

Starting Soon:

An Introduction to Managed Aquifer Recharge (MAR) Training

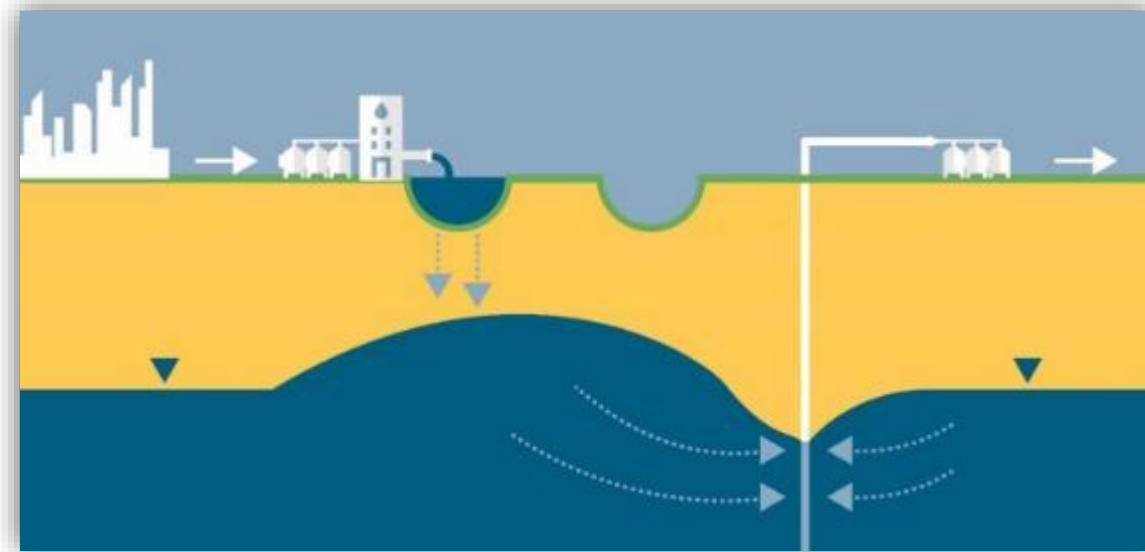
Housekeeping

- ▶ This event is being recorded; Event will be available On Demand after the event at the main training page

<https://clu-in.org/conf/itrc/MAR/>

- If you have technical difficulties, please use the Q&A Pod to request technical support
- ▶ Need confirmation of your participation today?
 - Fill out the online feedback form and check box for confirmation email and certificate

An Introduction to Managed Aquifer Recharge (MAR) (MAR-1, 2023)



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- ▶ Network - States, PR, DC

- ▶ Federal Partners



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- ▶ Academia

- ▶ Community Stakeholders

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Meet the ITRC Trainers



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Oklahoma DEQ
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Oklahoma DEQ
kelsey.bufford@deq.ok.gov

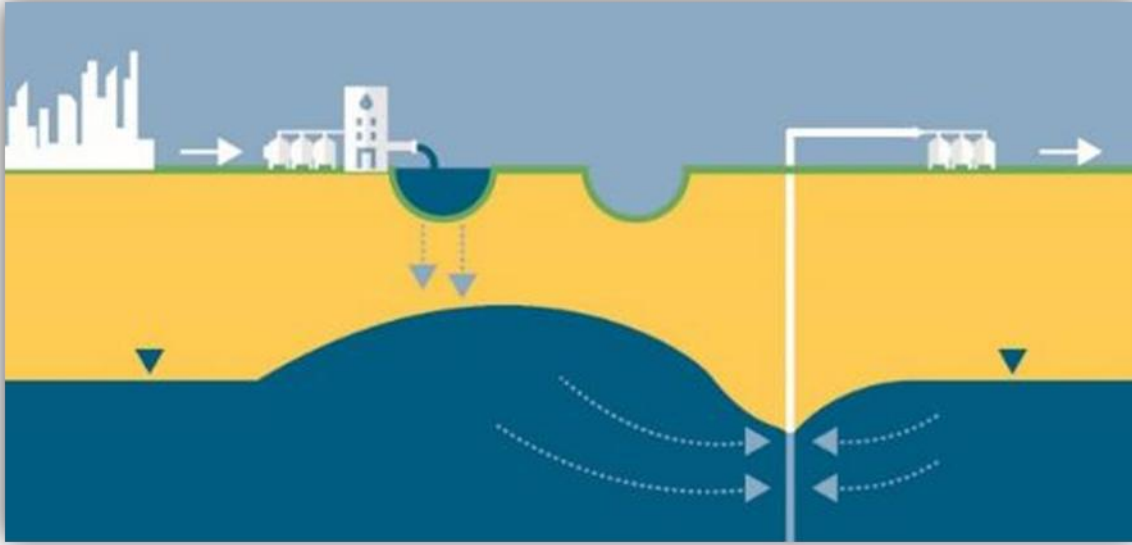


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jdavis@integral-corp.com

Managed Aquifer Recharge (MAR)



What is your level of knowledge/
experience concerning MAR?

- a) None
- b) Limited
- c) Moderate
- d) Expert

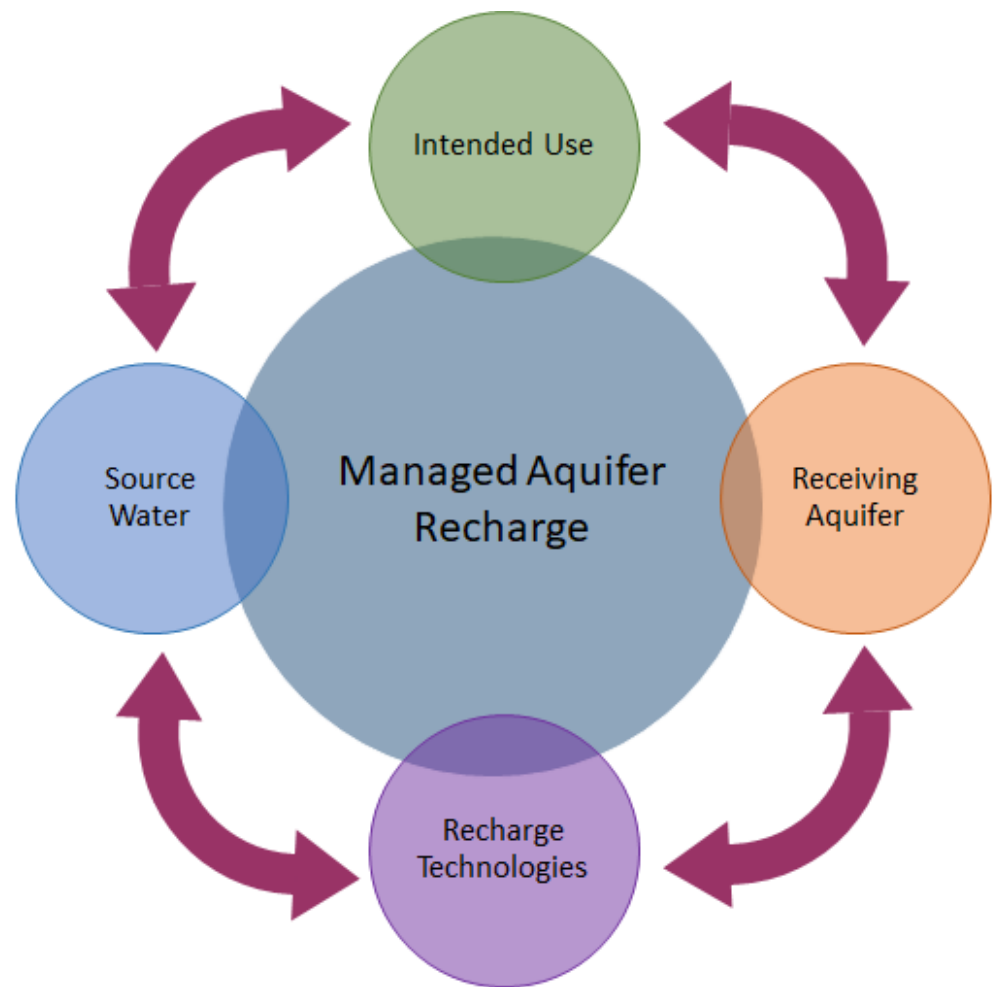


TRAINING OBJECTIVES

- Understand MAR and its applications
- Recognize MAR as a process rather than a technology
- MAR can be widely applied
- MAR's role in the future; addressing water supply resilience and climate impacts

Why MAR?

What is your water challenge?



What do you need to know about source water?

What do you need to know about the Receiving Aquifer?

Which Recharge Technology to select?

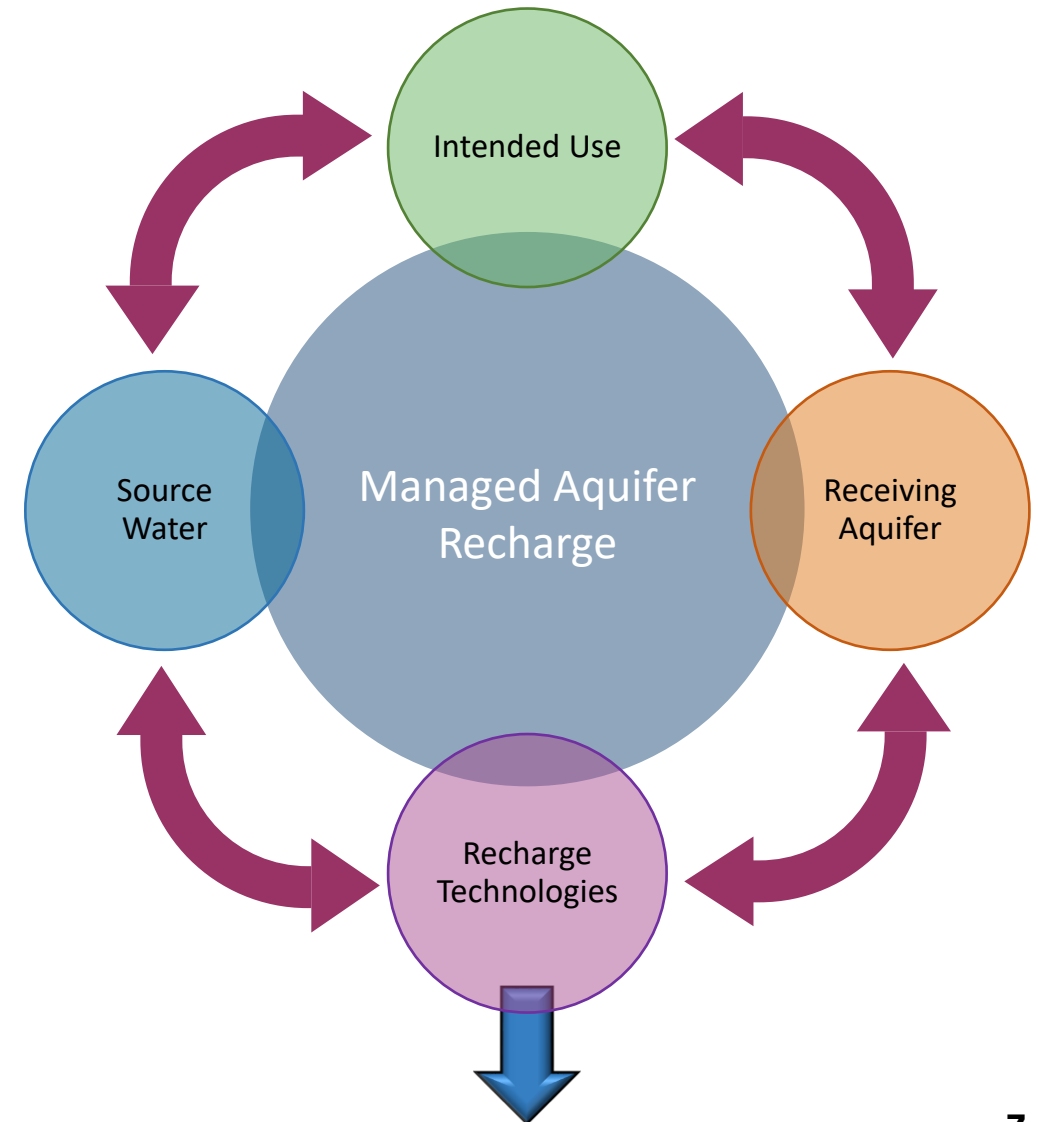
MAR Document Figure 1.1 MAR Process Model – Key Elements



Climate Change Impacts by Sector | US EPA
<https://www.epa.gov/climateimpacts/climate-change-impacts-sector>

Roadmap

- ▶ Introduction
- ▶ Intended Use
 - What is the problem you need to solve?
- ▶ Source Water
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- ▶ Recharge Technologies
 - How to make it happen?
- ▶ Case Study Examples

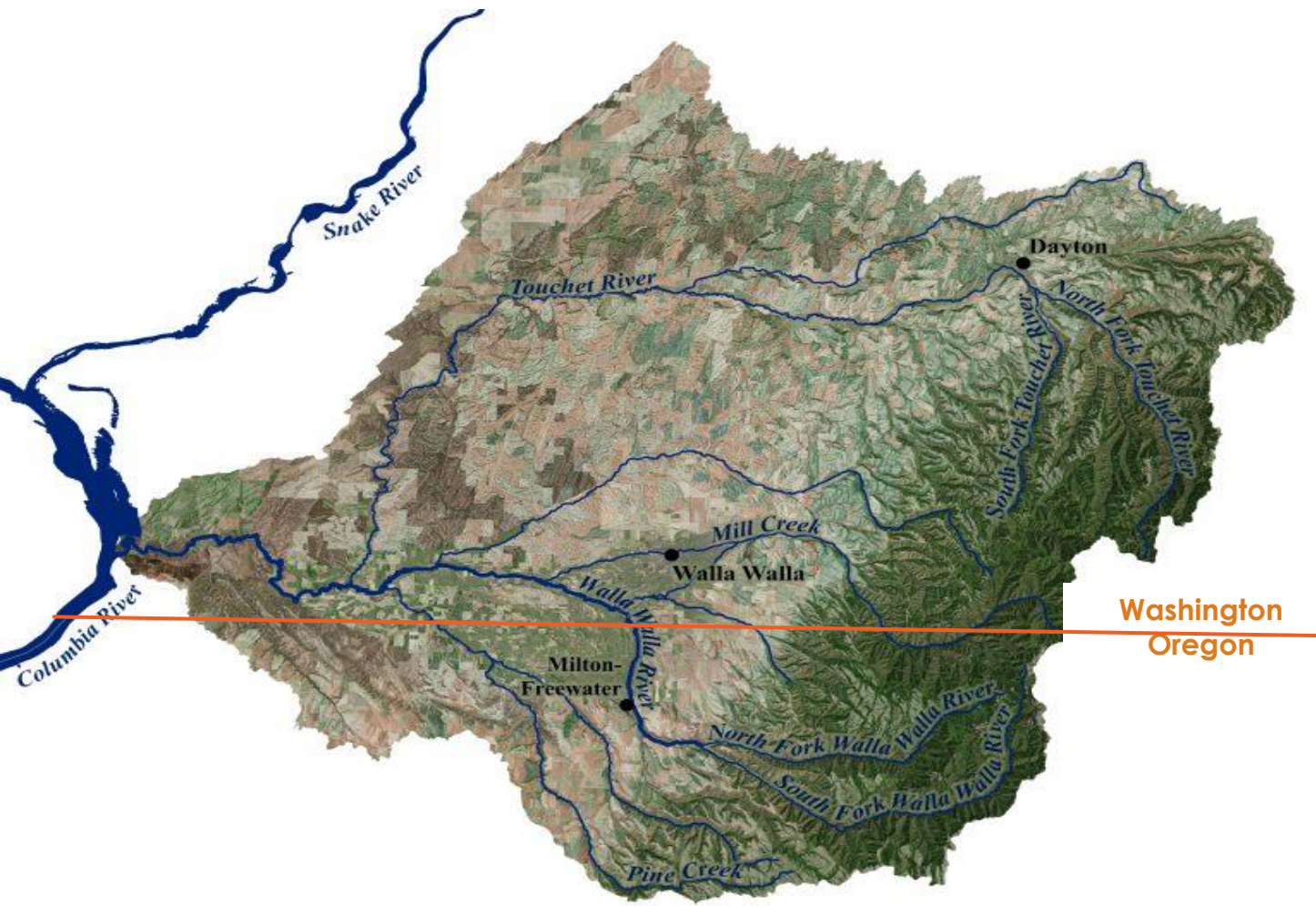
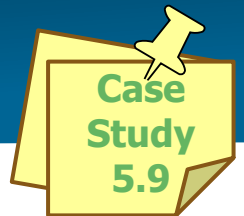


Case Studies



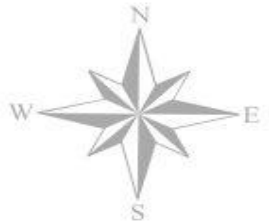
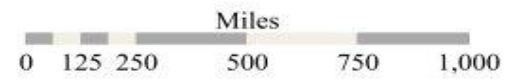
- ▶ 5.1 HRSD Sustainable Water Initiative for Tomorrow (SWIFT) Program; Southeast Virginia
- ▶ 5.2 Reduce the Concentration of Naturally Occurring Arsenic and Other Trace Metals in Recovered Water during Aquifer Storage and Recovery (ASR) Operations; Deland, Florida
- ▶ 5.3 Seawater Intrusion/Replenishment in Southern Los Angeles County; Southern Los Angeles County, California
- ▶ 5.4 San Antonio Water System H2Oaks Center Aquifer Storage and Recovery (ASR) Project; San Antonio, Texas
- ▶ 5.5 Salinas Valley Groundwater Basin; Monterey County, California
- ▶ 5.6 Idaho's Eastern Snake Plain Aquifer MAR Program; Eastern Snake Plain, Idaho
- ▶ 5.7 South Hillsborough Aquifer Recharge Project (Apollo Beach); Hillsborough County, Florida
- ▶ 5.8 Mustang Creek Watershed Dry Well Pilot Study; Merced County, California
- ▶ 5.9 Walla Walla Basin Watershed; Oregon/Washington
- ▶ 5.10 Clark Fork River Basin MAR Modeling; Deer Lodge, Montana
- ▶ 5.11 Army Post Road ASR Well; Des Moines, Iowa
- ▶ 5.12 South Metro Water Supply Authority Regional ASR Groundwater Model Scope of Work; Aurora, Colorado

Walla Walla Basin Watershed



Located in southeast Washington and northeast Oregon

Covers an area of dry land in the rain shadow of the Cascades



Walla Walla River Basin – CTUIR Fish Habitat Restoration Efforts in the Walla Walla River Basin
<https://wallawallariver.org/>

Water Challenges

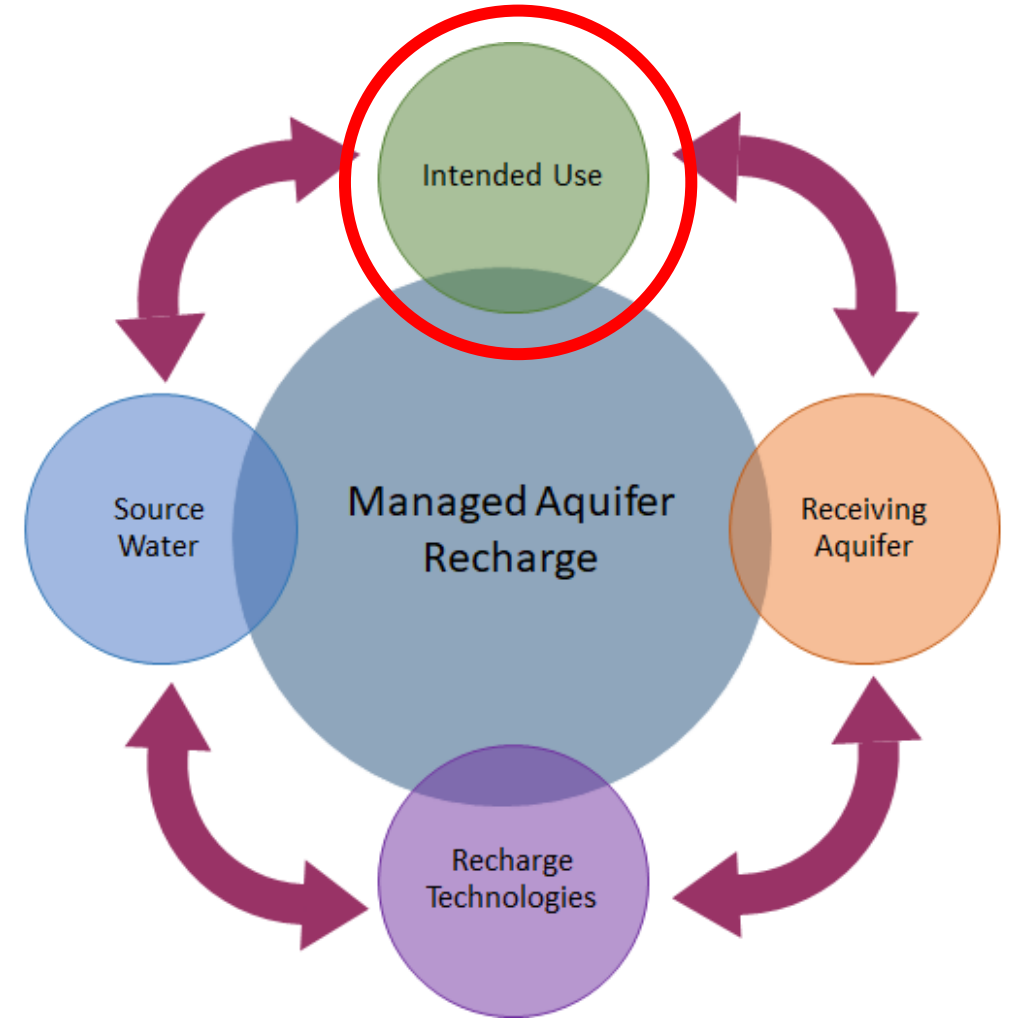
- Increase in development caused water levels to drop
- Insufficient stream flows to support aquatic life
- Loss of floodplain function due to channelization and flood control
- Seepage loss from the river to groundwater



MAR CS 5.9 Figure 2. Average gains or losses in flow of a segment of the Walla Walla River; Source: WWBWC (2017)

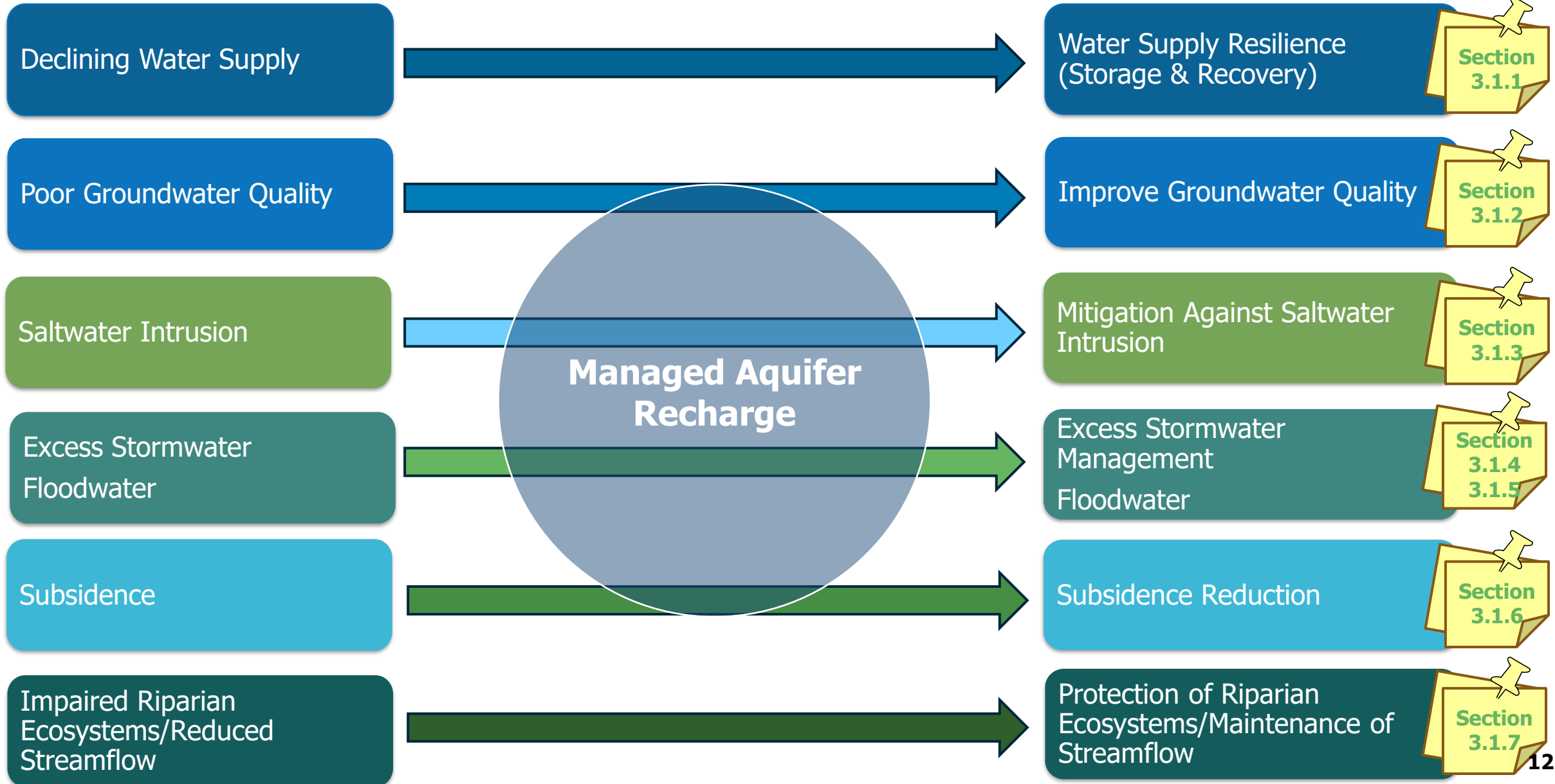
Roadmap

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Water Challenges

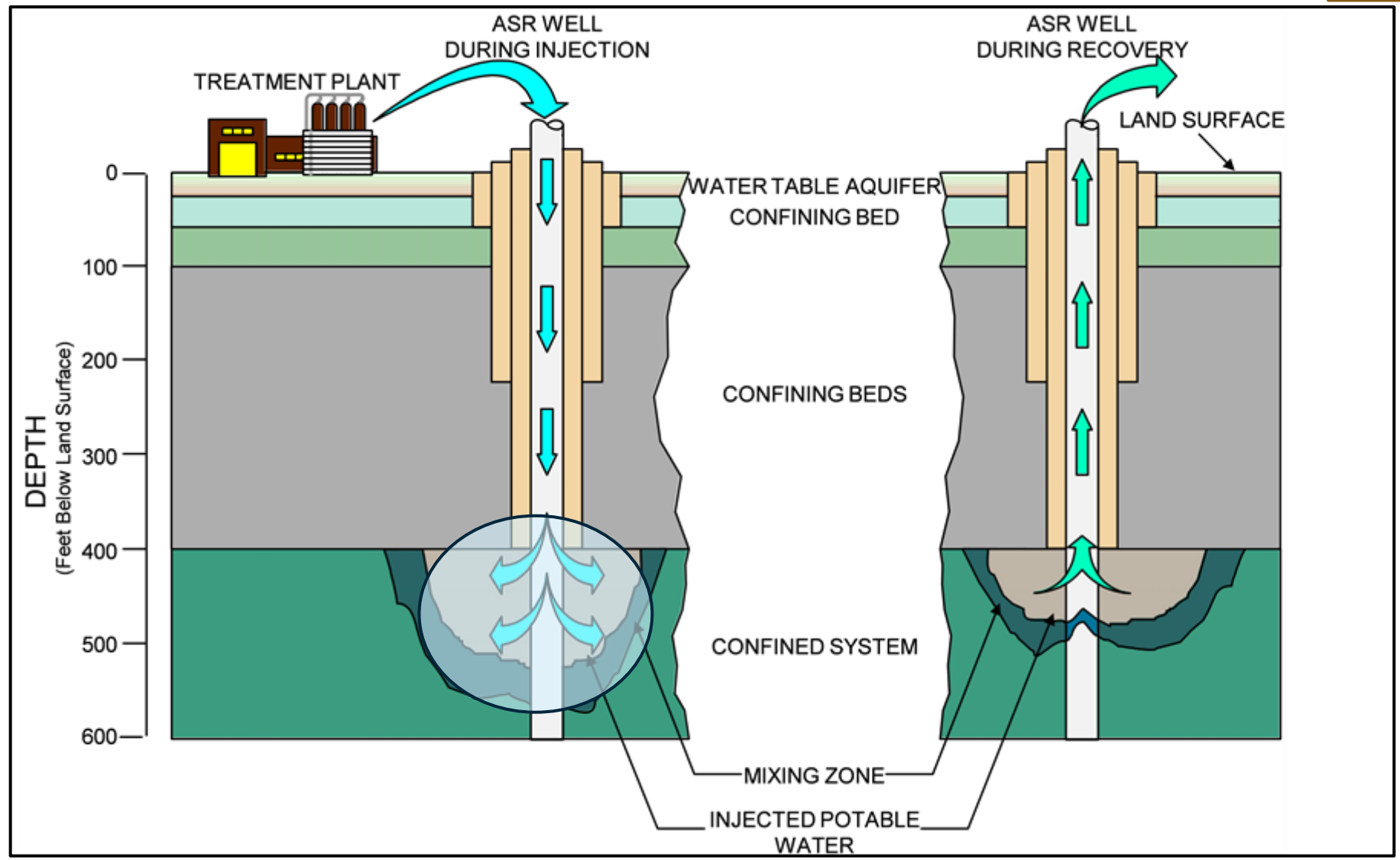
MAR Solutions



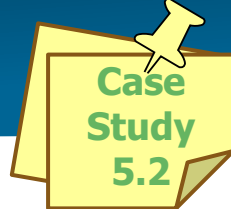
Water Supply Resilience (Storage And Recovery)

Sustainability of a long-term water resource

Example: Scottsdale, AZ



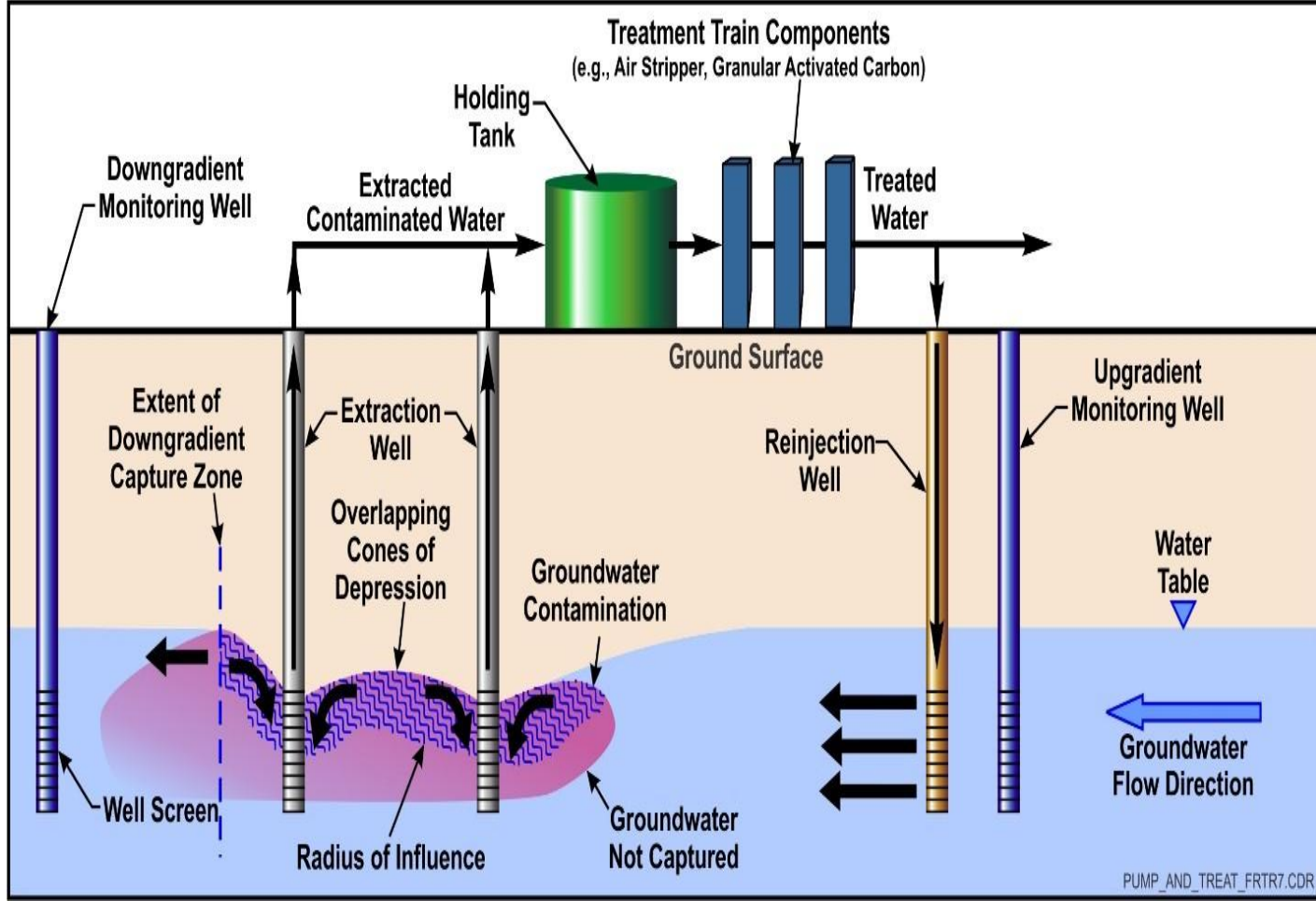
Improve Groundwater Quality



Repurpose treated water

Improve marginal quality water

Increase quantity of available water



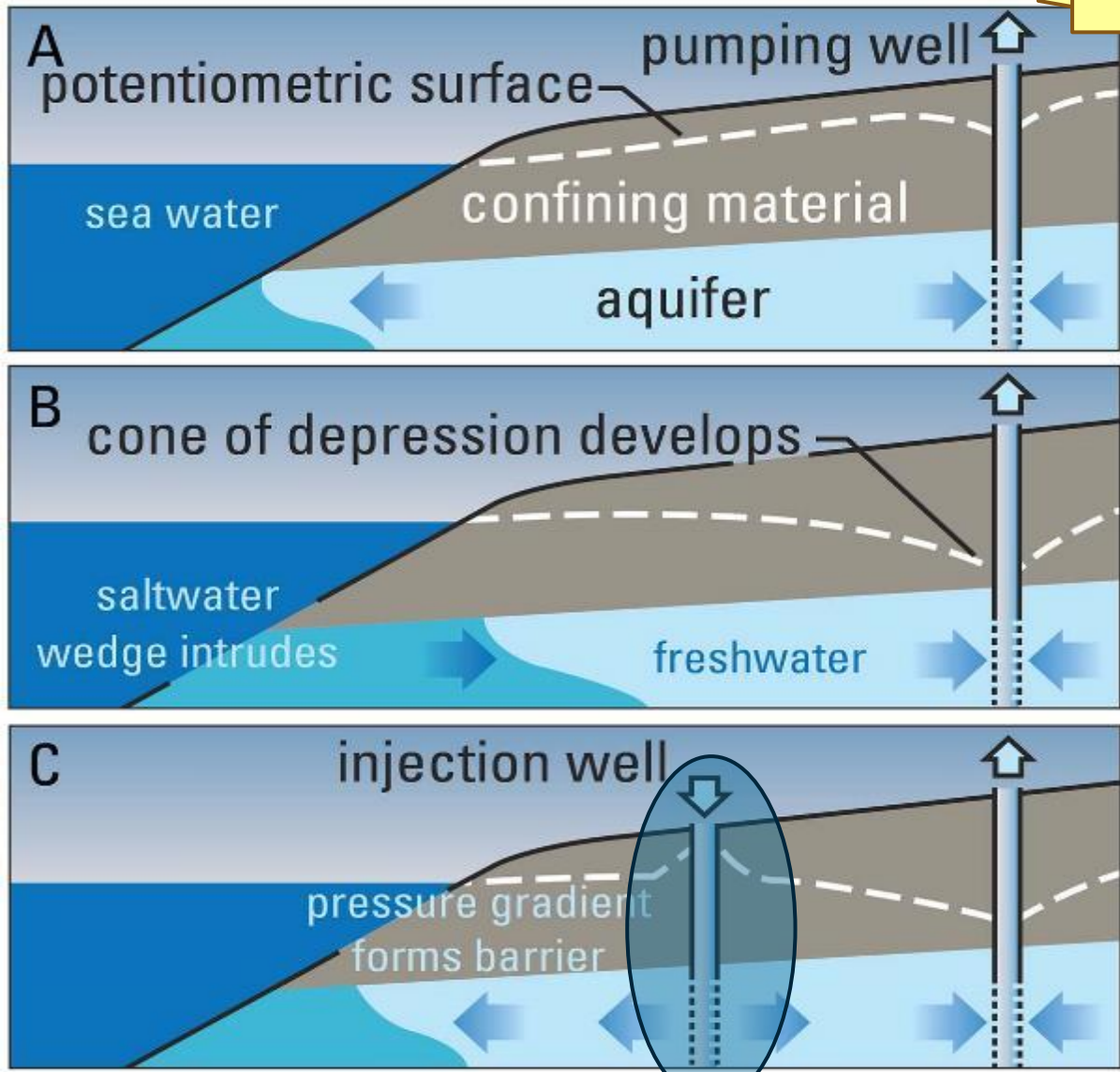
Mitigation Against Saltwater Intrusion

Case Study 5.3

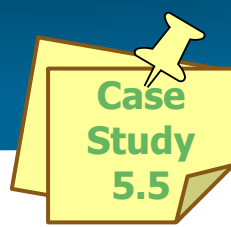
Natural conditions

Pumping the aquifer

Use of MAR to mitigate saltwater intrusion



Flood Water/Excess Stormwater Management



Help reduce flood risk & boost groundwater supplies

Intended Uses:

- Increase flows into adjacent streams or rivers
- Support agricultural activities
- Create bird and terrestrial habitat (Ecosystem Enhancement)
- Recharge depleted aquifers
- Enhances water supply resilience
- Reduces flood risk and increases drought preparedness
- Improve water quality
- Adapt to climate change



Subsidence Reduction

Case
Study
5.1

Frederick, Maryland

Recharge the aquifer to offset
recovery of water to slow
land subsidence



[What is a sinkhole? | U.S. Geological Survey \(usgs.gov\)](https://www.usgs.gov/faqs/what-a-sinkhole#multimedia)
<https://www.usgs.gov/faqs/what-a-sinkhole#multimedia>

Land Subsidence in the United States, Fact
Sheet 165-00

<https://water.usgs.gov/ogw/pubs/fs00165/>



Riparian Ecosystems Protection/ Streamflow Maintenance

Case
Study
5.6



[Flood-MAR: Harnessing Flood Waters to Advance Sustainable Water Management \(ca.gov\)](https://water.ca.gov/News/Blog/2018/July-18/Flood-MAR-Harnessing-Flood-Waters-to-Advance-Sustainable-Water-Management)

<https://water.ca.gov/News/Blog/2018/July-18/Flood-MAR-Harnessing-Flood-Waters-to-Advance-Sustainable-Water-Management>

Benefits:

- Increase climate change resilience
- Restore water bodies
- Protect and improve water quality
- Provide fish and wildlife habitats
- Store flood waters
- Maintain surface water flow during dry periods

Sacramento River Valley, CA

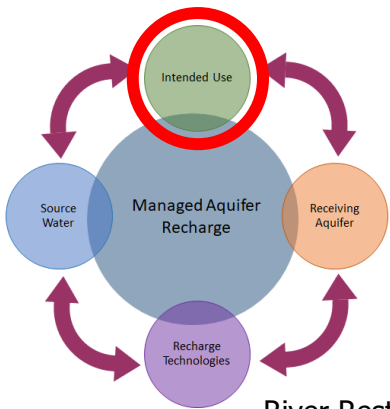
Walla Walla Basin Watershed Example – Intended Use

Case Study 5.9

Water Supply Resilience

Protection of Riparian Ecosystems

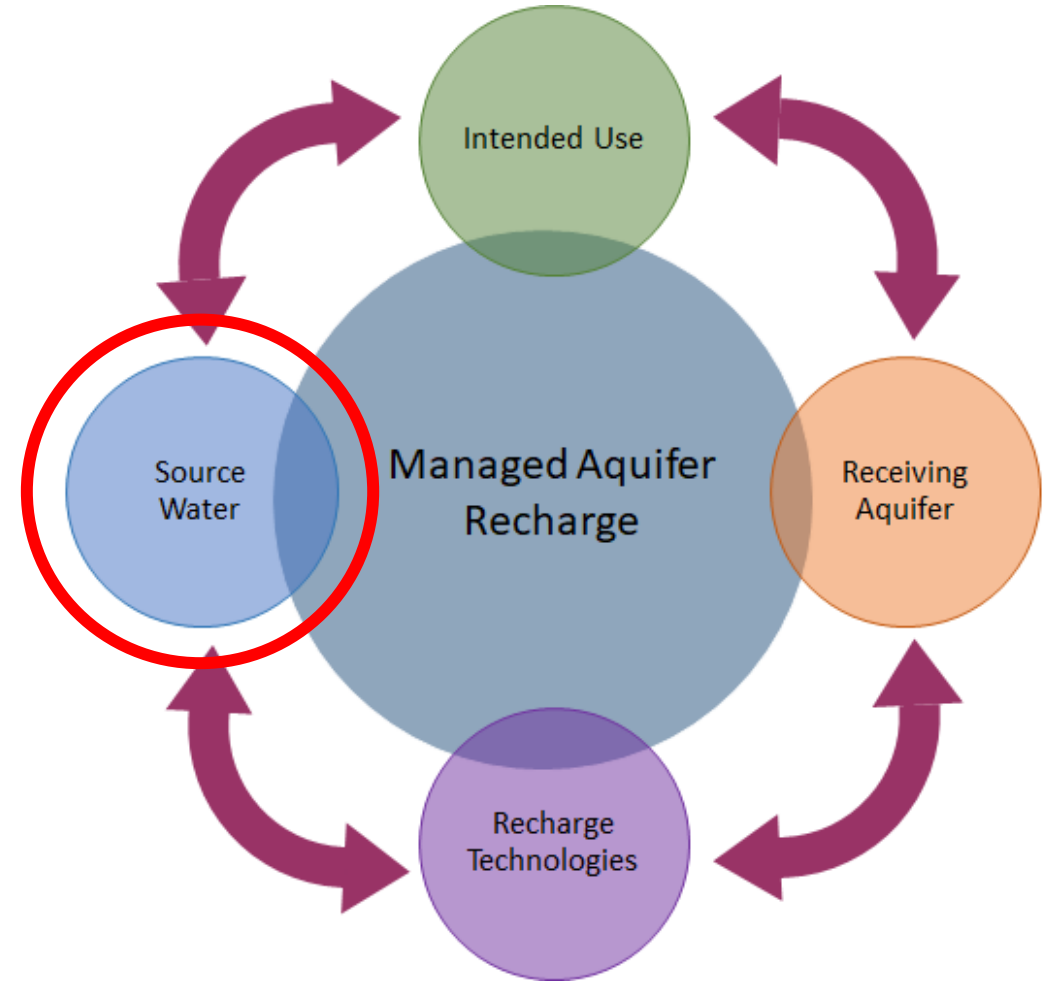
Maintenance of Streamflow



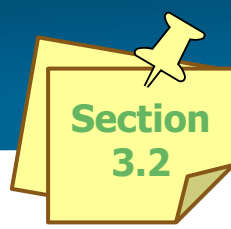
River Restoration in the Walla Walla Basin ([arcgis.com](https://ctuirgis.maps.arcgis.com/apps/MapJournal/index.html?appid=56ee9d323eb94d0bb2ea85ed4e1327e2))
<https://ctuirgis.maps.arcgis.com/apps/MapJournal/index.html?appid=56ee9d323eb94d0bb2ea85ed4e1327e2>

Roadmap

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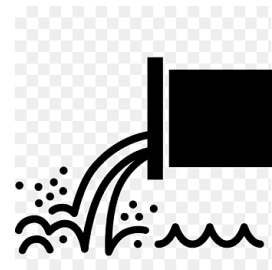
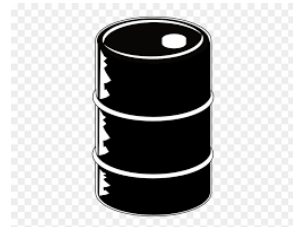
Source Water – Things to Consider



- ✓ Origin
- ✓ Availability
- ✓ Quality Considerations
- ✓ Regulatory Issues
- ✓ Other?

Origin

Many sources of water are available to utilize, each with varying advantages and constraints that need to be considered in the context of specific projects.



Origin

1

Surface Water

2

Treated Drinking Water

3

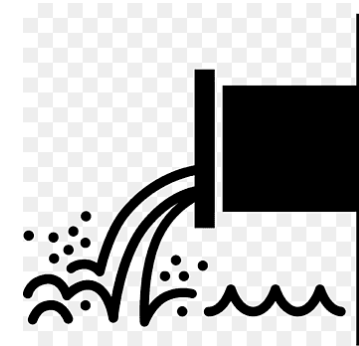
Highly Treated Wastewater

4

Captured Water

5

Flood Water



Origin

6 Industrial Process Water



7 Agricultural Return Flows



8 Produced Water/ Saline Waters

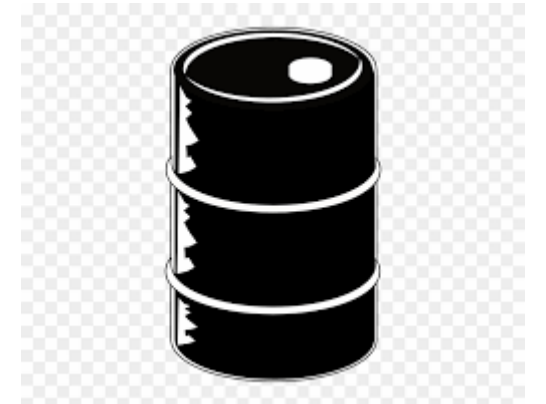


Origin

9 Dewatering Flows

10 Environmental Remediation Sites

11 Groundwater Transfer



Availability

When considering source waters for MAR projects, a variety of issues impact the availability of source waters.

1 Volume and Duration of Flow

$$Q = V/t$$

2 Proximity/Conveyance



3 Ownership/Water Rights

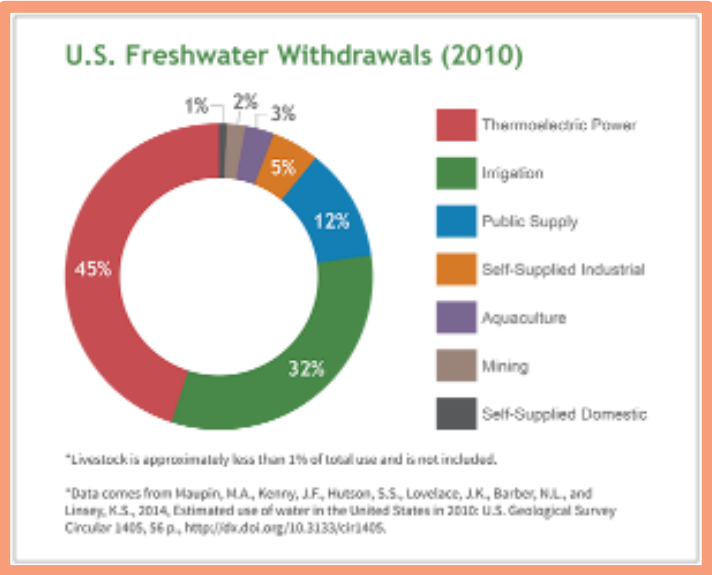
**“Whiskey is for drinking;
water is for fighting over”**

Mark Twain

Availability

When considering source waters for MAR projects, a variety of issues impact the availability of source waters.

4 Competing Uses/Stakeholders



[How We Use Water | WaterSense | US EPA](https://www.epa.gov/watersense/how-we-use-water_)
https://19january2021snapshot.epa.gov/watersense/how-we-use-water_.html



5 Regulatory Limitations

Regulatory Issues

Source waters for MAR projects must meet federal and state-specific water quality standards.

MCLs

Intended use modifications

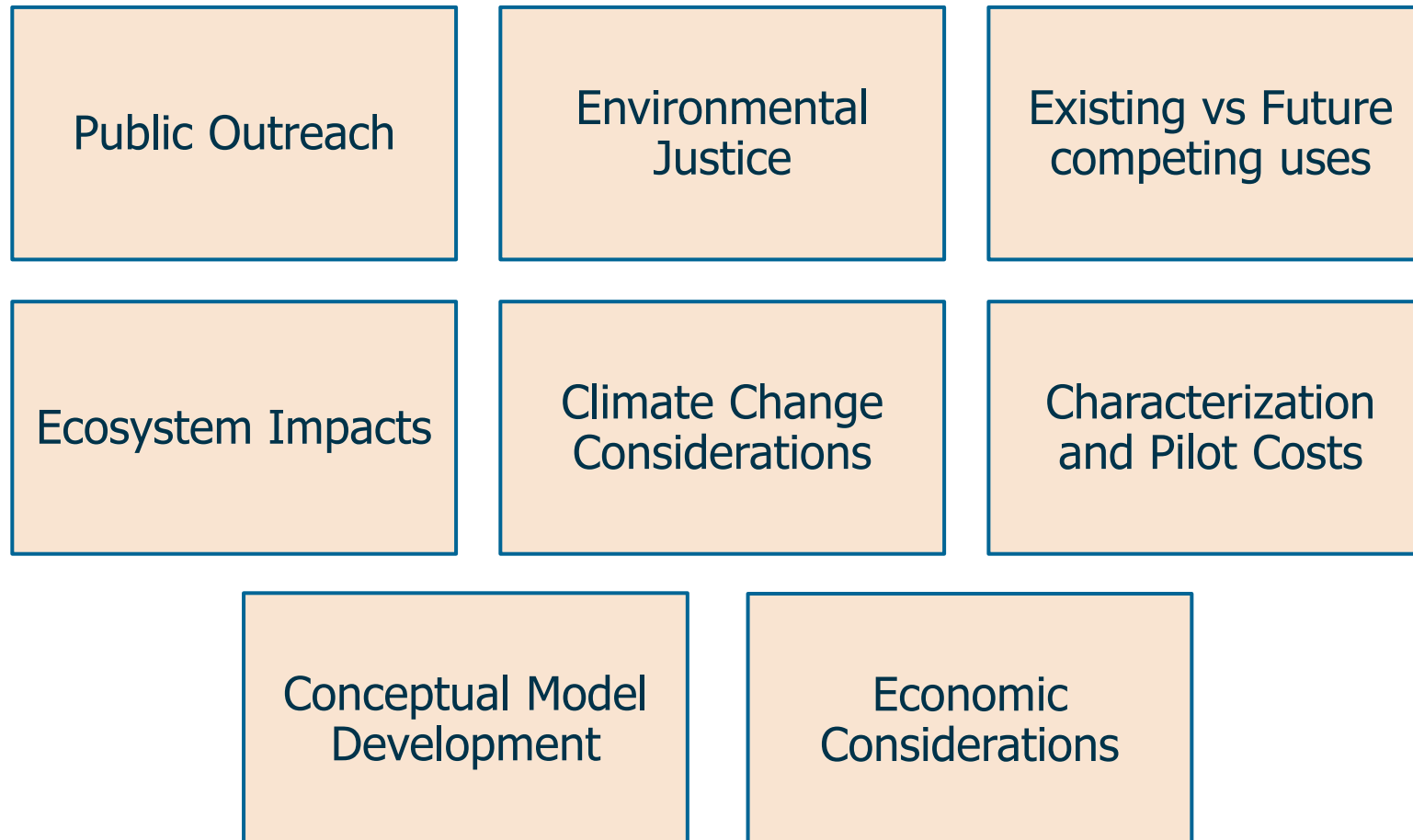
State specific rules

Receiving ground water quality

See MAR Document Section 2.5 and Section 3.5

Other (Potential) Source Water Issues

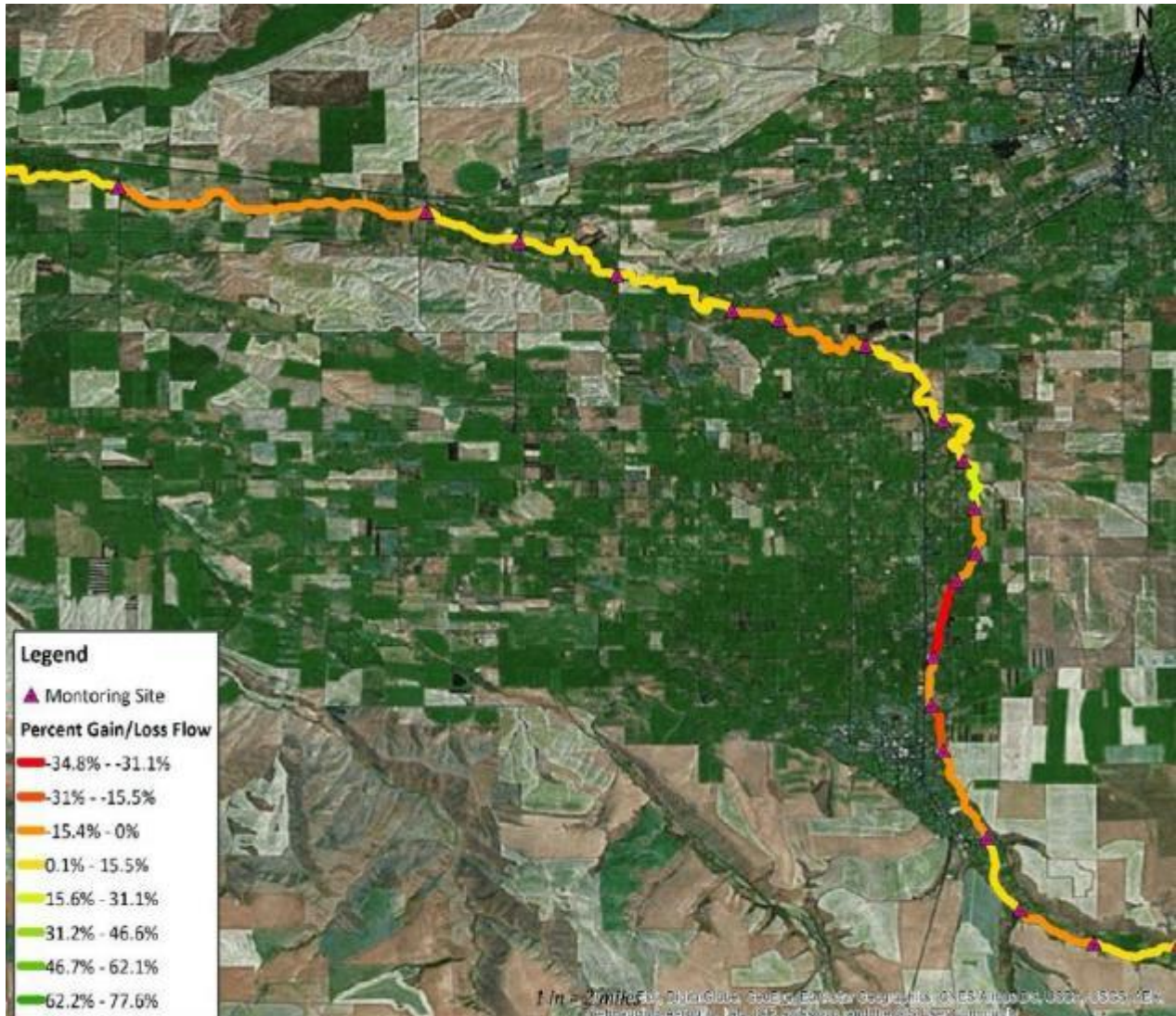
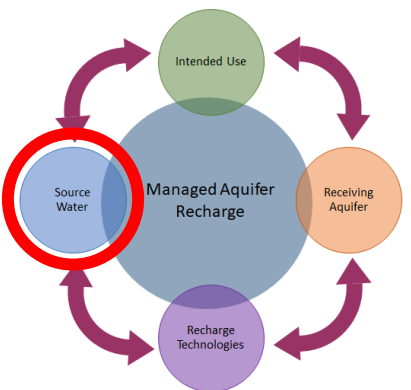
Each MAR project will have unique considerations dependent on location, intended use, and design.



Walla Walla Basin Watershed Example – Source Water

Case Study 5.9

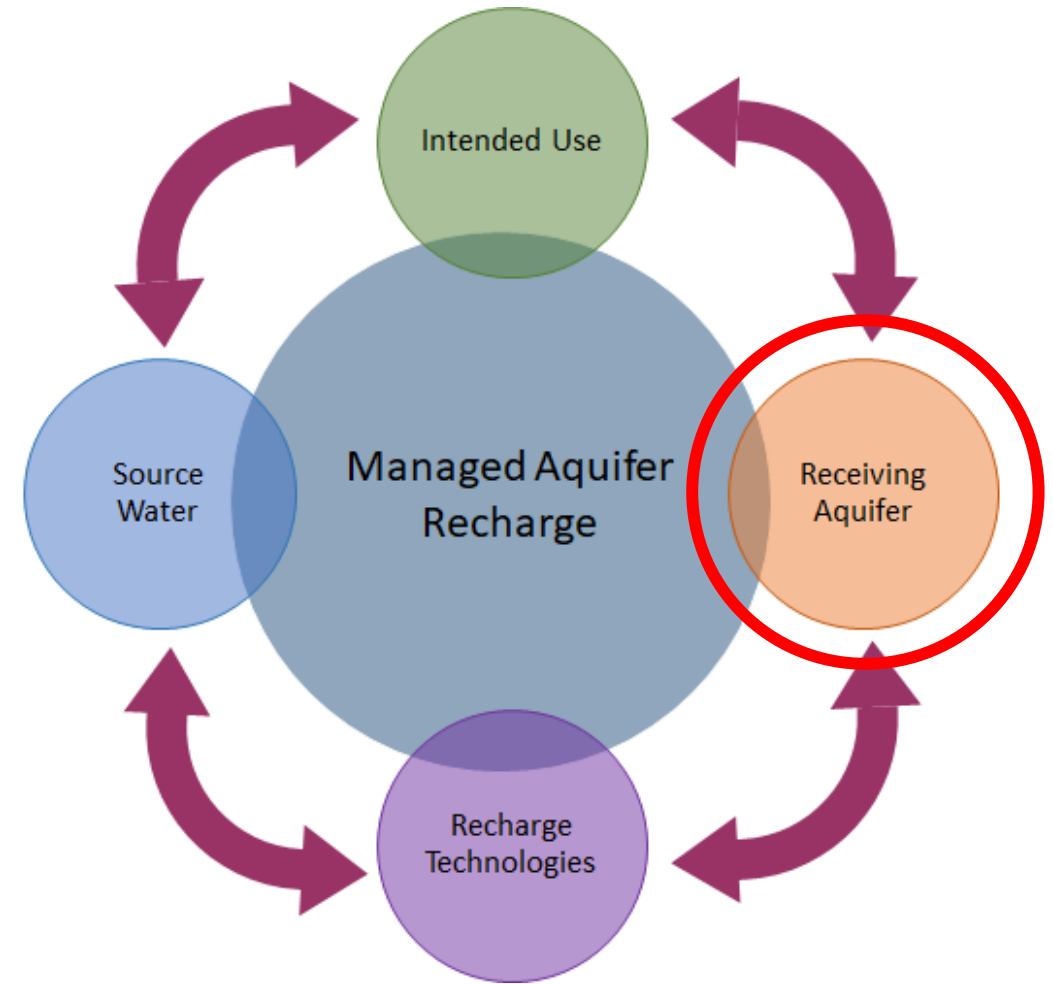
- ✓ Origin
- ✓ Availability
- ✓ Quality Considerations
- ✓ Regulatory Issues
- ✓ Other?



MAR CS 5.9 Figure 2. Average gains or losses in flow of a segment of the Walla Walla River; Source: WWBWC (2017)

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Receiving Aquifer

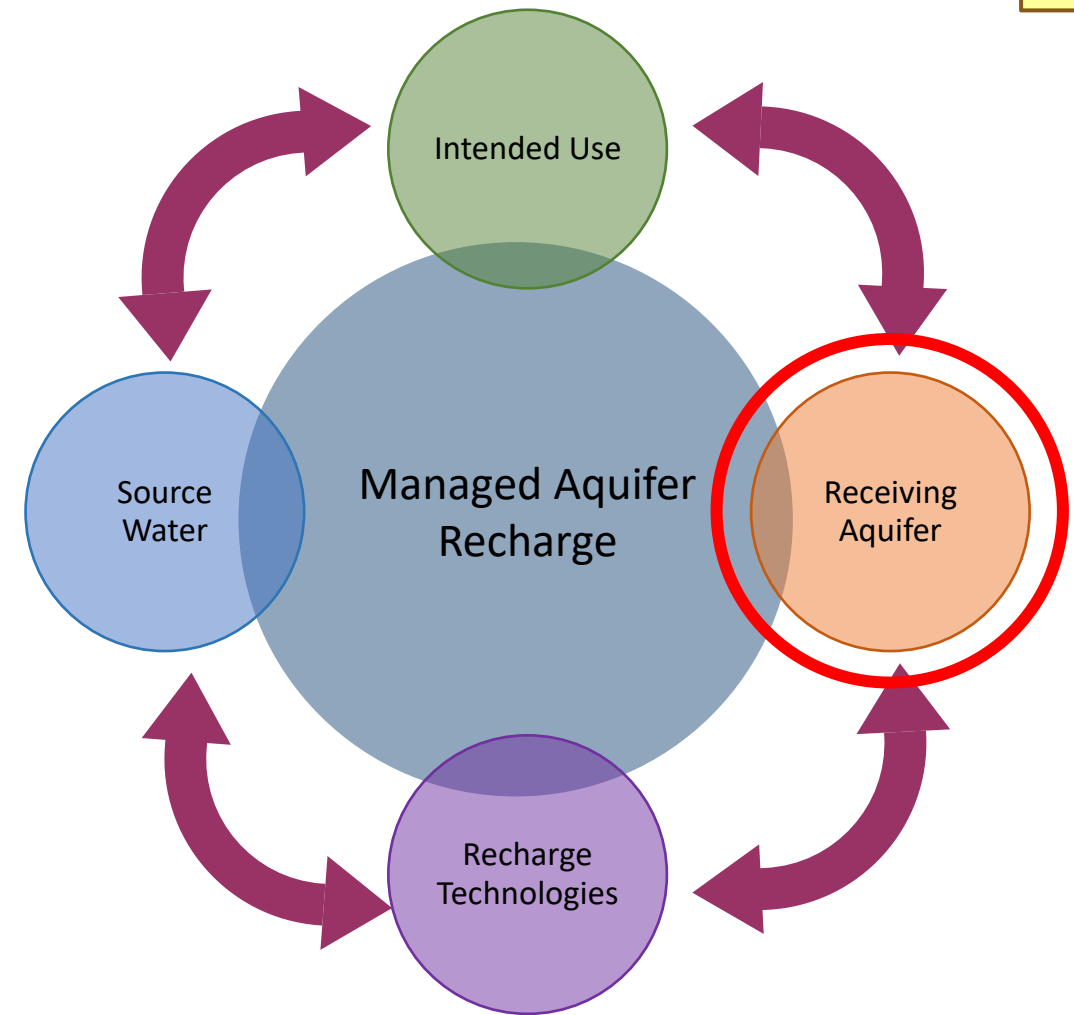
Hydrogeologic Setting and Storage Potential

Site Conditions & Land Use

Geotechnical Considerations

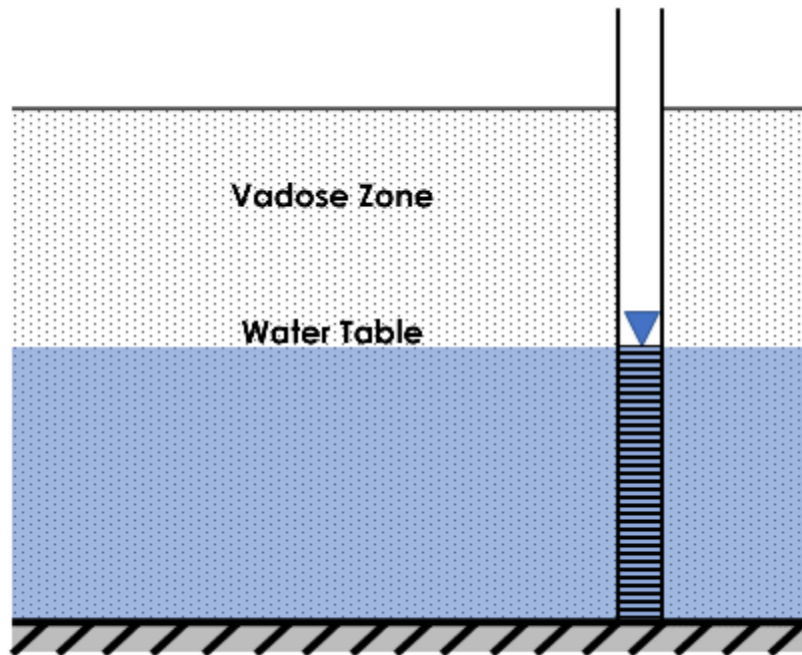
Geochemical Compatibility between Source Water and Receiving Aquifer

Modeling



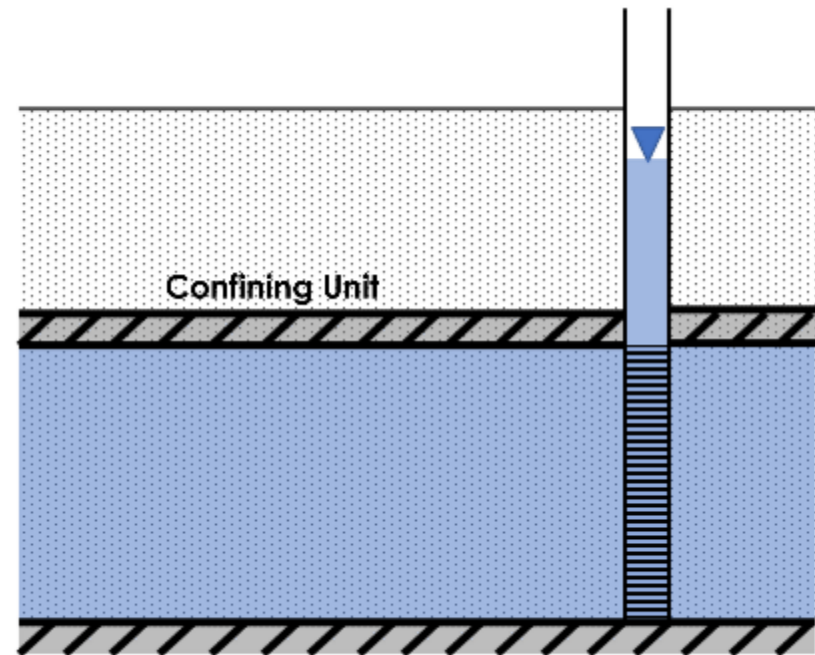
Hydrogeologic Setting

Unconfined Aquifer



Aquifer **can be** recharged via infiltration

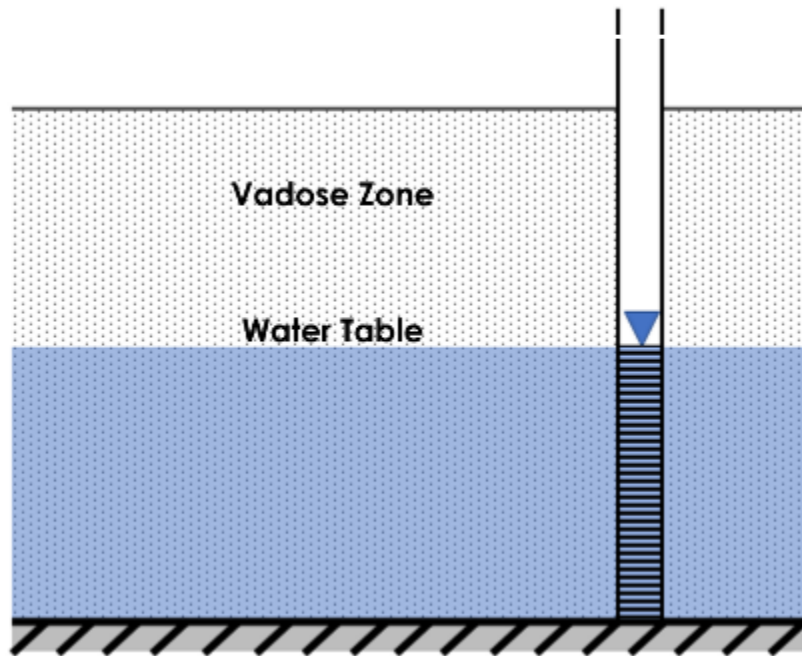
Confined Aquifer



Aquifer **must be** recharged via injection

Recharging an Unconfined Aquifer

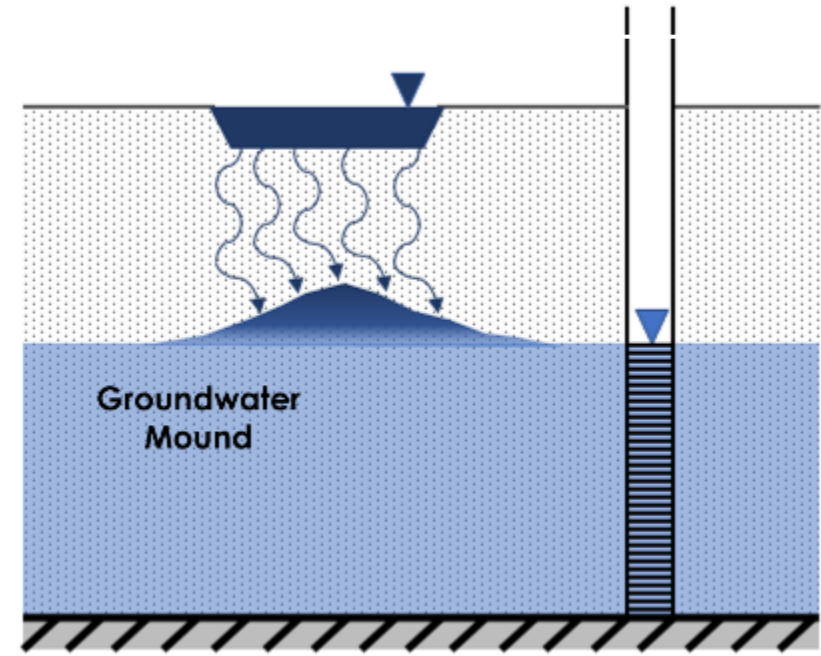
Unconfined Aquifer



Aquifer can be recharged via infiltration



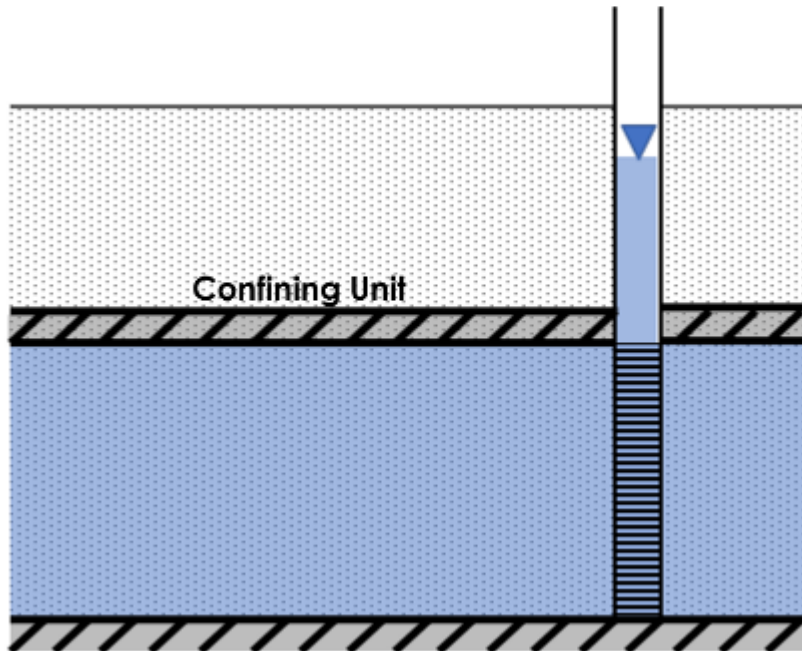
Infiltration Basin



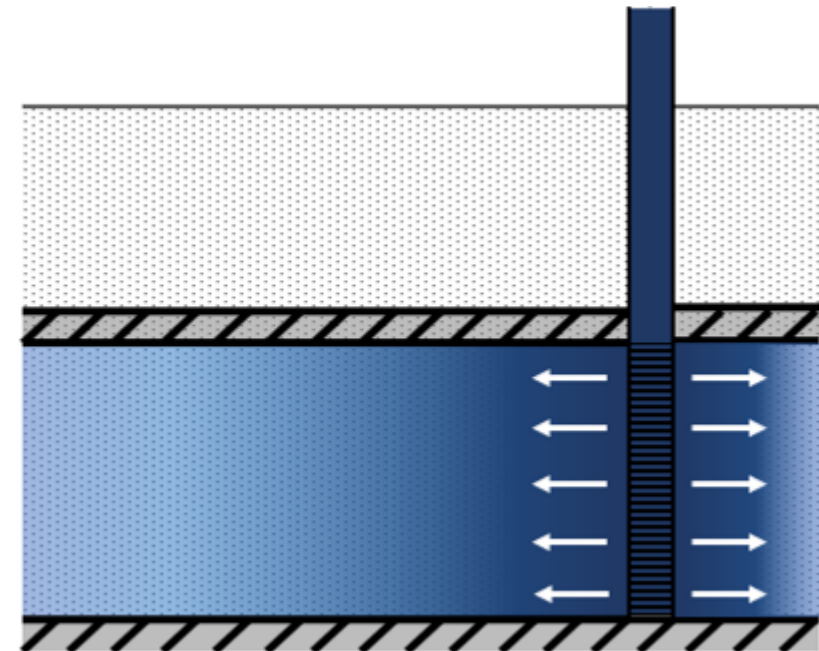
Water stored in groundwater mound that forms in vadose zone

Recharging a Confined Aquifer

Confined Aquifer



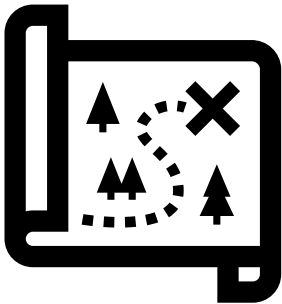
Injection Well



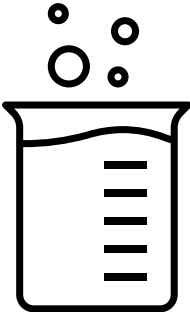
Aquifer must be recharged via injection

Injected water displaces native groundwater in aquifer

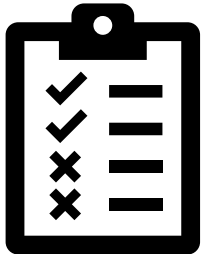
Site Conditions and Land Use



Land availability/competing uses



Water quantity/quality impacts to existing users



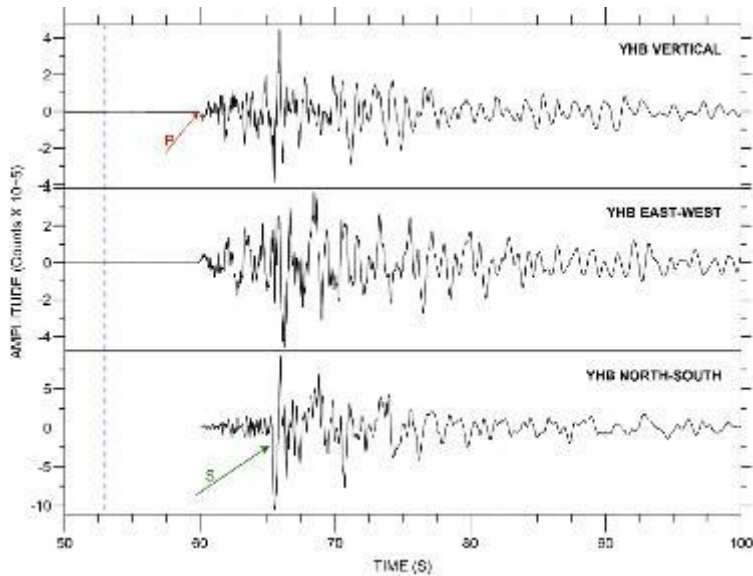
Existing aquifer restrictions



Proximity to known contamination

Geotechnical Considerations

Seismicity



[Locating earthquakes in the Yellowstone region | U.S. Geological Survey \(usgs.gov\)](https://www.usgs.gov/observatories/yvo/news/locating-earthquakes-yellowstone-region)
<https://www.usgs.gov/observatories/yvo/news/locating-earthquakes-yellowstone-region>

Liquefaction



[Women in Science - Responding to Ridgecrest, CA earthquake July 2019 | U.S. Geological Survey \(usgs.gov\)](https://www.usgs.gov/media/images/women-science-responding-ridgecrest-ca-earthquake-july-2019-5)
<https://www.usgs.gov/media/images/women-science-responding-ridgecrest-ca-earthquake-july-2019-5>

Slope Failures



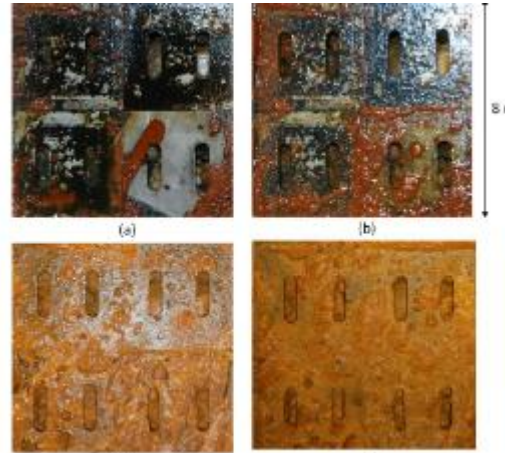
[2018 Potter Hill landslide 2, Anchorage, AK | U.S. Geological Survey \(usgs.gov\)](https://www.usgs.gov/media/images/2018-potter-hill-landslide-2-anchorage-ak)
<https://www.usgs.gov/media/images/2018-potter-hill-landslide-2-anchorage-ak>

Geochemical Compatibility Considerations

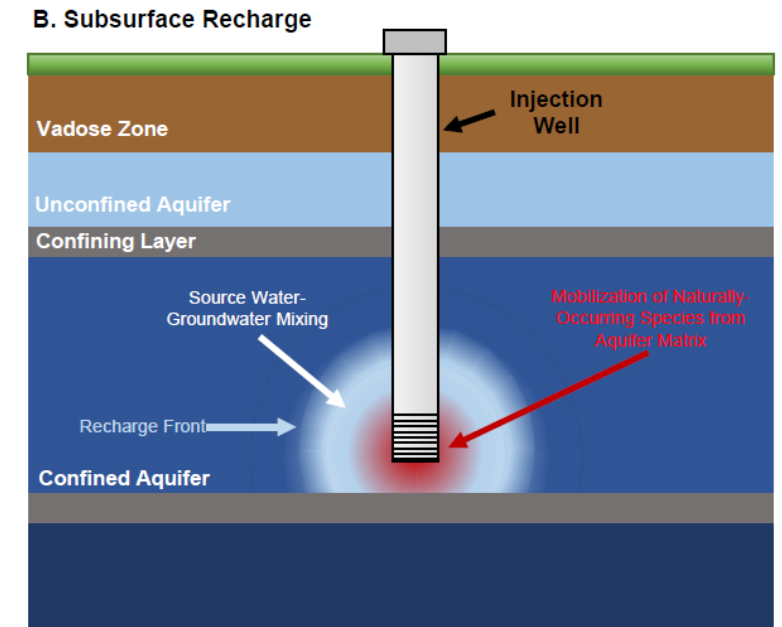
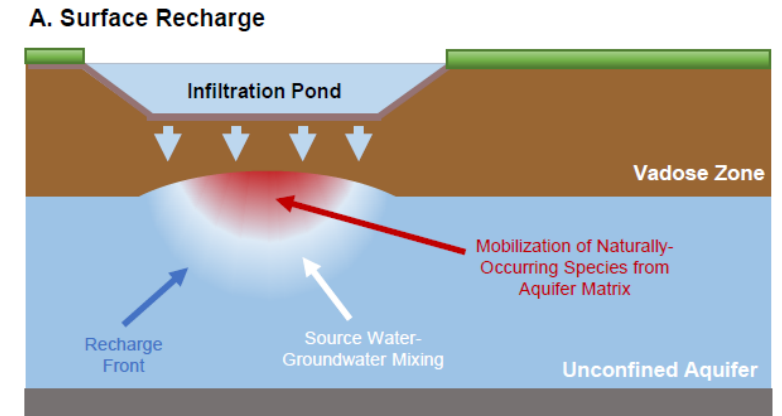
Potential problems:

- Injection well fouling/corrosion
- Aquifer clogging - mineral precipitation
- Aquifer clogging - clay swelling/dispersion
- Dissolution of aquifer matrix
- Mobilization of contaminants (e.g., arsenic)

Important to characterize the chemistry of source water and receiving aquifer



MAR Document Figure 3.9.
Example of well screen clogging after (a) 1, (b) 20, (c) 29, and (d) 73 days
Source: Source: Camprovin et al. (2017)



MAR Document Figure 3.7. Geochemical reactions and recharge fronts.

Source: Beth Hoagland, SSPA. Used with Permission

Modeling

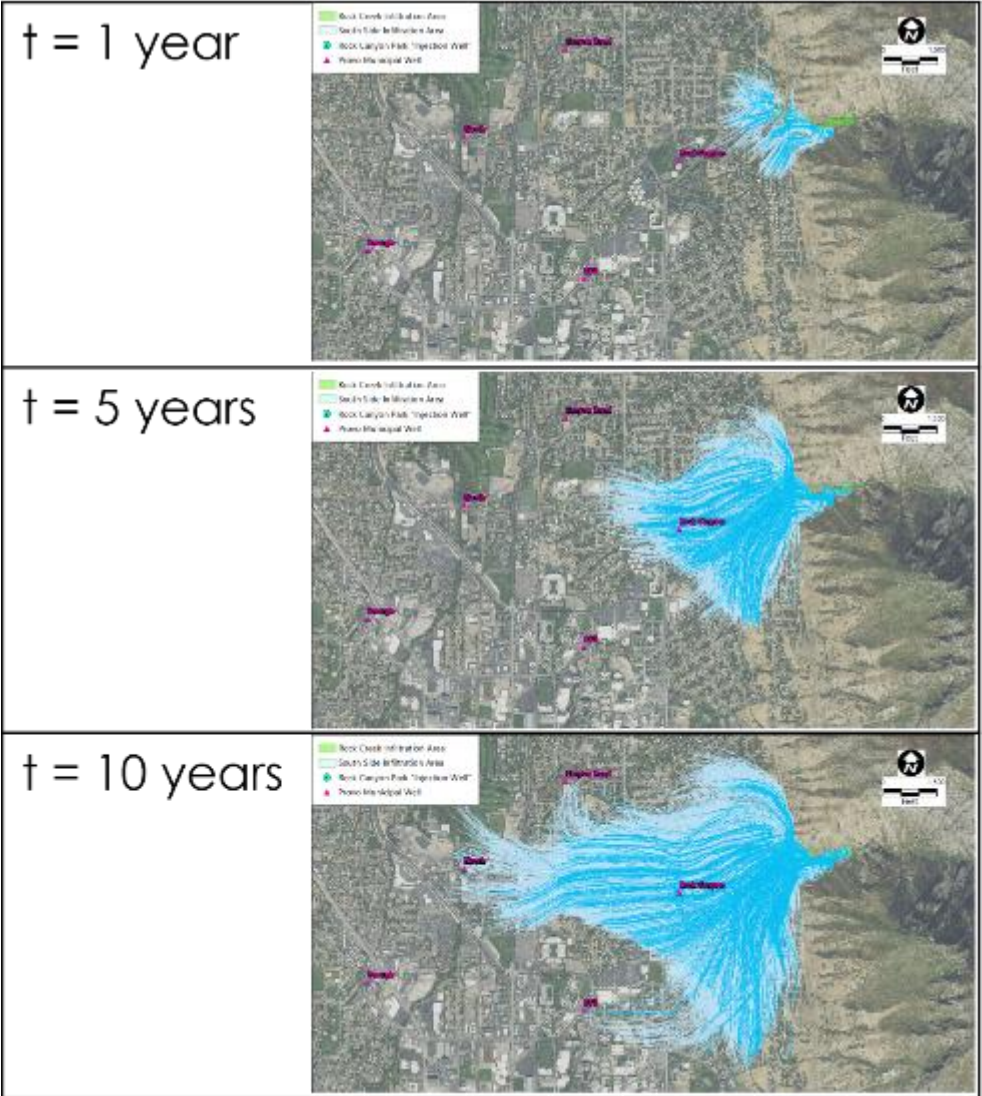
Simulation of future MAR system performance is key to design/permitting

Predictive

Interpretive

Regulatory

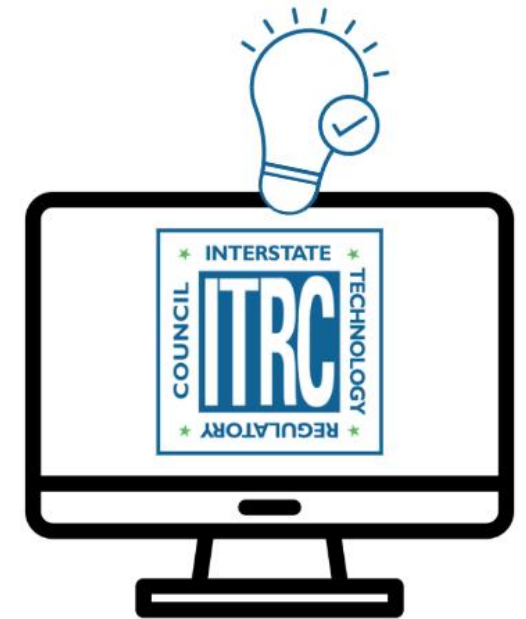
Communication



Poll Question

Which of the following is NOT a potential challenge related to the receiving aquifer?

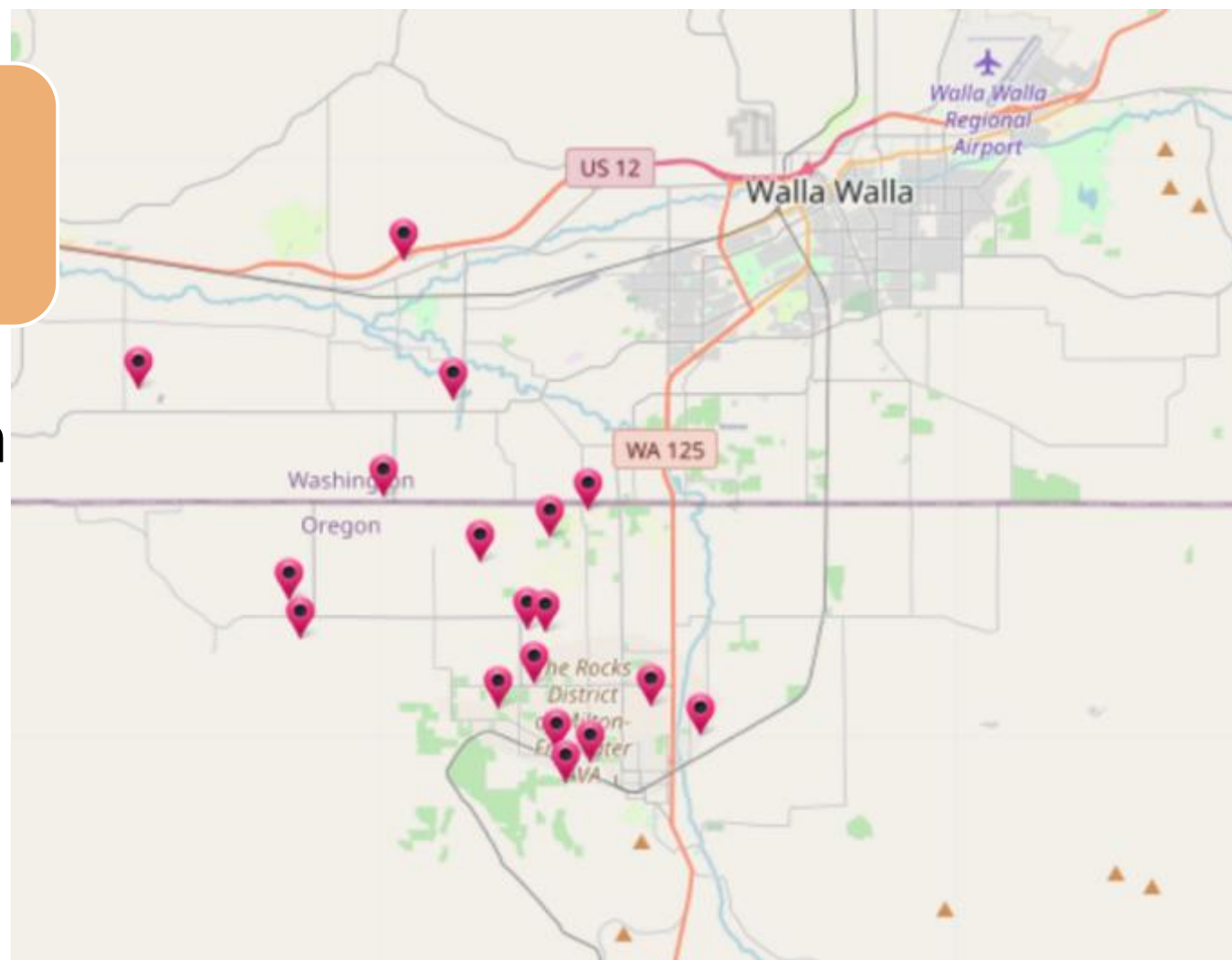
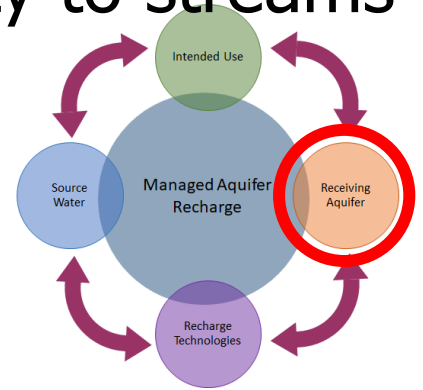
- A. Mobilization of naturally-occurring contaminants
- B. Artesian conditions
- C. Degraded water quality for existing aquifer users
- D. Increased risk of liquefaction



Walla Walla Basin Watershed

RECEIVING AQUIFER

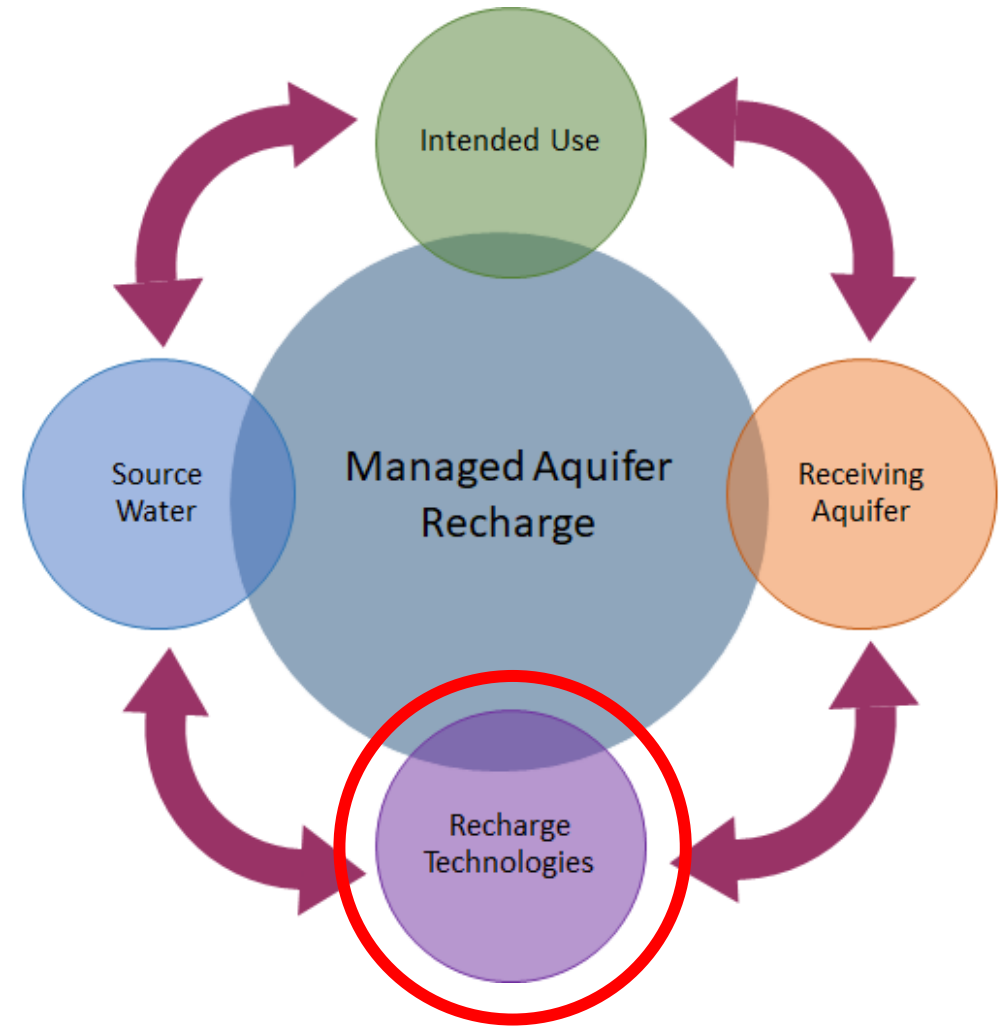
- Alluvial aquifer of the Milton-Freewater alluvial fan
- Unconfined
- High degree of hydraulic connectivity to streams



MAR Case Study 5.9 Figure 3. Recharge locations of the WWBWC
Source: WWBWC (2023)

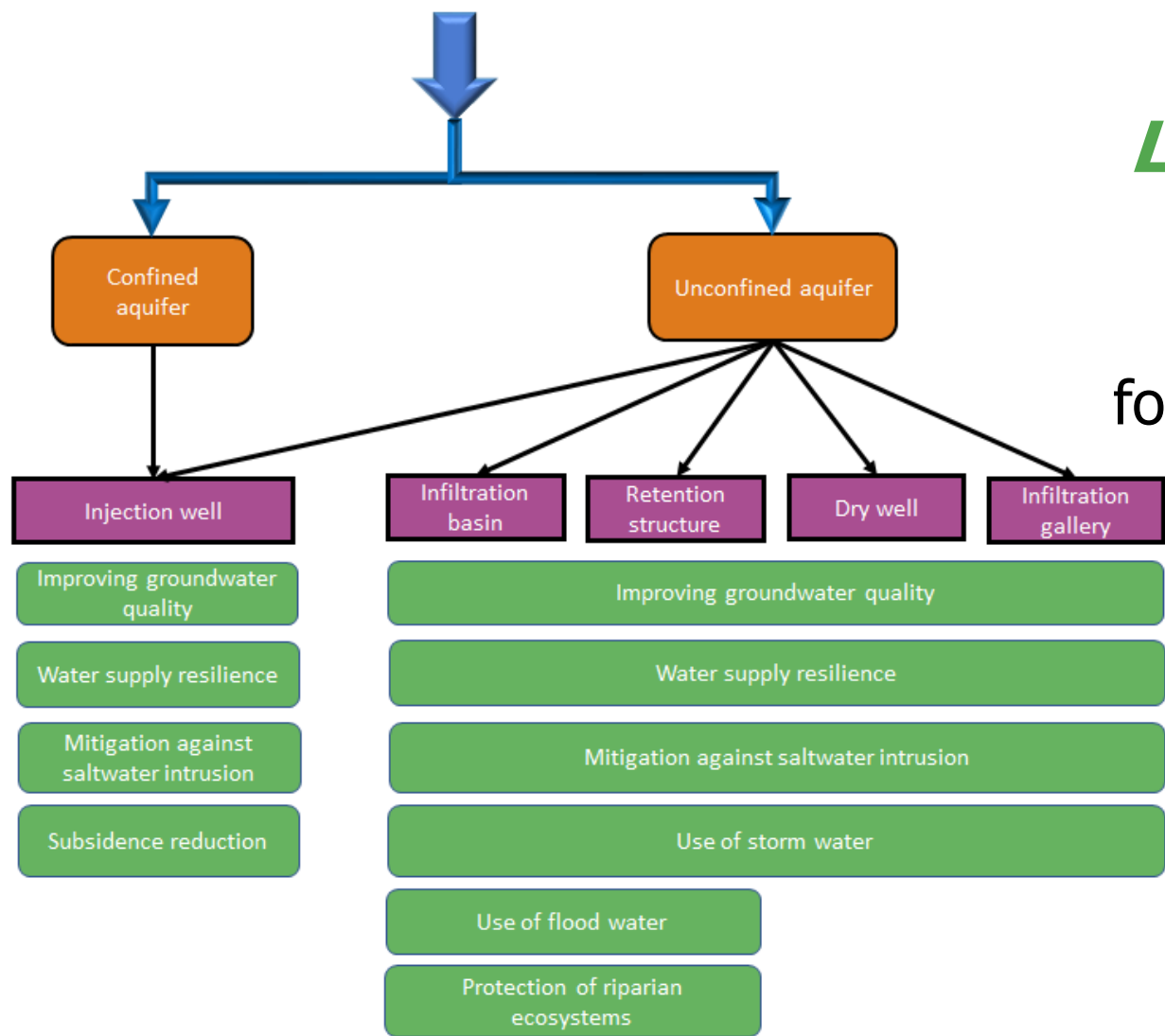
Roadmap

- ▶ Section 1 – Introduction
- ▶ Section 2 – Intended Use
 - What is the problem you need to solve?
- ▶ Section 3 – Source Water
 - What is the source of the solution?
- ▶ Section 4 – Receiving Aquifer
 - Where is the problem to be addressed?
- ▶ Section 5 – Recharge Technologies
 - How to make it happen?
- ▶ Section 6 – Case Study Examples



How to make it happen (Recharge Technologies)

What Recharge Technologies are appropriate?



*Let's get it in the ground!
But how?*

Many methods exist and the following are the most common:

- Injection Wells
- Infiltration Basins
- Retention Structures
 - Dry Wells
- Infiltration Galleries

Receiving Aquifer

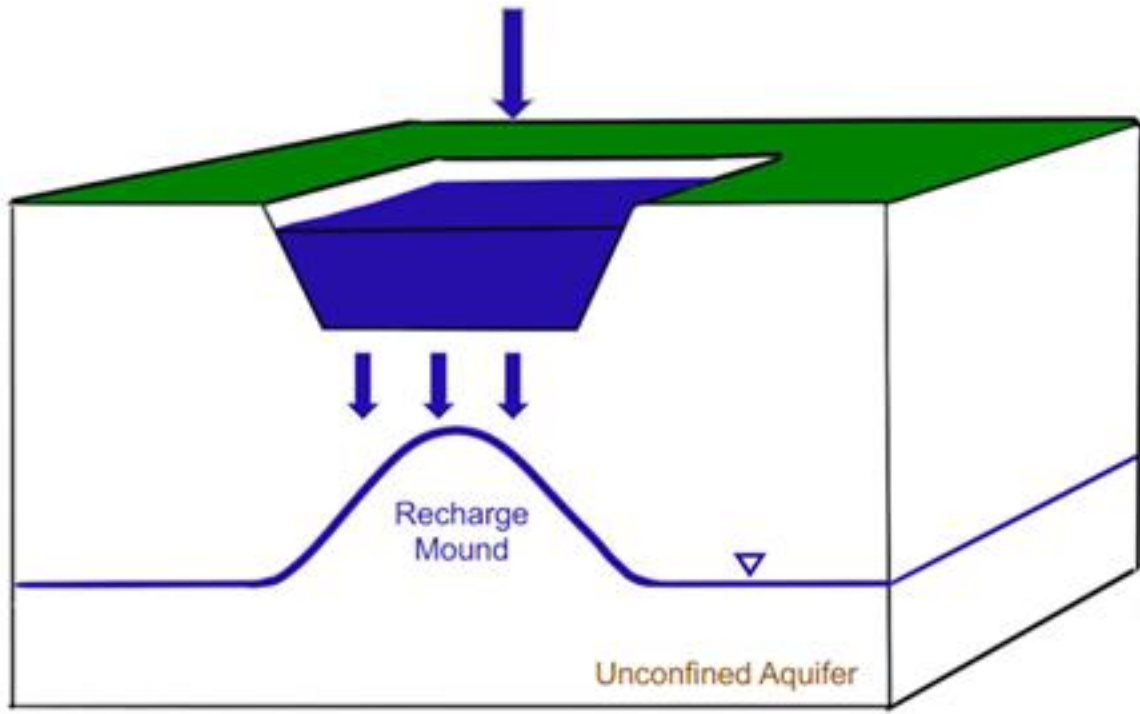
Recharge Technologies

Intended Uses

Infiltration Basins

See Case Study 5.9

Surficial ponds used for percolating water into unconfined aquifers



Infiltration Basin

Pros:

- Cost-effective compared to other technologies
- May provide secondary benefits, such as aquatic habitat for birds
- Lower energy demands

Cons:

- Large footprint
- Prone to clogging
- Only applied to unconfined aquifers

MAR Document Figure 3–2. Infiltration Basin

Injection Wells

See Case Study 5.4

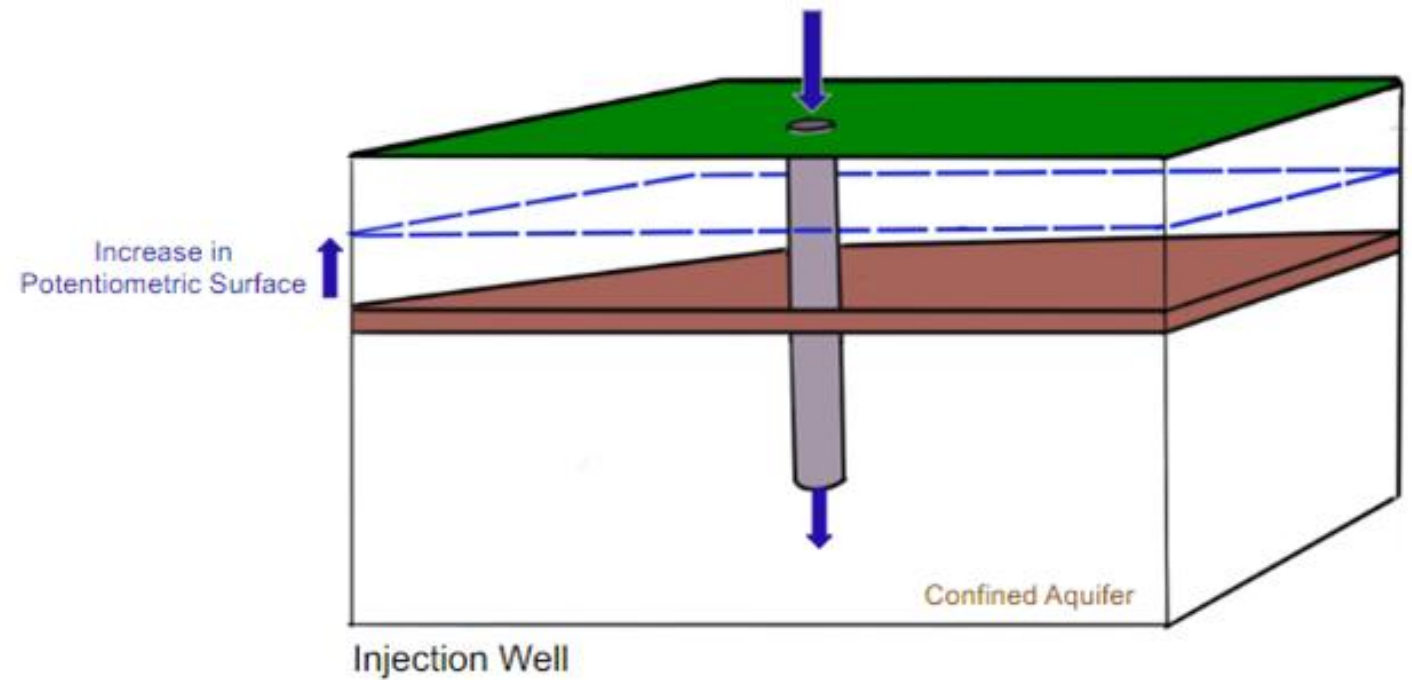
Utilized in confined aquifers or unconfined aquifers with low permeability layers

Pros:

- Flexible orientation (horizontal or vertical installation)
- Requires less land than other MAR technologies

Cons:

- Can be expensive to construct, operate, and maintain (ex. clogging)
- May require pretreatment of source water
- Higher energy demand

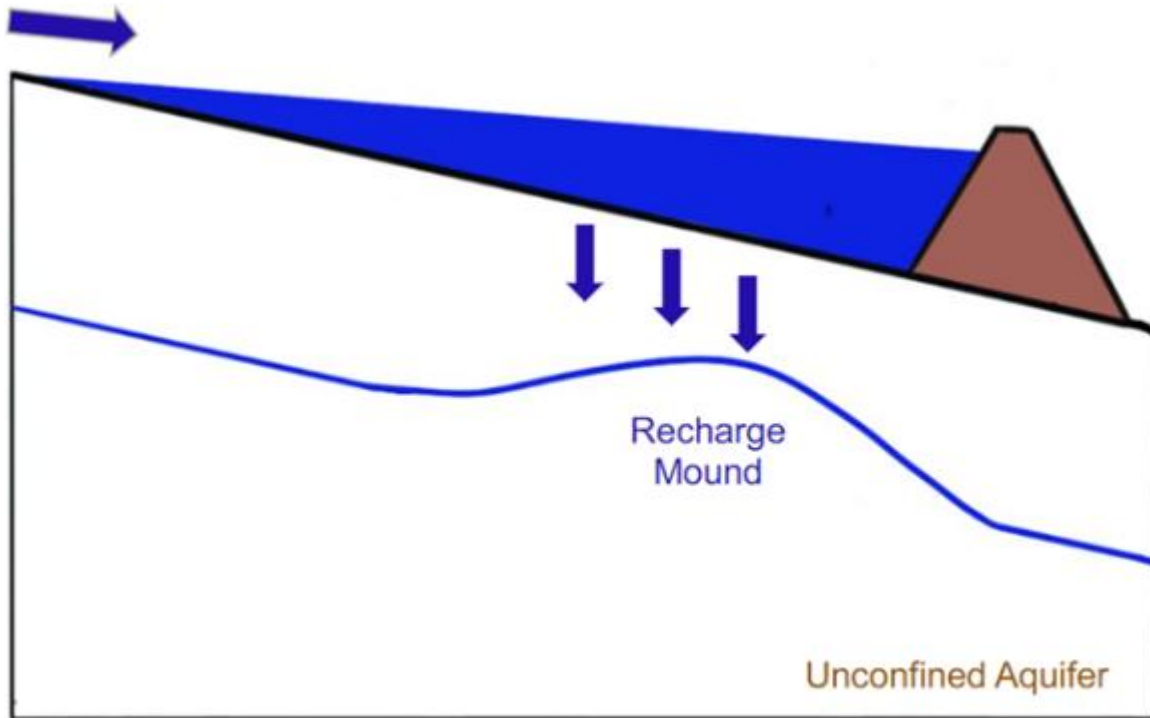


MAR Document Figure 3–4. Injection Well

Retention Structures

See Case Study 5.6

Uses natural features to recharge unconfined aquifers by creating barriers such as dams



Retention Structure

MAR Document Figure 3–3. Retention Structure

Pros:

- Can utilize natural features
- Can be cost-effective

Cons:

- Infiltrates only unconfined aquifers
- Relying only on native features can limit where it can be applied

Drywell

See Case Study 5.8

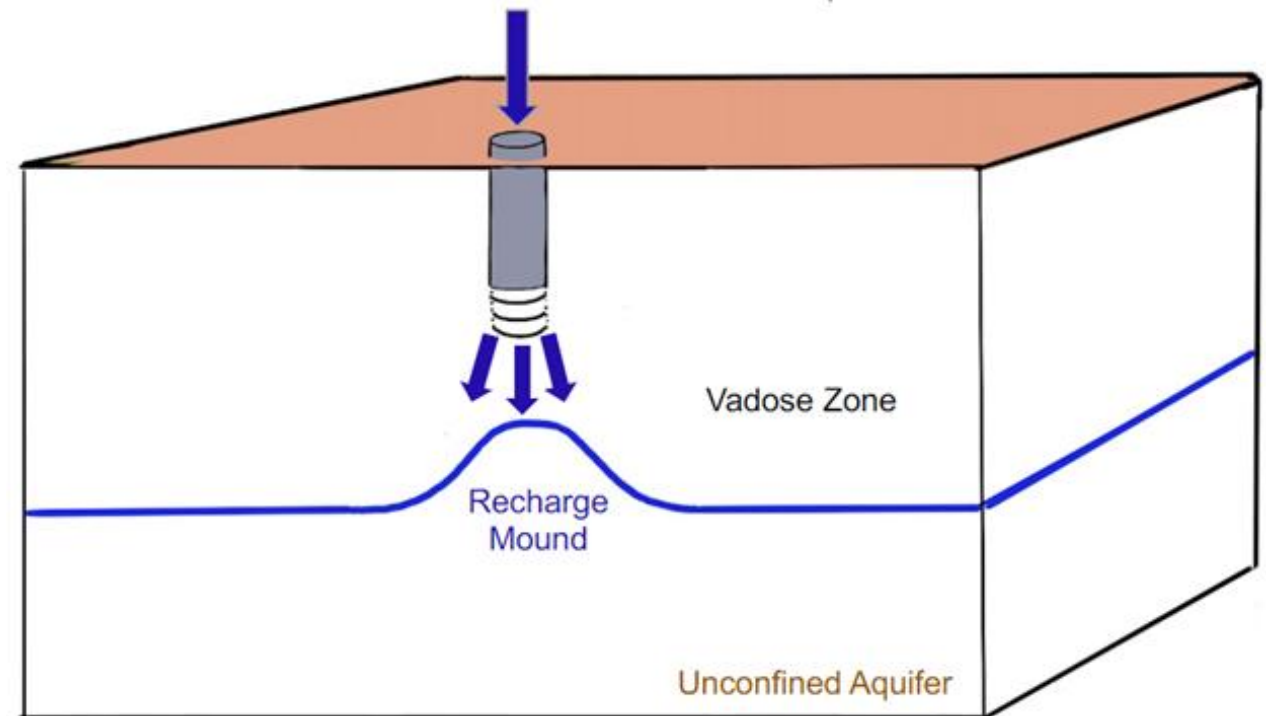
Gravity-fed well typically designed to recharge stormwater into the vadose zone

Pros:

- Smaller footprint than infiltration basins
- Can penetrate low-permeability layers

Cons:

- Recharge capacity dependent on the hydraulic conductivity of surrounding soils (unlike injection wells)



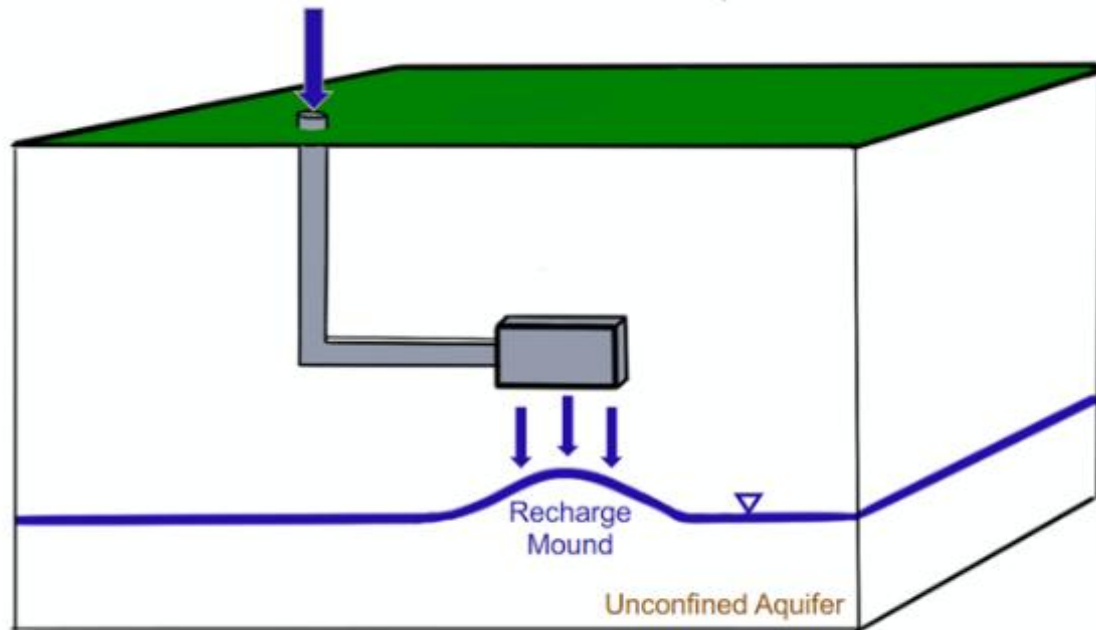
Dry Well

MAR Document Figure 3-5. Dry Well

Infiltration Gallery

See Case Study 5.9

Below-ground structures that allow for rapid infiltration of water through the vadose zone



Infiltration Gallery

MAR Document Figure 3–6. Infiltration Gallery

Pros:

- Can be placed at near-surface or deeper depths
- Land above can be developed for other beneficial uses

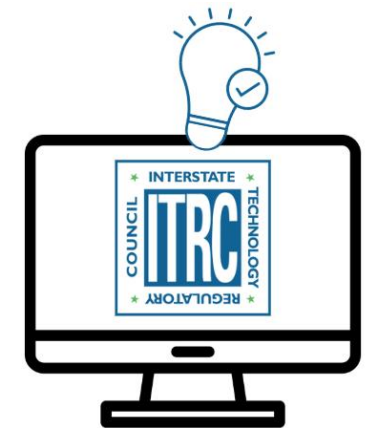
Cons:

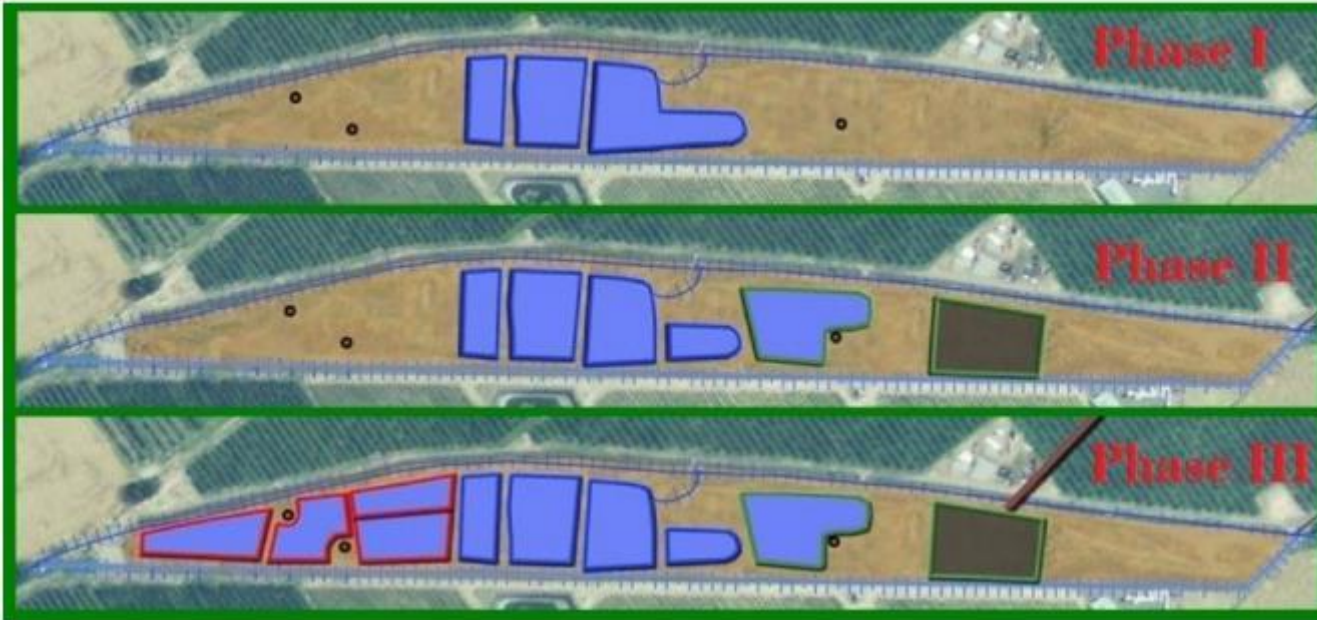
- Subject to clogging
- Susceptible to intrusion of plants

Poll Question

The reasons why injection wells may be the preferred recharge technology are

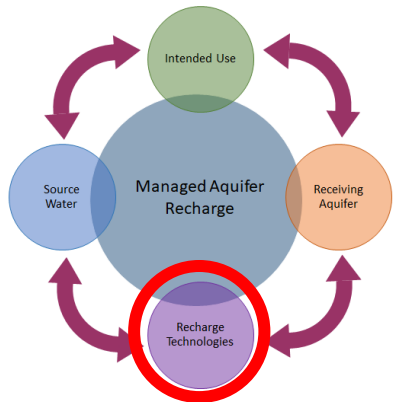
- A. Land is expensive and the water quality requirements are easier
- B. Injection wells are inexpensive to build and surface infiltration is too slow
- C. The receiving aquifer is confined and the footprint for injection wells is small
- D. Injection wells are more likely to win water sustainability awards





MAR Case Study 5.9 Figure 7. Phased approach of MAR at the Johnson site.

Source: WWBWC (2023)



RECHARGE TECHNOLOGIES

- Infiltration Galleries and Basins
 - A total of 19 recharge sites constructed
 - Johnson Recharge site the largest over 51,000 acre-feet since 2004
 - Developed under a phased approach
 - Designed based on cost/benefit analysis of different gallery types

Walla Walla Basin Watershed

▶ INTENDED USE

- Walla Walla River Aquatic Habitat Restoration
- Enhance and improve river and streams

▶ SOURCE WATER

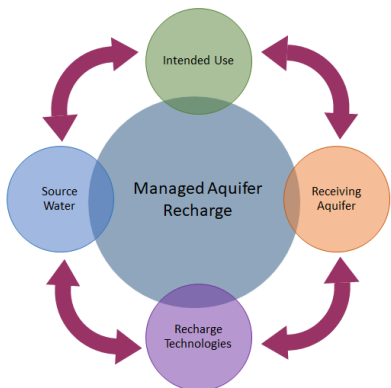
- Walla Walla River

▶ RECEIVING AQUIFER

- Alluvial aquifer of the Milton-Freewater alluvial fan

▶ RECHARGE TECHNOLOGIES

- Infiltration Galleries and Basins



Walla Walla River Basin – CTUIR Fish Habitat Restoration Efforts in the Walla Walla River Basin
<https://wallawallariver.org/>

LESSONS LEARNED AND OTHER CONSIDERATIONS



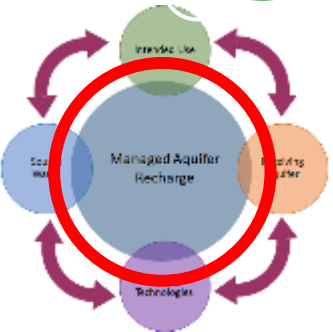
The aquifer maintains a high degree of hydraulic connectivity to streams and rivers; therefore, aquatic habitat restoration would not be possible without incorporating Managed Aquifer Recharge



Consideration of recharge volumes with respect to achieving project success requires realistic timelines



To date, the project goal of recharging 20,000 acre-feet per year has not yet been achieved; but foundational structure exist, which includes stakeholder collaboration within this transboundary watershed



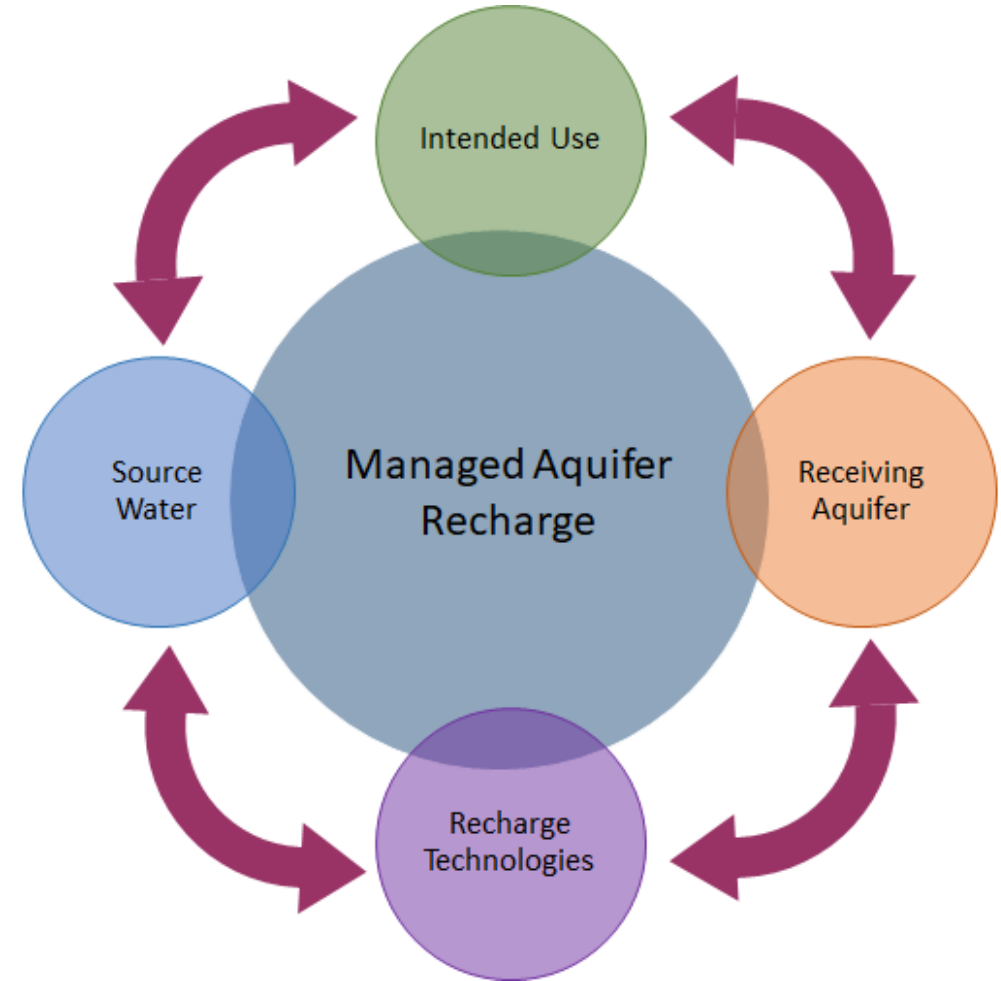
Questions?



Created by Team Member Carrie Ridley

Roadmap

- ▶ Introduction
- ▶ Intended Use
 - What is the problem you need to solve?
- ▶ Source Water
 - What is the source of the solution?
- ▶ Receiving Aquifer
 - Where is the problem to be addressed?
- ▶ Recharge Technologies
 - How to make it happen?
- ▶ Case Study Examples



HRSD Sustainable Water Initiative for Tomorrow (SWIFT) Program

Case Study 5.1



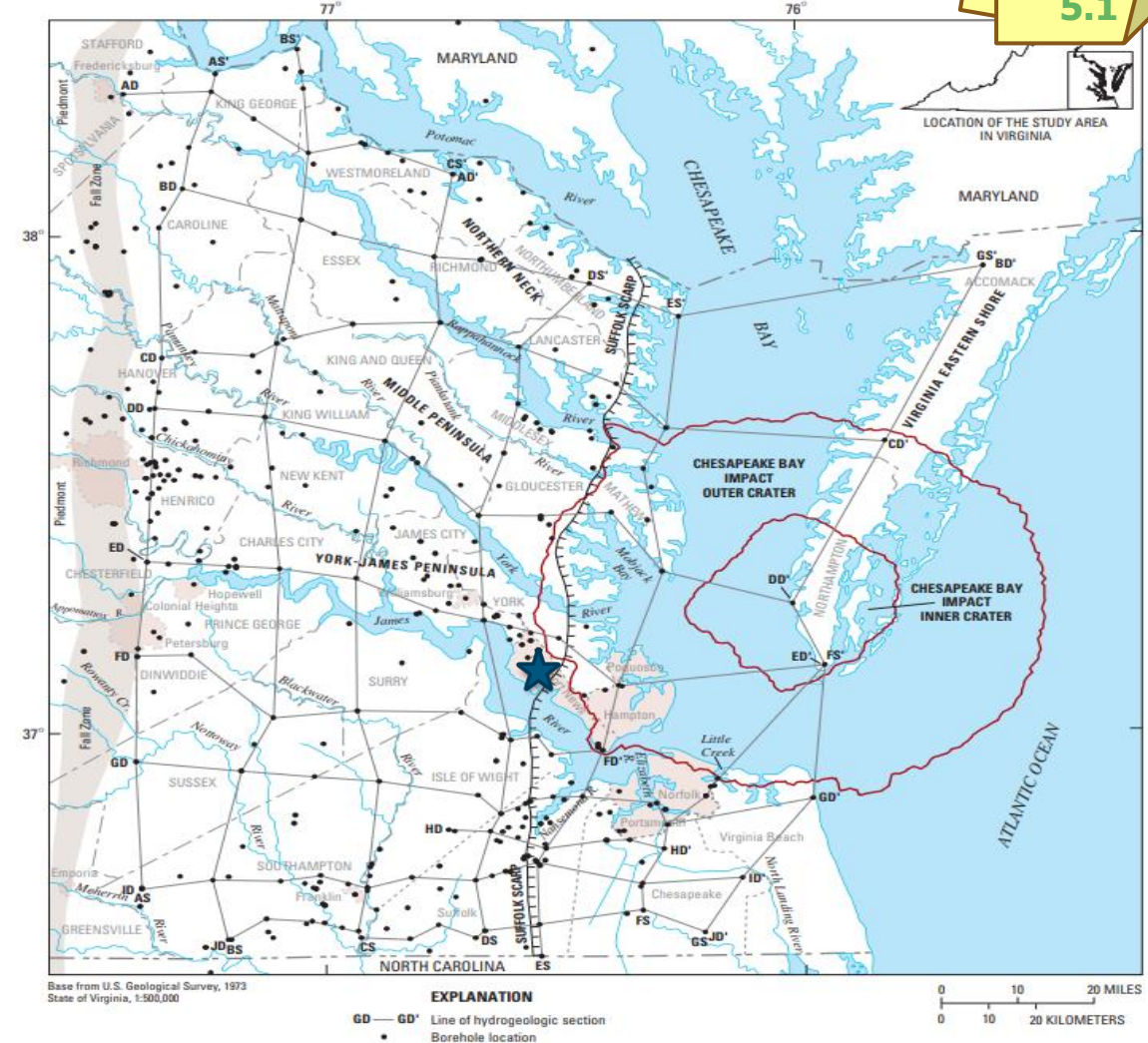
SWIFT Research Center rendering

Screen Capture from <https://youtu.be/IO9t1ijr6tw> - SWIFT Home | HRSD.com

Sustainable Water Initiative for Tomorrow (SWIFT)

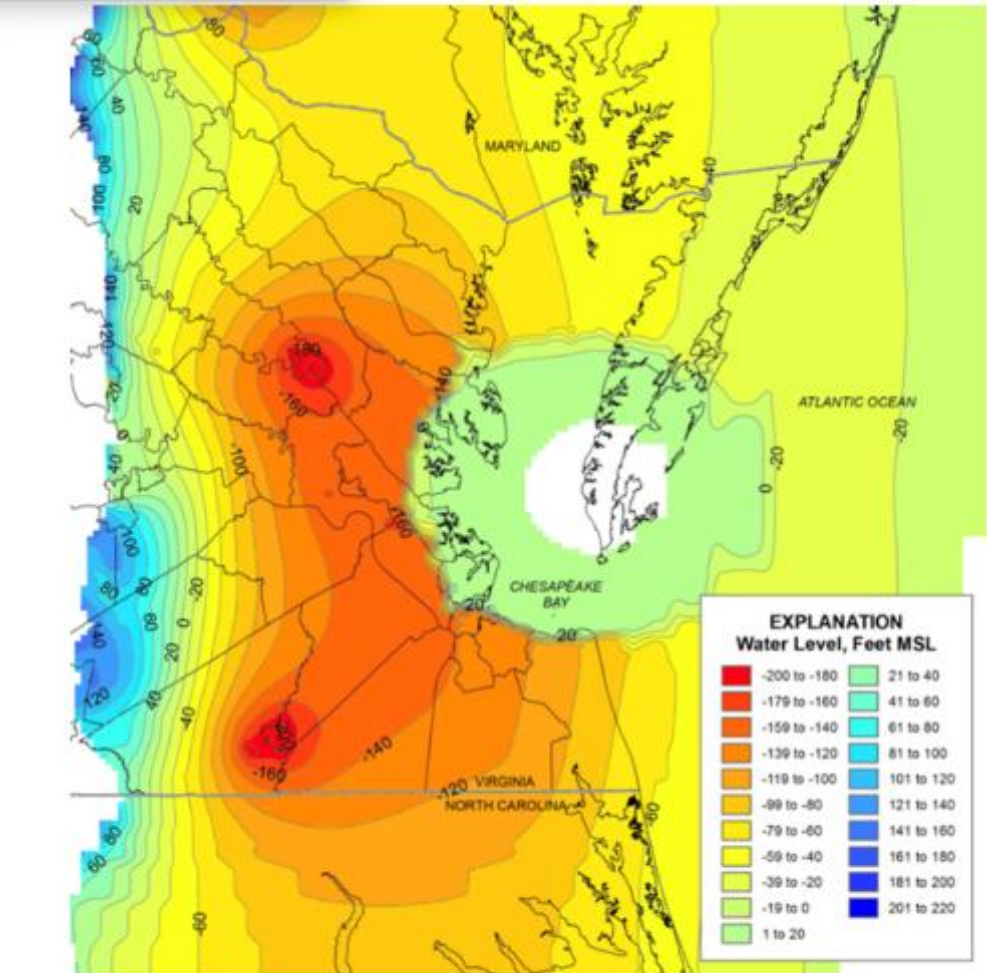
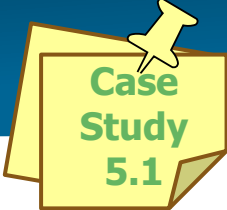
Case Study 5.1

- ▶ An innovative water treatment project in Eastern Virginia
 - ✓ Enhance the sustainability of the region's long-term groundwater supply
 - ✓ Protect the Chesapeake Bay
 - ✓ Address sea level rise and saltwater intrusion
- ▶ At full-scale, SWIFT will be implemented at up to five of HRSD's* wastewater treatment facilities with a total recharge capacity of up to 100 MGD

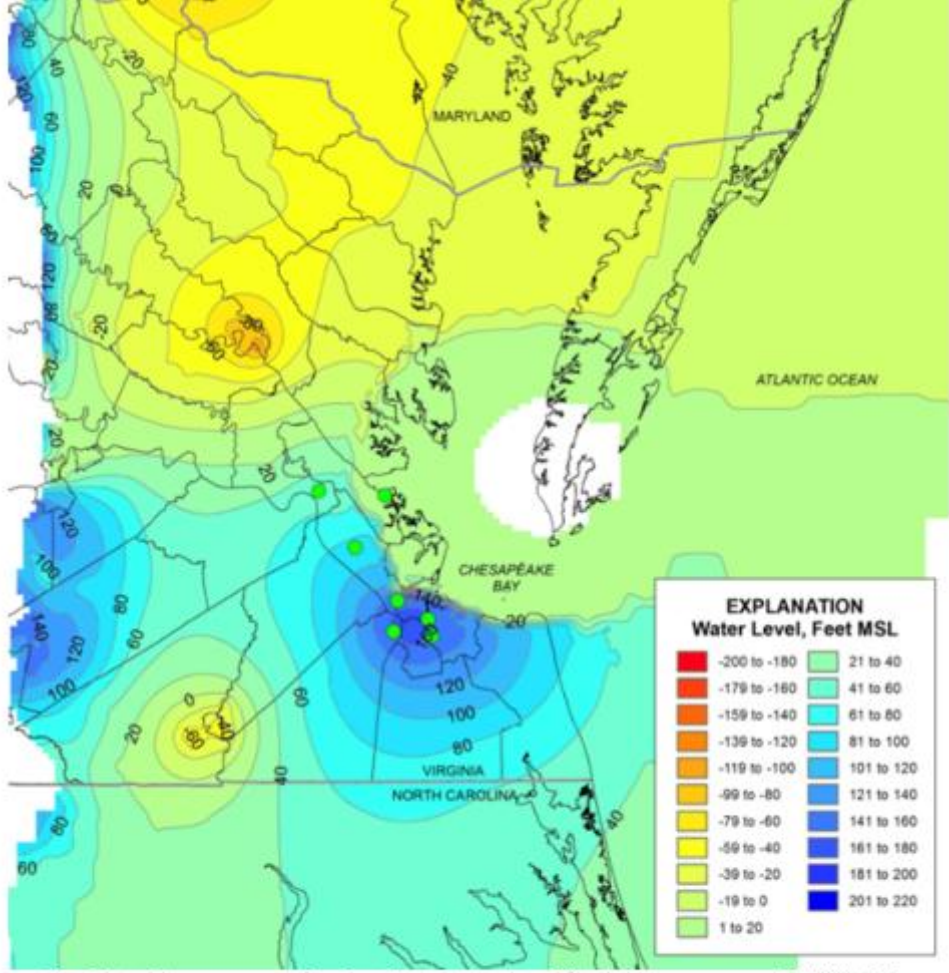


MAR Case Study 5.1 - Figure 1. Location of Virginia's coastal plain. [McFarland and Scott \(2006\); UpdatedPlate1 \(usgs.gov\)](#)
https://pubs.usgs.gov/pp/2006/1731/PDF_plates/PP1731plate1.pdf

Eastern Virginia Groundwater Management Area

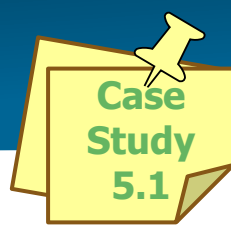


Predicted pressures in the Potomac Aquifer in 50 years without SWIFT replenishment.



Predicted pressures in the Potomac Aquifer in 50 years with SWIFT replenishment.

Intended Use



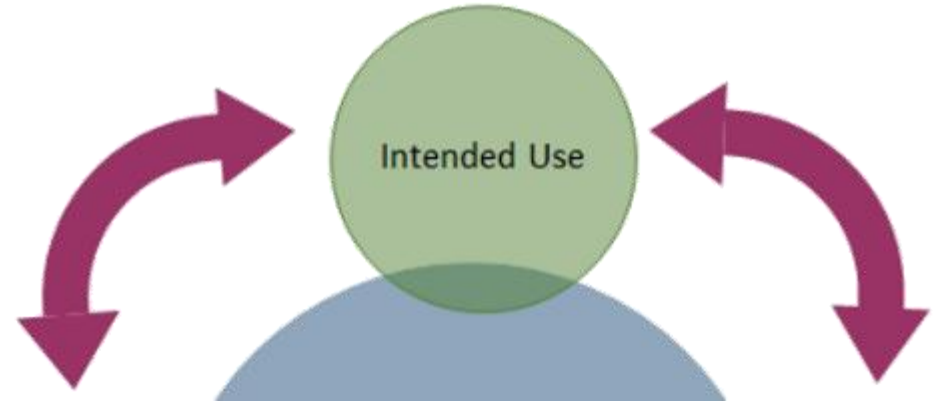
Help Chesapeake Bay by significantly reducing the amount of nutrients such as nitrogen and phosphorus that HRSD discharges to the James, Elizabeth and York rivers

Replenish dwindling groundwater supplies, allowing this natural resource to remain productive for generations to come

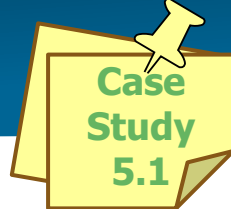
Fight sea level rise by reducing the rate at which land is sinking in Hampton Roads

Protect groundwater from saltwater intrusion due to a shrinking aquifer

Support Virginia's economy by providing businesses with the water they need to operate



Source Water Characteristics

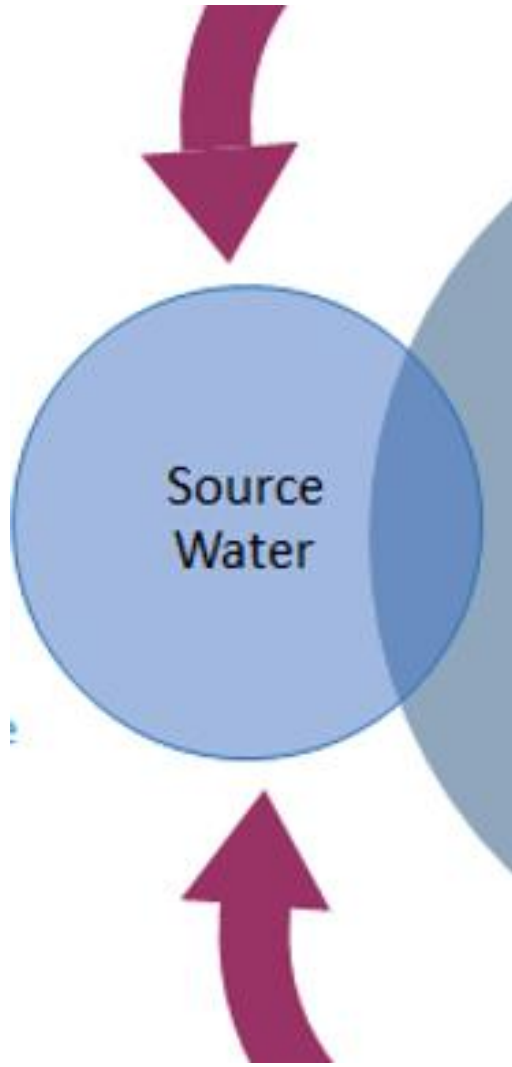


Highly treated secondary effluent

Including nitrogen and phosphorous removal

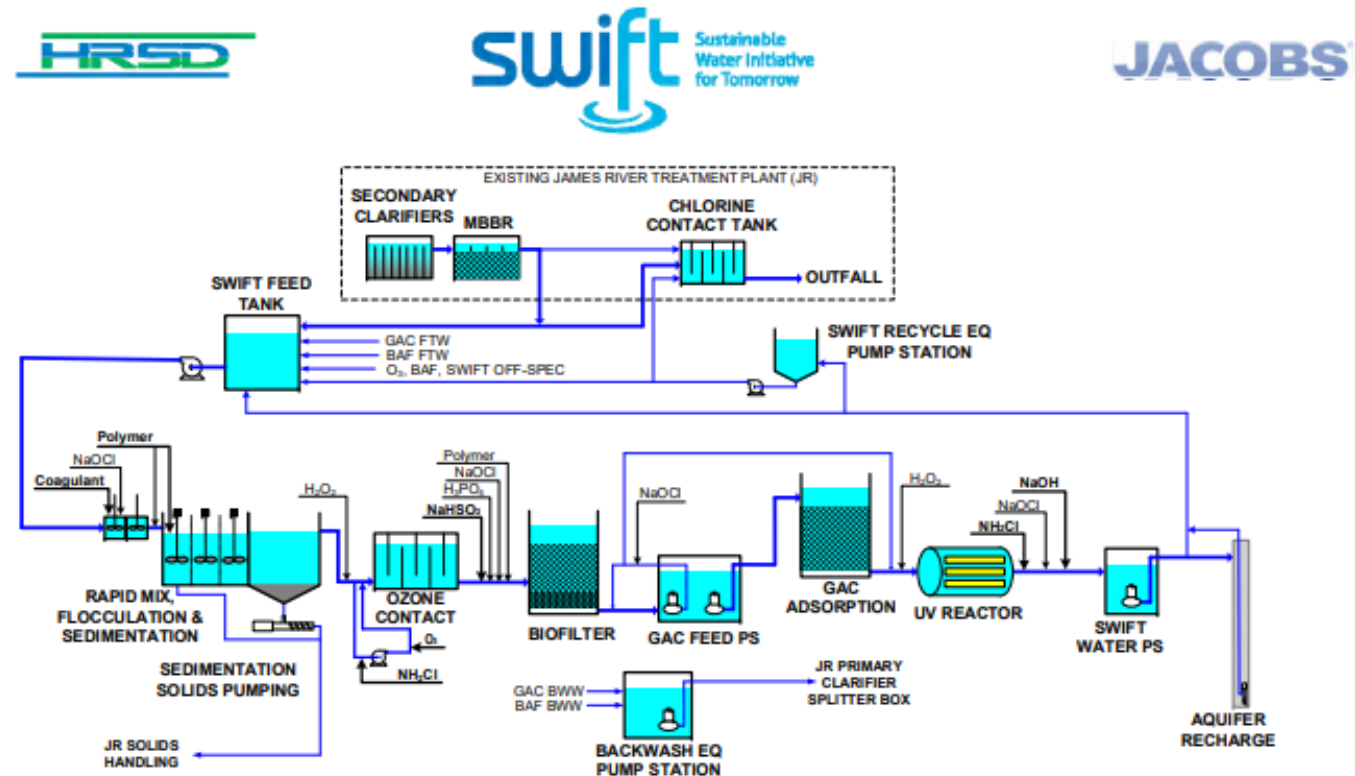
Treated to drinking water standards

Tested carbon-based and membrane-based treatments trains.



Source Water

- SWIFT tested two proven drinking water treatment technologies:
 - Membrane-Based
 - Carbon-Based Advanced Water Treatment Processes
- Create multiple barriers to remove potential contaminants and pathogens
- Stringently monitored throughout each stage
- Estimated capital cost of \$2.0B (\$0.055/gallon of capacity)



MAR Case Study 5.1 - Figure 2. James River SWIFT process flow diagram.

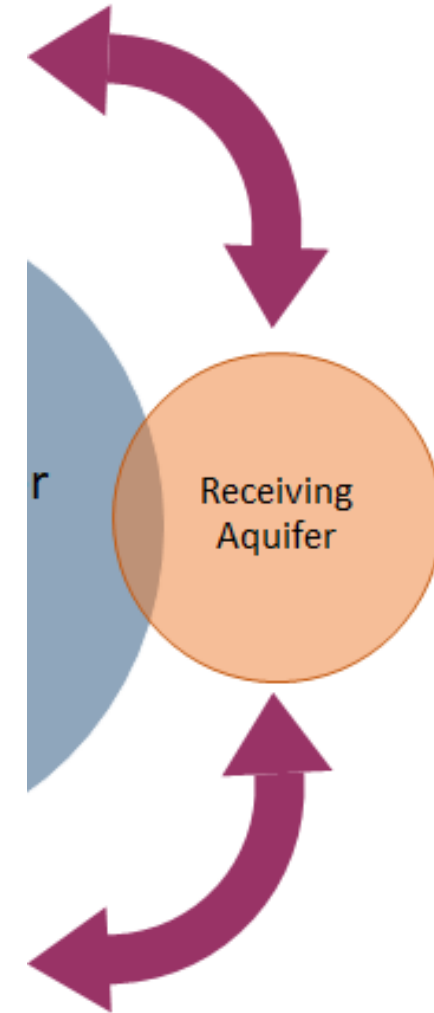
HRSD Permit Application - Part 2 (epa.gov)

https://www.epa.gov/system/files/documents/2022-06/HRSD_Permit_Application_Part2.pdf

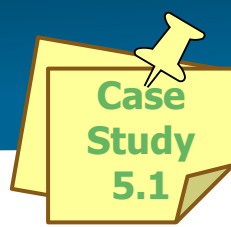
Parameter	Regulatory Limit
USEPA Drinking Water Primary Maximum Contaminant Levels (PMCL)	Meet all PMCL
Total Nitrogen (TN)	5 mg/L Monthly Average; 8 mg/L Max Daily
Turbidity	Individual Filter Effluent (IFE) <0.15 NTU 95% of time and never >0.3 NTU in two consecutive 15-minute measurements
Total Organic Carbon (TOC)	4 mg/L Monthly Average, 5 mg/L Maximum Instantaneous
Total Coliform	<2 CFU/100 mL 95% of collected samples within one calendar month, applied as the 95 th percentile
E. Coli	Non-Detect
TDS	No Limit

Potomac Aquifer System:

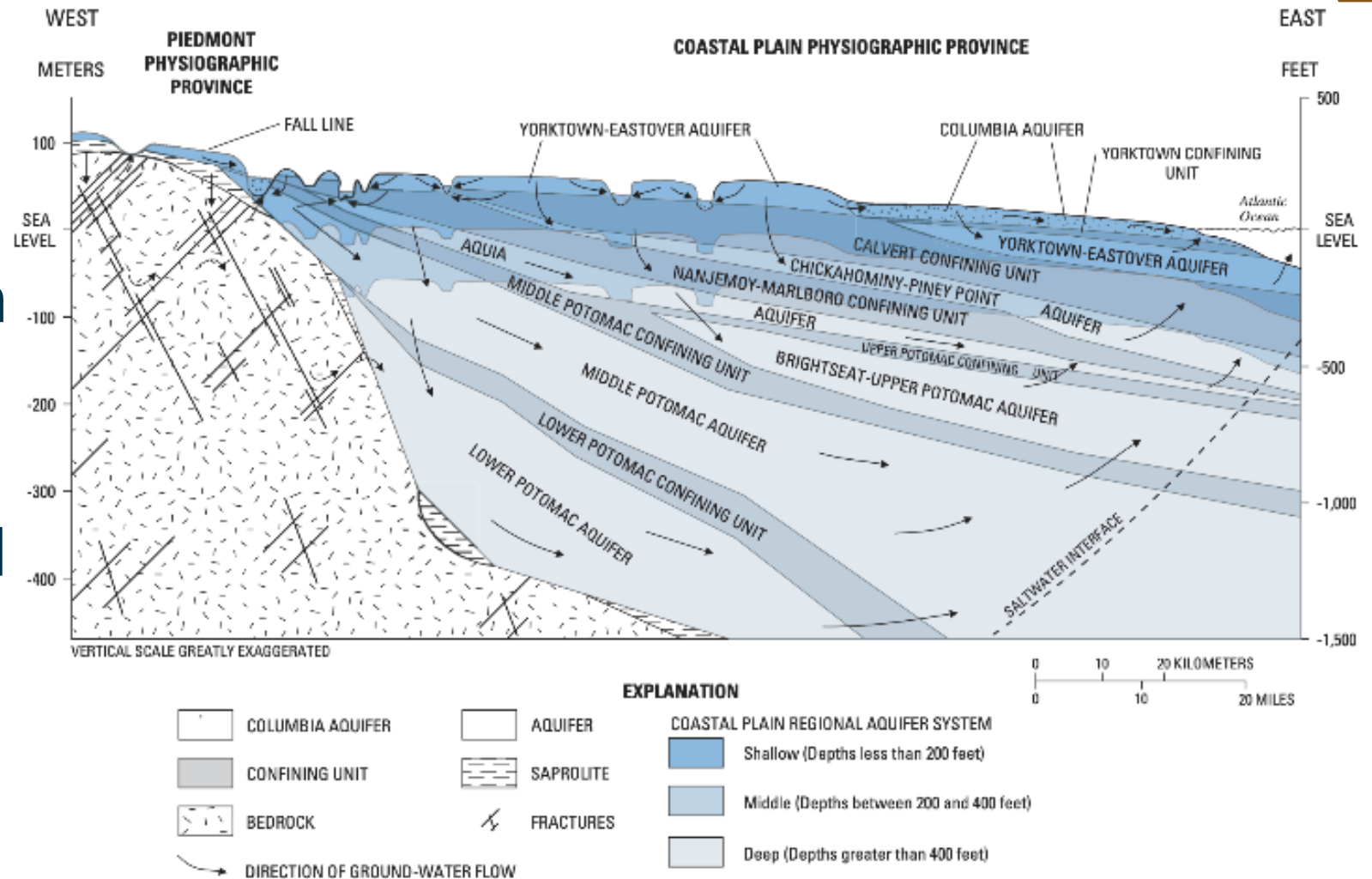
- Largest aquifer several 1000 feet thick
- Confined aquifer with Interbedded clays and sands
- Insufficient ability to recharge naturally
- Contains hundreds of trillions of gallons of pressurized water



Receiving Aquifer Hydrogeologic Setting

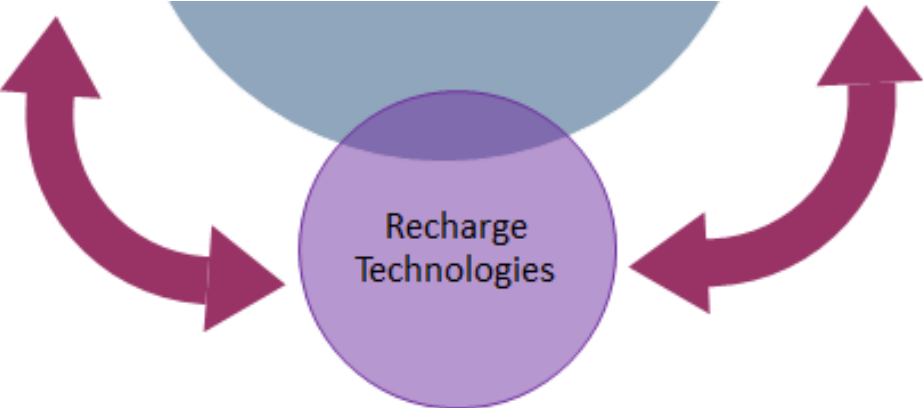
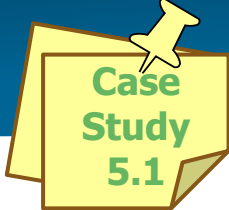


- 100 years of water withdrawal has significantly lowered pressure in aquifer
- Aquifer compaction has resulted in land subsidence and increased potential for saltwater contamination

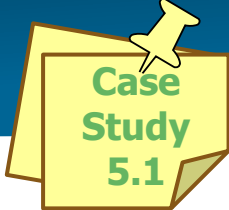


Aquifer Susceptibility in Virginia, 1998-2000. Water-Resources Investigations Report 03-4278, USGS (https://pubs.usgs.gov/wri/wri034278/wrir03_4278.pdf)

Recharge Technology



Recharge Technology



Site Schematic of the SWIFT System

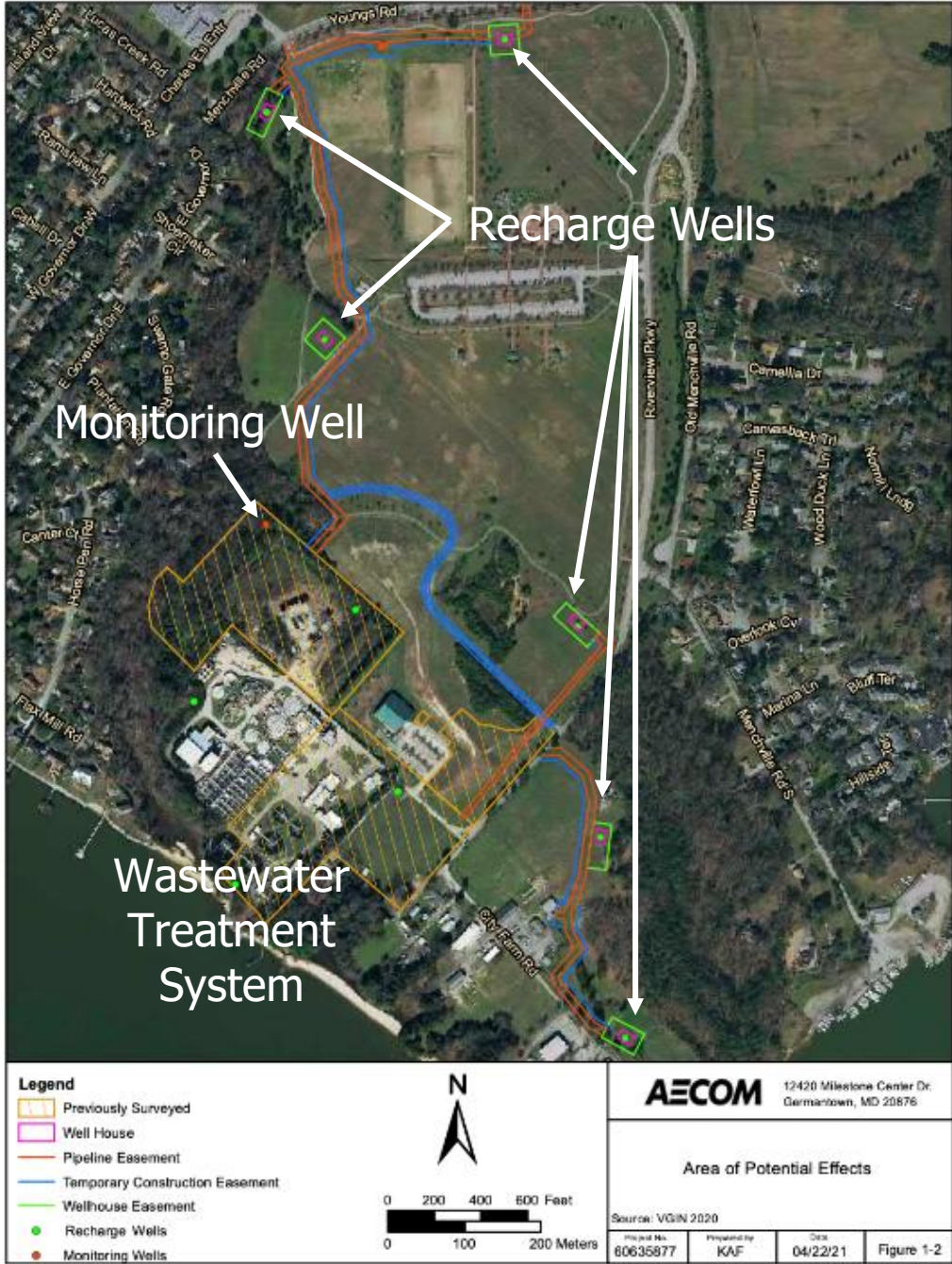
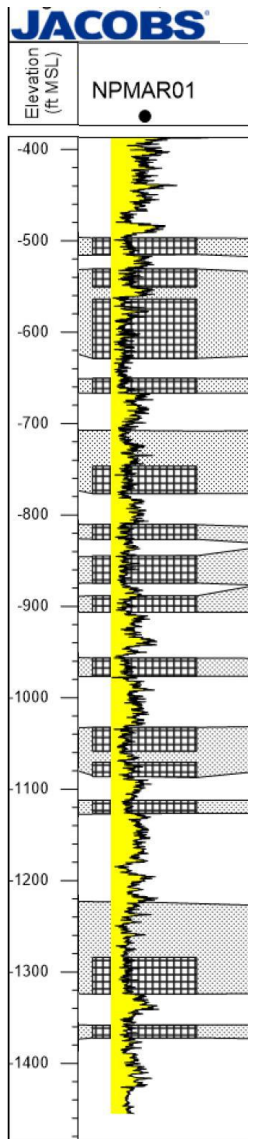
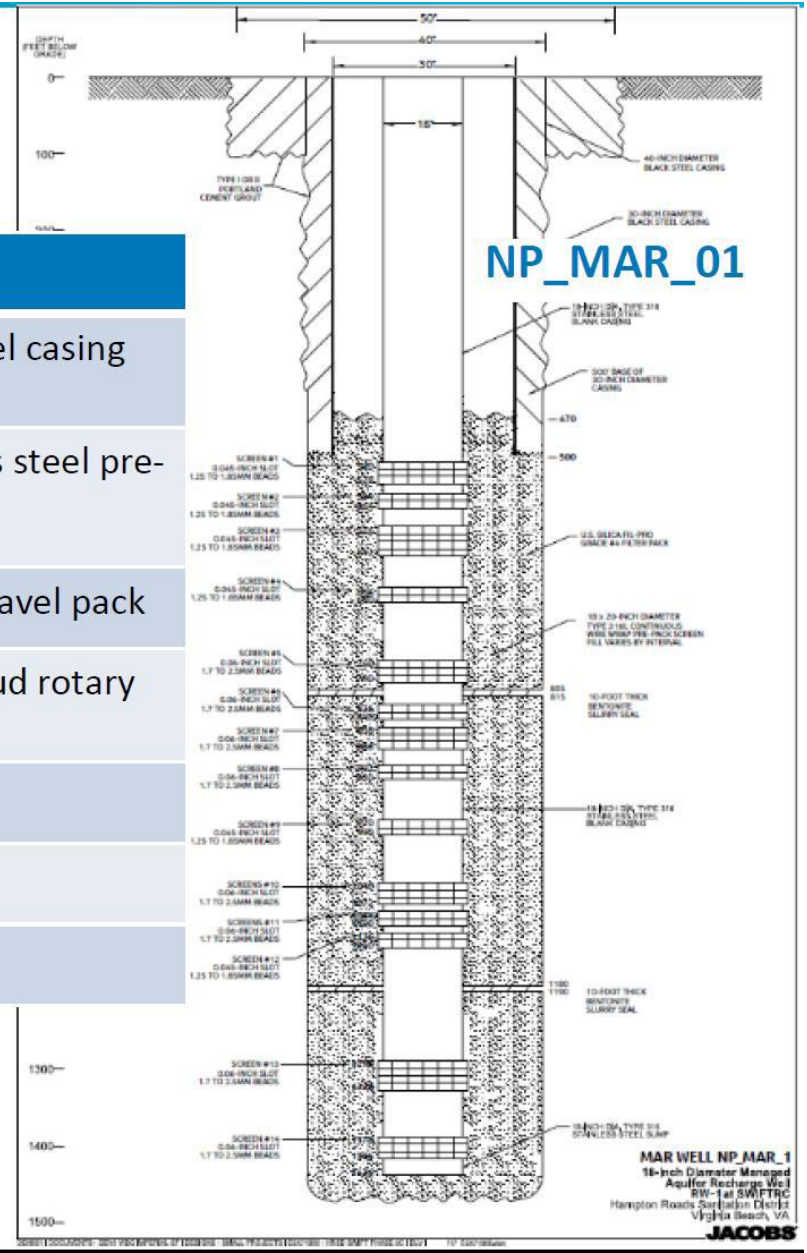


Image Courtesy of AECOM

Case Study 5.1

NP_MAR_01

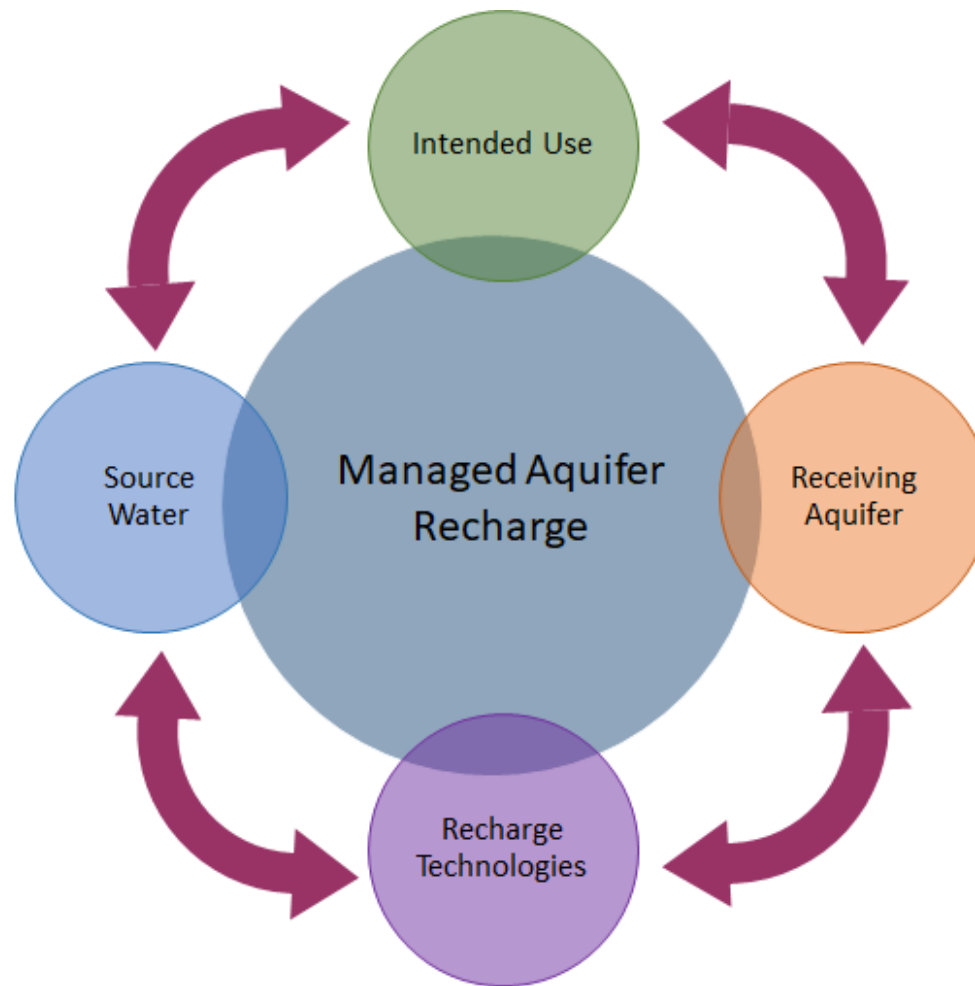
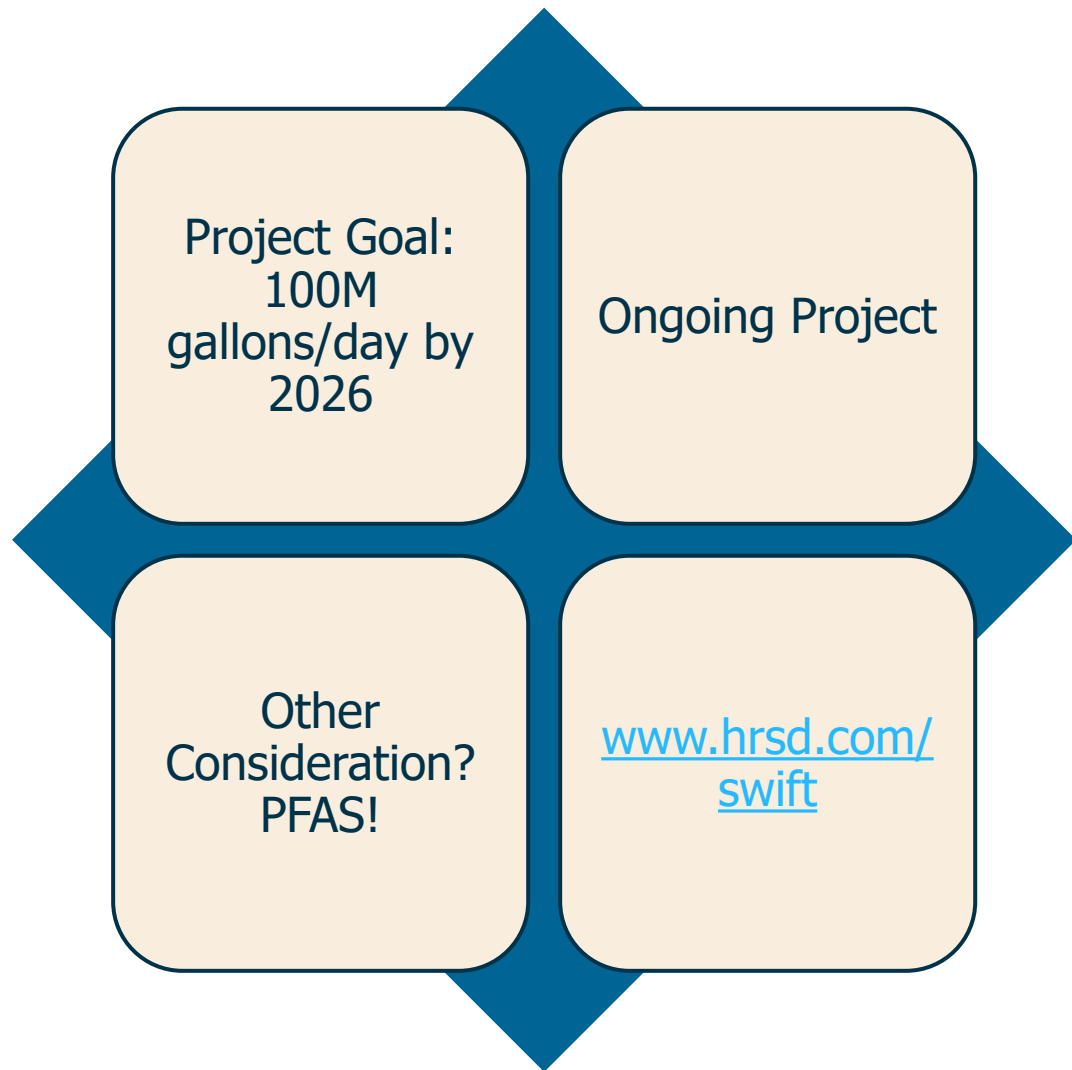
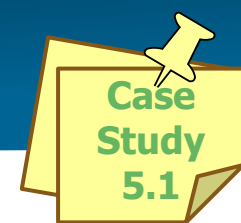
- 30" 316L stainless steel casing
- 18"x20" 316L stainless steel pre-packed screen
- Si spherical beads + gravel pack
- Reverse circulation mud rotary drilling
- Overlap construction
- 14 screen zones
- 342' of screen



MAR-01: Multi-Screen, Multi-Aquifer Recharge Well



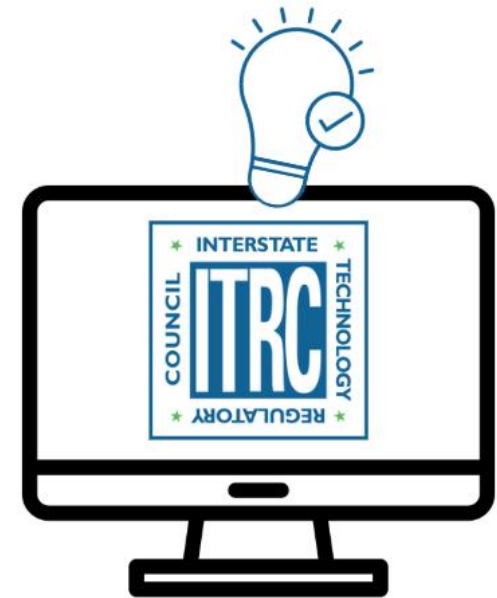
HRSD Sustainable Water Initiative for Tomorrow (SWIFT) Program



Poll Question

What was the source water component of the SWIFT MAR Project design?

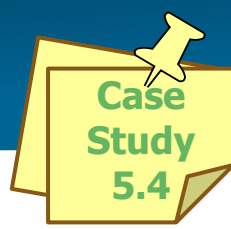
- A. Chesapeake Bay water
- B. Treated wastewater
- C. Desalinated seawater
- D. Surface water



San Antonio Water System H2Oaks Center Aquifer Storage and Recovery (ASR) Project



San Antonio H2Oaks ASR Case Study

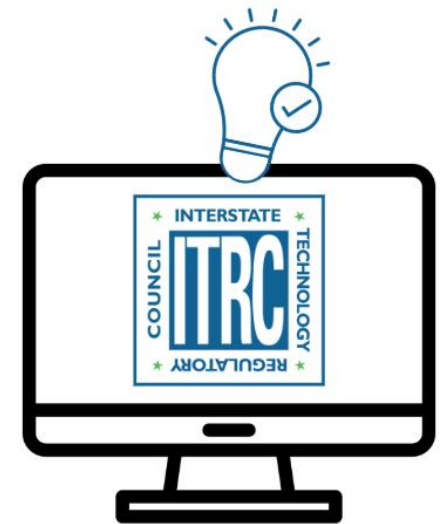


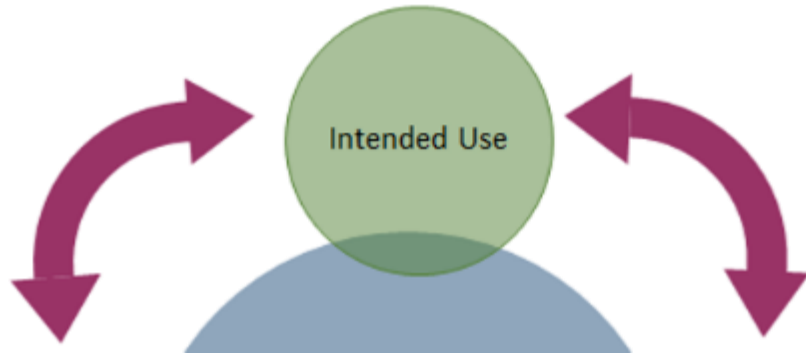
- Obtains most of its water from the Edwards Aquifer
- Does not need its full allocation in wet years

- Regulates withdrawals from the Edwards Aquifer
- Can impose restrictions in drought years

Poll Question

- ▶ What should San Antonio do with the excess Edwards Aquifer water available to them in wet years?
 - A. Don't pump it, leave it in in the Edwards Aquifer
 - B. Pump it, discharge it into a surface water reservoir
 - C. Pump it, inject it into a different aquifer
 - D. Pump it, sell it to a different water provider

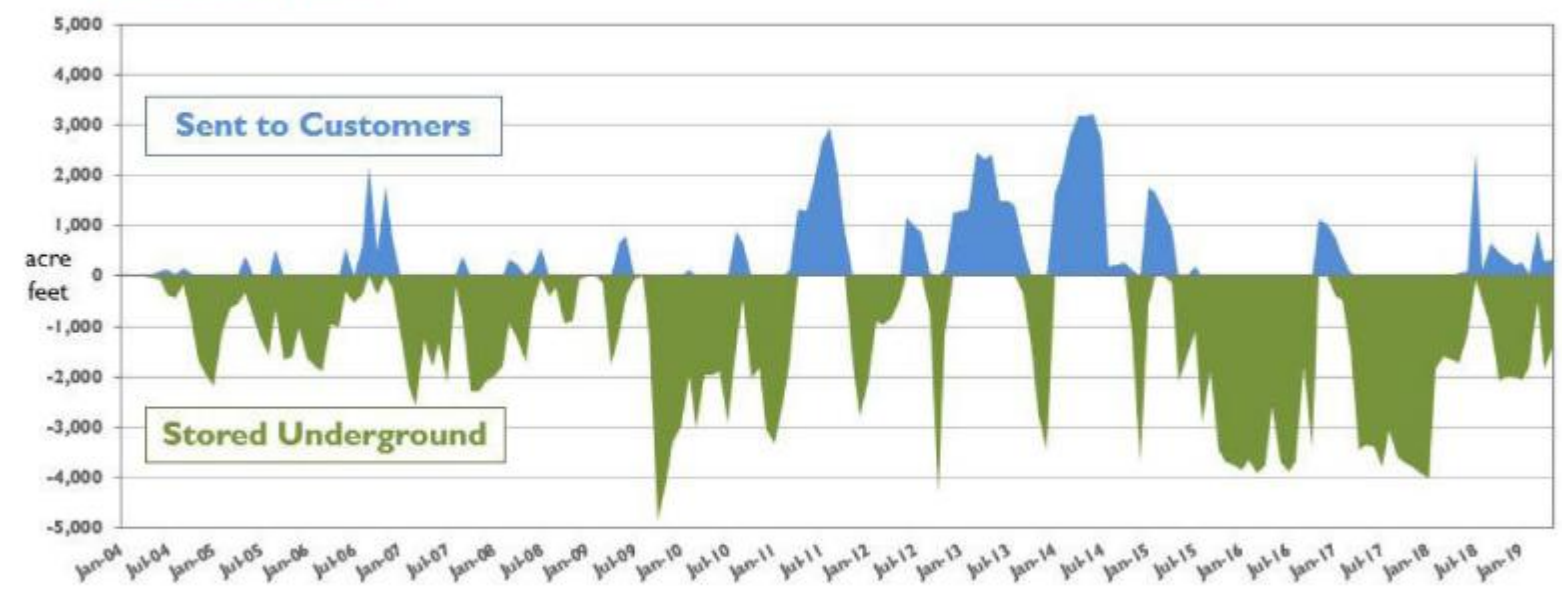




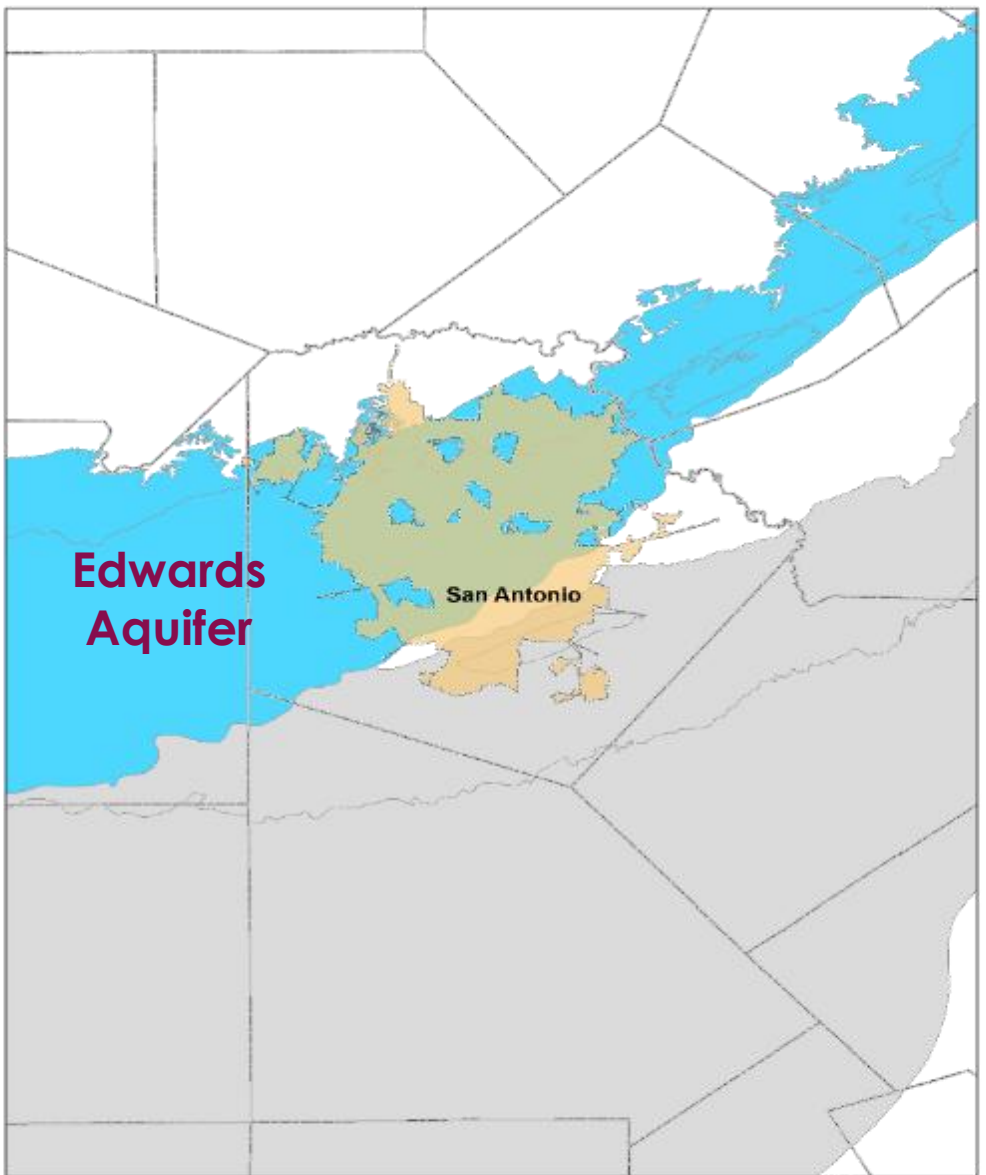
Water Supply Resilience

- Store water during wet years
- Withdraw this water in dry years

ASR Production and Storage Volumes by Month 2004 to May 2019

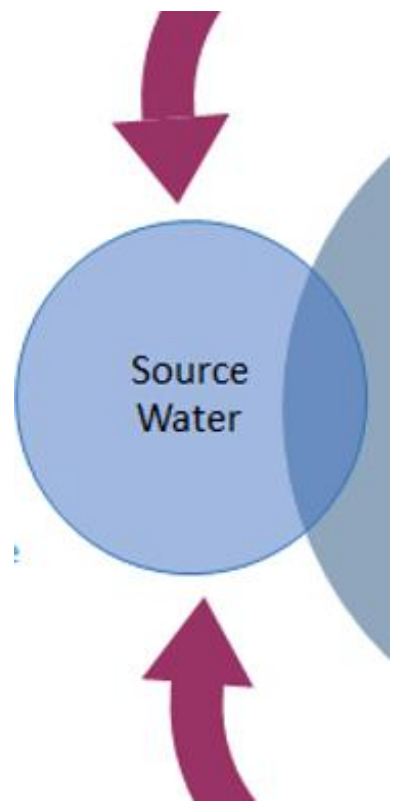


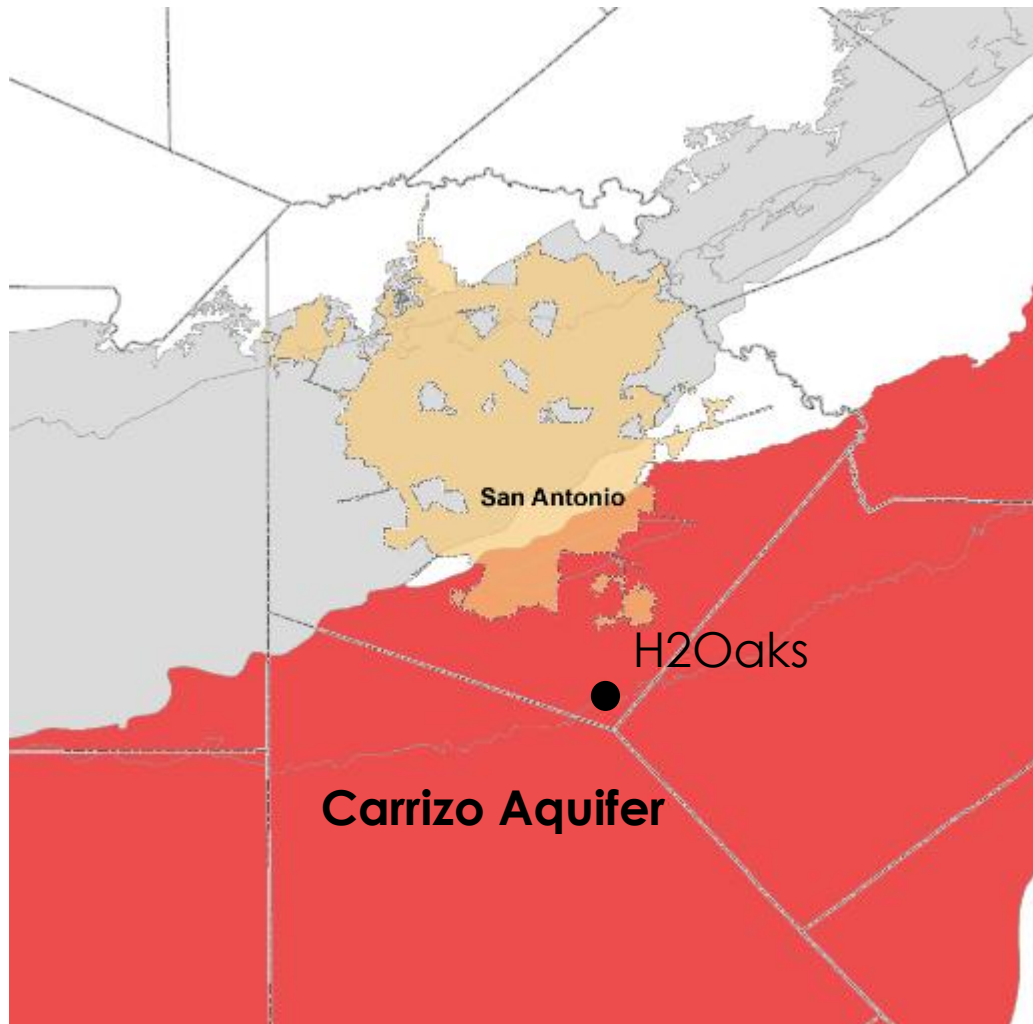
MAR Case Study 5.4 Figure 4. SAWS H2Oaks ASR production and storage volumes by month. Thompson (2019)



Edwards Aquifer

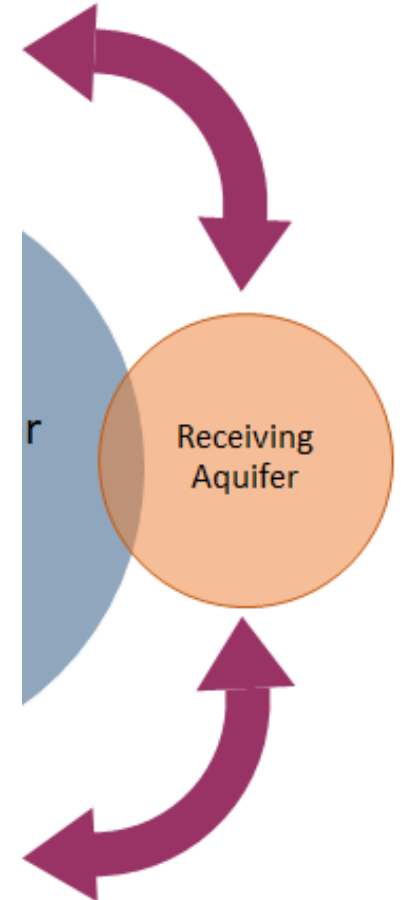
- Limestone aquifer with karst features
- Close to the surface in San Antonio
- Excellent water quality
- Disinfected prior to injection





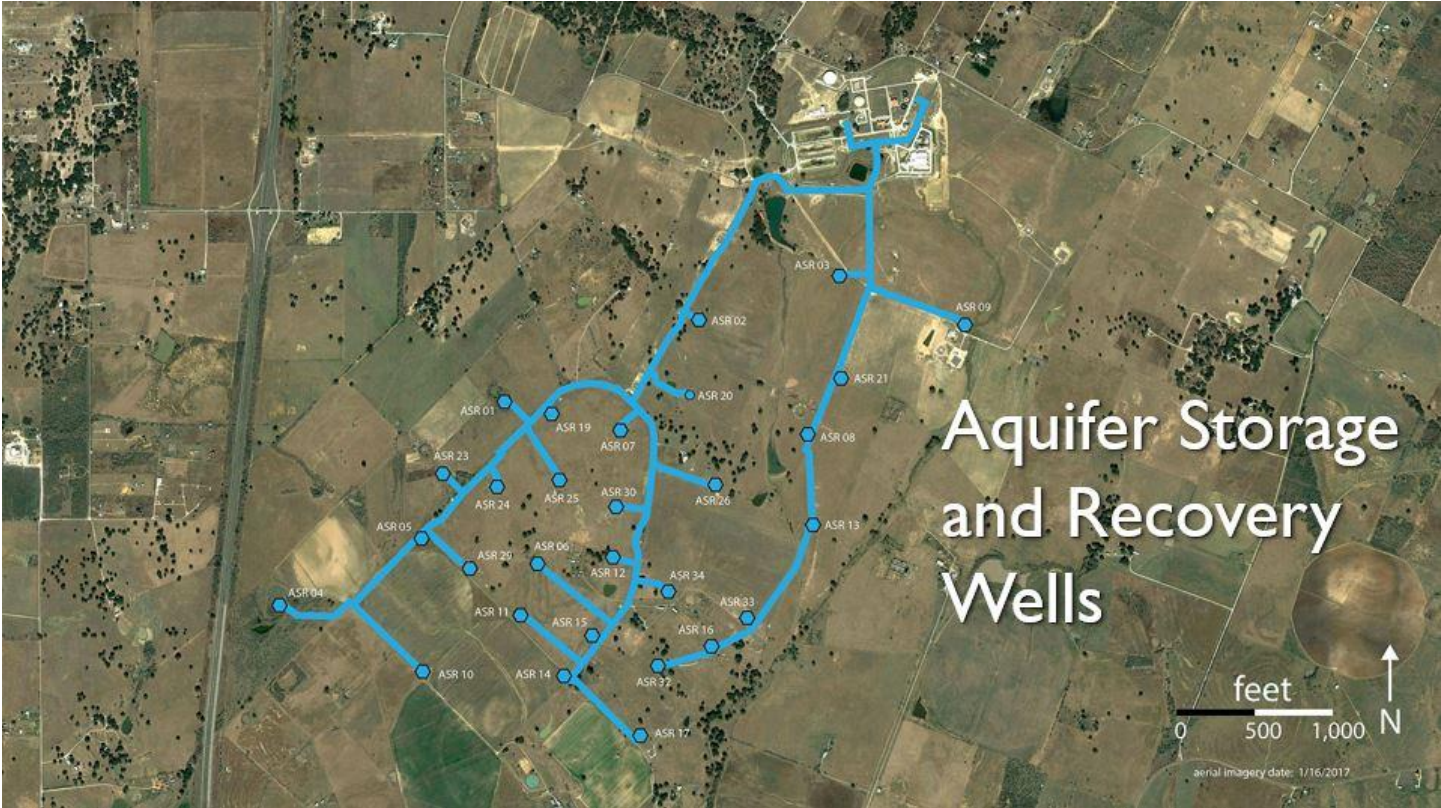
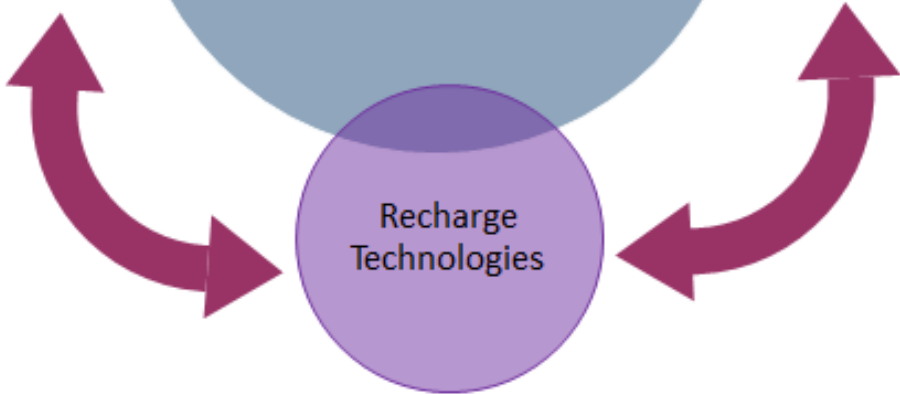
Carrizo Aquifer

- Confined sandstone aquifer
- 400 to 700 feet deep
- Marginal water quality
 - pH = 5.5
 - High dissolved solids, iron, and manganese




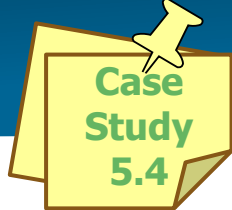
ASR Wells

- 29 ASR wells
- Injection capacity of 74 mgd
- Land available for agricultural uses
- Addressed corrosion of well casings and screens



MAR Case Study 5.4 Figure 2. SAWS H2Oaks ASR well fields. Source: Morrison (2022)

Lessons Learned – Stakeholder Engagement



Water quantity/quality concerns from existing Carrizo users

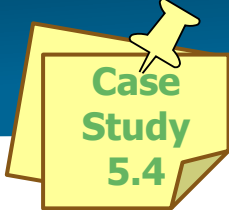







Agreement between SAWS and Evergreen Underground Water Conservation District



Monitoring and Mitigation Plan

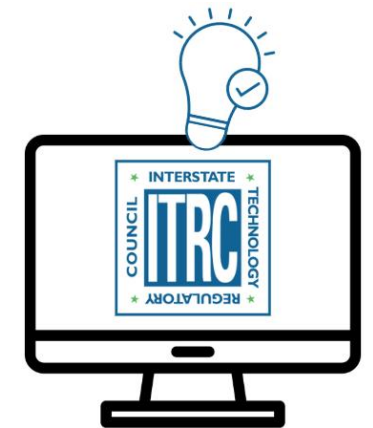
San Antonio H2Oaks ASR Case Study



WATER SOURCE AT A GLANCE	PROJECT					
	Edwards Aquifer water stored in Carrizo	HOUSEHOLDS SERVED 59,500	WATER DISTRIBUTED IN 2022 14,900 AF	% OF WATER DISTRIBUTED IN 2022 4.4%	WATER STORED IN 2022 11,600 AF	TOTAL AMOUNT STORED END OF 2022 189,000 AF

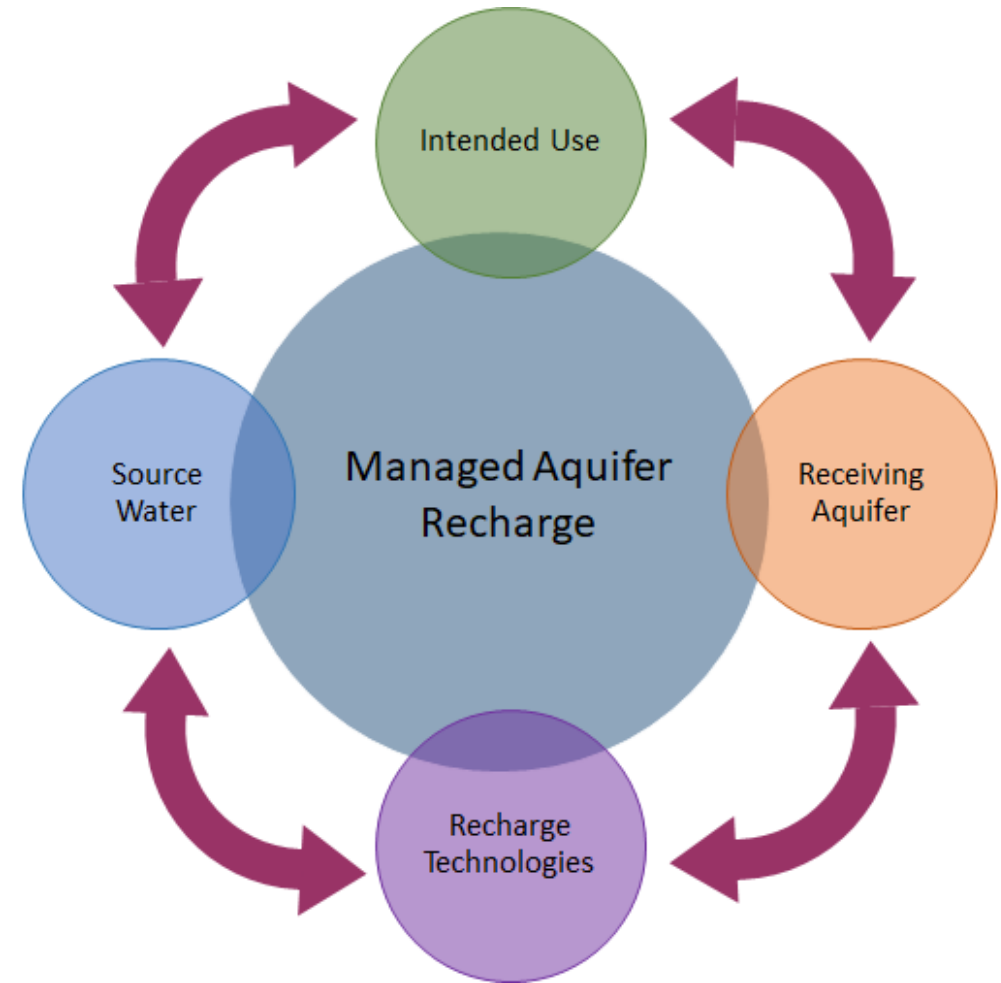
Poll Question

- ▶ Which of these was a concession made by SAWS to existing users of the Carrizo Aquifer?
 - A. Treated wastewater cannot be used as source water
 - B. No native Carrizo groundwater may be extracted
 - C. SAWS must replace all private wells with public supply
 - D. H2Oaks was annexed into the Evergreen Underground Water Conservation District



What did we learn today?

- MAR is a **PROCESS**: not a formula or linear flowchart
- **WIDELY APPLIED** to all types of aquifers: unconsolidated sediments, floodplains, crystalline or karst bedrock
- Future of MAR is now, addressing **WATER SUPPLY RESILIENCE**



MAR Recap



MAR Case Study Figure 6. The Johnson Aquifer recharge site.
Source: WWBWC (2023).



Walla Walla River Basin – CTUIR Fish Habitat
Restoration Efforts in the Walla Walla River Basin
<https://wallawallariver.org/>

MAR Recap

- ▶ Head to the Guidance Document and find:
 - Section 2.0: Project Planning
 - Stakeholder Engagement
 - Regulatory Considerations
 - Permitting
 - Section 3.6: Data & Modeling
 - Appendix B: Water Quality Parameters
 - Appendix C: State, Territory & Tribal Regulatory Contacts

Questions

ITRC Managed Aquifer Recharge (MAR) Guidance Document mar-1.itrcweb.org



Certificate of Completion <https://clu-in.org/conf/itrc/mar/>
(emailed after you complete the Feedback Form)