Historic Analysis of ASR Operations in the US as of 2013

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Acknowledgments

- Frederick Bloetscher, Ph.D., P.E., Florida Atlantic University
- Joseph J. Danko, Ph.D., Brown University
- Samuel Ratick, Ph.D., Clark University

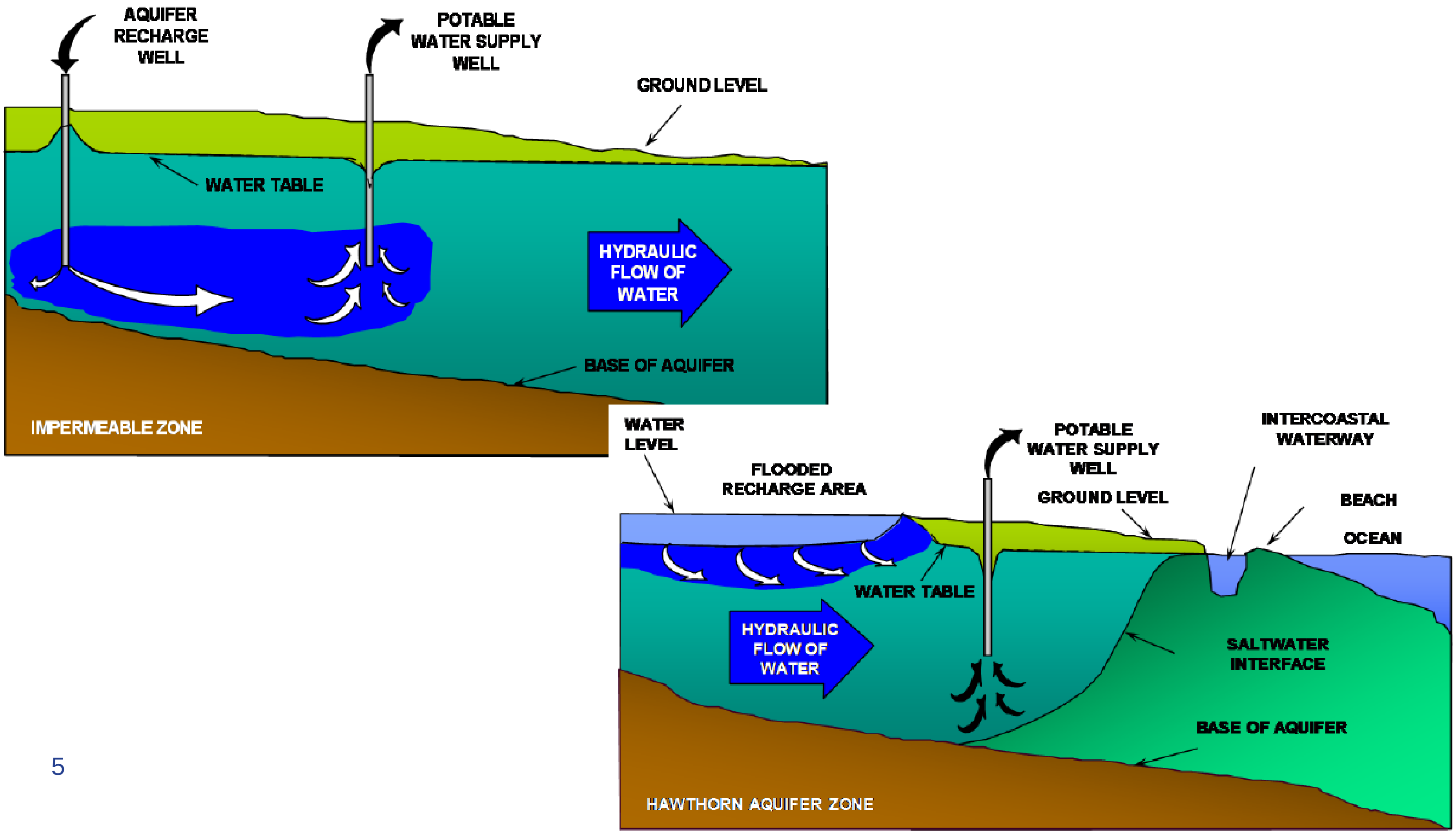
Introduction

- 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)

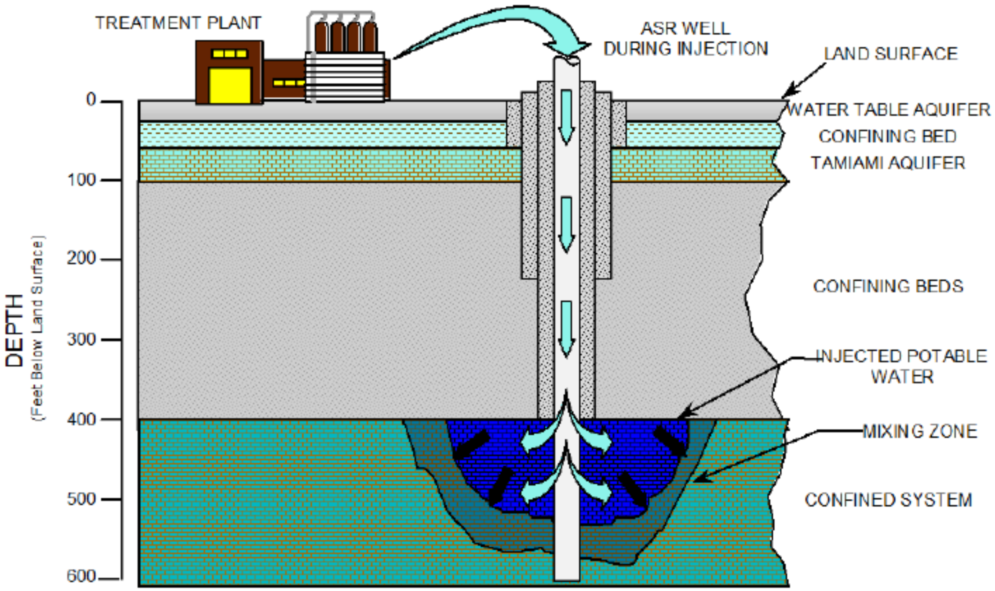
Introduction

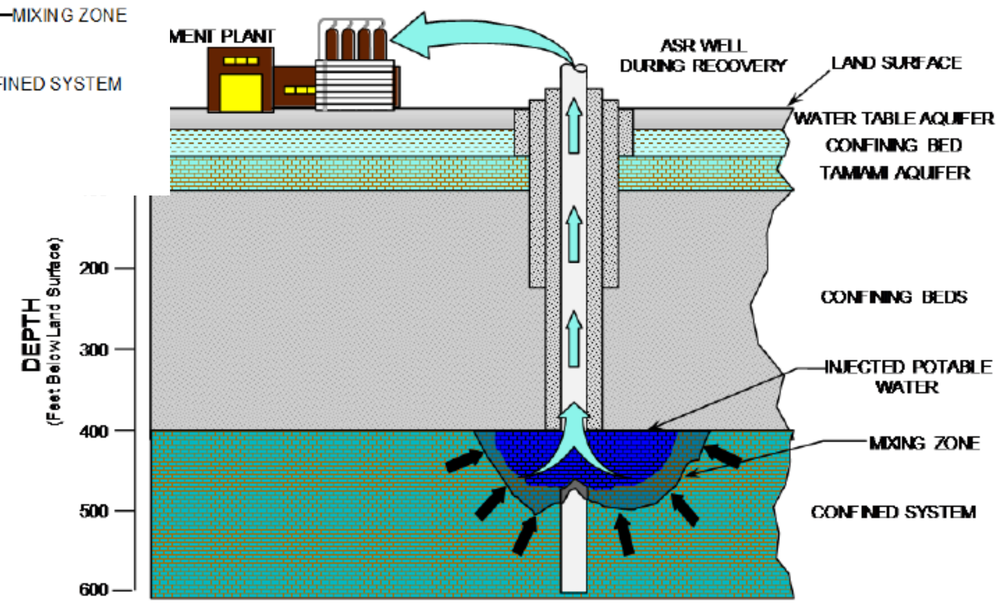
- The concept of ASR has been applied in the U.S. since the late 1960s and limited development occurred until the 1990s.
- Common applications are the injection of potable or raw water into an aquifer with the intention to provide future withdrawal for augmentation of water supplies at a later time
- In the U.S., ASR wells are covered under EPA's UIC program and delegated state programs

Introduction



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

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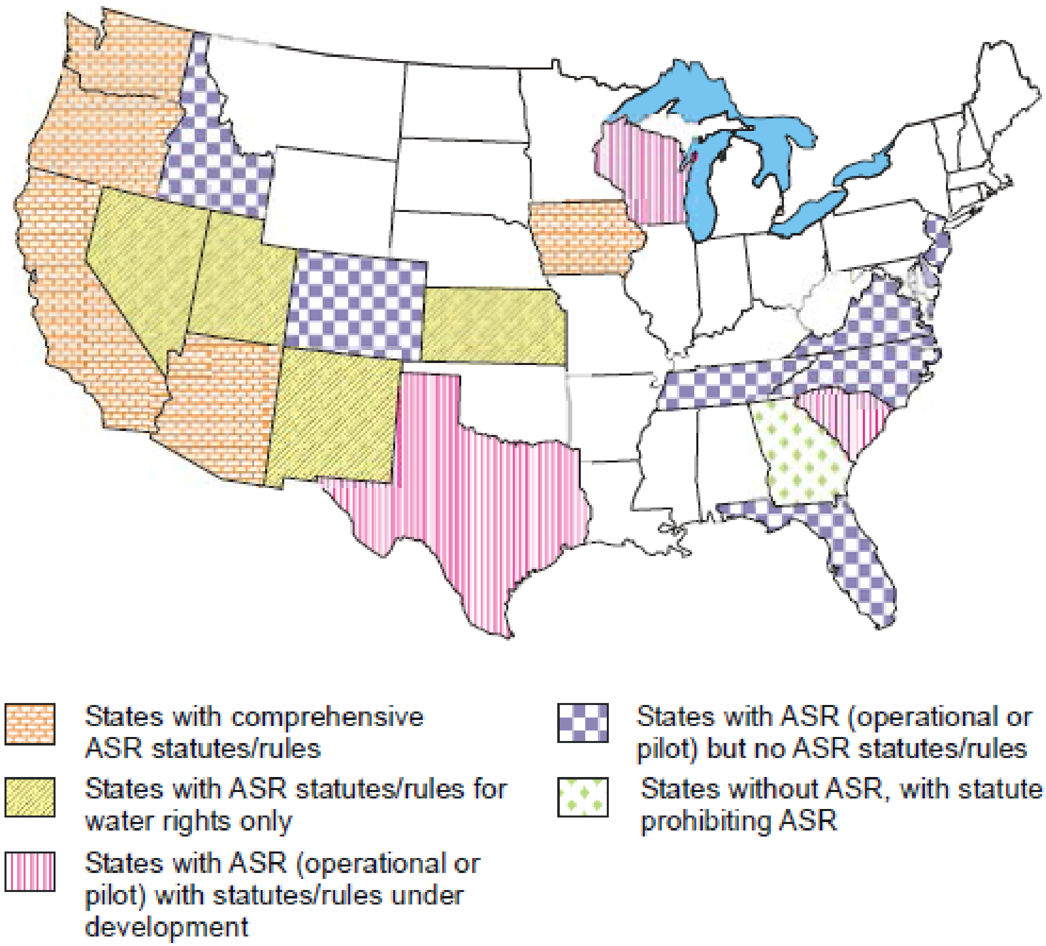
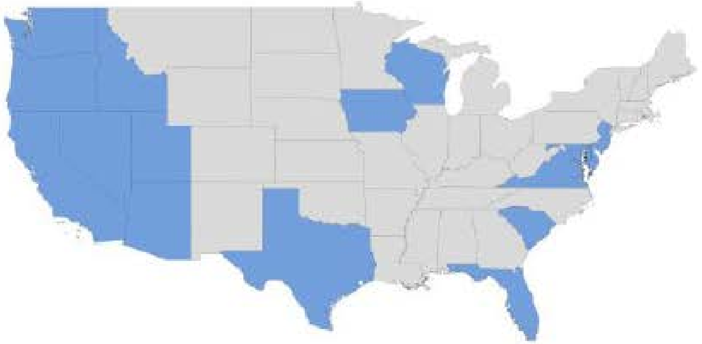
Introduction



States with ASR-specific Statutes or rules (AWWA, 2002)

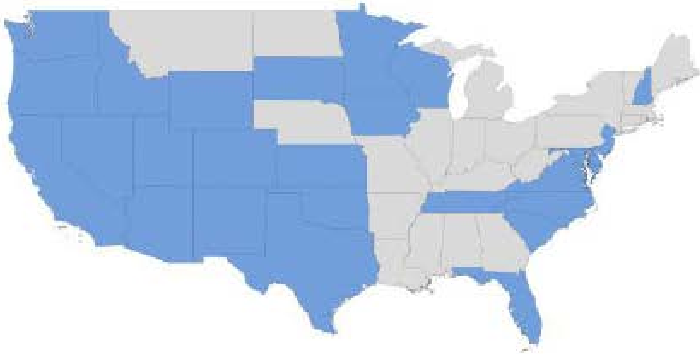
Introduction

1985 – ASR Projects in 3 states



2001 – ASR Projects in 15 states

1995 – ASR Projects in 8 states



2010 – ASR Projects in 27 states

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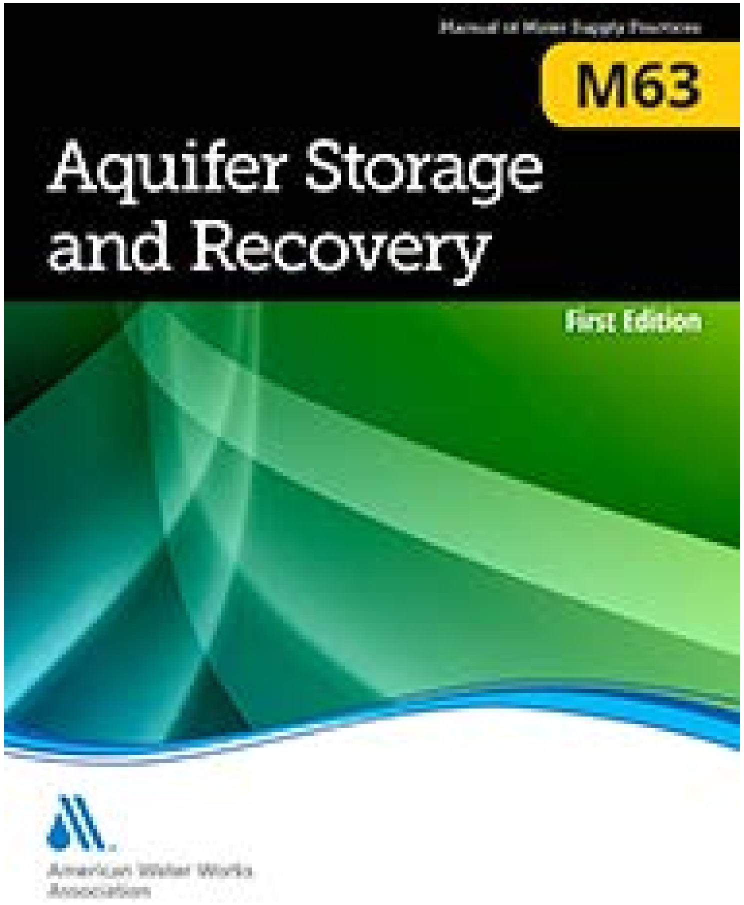
Introduction

- A survey was conducted in 2013 by Dr. Fred Bloetscher of Florida Atlantic University for the development of an American Water Works Association (AWWA) manual of practice on ASR (M63)
- The survey identified 204 ASR sites in the U.S. for which data were collected



Introduction

- In addition to M63 (published in 2015), two 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. (in press) Can Prior Experience Provide a Means to Predict Success of Future Aquifer Storage and Recovery Systems. American Journal of Engineering Education.

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

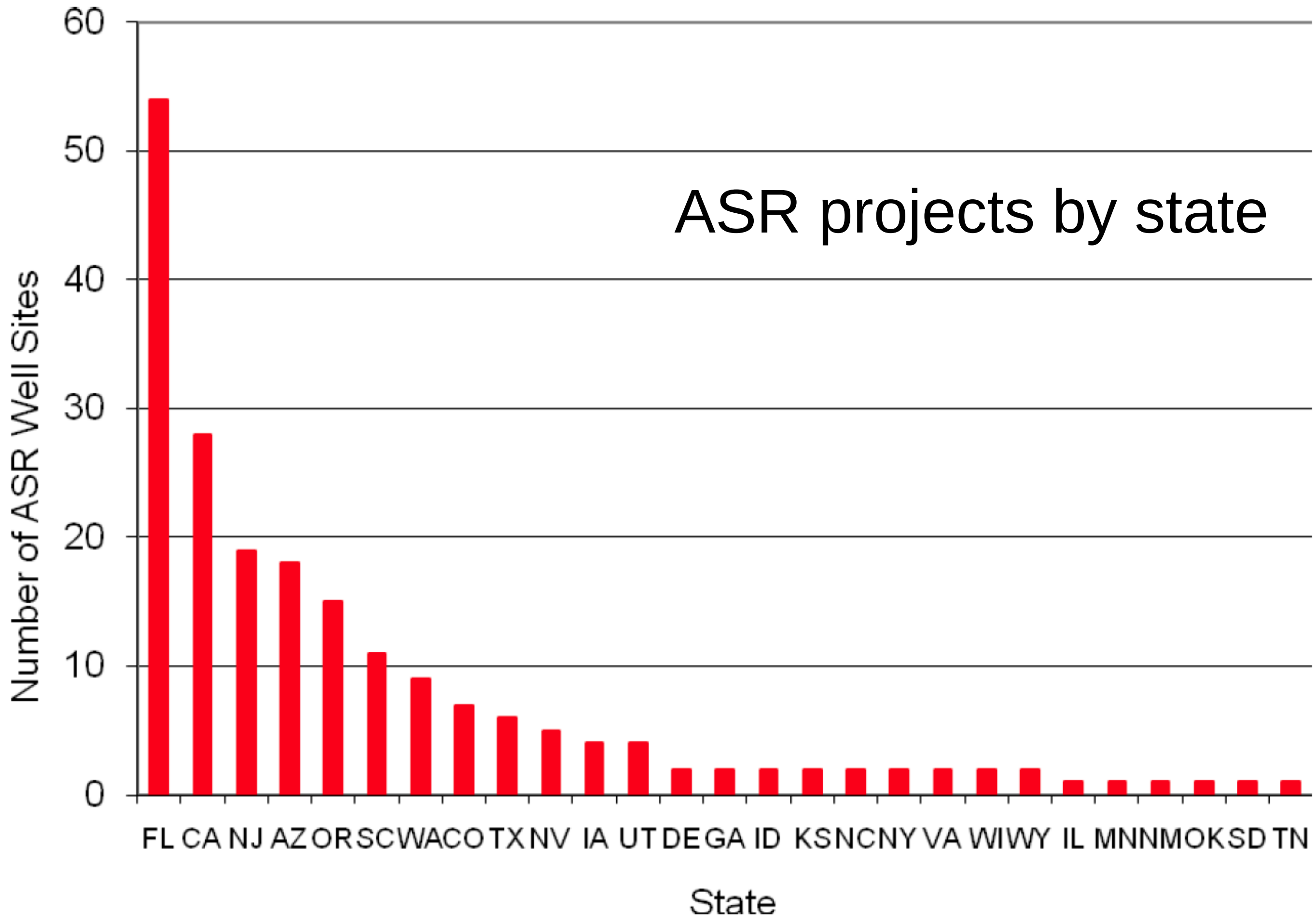
- Data elements:
  - Injection zone
    - Formation – limestone, sand, sandstone, basalt, or alluvial
    - Transmissivity
    - Total dissolved solids of water in injection formation
    - Type of confinement – clay, dolomite, silt, shale, sandstone, basalt, or none
    - Number of monitoring wells

Descriptive Statistics

	Number of ASR wells in the project	Storage Cycles	injection Cap (MGD)	Withdr Capacity (MGD	Ratio in/out	Peak Flow on Site (MGD)
Min	0	0	0	0	0	0
Max	87	74	15	15	2.5	714
Avg	3.6	5.0	1.4	2.0	0.8	8.8
Std Dev	7.9	10.5	1.9	2.3	0.3	55.9

	Depth of Casing	Depth of well	Injection Horizon	Casing Diam. (in)	Transm gpd/sf	TDS
Min	9	33		5.5	0.65	50
Max	2185	3832	3832	40	300000	37000
Avg	622	815	236	15	35206	2151
Std Dev	443	568	381	6	60654	4823

Descriptive Statistics



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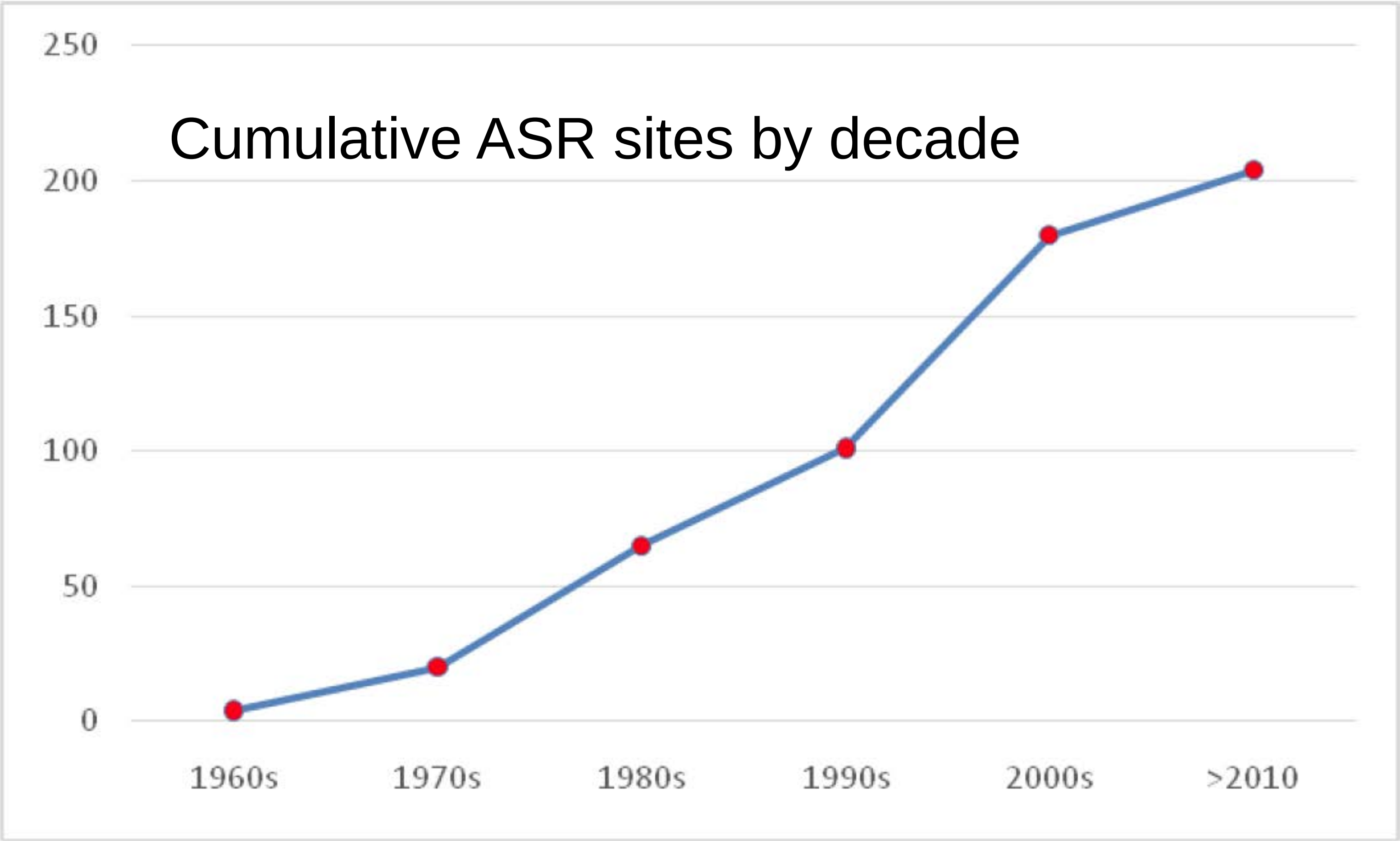

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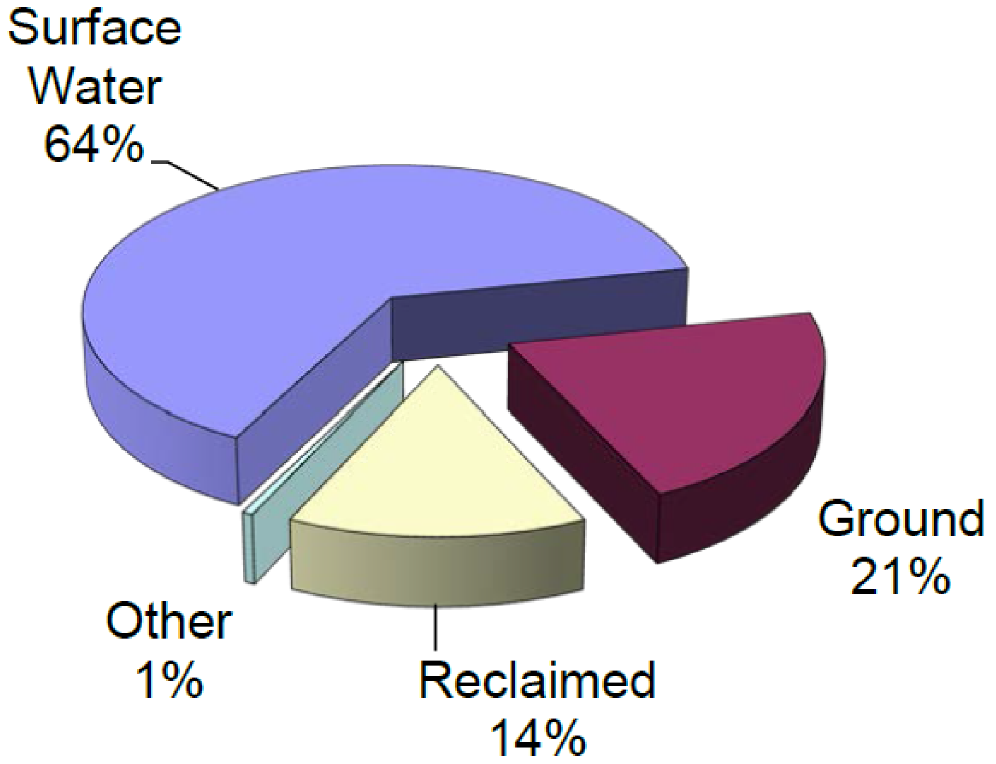
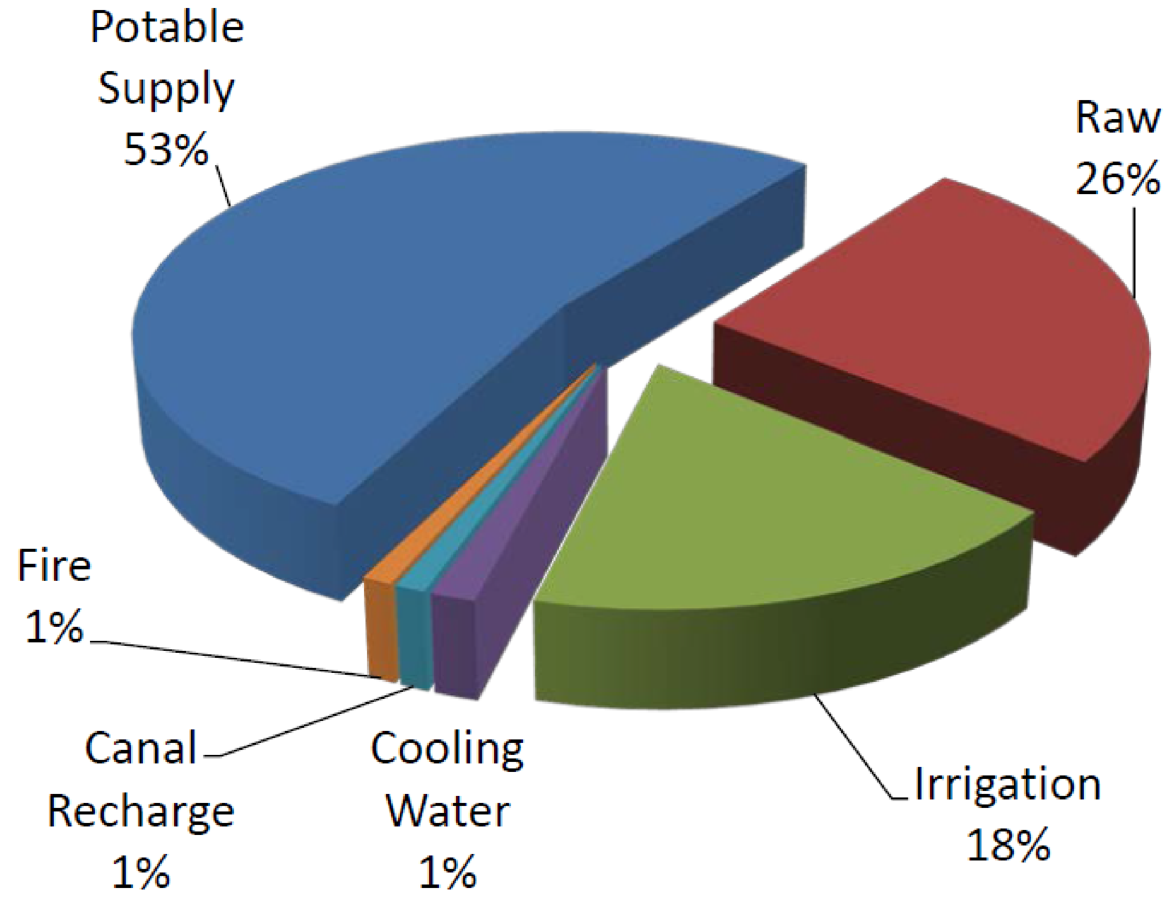


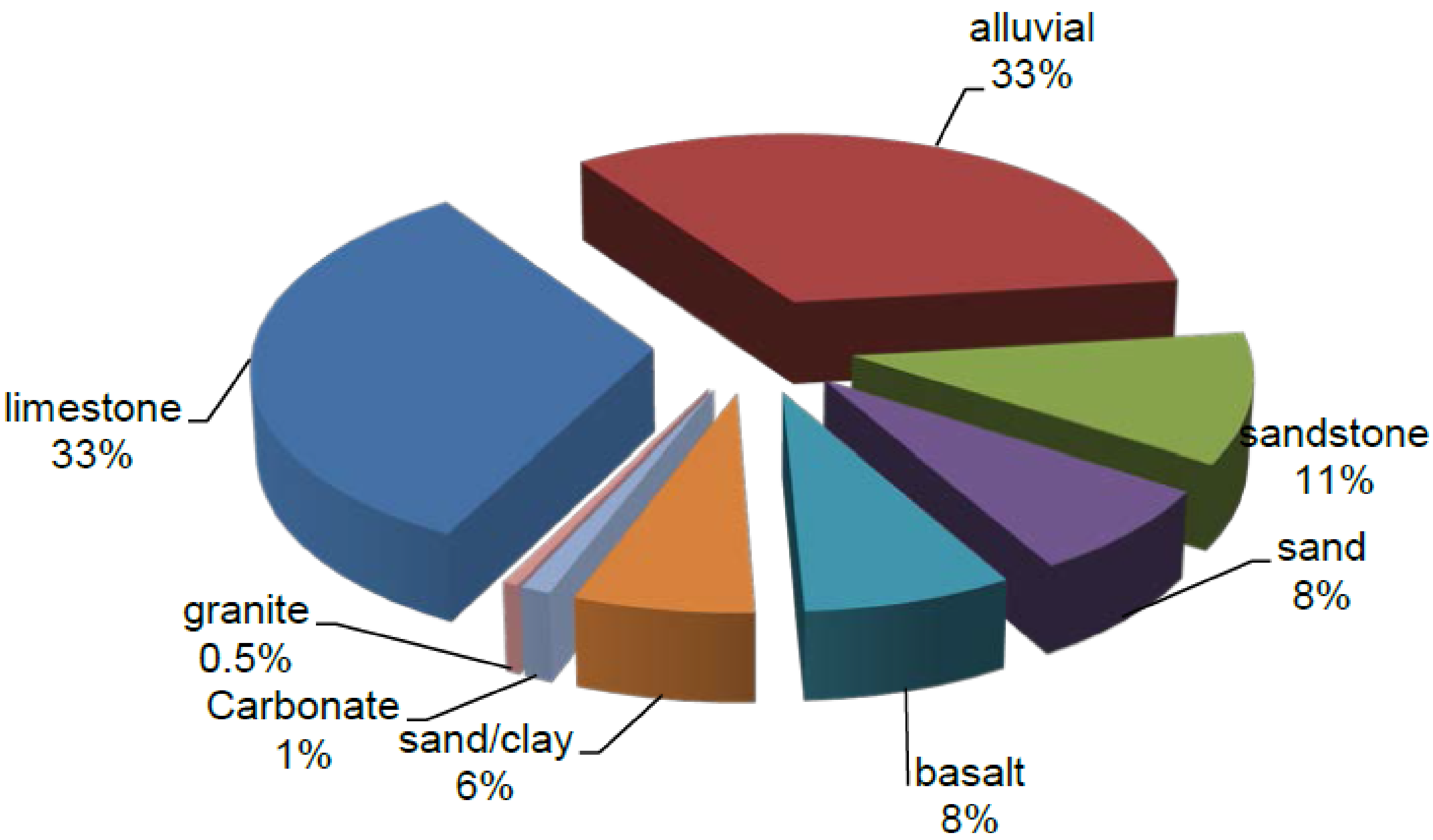
Sources of water used for ASR programs

Descriptive Statistics



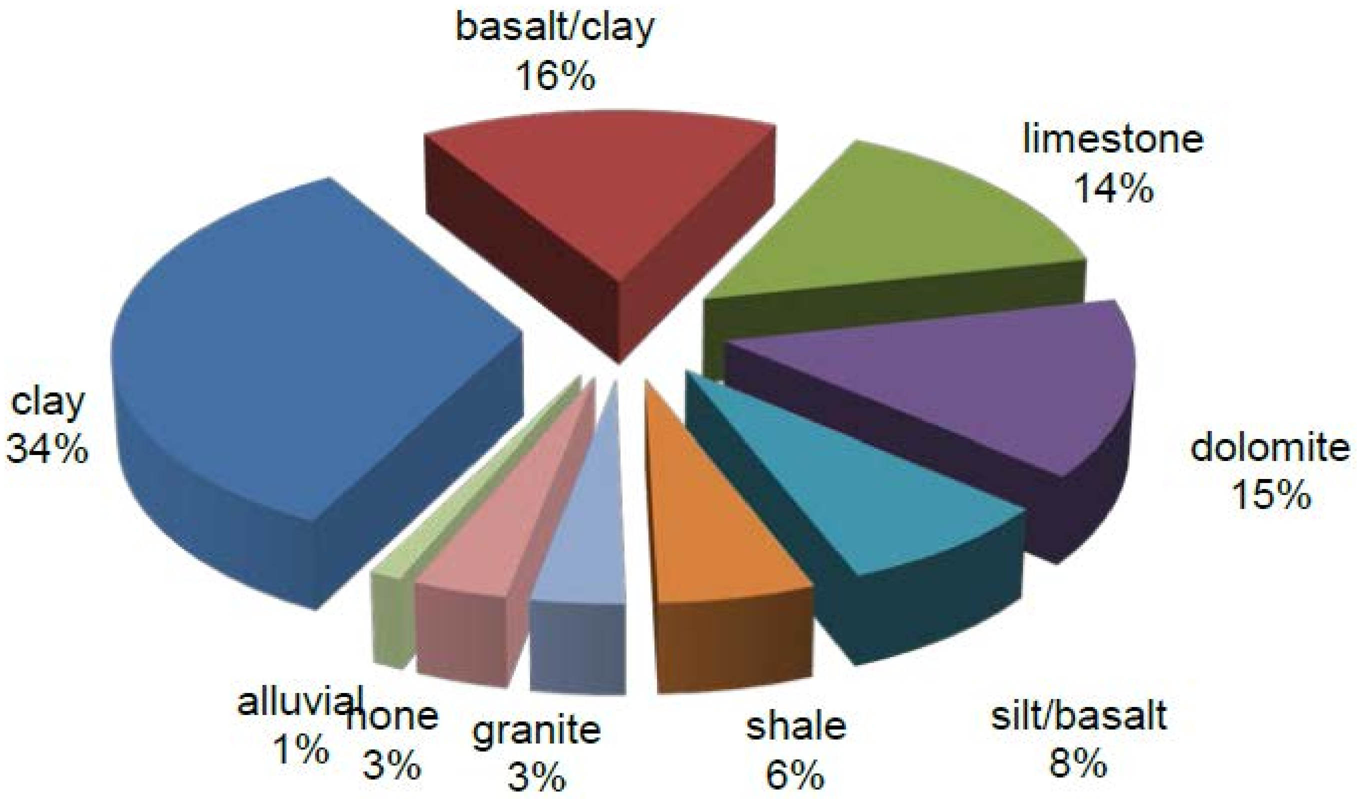
Uses of water recovered from ASR programs

Descriptive Statistics



Injection formation type

Descriptive Statistics



Confining unit formation type

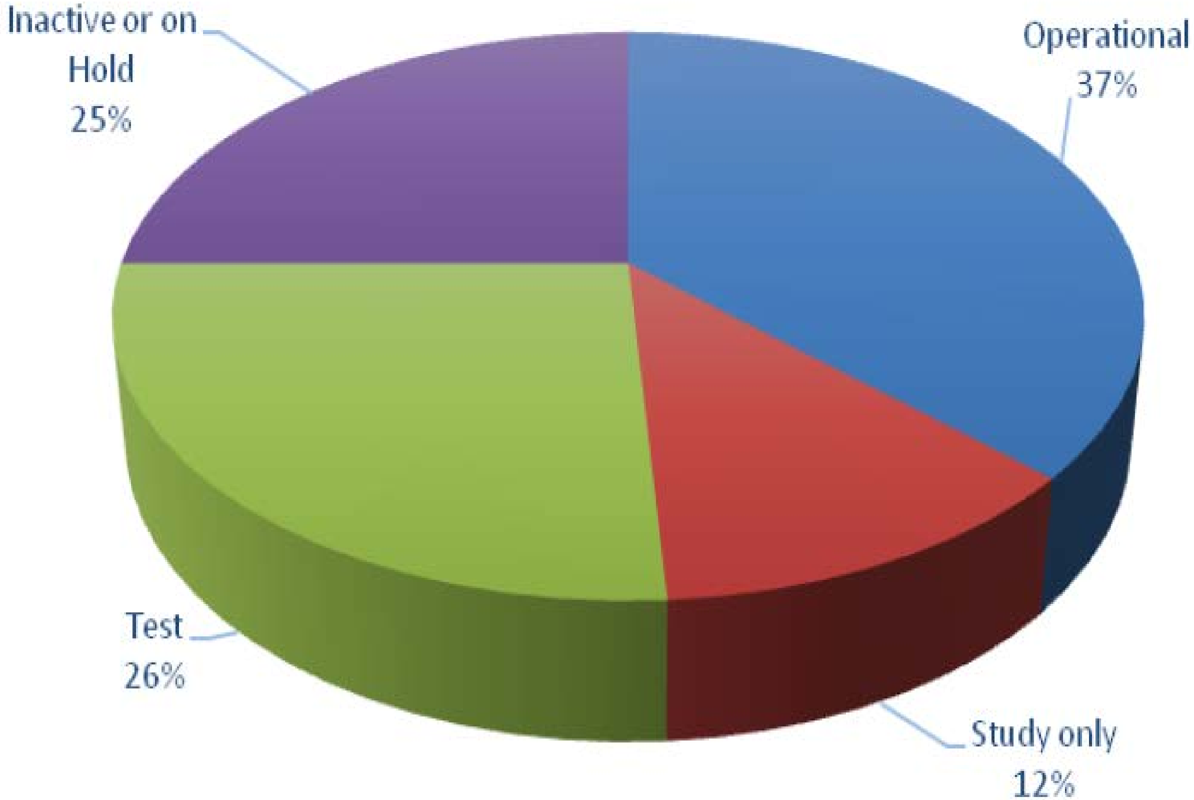
Geographic Distribution

- 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

Data Analysis

- 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
  - 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

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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

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

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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

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 tool box for water systems to address water availability challenges
- Success of ASR project is not guaranteed but careful planning and forward thinking can help

Questions

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