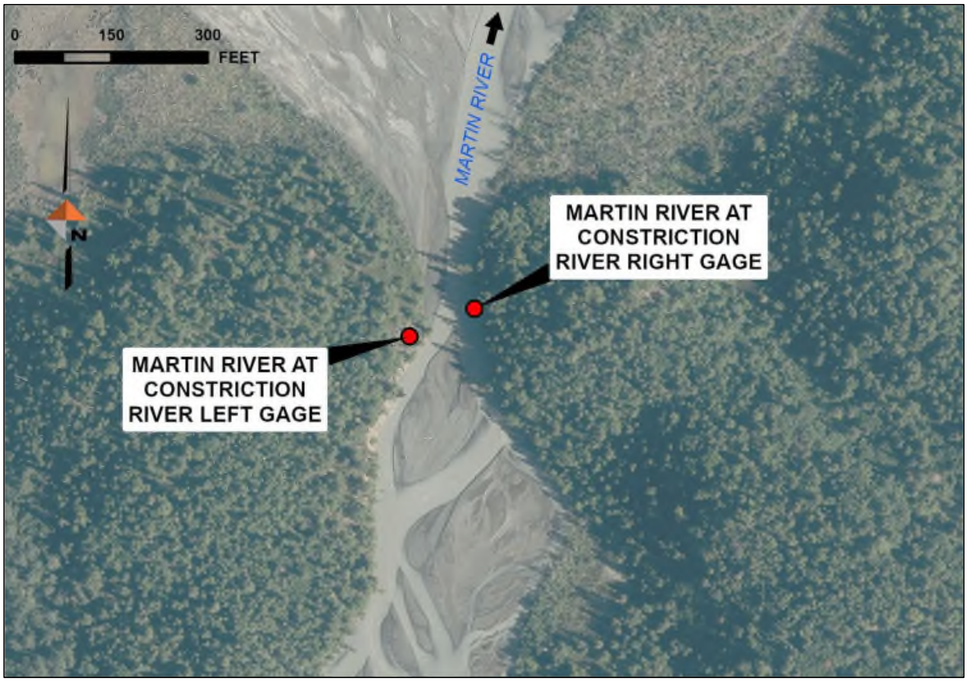


Figure 2. Martin River at Constriction Gage Location

Figure 3. Martin River at Constriction (Looking Downstream)

Figure 4. Constriction River-Left Gage (Left) and River-Right Gage (Right)

RED LAKE BASIN OUTLET

This gage is located near the outlet of Red Lake, in the channel constriction before its confluence with the Martin River. The outlet channel appears to have stable geometry. The gage is located between apparently stable grade control features upstream and downstream, consisting of medium-sized boulders. Figure 5 shows the location of the gage, and Figure 6 shows a photograph of the gage.

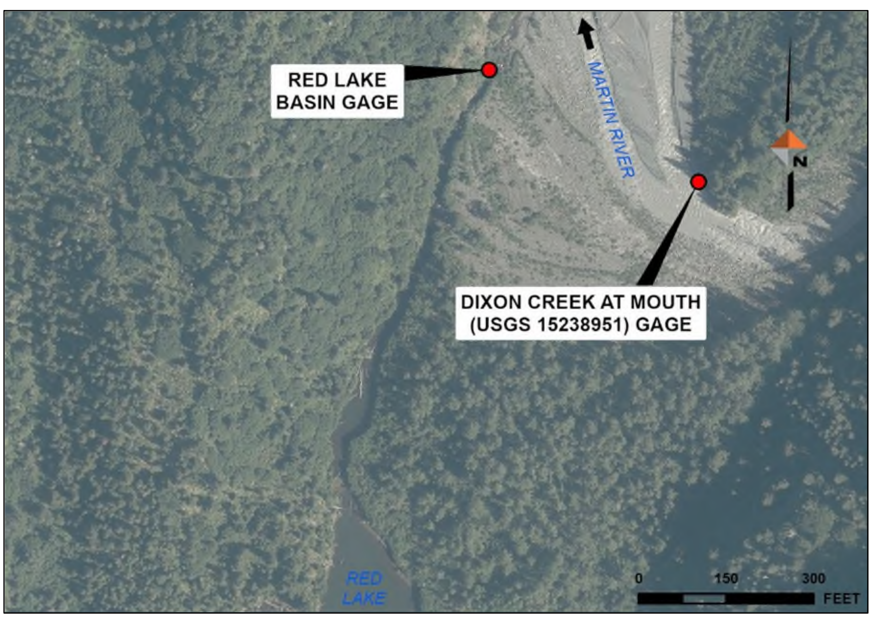


Figure 5. Red Lake Basin Outlet Gage Location

Figure 6. Red Lake Basin Outlet Gage

MID-REACH LAKE BASIN OUTLET

This gage is located near the outlet of a mid-reach lake upstream of the drainage's confluence with the Martin River. Figure 7 shows the location of the gage, and Figure 8 shows a photograph of the gage. The channel at the site is shallow and appears to be overtopped during high-flow events in the Martin River.

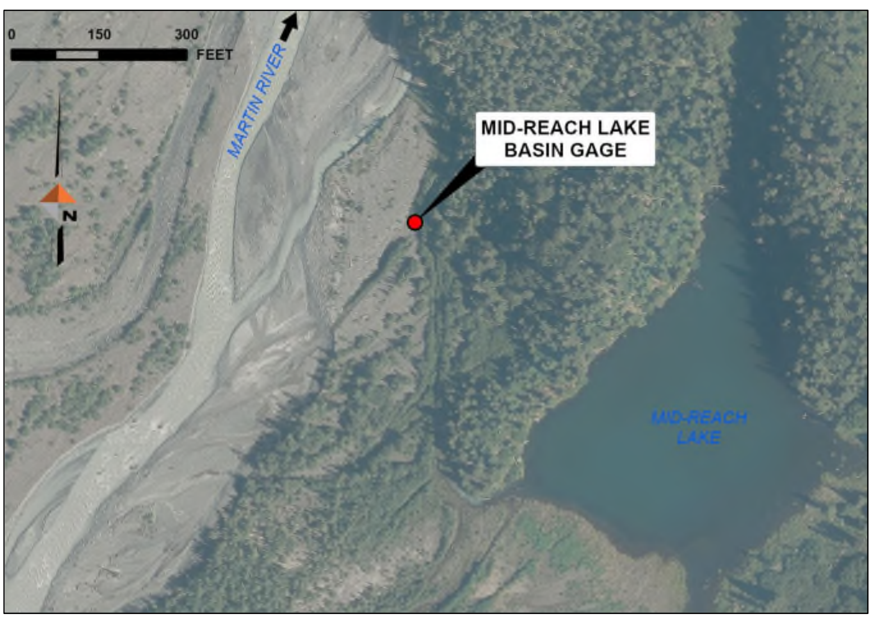


Figure 7. Mid-Reach Lake Basin Outlet Gage Location

Figure 8. Mid-Reach Lake Basin Outlet Gage

DIXON CREEK AT MOUTH (USGS 15238951)

The USGS has operated a stage gage at Dixon Creek at the Mouth since April 13, 2023. Figure 9 shows the location of the USGS gage, and Figure 10 shows a photograph of the gage. USGS-published continuous discharge data are not yet available for the site because they are still in the process of creating a gage rating curve. Provisional stage data are available on the USGS website, and the USGS has measured discharge twice at the site.

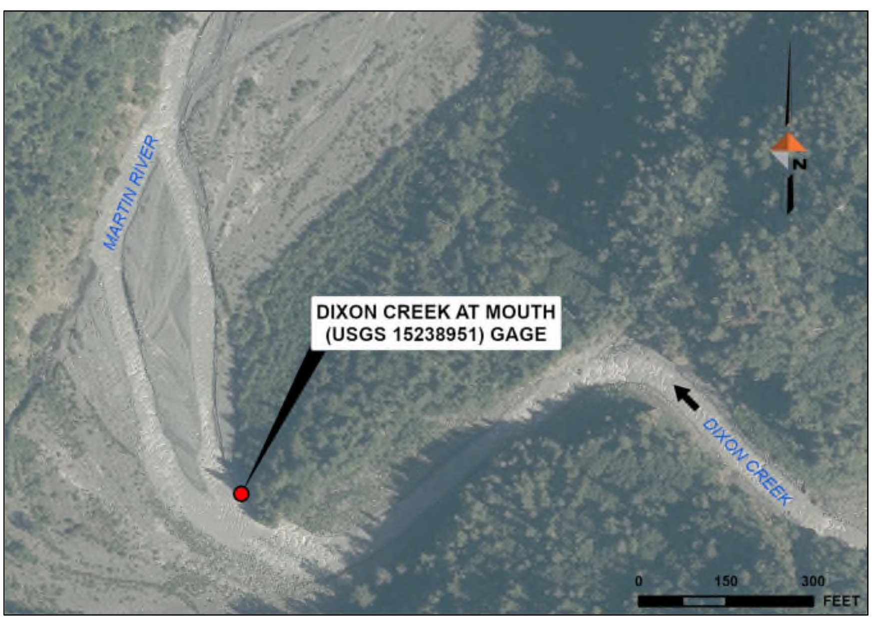


Figure 9. Dixon Creek at Mouth (USGS 15238951) Gage Location

Figure 10. Dixon Creek at Mouth (USGS 15238951) Gage

2023 DISCHARGE MEASUREMENTS

Table 1 presents the discharge measurements collected along the Martin River/Dixon Creek watercourse in 2023.

Table 1. 2023 Discharge Measurements

Date	Measured discharge (cfs)			
	Martin River at Constriction	Red Lake Basin Outlet	Mid-Reach Lake Basin Outlet	Dixon Creek at Mouth[1]
4/24/2023	-	2.07	1.19	-
4/25/2023	23.14	-	-	-
5/26/2023	186.2	39.2	2.94	-
6/23/2023	-	12.3	1.03	-
7/12/2023	-	-	-	927
7/20/2023	900	4.2	1.09	-
8/16/2023	-	-	-	1,010
8/24/2023	1,291	-	-	-
8/31/2023	2,030	-	-	-
9/19/2023	346	10.8	1.43	-

[1] USGS collected the discharge measurements for Dixon Creek at Mouth.

STREAMGAGE RATING CURVES

MARTIN RIVER AT CONSTRICTION

Figure 11 presents the rating curve for the Martin River at Constriction gage using the river-left constriction gage and four data points for which accurate stage and discharge data are available. A power equation ($Q = 323h^{2.01}$) was fit to the data with a coefficient of determination (i.e., R^2) of 0.96.

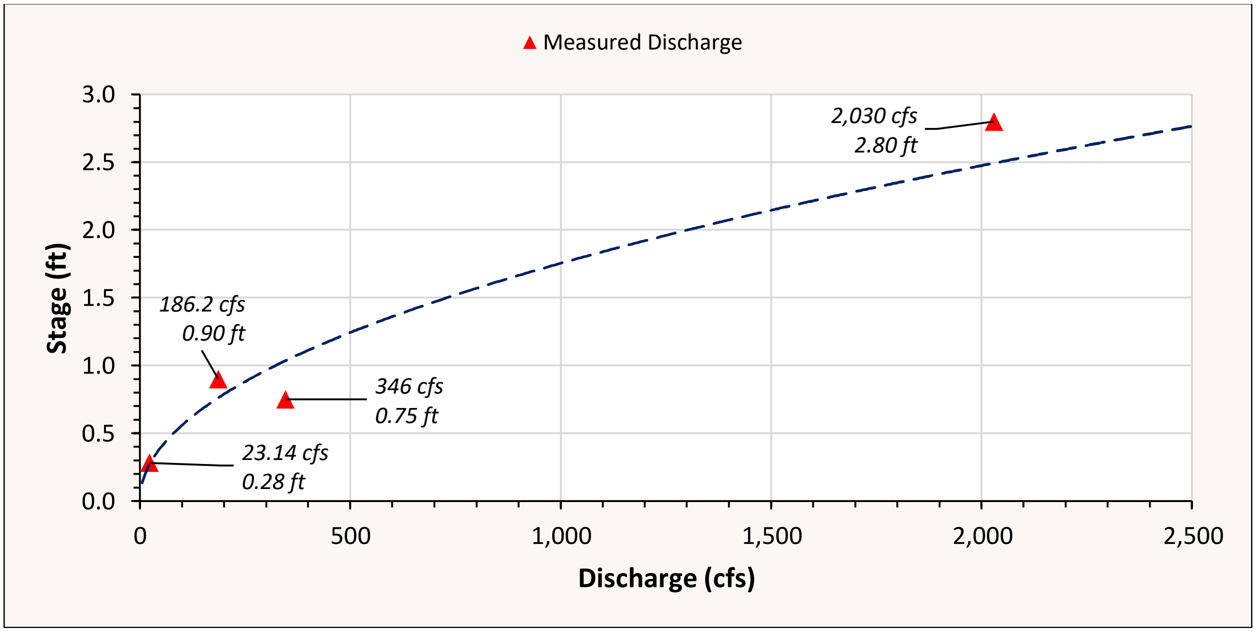


Figure 11. Martin River at Constriction Streamgage Rating Curve

RED LAKE BASIN OUTLET

Figure 12 presents the rating curve for the Red Lake Basin Outlet gage using five data points. A power equation ($Q = 2.28h^{4.05}$) was fit to the data with a coefficient of determination of 0.97.

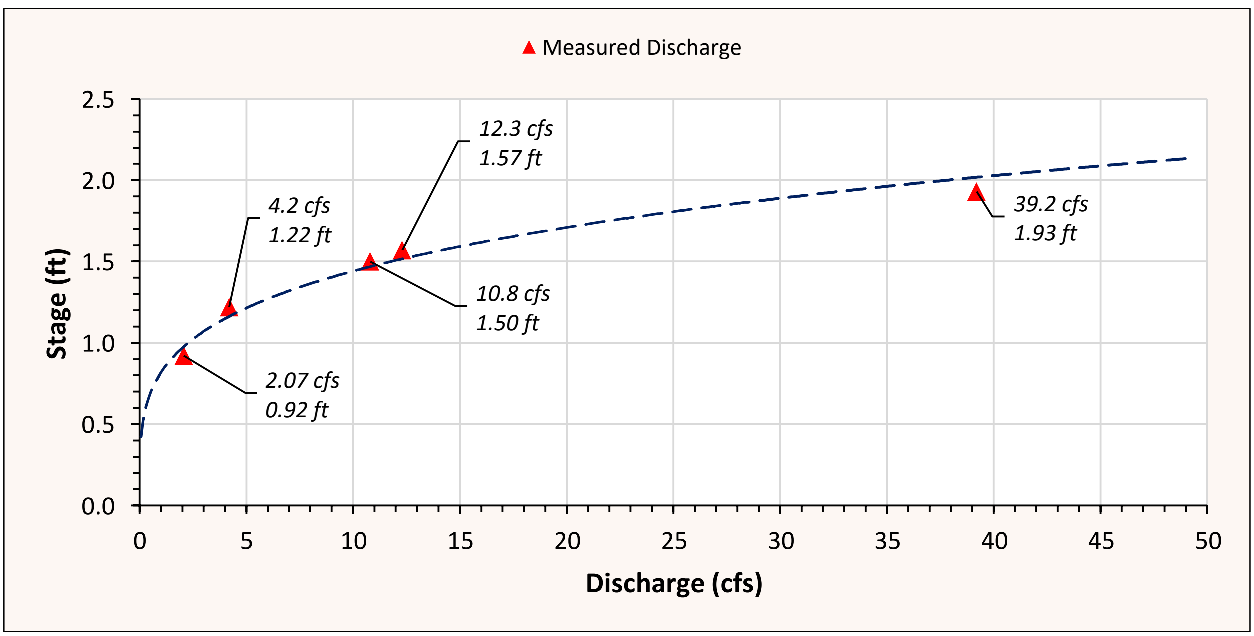


Figure 12. Red Lake Basin Outlet Streamgage Rating Curve

MID-REACH LAKE BASIN OUTLET

Figure 13 presents the rating curve for the Mid-Reach Lake Basin Outlet gage using five data points. A power equation ($Q = 15.8h^{3.47}$) was fit to the data with a coefficient of determination of 0.82.

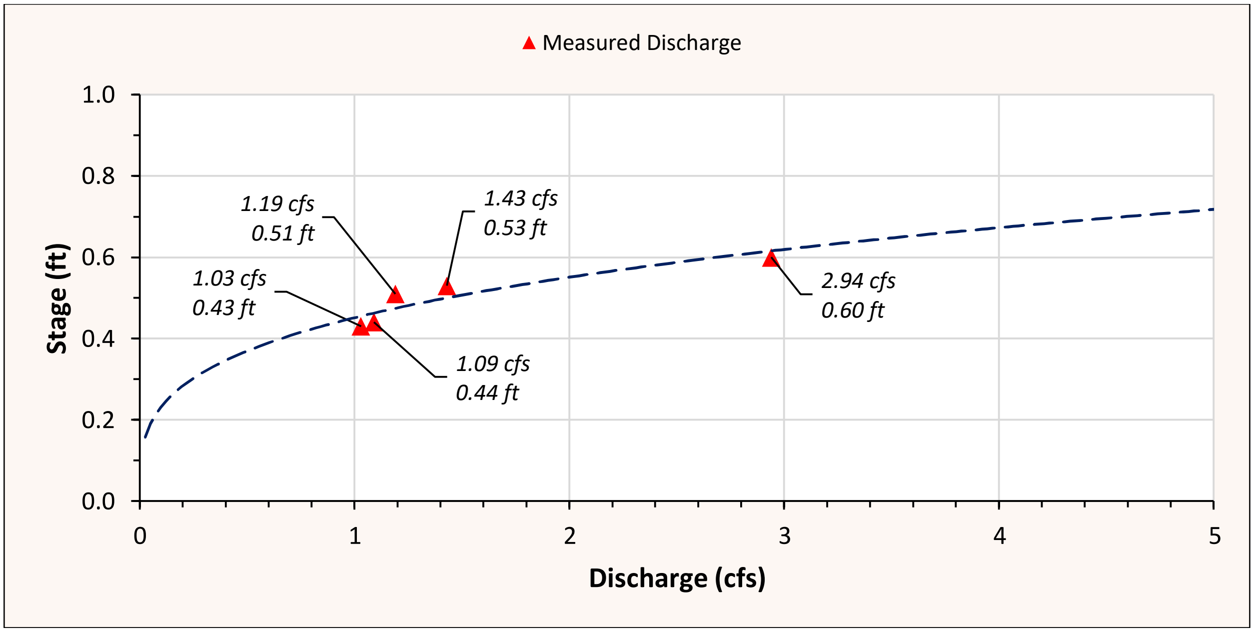


Figure 13. Mid-Reach Lake Basin Outlet Streamgage Rating Curve

DIXON CREEK AT MOUTH

Only two discharge measurements are currently available for Dixon Creek at the Mouth, taken at relatively similar flow rates. DOWL developed a provisional rating curve for the site by estimating Dixon Creek discharge on days that measured discharge data for Martin River at the Constriction are available. It was assumed that Dixon Creek at Mouth discharge can be estimated by subtracting Red Lake Outlet and Mid-Reach Lake Outlet daily average discharge from the DOWL-measured Martin River at Constriction discharge. This assumption is further discussed later in this document. Table 2 presents the measured and estimated Dixon Creek at Mouth discharge and stages and presents the provisional rating curve ($Q = (4.99 \times 10^{-5})h^{9.23}$).

Table 2. Basis of Dixon Creek at Mouth Provisional Rating Curve

Date	Discharge (cfs)	Stage (ft)	Notes
4/25/2023	20	4.16	Estimated[2]
5/26/2023	152	4.97	Estimated[2]
7/12/2023	927	6.12	Stage and discharge measured by USGS
7/20/2023	894	6.19	Estimated[2]
8/16/2023	1,010	6.28	Stage and discharge measured by USGS
8/24/2023	1,289	1,289	Estimated[2]
8/31/2023	2,008	6.70	Estimated[2]
9/19/2023	334	5.14	Estimated[2]

[2] $Q_{Mouth} = Q_{Constriction} - Q_{Red\ Lake} - Q_{MR\ Lake}$

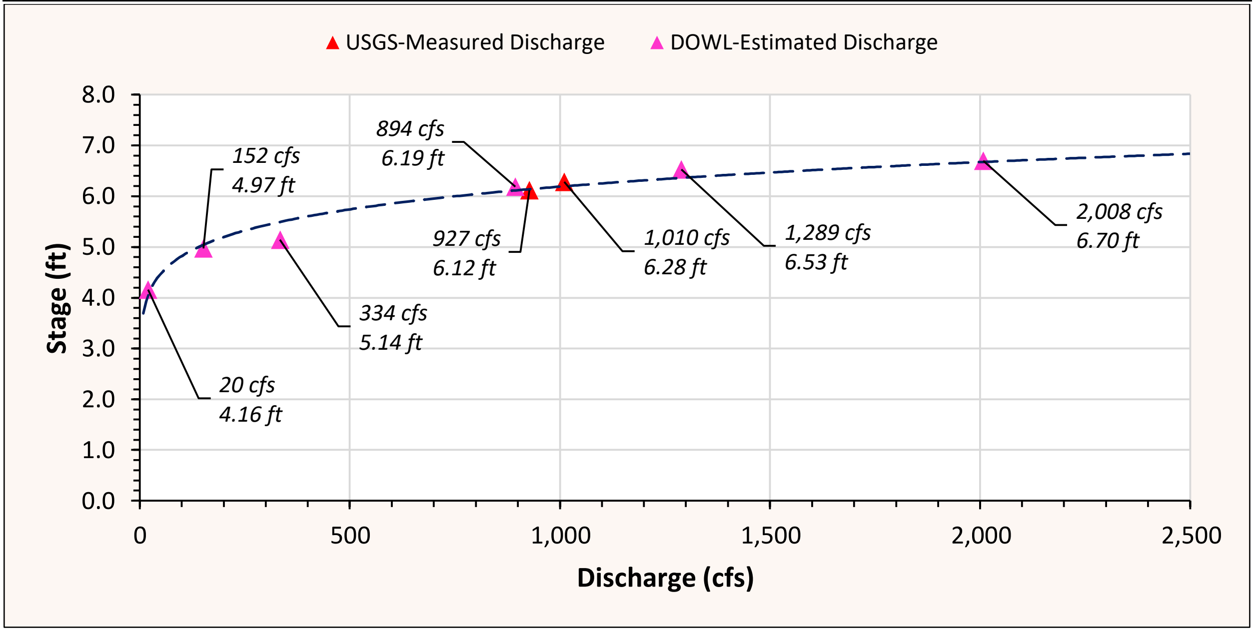


Figure 14. Dixon Creek at Mouth Provisional Streamgage Rating Curve

CONTINUOUS STREAMFLOW DATA

MARTIN RIVER AT CONSTRICTION

Figure 15 presents the 2023 continuous streamflow record for the Martin River at Constriction gage. DOWL developed the continuous streamflow record by applying the gage rating curve in Figure 11 and filtering erroneous stage measurements from the dataset. Attachment 1 includes tabulated daily average discharge values. Note the gap in the dataset from July 16 to August 31 – this is due to the stage gage malfunctioning.

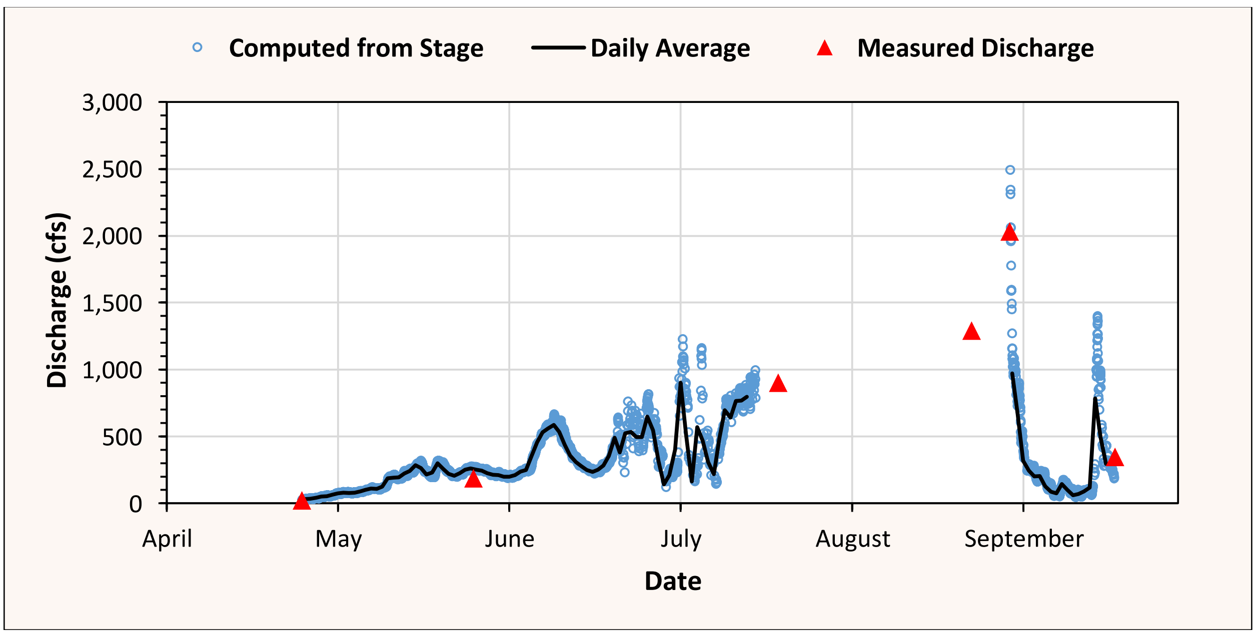


Figure 15. Martin River at Constriction Continuous Streamflow Record

RED LAKE BASIN OUTLET

Figure 16 presents the 2023 continuous streamflow record for the Martin River at Constriction gage. DOWL developed the continuous streamflow record by applying the gage rating curve in Figure 12 and filtering erroneous stage measurements from the dataset. Attachment 1 includes tabulated daily average discharge values. The data gap from April 28 to June 24 is reasonably filled out by interpolating between the available data.

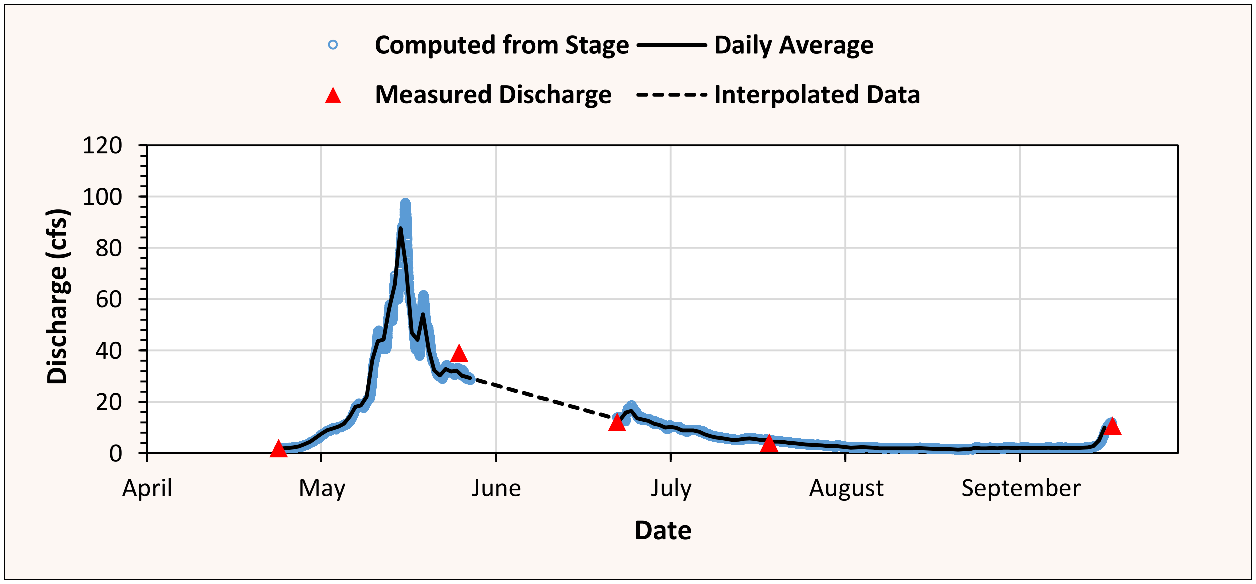


Figure 16. Red Lake Basin Outlet Continuous Streamflow Record

MID-REACH LAKE BASIN OUTLET

Figure 17 presents the 2023 continuous streamflow record for the Martin River at Constriction gage. DOWL developed the continuous streamflow record by applying the gage rating curve in Figure 13 and filtering erroneous stage measurements from the dataset. Attachment 1 includes tabulated daily average discharge values.

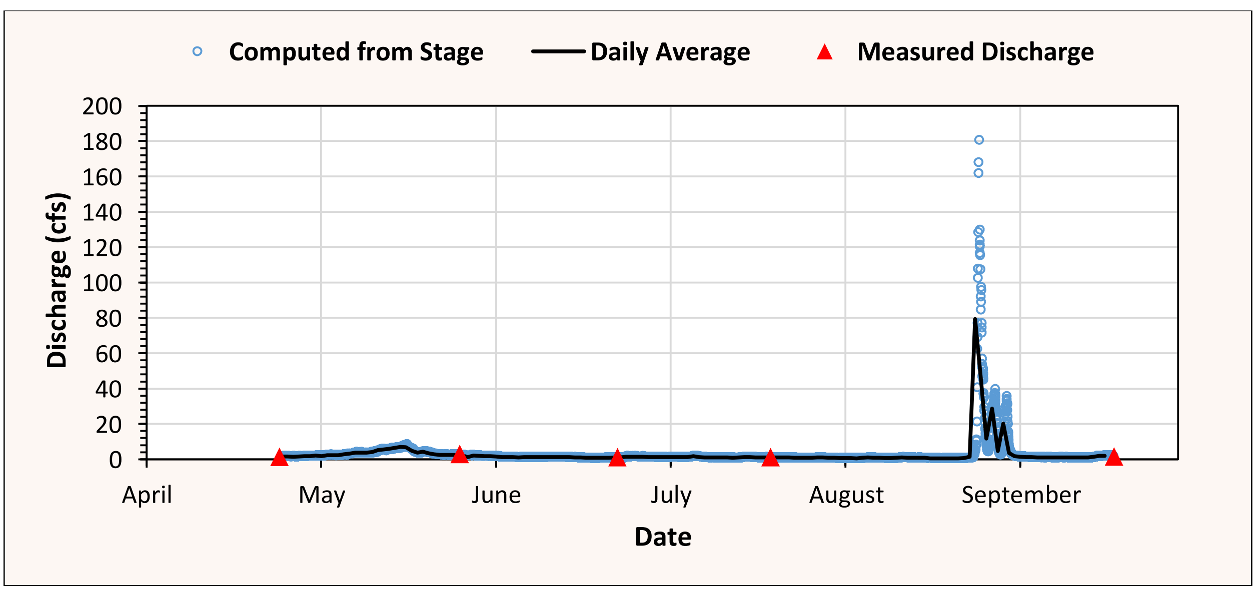


Figure 17. Mid-Reach Lake Basin Outlet Continuous Streamflow Record

DIXON CREEK AT MOUTH

Given the data gaps in the Dixon Creek at Mouth and Martin River at Constriction datasets, DOWL used a combination of the datasets to develop a best-estimate daily average flow hydrograph for Dixon Creek at the Mouth. Figure 18 presents the best-estimate hydrograph, and Attachment 1 includes tabulated values.

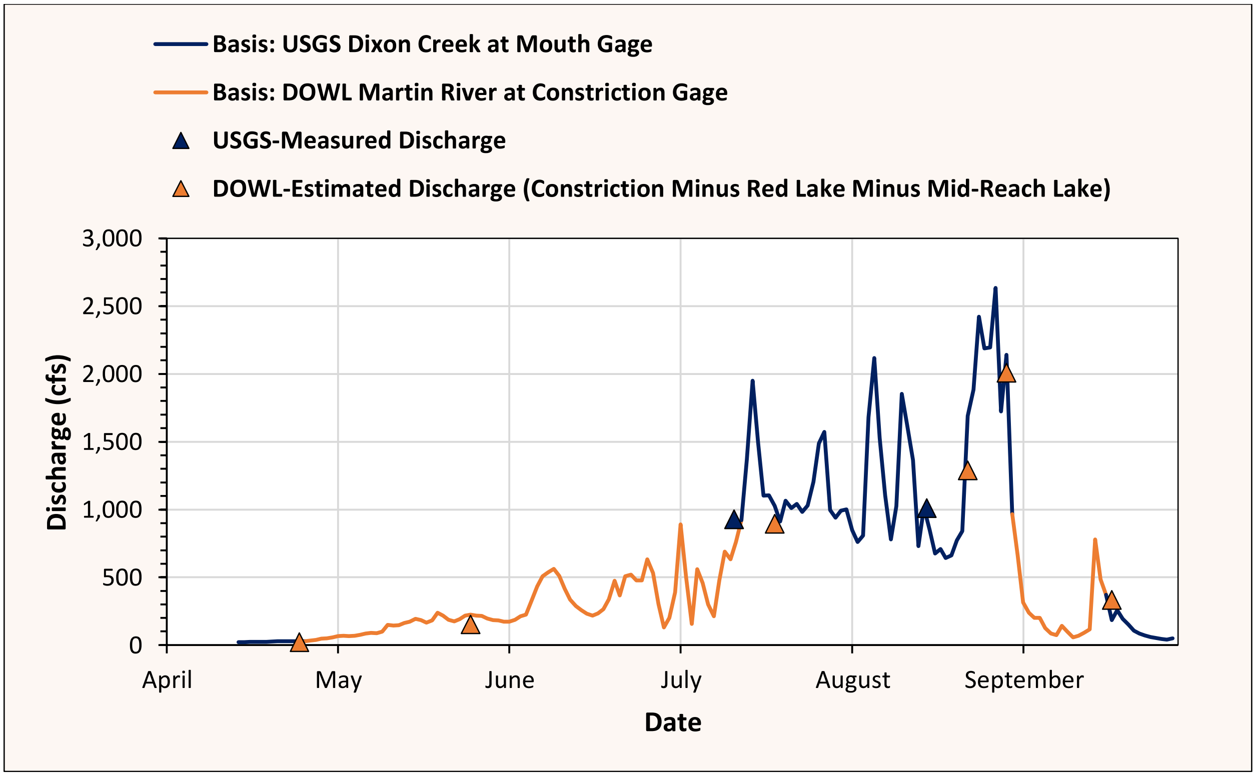


Figure 18. Dixon Creek at Mouth Best-Estimate Streamflow Record

The 2023 Dixon Creek at Mouth hydrograph shown in Figure 18 is based on the following assumptions:

- DOWL assumes that Dixon Creek at Mouth discharge can be estimated by subtracting Red Lake and Mid-Reach Lake Basin discharge from Martin River at Constriction discharge. Inherent in this assumption is that the purple drainage shown in Figure 19 contributes negligibly to Martin River discharge. For comparison purposes, this is a 5.36 mi^2 area, the Red Lake Basin is a 3.56 mi^2 area, and the Red Lake Basin does not contribute significantly to Martin River Discharge. Both the purple drainage area and the Red Lake Basin share relatively similar, non-glaciated, hydrologic characteristics, although Red Lake itself may attenuate discharge in a way that the purple basin does not.

- The Martin River at Constriction streamgage rating curve is based on more measured data than the provisional Dixon Creek at Mouth streamgage rating curve. Therefore, DOWL assumes that when Martin River at Constriction data are available, a more accurate estimate of Dixon Creek at Mouth discharge is provided using the Constriction dataset as the estimate basis.

- For times when Martin River at Constriction discharge data are unavailable, DOWL filled the gaps in the dataset using provisional USGS Dixon Creek at Mouth stage data and the Figure 14 rating curve.

As more data become available (e.g., a USGS-published rating curve for Dixon Creek at the Mouth), DOWL will review and update discharge records as necessary.

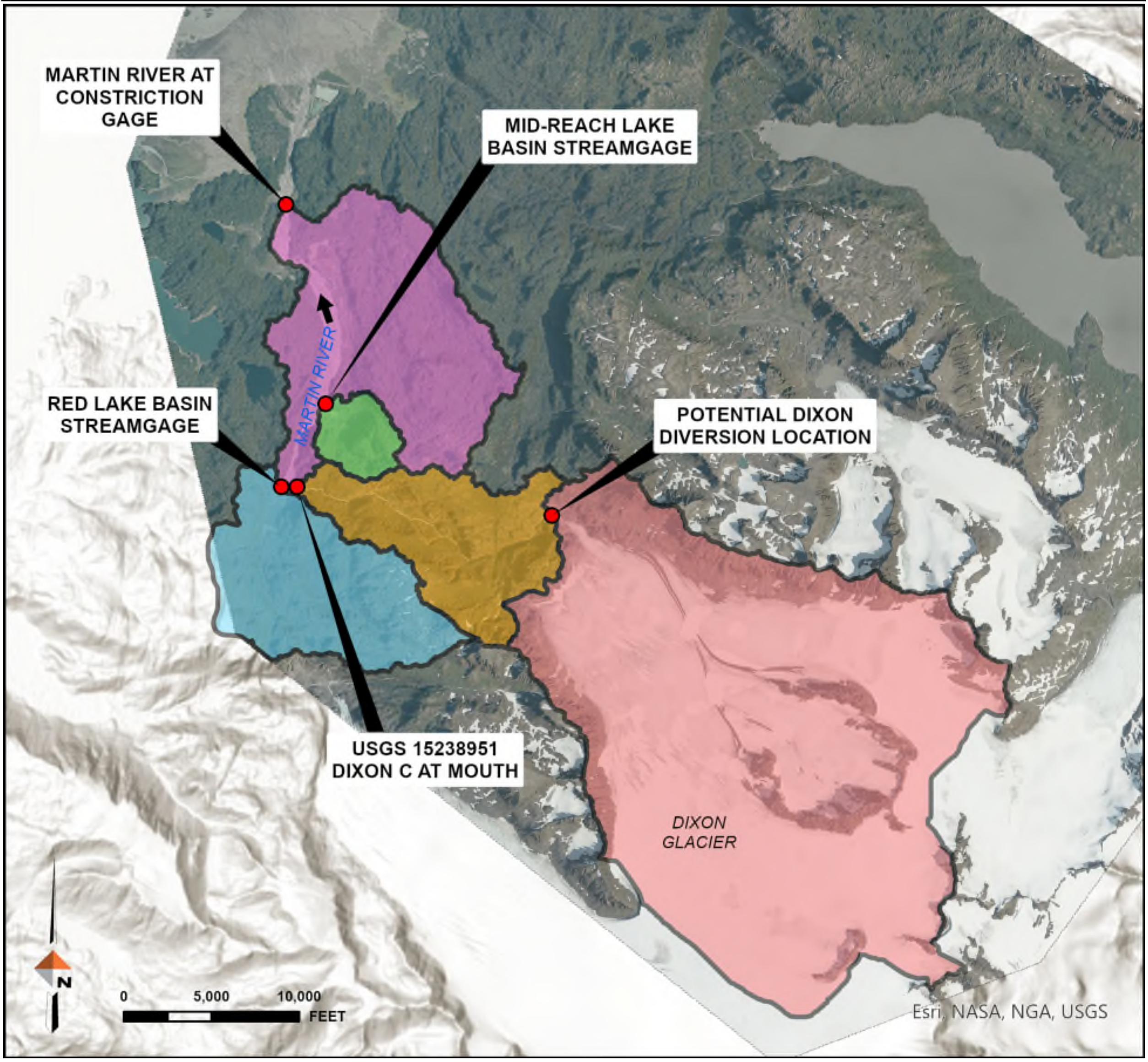


Figure 19. Martin River/Dixon Creek Drainage Basins

Attachment 1: Tabulated Streamflow Data

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
4/14/2023	-	-	-	-	21	21	USGS Mouth Gage [E]
4/15/2023	-	-	-	-	21	21	USGS Mouth Gage [E]
4/16/2023	-	-	-	-	22	22	USGS Mouth Gage [E]
4/17/2023	-	-	-	-	22	22	USGS Mouth Gage [E]
4/18/2023	-	-	-	-	22	22	USGS Mouth Gage [E]
4/19/2023	-	-	-	-	22	22	USGS Mouth Gage [E]
4/20/2023	-	-	-	-	24	24	USGS Mouth Gage [E]
4/21/2023	-	-	-	-	26	26	USGS Mouth Gage [E]
4/22/2023	-	-	-	-	29	29	USGS Mouth Gage [E]
4/23/2023	-	-	-	-	29	29	USGS Mouth Gage [E]
4/24/2023	-	-	-	-	27	27	USGS Mouth Gage [E]
4/25/2023	-	1.8	1.5	-	26	26	USGS Mouth Gage [E]

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
4/26/2023	30.9	2.0	1.5	27.4	26	27	DOWL Constriction Gage [D]
4/27/2023	34.5	2.2	1.4	30.9	26	31	DOWL Constriction Gage [D]
4/28/2023	40.6	2.6	1.5	36.5	28	37	DOWL Constriction Gage [D]
4/29/2023	50.2	3.4	1.7	45.1	29	45	DOWL Constriction Gage [D]
4/30/2023	53.9	4.5	1.7	47.7	29	48	DOWL Constriction Gage [D]
5/1/2023	64.2	5.9	2.0	56.3	30	56	DOWL Constriction Gage [D]
5/2/2023	74.3	7.6	1.7	65.0	32	65	DOWL Constriction Gage [D]
5/3/2023	78.7	8.9	2.3	67.5	31	68	DOWL Constriction Gage [D]
5/4/2023	76.5	9.6	2.3	64.6	30	65	DOWL Constriction Gage [D]
5/5/2023	80.3	10.3	2.2	67.8	31	68	DOWL Constriction Gage [D]
5/6/2023	88.4	11.4	2.7	74.3	34	74	DOWL Constriction Gage [D]
5/7/2023	99.9	14.2	3.1	82.6	39	83	DOWL Constriction Gage [D]

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
5/8/2023	110.5	18.1	3.6	88.8	40	89	DOWL Constriction Gage [D]
5/9/2023	107.1	18.6	3.6	84.9	38	85	DOWL Constriction Gage [D]
5/10/2023	123.7	21.9	3.6	98.2	50	98	DOWL Constriction Gage [D]
5/11/2023	188.0	36.5	4.0	147.5	81	148	DOWL Constriction Gage [D]
5/12/2023	192.1	43.7	5.1	143.3	63	143	DOWL Constriction Gage [D]
5/13/2023	193.4	44.4	5.5	143.5	71	144	DOWL Constriction Gage [D]
5/14/2023	223.1	56.2	5.9	161.0	81	161	DOWL Constriction Gage [D]
5/15/2023	242.8	65.8	6.3	170.7	90	171	DOWL Constriction Gage [D]
5/16/2023	285.2	87.7	6.9	190.6	119	191	DOWL Constriction Gage [D]
5/17/2023	262.7	72.8	6.8	183.1	88	183	DOWL Constriction Gage [D]
5/18/2023	215.4	47.0	4.8	163.6	73	164	DOWL Constriction Gage [D]
5/19/2023	229.2	44.2	3.6	181.4	114	181	DOWL Constriction Gage [D]

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
5/20/2023	298.5	54.2	4.3	240.0	160	240	DOWL Constriction Gage [D]
5/21/2023	259.4	40.5	3.4	215.5	122	216	DOWL Constriction Gage [D]
5/22/2023	220.1	32.3	2.8	185.0	94	185	DOWL Constriction Gage [D]
5/23/2023	206.8	30.3	2.5	174.0	90	174	DOWL Constriction Gage [D]
5/24/2023	224.6	32.9	2.4	189.3	113	189	DOWL Constriction Gage [D]
5/25/2023	251.5	31.7	2.5	217.3	140	217	DOWL Constriction Gage [D]
5/26/2023	260.7	32.1	2.4	226.2	135	226	DOWL Constriction Gage [D]
5/27/2023	251.4	30.1	2.2	219.1	118	219	DOWL Constriction Gage [D]
5/28/2023	244.0	29.5	1.1	213.4	108	213	DOWL Constriction Gage [D]
5/29/2023	225.0	28.9	2.0	194.1	95	194	DOWL Constriction Gage [D]
5/30/2023	212.0	28.3	1.8	181.9	93	182	DOWL Constriction Gage [D]
5/31/2023	210.7	27.6	1.7	181.4	96	181	DOWL Constriction Gage [D]

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
6/1/2023	199.3	27.0	1.6	170.7	92	171	DOWL Constriction Gage [D]
6/2/2023	198.4	26.4	1.5	170.5	97	171	DOWL Constriction Gage [D]
6/3/2023	210.5	25.8	1.2	183.5	114	184	DOWL Constriction Gage [D]
6/4/2023	237.3	25.2	1.2	210.9	139	211	DOWL Constriction Gage [D]
6/5/2023	249.4	24.6	1.2	223.6	151	224	DOWL Constriction Gage [D]
6/6/2023	355.9	24.0	0.9	331.0	330	331	DOWL Constriction Gage [D]
6/7/2023	456.5	23.3	1.1	432.1	438	432	DOWL Constriction Gage [D]
6/8/2023	532.0	22.7	1.1	508.2	493	508	DOWL Constriction Gage [D]
6/9/2023	558.7	22.1	1.1	535.5	531	536	DOWL Constriction Gage [D]
6/10/2023	585.9	21.5	1.1	563.3	543	563	DOWL Constriction Gage [D]
6/11/2023	532.2	20.9	1.2	510.1	554	510	DOWL Constriction Gage [D]
6/12/2023	438.1	20.3	1.2	416.6	422	417	DOWL Constriction Gage [D]

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
6/13/2023	356.8	19.7	1.2	335.9	387	336	DOWL Constriction Gage [D]
6/14/2023	308.1	19.0	1.2	287.9	338	288	DOWL Constriction Gage [D]
6/15/2023	277.5	18.4	1.1	258.0	279	258	DOWL Constriction Gage [D]
6/16/2023	250.1	17.8	1.0	231.3	248	231	DOWL Constriction Gage [D]
6/17/2023	234.7	17.2	0.9	216.6	236	217	DOWL Constriction Gage [D]
6/18/2023	252.2	16.6	0.8	234.8	287	235	DOWL Constriction Gage [D]
6/19/2023	283.0	16.0	0.7	266.3	364	266	DOWL Constriction Gage [D]
6/20/2023	354.9	15.4	0.7	338.8	411	339	DOWL Constriction Gage [D]
6/21/2023	491.2	14.7	0.8	475.7	555	476	DOWL Constriction Gage [D]
6/22/2023	381.5	14.1	0.8	366.6	850	367	DOWL Constriction Gage [D]
6/23/2023	522.8	13.5	0.9	508.4	968	508	DOWL Constriction Gage [D]
6/24/2023	533.7	12.9	0.9	519.9	1,169	520	DOWL Constriction Gage [D]

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
6/25/2023	494.4	15.8	1.4	477.2	1,371	477	DOWL Constriction Gage [D]
6/26/2023	494.2	16.4	1.3	476.5	1,071	477	DOWL Constriction Gage [D]
6/27/2023	647.4	13.5	1.3	632.6	1,157	633	DOWL Constriction Gage [D]
6/28/2023	546.3	13.0	1.3	532.0	1,047	532	DOWL Constriction Gage [D]
6/29/2023	316.7	12.5	1.2	303.0	778	303	DOWL Constriction Gage [D]
6/30/2023	140.4	11.4	1.1	127.9	629	128	DOWL Constriction Gage [D]
7/1/2023	211.2	10.9	1.1	199.2	519	199	DOWL Constriction Gage [D]
7/2/2023	401.2	10.0	1.1	390.1	1,014	390	DOWL Constriction Gage [D]
7/3/2023	901.3	10.2	1.2	889.9	1,265	890	DOWL Constriction Gage [D]
7/4/2023	515.6	9.8	1.1	504.7	1,079	505	DOWL Constriction Gage [D]
7/5/2023	163.7	8.8	1.1	153.8	1,176	154	DOWL Constriction Gage [D]
7/6/2023	570.2	8.8	1.2	560.2	1,162	560	DOWL Constriction Gage [D]

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
7/7/2023	469.8	8.8	1.6	459.4	1,254	459	DOWL Constriction Gage [D]
7/8/2023	309.1	8.3	1.1	299.7	934	300	DOWL Constriction Gage [D]
7/9/2023	218.4	7.3	1.0	210.1	821	210	DOWL Constriction Gage [D]
7/10/2023	484.1	6.6	0.9	476.6	827	477	DOWL Constriction Gage [D]
7/11/2023	696.6	6.1	0.9	689.6	1,067	690	DOWL Constriction Gage [D]
7/12/2023	640.4	5.8	0.9	633.7	913	634	DOWL Constriction Gage [D]
7/13/2023	766.1	5.4	0.9	759.8	922	760	DOWL Constriction Gage [D]
7/14/2023	767.8	5.1	0.8	761.9	920	920	USGS Mouth Gage [E]
7/15/2023	795.3	5.2	0.9	789.2	1,370	1,370	USGS Mouth Gage [E]
7/16/2023	-	5.6	1.2	-	1,949	1,949	USGS Mouth Gage [E]
7/17/2023	-	5.7	1.1	-	1,496	1,496	USGS Mouth Gage [E]
7/18/2023	-	5.4	1.0	-	1,102	1,102	USGS Mouth Gage [E]

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
7/19/2023	-	5.1	1.0	-	1,106	1,106	USGS Mouth Gage [E]
7/20/2023	-	5.1	1.0	-	1,026	1,026	USGS Mouth Gage [E]
7/21/2023	-	4.4	0.9	-	912	912	USGS Mouth Gage [E]
7/22/2023	-	4.5	0.9	-	1,066	1,066	USGS Mouth Gage [E]
7/23/2023	-	4.3	0.9	-	1,011	1,011	USGS Mouth Gage [E]
7/24/2023	-	4.0	0.9	-	1,041	1,041	USGS Mouth Gage [E]
7/25/2023	-	3.8	0.8	-	983	983	USGS Mouth Gage [E]
7/26/2023	-	3.6	0.8	-	1,030	1,030	USGS Mouth Gage [E]
7/27/2023	-	3.3	0.8	-	1,204	1,204	USGS Mouth Gage [E]
7/28/2023	-	3.2	0.8	-	1,487	1,487	USGS Mouth Gage [E]
7/29/2023	-	3.1	0.9	-	1,573	1,573	USGS Mouth Gage [E]
7/30/2023	-	3.0	0.9	-	996	996	USGS Mouth Gage [E]

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
7/31/2023	-	2.7	0.8	-	941	941	USGS Mouth Gage [E]
8/1/2023	-	2.8	0.7	-	991	991	USGS Mouth Gage [E]
8/2/2023	-	2.6	0.6	-	1,001	1,001	USGS Mouth Gage [E]
8/3/2023	-	2.3	0.6	-	848	848	USGS Mouth Gage [E]
8/4/2023	-	2.1	0.6	-	760	760	USGS Mouth Gage [E]
8/5/2023	-	2.2	0.4	-	808	808	USGS Mouth Gage [E]
8/6/2023	-	2.3	0.7	-	1,681	1,681	USGS Mouth Gage [E]
8/7/2023	-	2.2	0.9	-	2,117	2,117	USGS Mouth Gage [E]
8/8/2023	-	2.1	0.8	-	1,527	1,527	USGS Mouth Gage [E]
8/9/2023	-	1.8	0.8	-	1,104	1,104	USGS Mouth Gage [E]
8/10/2023	-	1.9	0.6	-	779	779	USGS Mouth Gage [E]
8/11/2023	-	1.8	0.6	-	1,025	1,025	USGS Mouth Gage [E]

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
8/12/2023	-	1.9	0.8	-	1,854	1,854	USGS Mouth Gage [E]
8/13/2023	-	1.8	1.0	-	1,619	1,619	USGS Mouth Gage [E]
8/14/2023	-	1.8	0.8	-	1,365	1,365	USGS Mouth Gage [E]
8/15/2023	-	1.8	0.8	-	731	731	USGS Mouth Gage [E]
8/16/2023	-	2.0	0.8	-	1,015	1,015	USGS Mouth Gage [E]
8/17/2023	-	1.9	0.8	-	851	851	USGS Mouth Gage [E]
8/18/2023	-	1.7	0.5	-	675	675	USGS Mouth Gage [E]
8/19/2023	-	1.6	0.5	-	708	708	USGS Mouth Gage [E]
8/20/2023	-	1.6	0.4	-	642	642	USGS Mouth Gage [E]
8/21/2023	-	1.6	0.5	-	661	661	USGS Mouth Gage [E]
8/22/2023	-	1.5	0.5	-	773	773	USGS Mouth Gage [E]
8/23/2023	-	1.4	0.5	-	841	841	USGS Mouth Gage [E]

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
8/24/2023	-	1.5	0.6	-	1,690	1,690	USGS Mouth Gage [E]
8/25/2023	-	1.5	1.3	-	1,884	1,884	USGS Mouth Gage [E]
8/26/2023	-	2.1	79.4	-	2,422	2,422	USGS Mouth Gage [E]
8/27/2023	-	1.9	45.7	-	2,187	2,187	USGS Mouth Gage [E]
8/28/2023	-	1.9	11.7	-	2,196	2,196	USGS Mouth Gage [E]
8/29/2023	-	2.0	28.6	-	2,635	2,635	USGS Mouth Gage [E]
8/30/2023	-	1.8	4.5	-	1,723	1,723	USGS Mouth Gage [E]
8/31/2023	-	2.1	20.2	-	2,141	2,141	USGS Mouth Gage [E]
9/1/2023	970.3	2.1	3.5	964.7	1,102	965	DOWL Constriction Gage [D]
9/2/2023	664.8	2.0	1.6	661.2	711	661	DOWL Constriction Gage [D]
9/3/2023	317.7	2.1	1.4	314.2	529	314	DOWL Constriction Gage [D]
9/4/2023	243.2	2.0	1.2	240.0	362	240	DOWL Constriction Gage [D]

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
9/5/2023	202.4	2.0	1.1	199.3	260	199	DOWL Constriction Gage [D]
9/6/2023	202.7	2.0	1.0	199.7	287	200	DOWL Constriction Gage [D]
9/7/2023	127.2	2.0	1.0	124.2	174	124	DOWL Constriction Gage [D]
9/8/2023	86.6	2.1	1.0	83.5	118	84	DOWL Constriction Gage [D]
9/9/2023	74.2	2.0	0.9	71.3	117	71	DOWL Constriction Gage [D]
9/10/2023	143.4	2.1	1.0	140.3	181	140	DOWL Constriction Gage [D]
9/11/2023	99.8	2.0	1.0	96.8	133	97	DOWL Constriction Gage [D]
9/12/2023	60.3	2.0	0.9	57.4	112	57	DOWL Constriction Gage [D]
9/13/2023	71.0	2.0	0.9	68.1	116	68	DOWL Constriction Gage [D]
9/14/2023	90.1	2.1	0.9	87.1	132	87	DOWL Constriction Gage [D]
9/15/2023	118.5	2.2	0.9	115.4	272	115	DOWL Constriction Gage [D]
9/16/2023	783.3	2.7	1.4	779.2	1,151	779	DOWL Constriction Gage [D]

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
9/17/2023	491.6	4.9	1.8	484.9	884	485	DOWL Constriction Gage [D]
9/18/2023	294.6	9.9	1.9	282.8	371	371	USGS Mouth Gage [E]
9/19/2023	-	-	-	-	183	183	USGS Mouth Gage [E]
9/20/2023	-	-	-	-	257	257	USGS Mouth Gage [E]
9/21/2023	-	-	-	-	192	192	USGS Mouth Gage [E]
9/22/2023	-	-	-	-	149	149	USGS Mouth Gage [E]
9/23/2023	-	-	-	-	104	104	USGS Mouth Gage [E]
9/24/2023	-	-	-	-	83	83	USGS Mouth Gage [E]
9/25/2023	-	-	-	-	69	69	USGS Mouth Gage [E]
9/26/2023	-	-	-	-	57	57	USGS Mouth Gage [E]
9/27/2023	-	-	-	-	50	50	USGS Mouth Gage [E]
9/28/2023	-	-	-	-	43	43	USGS Mouth Gage [E]

Date	Daily Average Discharge (cfs)					Best Estimate of Dixon Creek at Mouth Discharge (cfs)	Basis of Best Estimate
	Martin River at Constriction [A]	Red Lake Basin Outlet [B]	Mid-Reach Lake Basin Outlet [C]	Dixon Creek at Mouth [D] = [A]-[B]-[C]	Dixon Creek at Mouth, using USGS Provisional Data [E]		
9/29/2023	-	-	-	-	39	39	USGS Mouth Gage [E]
9/30/2023	-	-	-	-	49	49	USGS Mouth Gage [E]

Appendix B: Operational Model Results

OPERATIONAL MODEL

USING SYNTHETIC RECORD

INPUT

Minimum Instream Flow (MIF)

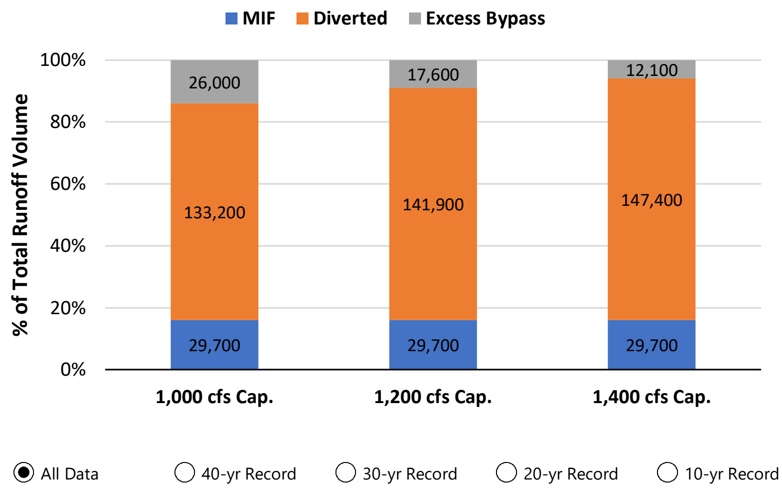
May:	100	cfs
June:	100	cfs
July:	100	cfs
August:	100	cfs
September:	100	cfs
October:	100	cfs

Diversion Tunnel Capacity

Scenario 1:	1,000	cfs
Scenario 2:	1,200	cfs
Scenario 3:	1,400	cfs

Statistical Range

Start Year:	1980
End Year:	2022



OUTPUT

Scenario 1: 1,000 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	2,800	2,100	600	0	75%	21%	4%
June	13,800	5,600	8,200	0	41%	59%	0%
July	62,700	6,100	47,300	9,200	10%	75%	15%
August	66,900	6,100	48,200	12,500	9%	72%	19%
September	31,900	5,800	22,800	3,400	18%	71%	11%
October	11,200	4,000	6,100	900	36%	54%	10%
Total	189,300	29,700	133,200	26,000	16%	70%	14%

Scenario 2: 1,200 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	2,800	2,100	600	0	75%	21%	4%
June	13,800	5,600	8,200	0	41%	59%	0%
July	62,700	6,100	50,900	5,700	10%	81%	9%
August	66,900	6,100	52,100	8,700	9%	78%	13%
September	31,900	5,800	23,700	2,500	18%	74%	8%
October	11,200	4,000	6,400	700	36%	57%	7%
Total	189,300	29,700	141,900	17,600	16%	75%	9%

Scenario 3: 1,400 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	2,800	2,100	600	0	75%	21%	4%
June	13,800	5,600	8,200	0	41%	59%	0%
July	62,700	6,100	53,100	3,500	10%	85%	5%
August	66,900	6,100	54,600	6,200	9%	82%	9%
September	31,900	5,800	24,300	1,900	18%	76%	6%
October	11,200	4,000	6,600	500	36%	59%	5%
Total	189,300	29,700	147,400	12,100	16%	78%	6%

OPERATIONAL MODEL

USING SYNTHETIC RECORD

INPUT

Minimum Instream Flow (MIF)

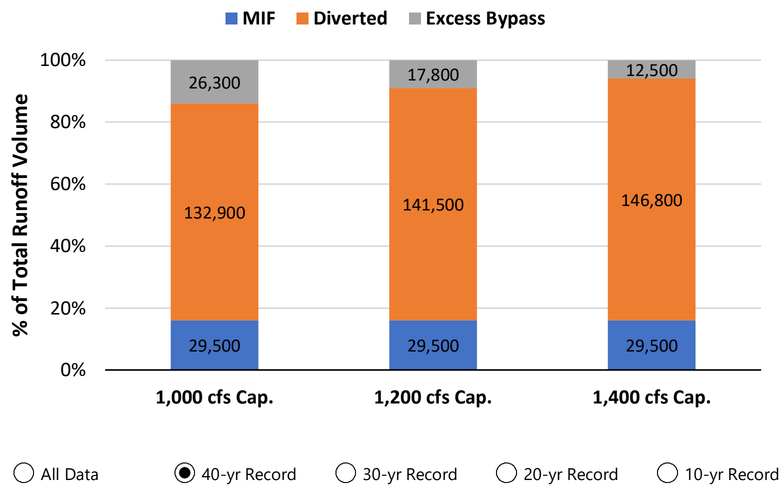
May:	100	cfs
June:	100	cfs
July:	100	cfs
August:	100	cfs
September:	100	cfs
October:	100	cfs

Diversion Tunnel Capacity

Scenario 1:	1,000	cfs
Scenario 2:	1,200	cfs
Scenario 3:	1,400	cfs

Statistical Range

Start Year:	1983
End Year:	2022



OUTPUT

Scenario 1: 1,000 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	2,800	2,100	700	0	75%	25%	0%
June	14,100	5,500	8,500	0	39%	60%	1%
July	62,700	6,100	47,100	9,400	10%	75%	15%
August	66,800	6,100	48,000	12,600	9%	72%	19%
September	31,200	5,700	22,200	3,300	18%	71%	11%
October	11,600	4,000	6,400	1,000	34%	55%	11%
Total	189,200	29,500	132,900	26,300	16%	70%	14%

Scenario 2: 1,200 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	2,800	2,100	700	0	75%	25%	0%
June	14,100	5,500	8,500	0	39%	60%	1%
July	62,700	6,100	50,700	5,900	10%	81%	9%
August	66,800	6,100	51,800	8,800	9%	78%	13%
September	31,200	5,700	23,100	2,400	18%	74%	8%
October	11,600	4,000	6,700	700	34%	58%	8%
Total	189,200	29,500	141,500	17,800	16%	75%	9%

Scenario 3: 1,400 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	2,800	2,100	700	0	75%	25%	0%
June	14,100	5,500	8,500	0	39%	60%	1%
July	62,700	6,100	52,900	3,700	10%	84%	6%
August	66,800	6,100	54,200	6,400	9%	81%	10%
September	31,200	5,700	23,600	1,900	18%	76%	6%
October	11,600	4,000	6,900	500	34%	59%	7%
Total	189,200	29,500	146,800	12,500	16%	78%	6%

OPERATIONAL MODEL

USING SYNTHETIC RECORD

INPUT

Minimum Instream Flow (MIF)

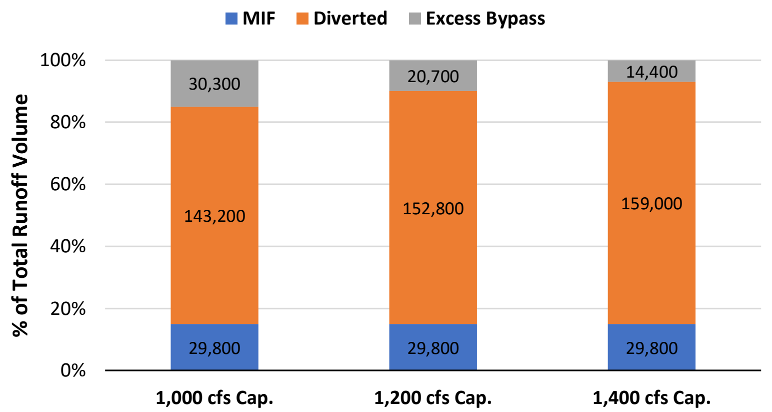
May:	100	cfs
June:	100	cfs
July:	100	cfs
August:	100	cfs
September:	100	cfs
October:	100	cfs

Diversion Tunnel Capacity

Scenario 1:	1,000	cfs
Scenario 2:	1,200	cfs
Scenario 3:	1,400	cfs

Statistical Range

Start Year:	1993
End Year:	2022



○ All Data ○ 40-yr Record ◉ 30-yr Record ○ 20-yr Record ○ 10-yr Record

OUTPUT

Scenario 1: 1,000 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	2,900	2,200	700	0	76%	24%	0%
June	15,100	5,600	9,500	0	37%	63%	0%
July	69,500	6,100	51,300	12,100	9%	74%	17%
August	70,200	6,100	51,000	13,000	9%	73%	18%
September	33,000	5,800	23,300	4,000	18%	71%	11%
October	13,000	4,000	7,400	1,200	31%	57%	12%
Total	203,700	29,800	143,200	30,300	15%	70%	15%

Scenario 2: 1,200 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	2,900	2,200	700	0	76%	24%	0%
June	15,100	5,600	9,500	0	37%	63%	0%
July	69,500	6,100	55,700	7,700	9%	80%	11%
August	70,200	6,100	54,900	9,100	9%	78%	13%
September	33,000	5,800	24,200	3,000	18%	73%	9%
October	13,000	4,000	7,800	900	31%	60%	9%
Total	203,700	29,800	152,800	20,700	15%	75%	10%

Scenario 3: 1,400 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	2,900	2,200	700	0	76%	24%	0%
June	15,100	5,600	9,500	0	37%	63%	0%
July	69,500	6,100	58,500	4,900	9%	84%	7%
August	70,200	6,100	57,400	6,600	9%	82%	9%
September	33,000	5,800	24,900	2,300	18%	75%	7%
October	13,000	4,000	8,000	600	31%	62%	7%
Total	203,700	29,800	159,000	14,400	15%	78%	7%

OPERATIONAL MODEL

USING SYNTHETIC RECORD

INPUT

Minimum Instream Flow (MIF)

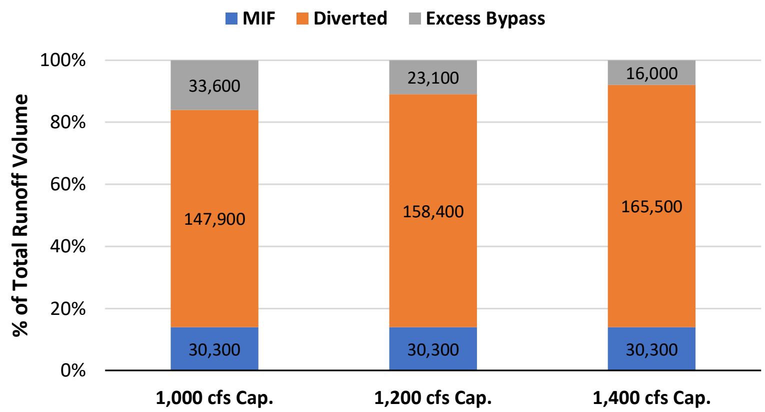
May:	100	cfs
June:	100	cfs
July:	100	cfs
August:	100	cfs
September:	100	cfs
October:	100	cfs

Diversion Tunnel Capacity

Scenario 1:	1,000	cfs
Scenario 2:	1,200	cfs
Scenario 3:	1,400	cfs

Statistical Range

Start Year:	2003
End Year:	2022



○ All Data ○ 40-yr Record ○ 30-yr Record ◉ 20-yr Record ○ 10-yr Record

OUTPUT

Scenario 1: 1,000 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	3,600	2,600	1,000	0	72%	28%	0%
June	16,500	5,700	10,800	0	35%	65%	0%
July	72,700	6,100	52,800	13,800	8%	73%	19%
August	72,500	6,100	51,000	15,400	8%	70%	22%
September	32,000	5,700	23,300	2,900	18%	73%	9%
October	14,900	4,100	9,000	1,500	28%	60%	12%
Total	212,200	30,300	147,900	33,600	14%	70%	16%

Scenario 2: 1,200 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	3,600	2,600	1,000	0	72%	28%	0%
June	16,500	5,700	10,800	0	35%	65%	0%
July	72,700	6,100	57,700	8,900	8%	79%	13%
August	72,500	6,100	55,300	11,100	8%	76%	16%
September	32,000	5,700	24,200	2,100	18%	76%	6%
October	14,900	4,100	9,400	1,000	28%	63%	9%
Total	212,200	30,300	158,400	23,100	14%	75%	11%

Scenario 3: 1,400 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	3,600	2,600	1,000	0	72%	28%	0%
June	16,500	5,700	10,800	0	35%	65%	0%
July	72,700	6,100	61,000	5,600	8%	84%	8%
August	72,500	6,100	58,200	8,200	8%	80%	12%
September	32,000	5,700	24,800	1,500	18%	78%	4%
October	14,900	4,100	9,700	700	28%	65%	7%
Total	212,200	30,300	165,500	16,000	14%	78%	8%

OPERATIONAL MODEL

USING SYNTHETIC RECORD

INPUT

Minimum Instream Flow (MIF)

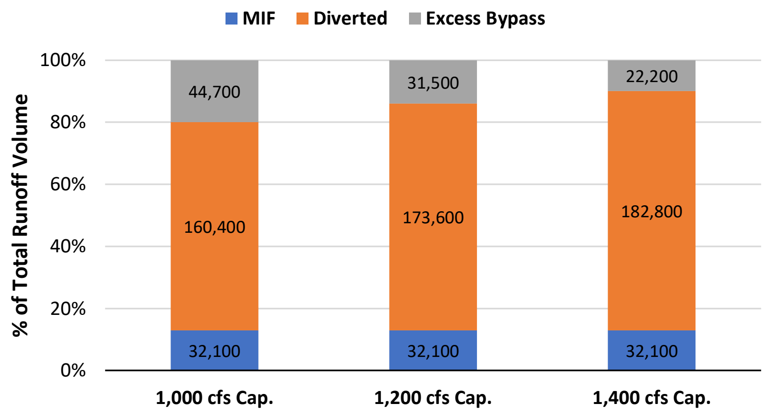
May:	100	cfs
June:	100	cfs
July:	100	cfs
August:	100	cfs
September:	100	cfs
October:	100	cfs

Diversion Tunnel Capacity

Scenario 1:	1,000	cfs
Scenario 2:	1,200	cfs
Scenario 3:	1,400	cfs

Statistical Range

Start Year:	2013
End Year:	2022



○ All Data ○ 40-yr Record ○ 30-yr Record ○ 20-yr Record ◉ 10-yr Record

OUTPUT

Scenario 1: 1,000 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	6,200	4,300	1,900	0	69%	31%	0%
June	19,000	5,900	13,000	0	31%	68%	1%
July	79,800	6,100	56,200	17,500	8%	70%	22%
August	81,300	6,100	52,500	22,600	8%	65%	27%
September	35,000	5,700	25,700	3,500	16%	73%	11%
October	17,200	4,000	11,100	1,100	23%	65%	12%
Total	238,500	32,100	160,400	44,700	13%	67%	20%

Scenario 2: 1,200 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	6,200	4,300	1,900	0	69%	31%	0%
June	19,000	5,900	13,000	0	31%	68%	1%
July	79,800	6,100	62,200	11,400	8%	78%	14%
August	81,300	6,100	58,000	17,200	8%	71%	21%
September	35,000	5,700	26,900	2,300	16%	77%	7%
October	17,200	4,000	11,600	600	23%	67%	10%
Total	238,500	32,100	173,600	31,500	13%	73%	14%

Scenario 3: 1,400 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	6,200	4,300	1,900	0	69%	31%	0%
June	19,000	5,900	13,000	0	31%	68%	1%
July	79,800	6,100	66,500	7,100	8%	83%	9%
August	81,300	6,100	61,900	13,200	8%	76%	16%
September	35,000	5,700	27,600	1,600	16%	79%	5%
October	17,200	4,000	11,900	300	23%	69%	8%
Total	238,500	32,100	182,800	22,200	13%	77%	10%

OPERATIONAL MODEL

USING 2023 MEASUREMENTS - MISSING OCTOBER DATA

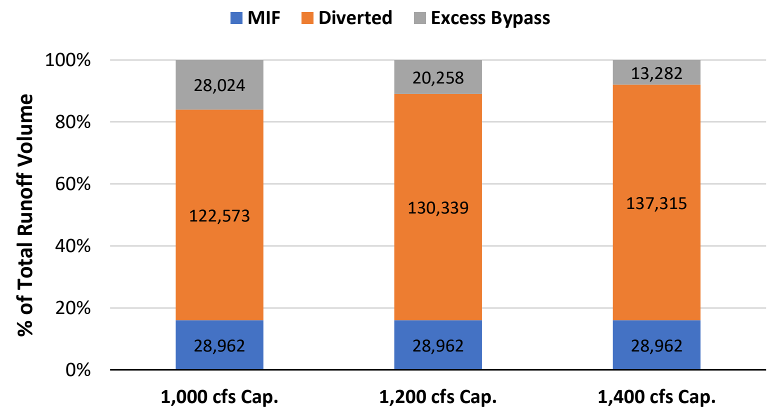
INPUT

Minimum Instream Flow (MIF)

May:	100	cfs
June:	100	cfs
July:	100	cfs
August:	100	cfs
September:	100	cfs
October:	100	cfs

Diversion Tunnel Capacity

Scenario 1:	1,000	cfs
Scenario 2:	1,200	cfs
Scenario 3:	1,400	cfs



OUTPUT

Scenario 1: 1,000 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	9,267	5,654	3,613	0	61%	39%	0%
June	21,514	5,949	15,565	0	28%	72%	0%
July	54,416	6,147	43,336	4,932	11%	80%	9%
August	81,807	6,147	52,567	23,092	8%	64%	28%
September	12,556	5,065	7,492	0	40%	60%	0%
October							
Total	179,559	28,962	122,573	28,024	16%	68%	16%

Scenario 2: 1,200 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	9,267	5,654	3,613	0	61%	39%	0%
June	21,514	5,949	15,565	0	28%	72%	0%
July	54,416	6,147	45,542	2,727	11%	84%	5%
August	81,807	6,147	58,128	17,532	8%	71%	21%
September	12,556	5,065	7,492	0	40%	60%	0%
October							
Total	179,559	28,962	130,339	20,258	16%	73%	11%

Scenario 3: 1,400 cfs Tunnel Capacity							
Month	Volume (acre-ft)				Percentage		
	Total Runoff	MIF	Diverted	Bypass in Excess of MIF	MIF	Diverted	Bypass in Excess of MIF
May	9,267	5,654	3,613	0	61%	39%	0%
June	21,514	5,949	15,565	0	28%	72%	0%
July	54,416	6,147	47,233	1,035	11%	87%	2%
August	81,807	6,147	63,412	12,247	8%	78%	14%
September	12,556	5,065	7,492	0	40%	60%	0%
October							
Total	179,559	28,962	137,315	13,282	16%	76%	8%