Moab UMTRA Project
Site History and Virtual Tour

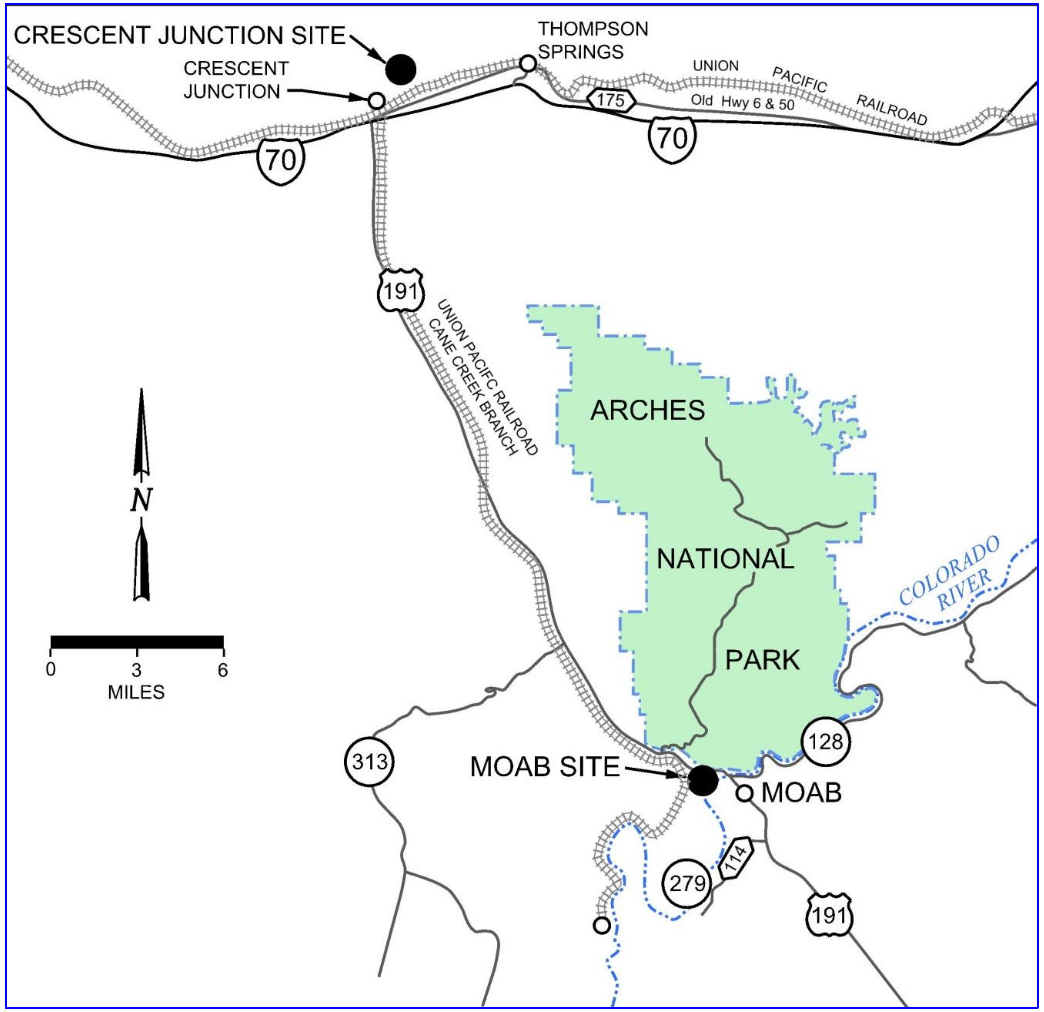
James Ritchey

Groundwater Technician

November 15, 2023

MOAB UMTRA PROJECT CRESCENT JUNCTION

Site Setting



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MOAB UMTRA PROJECT CRESCENT JUNCTION

Site Setting

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MOAB UMTRA PROJECT CRESCENT JUNCTION

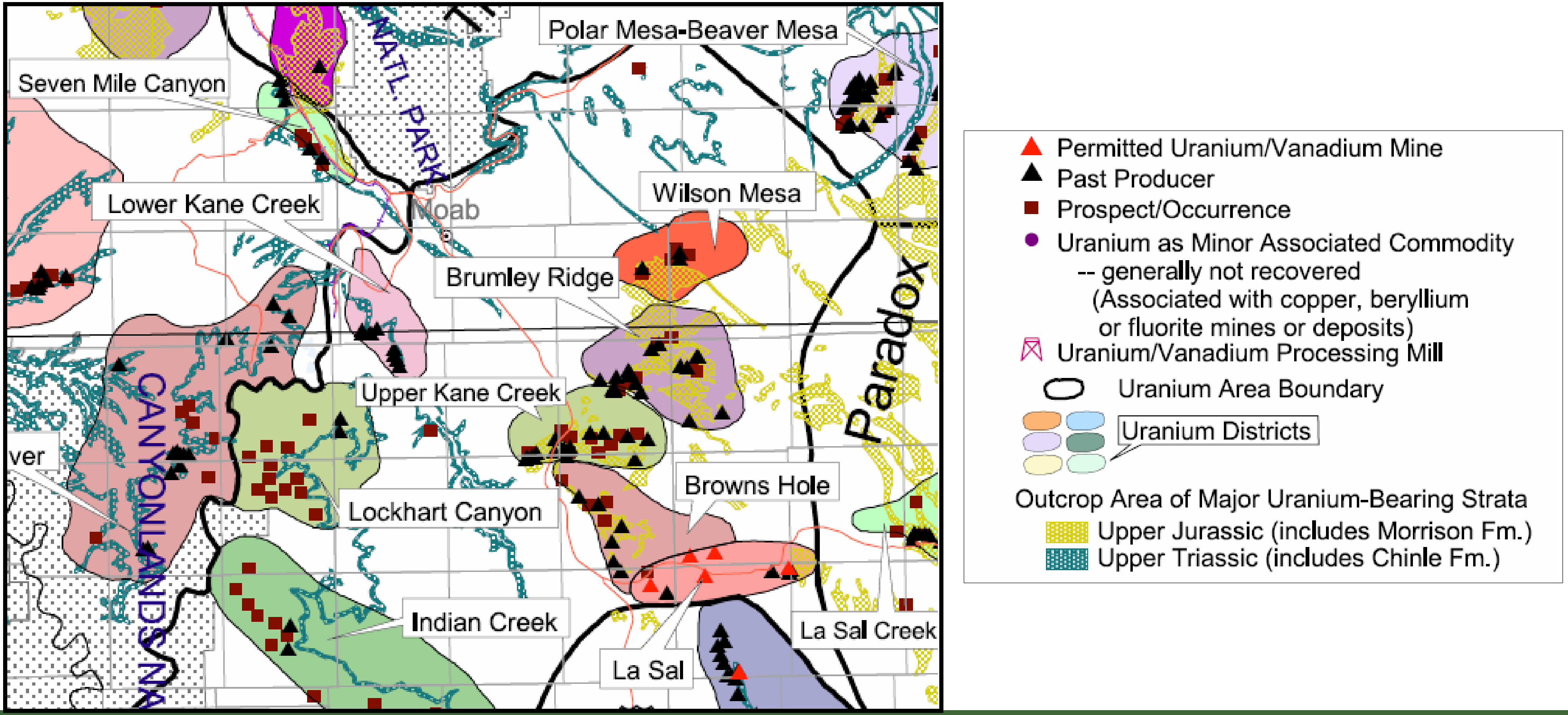
Site Background and Scope

- Former uranium ore-processing facility 1956 to 1984
- 480-acre site, 130 acres covered by mill tailings pile
- Toe of pile is 750 ft from west bank of Colorado River
- Relocate 16 million tons of uranium mill tailings to engineered disposal cell
- Actively remediate ground water and provide endangered fish species habitat protection at the Moab site

Uranium Discovery

- Charlie Steen
  - Discovery in July 1952, Lisbon Valley
  - Carnotite ($K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$) vs Uraninite ($UO_2$, but often found U_3O_8)

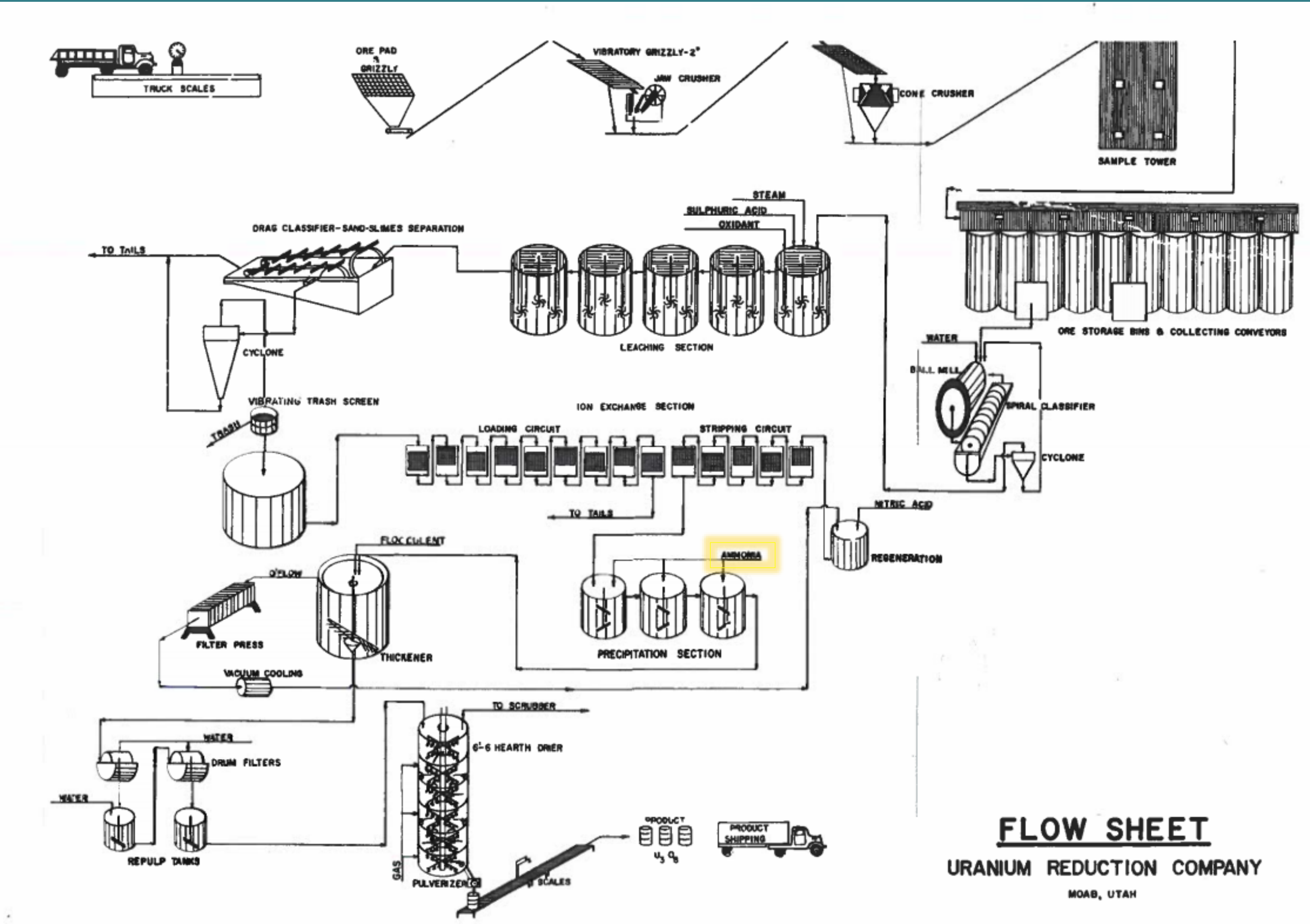
Regional Mining



Earliest Photo of Mill Site

Mill Site Development

Milling Process




Warehouse
NaClO3
30K NH3
HNO3
Thickener
Thickener
Thickener
NH3
Solid Storage
Plant Water Storage
Concentrator Building
Ore Receiving Station
Paint Shop
Laboratory Building
Reactivator
500K Gal Clearwell
Leaching Section
1,100 Ton H2SO4
1,100 Ton Na2CO3
Warehouse
Vanadium Leach Section
Grinding Bay
Crushing Plant
Vehicle Service & Storage
Machine Shop
Collecting Conveyor
Fine Ore Bins
Admin/Office
1973

The End of an Era

- 1984 – Mill Closed
- 1988 – Started Decommissioning Mill
- 1989 to 1995 – Interim Cover Placed on Tailings Pile
- 1998 – Atlas Declared Bankruptcy

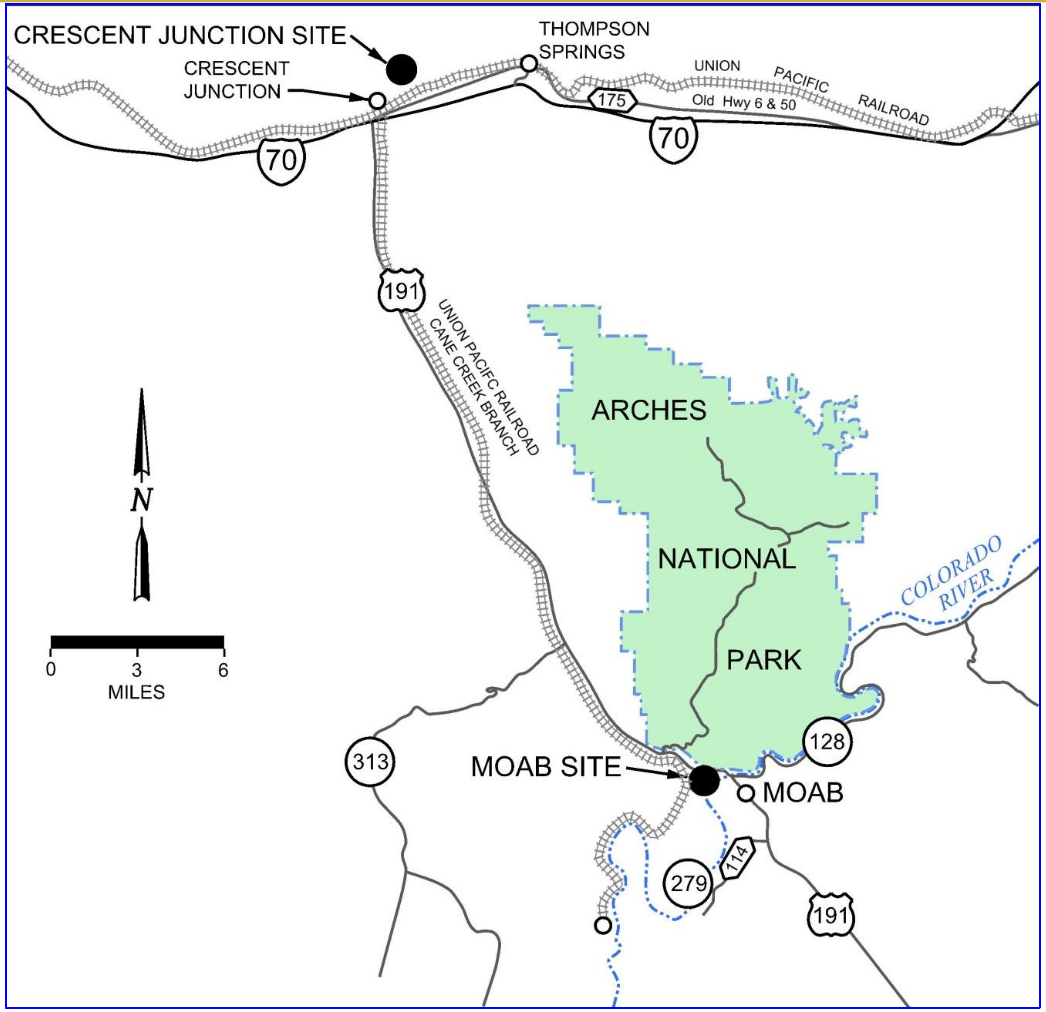
2000 – 2005: Characterization and Planning

- 2000 – Floyd D. Spence Act amended UMTRCA Title 1
  - DOE given responsibility for remediation of the Moab site
- 2000 to 2002 – Site Characterization
- 2003 – Site Observational Work Plan (SOWP) finalized
- 2003 – Initiation of Groundwater Interim Action
  - Objective: limit ecological risk from contaminated groundwater discharging to potential endangered fish species habitat areas along the Colorado River
- 2005 – Environmental Impact Statement (EIS)
  - Biological Assessment
  - Biological Opinion
  - Screening Level Risk Assessment
- 2005 – Record of Decision (ROD)

2009 – Excavation: First Train 4/20/09


Drying Beds
Excavation
Scale
Lidding
Rail Bench

Crescent Junction Disposal Cell



Crescent Junction Disposal Cell

2009 – Present: Remediation of Tailings

- 2009 – First shipment of tailings on 4/20/09
- 2010 – Off-pile Remediation
- 2023 – 14M Tons shipped (to be met this fall)
- Removing approximately 1 million tons each year

Over 85% complete!

QUESTIONS?

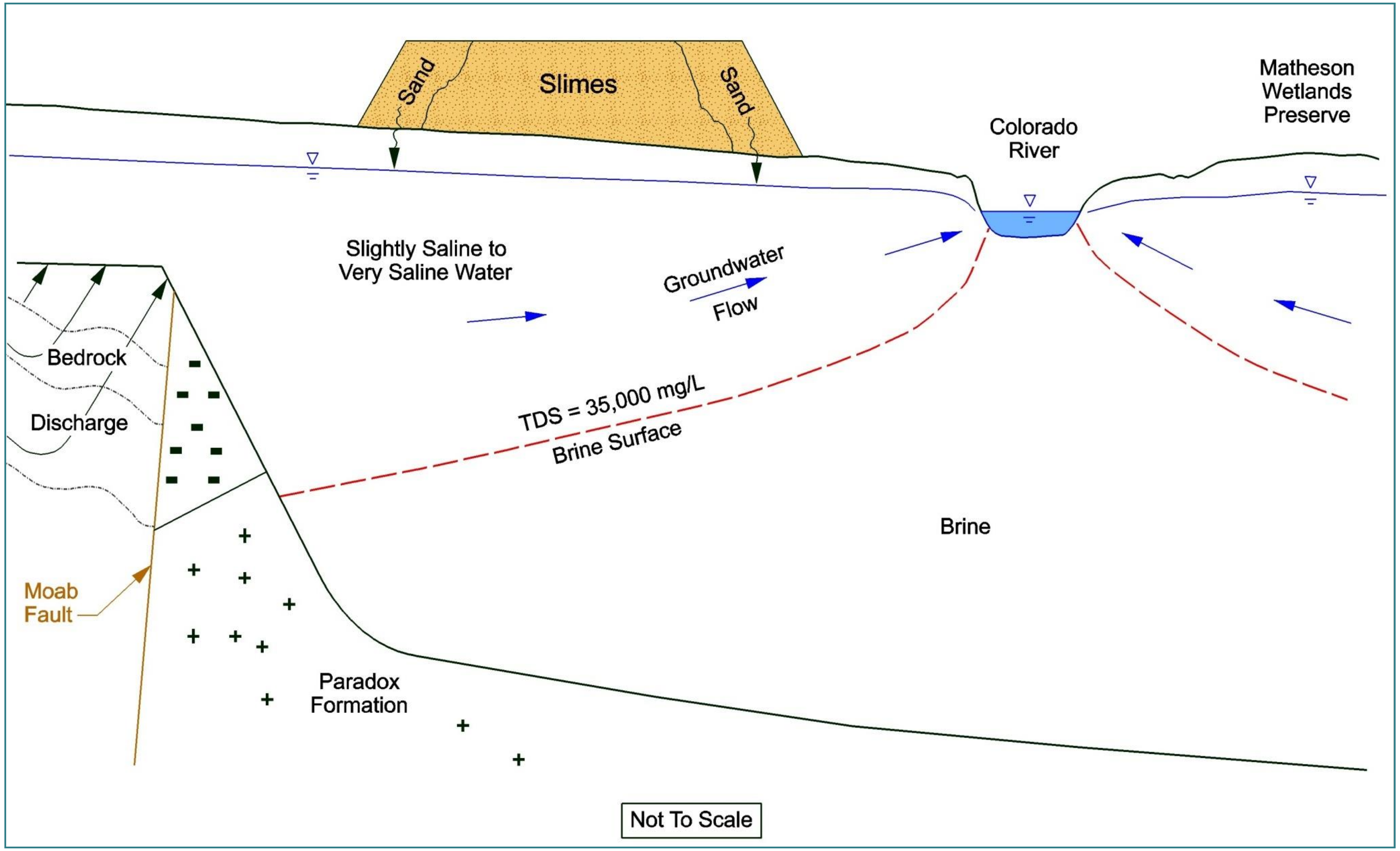
Moab UMTRA Project Groundwater Interim Action

Ken Pill

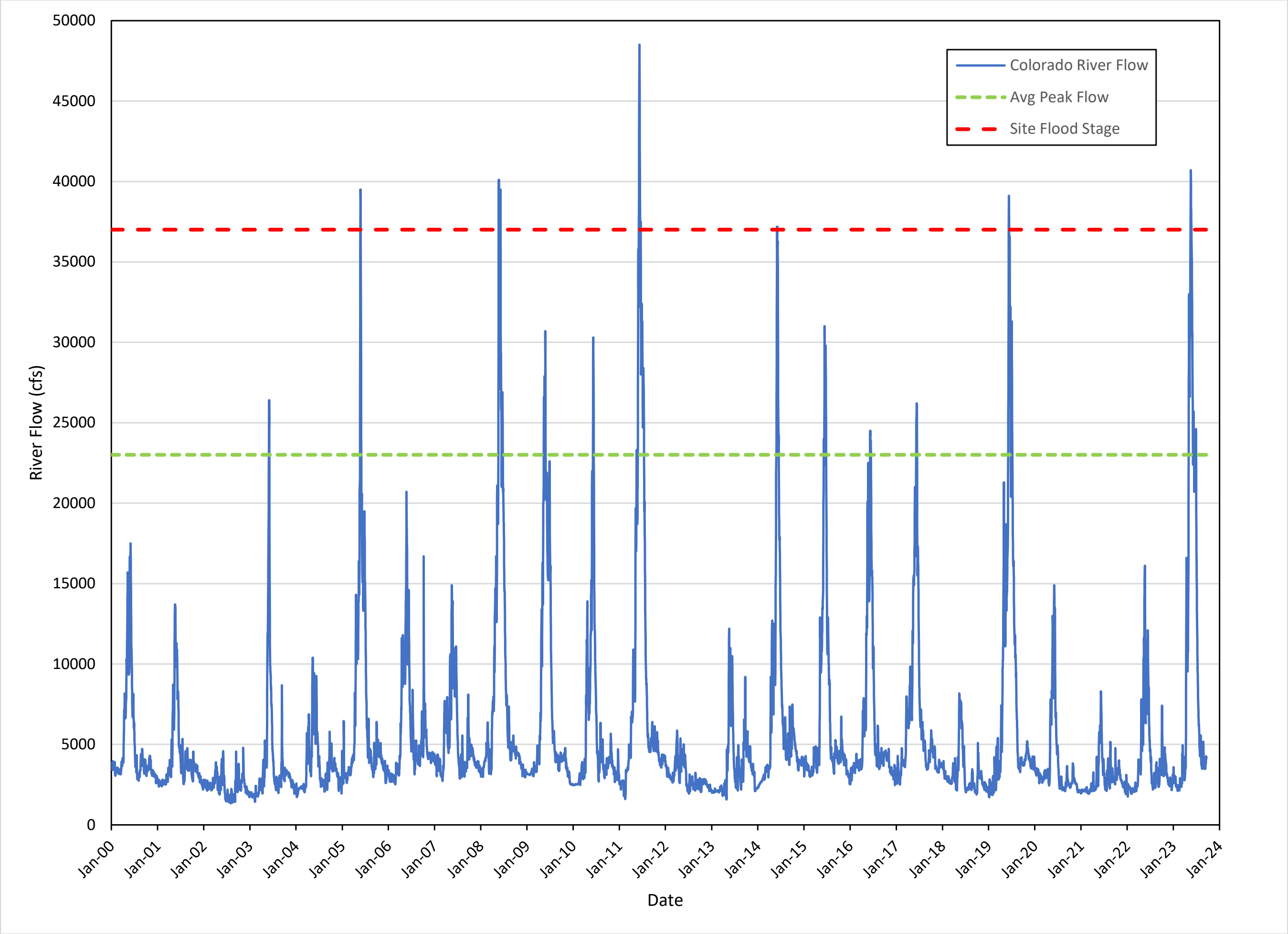
Groundwater Manager

November 15, 2023

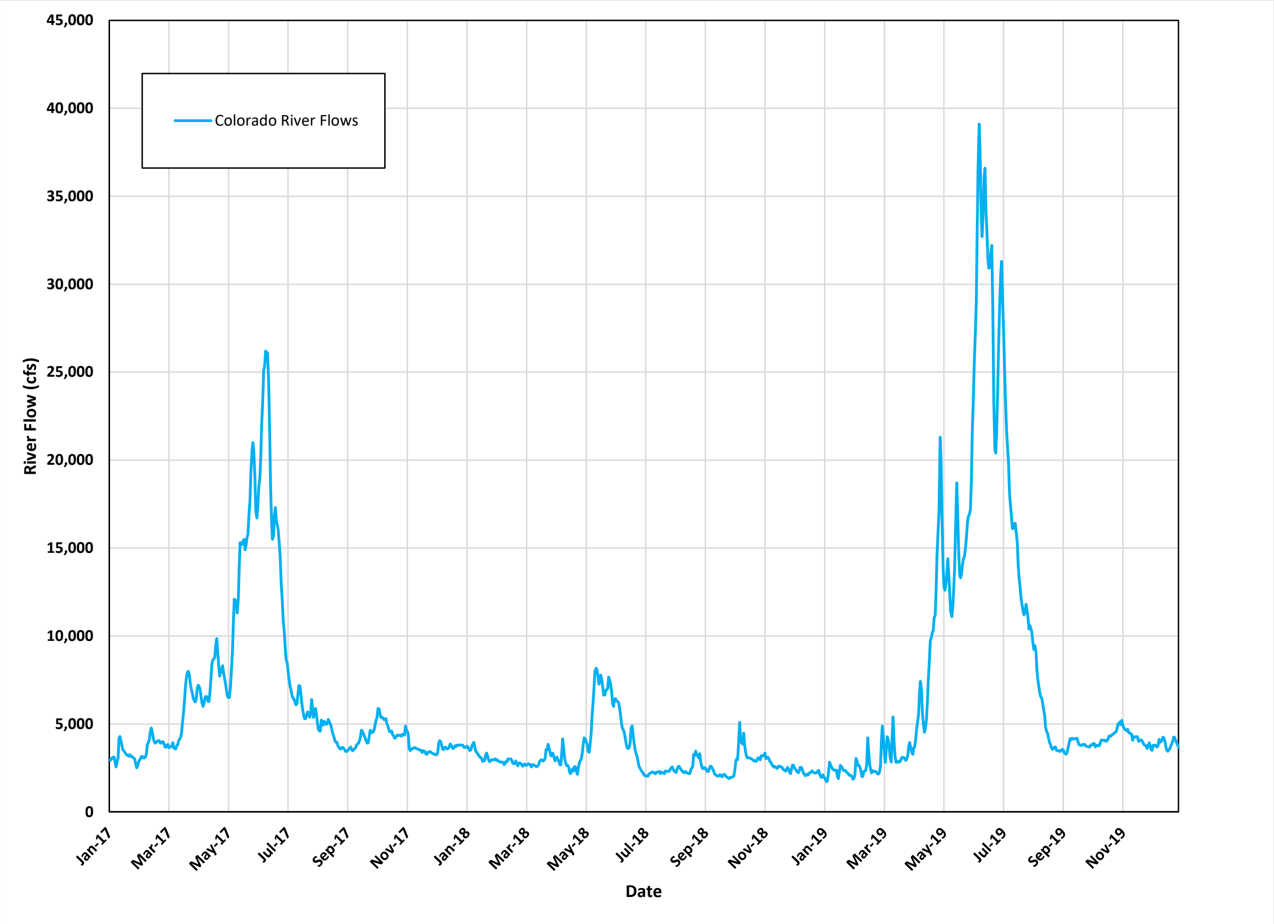
Groundwater System Conceptual Model



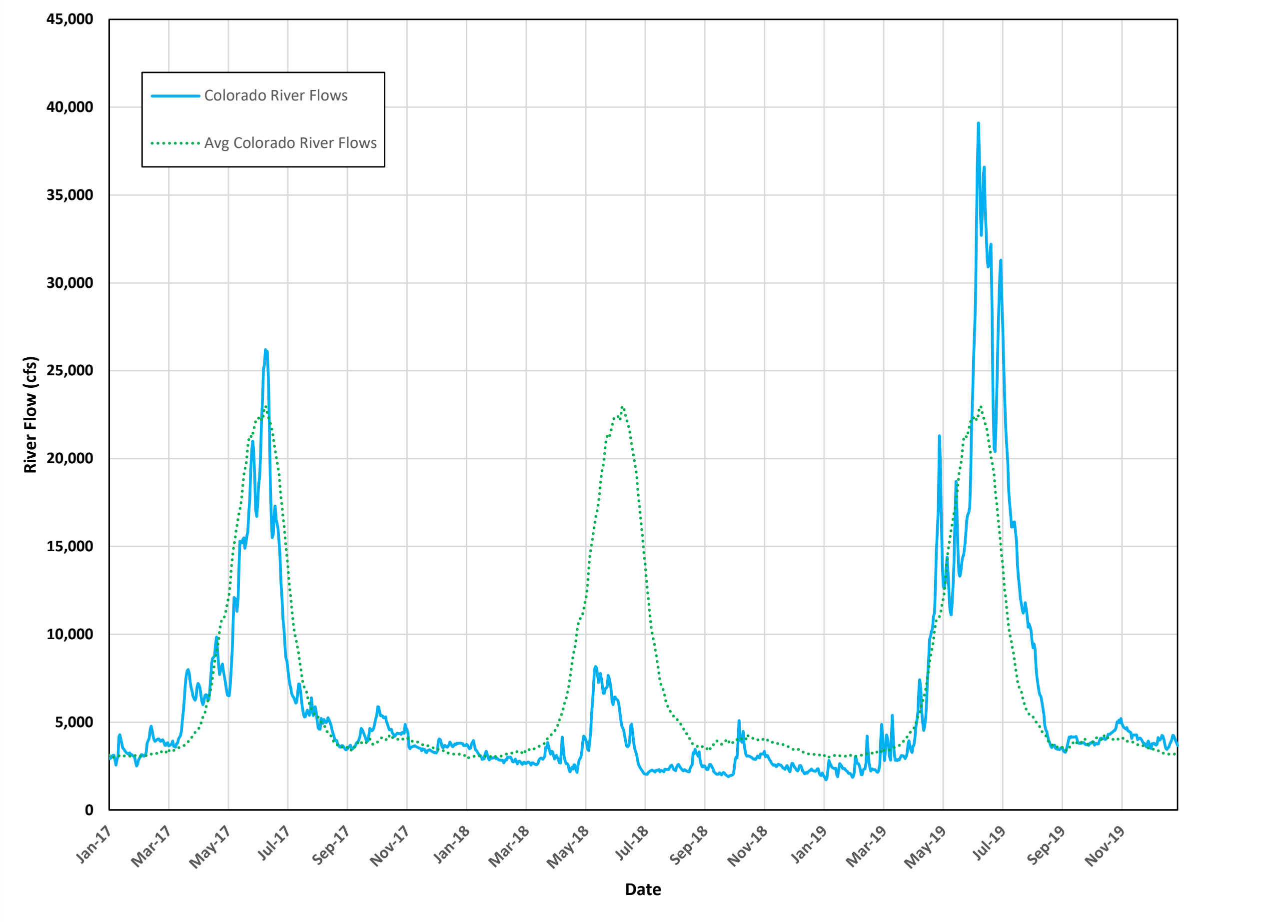
Colorado River Flows, 2000 - 2023



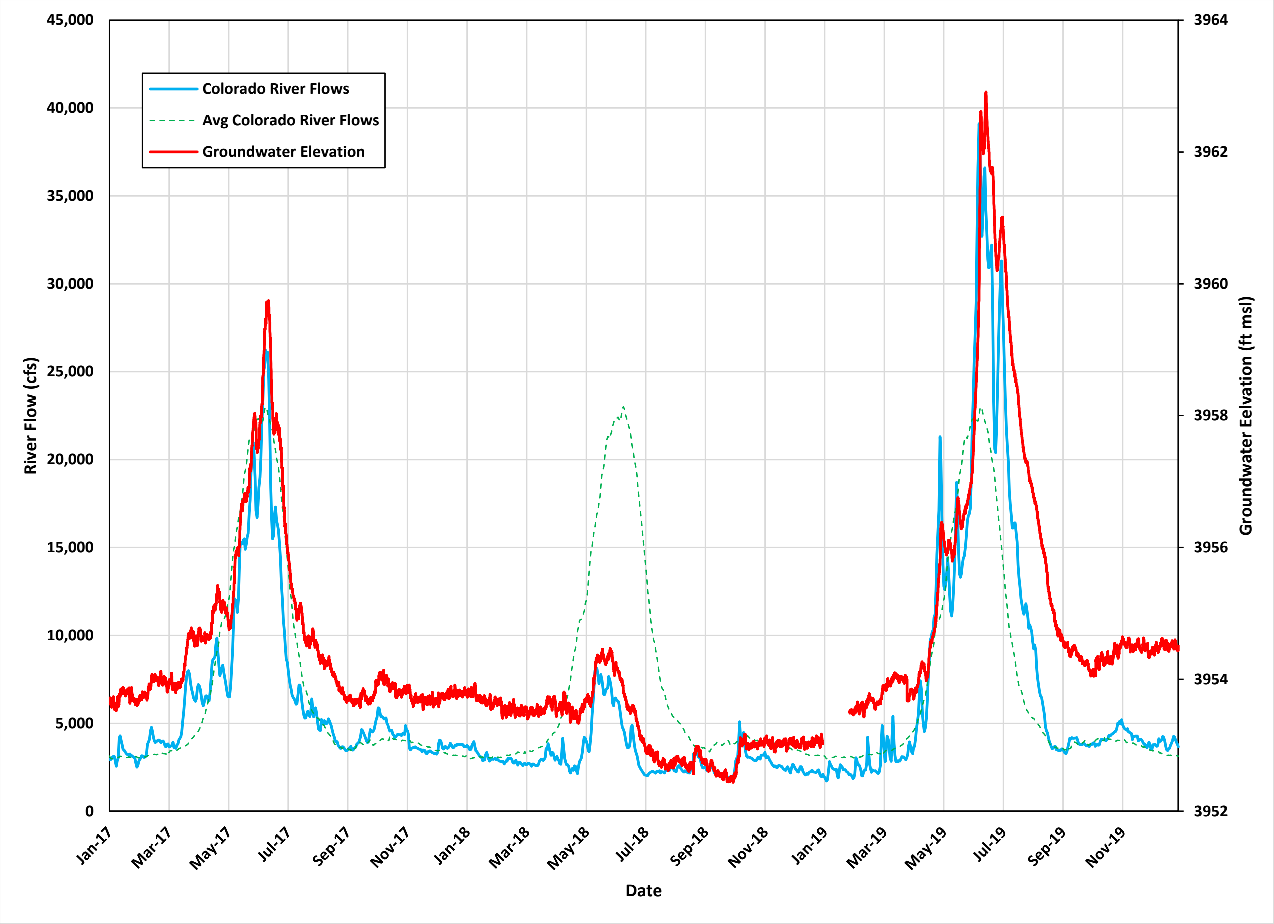
Groundwater/Surface Water Interaction



Groundwater/Surface Water Interaction

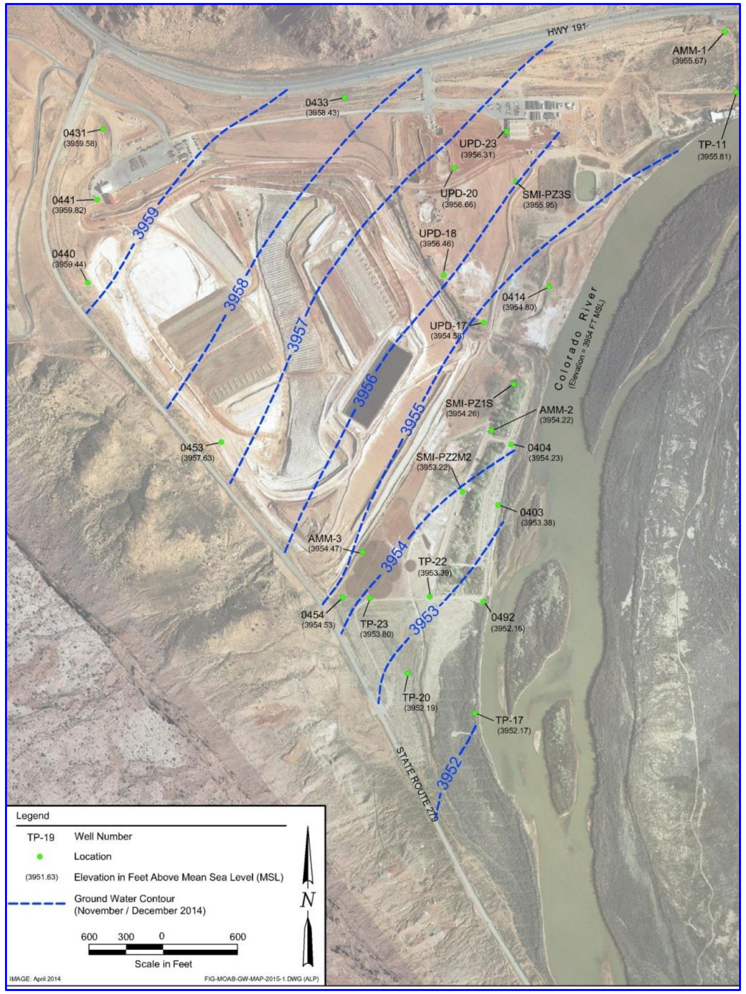


Groundwater/Surface Water Interaction



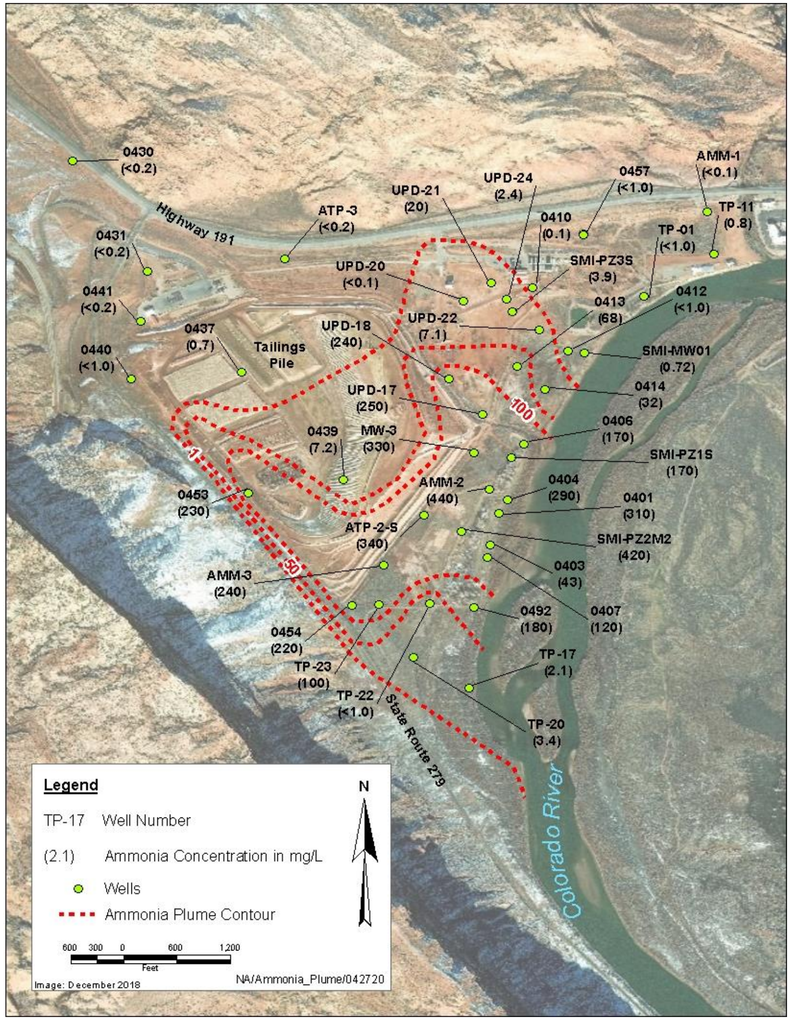
Groundwater Flow Direction

- Dec 2021 data
- During river base flow (river gaining) groundwater flow direction is towards SE
- Flow direction reverses within ~150 ft of riverbank during spring runoff flows (losing conditions)

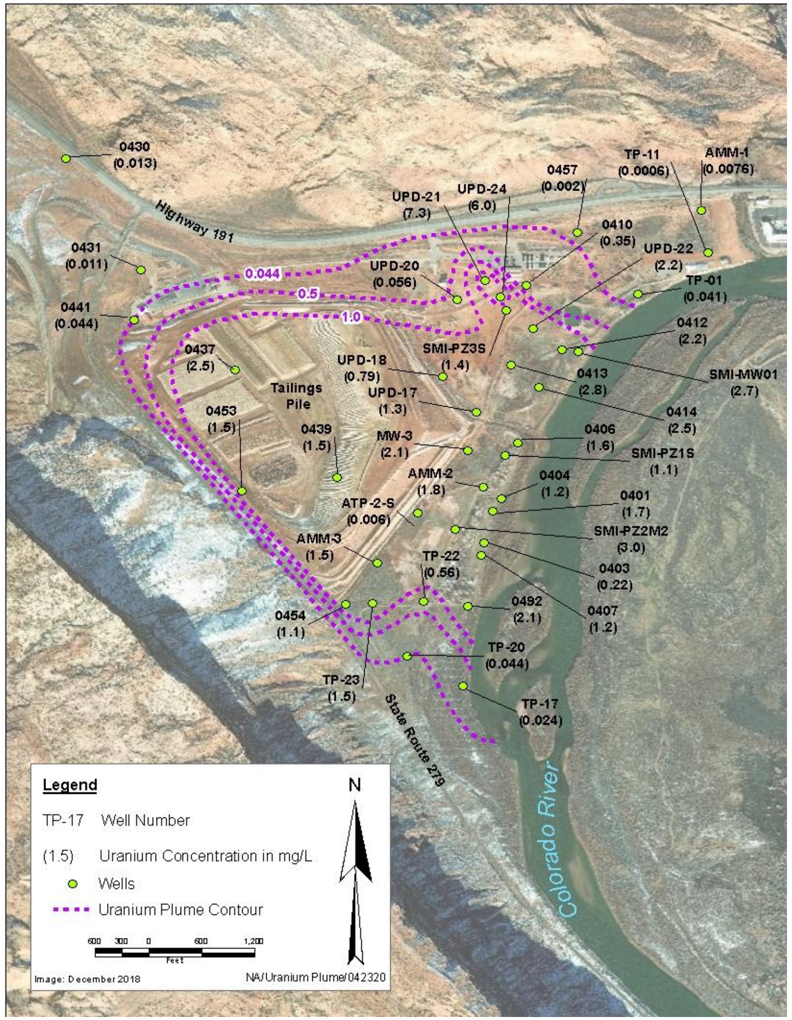


Shallow Zone Ammonia Plume

- Dec 2021 data
- Contaminant concentrations highest above brine interface
- Above 2,000 mg/L in some locations



Shallow Zone Uranium Plume

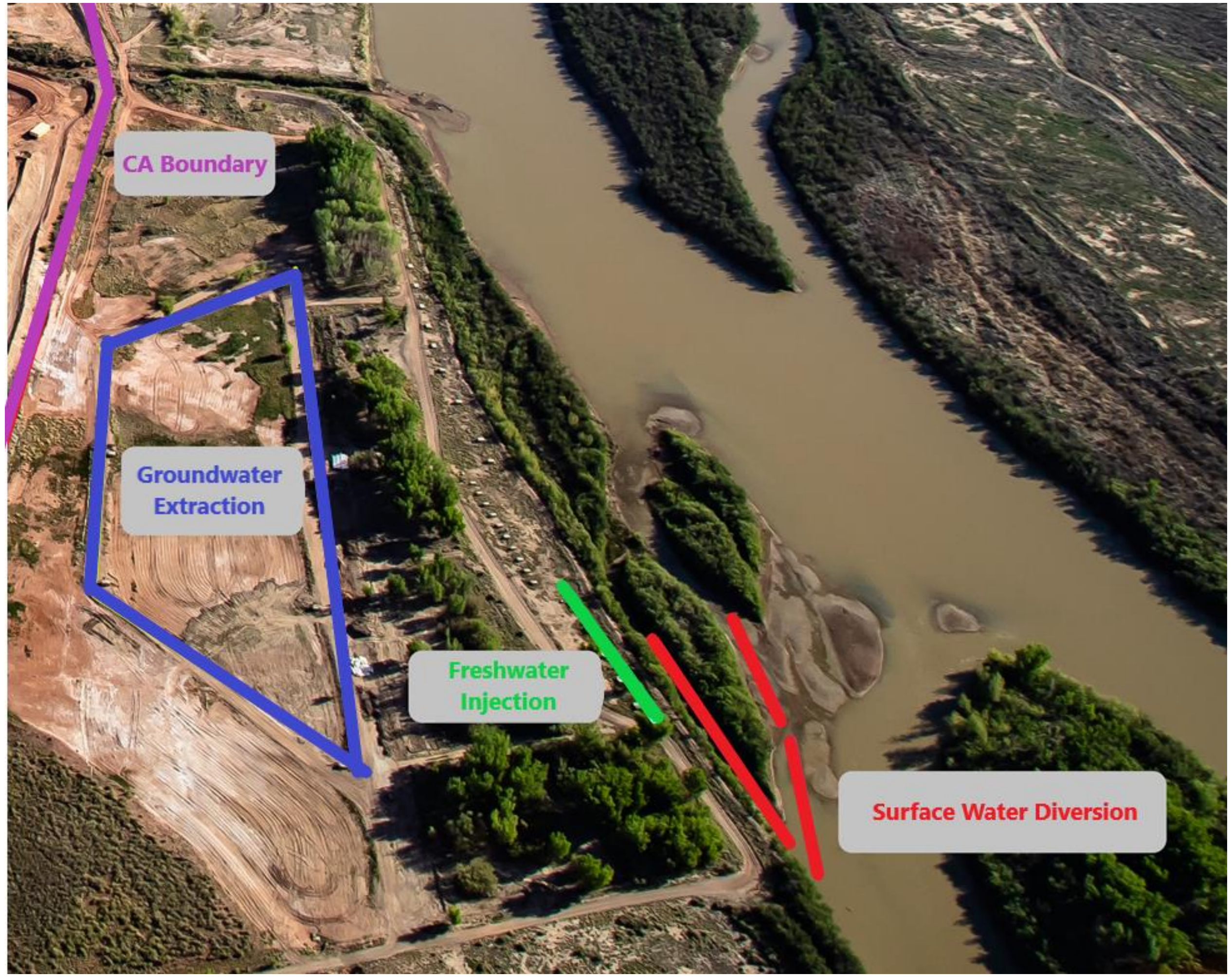


- Dec 2021 data
- U plume more widespread compared to NH3 plume
- Northeast portion of plume due to former processing facility/waste disposal activities
- Maximum concentration of 12 mg/L

Groundwater Program Interim Action Systems

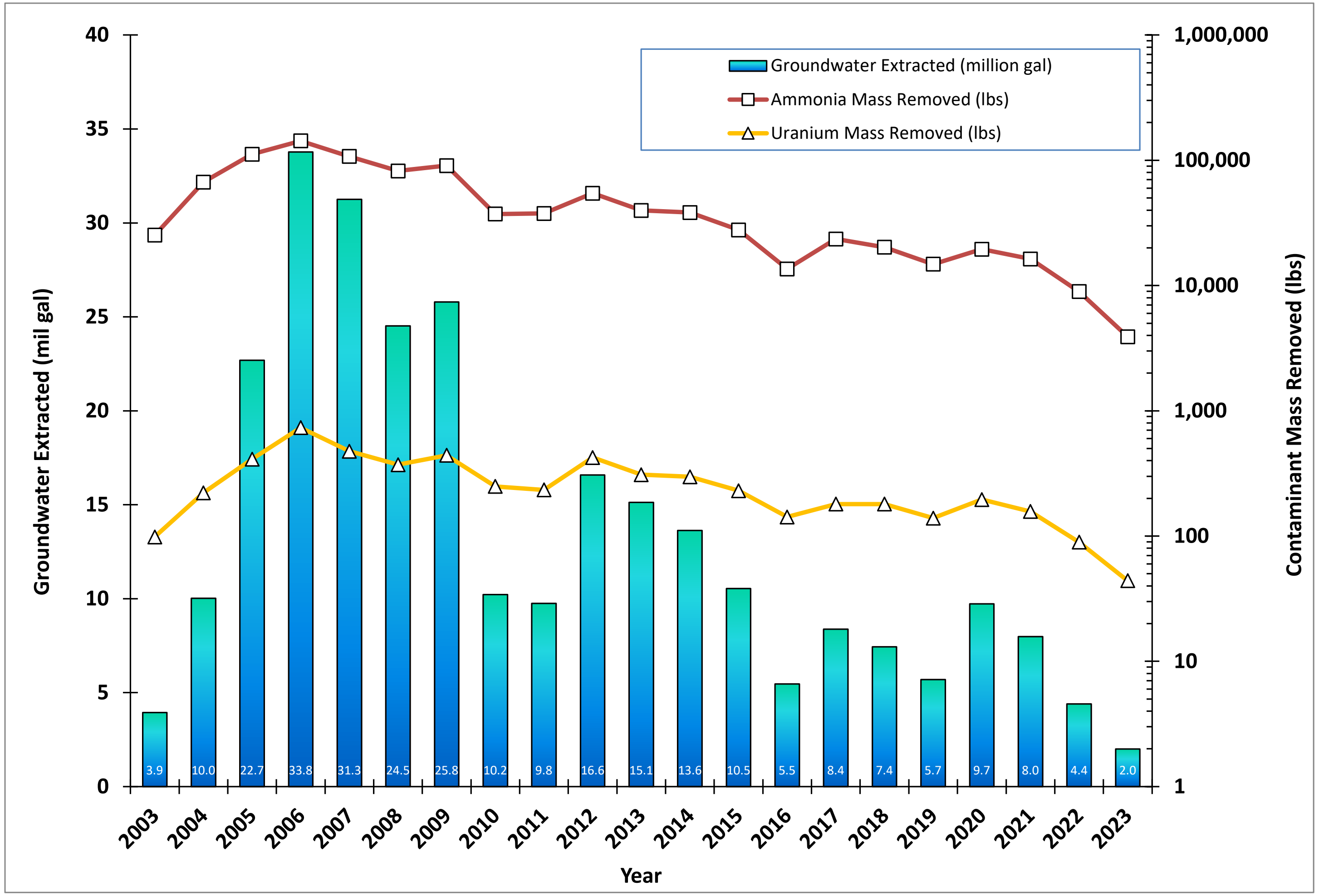
- Groundwater Contaminant Mass Removal
  - **Groundwater Extraction System** – pumps groundwater from the aquifer near the base of the tailings pile, used for CA dust control. Especially beneficial during drought conditions

- Critical Habitat Protection
  - **Freshwater Injection System** – injects filtered Colorado River water upgradient of habitat 15 to 35 ft below ground surface (bgs)
  - **Surface Water Diversion System** – delivers fresh water into habitat areas

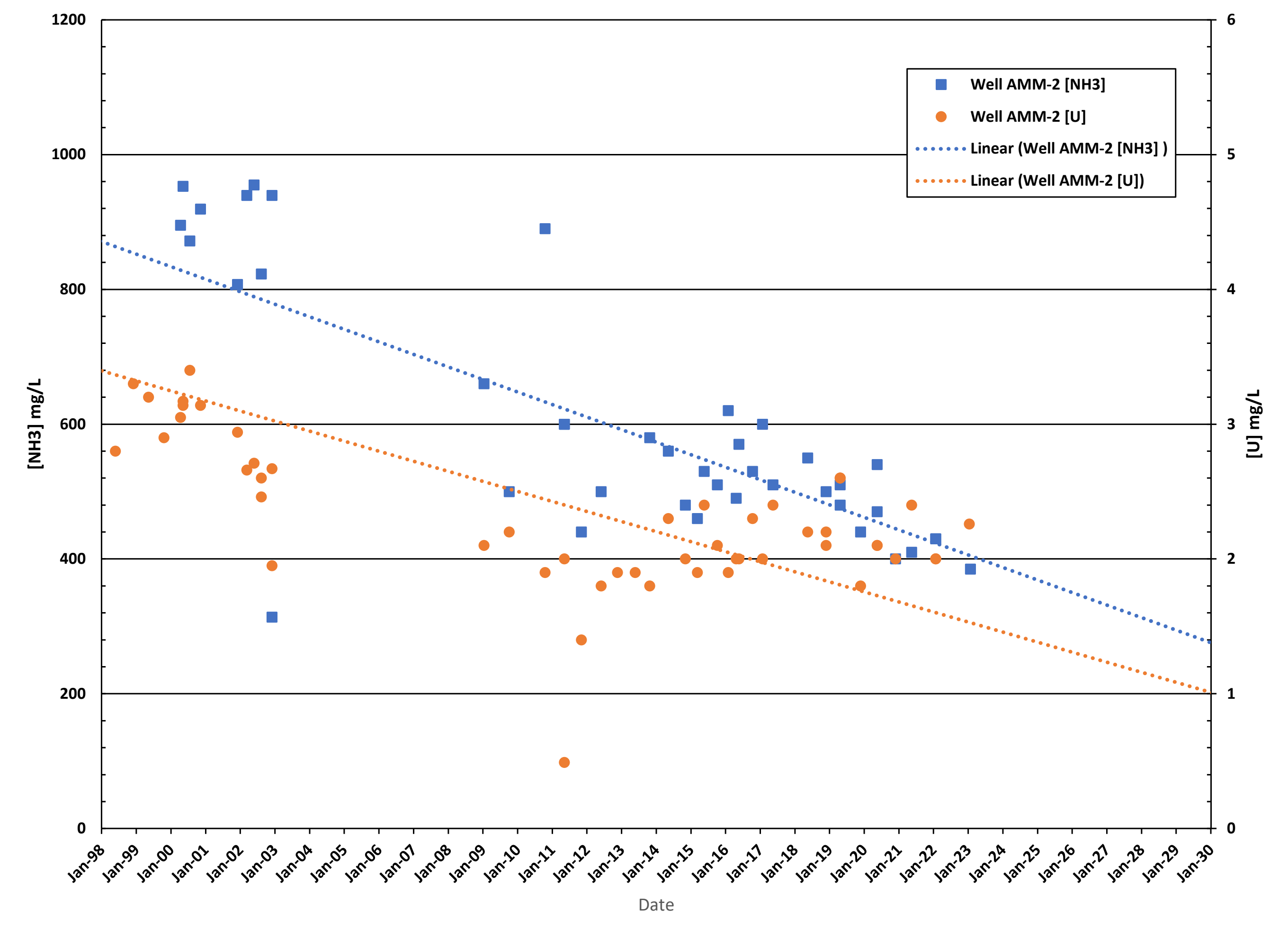


Groundwater Extraction System

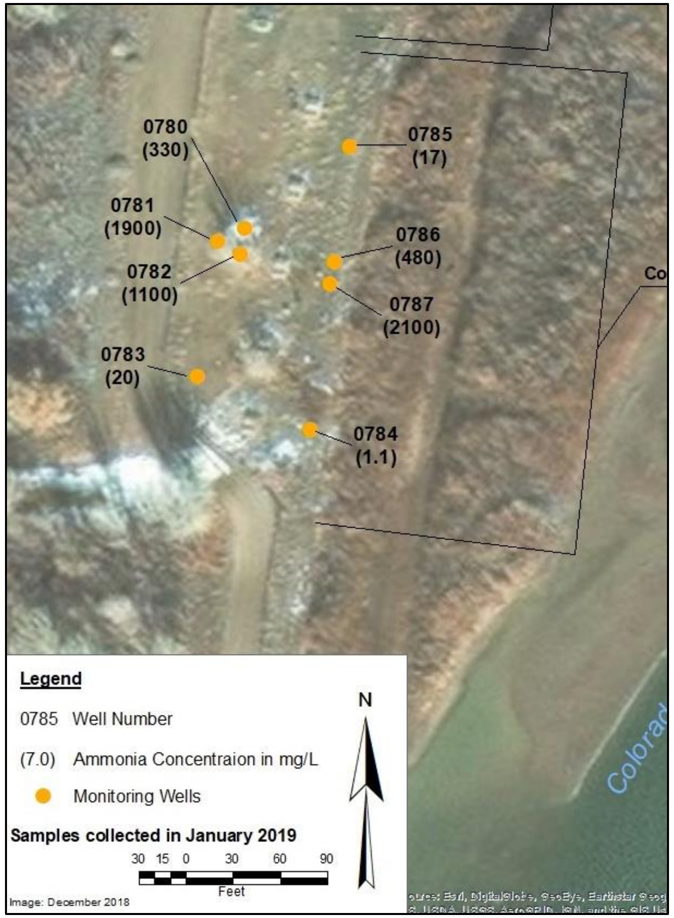
- As of Nov 2023
  - 279 mil. gal. groundwater extracted
  - 984,500 lbs NH3 removed
  - 5,650 lbs of U removed

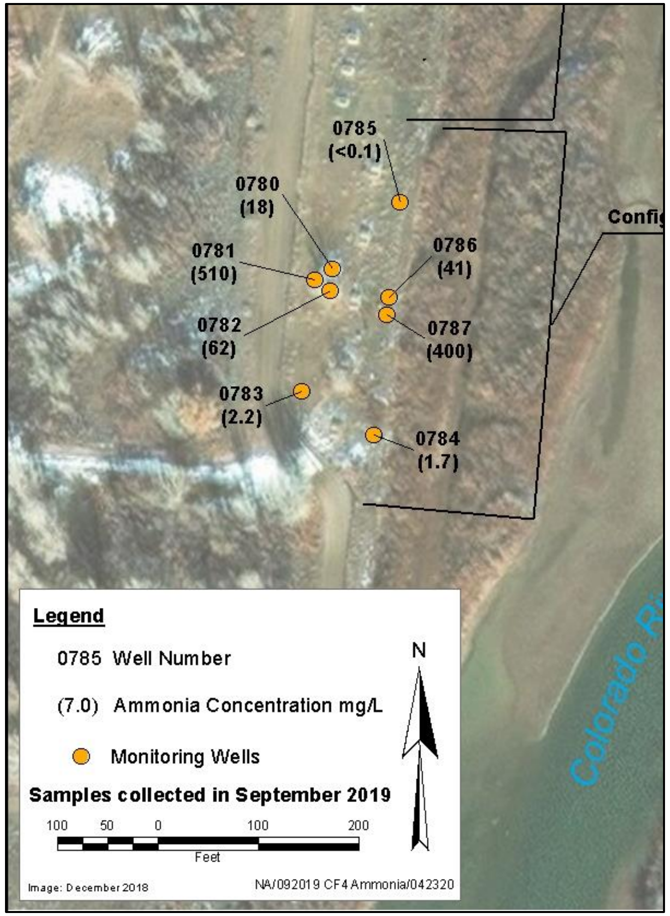


Groundwater Extraction System Impacts



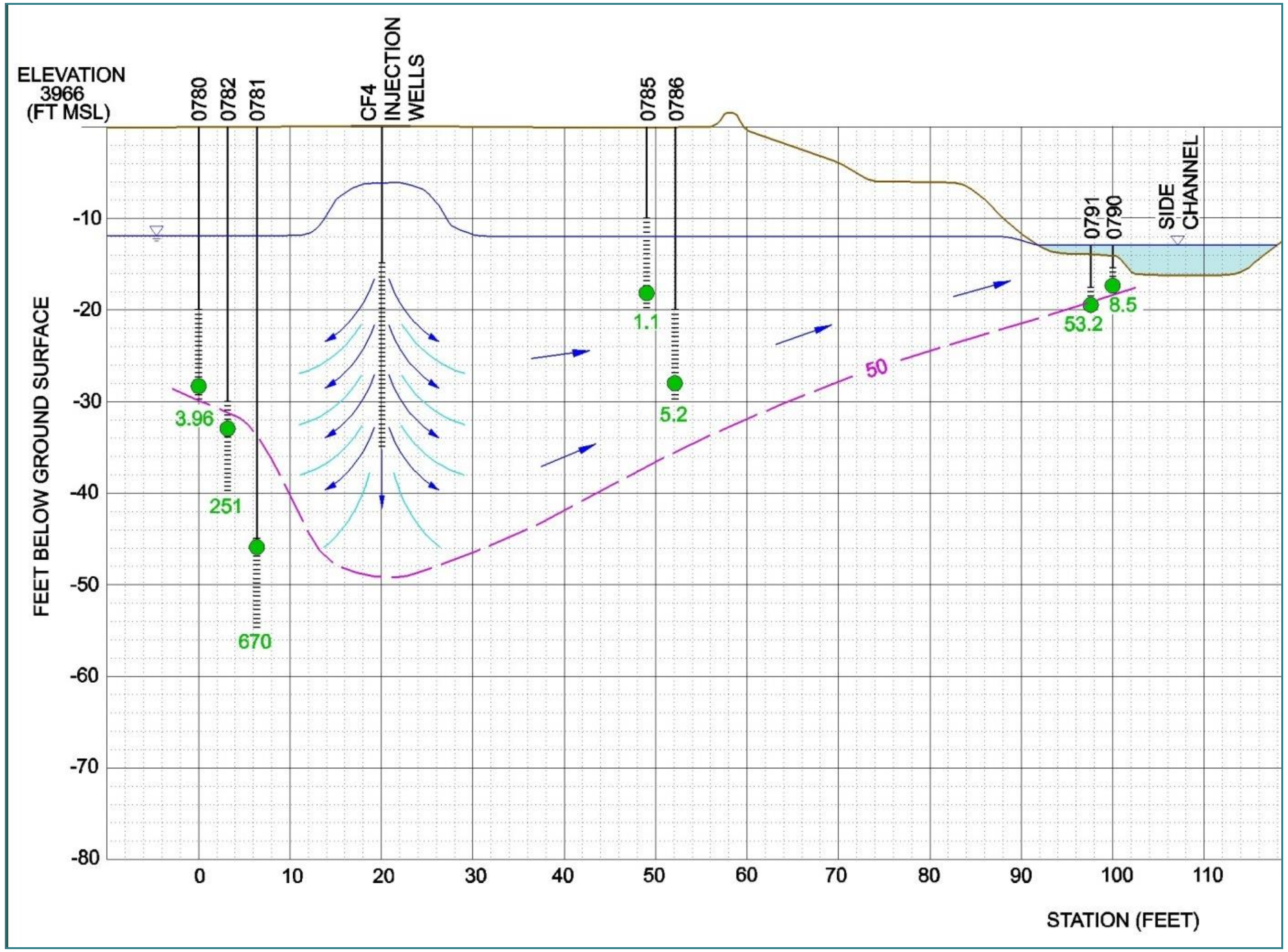
Freshwater Injection System





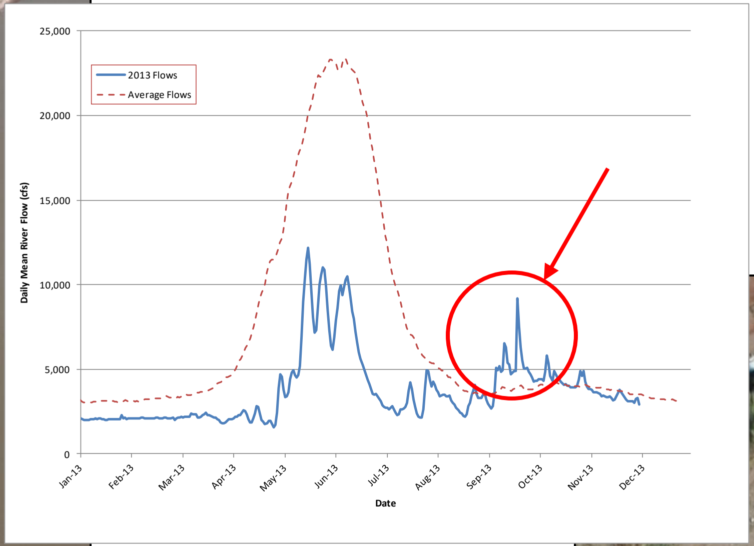
- After freshwater lens develops in response to runoff, system operated to supplement the lens
- Operating consistently since 2010
  - 111 mil. gal. injected through Nov 2023

Freshwater Injection System



Suitable Habitat Potential

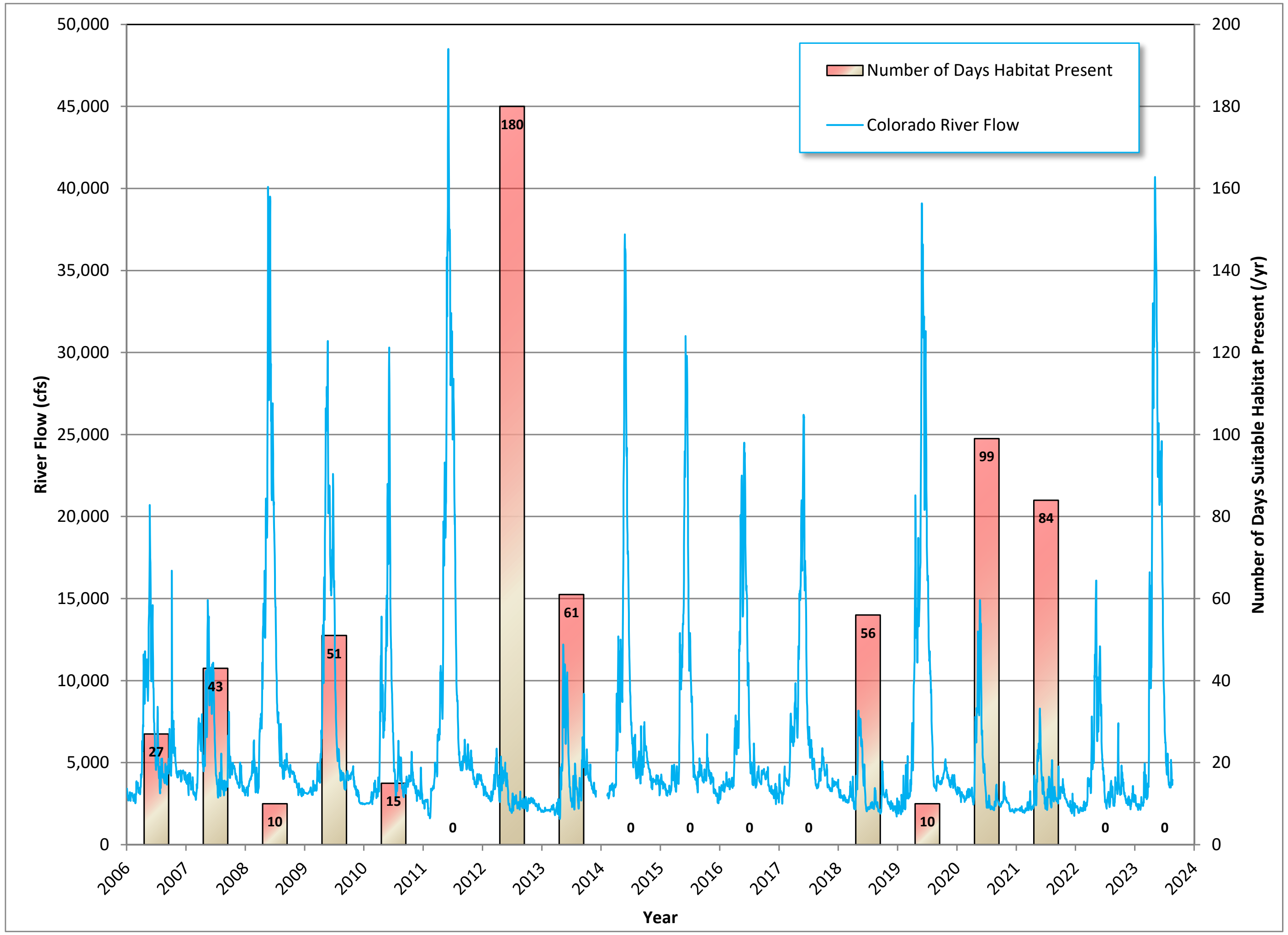
Side Channel Changes



Surface Water Diversion System

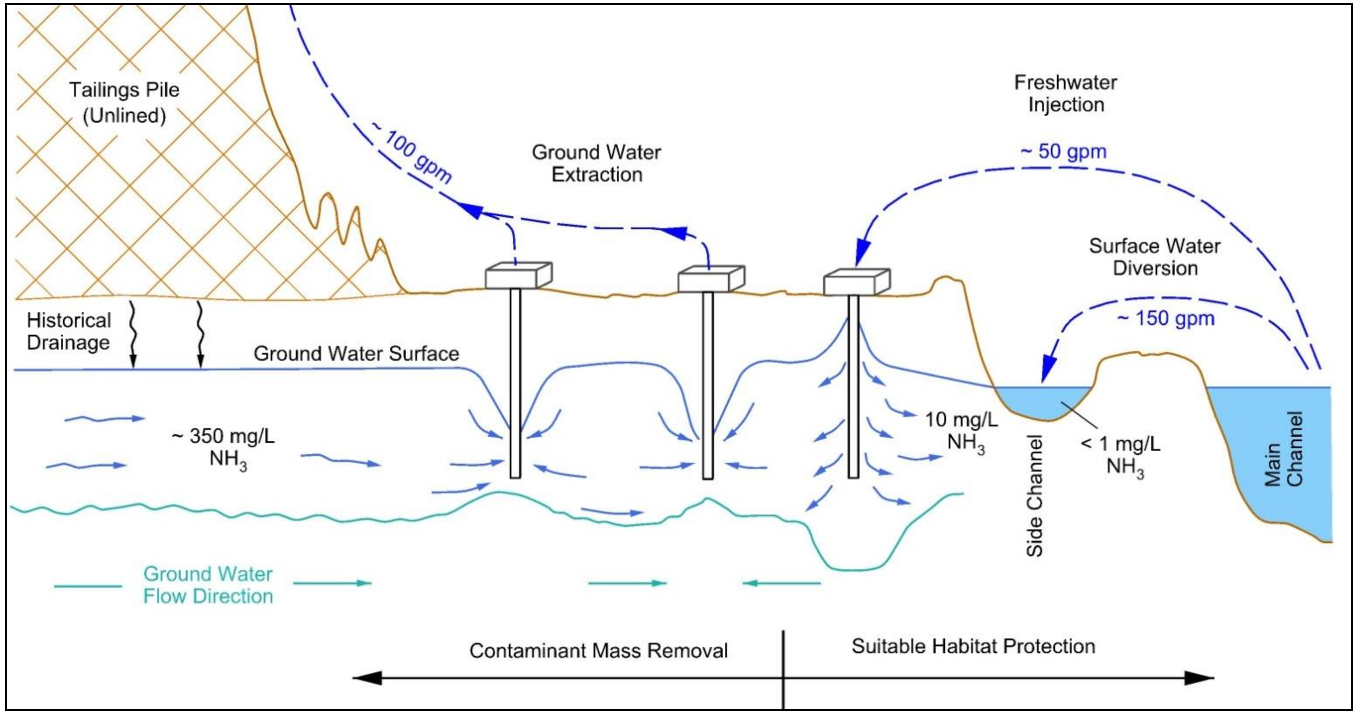
- Operation depends upon Colorado River flows and side channel configuration (dynamic system)
- System can apply water to areas where most effective at reducing ammonia concentrations based on sampling results
- Manifolds reduce erosion

Suitable Habitat Potential



Groundwater Program Activities - Summary

- Contaminant Mass Removal
  - Groundwater extraction near base of tailings
- Suitable Habitat Protection
  - Freshwater injection along riverbank
  - Surface water diversion directly into side channel



QUESTIONS?

Standards and GCAP Requirements

Elizabeth Moran
Environmental Manager
Moab UMTRA Project
November 15, 2023

MOAB UMTRA PROJECT CRESCENT JUNCTION

Overview

- What are the groundwater contaminants of concern and what is the regulatory driver?
- What are the surface/groundwater clean-up standards?
- What are the potential implications?
- How will the final compliance action plan be determined?

Regulatory Drivers

- 40 CFR 192 - Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings
- DOE Order 458.1 Radiation Protection of the Public and the Environment
- Endangered Species Act Critical Habitat
- FEIS - relocation of tailings pile from the Colorado River

Contaminants of Concern and Standards

PCOC	Standard (mg/L)	Source
Ammonia	3	Proposed in EIS
Arsenic	0.01	40 CFR 192 Sub A, Table 1
Copper	1.3	EPA Action Level
Manganese	0.05	EPA Secondary Drinking Water Regulation
Selenium	0.05	40 CFR 192 Sub A, Table 1
Sulfate	250	EPA Secondary Drinking Water Regulation
Uranium	0.044	40 CFR 192 Sub A, Table 1 (assumes U-234 and U-238 are in equilibrium, converted to mg/L)

Ammonia

- No regulatory groundwater standard
- A target goal of 3 mg/L in groundwater was proposed in the FEIS based on a 10-fold dilution
- High toxicity to aquatic life
- EPA Acute and chronic criteria

Uranium

- Exceeds the EPA standard in the groundwater (0.044 mg/L)
- Highest concentrations associated with the millsite plume
- No surface water regulations

Copper, Manganese, Selenium, Sulfate

- Copper and manganese have EPA acute and chronic criteria for aquatic life. Background manganese is also high at Matheson Wetlands.
- Selenium was identified with potential impacts to piscivore mammals and birds and EPA acute and chronic criteria for aquatic life. Background selenium is also elevated.
- Sulfate is elevated but there are no established wildlife benchmarks. Background sulfate is also high due to dissolution of the Paradox Formation.
- Elevated arsenic associated with the former millsite area.

Challenges

- Complex Site:
  - Freshwater/Brine Interface
  - Surface water/groundwater interactions
  - Two separate contaminant plumes
  - Adjacent critical habitat

Approaching Site Closure…

Groundwater Compliance Action Plan (GCAP)

- Prioritizes
  - Containing the spread of contaminants
  - Mitigating the threat to public health
- Contains:
  - Site Characterization
  - Groundwater Protection Standards
  - Hazard Assessment
  - Groundwater Corrective Action and Compliance Monitoring
  - Long-term Surveillance Plan
- Nuclear Regulatory Commission approval
- NUREG 1724/GCAP PEIS

Acceptable Strategies

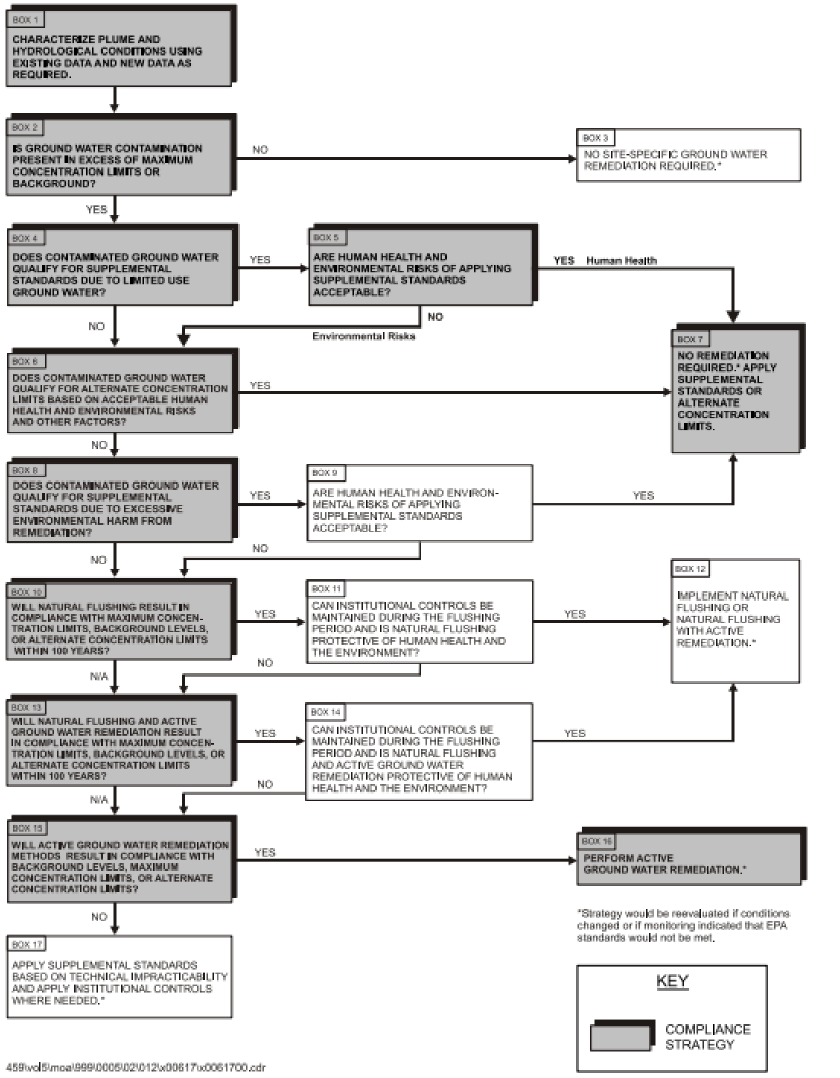
Strategy	Alternative			
	Proposed action	No action	Active remediation to background levels	Passive remediation
Active ground water remediation methods	X		X	
Natural flushing	X			X
No ground water remediation - Sites that qualify for supplemental standards or alternate concentration limits .	X			X
- Sites that meet maximum concentration limits or background levels (no impacts).	X			X

- No Remediation
- Natural Flushing (within 100 years)
- Active Remediation
- Active Remediation/Natural Flushing

Other Potential Strategies

- Supplemental Standards/Alternate Concentration Limits
  - Concentration of total dissolved solids >10,000 mg/L
  - Limited use aquifer
  - Must ensure projected of uses of groundwater are preserved
- Institutional Controls
  - Protect public health and environmental
- Alternate Concentration Limits
  - No excessive health or environmental risks

Compliance Strategy Selection Process



Closing

- The Groundwater Compliance Action Plan will:
  - Account for the constituents of concern and the impact on ecology and human health.
  - Determine the best remedial strategy, which may vary between the two contaminant plumes.
  - Involve stakeholder engagement.
  - Follow the requirements in 40 CFR 192 and NUREG 1724.

QUESTIONS?

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Moab Case Study: Risk and Environmental Protection Issues

Amoret Bunn

2023 Global Summit
on Environmental Remediation
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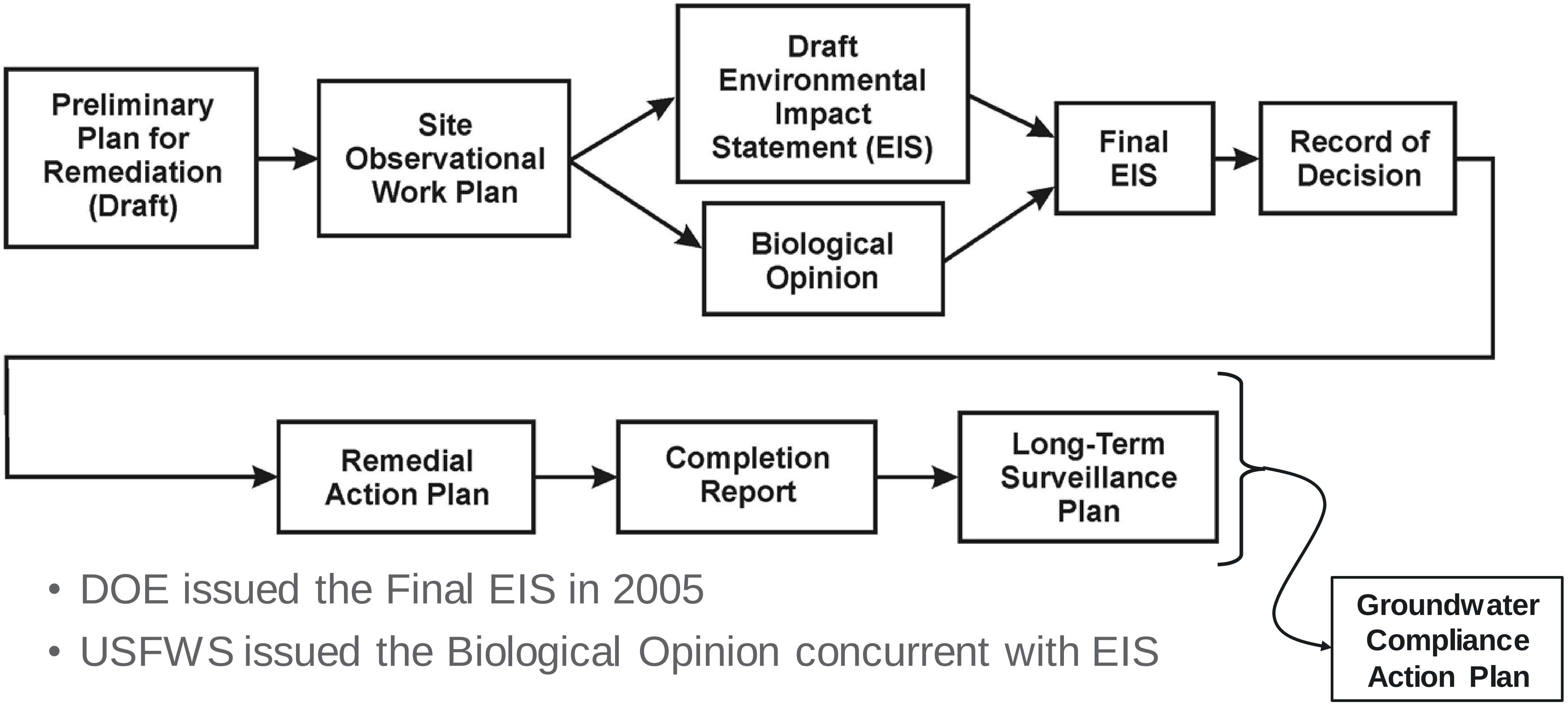
Outline

- What is risk?
- UMTRA Process and Moab Site
- Risk Issues for Consideration
  - Role of USFWS Biological Opinion
- Interim Actions
- Next Steps

2023 Global Summit

UMTRA Project Documentation Process



- DOE issued the Final EIS in 2005
- USFWS issued the Biological Opinion concurrent with EIS

2023 Global Summit

Risk Issues for Consideration - Human Health Risk

- EIS identified potential for public to be exposed to unacceptable levels of radon and other radiological hazard if the mill tailings pile remained at site.
- Relocation of the mill tailings pile to secure site at Crescent Junction addresses long-term public health risk

2023 Global Summit

Risk Issues for Consideration - Ecological Risk

- Release of contaminants from mill operations and from the mill tailings pile into groundwater and Colorado River is at levels exceeding risk levels for aquatic organisms
  - Contaminants of concern: Ammonia, Uranium, other metals
  - Chronic and Acute criteria for contaminants and aquatic organisms
  - Endangered Species Act
- Ecological risk is driving the interim actions with the groundwater and surface water

2023 Global Summit

Biological Opinion, USFWS, 2004

- Focus on fish species:

Common Name	Scientific Name	Status
Humpback chub	*Gila cypha*	Endangered
Bonytail	*Gila elegans*	Endangered
Colorado pikeminnow	*Ptychocheilus lucius*	Endangered
Razorback sucker	*Xyrauchen texanus*	Endangered

- “DOE assumes that by reducing near-surface groundwater ammonia concentrations to 3 mg/L they will be able to achieve chronic standards (0.6 mg/L ammonia) in all habitats.”
  - Based on ≥ 10-fold dilution factor from groundwater to surface water
- USFWS issued an Incidental Take Statement based on DOE’s implementation of an active groundwater remediation system

Ecological Risk Drivers

- Ammonia in groundwater emerging into surface water at levels that exceed acute and chronic criteria.
- Larval fish – Young-of-the-Year – can get into pools along shoreline where groundwater contamination enters the surface water
- Dynamic environment changes critical fish habitat over time
- Interim action minimize ecological risk

Critical fish habitat along shoreline of Colorado River

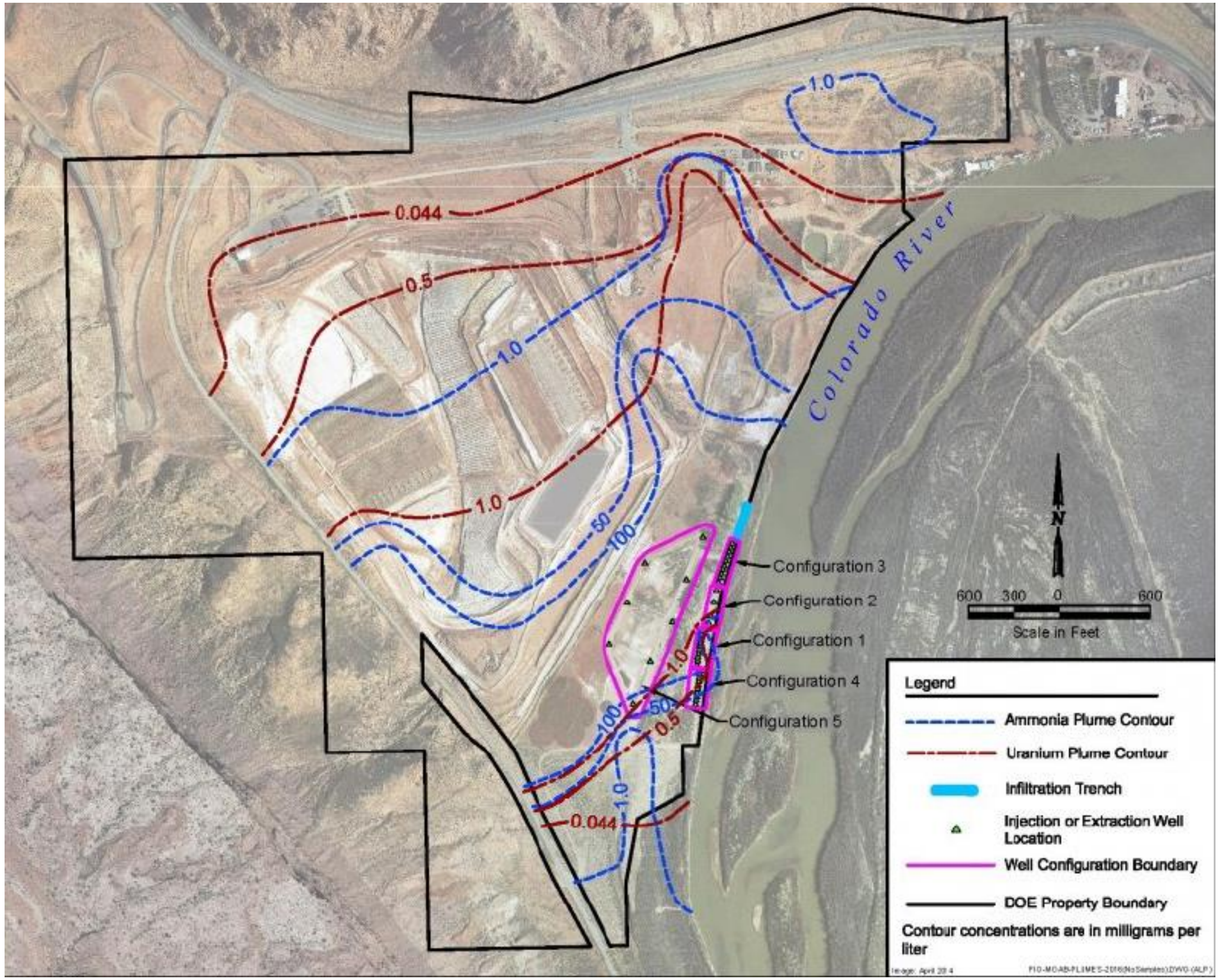
Measures Required by 2005 Biological Opinion

- Monitor backwater habitats near the Moab Site for any indication of fish being affected by surface water contamination.
- Evaluate the effectiveness of their initial action (diluting non-protective contaminant concentrations in backwater habitats by pumping clean river water).
- Address uncertainties associated with the groundwater remediation program.
- Reduce effects of surface water contamination in habitats along the south bank of the Colorado River if necessary.
- Reduce the effects of entrainment at all project pumping sites.

Environmental Protections Offered Through Interim Actions

Groundwater remediation system:

- Extraction of contaminant mass (ammonia and uranium) near the uranium mill tailings pile
- Injection of fresh water closer to the river to protect critical habitat areas for endangered fish species



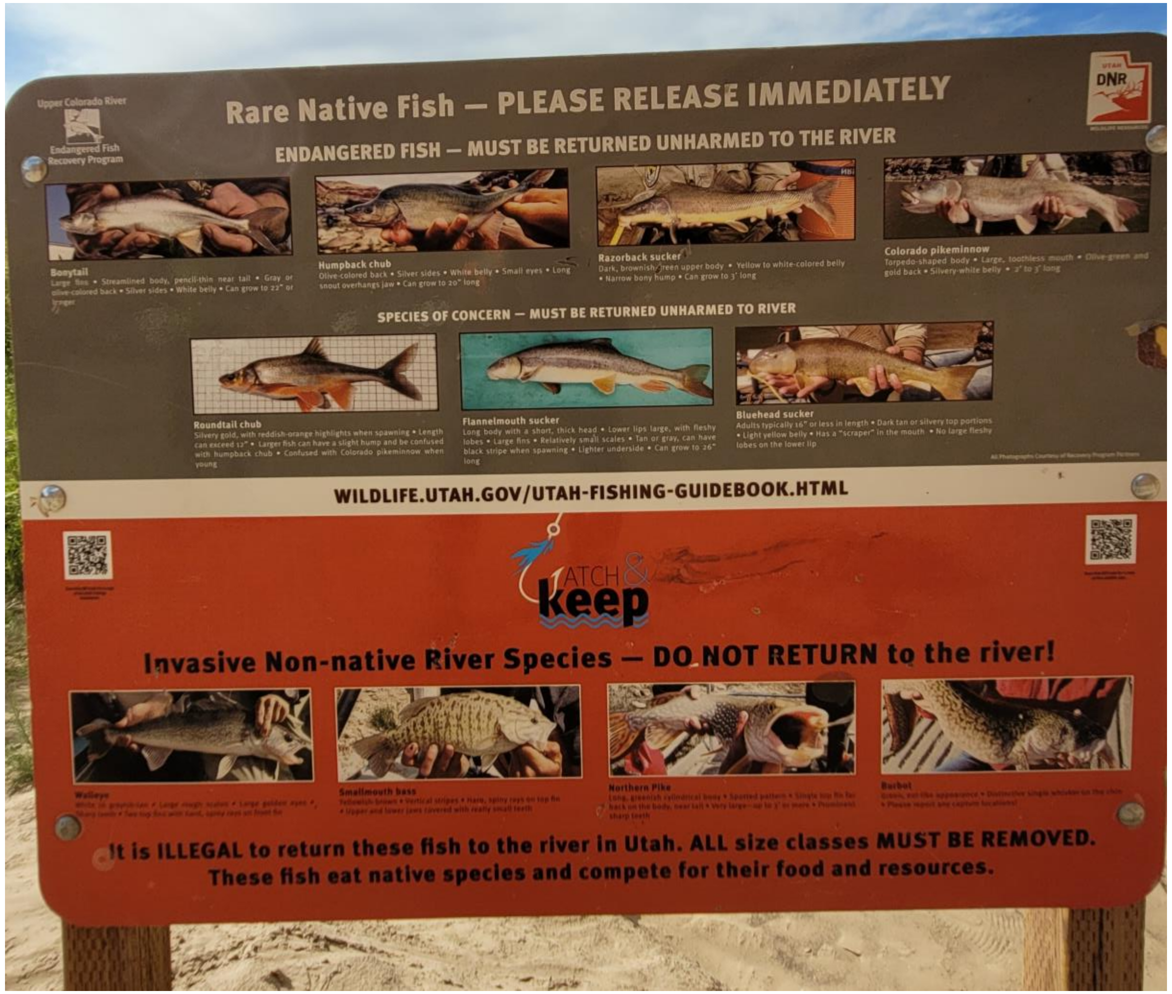
Ammonia and Uranium Concentration Contours and Interim Action Configurations

2023 Global Summit

Next Steps…

Groundwater Compliance Action Plan (GCAP) addresses ecological risk to aquatic organisms and mitigation measures within Biological Opinion

- Dynamics of Colorado River and interactions with site groundwater will change critical habitat
- Uncertainties in site conditions as remedial actions are ongoing adds challenges to modeling future conditions
- Adaptive site management approach can be protective and address final actions



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Thank You!
Questions

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Network of National Laboratories for NNLEMS Environmental Management and Stewardship

SRNL-MS-2023-00463

Case Study – DOE National Laboratory Collaboration Supporting Moab (Utah, Former Mill Site) Groundwater Corrective Action Plan Development

RemPlex Summit, 2023

Prepared by Brian Looney, Earth and Biological Sciences, Savannah River National Laboratory

for DOE EM and DOE LM on behalf of the NNLEMS teams

Savannah River National Laboratory is operated by Battelle Savannah River Alliance for the U.S. Department of Energy under Contract No. 89303321CEM000080.

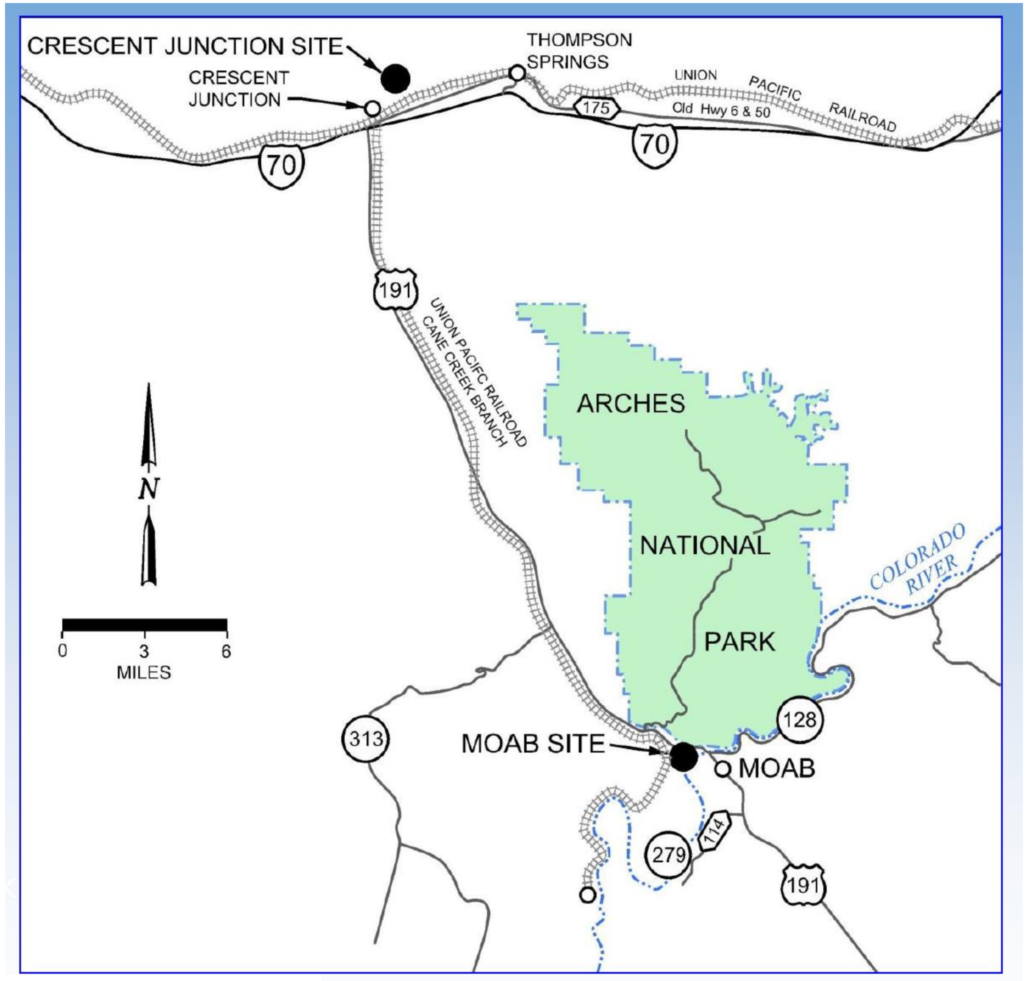
A brief History of Time

Carmelo Menendez
DOE-LM Sponsor
Director
Office of Legacy Management

Ike White
DOE-EM Sponsor
Senior Advisor for Environmental Management
Office of Environmental Management

- EM and LM have a successful history of working with the National Laboratories to encourage innovation, efficiency and effectiveness in soil and groundwater cleanup
- Carmelo Melendez, LM Director charged his organization with formalizing and extending the relationship – focusing on collaboration with the LM Applied Studies Program to advance LM environmental stewardship
- Ike White, EM Director, charged his organization to support high priority and high impact soil and groundwater topics
- Case study – National Laboratory collaborative support to help develop an efficient and effective *Groundwater Corrective Action Plan* for Moab

Moab -- location, features and “current” condition



Synopsis of Collaboration

- Approach
  - DOE EM +, DOE LM +, NNLEMS, and stakeholders (e.g., state agencies and Nuclear Regulatory Commission)
  - Actionable recommendations and time-phased strategy
  - Started by generating a long list of brainstorming ideas and then down-selected a short list for more detailed evaluation and consideration by DOE EM in developing and implementing a GCAP
  - Worked as a full team and in three topical teams –
    - Team 1: GCAP development status, requirements, and path forward (regulatory)
    - Team 2: Groundwater contamination related topics (data gaps, characterization and monitoring)
    - Team 3: Potential DOE response actions to include in the GCAP (remediation technologies)

GCAP = Groundwater Compliance Action Plan

Synopsis of recent NNLEMS support (2)

- Some details
  - Seven full team meetings
    - Kickoff meeting September 13-14, 2022
    - September 20& 27, October 11, November 15
    - Closeout meeting December 20, 2022
  - Five topical team meetings
    - October 3, 17 & 24, November 7 & 28
  - Five participating National Laboratories

- Outcome – a set of actionable, phased recommendations to advance development of a defensible GCAP
  - Recommendations were organized in alignment with the topical teams. Each phase was assigned defined risk management objective(s)

Moab Collaboration

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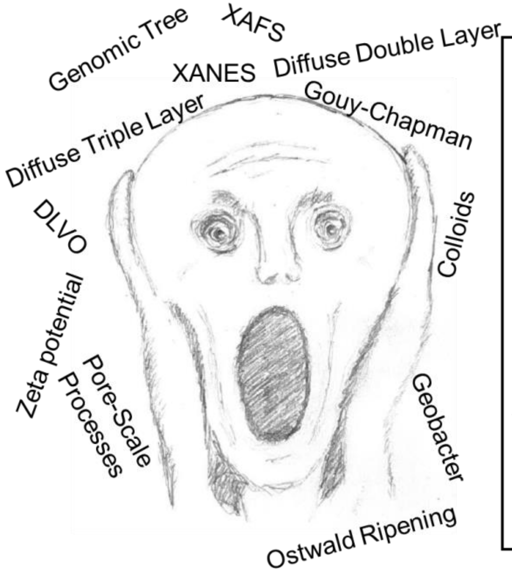
Sandia National Laboratories

Lawrence Livermore National Laboratory

BERKELEY LAB Bringing Science Solutions to the World

+ stakeholders, including Nuclear Regulatory Council and Utah Department of Natural Resources

Strategy – put science to work (but avoid paralysis by perceived complexity)



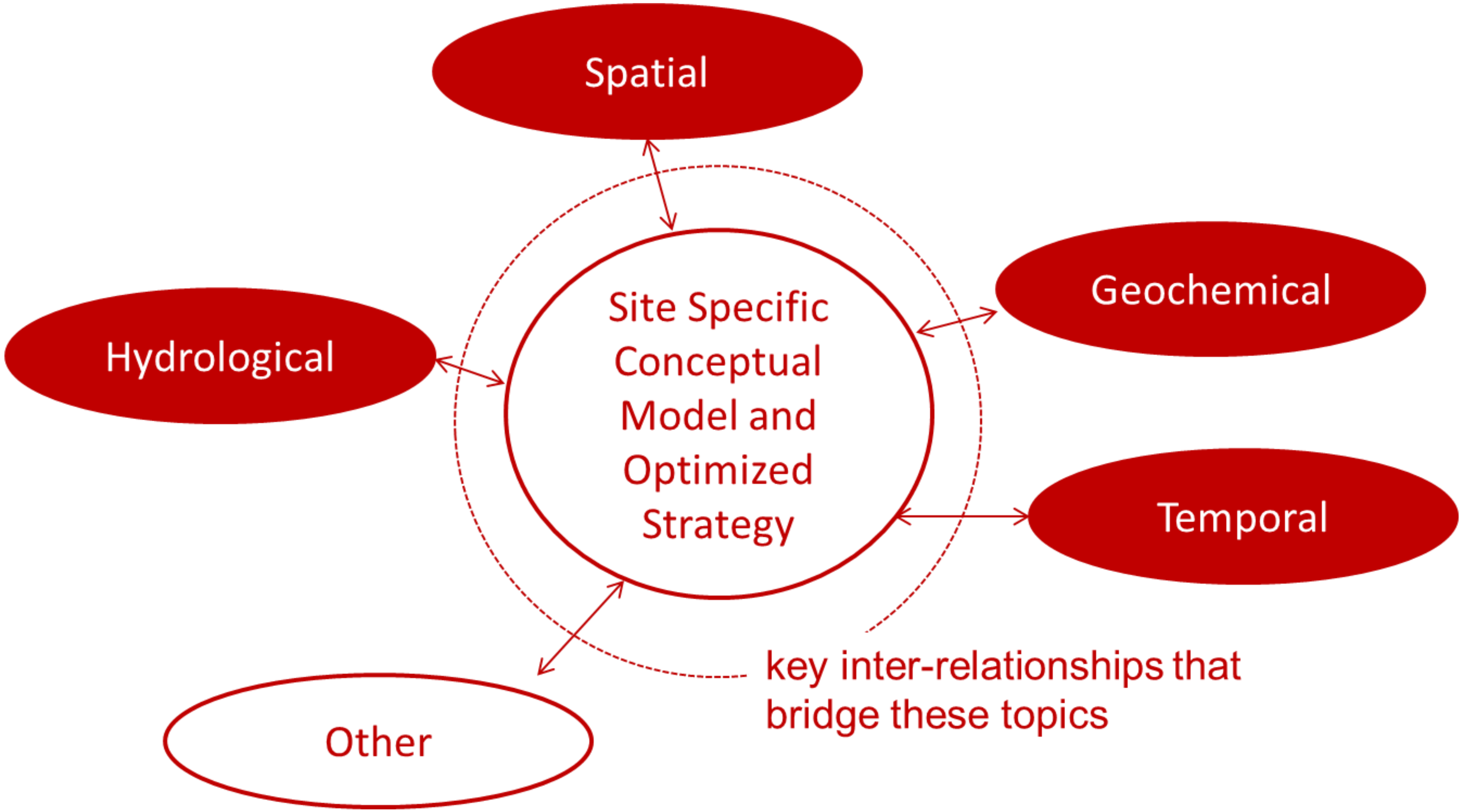
Begin With What You Know
- **Nature of source**
- **Contaminant distribution**
- **Bio-Geo-Chemical conditions of plume**
- **Background Bio-Geo-Chemical conditions**
- **Geological system and Hydrology**
- **General contaminant chemistry**

We often know 90% of what we need to know for Environmental Management Success

Focus on specific challenging or "intractable" problems & site-specific solutions

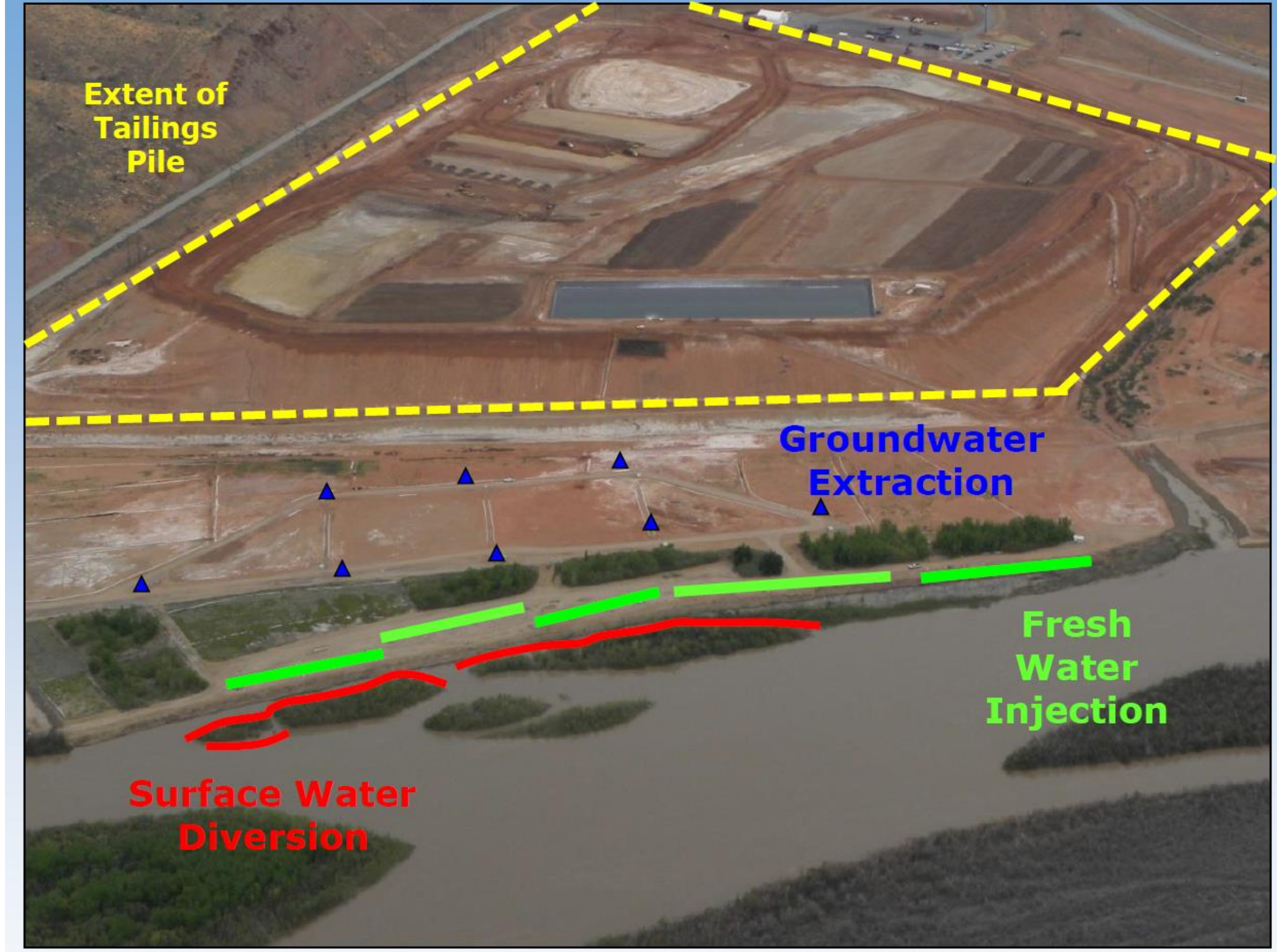
Leverage existing knowledge with key science concepts to improve the effectiveness of DOE's environmental investments

Technical Frameworks



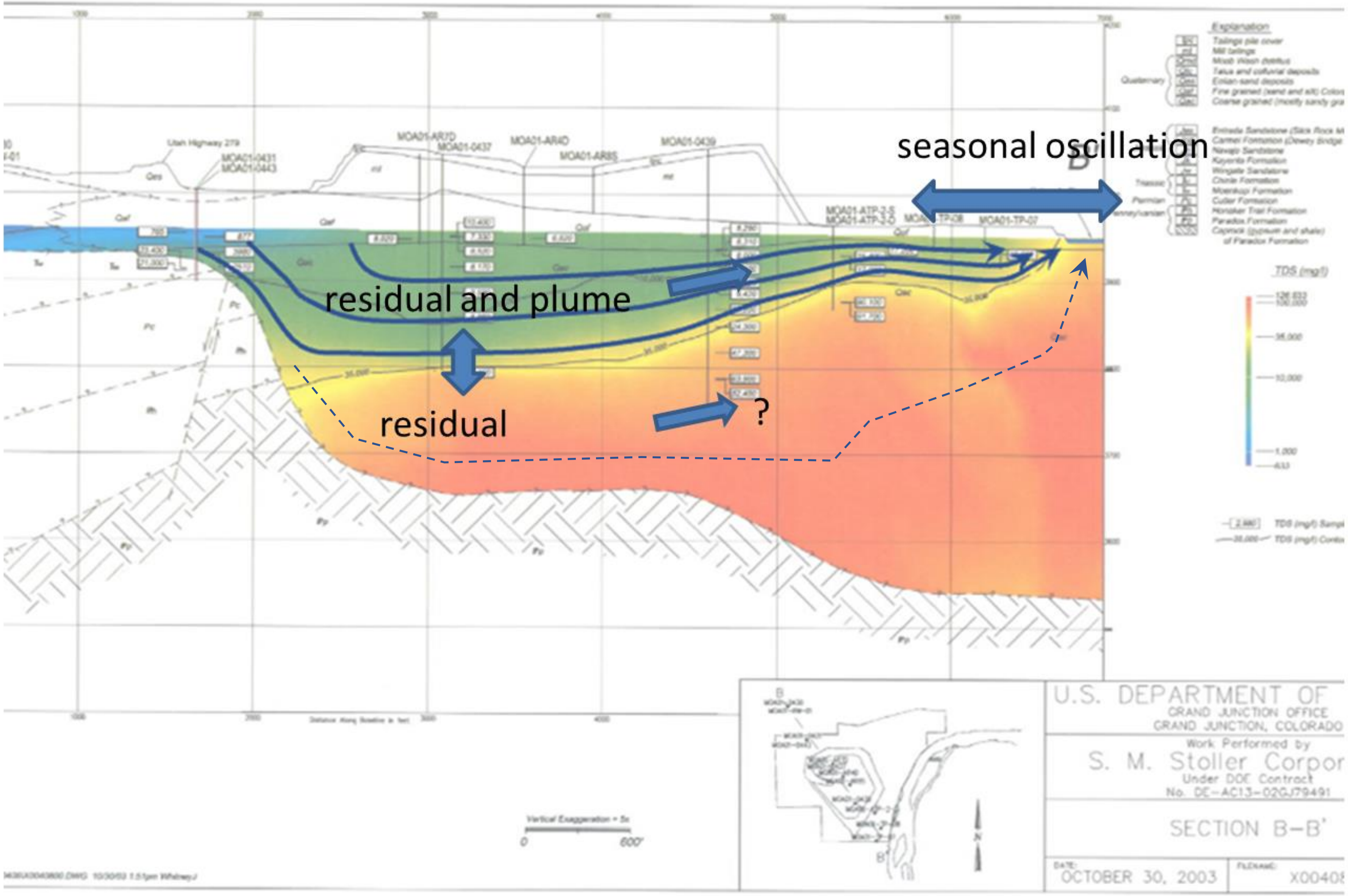
Organize information into technical frameworks and a usable conceptual model that helps identify areas of opportunity

Groundwater Interim Action



- **Groundwater Contaminant Mass Removal**
  - **Groundwater Extraction System** pumps groundwater from the aquifer near base of the tailings
  - Dust control in CA
  - Especially useful during drought conditions
- **Suitable Habitat Protection**
  - **Fresh Water Injection System** has the capability to inject diverted Colorado River water into 34 injection wells along the riverbank
  - **Surface Water Diversion System (Initial Action)** delivers fresh water into side channel to reduce ammonia concentrations

Spatial Zones – Conceptual Model



Network of National Laboratories for NNLEMS Environmental Management and Stewardship

Team 1 – GCAP Topics → Key Recommendations

Consider Adaptive Site Management Strategy (Complex Sites Paradigm)

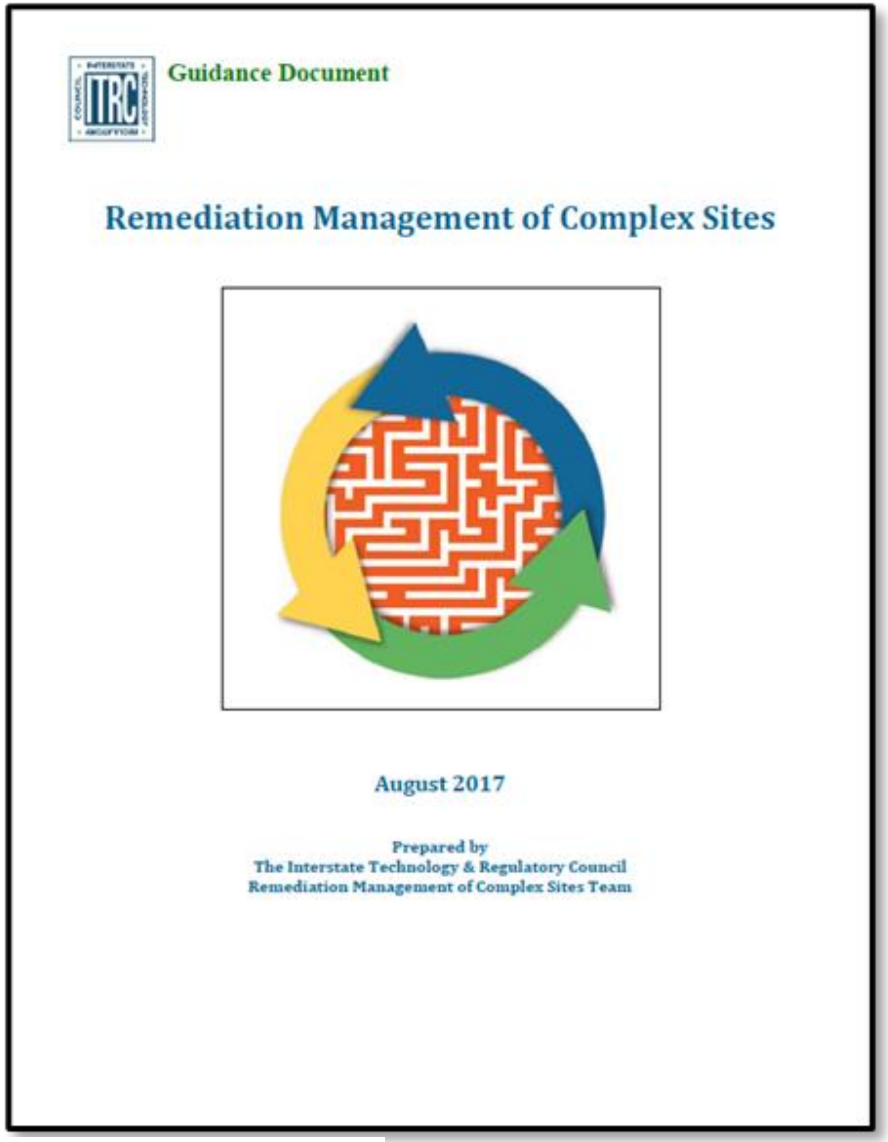
Refine biological impact assessment (factors) for Colorado River protection (if appropriate -- new ammonium standards, biotic ligand models, etc.)

Document Site-Specific GCAP Targets to protect Colorado River and meet stakeholder needs/expectations

Team 1 – GCAP Topics → Challenges at "Complex Sites"

Standard GCAP/Regulatory Strategy:
Linear "study, select, design, build, and operate" paradigm.

Emerging Management Strategy:
For Complex Sites, years of experience has led to the recognition that the **uncertainty inherent in environmental cleanup** requires a combined remedy, flexibility/responsiveness, and a plan to transition as site moves toward closure


Guidance Document

Remediation Management of Complex Sites

August 2017

Prepared by
The Interstate Technology & Regulatory Council
Remediation Management of Complex Sites Team

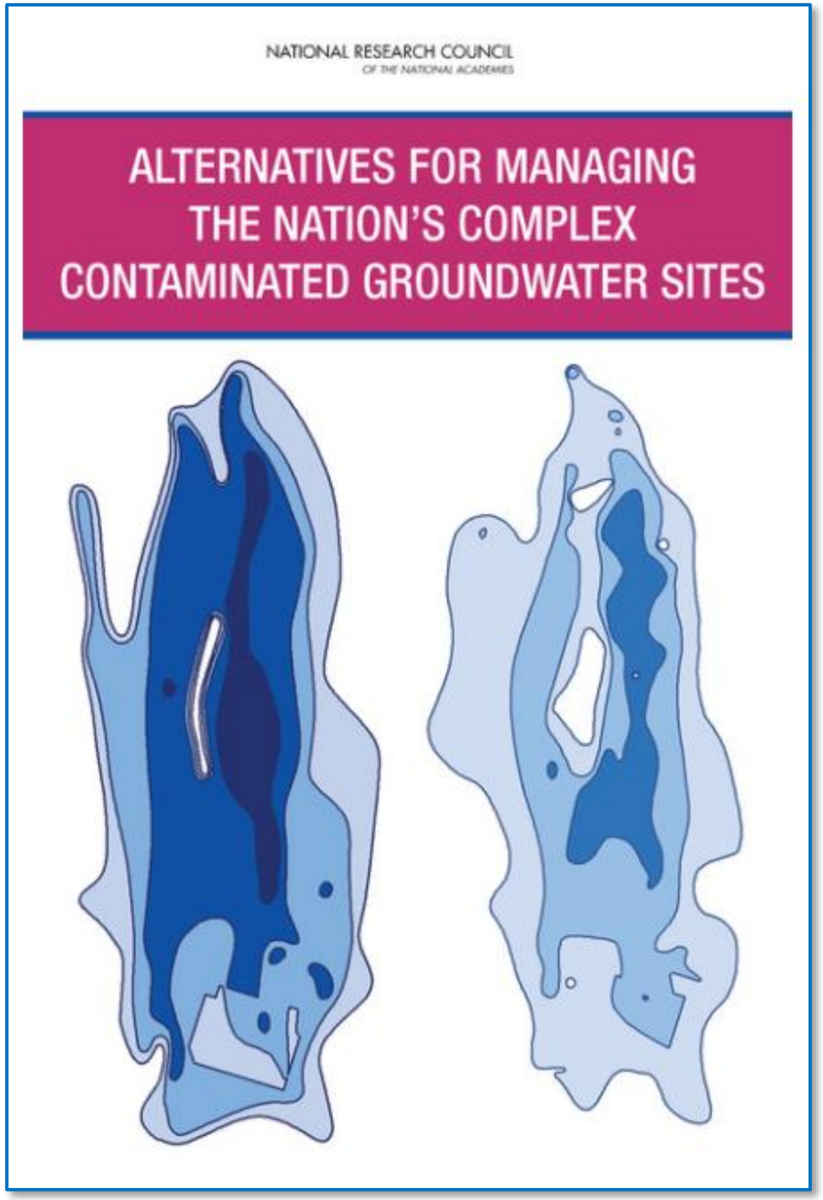
Complex Sites: History and Lessons Learned

Observations:

- Achieving MCLs throughout the aquifer unlikely at most complex groundwater sites in a time frame of 50-100 years.
- Individual technologies are generally not effective at addressing the different target zones within the contaminant plume

Most Effective Solution:

- Developed a combined remedy where technologies are optimally used to address key sub-objectives or target contamination zones
- Use interim and sequenced technologies in an organized and strategic manner – adjust based on performance metrics
- Adaptive Site Management



Adaptive Site Management

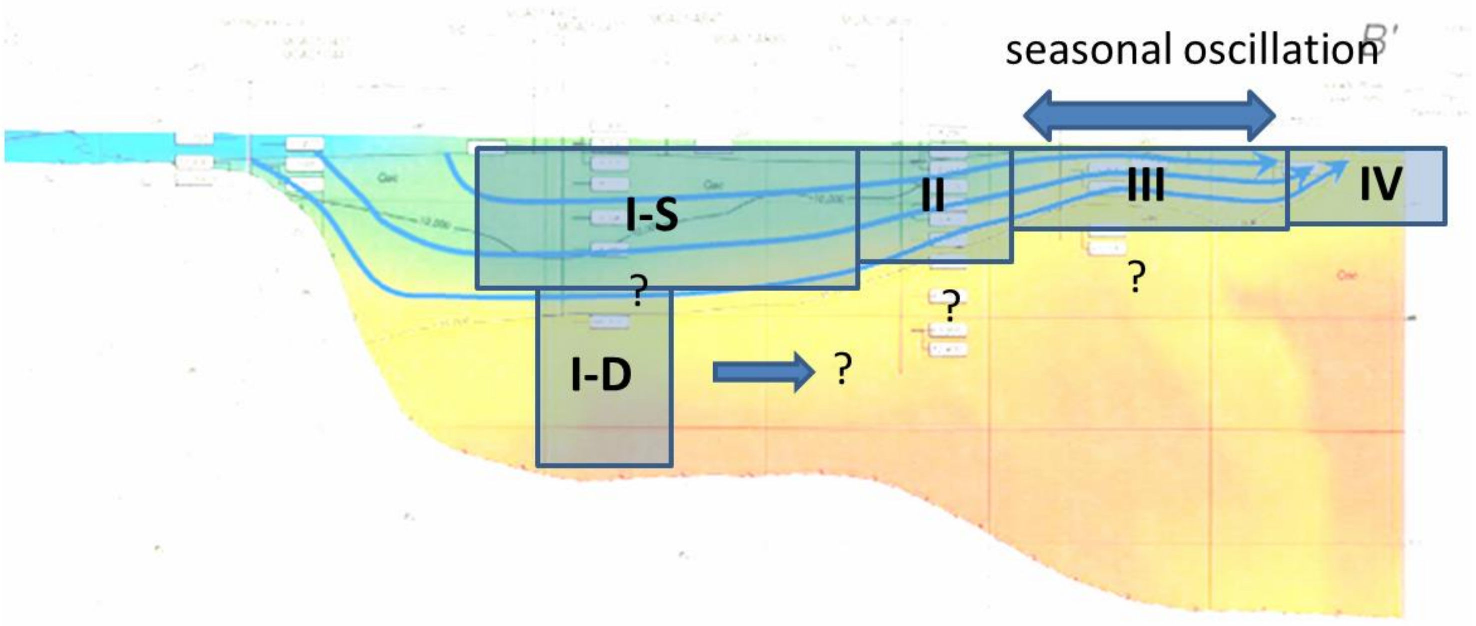
Adaptive Site Management definition –

- **A phased remediation where each phase has clear, measurable and achievable objectives**
- **The progression is timed so that data gaps are resolved, and modeling is enhanced to support implementation of the next phase(s) of activity**
- **Progression recognizes that sites and plumes evolve and that leading edge and trailing edge processes need to be understood and be factored into the planning**

Adaptive Site Management demonstrates a bias for action – encouraging steady progress toward end state

Key Point

Spatial Zones – Conceptual Model Overlay



I-S	Residual Source Zone (shallow)
I-D	Residual Source Zone (deep/brine)
II	Transition Zone
III	River Protection Buffer Zone
IV	River Management Zone

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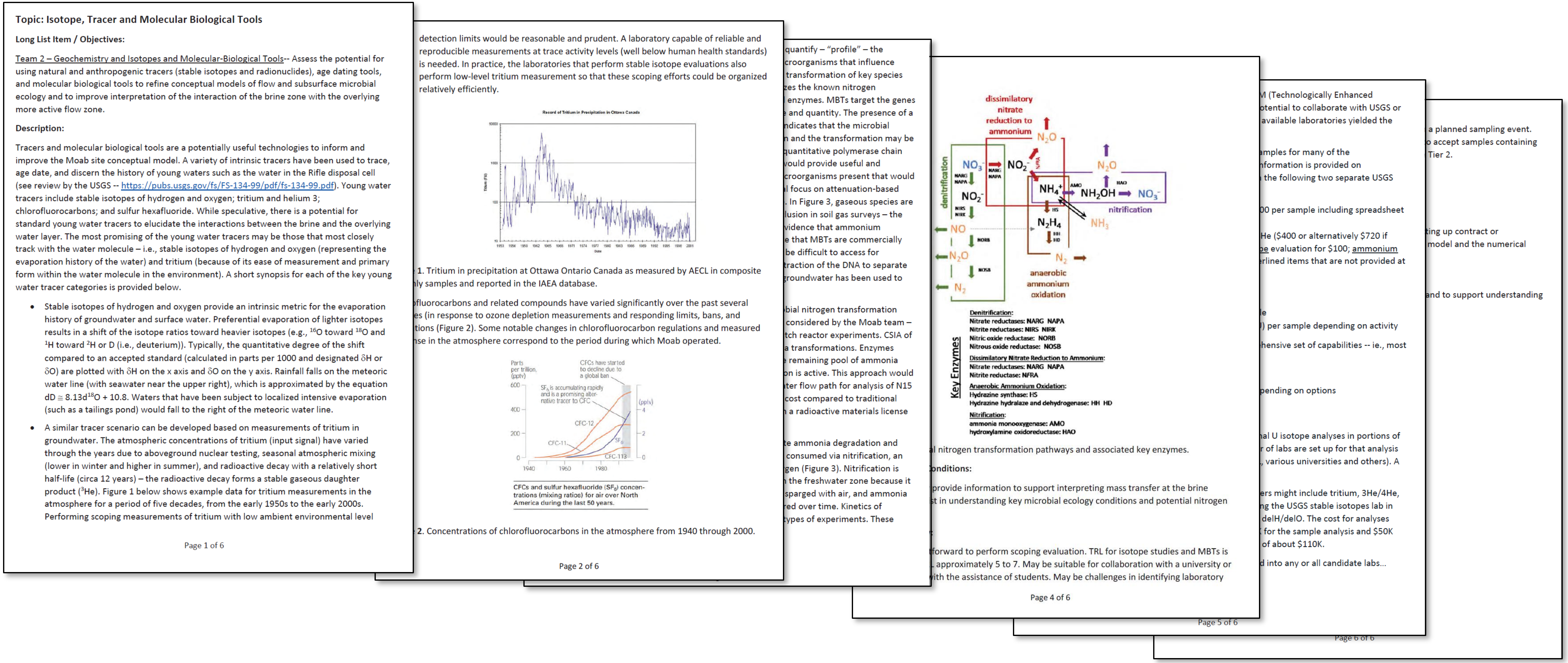
Team 2 – Data Gaps, Characterization and Monitoring → Key Recommendations

- **Refine Modeling** with focus on contaminant release and responses to potential GCAP actions
  - Conceptual, numerical and analytic models that account for brine interface and mass transfer, groundwater surface water interactions, and residual sources in the vadose zone
  - (Seven specific recommended activities)
- **Other**
  - Soil Gas Surveys
  - River sediment pore water sampling and geophysics
  - Groundwater age dating, isotopes and tracer/indicator measurements
  - Geochemical modeling (e.g., U solubility and brine interface)
  - (13 specific recommended activities)

Team 2 – Narratives → Key Recommendations



Topic: Isotope, Tracer and Molecular Biological Tools

Long List Item / Objectives:

Team 2 – Geochemistry and Isotopes and Molecular-Biological Tools-- Assess the potential for using natural and anthropogenic tracers (stable isotopes and radionuclides), age dating tools, and molecular biological tools to refine conceptual models of flow and subsurface microbial ecology and to improve interpretation of the interaction of the brine zone with the overlying more active flow zone.

Description:

Tracers and molecular biological tools are a potentially useful technologies to inform and improve the Moab site conceptual model. A variety of intrinsic tracers have been used to trace, age date, and discern the history of young waters such as the water in the Rifle disposal cell (see review by the USGS -- https://pubs.usgs.gov/fs/FS-134-99/pdf/fs-134-99.pdf). Young water tracers include stable isotopes of hydrogen and oxygen; tritium and helium 3; chlorofluorocarbons; and sulfur hexafluoride. While speculative, there is a potential for standard young water tracers to elucidate the interactions between the brine and the overlying water layer. The most promising of the young water tracers may be those that most closely track with the water molecule – i.e., stable isotopes of hydrogen and oxygen (representing the evaporation history of the water) and tritium (because of its ease of measurement and primary form within the water molecule in the environment). A short synopsis for each of the key young water tracer categories is provided below.

- Stable isotopes of hydrogen and oxygen provide an intrinsic metric for the evaporation history of groundwater and surface water. Preferential evaporation of lighter isotopes results in a shift of the isotope ratios toward heavier isotopes (e.g., ^{16}O toward ^{18}O and ^{1}H toward ^{2}H or D (i.e., deuterium)). Typically, the quantitative degree of the shift compared to an accepted standard (calculated in parts per 1000 and designated δH or δO) are plotted with δH on the x axis and δO on the y axis. Rainfall falls on the meteoric water line (with seawater near the upper right), which is approximated by the equation dD $\cong 8.13d^{18}O + 10.8$. Waters that have been subject to localized intensive evaporation (such as a tailings pond) would fall to the right of the meteoric water line.
- A similar tracer scenario can be developed based on measurements of tritium in groundwater. The atmospheric concentrations of tritium (input signal) have varied through the years due to aboveground nuclear testing, seasonal atmospheric mixing (lower in winter and higher in summer), and relatively short half-life (circa 12 years) – the radioactive decay forms a stable gaseous daughter product (^{3}He). Figure 1 below shows example data for tritium measurements in the atmosphere for a period of five decades, from the early 1950s to the early 2000s. Performing scoping measurements of tritium with low ambient environmental level

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detection limits would be reasonable and prudent. A laboratory capable of reliable and reproducible measurements at trace activity levels (well below human health standards) is needed. In practice, the laboratories that perform stable isotope evaluations also perform low-level tritium measurement so that these scoping efforts could be organized relatively efficiently.

Record of Tritium in Precipitation in Ottawa Canada

1. Tritium in precipitation at Ottawa Ontario Canada as measured by AECL in composite
ly samples and reported in the IAEA database.

fluorocarbons and related compounds have varied significantly over the past several
es (in response to ozone depletion measurements and responding limits, bans, and
tions (Figure 2). Some notable changes in chlorofluorocarbon regulations and measured
se in the atmosphere correspond to the period during which Moab operated.

CFCs and sulfur hexafluoride (SF_6) concentrations (mixing ratios) for air over North America during the last 50 years.

2. Concentrations of chlorofluorocarbons in the atmosphere from 1940 through 2000.

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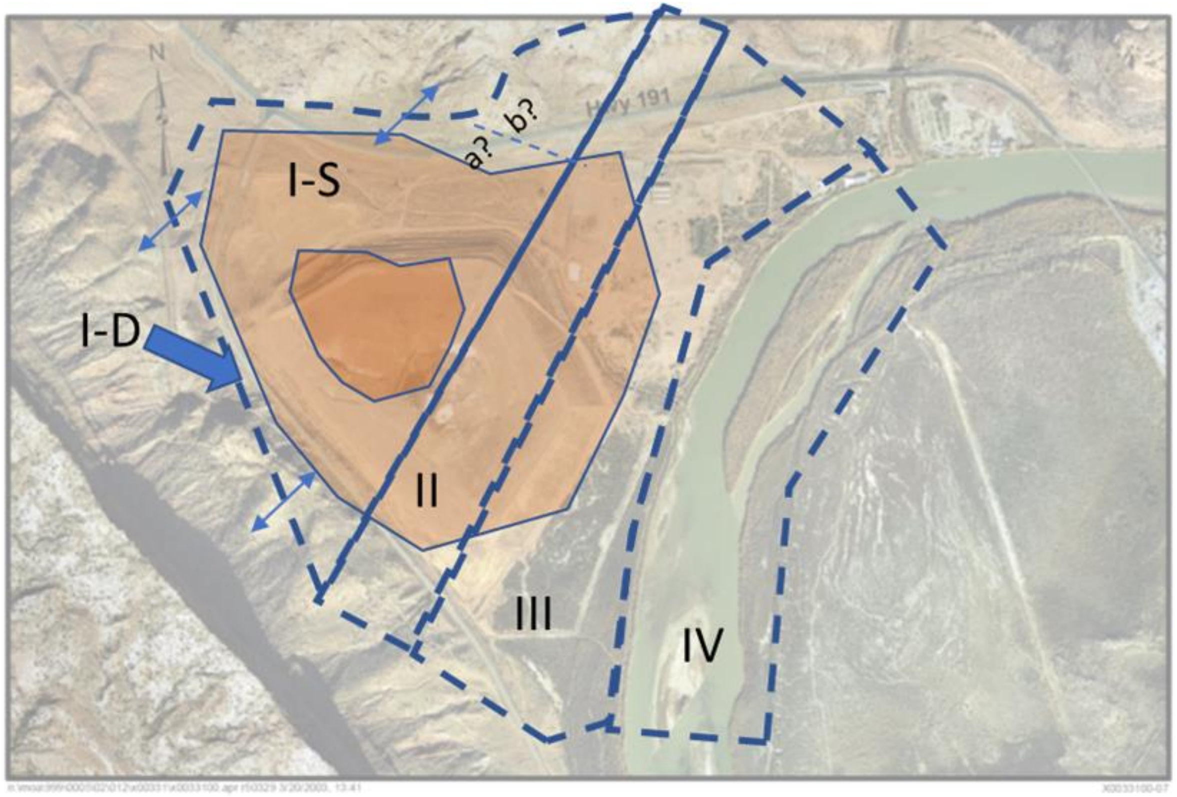
Team 2 – Potential GCAP Portfolio → Key Recommendations

- **Developed Portfolio of Ideas – Menu for future consideration recognizing data gaps need to be sufficiently addressed:**
    - Natural and Enhanced Attenuation
    - Source Zone Capping or Clogging (3 types)
    - In Situ Sequestration (U and ammonium)
    - Blending of Solid Phase Amendments
    - Moab Wash Reconfiguration
    - Permeable Reactive Barrier
    - Limited Pump and Treat

- **Discouraged several concepts**

<u>Spatial</u>/Temporal Zones and Associated Objectives

Notional Example



I-S	Residual Source Zone (shallow)
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Notes – depicted shading is notional and not based on data – it is intended to demonstrate how information on potential residual sources could be leveraged to inform adaptive site management

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2022 Moab Collaboration

- Final report presents a list of overarching consensus statements
- Recommended activities were prioritized near-term and mid-term to support development of an efficient and effective GCAP to facilitate transition to LM or LTM status after tailings removed
- Moab team and DOE EM Office have been proactive in implementing recommendations






Moab UMTRA Project Field Investigations Status Update

Ken Pill

Groundwater Manager

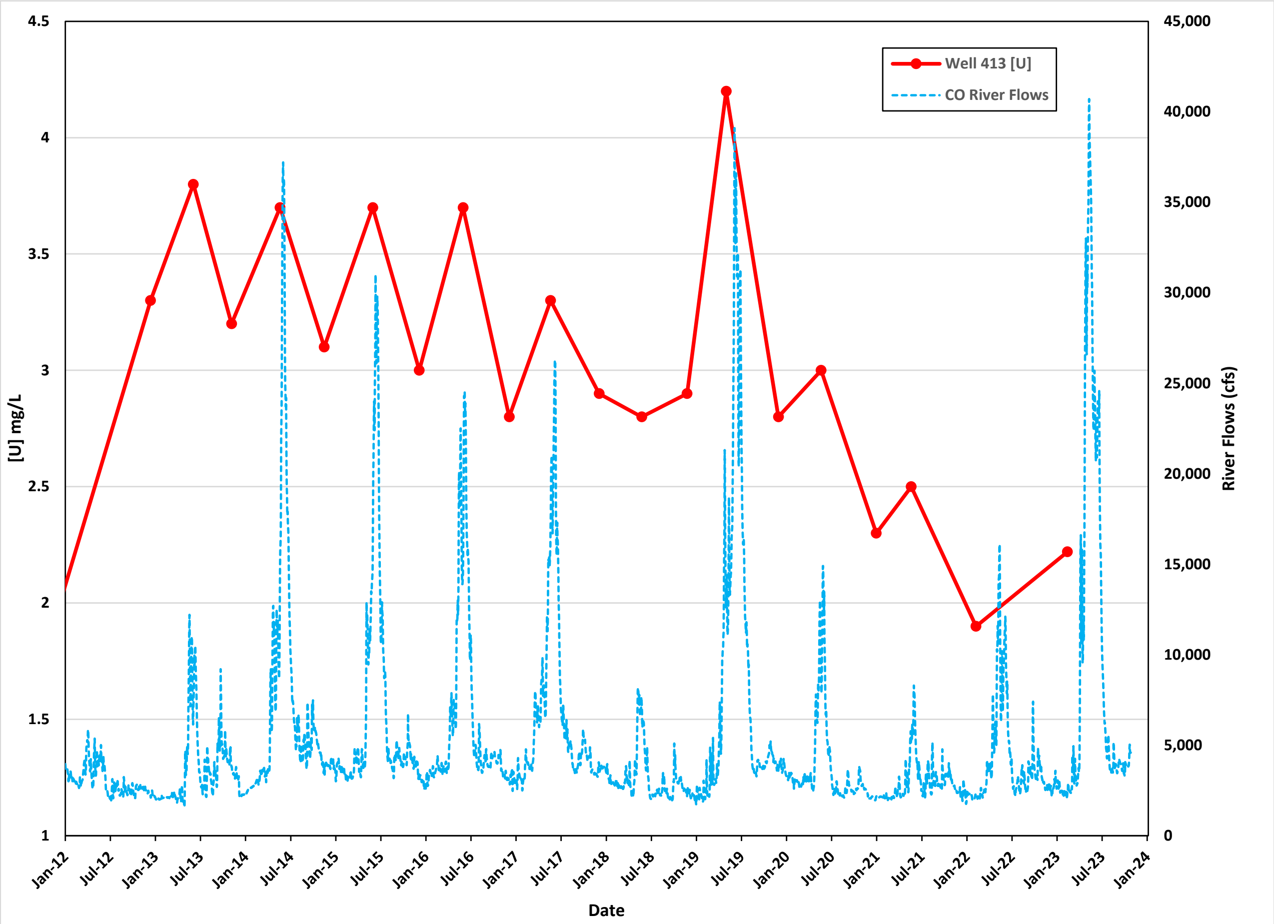
November 15, 2023

Upcoming Investigations

- Based on NNLEMS meetings Sept – Dec 2022
- All identified to address data gaps for a defensible GCAP
  - Hydroxyapatite: Ken Williams, LBNL
  - Secondary Source: Keaton Belli and Jennifer Nyman, Geosyntec
  - Soil Gas: Brian Looney, SRNL
  - Electrical Resistivity Tomography (ERT): Tim Johnson, PNNL
  - Streambed Sampling Investigation: Fred Day-Lewis, PNNL

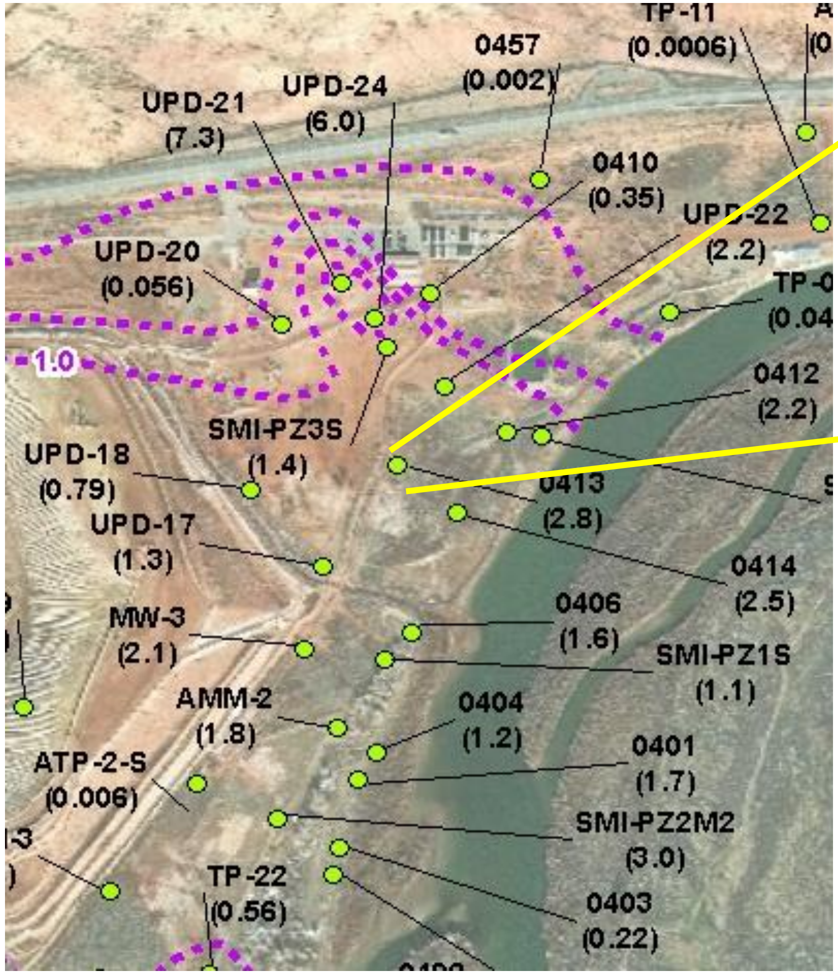
Hydroxyapatite Investigation

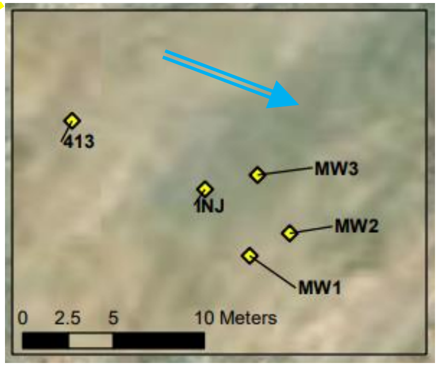
- Proof of principal developed based on Old Rifle Investigation (2017)
- Initiated work in Nov 2021
  - Well 413
  - NE U Plume
  - Outside of active remediation



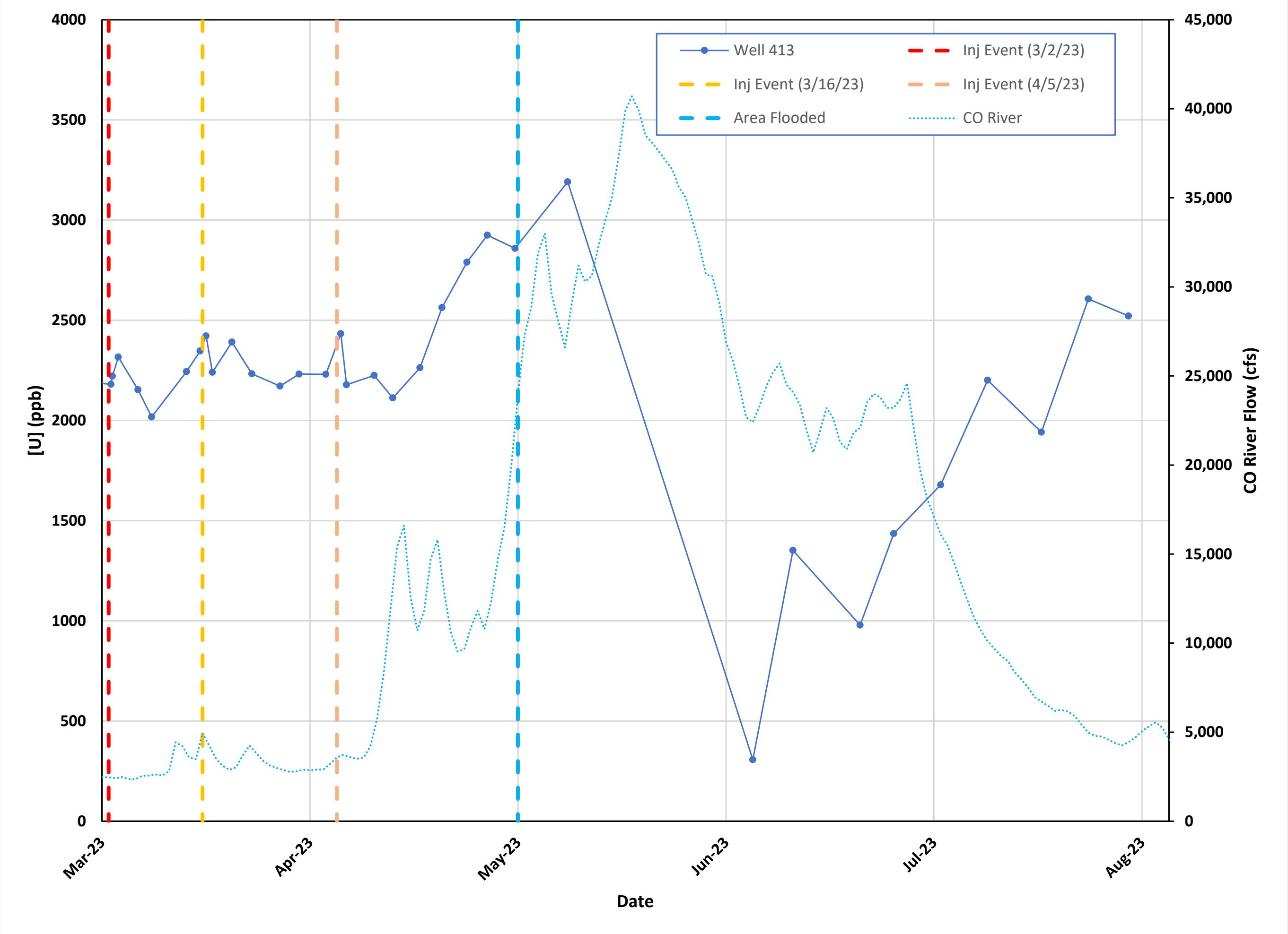
Hydroxyapatite Investigation

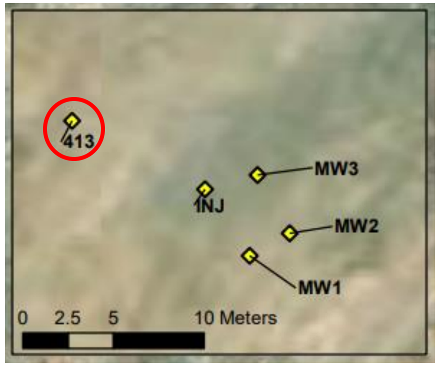
- Initiated work in Nov 2021
  - Tracer Tests (Br, 2 tests)
  - NMR Monitoring (14 events)
    - Dave Walsh (Vista Clara Presentation on Tuesday)
  - Chemical Injection (3 events)
  - Results



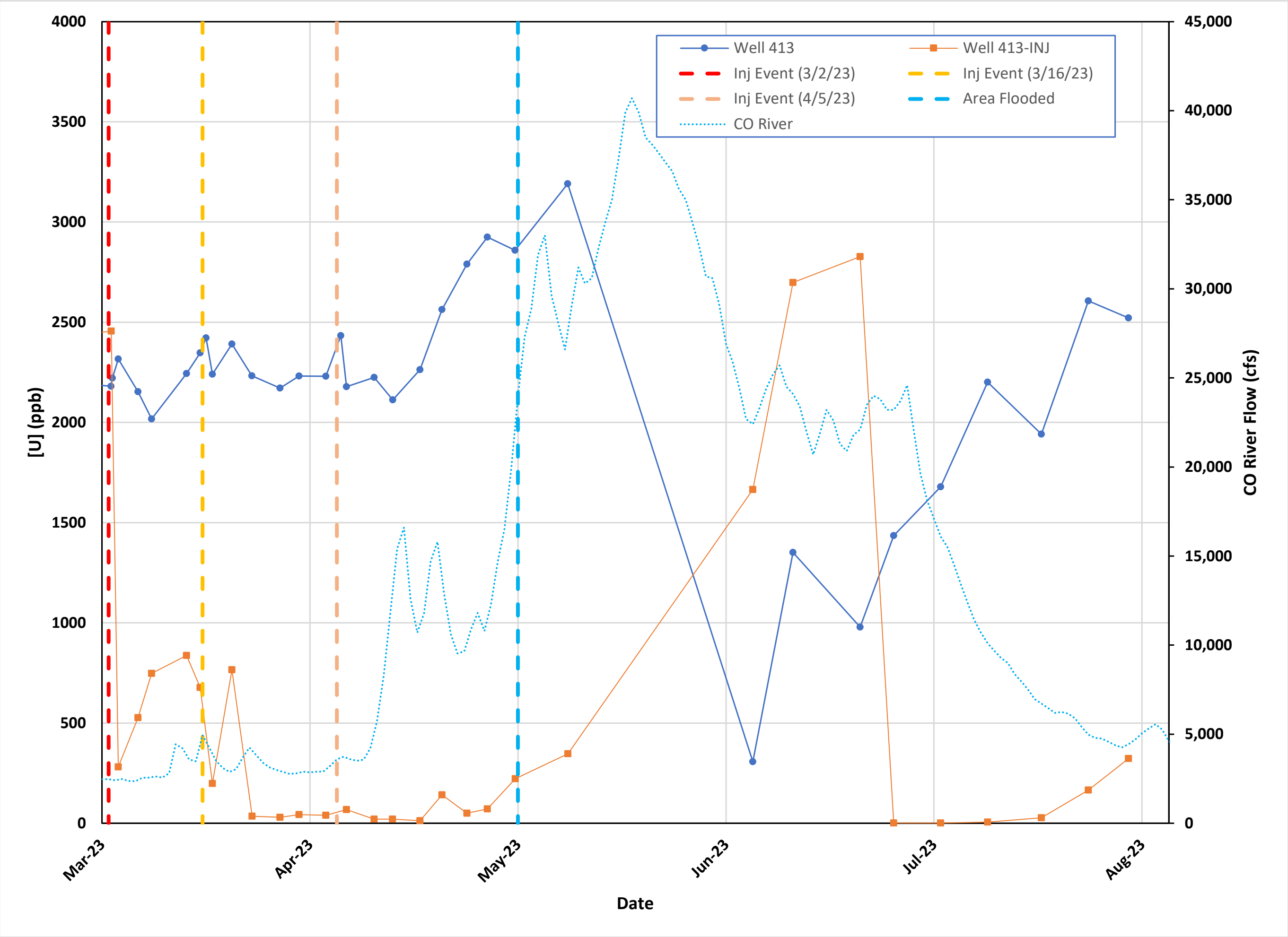


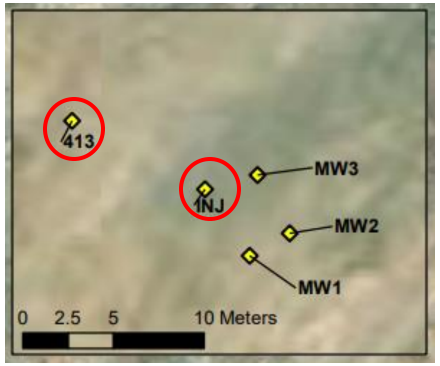
Hydroxyapatite Investigation Results



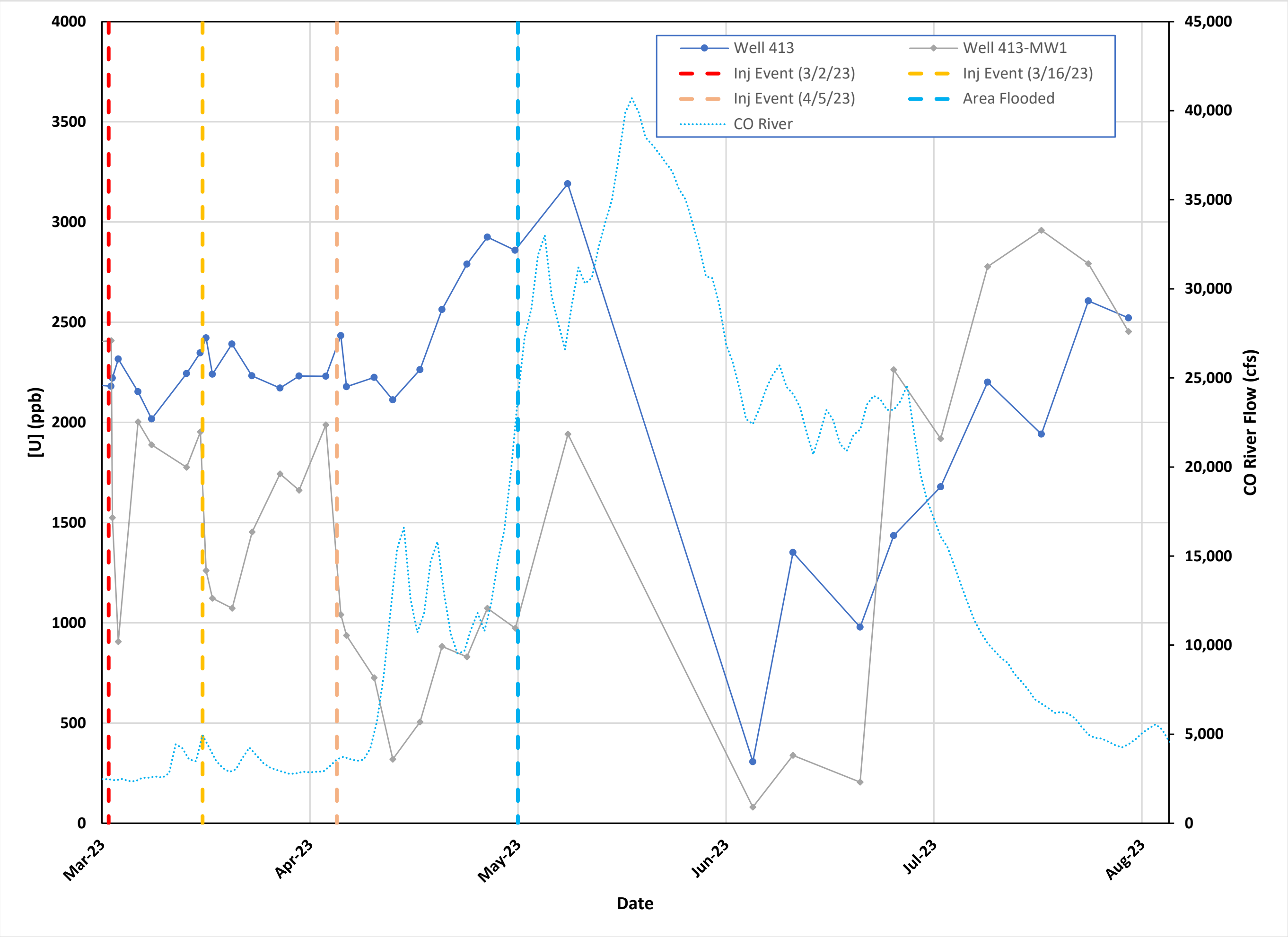


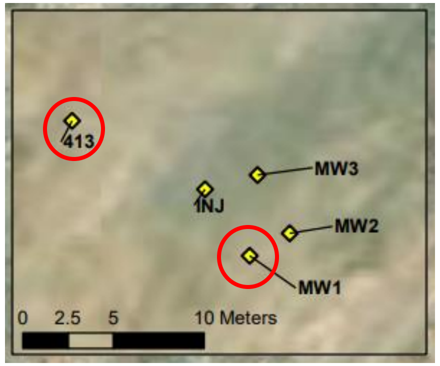
Hydroxyapatite Investigation Results



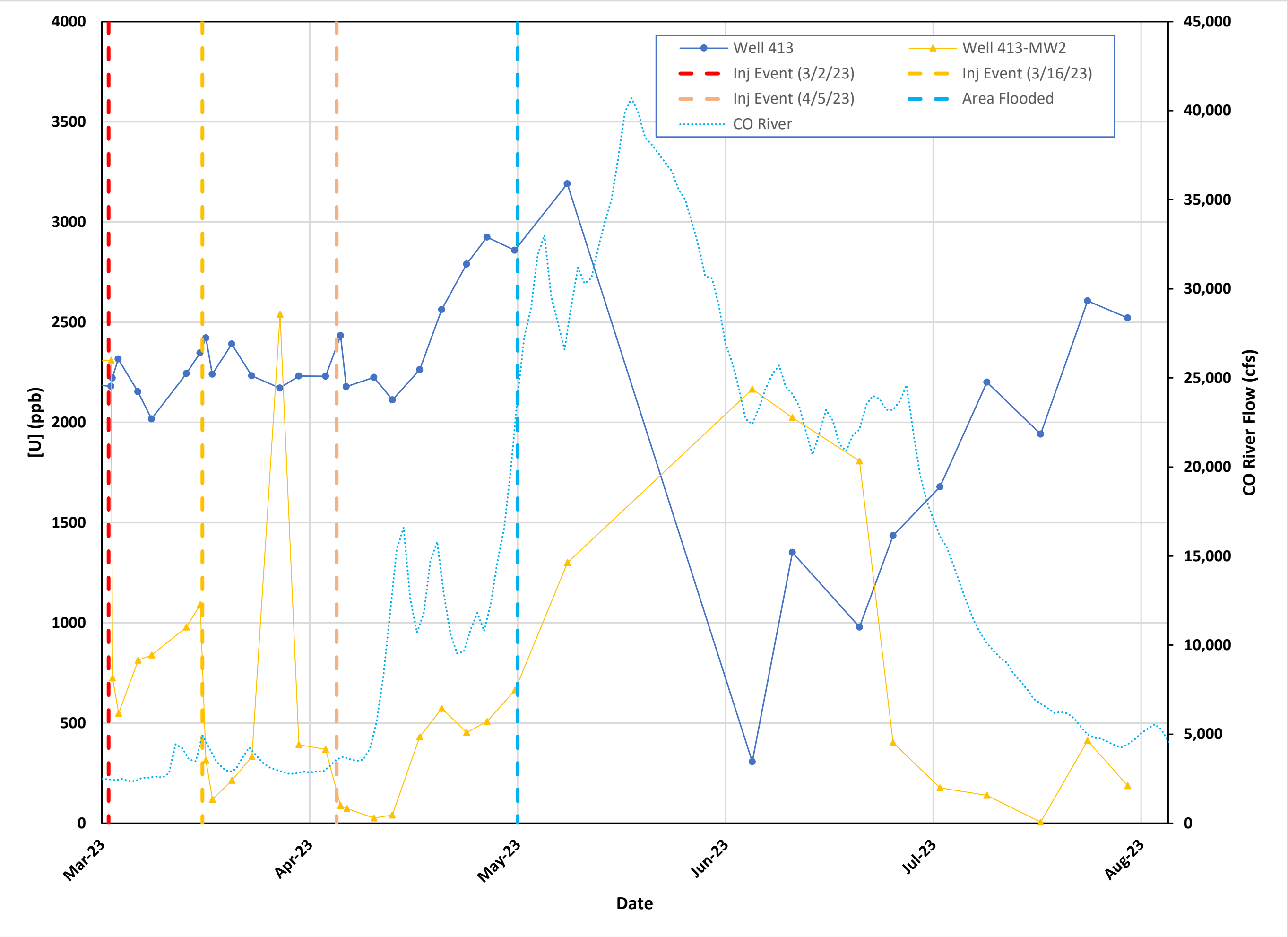


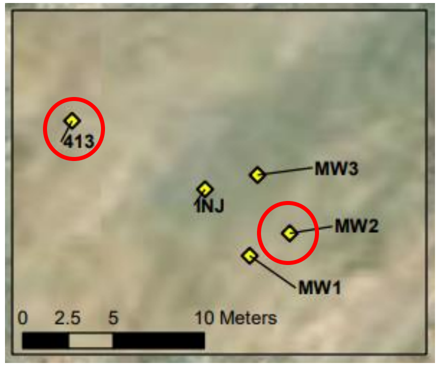
Hydroxyapatite Investigation Results



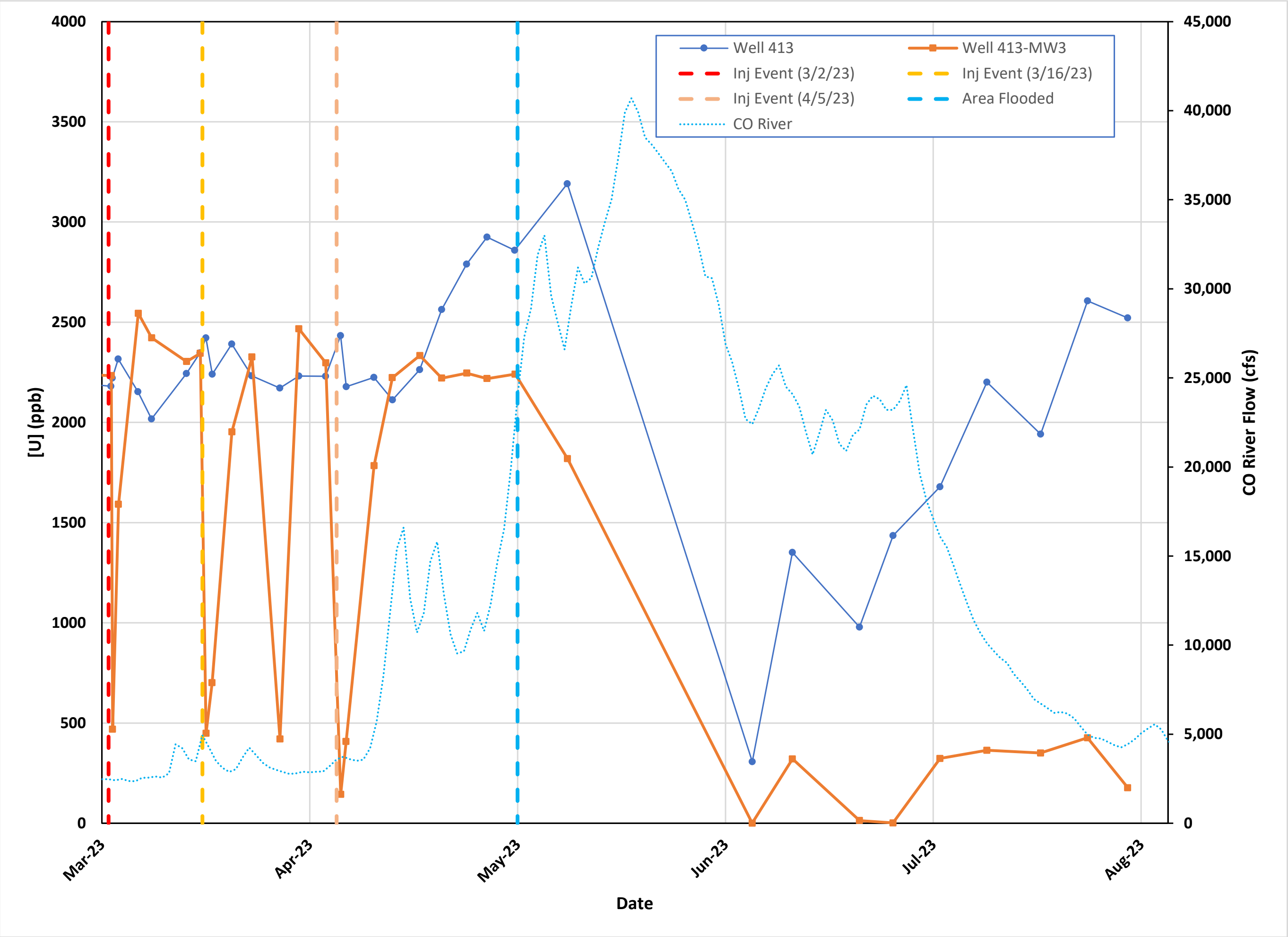


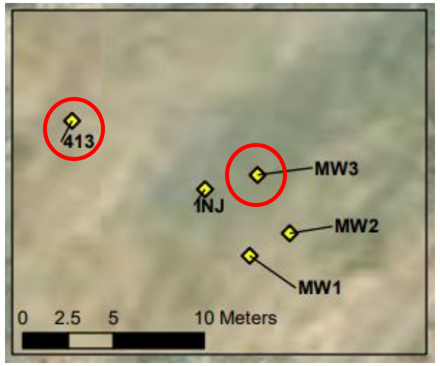
Hydroxyapatite Investigation Results





Hydroxyapatite Investigation Results



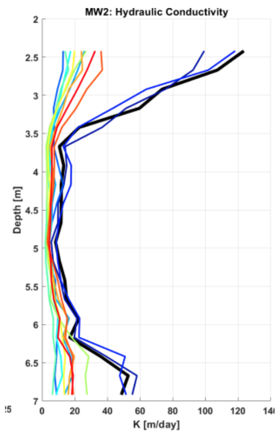


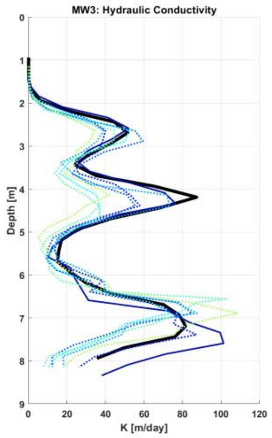
Hydroxyapatite Investigation - Continuation

- Two Proposals Submitted to Continue
  - Hydroxyapatite Extension
    - Impacts of flooding event
    - Ammonia removal through struvite precipitation
  - Geochemical Tracers
    - Groundwater age dating
    - Recharge sources
  - Funding

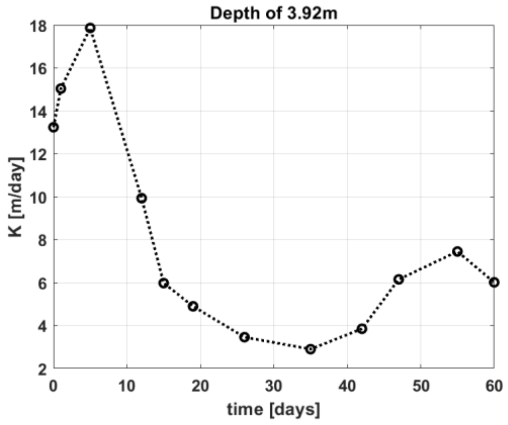
NMR Results

- Completed on 2 of 3 MWs
    - MW2 K response (3.9 m)
        - Decrease in free water content in response to precipitation in pores
        - Decrease in K detected
    - MW3 K response (3.6 m)
        - Some change in K between 4 and 5 m bgs

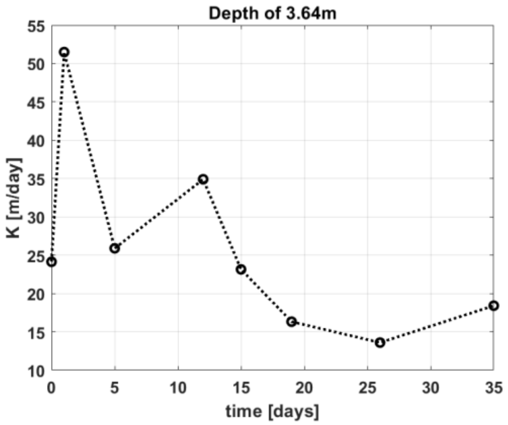




MW2



MW3



Secondary Source Investigation

- Based on recommendation from 2021 Moab Groundwater Summit for GCAP Preparation
  - Batch pore flushing and batch pore flushing model refinements
    - Column studies and batch reactor tests
  - Numerical modeling
    - Remedial time frame prediction under various groundwater remedies
  - Field investigation completed in October 2023

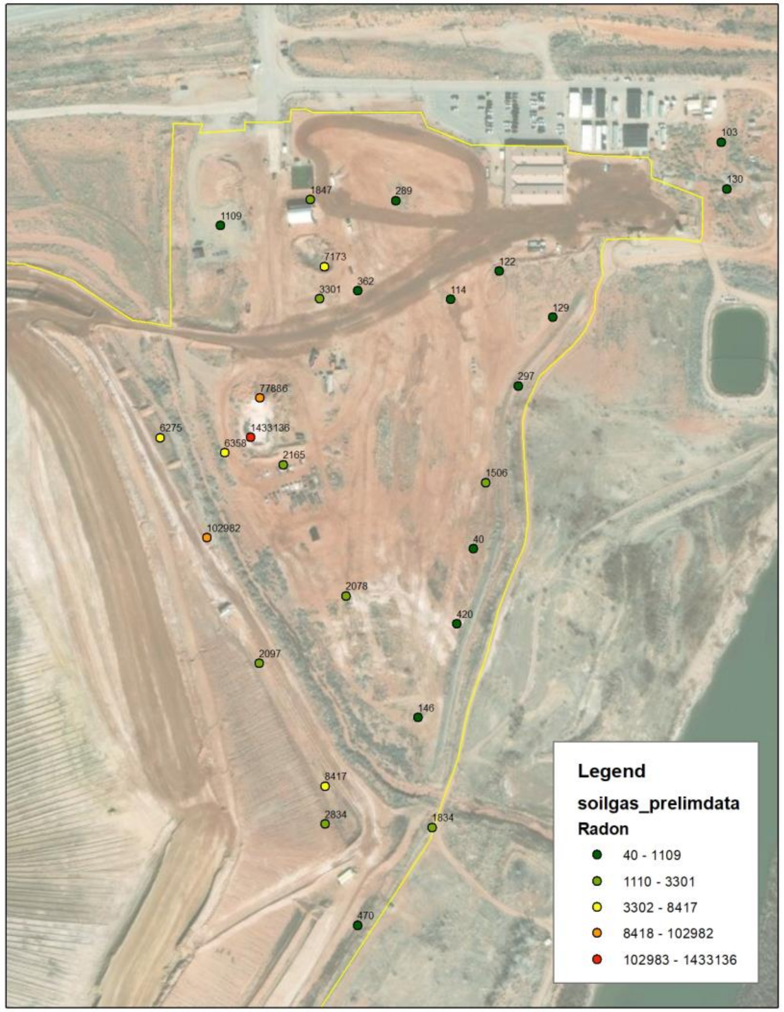
Secondary Source Investigation

- Preliminary data currently received from lab
- Keaton Belli, Jennifer Nyman, and Lisa Burgess (Geosyntec)

Sample ID	Collect Date/Time	Matrix	Result	Unit
Nitrogen, Ammonia				
BH-01-20231002	10/02/23 15:00	GROUND WATER	0.665	MG/L
UPD-18-20231003	10/03/23 10:30	GROUND WATER	192	MG/L
MW-3-20231003	10/03/23 12:35	GROUND WATER	320	MG/L
BH-05-20230927	09/27/23 14:10	GROUND WATER	235	MG/L
BH-04-20230928	09/28/23 10:15	GROUND WATER	116	MG/L
BH-05-2-3FT	09/27/23 08:15	SOIL	32.7	MG/KG
BH-05-9-10FT	09/27/23 08:45	SOIL	8.29	MG/KG
BH-05-14-15FT	09/27/23 08:50	SOIL	22.2	MG/KG
BH-05-24-25FT	09/27/23 10:25	SOIL	118	MG/KG
BH-04-2-3FT	09/27/23 16:05	SOIL	7.14	MG/KG
BH-04-7-8FT	09/28/23 08:10	SOIL	5.48	MG/KG
BH-04-10-11FT	09/28/23 08:30	SOIL	6.30	MG/KG
BH-04-18-19FT	09/28/23 08:45	SOIL	82.5	MG/KG
Uranium				
BH-01-20231002	10/02/23 15:00	GROUND WATER	14.4	UG/L
UPD-18-20231003	10/03/23 10:30	GROUND WATER	667	UG/L
MW-3-20231003	10/03/23 12:35	GROUND WATER	2210	UG/L
BH-05-20230927	09/27/23 14:10	GROUND WATER	593	UG/L
BH-04-20230928	09/28/23 10:15	GROUND WATER	2040	UG/L
BH-05-2-3FT	09/27/23 08:15	SOIL	1870	UG/KG
BH-05-9-10FT	09/27/23 08:45	SOIL	874	UG/KG
BH-05-14-15FT	09/27/23 08:50	SOIL	1250	UG/KG
BH-05-24-25FT	09/27/23 10:25	SOIL	1570	UG/KG
BH-04-2-3FT	09/27/23 16:05	SOIL	580	UG/KG
BH-04-7-8FT	09/28/23 08:10	SOIL	849	UG/KG
BH-04-10-11FT	09/28/23 08:30	SOIL	2110	UG/KG
BH-04-18-19FT	09/28/23 08:45	SOIL	1980	UG/KG

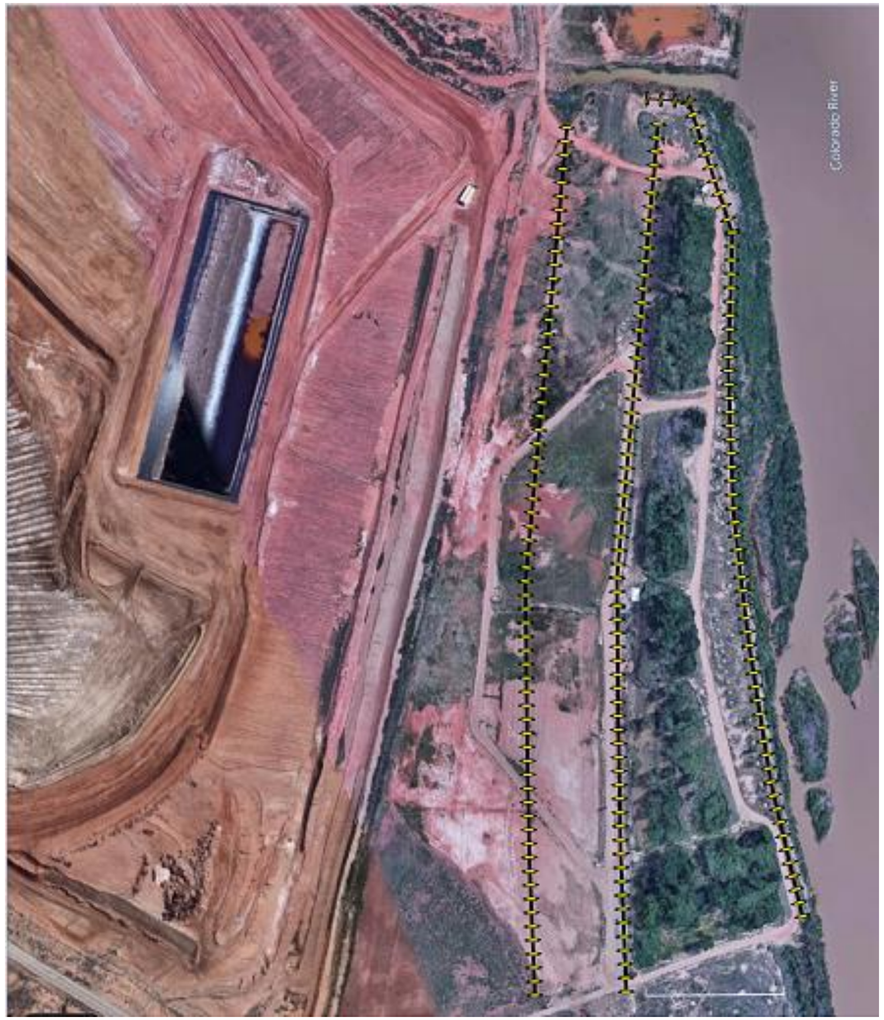
Soil Gas Survey Investigation

- Brian Looney, Holly Vermeulen, and Austin Coleman, SRNL
- Analysis of gas-phase samples to identify and refine secondary contaminant sources in vadose zone and shallow groundwater
  - Both ammonia and uranium
- Field work completed last week



ERT Investigation

- Tim Johnson, PNNL
- Use ERT to image subsurface structure and monitor stage-driven groundwater/surface water interaction
- Scheduled for March 2024



Streambed Sampling Investigation

- Fred Day-Lewis, PNNL
- Perform streambed sampling at multiple depths along one or more transects across the Colorado
  - Assess salinity in pore water
  - Potential flux of groundwater to the river
- Installation of temperature probes to record vertical temperature profiles
- Scheduled for March 2024

QUESTIONS?