Peer Review Summary

Batch Peer Review for Colorado River Simulation System (CRSS) Modeling of Post-2026 Alternatives

Date

January 16, 2026

Originating Office

Research and Modeling Group, Lower Colorado River Basin Region, Bureau of Reclamation

Reclamation Roles

Director or delegated manager: Genevieve Johnson, Acting Regional Director, Lower Colorado Basin Region, Bureau of Reclamation

Peer Review Lead: Alan Butler, Research and Modeling Group Manager, Lower Colorado Basin Region, Bureau of Reclamation

Peer Review Scope

Reclamation's Research and Modeling Groups within the Upper and Lower Colorado Basin Regions created a model for each alternative being analyzed in the Colorado River Basin Post-2026 National Environmental Policy Act (NEPA) process using the Colorado River Simulation System (CRSS) modeling platform. The Colorado River Basin Post-2026 NEPA process is being carried out to identify successor operating guidelines for Lakes Powell and Mead.

The subject of this review is whether the model for each NEPA alternative is a reasonable representation of the operational assumptions included in each alternative. The resource impacts associated with the modeling output are outside the scope of this review. This review is focused solely on whether the modeling approaches align with the alternatives' respective descriptions, and the reviewer should not provide advice or comment on a policy or decision. Specifically, the reviewer will respond to the following questions for each model:

Question 1: Did the modeling approach fully capture the set of operating assumptions associated with the alternative?

Question 2: Are any operating assumptions incompletely or incorrectly modeled in a way that substantively affects model output?

Peer Reviewer

Kevin Wheeler, DPhil, P.E., of Water Balance Consulting, served as the peer reviewer. Dr. Wheeler possesses extensive experience with prior versions of CRSS and a comprehensive familiarity with the RiverWare modeling platform, the software used to implement CRSS. In his role as a subcontractor to AECOM, the prime contractor supporting Reclamation in the Post-2026 NEPA process, Dr. Wheeler also had an established understanding of the alternatives represented in CRSS.

Summary of Reviewer Comments

Dr. Wheeler provided three deliverables to Reclamation:

1. A summary of key results from the Batch Peer Review for Colorado River Simulation System (CRSS) Modeling of Post-2026 Alternatives (summary)
2. Batch Peer Review for Colorado River Simulation System (CRSS) Modeling of Post-2026 Alternatives (report)
3. A Batch Peer Review – Ruleset Review Matrix Excel file (review matrix)

The summary and report are attached to this document, and the review matrix is posted on Bureau of Reclamation Peer Review website.

In summary, it was noted that:

While no concerns were found that would invalidate the results of the modeling exercise, several issues were identified that should be verified as concerns in the Draft EIS and remedied between the development of the Draft EIS and the Final EIS document. Three key issues of concern are highlighted in this summary, while others are described in additional reporting provided to Reclamation.

Additionally, in the Summary and Conclusions of the report it was noted that:

The batch peer review was conducted using the models and results provided by Reclamation along with written and verbal descriptions of the alternatives. Several concerns were identified, most of which are not expected to have a significant impact on the results. Three items of concern were brought forward to Reclamation during the *analysis since they could potentially have negative impacts. … These three concerns, as well as the others provided throughout this report, should be considered and addressed prior to the production of the Final EIS analysis.*

The three key issues that were highlighted are summarized below, along with Reclamation's responses.

The additional issues that were identified in the report are summarized, along with Reclamation's responses, in the attached table. Several responses state that Reclamation may "consider updating between the Draft EIS and the Final EIS." Any such updates will depend on the overall approach to updating modeling and resource analysis between the Draft EIS and Final EIS. Both the reviewer and Reclamation agree that none of the identified issues are substantive enough to affect the overall results used in the Draft EIS; therefore, decision-making does not hinge on addressing these identified issues.

The comments and responses provided in the following section and attached table are technical and assume a detailed understanding of the alternatives and modeling terminology used in CRSS. Readers seeking additional context or definitions of terms are referred to the Draft EIS [1]and its appendices[2], which provide comprehensive descriptions of the alternatives and modeling assumptions.

Key Issues Identified

1. **Consistency in transferring stored water accounts**

Summary of Comment: The model output of the No Action Alternative initially provided by Reclamation did not reflect any previously stored volumes in these [Intentionally Created Surplus (ICS)/Mexico's Water Reserve (MWR)] accounts nor demonstrate how these accounts would be used over time. A verification of whether the model used to produce the results of this Draft EIS included or excluded the graduated depletion of these accounts is necessary.

Response: All provided models can simulate operations with and without storage and delivery mechanisms, e.g., ICS, MWR, new assumed storage and delivery mechanisms. Reclamation provided the reviewer with both models and model output to assist in their review, and accidentally provided model output for the No Action Alternative from a model setup to run without storage and delivery mechanisms. Reclamation provided the reviewer updated/corrected data for a model run with storage and delivery mechanisms enabled

[1] Available at https://www.usbr.gov/ColoradoRiverBasin/post2026/draft-eis/index.html

[2] Specifically, Appendix A – *CRSS Model Documentation* and Appendix B – *Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water*

and also verified that the correct version of output data was being used throughout the Draft EIS.

2. **Powell Infrastructure Protection in the Enhanced Coordination Alternative**

Summary of Comment: As described in the document provided for the Enhanced Coordination Alterative, Powell Infrastructure Protection (PIP) releases.... are to be invoked when Lake Powell's physical elevation is projected to go below 3,525 ft in April or August. However, the results provided did not reflect these contributions of supplemental releases.

Response: The documentation provided to the peer reviewer incorrectly noted that the Enhanced Coordination Alternative included PIP releases. The Enhanced Coordination Alternative included in the Draft EIS does not include assumptions for PIP releases, as such the modeling correctly reflects the described alternative.

3. **Repeated execution of Upper Basin delivery restriction rules**

Summary of Comment: Rules that adjust Upper Basin agricultural aggregate diversions' 'available for diversion' slots were implemented without explicit execution constraints that limit their ability to fire multiple times. As a result, each time one of the rules is placed back on the agenda, the Available for Diversion slot inadvertently gets scaled further towards zero, resulting in Upper Basin users not depleting sufficient water and allowing extra water to inadvertently reach Lake Powell. This was particularly concerning for the alternatives that included PIP rules. The reviewer acknowledged that the frequency that this occurs was rare and only impacted 'Short Users 5 Above Powell' rule, which impacts two mainstream diversions and 7 diversions on the San Juan River. This issue occurs in less than 0.2% of timesteps. The issue occurred in the Continued Current Strategies, Basic Coordination, and Enhanced Coordination models, but not in the Maximum Operational Flexibility or Supply-Driven models. The No Action model did have constraints on the equivalent rules and therefore this issue was not of concern in this model.

Response: The most significant issue identified relates to differences in execution constraints in the No Action model compared to the other modeled alternatives. Because this issue affects only a very small number of timesteps and does not materially influence overall results, Reclamation elected not to re-run all models, or the No Action model alone, for the Draft EIS. Reclamation may consider updating these execution constraints between the Draft EIS and Final EIS. Reclamation will also evaluate whether the relevant rules should be permitted to execute multiple times. Given the underlying logic for adjusting the Available for Diversion slot, there may be circumstances—particularly when PIP releases occur—where a second execution is appropriate.

The additional issues that were identified in the report are summarized, along with Reclamation's responses, in the attached table.

Reclamation appreciates the diligent peer review by Dr. Wheeler and the substantial documentation of the peer review that was conducted. While not all identified issues will be addressed between the Draft and Final EIS, they will improve future versions of CRSS.

Attachment 1 – Detailed Comment Response Matrix

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
1	Batch Peer Review - Key issues Summary.pdf	Key Issue 1	No Action	Consistency in transferring stored water accounts - The model output of the No Action Alternative initially provided by Reclamation did not reflect any previously stored volumes in these [ICS/MWR] accounts nor demonstrate how these accounts would be used over time. A verification of whether the model used to produce the results of this Draft EIS included or excluded the graduated depletion of these accounts is necessary.	All provided models can simulate operations with and without storage and delivery mechanisms, e.g., ICS, MWR, new assumed storage and delivery mechanisms. Reclamation provided the reviewer with both models and model output to assist in their review, and accidentally provided model output for the No Action Alternative from a model setup to run without storage and delivery mechanisms. Reclamation provided the reviewer updated/corrected data for a model run with storage and delivery mechanisms enabled and also verified that the correct version of output data was being used throughout the Draft EIS.
2	Batch Peer Review - Key issues Summary.pdf	Key Issue 2	Enhanced Coordination	As described in the document provided for the Enhanced Coordination Alterative, Powell Infrastructure Protection (PIP) releases....are to be invoked when Lake Powell's physical elevation is projected to go below 3,252 ft in April or August. However, the results provided did not reflect these contributions of supplemental releases.	The documentation provided to the peer reviewer incorrectly noted that the Enhanced Coordination Alternative included PIP releases. The Enhanced Coordination Alternative included in the Draft EIS does not include assumptions for PIP releases, as such the modeling correctly reflects the described alternative.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
3	Batch Peer Review - Key issues Summary.pdf	Key Issue 3	Continued Current Strategies, Basic Coordination, Enhanced Coordination	...rules [that adjust Upper Basin agricultural aggregate diversion 'available for diversion' slots] were implemented without explicit execution constraints that limit their ability to fire multiple times. As a result, each time on of the rules is placed back on the agenda, the Available for Diversion slot inadvertently gets scaled further towards zero, resulting in Upper Basin users not depletion sufficient water and allowing extra water to inadvertently reach Lake Powell. This was particularly concerning for the alternatives that included PIP rules. Noted later - frequency was rare and only impacted 'Short Users 5 Above Powell) which impacts two mainstem diversions and 7 diversions on the San Juan. Number of impacted timesteps is less than 0.2%.	The most significant issue identified relates to differences in execution constraints in the No Action model compared to the other modeled alternatives. Because this issue affects only a very small number of timesteps and does not materially influence overall results, Reclamation elected not to re-run all models, or the No Action model alone, for the Draft EIS. Reclamation may consider updating these execution constraints between the Draft EIS and Final EIS. Reclamation will also evaluate whether the relevant rules should be permitted to execute multiple times. Given the underlying logic for adjusting the Available for Diversion slot, there may be circumstances—particularly when PIP releases occur—where a second execution is appropriate.
4	Batch Peer Review Report.pdf	Table 1; pg 6	All Alternatives	Some models contained more pre-start timestep values than others; the volume of data was inconsistent	The various alternatives use a different number of pre-start initialization months and thus do not import the same number of timesteps for some slots. Agree that it would alleviate confusion to import same number of months of pre-start initializing values in all alternatives; however it would not change model output. Consider updating between Draft EIS and Final EIS.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
5	Batch Peer Review Report.pdf	Figure 1; pg 10	All Alternatives	Assumed flows for Lees Ferry and Paria gages prior to the model start date ...had inconsistencies going back to 2003	Updates were implemented in all models for the Water Deliveries and Water Quality analysis, and in the Upper Basin resource analysis for the Basic Coordination, Enhanced Coordination, and Supply Driven alternatives; this ensured that resource analysis results of the 10-year flow at Lees Ferry were consistent across alternatives.
6	Batch Peer Review Report.pdf	ICS banking Volumes, pg. 10	No Action	See Issue Description for Issue #1	See response for Issue #1

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
7	Batch Peer Review Report.pdf	Table 8 pg 12 (not highlighted; repetative values are listed as a systematic errer)	No Action, Continued Current Strategies, Basic Coordination (Federal Contingency in report)	Accounting for Lower Basin shortages - Table 8 indicates....negative outflows [at BelowImperialDamColoradoR:OverDeliveryToMexico.Outflow] for each alternative. It is notable that the majority have the same magnitude, which is indicative of a systematic error.	This is a factor of the hydrologic trace being run through the model. When investigating the large negative outflows, and specifically the -18,584 af/month volume seen across multiple traces, multiple alternatives, in similar years it was deteremined this was due to the similarity of the total shortage volumes in the Lower Basin and the hydrologic traces themselves. The traces impacted in this specific example (213, 214, 215) are all from the CMIP3 NPC ensemble. Given how the traces were constructed it is possible and does happen that there are years and months with the same flow magnitudes between traces at all natural flow sites. The large negative outflow at the bottom of the system is caused by an extremely dry span of hydrology that has the same very dry month across the traces. In the alternative models, before hitting this month, several dry months (in which the hydrology does not match between traces) draws Lake Powell's elevation down low enough that Lake Powell is below its minimum power pool and is releasing water through the bypass tubes, passing what inflow it can, making the releases from Lake Powell across all alternatives very similar. This in turn draws pool elevations down at Lake Mead causing extended dead pool-related reductions.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
7 cont'd					When the month in question occurs, the dead pool-related reductions at Lake Mead is greater than the water available to be shorted from the water users in the Lower Basin, and all water users are fully shorted. Similar to Lake Powell, in this month Lake Mead is passing what inflow it can, causing the outflow from Lake Mead to be nearly identical between the alternatives. Lakes Mohave and Havasu will release water to ensure they maintain their rule curve storage. For Lake Havasu, this release is 119,008 af. The inflow at the AboveImperialDamColoradoR aggregate reach where the Imperial Natural Flow gains are modeled are -139,842.56 af for the month in question, and are large enough that they cannot be offset by the release from Lake Havasu and the Arizona forebeared return flow objects, causing a negative outflow at the bottom of the system. Therefore this is not an error, but a factor of dry hydrology which results in low pool elevations at Lakes Powell and Mead where they are only able to pass inflow followed by a month with the exact same dry hydrology. Reclamation's current assumptions with respect to natural flows allows negative natural flows in CRSS; however, those negative natural flows can cause issues, like this one, in special cases.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
8	Batch Peer Review Report.pdf	pg 14 - 16	All Alternatives	[walk through example of dead pool related reductions when hydrologic shortage exceeds the volume of 'shortable water'] The primary concern here is whether releases from Lake Mead should be adjusted to reflect the Level 4 hydrologic depth shortage condition. This occurrence was found to be the cause of many flows leaving the system under these conditions. This model behavior is something that Reclamation should reconsider.	During dead pool-related reductions, Southern Nevada Water Authority (SNWA) is assumed to share in the computed dead pool-related reductions, however they differ from other water users in the model as they divert water directly from Lake Mead rather than downstream of Lake Mead. It is assumed that water shorted from SNWA would be made available to higher priority downstream water users. As a simplifying assumption, water shorted from SNWA due to dead pool-related reductions is added on to Lake Mead's existing release, and Lake Mead's release is re-computed.
8 con'td					The issue is that in some years when all Lower Basin water users are completely shorted, the volume of water added to Lake Mead's release from reducing SNWA's use is greater than the miscellaneous uses, such as the assumed excess flows to Mexico, causing water to be present at the bottom of the system. Agree comment warrants further discussion on whether this additional water would be released in these instances and if the dead pool-related reductions and Lake Mead's release should be iterated over to account for this additional water from SNWA. As a note- outflow at the bottom of the system isn't only influenced by this logic and can be a factor of the distribution of natural flow in the Lower Basin as well, e.g., issue 7.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
8 con'td					Modeling impact - across all alternatives less than 3% of traces experienced a dead pool-related reduction of this magnitude and these occurred in between 0.000% and 0.006% of all years. During these occurrences Lake Mead is already at dead pool and is passing inflow, therefore the overall impact of not releasing this additional water from SNWA would be fairly small and cause minor differences to overall modeling results and negligible differences to overall trends. Will consider updating between Draft and Final EIS.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
9	Batch Peer Review Report.pdf	Pg 16	No Action, Continued Current Strategies, Basic Coordination	...there are many other cases when the OverDeliveryToMexico is used to compensate for minor errors in the allocation of Lower Basin Shortages, and these occur frequently and regardless of the value of Shortage.HydroShortageStageDepth.	TheOverDeliveryToMexico aggregate diversion object (which simulates the excess flows to Mexico) is shorted approximately 1-10 kaf in some months because the solve direction on Lower Basin reaches was set to solve either upstream or downstream instead of solving downstream only. When the Lower Basin would enter dead pool reductions for the first time in a year, it executes logic to cancel all conservation activities for the remainder of the year and the annual creation, delivery, and conservation balances to be recomputed. When this occurs, the interplay between this logic and reach solve direction would cause the reservoir objects for Lake Mohave and Lake Havasu to re-solve and propagate any changes upstream, invalidating the mass balance calculation Lake Mead had previously solved to set its desired release, and therefore the dead pool-related reduction volume for that month was incorrect. Issue was addressed by setting the solve direction on all Lower Basin reaches to solve downstream only, which rectified the issue. Issue was resolved in the Basic Coordination, Enhanced Coordination, and Supply Driven alternatives prior to Upper Basin resource analysis, and in all alternatives for water deliveries and water quality modeling.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
10	Batch Peer Review Report.pdf	Pg. 20	No Action	Rule differences found in 1) The limitations to *Available For Diversion* slot on reaches that supply water to Upper Basin Agriculture water users were aggregated in the No Action Alternative to two rules and broken up into stages in the other alternatives.... 2)Many, but not all, rules related to Upper Basin Reservoirs have gained a constraint that does not allow rules to successfully fire multiple times.....	Development was done to refine logic that limits the water available for diversion to Upper Basin agricultural water users and Upper Basin reservoir releases in the official CRSS model and official model ruleset, which assumes that all current operating policies extend through 2060. This model was the basis for all alternative models, while the ruleset was the basis for all alternatives models except the No Action alternative, which used the 'No Action' ruleset that has been developed and maintained from the No Action alternative in the 2007 Interim Guidelines as its basis. The aforementioned modeling development, which includes the issues described, was never pulled into this 'No Action' ruleset. A sensitivity analysis was performed and was found to have a minor impact on modeling results which did not change overall magnitudes of inflows being seen, and had minor impacts on the distributions of results for Powell metrics. The sensitivity analysis showed that the un-refined logic of the 'No Action ruleset' did not invalidate the trends seen in the No Action alternative. Decision was made not to re-run the model unless all models needed to be re-run for the Draft EIS. Consider updating between Draft EIS and Final EIS.

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11	Batch Peer Review Report.pdf	Pg. 20 - 21	Enhanced Coordination	[The alignment of gate flow volumes between the Enhanced Coordination and Maximum Flexibility Alternatives] was particularly notable given the Enhanced Coordination alternative is designed to make PIP releases...while the Maximum Operational Flexibility is not.	See response for Issue #2
12	Batch Peer Review Report.pdf	Rule 180; pg. 24	No Action	Powell Runoff Forecast: The UBDepletion.system_scalar and UBDepletion.demand_scalar slots have discontinuity that causes concerns. Slots are used to estimate UB Depletions via the UBDepletionsRange function in the Powell Runoff Forecast.	The shape of the implemented curve is intentional. Consider adding in-model documentation to improve transparency between the Draft EIS and Final EIS; these parameters are documented in Appendix A to the Draft EIS.
13	Batch Peer Review Report.pdf	Rule 179, pg. 25	No Action	Compute 602a Storage: A potential problem is the depletions are NOT shorted because the EqualizationData.PercentShortage = 0, therefore the 602a storage assumes all UB demands can be met, regardless of the UB statement that they can never be met.	Equalization determinations in the No Action Alternative are made using the Equalization Line, as documented in the 2007 Interim Guidelines, and therefore the 602a Storage computation does not affect results. The 602a Storage computation in the model is for informational purposes only and is computed using the same constants and parameters, such as the Upper Basin shortage percent, as used during the 2007 Interim Guidelines. The 602a storage volume slot does not affect results, but the inclusion of the 602a Storage computation in the model could be better documented to improve transparency. Consider improving in-model documentation between the Draft EIS and Final EIS. These parameters are documented in Appendix J in the Draft EIS.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
14	Batch Peer Review Report.pdf	Rule 178; pg 25	No Action	Compute 70R Assurance Level Surplus Volume: this rule also assumes the full UB Depletion Schedule can be met via the slot UBDepletion.UBDepletionEstimate used in the SumUBDemands function.	The UBDepletion.UBDepletionEstimate slot estimates the volume of Upper Basin depletions that can be satisfied in a given year, assuming knowledge of the current year's natural flow. It does not assume the full Upper Basin depletion demands can be satisfied each year (can be seen by comparing slot UBDepletion.UBDepletionEstimate to slot UBDepletion.AnnualUBDemands). Consider adding in-model documentation to improve transparency between Draft EIS and Final EIS.
15	Batch Peer Review Report.pdf	Rule 176, pg 25	No Action	PIP_April_Forecast_LogReg: I belive the Evaporation Estimation is incorrect here because it combines the forecasted April-March Inflow with evap estimated from previous December (@t-4) to Next March.	The evaporation estimation was implemented this way by design. Consider documenting rule more fully to improve transparency between the Draft EIS and Final EIS.
16	Batch Peer Review Report.pdf	Rule 100, pg 25	No Action	Taylor Park Rule Curve: incorrect execution constraint. Currently only fires if the outflow hasn't been set OR the rule has already fired successfully. This was obviously meant to only fire one with a NOT. Note: This has been corrected in the other models, but will create unpredictable differences between models.	This finding only impacts the No Action alternative as it was a part of the development that was not implemented in the No Action alternative mentioned in issues #3 and #10. Agree with comment and consider updating between the Draft EIS and Final EIS.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
17	Batch Peer Review Report.pdf	Rule 64, pg 25	No Action	Compute Nevada ICS and Other Resource Deliveries: The Nevada ICS.DesiredAnnualTake at 2026 but then also continues to increase for the full run period. Reclamation has explained this behavior is acceptable because it is later limited by actual use, however the discontinuous nature of the slot still raises concerns.	This is the desired, not actual, ICS delivery and thus is not limited by delivery constraints/last year to pull ICS from the ICS mechanism or ICS balances. This curve is driven by two assumptions: (1) To satisfy unmet demand, be it from the Nevada depletions being adjusted below their projected demand for the year due to shortage or due to additional SNWA demand. Nevada will attempt to withdraw ICS to mitigate this unmet demand. (2) To fully withdraw Nevada's ICS before it expires in 2036. Nevada will take their existing ICS balance, minus DCP ICS, and try to take delivery of the total remaining balance divided by the number of remaining years until EOCY 2036. This is what drives the 'discontinuous' nature of the desired delivery curve. The trace shown is likely a trace where Lake Mead is below pool elevation 1,025' most of the time from 2027-2036. SNWA is assumed to not be able to take delivery of any ICS below Lake Mead Pool elevation 1,025', causing the desired delivery to rises sharply through 2036. The desired delivery drops after EOCY 2036 because they are no longer able to withdraw their ICS. The slow uptick in desired use post 2036 due to increasing Nevada demands and shortage, resulting in unmet demand. Agree this could be better documented to improve transparency, and consider improving in-model documentation between Draft EIS and Final EIS.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
18	Batch Peer Review Report.pdf	Rule 49, pg 26	No Action	EOWYStorageForecasts: Diving into the functions - the SumDepletionsBelowVolume(Mead) does not take into consideration the shortages on water users downstream of Mead because the changes to the Depletion Requests only occur after the Powell Rules have fired and the individual water user shortages aren't incorporated into the forecasts.	The logic in question executes on a monthly timestep. When the logic executes in the month of January, due to the execution order of all the rules, the forecast would not include the policy shortages. However, the policy shortages do get set in the month of January and would be visible for the months of February through December. These forecasts, and the annual Lake Powell balancing releases dependent on them, are recomputed monthly and therefore will account for the annual policy shortage when the logic re-executes in February; impacting the monthly distribution of the Lake Powell Water Year release, but not the annual release volume. Agree with comment and consider updating between the Draft EIS and Final EIS.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
19	Batch Peer Review Report.pdf	Rule 11, pg 26	All Alternatives	Get Priority Group Water Available: This is equationg the Depletion Requests to the water available. That does not make sense because the definition of Hydrologic Shortage is when the Depletion Requests cannot be met. I believe this should refer to a fraction of the depletion on the aggregate water user.	In RiverWare, water users have three important slots: Depletion Schedule (hold the input depletion schedules) Depletion Requested (depletions after policy adjustments are made to the input depletion schedules) Depletion (actual water user depletion) The way this logic is working, it computes the release that would need to be made to satisfy all of the desired use downstream of Mead (looking at the depletion requested slot) and sees if the actual release it can make is less than this value. If so, there are dead pool-related reductions and the reduction (referred to in ruleset as hydrologic shortage volume) is the difference between the two.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
19 cont'd					At this point, a release has been set but has not actually been released, and thus the depletion requested slots are assumed to be further shorted based on priority. It is known at this stage that the depletion requests cannot be satisfied, however this is how much water use was anticipated by each water user after accounting for shortages, etc, and the starting point to make further reductions from. After these reductions are taken into account and water users depletion requests further adjusted to absorb the dead pool-related reductions, the water shorted from SNWA is added to the release, and then it is released downstream. Additionally - using the depletion fraction potentially would not provide a 'perfect' answer either, as resetting the depletion requested slots on Lower Basin water user would impact Lower Basin reservoir inflows and outflows. Computationally, RiverWare will release the water downstream as soon as a release is set, and then adjust the release with the subsequent rules that adjust Mead's release. However, the implemented logic acknowledges that the distribution of satisfied depletions/RiverWare applied shortages is incorrect, and uses the depletion requested slots to redistribute the RiverWare applied shortages by reducing the upstream depletion requested slots and ensuring the water gets where it needs to go as per the assumed priority-based shortages.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
20	Batch Peer Review Report.pdf	Rule 10, pg 26	All Alternatives	Hydrologically Short Water Users: Assigns the hydrologic shortage on water users by distributing the total hydrologic shortage volume using the same priority approach...however, is now using the Shortage.[State][Priority]_HydroShortAvail slot, which sums the Depletion Requests rather than the available depleted water to further reduce uses from.	The Depletion Requested slots are used instead of the available depleted water because the water user schedules are assumed to be adjusted prior to the release and so the volume in this slot is meaningless at this point in time. It would also take into account additional factors (such as actual instead of estimated evaporation, if a downstream reservoir did not hit their target release, etc) that in CRSS space Lake Mead is assumed to have no knowledge of and therefore it would be inappropriate to incorporate here.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
21	Batch Peer Review Report.pdf	IR NIIP, pg 26	All Alternatives	Fucntion CalcNIIPGWStorage uses AgUsesNavajoIndianIrrigationProject:AgricultureTribalPL.Fraction GW Return Flow, but cannot find this slot on model workspace.	Initial development of the groundwater object used a return flow method on the AgUsesNavajoIndianIrrigationProject aggregate diversion water users called 'SW GW Fractional Split' that was later abandoned because it did not allow for the appropriate routing of salinity. Currently, the model has no return flow method applied to the water users on the AgUsesNavajoIndianIrrigationProject aggregate diversion, and all salinity is passed to the downstream aggregate diversion site (SJBelowNavajo) while the return flow is passed to a bifurcation object that splits the water and passes some to SJBelowNavajo aggregate diversion as surface water and the rest to the groundwater object. This percent split is determined by a ModFlow model maintained by Keller-Blisner and gets re-run with every Natural Flow update. The percent split gets updated occasionally.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
21 cont'd					In RiverWare when this return flow method was abandoned and the AgUsesNavajoIndianIrrigationProject aggregate diversion's water user's method was changed the slots specific to the old method were never actually deleted, just hidden; this is a RiverWare issue. The function CalcNIIPGWStorage() calls one of the old method specific slots - Fraction GW Return Flow. While the slot is not seen on the workspace it still actually does exist and can be called by this function and accessed by right clicking on the slot's reference in the logic. This could create issues because while currently the percent split in the hidden slot is the percent split for the Natural Flow update being used in the alternative modeling, if the percent split changes with subsequent Natural Flow updates this slot would likely get missed in any model updates. Agree that comment would improve readability and prevent potential errors in logic execution; however, it would not change model output. Consider updating between Draft EIS and Final EIS.
22	Batch Peer Review Report.pdf	Rule 34, pg 27	Continued Current Strategies	Adjust Release to Protect 3,500 ft: The logic seems to result in the greater release of a 6 maf or Protect 3,500 ft, so it would not always protect 3,500 ft. Could be an error.	This is intentional and not an error. The Supplemental EIS to the 2007 Interim Guidelines allows for annual Lake Powell releases to be adjusted down as low as 6 maf in an effort to protect pool elevation 3,500 ft at Lake Powell, however, annual Lake Powell releases may not be adjusted lower than 6 maf.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
23	Batch Peer Review Report.pdf	Rule 26, pg 27	Continued Current Strategies	Reduce Mexico by Computed BWSCP Savings and Create BWSCP Savings: This no longer actually affects Mexico Requests in the CCS model. Potentially concerning.	In the official CRSS model prior to the Draft EIS this rule did adjust Mexico's demands. However, with the Draft EIS development, this rule and similar conservation rules compute annual and monthly conservation activity for the calendar year, then all adjustments to demands for all Lower Basin water users are now handled by rule 25 - LB Demand Adjustments (specifically, function 'Get User ICS'). Confirmed BWSCP activity and corresponding adjustments to Mexico's demands in model. Rule name should be updated.
24	Batch Peer Review Report.pdf	Multiple rules, pg 27	No Action	Repeat of Issue #3; Setting available for diversion on agricultural water users in UB	See response for Issue #10
25	Batch Peer Review Report.pdf	Multiple rules, pg 28	No Action	Repeat of Issue #3 and #10; Preventing rule from re-firing	See response for Issue #3 and Issue #10
26	Batch Peer Review Report.pdf	Rule 48, pg 29	Basic Coordination	Powell Operations Rule_UDSAlt: The minimum release specified in the documentation provided does not match the model provided by Reclamation.	The minimum release for Lake Powell in the Basic Coordination alternative documentation that was provided for peer review (5,000 cfs) was an old modeling assumption that was updated to reflect the LTEMP minimum release of 6,521 cfs in the Basic Coordination model, however it was not updated in the Basic Coordination alternative documentation document. Agree that comment would improve transparency; however, it would not change model output.
27	Batch Peer Review Report.pdf	Rule 11, pg 29	Basic Coordination	Repeat of issue #19	See response for Issue #19

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
28	Batch Peer Review Report.pdf	Rule 10, pg 29	Basic Coordination	Repeat of issue #20	See response for Issue #20
29	Batch Peer Review Report.pdf	Rule 336, pg 30	Enhanced Coordination	Set ICS Put and Take Dates_NA_DROA_On: According to the alternative description, I believe this rule should be active	The pertinent logic in the issue pertains to the assumption of PIP releases being active in the Enhanced Coordination alternative. See response for Issue #2.
30	Batch Peer Review Report.pdf	Rule 335, pg 30	Enhanced Coordination	Rule 335: Set ICS Put and Take Dates_NA_DROA_Off: This rule is currently active, which...eliminat[es] any Powell Infrastructure Protection (PIP)	See response for Issue #2
31	Batch Peer Review Report.pdf	Rule 306, pg 32	Enhanced Coordination	Set Combined Storage_EP: the description of this rule indicates a system-wide percent storage metric, but only considers Powell and Mead. The way the model is coded is consistent with the documentation.	Alternative assumptions were updated and the in-model function documentation was never updated to reflect. Agree that this is an inconsistency and the function documentation should be updated to reflect the updated modeling assumptions; however, the function is executing as expected and no changes to the logic are needed. Consider updating between Draft EIS and Final EIS.
32	Batch Peer Review Report.pdf	Rule 252, pg 32	Enhanced Coordination	DROA All Months Sets Flaming Gorge Daily April to July Schedule: Rule fires multiple times because it does not have any execution constraints; more of an efficiency thing because it is believed to always evaluate to the same value.	Agree that this comment would improve model efficiency; however it is not believed it would not change model output. Consider updating between Draft EIS and Final EIS.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
33	Batch Peer Review Report.pdf	Rule 245, pg 33	Enhanced Coordination	DROA Release Before Forecast Future Storage: This rule cannot fire with the most recent targets because constraining ExtendedOperaitions.DROA_May1Target is not set until Rule 83 DROA May1Target. It therefore would fire out of order. It might work because Rule 83 sets the values into the future, but will always be operating on the May 1st target set on the previous year as opposed to the current one.	No PIP (previously referred to as DROA) releases are modeled in the Enhanced Coordination Alternative (see Issue #2). Agree the inclusion of logic in the Enhanced Coordination ruleset can cause confusion; however, edits to this logic would not change model output as this logic does not execute in the Enhanced Coordination Alternative. Consider removing logic between Draft EIS and Final EIS.
34	Batch Peer Review Report.pdf	Rules 182 and 159, pg 33	Enhanced Coordination	Sum FPP Unused Tribal for JPs and Unused Tribal Desired Put: These rules are confusing and redundant. In 182 - dislike the UnusedTribal_FPP tag on both individual tribes and the aggregating water user, especially after it has been subjected to the 10% factor (e.g. FtYumaReservationPriority1:FtYumaReservation.UnusedTribal_FPP gets aggregated into CAPDiversion:CAPDiversion.UnusedTribal_FPP*.1). These slots therefore mean very different things on these users and will lead to confusion.	Agree that comment would improve efficiency and readability; however, it would not change model output. Consider updating and/or improving documentation between Draft EIS and Final EIS.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
35	Batch Peer Review Report.pdf	172, 167, 166, pg 33	Enhanced Coordination	Check Shortage Distribution if protection Pool is Enabled and Initialize Slots, Calculate Shortage Mitigation Actual Conversion from FPP, this rule becomes useless in the Pro-rata because there is no shortage mitigation allocated to CAP, MWD, SNWP. Flagged because it is misunderstood.	The Protection Pool is designed to work differently based on the shortage distribution scheme being used. In a priority-based shortage distribution scheme Protection Pool water is assumed to be distributed to specific water users as takes, while in a pro-rata shortage distribution scheme the total policy shortage volume for the Lower Basin is reduced instead of reducing the shortage to individual water users. While the enhanced coordination alternative distributes shortages by pro-rata, Reclamatino developed assumptions for priority-based shortages that were not used in the Draft EIS.
36	Batch Peer Review Report.pdf	Rules 127, 65, pg 34	Maximum Flexibilities	CR Objective_Critical Elevations_Powell vs CR Objective_Grand Canyon: There is an inconsistency in the approach used to model these two objectives. Both rules will reduce releases to keep water in Lake Powell to transfer water to Lake Powell from Lake Mead. However when this is done to protect Critical Elevations, the running balance is set to zero. When it is done to protect the Grand Canyon, the running balance at Powell increases.	Agree with comment - the running balance at Lake Powell needs to be increased to account for the transferred water. This only occurs in the portion of the logic where the volume needed for transfer exceeds what is available. Consider updating between Draft EIS and SEIS.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
37	Batch Peer Review Report.pdf	Rule 116, pg 36	Maximum Flexibilities	Check Annual LB Shortage Volumes_NGO: This rule triggers a stop when the re-summed policy shortage from the water users does not match the expected policy shortage. The values are supposedly rounded to two decimal places, however found that the rule stopped the run when the values were off with several more significant digits. Recommend a threshold exceedance rather than an absolute.	Agree that comment could improve model efficiency; however, depending on the threshold selected, this could impact model output. Consider updating rule between the Draft EIS and Final EIS.
38	Batch Peer Review Report.pdf	Expression Slot, pg 36	Maximum Flexibilities	Effective Powell Storage: Frequent instances were noted when the Powell.Effective storage became unstable and often negative.	Operations in this alternative are using the percent storage at CRSP reservoirs in the Upper Basin, and in very dry years Lake Powell's effective storage can go negative if the balance of the Conservation Reserve water in Lake Powell is large enough, which could potentially draw the computed CRSP storage negative too. Even if the CRSP and total system storages remain positive, the negative Lake Powell effective storage would draw the these volumes down lower than they would be if Lake Powell's effective storage were capped at zero, impacting Lake Powell's primary release. Consider discussing logic behavior to determine if this in intended or desired behavior and make updates as necessary between Draft EIS and Final EIS.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
39	Batch Peer Review Report.pdf	Rule 316, pg 37	All Alternatives (mentioned specifically in Supply Driven)	Set ICS Put and Take Dates: This model has ICS and DCP actively going until 2060, even though these existing programs are supposed to end. It appears that the contributions tables are zeroed out instead of the end dates in this rule set to 2026. In principle this could yield the same result, but many rules will be executed in this alternative that do not in the others, landing a significant chance for unintended differences between this and the other alternatives.	All alternatives have a version of this rule have DCP and ICS 'enabled' in the background. The ability to turn off ICS was developed, tested, and implemented in the Official CRSS model and was used in the alternative models for simplicity with the existing model framework. The logic does require ICS and DCP to execute to prevent model failure, but forces these mechanisms to solve to zero for all creation, delivery, and conservation balances. Setting the policy end dates to 2026 will have a similar effect to turning off ICS activity in the model by preventing ICS and DCP contributions or the delivery of stored ICS water. Would not change model output, but agree that removing would likely improve model run-time and the clarity of the model logic.
40	Batch Peer Review Report.pdf	Rule 310, pg 37	Supply Driven	Powell Deficit for PIP: Clearly by design, but this definition of a forecasted deficit differs substantially from other alternatives, therefore will be difficult to compare this individual effect.	Done intentionally in the Supply Driven Alternative to explore a wider range of potential operations; not an error.
41	Batch Peer Review Report.pdf	Rule 224, pg 37	Supply Driven	PIP Forecast FG Outflow and Storage: Rule fires every month and revises forecast until next year's April, but it always fails from January to March	Could not reproduce error in the model. Logic does not execute when PIP releases are triggered and slots set by this rule will remain 'NaN'. Confirmed across multiple traces that this rule will set a volume in the months of January through March when PIP releases are triggered for these months.

Issue #	Document	Location w/in Doc	Affected Model(s)	Issue Description	Reclamation Response
42	Batch Peer Review Report.pdf	Rule 157, pg 38	Supply Driven	Calc Static Shortage volumes_Specific Water Users Shortages Above 1.5maf_Transfer: This rule assigns hardcoded number and looks like a temporary measure. I believe the values it assigns are already getting overwritten. Reclamation should verify and remove this rule if so.	Logic was developed when exploring potential shortage distribution methods and will not execute with the final shortage distribution methods used in the Supply Driven alternative. Agree that comment would improve readability; however it would not change model output. Consider updating between Draft EIS and Final EIS.

Attachment 2 – Batch Peer Review for Colorado River Simulation System (CRSS) Modeling of Post-2026 Alternatives Summary

Summary of key results from the Batch Peer Review for Colorado River Simulation System (CRSS) Modeling of Post-2026 Alternatives

An external peer review was conducted on the models developed by the Bureau of Reclamation in support of the development of the Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead. Six models were reviewed that simulate the alternatives presented for consideration within the Environmental Impact Statement. These include a No Action Alternative (NA), a Continued Current strategies Alternative (CCS), a Basic Coordination Alternative (FC), an Enhanced Coordination Alternative (EC), a Maximum Operational Flexibility Alternative (MOF), and a Supply Driven Alternative (SD).

While no concerns were found that would invalidate the results of the modeling exercise, several issues were identified that should be verified as concerns in the Draft EIS and remedied between the development of the Draft EIS and the Final EIS document. Three key issues of concern are highlighted in this summary, while others are described in additional reporting provided to Reclamation.

Key Issue 1: Consistency in transferring stored water accounts

According to the descriptions provided for the No Action and Basic Coordination Alternatives, water previously conserved and stored in Lower Basin reservoirs under Intentionally Created Surplus (ICS), Lower Basin Drought Contingency Plan (DCP), Intentionally Created Mexico Allocation (ICMA) and Binational Water Scarcity Contingency Plan (BWSCP) can be can be withdrawn according to those plans over time, despite an assumption in these alternatives of the termination of these programs. However, the model output of the No Action Alternative initially provided by Reclamation did not reflect any previously stored volumes in these accounts nor demonstrate how these accounts would be used over time. A verification of whether the model used to produce the results of this DEIS included or excluded the graduated depletion of these accounts is necessary. In contrast, the Basic Coordination Alternative does properly model this previously stored water and its withdrawals over time. All other alternatives assume some continuation of conservation and storage, and existing stored water is assumed to be transferred into these programs according to the alternative designs.

The impact of this issue is expected to be isolated to the results of the No Action Alternative and particularly in the initial 10 years of the model runs when the majority of this previously stored water is expected to be used by the Lower Basin States and Mexico, yet with some impact until 2057 when some water from the DCP is expected to be available.

Key Issue 2: Powell Infrastructure Protection in the Enhanced Coordination Alternative

As described in the documentation provided for the Enhanced Coordination Alterative, Powell Infrastructure Protection (PIP) releases from the Upper Basin reservoirs of Flaming Gorge, Navajo, and the Aspinall Unit are to be invoked when Lake Powell's physical elevation is projected to go below 3,525 feet in April or August. However, the results provided did not reflect these contributions of supplemental releases. The cause of this was identified to be an incorrect rule being used that nullified the PIP releases. A verification of whether the model used to produce the results of this DEIS included or excluded PIP releases should be done by Reclamation.

The impact of this omission was evaluated by comparing full multi-trace executions of the Enhanced Coordination model (using the mid-elevation initial conditions only), with and without the PIP rules operating. Exceedance percentages of Lake Powell pool elevations revealed notable differences only in the lowest 15% of pool elevations when considering all time steps and across 400 traces. Within this limited range of dry conditions, the magnitude of these differences was notable with elevation differences at different exceedance levels (i.e. irrespective of individual traces or time steps) reaching a maximum of 23 ft at extreme low occurrences of events (< 0.5%). While it is unlikely that this omission of PIP releases will result in significant differences in the aggregated distributions presented in this DEIS, significant differences would be apparent when considering individual traces during hydrologically constrained conditions.

Key Issue 3: Repeated execution of Upper Basin delivery restriction rules

Water supplies and uses in the Upper Basin are simulated using a relatively course representation in CRSS, including aggregate water user objects representing multiple diversion and depletions. To simulate and highlight shortages faced by these water users on the model mainstem and unmodeled tributaries, Reclamation adopted a method by which diversion and depletion requests are input to the model, alongside five rules that apply limits to meet the associated demands as a static percent of natural flow available at their respective points of diversion. By default, RiverWare assumes that all water is available to water users at their point of diversion, and these five rules scale down the *Available for Diversion* slots on the reaches adjacent to groups of aggregate water users to represent diffuse hydrologic shortages in the Upper Basin. Each scaling factor is calibrated by Reclamation using the downstream gage. However, these rules were implemented without explicit execution constraints that limit their ability to fire multiple times. As a result, each time one of the rules is placed back on the agenda, the *Available for Diversion* slot inadvertently gets scaled further towards zero, resulting in Upper Basin users not depleting sufficient water and allowing extra water to inadvertently reach Lake Powell. This was particularly concerning for the alternatives that included Powell Infrastructure Protection rules.

The occurrence of multiple rule executions was analyzed across all the models provided by Reclamation. The issue occurred in the CCS, Basic Coordination, and Enhanced Coordination models, but not in the Maximum Operational Flexibility or Supply-Driven models. The No Action model did have constraints on the equivalent rules and therefore this issue was not of concern in this model. The frequency of occurrence of this issue was rare and appeared to only be affecting the fifth rule (Short Users 5 Above Powell), which affects two Colorado Mainstem diversions and seven diversions on the San Juan. This rule gets re-triggered by PIP activity in Navajo Reservoir. Although some model runs were affected with up to 212 of 400 traces, the actual number of time steps was less than 0.2%. It is recommended to constrain the possibility of any of these rules from firing multiple times.

Several other minor concerns were identified in the batch peer review, but none was expected to have a significant effect on the model output. The three areas of concern described in this summary, along with the other minor concerns provided in the full peer review report, should be considered and addressed prior to the production of the Final EIS analysis.

Attachment 3 – Batch Peer Review Plan for Colorado River Simulation System (CRSS) Modeling of Post-2026 Alternatives Report

Batch Peer Review for Colorado River Simulation System (CRSS) Modeling of Post-2026 Alternatives

Introduction

The analysis underpinning the majority of the ongoing Colorado River Post-2026 Operations Environmental Impact Statement uses the Colorado River Simulation System (CRSS). Starting with a Federal Register Notice in June 2022, United States Bureau of Reclamation (Reclamation) formally began the process of collecting and testing strategies for future management of the Colorado River. This includes the operations of the two major federal infrastructures of Glen Canyon Dam and Hoover Dam, which forms Lake Powell and Lake Mead respectively, and allocations to water users in the Lower Basin states of Arizona, Nevada and California. To develop and test potential management strategies, variations of CRSS model were developed to simulate the operations of the reservoirs using a wide variety of potential hydrologic scenarios. This report describes a peer review process to assess the various CRSS models developed for this purpose, document the findings, and identify any potential concerns.

Contents

Background

This CRSS model was developed in the late 1970s using FORTRAN code primarily as a planning tool for the operations of Lake Powell and Lake Mead. The model was converted to the modern RiverWare software in the 1990's and has been used in successive EIS processes since 2000, including the development of the Colorado River Interim Surplus Guidelines (2001), the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (2007), the Agreement Concerning Colorado River Drought Contingency Management and Operations (2019), the Supplemental Environmental Impact Statement for Near-term Colorado River Operations (2024), and well as the negotiated Minute 319 and 232 between the United States and Mexico, signed in 2012 and 2017 respectively.

As initially described in Reclamation's Description of Alternatives (2024) for the Post-2026 process and expanded upon through multiple stakeholder engagements and presentations, two versions of a baseline, labeled *No Action* and *Continued Current Strategies* (CCS), as well as 4 new alternatives including *Basic Coordination* (BC), *Enhanced Coordination* (EC), *Maximum Operational Flexibility* (MOF) and *Supply-Driven* (SD) Alternatives have been identified for analysis. Two variations of the *Supply-Driven* (SD) alternative have been developed including one using a priority-based system for allocating shortages to Lower Basin water users and another using a pro-rate allocation of shortages to Lower Basin water users. Variations of the CRSS model were developed for each of these alternatives. Each of these alternative models were developed from a pair of official models managed by Reclamation for long-term scenario planning. One model assumed that after 2026 the management of the river would revert to the pre-2007 assumptions (No Action) with limited existing authorities for managing shortages. The second model assumed river would be managed beyond 2026 according to the assumptions embedded up to the 2019 Drought Contingency Management and Operations for managing the river (Continued Current Strategies). The models define two 'baselines' and the 4 new alternatives differ significantly from these two baseline models in many respects. Reclamation has been in the process of developing these four alternatives for over a year with a staff of approximately 8 professional modelers with strong backgrounds in water resource engineering and programming. The Reclamation team has a robust process of internal Quality Assurance and Quality Control (QA/QC) to ensure the accuracy of the models produced; however, different individuals have different programming styles and potential errors in any such complex modeling process is not unexpected. The overarching objective of this external peer review was to provide a secondary review of the models provided by Reclamation to identify any potential areas of concern.

Two questions are asked in this peer review process:

Question 1: Did the modeling approach fully capture the set of operating assumptions associated with the alternative?

Question 2: Are there operating assumptions identified in the review that are incompletely or incorrectly modeled in a way that substantively affects model output?

Given the two baseline models were developed prior to this Post-2026 process, less emphasis is given to the logic embedded within them. Furthermore, these baseline models contain significant amounts of logic that include, and have evolved from, logic that was developed by many individuals since the 1970s. Although Reclamation has been undergoing a substantial effort to document this historical logic and that which has been developed in recent decades, a notable amount of logic in CRSS remains undocumented, rendering inherent limitations to third-party interpretation. Regardless, a general analysis of the model structure and rule logic was performed for these two baseline models, and the inputs and outputs were compared alongside those from the four alternatives developed for the Post-2026 models. These four new models, which have been developed by Reclamation staff with a greater focus on third-party accessibility, have gone through a comparatively more thorough review process. At the request of Reclamation, this study focused on the logic that differentiates these new alternatives rather than the logic that has long been part of the CRSS model or parts that are not expected to differ between the models.

Given the complexity of the models developed over decades, the multiple developers involved, and the nature of questions posed, it is not expected that all potential errors can be identified by this peer review.

Methodology

The peer review process consisted of three elements including a comparative analysis of selected inputs, a comparative analysis of selected outputs, and a review of logic pertinent to the Post-2026 process that are embedded in the model and rule sets provided. Not all elements of the models were reviewed, as the focus was on identifying operational assumptions most pertinent to the Post-2026 process. Reclamation's 2024 Alternatives Report and subsequent model descriptions provided the basis for what the models were expected to simulate, alongside oral clarifications of specific pieces of logic provided by Reclamation.

Input Analysis

The inputs to each of the models were extracted and compared between each other and with the documentation provided by Reclamation. Values and consistency of data inputs (i.e. *Input slots* in RiverWare parlance) for Reservoir conditions, diversion and depletion schedules for water users, and banking assumptions are shown in Tables 1 through 7 below.

Reservoirs

		J	F	M	A	M	J	J	A	S	O	N	D
BlueMesa.Pool Elevation	Ft	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	7487.07	7482.96	7478.24	7477.52
BlueMesa.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0.00
Crystal.Pool Elevation	Ft	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	6753.04	6753.04	6753.04	6753.04
Crystal.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0.00
FlamingGorge.Bank Storage	acre-ft	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	116036.92
FlamingGorge.Pool Elevation	Ft	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	6023.52
FlamingGorge.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	408.20
Fontenelle.Pool Elevation	Ft	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	6496.78	6494.24	6490.89	6486.07
Fontenelle.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	278.00
Havasu.LCR Input Efficiency	NONE	0.81	0.82	0.81	0.81	0.82	0.81	0.81	0.81	0.81	0.82	0.81	0.75
Havasu.Pool Elevation	ft	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	447.50	447.50	447.50	446.50
Havasu.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	577.90
Mead.Bank Storage	acre-ft	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	563841.08
Mead.Pool Elevation	ft	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	1063.12	1063.10	1062.34	1063.29
Mead.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	564.50
Mohave.LCR Input Efficiency	NONE	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Mohave.Pool Elevation	ft	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	640.01	633.00	635.00	639.51
Mohave.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	564.50
MorrowPoint.Pool Elevation	ft	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	7153.73	7153.73	7153.73	7153.73
MorrowPoint.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0.00
Powell.Bank Storage	acre-ft	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	4797686.26
Powell.Outflow	acre-ft/month	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	480000	500000	600000
Powell.Pool Elevation	ft	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	3579.52	3578.70	3577.78	3574.39
Powell.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	497.50
McPhee.Diversion Salt Concentration	mg/l	130	130	130	130	130	130	130	130	130	130	130	130
McPhee.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	250
Navajo.Pool Elevation	ft	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	6038.66	6039.72	6040.07	6039.82
Navajo.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	148.30
Starvation.Hydrologic Inflow	acre-ft/month	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Starvation.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	400.00
Strawberry.Available for Diversion	acre-ft/month	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Strawberry.Outflow	acre-ft/month	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

Strawberry.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	400.00
TMD Reservoir.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0.00
TaylorPark.Inflow Salt Concentration	mg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TaylorPark.Pool Elevation	ft	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	9311.50	9310.00	9308.50	9308.16
TaylorPark.Reservoir Salt Concentration	mg/l	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0.00

Table 1: Initialization Timesteps – No Action

	CCS	BC	EC	MOF	SD-65
BlueMesa.Pool Elevation	Consistent	Inconsistent Additional values 7-8/26	Inconsistent Additional values 7-8/26	Consistent	Inconsistent Additional values 1-8/26
BlueMesa.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent
Crystal.Pool Elevation	Consistent	Inconsistent Additional values 7-8/26	Inconsistent Additional values 7-8/26	Consistent	Inconsistent Additional values 1-8/26
Crystal.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent
FlamingGorge.Bank Storage	Consistent	Consistent	Consistent	Consistent	Consistent
FlamingGorge.Pool Elevation	Consistent	Inconsistent Additional values 7-11/26	Inconsistent Additional values 7-11/26	Consistent	Inconsistent Additional values 7-11/26
FlamingGorge.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent
Fontenelle.Pool Elevation	Consistent	Inconsistent Additional values 7-8/26	Inconsistent Additional values 7-8/26	Consistent	Inconsistent Additional values 1-8/26
Fontenelle.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent
Havasu.LCR Input Efficiency	Consistent	Consistent	Consistent	Consistent	Consistent
Havasu.Pool Elevation	Consistent	Inconsistent Additional values 7-8/26	Inconsistent Additional values 7-8/26	Consistent	Inconsistent Additional values 1-8/26
Havasu.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent
Mead.Bank Storage	Consistent	Consistent	Consistent	Consistent	Consistent
Mead.Pool Elevation	Consistent	Inconsistent Additional values 7-8/26	Inconsistent Additional values 7-8/26	Consistent	Inconsistent Additional values 1-8/26
Mead.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent
Mohave.LCR Input Efficiency	Consistent	Consistent	Consistent	Consistent	Consistent
Mohave.Pool Elevation	Consistent	Inconsistent Additional values 7-8/26	Inconsistent Additional values 7-8/26	Consistent	Inconsistent Additional values 1-8/26
Mohave.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent
MorrowPoint.Pool Elevation	Consistent	Inconsistent Additional values 7-8/26	Inconsistent Additional values 7-8/26	Consistent	Inconsistent Additional values 1-8/26
MorrowPoint.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent
Powell.Bank Storage	Consistent	Consistent	Consistent	Consistent	Consistent
Powell.Outflow	Consistent	Consistent	Consistent	Consistent	Consistent
Powell.Pool Elevation	Consistent	Inconsistent	Inconsistent	Consistent	Inconsistent

		Additional values 7-8/26	Additional values 7-8/26		Additional values 1-8/26
Powell.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent
McPhee.Diversion Salt Concentration	Consistent	Consistent	Consistent	Consistent	Consistent
McPhee.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent
Navajo.Pool Elevation	Consistent	Inconsistent Additional values 7-8/26	Inconsistent Additional values 7-8/26	Consistent	Inconsistent Additional values 1-8/26
Navajo.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent
Starvation.Hydrologic Inflow	Consistent	Consistent	Consistent	Consistent	Consistent
Starvation.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent
Strawberry.Available for Diversion	Consistent	Consistent	Consistent	Consistent	Consistent
Strawberry.Outflow	Consistent	Consistent	Consistent	Consistent	Consistent
Strawberry.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent
TMD Reservoir.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent
TaylorPark.Inflow Salt Concentration	Consistent	Consistent	Consistent	Consistent	Consistent
TaylorPark.Pool Elevation	Consistent	Inconsistent Additional values 7-8/26	Inconsistent Additional values 7-8/26	Consistent	Inconsistent Additional values 1-8/26
TaylorPark.Reservoir Salt Concentration	Consistent	Consistent	Consistent	No values 12/26	Consistent

Table 2: Consistency Across Models – Relative to No Action

Although differences were identified among the initial conditions of the reservoirs, they were isolated to salinity concentrations for the MOF Alternative and timesteps prior to the initialization timestep of the model (Dec 2026) for all other alternatives, therefore there are no expected impacts on the model results.

Demand Schedules

A comparison of input diversion and depletion schedules for 360 water users was conducted. It was found that Depletion Schedules and Diversion Schedules slots were identical across all models, therefore requiring no further analysis.

Reservoir Banking Assumptions

Initial ICS bank balances were extracted from all models and deemed comparable. The values and locations are listed in Tables 3-7.

	NA	CCS	BC	EC	MOF	SD
Arizona ICS.BICSInitialBalance	51,024	51,024	51,024	51,024	51,024	51,024
Arizona ICS.BrockInitialBalance	100,000	100,000	100,000	100,000	100,000	100,000
Arizona ICS.CAWCDInitialBalance	165,539	165,539	165,539	165,539	165,539	165,539
Arizona ICS.CRITInitialBalance	9,009	9,009	9,009	9,009	9,009	9,009

Arizona ICS.DCPInitialBalance	87,720	87,720	87,720	87,720	87,720	87,720
Arizona ICS.GRICInitialBalance	286,708	286,708	286,708	286,708	286,708	286,708
Arizona ICS.YDPInitialBalance	3,050	3,050	3,050	3,050	3,050	3,050
IID ICS.BICSInitialBalance	51,025	51,025	51,025	51,025	51,025	51,025
IID ICS.InitialBalance	50,000	50,000	50,000	50,000	50,000	50,000
MWD ICS.BICSInitialBalance	51,024	51,024	51,024	51,024	51,024	51,024
MWD ICS.BrockInitialBalance	65,000	65,000	65,000	65,000	65,000	65,000
MWD ICS.DCPInitialBalance	-	-	-	-	-	-
MWD ICS.InitialBalance	1,497,951	1,497,951	1,497,951	1,497,951	1,497,951	1,497,951
MWD ICS.YDPInitialBalance	24,397	24,397	24,397	24,397	24,397	24,397
Nevada ICS.BICSInitialBalance	51,024	51,024	51,024	51,024	51,024	51,024
Nevada ICS.BrockInitialBalance	400,000	400,000	400,000	400,000	400,000	400,000
Nevada ICS.DCPInitialBalance	-	-	-	-	-	-
Nevada ICS.InitialBalance	398,976	398,976	398,976	398,976	398,976	398,976
Nevada ICS.YDPInitialBalance	3,050	3,050	3,050	3,050	3,050	3,050
ICMA.BWSCPInitialBalance	175,500	175,500	175,500	175,500	175,500	175,500
ICMA.InitialBalance	150,000	150,000	150,000	150,000	150,000	150,000

Table 3: Initial Bank Balances identified in the models

Model descriptions provided for each alternative explain the assumed size and limitations of banking volumes, which were found in different parts of the individual models.

Recognizing that some models discontinue the future banking programs, the No Action, CCS and Federal Authorities models all use existing bank characteristics as included in the Mead Bank.Parameters table slot. However the NA and Federal Authorities do not utilize the Put limits.

	Max Capacity	Max Put	Max Take
	1000 acre-ft	1000 acre-ft	1000 acre-ft
0: Arizona	500	100	300
1: California	1700	400	400
2: Nevada	500	125	300
3: ICMA	1500	250	200
4: MWD	1650	NaN	NaN
5: IID	50	NaN	NaN
6: CAWCD	250	NaN	NaN
7: AZTribal	250	NaN	NaN

Table 4. Mead Bank Sizing, creation and delivery limits in No Action, CCA and Basic Coordination Alternatives

The corresponding slots in the Enhanced Coordination and Supply Driven alternative models are scalar slots on the P26_Mead_Conservation Bank object.

	AZ	CA	NV	Mex
Accumulation Limit	700,000	1,900,000	700,000	1,700,000
Creation Limit	466,667	733,333	50,000	250,000
Delivery Limit	620,000	980,000	70,000	330,000

Table 5. Mead Bank Sizing, creation and delivery limits in the Enhanced Coordination Alternative

	AZ	CA	NV	Mex
Accumulation Limit	3,000,000	3,000,000	1,000,000	1,000,000
Creation Limit	880,000	880,000	225,000	500,000
Delivery Limit	2,800,000	4,400,000	300,000	1,500,000

Table 6. Mead Bank Sizing, creation and delivery limits in the Supply Driven Alternative

In contrast to the above alternatives, the Maximum Operational Flexibility alternative has a Conservation Reserve bank that can be moved between Lake Powell and Lake Mead, with maximum total capacity of 8 maf. Of this volume, 5 is maf dedicated to contributions from the Lower Basin and 3 maf from the Upper Basin. These slots are found on P26_ConservationBank data object. There are no state-specified volumes for the bank and creation is limited only by how much users have put into the bank.

	acre-feet
P26_ConservationBank.LBMaxEOCYBankBalance	5,000,000
P26_ConservationBank.LBMaxAnnualPut	3,000,000
P26_ConservationBank.LBMaxAnnualTake	3,000,000

Table 7. Conservation Reserve Bank Sizing, creation and delivery limits in the Maximum Operational Flexibility Alternative

Other Notable Initial Conditions

Assumed flows for Lees Ferry and Paria gages prior to the model start date (January 2027) were compared with actual flow records extracted from Reclamation's HBD database. Discrepancies were identified comparing the actual flows going back to 2003. Given the 10-year cumulative flow at the Lees Ferry Compact point is near critical thresholds, this should be updated to reflect the latest gage readings.

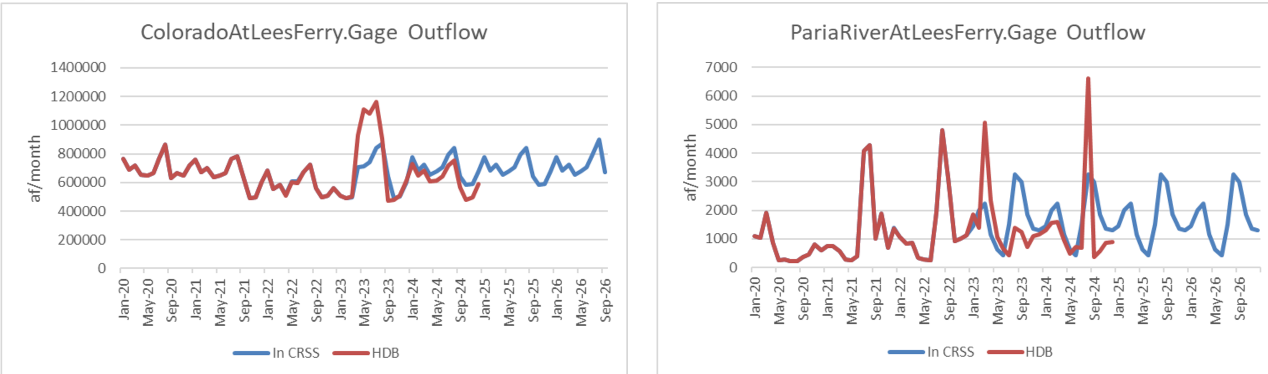

Figure 1. Inaccurate historical flows in critical gage locations

Extraneous Inputs

All models contain a significant number of unused inputs as initial conditions. Many of these slots refer to provisions developed for the surplus guidelines dating back to 2000 and the implementation of the Intentionally Created Surplus (ICS) in 2007. Several of these inputs were used for various model development efforts, and are often redundant or altogether not used, creating a significant amount of confusion as to what Reclamation considers active modeling. While it is outside of the current peer review process of modeling of the Post-2026 process, it is recommended that Reclamation remove all unused input data and only retain data being used in the model algorithms or data that is historical and accurate.

Model Output Comparison and Analysis

ICS Banking Volumes

Upon review of the model results provided by Reclamation, it became apparent that the No Action alternative does not retain previously held ICS volumes as stated in the description of alternatives. This can be seen in Figure 2, representing the maximum volumes of banked water across the No Action, CCS and Basic Coordination Alternatives.

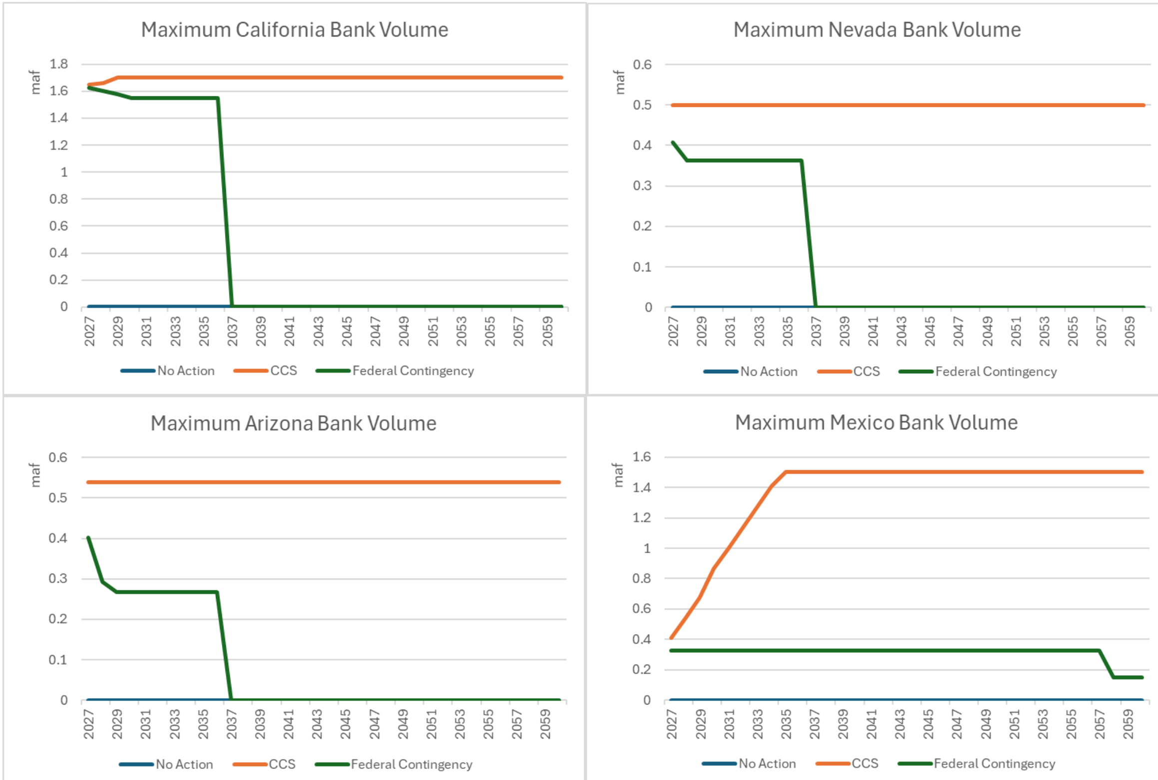

Figure 2. Maximum values of Lower Basin Banking volumes from No Action, Continued Current Strategies, and Basic Coordination Alternatives

Given the potential critical nature of this issue, Reclamation has been notified of this in advance of this report and is expected to verify if results provided for this review were indeed used in the production of the DEIS.

Accounting for Lower Basin Shortages

Several metrics were extracted that indicate cumulative potential problems across the basin. While these types of metrics may reveal problems, the exact sources of these problems are difficult to identify. Once such metric is a measurement of the ability of the model to account for all Lower Basin shortages as either Policy or Hydrologic Shortages. One simple way to identify some of these occurrences is the presence of negative flows in the downstream most reach of the model. In this case this is represented in the slot BelowImperialDamColoradoR:OverDeliveryToMexico.Outflow

Table 8 indicates the trace number, time step, and magnitude of each occurrence that resulted in negative outflows for each alternative. It is notable that the majority have the same magnitude, which is indicative of a systematic error. Of the163,200 time steps simulated (400 Traces x 34 years x 12 months/year) less than 0.0003% resulted in such conditions, with none occurring in the MOF or either distribution method used in the Supply-driven alternative.

BelowImperialDamColoradoR:OverDeliveryToMexicoOutflow
Count of Time Steps with Flows < 0

	No Action	**CCS**	**Fed Cont**	**EC**	**MOF**	**SD_65 Priority**	**SD_65 Pro-rata**
Count	2	4	2	3	0	0	0
Trace **Date** **Magnitude**	Trace 213 (Run212) 6/2057 -18584 af/mth	Trace 213 (Run212) 6/2057 -18584 af/mth	Trace 213 (Run212) 6/2057 -18584 af/mth	Trace 221 (Run 211) 6/2058 -60804 af/mth			
Trace **Date** **Magnitude**	Trace 215 (Run214) 6/2041 -18584 af/mth	Trace 214 (Run213) 6/2047 -18584 af/mth	Trace 215 (Run 214) 6/2041 -4024 af/mth	Trace 222 (Run 212) 6/2057 -18584 af/mth			
Trace **Date** **Magnitude**		Trace 215 (Run214) 6/2041 -18584 af/mth		Trace 215 (Run214) 6/2041 -18584 af/mth			
Date **Magnitude**		6/2046 -18584 af/mth					

Table 8. Number of modeled time steps where negative flows exit the modeled system

While these instances of negative flows clearly indicate areas of concern, the actual frequency of insufficient water being available to be reduced in the Lower Basin to meet hydrologic shortages is higher than the above negative outflow metric would indicate. The Shortage.HydroShortageStageDepth metrics indicates how 'deep' the hydrologic shortages to the Lower Basin cut into the Lower Basin Users. This slot indicates Stage 1) for shortages that only affect Arizona Priority 4 and Stage 1 Nevada users; Stage 2) for shortages that also impact Arizona Priority 3 & 2; Nevada remaining priority 8,7,4 & 2; and California Priority 4, 3b,3a, 2 & 1; Stage 3) for shortages that also impact Present Perfected Rights (PPRs), and Stage 4) for shortages that have cut back all uses in the Lower Basin. When Stage 4 is reached, effectively all consumptive water use gets shut off in the Lower

Basin, with some minor exceptions described below. The occurrences of the maximum hydrologic shortage stage depth is shown in Tables 9.

Number of Traces with Maximum Hydrologic Shortage Stage							
	Alternative						
Description	No Action	CCS	Fed Cont	EC	MOF	SD_65 Priority	SD_65 Pro-rata
No Hydrologic Shortage (NaN)	122	215	251	341	359	317	341
Stage 1	2	1	0	10	4	0	3
Stage 2	84	32	42	12	7	29	18
PPRs included (Stage 3)	186	144	99	27	30	52	35
All Users (Stage 4)	6	8	8	10	0	2	3
Trace Sum Check	400	400	400	400	400	400	400
Total traces with some hydrologic shortage occurring	278	185	149	59	41	83	59
Percent of Traces with some hydrologic shortage occurring	70%	46%	37%	15%	10%	21%	15%
Percent of traces with Stage 4 Lower Basin Shortage occurring at least once	1.50%	2.00%	2.00%	2.50%	0.00%	0.50%	0.75%

Table 9. The total number of traces with a maximum hydrologic depth stage across the modeled time range.

Similarly, the frequency of all individual time steps vs hydrologic stage depth is shown in Table 10.

Number of Modeled Time steps							
	Alternative						
Description	No Action	CCS	Fed Cont	EC	MOF	SD_65 Pri	SD_65 Pro
No Hydrologic Shortage (NaN)	133176	147598	149002	160391	162065	157638	159152
Stage 1	6046	2422	1088	838	10	333	1397
Stage 2	18248	9130	9829	1464	478	4089	2170
PPRs included (Stage 3)	5723	4041	3272	495	647	1137	478
All Users (Stage 4)	7	9	9	12	0	3	3
Trace Sum Check	163200	163200	163200	163200	163200	163200	163200
Percent of timesteps with some Lower Basin shortage occurring	18.40%	9.56%	8.70%	0.63%	0.70%	3.41%	2.48%
Percent of timesteps with Stage 4 Lower Basin shortage occurring	0.004%	0.006%	0.006%	0.001%	0.000%	0.002%	0.002%

Table 10. The total number of time steps at each Shortage Stage Depth.

Each time Stage 4 is reached, the combination of Policy and Hydrologic shortages exceeds the total amount of water that is made available from Lake Mead. In this case, rules in the model effectively zero the withdrawals from almost all demands below Lake Mead by setting the hydrologic shortage on almost all water users to equal their depletion requests. While one may expect no outflows downstream of the lowest reach (BelowImperialDamColoradoR:OverDeliveryToMexico), this is often not the case for various reasons, some of which are likely erroneous while others are unavoidable. Having any water exiting the system demanded further explanation. For demonstrative purposes, Table 11 indicates all the runs and time steps in the Basic Coordination model in which a Shortage.HydroShortageStageDepth = Stage 4 and lists the volume of water being discharged from the system. Selected examinations were conducted on these time steps to identify the source of these waters.

Trace	Timestep	BelowImperialDamColoradoR:OverDeliveryToMexico.Outflow
167	4/2051	97447
213	6/2057	-18584
216	5/2043	47889
216	6/2043	34896
220	1/2045	15066
217	3/2059	49304
246	4/2054	62988
391	5/2056	48417

Table 11. Example time steps of Stage 4 Shortage.HydroShortageStageDepth

Erroneous condition – No adjustment of Mead Outflows

One example provided here is for Trace 216, 5/2043 timestep. Releases from Lake Mead are made based on operations specified by the rule *Set Mead Outflow During Extreme Low Stochastic*, which resets Lake Mead outflows based on the minimum of 1) Mead Inflows less SNWP Diversion; 2) Outflows to meet current demands below Mead (constrained by a minimum release of zero); and 3) an outflow that would have been used for SNWPDiversion (Figure 3).

```
18  Set Mead Outflow During Extreme Low Stochastic
PRINT Mead.Inflow [ ]
PRINT SNWPDiversion.Total Depletion Requested [ ]
PRINT Mead.Storage [ @"t - 1" ]
PRINT CurrentDemandBelowMead ( )
Mead.Outflow [ ] = Min ( Min ( Max ( Mead.Inflow [ ] - SNWPDiversion:SNWPDiversion.Diversion Requested [ ] ,
                                     0.00 "acre-ft/month" ) ,
                               # Added in to ensure that the release is not increased beyond the total downstream demands
                               ComputeOutflowAtGivenStorage ( Mead ,
                                                              ComputeStorageAtGivenOutflow ( Mead ,
                                                                                             CurrentDemandBelowMead ( ) ) ) ) ,
                         ComputeOutflowAtGivenStorage_Critical ( Mead ,
                                                                 0.00 "acre-feet" + FlowToVolume ( SNWPDiversion:SNWPDiversion.Diversion Requested [ ] ,
                                                                                                   @"t" ) ) - 1.00 "acre-feet/month" )
```

Figure 3. CRSS logic determining Mead Outflows under extreme low hydrologic conditions

In this instance, Mead.Outflow is set based on the Mead.Inflow condition less the SNWP Diversion Request (328,396 – 39,297 = 199,099 af/month). In the *In Hydrologic Shortage* rule, the volume that needs to be shorted ($ "Shortage.TotHydrologicShortageVolume" []) is calculated as the current demands below Mead minus the limited Mead outflows (895,748 – 199,099 = 696,649 af/month). In the rule *Hydrologically Short Water Users*, the Domestic portion of this shortage is 608,919 af, which exceeds the sum of all water available to be hydrologically shorted (600,255 af) so the condition noted below does not apply and Level 4 reductions begin (Figure 4).

```
ELSE IF ( domShort <= Shortage.ArizonaStage2_HydroShortAvail [ ]
                    + Shortage.CaliforniaStage2_HydroShortAvail [ ]
                    + Shortage.NevadaStage2_HydroShortAvail [ ]
                    + Shortage.ArizonaP4_HydroShortAvail [ ]
                    + Shortage.NevadaStage1_HydroShortAvail [ ]
                    + Shortage.ArizonaPPR_HydroShortAvail [ ]
                    + Shortage.CaliforniaPPR_HydroShortAvail [ ]
                    + Shortage.NevadaPPR_HydroShortAvail [ ] ) THEN
```

Figure 4. Determination of Level 4 Hydrologic Stage Depth within 'Hydrologically Short Water Users' rule

After depletion requests are decreased to zero, the rule *Adjust Mead Release for Hydrologic Shortage Activities* increases the releases from Lake Mead by the Hydrologic Shortage volume (199,099 + 20,434 = 219,543 af/month), which is the final Mead release by the end of the timestep, regardless of the fact that almost all water users have no depletion requests. After a number of reductions in flows including 1) evaporation demands in Lake Mohave and Lake Havasu, 2) negative inflows downstream of Lake Mead, and 3) demands of the water users whose depletion requests are not zeroed out (OverDeliveryToMexico:OverDeliveryToMexico and YumaOperations:WelltonMohawkBypassFlows). A substantial portion of flow (47,889 af/month) is discharged from the BelowImperialDamColoradoR:OverDeliveryToMexico.Outflow, despite there being a Shortage.HydroShortageStageDepth of Stage 4 occurring. This is notable given the slot HydroShort_UnsatisfiedHydroShortageWater states 8664.35 af/month of unsatisfied hydrologic shortage exists while water is leaving the system unused.

The primary concern here is whether the releases from Lake Mead should be adjusted to reflect the Level 4 hydrologic depth shortage condition. This occurrence was found to be the cause of many flows leaving the system under these conditions. This model behavior is something that Reclamation should reconsider.

On the other hand, positive outflows may occur in BelowImperialDamColoradoR:OverDeliveryToMexico.Outflow during and Stage 4 shortages simply due to water being introduced as local inflows between Lake Mead and this downstream most reach that exceeds other losses. This is an unavoidable possibility in reality and would not be considered a potential modeling concern.

In addition to the cases of Stage 4 Shortages result in non-zero flows below the system, there are many other cases when the OverDepletionToMexico is used to compensate for minor errors in the allocation of Lower Basin Shortages, and these occur frequently and regardless of the value of Shortage.HydroShortageStageDepth. Figure 5 shows where these can be readily seen in model runs and Figure 6 shows the independence of these errors to HydroShortageStageDepth. While all are small in magnitude these should not be occurring, and especially when sufficient water is available from Lake Mead to meet other demands (Stage 1 -Stage 3 Shortage.HydroShortageStageDepth). A detailed diagnosis of this issue is beyond the scope of this peer review and should be conducted by Reclamation.

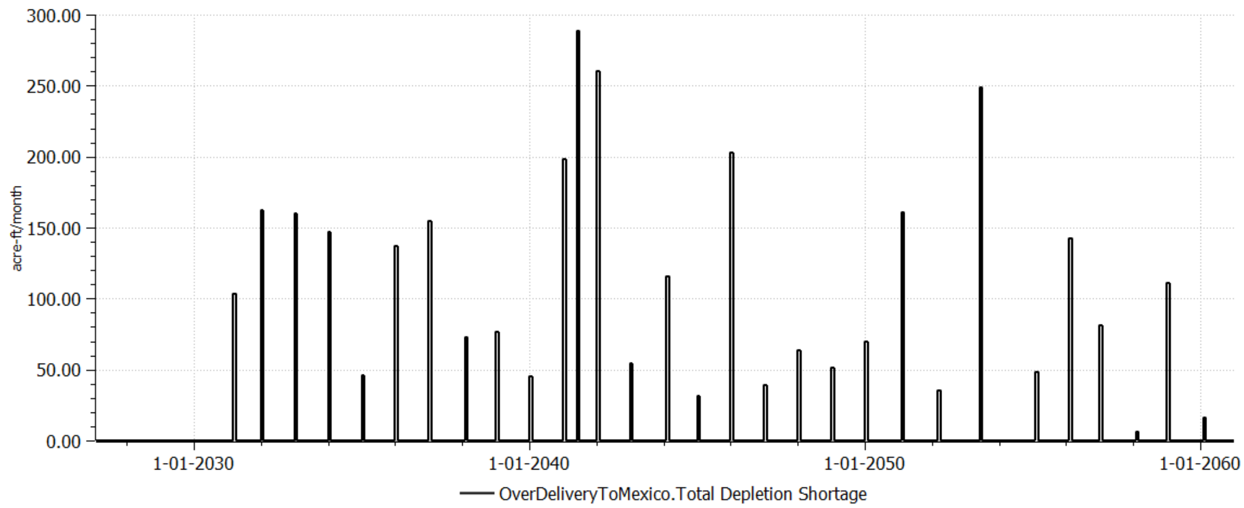

Figure 5. Single trace occurrences (Trace 215 No Action): of insufficient water reaching the end of the system being absorbed by the OverDeliveryToMexico water user

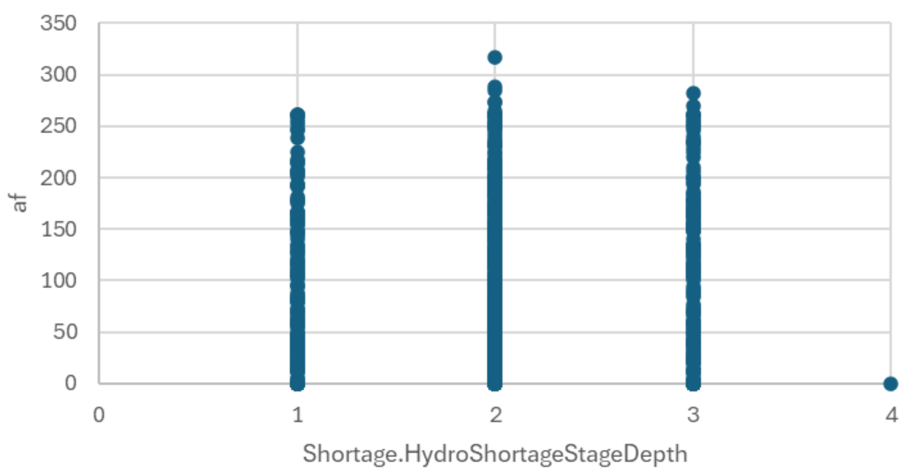

Figure 6. Volumes categorized by HydroShortageStageDepth of insufficient water reaching the end of the system and absorbed by the OverDeliveryToMexico water user (No Action).

Gage Comparisons

An analysis was conducted that compared modeled gage flow outputs across alternatives to observe when they align and when they differ. It is expected that some gage flows, particularly in the Upper Basin and tributaries, should align, while others gages downstream of storage reservoirs are not expected to align. Based on the design logic of the alternatives, these gages were grouped as follows:

Group1: All these gages are on tributaries that have no upstream modeled storage. The outflows from the following gages should be identical across all runs and timesteps.

- LittleSnakeNearLilyGage
- PariaRiverAtLeesFerryGage
- SanRafaelNearGreenRiverUTGage
- VirginAtLittlefieldGage
- WhiteNearWatsonGage
- YampaAtDeerlodgeGage
- YampaNearMaybellGage

Group 2: The outflows from the following Upper Basin gages are downstream of some reservoirs but upstream of all reservoirs subjected to Powell Infrastructure Protection (PIP) operations so they would be still expected to be identical between all models.

- ColoradoNearCameoGage
- ColoradoNearGlenwoodSpringsGage
- DoloresNearCiscoGage
- DuchesneNearRandlettGage
- GreenAtGreenRiverWYGage
- GreenBelowFontenelleGage
- TaylorBelowTaylorParkGage

Group 3: All these gages are downstream of at least one reservoir that is subject to PIP operations, thus differing reservoir releases and gages flows are expected

- ColoradoNearCiscoGage
- ColoradoNearCO_UTStateLineGage
- GreenAtGreenRiverUTGage
- GreenNearGreendaleGage
- GreenNearJensenGage
- GunnisonAtCrystalGage
- GunnisonBelowBlueMesaGage
- GunnisonNearGrandJunctionGage
- SanJuanNearArchuletaGage
- SanJuanNearBluffGage

Group 4: The following mainstem Lower Basin gages are downstream of Lake Powell and are expected to differ between all alternatives.

- ColoradoAtImperialDamGage
- ColoradoAtLeesFerryGage
- ColoradoBelowDavisGage
- ColoradoBelowHooverGage
- ColoradoBelowParkerGage
- ColoradoNearGrandCanyonGage
- LeeFerryCompactPointGage

Gage Group	Gage Name/File Name	No Action	CCS	Basic Coordination	Enhanced Coordination	Maximum Operational Flexibility	Supply Driven - 65 Priority	Supply Driven - 65 Pro-rata
1	LittleSnakeNearLilyGage	84019618	84019618	84019618	84019618	84019618	84019618	84019618
1	PariaRiverAtLeesFerryGage	4200938	4200938	4200938	4200938	4200938	4200938	4200938
1	SanRafaelNearGreenRiverUTGage	11462439	11462439	11462439	11462439	11462439	11462439	11462439
1	VirginAtLittlefieldGage	36573406	36573406	36573406	36573406	36573406	36573406	36573406
1	WhiteNearWatsonGage	103996143	103996143	103996143	103996143	103996143	103996143	103996143
1	YampaAtDeerlodgeGage	314960900	314960900	314960900	314960900	314960900	314960900	314960900
1	YampaNearMaybellGage	230941283	230941283	230941283	230941283	230941283	230941283	230941283
2	DuchesneNearRandlettGage	53320950	53320950	53320950	53320950	53320950	53320950	53320950
2	TaylorBelowTaylorParkGage	30835054	30835054	30835054	30835054	30835054	30835054	30835054
2	ColoradoNearCameoGage	543228407	541048436	541048436	541048436	541048436	541048436	541048436
2	ColoradoNearGlenwoodSpringsGage	328702901	327584442	327584442	327584442	327584442	327584442	327584442
2	DoloresNearCiscoGage	78774490	78807761	78807761	78807761	78807761	78807761	78807761
2	GreenAtGreenRiverWYGage	247224339	246860350	246860350	246860350	246860350	246860350	246860350
2	GreenBelowFontenelleGage	256207343	256391883	256391883	256391883	256391883	256391883	256391883
3	ColoradoNearCiscoGage	939672250	933098472	933075776	931822727	931822727	931822727	931822727
3	ColoradoNearCO_UTStateLineGage	860897759	854290712	854268017	853014967	853014967	853014967	853014967
3	GunnisonAtCrystalGage	240451125	241153706	241115551	240490954	240490954	240490954	240490954
3	GunnisonBelowBlueMesaGage	201425534	202128111	202089957	201465361	201465361	201465361	201465361
3	GunnisonNearGrandJunctionGage	341501975	342680717	342658021	341404970	341404970	341404970	341404970
3	SanJuanNearArchuletaGage	107247835	107700200	107698713	107577122	107577122	107577122	107577122
3	SanJuanNearBluffGage	239191867	238511715	238510744	238380964	238380964	238380964	238380964
3	GreenAtGreenRiverUTGage	782181784	788493970	788676135	777462814	777462814	787603809	787603809
3	GreenNearGreendaleGage	289525805	296320351	296503872	285238611	285238611	295588991	295588991
3	GreenNearJensenGage	604486699	611281247	611464768	600199509	600199509	610549887	610549887
4	ColoradoAtLeesFerryGage	1919165583	1909317518	1924042325	1897245276	1933976459	1979793136	1979793136
4	ColoradoNearGrandCanyonGage	1989083591	1979235536	1993960369	1967163287	2003894530	2049711210	2049711210
4	LeeFerryCompactPointGage	1923366442	1913518390	1928243226	1901446147	1938177389	1983994070	1983994070
4	ColoradoAtImperialDamGage	1248969599	1240078706	1257276157	1128912261	1251883617	1269585211	1206181803
4	ColoradoBelowDavisGage	1920138034	1889281038	1869533647	1807516677	1820765214	1861395179	1848988571
4	ColoradoBelowHooverGage	1939607211	1908873237	1888954899	1826968870	1840223360	1880911758	1868466971
4	ColoradoBelowParkerGage	1475627064	1467856511	1484883916	1333025247	1477275875	1488149023	1406265512

Table 12. Alignment of total gage flows across all time steps and traces

The values in Table 12 reflect the sum of all data at these inflow locations across time and runs. Like color coding reflects where values match along a row, and different colors reflect where these sums differ.

Most similarities and differences align with what is expected from this gage comparison analysis, however unexpected results occurred.

As expected, all gage flows in Group 1 are identical.

The first unexpected result is in Group 2 (highlighted yellow in Table 12), which indicates differences between the No Action Alternative and the other alternatives. Reasons for the differences were the identified during the comparative ruleset analysis (described below) where it was noted that several rules governing the operation of Upper Basin Reservoirs differed between the No Action Alternative compared to all other alternatives.

1) The limitations to *Available For Diversion* slot on reaches that supply water to Upper Basin Agriculture users were aggregated in the No Action Alternative to two rules and broken up into stages in the other alternatives, only affecting diversions after water is made available from upstream reservoirs. As expected, this should have no effect on reaches upstream of all reservoirs, but it does influence the order of execution of rules and the subsequent results, particularly below reservoirs.
2) Many, but not all, rules related to Upper Basin Reservoirs have gained a constraint that does not allow rules to successfully file multiple times NOT "HasRuleFiredSuccessfully"("ThisRule"). Inserting this logic avoids unintended multiple executions of rules and significantly affects the order of rule execution, therefore would influence results downstream of these reservoirs

These two rule differences explain the differences in modeled flows for those gages listed in Group 2, and specifically where there are differences between the No Action Alternative and the other alternatives. All rules should use identical logic for applying limitations to reach 'Available for Diversion' slots on reaches that are shorted. Furthermore, all rules should have identical constraints that do not allow the rules to be executed multiple times. This is particularly relevant for locations and rules that are not intended to differ between alternatives.

The second unexpected result identified in the gage comparison was the alignment between most of the gages in Group 3 between the Enhanced Coordination and Maximum Operational Flexibility alternatives. This was particularly notable given the Enhanced Coordination alternative is designed to make PIP releases from Flaming Gorge, Navajo, or the Aspinall Unit reservoirs, while the Maximum Operational Flexibility is not. Upon further investigation of this issue, it was noted that no PIP releases were occurring from either model, and a rule (Set ICS Put and Take Dates_NA_DROA_Off) was found to be active and incorrectly limiting the function of PIP releases in the Enhanced Coordination Alternative. Reclamation was promptly notified of this potential issue.

Another result was noted in Group 3, where the flows in some but not all Upper Basin gages in the Supply-Driven alternatives matched the flows in the Maximum Operation Flexibility alternative. Upon closer inspection, those that differed were on the Green River while gages on the Colorado above the confluence with the Green River, and gages on the San Juan River align. This is explained by Reclamation's assumption in the design of the Supply-Driven alternative that the entire volume for PIP releases would be provided from Flaming Gorge based on the Upper Basin States logic. As a result, this issue was not considered to be a potential error.

Finally, another expected result was observed between the Priority-based pro-rata Supply-Driven Alternatives where differences only occurred downstream of Lake Mead.

Identifying when things differ and were expected to be the same helps to identify potential areas of concern, however identifying the exact reason (or multiple reasons) for differences in such aggregate values is beyond the scope of a peer review. Reclamation was notified of the two potential errors identified in this process due to their potential for causing significant concerns in the results of the DEIS.

Lower Basin and Mexico Shortage Analysis

An analysis was performed on the model outputs to verify that the results were falling within expected ranges and with a relative order that matches the designs of the alternative.

Total policy shortages to Lower Basin water users and Mexico are reflected in the LBShort.AnnualLBMexicoShort slot. The full range of all output values are shown as exceedance percentages in Figure 7, indicating the expected maximum shortages (600 kaf for No Action, 625 kaf for CCS, 1.48 maf for Basic Coordination, 3.0 maf for Extended Authorities, and 4.0 maf for Maximum Operational Flexibility) were never exceeded.

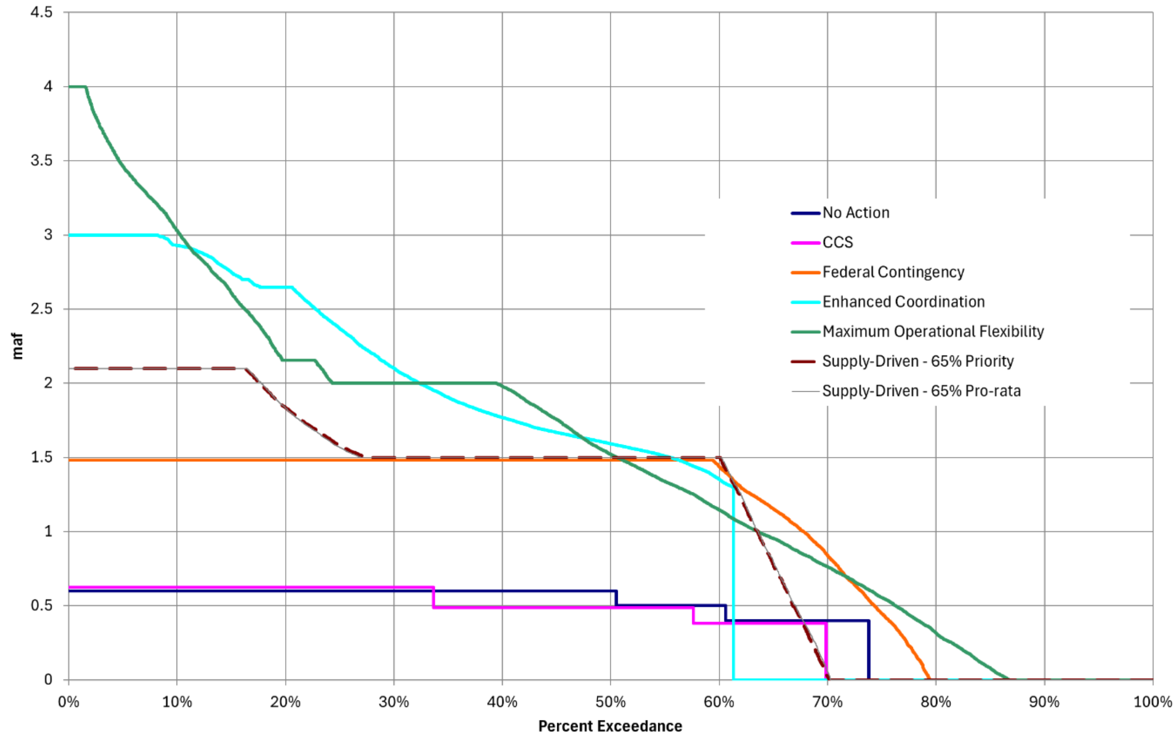

Figure 7. Exceedance Percentages of Lower Basin and Mexico Policy Shortage Volumes

Similarly, the LBHydrologicShortage.AnnualLBMXMiscHydrologicShortage reports the total hydrologic shortages for Lower Basin and Mexico water users. Figure 8 reflects the expected relative order of increasing magnitude and percent exceedance (Maximum Operational Flexibility < Enhanced Coordination < Basic Coordination < CCS < No Action).

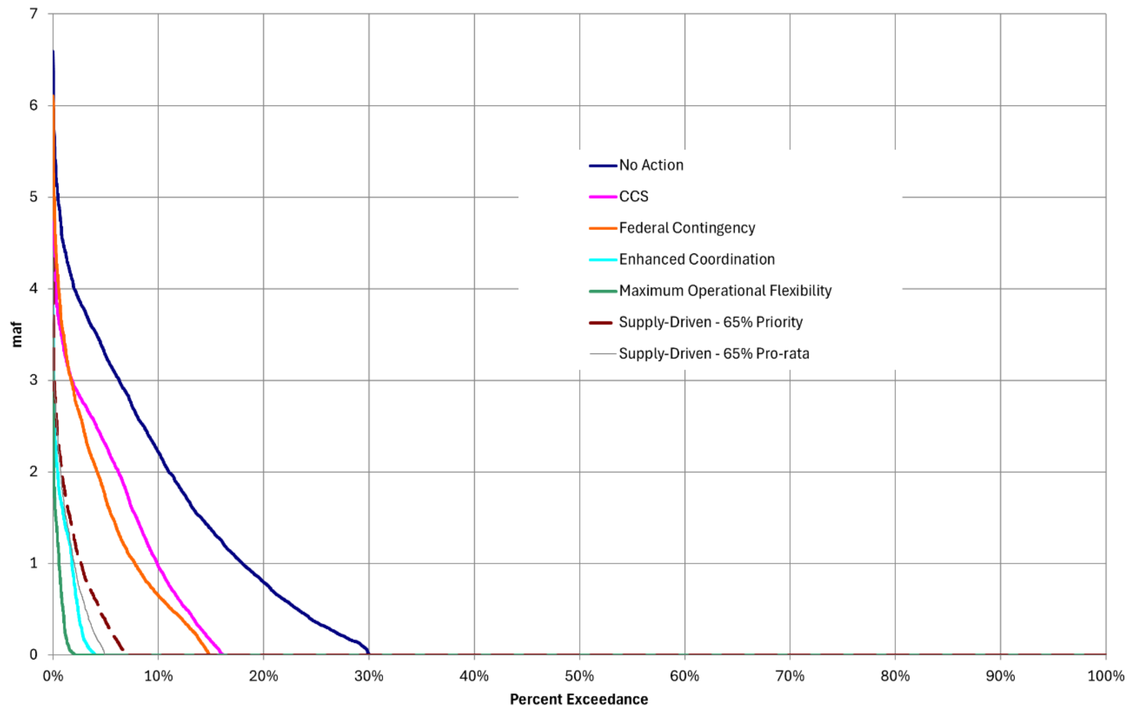

Figure 8. Exceedance Percentages of Lower Basin and Mexico Hydrologic Shortage Volumes

The slot LBHydrologic.ShortageAnnualTotalShortage combines these two elements of policy and hydrologic shortages shows the relative magnitudes and percent exceedance of years for each value. All values fall within expected ranges and relative orders among alternatives.

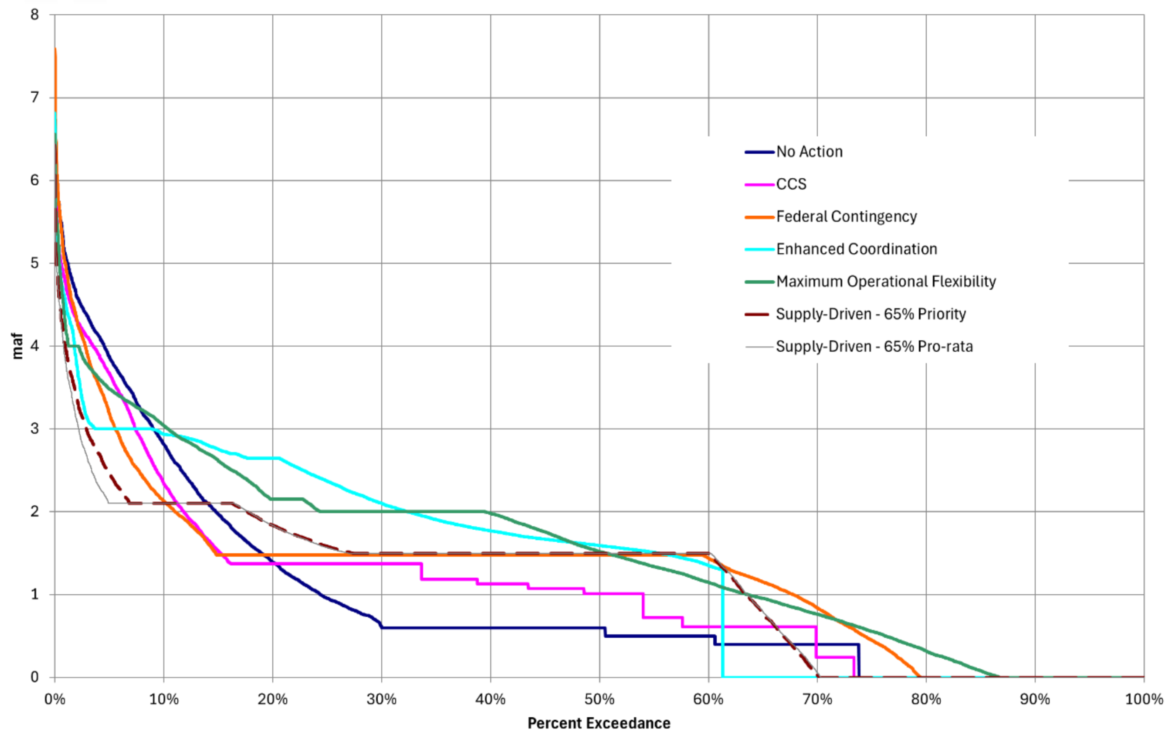

Figure 9. Exceedance Percentages of Total Lower Basin and Mexico Policy + Hydrologic Shortage Volumes

Ruleset Analyses

A review of rule logic was first conducted for the No Action Alternative and Continued Current Strategies, followed by reviews of all other alternatives. Concerns were noted, along with comments noted during the review process. Concerns highlighted in red text warrant further consideration and review by Reclamation due to the possible negative implications on the modelled outputs. Concerns highlighted in yellow highlights indicate rules that warrant attention by Reclamation but were not believed to have a significant effect on the modelled outputs.

Concerns identified in the No Action Ruleset

Rule 180: Powell Runoff Forecast

Through the UBDepletionsRange function, this calls the function UBDepletionEstimate, which uses UBDepletion.system_scalar and UBDepletion.demand_scalar, both of which have a strange discontinuity that raises concerns. This forecast method uses a regression that is not documented to my knowledge.

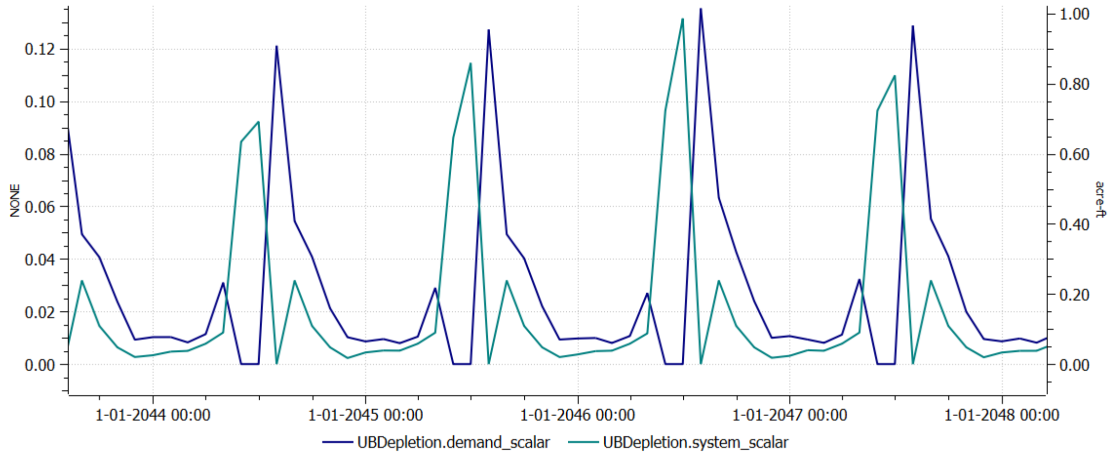

Figure 10. Discontinuities in UB Depletion.Demand Scalar and UB Depletion.system_scalar slots in the No Action Alternative

Furthermore, by using the UBDepletion.AnnualUBDemands slot, the forecast rule does not consider the UB demand limitations recently implemented by Reclamation.

Rule 179: Compute 602a Storage

A potential problem is the depletions are NOT shorted because the EqualizationData.PercentShortage = 0, therefore the 602a storage assumes all UB demands can be met, regardless of the UB statement that they can never be met.

Rule 178: Compute 70R Assurance Level Surplus Volume

This rule also assumes the full UB Depletion Schedule can be met via the slot UBDepletion.UBDepletionEstimate used in the SumUBDemands function.

Rule 176: PIP_April_Forecast_LogReg

I believe the Evaporation Estimation is incorrect here because it combines the forecasted April-March Inflow with evap estimated from previous December (@t-4) to Next March.

Rule 100: Taylor Park Rule Curve

Incorrect execution constraint. Currently only fires if the outflow hasn't been set OR the rule has already fired successfully. This was obviously meant to only fire one with a NOT. Note: This has been corrected in the other models, but will create unpredictable differences between models.

Rule 64: Compute Nevada ICS and Other Resource Deliveries

The Nevada ICS.DesiredAnnualTake at 2026 but then also continues to increase for the full run period. Reclamation has explained this behavior is acceptable because it is later limited by actual use, however the discontinuous nature of the slot still raises concerns.

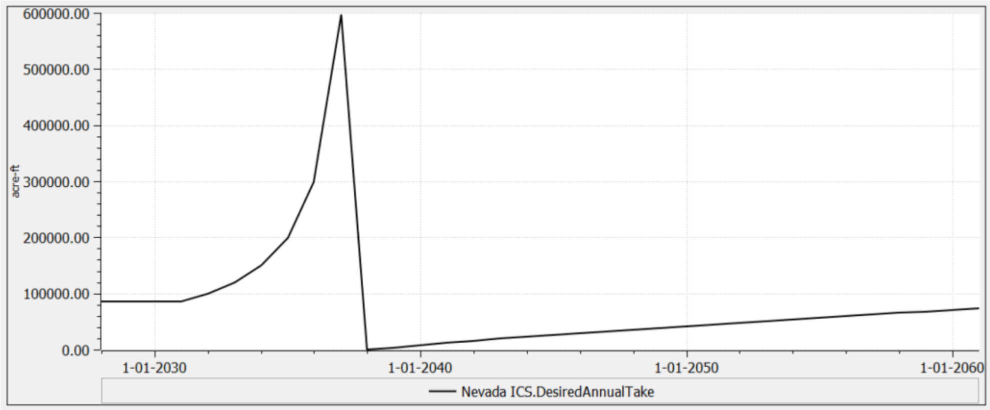

Figure 11. Discontinuities in Nevada ICS.DesiredAnnualTake slots in No Action Alternative

Rule 49: EOWYStorageForecasts

ForecastMeadRelease > SumDemandsDownstreamofMead > SumDepletionsBelowVolume (Mead), does not take into consideration the shortages on water users downstream of Mead because the changes to the Depletion Requests only occur after the Powell Rules have fired (LB Demand Adjustments). The recent effort to first determine LB policy shortages on each water user does not get incorporated into the EOWY forecasts for Mead or Powell.

Rule 11: Get Priority Group Water Available

This is equating the Depletion Requests to the water available. That does not make sense because the definition of Hydrologic Shortage is when the Depletion Requests cannot be met. I believe this should refer to a fraction of the depletion on the aggregate water user.

Rule 10: Hydrologically Short Water Users

Assigns the *.HydrologicShortage on water users by distributing the $ "Shortage.TotHydrologicShortageVolume" using the same priority approach as was done in the Policy Shortage rules. However this is now using the Shortage.StatePriority_HydroShortAvailable slots (e.g. Shortage.ArizonaP4_HydroShortAvail) slot, which sums the Depletion Requests rather than the available depleted water to further reduce uses from.

Initialization Rule: DetermineNIIPInitStorage

Function CalcNIIPGWStorage Uses AgUsesNavajoIndianIrrigationProject:AgricultureTribalPL.Fraction GW Return Flow, but cannot find this slot. Used via DetermineNIIPInitStorage

Additional concerns identified in the Continued Current Strategies ruleset

Rule 114: Taylor Park Rule Curve

This has been corrected in the CCS, but will create unpredictable differences between NA and CCS models.

Rule34: Adjust Release to Protect 3500

This logic seems to result in the greater release of a 6maf or Protect 3500 ft, so it would not always protect 3500 ft. Could be an error.

Rule 26: Reduce Mexico by Computed BWSCP Savings and Create BWSCP Savings

This no longer actually affects Mexico Requests in the CCS model. Potentially concerning.

Multiple Rules: Changes to Rules for Shorting UB Users

The following rules were introduced to systematically short Upper Basin agriculture users in groups and after reservoirs above groups of water users have been operated. While this is likely to be preferred in the CCS model, it will cause differences in rule execution order between the CCS and the NA models.

Rule 88:	Short Users 5 Above Powell
Rule 104:	Short Users 4 Below Aspinall
Rule 113:	Short Users 3 Below Taylor Park
Rule 146:	Short Users 2 Below Fontenelle
Rule 183:	Short Users 1 Above Fontenelle

Table 13. New rules in CCS model that replaces "Short Mainstem Users" and "Short Trib Users"

While the distributed implementation of these rules is an improvement to the method used in the No Action model, these rules were implemented without execution constraints and therefore may inadvertently execute multiple times, setting up the possibility that they will over-restrict water use in the Upper Basin. This concern was considered sufficiently critical, so Reclamation was notified, and a detailed frequency analysis was conducted to evaluate their potential impact. A counter was inserted into each of the five new rules to record how often each was fired multiple times and it was demonstrated that this issue occurred only the one rule (*Short Users 5 Above Powell*) which affects two Colorado Mainstem diversions and seven diversions on the San Juan, triggered by activity in Navajo Reservoir. The results shown in Table 14 reflect the frequency of multiple executions of the *Short Users 5 Above Powell* rule, demonstrating that, although up to 212 traces are out of 400 affected, the total number of time steps is exceedingly small. As a result, no immediate modifications to correct this are required.

	Traces with multiple executions (out of 400)	Number of time steps with multiple executions (out of 163,200 timesteps)	Percent of time steps with multiple executions
Continued Current Strategies	199	349	0.214%
Basic Coordination	212	359	0.220%
Enhanced Coordination	5	6	0.004%
Maximum Operational Flexibility	0	0	0.000%
Supply-Driven	0	0	0.000%

Table 14. Frequency of 'Short Users 5 Above Powell' rule inadvertently executing multiple times

Multiple Rules: Changes to execution constraints of Upper Basin Rules

The following rules were modified with the addition of an execution constraint that allows the rule to only fire once. While this is likely to be preferred in the CCS and other alternatives, it will cause differences in rule execution order between the NA models.

Calculate May Release Volume
Annual Daily Black Canyon Flow Determination
Annual Daily Whitewater Flow Determination
Calculate Gunnison Flow Targets
Calculate Daily Jensen Flows
Fill Daily Flaming Gorge Releases for Months Outside of April-August
Set Flaming Gorge Daily April to July Schedule
Release to Meet ULDE
Spring Flow Hydrologic Classification
Base Flow Operations
Base Flow Hydrologic Classification
Calc Percent Exceedance
Calc April July Volume Monthly
ForecastFutureFGInflow-total average
Min Flow
Min Elevation
Safe Channel Capacity
Set Fontenelle Outflow
Set January-March Initial Baseflow
Set Unset Outflow
StarvationReservoirBaseOperations
StrawberryReservoirBaseOperations
Adjust ULS Diversion per Water Available
SetDuchesneDiversions

Set McPhee Outflow
Compute Fish Pool
Compute Fish Release
Satisfy Dolores Project Exports
October Fish Pool Reset

Table 13. Rules that have an execution constraint to only allow a single execution, which were not included in the No Action Alternative

Additional Concerns identified in the Basic Coordination ruleset

Rule 48: Powell Operations Rule_UDSAlt

The minimum release specified in the documentation provided does not match what is in the model provided by Reclamation. The documentation states "The monthly outflow has a minimum constraint of 5,000 cfs and maximum constraint of 48,100 cfs," which in the model can be found through the Powell Operations Rule_UDSAlt > function PowellRunoffSeasonStorage_UDSAlt > function PowellComputeRunoffSeasonRelease_UDSAlt > post-execution constraints.

The MinRelease =$ "UBRuleCurveData.ReservoirData" [STRINGIFY reservoir, "minRelease"] = 6520.835 cfs, which does not match the 5000 cfs as stated in the documentation.

The Max Constraint is correct from the Powell.Maximum Controlled Release table.

Rule 11: Get Priority Group Water Available

This seems to me to be incorrectly equating the water available to remedy hydrologic shortages to be the sum of the depletion requests across each of the state and priority categories. I believe this should be based on the depletions rather than the depletion requests because some water users might already be limited by their hydrologic shortage, so the depletion requests is not an accurate reflection of the amount of water they have available to contribute to offsetting a Lower Basin wide hydrologic shortage.

Rule 10: Hydrologically Short Water Users

This rule assigns the $ "Shortage.HydroShortageStageDepth" based on how far hydrologic shortages must cut into the hydrologically available water use, and assigns the hydrologic shortage to each water user based on the $ "Shortage.TotHydrologicShortageVolume" and the basinwide priority scheme. Is most cases, this would reduce the depletions from the uses downstream of Lake Mead to equal the amount of water that Lake Mead can release. However, in the case of a Stage 4 Shortage, all depletions are cut off completely by setting the Hydrologic Shortage equal to the Depletion Request for each user, but water is still being released from Lake Mead based on previous rules. The result is water passing through the Lower Basin without being consumed by any water user. See the numerical description above in *Erroneous condition – No adjustment of Mead Outflows* within the *Incomplete accounting for Lower Basin Shortages* section of this report.

Additional Concerns identified in the Enhanced Coordination ruleset

Rule 336: Set ICS Put and Take Dates_NA_DROA_On

According to the alternative description, I believe this rule should be active

Rule 335: Set ICS Put and Take Dates_NA_DROA_Off

This rule is currently active, which assigns $ "ExtendedOperations.ExtendedOperationsFlag" to zero, therefore eliminating any Powell Infrastructure Protection (PIP). This is contrary to the written description of this alternative; therefore, Reclamation was notified, and an analysis was performed to understand the relative impact of this concern.

An overall view of impacts of omitting the PIP operations are shown in Figure 12 as changes to exceedance percentages of Lake Powell elevations. Differences in the lowest 15% of modeled outputs are apparent, and elevation differences at different exceedance levels (i.e. irrespective of individual traces or time steps) reaches a maximum of 23 ft at extreme low occurrences of events (< 0.5%). Due to the complex non-linear behavior of the system over time, actual elevation differences at individual time steps become increasingly difficult to attribute to the PIP operations.

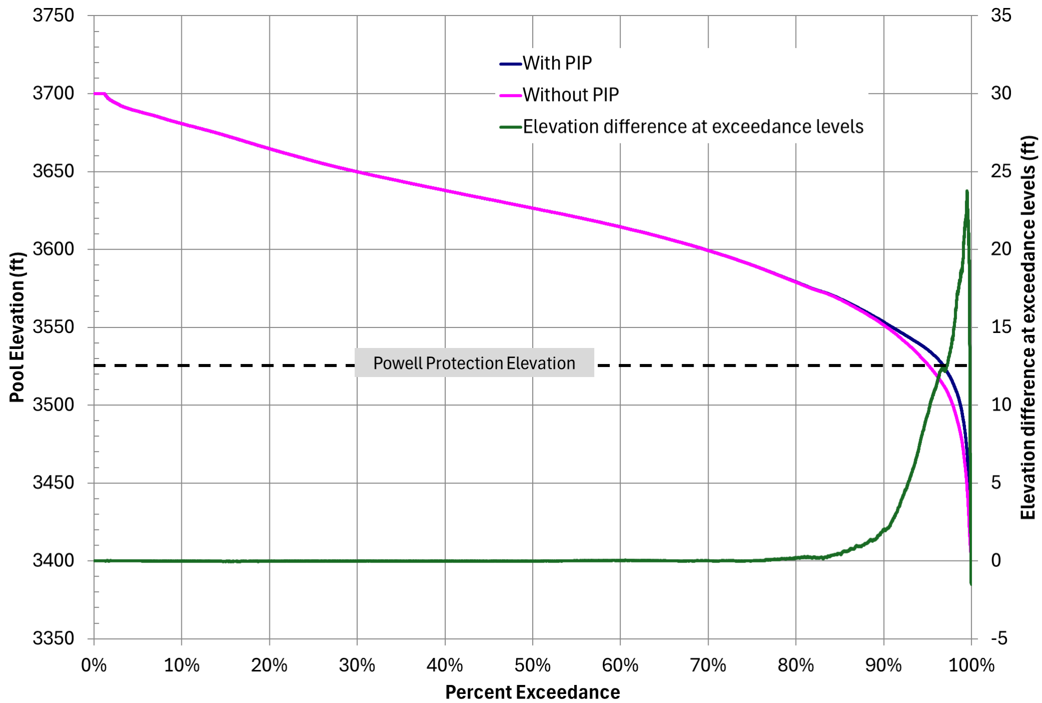

Figure 12. Exceedance percentages of Lake Powell pool elevation with and without Powell Infrastructure Protection (PIP) operations in the Enhanced Coordination Alternative

A visual analysis of individual traces demonstrates the degree to which the PIP supports Lake Powell Elevations, but it also shows how draining water from upper units during PIP releases later decreases Lake Powell elevations when the upper units are refilled. In Trace 214 shown in Figure 13, PIP releases results in up to 30 ft of additional elevation in Lake Powell, but during recovery can result in a 35 ft relative decrease in elevation.

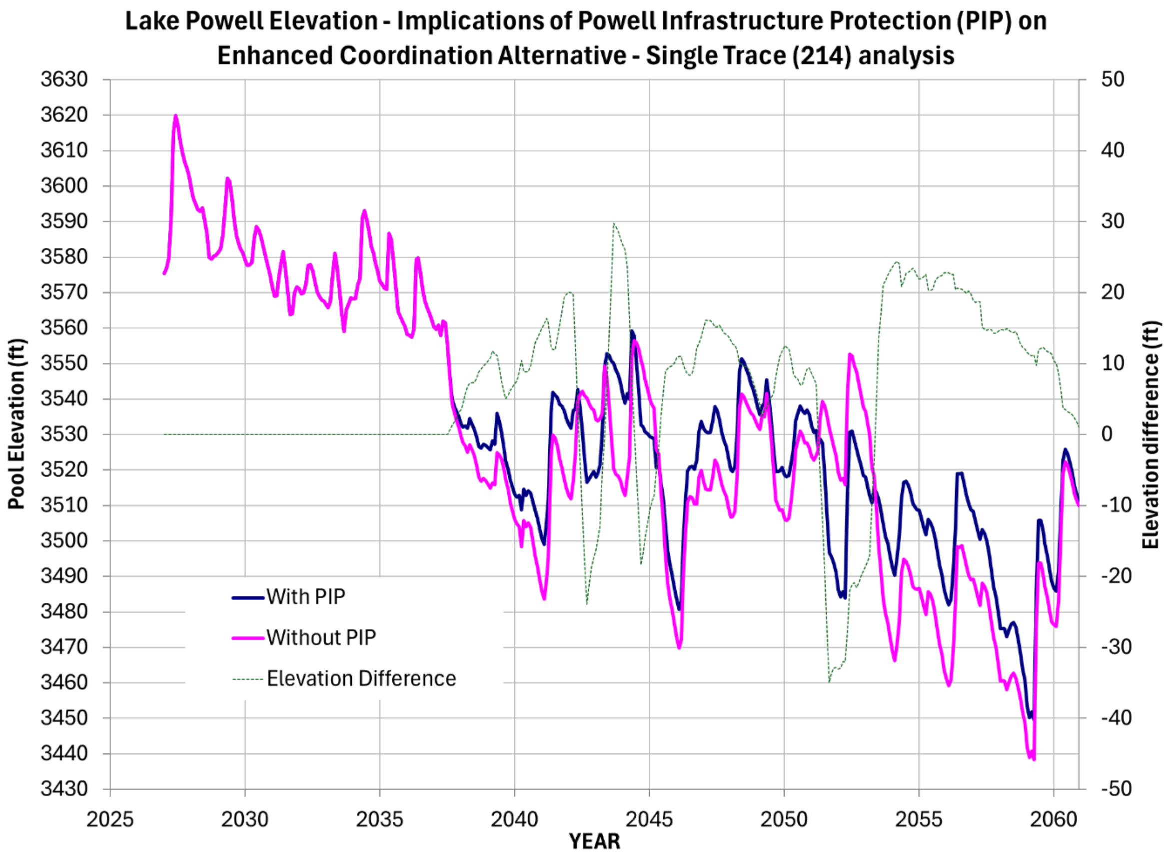

Figure 13. Single trace analysis (Trace 214) of Lake Powell pool elevation with and without Powell Infrastructure Protection (PIP) operations in the Enhanced Coordination Alternative

In conclusion the omission of PIP releases in the Enhanced Contingency Alternative is unlikely to result in significant differences in the aggregated distributions, but would be significant when considering individual traces during hydrologically constrained conditions.

Rule 306: Set Combined Storage_EP

The description of this rule indicates a system-wide percent storage metric, but it only considers Lake Mead and Powell. This is consistent with the rule documentation, so its just an internal documentation issue.

Function GetShortageTriggerValue_FAH ("Arizona") takes in an argument but never uses it.

Rule 252: DROA All Months Set Flaming Gorge Daily April to July Schedule

This rule fires multiple times because it does not have any single execution constraints. More of an efficiency issue I believe since I think it sets the same values repeatedly.

Rule 245: DROA Release Before Forecast Future Storage

This rule cannot fire with the most recent targets because constraining ExtendedOperaitons.DROA_May1Target is not set until Rule 83 DROA May1Target. It therefore certainly would fire out of order on the First April timestep. It might work on because Rule 83 sets values into the future (in April Set May-Next April, in August set August-Next April), but it will always be operating on the May 1st target set on the previous year as opposed to the current one. I really doubt this is the intended behavior.

Rule 182 and 159: Sum FPP Unused Tribal for JPs and Unused Tribal Desired Put

These rules are confusing and redundant. In 182, I don't like how the "UnusedTribal_FPP" name is used in both the individual tribes and the aggregating water user, especially after it has been subjected to the 10% factor, (e.g. FtYumaReservationPriority1:FtYumaReservation.UnusedTribal_FPP gets aggregated into CAPDiversion:CAPDiversion.UnusedTribal_FPP * 10%). These slots therefore mean very different things on these users and will lead to confusion - one is how much the tribe hasn't used, and the other reflects an aggregate bank of unused tribal water. The overall objective of rule 182 is repeated in Rule 159, producing the same numbers on an annual basis.

e.g. ΣCAPDiversion:CAPDiversion.UnusedTribal_FPP = P26_Mead_FederalProtectionPool.AZ_UnusedTribal_DesiredPut_Annual

These two rules should be combined and not written to the UnusedTribal_FPP on the aggregate level water users. Also, Rule 159 fires every month and sets values to December, so it is very inefficient.

Rules 173, 167, 166: Check Shortage Distribution if Federal Protection Pool is Enabled & Initialize Slots, Calculate Shortage Mitigation Actual Conversion from FPP, This rule becomes useless in the Pro-rata because there is no shortage mitigation allocated to CAP, MWD, SNWP

This is flagged simply because I don't understand why there would be not desired take inder pro-rata for CAP, MWD and SNWP (Rule 173). As a result, thortage mitigation does not get allocated in Rule 167, and Rule 166 becomes useless.

Additional Concerns identified in the Maximum Operational Flexibility ruleset

Rules 127 and 65: CR Objective_Critical Elevations_Powell vs CR Objective_Grand Canyon

There is an inconsistency in the approach used to model these two objectives.

The highlighted assignment in the code below (Figure 14) is in the section when there is not enough water in the CR to fully meet the objective of keeping Powell over 3510 ft, so it tries to move whatever it can by reducing Powell Releases. The 'running' Mead balance is set to zero (or nonOpNeut water) as expected, but then the $ "NGO_ConservationReserve.CR_Balance_Powell_Running" also gets set to zero here. My initial thought was that this would get set to a higher number (moving water into Powell), but perhaps this water is now considered allocated so it unavailable for future use.

```
CR Objective_Critical Elevations_Powell
127 CR Objective_Critical Elevations_Powell    RPL Set Not Loaded
            NGO_ConservationReserve.CR_Balance_Mead_Running_Hydro [ @"24:00:00 January 31, Current Year" ]
              = NGO_ConservationReserve.CR_Balance_Mead_Running [ @"24:00:00 January 31, Current Year" ]
                - Min ( # available in mead CR
                        Max ( ( NGO_ConservationReserve.CR_Balance_Mead_Running [ @"24:00:00 January 31, Current Year" ]
                                - # Hold back CR water that is not operationally neutral
                                  NGO_ConservationReserve.CRLBNonOpNeutralBank [ @"24:00:00 December 31, Current Year" ] ),
                              0.00 "acre-ft" ),
                        # What is needed after what is already available in powell
                        PowellVolDiff
                        - NGO_ConservationReserve.CR_Balance_Powell_Running [ @"24:00:00 January 31, Current Year" ] )
          ELSE
            # Volume needed exceeds whats in the CR. Transfer whatever we
            # can from Mead to Powell, sets Mead CR running balance to 0
            NGO_ConservationReserve.CR_Transfer_CriticalElevationPowell [ @"24:00:00 December 31, Current Year" ]
              = # Transfer from Mead to Powell
                Max ( ( NGO_ConservationReserve.CR_Balance_Mead_Running [ @"24:00:00 January 31, Current Year" ]
                        - # Hold back CR water that is not operationally neutral
                          NGO_ConservationReserve.CRLBNonOpNeutralBank [ @"24:00:00 December 31, Current Year" ] ),
                      0.00 "acre-ft" )
            # Update Powell CR running balance
            NGO_ConservationReserve.CR_Balance_Powell_Running [ @"24:00:00 January 31, Current Year" ]
              = 0.00 "acre-ft"
            # Update Mead CR running balance
            NGO_ConservationReserve.CR_Balance_Mead_Running [ @"24:00:00 January 31, Current Year" ]
              = 0.00 "acre-ft"
                + NGO_ConservationReserve.CRLBNonOpNeutralBank [ @"24:00:00 December 31, Current Year" ]
            # Update Mead CR running balance for hydro short use.
            NGO_ConservationReserve.CR_Balance_Mead_Running_Hydro [ @"24:00:00 January 31, Current Year" ]
              = 0.00 "acre-ft"
                + NGO_ConservationReserve.CRLBNonOpNeutralBank [ @"24:00:00 December 31, Current Year" ]
          END IF
        END IF
      ELSE
        # No action required for this objective
        NGO_ConservationReserve.CR_Transfer_CriticalElevationPowell [ @"24:00:00 December 31, Current Year" ]
          = 0.00 "acre-ft"
        NGO_ConservationReserve.CRObjective_CriticalElevationPowell [ @"24:00:00 December 31, Current Year" ]
          = 0.00 "acre-ft"
      END IF
    END IF
END WITH
```

Figure 14. Rule for the Conservation Reserve objective of meeting critical elevations in Lake Powell in the Maximum Operational Flexibility Alternative

However, a valid comparison is the Grand Canyon, where if the forecasted elevation falls below 3570, then the PowellVolDiff is negative, and Powell Releases needs to also decrease. In this case, the $ "NGO_ConservationReserve.CR_Balance_Powell_Running" gets is increased, as CR water is being moved from Mead to Powell.

```
S R 65 CR Objective_GrandCanyon                                          RPL Set I
          + Min ( # target transfer volume, or whatever is available in Powell CR
                  NGO_ConservationReserve.CR_Balance_Powell_Running [ @"24:00:00 January 31, Current Year" ] ,
                  PowellVolDiff )
   ELSE
     IF ( ( # Powell too low, transfer CR volume from Mead
            PowellVolDiff < 0.00 "acre-ft" ) ) THEN
       NGO_ConservationReserve.CR_Transfer_GrandCanyonTarget [ @"24:00:00 December 31, Current Year" ]
         = # NEGATIVE VALUE (to reduce Powell's release)
           - Min ( # target transfer volume, or whatever is available in Mead CR
                   Max ( ( NGO_ConservationReserve.CR_Balance_Mead_Running [ @"24:00:00 January 31, Current Year" ] ,
                           - # Hold back CR water that is not operationally neutral
                           NGO_ConservationReserve.CRLBNonOpNeutralBank [ @"24:00:00 December 31, Current Year" ] ) ,
                         0.00 "acre-ft" ) ,
                   - PowellVolDiff )
       # Update Powell CR running balance (add transfer volume)
       NGO_ConservationReserve.CR_Balance_Powell_Running [ @"24:00:00 January 31, Current Year" ]
         = NGO_ConservationReserve.CR_Balance_Powell_Running [ @"24:00:00 January 31, Current Year" ]
           + Min ( # target transfer volume, or whatever is available in Mead CR
                   Max ( ( NGO_ConservationReserve.CR_Balance_Mead_Running [ @"24:00:00 January 31, Current Year" ] ,
                           - # Hold back CR water that is not operationally neutral
                           NGO_ConservationReserve.CRLBNonOpNeutralBank [ @"24:00:00 December 31, Current Year" ] ) ,
                         0.00 "acre-ft" ) ,
                   - PowellVolDiff )
       # Update Mead CR running balance (subtract transfer volume)
       NGO_ConservationReserve.CR_Balance_Mead_Running [ @"24:00:00 January 31, Current Year" ]
         = NGO_ConservationReserve.CR_Balance_Mead_Running [ @"24:00:00 January 31, Current Year" ]
           - Min ( # target transfer volume, or whatever is available in Mead CR
                   Max ( ( NGO_ConservationReserve.CR_Balance_Mead_Running [ @"24:00:00 January 31, Current Year" ] ,
                           - # Hold back CR water that is not operationally neutral
                           NGO_ConservationReserve.CRLBNonOpNeutralBank [ @"24:00:00 December 31, Current Year" ] ) ,
                         0.00 "acre-ft" ) ,
                   - PowellVolDiff )
     ELSE
```

Figure 15. Rule for the Conservation Reserve objective of meeting Grand Canyon criteria in the Maximum Operational Flexibility Alternative

This is making sense to me, but the case above (protecting Powell) is not yet.

So my concern is when releases are being reduced from Powell so to move CR water from Mead to Powell, why would the 'running' balance in Powell not always increase?

One of these two approaches is likely acceptable, but they should at least be consistent.

Rule 116: Check Annual LB Shortage Volumes_NGO

This rule triggers a stop when the ActLBPolShort =! ExpLBPolicyShort and both values are supposedly rounded to two decimal places, however I managed to make it trigger this stop even when the results of the two values seemed identical. Further analysis indicated there were slightly different and several more significant digits added into the values. It is recommended to apply a threshold exceedance rather than an absolute "=!"

Expression Slot: Effective Powell Storage

Frequent instances were noted when the Powell.Effective Storage became unstable and often negative.

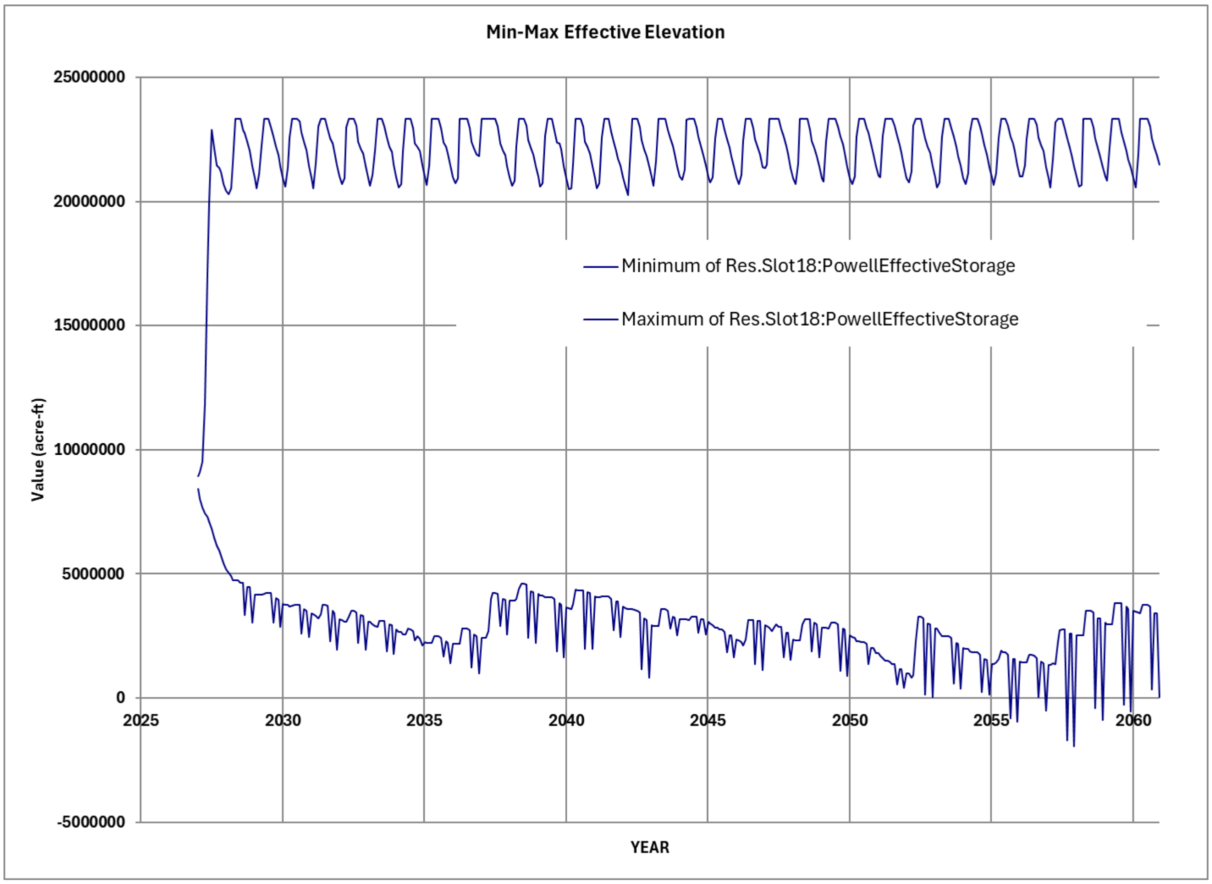

Figure 16. Example of instability in the Minimum Effective Lake Powell Storage

An example from Trace 340 is shown below. The instability is because only the September and December time steps of NGO_ConservationReserve.CR_Balance_Powell contain values, so the effective storage oscillates. This instability may not have a detrimental effect if these values outside of September and December are not used. However, the negative values are problematic and should be addressed. The cause of the negative values is that the balance of Conservation Reserve in Powell can exceed the actual Powell Storage Volume.

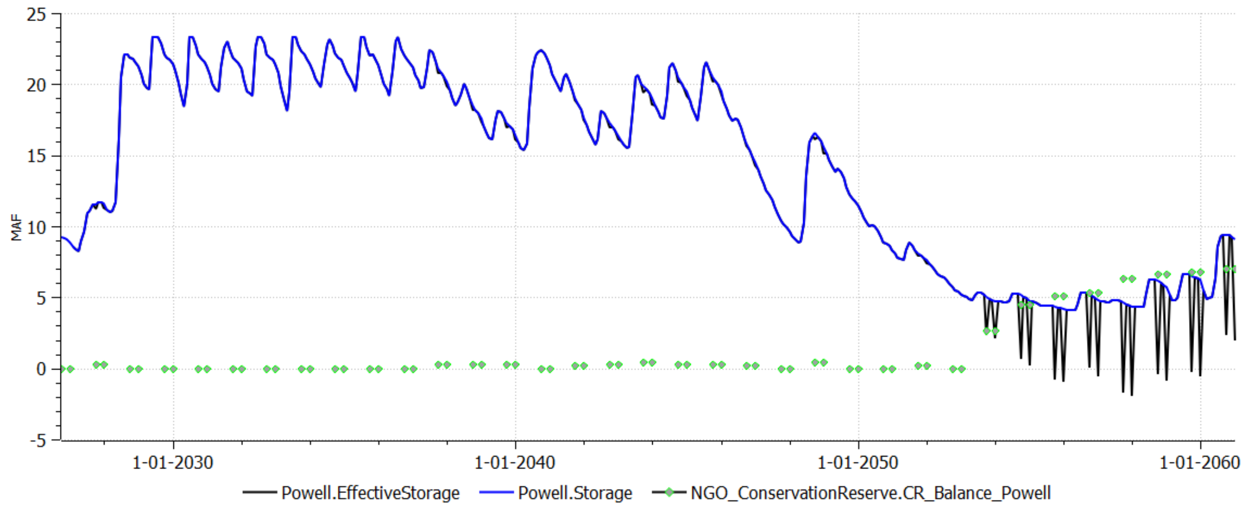

Figure 17. Example of negative numbers in the Effective Lake Powell Storage

It is clear that the Powell.Elevation Volume Table has been adjusted to allow these negative values, however this solution fails when this negative effective storage falls below 5 maf, causing the Powell. EffectiveElevation expression slot to fail and terminate the run.

Additional Concerns identified in the Supply-Driven ruleset

Rule 316: Set ICS Put and Take Dates

This model has the ICS and DCP activity going until 2060, even though these existing programs are supposed to end. It appears that the contributions tables are zeroed out instead of the end dates in this rule set to 2026. In principle this could yield the same result, but many rules will be executed in this alternative that do not in the others, lending a significant chance for unintended differences between this and the other alternatives.

Rule 310: Powell Deficit for PIP

Clearly by design, but this definition of a Forecasted deficit differs substantially from other alternatives, therefore will be difficult to compare this individual effect.

Rule 224: PIP Forecast FG Outflow and Storage

Rule fires every month and revises forecast until next year's April, but it always fails from January to March.

Rul 157: Calc Static Shortage Volumes_Specific Water Users Shortages Above 1.5 maf_Transfer

This rule assigns hardcoded number and looks like a temporary measure. I believe the values it assigns are already getting overwritten. Reclamation should verify and remove this rule if so.

Summary and Conclusions

The batch peer review was conducted using the models and results provided by Reclamation along with written and verbal descriptions of the alternatives. Several concerns were identified, most of which are not expected to have a significant impact on the results. Three items of concern were brought forward to Reclamation during the analysis since they could potentially have negative impacts. These include:

1) Consistency in transferring stored water accounts. This issues was identified by the lack of populated accounts in the results provided by the No Action Alternative. Reclamation should verify if the results provided for this review were the same as those provided for the impact analysis
2) Powell Infrastructure Protection was disabled in the model and outputs provided for the Enhanced Coordination Alternative. This issue of concern is unlikely to significantly change the aggregate statistics in the DEIS, but would have a significant when looking at individual dry traces. Reclamation should further consider the implications of this omission.
3) Repeated execution of Upper Basin delivery restriction rules. This issue has the potential to negatively impact the results, but the occurrence is sufficiently rare that it is very unlikely to have negative impacts on the results in the DEIS.

These three concerns, as well as the others provided throughout this report, should be considered and addressed prior to the production of the Final EIS analysis.