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Technical Memorandum | Final

To:	**Blaine Dwyer (Boyle | AECOM)**
Distribution:	**Distribution List**
From:	**Kevin Wheeler, Ben Harding (AMEC Earth & Environmental)**
Subject:	**CRWAS Phase 1 | Task 8.1 | Colorado River Compact Overview and Analysis | Summarize Key Issues**
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CRWAS Phase I included a public comment period on the draft CRWAS Phase I Report and public outreach workshops to solicit feedback from stakeholders on the Study. CWCB and the CRWAS technical team used these forms of feedback to refine Study deliverables, such as this technical memorandum, which may include content that has been updated. Please refer to the revised CRWAS Phase I Report (posted at http://cwcb.state.co.us) for updated information associated with this technical memorandum. Note that the numbers in this memorandum cannot anticipate future changes in policy. Thus, they are meant to be illustrative and not definitive.

Introduction

This Technical Memorandum summarizes information developed as part of Task 8 of the Colorado River Water Availability Study (CRWAS or Study).

The objective of Task 8 is to analyze Colorado River Compact provisions based on previous investigations of the current Compact setting and in relation to implementation of recent guidelines.

The activities were initially scoped to include analysis of water available to Colorado but have since been re-scoped, at the direction of the CWCB, to limit the analysis to water availability of the Upper Basin.

This Task 8.1 memorandum reviews key topics relevant in estimating water availability in the Upper Basin under a range of operating scenarios and hydrologic conditions in which provisions in the Colorado River Compact might be implicated. The information presented in this memorandum is limited to that which will be relevant to the approach to be developed in CRWAS Subtask 8.2. Subsequent sections of this technical memorandum discuss: 1) Requirements of CRWAS; 2) Relevant Legal Framework; 3) Current Operating Procedures; 4) Planning Methodology; 5) Planning Scenarios; 6) Outline of Suggested Methodology; 7) References; and 8) an Appendix containing a description of the

assumptions used in the Bureau of Reclamation's Colorado River Simulation System (CRSS).

Neither this study nor this document constitutes the state of Colorado's interpretation of any portion of the Colorado River Compact (45 Stat. 1057); the Upper Colorado River Basin Compact (63 Stat. 31); the Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, Treaty Between the United States of America and Mexico (Treaty Series 994, 59 Stat. 1219); the United States/Mexico agreement in Minute No. 242 of August 30, 1973, (Treaty Series 7708; 24 UST 1968); the Consolidated Decree entered by the Supreme Court of the United States in *Arizona v. California* (547 U.S 150 (2006)); the Boulder Canyon Project Act (45 Stat. 1057); the Boulder Canyon Project Adjustment Act (54 Stat. 774; 43 U.S.C. 618a); the Colorado River Storage Project Act (70 Stat. 105; 43 U.S.C. 620); the Colorado River Basin Project Act (82 Stat. 885; 43 U.S.C. 1501); the Colorado River Basin Salinity Control Act (88 Stat. 266; 43 U.S.C. 1951); the Hoover Power Plant Act of 1984 (98 Stat. 1333); the Colorado River Floodway Protection Act (100 Stat. 1129; 43 U.S.C. 1600); or the Grand Canyon Protection Act of 1992 (Title XVIII of Public Law 102-575, 106 Stat. 4669).

Requirements of CRWAS

The CWCB has directed that Task 8 produce a quantitative estimate of the amount and timing of any flow supplementation in the Upper Colorado River Basin that would be required under conditions in which provisions in the Colorado River Compact might be implicated. Supplementation flows refer to the additional flows that would potentially be required in the Upper Colorado River Basin to meet projected water demands in that Basin while simultaneously meeting the cumulative flow provisions in the Colorado River Compact. Making such an estimate will require a practical understanding of the legal and operational framework used for making decisions about water apportioned between the Upper and Lower Basins, the available tools, and the required data. Key topics can be generally separated into four components including the legal framework, the operating procedures, the available planning methodology, and appropriate planning scenarios. This memorandum identifies and discusses each of these four areas.

Relevant Legal Framework

The legal framework and operating procedures that govern the management of the Colorado River are defined in a suite of documents frequently referred to as "the Law of the River". A subset of these documents is directly relevant to determining the extent to which supplementation flows to the Lower Basin may be desirable. The general legal framework is based on the Colorado River Compact of 1922 and Upper Colorado River Basin Compact of 1948. Through the Colorado River Compact, the basin states apportioned water between the Upper Basin and Lower Basin and identified how they would comply with any obligation to Mexico. The Upper Colorado River Basin Compact defines Colorado's portion of the water apportioned to the Upper Basin.

These documents and other legal documents governing the apportionment of water in the Colorado River Basin are readily accessible through the U.S. Bureau of Reclamation "Law of the River" web site. (U.S. Bureau of Reclamation, 2008)

Colorado River Compact

Relevant provisions of the Compact include:

- Article II(a): The term "Colorado River System" means that portion of the Colorado River and its tributaries within the United States of America.
- Article III(a): There is hereby apportioned from the Colorado River System in perpetuity to the Upper Basin and to the Lower Basin respectively the exclusive beneficial consumptive use of 7,500,000 acre-feet of water per annum, which shall include all water necessary for the supply of any rights which may now exist.
- Article III(b): In addition to the apportionment in paragraph [III](a), the Lower Basin is hereby given the right to increase its beneficial consumptive use of such waters by one million acre-feet per annum.
- Article III(c): If, as a matter of international comity, the United States of America shall hereafter recognize in the United States of Mexico any right to the use of any waters of the Colorado River System, such waters shall be supplied first from the waters which are surplus over and above the aggregate of the quantities specified in paragraphs [III](a) and [III](b); and if such surplus shall prove insufficient for this purpose, then, the burden of such deficiency shall be equally borne by the Upper Basin and the Lower Basin, and whenever necessary the States of the Upper Division shall deliver at Lee Ferry water to supply one-half of the deficiency so recognized in addition to that provided in paragraph [III](d).
- Article III(d): The States of the Upper Division will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75,000,000 acre-feet for any period of ten consecutive years reckoned in continuing progressive series beginning with the first day of October next succeeding the ratification of this compact.

1944 Treaty with Mexico

Relevant provisions of the Treaty include:

- Article 10: Of the waters of the Colorado River, from any and all sources, there are allotted to Mexico:
- Article 10(a): A guaranteed annual quantity of 1,500,000 acre-feet (1,850,234,000 cubic meters) to be delivered in accordance with provisions of Article 15 of this treaty.
- Article 10(b): Any other quantities arriving at the Mexican points of diversion, with the understanding that in any year in which, as determined by the United States Section, there exists a surplus of waters of the Colorado River in excess of the amount necessary to supply uses in the United States and the guaranteed quantity of 1,5000,000 [sic] acre-feet (1,850,234,000 cubic meters) annually to Mexico, the United States undertakes to deliver to Mexico, in the manner set out in Article 15 of this Treaty, additional waters of the Colorado River system to provide a total quantity not to exceed 1,700,000 acre-feet (2,096,931,000 cubic meters) a year. Mexico shall acquire no right beyond that provided by this subparagraph by the use of the waters of the Colorado River system, for any purpose whatsoever, in excess of 1,5000,000 [sic] acre-feet (1,850,234,000 cubic meters) annually.

> In the event of extraordinary drought or serious accident to the irrigation system in the United States, thereby making it difficult for the United States to deliver the guaranteed quantity of 1,5000,000 [sic] acre-feet (1,850,235,000 cubic meters) a year, the water allotted to Mexico under subparagraph (a) of this Article will be reduced in the same proportion as consumptive uses in the United States are reduced.

Note: Article 15, not reproduced here, defines the schedule of delivery of the amounts of water quantified in Article 10.

Current Operating Procedures

Relevant operational procedures are identified in documents (including statutes, rules and regulations, compacts and operating procedures) that determine the operation and management of the principal reservoirs and associated facilities. Management decisions evolve to plan for and respond to a variety of potential hydrologic conditions and, as this evolution occurs, new documents are generated that describe these procedures. The latest document, titled Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement, provides a comprehensive review of these operating procedures, including the most recent refinements to the operating procedures ("Lower Colorado River Guidelines EIS" or "EIS", U.S. Bureau of Reclamation, 2007a). The Record of Decision based on the EIS, issued in December 2007, identified the preferred alternative and outlined the operation of Lakes Powell and Mead (U.S. Bureau of Reclamation, 2007b). The guidelines provide for a schedule of shortages to contract deliveries from Lake Mead under specified conditions in that reservoir, and also provide for coordinated operation of Lake Mead and Lake Powell. A summary of the provisions of the guidelines as they relate to coordinated operations, which address releases from Lake Powell, is shown below. Note the references to the pool elevations of Lake Mead throughout this figure. The elevation at which the upper operational tier begins, where equalization occurs, is specified in the table reproduced as Figure 2.

Figure 1.
Lake Powell Operational Tiers
(From Reclamation, 2007b)

Lake Powell Operational Tiers (subject to April adjustments or mid-year review modifications)		
Lake Powell Elevation (feet)	**Lake Powell Operational Tier**	**Lake Powell Active Storage** (maf)
3,700		24.32
	Equalization Tier equalize, avoid spills or release 8.23 maf	
3,636 – 3,666		15.54 – 19.29
(see table below)	**Upper Elevation Balancing Tier** release 8.23 maf; if Lake Mead < 1,075 feet, balance contents with a min/max release of 7.0 and 9.0 maf	(2008 – 2026)
3,575		9.52
	Mid-Elevation Release Tier release 7.48 maf; if Lake Mead < 1,025 feet, release 8.23 maf	
3,525		5.93
	Lower Elevation Balancing Tier balance contents with a min/max release of 7.0 and 9.5 maf	
3,370		0

Figure 2.
Lake Powell Equalization Elevation
(From Reclamation, 2007b)

Lake Powell Equalization Elevation Table	
Water Year	Elevation (feet)
2008	3,636
2009	3,639
2010	3,642
2011	3,643
2012	3,645
2013	3,646
2014	3,648
2015	3,649
2016	3,651
2017	3,652
2018	3,654
2019	3,655
2020	3,657
2021	3,659
2022	3,660
2023	3,662
2024	3,663
2025	3,664
2026	3,666

As shown in Figure 1, and language in Section 6 of the 2007 Record of Decision (Reclamation 2007b), coordinated operations in Lake Mead will influence releases from Lake Powell. Therefore the conditions in Lake Mead influence the cumulative total amount passing Lee Ferry which could influence the supplemental water needs.

Planning Methodology

A long-range planning methodology for the Colorado River has been developed by the Bureau of Reclamation and is utilized as the means by which management policies and operational guidelines are evaluated and selected. Maintaining a general consistency with the key components of this methodology will help gain acceptance by the numerous stakeholders in the River's operations.

Central to the decision making process is the Colorado River Simulation System (CRSS) model implemented in the RiverWare software and maintained by the Bureau of Reclamation. Components and inputs to CRSS generally include 29 hydrologic inflow locations, 12 storage reservoirs with physical parameters (individual reservoir storage capacity, evaporation rates, reservoir release capabilities, etc.) and approximately 115 modeled diversion locations including diversion and depletion schedules. Operational rules for current or proposed operating policies are also considered input.

The CRSS model is widely accepted by participants (federal and state agencies, water suppliers, and environmental / recreational interests in the most recent interstate discussions) as an appropriate tool for evaluating and comparing policies and operational guidelines. CRSS was used for the analyses of water availability and analyses of streamflow and reservoir contents conducted as part of the development of the Lower Colorado River Guidelines EIS (Reclamation, 2007a). As such, the CRSS model can be considered the most authoritative repository of information related to the rules that currently govern the operation of the major Federal facilities on the Colorado River. While some of these rules are matters of ongoing contention among the Basin States and other stakeholders, the CRSS rules are the best compilation of these operating rules available for assessing water availability.

Model Information

Information about CRSS, the operating rules and system characteristics include:

- Model Access - The current CRSS Model is accessible via the Colorado River Stakeholder Modeling Work Group Website (2009; requires login account).
- Model Description - A general description of CRSS is in Appendix A of the Colorado River Guidelines EIS (Bureau of Reclamation, 2007a).
- Modeling Assumptions - Current Modeling Assumptions are summarized by Reclamation as a document. The version of that document that is current at the time of this writing is attached as Appendix A to this memo.

Planning Scenarios

The apportionments of water set out in the 1922 Compact and the Mexico Treaty, combined with the amount of consumptive use in the Upper Colorado River Basin and the total amount of water available in the Colorado River Basin determine the extent of possible required supplementation flows. While the amount of natural flow in the Basin is highly variable, and there is uncertainty and contention about current and future levels of consumptive uses and losses in the states of the Basin, the most widely accepted basis for planning studies are those developed by the Bureau of Reclamation in the process of adopting interim guidelines.

Formal studies for operational and planning purposes are conducted by Reclamation and other stakeholders using CRSS. The CRSS model contains data that represent the natural inflows to the system and current and projected levels of water use throughout the Basin.

Information about inflows and depletions currently used in CRSS can be found at:

- Natural Inflows - Data and documentation of the Reclamation Natural Flow data are found at the Colorado River Basin Natural Flow and Salt Data web site (2008).
- Depletions - Data and documentation of the Depletion Schedules used by Reclamation is found in the Colorado River Guidelines EIS (Bureau of Reclamation, 2007a).
    - Appendix C for the Upper Basin Depletions
    - Appendix D for the Lower Basin Depletions

Planning studies also include modifying and testing alternative operational rules within CRSS. Implementing alternative operational rules and policy requires a thorough understanding of the existing CRSS rule structure and implementation of existing policy and the ability to make alterations to the CRSS rules that can be understood and verified by others.

Outline of Suggested Methodology

An approach is suggested whereby the CRSS model is modified to provide the appropriate amount of supplementation flow. As currently implemented, the CRSS model tracks the amount of water that passes Lee Ferry and accumulates the volumetric quantity on a 10-year running basis. However the model does not currently modify its operation when this cumulative volume does not reach at least 75 million acre feet over a 10-year period. The suggested approach is modify CRSS so that the model will add a quantity of water to the system at Lee Ferry sufficient to maintain the cumulative 10-year flow at no less than 75 million acre-feet. The amounts of water added to the system at Lee Ferry will be the supplementation flow amount.

The streamflows that would serve as the basis for the suggested approach would be the current Colorado River Basin Natural Flow data (Colorado River Basin Natural Flow and Salt Data web site, 2008), adjusted to reflect projected future climate conditions and re-sequenced to reflect the patterns of drought and wet spells contained in the paleo record. The adjustments and re-sequencing to be applied to the CRSS natural flows would be the same as those that are to be applied to the CRDSS natural flows for the intra-state analysis.

Where to find more detailed information:

Details on the approach to be used to simulate the effects of the provisions of the Colorado River Compact are provided in the CRWAS Technical Memorandum *Task 8.2 Colorado River Compact Overview and Analysis, Approach*.

References

Bureau of Reclamation. “Final Environmental Impact Statement: Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead”. Boulder City Nevada, November 2, 2007. (a)

Bureau of Reclamation. “Record of Decision Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead”. Washington D.C., December, 2007. (b)

Colorado River Basin Natural Flow and Salt Data. September 2008. United States Bureau of Reclamation. November 21, 2008. http://www.usbr.gov/lc/region/g4000/NaturalFlow/index.html

Colorado River Stakeholder Modeling Workgroup. 2009. United States Bureau of Reclamation. April 30, 2009. http://bcportals.com/usbr-crs/

Law of the River. March, 2008. United States Bureau of Reclamation. November 21, 2008. http://www.usbr.gov/lc/region/pao/lawofrvr.html

Appendix A: CRSS Modeling Assumptions

January 2009

All modeling assumptions, except for those listed in this document are identical to the FEIS Basin States Alternative. Appendix A of the FEIS describes the detailed modeling assumptions. Upper and Lower Basin demand schedules are contained in Appendices C and D, respectively. Appendix M describes the modeling assumptions specific to the ICS mechanism. Appendix N describes techniques relating to the generation hydrologic inflow scenarios.

- January 2009 initial conditions (historical) for all modeled reservoirs
  - Powell: 3617.89 ft
  - Mead: 1110.97 ft
- Run duration 2009 - 2026
- Future inflows are represented through 3 different hydrologic scenarios
  - Index Sequential Method (ISM) used on observed historic period of record (1906-2006) – Direct Natural Flow
  - ISM used on tree-ring reconstructed streamflow (762-2005) – Direct Paleo
  - Nonparametric conditioning resampling technique that blends observed historic and tree-ring reconstructed streamflows – Nonparamteric Paleo Conditioned
- Maximum total ICS of 2.1 maf

Lake Powell Coordinated Operation

The Lake Powell operation consists of 4 operational tiers:

- Equalization (above the Equalization Line)
- Upper Elevation Balancing (between 3,575 feet and the Equalization Line)
- Mid-Elevation Releases (between 3,525 feet and 3,575 feet)
- Lower Elevation Balancing (below 3,525 feet)

The operational tier is determined annually based on the Lake Powell January 1 elevation. Because the determination is based on the January 1 elevations, the Lake Powell operational tier may not shift within the water year (two exceptions – see Upper Elevation Balancing Tier below). However, during Equalization and balancing operations, the release amount for the water year is still adjusted monthly based on the end-of-water year (EOWY) forecast.

Equalization Tier

- If the forecasted Lake Mead EOWY storage drops below 1,105 feet, the release from Lake Powell is adjusted until the first of the following three conditions occur: 1) the forecasted Lake Mead EOWY storage comes above 1,105 feet, 2) the forecasted Lake Powell EOWY storage drops below 20 feet under the Equalization Line, or 3) Lake Powell and Lake Mead are equalized.

Upper Elevation Balancing Tier

- If the January 1 Lake Mead elevation is below 1,075 feet, balancing releases are made from Lake Powell with a minimum and maximum release of 7.0 maf and 9.0 maf.
- If the January 1 Lake Mead elevation is at or above 1,075 feet, the Lake Powell release is 8.23 maf. Two exceptions are listed below.
  - If, in April, the forecasted Lake Mead EOWY elevation is less than 1,075 feet and the forecasted Lake Powell EOWY elevation is at or above 3,575 feet, balancing releases are made from Lake Powell with a minimum and maximum release of 8.23 maf and 9.0 maf.
  - If, in April, the forecasted Lake Powell EOWY elevation is above the Equalization Line, releases from Lake Powell are made according to the Equalization Tier.

Mid-Elevation Release Tier

- If the January 1 Lake Mead elevation is at or above 1,025 feet, the release from Lake Powell is 7.48 maf.
- If the January 1 Lake Mead elevation is below 1,025 feet, the release from Lake Powell is 8.23 maf.

Lower Elevation Balancing Tier

- If the January 1 Lake Powell elevation is below 3,525 feet, balancing releases are made from Lake Powell with a minimum and maximum release of 7.0 maf and 9.5 maf.