PREPARED FOR:

THE COLORADO RIVER AUTHORITY OF UTAH

PREPARED BY:

BOWEN COLLINS & ASSOCIATES

Jones & DeMille Engineering

VOLUME 1: REPORT

JUNE 2023

METERING AND GAGING GAP ANALYSIS

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VOLUME 1
REPORT

JUNE 2023

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6/30/2023

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VOLUME 1: REPORT

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DISCLAIMER

This report is not intended to be definitive of measurement devices and gages that should or will be installed in Utah. The proposals and recommendations in this report are not final. Inclusion of a measurement device or gage in this report does not obligate the Authority or any other Utah state agency or entity to install, operate, or maintain such measurement device or gage.

EXECUTIVE SUMMARY

STUDY PURPOSE

This executive summary provides an overview of the Metering and Gaging Gap Analysis Study that was completed for the Colorado River Authority of Utah (Authority). The primary purpose of the study was to identify water supply and use measurement gaps in the Colorado River system in Utah, which is defined for the purposes of this study as the Colorado River and its tributaries in Utah and includes flow measurement stations located outside of Utah, near its borders with Wyoming and Colorado (study area). The study area is shown in Figure ES-1. The results of this study help improve understanding of Colorado River water supply in the study area and will allow the Authority to work with others, particularly with the Utah Division of Water Rights (DWRi) and Division of Water Resources (DWRe), to improve, expand, and support a water measurement network that produces sound and transparent data that is publicly available. The study was completed as part of the Authority's five-year Management Plan (Management Plan), which aims to fulfill the Authority's mission to protect, conserve, use, and develop Utah's waters of the Colorado River system.

The Management Plan identifies three priority areas: measurement, hydrology and operations, and drought mitigation. These priorities address the urgent need to efficiently utilize Utah's Colorado River water amidst a prolonged drought, changing climate conditions, and declining reservoir storage.

This study focused on identifying existing and retired stream and diversion gaging and flow measurement stations, major and minor diversions, and assessing gaging and water measurement infrastructure in the study area. Work was performed to compile information on water measurement infrastructure that includes location, flow data period of record, general condition, equipment used, and automated data transmission methods for active, inactive, and retired gaging stations. When the terms "water measurement infrastructure" or "gage" are used in this report, they reference the flow measurement structure, telemetry/communications equipment, and other facilities that are needed to collect and record flow data from a flow measurement location and transmit real-time data offsite so it can be publicly accessed from the internet.

The Engineering Team, comprised of staff from Bowen, Collins and Associates and Jones and DeMille Engineering, conducted the study and completed the following major tasks:

- Collected and reviewed existing Geographic Information System (GIS) data.
- Coordinated with agencies that own, operate, or manage the gages.
- Compiled existing gage information.
- Analyzed data gaps.
- Developed preliminary cost and prioritization criteria.

Stakeholders from the Authority, DWRi, DWRe, United States Geological Survey (USGS), and other water management organizations actively participated throughout the project and provided valuable input and guidance.

The major deliverables associated with this study include:

- A digital geodatabase of existing and proposed water measurement infrastructure.

- A report that summarizes the work performed and identifies water gaging and metering data gaps.
- General prioritization and cost information associated with proposed improvements to address the identified water measurement data gaps.
- A separate Technical Appendix that includes background information compiled during the study.

This study was completed to lay the foundation for plans and actions that will help the Authority accomplish the Measurement element defined in the Management Plan. The completion of the study represents a significant step towards improving the measurement and understanding of Colorado River water use in Utah. By enhancing Utah's water measurement network and addressing identified water metering and measurement infrastructure data gaps, the Authority aims to fulfill its mission while ensuring a sustainable and resilient water supply for Utah and the Colorado River Basin as a whole.

DATA COLLECTION AND COMPILATION

A significant data collection process was completed as part of this study to compile existing gage and meter data and improve the understanding of the existing flow measurement network in the study area on both rivers and canals. The primary sources of gage data were federal and state agencies, including the USGS, the United States Bureau of Reclamation (Reclamation), and the DWRi. The data from these sources were collected in different formats, such as GIS and tabular data, and were compiled into a single geodatabase for analysis.

A list of attributes was developed in consultation with the Authority and stakeholders to capture key information about each existing gage. Those attributes included gage characteristics such as coordinates of location, flow capacity, gage status, general condition, and telemetry status. A set of general system questions was also developed to collect additional information and qualitative insights from stakeholder interviewees.

Stakeholder interviews were conducted to obtain missing data on existing flow measurement infrastructure, validate existing information and gage locations, and identify locations that could benefit from additional flow measurement infrastructure. Individuals from various groups, including DWRi Regional Engineers, DWRi Distribution Engineers, water conservancy districts, and irrigation companies participated in interviews. Data collection tools were developed using ESRI ArcGIS Online products, allowing multiple interviews to occur simultaneously and enabling real-time updates of the data.

Between January and March 2023, a total of 20 in-person interviews and 5 phone/virtual interviews were conducted by the Engineering Team. The interviews were mainly conducted with DWRi Regional and Distribution engineers, river commissioners, and water conservancy district staff (interviewees). The interview process not only generated data for the geodatabase, but also provided valuable insights. Insights gained during the interviews included a general understanding of flow magnitude on rivers and canal diversions, information on the length and availability of historic flow records and the general condition of each gage. Information on the status of automation and telemetry at existing metering and gaging stations was also collected.

At the beginning of the interview process, the Authority's stated goal was to collect detailed information on meters and gages that had capacities of 50 cubic feet per second (cfs) and larger.

However, based on input provided by the Authority and DWRi as the study progressed, it was later decided to have the Engineering Team collect location data on all known gaging and metering devices (regardless of size) in the study area and to collect detailed information on existing gages that had capacities of 10 cfs and larger. Doing so would collect data on gages that account for most of the cumulative diverted flow in the study area.

Ultimately, the information that was collected and processed indicated that there are 761 existing gage locations in the study area, as summarized in Table ES-1. As the information in Table ES-1 indicates, the study area contains about 73 nonretired (i.e., active and inactive) canal gages, 256 nonretired diversion gages, and 141 nonretired stream gages. This information is illustrated in Figure ES-2. These gages served as the basis for performing the metering and gaging gap analysis and identifying potential areas of improvement associated with measurement infrastructure in the Colorado River system in Utah.

Table ES-1
Existing Gage Summary

Gage Status	Canal	Diversion	Stream	Total
ACTIVE[1]	81	216	133	430
INACTIVE[2]	3	20	16	39
RETIRED[3]	4	13	274	291
Total	**88**	**249**	**423**	**760**

[1] ACTIVE gages include measurement infrastructure that is currently operating and recording data.
[2] INACTIVE gages include measurement infrastructure that still exists and is not operating. For the purposes of the gap analysis, it was assumed INACTIVE gages should remain active. Therefore, the 39 inactive gages were included in the 470 existing gages analyzed for gaps.
[3] RETIRED gages include measurement infrastructure that intentionally was removed or demolished and is not capable of operating. While the geodatabase contains these locations, these locations were not included in the gap analysis. Any USGS sites proposed for recommissioning are included in the set of proposed gages.

In addition to reviewing and providing information on existing gages in the study area, interviewees also identified 165 locations where they could benefit from additional gages to assist with various water management duties. Some of the interviewee-proposed gages could be classified as “wants” and not “needs,” but all proposed gages were considered to ensure that potential gaps in the study area were documented. Information for each of the flow measurement infrastructure gaps was collected and added to the geodatabase.

GAP ANALYSIS

A gap analysis was completed on the flow measurement infrastructure data to determine the difference between the data desired to monitor water supply and use in the study area and the data that is currently available. The analysis focused on two main aspects: surface water supply (measured by stream gages and reservoir elevation gages) and surface water use (measured by diversions and canal gages). Existing gage locations were evaluated based on desired baseline criteria, such as the condition of the gage, quality of flow data, and availability of instrumentation and telemetry for data transmission and archiving. Existing gages that failed to meet the desired baseline criteria were considered to have one or more gaps.

Details of the gap analysis for existing flow measurement infrastructure are summarized in Section 3 of the report. In addition, improvements associated with new measurement infrastructure were proposed at 182 locations to address identified gaps associated with Instream Measurement; Operations; and Research, Modeling, and Planning. The locations of proposed measurement infrastructure were either identified by interviewees or identified during the gap analysis. Spatial metrics (described in the Technical Appendix B) were utilized to evaluate potential locations for proposed gages where flow data would benefit the above purposes.

It should be noted that multiple types of gaps may exist at a single existing or proposed gage location. For example, there are multiple locations where a proposed stream gage simultaneously fills three types of gaps (Operations; Research, Modeling, and Planning; and Instream Measurement). Table ES-2 shows the number of gap types examined and the total number of gage locations with gaps. Counts are grouped by gap type and location type (existing or proposed). The explanation above summarizes why the number of locations for proposed flow measurement infrastructure is much smaller than the number of gaps identified in Table ES-2.

Table ES-2
Summary of Identified Gaps

Gage Status	Type of Gap[1]	Canal Gage	Diversion Gage	Stream Gage	Total[2]
Existing	Telemetry	47	141	54	242
	Data Quality	70	207	61	338
	Historic Data Accessibility	44	107	22	173
	Total Existing with a Gap[3]	**73**	**234**	**80**	**387**
Proposed	Instream	5	31	40	76
	Operations	7	75	90	172
	Research, Modeling, & Planning	0	0	30	30
	Total Proposed Locations[4]	**7**	**75**	**100**	**182**

[1] Multiple gap types may be present at a single location. Due to this overlap in type of gaps, the total number of gaps by type of gage (Diversion/Canal or Stream) can only be determined by adding the subtotal rows together. Adding the counts of gaps for individual types together will result in significant overestimation of the total number of gage improvements required to resolve the identified gaps.
[2] Stream gages are measurement infrastructure measuring flows in a stream. Diversion gages are measurement infrastructure measuring flow diverted out of a stream at a point of diversion. Canal gages are gages that measure flows in or diverted from a canal.
[3] The counts of gaps presented in this table do not reflect the extent or priority of gaps, nor do the counts indicate all improvements will be implemented. The detailed information contained in the report and geodatabase should be used to plan improvements as described in the Conclusions section of this document and Section 5 of the report.
[4] There are 12 historic USGS stream gaging sites included in the 100 total stream gages.

CONCEPTUAL COSTS AND GENERAL GAP PRIORITIZATION CRITERIA

Conceptual costs associated with both installation and annual operation were developed for different types of measurement devices and telemetry equipment that could be used to address the identified flow measurement infrastructure gaps. The conceptual costs were categorized based on gage capacity, material, service life, and other factors.

Criteria were also defined to develop a preliminary prioritization that could be used by the Authority and other key stakeholders to develop a detailed plan to fund and implement improvements that would resolve the highest-priority measurement infrastructure gap deficiencies in the study area. The general prioritization approach categorized the identified gaps into high, medium, and low priorities for both existing and proposed measurement infrastructure. The general prioritization of improvements to address identified gaps at existing gages is presented in Figure ES-3. The locations of prioritized, proposed measurement infrastructure to address gaps where gages do not currently exist are shown in Figure ES-4. Conceptual costs and general project prioritization information are also presented in Table ES-3.

Table ES-3
Summary of General Prioritization and Cost Evaluation of Addressing Gaps

Existing Gage Priority	Type	Count	Capital Cost ($)	Annual Cost ($)
HIGH	Canal	23	294,000	25,300
	Diversion	40	0	44,000
	Stream	6	0	6,600
HIGH Subtotal		**69**	**294,000**	**75,900**
MEDIUM	Canal	33	253,500	36,300
	Diversion	49	0	53,900
	Stream	14	0	15,400
MEDIUM Subtotal		**96**	**253,500**	**105,600**
LOW	Canal	12	46,500	13,200
	Diversion	45	136,500	49,500
	Stream	63	0	69,300
LOW Subtotal		**120**	**183,000**	**132,000**
Existing Gage Subtotal		**285**	**730,500**	**313,500**
Proposed Gage Priority	**Type**	**Count**	**Capital Cost**	**Annual Cost**
HIGH	Canal	2	88,000	4,400
	Diversion	12	657,500	40,800
	Stream	19	842,200	182,800
HIGH Subtotal		**33**	**1,587,700**	**228,000**
MEDIUM	Canal	5	124,100	9,000
	Diversion	37	981,800	70,400
	Stream	56	2,353,200	580,600
MEDIUM Subtotal		**98**	**3,459,100**	**660,000**
LOW	Canal	0	0	0
	Diversion	4	67,600	6,600
	Stream	34	1,078,500	243,100
LOW Subtotal		**38**	**1,146,100**	**249,700**
Proposed Gage Subtotal		**169**	**6,192,900**	**1,137,700**
All Gaps - Total		**454**	**6,923,400**	**1,451,200**

FUNDING CONSIDERATIONS

The conceptual cost data summarized in Table ES-3 indicates that is may cost close to $6.9 million in 2023 dollars to construct or install proposed measurement infrastructure to resolve all gaging and metering gaps identified during this study. It may cost about $1.88 million ($294,000 for existing gages and $1,587,700 for proposed gages) to install measurement infrastructure that will resolve only identified high-priority deficiencies. In addition, as Table ES-3 shows, each existing or proposed gage or meter will have annual operation and maintenance costs, which should also be considered in operating budgets of the entities responsible for operating the measurement infrastructure.

Most of the existing diversion and canal gages are owned and operated by private entities. Most of the stream gages are operated by the USGS and funded under a cooperative agreement where a funding partner pays for 61 percent of the gage construction and annual operation and the USGS funds the remaining 39 percent. Gage ownership, operation, and maintenance issues should all be considered as a plan is developed and implemented to install additional water measurement infrastructure. Those considerations lead to the following questions that were not addressed in detail during this study:

- Who will pay for improvements to address the identified metering and gaging gaps?
- If the Authority recommends installing a new gage on a private system or on a stream, what entity will own, construct, operate, and maintain that gage and associated equipment?
- How will the Authority coordinate with other parties to ultimately obtain additional real-time flow measurement data that will allow them to better accomplish their mission?

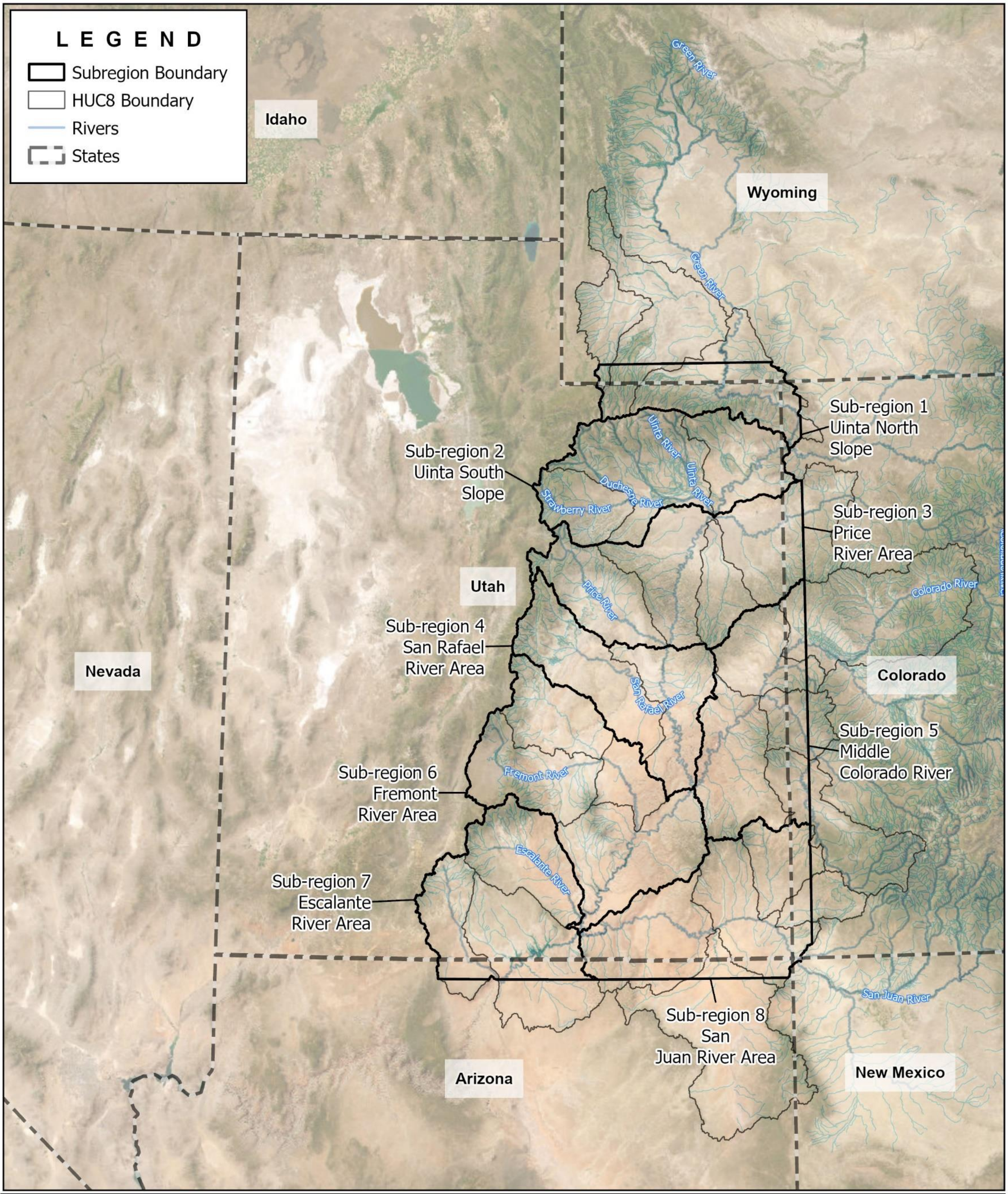
There are federal and state funding or grant programs that may have funding available for individual water users, irrigation companies, municipalities, and distribution entities to purchase and install new measurement infrastructure. These programs include:

- Reclamation WaterSMART Grant Program
- USGS stream gaging partnership program
- American Rescue Plan Act (ARPA)
- Inflation Reduction Act of 2022 (IRA)
- Bipartisan Infrastructure Law Drought Contingency Plan
- Natural Resources Conservation Service Environmental Quality Incentives Program (NRCS EQIP, in conjunction with WaterSMART)
- State of Utah appropriations and programs, such as the Utah Department of Agriculture and Food (UDAF) Agricultural Water Optimization Grant.

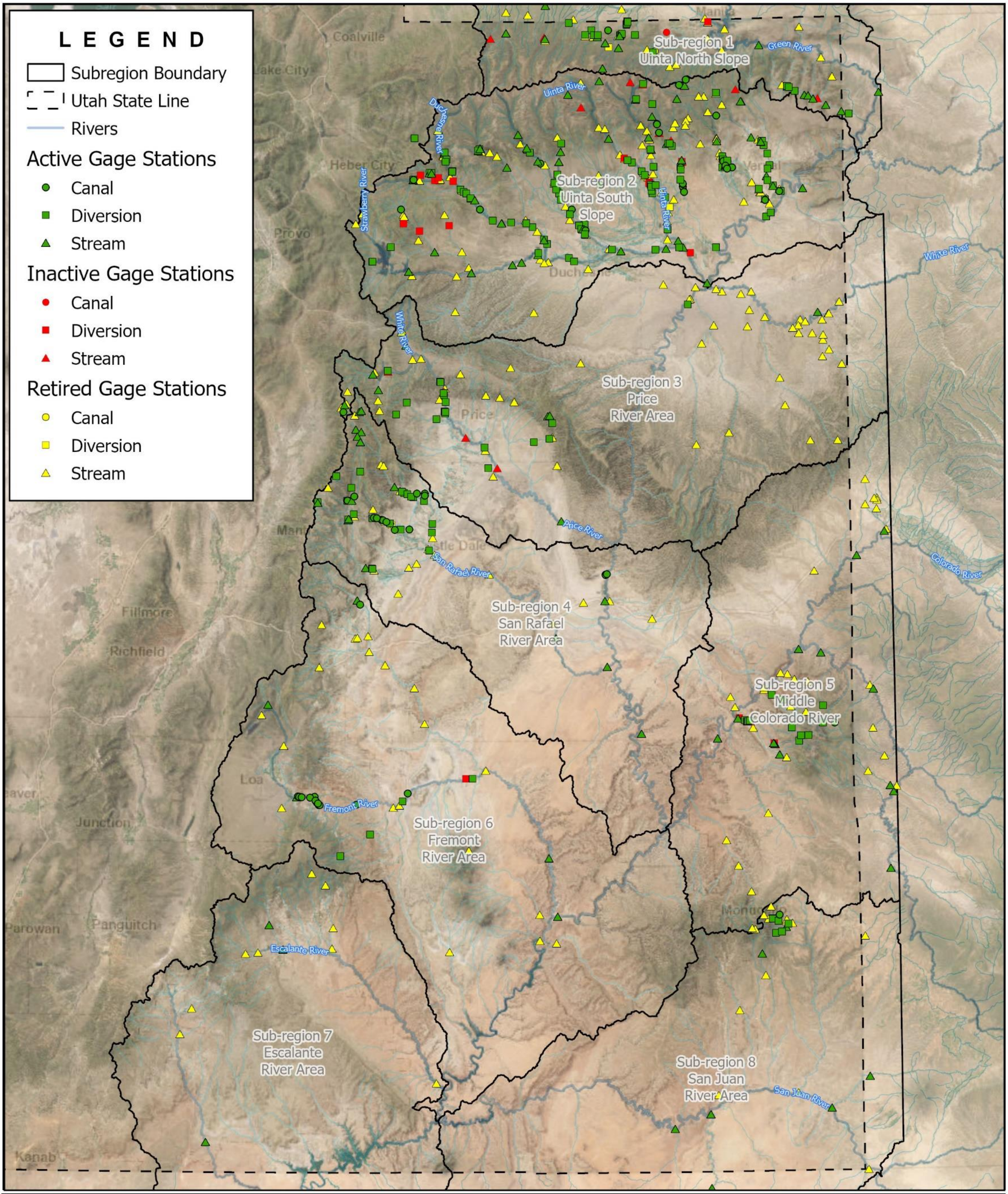
Each program identified above has different eligibility requirements and more information can be found on each respective program's website. In addition, soliciting additional funding for existing programs (for example, petitioning state and federal legislatures to fund more USGS stream gaging stations in the study area) are also possible sources of funding for additional measurement infrastructure. It should be noted that the USGS has a challenge where funding for their instream flow measurement program has been flat for years – which essentially means budget cuts are required almost every year due to inflation. Increased funding for the stream gaging program is needed to cover costs to operate stream gages or more and more gages could be decommissioned, potentially counteracting the progress that will be made by filling measurement gaps identified in this study.

CONCLUSIONS

It is anticipated that the Authority and other key stakeholders will use the report, digital geodatabase, and associated data and tools to adjust or revise the preliminary project prioritization based on judgement, preferences, magnitude of the data gap, and other factors as a more detailed implementation plan is developed to address the identified data gaps. The database and tools that were developed during this study provide a foundation for understanding metering and gaging gaps in the study area and enable decision-makers to plan and schedule improvements to address identified data gaps. The metering and gaging gaps identified in this study, with the associated general priorities, are subject to detailed review and refinement by the Authority in partnership with DWRi, DWRe, and other key stakeholders before improvements proposed to fill data gaps are implemented. It is anticipated that some of the proposed measurement infrastructure identified in this study will not be installed or constructed based on gap magnitude, relative benefit, and cost. Ultimately, addressing the metering and gaging gaps in the study area will be an ongoing process and will require collaboration and cooperation between federal, state, and local entities. The report and its associated deliverables were developed to support the Authority's mission by providing insights and tools that can be used to help accomplish the goals defined in the Measurement element of the Management Plan.



BOWEN COLLINS & ASSOCIATES / Jones & DeMille Engineering	STUDY AREA	NORTH:	SCALE: 1 in = 60 miles
	COLORADO RIVER AUTHORITY OF UTAH METERING AND GAGING GAP ANALYSIS		FIGURE NO. ES-1



BOWEN COLLINS & ASSOCIATES

Jones & DeMille Engineering

SUMMARY OF EXISTING AND RETIRED GAGES

COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

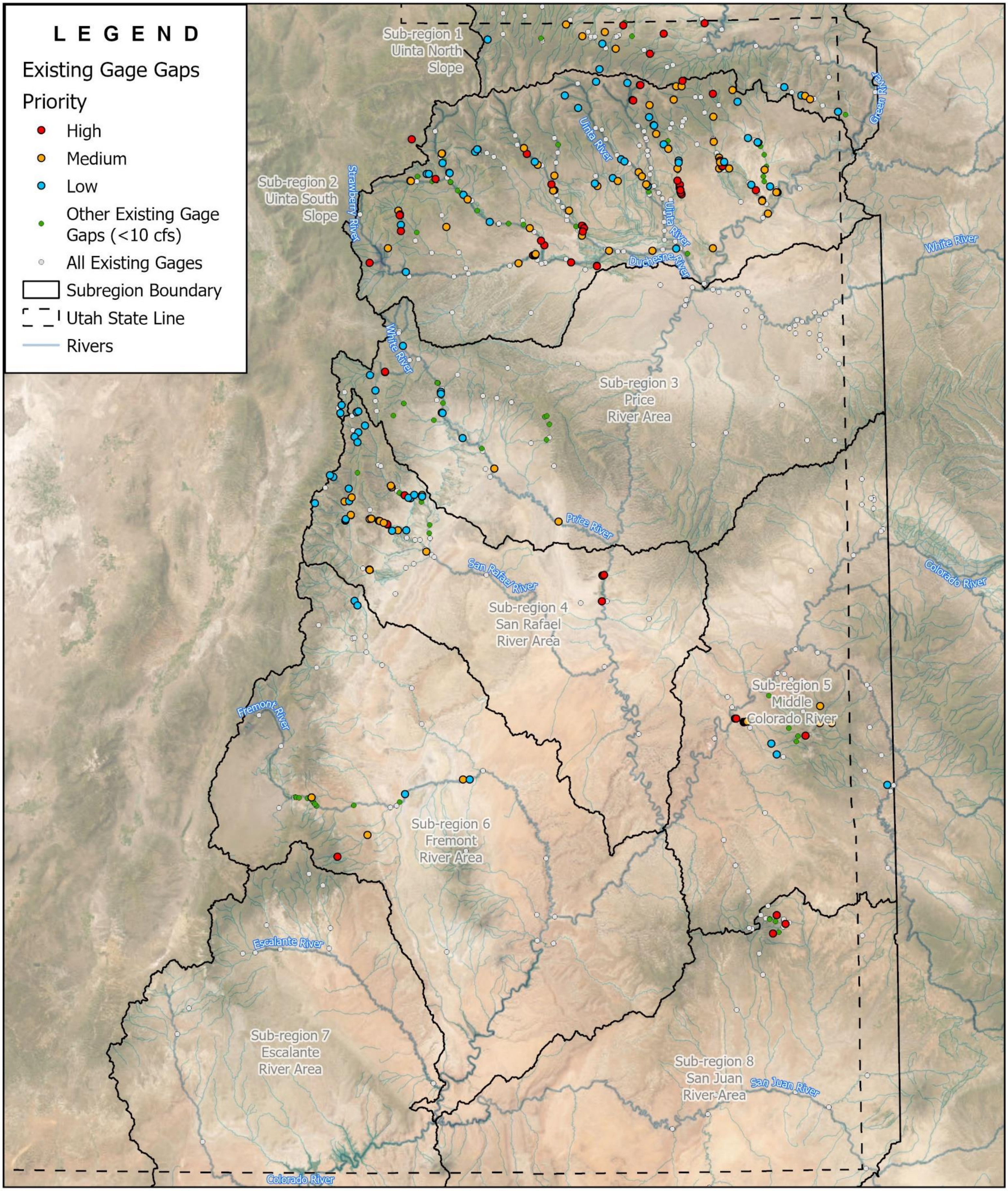
NORTH

SCALE:

1 in = 30 miles

FIGURE NO.

ES-2



BOWEN COLLINS & ASSOCIATES

Jones & DeMille Engineering

EXISTING GAGE GAP PRIORITIZATION

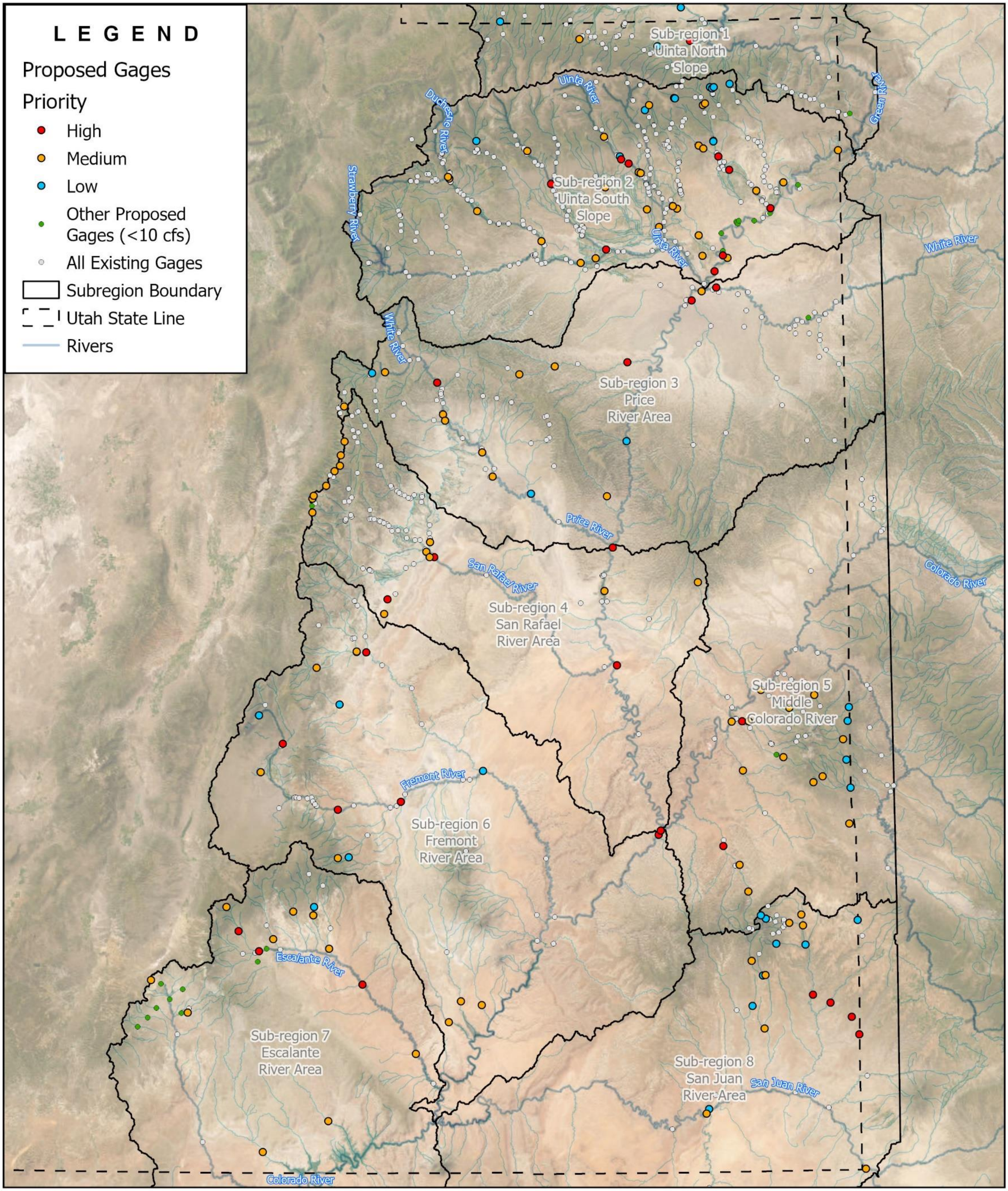
COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH: NORTH

SCALE: 1 in = 30 miles

FIGURE NO. ES-3



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PROPOSED GAGE
GAP PRIORITIZATION

COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH: NORTH

SCALE: 1 in = 30 miles

FIGURE NO. ES-4

SECTION 1: INTRODUCTION AND PURPOSE OF STUDY

1.1 MISSION AND MANAGEMENT PLAN

The mission of the Colorado River Authority of Utah (Authority) is to "protect, conserve, use and develop Utah's waters of the Colorado River System." In April of 2022, the Authority adopted a 5-year Management Plan (Management Plan) including a focus on measurement, hydrology and operations, and drought mitigation. The Management Plan indicates, "improved understanding of Colorado River water use is at the core of the Authority's mission and is a basic requirement of effective and equitable water management. The expansive Colorado River region in Utah, and extensive dependence on Colorado River water, complicates measurement of water availability and use, while simultaneously highlighting its importance. Building on existing infrastructure, the Authority will improve, expand, and support a measurement network that produces sound and transparent data that is publicly available."

Performing a metering and gaging gap analysis was identified as the first step toward improving the Authority's understanding of Colorado River water use and developing the flow measurement infrastructure necessary for establishment and administration of drought mitigation measures, in addition to supporting other Mission commitments. The purpose of this gap analysis study is to establish a clear understanding of current measurement conditions, identify gaps in, and risks to, data, funding, maintenance, and other factors that influence the quality, coverage, and access to Colorado River water distribution and diversion measurements in the study area.

In the fall of 2022, following a competitive procurement process, the Authority awarded a contract to Bowen Collins and Associates, who partnered with Jones and DeMille Engineering (collectively, the Engineering Team), to complete the *Metering and Gaging Gap Analysis Study*. This report summarizes the activities performed as part of the study.

1.2 SCOPE OF WORK

The Scope of Work for the study was originally defined in the Request for Proposals (RFP) that was issued in August 2022 and was further refined and included in the "Metering and Gaging Gap Analysis Project Tasks and Deliverables" that was included as Attachment B.1 of the contract between the Authority and Bowen Collins and Associates.

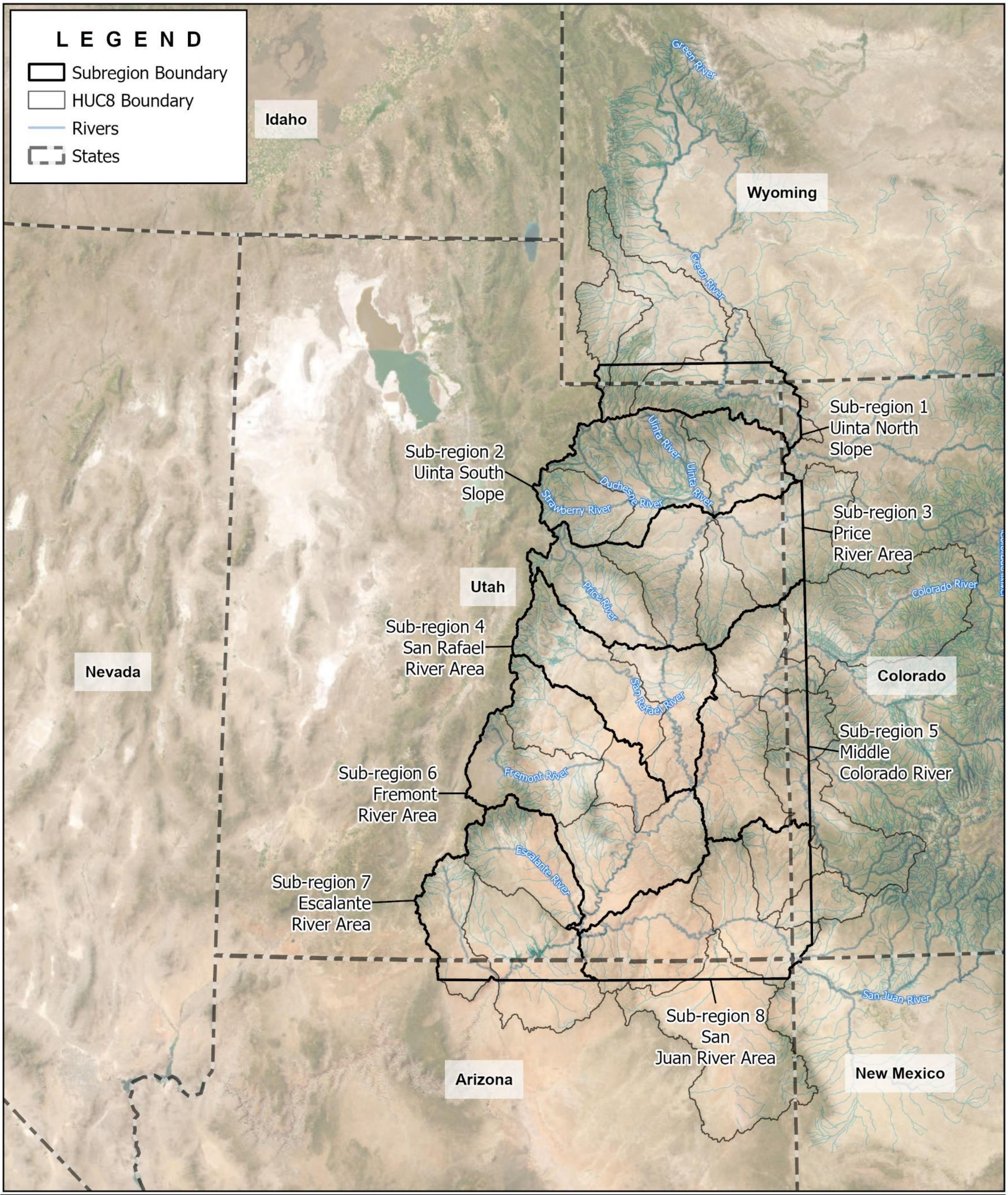
As noted, the Authority retained the team of Bowen Collins and Associates and Jones and DeMille Engineering to complete this study. The Engineering Team worked together to complete the major tasks listed below.

1. **Manage the Project and Participate in Stakeholder Workshops.** This task included frequent progress/coordination meetings with Authority representatives and the Engineering Team. These meetings were key to planning data collection interviews and key stakeholder meetings. Several workshops were also held with key project stakeholders where progress was reported, and input and direction were provided to the Engineering Team.
2. **Collect and Review Existing Geographic Information System (GIS) Gage Data.** This task was performed to collect and review existing gage GIS data that could be used to develop a GIS database (geodatabase) of relevant gaging data.
3. **Perform Agency Coordination and Data Collection.** This task was performed to coordinate with stakeholders to determine the accuracy of available gage GIS data, the accessibility of water measurement records in the study area, and to solicit input on existing flow measurement infrastructure and on known metering and gaging gaps within the study area.

4. **Compile Collected Gage Information.** This task was performed to compile key gage information in a geodatabase and summarize general information on the gages for use in the gap analysis.
5. **Complete the Metering and Gaging Gap Analysis.** This task was performed to define gaps between existing and desired flow measurement/gaging data.
6. **Compile Cost Data, Project Prioritization, and Report.** This task was performed to develop concept level cost and prioritization criteria that the Authority and other State Agencies can use to plan for proposed improvements to address identified water measuring data gaps. A report was also prepared to document the work performed as part of this study.

As one of several deliverables, this report summarizes the means and methods employed by the Engineering Team to complete the tasks required by the contractual scope of work. It also summarizes the results of the Metering and Gaging Gap Analysis Study at a high level, recognizing a large volume of information has been collected and is most effectively provided to the Authority as metadata in a geodatabase.

The study area incorporates the Colorado River drainage and its tributaries in Utah, as well as areas within adjacent states that are close to the Utah state boundary. The study area and the eight subregions that were used during the study are shown in Figure 1-1. Additional information on the subregions is included later in this report.



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STUDY AREA

COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

SCALE: 1 in = 60 miles

FIGURE NO. 1-1

1.3 PARTICIPATION OF KEY STAKEHOLDERS

The Engineering Team would like to express appreciation for the time, effort, and critical input that individuals from the following entities provided during this study:

- Colorado River Authority of Utah
- Utah Division of Water Rights (DWRi)
- Utah Division of Water Resources (DWRe)
- United States Geological Survey (USGS)
- Follum Hydrologic Solutions (Authority Contractor)
- Precision Water Resources Engineering (Authority Contractor)
- Utah Water Conservancy Districts
    - Central Utah Water Conservancy District
    - Duchesne County Water Conservancy District
    - Emery Water Conservancy District
    - Uintah Water Conservancy District
- Appointed River Commissioners
- Sheep Creek Irrigation Company
- Wyoming State Engineer's Office
- Upper Colorado River Commission

Representatives from these organizations provided valuable input during the project duration that related not only to the gap analysis, but to the application of the study results and the geodatabase to modeling and water management efforts in the study area.

Five stakeholder workshops were held during the study to discuss issues, exchange information, discuss data collection and analysis approaches, and receive direction at key points during the study. A summary of the workshops is provided below. Workshop documentation is included in Appendix D.

- **November 4, 2022, Kickoff Workshop.** The Engineering Team met with Authority staff to review the project goals, schedule, and the approach to data collection efforts.
- **November 29, 2022, GIS Data Collection Standardization Workshop.** Engineering Team members met with Authority staff and several Authority contractors who may utilize data from the database to discuss details of data collection and organization. Discussion items included data and file formats, data organization, metadata, quality control approaches, data access and storage, and potential end users of the data. The feedback received during this meeting informed subsequent data collection and organization efforts.
- **April 5, 2023, Progress and Coordination Meeting.** The Engineering Team met with Authority staff and certain stakeholders to present the preliminary results of the GIS data collection efforts and review the geodatabase contents. Valuable input was received and enabled the Engineering Team to continue moving forward with the study.

- **May 15, 2023, Progress and Coordination Meeting.** The Engineering Team met with Authority staff and stakeholders to present the preliminary results from the Gap Analysis task and to receive input regarding gap categories and prioritization of gaps.
- **June 26, 2023, Meeting to Review Draft Deliverables.** The Engineering Team met with Authority staff to discuss review comments and related recommendations on the draft report and associated deliverables.

SECTION 2: DATA COLLECTION AND COMPILATION

2.1 COLLECTION AND ORGANIZATION OF EXISTING DATA

Gage data were gathered from federal and state agencies to provide a baseline for understanding the location and key characteristics of existing gages. The primary sources of gage data included the USGS, the United States Bureau of Reclamation (Reclamation), and DWRi. The USGS and Reclamation gage data were delivered in GIS format (accessed Dec. 12, 2022). The DWRi data were delivered in a tabular format (accessed Dec. 19, 2022), and many individual gage records data did not include location information. Gage locations and attribute information from the three entities were compiled into a single data layer. Other data collected to support the Gap Analysis effort include stream location data from the National Hydrography Dataset (NHD) and watershed boundaries using hydrologic unit codes (HUC) for watershed identification.

When the terms "water measurement infrastructure" or "gage" are used in this report, it references the flow measurement structure, telemetry/communications equipment, and other facilities that collect and record flow data from a gage location and transmit the data offsite so real-time flow information can be publicly accessed from the internet. For clarity, this report uses the following terms to further describe gaging infrastructure:

- **Active** – the measurement infrastructure is currently operational and providing flow data.
- **Inactive** – the measurement infrastructure is currently not operational or providing flow data, but the location has not been retired.
- **Retired** – the measurement infrastructure has been abandoned in place or demolished; new measurement infrastructure would be needed to resume flow measurements.
- **Existing** – includes Active and Inactive sites for the purposes of this study.
- **Proposed** – includes locations of potential measurement infrastructure that could address gaps in the metering and gaging system in the study area where no measurement infrastructure currently exists.
- **Proposed for Rehabilitation** – specifically refers to retired USGS stream gaging sites that operated historically and were proposed as a potential measurement location.
- **Stream gage** – includes measurement infrastructure that measures flow in a natural river or stream.
- **Diversion gage** – includes measurement infrastructure that measures flow diverted from a stream via a diversion structure at or downstream from a point of diversion.
- **Canal gage** – includes measurement infrastructure that measures flow in or diverted from canals. Canal gages generally are located downstream of a diversion that supplies water to the canal.

Working with the Authority and stakeholders, the Engineering Team developed a list of attributes, or characteristics, that were important to capture for each existing gage in the study area. Gage attributes included critical characteristics, such as approximate maximum flow or gage capacity, whether the gage is active, and additional supplemental information to be used in the gap analysis. Several attributes included domains, or a range of values, to streamline data collection and standardize data inputs (see Appendix A for a full list of gage attributes and domains). The Engineering Team conducted a series of stakeholder interviews to obtain these gage attributes for existing gages. In addition, the Engineering Team developed a list of general system questions to ask interviewees to capture a broader, more qualitative view of the local or regional gage network.

Initially, the project scope requested that detailed data be collected for all flow gages with capacities 50 cubic feet per second (cfs) and larger. However, it became clear as the project progressed that a lower threshold was more appropriate and would account for a larger amount of Colorado River system water diverted in the study area. After the initial data collection effort was completed, the measurement capacities of existing and proposed diversion gages were plotted in a cumulative distribution curve to evaluate the estimated proportion of diverted flows accounted for at various thresholds of gage measuring capacity. This curve is shown in Figure 2-1. Based on the data illustrated in Figure 2-1 and feedback received during the April 5, 2023, progress meeting, the Authority requested that the detailed data threshold be lowered to include gages 10 cfs and larger.

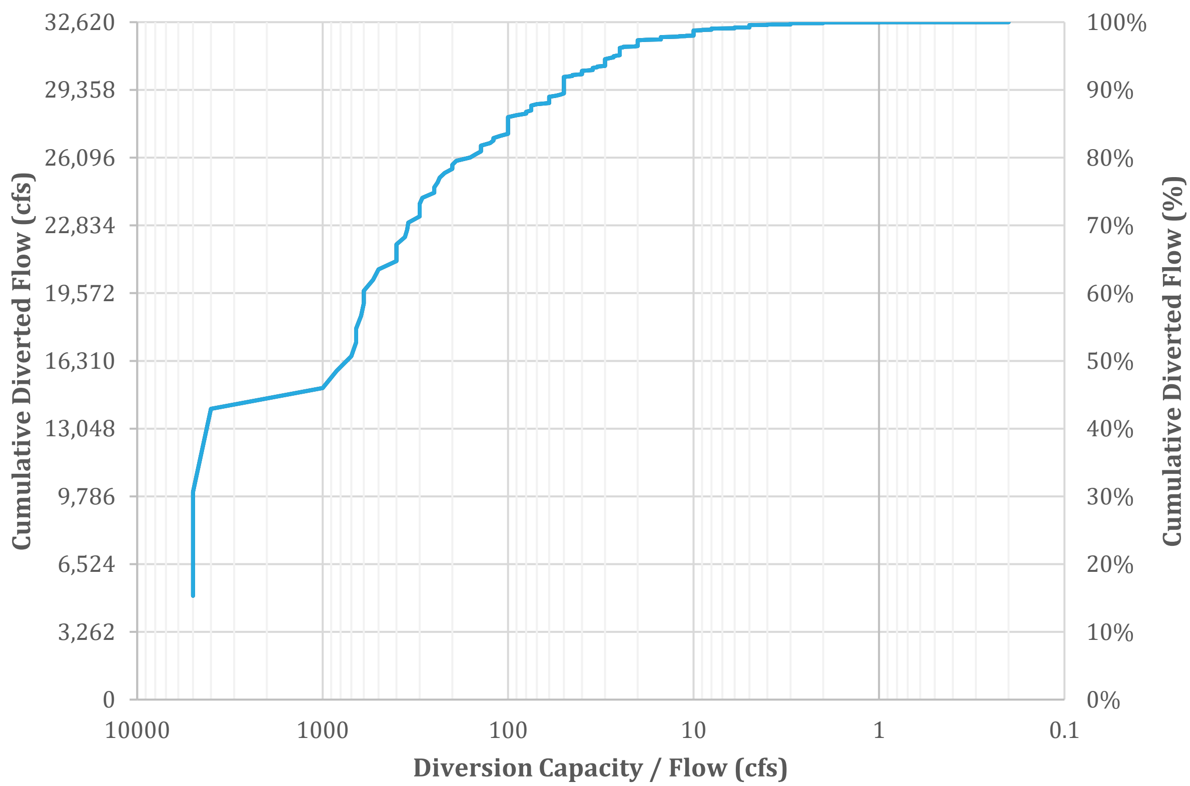


Figure 2-1: Estimated Relationship Between Cumulative Diverted Flow and Diversion Capacity

2.2 STAKEHOLDER INTERVIEWS

2.2.1 PURPOSE OF INTERVIEWS

Although there are existing datasets that identify where gages and meters are located, some of the datasets were incomplete and did not contain the breadth and type of information needed to perform a metering and gaging gap analysis for the study area. The Engineering Team determined that interviewing key stakeholders was the most effective method to gather missing information as well as confirm the accuracy of existing data. Interviews were conducted with individuals that manage, own, operate, or maintain the gages and meters and would have the most detailed knowledge about their operation and potential gaps.

2.2.2 CONTACTS

Contacts for potential interviewees were identified from the following groups: DWRi Regional Engineers, DWRi Distribution Engineers, water conservancy districts, river commissioners, irrigation company officers/operators, ditch riders, and individual irrigators within the study area. A contact list was developed to identify and track contact information for each known person or entity that would have knowledge of existing gages and input for proposed gages (See Table A-1 in Appendix A). A condensed contact list was developed from the larger list and the Authority sent each person on the condensed list a letter to describe the purpose of the study and notify them that their participation may be requested in the interviews. Section 2.2.5 describes the interviews in greater detail and Appendix A (Table A-2) includes a list of all individuals who participated in the interviews.

2.2.3 DATA COLLECTION TOOLS

2.2.3.1 ArcGIS Online Interview Application

An ArcGIS Online map interface was developed to assist in the data collection. Using an online interface allowed multiple interviews to occur simultaneously and enabled the data to be entered and updated in real-time. This approach prevented interviewers from making duplicate entries and was convenient as the data could be accessed anywhere the interviewer had a stable internet connection. Existing gage data were displayed on a digital map projected on a screen and the interviewees had multiple base maps available, including detailed aerial imagery, to utilize during the interview to edit or add to the existing dataset. Only the Engineering Team interviewers had edit privileges in this interface to ensure data integrity (see screenshot of map in Appendix A).

2.2.3.2 Survey123

Survey 123 is a web-based GIS input form that allows users with an internet link to easily add data to a geodatabase. This method was utilized to collect gage data from interviewees both before and after the interviews.

- **Existing Gages** – A Survey123 form was used by interviewees to input the location and attributes of existing gages that were not included in the original datasets (See screenshot of form in Appendix A). These data are included as an individual geospatial data layer in the final geodatabase deliverable (see Appendix C for a description of the geodatabase contents).
- **Proposed Gages** – A separate Survey123 form was utilized to allow interviewees to input locations and attributes of potential gages where they felt a gage could be beneficial for the purposes of this study (see screenshot of form in Appendix A).

2.2.3.3 ArcGIS Online Dashboard

An online dashboard was created and shared with the Authority (and later interested stakeholders) to provide a visual and transparent means of tracking the real-time progress of the data entry. The dashboard displayed the number of existing and proposed gages with their associated locations and attributes (see screenshot of dashboard in Appendix A).

2.2.3.4 System Questionnaires

A general system questionnaire was developed and sent to each interviewee to request general qualitative feedback about the river system and the gages that they oversee (see Appendix A). The responses were incorporated into the geodatabase for reference and used later to help identify different types of measuring and metering gaps.

2.2.3.5 Gage Attributes

A list of approximately 29 desired gage attributes (e.g., telemetry, consistency of data collection) was sent to each interviewee prior to the interview to allow the participant time to gather this information in advance of the interviews. The responses to questions listed in Table 2-1 were recorded for each gage and entered as attributes into the geodatabase. If the interviewees were unable to provide the information during the interview, they had an opportunity to provide it later by either entering it into one of the Survey123 online forms, or through a follow up phone interview.

Table 2-1
List of Gage Attribute Questions for Interviewees

Question Number	Attribute Question
1	Common or local name of gage or measuring station?
2	Name of the canal/river/stream being measured?
3	Latitude coordinate of the gage/measuring station in decimal degrees?
4	Longitude coordinate of the gage/measuring station in decimal degrees?
5	Name of the owner/agency of the gage/measuring station?
6	Name of the entity that maintains and operates the gage/measuring station (if different than owner)?
7	Type and description of gage or measurement device?
8	Current status of the gage or measuring station?
9	If no longer active, provide a description why the gage/measuring station is no longer active?
10	What type(s) of data are collected at this measuring station?
11	What is the condition of the measuring station?
12	What telemetry, if any, is used to automate data transmission?
13	If no telemetry, what equipment would be needed to automate data transmission?
14	What year did measurements begin?
15	In what year was the most recent measurement taken?
16	How consistent has the data collection been over time?
17	What is the frequency of data collection?
18	Gage operation typically starts in which month? (January if year-round)
19	Gage operation typically ends in which month? (December if year-round)
20	What is the format of the data collected?
21	Please provide an annual cost breakdown for the operation and maintenance of the measuring station.
22	What is the funding source for gage operation and maintenance?
23	What is the approximate maximum flow measured by the gage in cfs?
24	Note about the gage.
25	What is the station information source (USGS, DWRi, USBOR, etc.)?
26	Information is provided by….?
27	Gage type? (Stream, Diversion, or Canal)
28	Diversion Type? (Agricultural; municipal & Industrial, Municipal, Industrial & Agricultural; Return Flows)
29	Is diversion a dry dam?

2.2.4 INTERVIEW PROCESS

An interview protocol was established to help maintain consistency across multiple interviewers during the data collection process. The protocol is summarized below.

2.2.4.1 Pre-Interview

- Send Letters and Infographic Sheet from the Authority to interviewees
- Contact Interviewees to make appointment and briefly orient them on the upcoming interview
- Email General System Questionnaire
- Email Map Series for the Subject Area that contain existing data
- Email list of Gages with Unknown Locations for the applicable river system
- Email link to Survey 123 Form for EXISTING gages for interviewee to input any missing EXISTING gages prior to the interview (if they chose)
- Email link to Survey 123 Form for PROPOSED gages for interviewee to input locations of any PROPOSED gages that could fill known data gaps prior to the interview (if they chose).

2.2.4.2 Interview

- Verify accuracy of locations of existing gages shown on the previously provided PDF map series
- Update gage locations in GIS if any are incorrect
- Review any missing gages that were input by the interviewee before the interview
- Review the list of gages with no coordinates and drop a pin and input known attributes (match the name exactly to link to DWRi database)
- Discuss and input Proposed Gage locations, with explanation as to why a new gage at this location would be beneficial (they can use the Survey123 Form to enter additional gages after the interview)
- Input answers to the “General System Questionnaire” into the database form provided
- Collect available information on smaller gages (less than 10 cfs capacity) that interviewee has knowledge of (time permitting), or have them enter that information later using the Survey123 Form for EXISTING gages
- Collect any additional notes or information that could be useful to the Authority in the gap analysis
- Schedule an additional appointment (if needed) or otherwise arrange for any needed follow-up.

2.2.4.3 Post Interview

- Update geodatabase with missing gage locations and other data that were provided (if not already done during interview)
- Make additional post-interview notes to include with General Questionnaire record (if any)
- Process information collected and compile a list of the existing gages with measurement capacities greater than 10 cfs to solicit more detailed attributes

- Send the list of the gages with capacities 10 cfs and greater to the interviewee and request the additional detailed attribute information per the "Gage Station GIS Attributes" form provided
- Follow up on any additional appointments or information requests and repeat the interview process (if needed).

2.2.5 INTERVIEWS CONDUCTED

Between January and March of 2023, twenty in-person interviews were conducted with an additional five phone/virtual interviews to follow up on remaining data collection.

2.2.5.1 Interview timeline

Interviews were scheduled starting in January 2023 and were completed by mid-March to avoid overlap with the spring irrigation season.

2.2.5.2 Interview locations

Interviews were scheduled and conducted in geographical areas determined primarily by sub-region or river system. The state was divided into 8 sub-regions (see Figure 1-1), namely:

1. Uinta North Slope
2. Uinta South Slope
3. Price River
4. San Rafael River
5. Middle Colorado River
6. Fremont River
7. Escalante River
8. San Juan River

Interviews were conducted at the state regional water rights offices or a nearby Jones and DeMille office. The interviews were scheduled by river system so river commissioners and conservancy district staff participated only for systems that they manage.

2.2.5.3 Interviewees

Interviews were conducted with a subset of the individuals identified in the contact list. Interviewees included DWRi Regional Engineers and Distribution Engineers in the Vernal, Price, Richfield, and Cedar City Offices; the Division 4 field staff of the Wyoming State Engineer's Office (WSEO)[*]; river commissioners; and individuals from water conservancy districts within the study area. After the initial interviews, it was determined that most of the information on existing gaging infrastructure could be obtained from these interviewees and that contacting individual irrigation companies or irrigators was not necessary. One exception is that interviews were conducted with representatives from the Sheep Creek Irrigation Company because DWRi Regional or Distribution Engineers were not as familiar with their facilities.

[*] The North Slope of the Uinta Mountains is administered and regulated as a joint effort between DWRi and WSEO.

2.2.5.4 Data entry

The interview process largely followed the established interview protocol. The ArcGIS Online map that was created for the interview process was shown to the group on a large screen. While viewing the map, the interviewer selected the gage points that came from the initial datasets and verified the accuracy of the location and the attributes of each point. A spreadsheet for each river system containing gages with unknown locations (obtained from DWRi) was reviewed and those gages were entered into the database with a name matching the spreadsheet. Next, with the aid of a high-resolution aerial imagery base map, interviewees directed the interviewer to locations of existing gages that were missing from the existing database. In many cases, the imagery was detailed enough to clearly see the diversion structure or exact gage location. The common name of each gage was input along with other known attributes. During this process of following rivers and canals on the map, locations were identified by interviewees where proposed gages could potentially fill known data gaps. Notes pertaining to each gage (e.g., the priority of proposed gages) were also recorded in the notes section if provided by the interviewee.

2.2.5.5 Follow-up

Some interviews took longer than anticipated and not all the desired information was collected in the initial interview. Follow-up interviews were scheduled where necessary to gather the remaining information. These consisted of in-person interviews and several virtual meetings. After the initial data were collected and reviewed by DWRi staff, it was determined that additional attributes would be useful to obtain for each gage, such as the type of gage (stream, diversion, or canal). For diversion gages only, the diversion type (agricultural, municipal and industrial, a combination of all three, or return flows), and whether the diversion is a dry dam were also collected. These additional attributes were solicited from the interviewees and input into the digital geodatabase.

2.3 INTERVIEW FINDINGS

The interview process generated data to populate the geodatabase, but there were other observations that are worth noting, namely: interviewee attitudes, trends and common themes, initial known gaps, and general information about proposed gages.

2.3.1 INTERVIEWEE ATTITUDES

As stated earlier, the majority of those interviewed were DWRi Regional and Distribution Engineers, river commissioners, and conservancy district staff. There were also a few irrigation company officers and irrigators. By and large, the requests for the interviews were welcomed and the attitudes of those that were interviewed were very positive and helpful.

DWRi engineers, river commissioners, and conservancy district staff were eager to contribute and were very willing to spend time to help gather the requested data. They recognized the value of the study and were also interested in discussing additional gages that would help improve the understanding of water supply and use in the study area and improve system operations.

Representatives from conservancy districts also contributed in a positive way and shared a wealth of knowledge. Conservancy districts indicated that they typically have the gages, meters, automation, and telemetry in place to operate their systems effectively, but expressed that more gages would certainly be welcomed.

Initially, some irrigation company officers and individual irrigators were somewhat reluctant and skeptical to meet and share information. During the interview, as they came to understand that the purpose of the study was to compile an inventory of existing gages and was being performed as a collaborative effort to assist in the Authority's mission to help protect Utah's waters of the Colorado River system, they became more willing to share information and offer locations for proposed gages.

Overall, once informed, all interviewees seemed interested and quite willing to offer the information that was being requested. They were interested in staying informed as to the study progress and results.

2.3.2 COMMON THEMES

The interviews revealed common trends and themes in terms of metering and gaging gaps.

2.3.2.1 Additional Gages

There was a common theme of desiring additional gages to better understand the flows on rivers and canal diversions, including the fluctuating nature of the flows. Some mentioned that additional gage data would help to better manage water rights associated with the diversions and rivers. For example, some water rights are dependent on flows coming from the fork of a river that has no gage. Knowing what the flows are from each fork of a river could help those that manage the water to do so more equitably if rights are dependent upon the amount of water supplied by each fork of the river.

2.3.2.2 Telemetry/Real-time Monitoring

Improving telemetry and automation of data collection was another common desire. The ideal scenario is to provide online real-time flow data at gaging and metering locations. As stated previously, in this report the term "measurement infrastructure" generally refers to the gage or metering devices, the telemetry, and the internet connectivity required to accomplish this objective.

2.3.2.3 Funding

Funding was one of the most frequently discussed concerns. Entities continually face budget shortfalls, which make it difficult to invest in new infrastructure without outside funding assistance.

2.3.3 AREAS OF IMPROVEMENT IDENTIFIED DURING INTERVIEWS

Many areas of improvement with respect to metering and gaging within the study area were qualitatively identified during the interviewing process. Addressing every area of improvement would require a combination of infrastructure enhancement, political cooperation, legal agreements, etc. The sections below summarize the key findings, which helped inform the types of gaps considered in the Gap Analysis (see Section 3). These findings may also help inform future efforts and programs sponsored by the Authority and other key stakeholders.

2.3.3.1 Borders

The Colorado River Basin within Utah is complex and has contributing watersheds from the neighboring states of Wyoming and Colorado. Gages on streams and rivers along Utah's shared borders with those states identify where and how much water is entering or leaving Utah. Potential locations for such gages were identified by interviewees.

2.3.3.2 Tribal

Native American Tribes located in the Upper Colorado River Basin in Utah include the Ute Indian Tribe, Ute Mountain Ute Tribe, and the Navajo Nation. Water is being diverted and used on Tribal lands within Utah, but there is limited water use data available from Tribal entities. Gages near Tribal boundaries, as well as further efforts to collaborate with Tribal entities on Colorado River System issues, might be considered to address gaging data gaps on or near Tribal lands.

2.3.3.3 Flow Data Quality

There are many existing gages and meters throughout the study area. Interviewees expressed a high level of confidence in the quality of USGS gage data due to the rigorous and detailed process that is used to collect, calibrate, analyze, and publish the data. However, there was less confidence in the quality of flow data obtained from gages and meters installed by irrigation companies and irrigators due to a lack of regular maintenance and calibration efforts, largely a result of limited resources.

2.3.3.4 Flash Flood Data

There are many watersheds in Utah that often produce large flash floods. This makes collecting accurate data on rivers, streams, and diversions difficult in many areas. This is due to several factors:

- **Damaging Flows** – Flash floods may damage gage or measurement infrastructure. Flows are often debris laden and can lead to scouring, clogging, or other damage.
- **Large Flow Rates** – Flash flood flows can exceed the capacity of the measuring device which may not capture flows from larger events. Larger gages could be utilized, but accuracy for smaller flows would typically decrease in larger measuring devices.

2.3.3.5 DWRi Data Quality

Some data in the DWRi database appear to be outdated, missing, or incomplete. For example, some records in the DWRi database provided to the Engineering Team contained the name of a device only with no location data.

2.3.3.6 Telemetry

Many existing gages or meters are manually read using a staff gage or other method without ongoing automated logging of data or transmission to a central location. Installation of phone, radio, satellite, or hardwire equipment or upgrades may be installed to fill this gap on many existing gages.

2.3.3.7 Return Flows

It was found that tailwater or return flows to rivers at the end of canals or at overflow gates on diversion structures are rarely measured. Filling this data gap would be useful to better understand return flows.

2.3.3.8 Known Water Conflict Areas

Interviews revealed that entities that have installed gages and telemetry and publish real-time data have experienced a dramatic decrease or near elimination of water user conflicts.

2.3.3.9 Proposed Gages

A number of potential gages were identified by interviewees (engineers and operators) during the interviews at locations that could provide system benefits, such as improving on-the-ground operations or providing information on water supply and use.

2.4 FINALIZING THE GEODATABASE

Finalizing the geodatabase after data collection involved four main steps: classification of gages, data cleaning, data analysis, and organization of the geodatabase structure. Figure 2-2 provides a graphical overview of the geodatabase finalization process and the measures taken in each step.

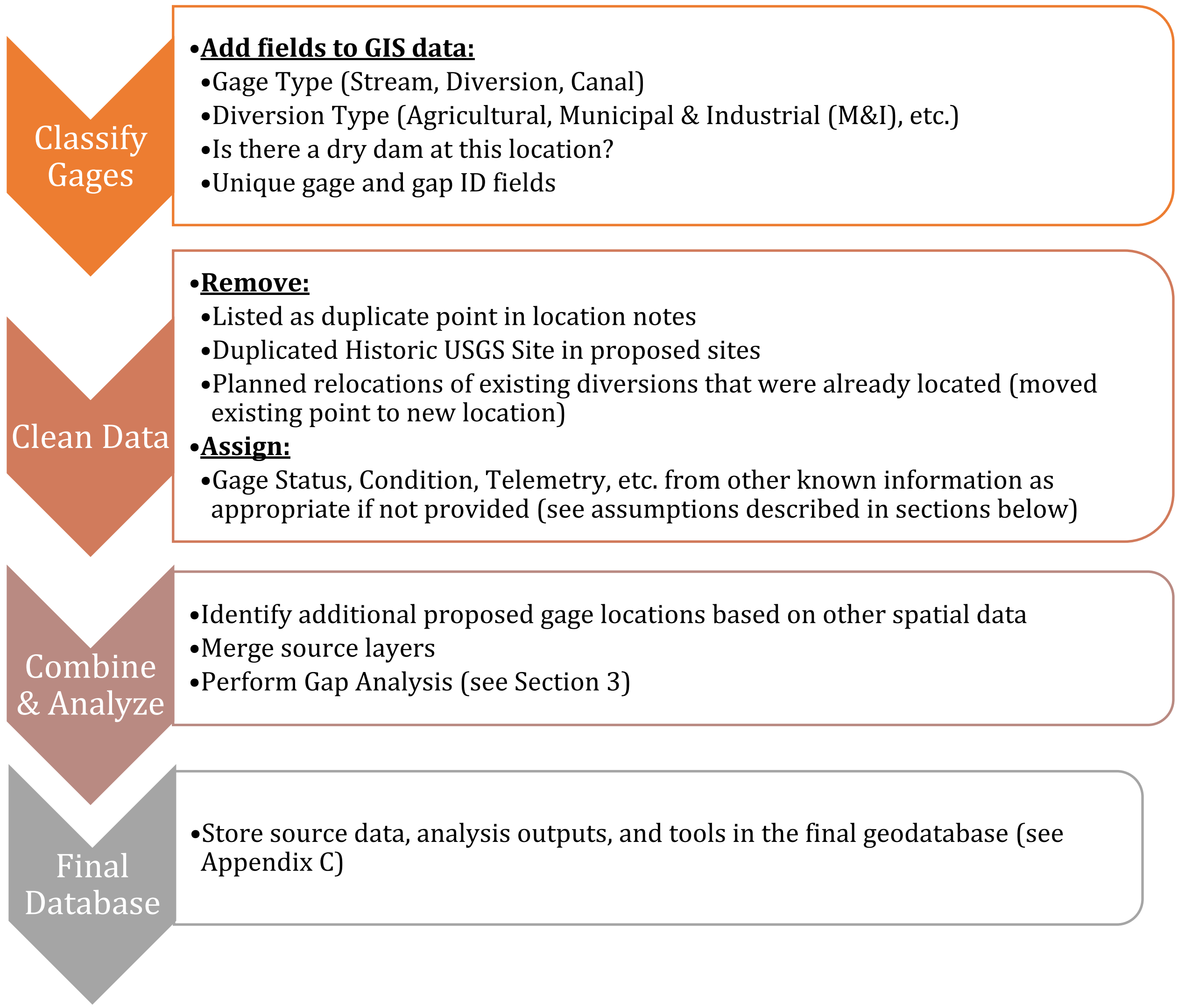


Figure 2-2: Geodatabase Finalization Process (Data Cleaning)

2.5 ANALYSIS OF CURRENT CONDITIONS

In the first round of interview meetings, interviewees provided location data and limited information about all known existing gages. Although the study focus was on gages with capacities of 10 cfs and larger, there were many gages with less than 10 cfs capacity for which data were collected. Virtual follow-up meetings were scheduled with interviewees to populate the additional desired information in the database for gages above the 10 cfs threshold. Thus, for gages with capacities less than 10 cfs, the information has varying levels of completeness in the collected data and final geodatabase. A 10 cfs threshold was determined to be appropriate for this study. At the beginning of the study, the Authority's stated goal was to collect detailed information on meters and gages that had capacities of 50 cfs and larger. As the study progressed, the decision was made by the Authority, with input from the DWRi, to have the Engineering Team collect detailed information from interviewees on existing gages that had capacities of 10 cfs and larger. Doing so would collect data on gages that account for most of the cumulative diverted flow in the study area. Subsequent efforts could expand to include gages that measure less than 10 cfs.

This section summarizes several statistics that characterize gage trends within the portion of the Upper Colorado River Basin that is located in Utah. Figures depicting these trends and gage locations are included at the end of this section. For clarity and brevity, figures that summarize findings are presented at the scale of the entire study area and show minimal detail. Companion deliverables have been provided in conjunction with this report and depict a higher level of detail. The companion deliverables include the following:

1. An ESRI geodatabase containing GIS data and tools as described in Appendix C
2. A KMZ file displaying the source data and gap analysis results from the Geodatabase in Google Earth (for viewers who are unfamiliar or who don't have access to ESRI GIS products)
3. A table of prioritized gaps resulting from the gap analysis in a Microsoft Excel spreadsheet.

2.5.1 EXISTING GAGE STATUS AND TYPE

Most, but not all, gage point locations indicated the status of the measurement infrastructure (Active, Inactive, Retired). USGS stream gages that were not providing current conditions information on the USGS website as of March 2023 were assumed to be retired, while those providing real-time information were assigned the Active status if not previously assigned. The diversion and canal gages without an assigned status code were located during the interview process and provided information about measurement intervals or the measurement devices at the location. These gages were assumed to be Active.

After the interviews and data cleaning process were complete, a total of 760 existing and retired measurement locations had been identified, as summarized in Table 2-2 and shown in Figure 2-3 (refer to Figures 2-3 through 2-10 included at the end of this section).

Most retired sites are historic USGS stream gages that were removed or decommissioned. The identified existing (e.g., active or inactive) sites also included 240 diversion gages and 145 stream gages. Of the active stream gages, 66 are currently operated by the USGS. The remainder of the gages include inline measurement devices like weirs or flumes that are operated by other parties.

The spatial distribution of the existing gage stations shown in Figure 2-3 indicates that there is a distinct lack of metering in southern subregions (Escalante, Fremont, San Juan). Based on the Engineering Team's observations during data collection, measurement infrastructure is not as prevalent in these regions in part due to their arid climate and more ephemeral and intermittent streamflow patterns. Most stream gages in these regions are either retired or located many miles downstream from areas of consumptive use. The lack of gaging on Tribal lands is also evident in the eastern portion of the Price River subregion. The Uinta North Slope, Uinta South Slope, Price River, San Rafael River, and Middle Colorado regions of the state have a more extensive coverage of active gages than the other regions of the state.

Table 2-2
Existing and Retired Gage Summary

Gage Status	Canal	Diversion	Stream	Total
ACTIVE	81	216	133	430
INACTIVE	3	20	16	39
RETIRED	4	13	274	291
Total	**88**	**249**	**423**	**760**

2.5.2 EXISTING GAGE CONDITIONS

The general physical condition of existing gages is presented in Table 2-3 Table 2-3 Existing Gage Conditionand illustrated in Figure 2-4. In general, most of these gages may need little to no maintenance beyond routine cleaning or calibration (335 of 469). Information about the condition of 100 existing gages was not collected during the interviews, most of which have measurement capacities below the 10 cfs threshold established as part of this study. The remaining gages (32 of 470) may require more significant upgrades or complete replacement to achieve defined baseline operational standards. This amounts to less than 7 percent of existing gages where significant rehabilitation or replacement is recommended. The collected data suggests that operators generally maintain their gages to the degree required for operation, but the gages themselves would benefit from more regular maintenance.

Figure 2-4 confirms this finding spatially. Most gaging stations in the region are colored yellow to show that some minor repairs may be needed, which is consistent with the general themes discovered during the interviews.

Table 2-3
Existing Gage Condition

Condition	Canal	Diversion	Stream	Total
Good - No Maintenance Needed	3	48	79	130
Operational - Minor Maintenance Recommended	47	120	38	205
Poor – Repair Recommended	1	9	5	15
Very Poor - Not Operational	1	9	7	17
Not Specified[1]	32	50	20	100
Total	**84**	**236**	**149**	**469**

1. Condition was unknown during interviews, or the gage capacity is below 10 cfs and detailed information was not collected in follow-up meetings. See Section 3 for assumptions regarding existing gage condition made to complete the gap analysis.

2.5.3 EXISTING DIVERSION GAGE CAPACITY

Diversion gages are critical for quantifying both demands and consumptive use. Table 2-4 summarizes the measurement capacity of existing diversion gages identified during the data collection process.

The summary statistics described in Sections 2.5.5 through 2.5.7 show large numbers of gages that are missing information about measurement frequency, measurement consistency, and the format of flow records. While there are some diversion and canal gages measuring greater than 10 cfs where this information was unknown, gages diverting less than 10 cfs are the largest contributor to the unknown or blank data fields in those categories. According to Figure 2-1, those gages account for less than 5 percent of the cumulative diverted flow in the Study Area.

Table 2-4
Existing Diversion Gage Measurement Capacity

Gage Capacity (cfs)	Canal	Diversion	Stream	Total
< 10	16	80	5	101
10 - 25	7	42	12	61
25 - 50	13	34	11	58
50 - 100	11	20	20	51
100 - 250	5	19	6	30
250 - 500		8	9	17
> 500	1	8	22	31
Not Specified[1]	31	25	64	120
Total[1]	**84**	**236**	**149**	**469**

1. Measurement capacity was unknown during interviews, or the gage capacity is below 10 cfs and detailed information was not collected in follow-up meetings. See Section 5 for assumptions regarding measurement capacity made to prioritize gaps and estimate budgetary improvement costs.

2.5.4 DIVERSION AND CANAL GAGE TELEMETRY

To effectively manage and monitor water on a real-time basis, gages should be equipped with instrumentation and telemetry to automatically save and transmit flow measurements over time. The Active USGS stream gages identified in the geodatabase report current information on the USGS website. Therefore, those sites should have adequate active telemetry equipment. Retired gages of all types were not evaluated for telemetry gaps as those locations have been abandoned or removed entirely. Other active and inactive gages were determined to have telemetry gaps if 1) the geodatabase information indicated what telemetry would be required to automate data transmission, 2) the geodatabase indicated no telemetry equipment was present, or 3) information about gage telemetry was not provided during the interviews.

Table 2-5 presents the existing diversion and canal gage telemetry status. The data presented in Table 2-5 indicates that 50 percent (224 of 469) of the existing gages have some sort of telemetry gap. These gaps exist at gages where flow data is collected at regular intervals, but the data is not transmitted, or at gages that require manual reading by an operator. Installing telemetry at major points of diversion would improve real-time water management/monitoring efforts.

Figure 2-6 illustrates the telemetry status at existing diversion gages in the study area. The data collected for the Escalante and Fremont River subregions show a distinct lack of diversion data. Most of the water diverted in these two subregions serves a few large irrigation companies whose diversions were not previously located. In addition, many of the diversion gages in the other subregions do not have telemetry.

Table 2-5
Diversion and Canal Gage Telemetry Gaps

Telemetry Gap	Canal	Diversion	Stream	Total
No	27	112	86	225
Yes	57	124	63	244
Total	**84**	**236**	**149**	**469**

2.5.5 EXISTING GAGE MEASUREMENT FREQUENCY

Frequent flow measurement also benefits real-time water management and implementation of drought mitigation programs. Table 2-6 summarizes the measurement frequency of existing gages identified in the interviews. The data show a significant gap in understanding the measurement frequency at existing gages. Of the 469 total existing gages, the measurement frequency of 188 of the existing gages (roughly 40 percent) was not specified. Approximately 67 percent of gages with known measurement frequencies (189 of 281 gages) collect flow measurements at hourly or sub hourly intervals. Most of the remaining gages are read intermittently (79 of 281 gages).

Most of the gages with unspecified measurement frequency are those measuring less than 10 cfs. There are some gages measuring 10 cfs or more that have unspecified measurement frequency. If measurement frequency is not known or specified, it is likely that the readings are not taken hourly or sub-hourly, as those intervals are strongly correlated with installed telemetry.

Figure 2-7 illustrates the collected data associated with measurement frequency for existing gages in the study area. Most gages in the San Rafael River, Price River, and Uinta North and South subregions collect flow data at the most frequent intervals. Each subregion also shows several gages that are read intermittently.

Table 2-6
Existing Gage Measurement Frequency

Measurement Frequency	Canal	Diversion	Stream	Total
Real-time (sub-hourly)	10	52	27	89
Hourly	18	66	16	100
Daily	1	5	3	9
Monthly		2	2	4
Intermittent	17	40	22	79
Not Specified[1]	38	71	79	188
Total	**84**	**236**	**149**	**469**

1. Measurement frequency was unknown during interviews, or the gage capacity is below 10 cfs and detailed information was not collected in follow-up meetings. See Section 3 for assumptions regarding measurement frequency made to complete the gap analysis.

2.5.6 EXISTING GAGE METHOD OF DATA STORAGE

The method of data storage was also of interest to the Authority. Table 2-7 summarizes the format in which flow records are kept at existing gages. This information was not specified or unknown by interviewees for most gages (202 of 469); however, it may be assumed that flow records for diversion and canal gages are stored in hard copies or scans more often than stream gages. Of the gages with known data format (267 gages), 187 gages kept records in a digital format (e.g., spreadsheet). Most others with a known format stored records in a hard copy format (e.g., scanned PDF).

Figure 2-8 illustrates the format of records at existing gages. Most records that are kept in a digital format tend to coincide with gages that measure flow at sub-hourly or hourly intervals.

Table 2-7
Existing Gage Method of Data Storage

Storage Method	Canal	Diversion	Stream	Total
Digital	30	116	41	187
Hard copy	18	38	21	77
Scanned PDF		1	2	3
Not Specified[1]	36	81	85	202
Total	**84**	**236**	**149**	**469**

1. Section 3.3.3 of this report describes how gages where the storage method was not specified were handled during the Gap Analysis.

2.5.7 EXISTING GAGE DATA CONSISTENCY

While analyzing the period of record at every gage was not part of the scope of this study, the interviewers collected data to generally determine if the period of record at a gage had extended periods where no flows were recorded. Table 2-8 and Figure 2-9 summarize and illustrate the consistency of the flow measurements over the period of record at existing gages. Of the 469 existing gages, 193 of the gages did not have data consistency specified. Of the 276 remaining gages, 232 gages (approximately 84 percent) have no interruptions in the period of record. This finding is consistent with the maintenance themes identified during the interviews in that most existing gages are maintained with enough regularity to ensure continuous operation, but funding and upkeep were challenges mentioned consistently operators.

Table 2-8
Existing Gage Data Consistency

Historical Measurement Consistency	Canal	Diversion	Stream	Total
Less than 5 years missing data	8	20	3	31
More than 5 years missing data	0	6	6	12
No Interruptions	39	141	52	232
Not Specified[1]	37	69	88	193
Total	**84**	**236**	**149**	**469**

1. Measurement consistency was unknown during interviews, or the gage capacity is below 10 cfs and detailed information was not collected in follow-up meetings. See Section 3 for assumptions regarding existing gage condition made to complete the gap analysis.

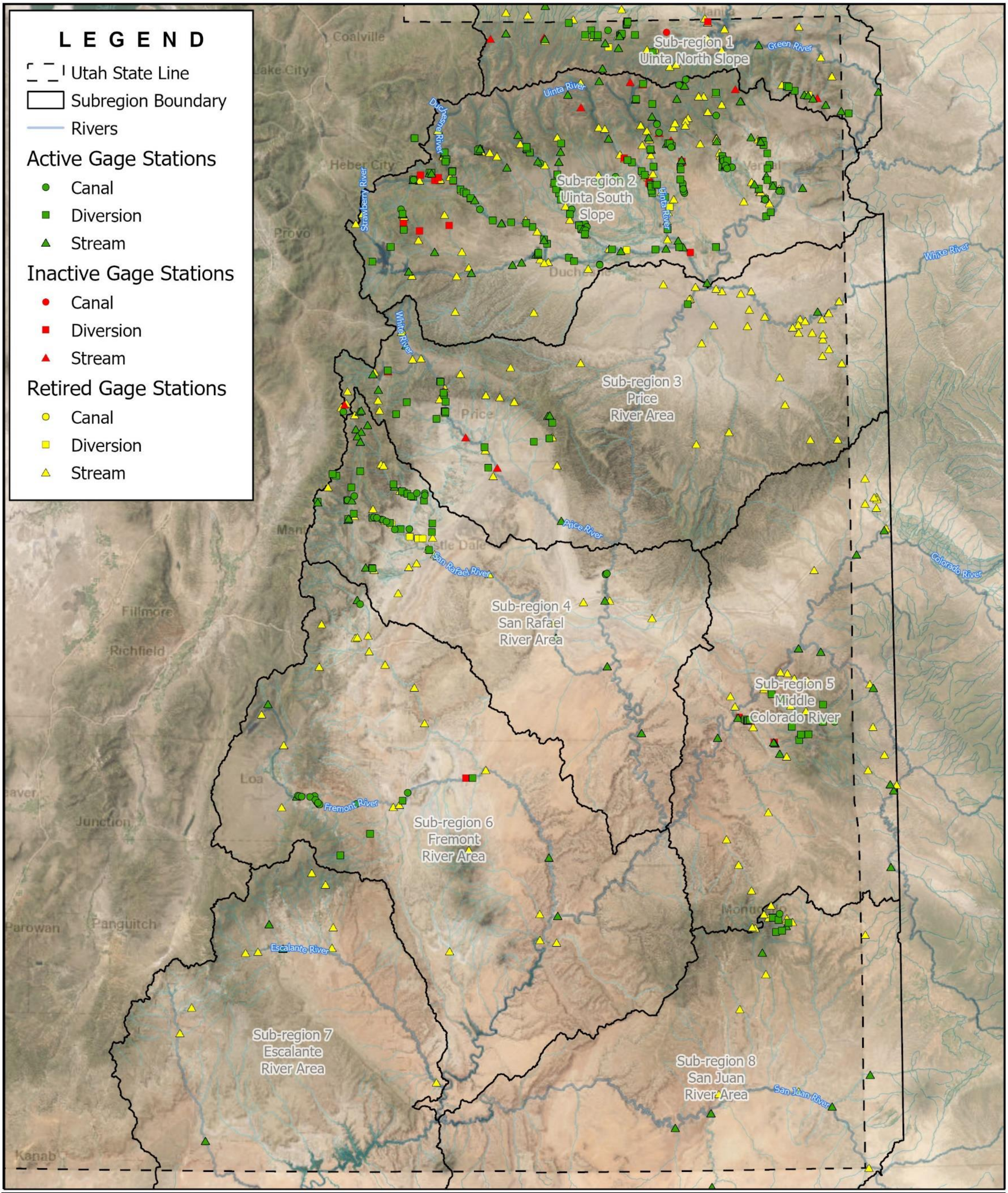
2.5.8 PROPOSED GAGING FROM INTERVIEWS

During the interviews, interviewees suggested 165 locations that would benefit from either a new gage station or new metering device. Figure 2-10 illustrates these proposed locations and Table 2-9 summarizes the counts of the proposed locations. Just under half of the proposed gages were stream gages intended to measure return flows or aid in apportioning water, and many gages are metering devices on canals or diversions. There were 12 retired USGS gages proposed for rehabilitation among the 82 proposed stream gages.

Table 2-9
Proposed Metering and Gage Station Locations

Request Type	Canal	Diversion	Stream	Total
New Gage	7	76	70	153
Recommission Historic USGS Gage	0	0	12	12
Total	**7**	**76**	**82**	**165**

While proposed gage locations identified by interviewees formed the basis for identifying most of the Operations gaps (see Section 3.4.2), an initial review of these proposed gages with the Authority and DWRi revealed that some of the identified locations are non-critical locations for managing water in the study area. These locations were still included in the Gap Analysis as a means of documenting the entire range of potential gaps in the study area. Therefore, the proposed gage locations suggested by the interviewees are not to be considered as an official list of all gages that are proposed or recommended to be installed.



BOWEN COLLINS & ASSOCIATES

Jones & DeMille Engineering

SUMMARY OF EXISTING AND RETIRED GAGES

COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

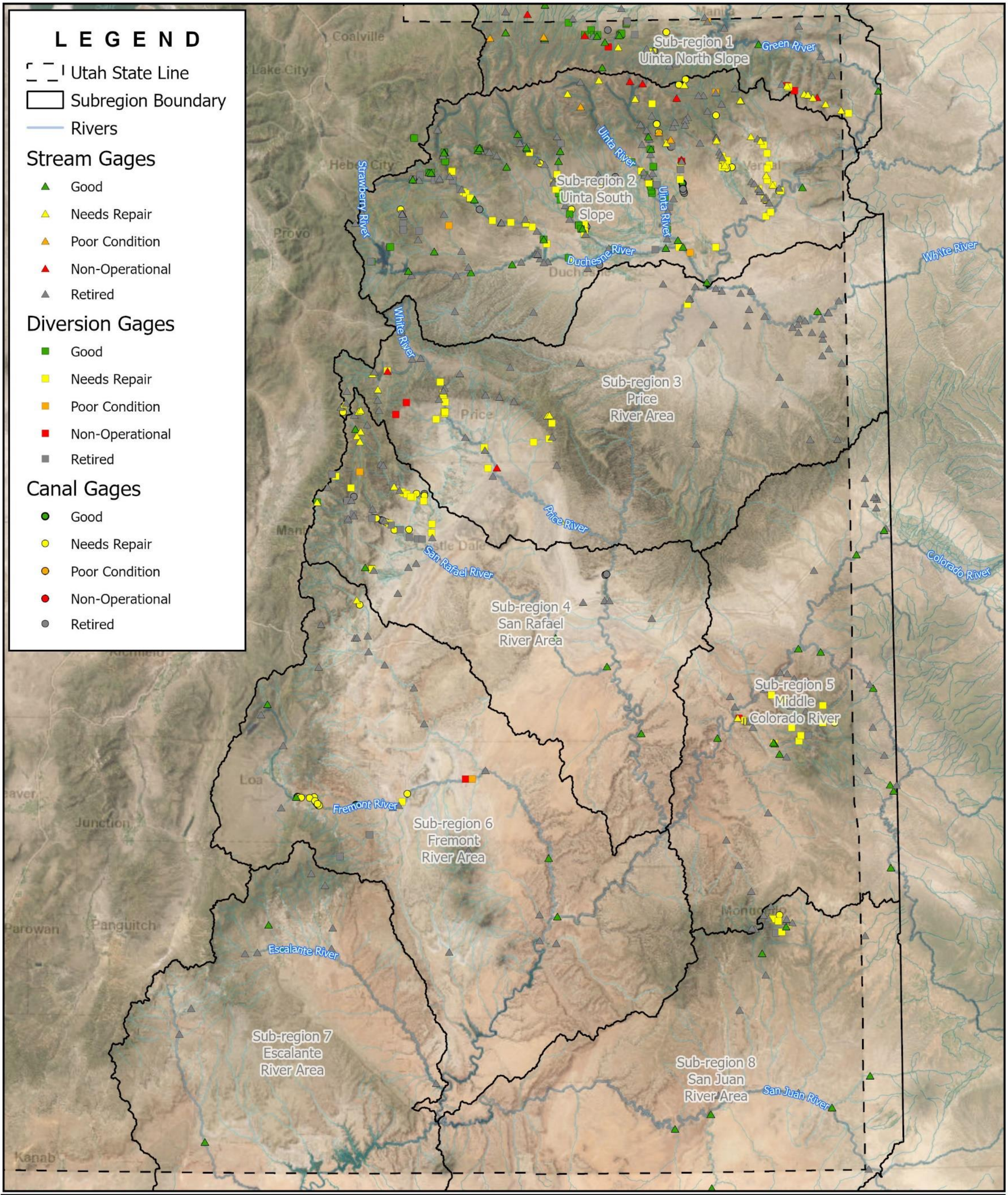
NORTH

SCALE:

1 in = 30 miles

FIGURE NO.

2-3



BOWEN COLLINS & ASSOCIATES

Jones & DeMille Engineering

SUMMARY OF GAGE CONDITION

COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

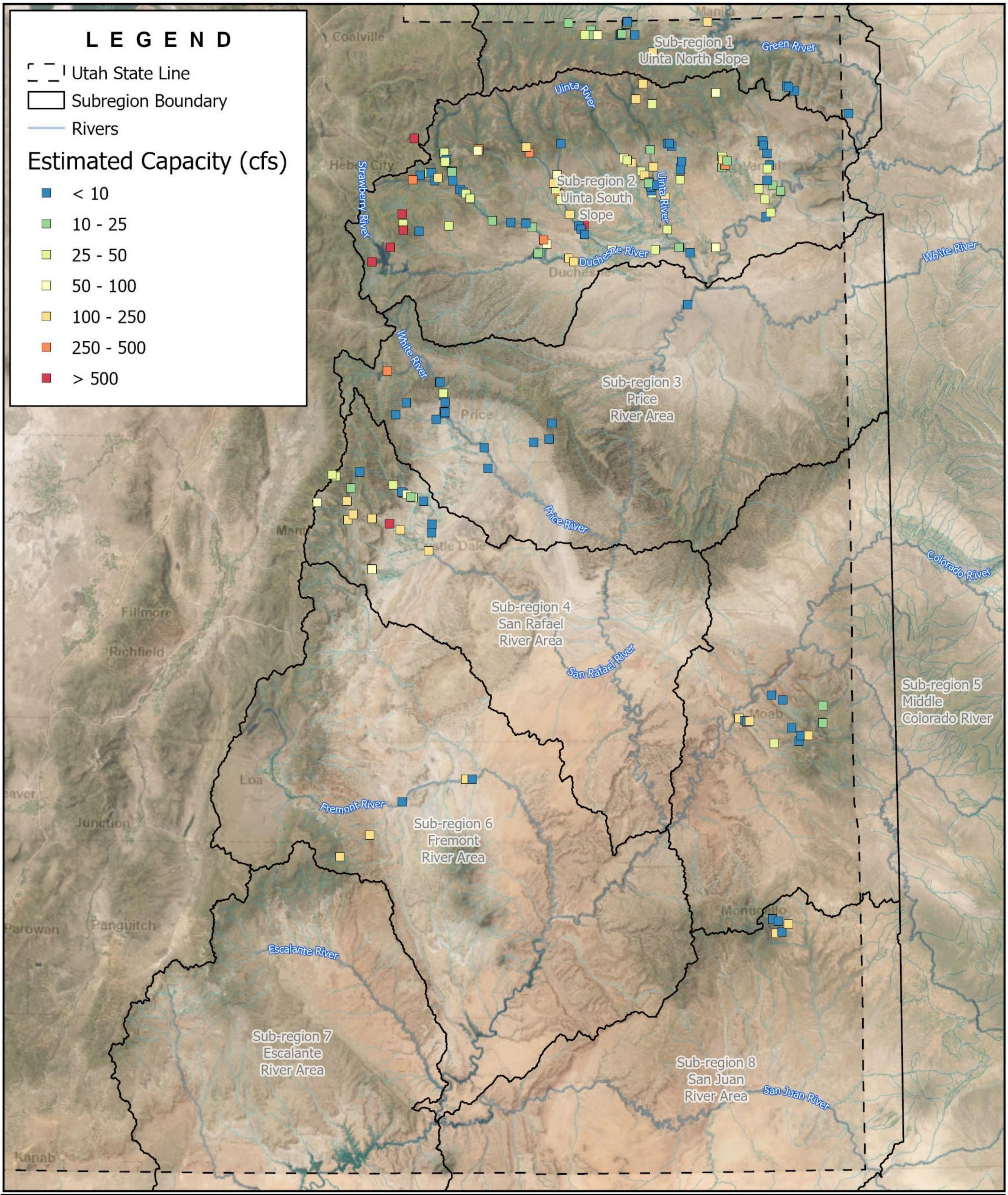
NORTH

SCALE:

1 in = 30 miles

FIGURE NO.

2-4



BOWEN COLLINS & ASSOCIATES

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SUMMARY OF DIVERSION GAGE CAPACITY/FLOW

COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

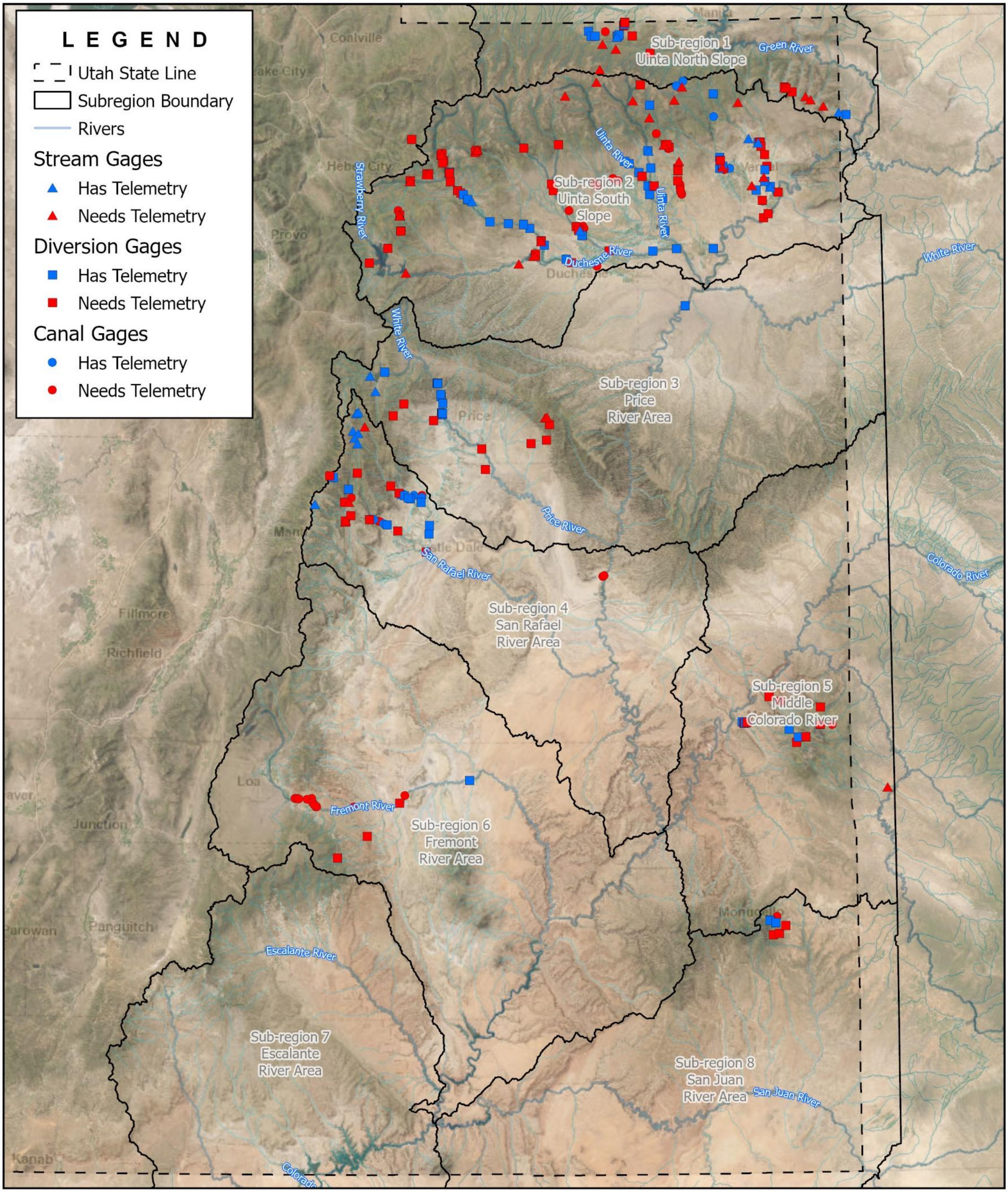
NORTH

SCALE:

1 in = 30 miles

FIGURE NO.

2-5



BOWEN COLLINS & ASSOCIATES

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TELEMETRY STATUS AT EXISTING GAGES

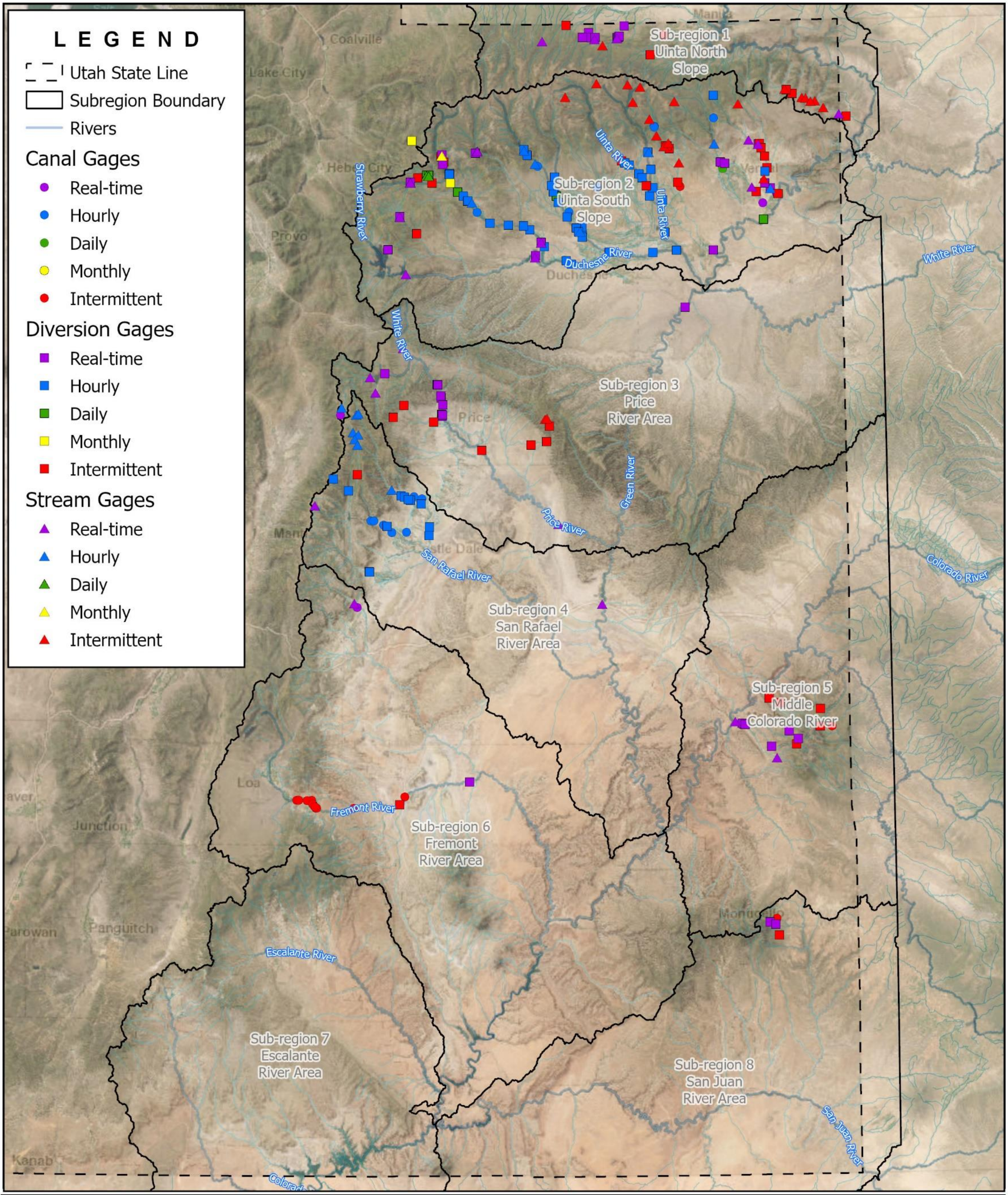
COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

SCALE: 1 in = 30 miles

FIGURE NO. 2-6



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GAGE MEASUREMENT FREQUENCY

COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

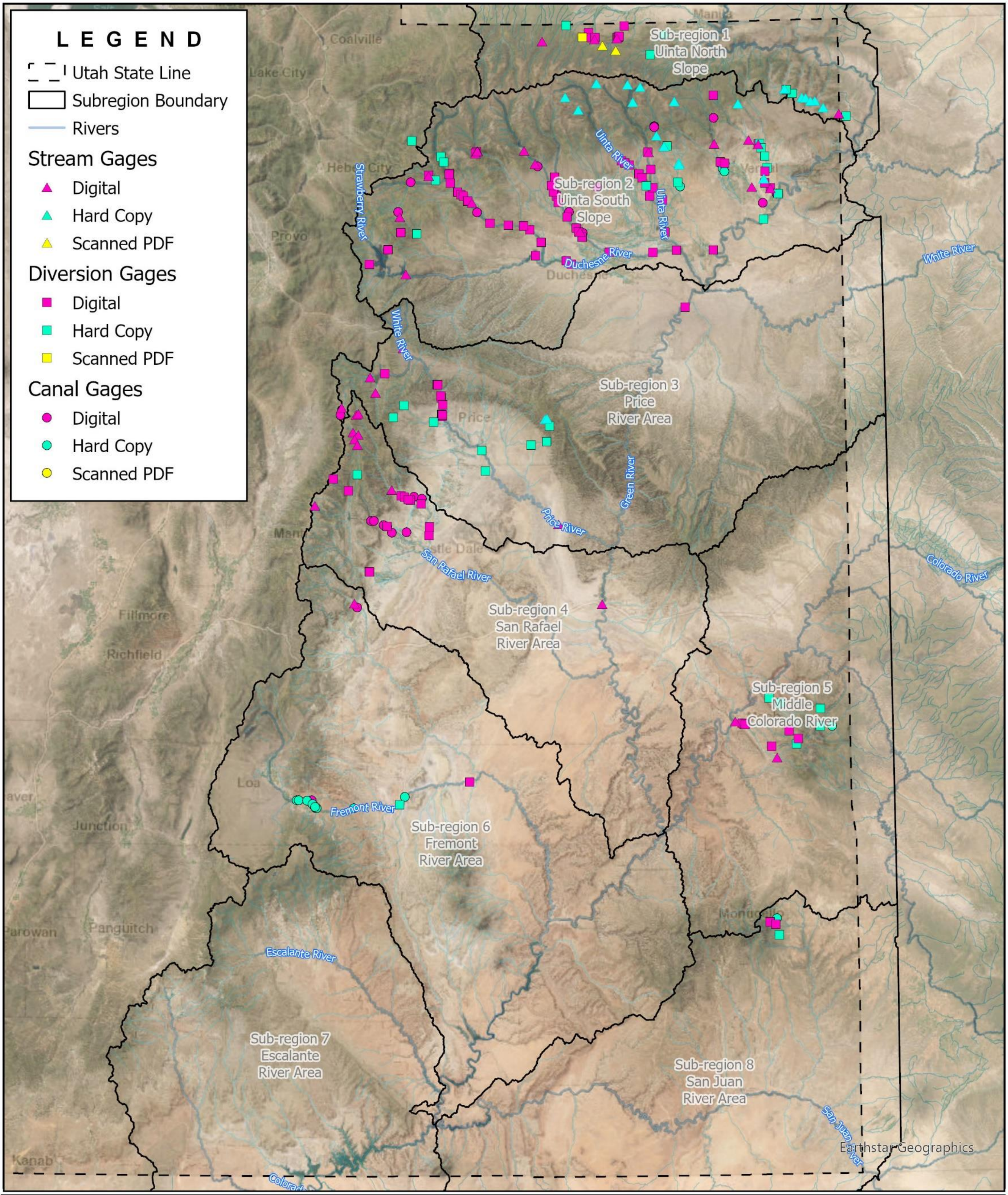
NORTH

SCALE:

1 in = 30 miles

FIGURE NO.

2-7



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FORMAT OF RECORDS EXISTING GAGES

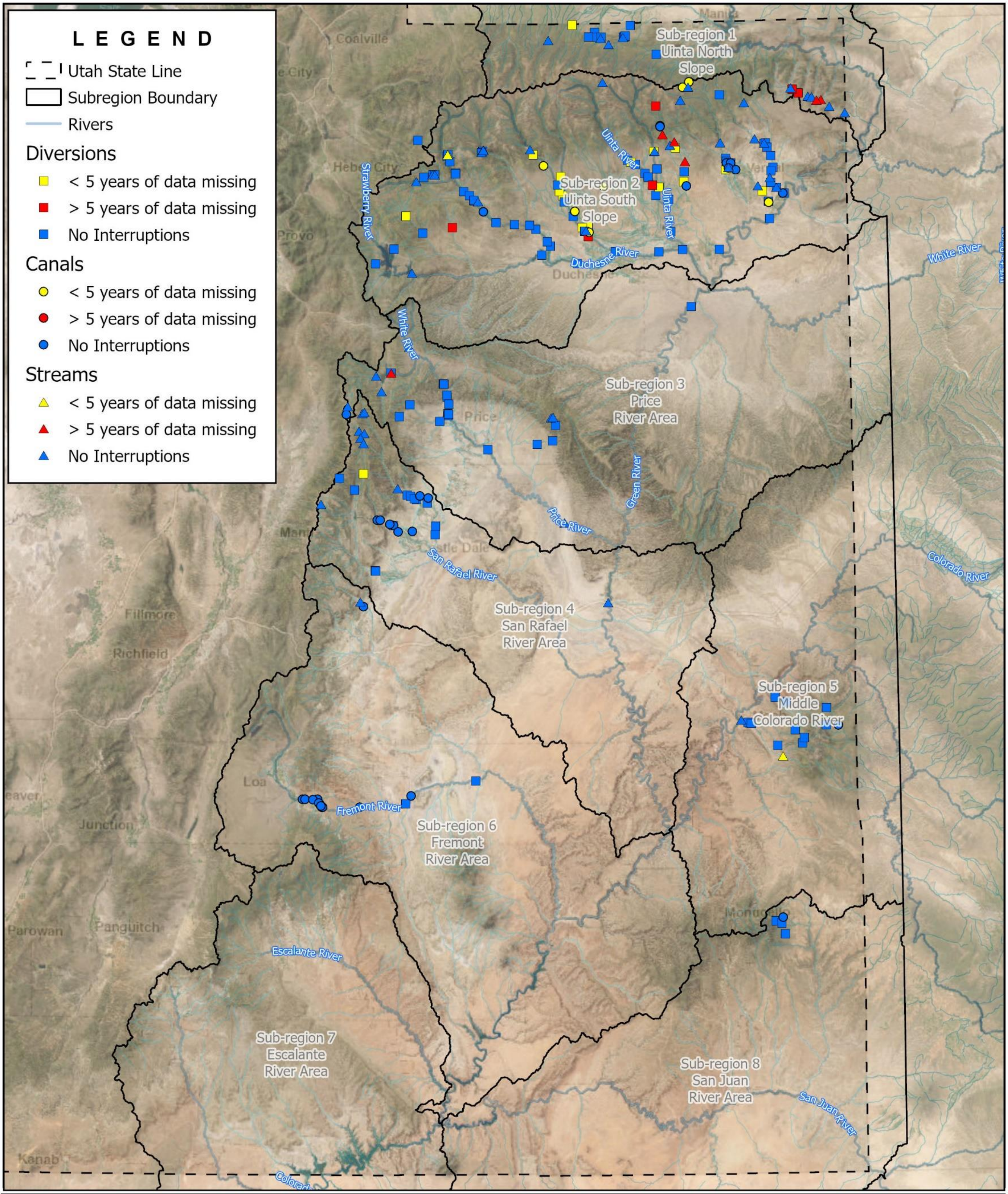
COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

SCALE: 1 in = 30 miles

FIGURE NO. 2-8



BOWEN COLLINS & ASSOCIATES

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CONSISTENCY OF DATA COLLECTION

COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

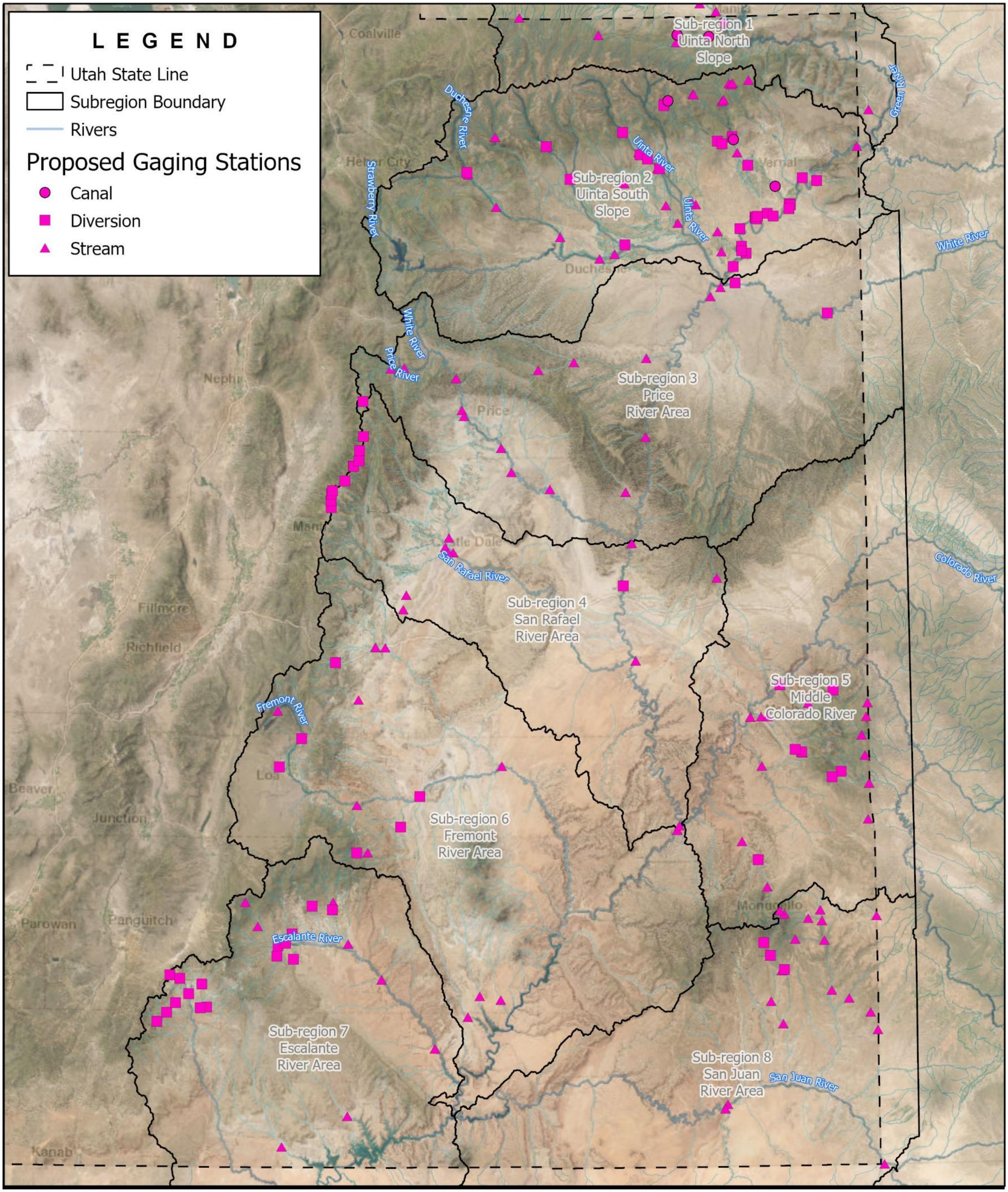
NORTH

SCALE:

1 in = 30 miles

FIGURE NO.

2-9



BOWEN COLLINS & ASSOCIATES

Jones & DeMille Engineering

SUMMARY OF PROPOSED GAGE STATIONS

COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

NORTH

SCALE:

1 in = 30 miles

FIGURE NO.

2-10

SECTION 3: GAP ANALYSIS

3.1 GOALS OF THE GAP ANALYSIS

This report section summarizes the work performed to define metering and gaging data gaps in the study area.

3.1.1 IDENTIFY GAPS IN MEASUREMENT INFRASTRUCTURE TO QUANTIFY SUPPLY AND DEMAND

For the purposes of this study, a data gap is the difference between the desired baseline data that would be useful in managing water supply and demand in Utah's Colorado River System and the data that is currently available (see Figure 3-1). It is unlikely that all identified gaps will be addressed with an improvement of some kind. However, identifying metering and gaging data gaps throughout the study area, even if a gap is not addressed, provides context for water management decisions.

The surface water supply is primarily measured by stream gages (which quantify outflows from an upstream drainage area) and reservoir elevation gages (which quantify storage volumes in reservoirs). Surface water demand is primarily quantified by diversions (water diverted from a surface water supply) and depletion (the proportion of diverted water that does not return to the surface water supply). Diverted water is typically measured at or near the location where water is diverted or near the place of water use, while depletion may be determined by calculating the difference between the volume of water diverted and the volume of water that returns to streams as return flows or through other approaches (i.e., crop consumptive use). Under state law, water users must construct or install and maintain measuring devices at each location where water is diverted from a source and make the measuring device accessible to DWRi.

Figure 3-1: Conceptual Definition of a Gap

To identify metering and gaging data gaps, it is first necessary to define the desired condition of existing metering devices and the locations within the study area where flow measurement would be beneficial. Afterwards, existing measurement locations that do not meet the desired standard and locations for potential measurement stations can be determined.

3.2 GAP DEFINITIONS

The following subsections describe how deficiencies were identified at existing gage sites and the process for identifying spatial metering/gaging gaps in areas where additional gages are desired.

3.2.1 MEASUREMENT INFRASTRUCTURE STANDARDS AND GAPS

At existing measuring locations, the gage deficiencies identified in Section 2 translate to a series of gaging gaps that could be addressed to help achieve the Authority's mission. These types of gaps are considered nonspatial gaps as they are determined based on the status and condition of the gage only, and not on location specific, or spatial, criteria. The gap analysis described in this report assumes the following standard for all measurement infrastructure:

1. The gage is in good operating condition (requires no maintenance beyond routine cleaning and/or calibration, etc.).
2. The gage provides high-quality flow data at hourly or sub-hourly measurement intervals.
3. The gage is equipped with instrumentation and telemetry for data transmission and archiving for public online access.

Existing gages that fail to meet one or more of these criteria were considered to have a gap.

Both active and inactive gages may also have an abundance of historical data that could aid in modeling and research efforts; however, this data may not be stored in a digital format or shared online. This also represents a gap in available data.

3.2.2 CRITICAL GAGING LOCATIONS AND GAPS

In general, it is more critical to measure flows where there are many water users sharing a limited source, which generally occurs in areas of concentrated consumptive use rather than in remote regions. An improved understanding of water supply and use can be beneficial for purposes such as management of available water in, shepherding water, or improving system operations. Trans-basin diversions and locations where rivers or streams may be entirely diverted (dry dams) are important locations to consider for water supply management and for shepherding water, respectively. In addition, measuring the flow at key border locations may also be helpful in understanding and managing Colorado River water in Utah, particularly as it relates to interstate water management efforts. If a gage is desired where none currently operates, a spatial data gap exists at that location.

In addition to evaluating flow measurement infrastructure desired to aid in system operations, other research, modeling, and planning purposes may also benefit from additional gaging at strategic locations. The Utah Geological Survey (UGS) is currently conducting multiple water balance studies in key watersheds. These water balance studies require a well-defined outlet point and quality flow data at the hydrologic bottom of the drainage area to accurately characterize other hydrologic processes in the upstream basin. Additionally, modeling efforts benefit from gaging major confluences and adequately measuring return flows downstream from places of use. Coordination with stakeholders involved with the development of the Utah Colorado River Accounting and Forecasting (UCRAF) model confirmed that additional gages to measure flows near confluences and to capture return flows are priorities for improving UCRAF modeling efforts.

The USGS conducted an analysis of the nationwide stream gage network in 2020 to identify priority areas to maintain and add gaging stations (Konrad et al, 2020; see Konrad et al, 2023, for version 2.0). This analysis evaluated the distribution of key hydrologic variables throughout the contiguous United States, including the Colorado River System in Utah, and identified priority areas to maintain and add stream gages. The results of this study were also considered while performing the gap analysis. Filling metering and gaging gaps for Operations, Modeling, Research, or Planning purposes could simultaneously improve the coverage and resolution of the USGS network.

3.2.3 GAP CATEGORIES

Identified gaps at existing and proposed gage locations were grouped into six types of gaps (e.g., telemetry), each with multiple levels of gap categories. Gap categories range from 0 (no gap) to 2 or higher (significant improvement would be required to address the gap). A single gage or location could have multiple types of assigned gaps, with varying gap categories, which will facilitate prioritization of gaps using multiple metrics (covered in Section 5). The purpose of further assigning gap categories to each gap is to better characterize the gap severity at each gage location. For example, a data quality/maintenance gap where additional maintenance is recommended (a gap category of 1) represents a less significant gap than a data quality/maintenance gap where a full gage replacement may be proposed (a gap category of 3). Measurement infrastructure with a gap category of 0 are also summarized in this section to provide a full picture of locations without a specific type of gap and highlight gaging trends within the study area. For example, identifying the locations without data quality / maintenance gaps can provide a general understanding of how well gaging devices are maintained in the study area. The gap classification scheme used in this study is summarized in Table 3-1.

The gap categories defined in Table 3-1 are not intended to be used by themselves for prioritization of identified gaps. Other considerations, including (but not limited to) the magnitude of flow measured at that location, the cost of the improvements to address the gap, and other stakeholder priorities should be considered to further prioritize identified metering gaps. For example, a gage with a telemetry gap category of 2 that measures 5 cfs would likely have a lower priority to address than a gage with a telemetry gap category of 1 that measures 100 cfs. Although higher number gap categories generally correlate with a higher effort or cost of improvements to fill the gap, a gap category of 2 may not necessarily be a higher priority to fill than a gap category of 1. The priority level assigned to gaps should be determined using separate prioritization criteria. General gap prioritization criteria are discussed in detail in Section 5. It is anticipated that the Authority will determine the final gap prioritization criteria in consultation with key stakeholders after delivery of this report.

Table 3-1
Gap Classification Scheme

Gap Type	Gap Category	Description
Gaps at Existing Gage Locations		
Telemetry	0	Gage currently has automated instrumentation recording measurements and telemetry transmitting data.
	1	Gage currently has automated instrumentation recording measurements but requires telemetry to transmit data.
	2	Gage does not have real-time instrumentation and telemetry.
Data Quality / Maintenance	0	Gage is in good condition and requires no maintenance beyond routine cleaning or calibration; Little concern about data quality.
	1	Gage is currently operating but could use minor maintenance beyond routine cleaning or calibration; Minor concern about data quality.
	2	Gage is in poor condition and requires significant repairs; High concern about data quality.
	3	Gage is in very poor condition and requires complete replacement; Not collecting data, or data considered invalid.
Historic Data Accessibility	0	Historic data is stored in a digitally readable format (online, spreadsheets, etc.) and is easily shared.
	1	Scans of the historic data are available but should be converted to a digitally readable format for sharing data.
	2	Historic data is stored on paper only and should be converted to a digitally readable format.
Gaps at Proposed Gage Locations Where Existing Gages Do Not Exist		
Instream Measurement	0	Additional gaging is not proposed at this location to enhance the coverage of the USGS stream gage network.
	1	Measurements at this location would enhance the metering coverage of the USGS stream gage network in a priority area.
Operations	0	Additional gaging is not proposed at this location to improve system operations or the understanding of water supply and use.
	1	Measurements at this location would improve system operations or the understanding of water supply and use.
Research, Modeling, and Planning	0	Additional gaging is not proposed at this location for a research, modeling, or planning purpose.
	1	Measurements at this location would benefit a research, modeling, or planning purpose (such as the UCRAF model or a water balance study).

3.3 EXISTING GAGE LOCATIONS

The analytical methods and results for the three gap types associated with existing measurement infrastructure are described below. The gaging gap analysis primarily focuses on active and inactive measurement stations under the assumption that retired gages were intentionally taken out of operation, whereas inactive and active gages are intended to continue operating. However, some retired gages were included in the analysis if they were proposed for reinstallation. Addressing these gaps associated with retired gages would require a new installation, so these gaps are included with the Proposed Measurement Locations analysis (see Section 3.4). Locations without gaps in any category are not assigned a priority level later in this report (see Section 5).

3.3.1 TELEMETRY GAPS

3.3.1.1 Analysis

Data collected during interviews were used to determine telemetry gaps at each existing gage location. That data included the type of telemetry that is currently being used at the gage location as well as the flow measurement frequency. Most active gaging devices record flow measurements on daily, hourly, or sub-hourly time scales and have operating telemetry equipment, while gaging devices with monthly and intermittent readings generally do not currently have telemetry equipment. This informed the following key assumptions for assigning telemetry gaps where information was unavailable or unknown during the data collection process:

1. Gages where the data collected did not indicate telemetry is currently installed should have telemetry equipment added to meet the baseline measuring device standards established for the gap analysis.
2. Gages recording flow data at daily, hourly, or sub-hourly intervals were assumed to have instrumentation that automatically records the data in addition to operating telemetry equipment. It does not make sense that a gage that records flow measurements at these intervals must be manually read by operators.
3. Where gages record monthly or intermittent readings, it was assumed that an instrumentation upgrade to automatically record and measure data would be provided. The basis for this assumption is that sites with monthly or intermittent readings are measured infrequently and are most likely manually read by operators. To remove this hurdle to measuring and reporting flow at these locations at the intervals desired for effective water management, instrumentation should be upgraded to a system that includes automated measurement and data transmittal.

3.3.1.2 Results

Gap categories were assigned based on the criteria presented in Table 3-1. Figure 3-2 illustrates the locations that have telemetry gaps in the study area (for reader convenience, Figures 3-2 through 3-7 are included at the end of this section). Note that most telemetry gaps fall under the gap category of 2, meaning that the gage could benefit from both instrumentation to automate the capture of flow measurement data and telemetry to transmit the data to a central location. Table 3-2 summarizes the existing gages (active and inactive) in each gap category by type. Gages with a gap category of 0 need no improvement, leaving 244 gages with some sort of telemetry gap (categories 1 or 2). As over half of canal and diversion gages have telemetry gaps, this gap category represents a key improvement area in metering within the study area.

Table 3-2
Summary of Telemetry Gaps

Gage Status	Gap Category*	Canal	Diversion	Stream	Total
ACTIVE	0	26	109	83	218
	1	5	27	15	47
	2	50	80	35	165
ACTIVE Subtotal		**81**	**216**	**133**	**430**
INACTIVE	0	1	3	3	7
	1	0	0	0	0
	2	2	17	13	32
INACTIVE Subtotal		**3**	**20**	**16**	**39**
Total		**84**	**236**	**149**	**469**

Notes:
0 = No action
1 = Install telemetry
2 = Install telemetry + upgrade instrumentation

3.3.2 DATA QUALITY / MAINTENANCE

3.3.2.1 Analysis

Data quality is highly dependent on the condition of measuring devices. For this reason, active and inactive measuring devices were assigned a data quality/maintenance gap category based on the condition rating determined during interviews. Several key assumptions were made to perform this analysis where the information was not available or unknown during the data collection process:

1. Metering devices measuring flow at diversions and canal turnouts were assumed to be active if no status (active, inactive, or retired) was recorded. All stream gages in the dataset had a status assigned and such an assumption was not necessary.
2. Where no gage condition information was supplied in the dataset, it was assumed that active gages required minor maintenance and inactive gages required substantial repairs.

3.3.2.2 Results

Figure 3-3 illustrates the locations in the study area that have data quality/maintenance gaps at existing measurement locations, grouped by the type of gage. Most of the data quality/maintenance gaps are assigned a gap category of 1, meaning minor maintenance work like a routine cleaning or calibration is required (perhaps overdue) for continued capture of high-quality flow data. This indicates that most active gages identified within the study area are currently being maintained relatively well. Table 3-3 summarizes the number of gages in the study area that fall in each category. As gage condition is the primary driver of the quality of data the gage provides, Data Quality gaps correspond to the condition of the gage. Other metrics important for describing the quality of data recorded at a gage (such as measurement frequency) should be considered during prioritization of data quality gaps.

Table 3-3
Summary of Data Quality Gap

Status	Gap Category*	Canal	Diversion	Stream	Total
ACTIVE	0	3	46	79	128
	1	77	161	52	290
	2	0	5	0	5
	3	1	4	2	7
ACTIVE Subtotal		**81**	**216**	**133**	**430**
INACTIVE	0	0	2	0	2
	1	1	3	1	5
	2	2	10	10	22
	3	0	5	5	10
INACTIVE Subtotal		**3**	**20**	**16**	**39**
Total		**84**	**236**	**149**	**469**

Notes:
0 = No action
1 = Minor maintenance/repairs
2 = Significant repairs
3 = Complete Replacement

3.3.3 HISTORIC DATA ACCESSIBILITY

3.3.3.1 Analysis

The historic data accessibility category relates to the format in which measurement records are kept. This information was collected during the interview process summarized in Section 2. The gap categories correlate with the level of effort required to convert the measurement data to a digital, shareable format. If no data format was specified for an active or inactive measuring station, the following assumptions were applied:

- Historic data at stream gages was assumed to be already digitized. This corresponds to a gap category of 0.
- Historic data at canal or diversion gages was assumed to be paper copies that had been previously scanned to a digital file. This corresponds to a gap category of 1.

3.3.3.2 Results

Figure 3-4 illustrates the locations of existing gages that have historic data accessibility gaps in the study area. Table 3-4 summarizes the counts of gages that fall into each gap category. While this gap type is derived directly from the format of flow records for each existing gage, the counts vary from those in Table 2-7 due to the assumptions made for the gap analysis described above in Section 3.3.

In general, canal and diversion gages show high proportions of gages that store data in formats that complicate access to historic flow data (gap categories 1 and 2). While adequate telemetry and instrumentation would solve this issue in the future, digitizing the historic data can provide benefits for modeling, research, and establishing a historic baseline. Efforts may be undertaken to digitize historic flow data as gages are improved for other reasons to make the historic records available for use.

Table 3-4
Summary of Historic Data Accessibility Gaps

Status	Gap Category*	Canal	Diversion	Stream	Total
ACTIVE	0	29	114	116	259
	1	35	67	2	104
	2	17	35	15	67
ACTIVE Subtotal		**81**	**216**	**133**	**430**
INACTIVE	0	1	2	10	13
	1	1	15	0	16
	2	1	3	6	10
INACTIVE Subtotal		**3**	**20**	**16**	**39**
Total		**84**	**236**	**149**	**469**

Notes:
0 = No action
1 = Data entry
2 = Scan hard copy + data entry

3.4 PROPOSED MEASUREMENT LOCATIONS

One of the Authority's primary goals is to identify ways to collect more desired real-time flow data within the study area. Improving the existing gages as described previously is one way to provide that data. The other way is to install new gages at strategic locations where the existing network does not provide the desired level of flow measurement coverage. These types of gaps are considered "spatial gaps." Proposed measurement locations to fill a spatial gap were identified through interviews or spatial analysis of watershed metrics by the Engineering Team after the interviews were concluded. Proposed measurement locations that could address identified spatial gaps are assigned to one or more of three categories: Instream Measurement; Operations; and Research, Modeling, and Planning. These spatial gap categories are described in the following sections.

3.4.1 INSTREAM MEASUREMENT

3.4.1.1 Analysis

Instream Measurement gaps include coverage gaps in the streamflow network as identified by the USGS Network Analysis previously mentioned. The outputs of the USGS Network Analysis indicate priority areas to maintain or add gaging sites to enhance the coverage, resolution, and representation of key data types throughout the continental United States. For this gap analysis, the results for three flow variables (minimum, maximum, and median annual average flows) were extracted for the Utah portion of the Colorado River Basin. These results are illustrated in Figure 3-5.

The USGS Network Analysis priority areas are too general to be used for recommending specific gaging sites. Therefore, for the purposes of this study, additional gages were proposed where additional data could resolve Operations or Research, Modeling, and Planning gaps only; however, if an additional stream gage is proposed to fill one or both of these spatial gap categories was located within a priority area identified by the USGS Network Analysis, the gage was also considered an Instream Measurement gap.

3.4.1.2 Results

Figure 3-5 illustrates the locations where Instream Measurement gaps exist. The distribution of Instream Measurement gaps in the study area indicates that stream flows are being adequately measured in several areas, but also highlights where new, strategically placed gages could improve the overall reliability and coverage of the measurement network. Table 3-5 summarizes the number of Instream Measurement gaps by gage type.

Table 3-5
Summary of Instream Measurement Gaps

Gage Type	Instream Measurement Gaps
Canal	0
Diversion	0
Stream	43
Total	**43**

3.4.2 OPERATIONS

3.4.2.1 Analysis

Operations gaps were primarily determined during the interview process described in Section 2. Interviewees provided detailed information about existing gages (e.g., telemetry status, method of data collection) and identified locations where additional gages could benefit water management efforts. Metering installation or enhancements were proposed at many existing points of diversion, as well as several additional stream gaging sites. Details provided about these proposed points indicated that these locations could provide a range of operational benefits, such as improving the understanding of water supply and use or aiding DWRi's distribution and accounting efforts. Accordingly, proposed gages that were identified in interviews were classified generally as Operations gaps for the purposes of this report. Initial conversations with DWRi suggest that not all identified gaps are critical to fulfilling their administrative responsibilities in the study area. Further coordination with stakeholders is recommended before decisions about metering and gaging improvements are finalized.

Additionally, the Engineering Team used a series of spatial metrics (such as incremental agricultural areas, incremental drainage area, groupings of water rights, density of upstream hydrometeorological stations, etc.) to help identify spatial "hot spots" with large clusters of water use, points of diversion, and allocated water rights (see Appendix B). If no existing or proposed gages were identified in areas where the metrics indicated a metering gap was present, a proposed gage was added during the gap analysis. It is anticipated that other minor gaps may be identified as the Authority works with DWRi and other partners to prioritize and address the metering gaps in the study area.

3.4.2.2 Results

Figure 3-6 illustrates locations in the study area that were identified to have Operations gaps. Table 3-6 summarizes the number of gaps by gage type.

Table 3-6
Summary of Operations Gaps

Gage Type	Operations Gaps
Canal	7
Diversion	76
Stream	100
Total	**183**

3.4.3 RESEARCH, MODELING, AND PLANNING

3.4.3.1 Analysis

Gaps in measurement data used for Research, Modeling, and Planning include measurement infrastructure that would benefit water balance studies, the UCRAF Model, or other data of interest to the Authority and its partners. Areas with higher densities of measuring stations, major ungaged confluences, ungaged border crossings (such as rivers crossing state lines), and other factors were evaluated to identify metering gaps associated with Research, Modeling, and Planning. If existing or proposed gages did not exist in these areas, a proposed gage was added to fill the gap during the gap analysis.

3.4.3.2 Results

Figure 3-7 illustrates the locations in the study area that have Research, Modeling, and Planning gaps and Table 3-7 summarizes the number of these gaps. The 43 Research, Modeling, and Planning gaps were determined manually during the gap analysis by the Engineering Team. Of the 43 potential locations, 29 locations represent new gages proposed after careful analysis of spatial metrics for the purposes of measuring water near a key border location, study watershed outlet, confluence, or return flow. The remaining 14 locations were identified during interviews and also could address Operations Gaps.

Table 3-7
Summary of Research, Modeling, and Planning Gaps

Gage Type	Research, Modeling, & Planning Gap
Canal	0
Diversion	0
Stream	43

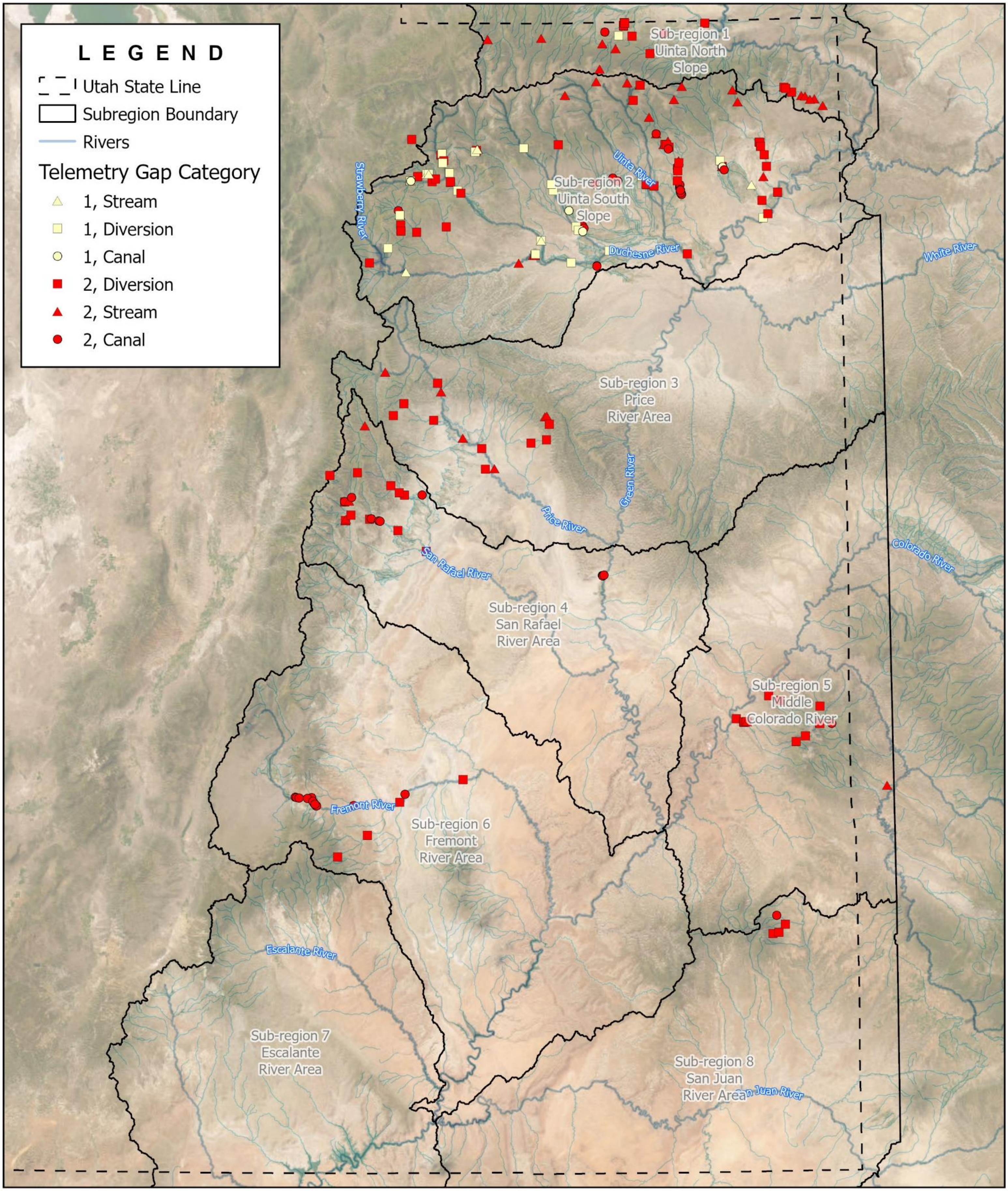
3.5 GAP SUMMARY

A location, either existing or proposed, may have multiple types of gaps. For example, there are multiple locations where a proposed stream gage simultaneously fills three types of gaps (Operations; Research, Modeling, & Planning; and Instream Measurement). Table 3-8 summarizes the number of gap types examined and the total number of locations with gaps. Counts are grouped by gap type and location type (existing or proposed).

Table 3-8
Summary of Identified Gaps

Gage Status	Type of Gap[1]	Canal Gage	Diversion Gage	Stream Gage	Total[2]
Existing	Telemetry	47	141	54	242
	Data Quality	70	207	61	338
	Historic Data Accessibility	44	107	22	173
	Total Gages with a Gap[3]	**73**	**234**	**80**	**387**
Proposed	Instream	5	31	40	76
	Operations	7	75	90	172
	Research, Modeling, & Planning	0	0	30	30
	Total Proposed New Locations[4]	**7**	**75**	**100**	**182**

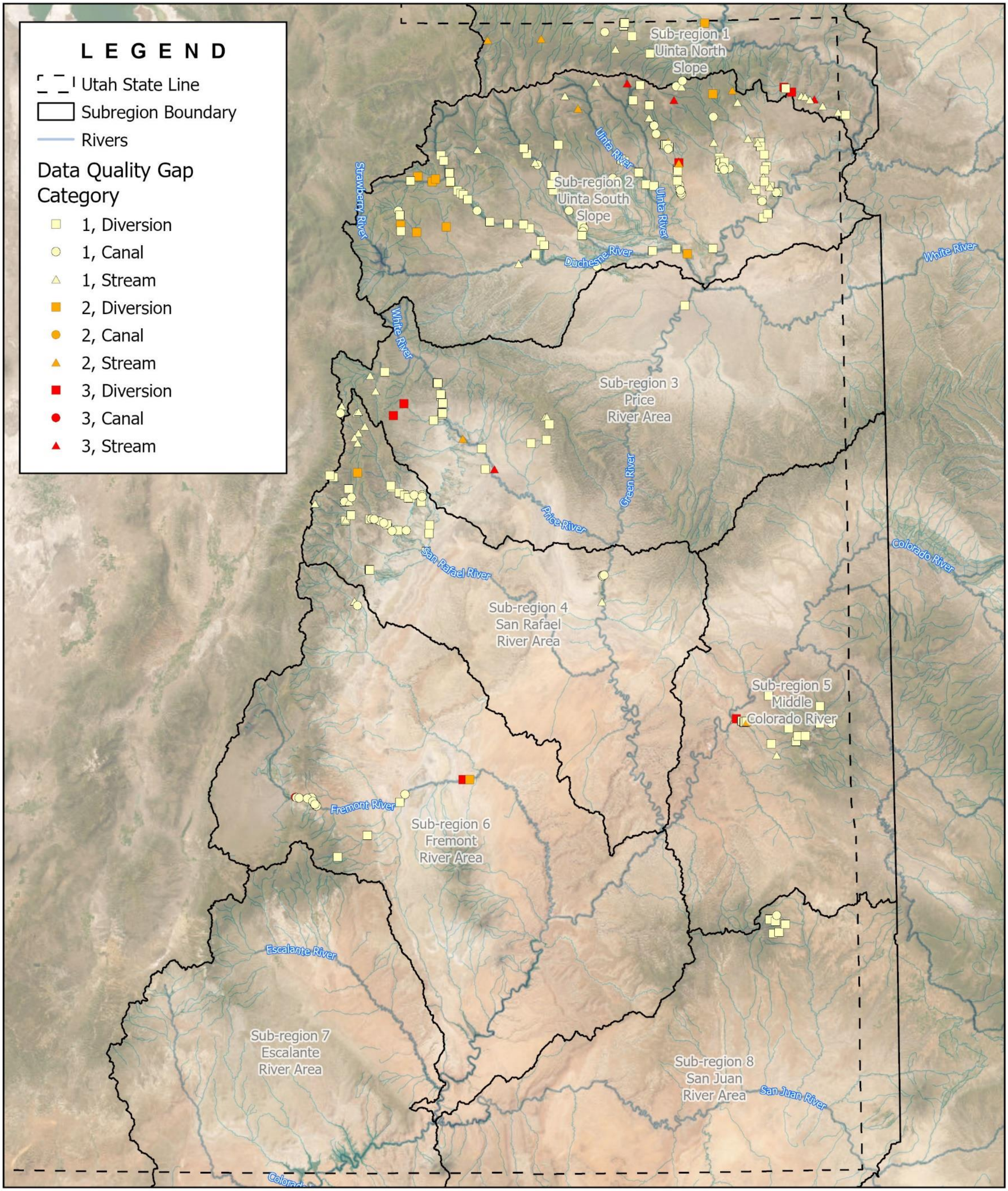
[1] Multiple gap types may be present at a single location. Due to this overlap in type of gaps, the total number of gaps by type of gage (Diversion, Canal or Stream) can only be determined by adding the subtotal rows together. Adding the counts of gaps for individual types together will result in significant overestimation of the total number of gage improvements required to resolve the identified gaps.
[2] Stream gages are measurement infrastructure measuring flows in a stream. Diversion gages are measurement infrastructure measuring flow diverted out of a stream at a point of diversion. Canal gages are gages that measure flows in or diverted from a canal.
[3] The counts of gaps presented in this table do not reflect the extent or priority of gaps, nor do the counts indicate all improvements will be implemented. The detailed information contained in the report and geodatabase should be used to plan improvements as described in the Conclusions section of this document and Section 5 of the report.
4 There are 12 historic USGS stream gaging sites included in the 100 total.



BOWEN COLLINS & ASSOCIATES

Jones & DeMille Engineering

TELEMETRY GAPS	NORTH:	SCALE: 1 in = 30 miles
COLORADO RIVER AUTHORITY OF UTAH METERING AND GAGING GAP ANALYSIS	NORTH	FIGURE NO. 3-2



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DATA QUALITY GAPS

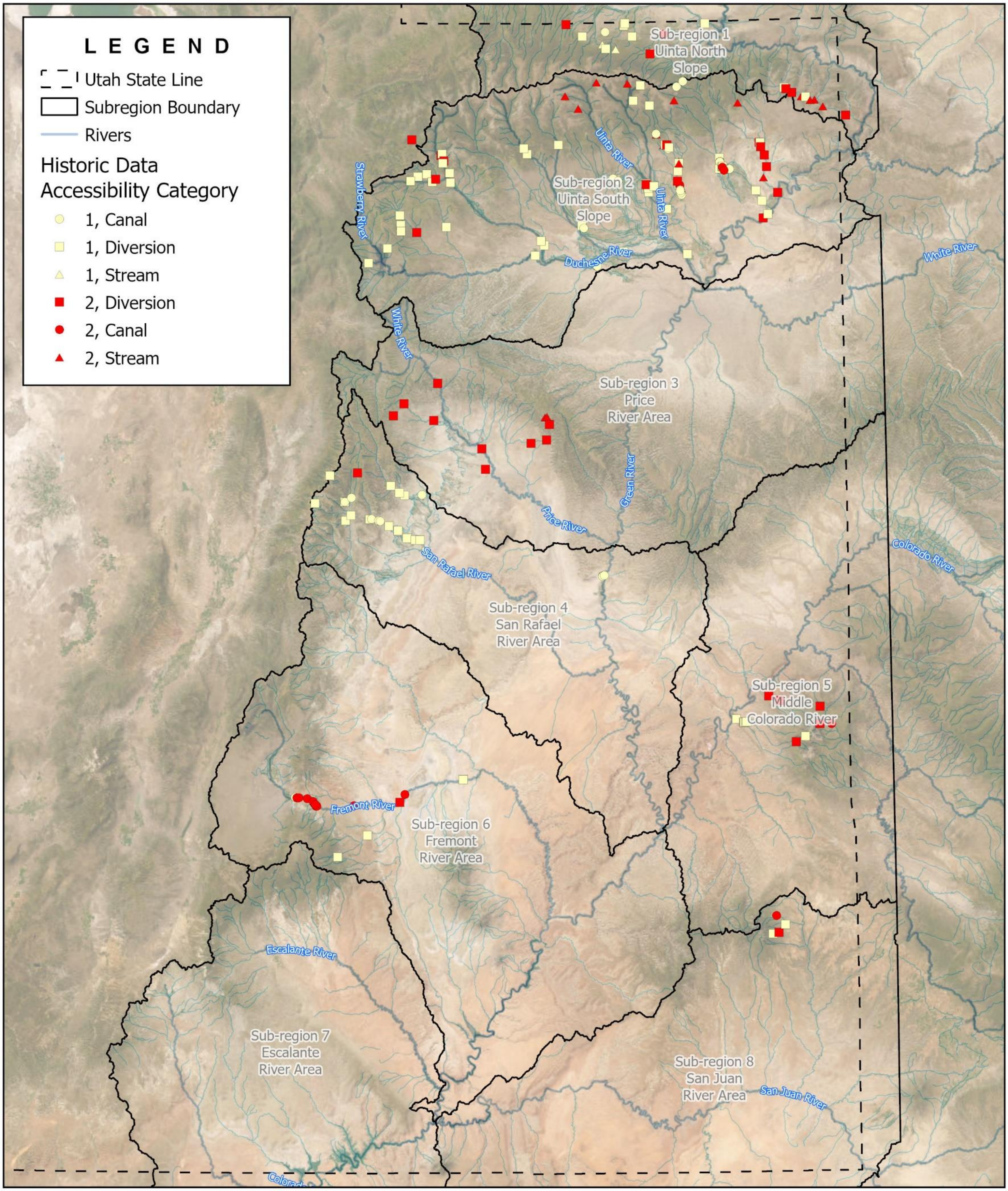
COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

SCALE: 1 in = 30 miles

FIGURE NO. 3-3



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HISTORIC DATA ACCESSIBILITY GAPS

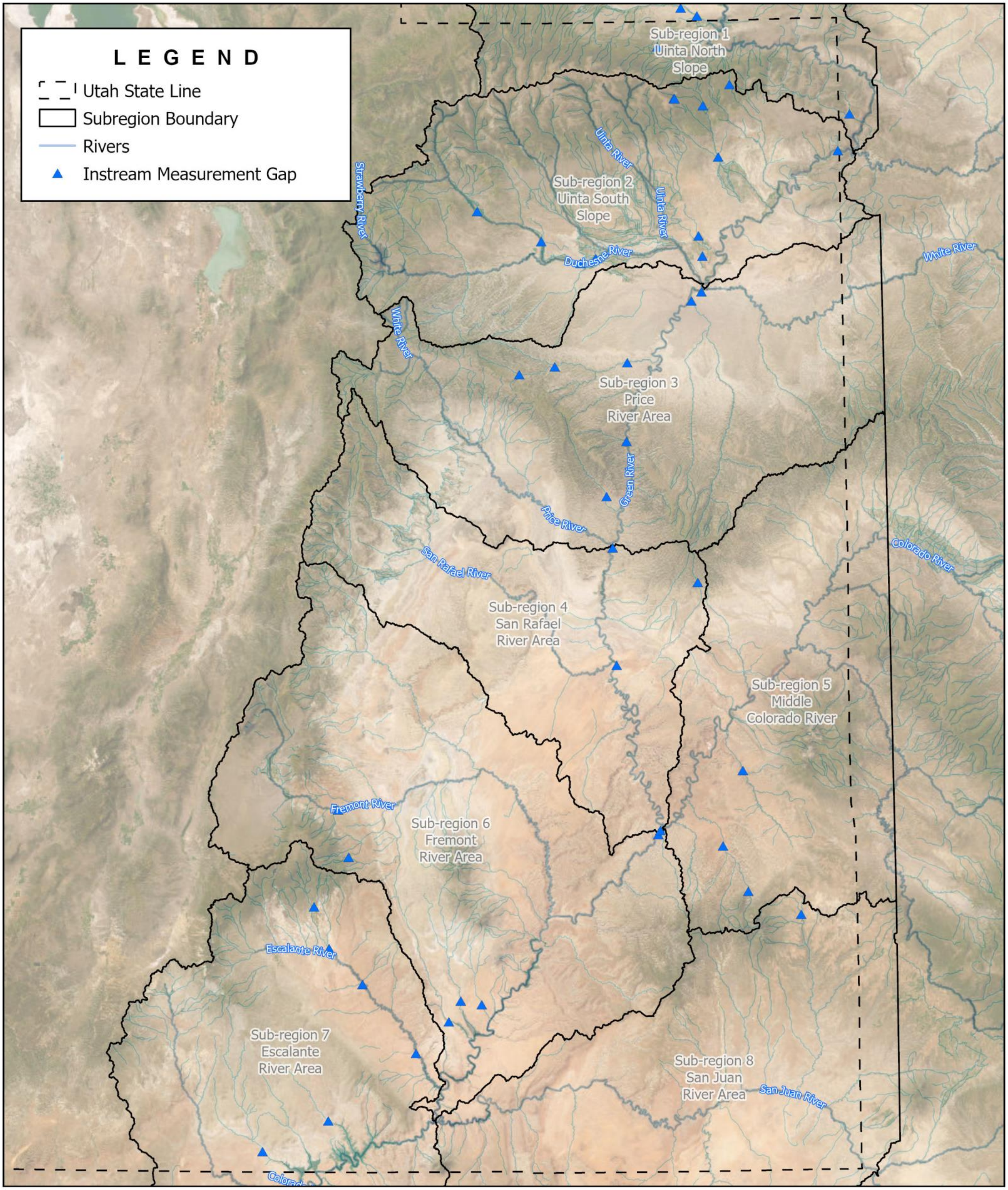
COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

SCALE:

FIGURE NO. 3-4



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INSTREAM MEASURMENT GAPS

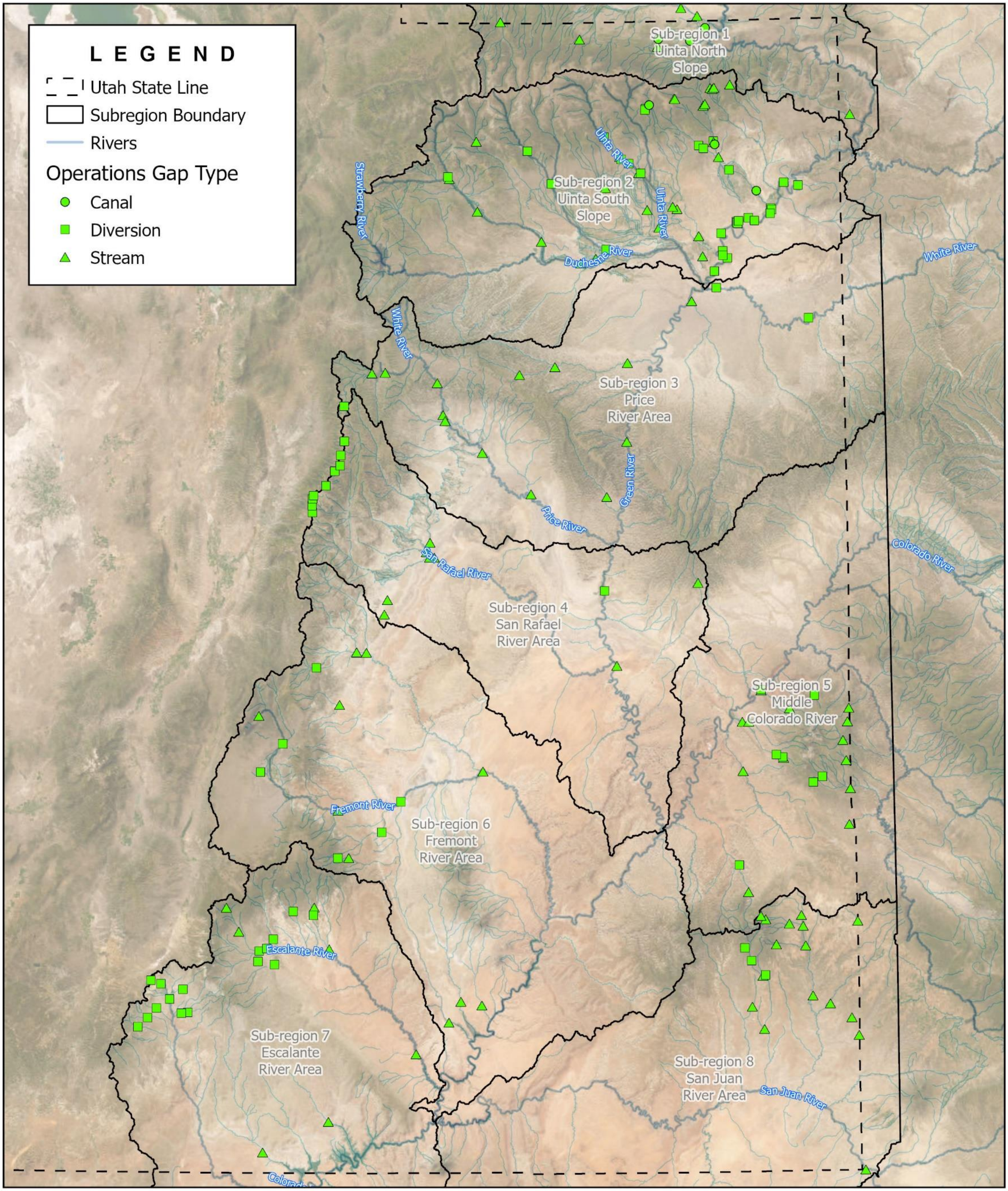
COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

SCALE: 1 in = 30 miles

FIGURE NO. 3-5



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OPERATIONS GAPS

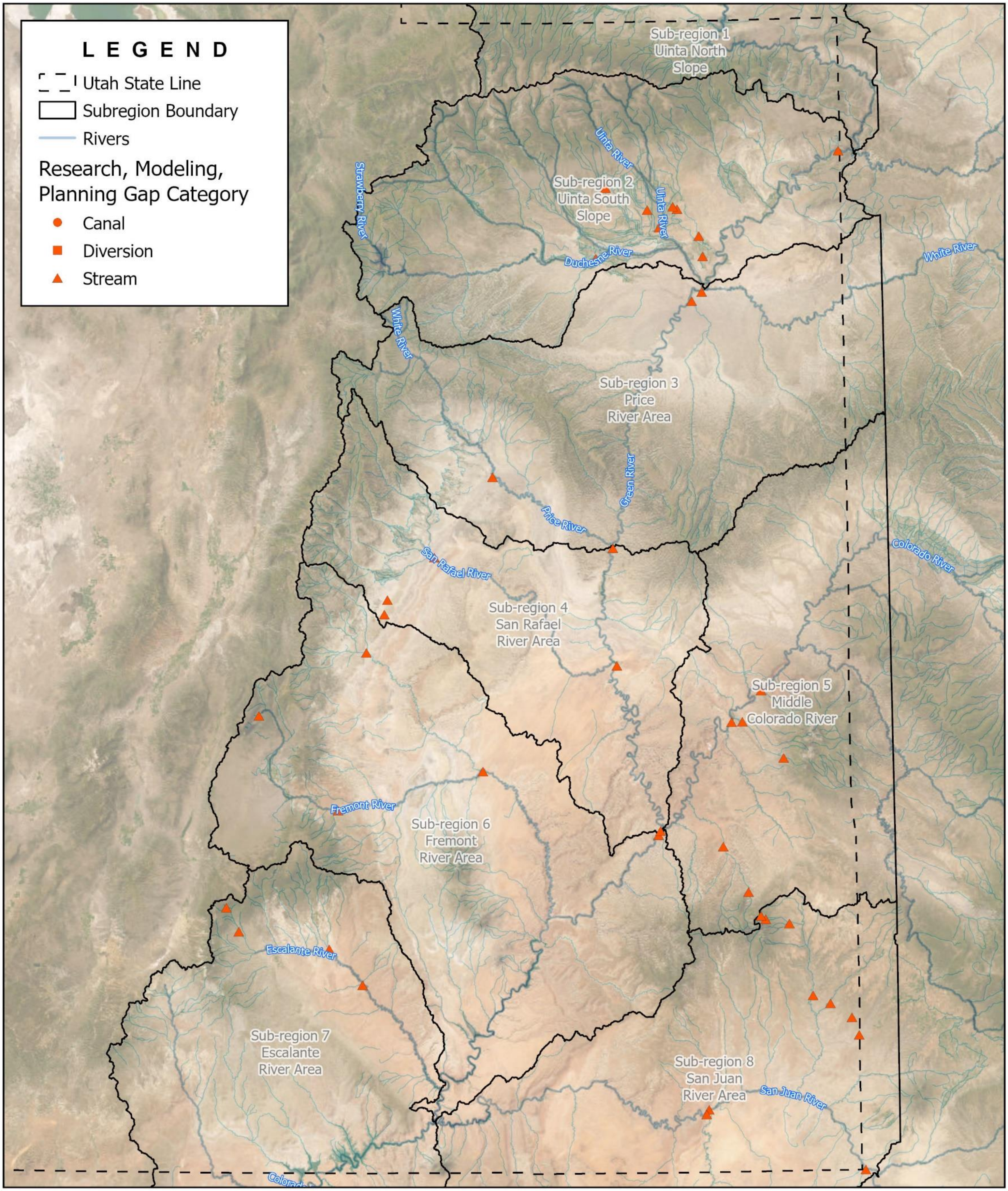
COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

SCALE: 1 in = 30 miles

FIGURE NO. 3-6



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RESEARCH, MODELING, & PLANNING GAPS

COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

SCALE: 1 in = 30 miles

FIGURE NO. 3-7

SECTION 4: BUDGETARY IMPROVEMENT COSTS

4.1 METERING AND GAGING ALTERNATIVES

There are several types of measurement infrastructure that can be used to measure and transmit flow data for stream gages, diversion gages or meters, and canals. Typical alternatives are described below.

4.1.1 STREAM GAGES (TYPICALLY USGS)

4.1.1.1 Rated Stream Sections

- Advantages –
    - Trusted data – USGS data quality control process is rigorous, and data is stored online and made publicly available in perpetuity.
    - Accuracy – Gage typically calibrated 7-9 times per year.
    - Stakeholders are able to assist with cost share on gages.
    - Almost always needs a funding partner for each gage location (USGS program currently provides 39 percent of cost to install and operate the gage with the cooperating partner being responsible for the remaining 61 percent).
    - Ideal for larger river sections and less costly as opposed to a structure.
- Disadvantages –
    - Costly to install and maintain.
    - High initial cost for gages on larger rivers unless located on an existing bridge (could require cable bridge).
    - USGS stream gaging program currently has fixed funding constraints.
    - Sensitive to flood events – needs to be re-calibrated when debris, vegetation, and stream section changes occur due to flooding.

4.1.2 DIVERSION GAGE

4.1.2.1 Inline meters (pipeline or culvert meters)

- Advantages –
    - Accurate through a wide range of flow rates.
    - Ease of installation.
    - Ultrasonic and some magnet gages are not intrusive to pipes.
    - Ultrasonic and some magnet gages are typically not affected by debris and can accommodate dirty water.
    - Not susceptible to flooding.
    - Can be concealed in an enclosure.
- Disadvantages –
    - Impeller type gages are susceptible to clogging due to debris and requires screening.

  - Lower service life (~20 years) and high battery costs for replacement.
  - Most must have a full pipe for accurate flow measurements.
    - No visual verification of flow.

4.1.2.2 Weirs

- Advantages –
  - Visual flow verification.
  - Simple operation.
  - Can be designed for various flow rates and applications.
  - Typically easier to construct than a flume.
- Disadvantages –
  - Requires debris removal periodically.
  - Requires a drop in the conveyance channel (not suitable in overly flat conveyances).
  - Prone to deposition of sediment upstream of the weir.

4.1.2.3 Flumes

- Advantages –
  - Most widely used for open channel diversion gages.
  - Visual flow verification.
  - Typically less channel drop required as compared to a weir.
  - More tolerance to submergence.
  - Sediment and floating debris pass through structure easier.
  - Can be pre-fabricated off-site.
- Disadvantages –
  - Typically more expensive and complicated to construct than a weir.
  - Must be level to be accurate (settlement can cause inaccurate readings).

4.1.2.4 Canal Gates or other control structures

- Advantages –
  - Can be calibrated in place based on gate opening.
  - Gate typically already exists for flow control.
- Disadvantages –
  - Inaccuracy due to clogging or debris.
  - Inaccuracy due to upstream head conditions.
  - Semi-complex calibration and flow rating process.

4.1.3 TELEMETRY ALTERNATIVES

4.1.3.1 Hardwire or Fiber Optic

- Advantages –
  - Data speed, security, and reliability due to physical connection
  - Utilizes existing grid power and communication networks.
- Disadvantages –
  - Must provide conduits, raceways, and wires.
  - Wires can be damaged by excavation or other activities.
  - Requires "hardwire" connection for power and communications. Not suited for remote locations.

4.1.3.2 Radio

- Advantages –
  - Can use repeater technology to link to another radio within the system to "daisy chain" system together without having each gage within range of a base station.
  - Data subscription cost can be reduced to one gage (base station) if other gages are able to link to each other.
  - Can be solar powered.
  - Can be deployed in moderately remote areas.
- Disadvantages –
  - Ongoing subscription cost.
  - Limited range based on terrain.

4.1.3.3 Cell Phone or Similar Wireless Network

- Advantages –
  - As reliable as cell phone service.
  - Can be solar powered.
- Disadvantages –
  - Ongoing subscription costs.
  - Limited to cell service areas.

4.1.3.4 Satellite

- Advantages –
  - Does not need line of site or hardwire connection.
  - Can be solar powered.
  - Can be deployed virtually anywhere open to sky.
- Disadvantages –
  - Ongoing subscription costs

- Heavy tree canopy or limited view to sky can cause communication issues.

4.2 CONCEPTUAL IMPROVEMENT COSTS

Conceptual costs for each type of infrastructure improvement are presented for budgeting purposes and are shown in 2023 dollars. Although the Authority may assist with facilitating funding for upgrades to existing gages or the addition of new gages, the gages would most typically be installed and maintained by other agencies (e.g., conservancy districts, DWRi, irrigation companies, etc.) or private water users. With very few exceptions, it was determined during the interviews that most existing stream gages that are not currently operable would likely require full replacement as opposed to rehabilitating the existing gage.

Although interviewees were asked to provide information about the annual cost to operate existing gages, the reported values were often rough estimates or completely unknown. The annual operational cost information for existing gages in the geodatabase is sparse, unverified, and did not show a clear pattern or follow expected cost trends. Therefore, the general cost numbers provided in this section are based primarily on discussions with USGS and DWRi personnel, the Engineering Team's recent project experience, and qualitative findings from the interviews not captured in the geodatabase.

Table 4-1 lists the typical capital and annual costs to install and operate the measurement infrastructure described in Section 4.1. The gage costs are grouped by size of the installation to account for the impact of size, material, and service life on costs. For example, a new weir to measure a low flow rate (10 cfs or less) would most likely be a sharp-crested weir fabricated from steel, but higher flow rates (50 cfs or more) would most likely be a broad-crested weir cast from concrete and constructed on-site. The steel weir would also have a design life roughly half the length of the concrete weir.

A flow rate is required to estimate budgetary costs for the improvements with a reasonable degree of confidence. The type, material, and size of measurement infrastructure depends greatly on the flow the gage must measure. Where gages did not have a measurement capacity or flow rate specified, average flow values for each gage type (stream, diversion, or canal) were assigned for the purposes of estimating costs and assigning a priority category as described in Section 5.2.1. The budgetary costs to address the gaps identified in the Gap Analysis are summarized in Section 5.2.3 by gap priority and gage type.

Table 4-1
Measurement Infrastructure Capital and Operation / Maintenance Costs

Measurement Infrastructure[1]	Size	Capital Gage Cost[2]	Installation Cost[3]	Total Capital Cost	Service Life (years)	Annual O&M Cost[4]
Pipeline Meter	Up to 36" Dia Pipe	$5,000	$2,500	$7,500	20	$500
	>36" to 72"	$10,000	$5,000	$15,000	20	$900
Weir	Up to 10 cfs	$4,500	$5,000	$9,500	25	$500
	>10 to 50	$8000	$6,000	$14,000	50	$400
	>50 to 200	$18,000	$15,000	$33,000	50	$800
	>200	$30,000	$25,000	$55,000	50	$1,300
Flume	Up to 10 cfs	$4,500	$4,500	$9,000	25	$500
	>10 to 50	$10,000	$8,000	$18,000	25	$900
	>50 to 200	$25,000	$25,000	$50,000	50	$1,200
	>200	$35,000	$40,000	$75,000	50	$1,700
Rated Section[5]	N/A	$12,000	$3,000	$15,000	30	$20,000

[1]Cost assumptions made from interviews, data, and experience of USGS staff, DWRi staff, and consultant team. Demolition costs for gage replacements are assumed to be 25% of installation costs.
[2]Includes equipment and materials for the construction of the gage, but not installation.
[3]Includes installation costs (labor with overhead) and an estimated average travel cost.
[4]Includes typical annual labor cost for maintenance, as well as replacement cost annualized over the service life of the gage (not including inflation).
[5]Does not include costs for large river locations that would require a cable bridge or similar apparatus.

Table 4-2 lists typical capital and annual costs (2023 dollars) to install and maintain telemetry at a gage. For the purposes of budgeting for telemetry gaps, this study conservatively assumes that all new telemetry installed would include Satellite telemetry equipment. The best telemetry option will be site-specific and should be re-evaluated as improvements are planned.

Table 4-2
Gage Telemetry Capital and Operation and Maintenance Costs

Telemetry Type[1]	Capital Equipment Cost	Installation Cost	Total Capital Cost	Service Life (years)	Monthly Subscription Cost[2]	Annual O&M Cost[3]
Hardwire or Fiber Optic[4]	$2,500	$4,500	$7,000	15	$0	$500
Radio	$4,000	$3,500	$7,500	15	$5	$600
Cell Phone Data	$4,000	$3,500	$7,500	10	$15	$1,000
Satellite	$4,000	$3,500	$7,500	10	$25	$1,100

[1]Cost assumptions made from interviews and data from USGS and DWRi staff.
[2]Radio systems can be linked together and provide upload services at one base station for several gauges. It was assumed that 3-5 gages could utilize one base station, so the subscription cost was assumed at $5 per gage for radio telemetry.
[3]Annual O&M costs include monthly data subscription costs.
[4]Does not include off-site costs to install hardwire or fiber optic utilities to the site.

The gap categories defined in Section 3 directly correspond to a particular action that would be taken to remediate metering and gaging gaps. Table 4-3 lists the recommended corrective actions that could be taken for each gap category and the major cost assumptions associated with the action. The assumptions listed in the Capital Cost and Annual Cost columns guided the costs estimated to implement each action.

Table 4-3
Gap Improvement Actions and Cost Assumptions

Gap Type	Gap Category	Action	Capital Cost	Annual Cost
Telemetry	0	No action	N/A	O&M
	1	Add Telemetry	Install[1]	O&M
	2	Add Telemetry + Instrumentation	Install[1]	O&M
Data Quality / Maintenance	0	No action	N/A	O&M
	1	Routine cleaning/calibration	1/2 O&M[2]	O&M
	2	Significant repairs	1/2 Install[2]	O&M
	3	Complete replacement	Install + Demo[3]	O&M
Historic Data Accessibility	0	No action	N/A	N/A
	1	Data entry	Labor[4]	N/A
	2	Scan hard copy + data entry	Labor[4]	N/A
Instream Measurement	0	No action	N/A	N/A
	1	Install Gage	By flow & type[5]	By flow & type[5]
Operations	0	No action	N/A	N/A
	1	Install Gage	By flow & type[5]	By flow & type[5]
Research, Modeling, & Planning	0	No action	N/A	N/A
	1	Install Gage	By flow & type[5]	By flow & type[5]

[1] Telemetry installation assumes Satellite telemetry costs per Table 4-2
[2] Annual costs for O&M include annualized replacement costs at the end of the service life of instrumentation. Gages with a Data Quality / Maintenance gap category of 1 are assumed to require extra maintenance beyond typical O&M costs. Gap category of 2 is assumed to require major repairs that cost roughly half the total capital cost to replace the gage in-kind.
[3] Demolition costs were assumed to be 25 percent of the installation costs.
[4] Labor, travel, and expense costs for digitizing historic records assumed to be 40 and 80 hours of time at $150/hr for gap categories 1 and 2, respectively.
[5] See Table 4-4 and Table 4-5.

In the cases where gap mitigation requires in-kind repairs and replacements at existing gages, the corresponding costs for the existing gage type listed in Table 4-1 are applied to the gap location. However, requested gages would be new installations if planned, and in-kind replacement is generally not applicable in those cases. To assign a budgetary cost for a requested gage, the gages in the existing dataset were classified by gage type, device class and flow rate to inform which type of device would most likely be installed if the requested location were planned and approved.

Table 4-4 summarizes the percent of existing types of measurement devices in the study area by flow rate. Note that the percentages in this table are based on the total number of existing gages within a flow rate category. Flumes less than 3 ft wide were considered “Small Flumes”, flumes between 3 ft and 10 ft wide were considered “Moderate Flumes”, and flumes larger than 10 ft wide were considered “Large Flumes.”

Table 4-4
Percent of Existing Measurement Devices by Flow Rate

	Device Class	Flow Grouping (cfs)								
		<= 5	6-10	11-25	26-50	51-100	101-200	201-500	501-1000	> 1000
Canal/Diversion	*Large Flume*	0%	0%	0%	0%	13%	69%	40%	0%	100%
	Moderate Flume	3%	7%	18%	37%	57%	15%	20%	0%	0%
	Small Flume	28%	37%	35%	9%	0%	0%	0%	0%	0%
	Meter on Pipe/Culvert	51%	56%	41%	46%	26%	8%	30%	67%	0%
	Weir or Gate	2%	0%	6%	9%	4%	8%	10%	0%	0%
	Calculated	17%	0%	0%	0%	0%	0%	0%	0%	0%
	Rated Section/Structure	0%	0%	0%	0%	0%	0%	0%	33%	0%
		<= 5	**6-10**	**11-25**	**26-50**	**51-100**	**101-200**	**201-500**	**501-1000**	**> 1000**
Stream	*Large Flume*	0%	0%	0%	0%	0%	0%	25%	0%	9%
	Moderate Flume	0%	100%	11%	68%	40%	0%	0%	0%	0%
	Small Flume	67%	0%	11%	16%	0%	0%	0%	0%	0%
	Meter on Pipe/Culvert	33%	0%	33%	11%	10%	0%	25%	0%	9%
	Weir or Gate	0%	0%	33%	0%	20%	0%	13%	25%	45%
	Rated Section/Structure	0%	0%	11%	5%	30%	100%	38%	75%	36%

Table 4-5 summarizes the flow measuring device types that likely would be installed at requested locations based on the device types in Table 4-4. Without an analysis of individual site conditions, the exact device type to be installed could not be determined. Therefore, the requested gage locations were assigned weighted costs based on the percentages in Table 4-4 to account for the possibility that any of the potential device types could be chosen for a site.

The conceptual cost estimates to resolve identified metering deficiencies are summarized in Section 5 along with general gap prioritization criteria to provide an approximation of the cost to address the gaps within a given priority level (low, medium, high). Conceptual costs for individual gaps are tabulated in Appendix E and included in a spreadsheet deliverable accompanying this report.

Table 4-5
Measurement Devices at Proposed Gage Locations by Flow Rate

Measurement Capacity (cfs)	Proposed/New Gage	
	Canal/Diversion	Stream
5 or less	*Small Flume, Calculated, Meter*	*Small Flume*
6-10	*Small Flume, Meter*	*Moderate Flume*
11-25	*Small/Moderate Flume, Meter*	*Meter, Weir*
26-50	*Moderate Flume, Meter, Weir*	*Moderate Flume*
51-100	*Moderate flume, Meter*	*Moderate Flume, Weir, Rated Section/Structure*
101-200	*Large Flume*	*Weir, Rated Section/Structure*
201-500	*Large Flume, Meter*	*Weir, Rated Section/Structure*
501-1,000	*Large Flume, Rated Section/Structure*	*Weir, Rated Section/Structure*
1,000 or more	*Large Flume, Rated Section/Structure*	*Weir, Rated Section/Structure*

4.3 POTENTIAL FUNDING OPPORTUNITIES

The conceptual costs for different measurement infrastructure and telemetry types listed in Tables 4-1 and 4-2 are shown in 2023 dollars. Each improvement will have an initial cost and ongoing operation and maintenance costs.

Most of the existing diversion and canal gages are owned and operated by private entities. Most of the stream gages are operated by the USGS and funded under a cooperative agreement whereby a funding partner pays for 61 percent of the gage construction and annual operation and the USGS funds the remaining 39 percent. Gage ownership, operation, and maintenance issues all should be considered as a plan is developed and implemented to install additional water measurement infrastructure. These considerations lead to the following questions that were not addressed in detail during this study:

- Who will pay for improvements to mitigate the identified metering and gaging gaps?
- If the Authority recommends installing a new gage on a private system or on a stream, what entity will own, construct, operate, and maintain that gage and associated equipment?
- How will the Authority coordinate with other parties to ultimately obtain additional real-time flow measurement data that will help them better accomplish their mission?

There are federal and state funding or grant programs that may have funding available for individual water users, irrigation companies, municipalities, and distribution entities to purchase and install new measurement infrastructure. These programs include:

- Reclamation WaterSMART Grant Program
- USGS stream gaging partnership program
- American Rescue Plan Act (ARPA)
- Inflation Reduction Act of 2022 (IRA)
- Bipartisan Infrastructure Law Drought Contingency Plan
- Natural Resources Conservation Service Environmental Quality Incentives Program (NRCS EQIP) Program (in conjunction with WaterSMART)
- Other programs funded by State Agencies
    - Utah Department of Agriculture and Food (UDAF) Agricultural Water Optimization Grant.

Each program identified above has different eligibility requirements and more information can be found on each respective program's website. In addition, soliciting additional funding for existing programs (for example, petitioning state and federal legislatures to fund more USGS stream gaging stations on the Colorado River) are also possible sources of funding for additional measurement infrastructure.

SECTION 5: GENERAL GAP PRIORITIZATION CRITERIA

5.1 GENERAL GAP PRIORITIZATION METHODOLOGY

Section 5 describes the process of evaluating spatial data (e.g., watershed characteristics, irrigated land use) and operational data (e.g., gage capacity/flow rate, cost, gap type) to develop general prioritization criteria for the identified gaps. The general prioritization results include categorized groups of low, medium, and high priority gaps. Evaluating various spatial and operational metrics for each proposed gage improvement resulted in general gap prioritization ranking criteria that can be referenced by the Authority and other stakeholders when determining how to resolve the identified gaps. The general prioritization results described in this section are not to be interpreted as a proposed order to address the gage deficiencies identified in Section 3. Rather, the gap priorities serve to illustrate which gaps, if resolved, would most improve the overall understanding of the Colorado River water supply and use within the study area. The general prioritization results will serve as a tool to assist the Authority, in consultation with DWRi and other stakeholders, in planning and implementing gaging improvements in the study area.

5.2 PRIORITIZATION METHOD

The general gap prioritization methodology described in this section is one approach for prioritizing metering and gaging gaps. As part of this Gap Analysis, the Engineering Team developed tools that will allow the Authority and other stakeholders to adjust the weights of the various prioritization metrics as discussion ensues regarding which metrics and gages are most important to prioritize. An ArcGIS toolbox is provided within the geodatabase deliverable accompanying this report and contains various geospatial tools to compute spatial and operational metrics. These tools will allow the Authority and other stakeholders to adjust the results of this initial analysis by allocating greater weight to one metric over another, therefore adjusting the overall gap prioritization. A guide describing how to use those tools is provided in Appendix C.

The initial prioritization results described in this section are generalized recommendations and may be modified subsequent to the completion of this report. The general prioritization results do not guarantee that an identified gap will be addressed or funded by the Authority, an agency of the state of Utah or other stakeholders. Items that were developed as part of this study (geodatabase, report, associated files) should be considered living files or documents as the Authority and other stakeholders begin to plan and implement gaging improvements in the study area.

5.2.1 PRIORITIZATION EQUATIONS

Three of the gap categories defined in Section 3 pertain to existing gage locations and the remaining three pertain to proposed new gage locations. Given these two subsets of gap types, two general prioritization equations were developed: one associated with resolving deficiencies on existing gages (Equation 5-1) and the other associated with new gages (Equation 5-2).

$$\boldsymbol{P}_{\text{existing}} = \left(\boldsymbol{G}_{\text{T}} + \boldsymbol{G}_{\text{DQ}} + \boldsymbol{G}_{\text{HDA}}\right) \times (\boldsymbol{M}_{\text{O}} + \boldsymbol{M}_{\text{RMP}}) \times (\boldsymbol{Q}_{\text{existing}}) \qquad \text{Equation 5-1}$$

$$\boldsymbol{P}_{\text{new}} = (\boldsymbol{G}_{\text{IM}} + \boldsymbol{G}_{\text{O}} + \boldsymbol{G}_{\text{RMP}}) \times (\boldsymbol{M}_{\text{O}} + \boldsymbol{M}_{\text{RMP}}) \times (\boldsymbol{Q}_{\text{new}}) \qquad \text{Equation 5-2}$$

Where:

- G_{T} = The Telemetry gap category (as an ordered factor) at an existing gage.
- G_{DQ} = The Data Quality gap category (as an ordered factor) at an existing gage.
- G_{HDA} = The Historic Data Accessibility gap category (as an ordered factor) at an existing gage.
- G_{IM} = The Instream Measurement gap category (as an ordered factor) at a new or requested gage.
- G_{O} = The Operations gap category (as an ordered factor) at a new or requested gage.
- G_{RMP} = The Research, Modeling, and Planning gap category (as an ordered factor) at a new or requested gage.
- M_{O} = The Operations spatial metric for the gap location.
- M_{RMP} = The Research, Modeling, and Planning spatial metric for the gap locations.
- Q_{existing} = The existing mean annual flow or reported measurement capacity at an existing gage location.
- Q_{new} = The flow rate or anticipated measurement capacity at a proposed gage location.

These prioritization equations are the product of gap category factors, spatial metrics, and flow rate.

The gaps described in Section 3 were generally prioritized by the existing or expected measurement capacity of the existing or proposed gages. This approach prioritizes gages with higher flow rates in spatial areas where new gages with higher flow rates are recommended. The benefit of this method is that prioritizing gage improvements by their flow rate (from high to low flows) will result in the gage network being better able to measure, manage, and model greater proportions of the cumulative flow through the study area. However, this approach may not be the best outcome for regions with low capacity diversions and gages, as gage improvements would be de-prioritized in these regions.

One challenge with using flow rate to help prioritize identified gaging gaps is that not every gage has an assigned flow rate in the geodatabase. Flow rates for stream gages can be estimated by referencing other nearby stream gages or stream flow regression equations. However, the flow rate of any given diversion gage is often independent of other nearby gages and is difficult to estimate. For the purposes of this study, diversion gages with an assigned gap category but without a specified flow capacity were assigned a flow of 114 cfs (for ease of tracking), which is equal to the average capacity of diversion gages with an assigned flow rate within the study area. Similarly, stream gages and canal gages with an assigned gap category but without an assigned flow capacity were assigned a flow rate of 441 cfs and 56 cfs, respectively (for ease of tracking). These assumptions allowed the Engineering Team to complete the general prioritization process for all gaging gaps using a flow or gage capacity component.

5.2.2 SETTING SPATIAL METRIC WEIGHTS

The process of computing aggregate spatial prioritization metrics involved setting weights on 12 gage and spatial variables attached to each gage location. Table 5-1 shows the weighting scheme used to compute the spatial prioritization metrics for this study. Additional information on the Metric Variables and Metric Descriptions shown in the table are provided in Appendix B and Equation B-4. The Operations spatial prioritization metric placed the heaviest weight on identified dry dams, trans-basin deliveries, and return flows. The Research, Modeling, and Planning spatial prioritization metric placed the heaviest weight on UGS study watershed outlets, return flows, stream confluences, and modeling benefits.

As noted previously, the gap analysis outputs and metrics facilitate flexible prioritization of gaps using single variables or combinations of indicators for future prioritization work.

Table 5-1
Example Weighting Matrix for Computing Spatial Prioritization Metrics

Metric Variable[1]	Metric Description[1]	Operations	Research, Modeling, & Planning
RF	Return Flows	1	1
IAA	Agriculture Areas	0.5	0.5
DD	Dry Dam	2	0
WR	Surface Water Rights	0.33	0
DP	Indicated Priority	0.25	0
TB	Trans-basin Flows	1	0.25
SB	Proximity to State Line	0.1	0.25
CONF	Drainage Areas and Confluences	0	1
WB	Density of Upstream Hydrologic Measurement Stations	0	0.25
SW	Study Watershed Outlets	0	2
MOD	Modeling Importance	0	1
USGS	USGS Instream Gage Recommendations	0	0.33

1. See Appendix B for additional information on prioritization methodology, spatial metrics, and gage metrics.

5.2.3 PRIORITIZATION RESULTS AND FIGURES

General spatial priority metrics for each gap were calculated using variable weights (see Equation C-4 in Appendix B). These spatial metrics were then utilized in Equation 5-1 and Equation 5-2 to compute a weighted flow rate value, or Prioritization Score, at each gap location and prioritize (low, medium, high) gap improvements. Existing gages with a prioritization score of 0 have no gaps and were not prioritized. Only existing gages with gaps and proposed gages with flow measurement capacities greater than or equal to 10 cfs were prioritized as part of this study.

Table 5-2 summarizes the general priorities assigned to gaps identified in this study. The prioritization score for a gap reflects the relative importance of the gap by weighting the flow rate. Gage capacity/measured flow is the most influential factor in determining the prioritization score. The base assumption is that deficiencies on gages that measure large flows are a higher priority to resolve than deficiencies on gages that measure small flows. Figure 5-1 shows the general priorities of the existing gage gaps and Figure 5-2 shows the general priorities of the proposed gage gaps at locations where existing gages do not exist. The full table of gages with gaps and their assigned priorities are included in the digital deliverable accompanying this report.

Table 5-2
Gap Priority Classification based on Prioritization Scores

Priority	Prioritization Score[1]	
	Canal / Diversion Gage	Stream Gage
Low	Less than 10	Less than 200
Medium	10 – 100	200 – 2,000
High	More than 100	More than 2,000

1. Scores developed using Equation 5-1 and Equation 5-2. Classification thresholds were determined by analyzing the prioritization score distributions and selecting thresholds that reflected fewer High priority gaps than Medium and Low priority gaps.

Table 5-3 provides a summary of the gap prioritization evaluation. The analysis considered addressing gaps on existing gages and adding new proposed gages, prioritized as high, medium, and low based on the prioritization calculations described above. Table 5-3 also provides a preliminary estimate for the costs associated with addressing the prioritized gaps on existing and proposed gages.

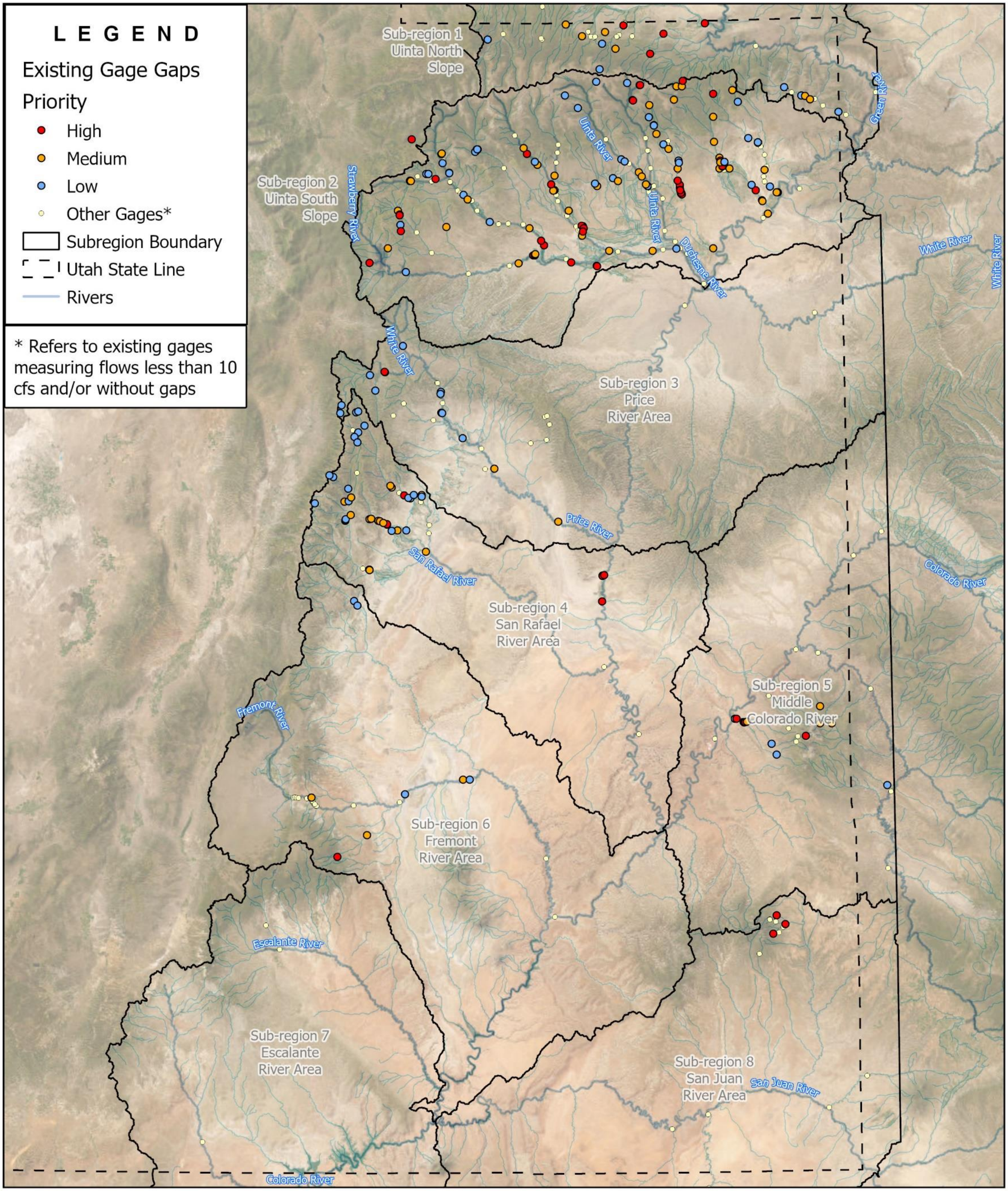
5.2.4 ALTERNATE PRIORITIZATIONS

The cost estimate is based on assumptions described in Section 4 and represents an approximate cost to address all gaps identified through the Gap Analysis. In practice, a subset of the identified gaps may be selected by the Authority and other stakeholders to address, which will alter the conceptual cost estimate.

The prioritization method described above uses flow rate as a substantial component of the priority calculation. If an alternate prioritization approach is desired (i.e., less focus on flow rate), Equation 5-1 and Equation 5-2 can be modified to account for other gage attributes (see Appendix C for more information). For example, prioritizing from low to high cost can be accomplished by replacing the flow component with the reciprocal of the estimated cost. This would result in assigning a higher priority to rehabilitation of existing gages, as the higher cost to install new gages would lower their priority. Other prioritization schemes based on gap type or on a particular prioritization metric could be developed in a similar way.

Table 5-3
Summary of General Prioritization and Cost Evaluation of Addressing Gaps

Existing Gage Priority	Type	Count	Capital Cost ($)	Annual Cost ($)
HIGH	Canal	23	294,000	25,300
	Diversion	40	0	44,000
	Stream	6	0	6,600
HIGH Subtotal		**69**	**294,000**	**75,900**
MEDIUM	Canal	33	253,500	36,300
	Diversion	49	0	53,900
	Stream	14	0	15,400
MEDIUM Subtotal		**96**	**253,500**	**105,600**
LOW	Canal	12	46,500	13,200
	Diversion	45	136,500	49,500
	Stream	63	0	69,300
LOW Subtotal		**120**	**183,000**	**132,000**
Existing Gage Subtotal		**285**	**730,500**	**313,500**
Proposed Gage Priority	**Type**	**Count**	**Capital Cost ($)**	**Annual Cost ($)**
HIGH	Canal	2	88,000	4,400
	Diversion	12	657,500	40,800
	Stream	19	842,200	182,800
HIGH Subtotal		**33**	**1,587,700**	**228,000**
MEDIUM	Canal	5	124,100	9,000
	Diversion	37	981,800	70,400
	Stream	56	2,353,200	580,600
MEDIUM Subtotal		**98**	**3,459,100**	**660,000**
LOW	Canal	0	0	0
	Diversion	4	67,600	6,600
	Stream	34	1,078,500	243,100
LOW Subtotal		**38**	**1,146,100**	**249,700**
Proposed Gage Subtotal		**169**	**6,192,900**	**1,137,700**
All Gaps - Total		**454**	**6,923,400**	**1,451,200**



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EXISTING GAGE GAP PRIORITIZATION

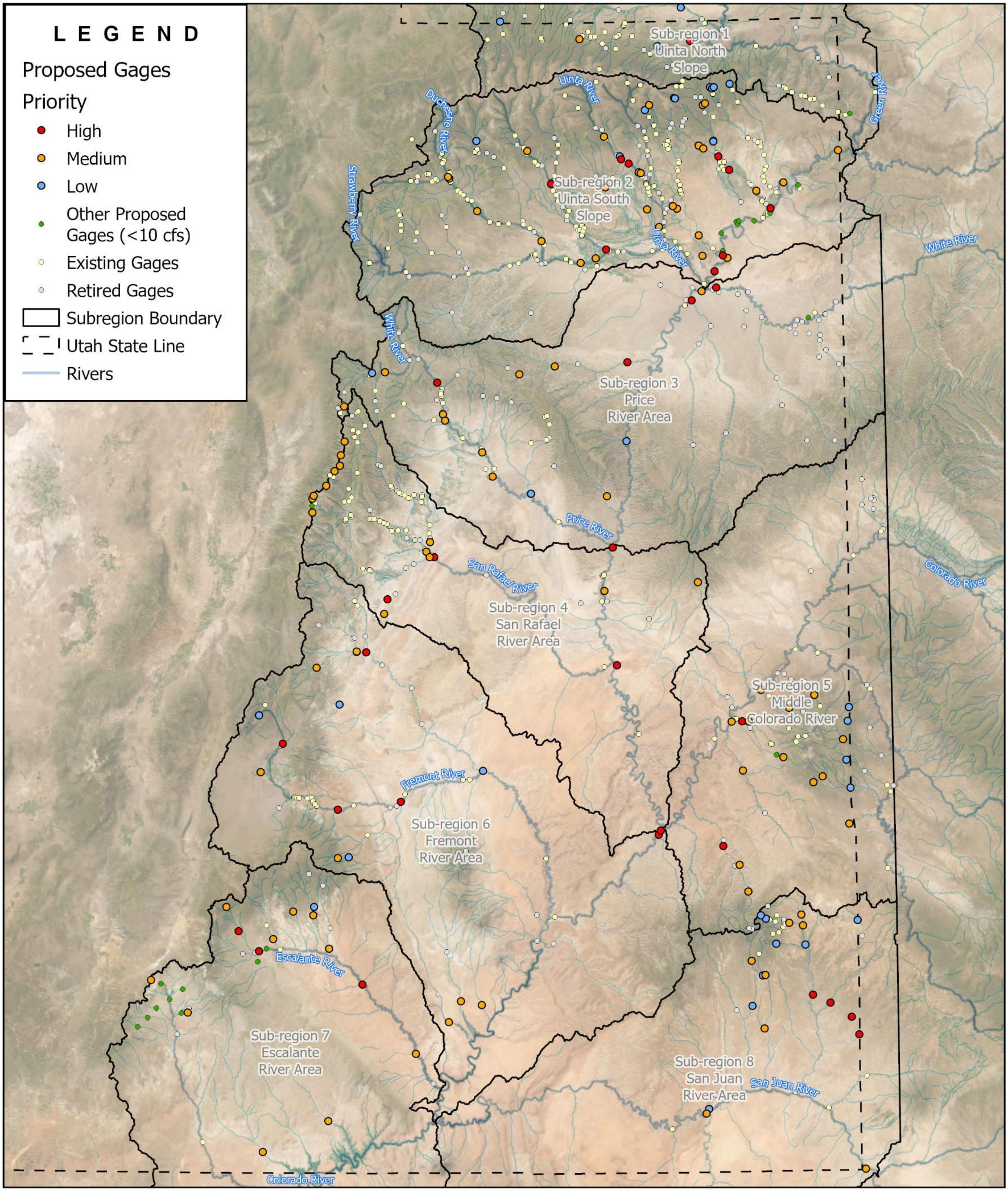
COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

SCALE: 1 in = 30 miles

FIGURE NO. 5-1



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PROPOSED GAGE GAP PRIORITIZATION

COLORADO RIVER AUTHORITY OF UTAH

METERING AND GAGING GAP ANALYSIS

NORTH:

SCALE: 1 in = 30 miles

FIGURE NO. 5-2

SECTION 6: SUMMARY

The Authority commissioned this Metering and Gaging Gap Analysis Study to establish a clear understanding of current measurement conditions, identify gaps in, and risks to, data, funding, maintenance, and other factors that influence the quality, coverage, and access to natural distribution and diversion measurements throughout the Colorado River System in Utah. Through collaboration with DWRi regional engineers, river commissioners, water conservancy districts, and other stakeholders, key information was obtained about existing gages and potential new gages in the study area. The collected data was compiled in a geodatabase that was used in a variety of ways to define gap types and develop prioritization criteria on a large scale. Based on the type of gap(s) assigned to each location, potential improvements (and their associated cost) were conceptually estimated

The data and tools provided in this report and the accompanying digital geodatabase may be used to adjust or revise the preliminary improvement prioritization as a more detailed implementation plan is developed to address identified data gaps. The database and tools that were developed during this study provide a foundation for understanding metering and gaging gaps in the study area and enable decision-makers to plan and schedule improvements to address identified data gaps.

Ultimately, addressing the metering and gaging gaps in the study area will be an ongoing process and will require collaboration and cooperation between federal, state, and local entities. The report and its associated deliverables were developed to support the Authority's mission by providing insights and tools that can be used to help accomplish the goals defined in the Measurement element of the Management Plan.

SECTION 7: REFERENCES

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