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Lower Rio Grande Managed Aquifer Recharge (MAR)

Phase I Study Report

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This report was prepared under contract with the New Mexico Interstate Stream Commission (NMISC).

The findings, interpretations, and recommendations are those of the authors and do not necessarily represent the official views or policies of NMISC.

Certifications

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Executive Summary

Purpose and Background

The Lower Rio Grande (LRG) Managed Aquifer Recharge (MAR) Phase I Study was initiated by the New Mexico Interstate Stream Commission (NMISC) to evaluate opportunities to enhance groundwater storage through managed recharge within the Rincon and Mesilla Valleys of southern New Mexico.

The study supports NMISC's broader mission to develop adaptive water-management strategies that improve drought resilience, sustain agricultural and municipal water supply, and mitigate groundwater depletion in the Rio Grande Basin.

Phase I focused on identifying, characterizing, and prioritizing existing hydraulic structures—such as flood-control dams, drains, and arroyos—that can be adapted or retrofitted to facilitate recharge. The study integrated hydrologic, geologic, engineering, and regulatory data within a unified geospatial framework to establish a defensible, data-driven foundation for Phase II feasibility and pilot implementation.

Phase I

Approach and Methodology

Phase I was conducted collaboratively by Lynker Corporation, the NMISC, and partner agencies including EBID, IBWC and OSE. The effort compiled more than 30 datasets from federal, state, and local sources and standardized them into a centralized MAR geodatabase. Analytical components included:

- **Site Identification and Screening:** Over 30 existing flood-control and water-management structures were evaluated using spatial overlays, ownership boundaries, and hydrologic connectivity criteria.
- **Field Reconnaissance:** A basin-wide field verification campaign (June 2025) confirmed infrastructure conditions, infiltration characteristics, and logistical feasibility at seven representative sites.
- **Conceptual Site Models (CSMs):** Developed for seven representative structure types, each characterizing hydrologic source, infiltration mechanism, aquifer target, and monitoring approach.
- **Technology Screening:** Five MAR technology classes were evaluated—(1) dam-based recharge, (2) conveyance/drain-based recharge, (3) engineered infiltration systems, (4) pre-treatment systems, and (5) monitoring and automation technologies—using weighted multi-criteria evaluation.

- **Ranking and Prioritization:** Sites and technologies were ranked based on effectiveness, implementability, regulatory compatibility, and cost, supported by decision diagrams illustrating a watershed-integrated approach.

Key Findings

The Phase I analysis confirms that the Lower Rio Grande Basin possesses multiple, feasible MAR opportunities that can be implemented incrementally to improve aquifer storage and operational flexibility. Hydrologic and hydrogeologic findings include:

- **Hydrologic Opportunity:** Seasonal runoff, particularly during the late summer-early fall monsoon period, provide recurring recharge potential. Flood-control infrastructure already captures thousands of acre-feet of runoff that could be managed for infiltration.
- **Hydrogeologic Favorability:** Most candidate structures are underlain by coarse alluvium and upper Santa Fe Group deposits with vadose-zone thicknesses less than 25 meters, enabling effective percolation.
- **Infrastructure Readiness:** Many existing flood-control and irrigation facilities are structurally sound and can be upgraded with minimal modification to support MAR.
- **Monitoring and Data Infrastructure:** The Phase I geodatabase provides a spatially referenced platform for continued data integration, version control, and coordination with NM Open Data frameworks.

Example MAR Applications

Three representative example sites were developed to illustrate the range of MAR technologies applicable across the basin:

- Tortugas Dams / Boggy Spur System – Combines recharge enhancement at existing dams and ponds, engineered infiltration basins, bioretention forebays, conveyance-based recharge, and automated monitoring systems.
- Green Canyon Dam – Demonstrates outlet-control modification (Smart Inlet Control), vegetation management, and seepage-channel lining to optimize recharge downstream of the Derry Fault.
- Rincon Arroyo – Illustrates nature-based recharge using drop structures and check dams with gabion armoring to enhance infiltration and reduce erosion.

Conceptual cost estimates indicate implementation costs between \$100,000 and \$200,000 per site, depending on the extent of structural and monitoring components.

Across all components, the cumulative basin-wide planning cost was approximately \$360,000, yielding a favorable cost-to-benefit ratio when compared to expected recharge volumes of 1,000–3,000 acre-feet annually.

Phase I Recommendations

The study identifies four near-term opportunities for MAR advancement, listed in the order of practical feasibility:

- **Tortugas Dams / Boggy Spur:** Advance to pilot-scale implementation integrating engineered recharge, automation, and pre-treatment.
- **Green Canyon Dam:** Advance to feasibility with pilot testing for Smart Inlet and discharge-channel retrofits ultimately improving flow routing to more favorable MAR areas.
- **Caballo / Hatch Valley Arroyo Complex:** Retain as Phase II planning candidate pending additional geotechnical and ownership data.
- **Rincon Arroyo:** Advance to direct feasibility design focused on distributed check dams and infiltration terraces.

Permitting will require coordination with OSE, NMED, USACE, and local entities such as EBID and SWCDs, but no major regulatory impediments were identified.

Phase II

Scope and Budget

Phase II will refine design and performance estimates through field investigations, modeling, and pilot demonstration. Key tasks will include:

- Geotechnical and infiltration testing;
- Continuous-simulation runoff and groundwater modeling;
- 30% design alternatives and cost-benefit evaluation; and
- Pilot monitoring and automation integration.

The estimated Phase II budget ranges from \$1.2 to \$1.8 million over a 24-month period, including pilot testing at two sites and feasibility studies for two others.

Monitoring and Data Improvements

Phase II will also expand the instrumentation network (TDR, DTS, and pressure transducers), improve data QA/QC workflows, and maintain the NMISC geodatabase as

the authoritative MAR data repository. Targeted data-gap reduction tasks include acquisition of missing WR-09 forms, O&M inspection reports, and new field measurements of infiltration capacity and aquifer response.

Conclusions

The Phase I MAR Study demonstrates that Managed Aquifer Recharge is technically feasible, cost-effective, and operationally compatible with existing infrastructure in the Lower Rio Grande Basin.

By advancing high-priority projects through pilot testing and detailed feasibility under Phase II, NMISC can establish a replicable MAR framework that enhances aquifer sustainability, augments supply reliability, and provides long-term resilience to drought and climate variability.

Acronyms & Abbreviations

ac-ft	Acre-foot	Volume unit used for water storage and discharge.
ASTM	American Society for Testing and Materials	Organization providing standards for well construction, development, and conceptualization (e.g., D5092, D5521, D5979).
ARMs	Ancillary Recharge Methods	Non-traditional or secondary recharge approaches (per Kebede et al. 2024).
CAD	Computer-Aided Design	Engineering drawing and design platform used in cost estimating.
CFS	Cubic Feet per Second	Flow-rate unit for runoff and stream discharge.
CSM	Conceptual Site Model	Integrated depiction of hydrologic, geologic, and operational conditions at each MAR site.
CY	Cubic Yard	Volume unit for earthwork calculations.
DACFC	Doña Ana County Flood Commission	Local flood-control authority managing structures within Mesilla Valley.
DEM	Digital Elevation Model	Topographic raster dataset derived from LiDAR used for watershed delineation.
DNR / NRCS	Department of Natural Resources / Natural Resources Conservation Service	Federal agency responsible for original construction of many flood-control dams.
DO	Dissolved Oxygen	Water-quality parameter monitored at MAR sites.
DOA	Doña Ana	County name used in flood-control structure references.
DTS	Distributed Temperature Sensing	Fiber-optic temperature profiling used to measure infiltration across recharge basins.
EBID	Elephant Butte Irrigation District	Primary irrigation and water-delivery district; co-operator and data provider.
EPA	U.S. Environmental Protection Agency	Regulatory authority for water quality and UIC permitting.
ER	Engineering Regulation	USACE document series; e.g., ER 1110-2-1302 for cost-engineering standards.
FIM	Flood Inundation Mapping	Modeling toolset used to delineate flood extents in hydrologic analyses.
GIS	Geographic Information System	Spatial data platform used for mapping and screening analyses.
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling System	USACE rainfall-runoff modeling software used for MAR hydrology.
HUC	Hydrologic Unit Code	Watershed delineation system used in hydrography mapping.
IBWC	International Boundary and Water Commission	Binational U.S.–Mexico agency overseeing river management and flood control.
IGE	Independent Government Estimate	Federal cost-engineering term (USACE standard).
IoT	Internet of Things	Networked sensor and telemetry systems used for “smart” stormwater management.
ISC / NMISC	New Mexico Interstate Stream Commission	Project sponsor and lead agency for the MAR Program.

Acronyms & Abbreviations

LiDAR	Light Detection and Ranging	Remote-sensing technology used for high-resolution elevation data.
LoRaWAN	Long-Range Wide Area Network	Low-power wireless protocol for telemetry at remote MAR sites.
LRG	Lower Rio Grande	The basin and study area of the Phase I MAR project.
MAR	Managed Aquifer Recharge	Intentional recharge of surface water to groundwater for storage and recovery.
MCM	Million Cubic Meters	Metric volume unit used in international MAR studies.
MSL	Mean Sea Level	Vertical datum used for spillway and elevation references.
NbS	Nature-Based Solutions	Ecosystem-oriented methods for recharge enhancement.
NID	National Inventory of Dams	Federal database of dam structures used for inventory cross-checks.
NMED	New Mexico Environment Department	State agency responsible for water-quality and discharge permitting.
NMBGMR	New Mexico Bureau of Geology & Mineral Resources	Technical partner providing geologic framework data.
NMOSE / OSE	New Mexico Office of the State Engineer	State regulator of surface and groundwater rights and dam safety.
NOAA	National Oceanic and Atmospheric Administration	Source of hydrometeorological data (precipitation, temperature).
NRCS	Natural Resources Conservation Service	Federal agency responsible for early dam design and soil surveys.
NTU	Nephelometric Turbidity Unit	Measure of water clarity used in MAR water-quality thresholds.
NWIS / USGS	National Water Information System / U.S. Geological Survey	Federal source of streamflow, groundwater, and geologic data.
O&M	Operations and Maintenance	Activities required to maintain dam and MAR structure performance.
ORP	Oxidation-Reduction Potential	Redox indicator for water-quality monitoring.
PFAS	Per- and Polyfluoroalkyl Substances	Emerging contaminants occasionally screened in MAR feasibility.
PRISM	Parameter-elevation Regression on Independent Slopes Model	Climate dataset providing long-term precipitation estimates.
QA/QC	Quality Assurance / Quality Control	Data-management and field-measurement verification process.
RTC	Real-Time Control	Smart automation of valves, gates, or pumps for dynamic recharge operations.
RWH-MAR	Rainwater-Harvesting Managed Aquifer Recharge	Combined technique modeled in comparative international case studies.
SB	Santa Fe Group / Basin	Regional geologic formation underlying much of the LRG aquifer system.
SMAP	Soil Moisture Active Passive (NASA)	Satellite soil-moisture dataset integrated into hydrologic analysis.

Acronyms & Abbreviations

SOP	Standard Operating Procedure	Protocols for MAR operation, monitoring, and maintenance.
SP	Self-Potential	Geophysical method for identifying gaining or losing river reaches.
SSCAFCA	Southern Sandoval County Arroyo Flood Control Authority	Source of regional hydrology guidance used for modeling consistency.
SWCD	Soil and Water Conservation District	Local sponsors/owners of flood-control dams (Caballo, Doña Ana).
TDR	Time-Domain Reflectometry	In-situ moisture sensor for infiltration and drainage monitoring.
TDS	Total Dissolved Solids	Water-quality parameter monitored in wells and basins.
UIC	Underground Injection Control	EPA program governing direct-injection recharge wells.
USACE	U.S. Army Corps of Engineers	Federal engineering agency; provides hydrologic/cost-engineering standards.
USBR	U.S. Bureau of Reclamation	Federal agency managing Rio Grande water deliveries and reservoirs.
USGS	U.S. Geological Survey	Federal agency providing hydrologic, geologic, and groundwater data.
WR-09	Water-Rights Form 09	OSE dam-registration form referenced for data gaps and compliance.
WMS	Watershed Modeling System	Software used for flood and recharge simulation in comparative studies.
WWTP	Wastewater Treatment Plant	Source of advanced-treated water in certain MAR contexts.
yrs / WY	Years / Water Year	Hydrologic time convention used in statistical summaries.

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1. Introduction and Background

The Lower Rio Grande (LRG) Managed Aquifer Recharge (MAR) Study was commissioned by the New Mexico Interstate Stream Commission (NMISC) under Work Order No. LRG25-Lynk01, titled “Managed Aquifer Recharge Opportunities Assessment in the Lower Rio Grande – Phase I: Existing Structure Screening and MAR Project Conceptual Designs.”

This effort was authorized under the NMISC’s Lower Rio Grande Basin Program and forms part of the agency’s FY2025 and FY2026 Work Plan, specifically Element 3 (Stormwater Capture and Aquifer Recharge) and Element 7 (Hydrologic Studies). The NMISC Work Order Manager is Mr. Ryan Serrano, Lower Rio Grande Bureau Chief, supported by Ms. Christina Hernandez of the NMISC Las Cruces Office.

Lynker Corporation (Lynker) was contracted to provide technical support and conduct the Phase I assessment, with Mr. Peter Guerra, Principal Environmental Engineer serving as Project Manager and Dr. Jim McCord, PE, PhD, as Principal Hydrogeologic Engineer; and Dr. Graeme Aggett as Chief Scientist and Principal Geomorphologist.

The Phase I study aims to evaluate, screen, and prioritize existing hydraulic structures—including flood-control dams, arroyos, diversion works, and groundwater drains—across the Rincon and Mesilla Valleys for potential use or modification as Managed Aquifer Recharge facilities. This effort represents the first Phase in a multi-phase NMISC initiative to improve aquifer sustainability, flood management, and surface-water/groundwater integration in the Lower Rio Grande Basin.

The primary objectives of Phase I are to:

- Identify and inventory existing hydraulic structures and evaluate their suitability for MAR applications.
- Compile and analyze hydrologic, geologic, climatic, and operational datasets relevant to MAR feasibility.
- Develop Conceptual Site Models (CSMs) and a screening framework for ranking potential MAR project opportunities.
- Recommend specific sites and structures for detailed Phase II engineering analyses and feasibility evaluations

The study supports the NMISC’s statutory mission to develop, conserve, and protect New Mexico’s water resources through data-driven, multi-stakeholder planning that ensures the sustainable use of surface and groundwater within the Lower Rio Grande watershed.

1.1. Project Context and Purpose

The Lower Rio Grande Basin faces persistent water-supply challenges, including declining groundwater levels, aquifer overdraft, and surface-water shortages associated with variable climate and compact-driven delivery obligations. The NMISC, working in concert with the Office of the State Engineer (OSE), is charged by statute with investigating and developing new water supplies and management strategies to ensure the sustainability of New Mexico's water resources.

Within this framework, Managed Aquifer Recharge (MAR) offers a promising method for capturing, retaining, and infiltrating surface water flows—particularly floodwater, storm runoff, or controlled reservoir releases—into underlying aquifers for long-term storage and recovery. By leveraging existing hydraulic infrastructure such as flood-control and diversion structures, MAR can cost-effectively enhance aquifer storage, improve drought resilience, and reduce evaporative losses compared to surface storage.

The Phase I MAR Study therefore focuses on identifying and screening potential MAR opportunities across the Rincon and Mesilla Valleys, from Caballo Dam in the north to the New Mexico–Texas state line in the south. This corridor encompasses the Rio Grande alluvial valley, adjacent arroyos, and valley-fill and Santa Fe Group aquifers, which are hydrologically interconnected and critically important to irrigation, municipal supply, and environmental flows. Figure 1 shows the study area as well as boundaries of the major surface watershed, groundwater basins, the Elephant Butte Irrigation District, and Dams owned and/or operated by EBID under oversight of the New Mexico Office of the State Engineer (NMOSE).

1.2. Stakeholders and Collaboration

The New Mexico Interstate Stream Commission (NMISC) leads the project in close coordination with federal, state, local, and regional stakeholders involved in water management, flood control, and aquifer sustainability in the Lower Rio Grande Basin. Key collaborators include:

- Office of the State Engineer (OSE) – Regulatory oversight and technical coordination.
- Elephant Butte Irrigation District (EBID) – Cooperator providing data, infrastructure access, and operational expertise.
- Caballo and Doña Ana Soil and Water Conservation Districts (SWCDs) – Owners or sponsors of numerous flood-control dams.
- U.S. Bureau of Reclamation (USBR) and U.S. Army Corps of Engineers (USACE) – Technical partners in regional hydrologic and sediment-transport modeling.
- International Boundary and Water Commission (IBWC) – Binational agency overseeing water distribution and flood-control infrastructure along the U.S.–Mexico border, coordinating with NMISC on projects near the international boundary.

- U.S. Geological Survey (USGS) – Data provider for hydrogeologic, climatic, and hydrometric datasets.
- Tribal Nations and Pueblos of the Lower Rio Grande watershed, including the Piro-Manso-Tiwa Tribe of the Las Cruces area, who hold cultural and historical interests tied to Rio Grande water resources.
- Regional and municipal water providers, acequia associations, agricultural organizations, and conservation groups – representing key local interests in sustainable water management.

Through this collaborative framework, the NMISC ensures that the Lower Rio Grande MAR Program aligns with state policies, federal mandates, and international and interstate water-delivery obligations, while promoting transparent, science-based, and equitable management of shared water resource.

2. Procedures, Methodologies & Analyses

The Phase I Lower Rio Grande (LRG) Managed Aquifer Recharge (MAR) Study was designed to establish a robust, data-driven foundation for evaluating the feasibility of MAR implementation within the Rincon and Mesilla Valleys of southern New Mexico. The study's methodologies integrate hydrologic, hydrogeologic, geospatial, and engineering analyses to identify, screen, and prioritize existing hydraulic structures that could support recharge enhancement in the Lower Rio Grande Basin.

The Phase I analytical framework emphasizes a tiered approach, beginning with comprehensive data compilation and integration, followed by geographic information system (GIS)-based analysis, hydrologic and hydrogeologic assessment, and site-specific conceptualization. This process ensures that potential MAR opportunities are evaluated consistently, transparently, and with sufficient technical rigor to support later design and feasibility studies under Phase II.

At the outset, Task 1.1 (Data Compilation and Inventory) focused on acquiring, reviewing, and standardizing all relevant datasets necessary to characterize the hydrologic and physical setting of the study area. Data sources included the NMOSE and NMISC REST GIS services, EBID infrastructure records, and federal datasets from the U.S. Geological Survey (USGS), NOAA, U.S. Department of Agriculture (USDA), and the PRISM Climate Group. Additional information on flood-control structures was obtained from the Caballo and Doña Ana Soil and Water Conservation Districts (SWCDs) and the International Boundary and Water Commission (IBWC). These data were compiled into a unified geodatabase to support spatial and statistical analyses.

Subsequently, Task 1.2 (Field Site Visits) was conducted to validate existing data, document physical site conditions, and evaluate accessibility, infrastructure integrity, and hydrologic context. The field observations informed the refinement of conceptual

site descriptions and confirmed the representativeness of selected sites within the basin.

Building on this foundation, the analytical procedures in Task 2 (MAR Conceptual Site Models and Site Screening) focused on developing Conceptual Site Models (CSMs) to illustrate the hydrologic interactions between source waters, recharge mechanisms, and receiving aquifers. Screening criteria were developed based on parameters such as catchment area, runoff potential, reservoir capacity, soil and geologic structures and properties (e.g., permeability), proximity to aquifers, and operational feasibility. Each site was evaluated using a scoring matrix to identify those most suitable for MAR pilot or full-scale development.

This tiered methodology—data compilation, field validation, and screening-level conceptual modeling—provides a structured and replicable approach for assessing MAR feasibility across the LRG Basin. It ensures that Phase I results are both scientifically defensible and practically applicable, forming a clear basis for prioritizing candidate sites and technologies for more detailed Phase II analysis and engineering design.

2.1. Data Discovery, Compilation, and QA/QC

The Task 1.1 Technical Memorandum documents Lynker Corporation's initial data collection, review, and synthesis activities. The purpose of this task was to assemble and organize all available datasets required to evaluate potential MAR opportunities within the LRG Basin, specifically the Rincon and Mesilla Valleys between Caballo Dam and the New Mexico–Texas border.

The objective of Task 1.1 was to establish a geospatial and data-driven foundation for screening and analyzing existing hydraulic and flood-control structures that could be adapted for MAR implementation. The work began following a project kickoff meeting on April 1, 2025, after which Lynker developed a Request for Information (RFI) outlining desired datasets. The ISC responded with access to its online GIS REST data services and supplemental materials from cooperating agencies.

Using these resources, Lynker conducted an extensive review of datasets describing hydrologic, geologic, topographic, climatic, and infrastructure conditions. Through spatial analyses of NMOSE and NMISC data, Lynker identified 30 flood-control and water-management structures—owned primarily by the Elephant Butte Irrigation District (EBID), IBWC, Caballo SWCD, and Doña Ana SWCD—as candidates for MAR evaluation. These structures include small dams, arroyos, and detention features with potential to retain stormwater for aquifer recharge. The list was updated in coordination with ISC and EBID representatives during an April 24, 2025 meeting.

The memo provides detailed discussion of the data types and sources compiled for the study:

- Hydraulic infrastructure: dam locations, ownership, and characteristics from NM OSE “Dams_LRG” files and EBID boundaries.
- Hydrology and hydrography: USGS National Hydrography Dataset (HUC 08–12 basins) for stream delineation and flow network mapping.
- Topography: one-meter LiDAR DEM data from the USGS 3DEP program for catchment and flood-inundation analysis.
- Geology and soils: surface and subsurface datasets from USGS and USDA Soil Survey Program for permeability and storage evaluation.
- Climate and hydrometeorology: precipitation and temperature records from PRISM, GridMET, NOAA HADS, and USGS networks, supplemented by evapotranspiration data from OpenET and soil-moisture products from NASA SMAP and Sentinel-1.
- Land use and vegetation: classified imagery from USGS Land Cover, Landsat, and SPOT for assessing runoff, infiltration, and recharge potential.

The datasets were organized into a centralized geodatabase structured for use in GIS and hydrologic modeling applications. Lynker’s preliminary analyses confirmed the availability of sufficient regional data to proceed with Phase I screening but noted remaining needs for engineering drawings, WR-09 dam forms, geotechnical studies, and monitoring reports to refine structure-specific assessments.

The memo concludes with recommended next steps, including:

1. Continuing to obtain outstanding O&M and design data from OSE and EBID.
2. Developing watershed-scale water-yield estimates using National Water Model (NWM) and Flood Inundation Mapping (FIM) tools.
3. Selecting representative structures for field verification and site visits (scheduled for late May 2025).
4. Advancing toward MAR Conceptual Site Model development and screening methodology design in Task 2.

Overall, Task 1.1 established the analytical framework, identified 30 candidate MAR sites, and compiled the geospatial datasets necessary to support the forthcoming hydrologic and engineering evaluations in Phase I of the Lower Rio Grande MAR Feasibility Study.

2.2. Hydraulic Structure Identification & Selection

A key component of Task 1.1 under the Phase I Lower Rio Grande (LRG) Managed Aquifer Recharge (MAR) Study was the systematic identification, screening, and cataloging of existing hydraulic and flood-control structures within the Rincon and Mesilla Valleys that could serve as potential MAR sites. The objective of this effort was

to establish a defensible and data-driven inventory of candidate structures suitable for further hydrologic and engineering assessment in Phase II.

The identification process began with the acquisition and integration of multiple geospatial datasets provided by the New Mexico Office of the State Engineer (OSE) and Interstate Stream Commission (ISC) through the state's ArcGIS REST data services. The primary dataset utilized for this task was the OSE_Dams_LRG feature layer, which catalogs dam locations, attributes, and ownership across the Lower Rio Grande Basin. Supplemental data layers included the Elephant Butte Irrigation District (EBID) boundaries, county polygons, hydrologic unit code (HUC) basins, and river and conveyance line features.

A spatial overlay analysis was conducted to identify flood-control and water-retention structures located within or adjacent to the EBID service area. The analysis intersected the "OSE_Dams_LRG" dataset with EBID boundary polygons, isolating structures that lie within or immediately upstream of the managed irrigation network. This procedure identified seven dams located within the spatial overlap zone and an additional fifteen structures with EBID ownership or operational association listed in their attribute tables.

Further manual review of dam directories, spatial attributes, and ownership records expanded this set to include other nearby flood-control structures, yielding a preliminary inventory of approximately 23 candidate dams for MAR consideration.

Lynker performed an iterative refinement of this preliminary list using an elimination and prioritization logic designed to focus the Phase I evaluation on structures with practical MAR potential. Elimination criteria included:

- Redundant entries or structures already included under larger systems;
- Dams located outside the Lower Rio Grande Basin hydrologic boundary;
- Structures lacking identifiable storage, conveyance, or operational access; and
- Sites with clear functional or administrative exclusion (e.g., private-use ponds or inactive detention features).

The refined list was reviewed in coordination with NMISC and EBID staff during the April 24, 2025 coordination meeting. At that meeting, ownership records, structure condition, and operational information were verified, and a final list of 30 flood-control structures was agreed upon for Phase I analysis.

This final inventory included structures managed by the Elephant Butte Irrigation District (EBID), Caballo Soil and Water Conservation District (SWCD), Doña Ana County Flood Commission (DACFC), and the International Boundary and Water Commission (IBWC), with original construction primarily undertaken by the U.S. Department of Agriculture – Natural Resources Conservation Service (NRCS). Ownership and operation responsibilities were documented in the Final Structure List (Table 3) included in the Task 1.1 Technical Memo.

The resulting 30-structure inventory spans the entire LRG project area—from Caballo Dam and the Rincon Valley in the north to Tortugas and Picacho sites near Las Cruces and Anthony Arroyo near the southern terminus of the EBID boundary. To visualize the spatial distribution of the candidate structures, Lynker developed two detailed mapping products:

- [Figure 2](#) – Northern Study Area Structures: showing the Rincon Valley through central Doña Ana County, including the Caballo Arroyo, Hatch Valley Arroyo, and Crow Broad Placitas dam groups; and
- [Figure 3](#) – Southern Study Area Structures: showing the Mesilla Valley through the Las Cruces and Anthony sub-basins, including Dona Ana, Fillmore, Tortugas, and Apache-Brazito-Mesquite structures.

These maps serve as the foundational spatial reference for all subsequent hydrologic, geomorphic, and recharge feasibility analyses. Each mapped site is cross-referenced to its corresponding entry in Table 3: Final List of Thirty Dams with attributes including official and common names, NID identifiers, ownership, construction agency, sponsor, and operations and maintenance (O&M) responsibility

The Hydraulic Structure Identification and Selection task successfully established the baseline dataset for MAR feasibility screening in the LRG Basin. The 30 identified structures collectively represent a diverse range of hydrologic settings, drainage areas (ranging from ~7 to 70 square miles), storage capacities (hundreds to several thousand acre-feet), and infrastructure conditions.

These sites form the core focus of the subsequent hydrologic yield, sedimentation, and recharge analyses planned for Phase I Tasks 2 and 3. As the study progressed, Lynker and NMISC further refined these structures' MAR potential using water yield modeling, field verification, and Conceptual Site Model (CSM) development to prioritize candidate projects for Phase II feasibility evaluation.

2.3. Review of Pertinent Studies and Publications

Lynker reviewed and compiled information to support this study from publications and reports. The subsequent subsections are grouped by reference type and provide summaries relevant to this Phase I LRG MAR study.

2.3.1. LRG Specific Studies

Three references documenting investigations set within the Lower Rio Grande watershed, with emphasis on the Mesilla Basin/Valley, with each contributing evidence needed to site, design, and permit MAR. Together they address (1) where recharge is hydrogeologically favorable, (2) whether near-surface materials can actually take water at meaningful rates, and (3) how the river exchanges water with the aquifer at the reach scale, which are all key inputs to Phase I screening and Phase II feasibility.

Draft Lower Rio Grande Recharge Feasibility Study – Background Evaluation (DBS&A, Dec 15, 2022).

Prepared for NMISC, this background study delineates the Mesilla Basin project area, compiles hydrogeologic and environmental constraints, and pinpoints sub-basins with the best MAR potential. Using literature review and a basin-wide environmental screen, the report highlights Las Cruces Bench, Fairacres, and Mesquite as favorable zones where Upper Santa Fe Group deposits are well connected to Rio Grande alluvium. It documents rising TDS southward, seasonal salinity variability, and localized geothermal/brine influences, then inventories wells, permits, flood hazards, and regulated sites to guide siting. A 2022 multi-agency field tour (ISC, USBR, NRCS, EBID, DBS&A) scoped candidate infrastructure (e.g., Leasburg & Mesilla Diversion Dams, drains, arroyos), and the report recommends progressing a pilot near the Mesilla Drain with agency coordination (including IBWC) and risk assessments for large dams pursued separately. The overarching objective was to improve stormwater management, mitigate pumping-related cones of depression, and maintain groundwater flow toward the Rio Grande.

Infiltration Testing and Soil Sampling along the Mesilla Drain (DBS&A, June 28, 2023):

Focused on a ~1.4-mile reach of the Mesilla Drain (between Pajaro Rd and the Eastside Canal), DBS&A conducted double-ring infiltrometer and Guelph permeameter tests at five sites (MD#1–MD#5), with companion lab analyses (ASTM D5084, D6913/7928, etc.). Field infiltration spanned roughly 8.5×10^{-4} to 3.3×10^{-2} cm/s, with saturated hydraulic conductivity from labs ranging 2.1×10^{-4} to 3.2×10^{-2} cm/s, which are generally consistent and indicative of sandy to loamy materials capable of surface infiltration; only MD#1 (finer textures) showed lower rates. The report concludes that conditions are suitable for MAR via surface infiltration, recommends proceeding with a pilot, and calls for ongoing monitoring of infiltration performance.

Gradient Self-Potential Logging in the Rio Grande to Identify Gaining and Losing Reaches across the Mesilla Valle (Ikard, Teeple & Humberson, 2021)

USGS and IBWC implemented waterborne gradient self-potential (SP) logging over ~72 km of the Rio Grande (Leasburg Dam to Canutillo, TX) to delineate gaining vs. losing reaches during bankfull flow. Results show a net losing condition from Leasburg to Mesilla Diversion Dam (with localized gains), transitioning to neutral/mild gain then mild–moderate gain just below Mesilla Diversion before switching back to losing toward the state line. The SP-inferred exchange patterns are corroborated by historic seepage runs, vertical gradients, and resistivity profiles—establishing a defensible reach-scale map of surface-water/groundwater interaction to guide MAR siting and monitoring.

These studies are germane for the Phase I LRG MAR Study for the following reasons:

- Where to look (regional siting): The feasibility background locates hydrogeologically favorable subdivisions (Las Cruces Bench, Fairacres, Mesquite) and flags environmental/permitting context—direct inputs to Task 1.1 screening and CSM development.

- Can the ground take water (site viability): The Mesilla Drain testing provides measured infiltration/ K_{sat} ranges suitable for surface infiltration MAR, validating a priority pilot area and informing screening scores (effectiveness/implementability/cost).
- How the river behaves (reach-scale targeting): The SP logging maps consistent losing segments (favorable for infiltration capture) and gaining segments (important for monitoring/avoidance), aligning with Phase I's spatial overlay and future model constraints.

Together, these works supply the hydrostratigraphic context, measured infiltration capacity, and river–aquifer exchange framework that Phase I needs to identify high-value MAR opportunities and de-risk Phase II feasibility and design.

2.3.2. Relevant MAR Related Studies

Seven relevant technical references that provide examples of MAR (and enabling practices) in arid–semiarid climates. Collectively they span reservoir-based MAR, rainwater-harvesting + MAR (RWH-MAR), reach-scale targeting, hillslope/mountain recharge opportunities, smart stormwater operations, and low-cost monitoring, each directly translatable to the Lower Rio Grande context.

Central Saudi Arabia Case Study (Al-Othman, 2011):

Assesses artificial recharge in an extremely arid setting where dam reservoirs are used to enhance infiltration. Water-level responses in the impoundment are analyzed to infer infiltration and recharge effectiveness under high evaporation and limited rainfall. The study demonstrates that strategically sited small dams can meaningfully augment aquifer storage even where diffuse recharge is minimal, provided sediment management and percolation pathways are maintained. Implications include sizing detention, accounting for evaporation losses, and using pool stage behavior as a performance proxy—useful principles for dam-centric MAR screening in the LRG.

Nature-based solutions (NbS) for recharge (systematic review) (Kebede et al. 2024):

A review of NbS classified into MAR vs. “ancillary recharge methods” (ARMs). Most MAR studies (50/61) report increased recharge, while ARMs show mixed results. Key gaps include long-term performance, cost–benefit, and scalability; opportunities include integrating monitoring and standardized evaluation frameworks. Guidance emphasizes choosing interventions with strong hydrologic drivers (head gradients, permeability), managing clogging, and building tractable monitoring plans. For LRG, the synthesis supports favoring MAR configurations with clear hydraulic controls and measurable outcomes.

Sand Hollow Reservoir, Utah (MAR accounting), USGS OFR 2022-1089 (Marston, 2024):

Updates a long-running reservoir-MAR program in an arid basin: ~159,000 ac-ft recharged to the Navajo Sandstone (2002–2018), with concurrent municipal

withdrawals from wells and drains and detailed water-budgeting (storage change, evaporation, seepage). The report couples stage, pumping, drain flows, met data, and tracers to quantify timing and movement of recharge. Lessons for LRG include off-channel reservoir MAR viability, the magnitude of evaporation penalties, the value of drains/wells for beneficial capture, and the need for integrated budget + geochemistry to verify recharge arrival

RWH-MAR in El Qaa Plain, South Sinai (Abd-Elaty et al., 2024):

Combines Watershed Modeling System (WMS) with SEAWAT to test RWH-MAR under multiple flood-return periods. Modeled outcomes show aquifer potentiality rising from ~21.7 to 24–49 MCM/yr as event magnitude increases; groundwater storage gains ~12–127% across scenarios. The study illustrates routing flash-flood runoff to recharge wells and storage dams to buffer drought, mitigate hazards, and build groundwater reserves. For LRG, the integrated surface–subsurface design approach and explicit sizing for flood volumes parallel arroyo/dam MAR opportunities in Rincon–Mesilla.

Hillslope & mountain MAR (review) (Meles et al., 2024):

Argues for expanding MAR to hillslopes/mountain fronts, leveraging coarser deposits, shorter vadose zones, and better connectivity (vs. valley-floor clays). Literature suggests hillslopes can supply ~15–50% of valley-floor recharge. Proposes repurposing roadside channels and using lineaments/faults/alluvial fans as fast-path targets; highlights uncertainties (heterogeneity, quality risks) and the need for new monitoring/analysis tools. For LRG, this broadens siting beyond valley-floor dams to fan-toe arroyos and mountain-front conduits, aligned with Phase I screening logic.

“Smart” stormwater management roadmap (Sweetapple et al., 2023):

Reviews barriers and a path to deploy IoT/real-time control (RTC) for stormwater storage/conveyance amid climate non-stationarity and aging infrastructure. While technical barriers are shrinking, socio-economic hurdles (trust, cost, governance) persist. The proposed “smart stormwater wheel” gives a phased methodology to add sensing, analytics, and optimization. For LRG MAR, this supports dynamic operation of detention pools, gates, and release timing to favor infiltration windows, manage sediment, and coordinate with irrigation networks—complementing structural MAR retrofits.

Flood-MAR: Using Flood Water for Managed Aquifer Recharge to Support Sustainable Water Resources (white paper) (California Department of Water Resources, 2018):

Presents a comprehensive framework for capturing and recharging floodwaters (i.e., Flood-MAR) and how the implementation can strengthen groundwater sustainability, reduce flood risk, and improve resilience to climate extremes, addressing challenges like declining snowpack, drought, and variable floods. The paper highlights key barriers such as conveyance limits, permitting, and coordination among agencies, while emphasizing co-benefits like water supply reliability, drought preparedness, and ecosystem support. It calls for pilot projects, partnerships, and data-driven research to scale implementation. Though focused on California, Flood-MAR concepts such as

aquifer recharge, stormwater capture, and low-cost monitoring are directly applicable to regions like the LRG, where episodic floodwaters can be turned into sustainable groundwater resources.

These references are relevant to the Phase I LRG MAR Study because they collectively validate MAR feasibility in arid/semiarid settings, quantify expected recharge magnitudes (and evaporation losses), and provide design/operations playbooks: dam-pool infiltration (Saudi Arabia), reservoir MAR budgeting (Sand Hollow), RWH-MAR sizing with coupled models (Sinai), hillslope/mountain-front siting (new LRG candidates), and smart/IoT monitoring + RTC to operate structures adaptively and track performance. Consistent with lessons from California's Flood-MAR, they emphasize the value of integrating flood and groundwater management, using existing infrastructure for recharge, and coordinating operations to efficiently capture short-duration flood pulses. Together, these studies inform Task 1.1–2 (screening, CSMs, priority selection) and de-risk Phase II by clarifying where MAR is most effective, how to run it, and what to monitor to verify success.

2.3.3. MAR Monitoring Technology Methods and Applications

These relevant technical references describe and evaluate methods and applications of MAR monitoring technologies in arid–semiarid settings. Together they demonstrate how high-resolution heat-as-a-tracer tools (DTS), in-situ moisture sensors (TDR), and low-power telemetry can quantify basin infiltration, detect clogging, and provide real-time operational intelligence—capabilities that map directly onto Phase I candidate structures in the Lower Rio Grande (LRG) (e.g., flood-control dams, detention dikes, drains, and canal reaches).

Distributed Temperature Sensing (DTS) in a recharge basin. (Medina et al., 2020):

A fiber-optic DTS array (spiral layout at two depths) was deployed across a spreading basin recharged with advanced-treated water. Diurnal heat propagation through wetted sediments yielded spatially explicit infiltration rates that matched water-balance metering within ~5%. DTS maps revealed persistent high/low-rate zones and temporal transitions linked to clogging, supporting targeted maintenance and improved O&M scheduling. The study validates DTS as an operations tool to quantify recharge efficiency, diagnose clogging, and optimize cleaning cycles so limited recharge windows produce maximal yield.

Time-Domain Reflectometers (TDR) in bioinfiltration systems, (Ahmed & Borst, 2019/2021):

TDR probes at multiple depths in six tree-box filters continuously tracked volumetric water content across 121 storms. Event data and a Green–Ampt framework produced infiltration and drainage rates; both declined 20–38% in year two, evidencing aging/clogging and seasonal variability. The method turns routine storms into repeated, non-intrusive “tests” of infiltration performance and flags maintenance needs—directly transferable to MAR forebays, drains, and basin pretreatment cells.

LoRaWAN low-power water-quality telemetry. (Jabbar et al. 2024):

A solar-powered, floating, LoRaWAN node (pH, TDS, turbidity, temperature) streamed data to The Things Network and dashboards; field results agreed with laboratory instruments and achieved reliable long-range transmission. The architecture provides a practical template for distributed source-water and basin effluent monitoring at MAR sites, enabling near-real-time tracking of turbidity/clogging indicators and geochemical conditions at low cost and power.

ASTM Guidance for MAR Monitoring

ASTM D5092/D5092M: Design & Installation of Groundwater Monitoring Wells

Why it matters for MAR:

D5092 establishes construction practices that ensure defensible heads and chemistry—critical for detecting recharge arrival, vertical gradients, and potential mobilization of salts or trace constituents.

Nest strategy:

At key dams/dikes (e.g., Tortugas Site 1, Picacho North, Green Canyon), install nested wells (e.g., shallow alluvium screen + intermediate Santa Fe Group screen) along projected flow paths: upgradient sentinel, adjacent to basin/pool toe, and downgradient pathway at 0.5–2 km.

Drains/canals (Lucero Detention Dike, Leasburg reach, Boggy Spur): Pair a shallow toe-line well with a mid-depth well ~100–300 m downgradient to resolve vertical gradients and travel time from in-channel recharge features.

Construction details:

PVC or stainless to match analytes; screen slot size from grain-size analysis; bentonite/cement seals isolating screened intervals; documented elevations for accurate gradients; development per D5521 (below).

ASTM D5521: Development of Groundwater Monitoring Wells in Granular Aquifers

Why it matters for MAR:

Proper development restores formation permeability and minimizes filter-cake bias, preventing underestimation of hydraulic conductivity or artifactual turbidity/chemistry.

Application:

Specify surge-block/pump development to stable turbidity (<5–10 NTU above background) and drawdown recovery criteria; re-develop if construction sediment or basin fines migrate following initial recharge events or maintenance.

ASTM D5979: Conceptualization and Delineation of Groundwater Flow Paths and Hydrologic Processes

Why it matters for MAR:

D5979 provides the CSM framework to integrate geology, stresses, boundaries, and monitoring data so siting, tracer tests, and performance metrics are defensible.

Application:

For each candidate structure group (e.g., Crow Broad Placitas/Green Canyon; Tortugas/Picacho; Lucero/Leasburg), build a CSM that couples lidar-derived catchments, HUC flow lines, aquifer units, drains/canals, and pumping centers; define hypotheses for losing vs. gaining segments, short-circuit risks, and expected mounding to target wells and sensors.

Sensor Siting, Parameters, Telemetry and O&M Triggers

DTS (fiber-optic) siting (Medina et al.):

Where: Basin floors, detention pools, and in-channel recharge reaches downstream of dams (e.g., Tortugas discharge, Picacho North pool margins, Crow Broad Placitas forebays).

How: Spiral/serpentine cables at two depths (e.g., 10–20 cm and 40–60 cm) across transects from inlet to outlet.

What it measures: Spatial infiltration maps (heat as tracer) to identify hot/cold spots, track clogging, and optimize sediment removal cycles.

TDR siting (Ahmed & Borst)

Where: Pretreatment cells, forebays, and drain/channel banks likely to clog; embankment toes and former groundwater drains (e.g., Boggy Spur).

How: 3–4 depths (e.g., 10/30/60/100 cm) to capture event infiltration, field capacity, and drainage.

What it measures: Event-based infiltration and post-event drainage; seasonal/aging trends that signal clogging or biofilm growth.

Well network parameters (per D5092/D5521)

Hydraulic: Continuous water level (15-min) in nests for vertical gradients and mounding; occasional slug tests for hydraulic conductivity (K).

Geochemical (baseline & trend): Electrical Conductance and Total Dissolved Solids (EC/TDS), temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), alkalinity, major ions; turbidity near basins; redox species (NO₃⁻, Fe/Mn) where relevant; targeted PFAS/metals only where source-risk warrants.

Tracing (optional): Heat-pulse, salt, or fluorescein tests during controlled releases to validate travel times in priority corridors.

Telemetry & data system (Jabbar et al.)

Backhaul: LoRaWAN for basin/drain sensors; cellular for far-field wells; solar power standard.

Cadence: 5–15 min for levels/T /EC; 1–5 min for DTS/TDR during storms; auto-summaries for event metrics (infiltration, drawdown recovery).

Dashboards/alerts: Threshold-based notifications to field staff; open APIs for integration with screening matrices and O&M logs.

O&M triggers (example thresholds to embed in SOPs)

Infiltration decline: DTS/TDR shows ≥ 25 –30% drop vs. seasonal baseline at a cell/transect → inspect & rehabilitate (rake, skim, rip, or replace media).

Turbidity exceedance: Effluent or nearby toe-well turbidity >10 NTU above background for >24 h → pause recharge, inspect pretreatment.

Mounding/gradient reversal: Downgradient vertical gradient <0.02 downward or reversal to upward for >48 h → reduce loading rate and reassess conveyance throttling.

Redox shifts: Persistent DO <1 mg/L and ORP <0 mV near sensitive wells → adjust loading intervals / add drying cycles to limit bio-clogging.

The cited studies and guidance are relevant to the Phase I LRG MAR Study because they provide the measurement backbone—DTS for spatial infiltration, TDR for event-scale drainage and aging, and LoRaWAN for scalable telemetry—while guidance contained in ASTM D5092/D5521/D5979 anchor defensible well construction, development, and CSMs. Tailored to the LRG portfolio, this toolkit converts Phase I screening into actionable pilot designs: where to monitor, what to measure, how to transmit it, and when to maintain. It reduces technical and permitting risk ahead of Phase II by ensuring that performance, protection, and compliance are monitored with methods already proven in arid-region MAR.

2.3.4. MAR Standards for Engineering and Cost Estimating

The references described in this subsection evaluate engineering standards and cost-estimating methods for MAR-type projects—from hydrology and hydraulics design criteria and municipal unit-price schedules to federal cost-engineering policy and detailed earthwork estimating practice. Together they anchor defensible quantities, unit prices, contingencies, and risk treatments needed to screen and budget Phase I Lower Rio Grande (LRG) MAR concepts.

City of Las Cruces Design Standards (Chapter 32):

Local criteria for streets, urban drainage, detention pond design, operations/maintenance, soils testing, erosion control, and construction details. Establishes analysis methods, design storms, hydraulic requirements, and O&M expectations applicable to LRG MAR retrofits within the jurisdiction—essential for siting compliance and for estimating quantities consistent with city standards.

SSCAFCA Hydrology Manual (Apr 2020):

Regional hydrology guidance recommending HEC-HMS, Curve Number losses, and frequency-storm temporal distributions for design storms (100-yr for ponds/dams; 500-yr for spillways). Emphasizes calibration with long-term rain-runoff data and delineates modeling components (loss, transform, routing), PFDS precipitation inputs, and depth-area reduction caution for large basins. Useful for sizing MAR detention/retention retrofits, setting consistent hydrologic assumptions for peak-flow control and storage routing in LRG.

Earthwork Cost Estimate Report – Appendix H (2023):

A full earthwork reclamation cost framework: quantity takeoffs tied to design drawings; production-based equipment costing (EquipmentWatch, CAT Performance Handbook), NM heavy-engineering labor, and haul/push distances; direct quotes; plus 30% indirects and 17.5% O&M indirects per stakeholder agreement. Includes long-term O&M modeling, road and channel details, and standardized steps from quantities → unit costs → totals → indirects. Highly transferable to MAR basin construction: excavation/haul, embankment grading, riprap/filters, cover placement, and post-construction O&M costing.

USACE ER 1110-2-1302 (2016) – Civil Works Cost Engineering:

Policy for federal cost products (quantities, estimates, schedules, risk, Total Project Cost). Requires estimates “as though the Government were competing for award,” classification by design maturity, Work Breakdown Structure, escalation/inflation, and risk/contingency development within an Agency Technical Review framework. Sets quality, documentation, and IGE/budget estimate standards that Phase I MAR screening can mirror when building defensible planning-level costs and contingencies.

City Engineer's Estimated Unit Prices – 2025 (City of Albuquerque):

An annually updated spreadsheet of municipal unit bid prices across divisions (clearing/excavation, drainage, storm sewer, riprap, manholes, etc.), with inflation adjustments. Provides current market signal for local labor/equipment/material rates, supporting bottom-up unit pricing or reasonableness checks for MAR-related scopes (channels, detention, utilities).

ConstructEstimates – “How to Estimate Earthworks Cost” (2024):

The website: <https://constructestimates.com/how-to-estimate-earthworks-cost/>, outlines drivers (soil/rock, excavation depth, haul/lead distance, site access, equipment & labor), three volume methods (average end-area, grid-cell, cross-section), and tools (DTMs/3D, estimating software). Stresses uncertainty management and contingency planning, frequent estimate updates, and documenting assumptions. Helpful for LRG MAR to select volume methods by site complexity and to size contingencies tied to geotechnical/haul risk.

Autodesk Digital Builder – “A Guide to Excavation Costs” (Updated Feb 12, 2025):

The website: <https://www.autodesk.com/blogs/construction/a-guide-to-excavation-costs/>, explains how excavation is priced (per CY/hour), shows cost components (grading, cut/fill balance, leveling, terrain, equipment, labor), and simple volume→cost conversion. Provides typical ranges and highlights factors (location, access, seasonality) that shift unit rates. Useful as a market-context cross-check when applying local unit prices and production-based estimates on LRG MAR embankments, forebays, and channels.

These set of references are germane to the Phase I LRG MAR Study because, together, these sources let us (1) compute hydrology-driven storage and conveyance quantities, (2) convert them into traceable unit-price estimates with appropriate indirects/contingencies, and (3) present planning-level costs for prioritizing Phase I MAR candidates before Phase II feasibility/design.

2.4. Site Visits by SMEs

As part of the Phase I Lower Rio Grande Managed Aquifer Recharge (MAR) Study, a field site visit was conducted on June 5, 2025, to examine representative hydraulic structures in the Rincon and Mesilla Valleys of the Lower Rio Grande Basin.

The purpose of the field event was to:

- Observe physical site conditions of existing flood-control and drainage structures with MAR potential;
- Discuss hydrologic, geomorphic, and operational characteristics relevant to recharge feasibility; and
- Identify priority sites for further evaluation under Phase II.

The field itinerary covered structures from Las Cruces north to Hatch, New Mexico, representing a gradient of watershed size, land use, and geomorphic setting. Additional information on the June 5, 2025 field site visit, including participants, itinerary, and site observations, are detailed in Appendix A.

This field effort successfully verified key candidate MAR structures and refined priorities for continued evaluation. The revised itinerary improved spatial coverage and ensured inclusion of representative geomorphic and operational conditions across the Lower Rio Grande Basin. Findings from these visits will directly inform the Conceptual Site Model (CSM) development and screening analyses in subsequent Phase I tasks.

Table 1. Summary of Site Visits and Pertinent Data

Site Name	Structure Type	Storage (ac-ft)	Drainage Area (mi ²)	Key MAR Potential / Observations
Tortugas Site 1 Dam	Flood-control Dam	1,020 (ac ft flood) / 305 (ac ft sediment)	20.7	Large, well-maintained structure; favorable flood-pool infiltration potential via former groundwater drain.
Boggy Spur	Groundwater Drain / Conveyance	—	—	Downstream of Tortugas; potential MAR conveyance or infiltration reach.
Picacho North Dam	Flood-control Dam	3,945 (ac ft flood) / 680 (ac ft sediment)	7.8	High potential MAR site in discharge channel and flood pool.
Leasburg Main Canal & Lucero Detention Dike	Conveyance / Detention	—	—	Demonstrates surface-groundwater connectivity; recharge potential near levee toe zones.
Crow Broad Placitas No. 1 Dam	Flood-control Dam	4,086 (ac ft flood) / 2,645 (ac ft sediment)	69.4	Large watershed; potential MAR in flood-pool area; regional significance for sediment management.
Green Canyon Dam	Flood-control Dam	1,620 (ac ft flood) / 1,320 (ac ft sediment)	30.8	Deep impoundment; favorable geomorphic conditions for controlled recharge via infiltration galleries.
Caballo Arroyo Dam No. 2	Flood-control Dam	—	—	Moderate storage volume; near-surface permeable deposits; good MAR pilot potential.
Note: Data derived primarily from Lynker Task 1.1 Technical Memo and presentation materials.				

2.5. Hydrologic & Hydrogeologic Analysis

A screening level assessment of each of the dams visited and the Rincon Arroyo were conducted to assess the hydrology and geology to support a screening level evaluation. Rincon Arroyo was added to the list of sites evaluated for MAR due to the size of the contributing watershed and its location.

Watershed delineation was determined using the 1-meter LiDAR DEM and HUC scaling. Daily precipitation over a 16-year period (2009-2025) were developed for each watershed using PRISM to estimate the daily depth of precipitation and the portion of the watershed receiving precipitation. Land cover and corresponding runoff coefficients for each watershed were estimated using the methods and data as shown in Figure 4.

Figures 5 through 11 show the results of watershed (contributing area) assessment and land cover/runoff coefficient mapping. Additionally, these figures include geologic cross sections generated from the USGS 3D Geologic Framework Model of the LRG (USGS, 2017). Results from the screening level hydrologic and hydrogeologic evaluations are provided in the subsections below.

2.5.1. Tortugas Dams No. 1 and No. 2

As shown in Figure 5 the geologic cross-section reveals that the shallow alluvium and upper Santa Fe unit extends from the valley floor at the Boggy Spur to the storage area at Tortugas Dam No. 1. No significant, shallow faults appear between the dams and the valley-fill alluvium. The water-table aquifer in the study area is relatively shallow and contained in the fluvial-alluvial deposits (e.g., Piedmont alluvium) contained in the surface water channels above and below the Tortugas dams. Additionally, the Salopek Pond located between the Boggy Spur and the Tortugas dams provides a unique feature that can be exploited for enhancing recharge to the Mesilla basin aquifer. The hydrogeologic setting in the Tortugas dams study area is amenable to MAR.

Considering the principal spillway invert elevations at 4,095.0 feet mean sea level (MSL) and 3,959.25 feet MSL the corresponding reservoir-stage-storage rating curves for Tortugas Dam No. 1 and No. 2, respectively, the average monthly, peak daily for each month, and annual variability in the stored and discharged volumes of floodwater are shown in Table 2 and Table 3, as well as the corresponding charts.

Table 2. Tortugas Dam No. 1: Average Monthly, Peak Daily by Month, and Annual Statistics of Stored and Discharged Floodwater

MONTH	STORAGE		DISCHARGE	
	AVE. (AF)	PEAK (AF/DAY)	AVE (AF)	PEAK (AF/DAY)
OCT	301	209	251	724
NOV	186	209	107	395
DEC	302	209	98	504
JAN	199	209	94	261
FEB	135	204	46	280
MAR	145	209	53	620
APR	77	200	3	22
MAY	118	209	68	363
JUN	215	209	193	1,021
JUL	657	209	623	591
AUG	666	209	663	884
SEP	430	209	402	601
ANNUAL STATISTICS				
MIN	1,892	AF	635	AF
AVE	3,428	AF	2,599	AF
MAX	5,164	AF	5,021	AF

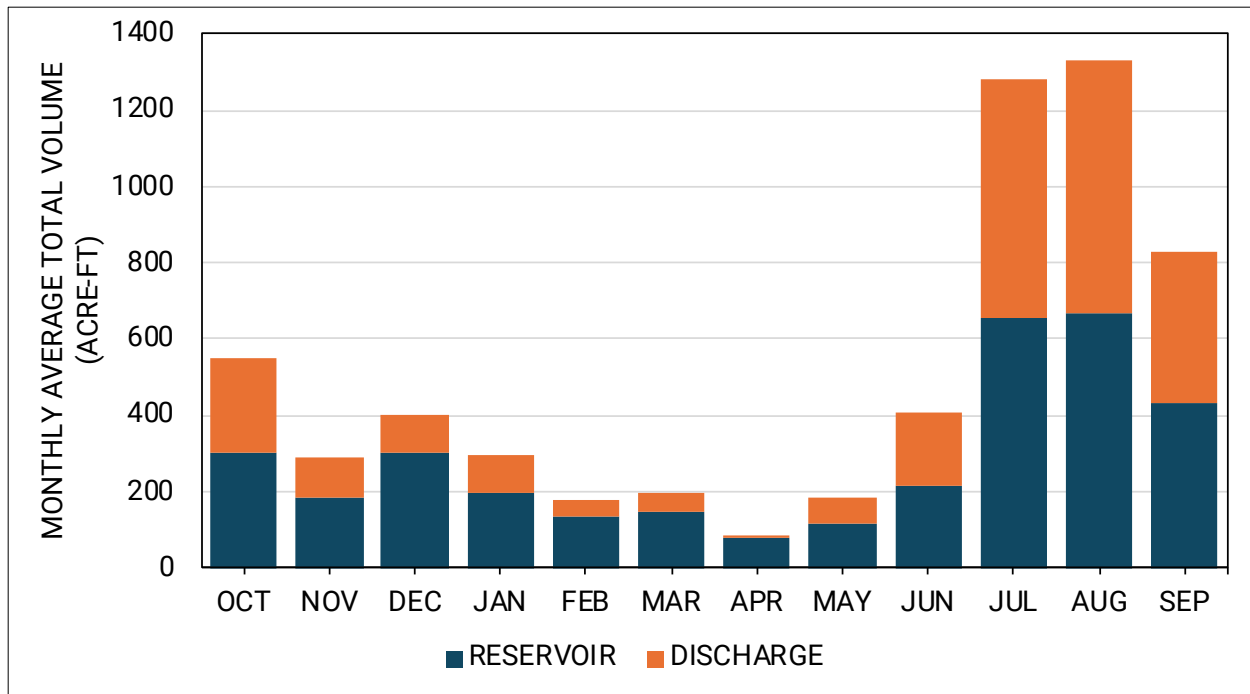


Chart 1. Tortugas Dam No. 1: Average Monthly Stored and Discharged Floodwater.

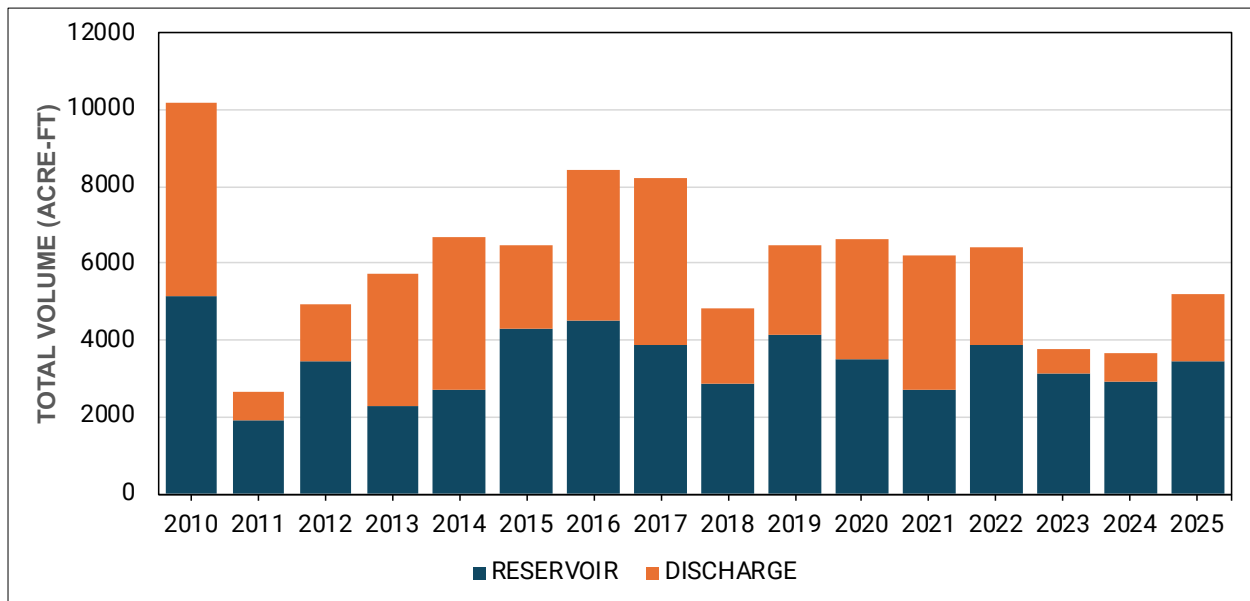


Chart 2. Tortugas Dam No. 1: Total Annual Storage and Discharge – Water Years 2010 – 2025.

Table 3. Tortugas Dam No. 2: Average Monthly, Peak Daily by Month, and Annual Statistics of Stored and Discharged Floodwater.

MONTH	STORAGE		DISCHARGE	
	AVE. (AF)	PEAK (AF/DAY)	AVE (AF)	PEAK (AF/DAY)
OCT	0.046	0.093	-	-
NOV	0.031	0.056	-	-
DEC	0.033	0.061	-	-
JAN	0.027	0.045	-	-
FEB	0.015	0.037	-	-
MAR	0.016	0.087	-	-
APR	0.006	0.019	-	-
MAY	0.020	0.053	-	-
JUN	0.043	0.121	-	-
JUL	0.108	0.139	-	-
AUG	0.098	0.097	-	-
SEP	0.075	0.079	-	-
ANNUAL STATISTICS				
MIN	0.245	AF	-	AF
AVE	0.517	AF	-	AF
MAX	0.747	AF	-	AF

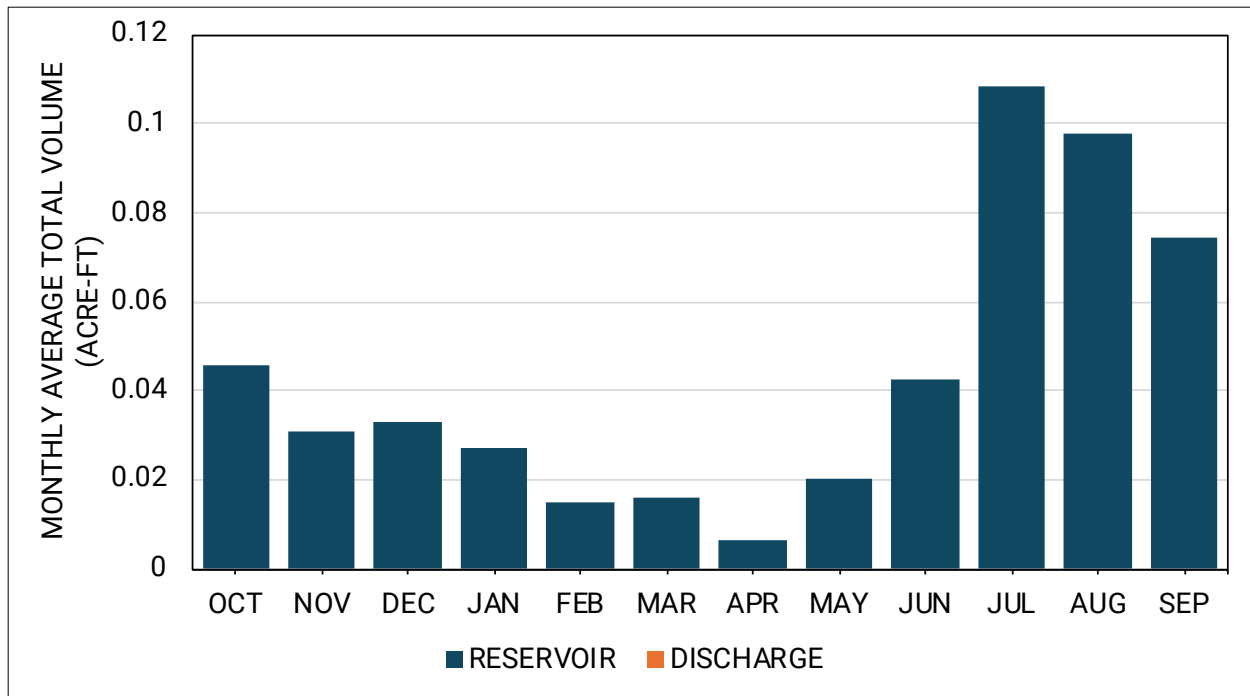


Chart 3. Tortugas Dam No. 2: Average Monthly Stored and Discharged Floodwater.

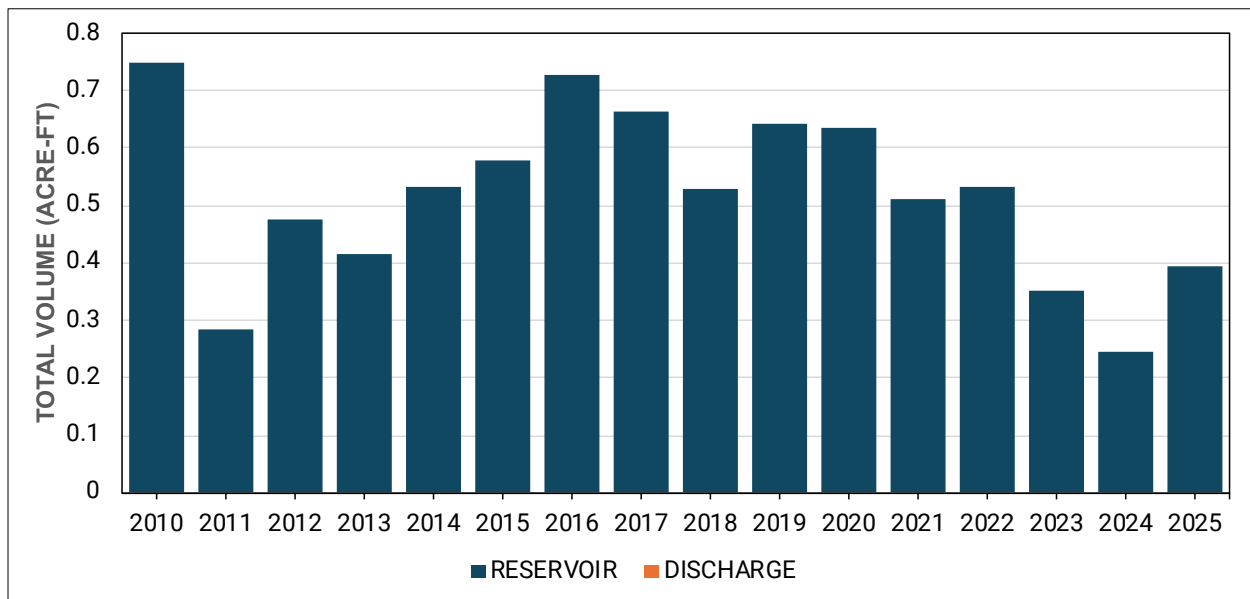


Chart 4. Tortugas Dam No. 2: Total Annual Storage and Discharge – Water Years 2010 – 2025.

Based on the screening-level hydrologic analyses of Tortugas Dams No. 1 and 2, the floodwater managed at Tortugas Dam No. 2 is negligible, accounting for less than 0.02% of the total floodwater between the two dams. Additionally, considering the principal spillway inlet elevation and the rating curve for Tortugas Dam No. 2, no discharge from this dam is predicted by the screening-level analysis. Therefore, only the

analyses results performed for Tortugas Dam No. 1 need to be considered for the quantitative screening assessment of MAR at these dams.

The Tortugas No. 1 Dam average annual stored and discharged floodwater volumes are approximately 3,400 ac-ft and 2,600 ac-ft. Over the 16 water-years evaluated the annual stored volume varies approximately $\pm 50\%$ of the average, while the discharged volumes vary between approximately -75% and $+90\%$ of the average. More than 55% of the total combined (sum of discharged and stored) annual floodwater volume is, on average, contained in the last quarter of the water year (July – September). The first quarter of the water year (October – December) accounts for approximately 20% of the total combined annual floodwater volume. The remaining annual floodwater volume is approximately evenly split between quarters 2 and 3 of the water year.

2.5.2. Picacho North Dam

As shown in Figure 6 the geologic cross-section reveals that the shallow alluvium and upper Santa Fe unit extends from the valley floor between the lateral where combined discharge flows from Picacho North and Picacho South dams discharge and the storage area at the Picacho North Dam. No significant, shallow faults appear between the dams and the valley-fill alluvium. The water-table aquifer in the study area is relatively shallow and contained in the alluvial deposits contained in the surface water channels above and below the dam. Additionally, the drain downstream of the Picacho dams is instrumented with A telemetric flume and groundwater monitoring wells that provide baseline data and in-place monitoring to support a MAR pilot study. The hydrogeologic setting in the Picacho dams study area is amenable to MAR.

Considering the principal spillway invert elevation at 3918 feet MSL and the corresponding reservoir-stage-storage rating curves for the Picacho North Dam, the average monthly, peak daily for each month, and annual variability in the stored and discharged volumes of floodwater are shown in Table 4 and the corresponding figures.

Table 4. Picacho North Dam: Average Monthly, Peak Daily by Month, and Annual Statistics of Stored and Discharged Floodwater.

MONTH	STORAGE		DISCHARGE	
	AVE. (AF)	PEAK (AF/DAY)	AVE (AF)	PEAK (AF/DAY)
OCT	38	23	148	458
NOV	27	23	80	224
DEC	44	23	81	118
JAN	32	23	67	214
FEB	26	23	33	159
MAR	24	23	24	152
APR	13	23	14	124
MAY	21	23	35	109
JUN	33	23	59	245
JUL	93	23	284	373
AUG	111	23	289	288
SEP	56	23	182	229
ANNUAL STATISTICS				
MIN	329	AF	529	AF
AVE	517	AF	1,296	AF
MAX	705	AF	2,132	AF

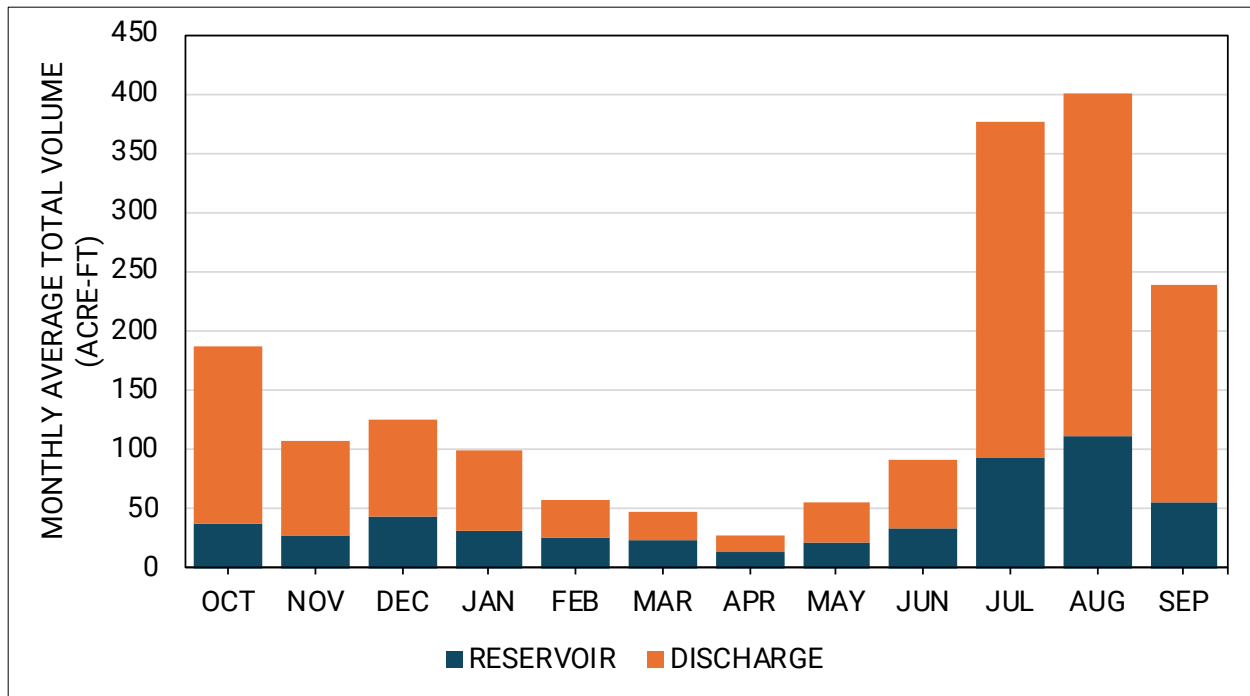


Chart 5. Picacho North Dam: Average Monthly Stored and Discharged Floodwater.

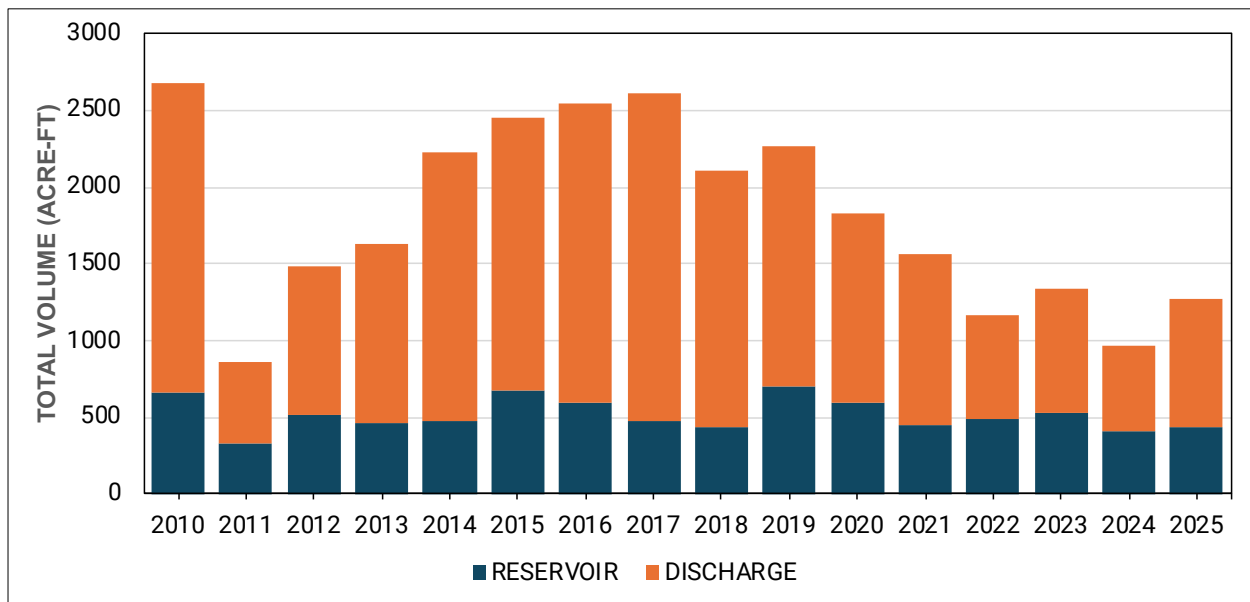


Chart 6. Picacho North Dam: Total Annual Storage and Discharge – Water Years 2010 – 2025.

The Picacho North Dam average annual stored and discharged floodwater volumes are approximately 500 ac-ft and 1,300 ac-ft. Over the 16 water-years evaluated the annual stored volume varies approximately $\pm 36\%$ of the average, while the discharged volumes vary between approximately -60% and $+65\%$ of the average. More than 55% of the total combined (sum of discharged and stored) annual floodwater volume is, on average,

contained in the last quarter of the water year (July – September). The first quarter of the water year (October – December) accounts for approximately 23% of the total combined annual floodwater volume. The remaining annual floodwater volume is approximately evenly split between quarters 2 and 3 of the water year.

2.5.3. Crow Broad Placitas No. 1 Dam

As shown in Figure 7 the geologic cross-section reveals that the shallow alluvium and upper Santa Fe unit extends from the valley floor to the storage area at the Crow Broad Placitas No. 1 Dam. Although no significant, shallow faults appear between the dams and the valley-fill alluvium, a trough in the basement rock forms a deepening of the Santa Fe groups below and in the vicinity of the dam. The dam itself lies between the Rincon and Mesilla groundwater basins (Figure 3) and the trough may demark the transition or divide between them. The water-table aquifer in the study area is likely relatively shallow and contained in the alluvial deposits that fill the surface water channels above and below the dam; however, there is little data on the shallow aquifer in this study area and additional hydrogeologic data is needed to assess this basin transition zone. The hydrogeologic setting in the Crow Broad Placitas study area is uncertain with respect to its amenability to MAR.

Considering the principal spillway invert elevation at 4,058.9 feet MSL and the corresponding reservoir-stage-storage rating curves for the Crow Broad Placitas No. 1 Dam, the average monthly, peak daily for each month, and annual variability in the stored and discharged volumes of floodwater are shown in Table 5 and the corresponding charts.

Table 5. Crow Broad Placitas No. 1 Dam: Average Monthly, Peak Daily by Month, and Annual Statistics of Stored and Discharged Floodwater.

MONTH	STORAGE		DISCHARGE	
	AVE. (AF)	PEAK (AF/DAY)	AVE (AF)	PEAK (AF/DAY)
OCT	1,509	2,451	29	462
NOV	1,017	2,379	32	454
DEC	1,148	945	48	755
JAN	900	2,356	11	183
FEB	661	1,577	-	-
MAR	437	1,015	-	-
APR	242	634	-	-
MAY	524	1,503	-	-
JUN	1,402	1,584	51	347
JUL	3,325	2,482	638	2,079
AUG	3,471	2,343	303	1,006
SEP	2,281	1,885	482	2,616
ANNUAL STATISTICS				
MIN	8,808	AF	-	AF
AVE	16,912	AF	1,593	AF
MAX	24,728	AF	5,247	AF

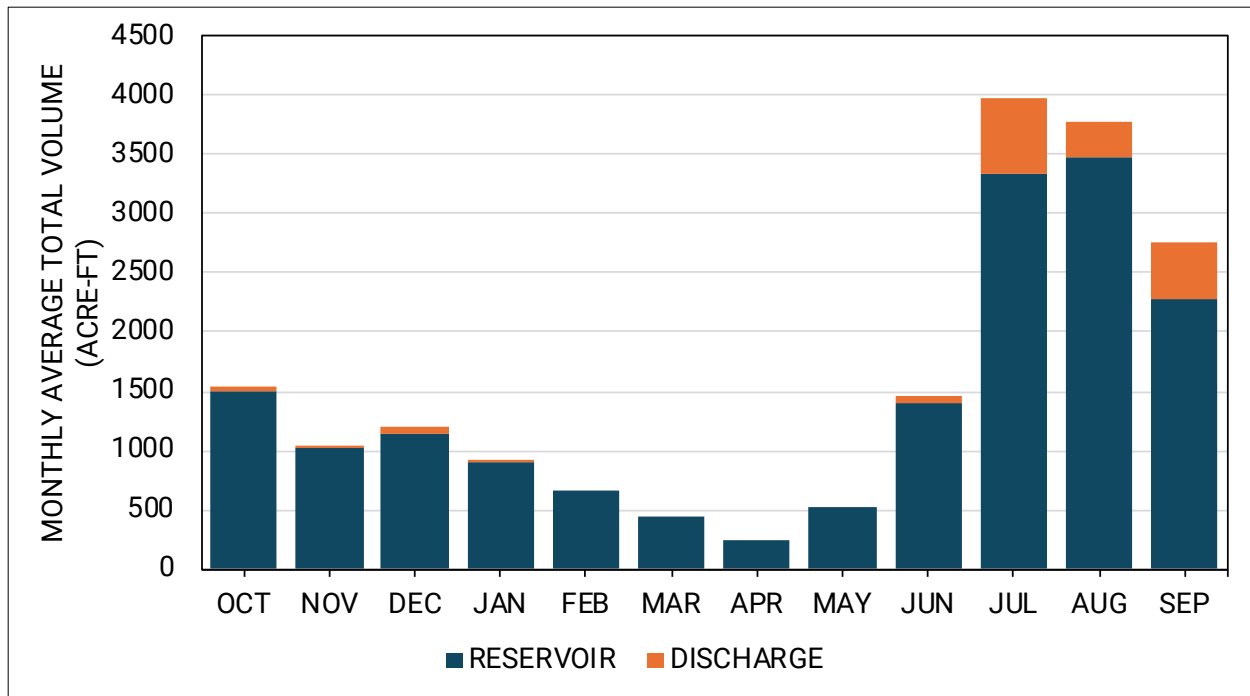


Chart 7. Crow Broad Placitas No. 1 Dam: Average Monthly Stored and Discharged Floodwater.

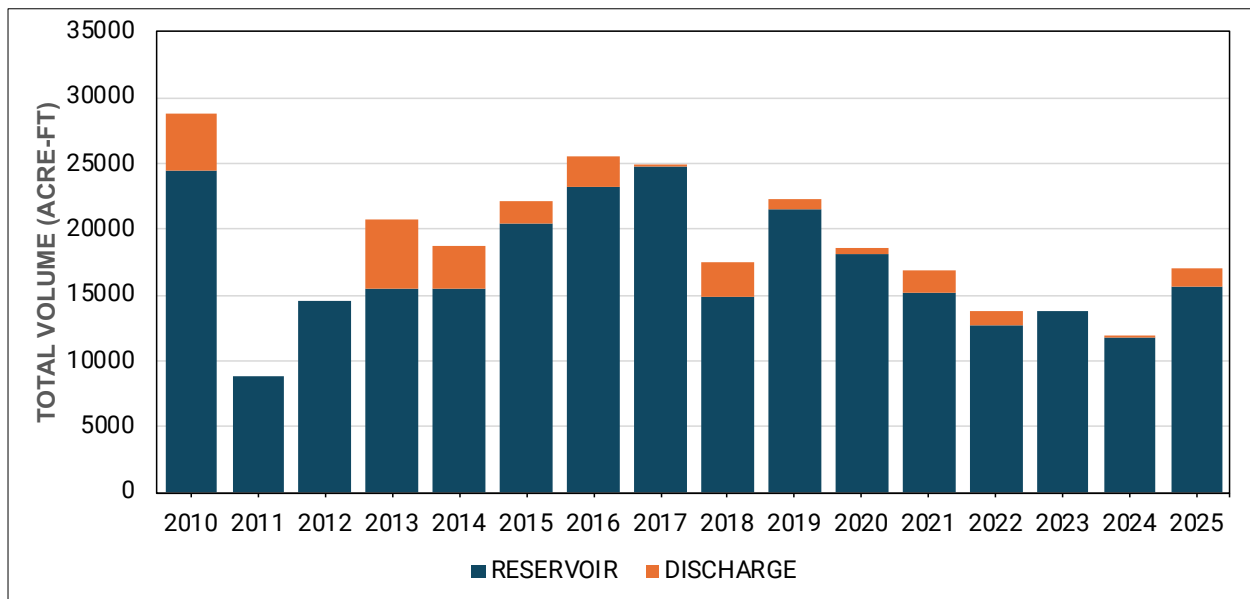


Chart 8. Crow Broad Placitas No. 1 Dam: Total Annual Storage and Discharge.

The Crow Broad Placitas No. 1 Dam average annual stored and discharged volumes are approximately 17,000 ac-ft and 1,600 ac-ft. Over the 16 water-years evaluated the annual stored volume varies approximately $\pm 47\%$ of the average, while the discharged volume varies between zero and +230% of the average. More than 55% of the total combined (sum of discharged and stored) annual floodwater volume is, on average,

contained in the last quarter of the water year (July – September). The first quarter of the water year (October – December) accounts for approximately 20% of the total combined annual floodwater volume. The remaining annual floodwater volume is approximately evenly split between quarters 2 and 3 of the water year, with no discharge estimated between February and May.

2.5.4. Crow Broad Placitas No. 2A Dam

As shown in Figure 8 the geologic cross-section reveals that the shallow alluvium and upper Santa Fe unit extends from the valley floor to the storage area at the Crow Broad Placitas No. 2A Dam. The dam is in the central portion of the Rincon groundwater basin (Figure 2) on the west side of the Rio Grande. The water-table aquifer in the study area is likely relatively shallow and contained in the alluvial deposits in the surface water channels above and below the dam. The hydrogeologic setting in the Crow Broad Placitas No. 2A Dam study area is likely amenable to MAR.

Considering the principal spillway invert elevation at 4,164.8 feet MSL and the corresponding reservoir-stage-storage rating curves for the Crow Broad Placitas No. 2A Dam, the average monthly, peak daily for each month, and annual variability in the stored and discharged volumes of floodwater is shown in Table 6 and the corresponding charts.

Table 6. Crow Broad Placitas No. 2A Dam: Average Monthly, Peak Daily by Month, and Annual Statistics of Stored and Discharged Floodwater.

MONTH	STORAGE		DISCHARGE	
	AVE. (AF)	PEAK (AF/DAY)	AVE (AF)	PEAK (AF/DAY)
OCT	4,410	3,704	2,546	7,266
NOV	3,327	3,940	2,598	8,817
DEC	4,642	3,940	1,202	4,997
JAN	3,590	3,940	1,209	8,157
FEB	2,760	3,940	1,173	6,558
MAR	2,190	3,919	19	285
APR	1,320	3,786	45	447
MAY	1,686	3,940	751	5,409
JUN	4,166	3,870	2,987	9,143
JUL	8,521	3,804	12,212	8,181
AUG	8,634	3,940	9,976	9,478
SEP	7,423	3,940	6,787	11,246
ANNUAL STATISTICS				
MIN	34,782	AF	8,450	AF
AVE	52,648	AF	41,485	AF
MAX	70,592	AF	69,409	AF

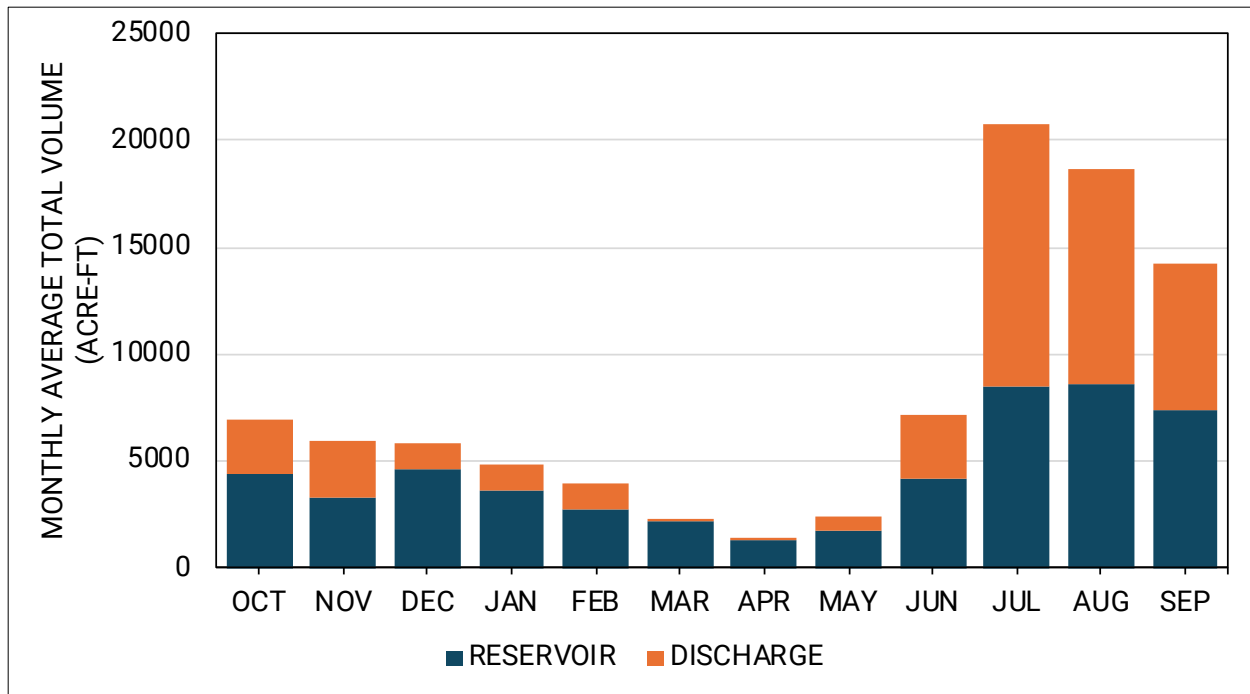


Chart 9. Crow Broad Placitas No. 2A: Average Monthly Stored and Discharged Floodwater.

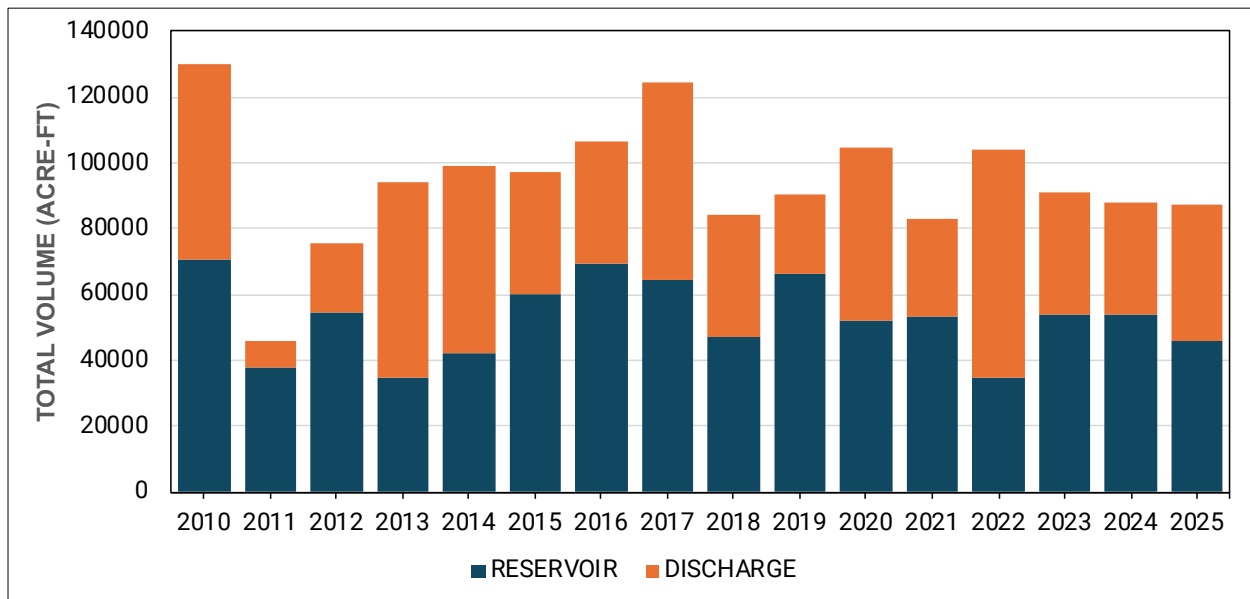


Chart 10. Crow Broad Placitas No. 2A: Total Annual Storage and Discharge.

The Crow Broad Placitas No. 2A Dam average annual stored and discharged volumes are approximately 52,600 ac-ft and 41,500 ac-ft. Over the 16 water-years evaluated the annual stored volume varies approximately $\pm 34\%$ of the average, while the discharged volume varies between -80% and +67% of the average. More than 55% of the total combined (sum of discharged and stored) annual floodwater volume is, on average,

contained in the last quarter of the water year (July – September). The first quarter of the water year (October – December) accounts for approximately 20% of the total combined annual floodwater volume. The remaining annual floodwater volume is approximately evenly split between quarters 2 and 3 of the water year.

2.5.5. Rincon Arroyo

As shown in Figure 9 the geologic cross-sections reveal that the shallow alluvium and upper Santa Fe unit extends from the Rio Grande up the main channel of the Rincon Arroyo. The water-table aquifer in lower elevation portion of the study area is relatively shallow and contained in the valley-fill alluvial deposits. The upper portions of the main channel of the Rincon Arroyo are filled with alluvium (e.g., Piedmont alluvium); however, data supporting the presence of an aquifer in these deposits was not found. Faults between the arroyo's crossing at I-25 and the railroad bridge generate a thinning of the Santa Fe units that could separate up and downstream units. Furthermore, the basement rock uplift in this faulted zone appear to generate a downward slope emptying into a thicker Upper Santa Fe unit overlain by the alluvial valley fill. Additionally, the arroyo crossing at I-25 is instrumented with an automated flow gauge that provide baseline data and in-place monitoring to support a MAR pilot study. The hydrogeologic setting of the study area, specifically between the arroyo crossing at I-25 and the railroad bridge, is amenable to MAR. The Piedmont Alluvial fill in the arroyo above the I-25 crossing may also be amenable to MAR, however, additional hydrogeologic characterization is needed in this area to confirm connection with the shallow alluvial aquifer as well as the impasse potentially imposed by the faulting and resulting uplift.

Since a dam is not present on the Rincon Arroyo storage volumes were not considered. The average monthly, peak daily for each month, and annual variability in the discharged volumes of floodwater is shown in Table 7 and the corresponding charts.

Table 7. Rincon Arroyo: Average Monthly, Peak Daily by Month, and Annual Statistics of Discharged Floodwater.

MONTH	STORAGE		DISCHARGE	
	AVE. (AF)	PEAK (AF/DAY)	AVE (AF)	PEAK (AF/DAY)
OCT	-	-	2,714	3,863
NOV	-	-	2,032	4,288
DEC	-	-	2,091	1,809
JAN	-	-	1,527	4,168
FEB	-	-	1,267	2,993
MAR	-	-	811	1,701
APR	-	-	583	1,946
MAY	-	-	1,077	2,115
JUN	-	-	2,573	2,594
JUL	-	-	7,398	3,074
AUG	-	-	7,312	4,656
SEP	-	-	5,430	4,618
ANNUAL STATISTICS				
MIN	-	AF	19,013	AF
AVE	-	AF	34,799	AF
MAX	-	AF	47,893	AF

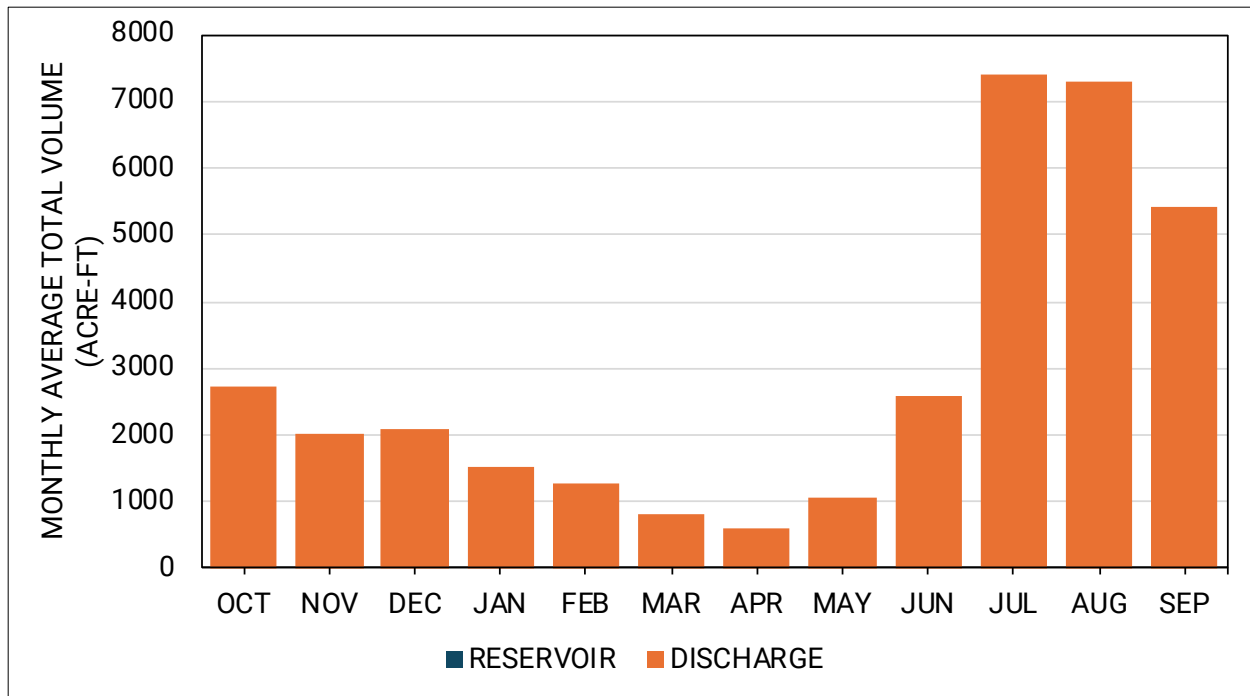


Chart 11. Rincon Arroyo: Average Monthly Discharged Floodwater.

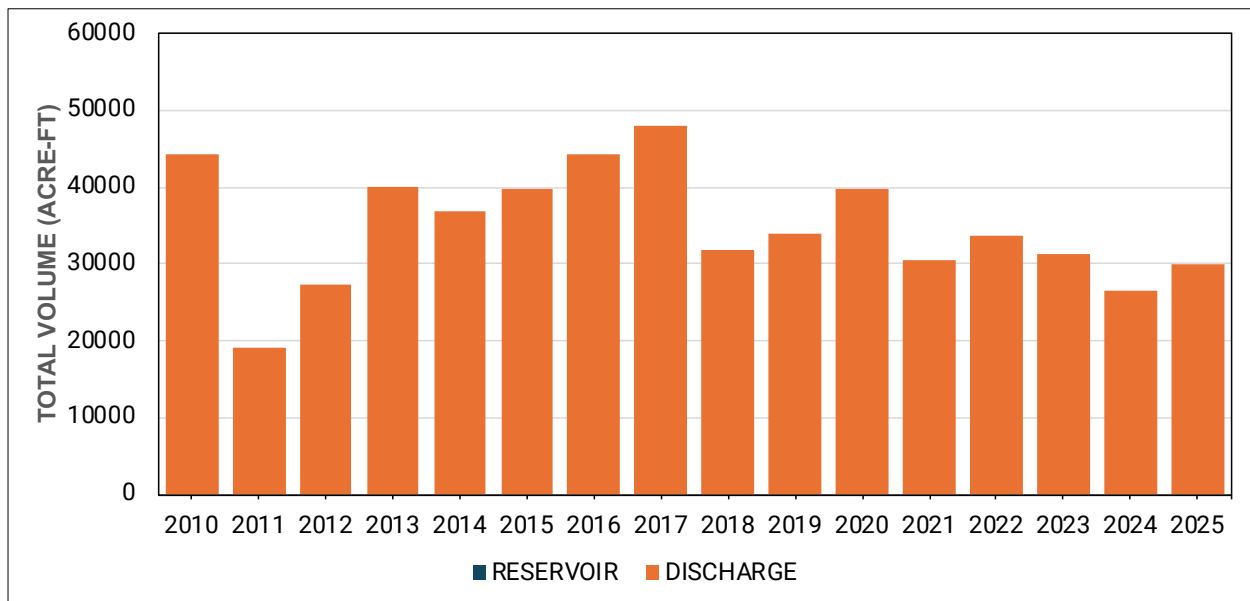


Chart 12. Rincon Arroyo: Total Annual Discharge – Water Years 2010 - 2025.

The Rincon Arroyo average annual discharged floodwater volume is approximately 34,800 ac-ft. Over the 16 water-years evaluated the annual discharged volume varies between approximately -45% and +37% of the average. More than 55% of the total annual floodwater volume is, on average, contained in the last quarter of the water year (July – September). The first quarter of the water year (October – December) accounts

for approximately 20% of the total annual floodwater volume. The remaining annual floodwater volume is approximately evenly split between quarters 2 and 3 of the water year.

2.5.6. Hatch Valley Arroyo / Caballo Arroyo Dams Study Area

As shown in Figure 10 the geologic cross-section reveals that the shallow alluvium and upper Santa Fe unit extends from the valley floor to the storage area at the watersheds at and between Caballo Arroyo Dam No 2 to the north and Hatch Valley Arroyo Dam No. 3 to the south. The watersheds of this study area include an undammed area between Hatch Valley Arroyo Dam No. 6 and Hatch Valley Arroyo Dam No. 1 and are in the central portion of the Rincon groundwater basin (Figure 2) on the east side of the Rio Grande. The water-table aquifer in the study area is likely relatively shallow and contained in the alluvial deposits in the surface water channels above and below the dam. The hydrogeologic setting in the Hatch Valley Arroyo-Caballo Arroyo Dam study area is likely amenable to MAR.

Considering the principal spillway invert elevations of the six dams in the study area and the corresponding reservoir-stage-storage rating curves for the Hatch Valley Arroyo and Caballo Arroyo dams, the average monthly, peak daily for each month, and annual variability in the stored and discharged volumes of floodwater is shown in Table 7 and the corresponding charts.

Table 8. Hatch Valley Arroyo / Caballo Arroyo Dams: Average Monthly, Peak Daily by Month, and Annual Statistics of Stored and Discharged Floodwater.

MONTH	STORAGE		DISCHARGE	
	AVE. (AF)	PEAK (AF/DAY)	AVE (AF)	PEAK (AF/DAY)
OCT	171	189	139	318
NOV	129	202	134	358
DEC	169	154	106	177
JAN	117	197	76	310
FEB	91	146	71	230
MAR	76	144	29	69
APR	53	168	28	124
MAY	85	167	50	118
JUN	174	134	137	280
JUL	449	174	505	464
AUG	392	183	479	602
SEP	329	169	403	679
ANNUAL STATISTICS				
MIN	1,443	AF	730	AF
AVE	2,232	AF	2,155	AF
MAX	2,909	AF	3,037	AF

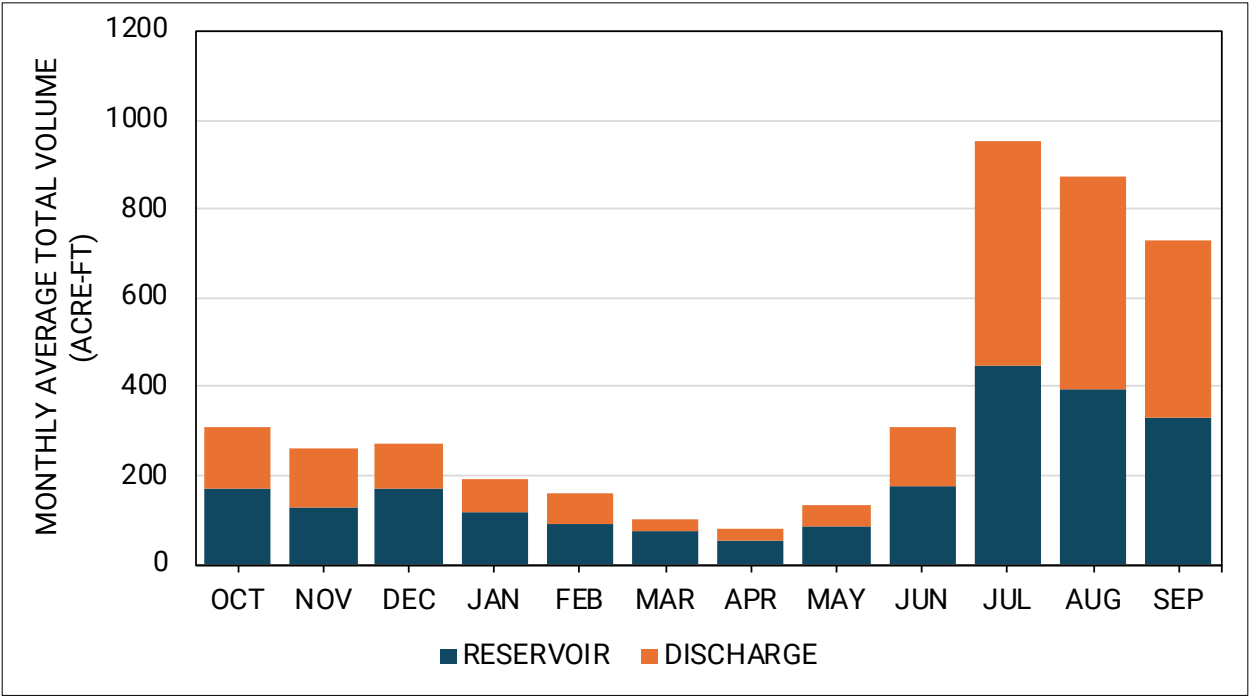


Chart 13. Hatch Valley Arroyo / Caballo Arroyo Dams: Average Monthly Stored and Discharged Floodwater.

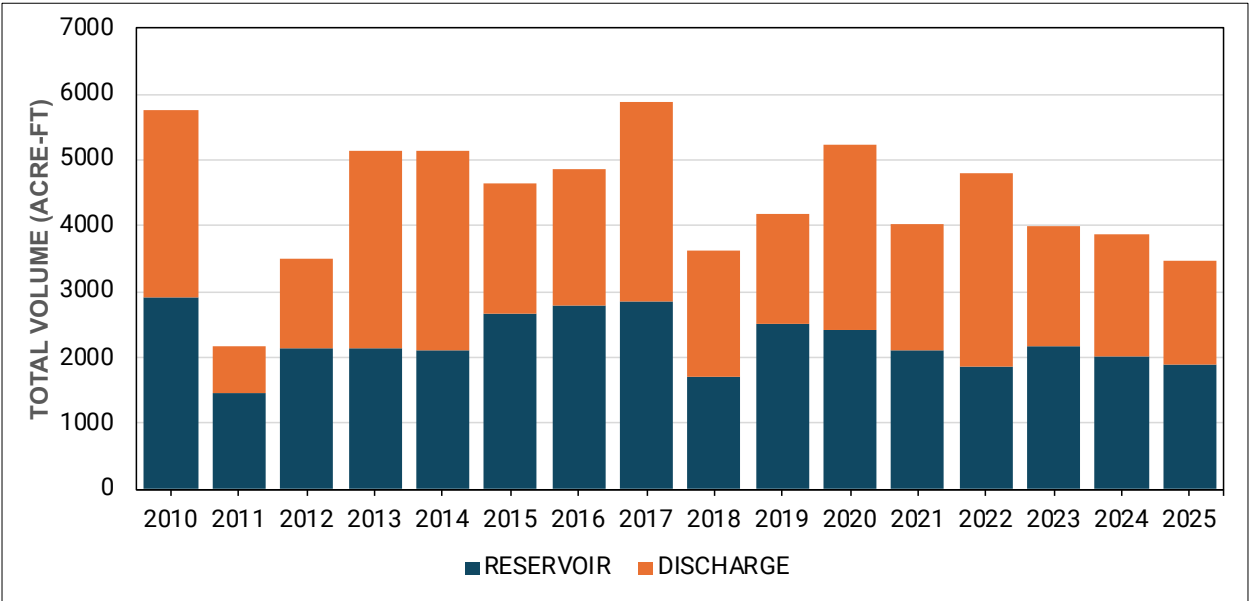


Chart 14. Hatch Valley Arroyo / Caballo Arroyo Dams: Total Annual Storage and Discharge – Water Years 2010 – 2025.

The combined, six Hatch Valley Arroyo / Caballo Arroyo Dams average annual stored and discharged volumes are approximately 2,200 ac-ft and 2,200 ac-ft. Over the 16 water-years evaluated the annual stored volume varies approximately - 35% to +30% of the average, while the discharged volume varies between -66% and +41% of the average. More than 55% of the total combined (sum of discharged and stored) annual floodwater volume is, on average, contained in the last quarter of the water year (July – September). The first quarter of the water year (October – December) accounts for approximately 20% of the total combined annual floodwater volume. The remaining annual floodwater volume is approximately evenly split between quarters 2 and 3 of the water year.

The average monthly, peak daily for each month, and annual variability in the discharged volume of floodwater for the undammed portion of the combined watershed that contains the six Hatch Valley Arroyo and Caballo Arroyo dams is shown in Table 9 and the corresponding charts.

Table 9. Undammed Flows in the Hatch Valley Arroyo / Caballo Arroyo Dams Study Area: Average Monthly, Peak Daily by Month, and Annual Statistics of Stored and Discharged Floodwater.

MONTH	STORAGE		DISCHARGE	
	AVE. (AF)	PEAK (AF/DAY)	AVE (AF)	PEAK (AF/DAY)
OCT	-	-	733	567
NOV	-	-	463	849
DEC	-	-	442	442
JAN	-	-	324	566
FEB	-	-	231	397
MAR	-	-	153	193
APR	-	-	135	317
MAY	-	-	257	322
JUN	-	-	765	581
JUL	-	-	2,978	891
AUG	-	-	3,220	1,132
SEP	-	-	1,662	1,510
ANNUAL STATISTICS				
MIN	-	AF	5,254	AF
AVE	-	AF	11,357	AF
MAX	-	AF	18,717	AF

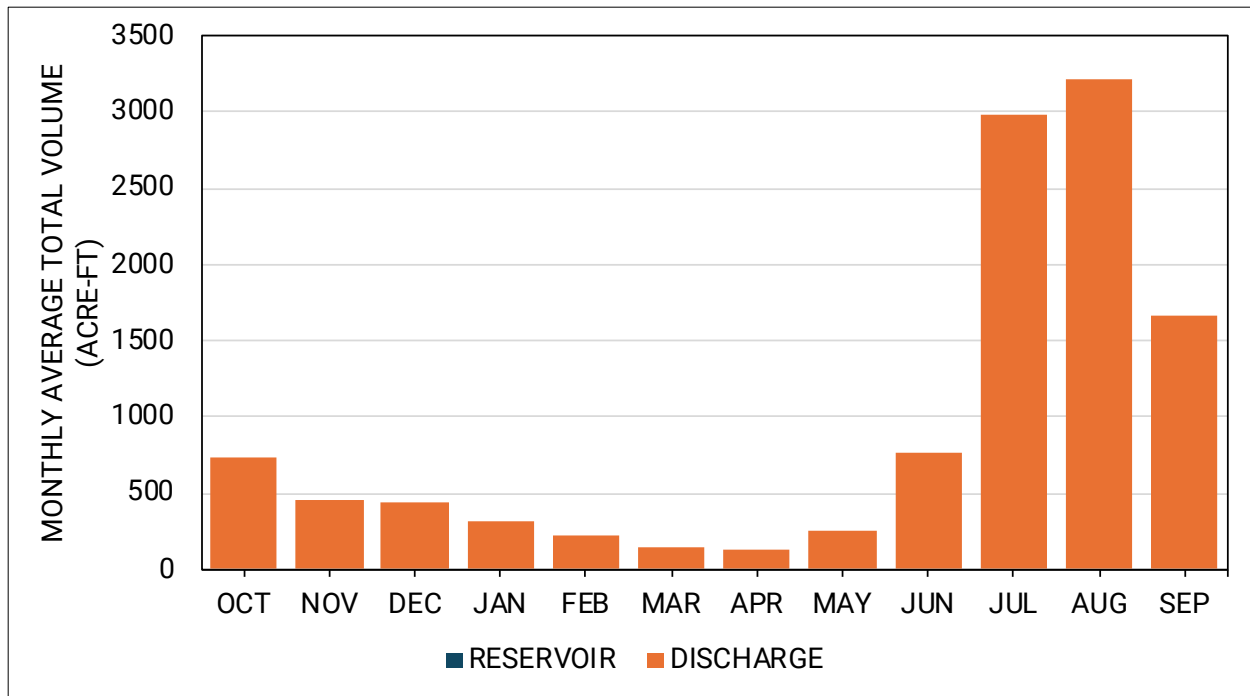


Chart 15. Undammed Flows in the Hatch Valley Arroyo / Caballo Arroyo Dams Study Area: Average Monthly Stored and Discharged Floodwater.

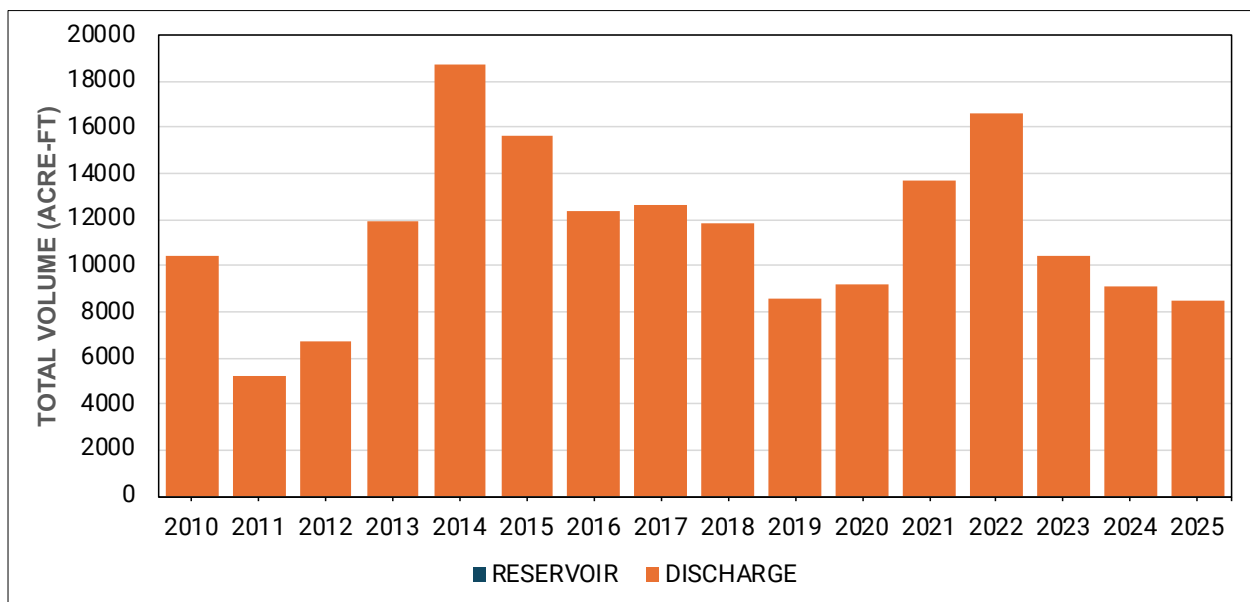


Chart 16. Undammed Flows in the Hatch Valley Arroyo / Caballo Arroyo Dams Study Area: Total Annual Storage and Discharge – Water Years 2010 – 2025.

The undammed watershed portion of the Hatch Valley Arroyo / Caballo Arroyo Dams study area average annual discharged volume is approximately 11,400 ac-ft. Over the 16 water-years evaluated the annual discharged volume varies between -54% and +65% of the average. Approximately 70% of the total annual floodwater volume is, on average,

contained in the last quarter of the water year (July – September). The first quarter of the water year (October – December) accounts for approximately 14% of the total annual floodwater volume. Quarters 2 and 3 of the water year accounts for approximately 6% and 10% of the total annual floodwater volume, respectively.

2.5.7. Green Canyon Dam

As shown in Figure 11 the geologic cross-section reveals that the shallow alluvium and upper Santa Fe unit is divided between the valley-floor and Green Canyon Dam by a severe uplift of the basement rock imposed at the Derry fault, which aligns with and is in the general vicinity of I-25. The basement rock uplift along the Derry fault appears to separate the shallow Rincon basin aquifer west of I-25 from the surficial sediments east of I-25. The dam is in the central/northern portion of the Rincon groundwater basin (Figure 2) on the east side of the Rio Grande. The water-table aquifer in the study area is likely relatively shallow and contained in the alluvial deposits in the surface water channels above and below the dam. The hydrogeologic setting in the Green Canyon study area is amenable to MAR; however, enhancing recharge at the dam storage area and the surface water channel east of I-25 may not be beneficial to users on the west side of I-25 due to the impasse imposed by the Derry fault.

Considering the principal spillway invert elevation at approximately 3 feet above the storage area floor, the average monthly, peak daily for each month, and annual variability in the stored and discharged volumes of floodwater is shown in Table 10 and the corresponding charts.

Table 10. Green Canyon Dam: Average Monthly, Peak Daily by Month, and Annual Statistics of Stored and Discharged Floodwater.

MONTH	STORAGE		DISCHARGE	
	AVE. (AF)	PEAK (AF/DAY)	AVE (AF)	PEAK (AF/DAY)
OCT	278	186	328	808
NOV	193	186	285	815
DEC	275	186	200	406
JAN	203	186	166	827
FEB	140	186	147	603
MAR	171	186	27	175
APR	89	186	110	737
MAY	142	186	78	501
JUN	269	186	336	834
JUL	645	186	1,087	715
AUG	543	186	1,033	859
SEP	474	186	1,099	1,435
ANNUAL STATISTICS				
MIN	2,248	AF	1,731	AF
AVE	3,423	AF	4,892	AF
MAX	4,691	AF	7,624	AF

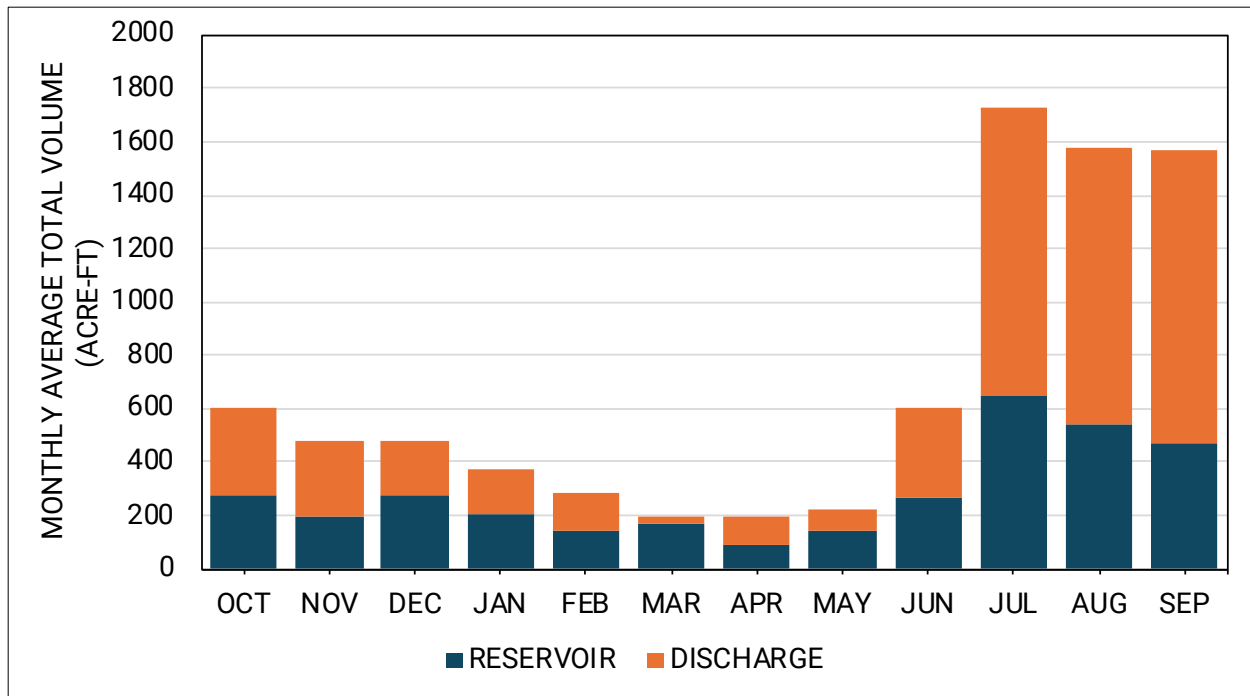


Chart 17. Green Canyon Dam: Average Monthly Stored and Discharged Floodwater.

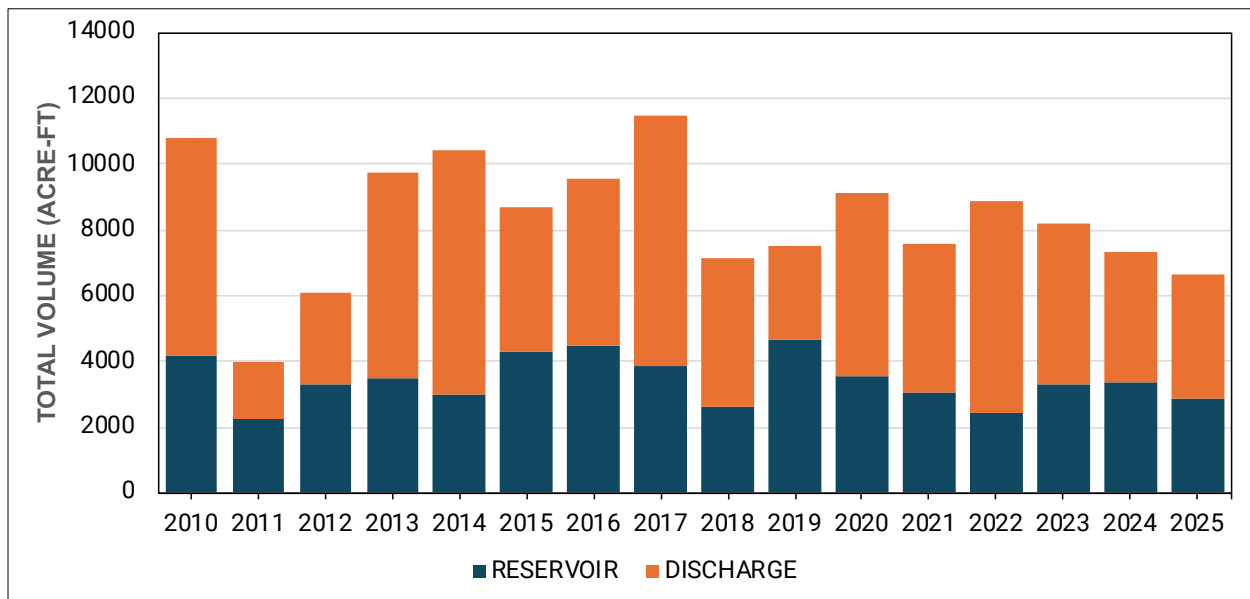


Chart 18. Green Canyon Dam: Total Annual Storage and Discharge – Water Years 2010 - 2025.

The Green Canyon Dam average annual stored and discharged volumes are approximately 3,400 ac-ft and 4,900 ac-ft. Over the 16 water-years evaluated the annual stored volume varies approximately $\pm 36\%$ of the average, while the discharged volume varies between -65% and $+56\%$ of the average. More than 58% of the total combined (sum of discharged and stored) annual floodwater volume is, on average, contained in

the last quarter of the water year (July – September). The first quarter of the water year (October – December) accounts for approximately 19% of the total combined annual floodwater volume. The remaining annual floodwater volume is approximately evenly split between quarters 2 and 3 of the water year.

2.6. Conceptual Site Models (CSMs) Development

The development of Conceptual Site Models (CSMs) represents the integrative step linking the hydrologic, geologic, and operational datasets compiled in Task 1.1 with the site-specific hydrologic analyses and field observations performed under Task 1.2. The CSMs describe the functional pathways by which surface-water sources are captured, detained, and infiltrated into subsurface aquifers, forming the scientific and engineering basis for MAR screening and subsequent feasibility evaluation.

2.6.1. Purpose and Framework

The CSMs serve multiple purposes within the Phase I MAR Study framework:

- Establish a consistent basis for comparing diverse structures (dams, drains, arroyos, canals) and hydrogeologic settings.
- Depict the physical interactions among source-water inputs, infiltration mechanisms, vadose-zone transport, and groundwater storage.
- Identify site-specific opportunities and constraints influencing recharge potential, implementability, and monitoring requirements.
- Support technology screening and the assignment of appropriate MAR typologies for each candidate site.

The CSMs were constructed following ASTM D5979 (Conceptualization and Delineation of Groundwater Flow Paths and Hydrologic Processes), supplemented by field reconnaissance, geologic cross-sections from the USGS 3D Geologic Framework Model, and hydrologic yield analyses summarized in Section 2.5. Each CSM integrates the following components:

- Source-Water Inputs: stormwater runoff, flood releases, or operational drainage from EBID or IBWC conveyance systems.
- Recharge Pathway: surface infiltration through flood-pool sediments, channel alluvium, or engineered galleries and injection wells.
- Receiving Aquifer: shallow alluvial and upper Santa Fe Group units of the Rincon and Mesilla basins.
- Boundary Conditions: geomorphic or structural features (e.g., Derry Fault, basin divides) that influence flow connectivity.
- Operational and Monitoring Elements: pretreatment, flow control, and instrumentation (e.g., DTS/TDR sensors, observation wells).

2.6.2. Generic MAR Typologies

To ensure consistent evaluation, Phase I adopted a typology-based CSM framework to define five generic MAR configurations as follows:

- Dam-Based Infiltration CSM: Recharge via flood-control or detention-dam impoundments where stored stormwater infiltrates through basin sediments to underlying aquifers.
 - Representative Sites: Tortugas No. 1, Picacho North, Crow Broad Placitas No. 2A, Green Canyon, Hatch/Caballo Arroyo system.
 - Key Processes: temporary storage, infiltration through coarse alluvium, limited surface evaporation, potential clogging near spillway inlets.
- Channel-or Drain-Enhanced Recharge CSM: Infiltration through managed reaches of existing drains, canals, or ephemeral channels.
 - Representative Sites: Boggy Spur, Leasburg Main Canal, Lucero Detention Dike.
 - Key Processes: flow-through infiltration during storm or operational releases; hydraulic connectivity to adjacent alluvial aquifer; requires sediment management and water-quality monitoring.
- Arroyo/Mountain-Front Recharge CSM: Capture of episodic runoff from arroyos and alluvial fans at the basin margins.
 - Representative Sites: Rincon Arroyo reach, upper Caballo Arroyo complex.
 - Key Processes: high-energy flash floods delivering coarse sediments with high permeability; short unsaturated zone; potential for fault-controlled recharge pathways.
- Engineered Infiltration System CSM: Constructed basins, infiltration galleries, or dry wells enhancing recharge in existing structures.
 - Representative Concepts: retrofits at Tortugas No. 1 and Picacho North; gallery installations at Green Canyon.
 - Key Processes: controlled ponding depths and residence times; pretreatment cells to minimize clogging; automation via smart valves and real-time control (RTC).
- Direct Injection CSM: Recharge via underground injection control (UIC) wells targeting deeper Santa Fe Group units.
 - Considered for sites with limited surface area or fine-grained surficial sediments (e.g., Crow Broad Placitas No. 1).
 - Key Processes: pretreatment to meet UIC standards; wellfield design for mounding and capacity control; high regulatory oversight.

Each typology was rated for effectiveness, implementability, and monitoring feasibility based on the MAR Technology Screening Matrix criteria. This classification anchors the later Site and Technology Screening (Section 2.7).

2.6.3. Structure-to-CSM Assignments

Based on the hydrologic and hydrogeologic analyses (Section 2.5), the 30 candidate structures were binned into CSM types reflecting their dominant recharge mechanisms. Table 11 summarizes the Structure-to-CSM assignments.

Table 11. Structure-to-CSM Assignments Summary.

Site/Group	CSM Type	Recharge Mechanism & Notes
Tortugas No. 1 Dam / Boggy Spur	Dam-Based Infiltration + Channel Recharge	Flood-pool infiltration to Mesilla Basin; existing drains provide conveyance and monitoring infrastructure.
Picacho North Dam	Dam-Based Infiltration / Engineered System	Detention in sandy alluvium with potential gallery retrofit and existing instrumentation.
Crow Broad Placitas No. 1 and No. 2A	Dam-Based / Direct Injection Hybrid	Deep storage and basement trough suggest vertical recharge to Santa Fe Group; data gap on fault controls.
Rincon Arroyo	Arroyo/Mountain-Front Recharge	Ephemeral flow reach above I-25; faulted zone favors focused infiltration near basin thickening.
Hatch Valley & Caballo Arroyo System	Dam-Based and Arroyo Recharge Complex	Multi-structure system capturing ~15 mi ² ; coarse deposits and distributed ponding favorable for MAR.
Green Canyon Dam	Engineered Infiltration System	Deep pool with fault-bounded basin; gallery concept proposed for controlled infiltration east of I-25.
Leasburg Main Canal / Lucero Dike	Channel Recharge	Coupled surface–subsurface flow paths adjacent to EBID irrigation network; potential for managed diversions.

This classification supports screening and ranking by clarifying each site’s primary hydrologic function, engineering modifications required, and monitoring complexity.

2.6.4. Hydrogeologic and Operational Assumptions

Each CSM incorporates screening-level assumptions derived from available data and literature:

- Infiltration rates based on DBS&A Mesilla Drain tests (10^{-4} – 10^{-2} cm/s).
- Hydraulic conductivity and storage from USGS LRG Framework Model (2017).
- Typical annual runoff volumes from the screening-level storage and discharge estimates for water years 2010 to 2025 (Tables 2A – 9).
- Vadose zone thickness of 5–25 m in valley settings; <10 m in arroyos and mountain-fronts.
- No significant water-quality impairment expected for stormwater inputs with basic pretreatment (vegetated swales, sediment basins).

- Instrumentation assumed per Medina et al. (2020) and Ahmed & Borst (2019): DTS/TDR arrays in forebays and toe zones with LoRaWAN telemetry for event response monitoring.

2.6.5 Integration with MAR Technology Screening

The CSMs developed in this section form the bridge to the technology screening criteria described in Section 2.7. Each site's assigned CSM was linked to specific MAR process components from the screening matrix—including pretreatment methods, infiltration designs, and monitoring technologies—to derive scores for Effectiveness, Implementability, and Cost. This tiered structure ensures that the subsequent ranking and prioritization directly reflect the scientific understanding captured within each Conceptual Site Model.

2.7. Site & Technology Screening

The technology and site screening establishes the analytic bridge between the Conceptual Site Models (CSMs) developed in Section 2.6 and the prioritization of MAR concepts for Phase II feasibility evaluation. The process applies a two-tiered framework:

1. MAR Technology Screening (Independent of Site) – evaluates the intrinsic feasibility, advantages, and limitations of MAR technology categories applicable to the Lower Rio Grande (LRG) Basin, independent of location; and
2. Site-Specific Screening – integrates those technologies with basin data and CSM assignments to determine where and how each MAR option can be most effectively implemented.

Together these tiers provide a robust decision basis consistent with the Integrated Watershed-Based Approach and Technology Category Evaluation frameworks illustrated in Figures 12 and 13.

2.7.1. Integrated Watershed-Based Approach

The Integrated Watershed-Based Approach Decision Diagram (Figure 12) presents a top-down logic structure that embeds MAR within basin-scale water-management planning. It begins at the watershed level, identifying available flood and stormwater sources, and progressively filters candidate MAR options through hydrologic, geologic, engineering, regulatory, and operational gates:

- Hydrologic Opportunity: availability and timing of source water (stormflow, operational surplus, return flow).
- Geomorphic & Hydrogeologic Feasibility: permeability, vadose-zone thickness, connectivity to target aquifers, and absence of short-circuiting.
- Infrastructure Adaptability: ability to modify existing dams, drains, and canals for recharge without compromising flood-control or delivery functions.

- Regulatory and Institutional Readiness: ownership, water-rights compatibility, environmental compliance, and coordination with OSE/EBID/IBWC.
- Monitoring and Adaptive Capacity: capacity for instrumentation (DTS, TDR, LoRaWAN) and responsive management.

This step-wise logic promotes system integration—capturing upstream runoff for recharge while maintaining downstream ecological and operational objectives—and defines when to advance from natural infiltration to engineered systems.

2.7.2. Technology Screening Independent of Site

Independent technology screening was conducted to compare MAR approaches on their intrinsic technical, environmental, and operational performance, prior to matching them to individual structures. Each technology category was evaluated on four core criteria:

- Effectiveness (E): theoretical recharge yield, reliability, and ability to enhance aquifer storage.
- Implementability (I): design maturity, constructability, and O&M complexity.
- Regulatory Compatibility (R): permitting pathway under state/federal frameworks.
- Relative Cost (C): approximate capital + O&M costs at conceptual level (–50 % / +100 % uncertainty).

Each criterion was scored 1–5 (low → high) based on the MAR Technology Screening Matrix developed by Lynker, NMISC and EBID and supported by literature cited in Section 2.3. Weighted composites (40 % E, 30 % I, 15 % R, 15 % C) produced normalized Technology Suitability Scores (TSS).

The independent MAR technology screening drew directly from the criteria matrices summarized in the Lynker–NMISC–LRG MAR Technologies Presentation (Rev C, 2025). Each technology category was evaluated for technical feasibility, applicability, cost efficiency, ease of implementation, and potential benefit-to-cost ratio (BCR) on a 1–5 ranking scale, where 5 = highest suitability.

The following subsections summarize the findings for each of the five principal MAR technology groups.

(1) Recharge Enhancement at Existing Dams and Ponds

These technologies retrofit or optimize existing detention and flood-control structures for infiltration and groundwater recharge. They typically require sediment-management measures, controlled pool operation, and minimal new land disturbance.

Table 12. Recharge Enhancement at Existing Dams and Ponds Screening Summary.

Technology	Implementation Summary	Effectiveness	Regulatory / Implementation	Cost Reasonability	Proven Use	Implementation Time
Infiltration Zones in Pools	Engineered pervious zones at the bottom of reservoir pools designed to enhance vertical recharge. Can be natural coarse sediment beds or constructed infiltration trenches.	4-5 – Enhances focused recharge in pooled areas. Dependent on subsurface geology.	4 – Requires integration with dam management and sediment control	4 – Minimal construction if natural coarse zones exist; moderate otherwise	4 – Used in projects like Sand Hollow and small retention ponds	4 – 1-2 years with design and excavation
Dam Tailwater Recharge	Diverts/enhances outflow from inlet structure for MAR and/or supply offset to irrigation ditches.	2-3 – Opportunistic and seasonally dependent with low frequency of dam discharge	3 – Requires flow diversion approvals and tracking flow volumes for water budget/offsets to Caballo dam release	2-3 – Low-cost where tailwater and land available. Construction and upkeep may not be worth	3 – Limited but proven in certain western U.S. projects	4 – 1-2 years, depending on permitting
Subsurface Dams / Check Dams	Below-grade or shallow surface barriers that impede subsurface flow to retain water and promote localized aquifer recharge.	4.5 – High effectiveness in ephemeral streams	4 – Often requires hydrologic study and landowner coordination	4.5 – Constructed with local materials; low O&M costs	4 – Common in India, Africa, and SW U.S.	4 – Typically <2 years
Retrofit of Stormwater Basins	Modifying stormwater basins (e.g., removing concrete lining, adding gravel base) to enable infiltration.	3-5 – Supports large volumes if maintained	3-5 – Typically falls within existing BMP frameworks	3-5 – High return; uses existing infrastructure	4.5 – Popular in urban recharge retrofits	3-5 – depends on scale of project

(2) Discharge / Conveyance-Based Recharge

This group targets infiltration along existing drains, canals, or stormwater conveyances. It offers operational flexibility, rapid implementation, and low construction cost but requires sediment control and coordination with irrigation deliveries.

Table 13. Discharge / Conveyance-Based Recharge Screening Summary.

Technology	Implementation Summary	Effectiveness	Regulatory / Implementation	Cost Reasonability	Proven Use	Implementation Time
Infiltration Trenches Along Channels	Excavated gravel-filled trenches alongside arroyos and drainage ditches to encourage lateral infiltration into adjacent permeable soils.	4 – Good for slow floodwater spreading	4 – Basic grading and trenching; low regulatory barrier	4 – Relatively low cost; local material use possible	3.5 – Used in Africa, SW US, and parts of India	4 – 1-2 years including design
Leaky Conveyance Channels	Unlined or semi-lined arroyos and drainage ditches designed to lose water during delivery, promoting continuous seepage into adjacent aquifers.	4.5 – Dual-purpose for delivery and recharge	3 – Water loss may conflict with delivery efficiency goals	4.5 – Lower than fully-lined canals; multi-benefit	4 – Seen in California, Texas, and Spain	4 – 1-2 years for retrofits or new builds
Spreading Channels	Low-gradient braided or meandering engineered channels to distribute flow over wide recharge zones and extend contact time.	4 – Increases recharge footprint and infiltration time	3.5 – May require channel regrading and vegetation clearance	4 – Similar in cost to basin earthwork	3.5 – Examples exist in Central Valley and India	3-4 – 2 years typical with design/permitting
Perforated Pipe Galleries	Subsurface pipe networks that distribute flows laterally beneath streambeds or recharge trenches; helps avoid clogging and increase infiltration area.	3.5 – Promotes even distribution but can clog	4 – Must meet water quality pre-treatment criteria	3 – High initial cost; low profile and low space needs	3 – Used in urban recharge and advanced retrofits	4 – Fast to install once trenching completed

(3) Engineered Infiltration and Recharge Systems

These include purpose-built basins, infiltration galleries, percolation ponds, or dry wells. They provide controllable and measurable recharge but require maintenance to prevent clogging and typically involve higher capital investment.

Table 14. Engineered Infiltration and Recharge Systems Screening Summary.

Technology	Implementation Summary	Effectiveness	Regulatory / Implementation	Cost Reasonability	Proven Use	Implementation Time
Trench Infiltration	Shallow excavated trenches backfilled with gravel/sand to capture stormwater and allow shallow percolation.	3 – Effective for small/medium flows but limited storage capacity.	4 – Relatively straightforward permitting, though water rights issues remain.	4 – \$50-\$150 per linear foot; scalable and cheaper than deep wells.	4 – Widely applied in stormwater management, proven in semi-arid areas.	4 – Can be implemented within 1-2 years.
Dry / Infiltration Wells	Vertical wells ~10–50 ft that inject stormwater directly into shallow aquifers via gravel pack.	4 – Can rapidly infiltrate water, though risk of clogging is high.	3 – Requires permits + stormwater treatment standards.	3 – \$30k-\$75k per well; long-term maintenance adds cost.	4 – Used in NM and AZ stormwater programs.	3 – Design, permitting, and drilling typically 2-3 years.
Vadose-Zone Injection Wells	Deeper wells (>100 ft) that bypass shallow clays to recharge directly into vadose zone above aquifer.	5 – Highly effective for delivering large recharge volumes where geology is favorable.	2 – Requires Class V UIC permits and extensive hydrogeologic analysis.	2 – \$500k-\$1.5M per well; drilling/permits expensive.	3 – Used in AZ/CA, but limited proven projects in NM.	2 – Long permitting/design cycles, often 3-5+ years.
Stormwater Diversion Structures	Weirs, gates, or diversions that direct flood flows into canals, spreading basins, or infiltration areas.	4 – Very effective at capturing episodic floodwater when infrastructure exists.	3 – Requires coordination with flood agencies + rights of diversion.	3 – \$250k-\$1M+ depending on structure complexity.	4 – Proven in CA Central Valley, some NM irrigation districts.	3 – Planning + construction usually 2-4 years.
Sediment Forebays	Forebays or ponds to settle sediments before floodwater flows into dam pools/retention basins.	4 – Reduces surface area and deepens floodwater ponding during lower volume storm events	4 – Easy to permit as best management practice.	4 – Lower cost (\$100k-\$500k per forebay).	5 – Commonly used across MAR and stormwater systems.	4 – Can be implemented in <2 years.

(4) Pre-Treatment Technologies

Pre-treatment systems are integral to all infiltration-based MAR methods. They remove suspended solids, nutrients, and organics before recharge, protecting aquifer quality and reducing clogging.

Table 15. Pre-Treatment Technologies Screening Summary.

Technology	Implementation Summary	Effectiveness for MAR	Regulatory / Implementation	Cost Reasonability	Proven Use	Implementation Time
Hydro-dynamic Separators	Subsurface swirl units installed at runoff inlets (parking lots, roads) to remove sediments, oils, debris using vortex decantation; ideal for pretreatment prior to recharge basins or infiltration systems	N/A – Effective for coarse particles; limited for fine turbulence-dependent sediment. No enhancement to MAR	3 – Considered structural BMP; regulated in MS4 permits	3.5 – Moderate cost; manufacturer-dependent; minimal land footprint	4 – Widely available deployed in urban stormwater systems	4 – Pre-manufactured units; firms deploy within construction season
Constructed Wetlands/ Bioretention Basins	Multi-cell sediment forebay, macrophyte zone, and bypass; retention ~48–72 hrs, bioretention and partial infiltration into underlying soils; used as BMP and recharge adjunct	2 – High pollutant removal and can support infiltration if underlain by permeable media. Reduced MAR due to ET	3 – Permits needed; subject to Clean Water Act design standards	3-4 – Generally cost-effective depending on project scale	2-4 – BRB Widely applied in urban green infrastructure and recharge systems. Wetlands generally not sustainable in NM	3-5 – 1-2 years for permitting, planting, and hydrologic commissioning

(5) Monitoring and Automation Technologies

Monitoring and automation enable performance tracking, system optimization, and adaptive management. Their integration is essential for quantifying infiltration rates and aquifer response.

Table 16. Monitoring and Automation Technologies Screening Summary.

Technology	Implementation Summary	Effectiveness of Monitoring	Regulatory / Complexity	Cost Reasonability	Proven Use	Implementation Time
Smart Inlet Controls	Automated inlets in detention/recharge systems manage water levels and release timing, often via IoT or weather-based control logic	4 – Improves infiltration efficiency and storage optimization	4 – Requires regulatory coordination; falls under MS4 or stormwater permits	2 – Moderate hardware and integration cost; savings in operations	4 – Used commercially (smartPOND installations)	2 – ~1-2 years (permits + system tuning)
Infiltration Rate Sensors	Sensor networks (e.g., TDR, DTS) within infiltration basins or vadose zone to monitor real-time infiltration and detect clogging or layering	4.5 – High data resolution supports better system design and predictive maintenance	3 – Some calibration needed; minimal regulatory oversight	4 – Equipment cost relatively low, but requires long-term maintenance	3.5 – Demonstrations and pilot studies exist	3 – 6-12 months deployment and calibration
Groundwater Monitoring Networks	Well sensors (pressure transducers, remote telemetry) capture real-time aquifer response to recharge; combined with regression/IOT frameworks	4.5 – Critical for validating recharge volumes and early warning	4 – Often required by GSPs or regulatory agencies. New monitoring wells require permitting with OSC	3-5 – Sensors and telemetry are commodity; per-well infrastructure modest	4 – Standard in many MAR programs and funded recharge studies	3 – ~6-12 months for well outfitting and baseline data
Water Quality Sensing Stations	IoT-enabled sensors (DO, pH, conductivity, turbidity) near project sites for automatic quality tracking	4 – Useful for early detection of contaminants before recharge or post-infiltration	4 – Data may feed into regulatory water quality reporting	2-3 – Moderate low-power sensor costs; some calibration & maintenance	3.5 – Proven in environmental studies and remote water systems	3 – ~6-9 months to deploy and calibrate full network

Technology	Implementation Summary	Effectiveness of Monitoring	Regulatory / Complexity	Cost Reasonability	Proven Use	Implementation Time
Channel Flow Monitoring	Installation of flumes and flow sensors in arroyos, ditches, and canals to monitor, measure, and record flow data	4.5 – Provides valuable data for calibration of water budget. Utilized as feedback to automated control features	5 – Data can support permit monitoring	3-4 – Equipment and maintenance costs can be high. Can utilize existing infrastructure	4 – Currently implemented by ISC/EBID in LRG.	3 – ~6-9 months to deploy and calibrate full network

Integrated Interpretation

When analyzed together, these five technology groups illustrate a progressive implementation pathway:

1. Start with Recharge Enhancement at Existing Dams/Ponds and Conveyance-Based Recharge for rapid, low-cost volume capture.
2. Integrate Pre-Treatment and Monitoring Technologies to ensure water-quality protection and long-term performance.
3. Advance to Engineered Infiltration and Injection Systems where greater control or capacity is required.

This tiered framework, anchored by Figures 12 and 13, forms the technical foundation for the Phase II feasibility analyses and pilot project prioritization.

2.7.3. Site-Specific Screening and Ranking

Each of the candidate sites (Section 2.5) was paired with the most compatible technology categories and evaluated against the same four criteria (E, I, R, C). Composite Site Technology Ranking Indices (STRI) were computed using identical weighting (40 % E, 30 % I, 15 % R, 15 % C)

Table 17. Screening-Level Evaluation of MAR Technologies by Site.

Site / CSM Type	Technology Category	E	I	R	C	Composite STRI	Screening Rank	Key Notes
Tortugas No. 1 Dam + Boggy Spur	Dam-Based Infiltration + Conveyance Recharge	5	4	4	3	4.35	1	Large flood pool, permeable alluvium, existing monitoring drains
Picacho North Dam	Dam-Based / Engineered Infiltration	4	4	4	3	4.05	2	Sandy substrate; gallery retrofit feasible
Hatch Valley / Caballo Arroyo System	Dam + Arroyo Recharge Complex	4	3	4	4	3.95	3	Distributed capture, low O&M, strong watershed synergy
Green Canyon Dam	Engineered Infiltration System	3	3	3	3	3.25	4	Good geomorphology; fault impasse constrains benefit area
Rincon Arroyo	Arroyo / Mountain-Front Recharge	3	4	4	2	3.35	5	Strong infiltration potential; limited hydrologic data
Crow Broad Placitas No. 2A Dam	Dam-Based / Direct Injection Hybrid	3	3	3	2	3.05	6	Deep storage; additional subsurface testing needed
Leasburg Main Canal / Lucero Dike	Conveyance-Based Recharge	2	4	5	4	3.65	7	Retrofit potential; minimal permitting risk
Crow Broad Placitas No. 1 Dam	Direct Injection / Engineered System	2	3	3	2	2.70	8	Fine surface sediments limit infiltration
Note: Composite STRI = $0.4 E + 0.3 I + 0.15 R + 0.15 (5 - C_{\text{normalized}})$; higher = greater priority. Scores are screening-level estimates subject to refinement in Phase II.								

2.7.4. Interpretation of Screening Results

When considered together, the technology-independent and site-specific screenings reveal a coherent pattern:

- **Top-performing MAR technologies** existing-dam retrofits, conveyance-based recharge, and engineered infiltration—align with high-ranking sites (Tortugas No. 1, Picacho North, Hatch–Caballo System).
- **Nature-based MAR (arroyo and watershed enhancements)** provides distributed recharge benefits and sediment control but offers lower volumetric certainty; it remains a complementary measure.

- **Direct-injection options** may be valuable in fine-grained or space-constrained areas (e.g., Crow Broad Placitas No. 1) but are cost-intensive and require regulatory coordination.
- **Pre-treatment and monitoring technologies** are universally applicable, essential to quantify recharge, detect clogging, and enable adaptive management.

The Integrated Watershed Decision Diagram (Figure 12) and Technology Category Evaluation (Figure 13) demonstrate how hydrologic opportunity and infrastructure adaptability funnel progressively toward site-specific MAR typologies, ensuring consistency between watershed priorities and engineering feasibility.

2.7.5. Key Findings and Path Forward

The key-findings and path forward are summarized in the bullets below:

1. The dual-tier screening confirms multiple viable MAR pathways for the Lower Rio Grande Basin.
2. High-ranking technologies and sites should advance to Phase II feasibility with field-verified infiltration and groundwater-response testing.
3. Early pilot projects—Tortugas No. 1 / Boggy Spur, Picacho North, and Hatch—Caballo Arroyo System—offer the best combination of hydrologic benefit and logistical feasibility.
4. Nature-based arroyo and drain enhancements should be integrated into a basin-wide hybrid MAR strategy consistent with NMISC’s watershed approach.
5. All pilot designs should embed instrumentation and telemetry (DTS, TDR, LoRaWAN) from inception to support adaptive O&M and performance verification.

2.8. Data Management & Geodatabase (Phase I)

A centralized Geodatabase (GDB) was developed during Phase I to support compilation, analysis, visualization, and long-term stewardship of all spatial and tabular datasets used in the Lower Rio Grande Managed Aquifer Recharge (MAR) Feasibility Study. The geodatabase serves as the authoritative repository for all spatial information exchanged between Lynker, NMISC, and partner agencies (e.g., EBID, IBWC, NMBGMR).

The GDB was designed following Esri ArcGIS Pro 3.x architecture and NMISC’s internal data-management protocols. It consolidates hydrologic, hydrogeologic, infrastructure, and MAR-screening datasets within a structured schema that supports relational queries and direct map publishing. A geodatabase schema design is foundational to the workflow, ensuring data traceability, interoperability, and version control. This approach promotes consistent data management across hydrogeologic, hydrologic, environmental, and monitoring domains. Version control, metadata documentation, and organized data packaging ensure QA/QC integrity and a seamless handoff of final

deliverables to NMISC. More details about database management are available in Appendix B.

2.9. QA/QC, Uncertainty, and Limitations

Quality assurance and quality control (QA/QC) were integral to all data compilation, analysis, and reporting activities conducted during Phase I of the LRG MAR Study. The QA/QC framework adhered to NMISC and Lynker data management protocols and followed principles outlined in the USGS Techniques and Methods Series Book 6, Chapter A24 (2016) for groundwater and surface-water investigations.

All Phase I deliverables underwent multi-tiered review to ensure internal consistency, transparency, and reproducibility:

- Source Verification: All spatial and tabular datasets were checked against authoritative sources (e.g., NM RGIS, NMBGMR, EBID, IBWC, and NM OSE).
- Geospatial QA: Layer coordinate systems and geodatabase schemas were verified for datum consistency (NAD 1983 UTM Zone 13N). Positional accuracy for all MAR site features was confirmed within ± 5 meters.
- Attribute QA: Coded value domains and lookup tables (e.g., site ID, dam name, structure type) were cross-validated with the NM OSE Water Rights (WR-09) registry and EBID infrastructure datasets.
- Analytical QA: Hydrologic and infiltration-rate calculations were reproduced independently by two analysts, and all automated ranking outputs were reviewed by a senior hydrogeologist for reasonableness.
- Document QA: Report text, tables, and figures underwent two levels of technical and editorial review to ensure consistent terminology and alignment with NMISC formatting conventions.

All QA/QC procedures and verification logs are archived within the Phase I project folder and referenced in the Geodatabase metadata.

2.9.1. Data Gaps and Information Limitations

The Phase I study synthesized a wide range of datasets from existing public and agency sources; however, several critical information gaps remain that influence the confidence level of screening results:

- WR-09 Forms (Water Rights Records): Historical and current WR-09 forms for certain dams, drains, and arroyos were incomplete or missing in OSE's public database. As a result, surface-water diversion, impoundment, or storage rights were not fully verified for all candidate structures. These data gaps will be resolved during Phase II by direct coordination with OSE and EBID to confirm water-rights status and operational constraints.

- Operations & Maintenance (O&M) and Inspection Reports: Routine O&M and dam safety inspection reports (particularly for EBID and county-managed structures) were inconsistently available. Some records lacked as-built drawings or infiltration maintenance notes. Consequently, assumptions about basin performance, sedimentation rates, and outlet-works conditions were based on secondary information or visual assessment from recent aerial imagery.
- Subsurface and Hydrogeologic Models: While the USGS and NMBGMR 3D Framework Model provided valuable structural context, detailed hydraulic property distributions (K, Sy) and vadose-zone thickness data were sparse in some sub-basins. These uncertainties limit precise estimation of infiltration rates and groundwater mounding potential. Future phases should incorporate field borings, infiltration testing, and refinement of the MODFLOW-based models to improve calibration and predictive reliability.

2.9.2. Sensitivity of Rankings to Key Inputs

The Phase I site and technology rankings were based on a structured multi-criteria evaluation (MCE) that utilized weighted scores for Effectiveness (E), Implementability (I), Regulatory Compatibility (R), and Cost (C). While this framework provides transparency and reproducibility, sensitivity testing indicated that final rankings are moderately dependent on several input assumptions:

- Hydrologic Opportunity and Volume Estimates: Variations in assumed runoff yield or infiltration potential ($\pm 25\%$) can shift composite scores by 0.2–0.3 units, potentially altering the rank order of sites with similar characteristics (e.g., Picacho North vs. Hatch/Caballo).
- Geotechnical and Permeability Parameters: Infiltration rates derived from analog sites or literature values exert the largest influence on the Effectiveness (E) criterion. Direct field testing could refine these parameters and reduce uncertainty by up to 50%.
- Operational and Regulatory Weighting: Adjusting the relative weighting between Implementability and Regulatory factors ($\pm 10\%$) changes the mid-tier rankings but not the overall top three priority sites.

A one-factor-at-a-time sensitivity analysis (OAT) demonstrated that Tortugas No. 1, Picacho North, and Hatch–Caballo remain robustly ranked among the top-tier candidates under all reasonable parameter perturbations.

2.9.3. Limitations of Screening-Level Methods

It is important to emphasize that the Phase I analyses were conducted at a screening-level resolution intended to identify and prioritize promising MAR opportunities rather than to provide design-level estimates of recharge performance. The following limitations apply:

- Data Resolution: Many input datasets (e.g., DEMs, soils, infiltration rates) are generalized at 10–30 m spatial resolution, limiting precision in slope, drainage, and percolation analyses.
- Assumed Uniform Conditions: Site scoring assumes representative conditions across each structure's footprint and does not account for local heterogeneities such as microtopography, perched zones, or variable sediment thickness.
- Temporal Variability: Hydrologic opportunity assessments are based on long-term average flow data and do not capture interannual or decadal variability in flood frequency or storm intensity.
- Simplified Economic Screening: Cost and benefit estimates are based on unit-cost factors and analog projects; no detailed engineering design or life-cycle cost analysis was performed.
- No Field Validation in Phase I: Field verification of infiltration, soil texture, and groundwater response was not performed at this stage. Such investigations will be required in Phase II feasibility analyses.

Despite these limitations, the screening-level approach provides a scientifically defensible and practical foundation for prioritizing sites for detailed investigation.

2.9.4. Path Forward for Reducing Uncertainty

To address the identified uncertainties and data gaps, the following actions are recommended for the Phase II MAR Feasibility Stage:

- Conduct targeted field characterization (borings, infiltration tests, geophysical profiling) at the top three priority sites.
- Acquire or digitize missing WR-09 forms and O&M inspection records to establish operational histories and design constraints.
- Integrate site data into refined hydrogeologic and groundwater flow models to test alternative recharge scenarios.
- Implement a data validation workflow within the project geodatabase to track uncertainty propagation and data lineage.
- Document all updates in the final data transfer package and technical report.

This approach ensures that uncertainties are progressively reduced and that NMISC will have a validated, traceable data framework supporting future MAR design, permitting, and construction.

3. Summary of Results

Phase I of the Lower Rio Grande (LRG) Managed Aquifer Recharge (MAR) Study established a comprehensive, data-driven foundation for identifying and prioritizing existing hydraulic structures suitable for MAR implementation across the Rincon and Mesilla Valleys. The analyses presented in Section 2 collectively demonstrate that multiple flood-control dams, drains, and arroyos within the study area possess favorable hydrologic and hydrogeologic characteristics to support recharge enhancement while complementing ongoing irrigation and flood-management operations.

3.1. Data Compilation and Site Identification

Through Task 1.1, Lynker and NMISC compiled, standardized, and integrated more than 30 federal, state, and local datasets into a unified GIS-based geodatabase. The process identified 30 candidate flood-control and water-management structures owned or operated primarily by EBID, IBWC, Doña Ana and Caballo SWCDs, and the County Flood Commission. These structures were selected through spatial overlays of NM OSE's Dams_LRG layer, EBID boundaries, and HUC-scale hydrologic units, refined through elimination criteria and stakeholder review. The resulting inventory spans the basin from Caballo Dam in the north to Anthony Arroyo near the Texas state line, forming the analytic backbone for subsequent hydrologic and engineering evaluations.

3.2. Field Verification

A multi-agency field reconnaissance (June 5 2025) verified six representative sites—Tortugas No. 1, Picacho North, Lucero Dike/Leasburg Canal, Crow Broad Placitas No. 1, Green Canyon, and Caballo Arroyo No. 2—capturing the diversity of geomorphic settings and infrastructure conditions within the LRG Basin. Observations confirmed the structural integrity of these facilities, favorable infiltration conditions at several flood-pool and channel areas, and practical access for future pilot testing. These ground observations validated model inputs and informed the conceptual site models.

3.3. Hydrologic and Hydrogeologic Findings

Screening-level hydrologic modeling using 1-m LiDAR DEMs, 16-year PRISM precipitation records, and USGS 3-D geologic data yielded the following general results:

- Floodwater Volumes: Average annual combined storage and discharge at major sites range from ~3,000 ac-ft (Tortugas No. 1) to >50,000 ac-ft (Crow Broad Placitas No. 2A).
- Seasonality: Across all sites, roughly 55–60 % of total floodwater occurs during July–September, indicating strong alignment with monsoonal runoff events ideal for opportunistic MAR.
- Hydrogeologic Suitability: Most sites are underlain by coarse alluvium and upper Santa Fe Group units with vadose-zone thicknesses < 25 m. Fault-bounded zones

such as the Derry Fault near Green Canyon may compartmentalize flow but do not preclude local recharge.

- Recharge-Favorable Settings: Tortugas No. 1, Picacho North, and the Hatch–Caballo Arroyo complex exhibit the highest combined potential based on runoff yield, permeability, and aquifer connectivity.

3.4. Conceptual Site Models

Seven representative CSMs were developed to characterize recharge pathways and governing processes at each candidate group. Five generic MAR typologies were defined: (1) Dam-Based Infiltration, (2) Channel/Drain Recharge, (3) Arroyo or Mountain-Front Recharge, (4) Engineered Infiltration Systems, and (5) Direct Injection. Each CSM integrates hydrologic source, infiltration mechanism, aquifer unit, and monitoring approach. These models provide the conceptual and analytical bridge to the screening and ranking framework in Section 2.7.

3.5. Technology and Site Screening

The dual-tier screening process evaluated MAR technologies both independently and within site context:

Technology Screening (Independent of Site):

- Five technology groups, Recharge Enhancement at Existing Dams, Discharge/Conveyance-Based Recharge, Engineered Infiltration Systems, Pre-Treatment Technologies, and Monitoring & Automation Technologies, were scored across four weighted criteria (Effectiveness 40 %, Implementability 30 %, Regulatory 15 %, Cost 15 %).
- Results indicate that dam retrofits and conveyance-based recharge systems offer the best near-term feasibility and cost-benefit performance, while engineered infiltration systems and smart monitoring technologies provide scalable, long-term management capability.

Site-Specific Screening:

- Composite Site Technology Ranking Indices (STRI) confirmed Tortugas No. 1 / Boggy Spur, Picacho North Dam, and the Hatch–Caballo Arroyo system as the highest-ranking MAR opportunities for early-Phase I implementation. Mid-tier candidates include Green Canyon and Rincon Arroyo, where additional geotechnical and water-rights verification is required.

3.6. Integrated Results

Overall, Section 2 analyses demonstrate that:

- The LRG Basin possesses multiple structures with strong hydrologic opportunity, favorable geologic conditions, and manageable regulatory pathways for MAR deployment.
- Hydrologic timing, infiltration capacity, and existing infrastructure connectivity collectively support a watershed-integrated MAR approach.
- Implementing MAR at priority sites could enhance aquifer storage by several thousand acre-feet annually while co-benefiting flood mitigation and operational flexibility.
- The data-management framework and geodatabase established under Phase I provide a durable platform for refinement, monitoring integration, and Phase II feasibility design.

3.7. Key Outcomes

1. Thirty candidate structures were inventoried and characterized with standardized attributes.
2. Seven structures were field-verified to validate data and refine CSMs.
3. Hydrologic analyses confirmed ample stormwater availability during monsoon periods.
4. Five MAR technology classes were screened and ranked; dam-based and conveyance-based methods scored highest.
5. Three top-priority sites were identified for Phase II feasibility assessment and pilot design.

Collectively, these results confirm that MAR implementation in the Lower Rio Grande Basin is technically feasible, regionally scalable, and operationally synergistic with existing infrastructure. The Phase I findings establish a defensible scientific and engineering foundation for Phase II pilot testing, design optimization, and eventual integration into basin-wide water-management strategies.

4. Conclusions

This Phase I study represents the first comprehensive, data-driven assessment of opportunities to enhance groundwater storage through existing hydraulic and natural features within the LRG Basin. This phase established the foundational datasets, conceptual models, and analytical tools necessary to evaluate the technical feasibility of MAR at basin, sub-basin, and individual-site scales.

The effort integrated hydrologic, hydrogeologic, infrastructure, and regulatory data from multiple agencies into a unified framework that supports objective site ranking and future design development. The following subsections summarize the principal outcomes of Phase I and identify key data and risk elements that must be addressed prior to, or concurrently with, Phase II feasibility and pilot implementation.

4.1. Synthesis of Phase I Findings

The Phase I effort demonstrated that the Lower Rio Grande Basin contains multiple viable MAR opportunities distributed across the Rincon and Mesilla Valleys. A total of 30 candidate flood-control and water-management structures were identified, characterized, and screened for MAR compatibility. Key findings are summarized as follows:

4.1.1. Hydrologic and Hydrogeologic Context

- Hydrologic availability: Monsoon-driven flood events (July–September) contribute more than half of annual runoff, creating seasonally concentrated opportunities for storm- and drain-based recharge.
- Hydrogeologic setting: Most candidate structures are underlain by coarse alluvial and upper Santa Fe Group materials with vadose-zone thicknesses < 25 m, favorable for rapid percolation and aquifer connection.
- Connectivity: Hydraulic continuity between surface infiltration zones and the regional aquifer is generally strong, particularly near the Tortugas, Picacho, and Hatch–Caballo systems.

4.1.2. Conceptual and Analytical Framework

- Conceptual Site Models (CSMs): Seven representative CSMs were developed encompassing dam-based, drain/conveyance, arroyo, engineered infiltration, and direct-injection typologies.
- These models clarify recharge mechanisms, hydrostratigraphic targets, and anticipated monitoring strategies.
- Screening methodology: A two-tier evaluation combined technology-independent and site-specific analyses using weighted criteria for Effectiveness, Implementability, Regulatory Compatibility, and Cost.

- Integrated decision framework: The watershed-based decision diagrams (Figures 12 and 13) ensured that site prioritization remained consistent with basin-scale water-management objectives.

4.1.3. Results and Prioritization

- Top-priority MAR opportunities:
 - Tortugas No. 1 Dam / Boggy Spur– highest hydrologic yield, existing monitoring infrastructure, and optimal infiltration conditions.
 - Picacho North Dam – moderate storage capacity and excellent hydrogeologic setting for infiltration galleries or basin retrofits.
 - Hatch–Caballo Arroyo System – large drainage area, distributed infiltration potential, and low incremental cost.
- Technology feasibility: Recharge enhancement at existing dams, conveyance-based infiltration, and engineered systems ranked highest for near-term implementation; nature-based and injection systems remain longer-term or complementary options.
- Cross-cutting enablers: Pre-treatment and monitoring technologies (DTS, TDR, LoRaWAN) are essential to ensure long-term system performance and adaptive management.
- Data integration: The Phase I geodatabase and standardized symbology establish a durable spatial platform for Phase II analysis, permitting, and stakeholder communication.

Phase I has successfully defined the hydrologic opportunities, technological pathways, and spatial priorities necessary to transition into pilot-scale testing and design refinement.

4.2. Key Data Gaps and Risks to be Addressed before/within Phase II

While Phase I provides a defensible screening framework, it also revealed several data deficiencies and uncertainties that could affect subsequent feasibility and design phases. Addressing these issues early in Phase II will be critical to reduce technical risk and regulatory uncertainty.

Data Gaps

- Water-Rights Documentation: Incomplete or missing WR-09 forms for certain dams, drains, and arroyos limit confidence in diversion, storage, and recharge entitlements. Verification with OSE and EBID will be required.
- O&M and Inspection Records: Routine inspection reports and sediment-removal histories are inconsistently archived, particularly for EBID and county structures. Updated engineering inspections will improve performance estimates.

- **Subsurface Characterization:** Limited borehole and infiltration-test data introduce uncertainty in hydraulic-conductivity and specific-yield values used for recharge potential estimates. Field verification and geophysical profiling should be prioritized.
- **Monitoring Data Integration:** Continuous water-level and infiltration monitoring networks are sparse; establishing baseline datasets will support calibration of Phase II hydrogeologic models.
- **Hydrologic Time-Series Completeness:** Some gage and precipitation datasets have gaps or differing record periods; homogenization and bias correction are required for robust model input.

Analytical and Programmatic Risks

- **Sensitivity of Ranking Criteria:** The multi-criteria scoring is moderately sensitive to assumptions regarding runoff yield, infiltration rate, and weighting of cost versus implementability. Sensitivity testing should continue as new data are incorporated.
- **Screening-Level Resolution:** Many datasets are at coarse spatial or temporal resolution; fine-scale topography and soil heterogeneity may alter site-specific feasibility outcomes.
- **Regulatory and Institutional Complexity:** Water-rights transfers, interagency coordination, and permitting (e.g., UIC authorization, NPDES compliance) may introduce schedule or scope risk if not engaged early.
- **Operational Integration:** Balancing MAR operation with existing flood-control and delivery objectives requires early engagement with EBID operations and IBWC maintenance planning.

Phase II Recommendations

1. Conduct detailed field investigations (borings, infiltration tests, and geotechnical sampling) at the top-ranked sites.
2. Develop refined groundwater and infiltration models for volumetric recharge estimation and mounding analysis.
3. Establish a basin-wide data-management and monitoring network to reduce data uncertainty.
4. Coordinate early with OSE, EBID, and IBWC to define regulatory pathways and operational constraints.
5. Integrate cost, risk, and performance metrics into a decision-support framework for Phase II pilot design.

In summary, Phase I confirms that strategically managed MAR can enhance aquifer sustainability in the Lower Rio Grande while providing complementary flood-control and operational benefits. With targeted data collection, improved model calibration, and structured stakeholder coordination, Phase II will advance from conceptual prioritization

to site-specific feasibility and pilot-scale implementation, forming the foundation for a long-term, watershed-integrated MAR program under NMISC leadership.

5. Example MAR Applications

To illustrate the range of Managed Aquifer Recharge (MAR) technologies evaluated and screened during Phase I, three representative sites were selected for conceptual application design:

- Tortugas Dams / Boggy Spur System
- Green Canyon Dam Site
- Rincon Arroyo

These sites were chosen to demonstrate contrasting hydrogeologic, geomorphic, and infrastructural conditions across the Lower Rio Grande Basin and to highlight the adaptability of MAR technologies to both engineered and natural systems. Tortugas Dams System, Green Canyon Dam Site, and Rincon Arroyo represent areas for which a system could be developed that would display MAR technologies for three use cases:

- Geologic conditions behind dam are amenable to aquifer recharge: Focus on improving MAR in inundated areas.
- Geologic conditions behind dam are not amenable to aquifer recharge: Focus on moving inundated water through dam into irrigation network.
- Flow path is not dammed: Focus on controlling runoff and improving MAR within channel.

Each site depicts a system of MAR technologies that are applicable at sites across the Lower Rio Grande with similar characteristics. Together, they showcase how combinations of recharge enhancement, conveyance, engineered infiltration, and monitoring technologies can be tailored to site-specific settings to optimize recharge performance, cost, and long-term sustainability.

5.1. Tortugas Dams / Boggy Spur System

Setting and Concept

The Tortugas Dams / Boggy Spur System, located east of Las Cruces near East University Avenue, includes the Tortugas No. 1 and No. 2 Dams, Salopek Pond, and the downstream Boggy Spur. The system captures runoff from the Tortugas Mountain watershed and conveys it through interconnected detention and drainage structures before discharging into the EBID drainage network.

The purpose of this example is to showcase how MAR technologies can be applied to dam systems in which the inundated area behind the dam has favorable geologic

conditions for aquifer recharge, and/or the runoff water may contain contaminants from the surrounding urban environment. In these cases, the focus should be on retention and pre-treatment of the water using inundation basins to maximize direct recharge to the aquifer.

Range of MAR Technologies Applied

This location represents the most comprehensive integration of MAR technologies identified in Phase I, incorporating nearly the full spectrum of measures considered for the basin:

- Recharge enhancements at existing dams and ponds
- Discharge / conveyance-based recharge
- Engineered infiltration and recharge systems
- Pre-treatment technologies
- Monitoring and automation technologies
- Proposed MAR Application

The proposed MAR application at the Tortugas Dams / Boggy Spur System (Figure 14) includes:

- Sediment Forebay and Vegetation Management: Installation of a sediment forebay upstream of the Tortugas No. 1 storage area in the main flow channel near the East University Avenue crossing. Vegetation control and re-contouring within the dam pool will enhance infiltration and reduce evapotranspiration losses.
- Bioretention Basin and Forebay Integration: At Salopek Pond, a combined bioretention basin and sediment forebay will improve water quality prior to infiltration. Infiltrated water from the bioretention basin will be piped to the Boggy Spur drain to enable discharge / conveyance-based recharge along the drain alignment.
- Instrumentation and Automation: Distributed temperature sensing (DTS), time domain reflectometry (TDR), and water-level transducers will be deployed for real-time recharge monitoring and adaptive O&M management.

This example demonstrates how a multi-component system can leverage existing flood-control infrastructure for aquifer recharge while integrating water-quality protection and automation for performance verification. The MAR technologies highlighted in this example can be applied to other dam systems including, but not limited to:

- Picacho North/South Dams
- Crow Broad Placitas No. 2A
- Hatch-Caballo East System Dams
 - Caballo Arroyo Dam No. 2
 - Caballo Arroyo Dam No. 3
 - Hatch Valley Arroyo Dam No. 1
 - Hatch Valley Arroyo Dam No. 2
 - Hatch Valley Arroyo Dam No. 3
 - Hatch Valley Arroyo Dam No. 6

5.2. Green Canyon Dam Site

Setting and Concept

The Green Canyon Dam Site is located northwest of Hatch along the I-25 corridor, where the dam intercepts ephemeral runoff from adjacent upland catchments. The area is underlain by coarse basin-fill alluvium that provides strong infiltration potential but is bounded to the east by the Derry Fault, which may locally restrict lateral flow toward the regional valley-floor, water-table aquifer.

The purpose of this example is to showcase how MAR technologies can be applied to dam systems in which the inundated area behind the dam **does not** have favorable geologic conditions for aquifer recharge, or it is more beneficial to route water into downstream canals. Therefore, the goal is to move water through the dam into the irrigation canals, and apply the volume of conveyed water to the overall water balance.

Range of MAR Technologies Applied

The Green Canyon site illustrates the application of MAR technologies to a medium-scale engineered dam environment, emphasizing operational enhancement and system monitoring. Technologies include:

- Recharge enhancements at existing dams and ponds
- Discharge / conveyance-based recharge
- Engineered infiltration and recharge systems
- Monitoring and automation technologies

Proposed MAR Application

The proposed application of MAR technologies at Green Canyon Dam (Figure 15) includes:

- Vegetation Management: Clearing and controlled revegetation within the flood-pool area to reduce evapotranspiration and maintain infiltration pathways.
- Smart Inlet Control: Installation of shallow subsurface drains tied into existing discharge piping at the principal spillway inlet to monitor infiltration and enable automated control of storage releases.
- Channel Lining and Flow Control: Lining of the discharge channel between the dam and the I-25 crossing to minimize infiltration and water loss upstream of the Derry Fault, ensuring recharge occurs in hydraulically favorable zones downstream.
- Instrumentation Integration: Utilization of existing gauge infrastructure and the addition of pressure transducers for continuous water-level and discharge monitoring.

This configuration showcases how MAR can be retrofitted into an existing flood-control facility using minimal structural modification while introducing smart controls for enhanced recharge management. The MAR technologies highlighted in this example can be applied to other dam systems including, but not limited to:

- Picacho North/South Dams System
- Crow Broad Placitas No. 1

5.3. Rincon Arroyo

Setting and Concept

The Rincon Arroyo is located near the town of Rincon, north of Hatch, and represents a natural, unlined ephemeral channel that conveys monsoonal runoff from the upland basin to the Rio Grande floodplain. The site's coarse-grained channel deposits and broad valley geometry make it an ideal demonstration area for nature-based and structural infiltration enhancement.

The purpose of this example is to showcase how MAR technologies can be applied to arroyos which do not have dams but accumulate flow volumes that merit consideration as a MAR implementation site.

Range of MAR Technologies Applied

The MAR technologies proposed for Rincon Arroyo focus on distributed, channel-based recharge improvements using modest engineering interventions:

- Discharge / conveyance-based recharge
- Engineered infiltration and recharge systems
- Monitoring and automation technologies

Proposed MAR Application

The conceptual MAR application for the Rincon Arroyo (Figure 16) includes:

- Drop Structures and Check Dams: Construction of a series of small drop structures and check dams between the I-25 and railroad bridge crossings to capture and infiltrate flood flows.
- Channel Armoring and Gabion Walls: Armoring of channel sidewalls with gabion baskets to resist erosion and undercutting while providing enhanced infiltration through permeable interfaces.
- Roller-Compacted Concrete (RCC) Structures: Use of locally excavated channel materials to construct RCC check dams and create flattened infiltration terraces.
- Staggered Spillways and Access Improvements: Incorporation of staggered spillway crests to distribute flow and reduce overtopping frequency, with a riprap-armored maintenance access way for heavy-equipment operation.
- Performance Monitoring: Installation of upstream and downstream groundwater monitoring wells to assess infiltration rates and aquifer response during and after storm events.

This example demonstrates a nature-based MAR strategy that combines erosion control with aquifer recharge enhancement, offering a scalable and low-maintenance solution for arid, ephemeral systems. The MAR technologies highlighted in this example can be applied to other dam systems including, but not limited to:

- Hatch-Caballo East System Un-Dammed Arroyos
- Green Canyon Dam (Within downstream canals)

5.4. Costing Analysis

Preliminary, screening-level cost estimates were developed to illustrate the potential magnitude of implementation costs for representative MAR technologies at the three example sites described in Sections 5.1 through 5.3. These estimates were prepared using standardized unit-cost assumptions and recent bid-tab data from regional earthwork and water-resources projects (City of Albuquerque 2025; USACE 2016; SSCAFCA 2020). They are intended for comparative planning only and carry an

estimated accuracy range of –50 % to +100 % consistent with a Class 5 (conceptual) estimate.

Each cost component corresponds to a primary MAR feature or enabling technology used in the conceptual site configurations:

- Sediment forebays and pre-treatment cells (Table 18)
- Bioretention and bioinfiltration basins (Table 19 and Table 20)
- Vegetation clearing and re-grading at dam/pond sites Table 21)
- Seepage-control canal improvements (Table 22)
- Site-specific implementation elements (Rincon Arroyo system – Table 23)

Table 18. Bioinfiltration Basin Construction and Annual O&M Cost Estimate.

Line Item	Qty	Unit	Unit Price	Cost
Clearing & grubbing	0.60	acre	\$3,500.00	\$2,089.07
Excavation (common)	3851.9	CY	\$54.41	\$209,579.26
Haul & disposal (soil)	3851.9	CY	\$22.00	\$84,740.74
Subgrade scarification/ripping	26000	SF	\$0.15	\$3,900.00
BSM – supply & place	2407.4	CY	\$68.00	\$163,703.70
Reservoir gravel layer	481.5	CY	\$79.35	\$38,205.56
Geotextile (nonwoven)	2888.9	SY	\$1.20	\$3,466.67
Mulch (surface)	240.7	CY	\$42.00	\$10,111.11
Curb cuts/inlet openings	2	each	\$1,400.00	\$2,800.00
Emergency overflow structures	1	each	\$2,200.00	\$2,200.00
Riprap inlet aprons	0	CY	\$208.60	\$0.00
Pretreatment forebay (LS)	1	LS	\$20,000.00	\$20,000.00
HDS unit (LS)	3	LS	\$85,000.00	\$255,000.00
Infiltration testing (count)	12	each	\$650.00	\$7,800.00
Technician time (testing & commissioning)	1	hr	\$120.00	\$120.00
Traffic control (LS)	1	LS	\$1,200.00	\$1,200.00
Trees (installed)	4	each	\$180.00	\$720.00

Line Item	Qty	Unit	Unit Price	Cost
Shrubs (installed)	65	each	\$38.00	\$2,470.00
Perennials/grass plugs (installed)	182	each	\$6.00	\$1,092.00
Subtotal				\$809,198.11
Mobilization				\$40,459.91
Sub + Mob				\$849,658.02
Contingency				\$127,448.70
Total Construction				\$977,106.72

Line Item	Qty (annual)	Unit	Unit Price	Annual Cost
Inspection & reporting	4	visit	\$250.00	\$1,000.00
Litter/debris removal	4	visit	\$200.00	\$800.00
Weed control	4	visit	\$350.00	\$1,400.00
Mulch top-up	308.15	CY	\$42.00	\$12,942.22
Surface raking/loosening	1	visit	\$300.00	\$300.00
Surface scrape – removal	96.30	CY	\$95.00	\$9,148.15
Surface scrape – haul/disposal	96.30	CY	\$65.00	\$6,259.26
Plant replacement – trees	1	each	\$220.00	\$220.00
Plant replacement – shrubs	1	each	\$45.00	\$45.00
Plant replacement – perennials	6	each	\$7.00	\$42.00
Forebay cleanout (if included)	5	visit	\$900.00	\$4,500.00
Total Annual O&M				\$36,656.63

The bioinfiltration basin estimate represents construction of a 0.3–0.5 acre engineered infiltration cell with media filtration and underdrain discharge.

Table 19. Bioretention Basin Construction and Annual O&M Cost Estimate.

Line Item	Qty	Unit	Unit Price	Cost
Clearing & grubbing	0.59	acre	\$3,500.00	\$2,079.11
Excavation (common)	2875.11	CY	\$54.41	\$156,434.80
Haul & disposal (soil)	2875.11	CY	\$22.00	\$63,252.44
BSM – supply & place	462.96	CY	\$68.00	\$31,481.48
Gravel drain layer	92.59	CY	\$79.35	\$7,347.22
Geotextile (nonwoven)	2875.11	SY	\$1.20	\$3,450.13
Underdrain cleanouts/obs wells	1	each	\$250.00	\$250.00
Mulch (surface)	46.29	CY	\$42.00	\$1,944.44
Curb cuts/inlet openings	1	each	\$1,400.00	\$1,400.00
Overflow structures	2	each	\$2,200.00	\$4,400.00
Temporary irrigation setup (LS)	1	LS	\$1,500.00	\$1,500.00
Traffic control (LS)	1	LS	\$1,200.00	\$1,200.00
Subtotal				\$274,739.63
Mobilization				\$13,736.98
Sub + Mob				\$288,476.61
Contingency				\$43,271.49
Total Construction				\$331,748.10

Line Item	Qty (annual)	Unit	Unit Price	Annual Cost
Inspection & reporting	4	visit	\$250.00	\$1,000.00
Litter/debris removal	4	visit	\$200.00	\$800.00
Weed control	4	visit	\$350.00	\$1,400.00
Plant replacement – trees	1	each	\$220.00	\$220.00
Plant replacement – shrubs	11	each	\$45.00	\$495.00
Plant replacement – perennials	4	each	\$7.00	\$28.00

Line Item	Qty (annual)	Unit	Unit Price	Annual Cost
Inlet/catch basin vacuum	5	visit	\$450.00	\$2,250.00
Underdrain jet/vac	0.5	event	\$900.00	\$450.00
Sediment removal & disposal	2	CY	\$95.00	\$190.00
Establishment watering (yr 1–N)	20	visit	\$120.00	\$2,400.00
Total Annual O&M				\$9,233.00

This system serves as a pre-treatment and polishing basin for the Tortugas / Salopek site, providing sediment and nutrient removal prior to infiltration.

Table 20. Storage Area Vegetation Clearing per Acre Cost Estimates.

Line Item	Qty	Unit	Unit Price	Cost
Mowing (light)	0.33	acre	\$600.00	\$199.80
Mowing (heavy)	0.33	acre	\$1,200.00	\$399.60
Hand cutting	0.33	acre	\$2,500.00	\$835.00
Trees ≤6" DBH	10	each	\$75.00	\$750.00
Trees 6–12" DBH	6	each	\$200.00	\$1,200.00
Seeding/restoration	5000	SF	\$0.20	\$1,000.00
Haul (calc from tons & density)	16.67	CY	\$20.00	\$333.33
Tipping (green waste)	5	ton	\$51.48	\$257.40
Mechanical emergent removal	1	acre	\$3,500.00	\$3,500.00
Subtotal				\$8,475.13
Mobilization				\$423.76
Sub + Mob				\$8,898.89
Contingency				\$1,334.83
Total				\$10,233.72

Table 21. Sediment Forebay Construction and Annual O&M Cost Estimates.

Line Item	Qty	Unit	Unit Price	Cost
Excavation	2222.2	CY	\$54.41	\$120,911.11
Concrete lining (area)	2100.0	SF	\$16.83	\$35,343.00
Riprap apron	77.8	CY	\$208.60	\$16,224.44
Subtotal				\$172,478.56
Mobilization				\$8,623.93
Sub + Mob				\$181,102.48
Contingency				\$27,165.37
Total				\$208,267.86

Line Item	Qty	Unit	Unit Price	Cost
Excavate/load sediment	100	CY	\$54.41	\$5,441.00
Disposal (tipping)	140	ton	\$51.48	\$7,207.20
Haul	100	CY	\$20.00	\$2,000.00
Total cleanout cost				\$14,648.20
Cost per CY				\$146.48

Table 22. Conveyance Structure Construction and Annual O&M Cost Estimates.

Scenario A: Earth Canal (unlined) + Riprap Apron

Line Item	Qty	Unit	Unit Price	Cost
Excavation	2741.08	CY	\$54.41	\$149,142.21
Seeding/restoration (side slopes; optional)	222249.81	SF	\$0.20	\$44,449.96
Riprap apron (inlet/outlet)	750	CY	\$208.60	\$156,450.00
Subtotal				\$350,042.18
Mobilization				\$17,502.11
Sub + Mob				\$367,544.29
Contingency				\$55,131.64
Total				\$422,675.93

Scenario B: Geomembrane-lined canal (HDPE 60-mil)

Line Item	Qty	Unit	Unit Price	Cost
Excavation	2741.08	CY	\$54.41	\$149,142.21
Geomembrane area (incl. anchors)	244474.8	SF	\$2.50	\$611,186.97
Cushion geotextile (layers)	49388.9	SY	\$1.20	\$59,266.62
Riprap apron (inlet/outlet)	15	CY	\$208.60	\$3,129.00
Subtotal				\$822,724.80
Mobilization				\$41,136.24
Sub + Mob				\$863,861.04
Contingency				\$129,579.16
Total				\$993,440.20

Scenario C: Riprap-lined canal

Line Item	Qty	Unit	Unit Price	Cost
Excavation	2741.08	CY	\$54.41	\$149,142.21
Geotextile underlayment	24694.42	SY	\$1.20	\$29,633.31
Gravel filter (volume)	2741.08	CY	\$79.35	\$217,504.77
Riprap lining (volume)	8231.47	CY	\$181.36	\$1,492,860.19
Riprap apron (inlet/outlet)	15	CY	\$208.60	\$3,129.00
Subtotal				\$1,892,269.48
Mobilization				\$94,613.47
Sub + Mob				\$1,986,882.96
Contingency				\$298,032.44
Total				\$2,284,915.40

O&M: Sediment Cleanout

Line Item	Qty	Unit	Unit Price	Cost
Excavate/load sediment	100	CY	\$54.41	\$5,441.00
Disposal (tipping)	140	ton	\$51.48	\$7,207.20
Haul	100	CY	\$1.40	\$140.00
Total cleanout cost				\$12,788.20
Cost per CY				\$127.88

Table 23. Rincon Arroyo (Figure 16) MAR System Cost Estimate.

Component	Line Item	Unit	Qty	Unit Price	Cost
Gabion baskets	Rock fill (volume)	CY	106893	\$135	\$14,430,622
	Excavation / trench	CY	16034	\$12	\$192,408
Riprap lined area	Riprap (installed)	CY	78623	\$145	\$11,400,351
	Bedding gravel	CY	11793	\$90	\$1,061,412
	Subgrade prep	SY	235869	\$1.50	\$353,804
Enhanced recharge area	Excavation	CY	5886	\$12	\$70,632
	Off-haul & disposal	CY	2943	\$32	\$94,176
	Permeable media (placed)	CY	1471	\$95	\$139,792
	Vegetation / stabilization	AC	1.8	\$1,800	\$3,283
	Inlet protection BMPs	EA	4	\$225	\$900
Drop structures	Concrete	CY	36	\$425	\$15,300
	Riprap	CY	60	\$145	\$8,700
	Formwork & rebar	LS	3	\$2,500	\$7,500
Exit check dam	Riprap	CY	12	\$145	\$1,740
Construction Subtotal					\$27,780,622
Contingency					\$5,556,124
Construction + Contingency					\$33,336,746
Annual Maintenance (percent of construction)					\$555,612
TOTAL (Construction + Contingency + Annual Maint.)					\$33,892,359

This cost represents a distributed MAR retrofit along the Rincon Arroyo corridor, combining low-head drop structures, armoring, and monitoring infrastructure.

5.5. Summary

Collectively, the Tortugas Dams / Boggy Spur, Green Canyon Dam, and Rincon Arroyo examples illustrate the versatility of MAR technologies across a gradient of infrastructure complexity and geomorphic conditions:

- The Tortugas System demonstrates a multi-component engineered integration suitable for urban-adjacent, heavily instrumented environments.
- The Green Canyon Dam example emphasizes retrofit opportunities and smart operational controls in existing flood-control facilities.
- The Rincon Arroyo case highlights distributed, nature-based recharge enhancements appropriate for rural and natural channels.

Together, these examples showcase how MAR can be strategically implemented throughout the Lower Rio Grande Basin to increase groundwater storage, reduce stormwater losses, and provide multi-benefit outcomes aligned with NMISC's watershed-based water-management objectives.

6. Recommendations

The Phase I Lower Rio Grande (MAR) Study establishes a scientifically defensible foundation for advancing MAR implementation within the Rincon and Mesilla Valleys. Building upon the hydrologic, geologic, and engineering analyses described in earlier sections, the following recommendations identify (1) priority projects for near-term development, (2) a Phase II scope and budget framework to guide feasibility-level work, and (3) targeted monitoring and data improvements to reduce key uncertainties.

6.1. Recommended MAR Projects

Phase I screening and conceptual design indicate that several sites are well suited for near-term advancement, representing a gradient of technical complexity, geographic setting, and data readiness:

Table 24. Recommended MAR projects from Phase I.

Recommended Project Area	Recommended Action	Primary Rationale
Tortugas Dams / Boggy Spur System	Advance to pilot-scale demonstration emphasizing recharge enhancement at existing dams, bioretention pretreatment, and conveyance-based infiltration.	Highest overall screening score; existing infrastructure, hydrologic data, and manageable permitting under local flood-control ownership.
Green Canyon Dam	Advance to feasibility with pilot testing for Smart Inlet and discharge-channel retrofits ultimately improving flow routing to more favorable MAR areas.	Demonstrates MAR in large detention setting; builds on existing monitoring network and EBID coordination.
Caballo / Hatch Valley Arroyo Complex	Retain as Phase II planning candidate pending additional geotechnical and ownership data.	Large watershed with multi-structure connectivity; requires inter-district coordination and detailed geomorphic analysis.
Rincon Arroyo	Advance to direct feasibility study focused on distributed, nature-based MAR through check-dams and gabion-armored infiltration terraces.	Represents unlined arroyo system; minimal structural modification required; strong local aquifer connectivity; permits primarily at state level.

Pilot vs. Direct Feasibility

- Pilot Projects – Tortugas Dams / Boggy Spur and Green Canyon Dam are recommended for limited-scale field construction and monitoring to verify infiltration rates, sediment management, and automation performance.
- Direct Feasibility Studies – Rincon Arroyo and the Caballo–Hatch Valley system should proceed directly to feasibility design and modeling based on existing hydrologic characterization, focusing on distributed, low-cost MAR configurations.

Permitting and Acceptance Considerations

Permitting requirements will vary by ownership and MAR typology:

- State Permits – OSE Change in Purpose/Use for recharge, and NMED Groundwater Discharge Permit (20.6.2 NMAC) where infiltration water quality is modified.
- Federal Consultation – USACE Section 404 (Clean Water Act) for structures in jurisdictional channels, and IBWC coordination near binational reaches.
- Local Acceptance – Coordination with EBID, Caballo SWCD, Doña Ana SWCD, and DAC Flood Commission to integrate MAR within existing O&M programs.

Early stakeholder engagement and demonstration of multiple co-benefits (flood-control performance, sediment management, and aquifer sustainability) will expedite regulatory acceptance.

6.2. Phase II Scope and Budget

Phase II will transition from conceptual screening to quantitative feasibility and pre-design analysis. The objectives are to:

1. Refine the hydrologic and hydrogeologic characterization of high-priority MAR sites;
2. Develop pilot-scale engineering designs with cost, risk, and performance metrics; and
3. Prepare implementation-ready documentation for capital investment and permitting.

6.2.1. Scope of Work

Task Group	Key Activities	Deliverables / Outcomes
1. Hydrologic and Geotechnical Investigations	Borehole logging, test pits, infiltration testing, grain-size and hydraulic conductivity analyses.	Refined infiltration and aquifer parameters; design-level geotechnical data packages.
2. Hydrologic and Recharge Modeling	Continuous-simulation modeling (HEC-HMS / GSSHA); unsaturated zone and groundwater response modeling (VS2DTI, MODFLOW 6 / USG).	Water-budget and mounding analyses; recharge efficiency and recovery timing estimates.
3. Engineering Design Alternatives	Preliminary layouts (1–3 options per site); grading, structures, automation, and O&M provisions.	30% conceptual drawings; cost and constructability evaluation.
4. Environmental and Permitting Assessments	NEPA screening, cultural and biological desktop reviews, and NMED regulatory coordination.	Draft permit pathway summary; agency concurrence plan.
5. Pilot Testing and Monitoring Plan	Instrumentation design (DTS, TDR, pressure transducers); baseline data collection; performance metrics.	Pilot operations manual and monitoring QA/QC plan.
6. Stakeholder Engagement and Reporting	Coordination with NMISC, OSE, EBID, SWCDs, and local governments.	Quarterly progress briefings and final Phase II Feasibility Report.

6.2.2. Schedule and Budget Framework

Phase II is envisioned as a 24-month effort, organized into two primary stages:

- Stage 1 (0–12 months): Investigations, baseline data collection, and pilot design.
- Stage 2 (12–24 months): Pilot implementation, monitoring startup, and feasibility documentation.

At a screening level, the Phase II budget is expected to range between \$1.2 – 1.8 million, apportioned approximately as follows:

Task Category	Approx. Budget (USD)	Percent of Total
Field Investigations / Testing	250,000 – 400,000	25 %
Modeling and Analysis	200,000 – 300,000	17 %
Engineering Design and Costing	300,000 – 450,000	25 %
Environmental / Permitting	100,000 – 150,000	8 %
Pilot Monitoring and Automation	200,000 – 300,000	17 %
Project Management / Stakeholder Coordination	100,000 – 200,000	8 %

This framework provides flexibility to scale pilot testing at Tortugas and Green Canyon while advancing feasibility for Rincon Arroyo and Caballo–Hatch Valley.

6.3. Monitoring and Data Improvements

Purpose

Continuous, defensible monitoring is critical to verify MAR performance, inform adaptive management, and reduce uncertainty in recharge estimates. Phase I identified key data limitations—particularly regarding subsurface hydraulic properties, structure O&M records, and long-term infiltration behavior—that should be prioritized for improvement.

1. Recommended Monitoring Enhancements
 - Instrumentation Network Expansion
 - Install nested monitoring wells (shallow + intermediate screens) at pilot and representative non-pilot sites.
 - Deploy DTS and TDR sensors in infiltration basins and channels to map spatial and temporal infiltration patterns.
 - Integrate LoRaWAN telemetry for real-time data transmission and early O&M alerts.

2. Data Management and Geodatabase Maintenance
 - Maintain and version the Phase I LRG MAR geodatabase as the authoritative repository for hydrologic, geologic, and monitoring data.
 - Adopt NM Open Data standards (ESRI REST services) to enable transparent data sharing among NMISC, OSE, EBID, and SWCDs.
 - Implement controlled versioning to archive updates from field sensors, test results, and model outputs.
3. Data Gap Reduction Tasks
 - Obtain missing WR-09 dam forms, O&M inspection reports, and as-built drawings to refine structural assessments.
 - Collect sediment-core and permeability data within infiltration zones to better constrain recharge modeling.
 - Develop a unified QA/QC framework for all new datasets, harmonizing formats, coordinate systems, and metadata.
4. Long-Term Performance Tracking
 - Establish standardized infiltration and recovery metrics, referenced to seasonal hydrographs.
 - Link the monitoring system to NMISC's statewide water-accounting platform for ongoing performance evaluation.

Expected Outcomes

Implementing these improvements will reduce uncertainty in recharge yield estimates, strengthen regulatory defensibility, and enable a smooth transition from pilot validation to basin-scale MAR management under subsequent phases of the NMISC Lower Rio Grande MAR Program.

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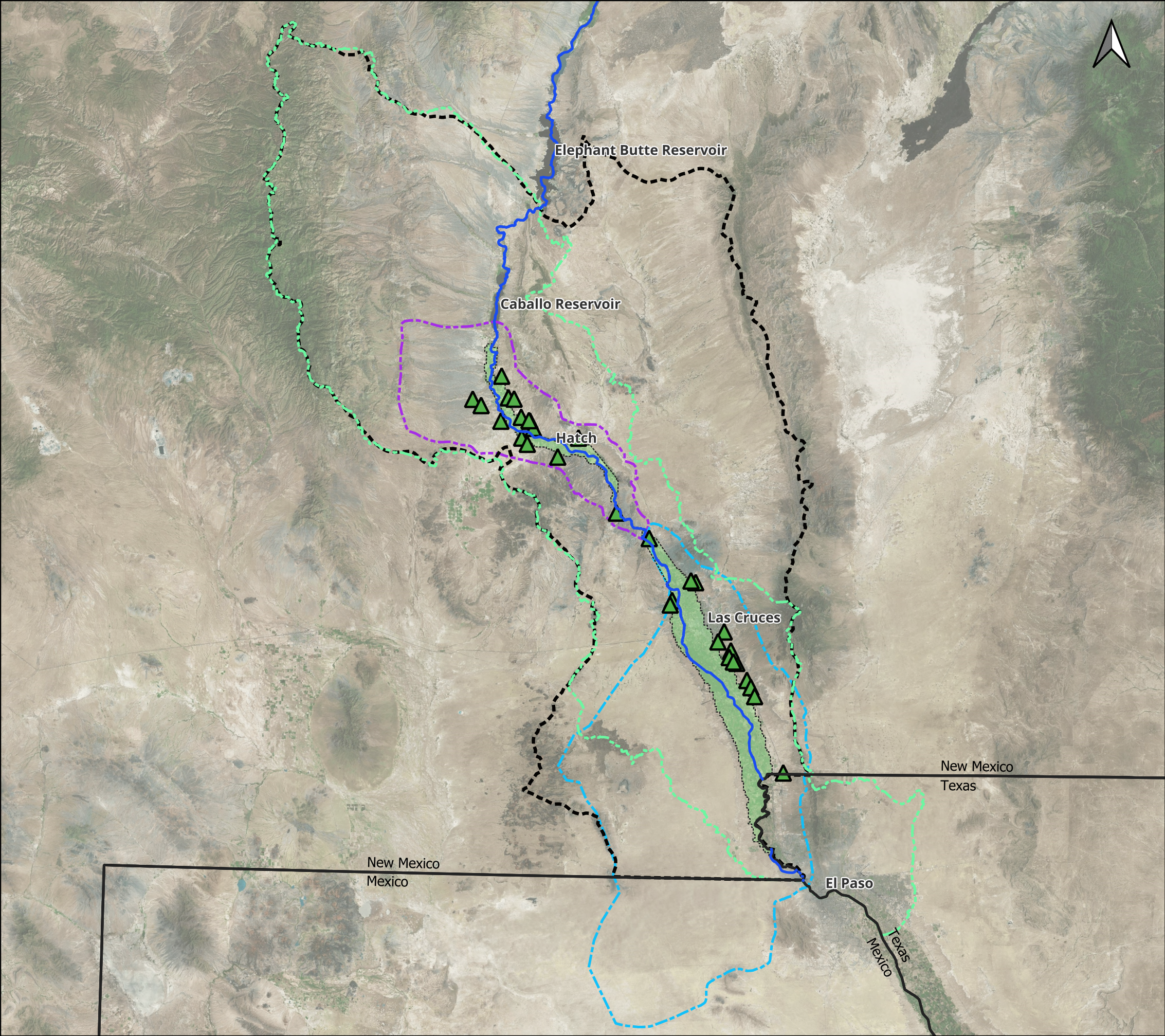
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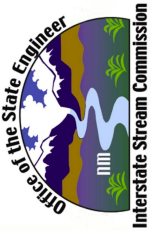
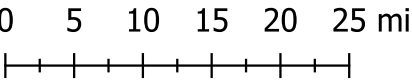
8. Figures

The following are Figures 1 to 16 referenced in the report.

- Figure 1: Phase 1 LRG MAR Study Location
- Figure 2: Phase 1 LRG MAR Study Dams: North Lower Rio Grande
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- Figure 4: Phase 1 LRG MAR Study: Legend/Key for Figures 5-11
- Figure 5: Phase 1 LRG MAR Study Focus Areas: Tortugas Dams 1 & 2
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- Figure 14: Phase 1 LRG MAR Study Examples: Tortugas System
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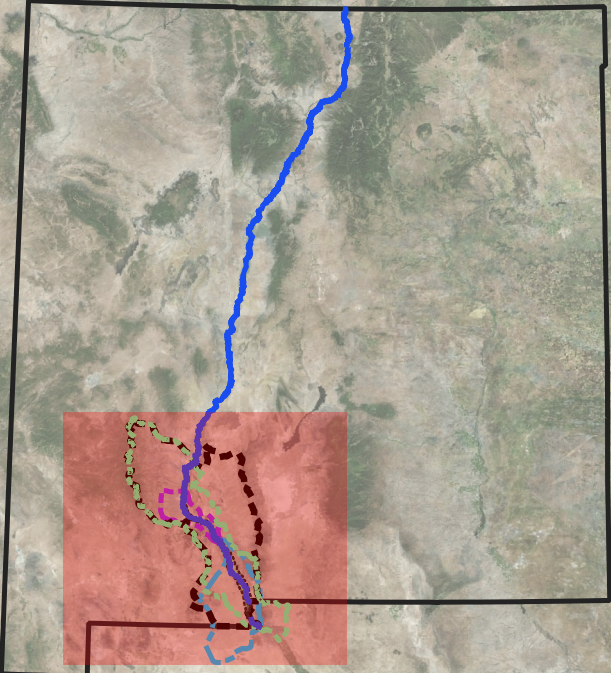
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 - ▭ Elephant Butte Irrigation District
 - ▭ USGS Huc10 LRG Surface Water Basin
- Groundwater Basins
- ▭ Lower Rio Grande
- LRG Groundwater Sub-Basins
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 - ▭ Mesilla
- State/International Boundaries
- Rio Grande



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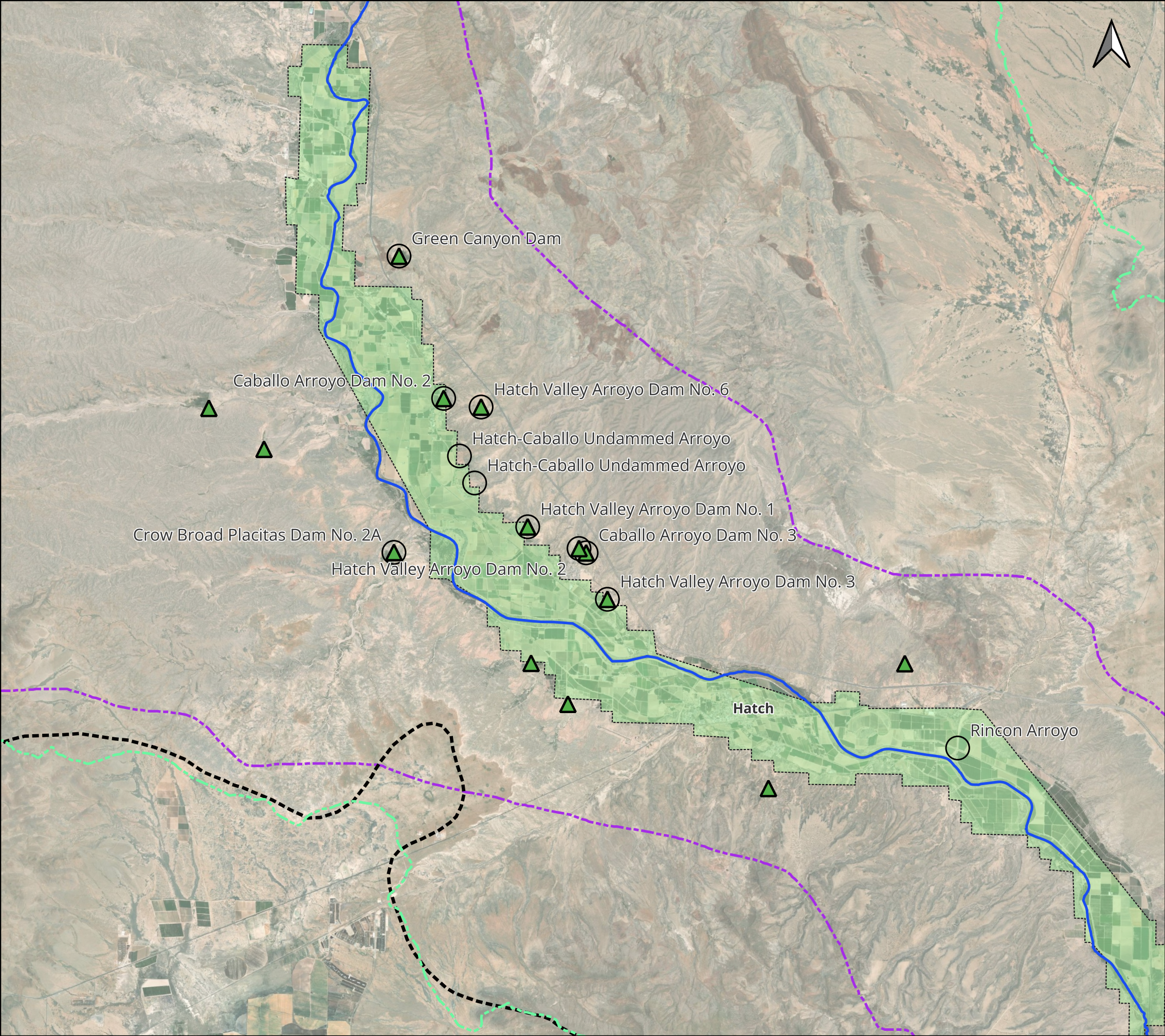
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Key Map

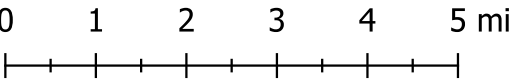


Phase 1 LRG MAR Study Location

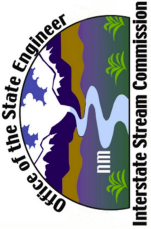
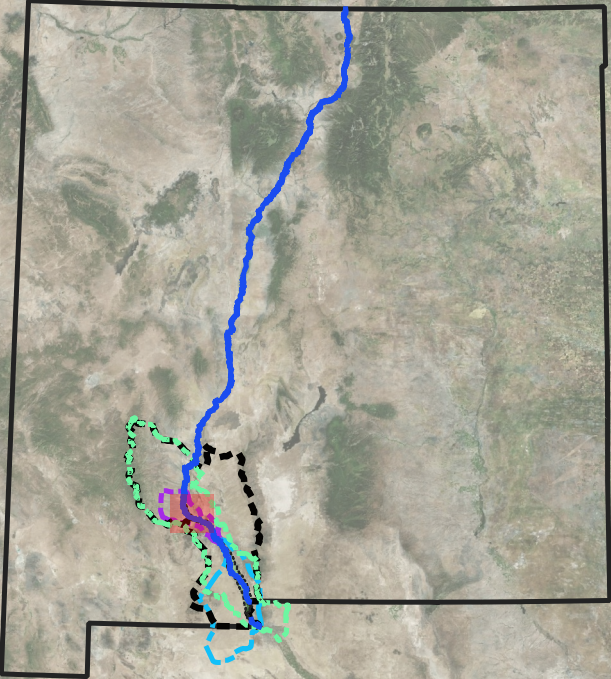
FIGURE
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- OSE Data
- EBID Dams
 - Mar Study Sites
 - Elephant Butte Irrigation District
 - USGS Huc10 LRG Surface Water Basin
- Groundwater Basins
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- LRG Groundwater Sub-Basins
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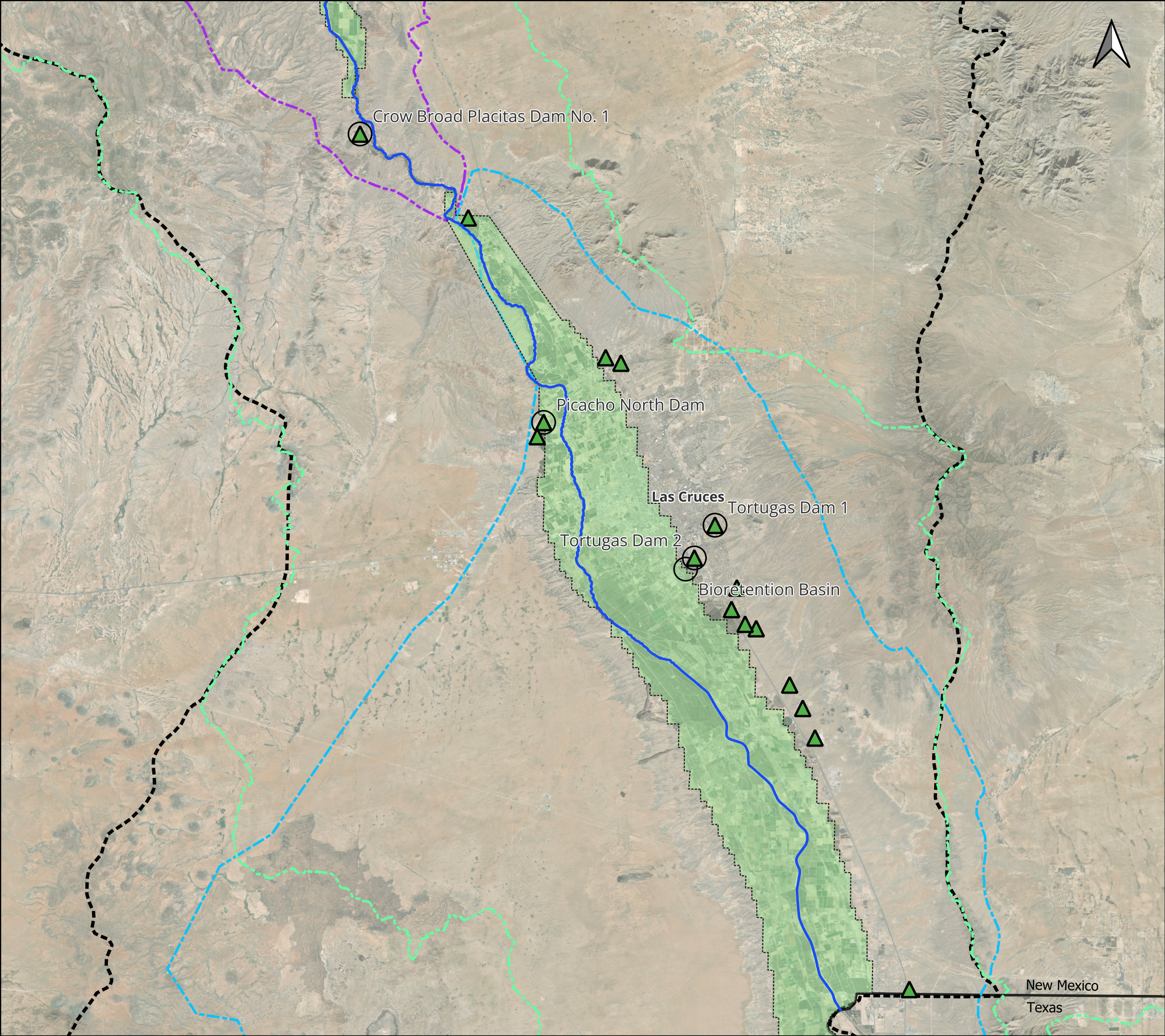
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Phase 1 LRG MAR Study Dams:
North Lower Rio Grande



OSE Data

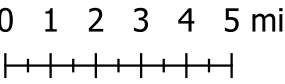
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- Mar Study Sites
- ▨ Elephant Butte Irrigation District
- ▨ USGS Huc10 LRG Surface Water Basin

Groundwater Basins

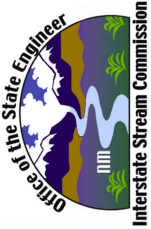
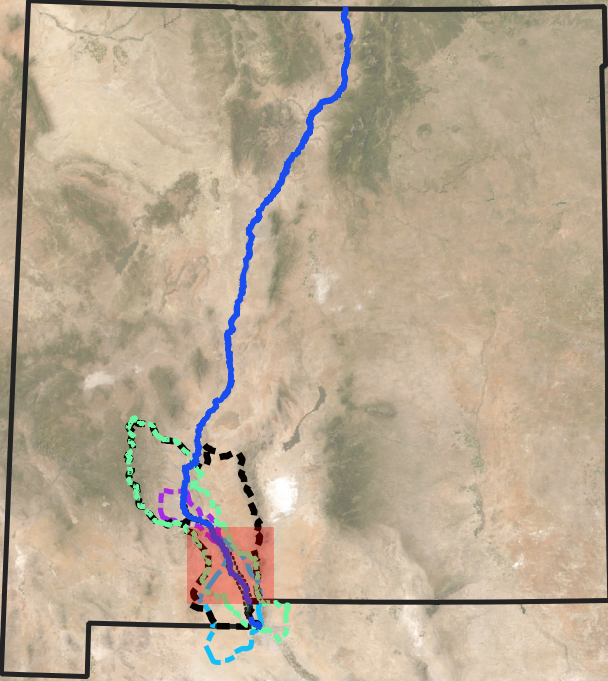
- ▨ Lower Rio Grande

LRG Groundwater Sub-Basins

- ▨ Rincon
- ▨ Mesilla
- ▭ State Boundary
- Rio Grande



Key Map

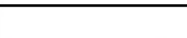
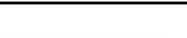


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Phase 1 LRG MAR Study Dams:
South Lower Rio Grande

Land-Cover Map Color Flood Shading Key				
Map value	General class	Color code	Sub-class	Runoff Coefficient
0	Terra Firma	True desert	FEFECC 3% short vegetation cover	0.6
1			FAFAC3 7% short vegetation cover	0.5875
2			F7F7B8 11% short vegetation cover	0.575
3			F4F4B3 15% short vegetation cover	0.5625
4			F1F1A8 19% short vegetation cover	0.55
5			EDEDA2 23% short vegetation cover	0.5375
6			EAEA9A 27% short vegetation cover	0.525
7			E7E792 31% short vegetation cover	0.5125
8			E4E48A 35% short vegetation cover	0.5
9			E0E081 39% short vegetation cover	0.4875
10		Semi-arid	DDDD79 43% short vegetation cover	0.475
11			DADA71 47% short vegetation cover	0.4625
12			D7D769 51% short vegetation cover	0.45
13			D3D360 55% short vegetation cover	0.4375
14			D0D058 59% short vegetation cover	0.425
15			CDCD50 63% short vegetation cover	0.4125
16			CACA48 67% short vegetation cover	0.4
17			C6C63F 71% short vegetation cover	0.3875
18			C3C337 75% short vegetation cover	0.375
19			C0C02F 79% short vegetation cover	0.3625
20		Dense short vegetation	BD8D27 83% short vegetation cover	0.35
21			B9B91E 87% short vegetation cover	0.3375
22			B6B616 91% short vegetation cover	0.325
23			B3B30E 95% short vegetation cover	0.3125
24			B0B006 100% short vegetation cover	0.3
25	Terra Firma	Tree cover	609C60 3m trees	0.71
26			5C985C 4m trees	0.696956522
27			589558 5m trees	0.683913043
28			549254 6m trees	0.670869565
29			508E50 7m trees	0.657826087
30			4C8B4C 8m trees	0.644782609
31			488848 9m trees	0.63173913
32			448544 10m trees	0.618695652
33			408140 11m trees	0.605652174
34			3C7E3C 12m trees	0.592608696
35			387B38 13m trees	0.579565217
36			347834 14m trees	0.566521739
37			317431 15m trees	0.553478261
38			2D712D 16m trees	0.540434783
39			296E29 17m trees	0.527391304
40			256B25 18m trees	0.514347826
41			216721 19m trees	0.501304348
42			1D641D 20m trees	0.48826087
43			196119 21m trees	0.475217391
44			155E15 22m trees	0.462173913
45			115A11 23m trees	0.449130435
46			0D570D 24m trees	0.436086957
47			095409 25m trees	0.423043478
48			055005 >25m trees	0.41
100	Wetland	Salt pan	BFC0C0 3% short vegetation cover	0.71
101			B7BDC2 7% short vegetation cover	0.70375
102			AFB8C4 11% short vegetation cover	0.6975
103			A8B8C6 15% short vegetation cover	0.69125
104			A0B6C9 19% short vegetation cover	0.685
105		Sparse vegetation	99B3CB 23% short vegetation cover	0.67875
106			91B1CD 27% short vegetation cover	0.6725
107			89AFD0 31% short vegetation cover	0.66625
108			82ACD2 35% short vegetation cover	0.66
109			7AAAD4 39% short vegetation cover	0.65375
110			73A7D6 43% short vegetation cover	0.6475
111			68A5D9 47% short vegetation cover	0.64125
112			64A3DB 51% short vegetation cover	0.635
113			5CA0DD 55% short vegetation cover	0.62875
114			549EE0 59% short vegetation cover	0.6225
115		Dense short vegetation	4D9BE2 63% short vegetation cover	0.61625
116			4599E4 67% short vegetation cover	0.61
117			3E96E6 71% short vegetation cover	0.60375
118			3694E9 75% short vegetation cover	0.5975
119			2E92E8 79% short vegetation cover	0.59125
120		Tree cover	278FED 83% short vegetation cover	0.585
121			1F8DF0 87% short vegetation cover	0.57875
122			188AF2 91% short vegetation cover	0.5725
123			1088F4 95% short vegetation cover	0.56625
124			0986F7 100% short vegetation cover	0.56
125	Wetland	Tree cover	55A5A5 3m trees	0.55375
126			53A1A2 4m trees	0.5475
127			519E9F 5m trees	0.54125
128			4F9B9C 6m trees	0.535
129			4D989A 7m trees	0.52875
130			489597 8m trees	0.5225
131			499294 9m trees	0.51625
132			478F91 10m trees	0.51
133			458B8F 11m trees	0.50375
134			43888C 12m trees	0.4975
135		Open surface water	418589 13m trees	0.49125
136			3F8286 14m trees	0.485
137			3D7F84 15m trees	0.47875
138			3B7C81 16m trees	0.4725
139			39797E 17m trees	0.46625
140			377678 18m trees	0.46
141			357279 19m trees	0.45375
142			336F76 20m trees	0.4475
143			316C73 21m trees	0.44125
144			2F6970 22m trees	0.435
145		Open surface water	2D666E 23m trees	0.42875
146			286368 24m trees	0.4225
147			296068 25m trees	0.41625
148			285D66 >25m trees	0.41
200			1964EB 20-29% of year	N/A
201			1555E4 30-39% of year	N/A
202			1147DD 40-49% of year	N/A
203			0E39D6 50-59% of year	N/A
204			0A2ACF 60-69% of year	N/A
205			071CC8 70-79% of year	N/A
206			030EC1 80-89% of year	N/A
207			00008A 90-100% of year	N/A
241	Terra Firma	Snow/ice	ffffff Snow/ice	N/A
244		Cropland	ff7d00 Cropland	0.45
250		Built-up	64dcdc Built-up	0.55
254		Ocean	111133 Ocean	N/A
255		No data		

Unit Name		Lithology & Setting		Hydro Behavior	
	Top_RC1_ft	Upper Rio Grande alluvium- floodplain/overbank	Silt-clay with fine sand; levee & floodplain drapes capping channel deposits.	Lower K; semi-confining cap; perched conditions locally.	
	Top_RC2_ft	Lower Rio Grande channel/point-bar alluvium	Medium-coarse sand & gravel; cross-bedded point bars & paleochannels.	High K; principal shallow aquifer near river.	
	Base_RC_ft	Contact- base of Rio Grande alluvium / top of Santa Fe Group	Unconformable contact; common hydraulic break.	Often marks drop in K and head discontinuity.	
	Top_USF1_ft	Upper Santa Fe Group- coarse axial- river facies (Camp Rice)	Sand/gravel with minor silt; weak calcic cement locally; terrace associations.	Moderate-high K; productive where saturated.	
	Top_USF2_ft	Upper Santa Fe Group- fine overbank & playa facies (Palomas)	Silty clay, mudstone, fine sand; clay drapes and interbeds.	Lower K; leaky aquitard separating USF1 lenses.	
	Top_MSF1_ft	Middle Santa Fe Group- channel/fan- delta sand & gravel lenses (Fort Hancock)	Interbedded with sandy mudstone; laterally variable coarse bodies.	Localized high K; strong heterogeneity.	
	Top_MSF2_ft	Middle Santa Fe Group- fine lacustrine & playa mudstone/siltstone	Thick fine-grained packages; laminated mudstone; evaporite lenses locally.	Low K; confining to semi-confining; low vertical K.	
	Top_LSF1_ft	Lower Santa Fe Group- proximal fan/apron facies (Hayner Ranch)	Sandy to gravelly alluvial fan lobes; volcanoclastic locally; channelized.	Variable K; coarse lobes transmit well, otherwise moderate-low.	
	Top_LSF2_ft	Lower Santa Fe Group- basin-floor fines (Rincon)	Mudstone/claystone with minor very fine sand; widespread.	Very low K; regional confining section.	
	Top_BSMT_ft	Pre-basin-fill bedrock (sedimentary, volcanic or crystalline)	Consolidated bedrock underlying basin-fill; composition varies by block.	Very low primary porosity; flow via fractures/karst where present.	
	Base_BSMT_ft	Computational lower boundary (below Top_BSMT)	Not a geologic unit; numeric model limit.	Use for grid truncation; no properties assigned.	

Land Cover Type		Runoff Coefficient (C)	
Impervious Surfaces		min	max
Paved areas (roads, parking lots)		0.85	0.95
Roofs		0.75	0.95
Urban Areas			
High-density residential/commercial		0.7	0.9
Low-density residential		0.3	0.5
Parks and Open Spaces			
Lawns, parks (good condition)		0.1	0.3
Agricultural Lands			
Cultivated fields (poor condition)		0.3	0.6
Pasture (good condition)		0.1	0.3
Natural Areas			
Forest (good condition)		0.05	0.25
Desert shrubland		0.3	0.6
Sagebrush with grass understory		0.35	0.55
Pinyon-juniper woodland		0.41	0.71

Runoff Coefficients calculated based on minimum and maximum runoff coefficients provided for each general class. Sub-class coefficients calculated by applying a scaling equation which provided a range of values representative of the sub-class' land cover type in relation to the general class under which it fell.

$$RC_{adj} = RC_{max} - (RC_{max} - RC_{min}) * \frac{MV - MV_{min}}{MV_{max} - MV_{min}}$$

RC_{adj} = Adjusted Runoff Coefficient
RC_{max} = Maximum Runoff Coefficient for General Class
RC_{min} = Minimum Runoff Coefficient for General Class
MV = Map Value
MV_{max} = Maximum Map Value for General Class
MV_{min} = Minimum Map Value for General Class



Office of the State Engineer
Interstate Stream Commission



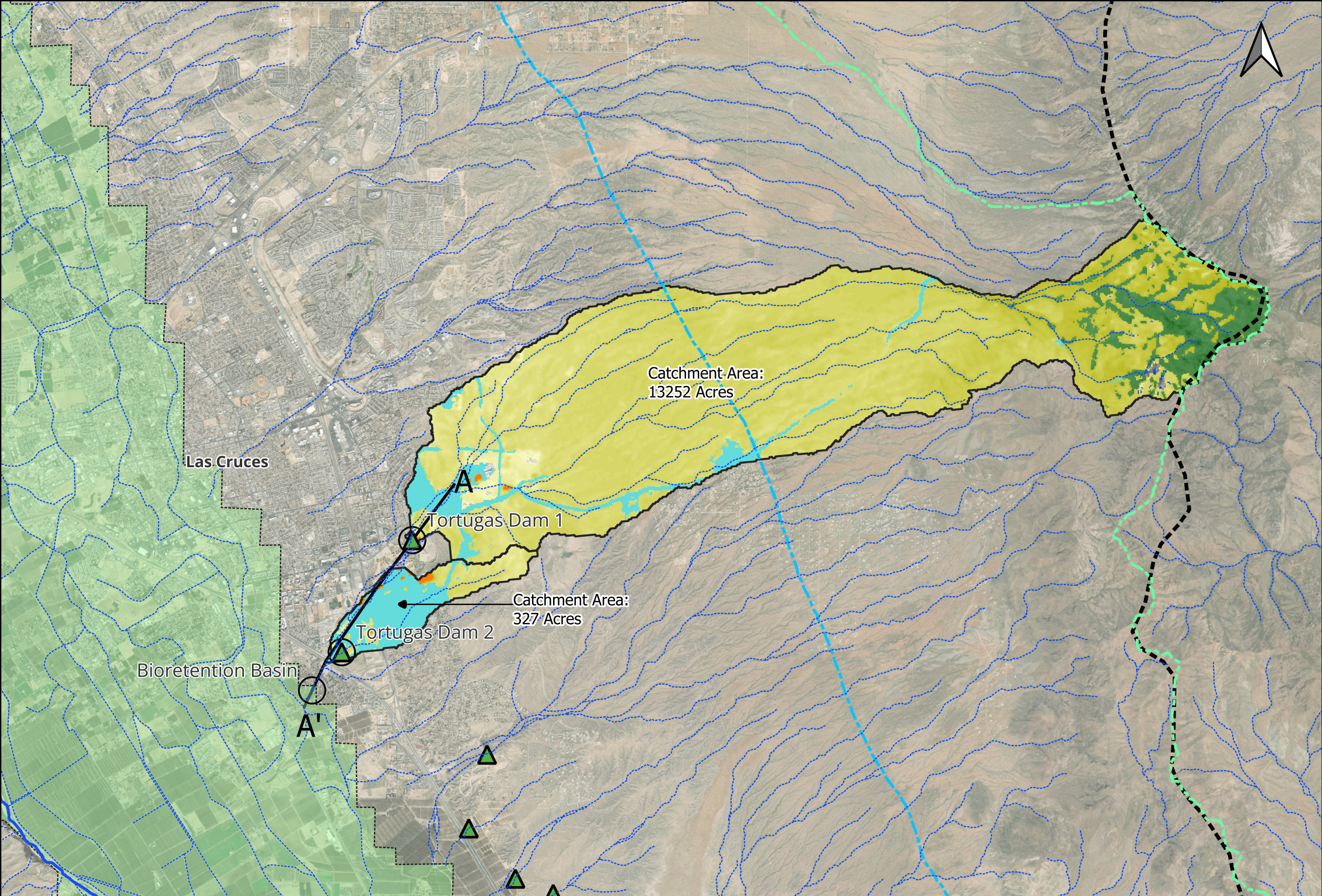
Lynker

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Checked By: PG
Check Date: 10/2/2025

New Mexico Interstate Stream Commission

Phase 1 LRG MAR Study:
Legend/Key for Figures 5-11

FIGURE 4



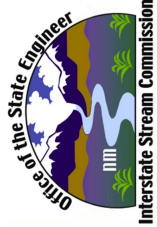
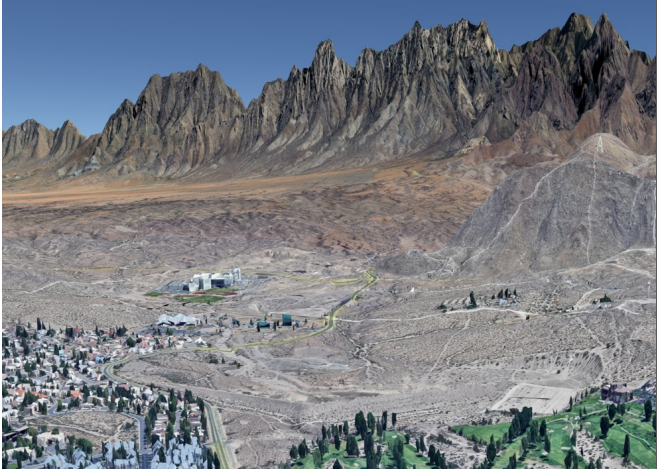
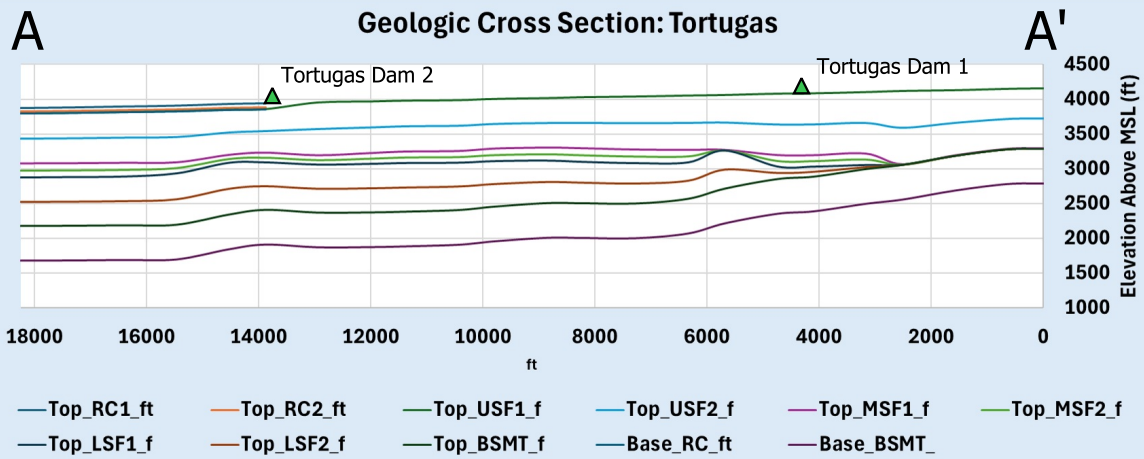
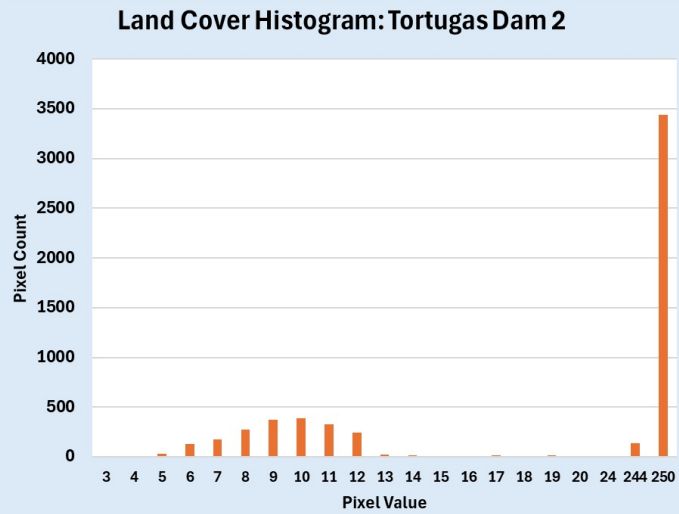
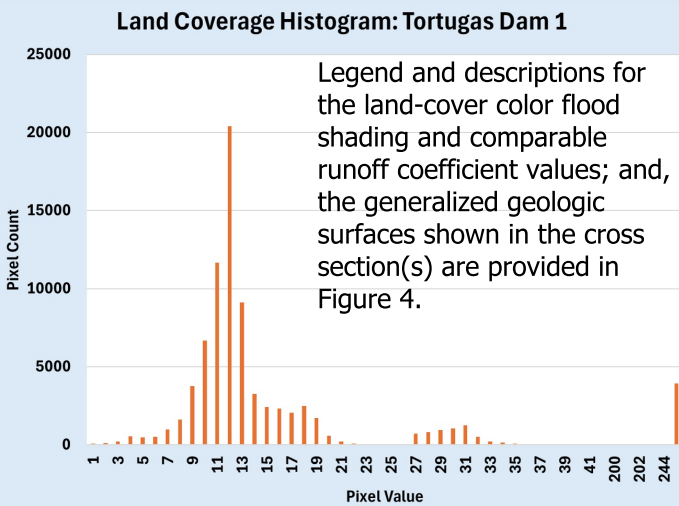
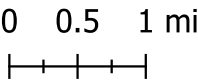
- OSE Data
- ▲ EBID Dams
 - Mar Study Sites
 - Elephant Butte Irrigation District
 - USGS Huc10 LRG Surface Water Basin

- Groundwater Basins
- Lower Rio Grande
- LRG Groundwater Sub-Basins
- Mesilla

MAR Study Data

Tortugas Dams

- Geologic Cross Section Line
- Catchment
- Rio Grande

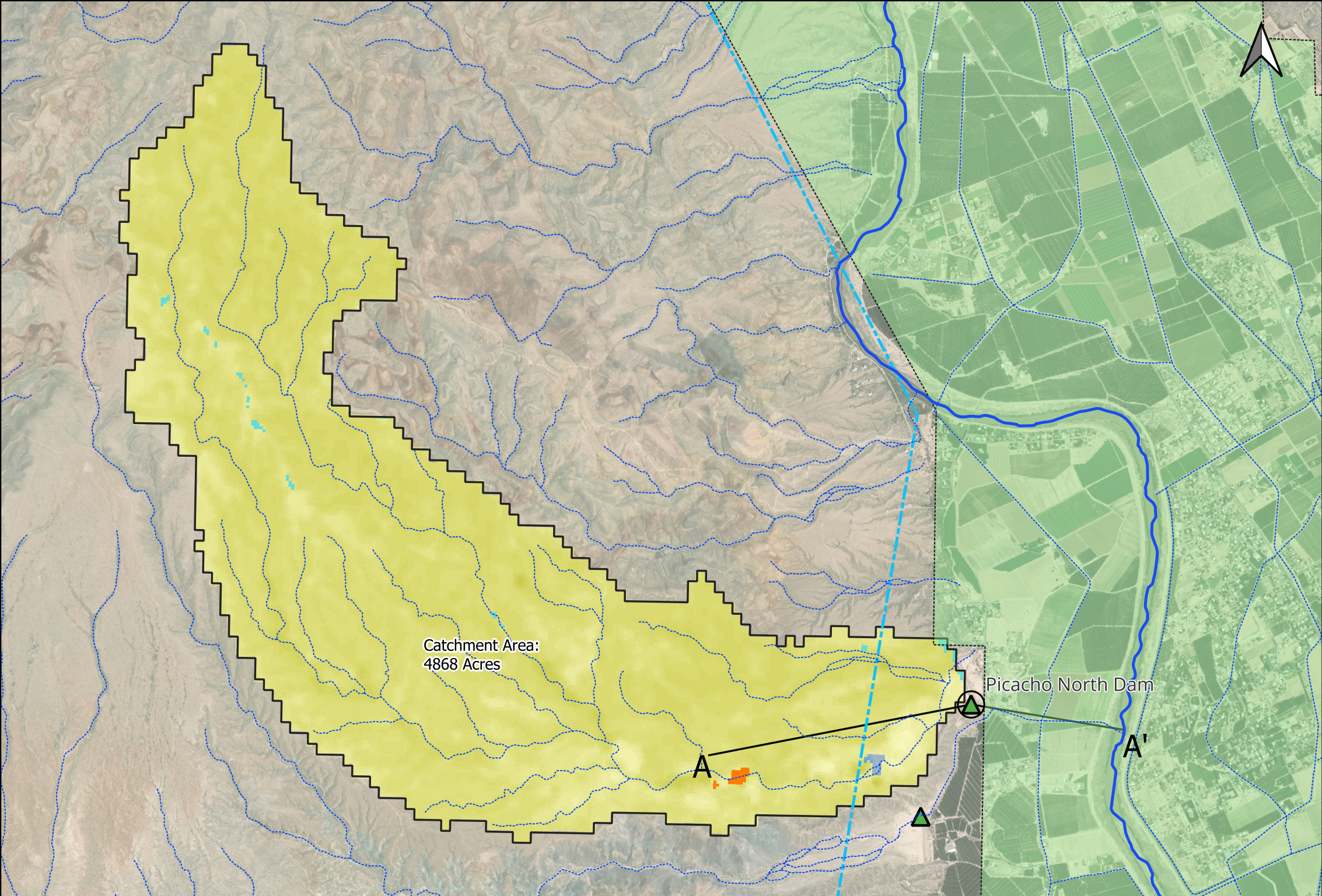


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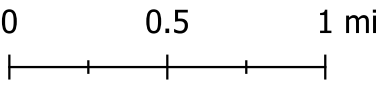
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Stream Commission

Phase 1 LRG MAR Study Focus
Areas:
Tortugas Dams 1 & 2

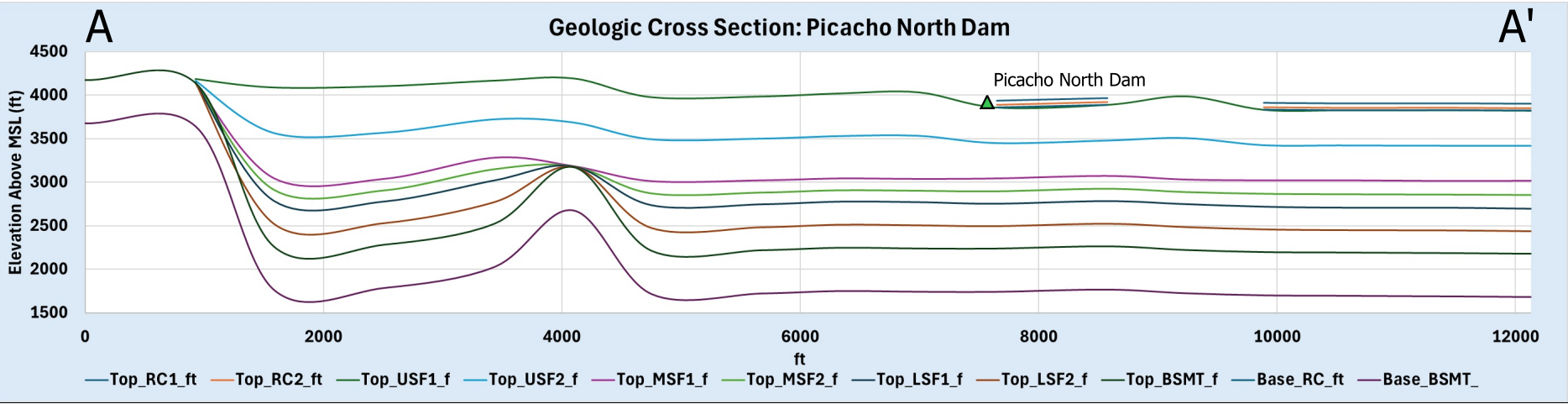
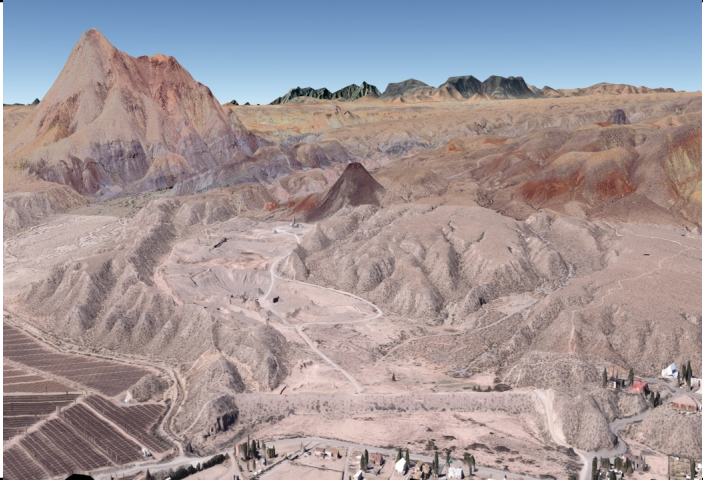
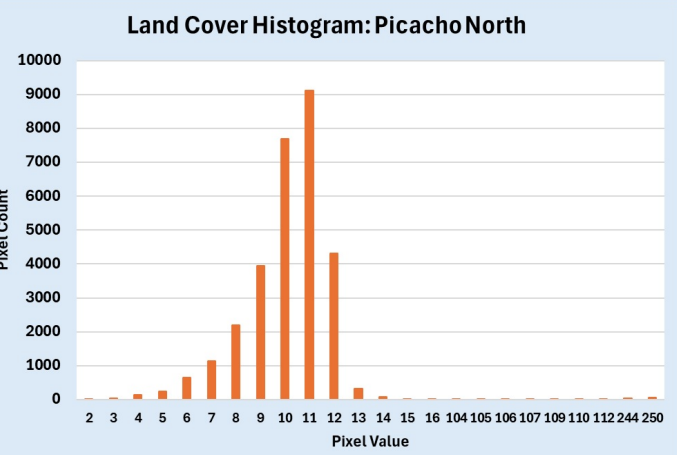
FIGURE
5

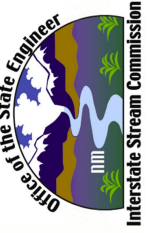


- OSE Data
- ▲ EBID Dams
 - Mar Study Sites
 - ▭ Elephant Butte Irrigation District
- LRG Groundwater Sub-Basins
- ▭ Mesilla
- MAR Study Data
- Picacho North Dam
- Geologic Cross Section Line
 - ▭ Catchment
 - Rio Grande



Legend and descriptions for the land-cover color flood shading and comparable runoff coefficient values; and, the generalized geologic surfaces shown in the cross section(s) are provided in Figure 4.



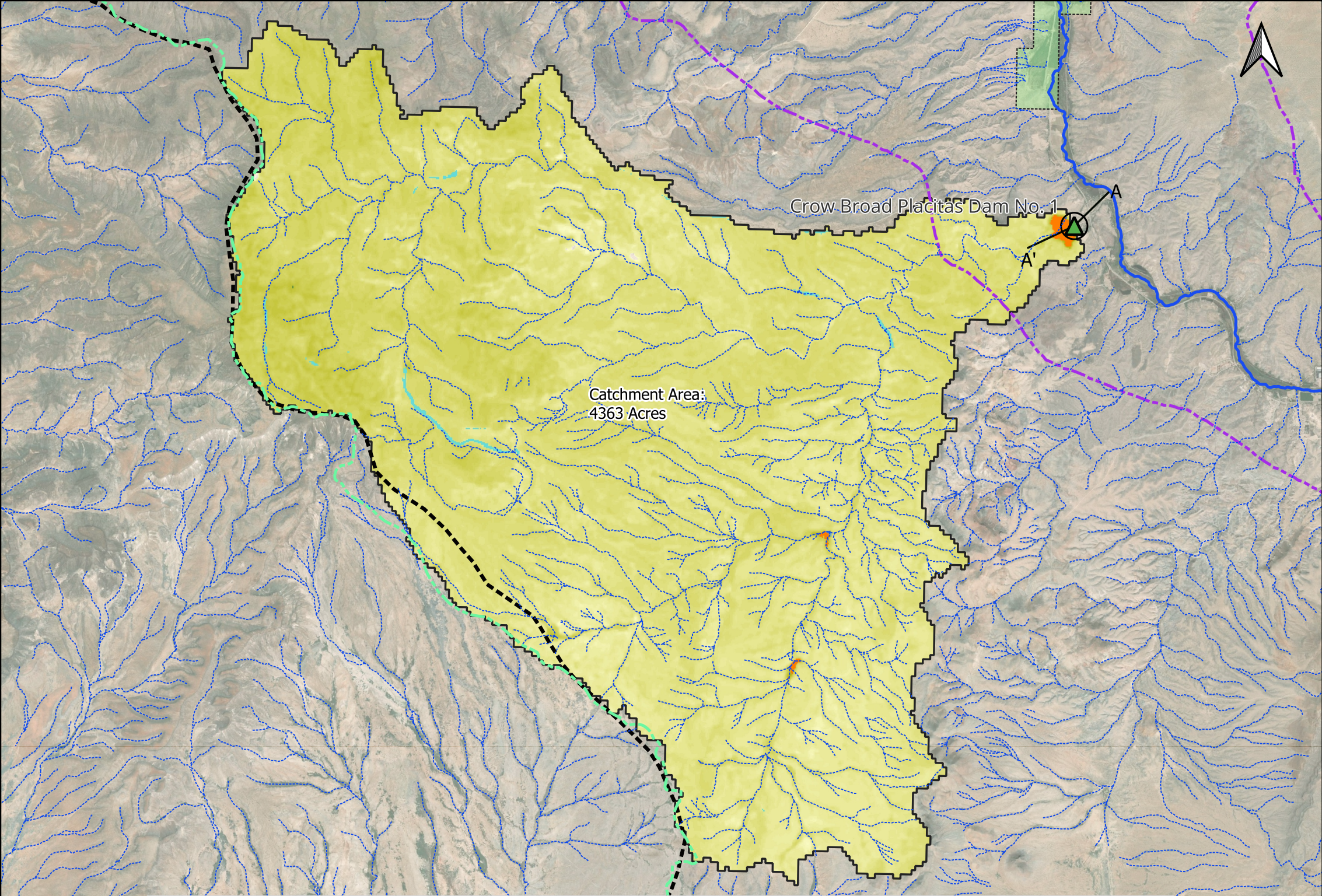


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Check Date: 10/28/2025

New Mexico Interstate Stream Commission

Phase 1 LRG MAR Study Focus Areas:
Picacho North

FIGURE 6



- Rio Grande
- OSE Data
 - EBID Dams
 - Mar Study Sites
 - Elephant Butte Irrigation District
 - USGS Huc10 LRG Surface Water Basin
- Groundwater Basins
 - Lower Rio Grande
- LRG Groundwater Sub-Basins
 - Rincon

Groundwater Basins

Lower Rio Grande

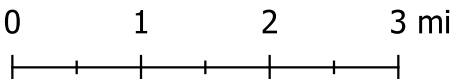
LRG Groundwater Sub-Basins

Rincon

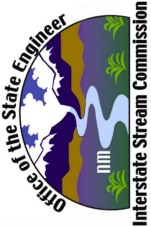
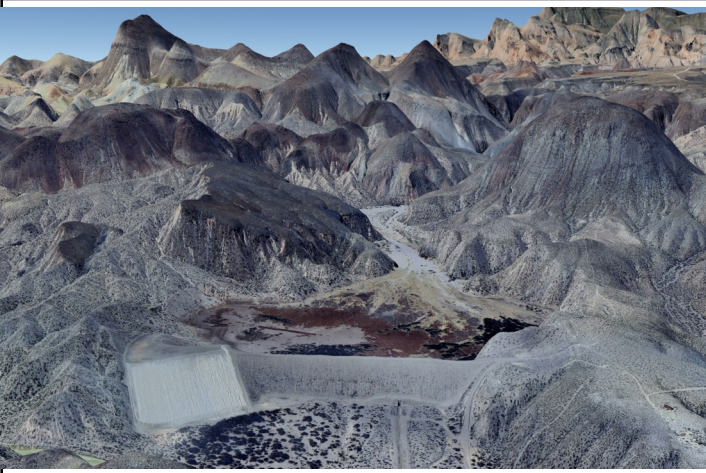
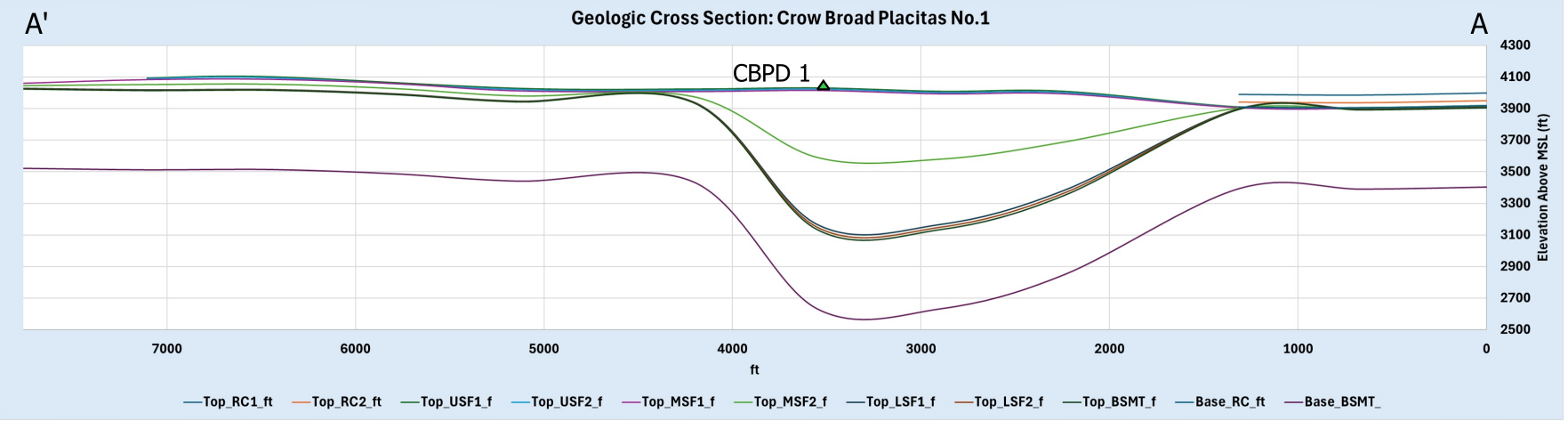
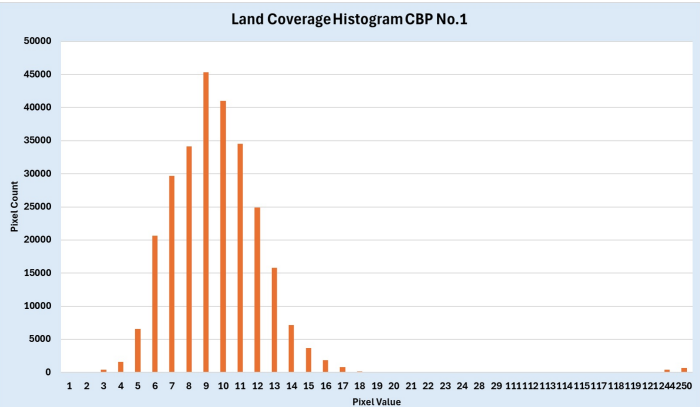
MAR Study Data

Crow Broad Placitas Dam No 1

- Geologic Cross Section Line
- Catchment



Legend and descriptions for the land-cover color flood shading and comparable runoff coefficient values; and, the generalized geologic surfaces shown in the cross section(s) are provided in Figure 4.

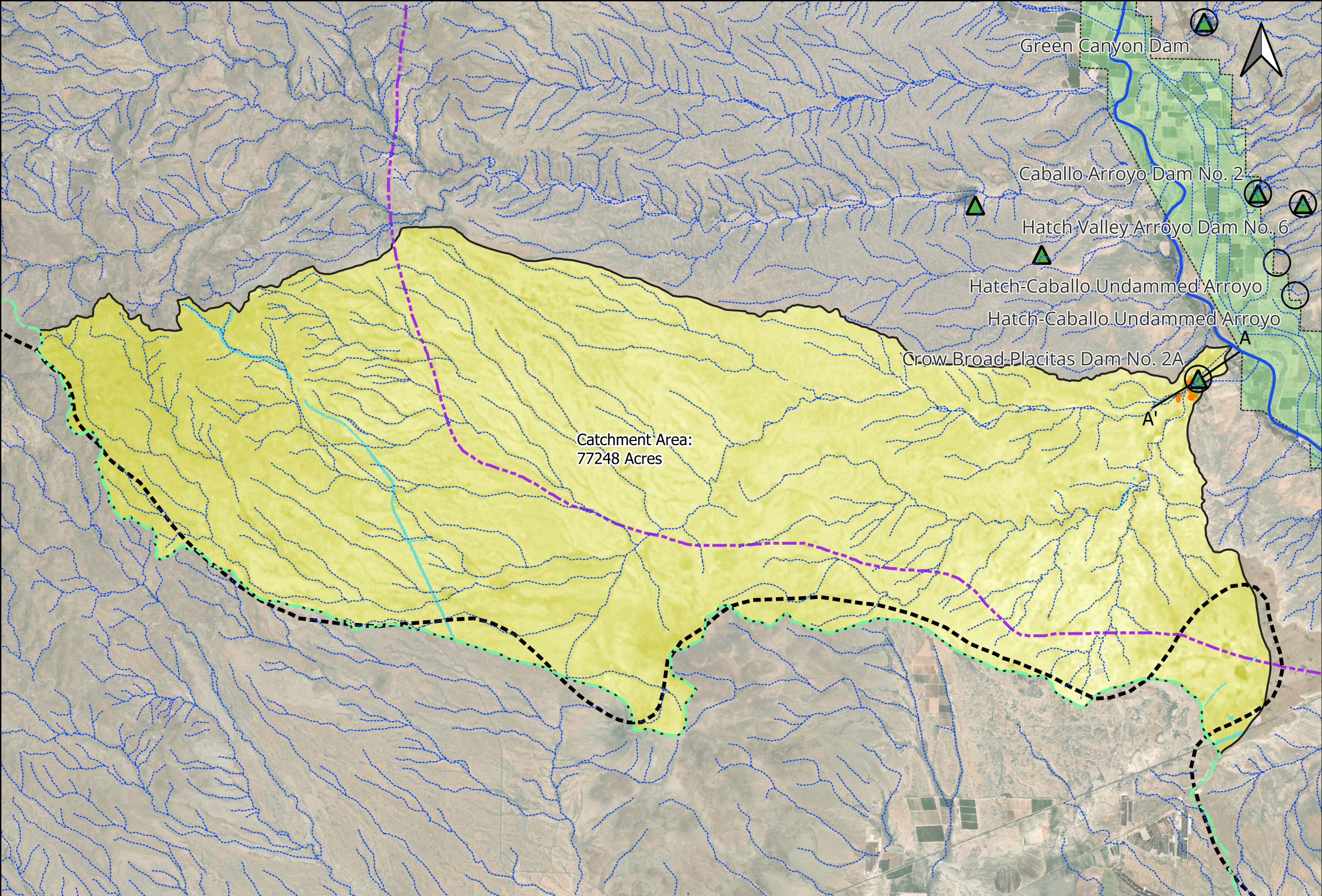


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10/28/2025

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Stream Commission

Phase 1 LRG MAR Study Focus
Areas:
Crow Broad Placitas Dam No. 1

FIGURE
7



OSE Data

- EBID Dams
- Mar Study Sites
- USGS Huc10 LRG Surface Water Basin

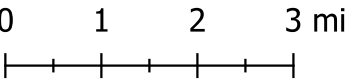
Groundwater Basins

- Lower Rio Grande
- LRG Groundwater Sub-Basins
- Rincon

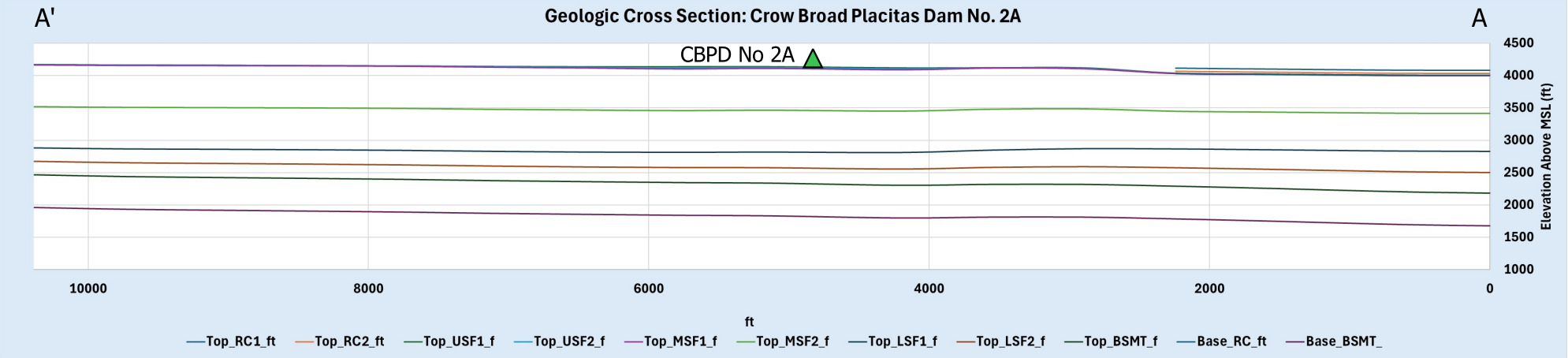
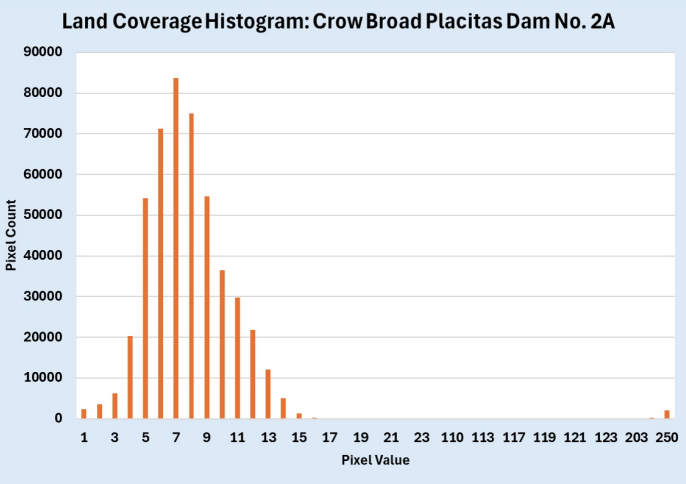
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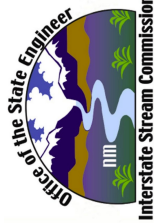
Crow Broad Placitas Dam No 2A

- Geologic Cross Section Line
- Catchment
- Rio Grande



Legend and descriptions for the land-cover color flood shading and comparable runoff coefficient values; and, the generalized geologic surfaces shown in the cross section(s) are provided in Figure 4.



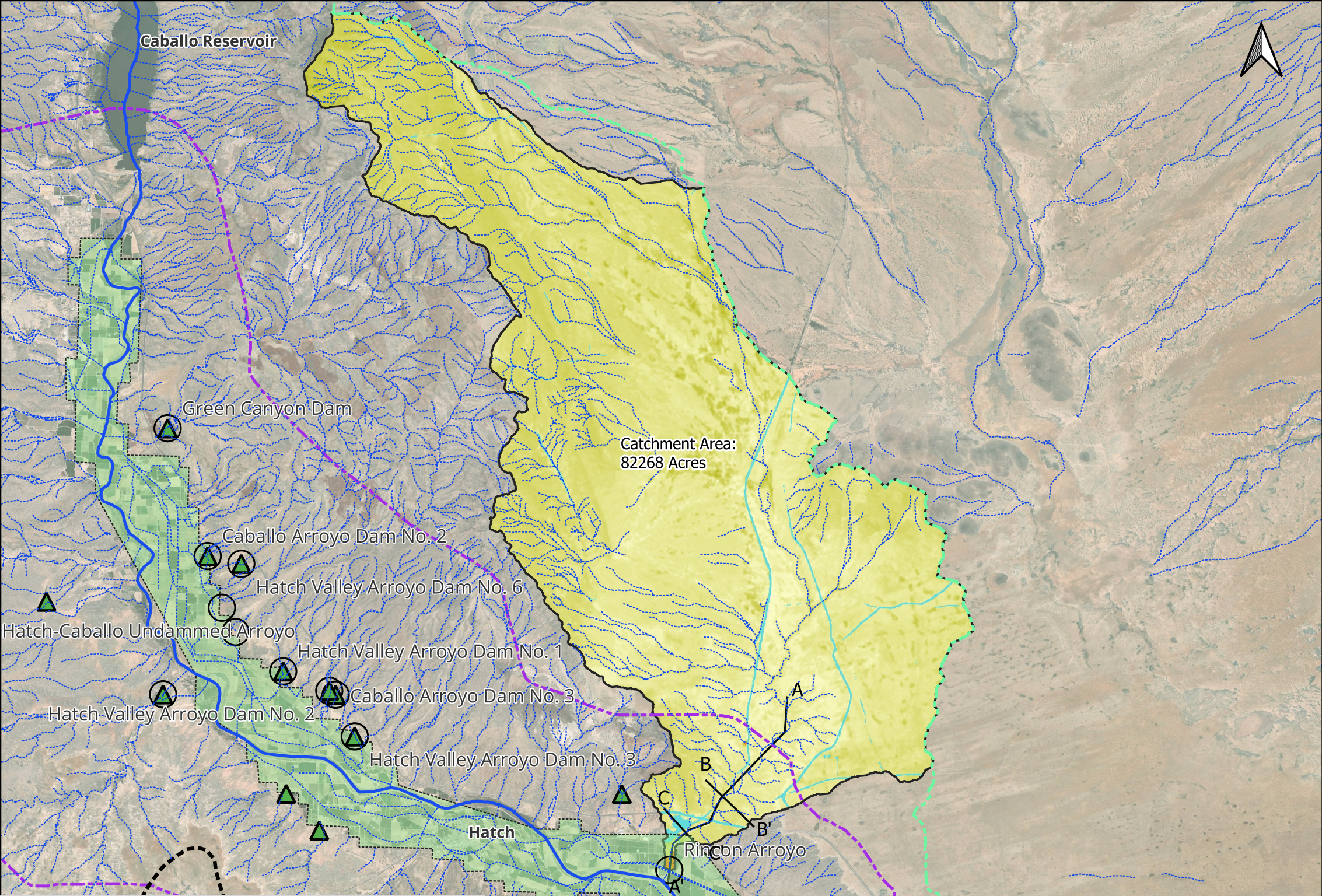


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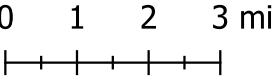
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Phase 1 LRG MAR Study Focus Areas:
Crow Broad Placitas Dam No. 2A

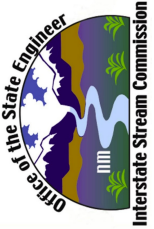
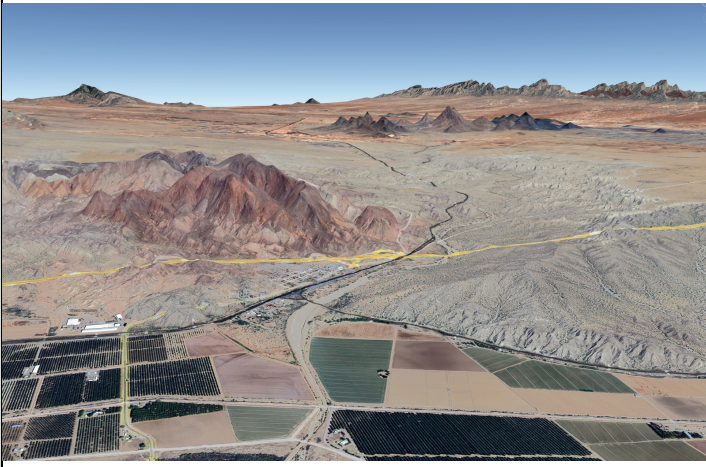
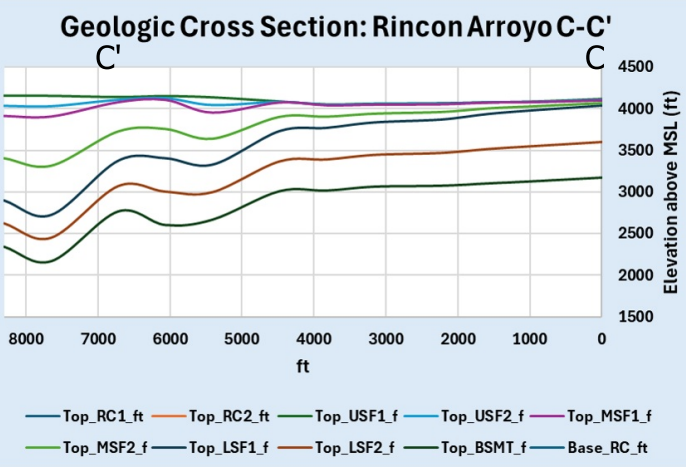
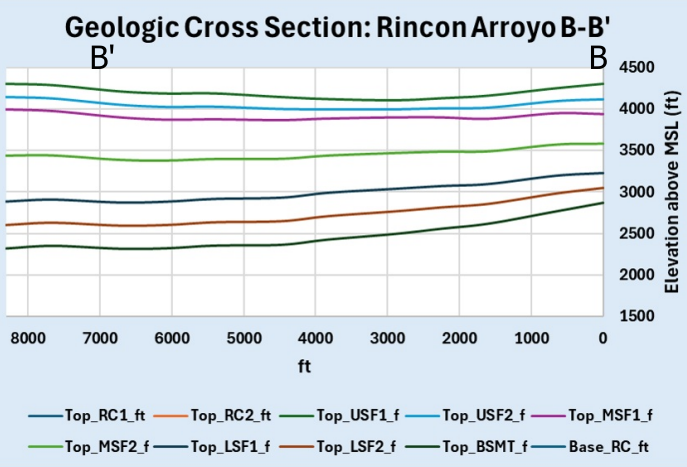
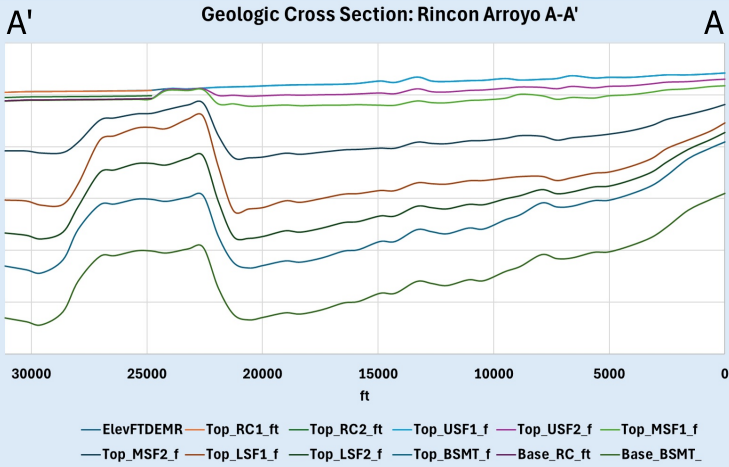
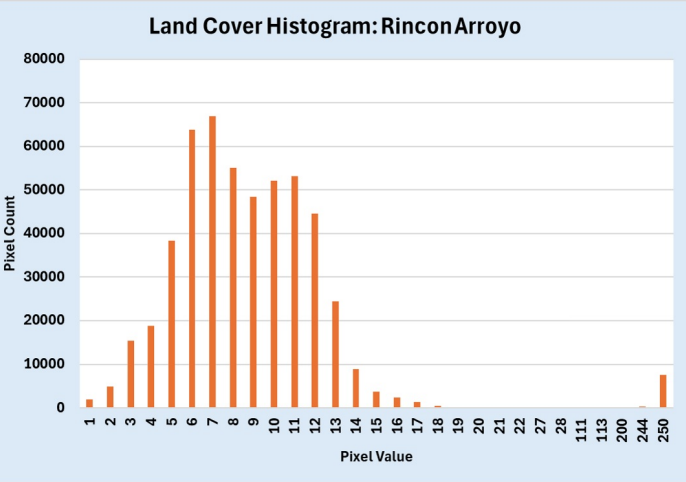
FIGURE 8



- OSE Data
- ▲ EBID Dams
 - Mar Study Sites
 - USGS Huc10 LRG Surface Water Basin
- Groundwater Basins
- Lower Rio Grande
- LRG Groundwater Sub-Basins
- Rincon
- MAR Study Data
- Rincon Arroyo
- Geologic Cross Section Line
 - Catchment
 - Rio Grande



Legend and descriptions for the land-cover color flood shading and comparable runoff coefficient values; and, the generalized geologic surfaces shown in the cross section(s) are provided in Figure 4.

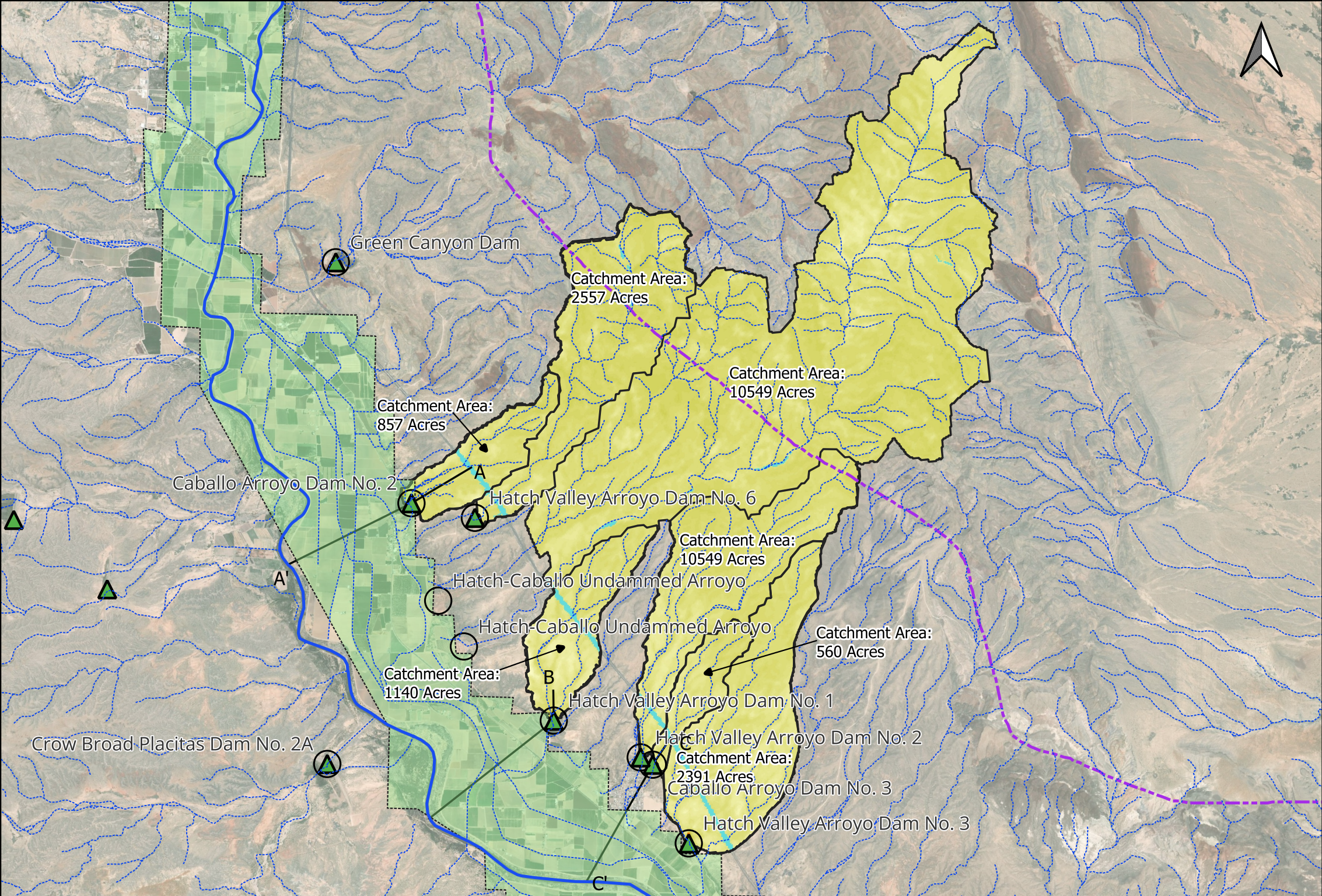


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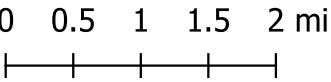
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Stream Commission

Phase 1 LRG MAR Study Focus
Areas:
Rincon Arroyo

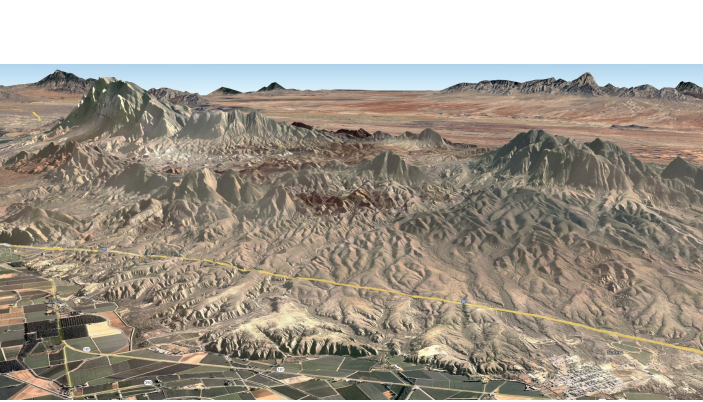
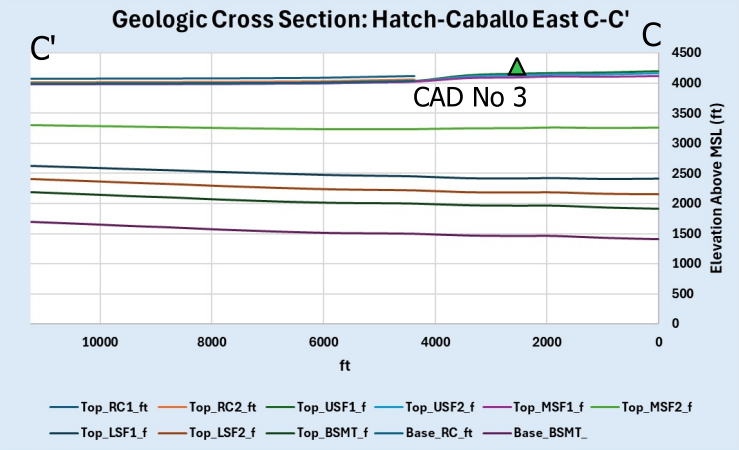
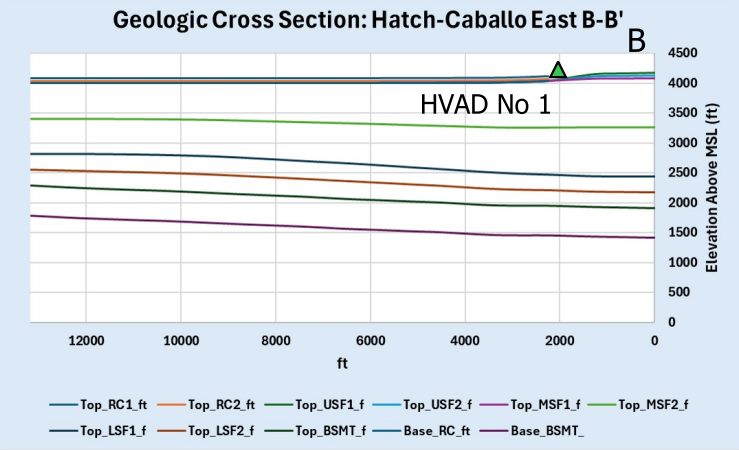
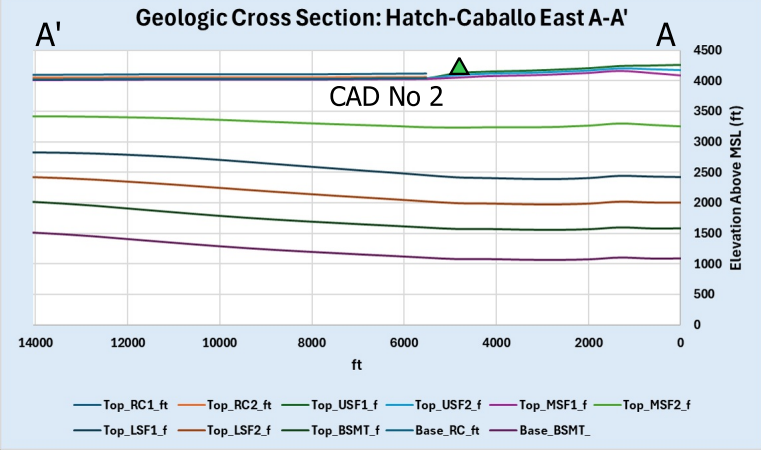
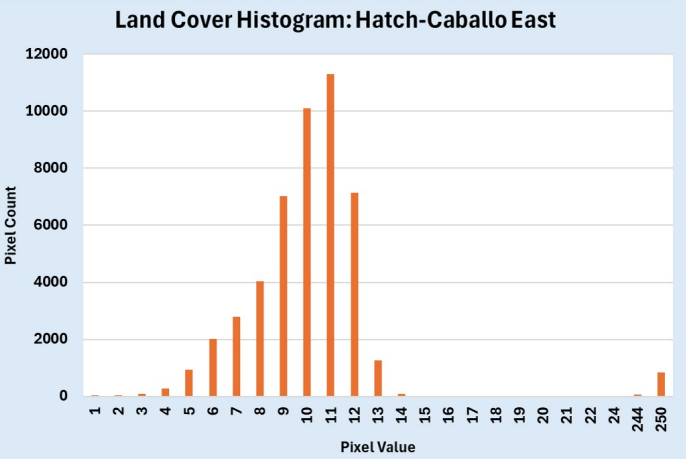
FIGURE
9



- OSE Data
- EBID Dams
 - Mar Study Sites
 - USGS Huc10 LRG Surface Water Basin
- LRG Groundwater Sub-Basins
- Rincon
- MAR Study Data
- Hatch-Caballo East Sites
- Geologic Cross Section Line
 - Catchment
 - Rio Grande



Legend and descriptions for the land-cover color flood shading and comparable runoff coefficient values; and, the generalized geologic surfaces shown in the cross section(s) are provided in Figure 4.

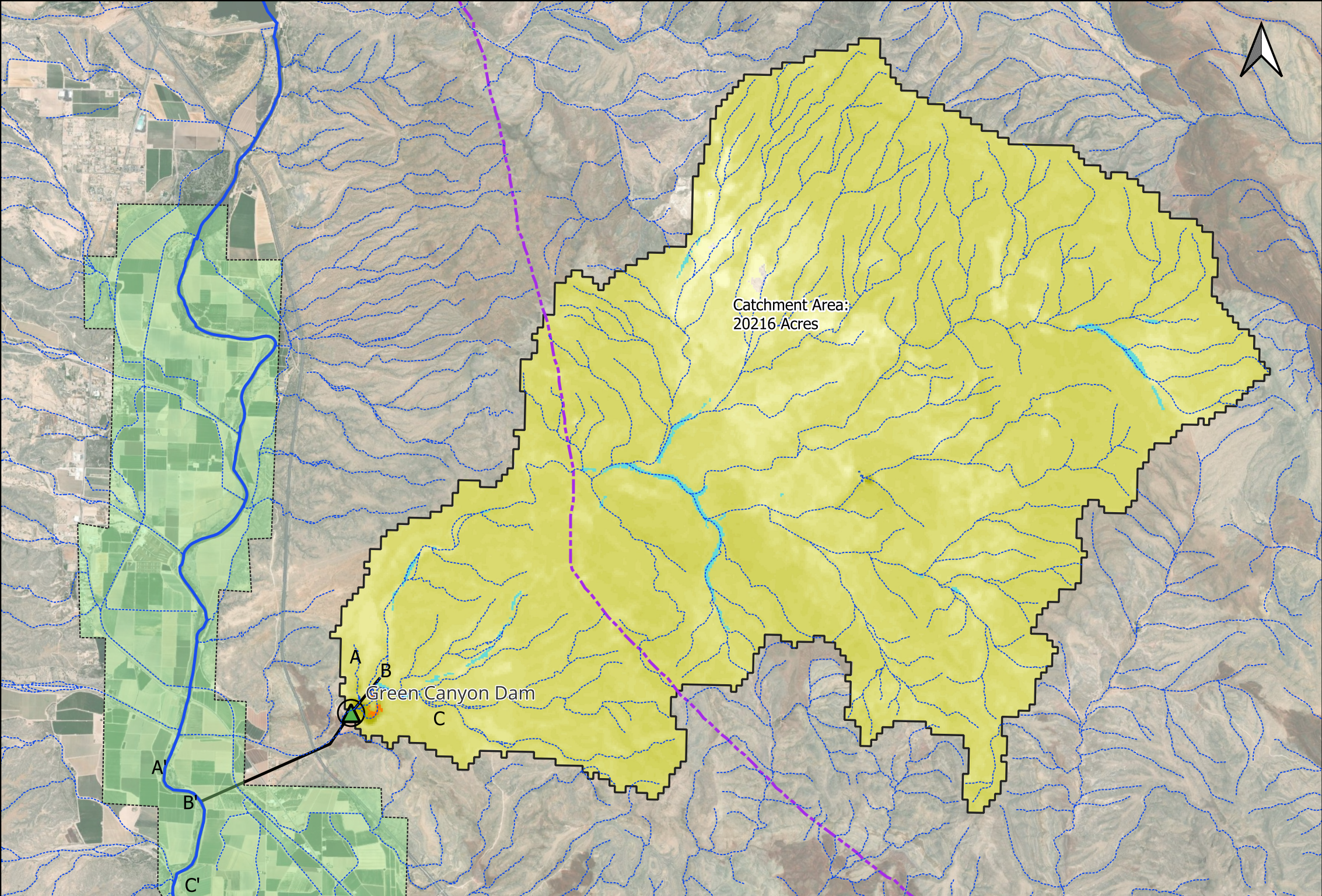


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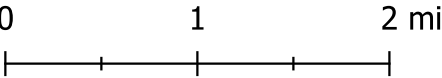
New Mexico Interstate Stream Commission

Phase 1 LRG MAR Study Focus Areas:
Hatch-Caballo East Sites

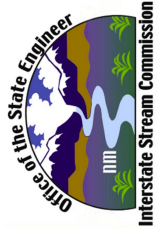
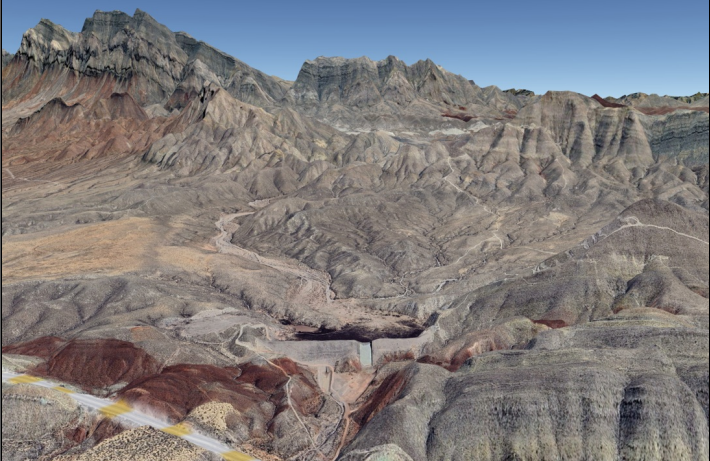
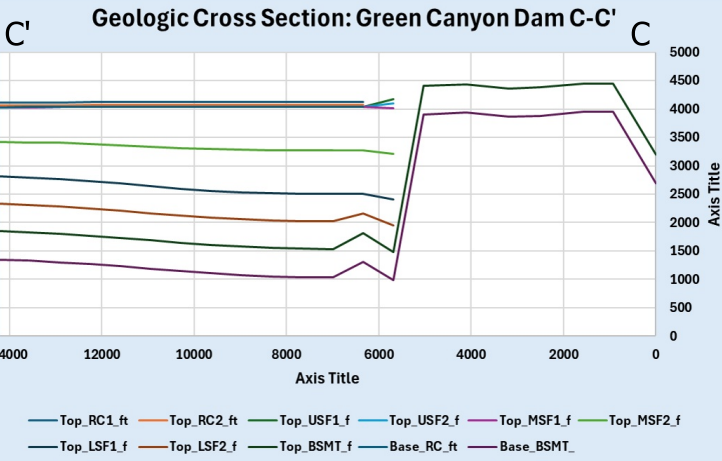
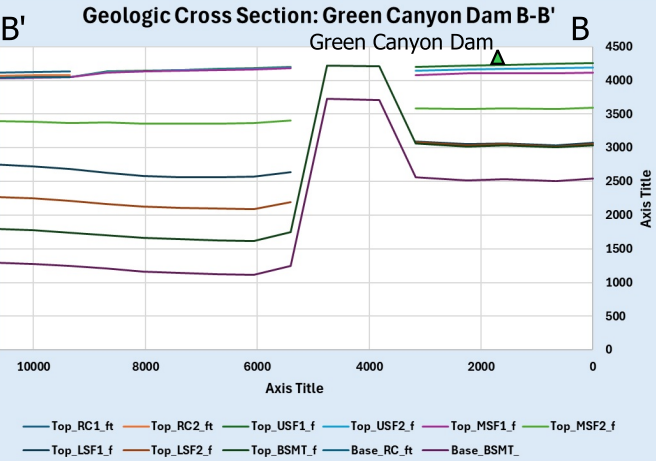
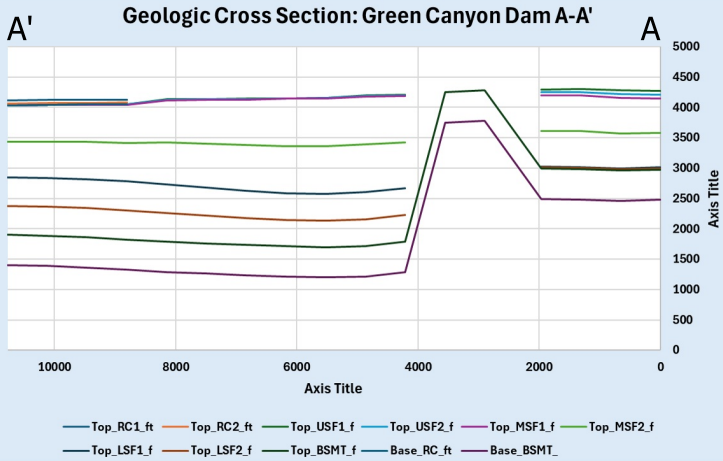
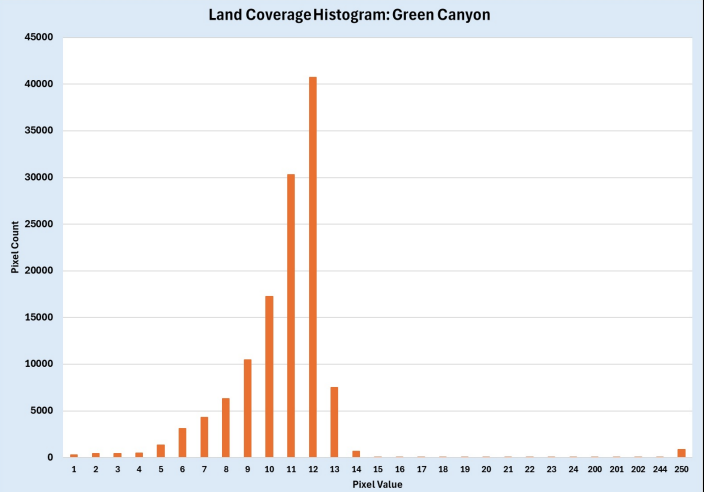
FIGURE 10



- OSE Data
- ▲ EBID Dams
 - Mar Study Sites
 - ▨ Elephant Butte Irrigation District
 - ▨ USGS Huc10 LRG Surface Water Basin
- LRG Groundwater Sub-Basins
- ▨ Rincon
- MAR Study Data
- Green Canyon Dam
- Geologic Cross Section Line
 - ▭ Catchment
 - Rio Grande



Legend and descriptions for the land-cover color flood shading and comparable runoff coefficient values; and, the generalized geologic surfaces shown in the cross section(s) are provided in Figure 4.



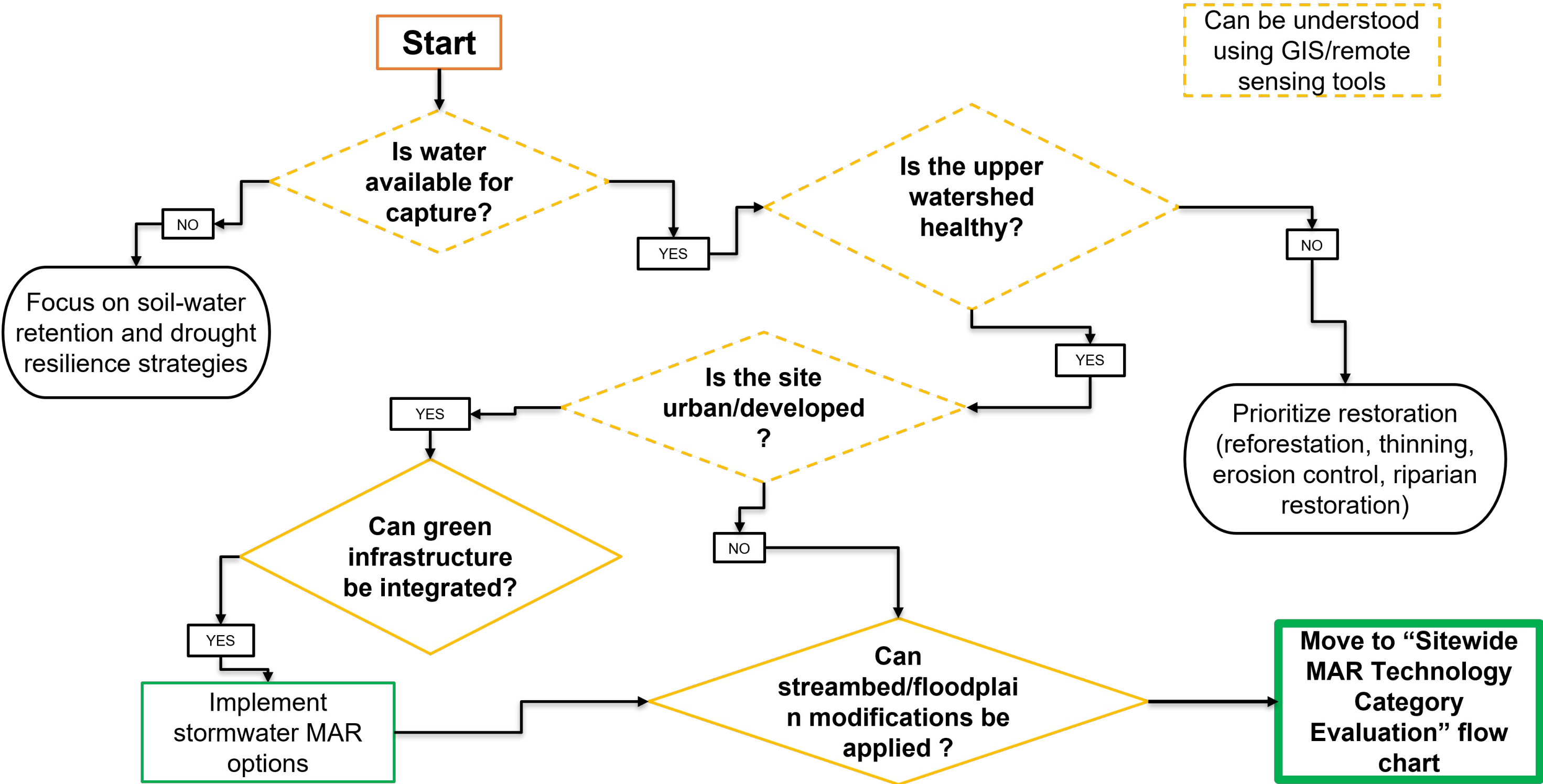
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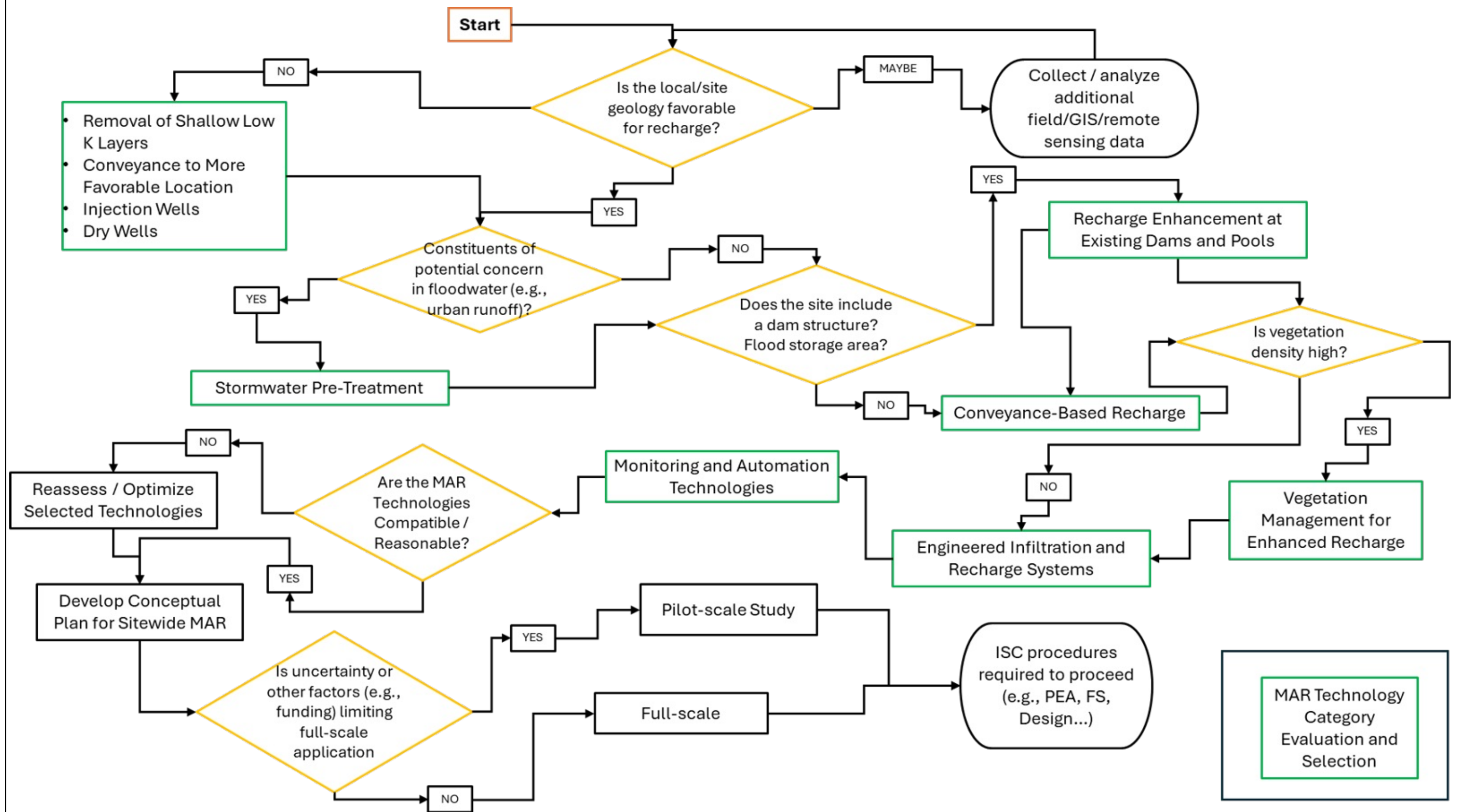
Phase 1 LRG MAR Study Focus
Areas:
Green Canyon Dam

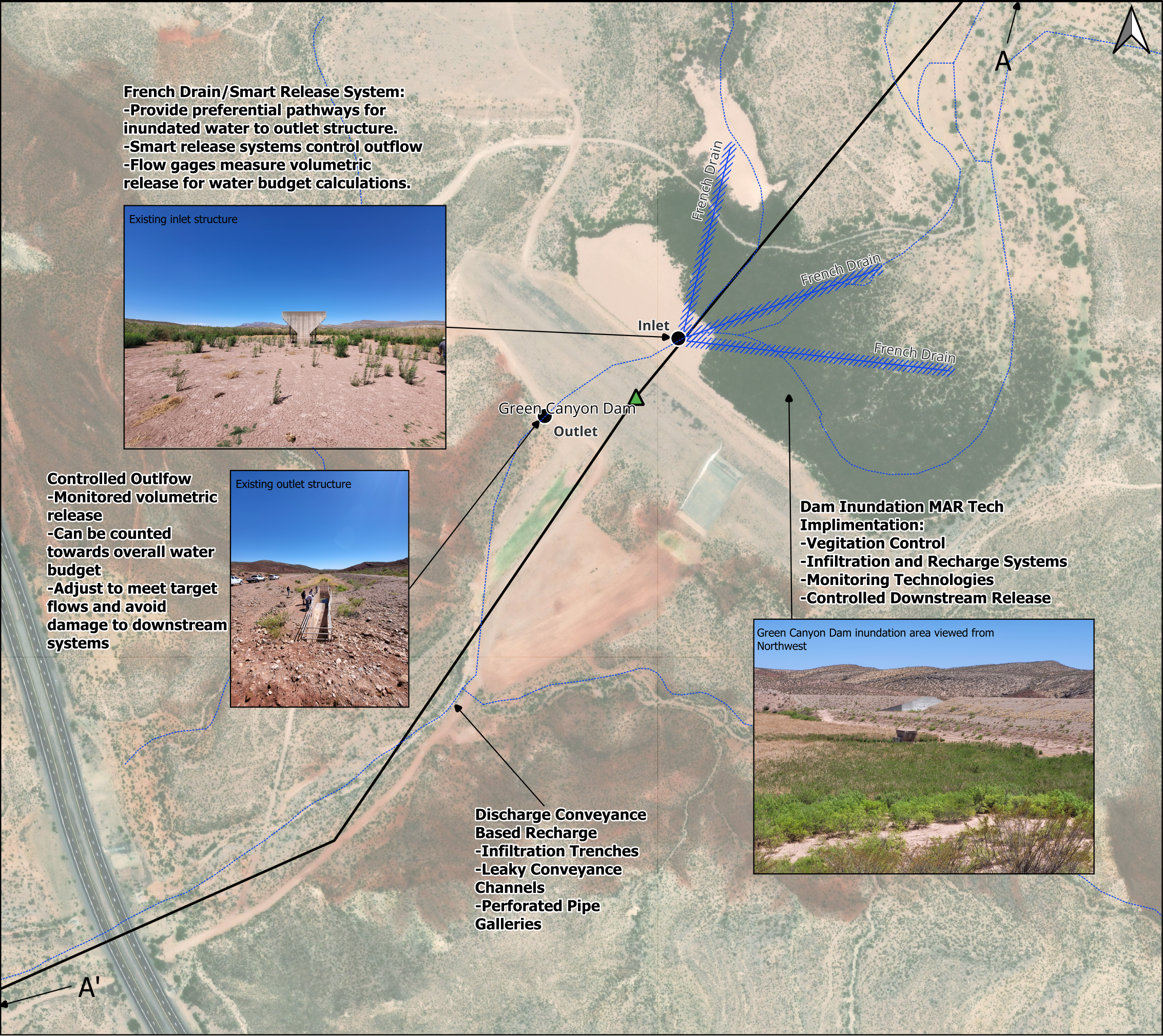
FIGURE
11

Integrated Watershed-Based Approach – Decision Diagram

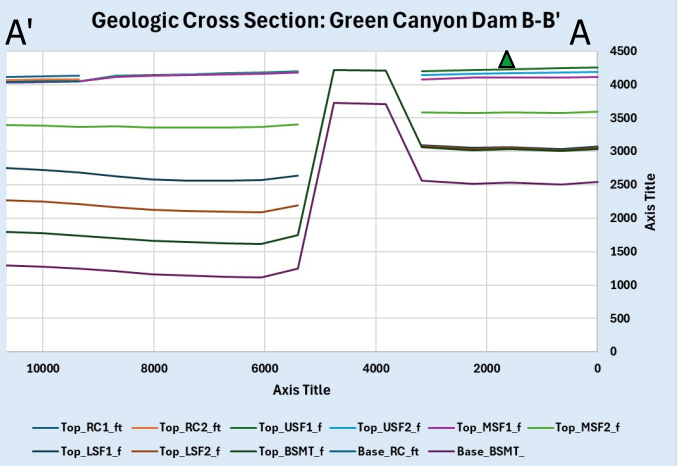
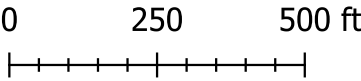


Sitewide MAR Technology Category Evaluation





- OSE Data
- ▲ EBID Dams
- MAR Study Data
- Green Canyon Dam
- Smart Control Systems
 - /// French Drains
 - Geologic Cross Section Line



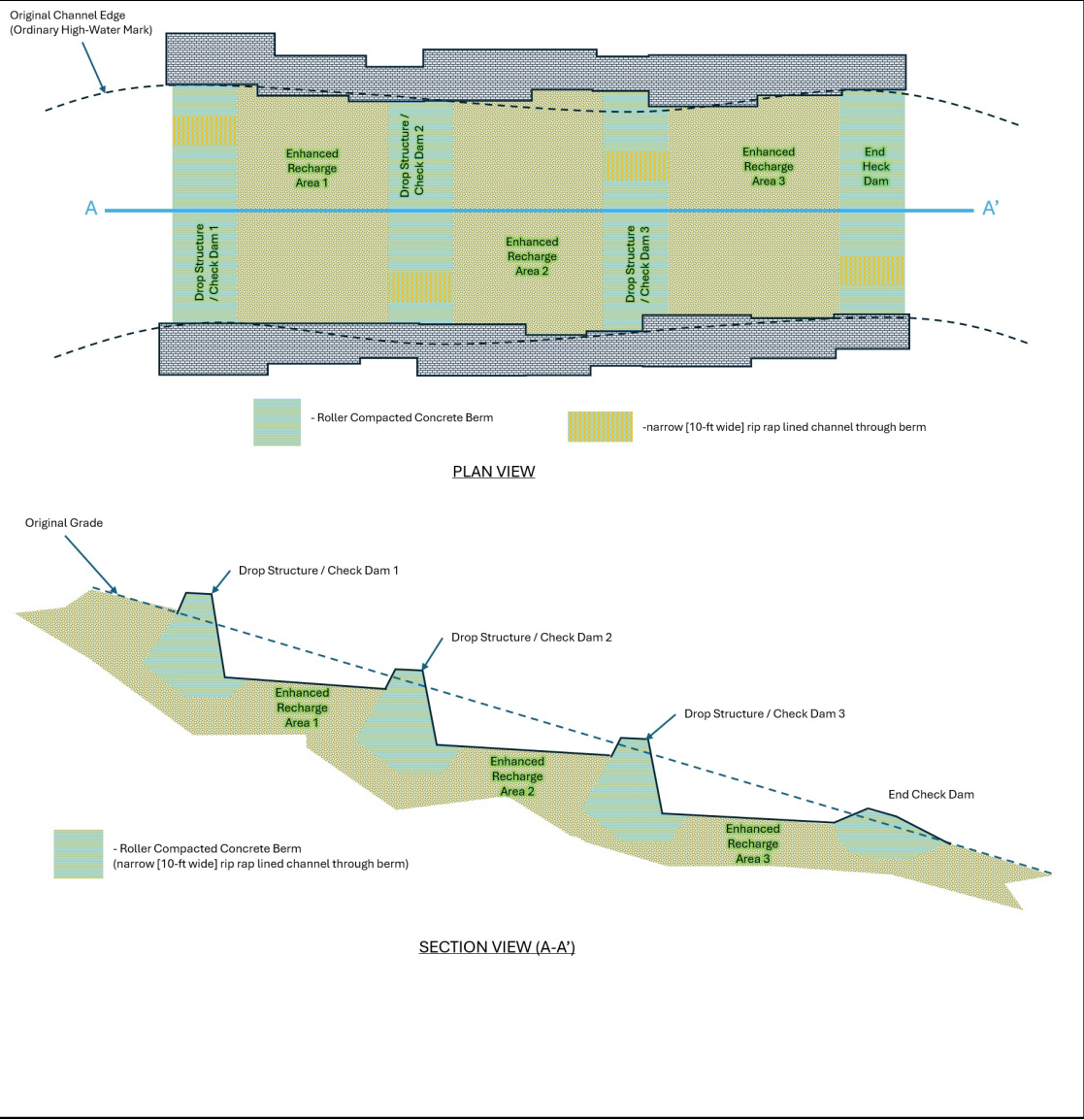
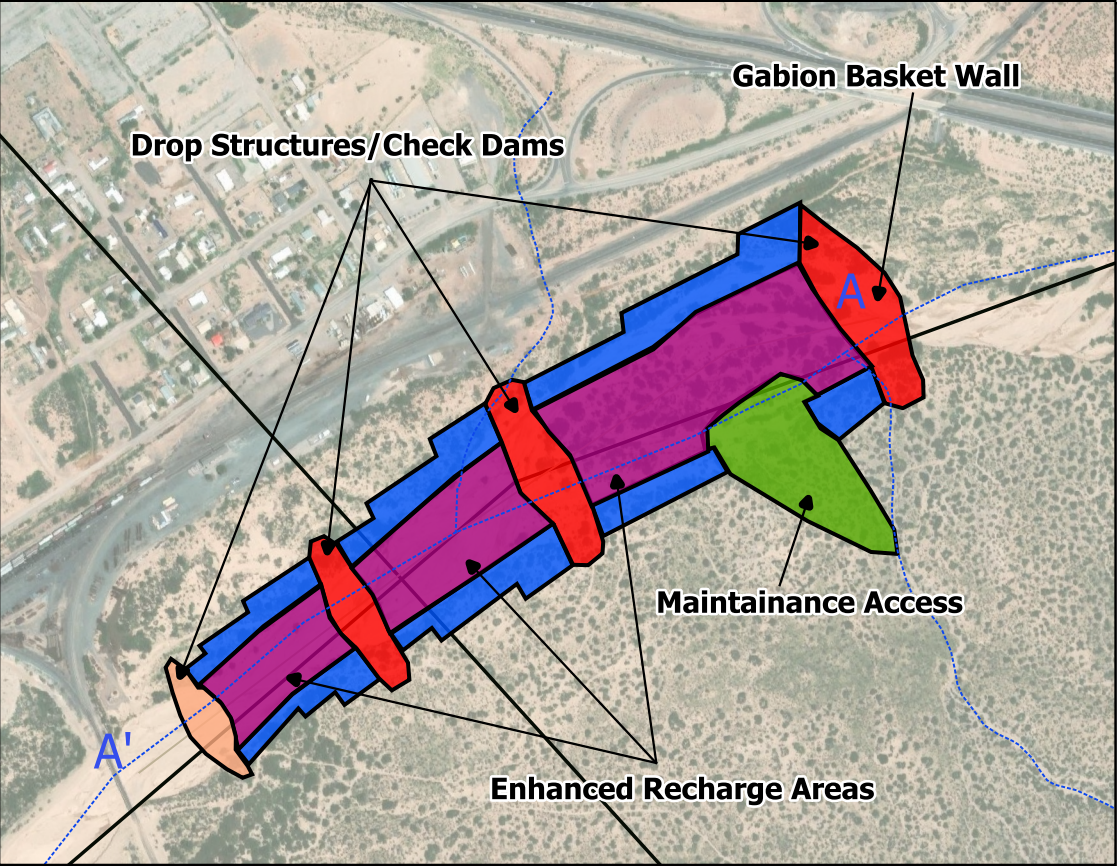
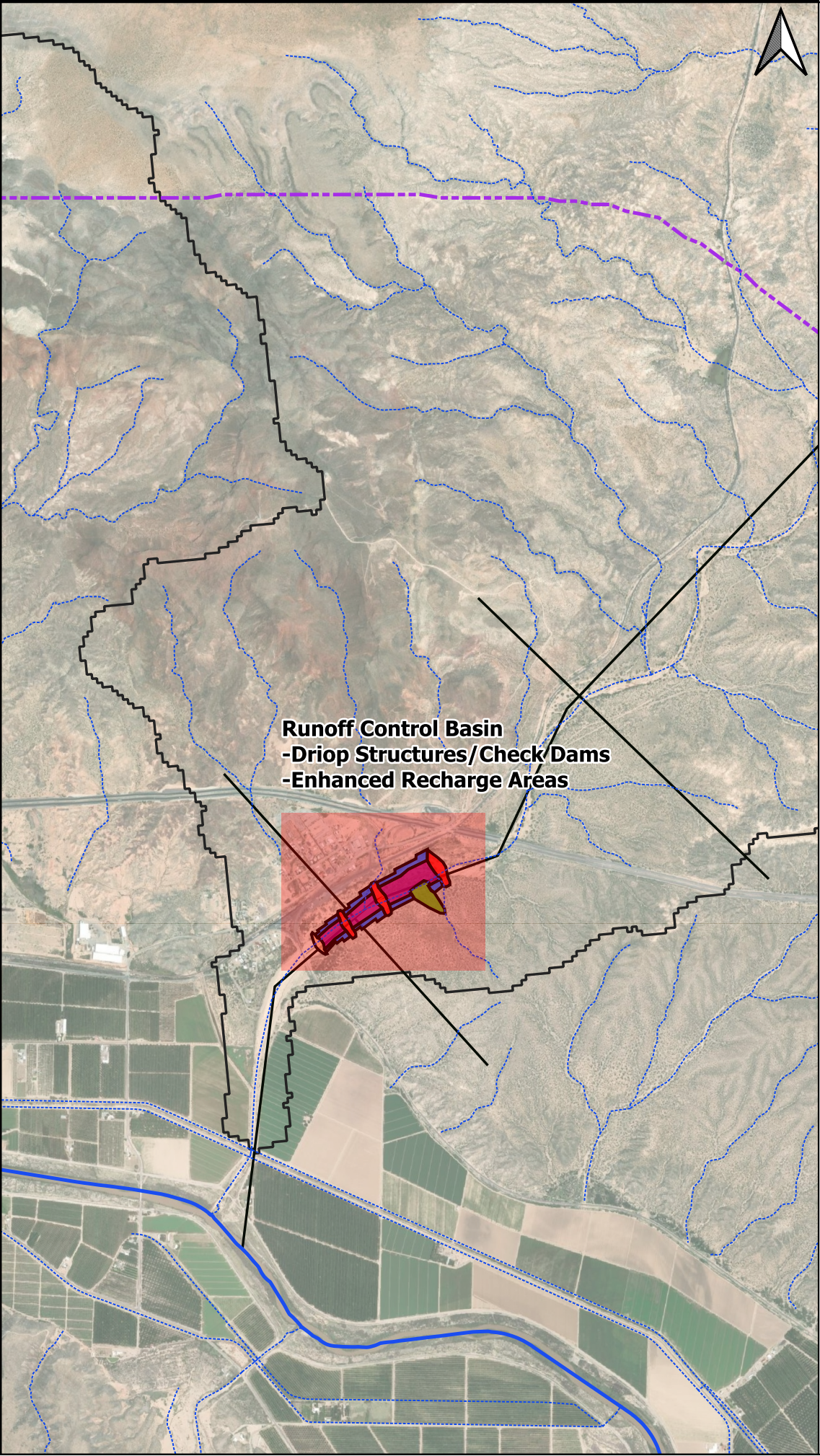
The uplift of basement rock creates a barrier in the Rincon aquifer leading to the reduction in value of recharge due to inundation at the Green Canyon Dam location. Based on this factor, moving water through the dam into the canal systems is likely the optimal way to maximize MAR and use of runoff.

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New Mexico Interstate Stream Commission

Phase 1 LRG MAR Study Examples:
Green Canyon Dam

FIGURE 15



OSE Data

LRG Groundwater Sub-Basins

Rincon

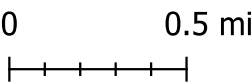
MAR Study Data

Rincon Arroyo

Geologic Cross Section Line

Catchment

Rio Grande





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Stream Commission

Phase 1 LRG MAR Study Examples:
Rincon System

FIGURE
16

9. Appendix

Appendix A

Appendix A provides details about the June 5, 2025 field visit conducted to evaluate potential Managed Aquifer Recharge (MAR) sites in the Lower Rio Grande Basin. Representatives from NMISC, OSE, EBID, and Lynker participated in site inspections to assess hydrologic and geologic conditions and refine candidate locations for future MAR feasibility analysis.

Participants in the field side visit included:

- New Mexico Interstate Stream Commission
 - Ryan Serrano – Lower Rio Grande Bureau Chief (Work Order Manager)
 - Christina Hernandez – Project Manager
- New Mexico Office of the State Engineer
 - Caitlyn Owens- Senior Water Resource Professional
 - Alfred Perrault- Water Resource Professional
- Elephant Butte Irrigation District
 - Alex Rubio- Senior Engineer Manager
 - Zachary Libbin – Consultant Principal Engineer
- Lynker Corporation
 - Dr. Jim McCord, PE, PhD – Principal Hydrogeologic Engineer
 - Peter Guerra – Project Manager and Principal Environmental Engineer

The team convened at Maverik #733, 3098 E. University Ave, Las Cruces, At 800 hours on Jun 5, 2025, for a safety briefing and route review. The original plan included visits to:

1. Tortugas Site 1 Dam
2. Picacho North Dam
3. Lucero Detention Dike
4. Crow Broad Placitas No. 1 Dam
5. Crow Broad Placitas No. 2A Dam
6. Green Canyon Dam

The route encompassed roughly 76 miles and six principal stops, divided by sub-regions:

- Group 1: Las Cruces / Picacho area
- Group 2: Radium Springs area
- Group 3: Hatch area

Following the morning discussions and a midday coordination meeting over lunch near Hatch, the field itinerary was adjusted. The group agreed to exclude visits to:

- Crow Broad Placitas No. 2A Dam (due to access limitations and time constraints)
- Sibley Green Dam (deferred to later evaluation)

In their place, Caballo Arroyo Dam No. 2 was added to the site list. This structure, located near Caballo SWCD boundaries, had been identified in the Phase I dataset as a high-priority MAR candidate based on its catchment size, reservoir volume, and proximity to recharge-favorable geology.

During the visits, participants observed a range of structure sizes and watershed characteristics:

- The Tortugas Site 1 Dam and Picacho North Dam exemplified large flood-control features adjacent to historical groundwater drains with promising infiltration areas.
- Lucero Detention Dike and Leasburg Main Canal Reach illustrated the hydraulic connectivity between storm-flow detention and irrigation conveyance systems.
- Crow Broad Placitas No. 1 Dam and Green Canyon Dam displayed substantial storage and sediment accumulation features that could support stormwater retention and recharge.

The newly added Caballo Arroyo Dam No. 2 represented a smaller but strategically located structure suitable for pilot-scale MAR assessment. Combining the five other Caballo Arroyo and Hatch Valley dams with the adjacent Caballo Arroyo Dam No. 2 increases the overall captured watershed improving the overall Caballo-Arroyo-Hatch-Valley Dam sites as a potential location for a full-scale MAR project.

The following pages include the corresponding slide deck that provides an overview of the site visit (including photos) and supporting studies.

SITE VISITS REVIEW

PROJECT: New Mexico ISC: Lower Rio Grande Managed Aquifer Recharge Investigations Phase I: Site Data Compilation, Analysis, and Screening

NM ISC / OSE

Ryan Serrano (ISC Lower Rio Grande Basin Manager), Christina Hernandez, Joseph Hennesey, Caitlyn Owens

Elephant Butte Irrigation District

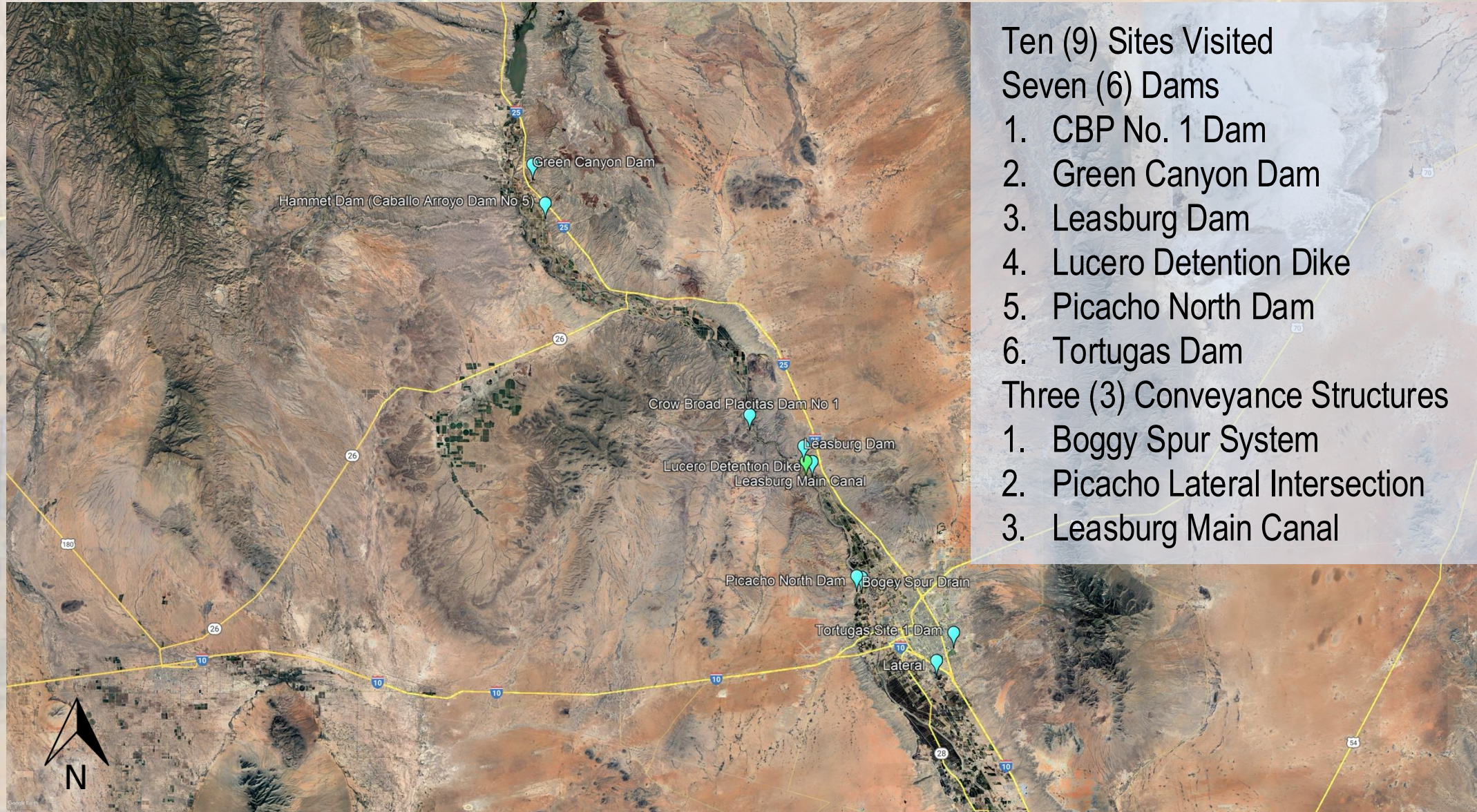
James Narvaez, J. Franzoy, J. Smith, A. Rubio

Lynker:

Subject Matter Experts: Dr. Jim McCord, PE; Dr. Graeme Aggett; Mr. Peter Guerra

Support Scientists and Engineers: Mr. Justin Clark, Mr. Joe Carilli

SITE VISIT LOCATIONS



Ten (9) Sites Visited

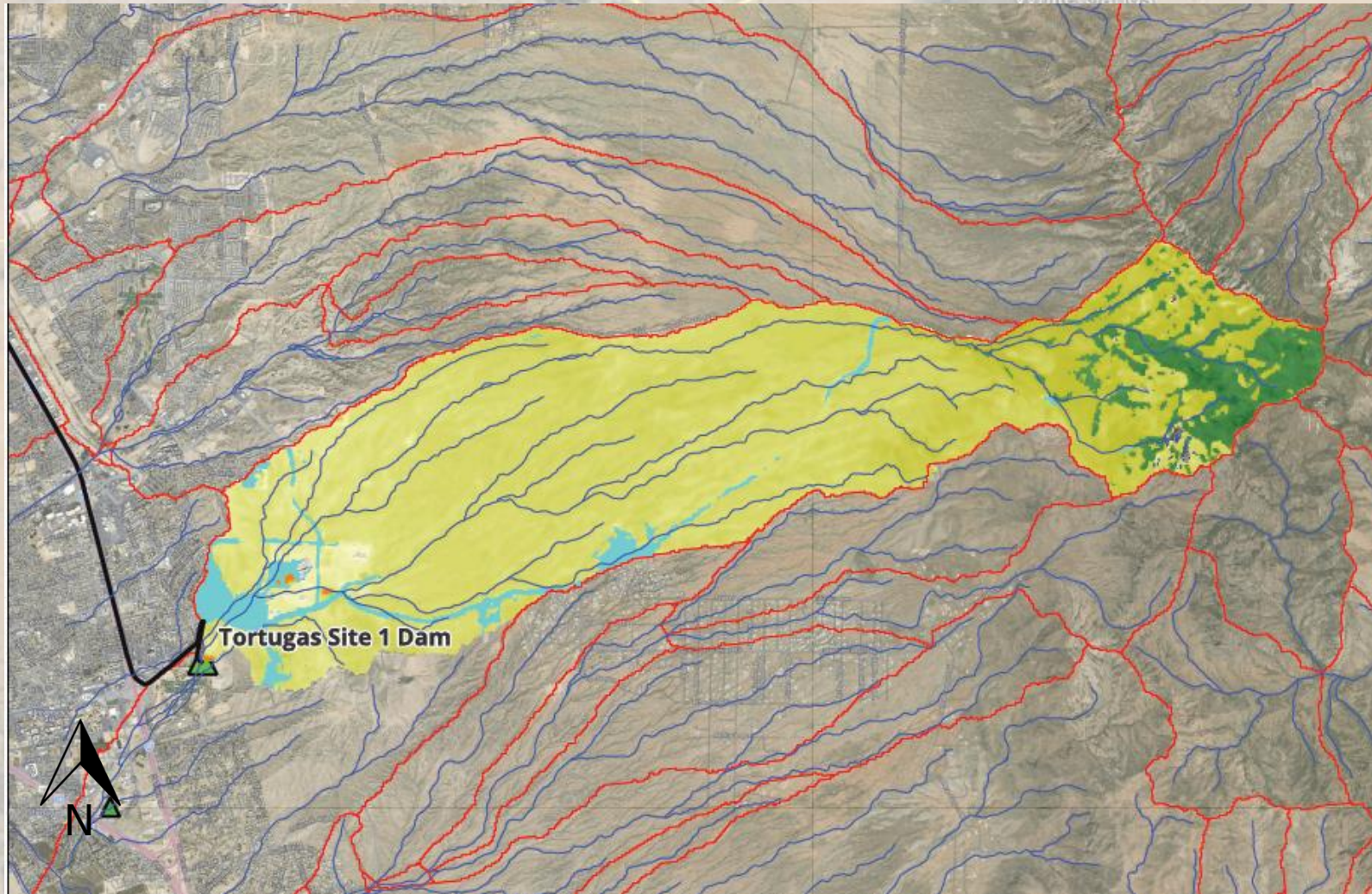
Seven (6) Dams

1. CBP No. 1 Dam
2. Green Canyon Dam
3. Leasburg Dam
4. Lucero Detention Dike
5. Picacho North Dam
6. Tortugas Dam

Three (3) Conveyance Structures

1. Boggy Spur System
2. Picacho Lateral Intersection
3. Leasburg Main Canal

Tortugas No. 1 Dam



Tortugas No. 1 Dam



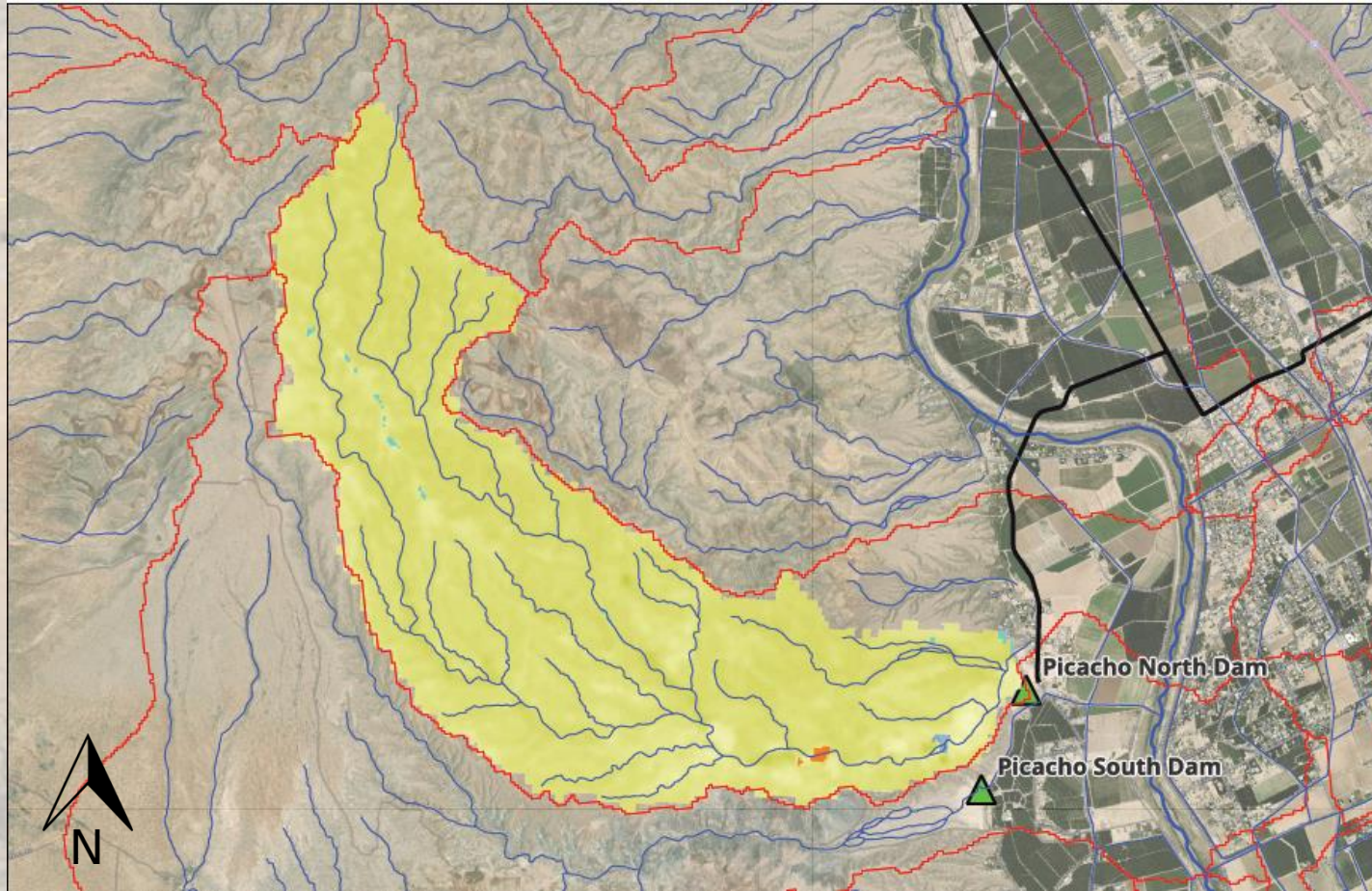
STRUCTURE HEIGHT: 56 FT
DAM LENGTH: 3,485 FT
FLOOD STORAGE: 1,020 ACFT
SEDIMENT STORAGE: 305 ACFT
DRAINAGE AREA: 20.7 SQ. MI.

LARGE DAM WITH HIGHEST
POTENTIAL FOR MAR IN THE
DISCHARGE CHANNEL, THE
FORMER GW DRAIN, AND THE
FLOOD POOL AREA.

Boggy Spur Drain



Picacho North Dam



S 180 SW 210 W 270 300
231°SW (T) 32°21'16"N, 106°51'17"W ±9ft ▲ 3988ft



Picacho North Dam



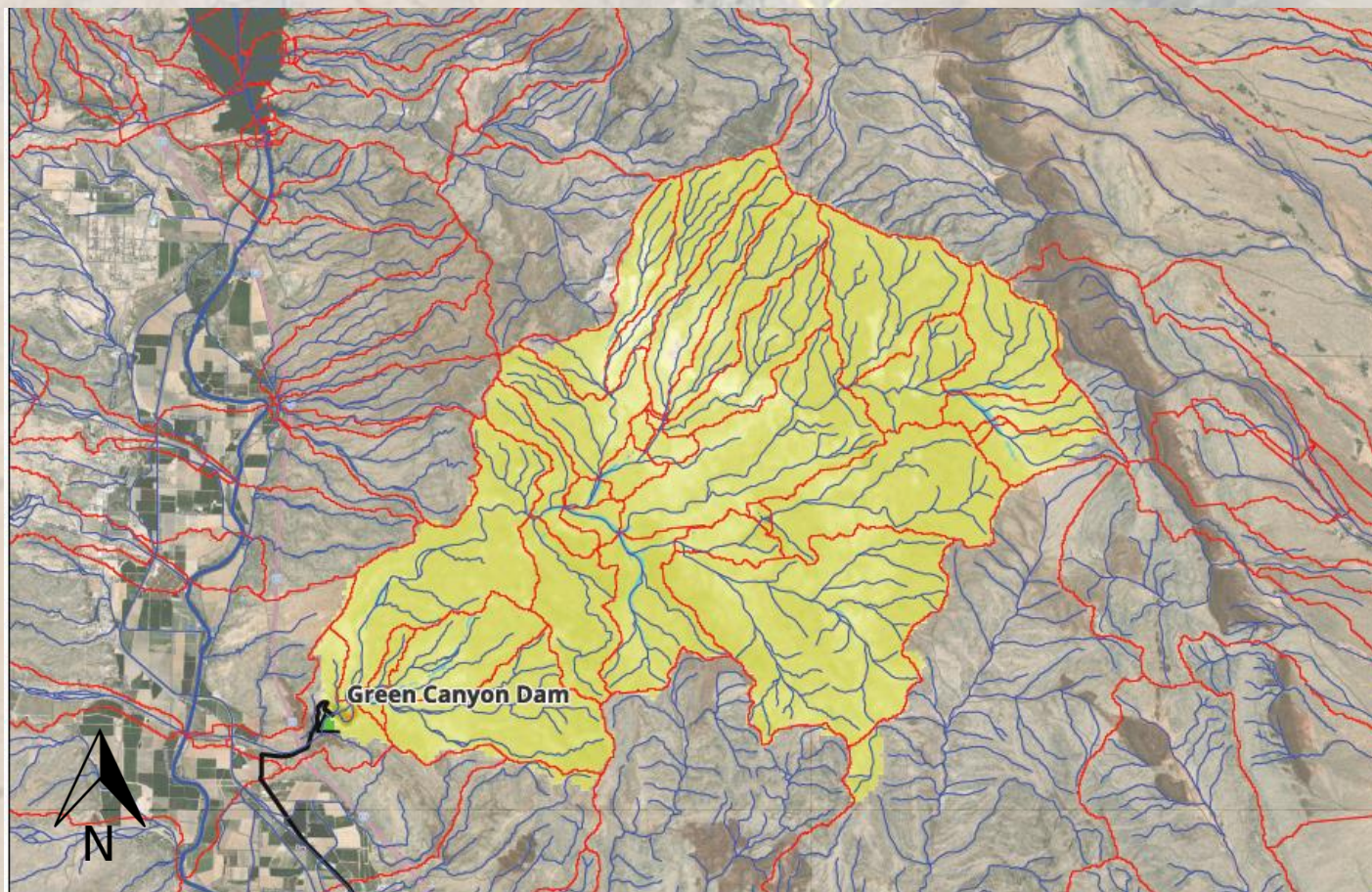
STRUCTURE HEIGHT: 43 FT
DAM LENGTH: 1,600 FT
FLOOD STORAGE: 3,945 ACFT
SEDIMENT STORAGE: 680 ACFT
DRAINAGE AREA: 7.8 SQ.MI.

LARGE DAM WITH HIGHEST
POTENTIAL FOR MAR IN THE
DISCHARGE CHANNEL AND THE
FLOOD POOL AREA.

Picacho North/South Lateral



Green Canyon Dam



Green Canyon Dam

STRUCTURE HEIGHT: 84.5 FT
DAM LENGTH: 1850 FT
FLOOD STORAGE: 1,620 ACFT
SEDIMENT STORAGE: 1,320 ACFT
DRAINAGE AREA: 30.84 SQ.MI.

LARGE DAM WITH HIGHEST
POTENTIAL FOR MAR IN THE
DISCHARGE CHANNEL AND THE
FLOOD POOL AREA.



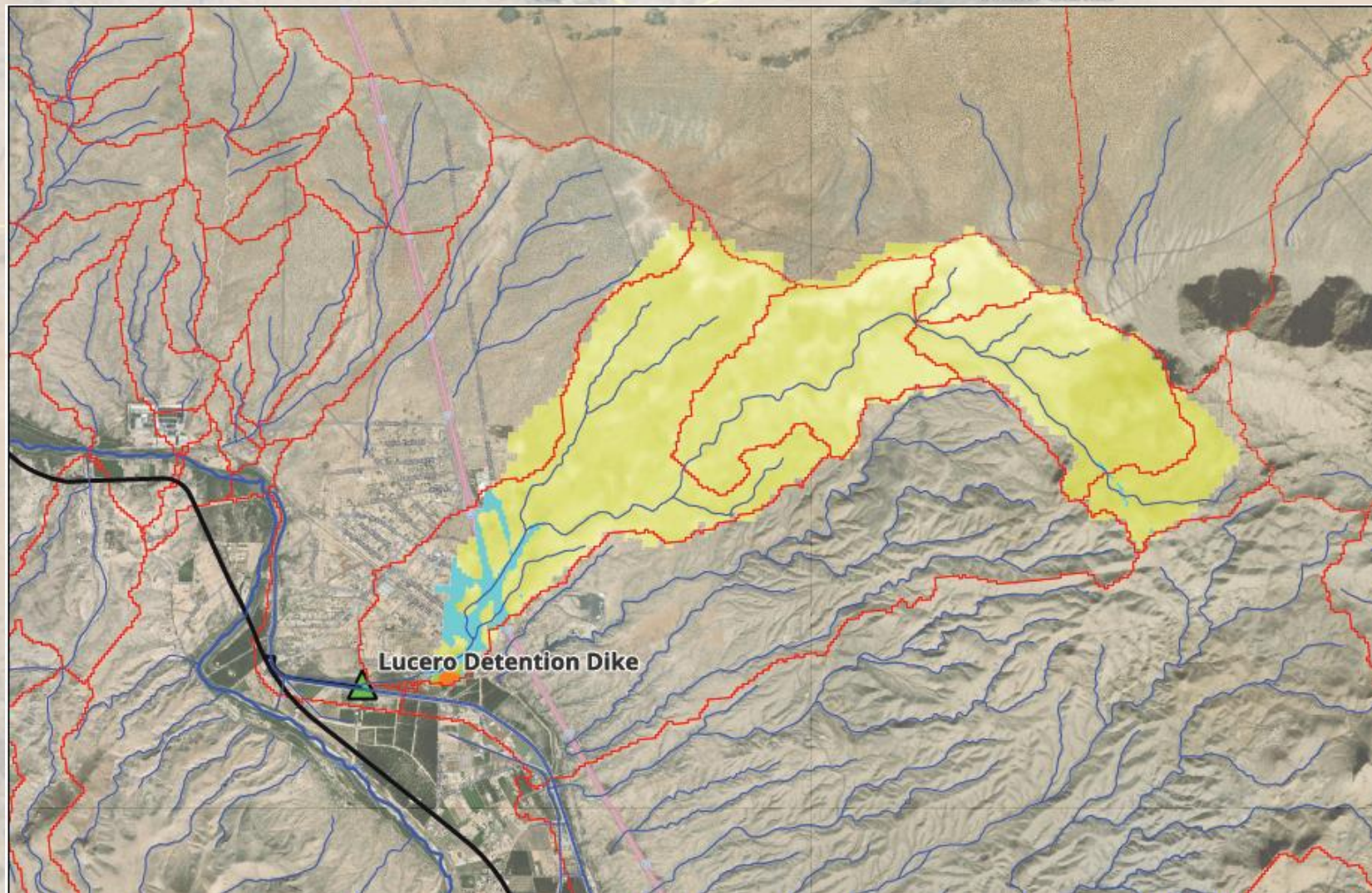
Leasburg Dam



Leasburg Main Canal and Lucero Detention Dike



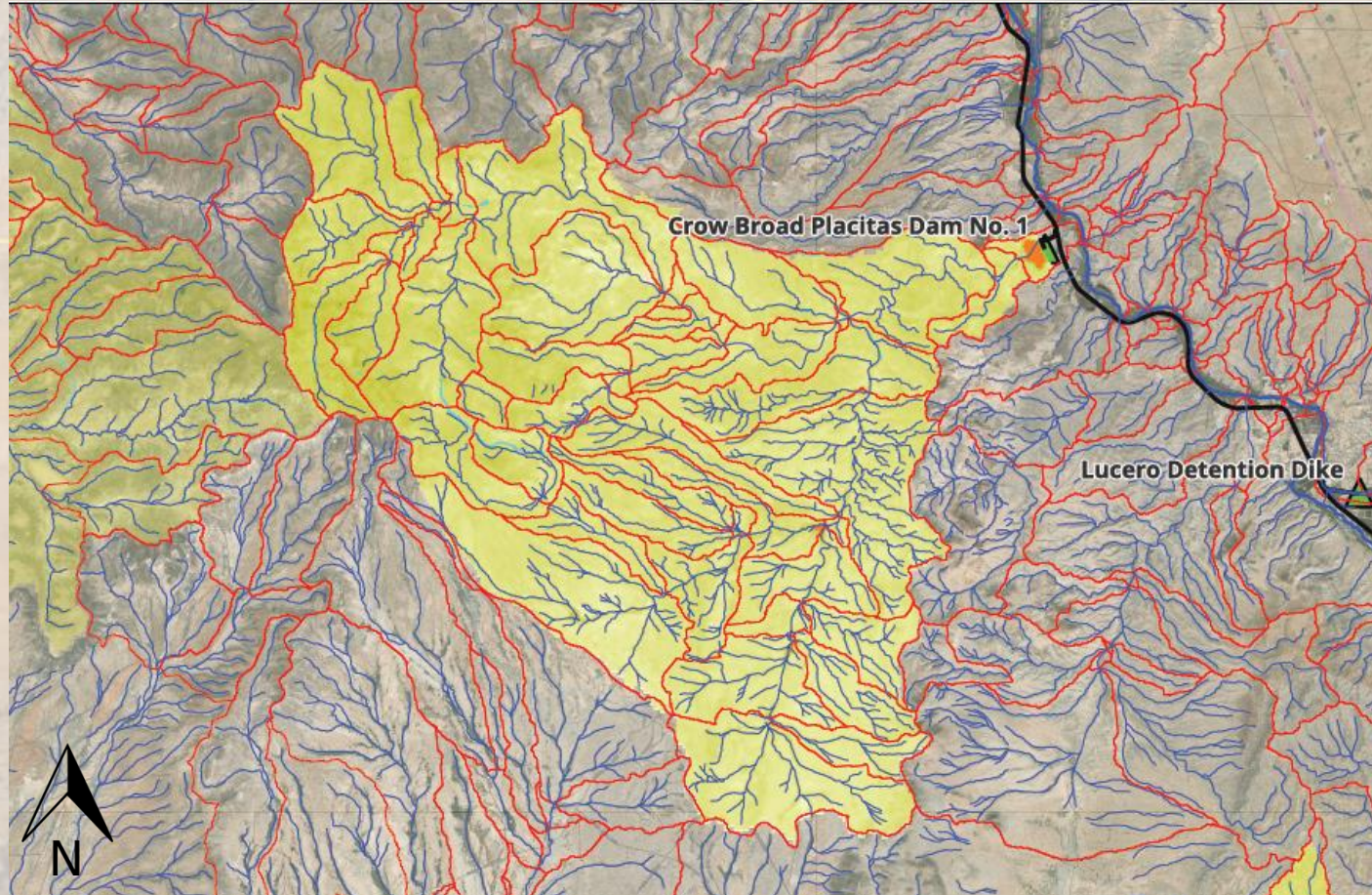
Lucero Detention Dike



Leasburg Main Canal and Lucero Detention Dike



Crow Broad Placitas No. 1 Dam



Crow Broad Placitas No. 1 Dam



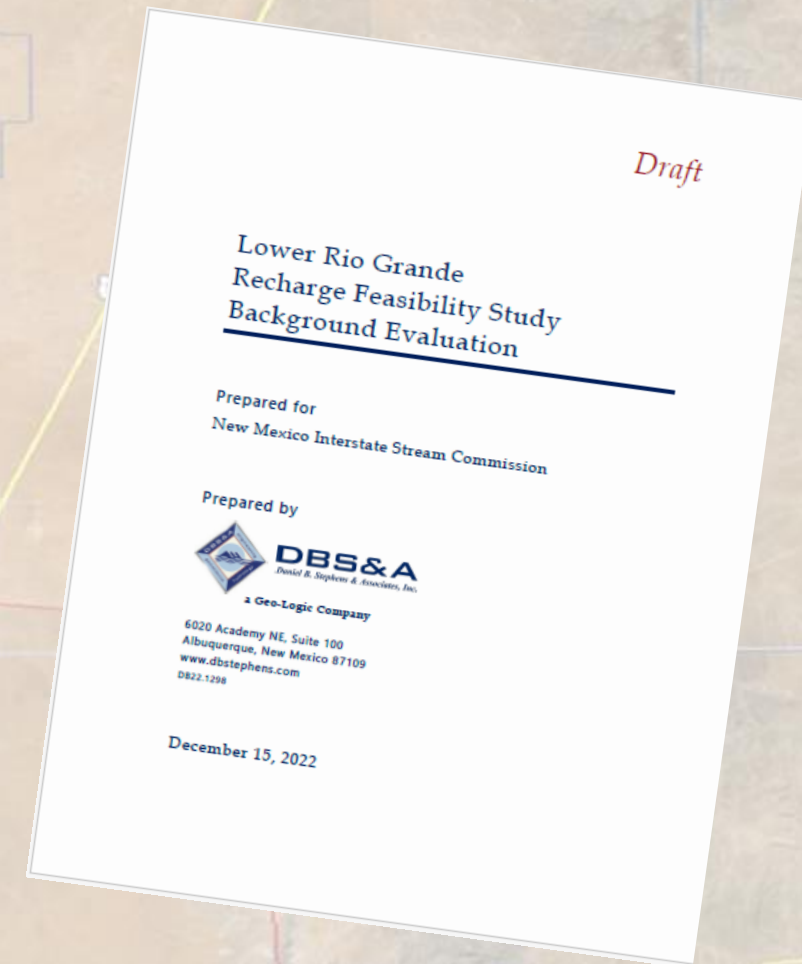
STRUCTURE HEIGHT: 71.5'
DAM LENGTH: 1434 FT
FLOOD STORAGE: 4086 ACFT
SEDIMENT STORAGE: 2645 ACFT
DRAINAGE AREA: 69.4 SQ.MI.

LARGE DAM WITH HIGHEST
POTENTIAL FOR MAR IN THE
DISCHARGE CHANNEL AND THE
FLOOD POOL AREA.

Lower Rio Grande Recharge Feasibility Study

Key Findings and Recommendations

- Project Objective: Enhance stormwater management, mitigate cones of depression, and support groundwater flow toward the Rio Grande.
- Study Area: Mesilla Basin, within Doña Ana County, NM.
- Hydrogeologic Setting: High potential in Las Cruces Bench, Fairacres, and Mesquite Subbasins for managed aquifer recharge.
- Water Quality: Increasing TDS levels southward; seasonal and spatial variability observed.
- Environmental Review: Minimal contamination risks at pilot site near Mesilla Drain; historic issues remediated.
- Recommendation: Proceed with pilot project along Mesilla Drain and coordinate with NMED GWQB for permitting and monitoring.



Mesilla Drain Pilot Project Site

Key Findings and Recommendations

- Purpose: Assess infiltration feasibility at the Mesilla Drain pilot recharge site.
- Testing conducted June 8–9, 2023 using double-ring infiltrometer and borehole percolation methods.
- Infiltration rates ranged from 0.58 to 3.89 in/hr, with an average of 2.27 in/hr (5.8×10^{-3} cm/s).
- Soil texture: predominantly sandy loam with minor gravel; consistent stratigraphy across test locations.
- Observed rates are suitable for managed aquifer recharge (MAR) using surface infiltration.
- Recommendation: Proceed with pilot recharge implementation; include ongoing infiltration monitoring.

Infiltration Testing and Soil Sampling along the Mesilla Drain

Prepared for
New Mexico Interstate Stream Commission
Santa Fe, New Mexico

Prepared by



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Albuquerque, New Mexico 87109
www.dbstephens.com
0822.1298

June 28, 2023

Gradient Self-Potential Logging in the Rio Grande to Identify Gaining and Losing Reaches across the Mesilla Valley

Key Findings and Recommendations

- Objective: Quantify canal seepage as a potential MAR method to mitigate groundwater depletion.
- Study focused on the Rincon Valley, NM using loss measurements and seepage meters.
- Estimated seepage from canals: 20,640 acre-feet/year (25.5 million m³/year).
- Canal seepage contributes significantly to shallow aquifer recharge during irrigation season.
- MAR via canal seepage offers low-cost, passive recharge without new infrastructure.
- Recommendation: Integrate seepage-derived recharge into water planning and groundwater models.



Appendix B

Appendix B provides a detailed overview of the geodatabase schema design, data management framework, and associated standards implemented during Phase I of the project.

Geodatabase Schema Design

The schema was organized to ensure data traceability, interoperability, and version control. Each feature class was defined within a thematic feature dataset to maintain spatial reference integrity (NAD 1983 UTM Zone 13 N).

Primary feature datasets include:

- Base Reference: Administrative boundaries, transportation, hydrography, and topography layers derived from USGS 3DEP and NM RGIS sources.
- Hydrogeologic Framework: Basin boundaries, structural features, aquifer zones, wells, geologic cross-sections, and infiltration-rate zones compiled from USGS LRG 3D Model and NMBGMR data.
- Hydrologic Infrastructure: Dams, drains, canals, diversion structures, and associated operational networks (EBID/IBWC datasets).
- MAR Candidate Sites: Point and polygon features representing each screened structure, attributed with key hydrologic, geologic, and scoring metrics.
- Environmental Constraints: Wetlands, floodplains, critical habitat, and land-ownership polygons for permitting and feasibility screening.
- Monitoring Networks: Existing and proposed piezometers, stream gages, infiltration galleries, and instrumentation sites.

Relational tables link site identifiers to time-series data (e.g., hydrologic yield, infiltration test results, and screening scores) using globally unique IDs (GUIDs) to ensure referential integrity.

Layer List and Symbology Standards

All map layers were symbolized according to NMISC/Lynker Phase I symbology standards, designed for readability and consistency across figures and web maps.

- Basemap Layers: muted grayscale terrain to emphasize feature overlays.
- Hydrographic Features: blue gradients scaled by perennial/ephemeral flow type.
- Structural Features: dams = solid red polygons; drains = blue lines; canals = aqua lines; MAR candidate sites = triangular icons color-coded by technology type.
- Screening Scores: graduated color ramp (green = high potential; yellow = moderate; red = low).
- Monitoring Assets: instrument icons differentiated by technology (TDR, DTS, piezometer).

Symbology layer (.lyrx) files were packaged within the GDB directory for consistent visualization during future NMISC use and map publication.

Versioning and Metadata Management

The geodatabase was established as a file-based geodatabase (FGDB) with ArcGIS versioning enabled to track all edits during Phase I. Version control followed a two-tier model:

1. “Work” Version – used for in-progress analysis and feature edits by Lynker analysts.
2. “Published” Version – locked for QA/QC review and final export.

Each feature class and table includes FGDC-compliant metadata documenting source, creation date, coordinate system, scale, and processing lineage. All versions were archived weekly and cross-checked against NMISC naming conventions.

Data Packaging and Handoff to NMISC

At Phase I completion, the geodatabase and associated map packages will be delivered as part of the official Information Transfer Package to NMISC. Deliverables will include:

- Master file geodatabase (.gdb) containing all feature datasets, domains, and relationship classes.
- ArcGIS Pro map package (.mpkx) with symbology and labeling.
- PDF map series illustrating site-specific CSMs, MAR typologies, and screening results.
- Data dictionary (.xlsx) defining fields, units, and attribute domains.
- Metadata index (.xml) compliant with FGDC and NM RGIS standards.

All digital materials will be organized under the directory structure with subfolders for Spatial_Data, Figures, Tables, and Metadata.

The final transfer and NMISC integration procedures will be confirmed upon report completion.

Note: The data management and geodatabase components will be updated and re-issued with the Final Report to incorporate any additional datasets, QA/QC revisions, and Phase II-readiness formatting requirements.