ASR Operations in the US: historic analysis with updates beyond the 2013 inventory

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Acknowledgments

- Joseph J. Danko, Ph.D., Brown University
- Samuel Ratick, Ph.D., Clark University

Introduction

- Aquifer storage is a tool employed for the management of water for both potable and non-potable water supplies to increase the efficiency of water system operations

- American Water Works Association (AWWA) Manual of Practice M21 "Groundwater" divides aquifer storage programs into four categories: Artificial Aquifer Creation, Aquifer Recharge, Aquifer Reclamation, and Aquifer Storage and Recovery (ASR)
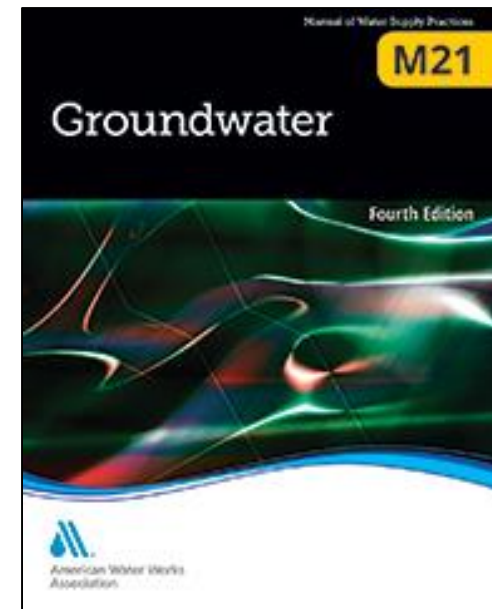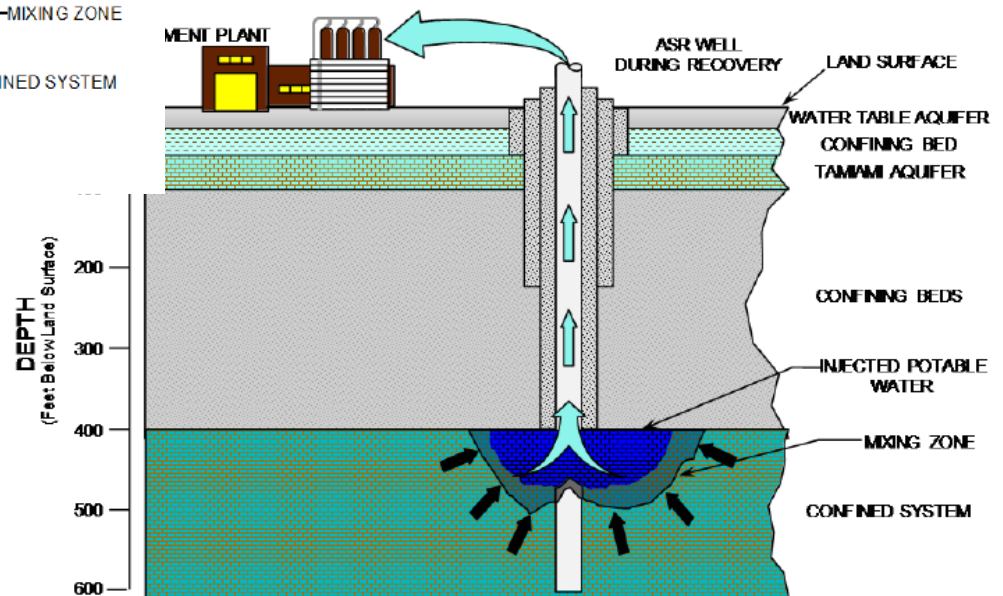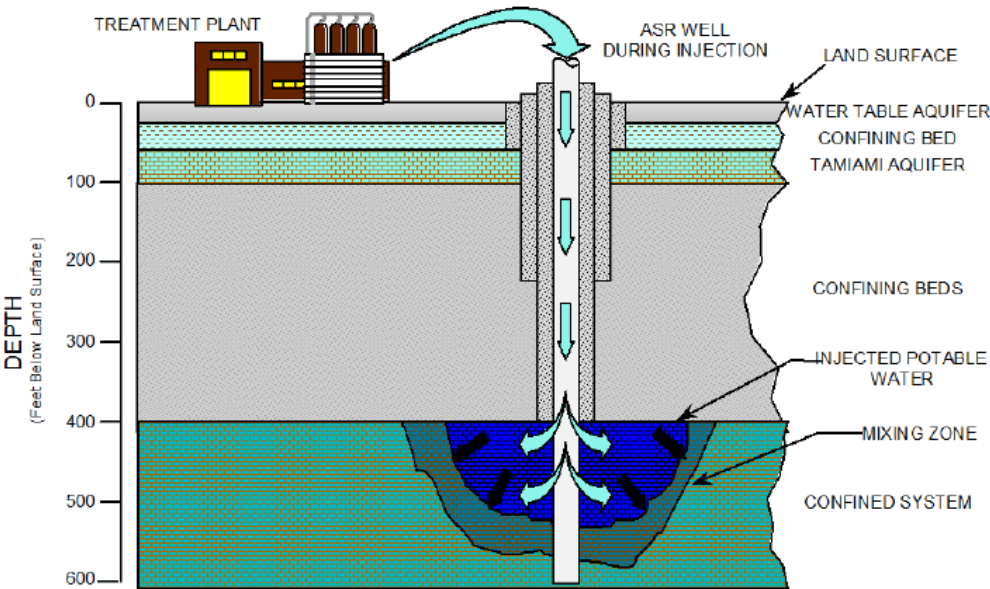
Introduction

- The concept of ASR has been applied in the U.S. since the late 1940s and limited development occurred until the 1990s.

- Common applications are the injection of potable or raw water into an aquifer with the intention to provide future withdrawal for augmentation of water supplies later

- In the U.S., ASR wells are covered under EPA's UIC program and delegated state programs

Introduction

Introduction

- **Regulatory requirements**
  - Federal underground injection control – Class V wells
  - State zones of discharge or mixing zone – allow exceedance of groundwater standards for some distance from the well
  - Water rights and allocations
  - Use of reclaimed water
  - Use of impaired water

Introduction

States with ASR-specific Statutes or Rules

Introduction

1985 – ASR Projects in 3 states
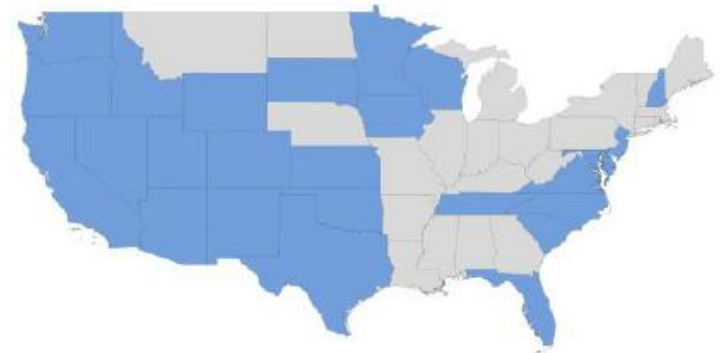
1995 – ASR Projects in 8 states
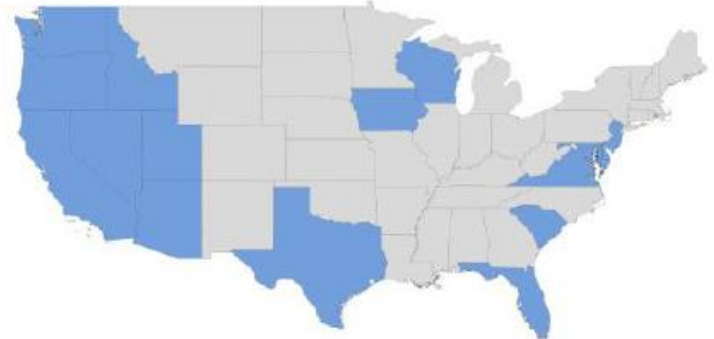
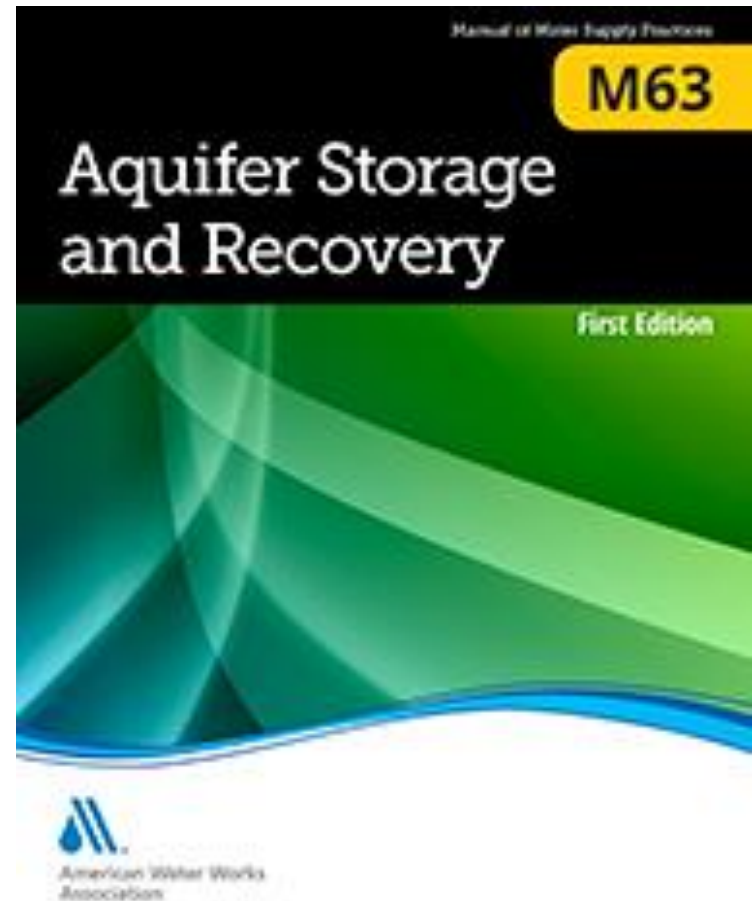2001 – ASR Projects in 15 states

2010 – ASR Projects in 27 states

Introduction

- A survey was conducted in 2013 by Fred Bloetscher of FAU for the development of an American Water Works Association (AWWA) manual of practice on ASR (M63) – published in 2015

- The survey identified 204 ASR sites in the U.S. for which data were collected

Introduction

- In addition to M63, three articles were published
  - Bloetscher, F., Sham, C.H., Danko III, J.J. and Ratick, S. (2014) Lessons Learned from Aquifer Storage and Recovery (ASR) Systems in the United States. Journal of Water Resources and Protection, 6, 1603-1629.
  - Bloetscher, F., Sham, C.H., Danko III, J.J. and Ratick, S. (2015) Status of Aquifer Storage and Recovery in the United States – 2013. British Journal of Science, 12(2), 70-88.
  - Bloetscher, F. (2018) Can Prior Experience Provide a Means to Predict Success of Future Aquifer Storage and Recovery Systems? American Journal of Environmental Engineering, 8(5), 181-200.

Data Collection Effort

- Data elements:
  - Well sites and status
    - State
    - Date the program was initiated or first well drilled
    - Stage of development/status – study, testing, operational, or abandoned
    - Number of wells drilled
    - Number of abandoned wells
    - Number of ASR wells onsite to accommodate design capacity
    - Number of abandoned wells or wells no longer in service

Data Collection Effort

- Data elements:
  - Operation status
    - Source of water – ground, surface, reclaimed, or industrial
    - Use of recovered water – irrigation, potable water supply, raw water supply, or surface water augmentation
    - Number of storage cycle (estimated; indicative of age)
    - Injection rate for individual well
    - Withdrawal rate for individual well
    - Inject and withdrawal ratio (calculated)
    - Peak flow (measure of total available capacity)
    - Total water stored (measure of storage)
    - Operational issues

Data Collection Effort

- Data elements:
  - Well characteristics
    - Depth of well casing below the surface
    - Depth of well borehole
    - Casing diameter
    - Presence of tubing and/or packer
    - Casing material – steel, PVC, fiberglass, stainless steel

Data Collection Effort

- Data elements:
  - Injection zone
    - Formation – limestone, sand, sandstone, basalt, or alluvial
    - Transmissivity
    - Total dissolved solids of water in injection formation
    - Type of confinement – clay, dolomite, silt, shale, sandstone, basalt, or none
    - Number of monitoring wells

Data Collection Effort

- At the 2019 GWPC UIC annual conference in Fort Worth, TX – received comments from attendees regarding potential changes due to
  - EPA's letter on Florida's ASR facilities
  - Texas drought in the early 2010s sparked interest in ASR as a part of the water management toolkit
- Working on finding funding to update the 2013 dataset
- Performed selected inquiries to gather updates

Data Collection Effort

- 2013 data clean-up (204 ASR sites)
  - Compilation of dataset – 24 predictor variables
  - Chi-square tests to determine if there is a statistically significant relationship between program status and each of the categorical variables
- 2019 selective inquiries to supplement dataset
  - Texas, Oregon, Washington, Utah, Florida, S. Carolina
  - Minor changes to the number of active ASR sites
  - About 30 sites have investigated or are considering investigating ASR, but less than 10 wells drilled

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Descriptive Statistics (2013 Dataset)

ASR projects by state
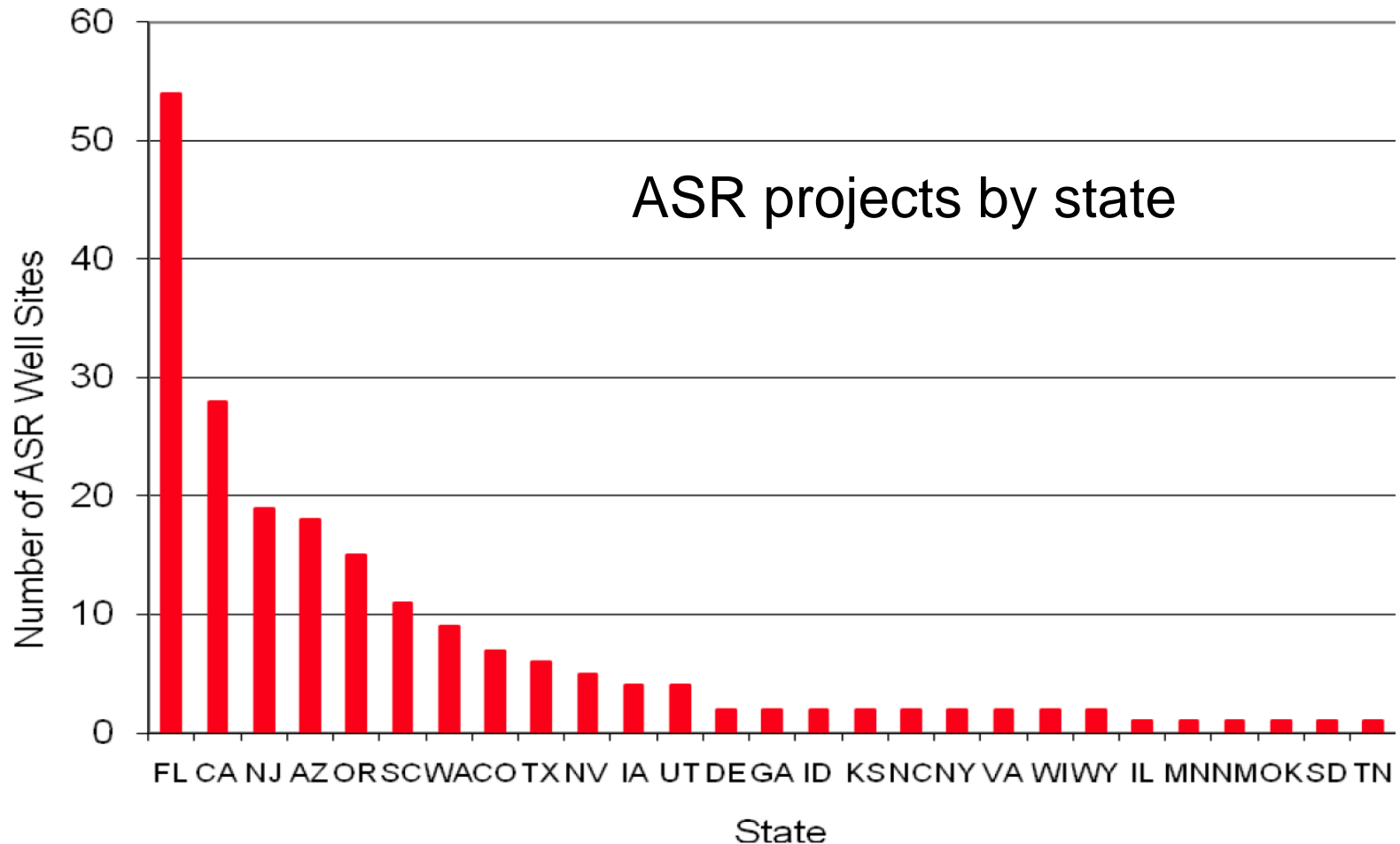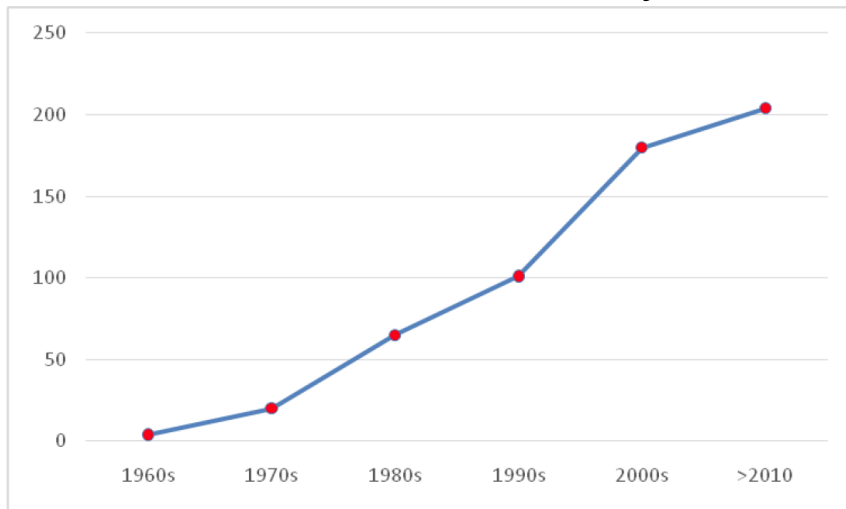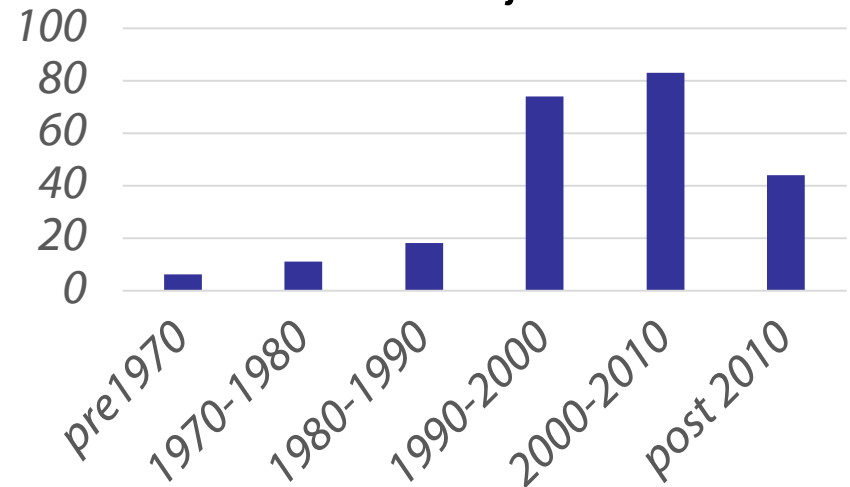
2019 Review – Biggest Changes – TX and UT
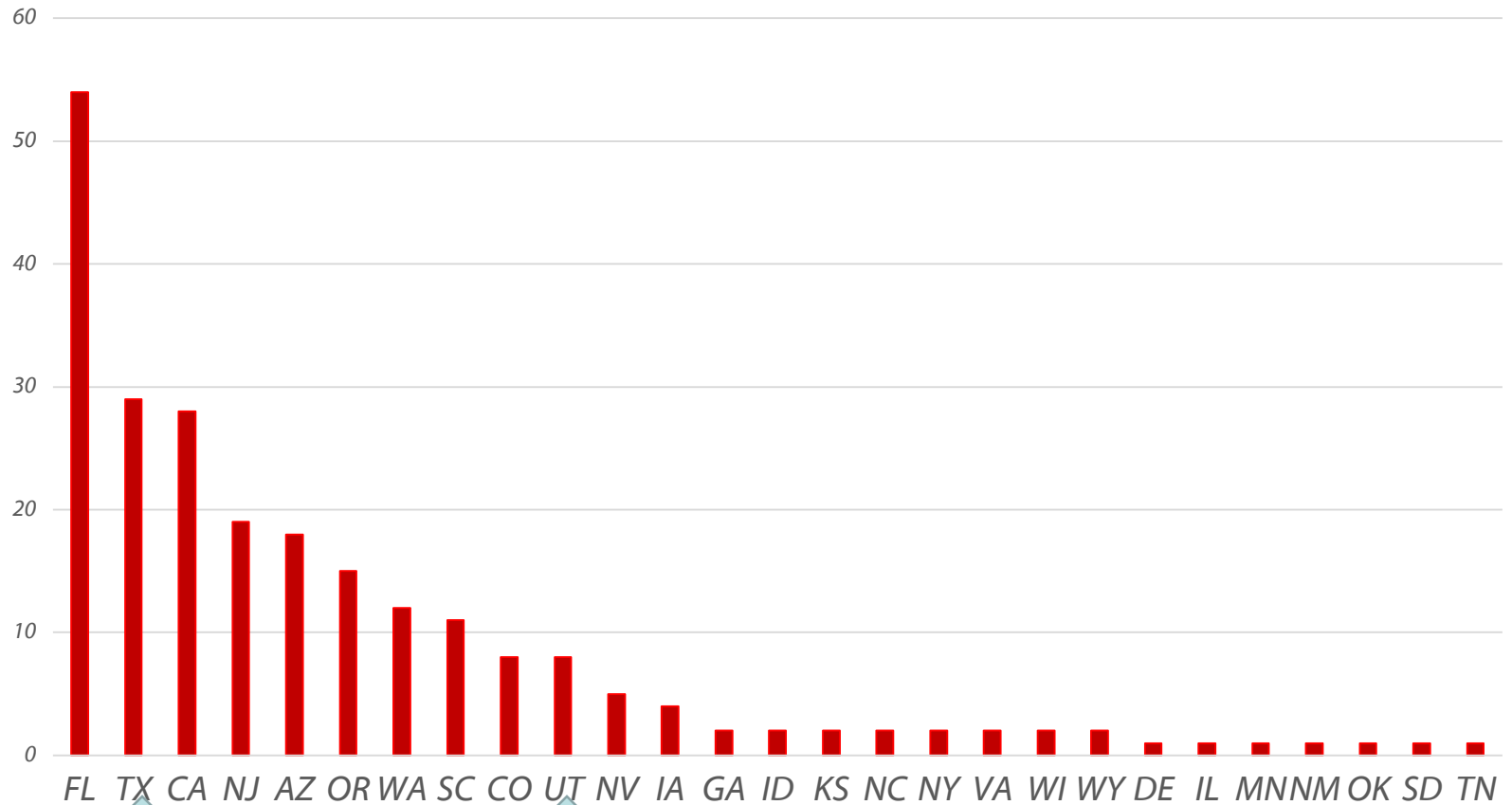
Descriptive Statistics (2013 vs 2019 datasets)

Cumulative ASR sites by decade

Date ASR Projects Started
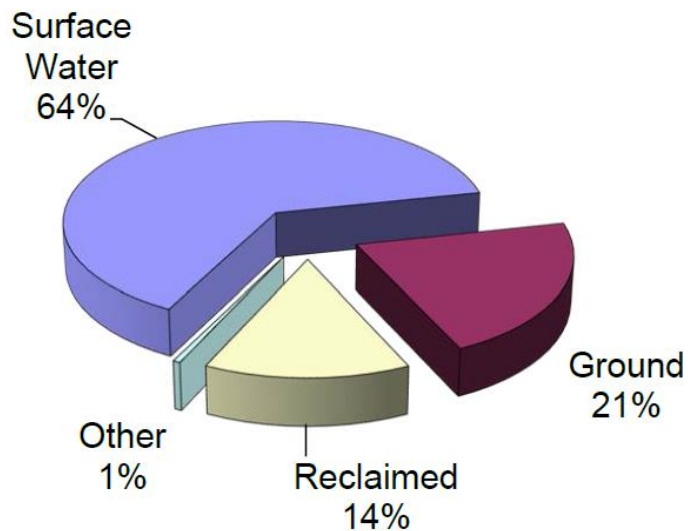
Descriptive Statistics

Sources of water used for ASR programs

Surface Water 64%
Ground 21%
Reclaimed 14%
Other 1%

Source of water for ASR Injection

Raw GW | PWS | Sruface water | Reclaimed water | Multiple sources
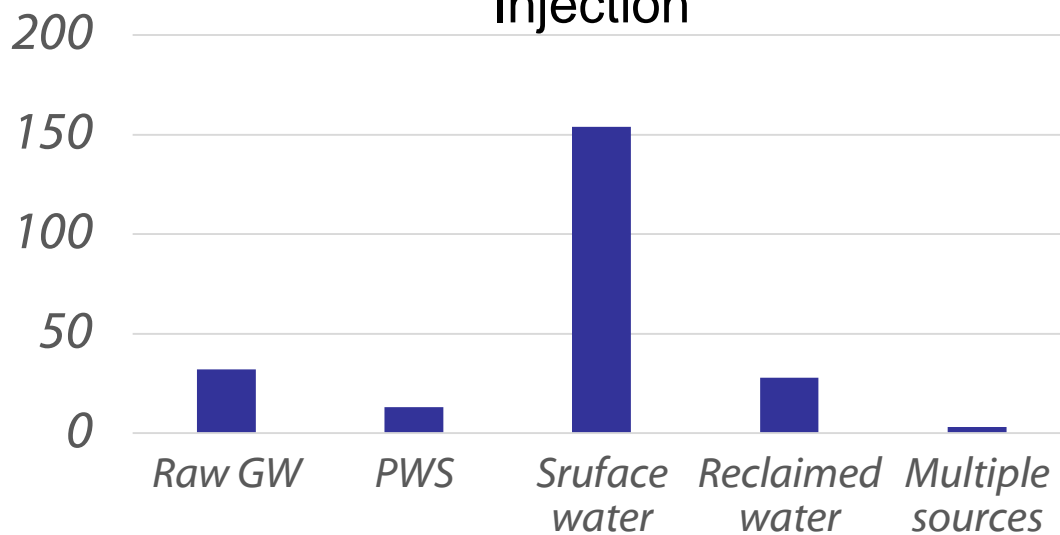
Descriptive Statistics

Uses of water recovered from ASR programs

Potable Supply 53%
Raw 26%
Fire 1%
Canal Recharge 1%
Cooling Water 1%
Irrigation 18%

Use of Recovered Water

Raw water, Irrigation, Potable, canal recharge, cooling, industry, fire dept, PWS
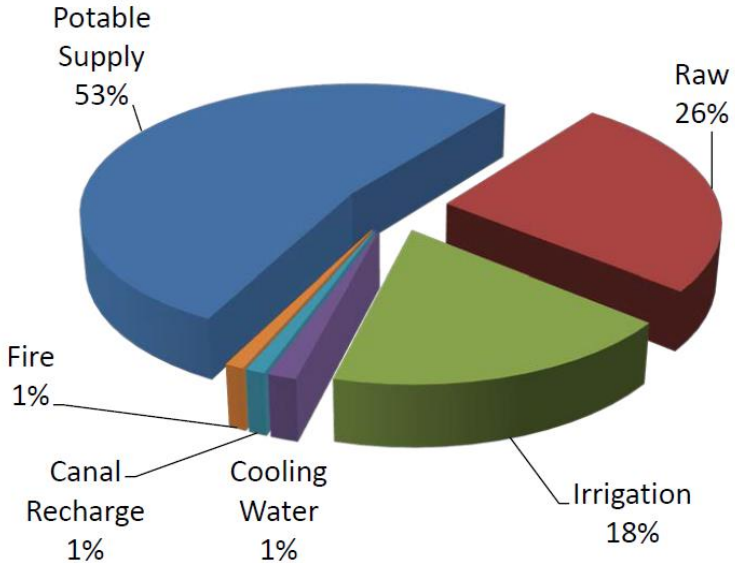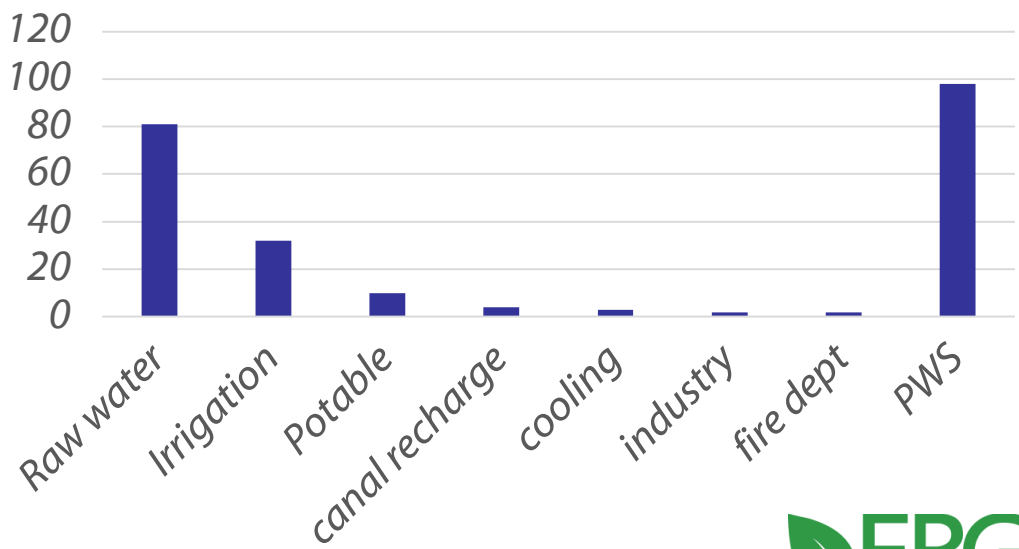
Descriptive Statistics
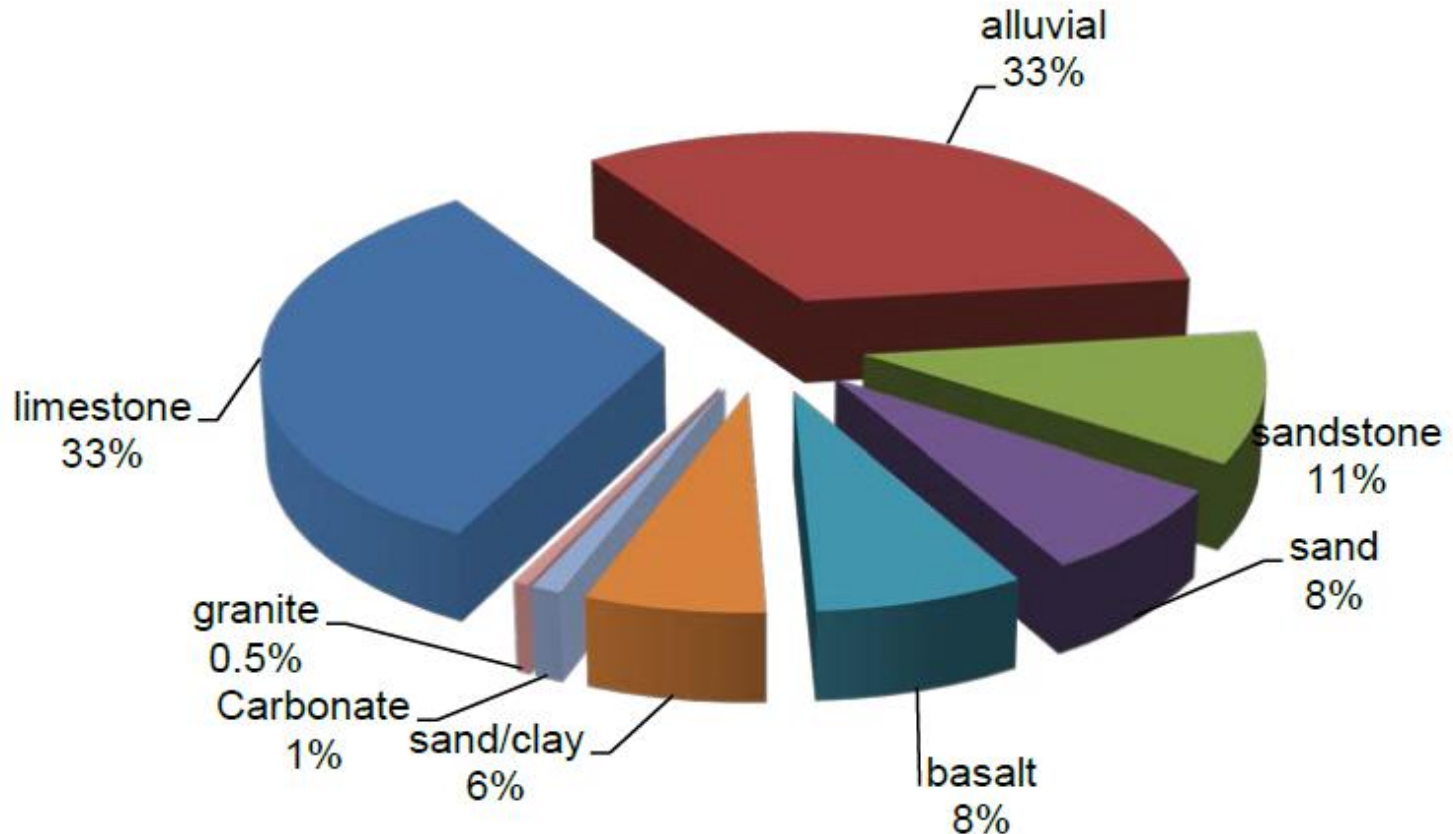
Injection formation type – note this has not changed much since wells have not been drilled

Descriptive Statistics
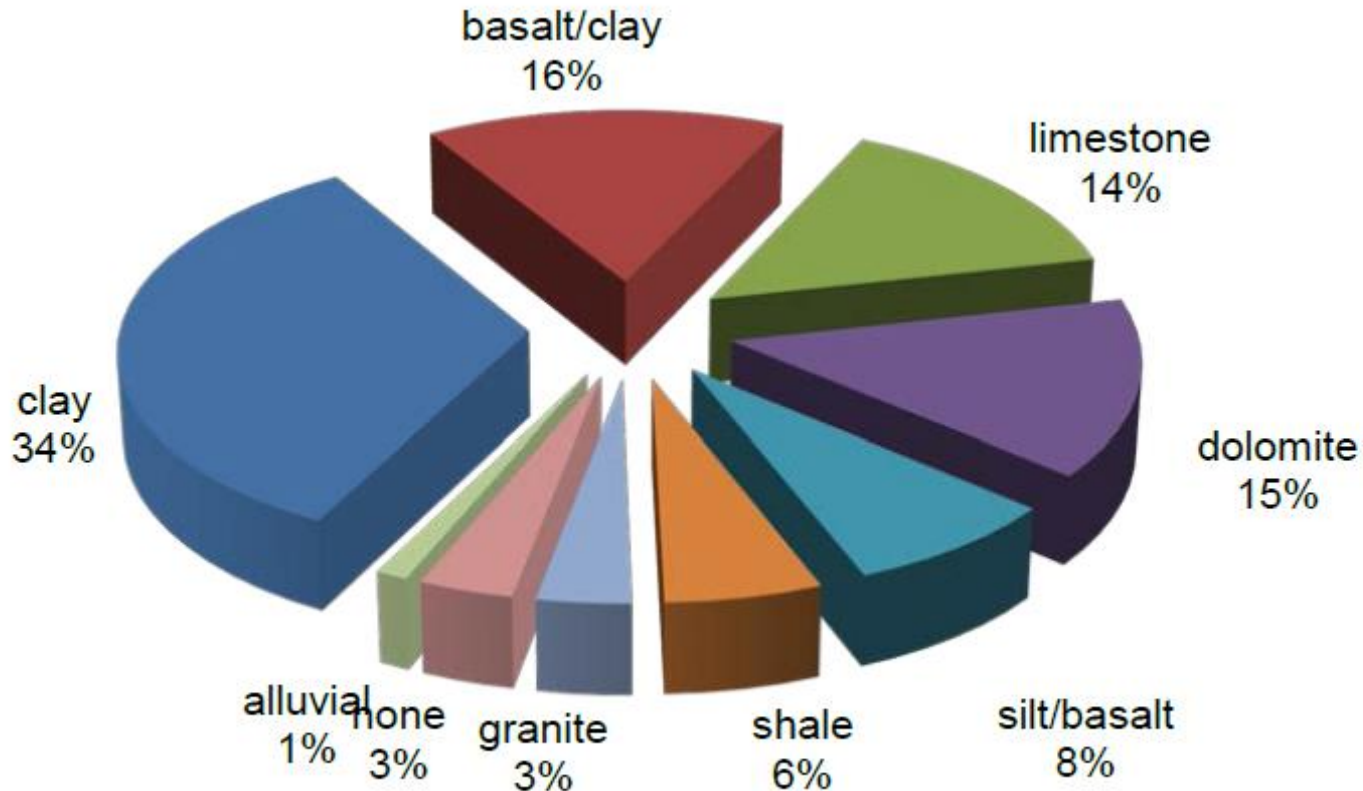
Confinement formation type – note this has not changed much since wells have not been drilled

Geographic Distribution

- Arizona
- California
- Colorado
- Delaware
- Florida
- Georgia
- Iowa
- Idaho
- Illinois
- Kansas

- Minnesota
- New Jersey
- Nevada
- New Mexico
- New York
- North Carolina
- Oklahoma
- Oregon
- South Carolina
- South Dakota

- Tennessee
- Texas
- Utah
- Virginia
- Washington
- Wisconsin
- Wyoming

Challenges

- **Clogging**
  - Mechanical
  - Chemical
  - Biological
- **Water Quality**
  - Leaching
  - Disinfection byproducts
  - Carbon dioxide
- **Low recovery and expectation**
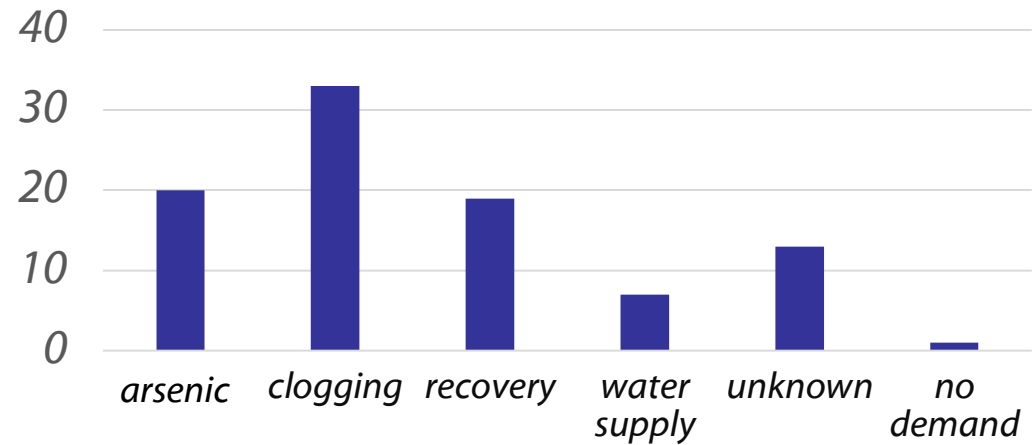
Descriptive Statistics

Status of ASR projects

- Operational systems have not changed
- Pre-study category added
- Inactive sites have increased

Status of ASR projects

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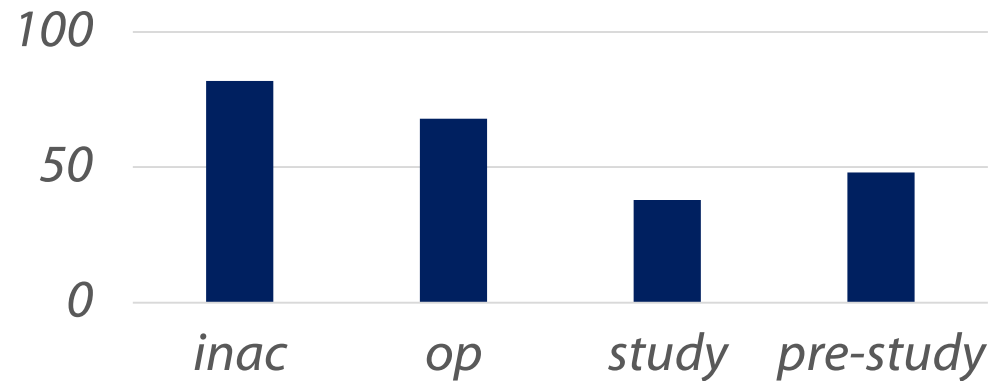
Data Analysis

- 2013 data clean-up (204 sites)
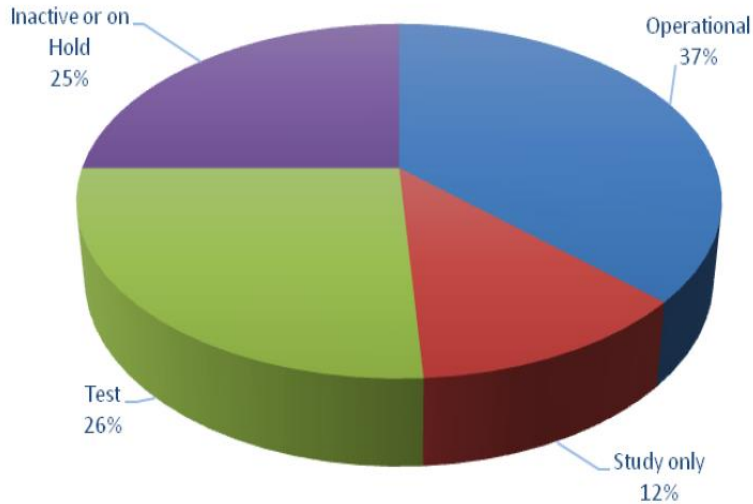 - Chi-square tests to determine if there is a statistically significant relationship between program status and each of the categorical variables

- 2018 minor update
  - Logistic regression to derive outcome of a dichotomous variable based on one or more predictor variables
  - Principal component analysis, factor analysis, and linear regression to determine if there is a means to predict ASR project success

- 2019 update (234 sites to date)
  - Ongoing

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Data Analysis

- Chi-square analysis results indicate that there are statistically significant associations ($p < 0.05$) between operational well status and Region, Operational Issues, Number of Storage Cycles, Casing Material, Well Depth, & Injection Formation

- Findings:

  - Midwest & Southeast – less operational systems

  - Operational systems – greater storage and recovery cycles, steel casings, and injection formations of alluvial, basalt, sand, and sand clay mixtures

Data Analysis

- Logistic regression results suggest that operation is less likely for ASR sites with deeper wells, clogging problems, and water quality issues

- Chi-square and logistic regression results indicate that there are no statistical differences for ASR systems being operational across different water sources, water uses, and confinement units

- Principal component analysis and linear regression have the potential to be used to predict the success for the test and study sites

Observations

- Although data on ASR projects were available, much were missing (e.g., drill logs, water quality, injection zone properties, and others), especially for older wells

- The lack of a centralized system for permitting makes data requirements high variable

- ASR should be in the toolbox for water systems to address water availability challenges

- Success of ASR project is not guaranteed but careful planning and forward thinking can help

Observations

- Washington, Oregon, and Utah evaluated potential sites for viability – Utah has added a couple, test wells drilled

- Texas examined 20 locations and determined to put the decisions on hold – looking for funding and as part of long-term plans – mostly studies

- Florida continued to be number one in ASR practice but has determined to put future projects on hold

- Georgia continued to ban ASR

- Wyoming studied concept but abandoned the effort

- There were 30 new entries since 2013

- Further investigation is needed to gain accurate picture

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Summary

- ASR allows communities to retain water that would otherwise be "lost"

- ASR projects have been with us for over 40 years, with over 200 sites in 27 states (at least investigated)

- There were 75 ASR systems in operation

- About 20% of systems had encountered issues such as clogging, metal leaching, and low recovery rate

Summary

- Most ASR sites are with one well – injecting into limestone, basalt, or alluvial formations

- Operational systems are associated with similar injection and withdrawal rates

- Successful systems store in excess of 500 MG

- ASR development are favored in certain geographic regions (e.g., AZ, NV, TX, CA, NC, SC, WA, OR), locations with greater numbers of storage cycles, use of steel casing, and injection formations such as alluvial, basalt, sand, and sand clay mixtures

Questions and Contact Information

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