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Recent Groundwater Conditions, Saipan, Commonwealth of the Northern Mariana Islands

Mariana Islands Water Operator Association
June 5, 2019

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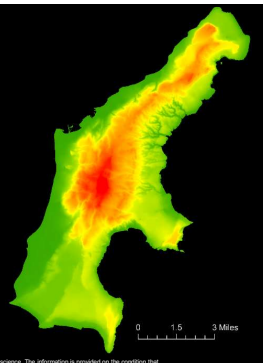
U.S. Geological Survey

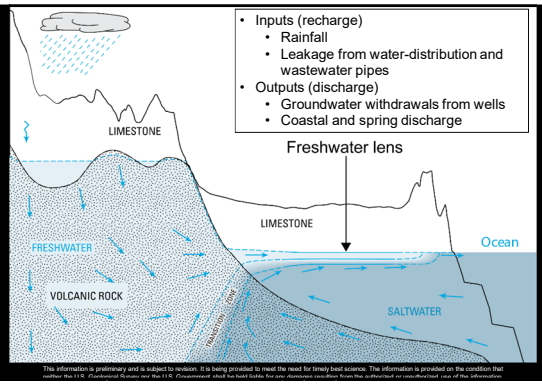
Prepared in cooperation with the Office of Grants Management, CNMI, and in collaboration with the Commonwealth Utilities Corporation

U.S. Department of the Interior
U.S. Geological Survey

Outline

- Hydrogeology of Saipan
- Data for groundwater characterization
  - Groundwater withdrawals
  - Chloride concentrations of pumped water
  - Salinity profiles at monitor wells
- Groundwater-monitoring network
- Strategy for groundwater monitoring
- Summary





Modified from Carruth, 2003

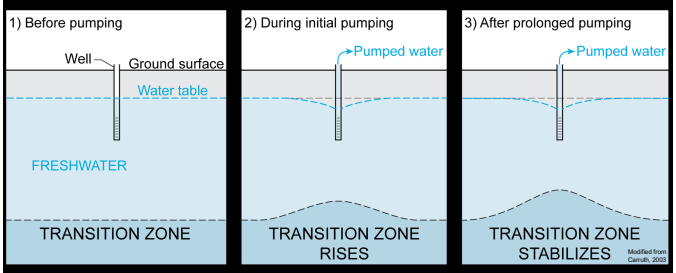
Controls on freshwater-lens thickness

- Recharge
  - Greater recharge rate → thicker lens
- Groundwater withdrawals
  - Greater withdrawal rate → thinner lens
- Rock permeability
  - Influenced by geologic heterogeneity, including faults and karst features
  - Greater permeability → thinner lens

Threats to the freshwater lens

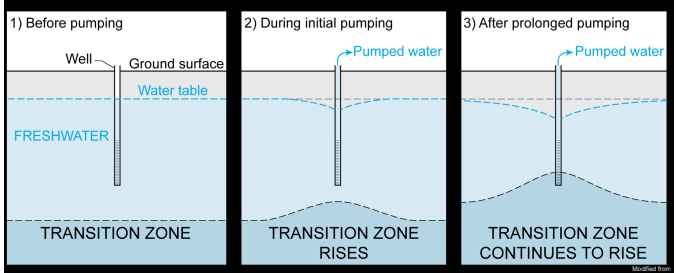
- Extended drought
  - Often following strong El Niño events
- Excessive groundwater withdrawal
  - Saltwater upconing on local scale
  - Loss of freshwater storage on regional scale
- Improper well construction

Production well drilled sufficiently above transition zone



Modified from Carruth, 2003

Production well drilled too close to the transition zone

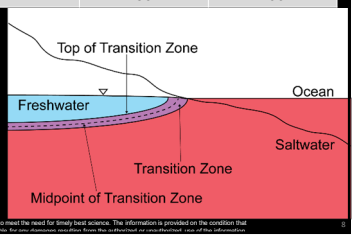


Modified from Carruth, 2003

Characterizing groundwater salinity

Physical property	Units	Top of transition zone	Midpoint of transition zone	Saltwater
Chloride concentration	mg/L	250	9,800	19,600
Specific conductance	µS/cm	1,400	25,000	50,000
Seawater salinity	%	~1	50	100

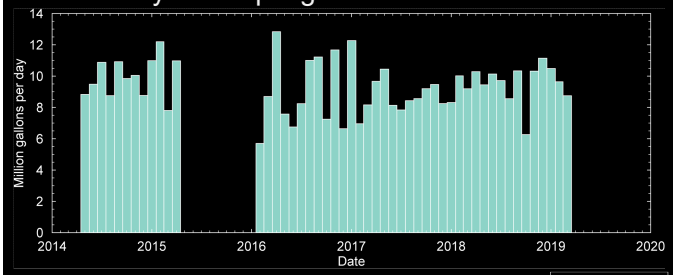
- U.S. EPA secondary standard for chloride concentration is 250 mg/L
- Freshwater:
  - < 1,400 µS/cm specific conductance
  - or
  - < 250 mg/L chloride concentration



Data used to characterize the freshwater-lens system

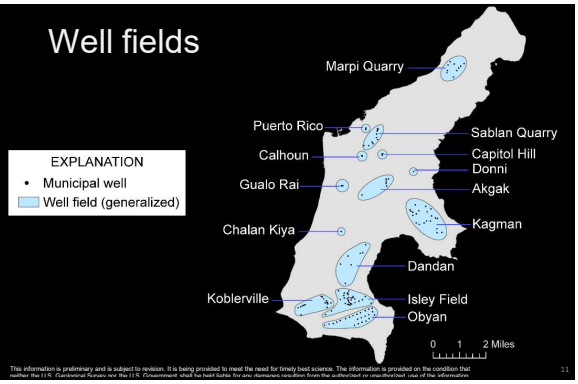
- Groundwater withdrawals
- Chloride concentrations of pumped water
- Salinity profiles from deep monitor wells
- Rainfall
- Water levels
- Sea level

Monthly municipal groundwater withdrawals

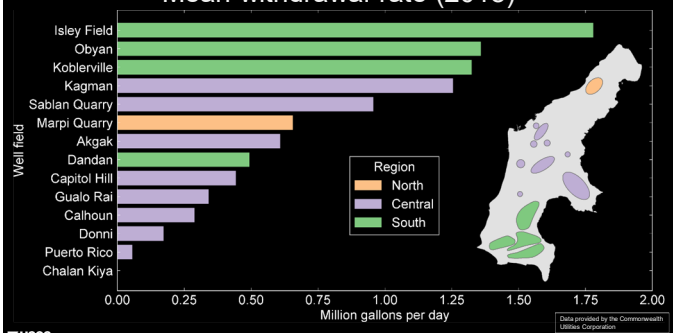


Data provided by the Commonwealth Utilities Corporation

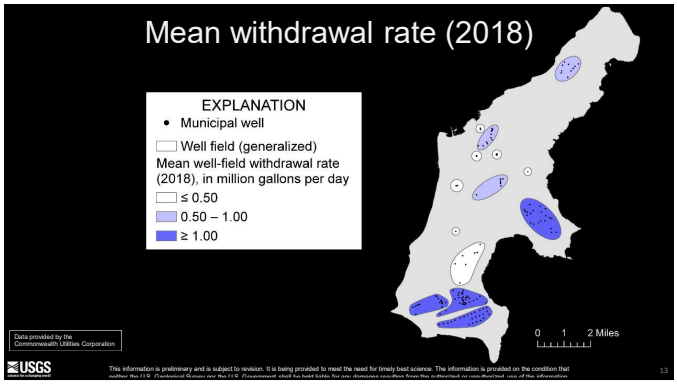
Well fields



Mean withdrawal rate (2018)



Data provided by the Commonwealth Utilities Corporation


Mean withdrawal rate (2018)
EXPLANATION
Municipal well
Well field (generalized)
Mean well-field withdrawal rate (2018), in million gallons per day
≤ 0.50
0.50 – 1.00
≥ 1.00
0 1 2 Miles
Data provided by the Commonwealth Utilities Corporation
USGS
This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that
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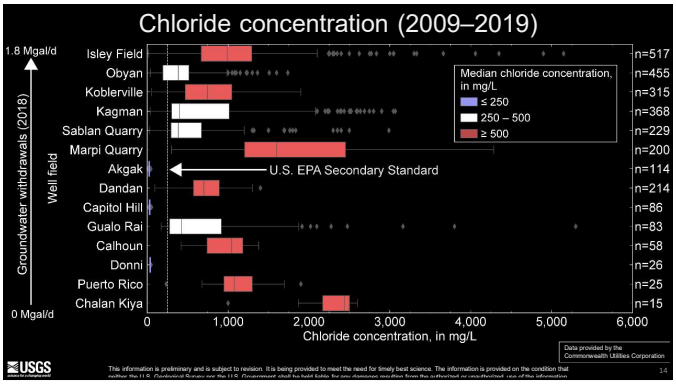
Chloride concentration (2009–2019)
1.8 Mgal/d
0 Mgal/d
Groundwater withdrawals (2018)
Well field
Isley Field
Obyan
Koblerville
Kagman
Sablan Quarry
Marpi Quarry
Akgak
Dandan
Capitol Hill
Gualo Rai
Calhoun
Donni
Puerto Rico
Chalan Kiya
U.S. EPA Secondary Standard
Median chloride concentration, in mg/L
≤ 250
250 – 500
≥ 500
n=517
n=455
n=315
n=368
n=229
n=200
n=114
n=214
n=86
n=83
n=58
n=26
n=25
n=15
0
1,000
2,000
3,000
4,000
5,000
6,000
Chloride concentration, in mg/L
Data provided by the Commonwealth Utilities Corporation
USGS
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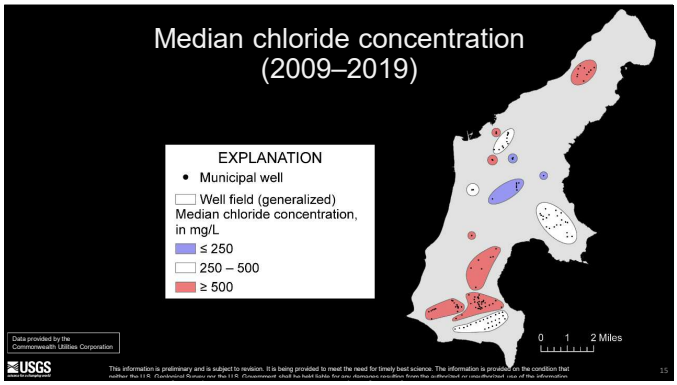
Median chloride concentration (2009–2019)
EXPLANATION
Municipal well
Well field (generalized)
Median chloride concentration, in mg/L
≤ 250
250 – 500
≥ 500
0 1 2 Miles
Data provided by the Commonwealth Utilities Corporation
USGS
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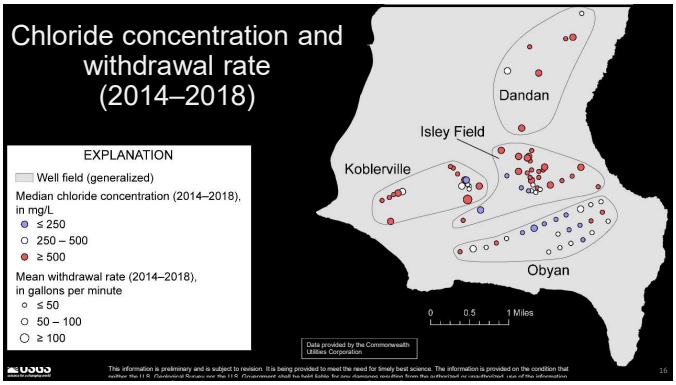
Chloride concentration and withdrawal rate (2014–2018)
Dandan
Isley Field
Koblerville
Obyan
EXPLANATION
Well field (generalized)
Median chloride concentration (2014–2018), in mg/L
≤ 250
250 – 500
≥ 500
Mean withdrawal rate (2014–2018), in gallons per minute
≤ 50
50 – 100
≥ 100
0 0.5 1 Miles
Data provided by the Commonwealth Utilities Corporation
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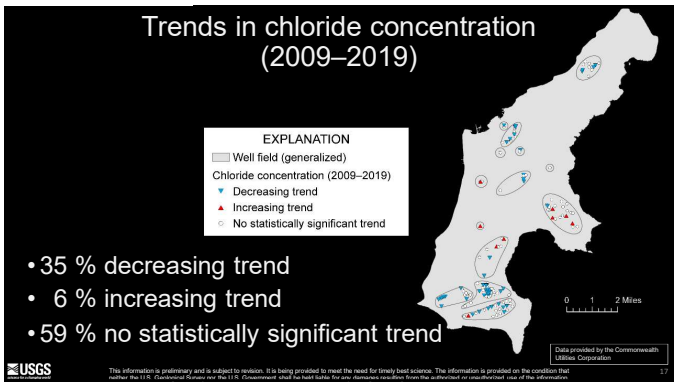
Trends in chloride concentration (2009–2019)
EXPLANATION
Well field (generalized)
Chloride concentration (2009–2019)
Decreasing trend
Increasing trend
No statistically significant trend
• 35 % decreasing trend
• 6 % increasing trend
• 59 % no statistically significant trend
0 1 2 Miles
Data provided by the Commonwealth Utilities Corporation
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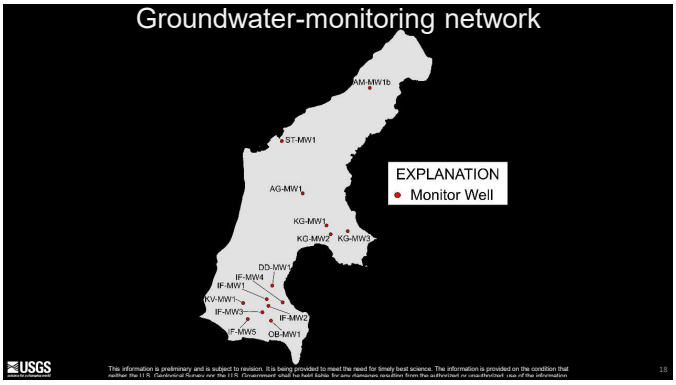
Groundwater-monitoring network
AM-MW1b
ST-MW1
AG-MW1
KG-MW1
KG-MW2
KG-MW3
DD-MW1
IF-MW4
IF-MW1
KV-MW1
IF-MW3
IF-MW2
IF-MW5
OB-MW1
EXPLANATION
Monitor Well
USGS
This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that
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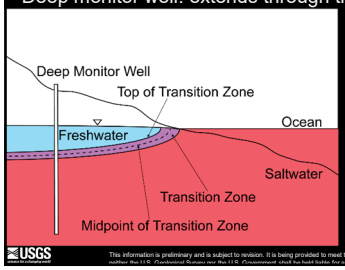
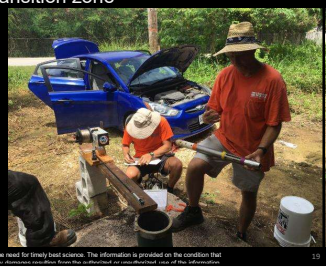
Salinity profiles

- Conductivity, Temperature, and Depth (CTD)
- Measure salinity distribution with depth
- Deep monitor well: extends through transition zone





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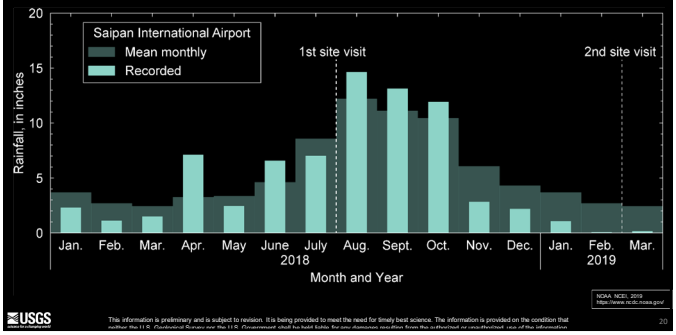
Rainfall context for salinity profiles, 2018–2019



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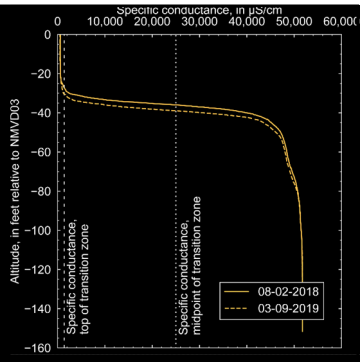
OB-MW1

- Freshwater thickness
  - 28–32 ft
- Midpoint of transition zone
  - Lowered by 3 ft after wet season



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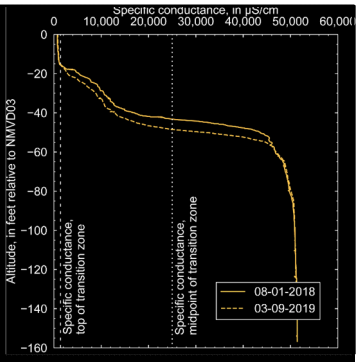
IF-MW2

- Freshwater thickness
  - 17 ft
- Midpoint of transition zone
  - Lowered by 6 ft after wet season



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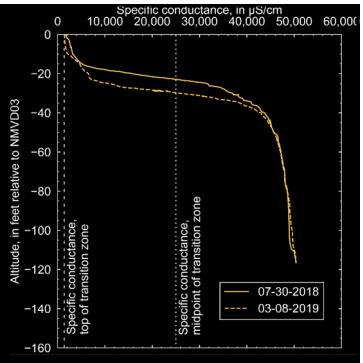
IF-MW4

- Freshwater thickness
  - No freshwater
- Midpoint of transition zone
  - Lowered by 7 ft after wet season



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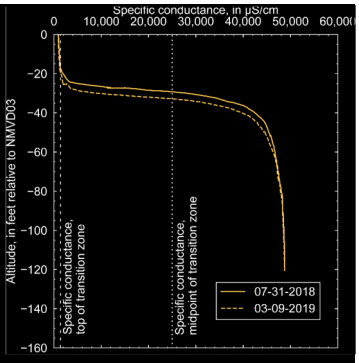
KG-MW3

- Freshwater thickness
  - 19–21 ft
- Midpoint of transition zone
  - Lowered by 4 ft after wet season



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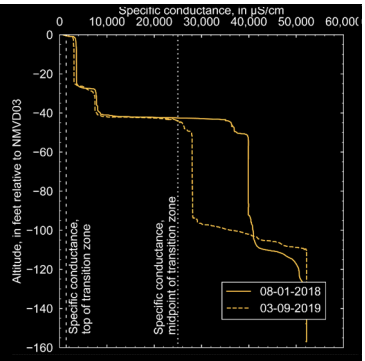
ST-MW1

- Freshwater thickness
  - 2 ft
- Midpoint of transition zone
  - Lowered by 1 ft after wet season
- Steps in profile may indicate borehole flow



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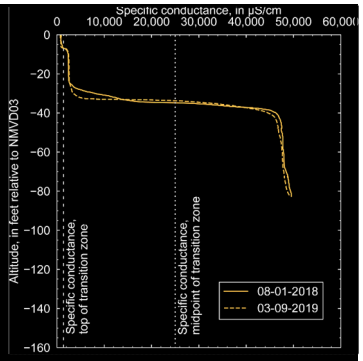
AM-MW1b

- Freshwater thickness
  - 8 ft
- Midpoint of transition zone
  - Raised by 1 ft after wet season



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Groundwater-monitoring network

- Critical for evaluating groundwater resources
  - Provides information on the resource over time
  - Can be used to monitor effects of groundwater development, climate, and land-use change
  - Deep monitor wells allow salinity characterization for full depth of groundwater system
    - Chloride-concentration data for pumped water may mask an underlying decrease in freshwater availability
  - Shallow monitor wells can be used for monitoring of groundwater levels
- Requires protection and maintenance to ensure that data can be collected consistently through time and remain comparable

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Well damage and maintenance IF-MW2

July 30, 2018

August 2, 2018

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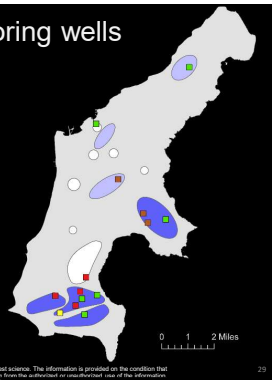
Groundwater-monitoring wells

EXPLANATION
- Usable deep monitor well
- Unusable deep monitor well
- Shallow monitor well
- Monitor well in non-freshwater-lens setting

Well field (generalized)
Mean well-field withdrawal rate (2018), in million gallons per day
- ≤ 0.50
- 0.50 – 1.00
- ≥ 1.00



Data provided by the Commonwealth Utilities Corporation

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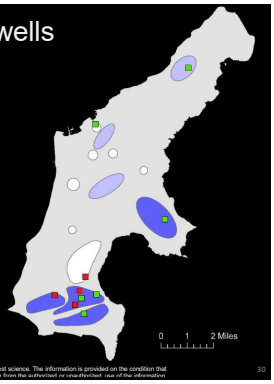
Deep monitor wells

EXPLANATION
- Usable deep monitor well
- Unusable deep monitor well

Well field (generalized)
Mean well-field withdrawal rate (2018), in million gallons per day
- ≤ 0.50
- 0.50 – 1.00
- ≥ 1.00



Data provided by the Commonwealth Utilities Corporation

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Strategy for groundwater monitoring

- Continue collection of monthly withdrawal data
- Increase frequency of chloride sampling at high-salinity municipal wells to quarterly
- Rehabilitate existing monitor wells
  - Clean wells that are blocked
  - Collect downhole geophysical data, then case and screen wells that are open boreholes
- Collect semi-annual salinity profiles at deep monitor wells
- Collect continuous water levels at select monitor wells
- Expand deep-monitor-well network in areas that lack coverage

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Summary

- Chloride concentration of pumped water (2009–2019)
  - Generally, chloride concentrations in municipal wells have decreased
    - 35 percent of wells have a decreasing trend
    - 6 percent of wells have an increasing trend
  - Most productive well fields
    - Isley Field, Koblerville, and Obyan (73 wells; 4.4 Mgal per day in 2018)
      - 45 percent of wells have a decreasing trend
      - Only 1 well has an increasing trend (OB-12)
    - Kagman (22 wells; 1.3 Mgal per day in 2018)
      - 4 wells with increasing trend and 1 well with decreasing trend

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Summary (continued)

- Salinity profiles at monitor wells
  - Seasonal variability of up to 10 feet at midpoint of transition zone
  - Freshwater thickness has substantial spatial variability
    - 17 feet of freshwater at IF-MW2 and no freshwater at IF-MW4 (2018)
      - 0.6-mile separation
    - Generally about 20 feet of freshwater in south, 10 feet or less in north
  - Unable to assess inter-annual variability
    - No comparable data that used similar methods
- Continued monitoring and long-term data collection are critical for groundwater management
  - More data lead to more informed management decisions and long-term sustainability

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