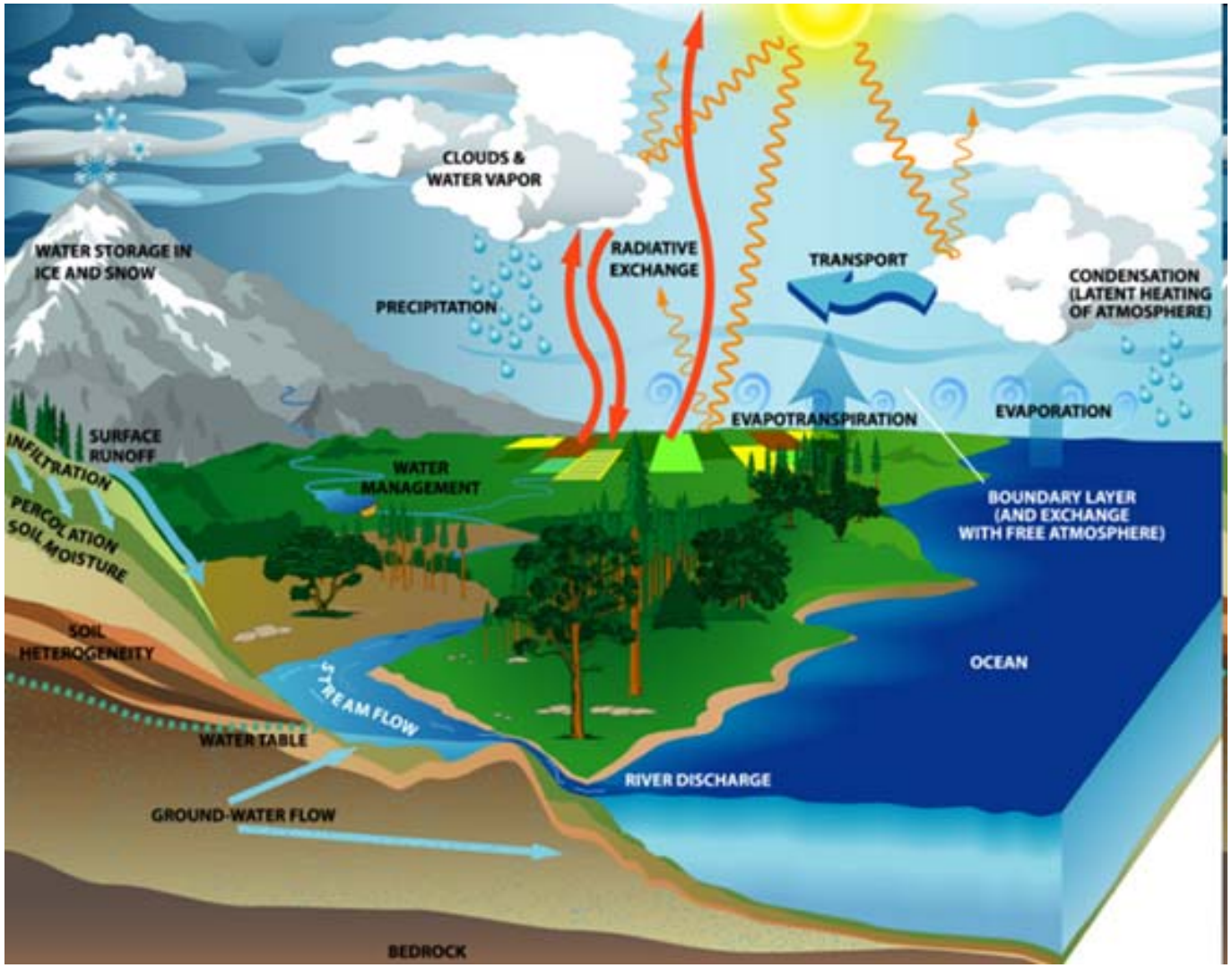
Fractured Rock Aquifer Sustainability

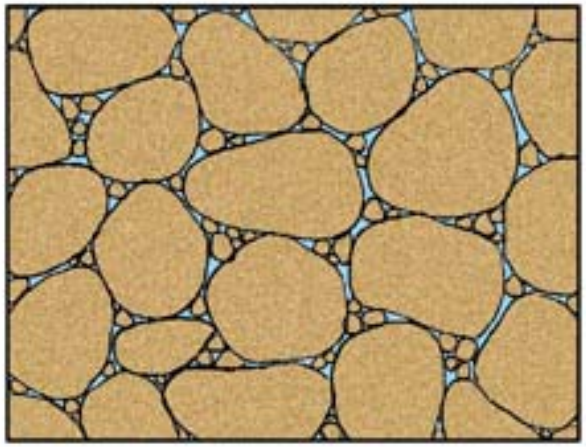
Monterey Peninsula Water Management District

Water Cycle and Groundwater



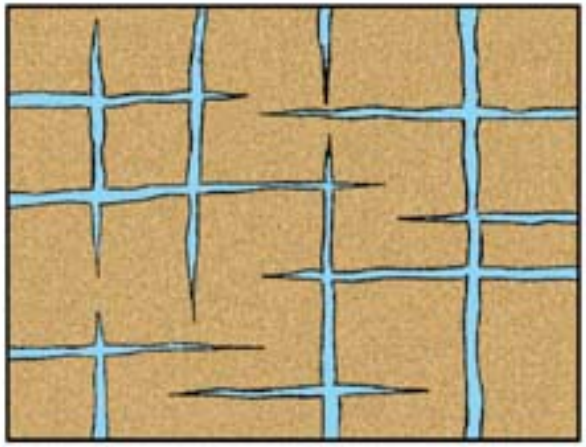
MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

Definition of Fractured Rock Aquifer



Fluvial Aquifer

Water exists in spaces between grains (primary porosity). Carmel Valley Alluvial Aquifer



Fractured Rock Aquifer

Water exists in fractures in non water bearing rocks (secondary porosity).

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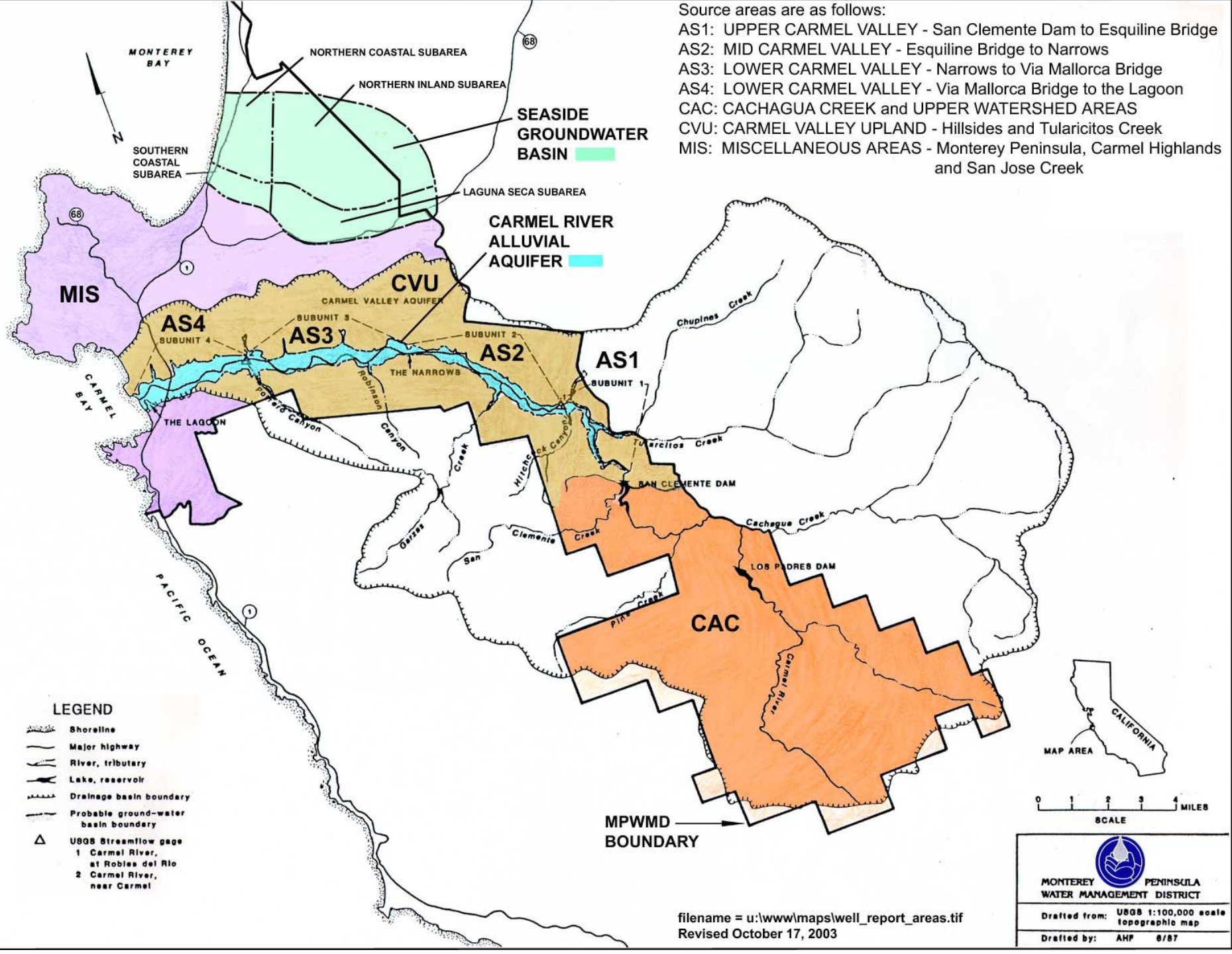
Source areas are as follows:
AS1: UPPER CARMEL VALLEY - San Clemente Dam to Esquiline Bridge
AS2: MID CARMEL VALLEY - Esquiline Bridge to Narrows
AS3: LOWER CARMEL VALLEY - Narrows to Via Mallorca Bridge
AS4: LOWER CARMEL VALLEY - Via Mallorca Bridge to the Lagoon
CAC: CACHAGUA CREEK and UPPER WATERSHED AREAS
CVU: CARMEL VALLEY UPLAND - Hillsides and Tularicitos Creek
MIS: MISCELLANEOUS AREAS - Monterey Peninsula, Carmel Highlands and San Jose Creek
MONTEREY BAY
NORTHERN COASTAL SUBAREA
NORTHERN INLAND SUBAREA
SEASIDE GROUNDWATER BASIN
SOUTHERN COASTAL SUBAREA
LAGUNA SECA SUBAREA
CARMEL RIVER ALLUVIAL AQUIFER
MIS
CVU
CARMEL VALLEY AQUIFER
AS4
SUBUNIT 4
AS3
SUBUNIT 3
AS2
SUBUNIT 2
AS1
SUBUNIT 1
THE NARROWS
THE LAGOON
CARMEL BAY
PACIFIC OCEAN
Chupines Creek
Robinson Canyon
Hitchcock Canyon
Tularcitos Creek
SAN CLEMENTE DAM
Cachagua Creek
Clemente Creek
LOS PADRES DAM
Pine Creek
CAC
Carmel River
MPWMD BOUNDARY
LEGEND
Shoreline
Major highway
River, tributary
Lake, reservoir
Drainage basin boundary
Probable ground-water basin boundary
USGS Streamflow gage
1 Carmel River, at Robles del Rio
2 Carmel River, near Carmel
CALIFORNIA
MAP AREA
0 1 2 3 4 MILES
SCALE
MONTEREY PENINSULA WATER MANAGEMENT DISTRICT
Drafted from: USGS 1:100,000 scale topographic map
Drafted by: AHP 6/87
filename = u:\www\maps\well_report_areas.tif
Revised October 17, 2003

Quality of Fractured Rock Aquifer

"Quality" in this context is defined as ability of aquifer to store and transmit water.

Poor Quality (low yield) Fractured Rock Aquifer ⟷ **High Quality (high yield) Fractured Rock Aquifer**

Little to no fractures	Non-connected small fractures	Connected small fractures	Connected small and large fractures

Sustainability of an Aquifer

- Production of water from any aquifer is sustainable when recharge is equal to or greater than production (safe yield).
- Changes in groundwater storage are observed through changes in water levels. Falling water levels over time indicate reduction of stored water and non-sustainable production.
- Long-term water level monitoring has not been completed within the pilot study area.

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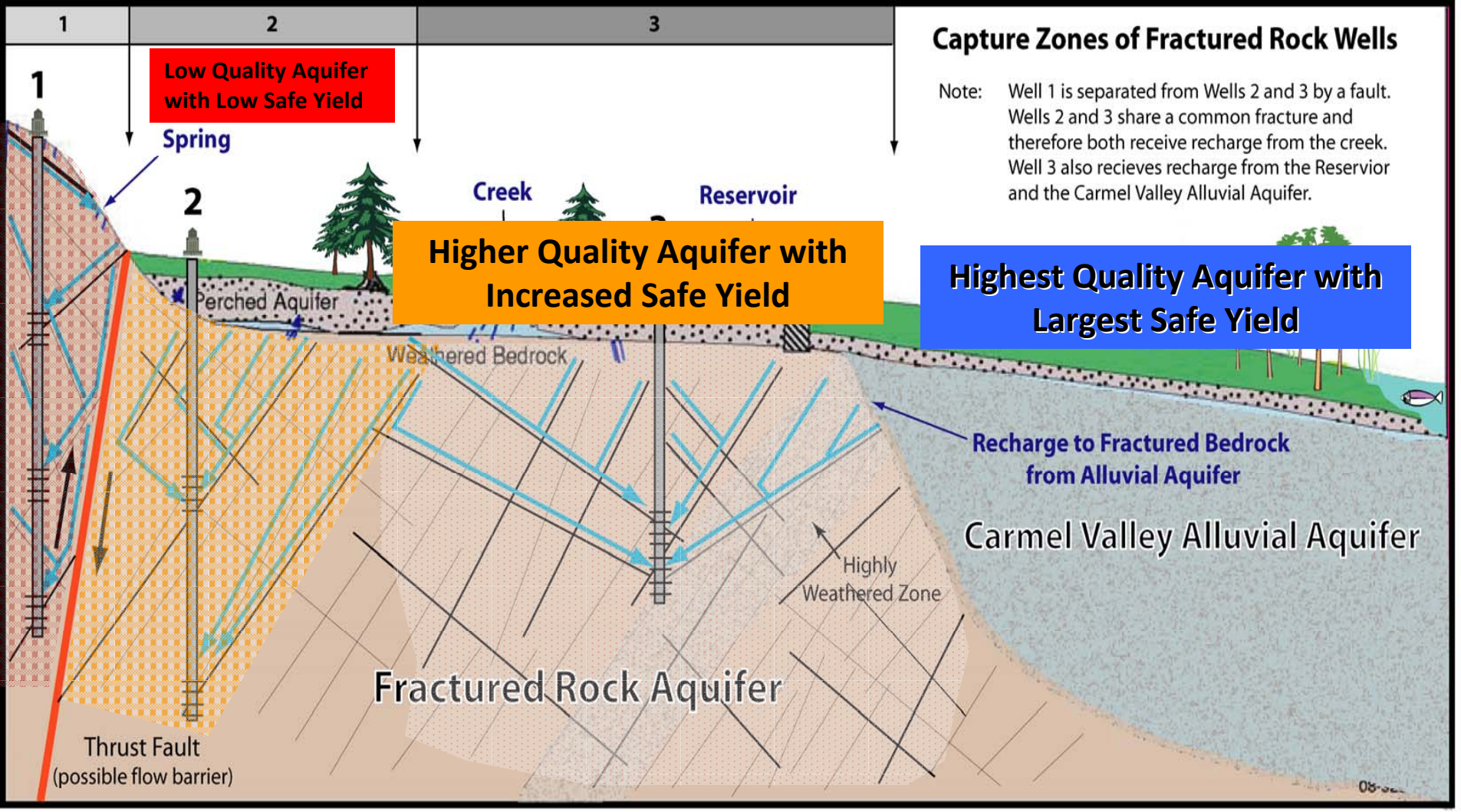

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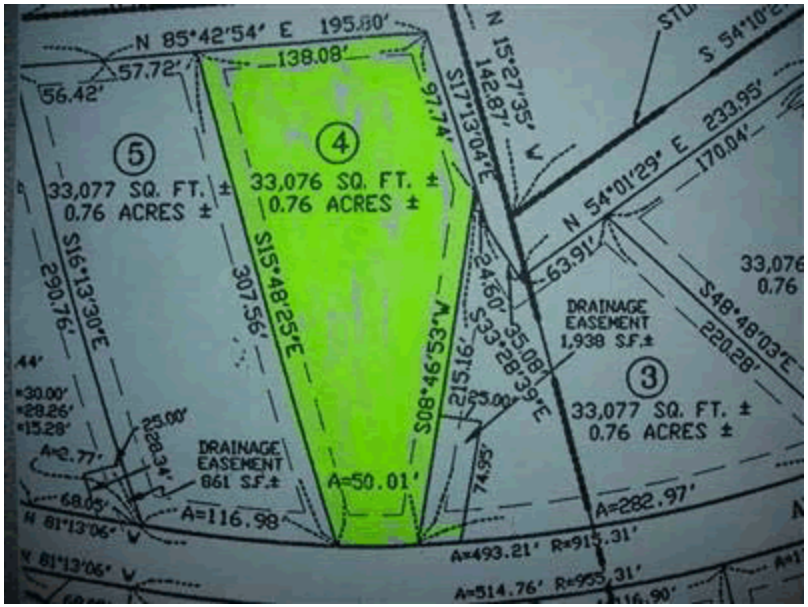
Conceptual Illustration of Recharge and Capture Zone Mechanisms in Fractured Rock Settings

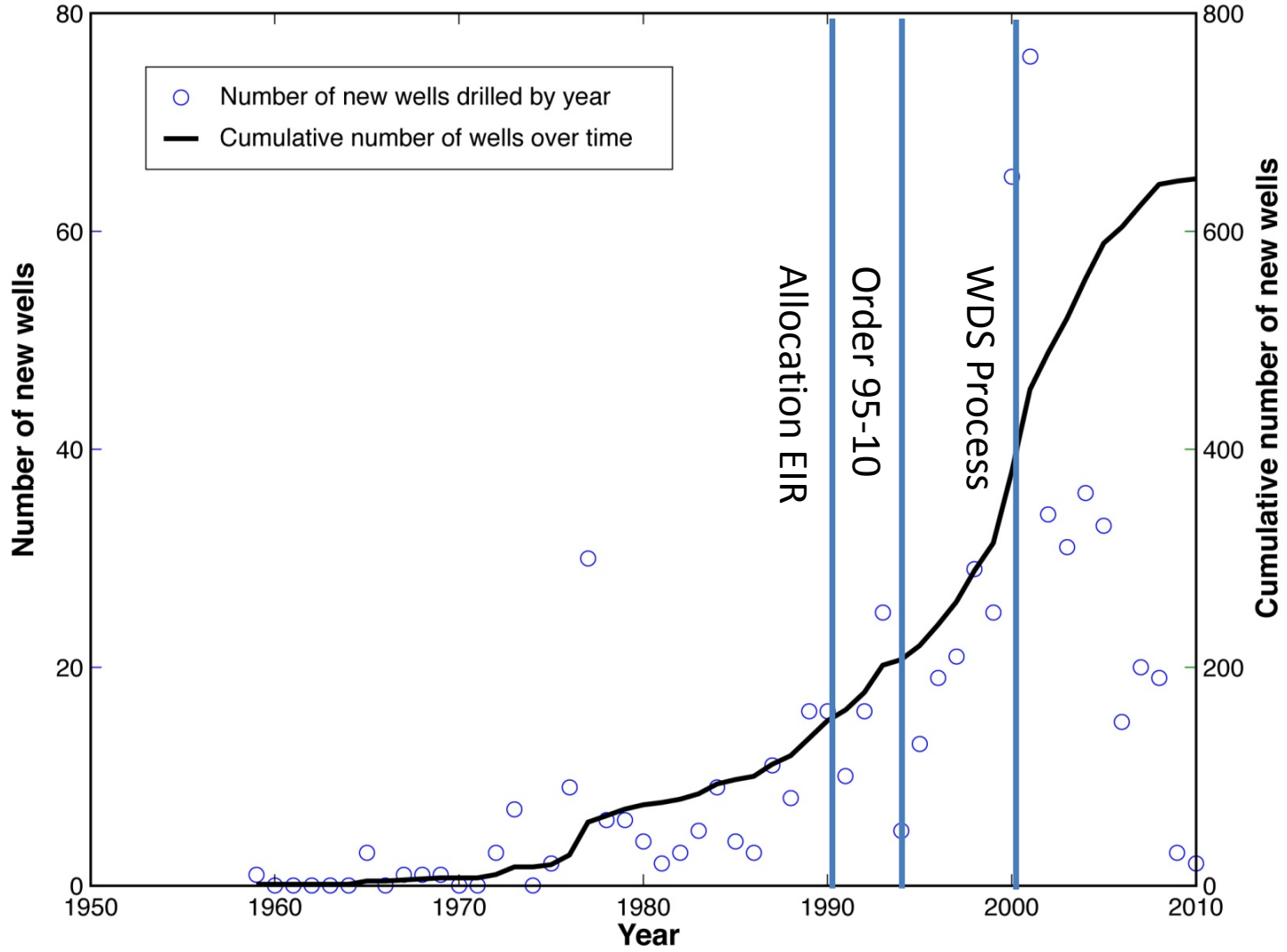
Motivation for Study

- Due to limitations on new water connections from the Cal-Am system, many land owners/developers have begun to drill groundwater wells as a source of supply to new or planned developments.
- Permits for wells are issued based upon performance of the well following drilling.
- A Water Distribution System Permit (WDS) does not guarantee a water for the life of the development.
- Can we learn anything from the data we already have in our files?



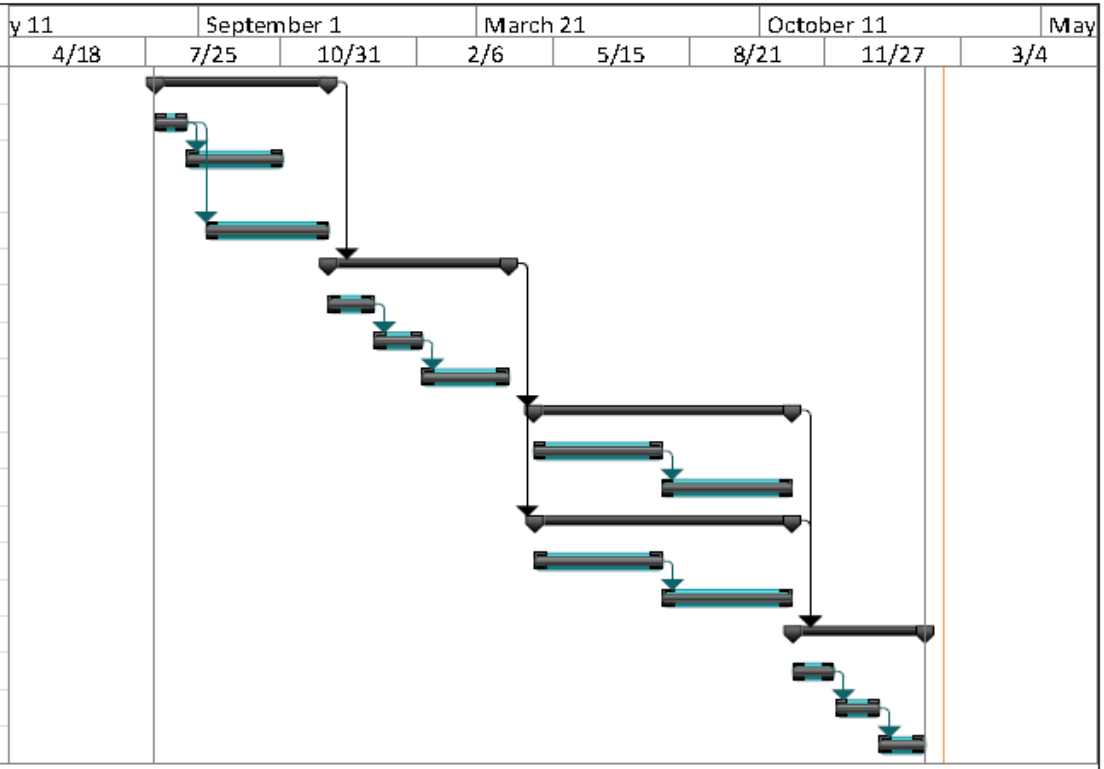
MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

Logged Fractured Rock Wells Drilled 1950-2010



MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

ID		Task Name
1	✓	**Compile Lithology Database**
2	✓	Review Ditsrict Fractured Rock Well Files
3	✓	Data Request to Monterey County Environmental Health and Water Resounces District
4	✓	Enter Lithology into database
5	✓	**Establish Monitor Nestowrk**
6	✓	Identify Potential Monitor Wells
7	✓	Field Verify Locations
8	✓	Deploy Data Loggers
9	✓	**Analize Aquifer Parameters**
10	✓	Compile Pump Test Data
11	✓	Process Spatial Data
12	✓	**Compile Production Data**
13	✓	Compile Production data
14	✓	Process Production Data
15	✓	**Evaluate Monitor Well Netowrk**
16	✓	Process Monitor Well Data
17	✓	Select New Monitor Locations
18	✓	Deploy New Monitoring Locations



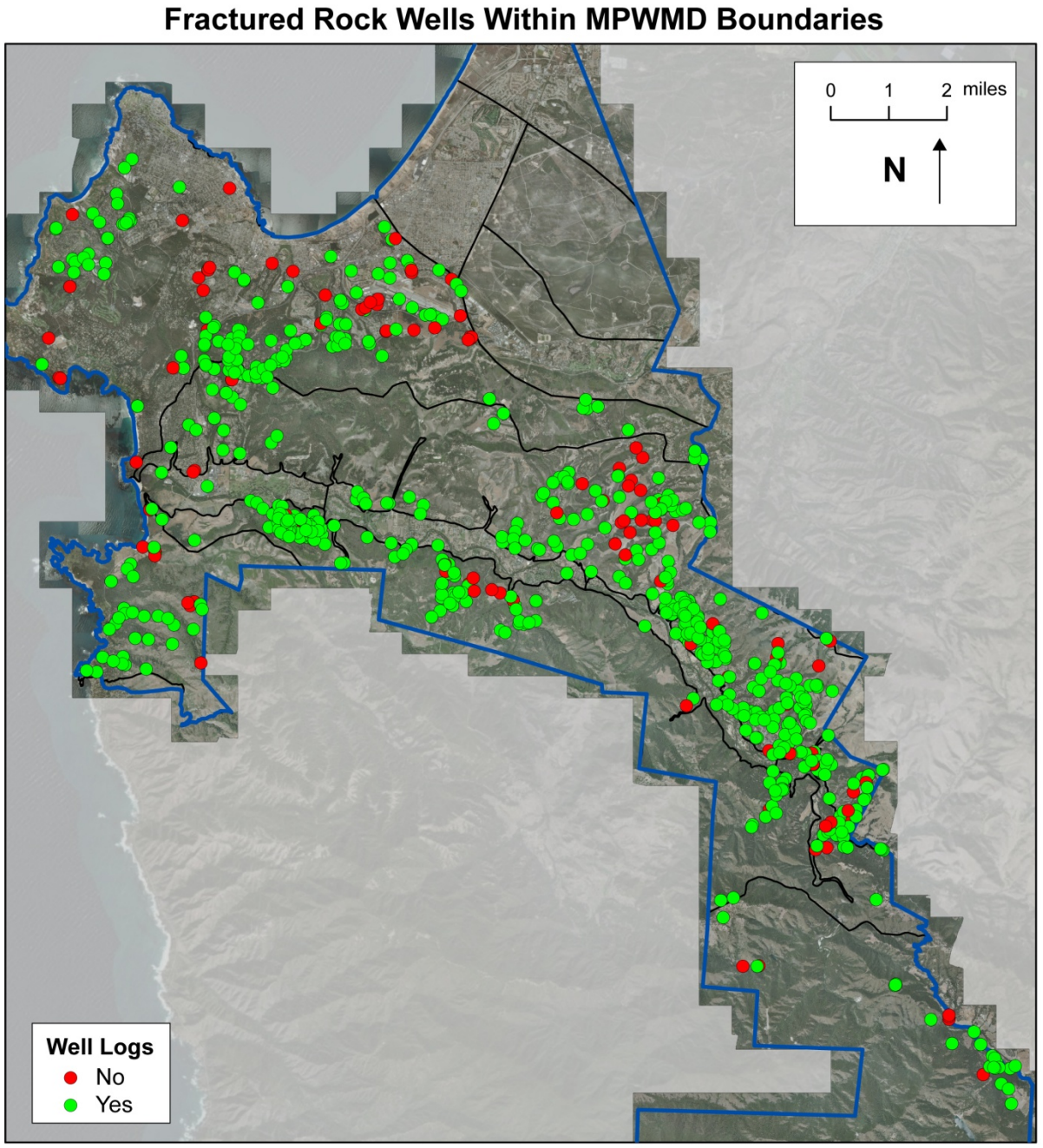
Fractured Rock Study Schedule to Date

Project: Fractured Rock Schedule
Date: Tue 2/21/12

Task		External Milestone		Manual Summary Rollup	
Split		Inactive Task		Manual Summary	
Milestone		Inactive Milestone		Start-only	
Summary		Inactive Summary		Finish-only	
Project Summary		Manual Task		Deadline	
External Tasks		Duration-only		Progress	

Sources of well records

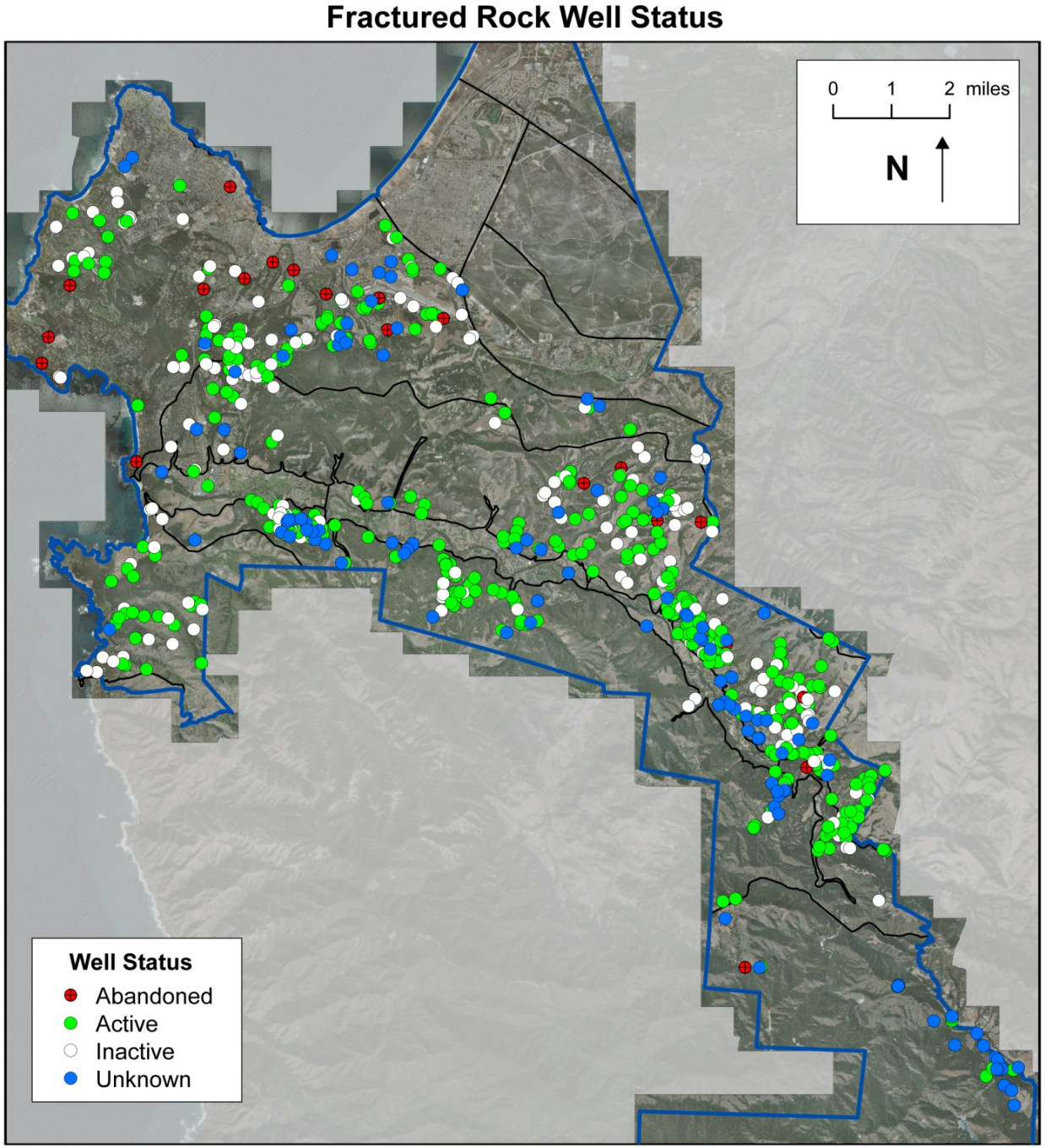
- Department of Water Resources
- MPWMD Well/Parcel files
- Monterey County Environmental Health Well Permitting
- Monterey County Water Resources District



Monterey Peninsula Water Management District

Sources of Well Status

- MPWMD well reporting
- Monterey County Environmental Health Destruction Records
- Monterey County Water Resources Agency



Monterey Peninsula Water Management District

Moving from Lithology to a Hydrogeologic Framework Model

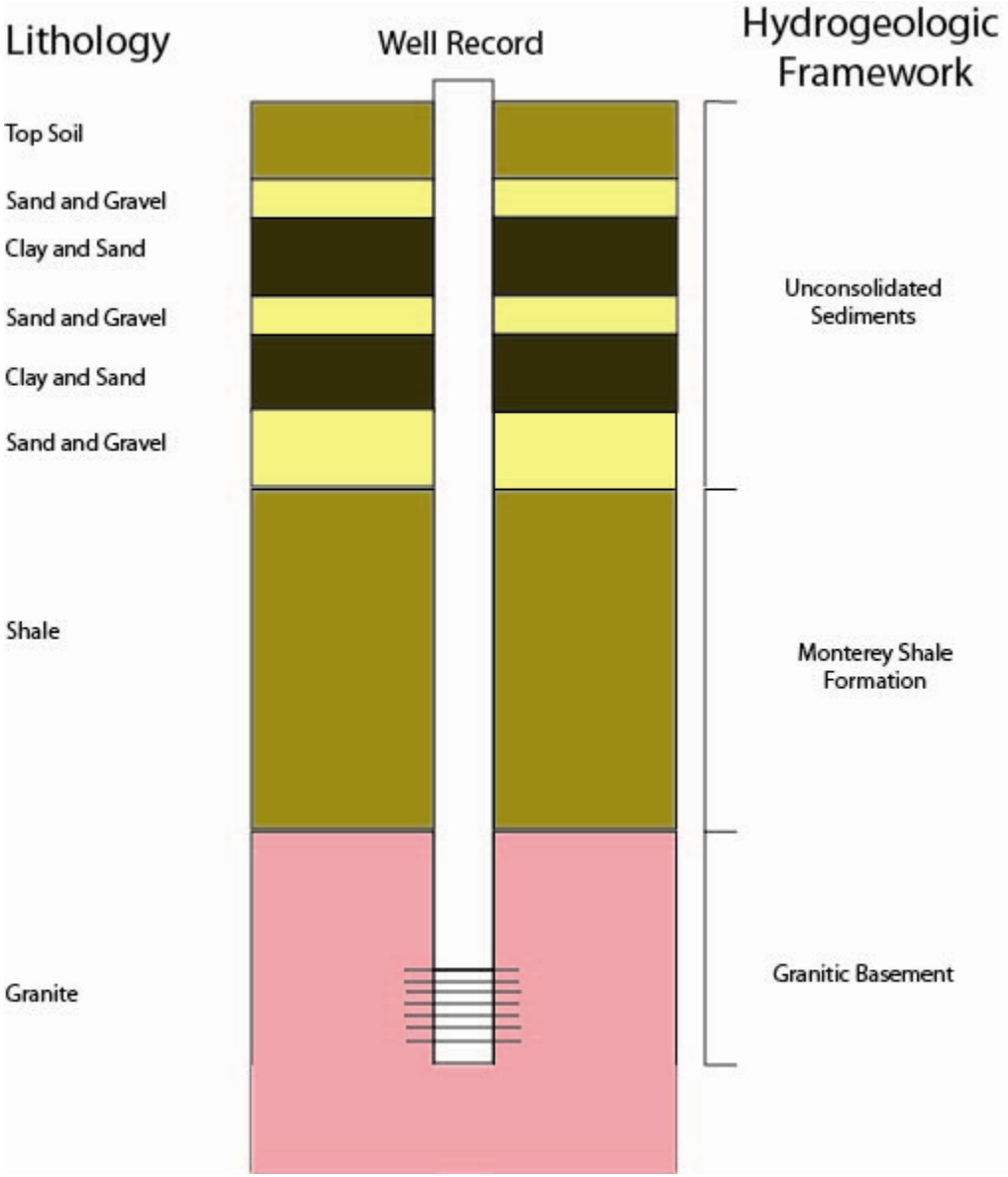
Enter Lithology Data into Database

↓

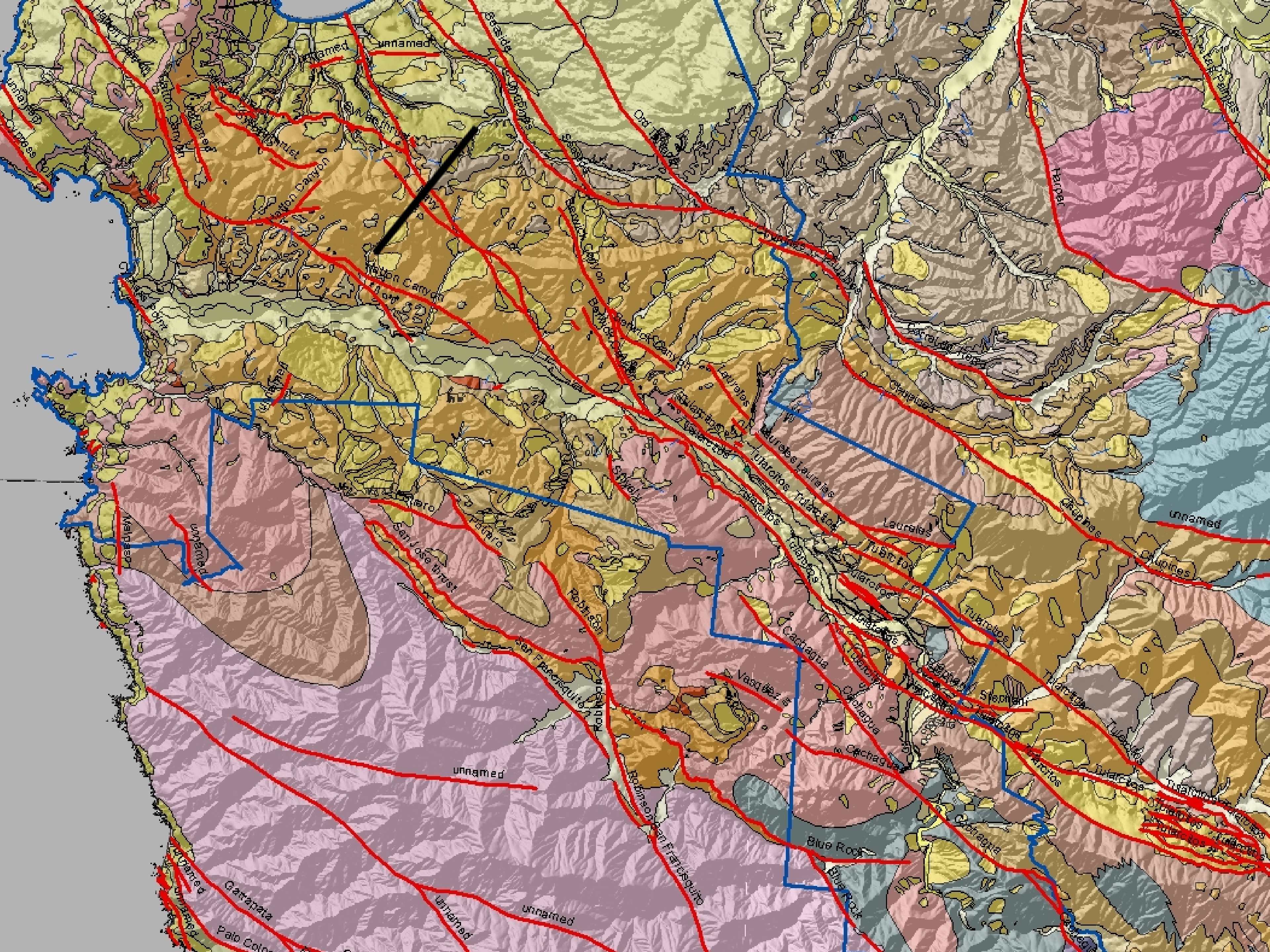
Group Lithology into Hydrogeologic Units

↓

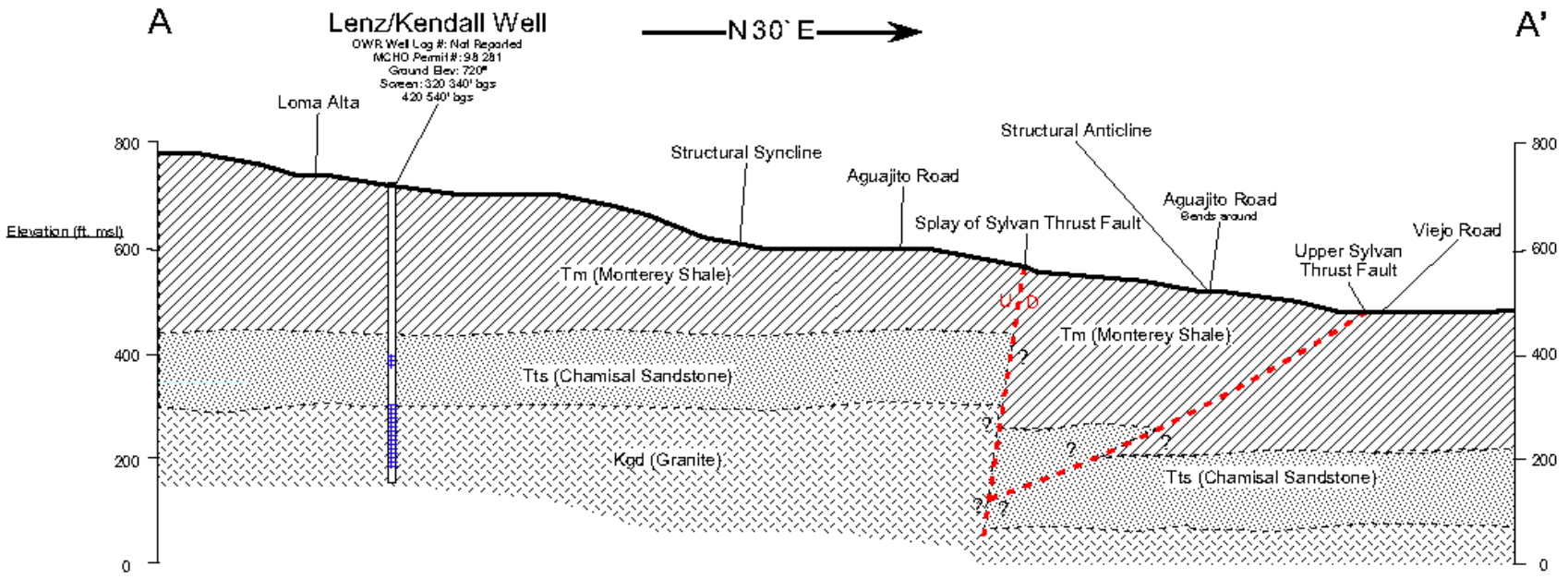
Assign Wells to Corresponding Hydrogeologic Unit



MONTEREY PENINSULA WATER MANAGEMENT DISTRICT



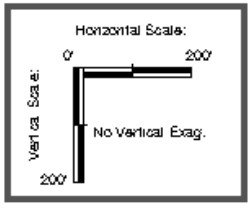
unnamed
Hatton Canyon
Laureles
Tularcitos
Chupines
Harper
San Jose Thrust
Robinson
San Francisquito
Vasquez
Cachagua
Blue Rock
Garrapata



EXPLANATION

Tm = Monterey Formation (porcelanite) - (Miocene) - Light brown to white, hard, brittle, platy.
Tts = Chamisal Sandstone (Miocene) - Marine deposition; buff to light-gray, poorly to well sorted arkosic sandstone, locally friable, locally conglomeratic.
Kgd = Granodiorite to Quartz Monzonite Basement Complex (Cretaceous)

NOTES:
This geologic cross section is a graphical representation only. Data used to create this cross section was obtained from Geologic Map (Figure 3) and Department of Water Resources Well Completion Report(s) - Appendix A. Faults (if applicable): Actual fault offset, and dip is uncertain. Fault motion is correct.



BIERMAN Hydrogeologic
A Professional Company
Hydrogeologic Consulting & Water Resource Management

CONCEPTUAL GEOLOGIC CROSS SECTION A-A'

APN: 103-102-016 & 017
Monterey County, California

FIGURE 4

Drawn By: AB, 4/01/09
File: Jenn/Figure 4/A-A'.cdr

Representative Hydrogeologic Unit Outcrops Exposed in Road Cuts

Unconsolidated Sediments

Monterey Shale

Granitic Basement

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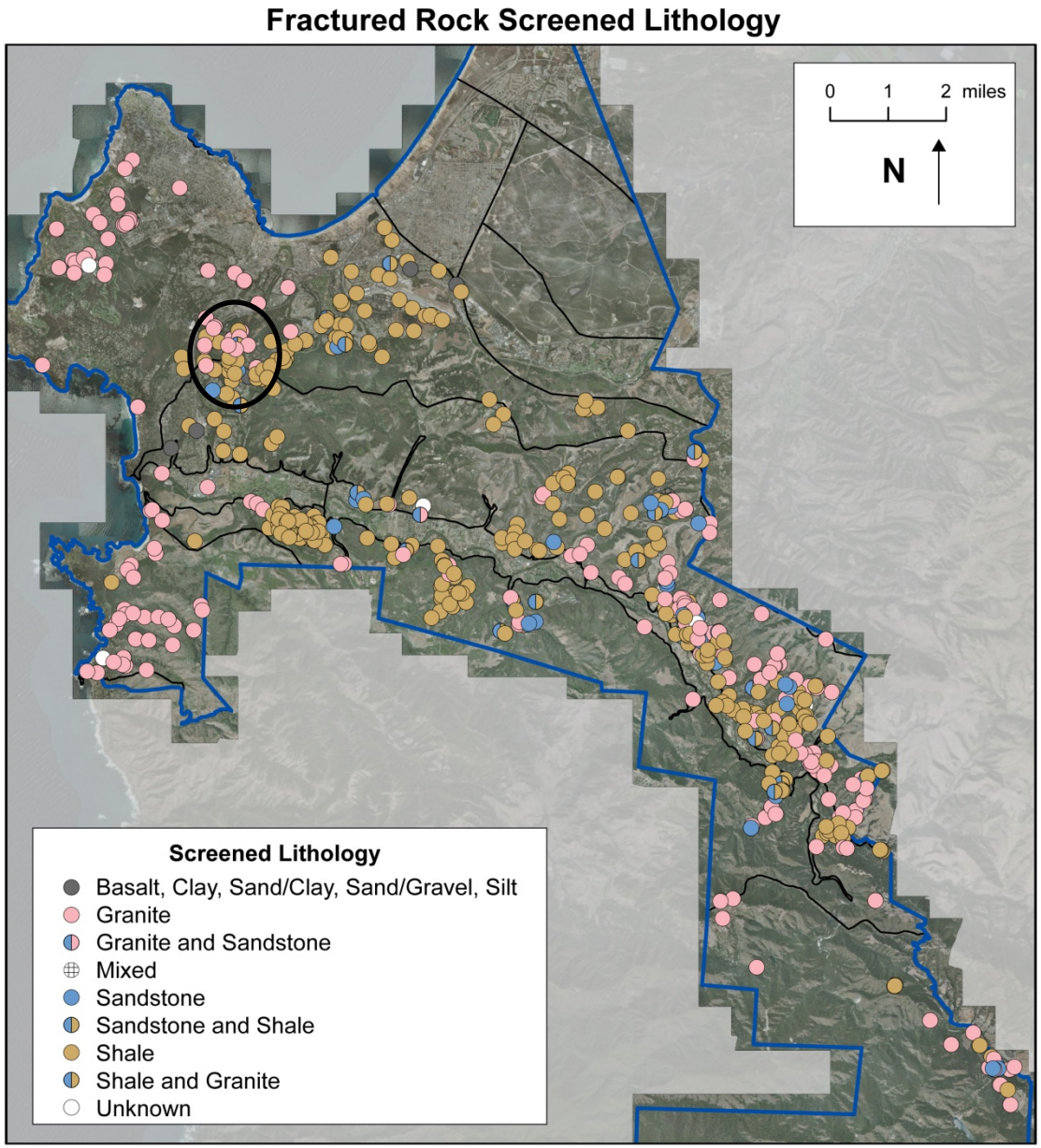
Assigning Wells to the Hydrologic Framework Model

Well screen intervals reported on DWR driller logs were used to assign the appropriate section of the Hydrogeologic Framework Model where each well primarily extracts water.



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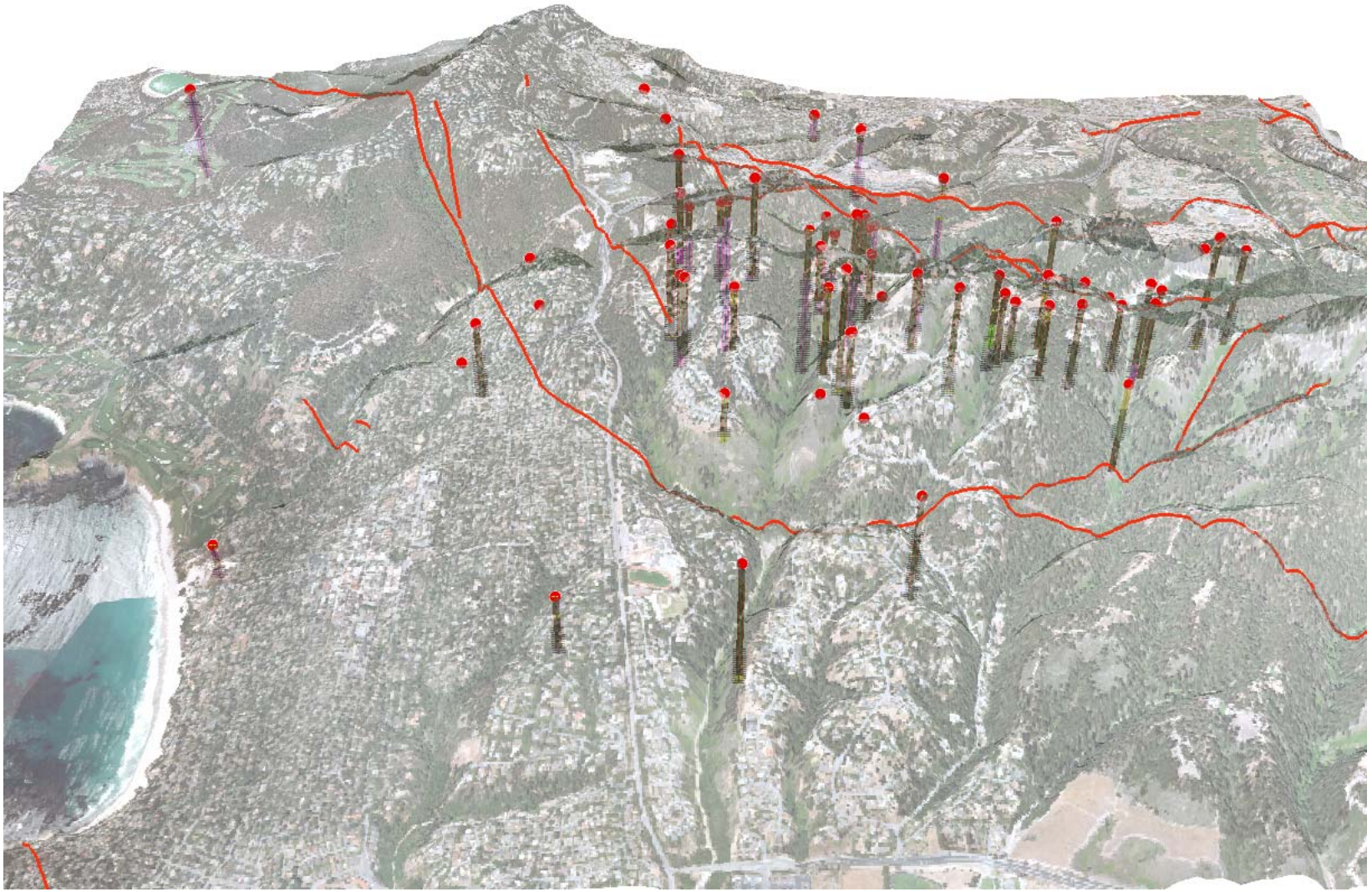
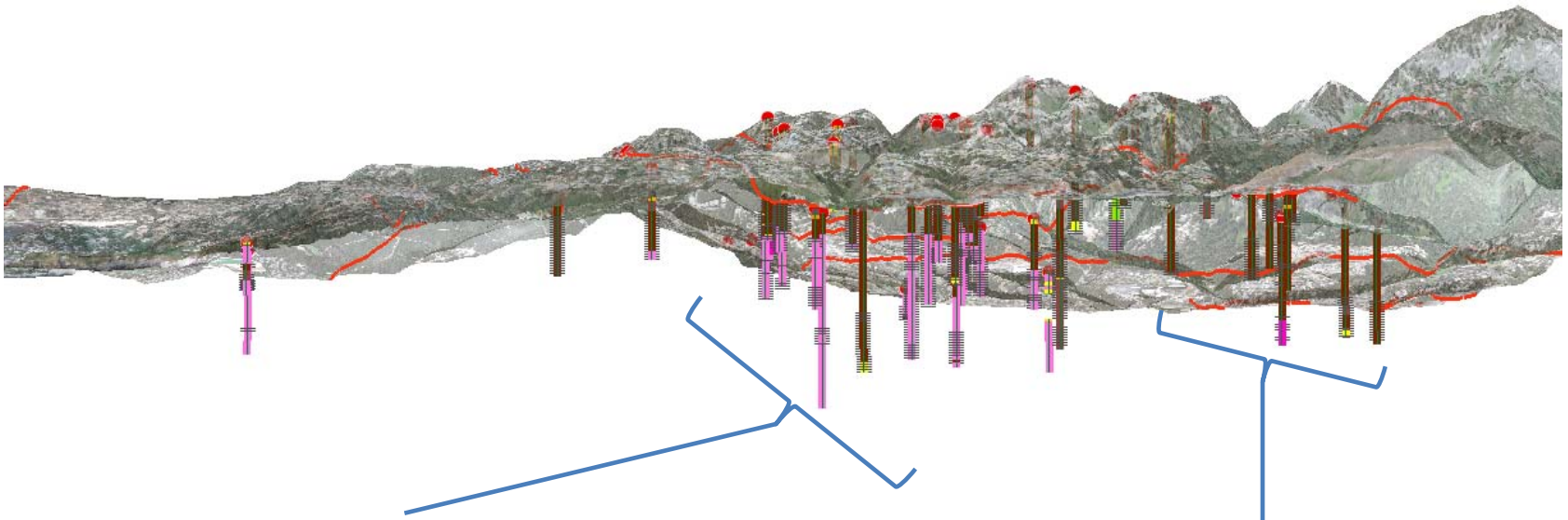


MONTEREY PENINSULA WATER MANAGEMENT DISTRICT



Under the northwest region of Aguajito area, the Granitic Basement is more shallow and wells are screened in the Granitic Section of the Hydrogeologic Framework Model

Under the southeast region of Aguajito area, the Granitic Basement is deeper and wells are screened in Monterey Shale Section of the Hydrogeologic Framework Model

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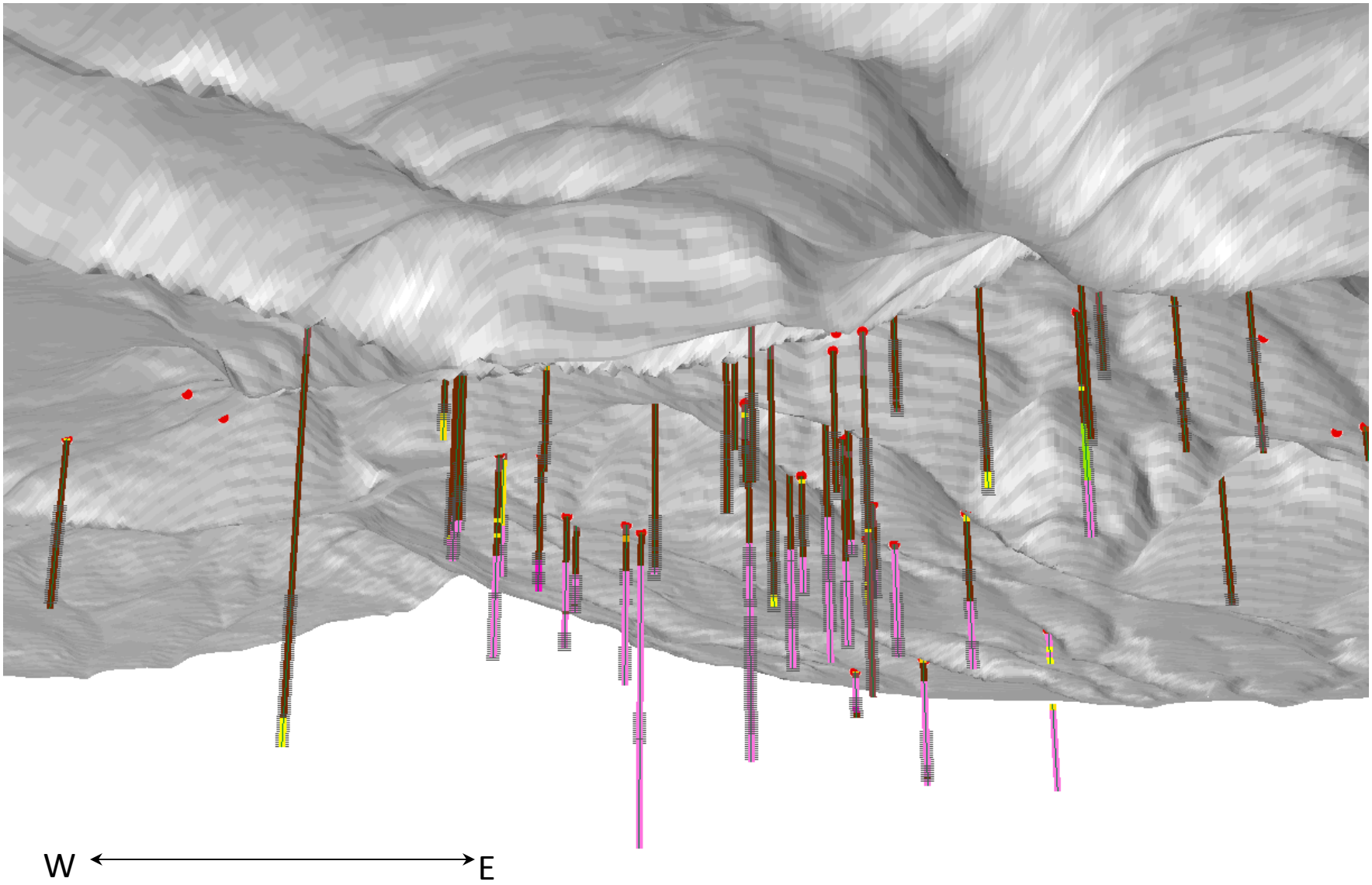

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Well Performance – Aquifer Quality

Pumping tests are performed upon well completion to calculate the ability of well to produce water.

- MPWMD water distribution system permits require 72 hour pumping tests during permitting process
  - Good quality data
  - Accurate aquifer parameters
  - Consistent methodology
  - Poor geographic coverage

- DWR pumping test
  - Data often incomplete
  - Can not be used to calculate aquifer parameters
  - Inconsistent methods
  - Good geographical coverage

These calculations are completed on data collected following well construction and are therefore a measure of how the well performed when it was new and not the sustainability of the well.

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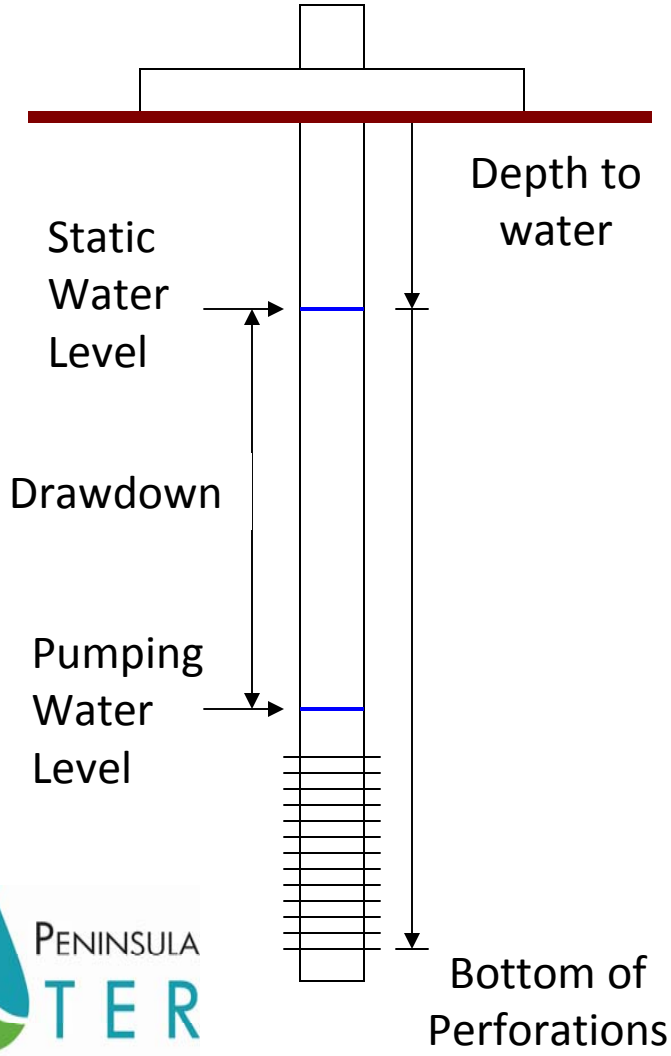
MPWMD Well Yield Calculation for Water Distribution System Permit

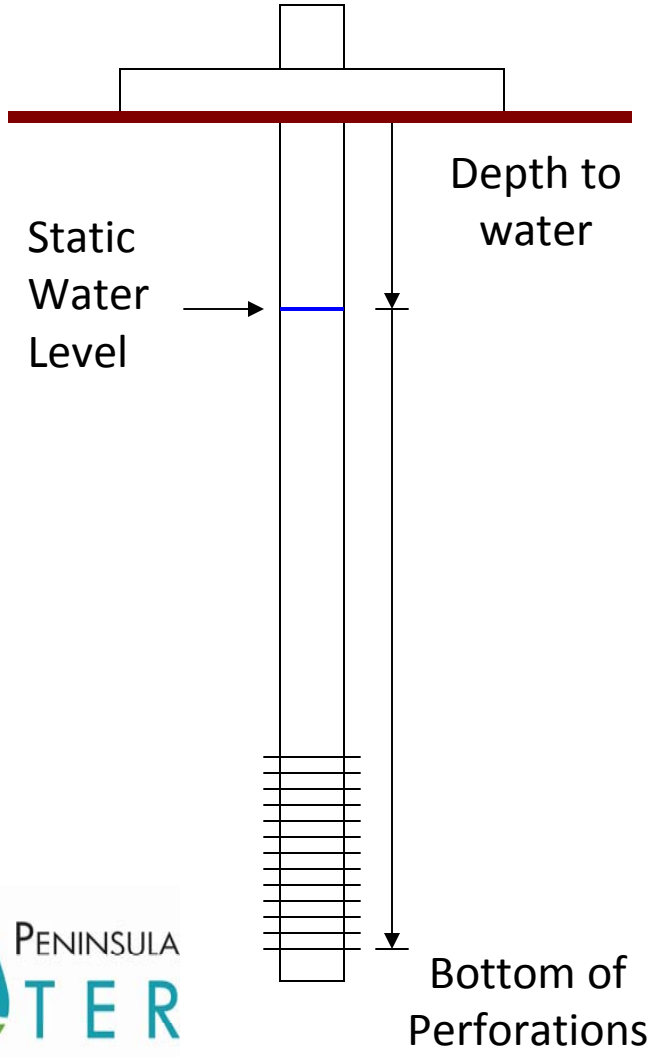


- **Available Drawdown** = 1/3 (depth to bottom of perforations – Static Water Level)
- **Specific Capacity**[1] = GPM / Drawdown
- **Calculated well yield** = Specific Capacity[1] * Available Drawdown
- Poor Geographical Coverage

Monterey Peninsula Water Management District

1. Specific Capacity calculated from first 24 hours of 72 hour pumping test.

DWR Drawdown Ratio



- Driller reports often do not report drawdown associated with pumping tests.
- In an attempt to normalize flow rate data reported on Drillers logs with depth, we created a "Drawdown Ratio."
- **Drawdown Ratio** = GPM / (Static Water Level – Depth to Bottom of Screens)
- Good Geographical Coverage

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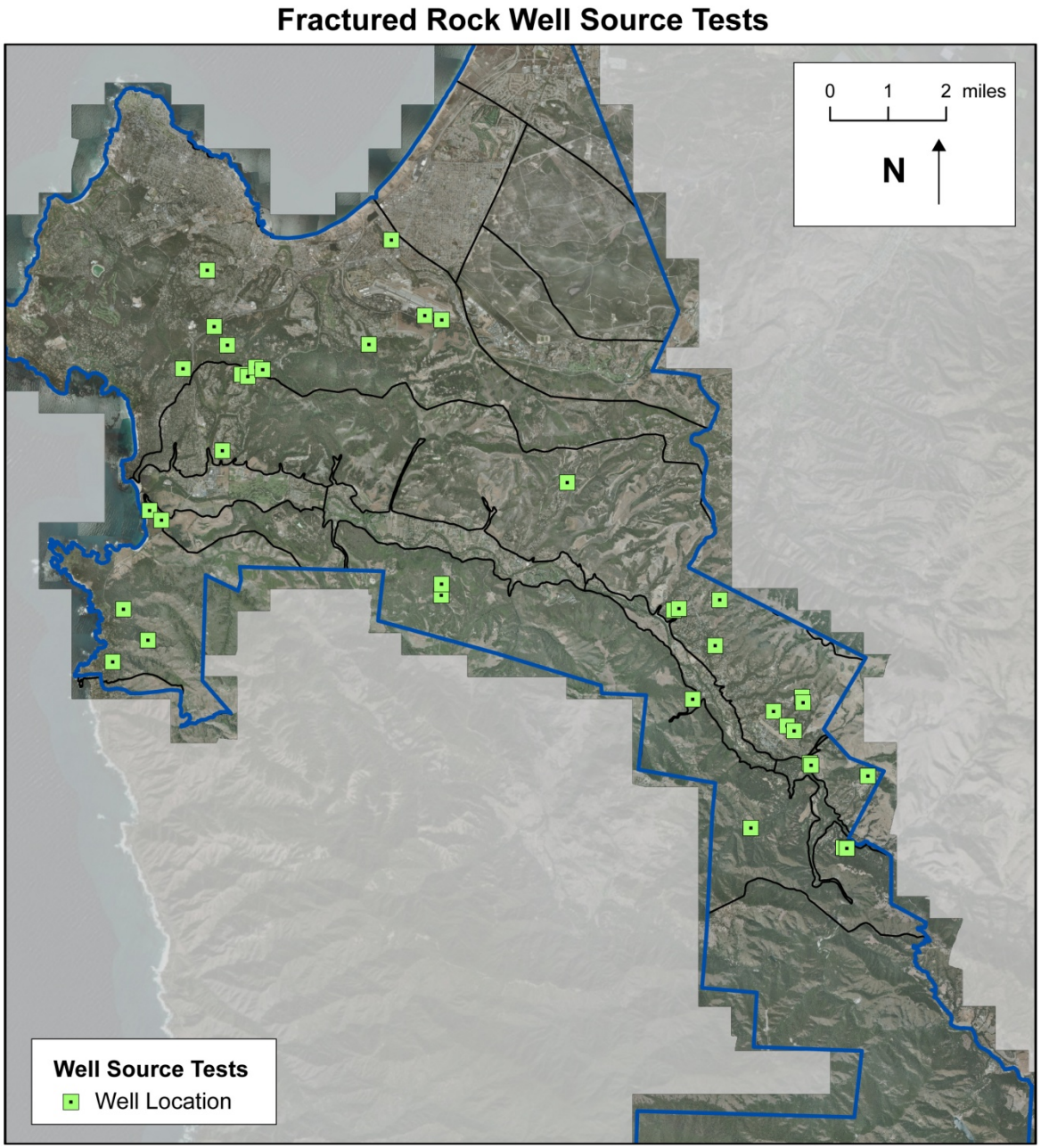
Distribution of Wells with MPWMD Well Yield Calculations

Prior to 2000, wells located on the same parcel as proposed water use did not require a Water Distribution System.

Replacement wells and Water Distribution Systems that qualify of exemptions do not require this test.



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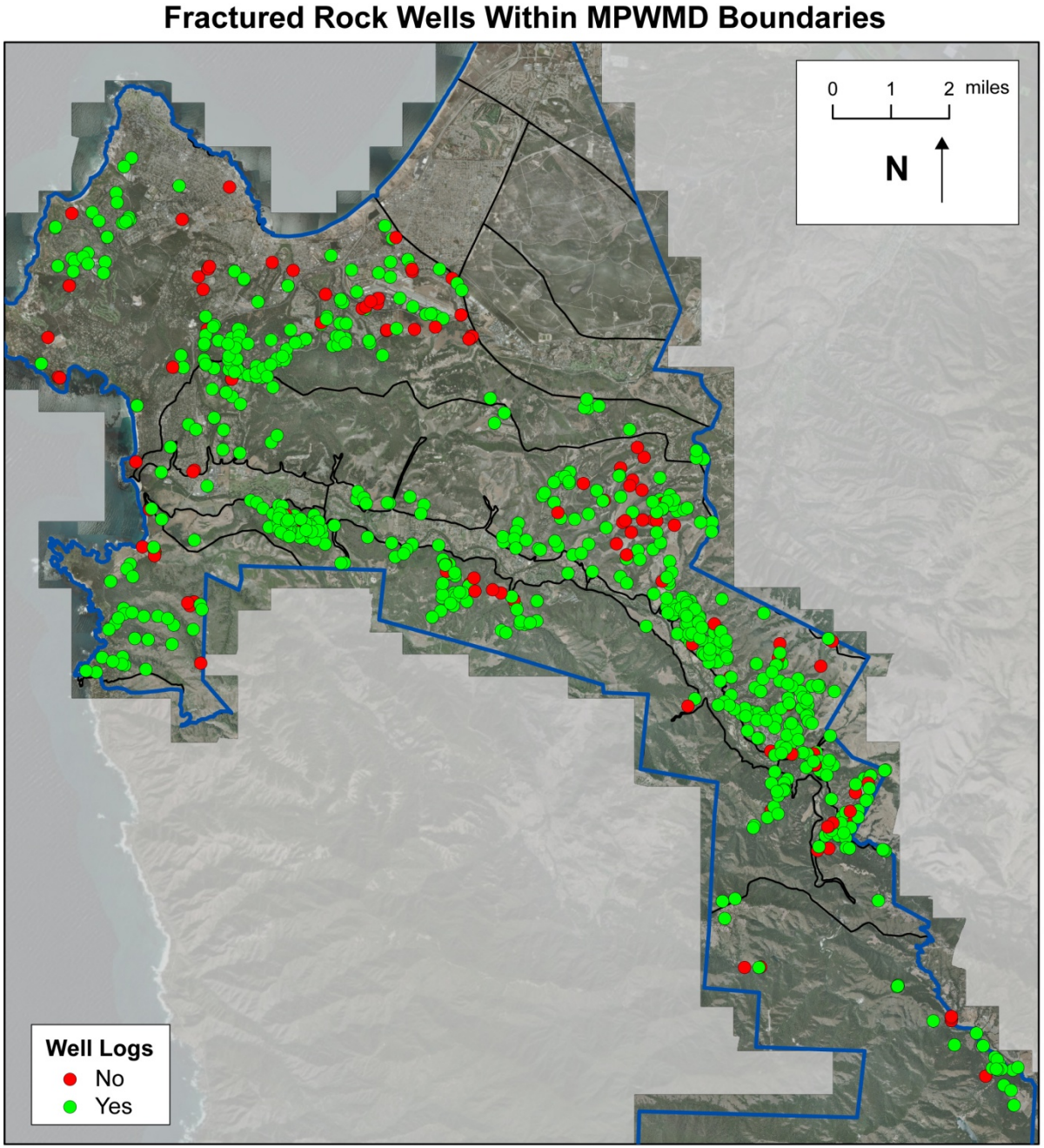
Distribution of DWR Well Logs Containing Pumping Data

Much greater distribution of data, however not all pump tests were completed using the same methods.

Permanent vs. Temporary Pump

Airlift Method

Do these less consistent methods lend reliable results?



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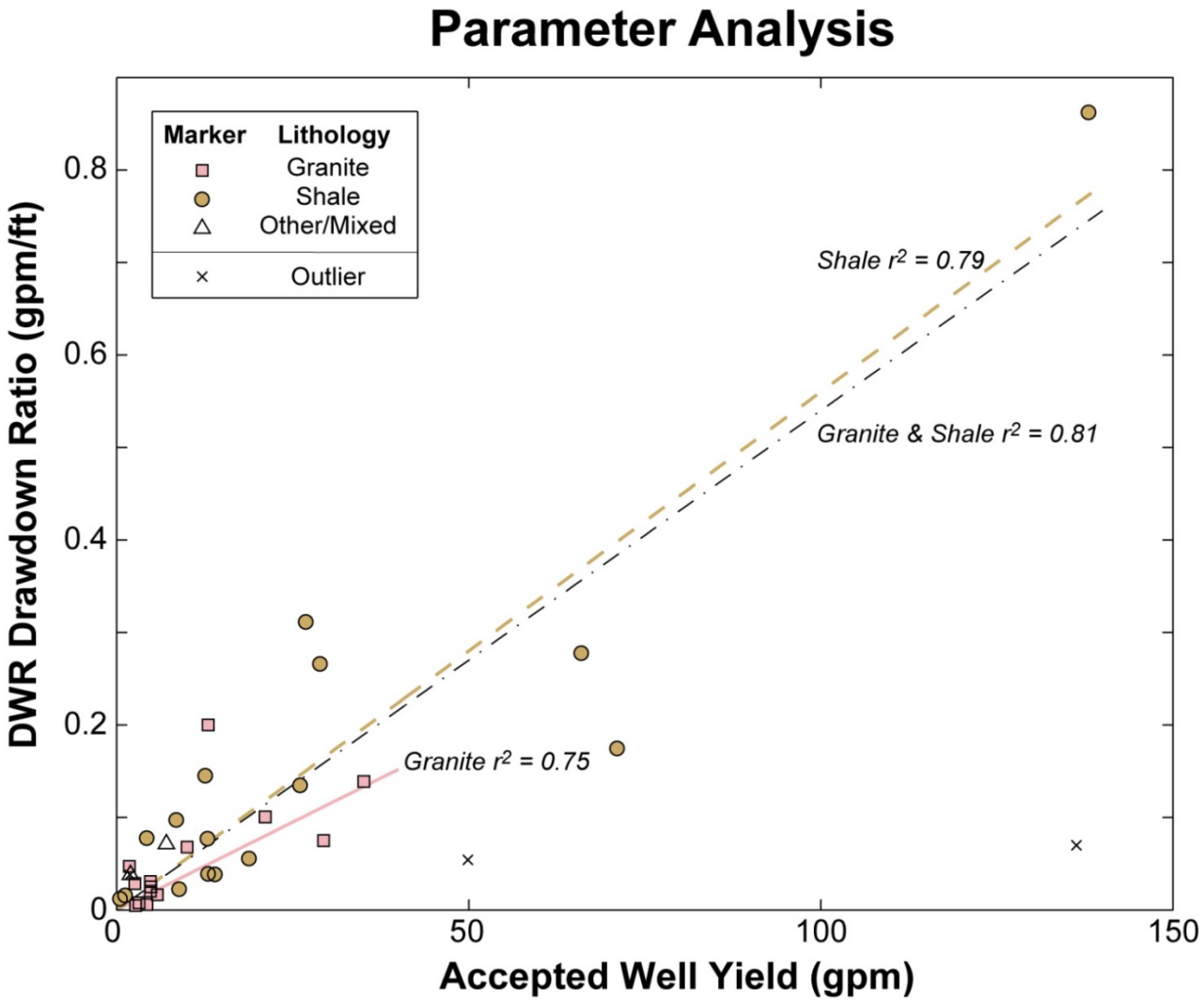
Comparison of Methods

When comparing DWR Drawdown calculations with Accepted well yield Calculations, they were within 20% of one another.

Wells producing water from the Monterey Shale had a slightly higher correlation than wells producing from the Granite.



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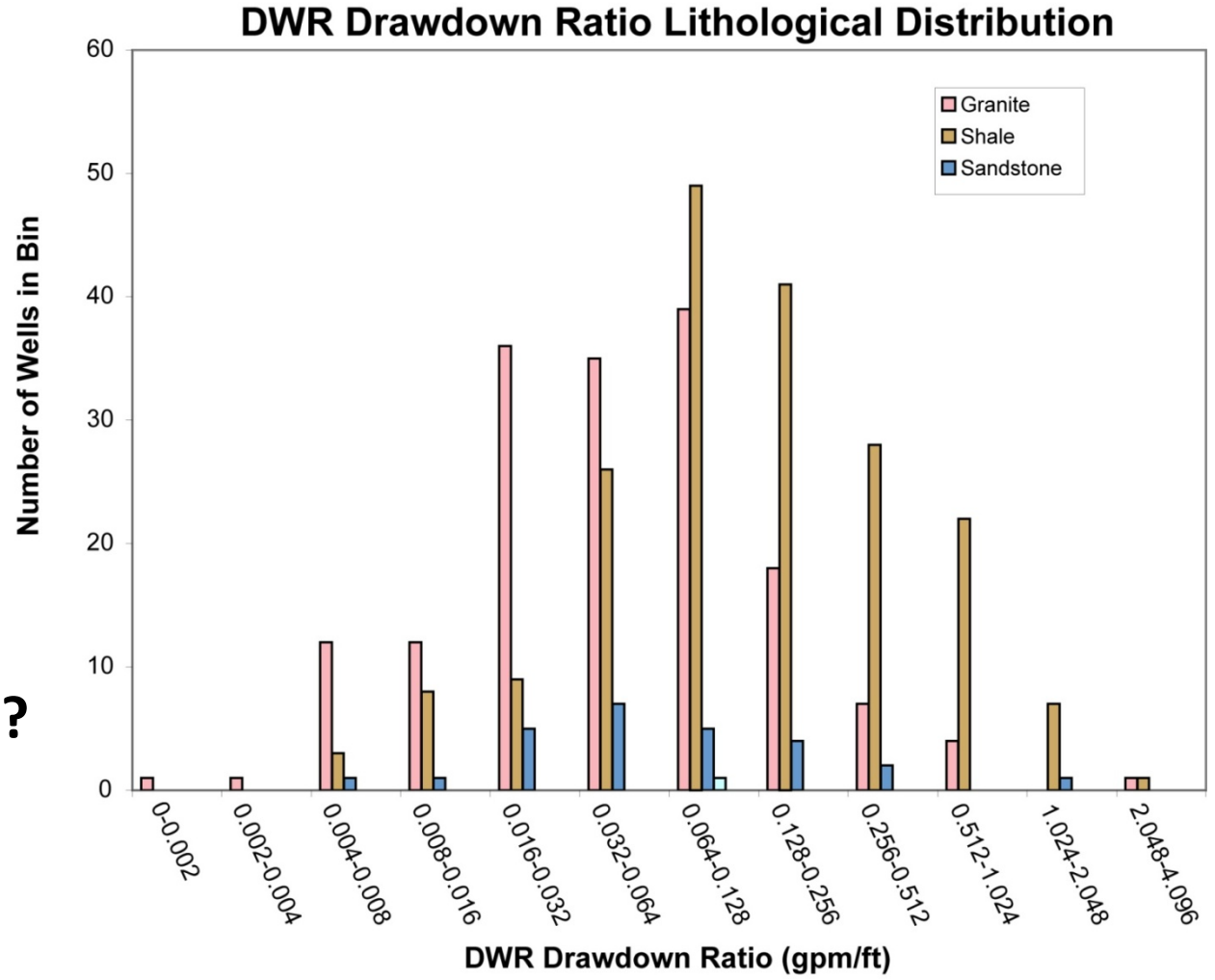
Distribution of DWR Drawdown Ratio by Hydrogeologic Framework Unit

On the average, wells extracting water from the Monterey Shale component of the Hydrogeologic Framework Model Scored 0.064 GPM/ft better than wells extracting water from the Granitic component.

What does this mean?



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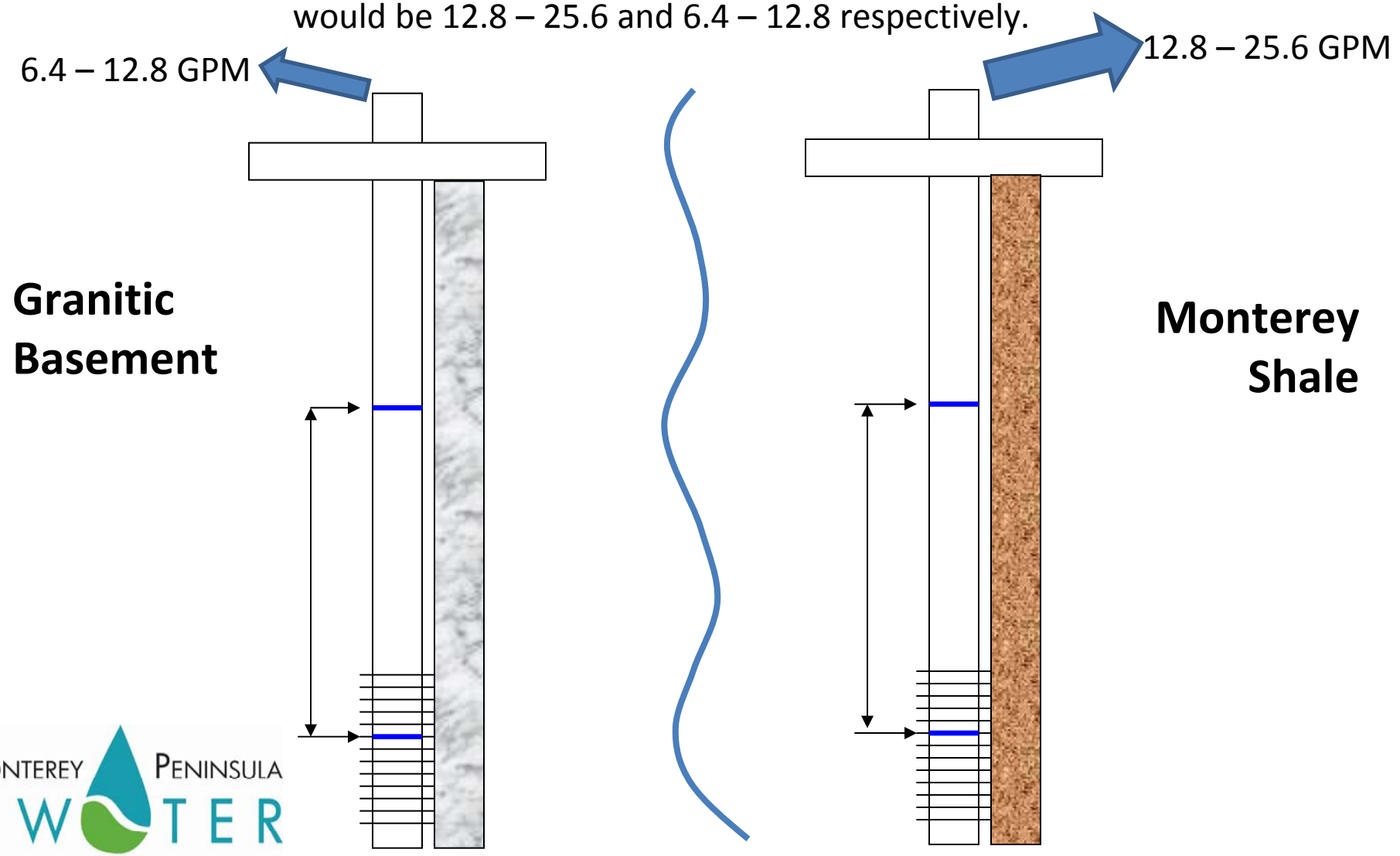
Monterey Shale vs. Granitic Basement

For two identically constructed wells one in the Monterey Shale and one in the Granite and both with 200 feet of available drawdown, their production volumes would be 12.8 – 25.6 and 6.4 – 12.8 respectively.



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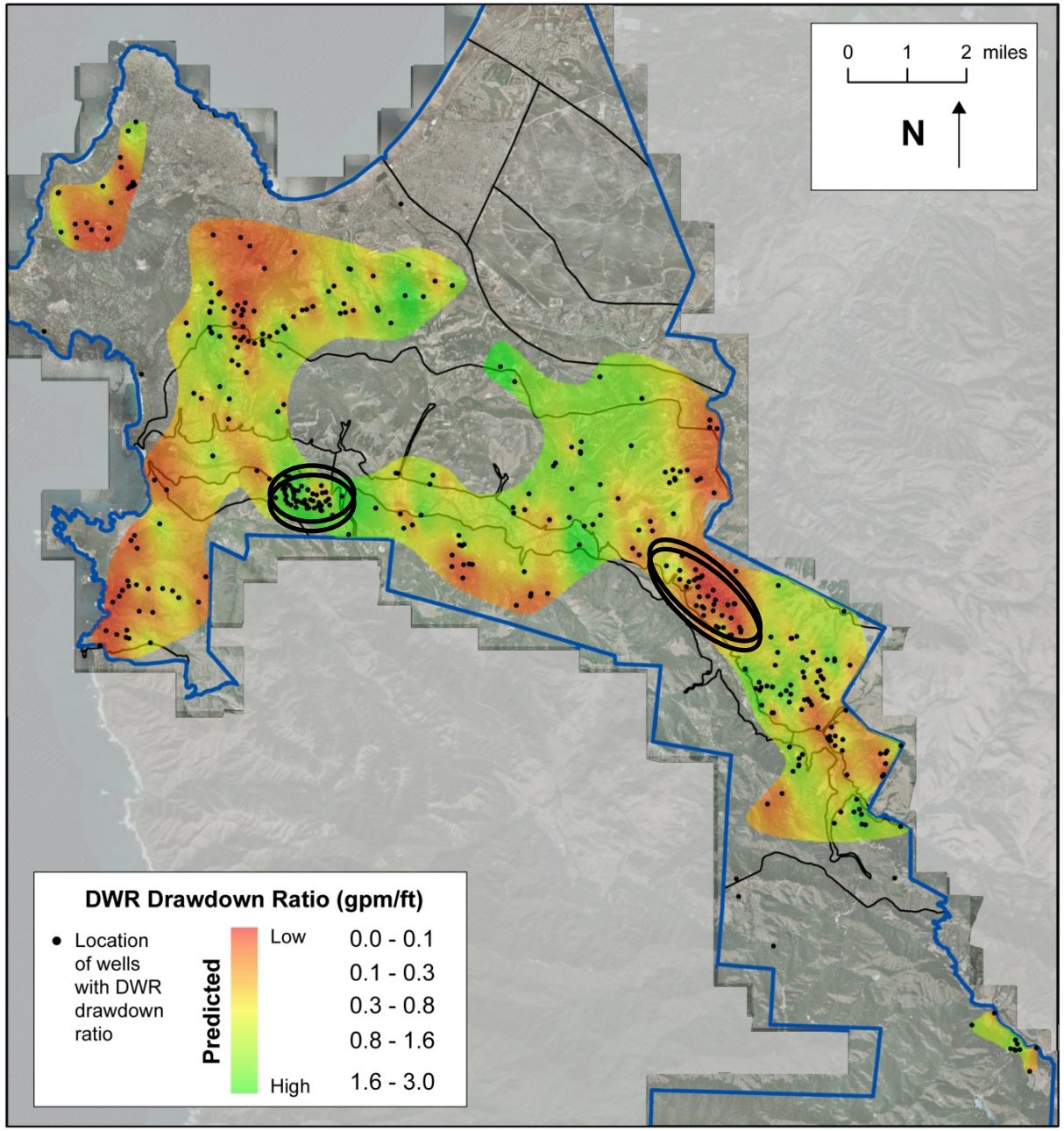
Estimated DWR Drawdown Ratio

Geostatistical analysis of wells with DWR Drawdown Ratio allow the District to 'Predict' the DWR Drawdown Ratio within some of the fractured rock regions of the District.

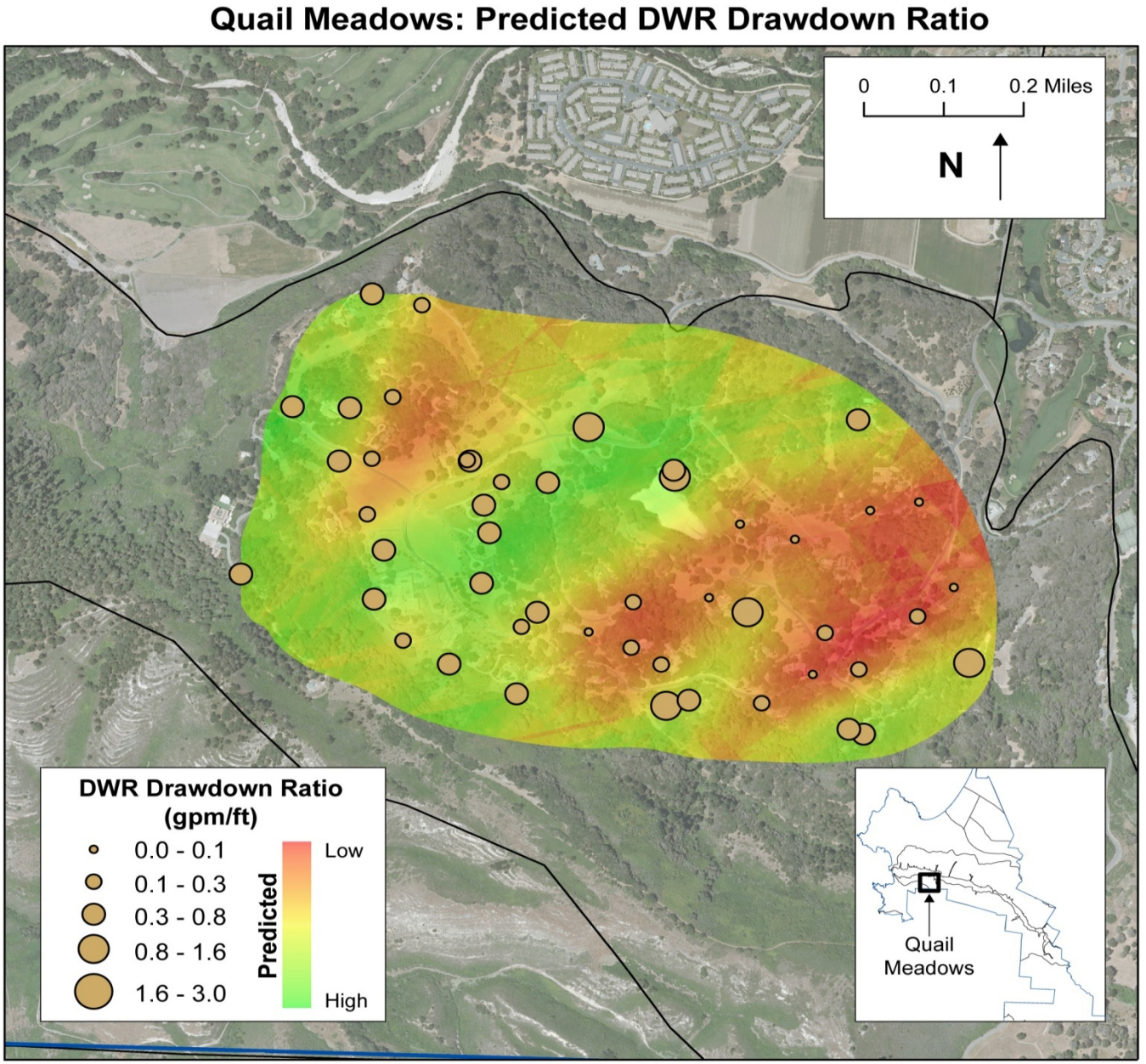
District staff use this map to help identify regions to seek monitor wells.



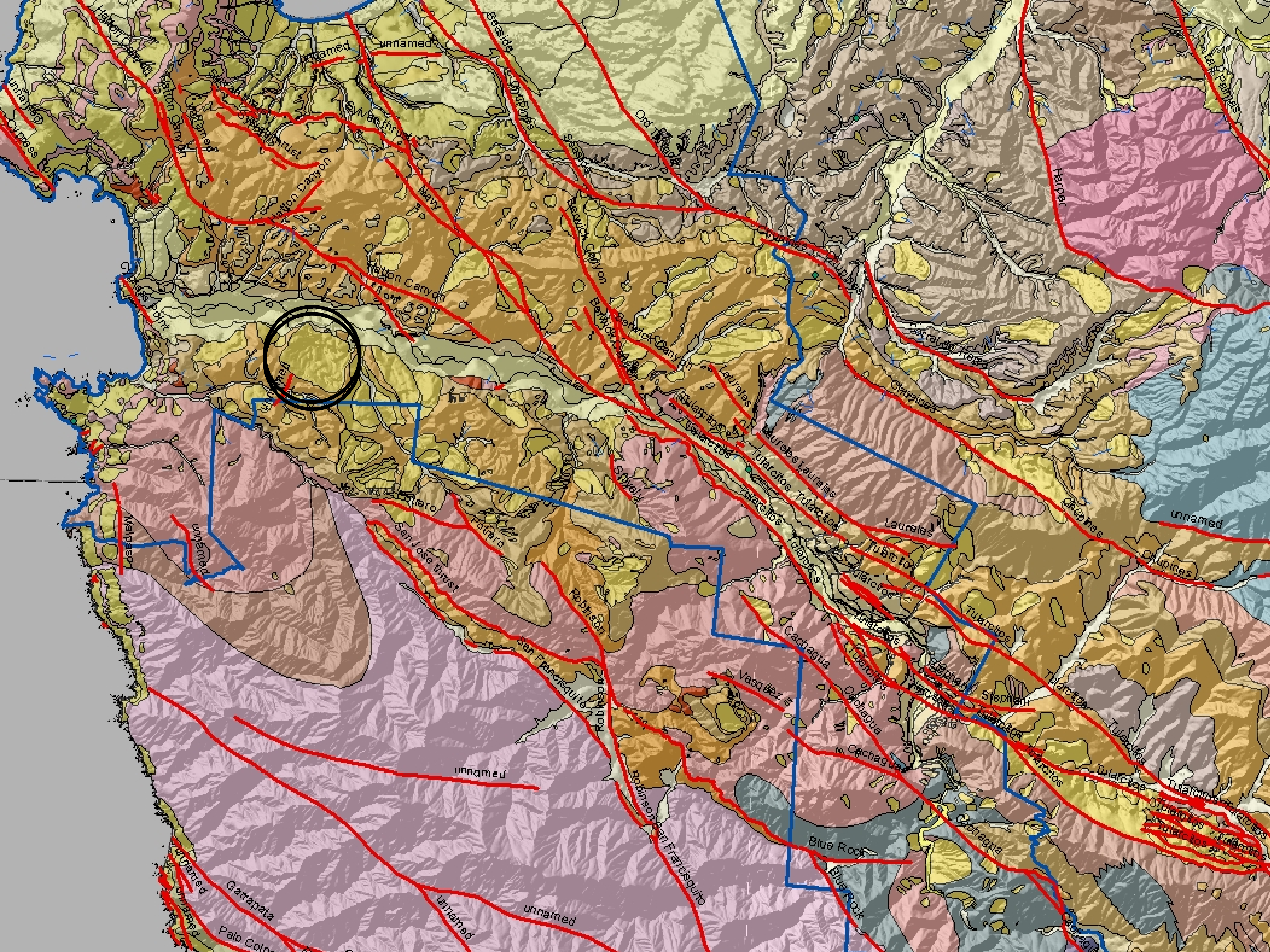
MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

The terrace above the valley floor on which Quail Meadows is located was formed by a large translational landslide that occurred 30,000 Years ago.

Wells in this region are screened in the Monterey Shale and exhibit high DWR Drawdown Ratios.

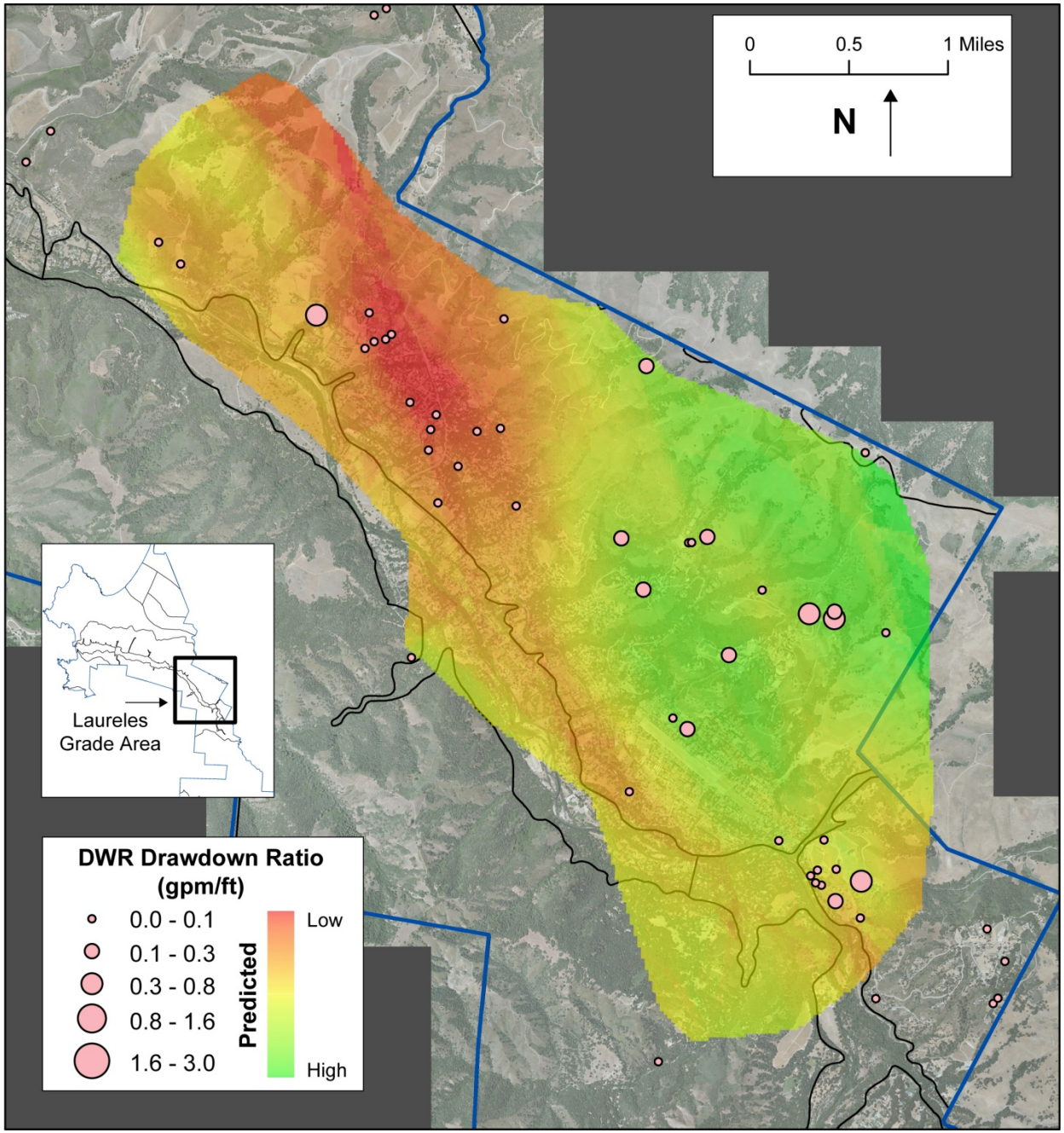


MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

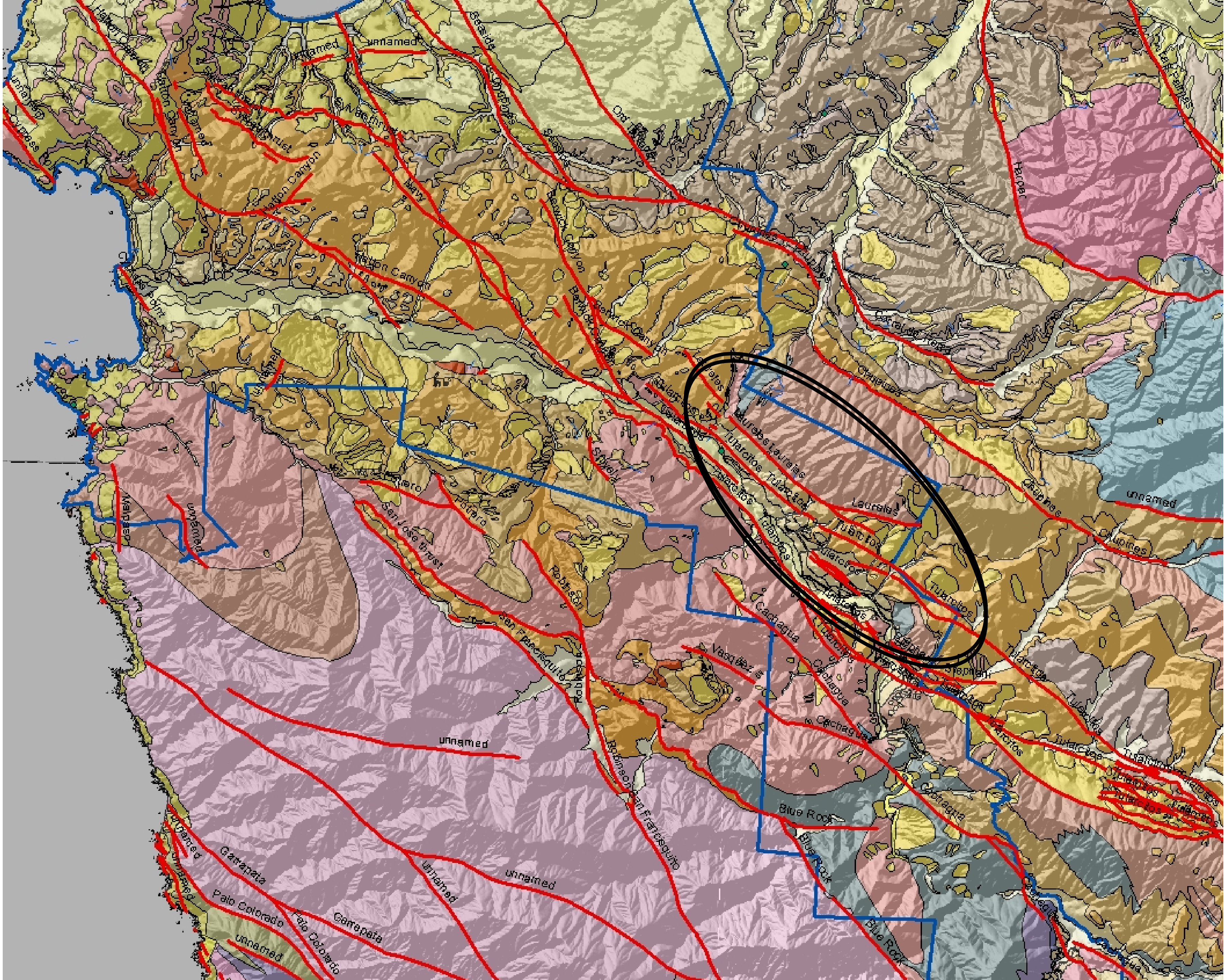

unnamed
Harper
Chupines
Laureles
Tularcitos
Cachagua
Vasquez
Blue Rock
Robinson
San Francisquito
San Jose thrust

Laureles Grade Transition Zone is formed as the Laureles and Turlacitos Fault Zones juxtapose the Granitic Basement against the Monterey Shale and overlying River Terrace near Carmel Valley Village.

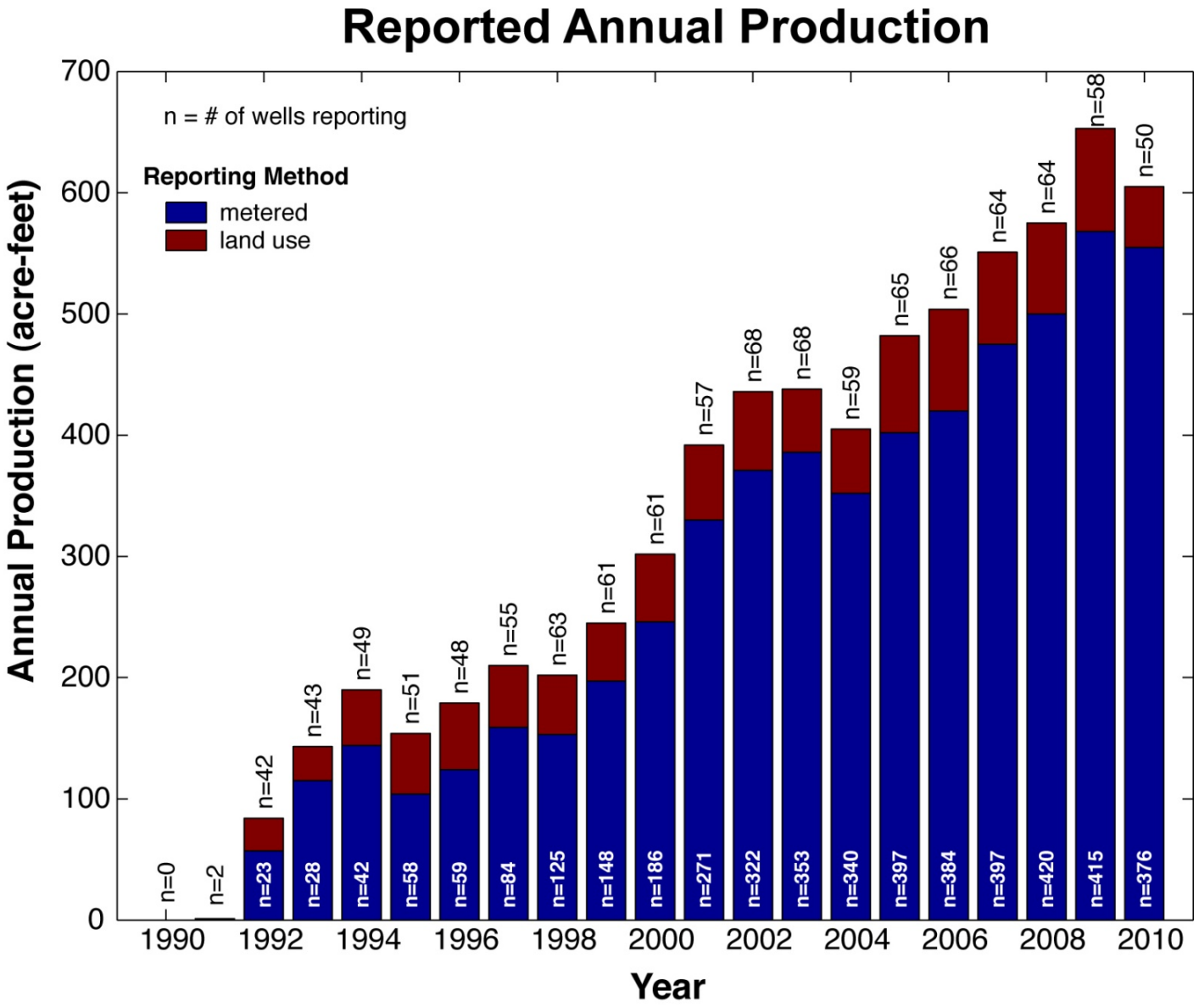
Wells screened in the Granitic Basement do not exhibit as high a DWR Drawdown Ratio as wells screened in the Monterey Shale or the River Terrace.



Monterey Peninsula Water Management District


unnamed
Harper
Chupines
Laureles
Tularcitos
Cachagua
Vasquez
San Jose Thrust
San Francisquito
Blue Rock
Garrapata
Palo Colorado
Robinson
Navy

Reported production includes all source areas designated as fractured rock source areas within MPWMD boundaries.



MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

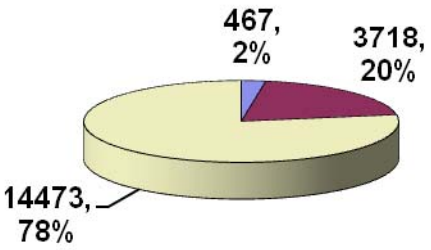
Production Breakdown by Water Year

Cal-Am

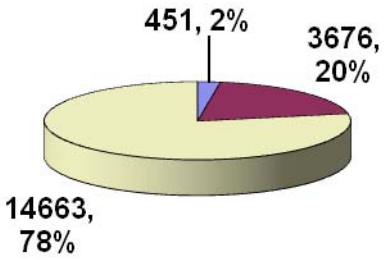
Private Fractured Rock

Private Non Fractured Rock

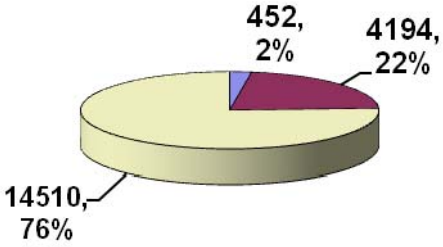
WY 2005



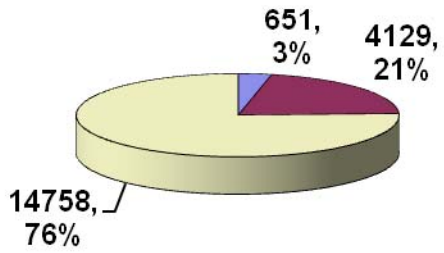
WY 2006



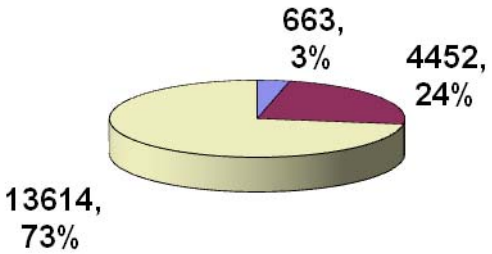
WY 2007



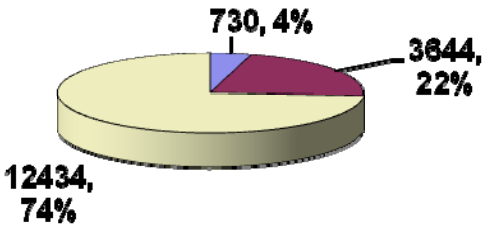
WY 2008



WY 2009



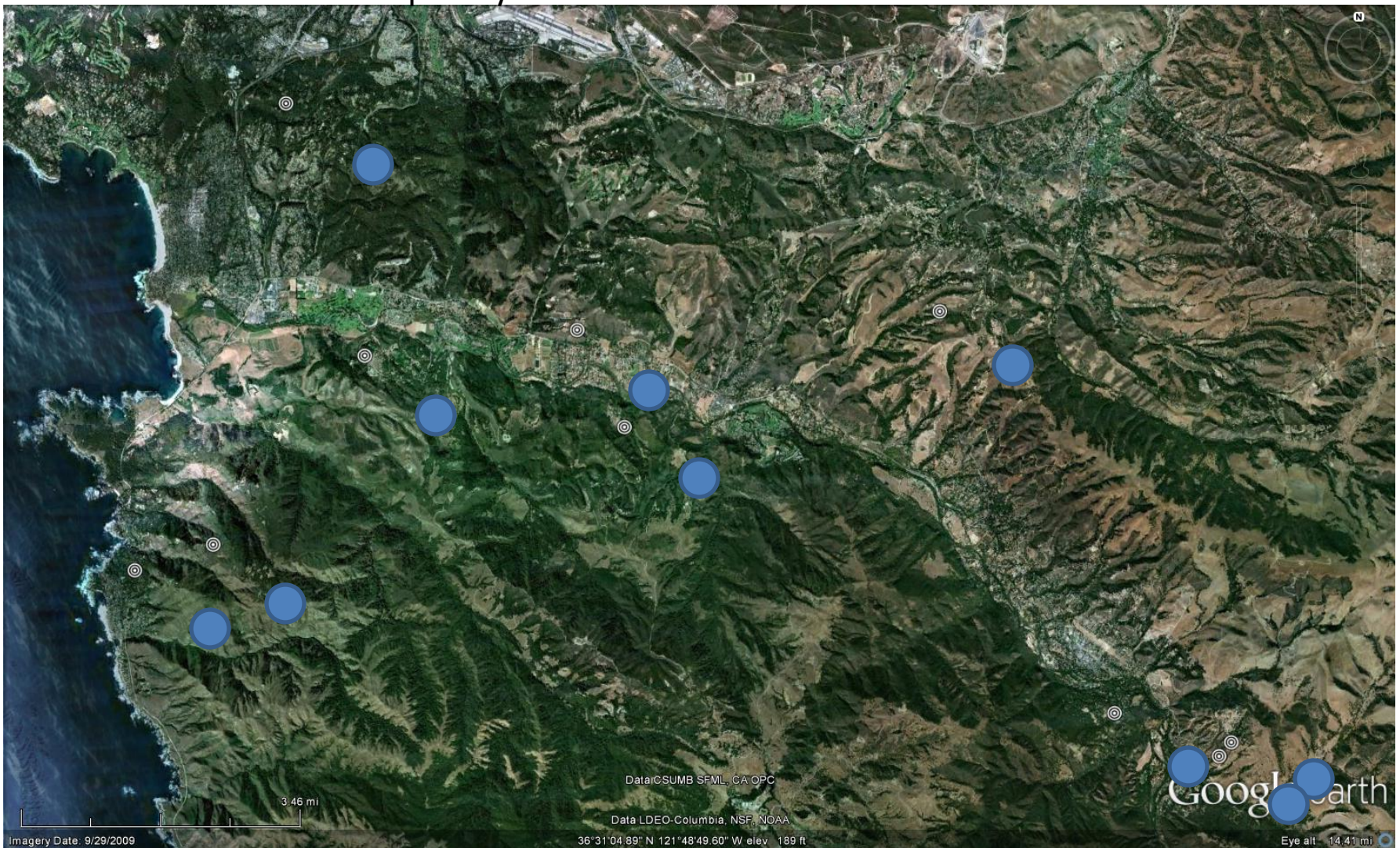
WY 2010



MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

Groundwater Level Monitoring

MPWMD staff have purchased and deployed six continuous water level loggers in fractured rock source areas beginning in January 2011. Monitoring locations have moved as staff adaptively monitors fractured rock wells.



Fractured Rock Monitoring Well Adaptive Monitoring Decision Process

Deploy Data Logger

Leave in well for 6 months

Are pumping influences from other wells present in the data

Yes

No recharge

Remove and re-deploy in new location

recharge

Leave in well for multiple seasons

No

Leave in well and watch for recharge

recharge

Leave in well for multiple seasons

No recharge

Is well Active

No

Remove and re-deploy in new location

Yes

Leave in well for multiple seasons

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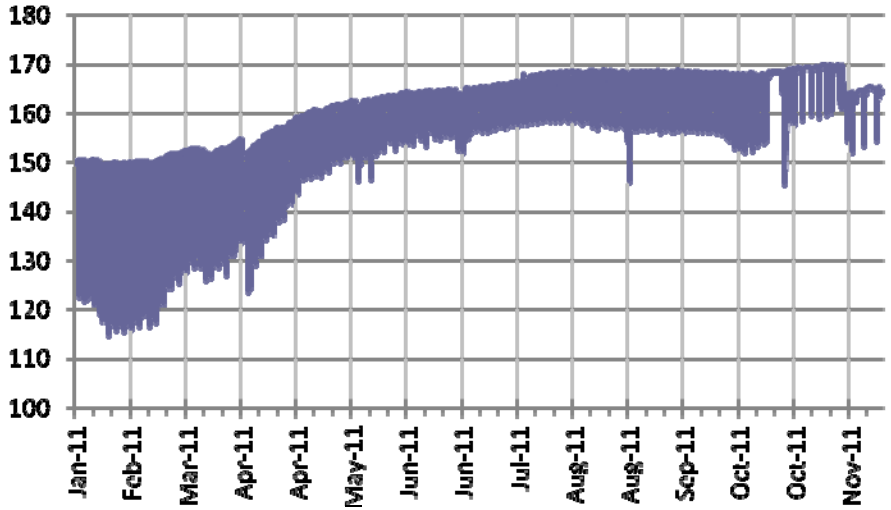
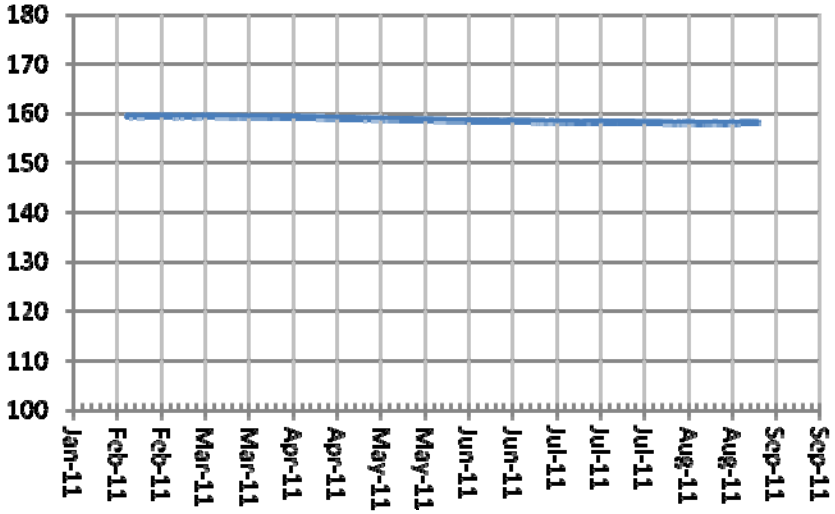
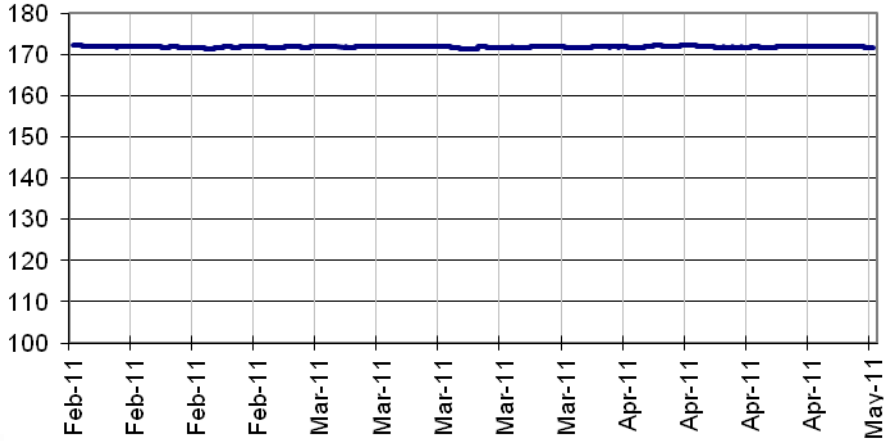
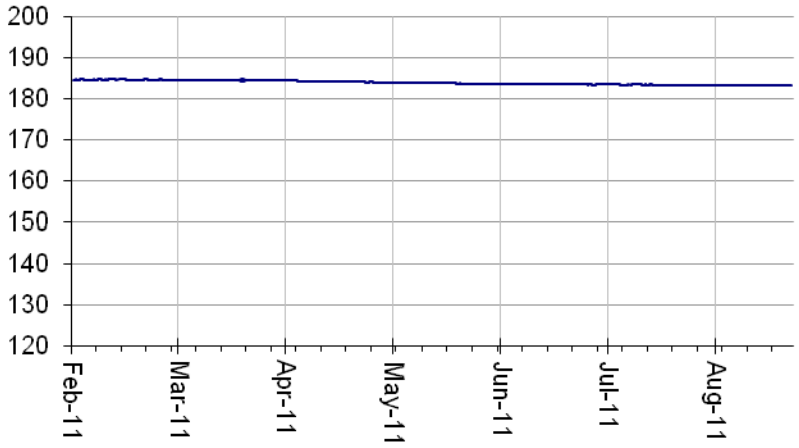
Hydrographs from Selected Monitor Wells









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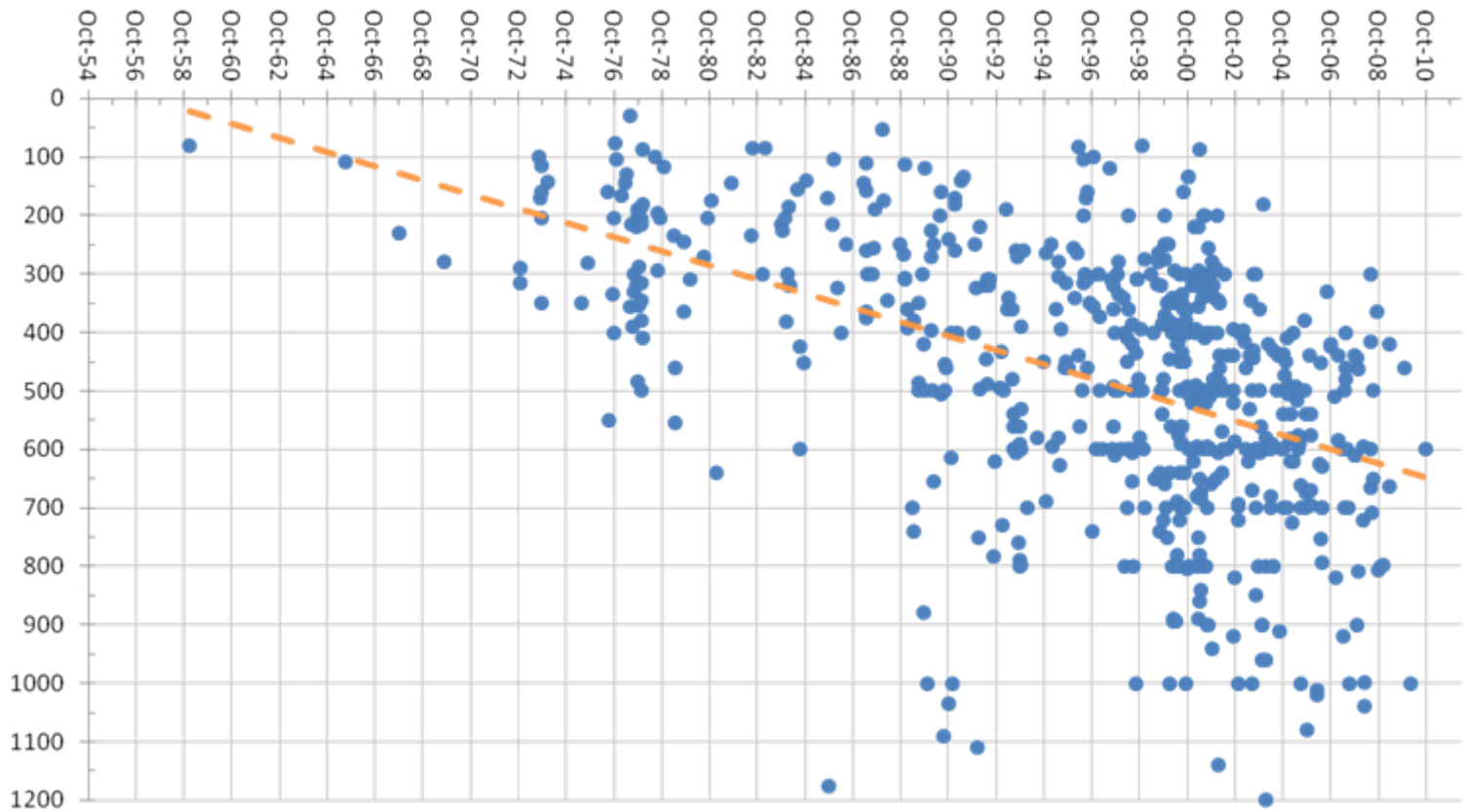
These are short term water level records that give us focused information on response of aquifer to pumping and recharge. Are there any long term trends available in the District's well files?

Depth of well by Drill Date



On average, depths wells completed have increased since 1960. This trend could represent declining water levels, but could also be influenced by advancements in drill technology making deeper wells more affordable.

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Conclusions

- Findings of Pilot Study were validated for District Scale Study.
  - Monterey Shale exhibits higher DWR Drawdown values than the Granitic Basement.
- More water level data is necessary to understand sustainability of fractured rock wells.
- Additional ongoing data collection is needed to help define and focus on areas of special concern.
- WDS process will provide more data regarding replacement of inadequate wells moving forward.

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Recommendations

- Continue to add to database;
  - DWR drawdown
  - WDS pump test data
  - Lithology/Hydrogeologic Framework
  - Production
- Continue to use predicted DWR Drawdown to refine the understanding of geologic control of well performance.
- Continue to collect water level data and adaptively monitor fractured rock wells;
  - Help with understanding of sphere of influence/recharge zones for wells for differing materials.
- Complete a larger scale broadcast water level monitoring effort.
  - Identify on a regional scale if water levels have fallen since wells were drilled.
- Amend WDS rules to include water level data collection as a component of the process for fractured wells.
- Commence effort to understand recharge to fractured rock aquifers.

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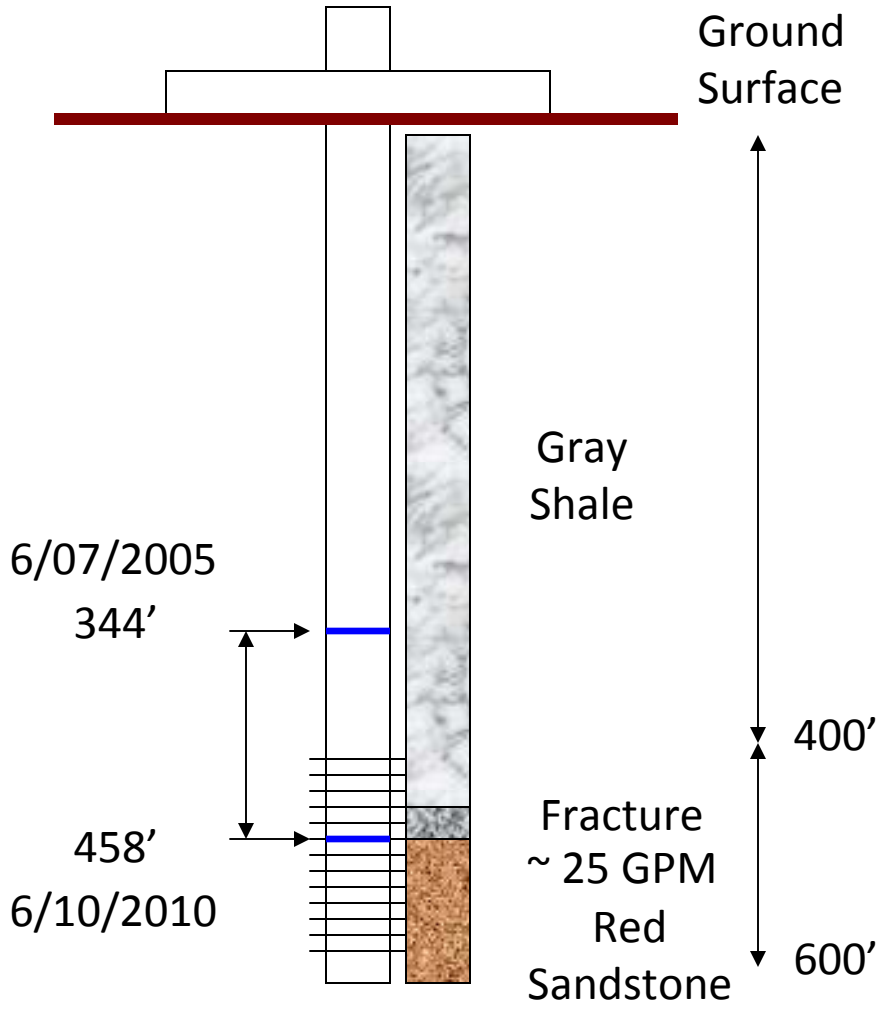
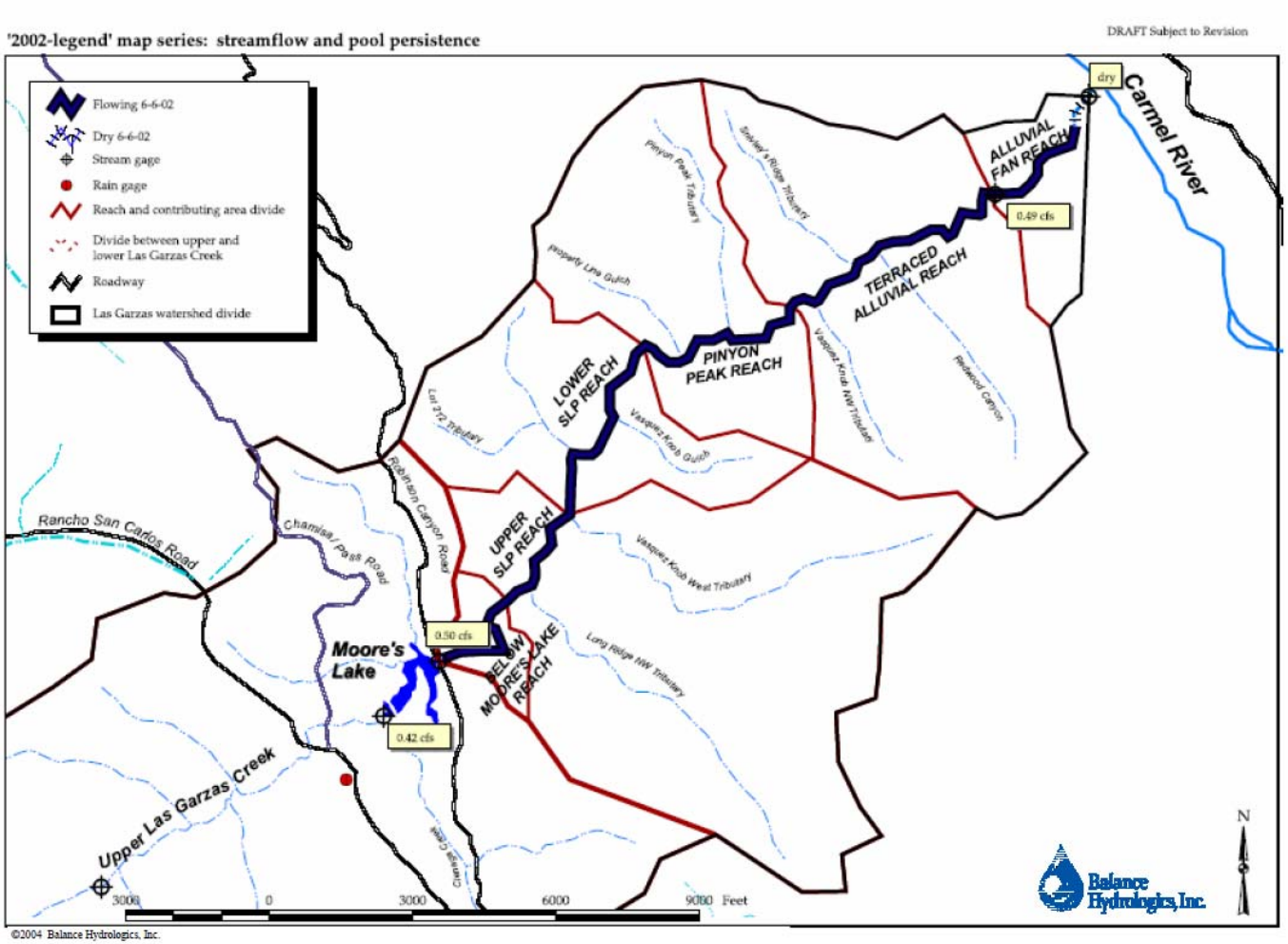
Example of WDS Process and Replacement Well Data Generation



Data from Monitor well

- Drilled as Production well in 6/2005
- 72 hour pump test completed as requirement for WDS permit.
- Well produced 6.2 GPM over the test and pumping water level was 19 feet below static.
- An observation well 550 feet from the pumping well was monitored and considered to be hydrogeologically disconnected from the pumping well.
- In June 2005 static water level was 344 feet BGS compared to June 2010 when static water level was measured to be 459 feet BGS.
- A total of 4.5 acre-feet was produced from the well between 2005 and 2010.
- A replacement well has been drilled 500 feet from the monitoring well and is not hydrogeologically connected to the monitor well.

Understanding Recharge to Fractured Rock Systems by Indirect Methods



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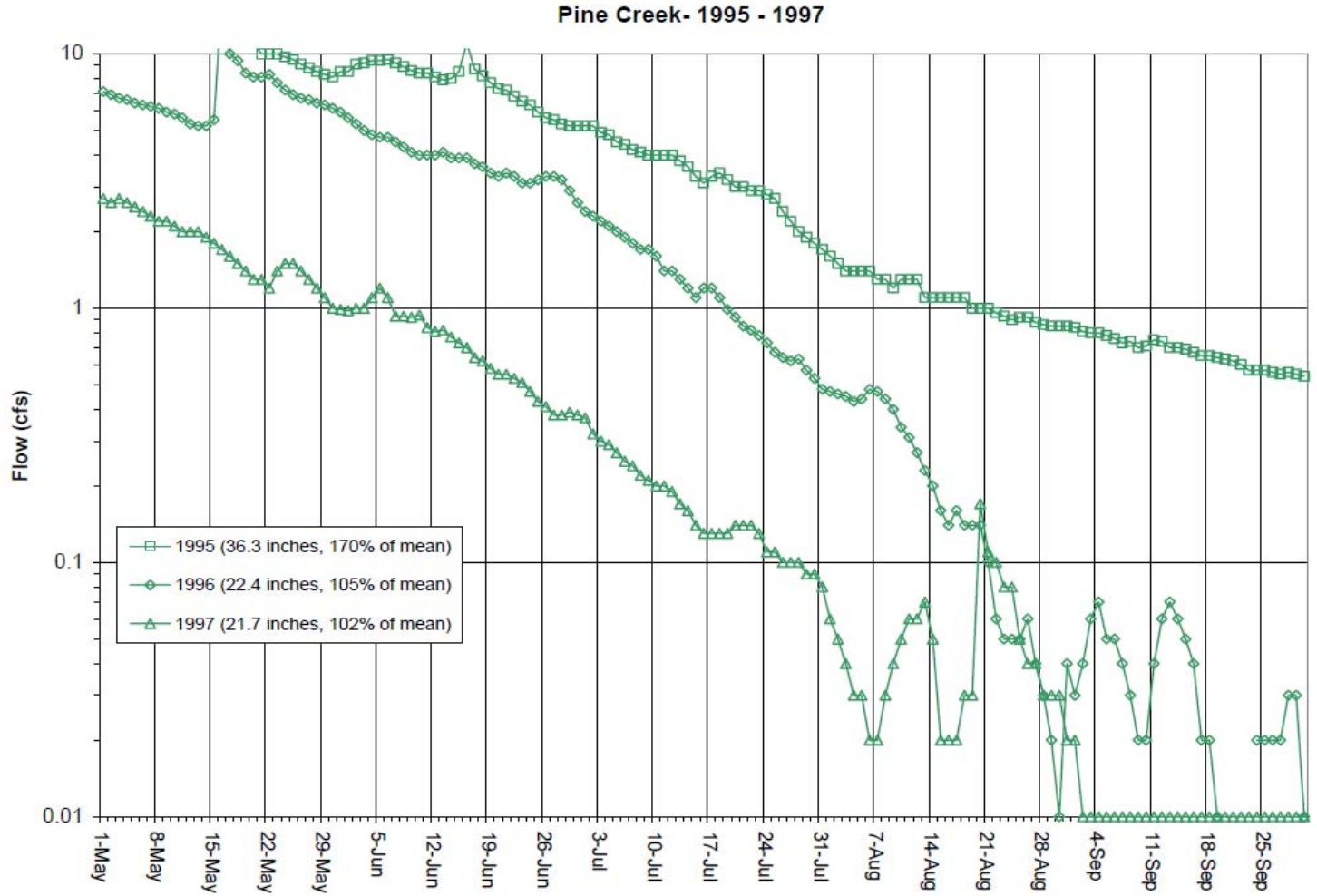
Analysis of Baseflow Hydrographs



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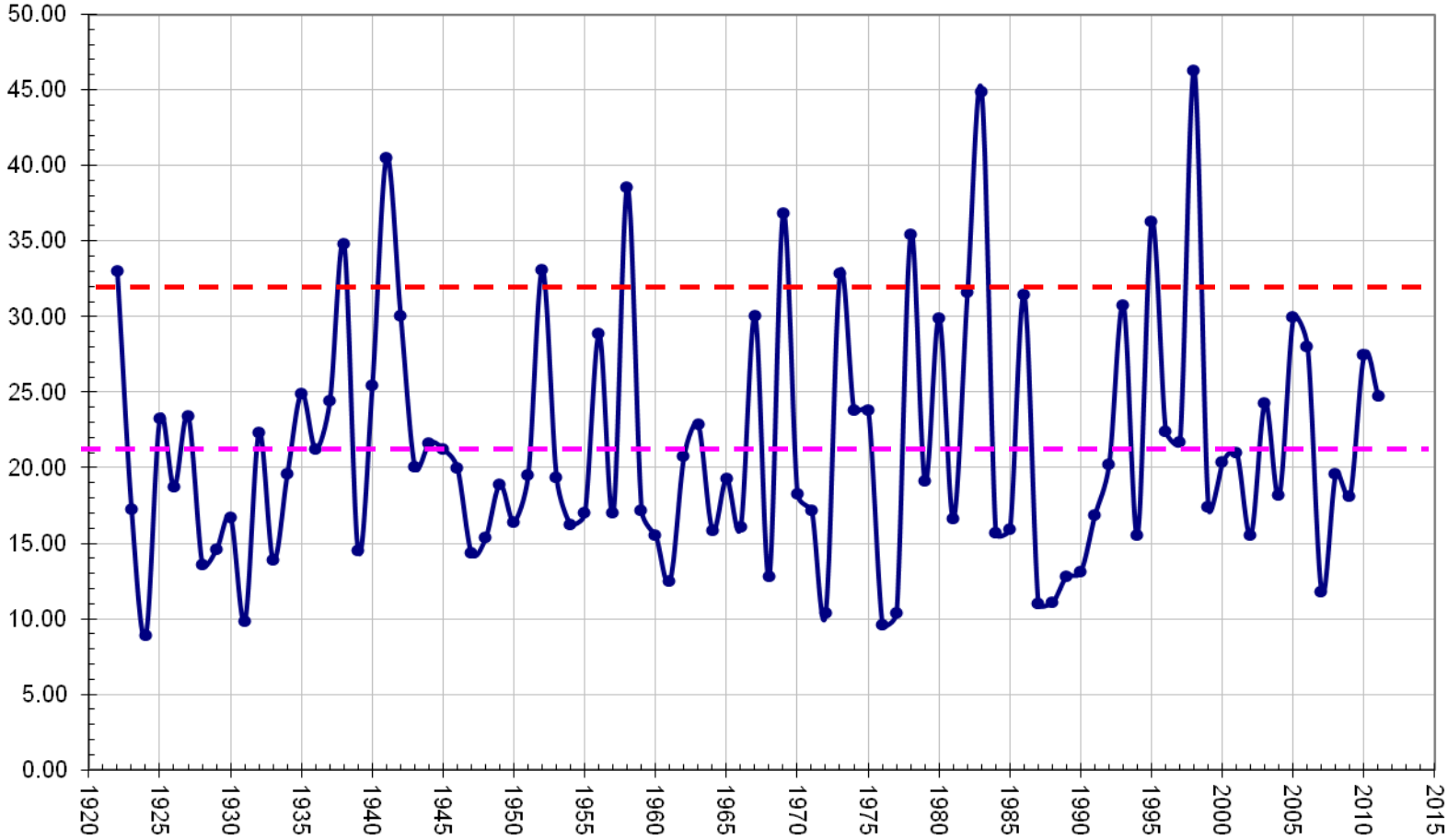
Threshold for Water Years Providing Baseflow to Pine Creek



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