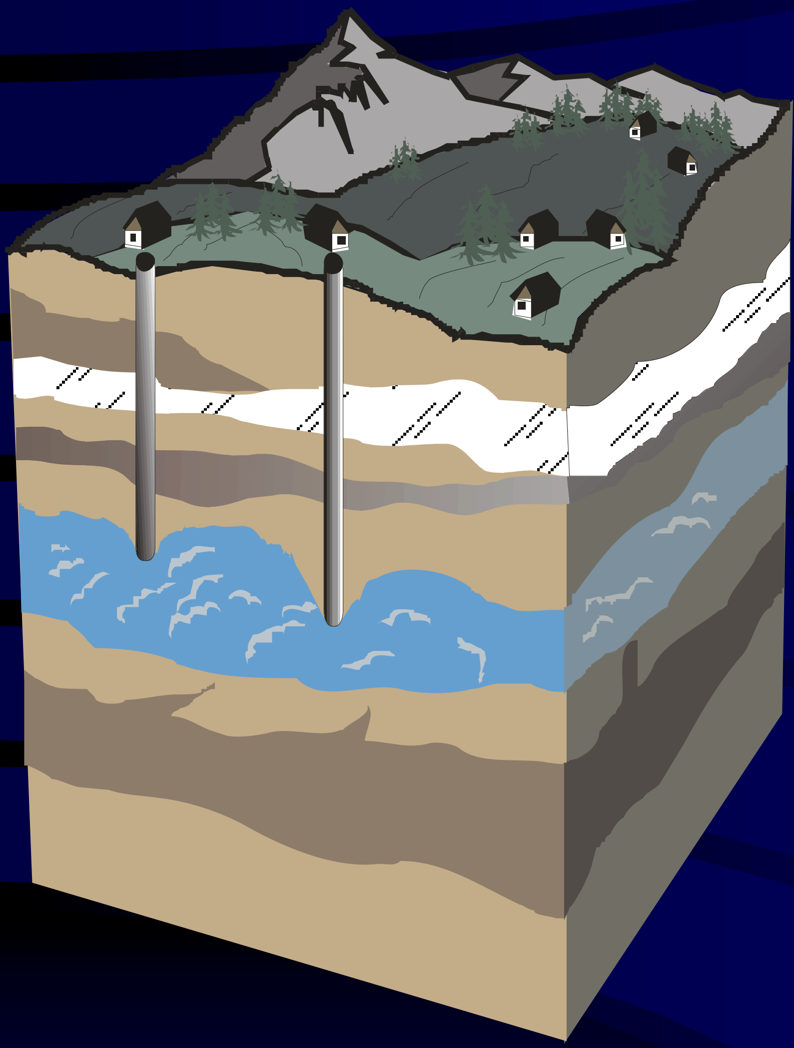

Local Wellhead and Aquifer Protection Study
Phase II

Municipality of Anchorage
Dept. of Health and Human Services
Environmental Services Division

MONTGOMERY WATSON

in association with GEONORTH GIS • DATABASE • CAD

Acknowledgments

- Municipality of Anchorage
  - Department of Health and Human Services
  - Anchorage Water and Wastewater Utility
- Steering Committee
  - Jim Cross, DHHS
  - Dr. Bruce Chandler, DHHS
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  - Sharon Minsch, On-Site W/W Tech Ad Bd.
  - Dr. Craig Woolard, On-Site W/W Tech Ad Bd.
  - Gordon Nelson, USGS

Project Team

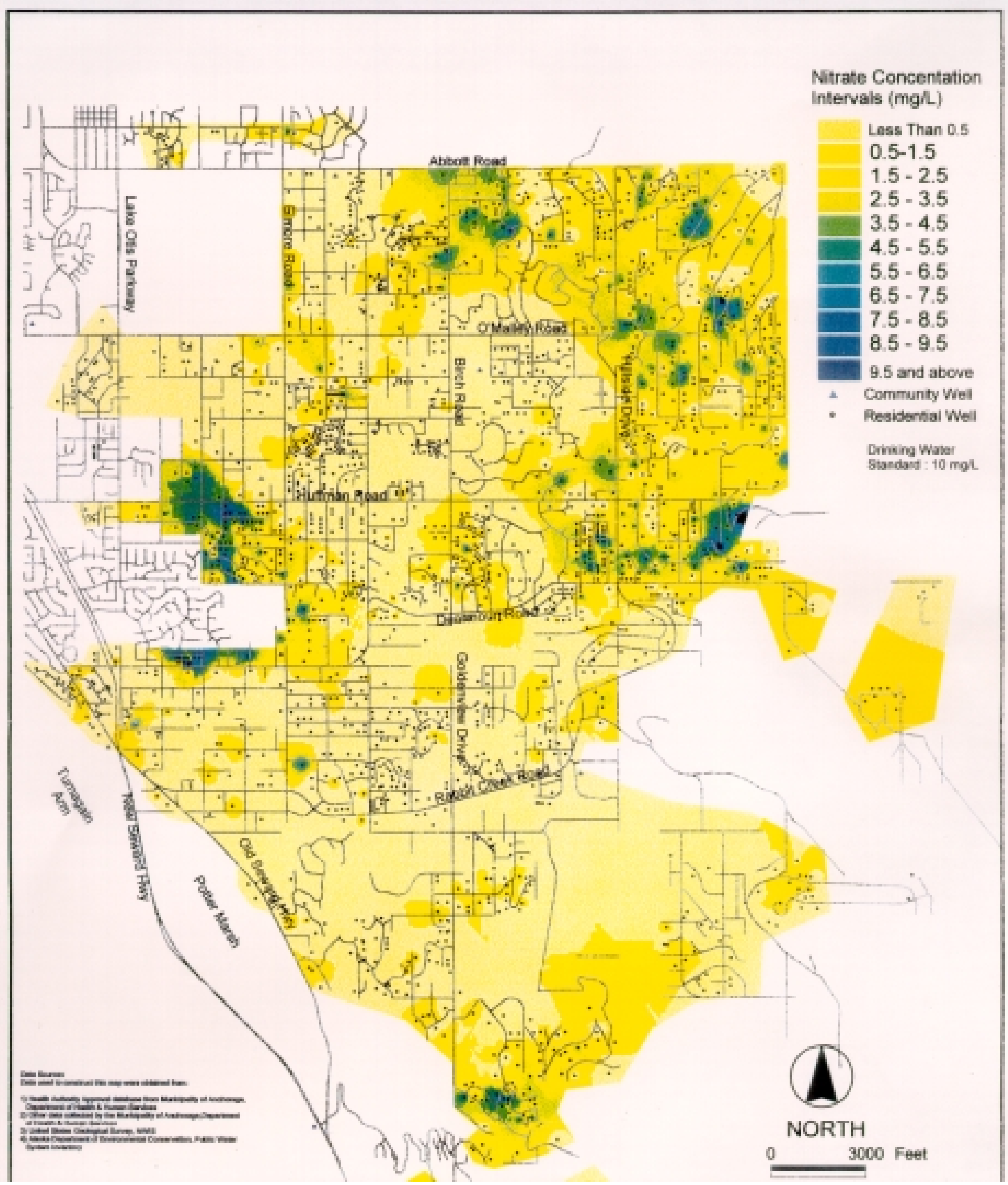
- Montgomery Watson
  - Bill Rice
  - Greta Myerchin
  - Larry Gall
  - Lida Fialova
  - Eric Gropp
  - Mel Langdon, P.E.
  - Victor Harris
  - Dana Stewart
  - Brett Jokela
- GeoNorth
  - Mark Pearson
  - Greg Daniels
- US Geological Survey
  - Dr. Bronwen Wang
  - Pat Strelakos
- Anchorage DHHS
  - Jeff Poet
- Arctic Pump & Well Service
  - Jim Sullivan

Study Background

- Over 14,000 lots have on-site water supply and/or wastewater disposal in Anchorage
- Development pressure is increasing on the margins of the city.
- Nitrate contamination has implications for public health:
  - methemoglobinemia
  - mobile precursor/indicator of sewage-borne pathogens

Findings from Phase I

- Nitrate occurrences concentrated in certain areas of the Hillside.
- Very few violations of WQ Stds. apparent.
- Limited time series of data available- Unable to discern long term trends.
- Lot size not necessarily the key to projecting nitrate occurrence.


Nitrate Concentation Intervals (mg/L)
Less Than 0.5
0.5-1.5
1.5 - 2.5
2.5 - 3.5
3.5 - 4.5
4.5 - 5.5
5.5 - 6.5
6.5 - 7.5
7.5 - 8.5
8.5 - 9.5
9.5 and above
Community Well
Residential Well
Drinking Water Standard : 10 mg/L
Abbott Road
O'Malley Road
Lake Otis Parkway
Elmore Road
Birch Road
Hillside Drive
Huffman Road
DeArmoun Road
Goldenview Drive
Rabbit Creek Road
Turnagain Arm
New Seward Hwy
Old Seward Hwy
Potter Marsh
NORTH
0
3000 Feet

Phase II Goals

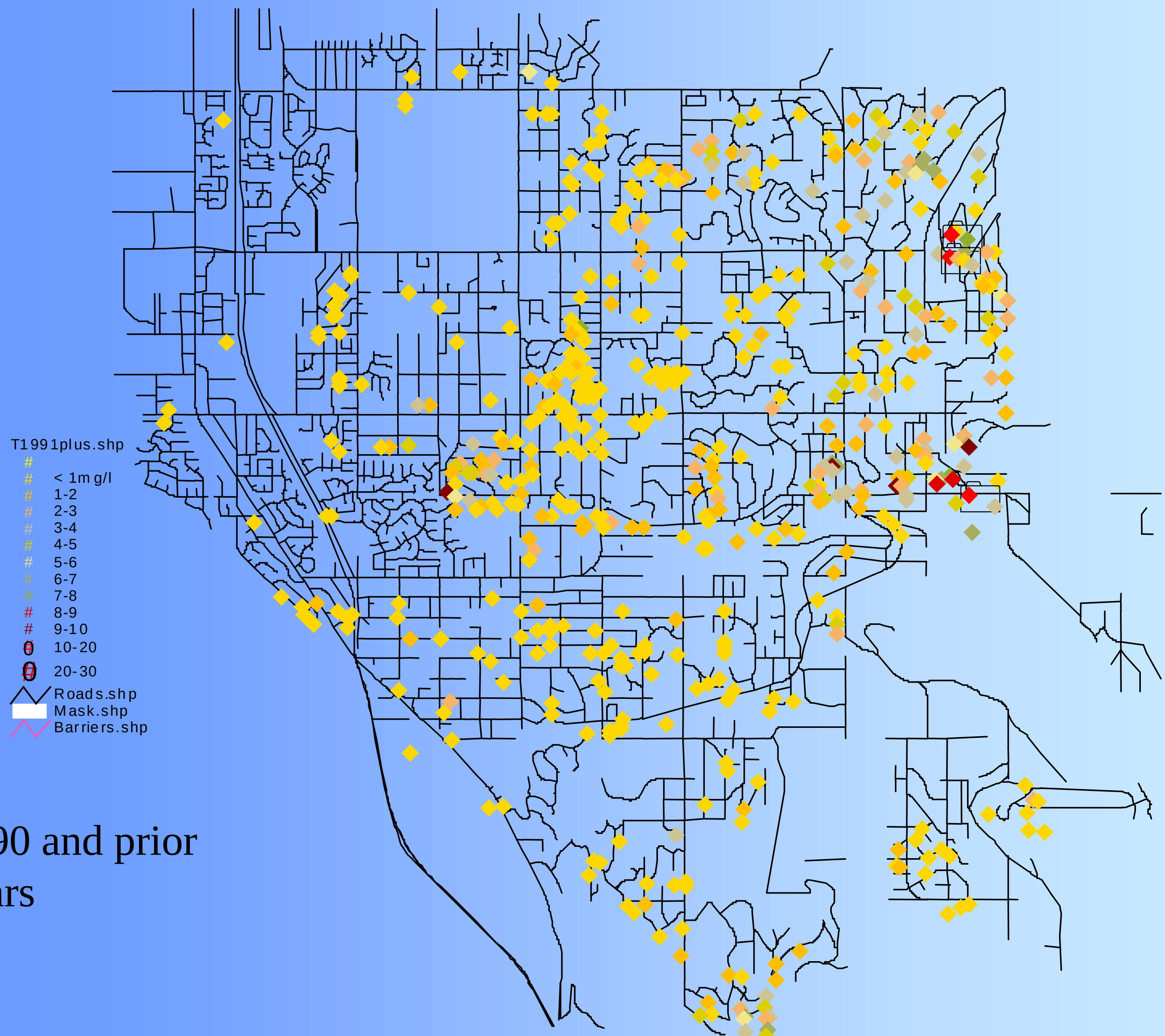
- Map best available data on NO3 occurrence.
- Identify primary factors associated with NO3 occurrence.
- ID and prioritize vulnerable areas of Muni.
- Develop long-term monitoring program.
- Present data and analysis to the public.

Principal data sources

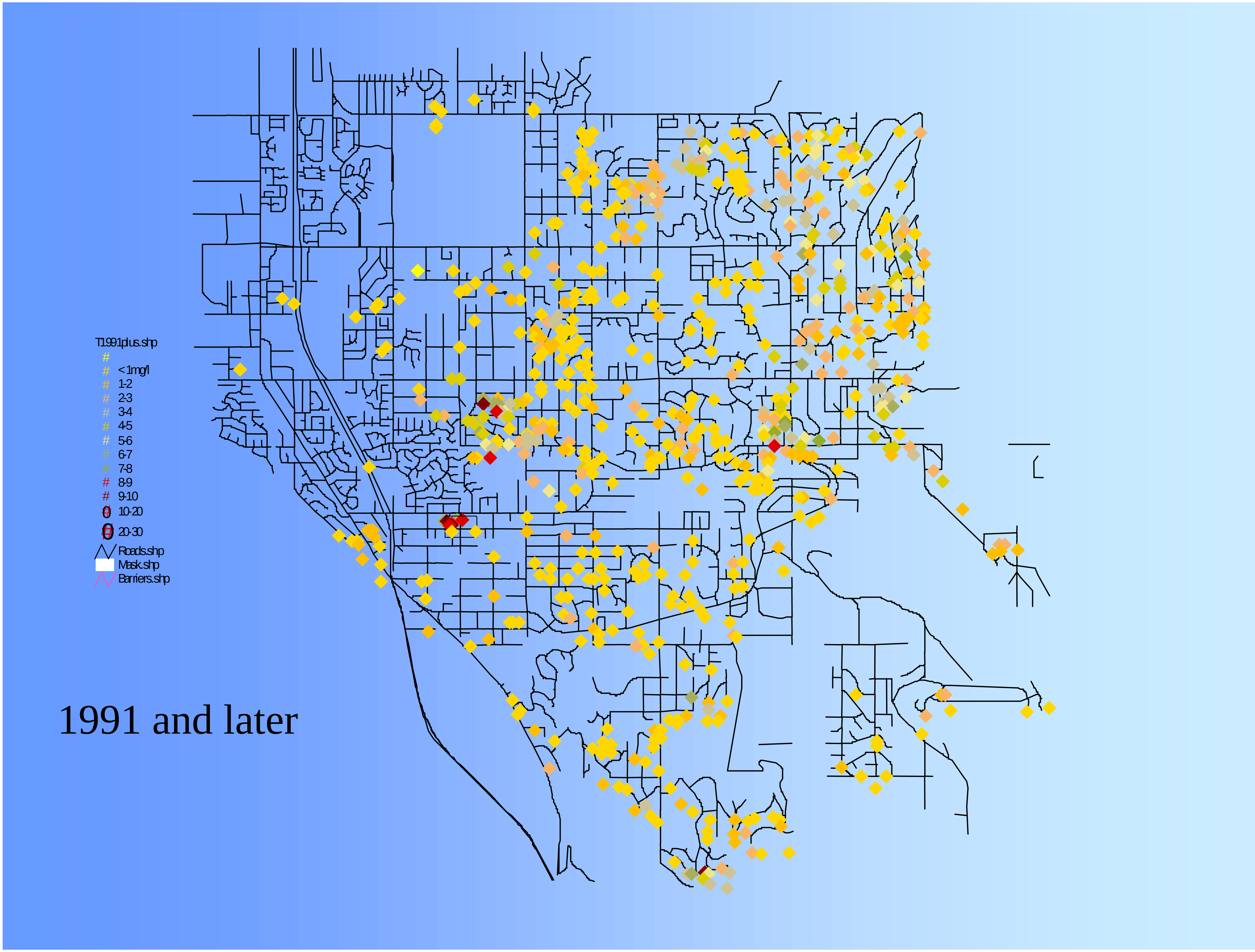
- DHHS HAA database (by GeoNorth)
- DHHS On-Site Wastewater files
- ADEC Nitrate data for Public Water systems
- Hillside Drainage Study maps
- USGS digital elevation models
- MOA GIS & CAMA data

Is nitrate increasing in private wells?

- Nitrate is reported for a private well when a property changes ownership.
- Sampling is irregular.
- Results are censored for values >10mg/L.
  - Seller must obtain Health Authority Approval
  - High nitrate results go unreported
- Trends might be gleaned from wide area mapping

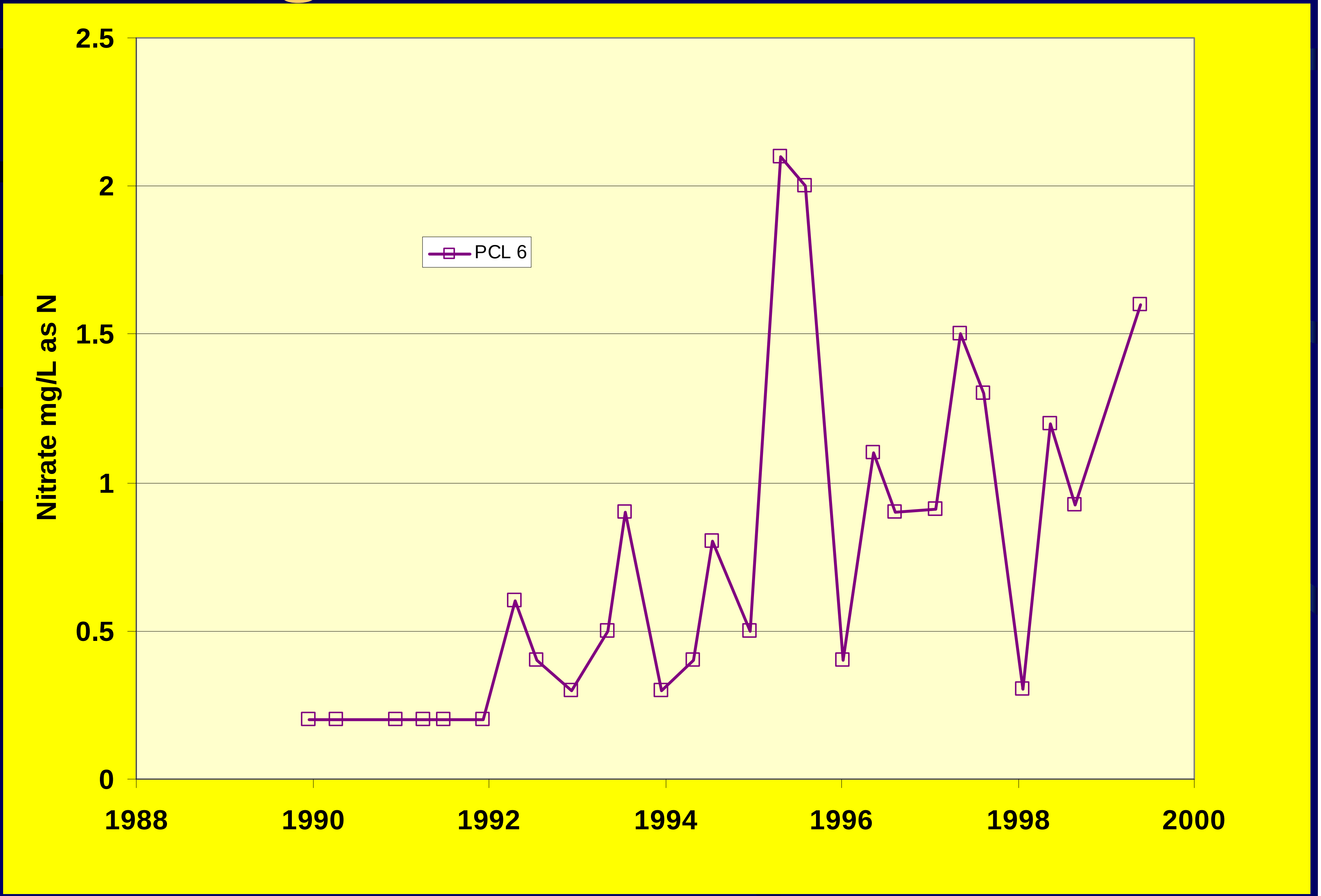


1990 and prior years

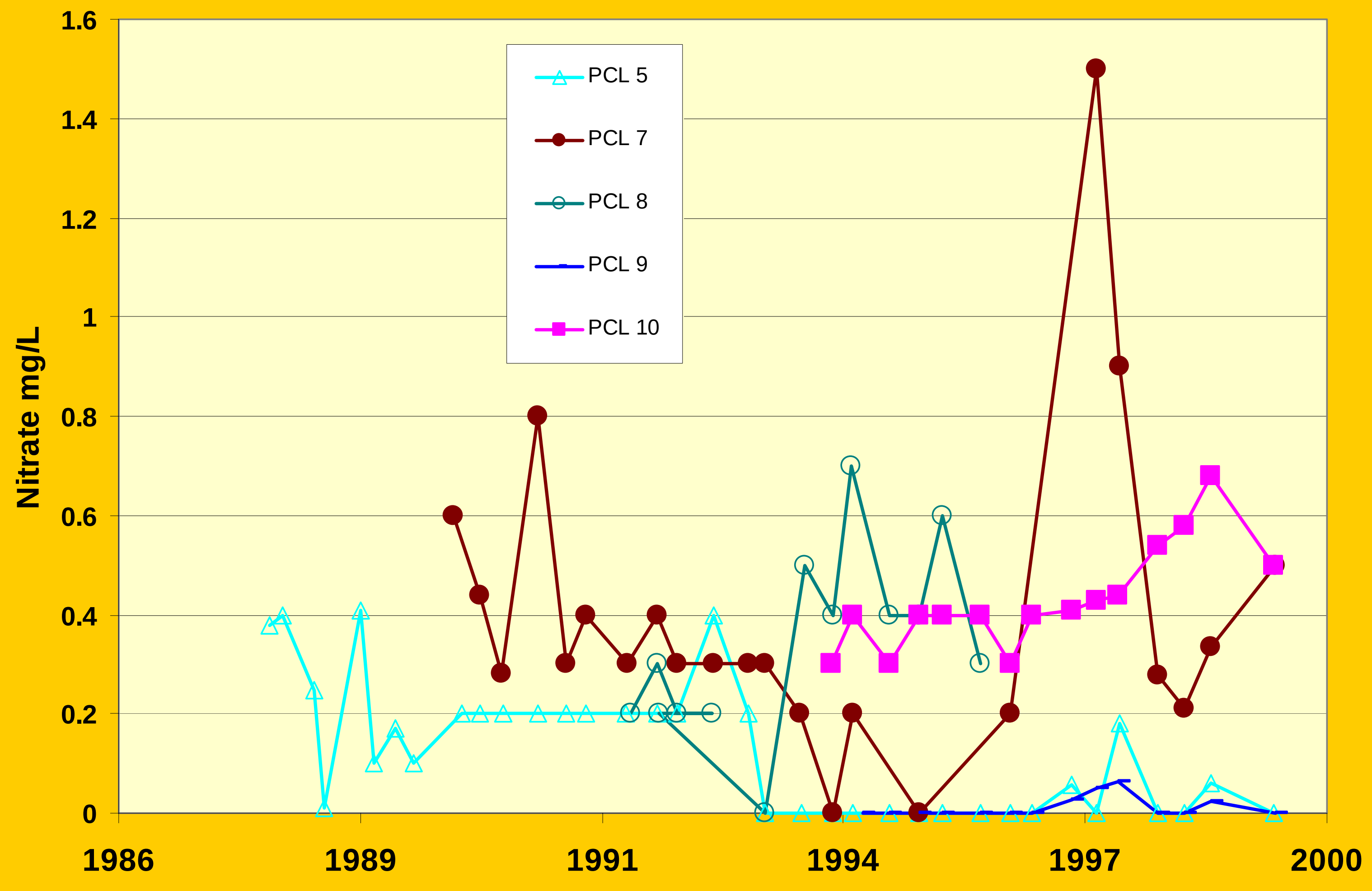


1991 and later

Time series data is available from monitoring at Peters Creek Landfill



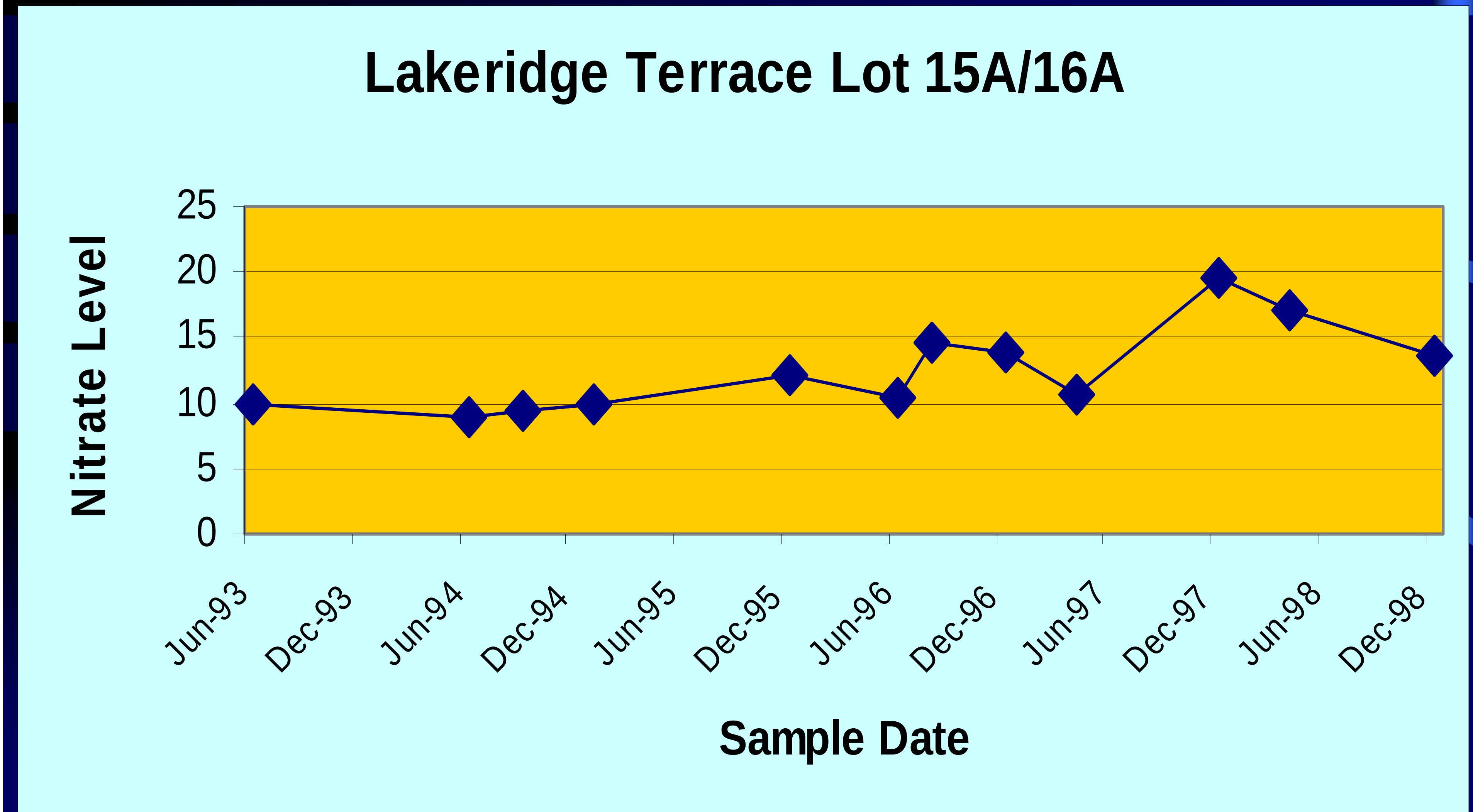
Other landfill wells do not suggest increasing trends in nitrates.



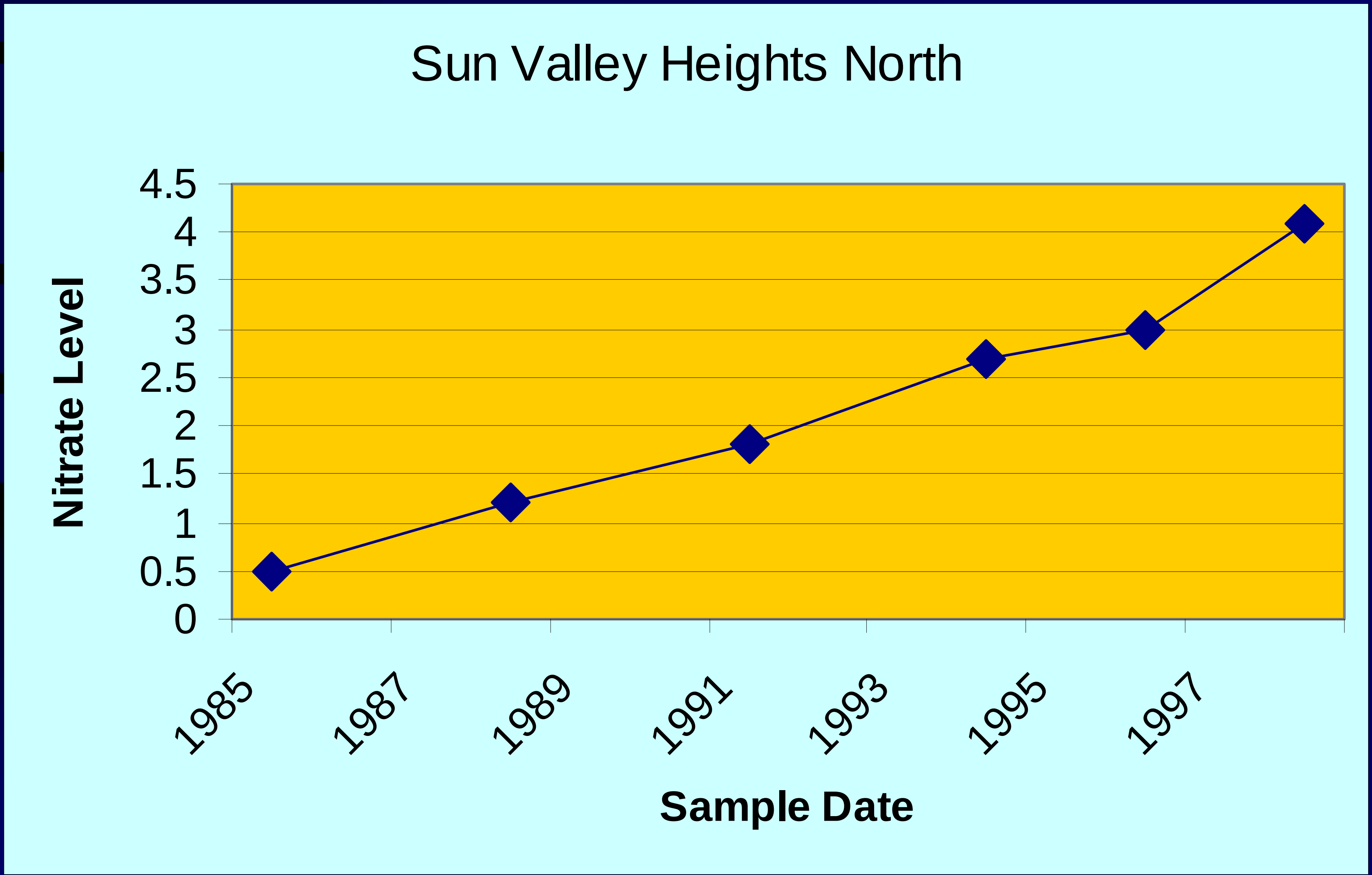
ADEC collects periodic data from public water systems.

- Annual monitoring required for Class A,B, and C systems; More often if NO3>5 mg/L
- Can be used to develop nitrate time series.
- Bias for results <10 mg/L unlikely.

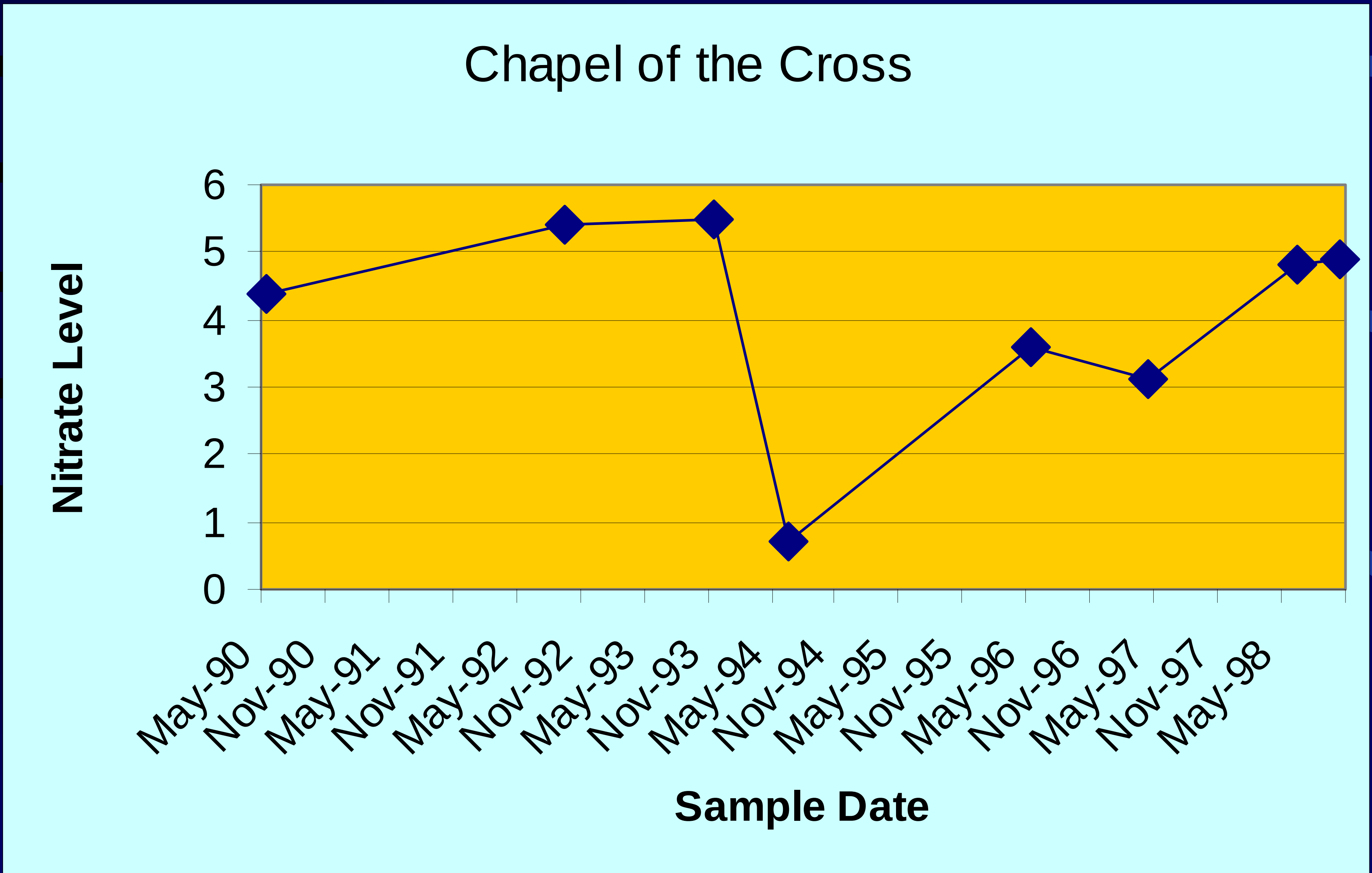
Some public wells regularly exceed drinking water criteria for NO3.



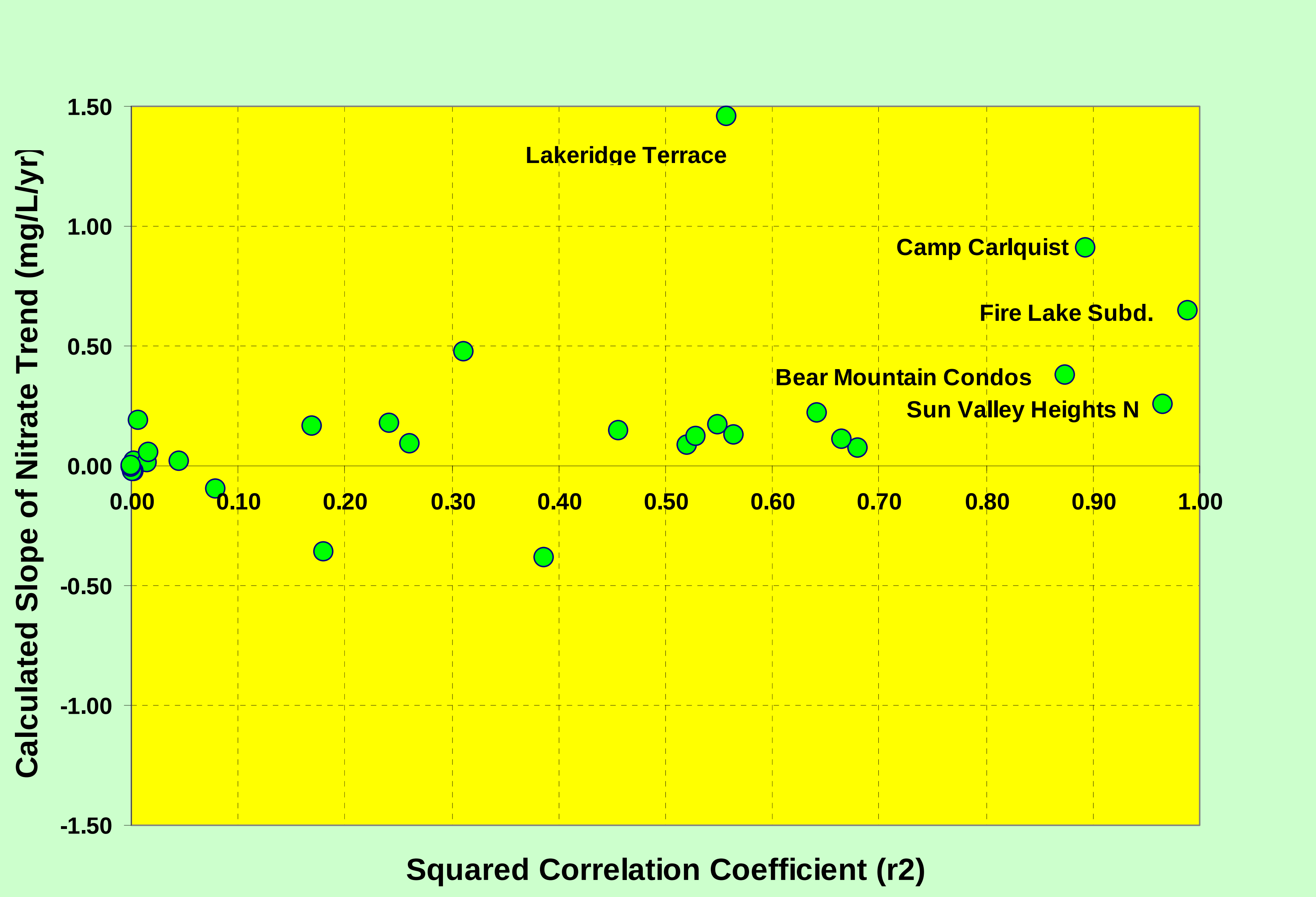
Trends for some wells are unmistakable.



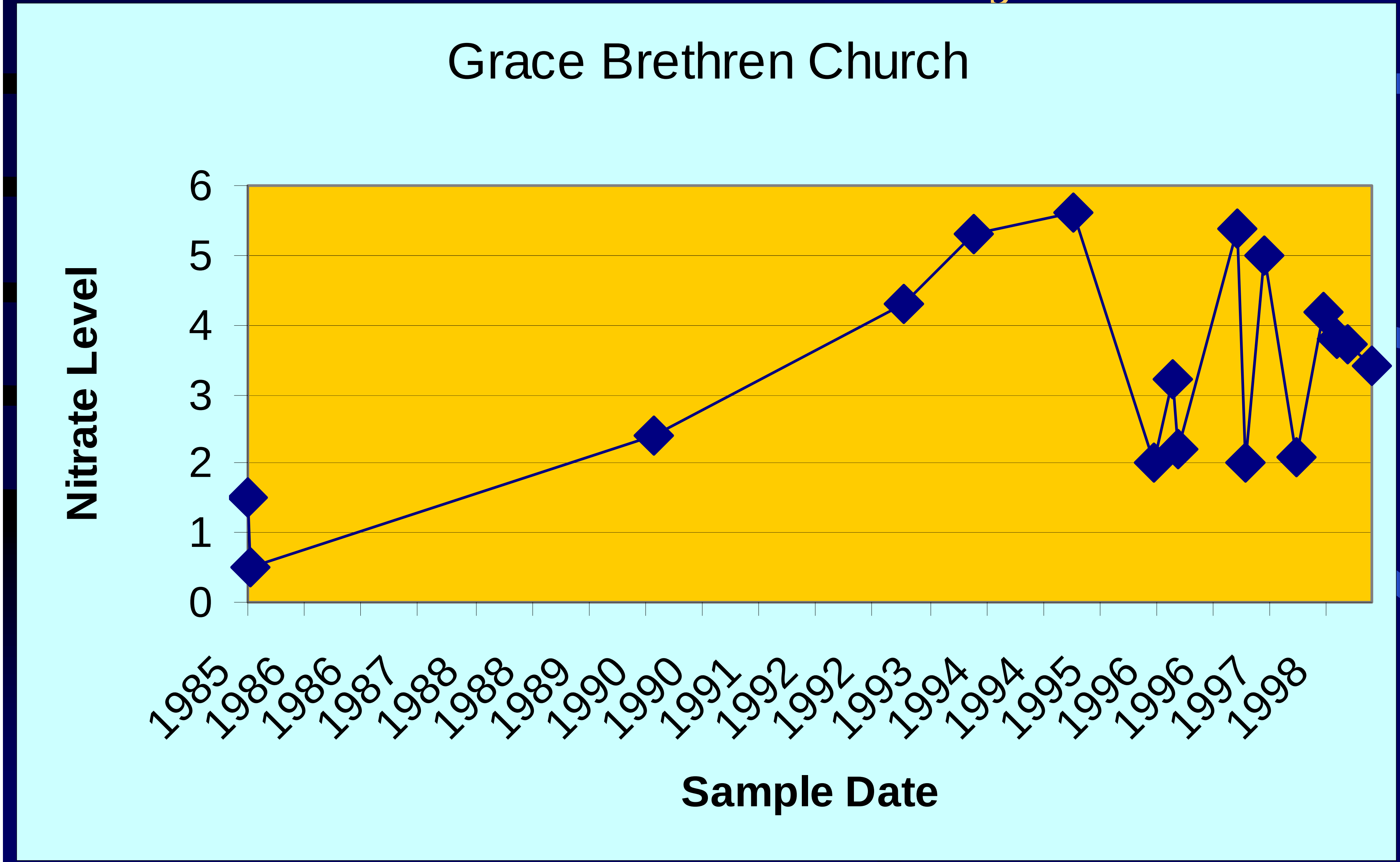
Not all time series are as compelling.



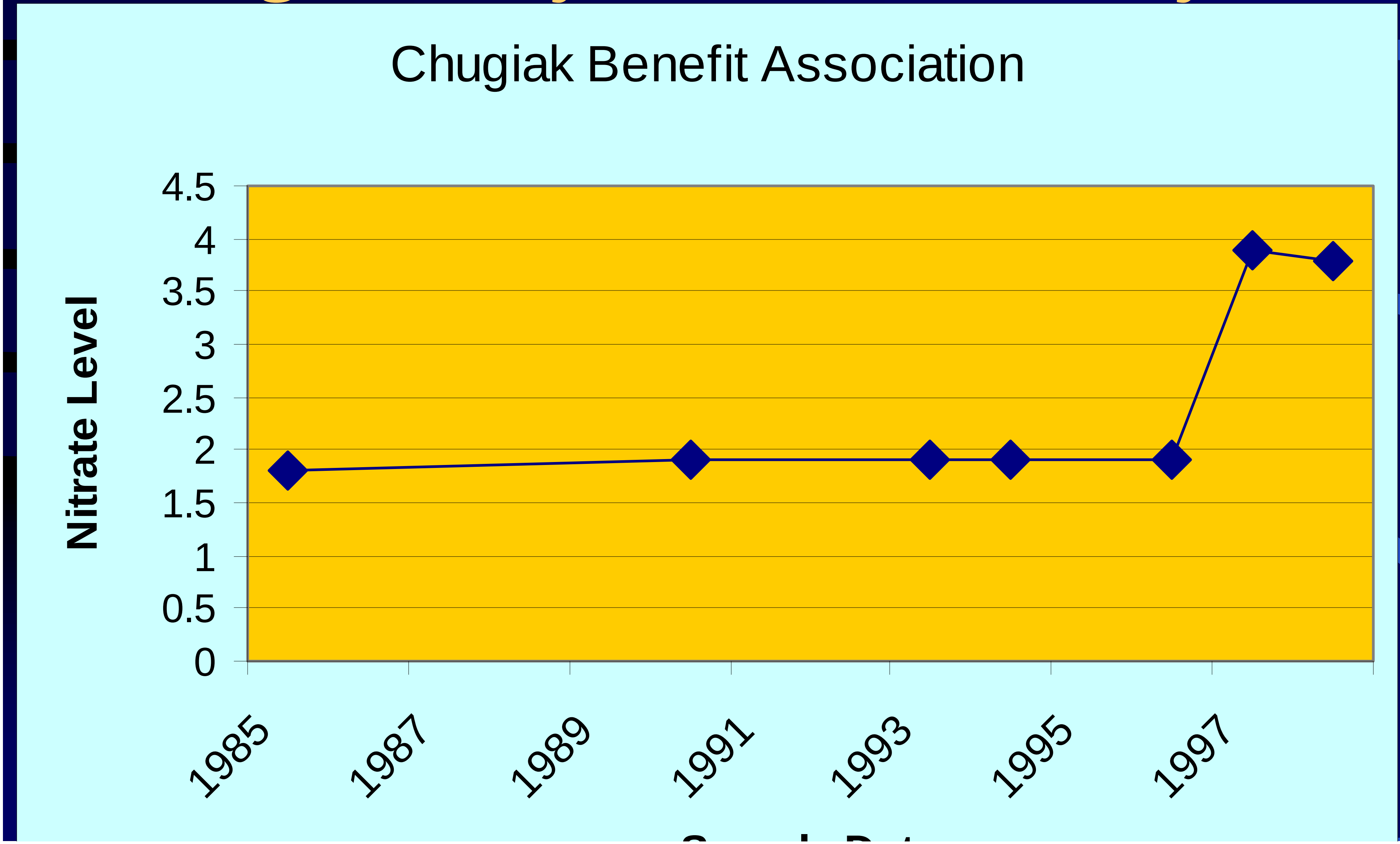
More trends are increasing than decreasing.



Statistical time series trends don't tell the whole story.



Step function increases will not be recognized by linear trend analysis



What factors contribute to nitrate vulnerability?

- Geologic Conditions
- Source Conditions
- Well Construction Conditions

Geologic factors provide the basis for NO_3 mobility

- Soil type/permeability
- Depth to bedrock
- Depth to groundwater
- Slope: Topographic and water table
- Preferential pathways

Well construction may also contribute to NO_3 occurrence

- Depth of well
- Distance to sources
- Screened or perforated interval
- Integrity of casing
- Surface condition

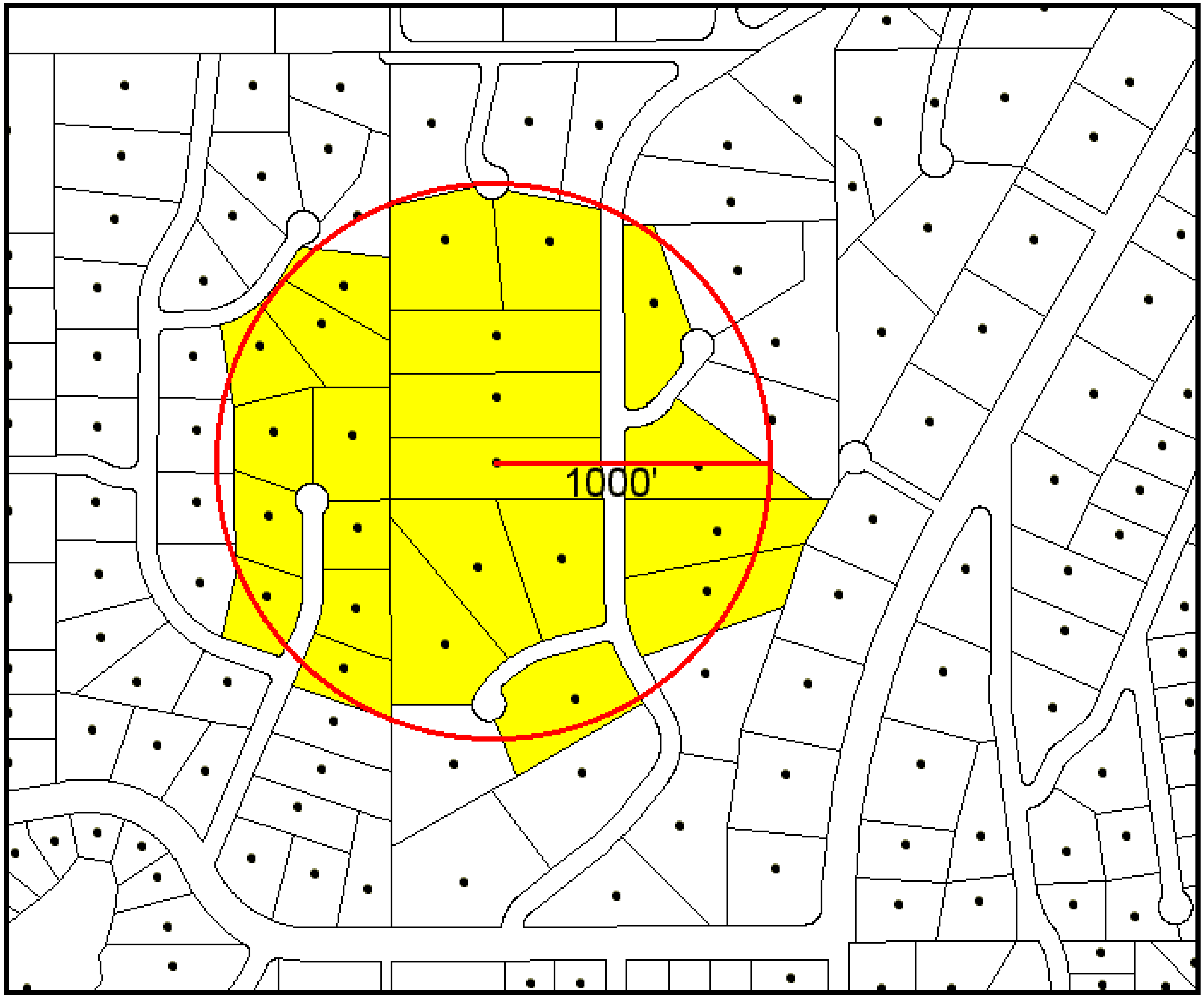
Prospective nitrate source factors may include:

- Dwelling density
- Lot density
- Bedroom density
- Nitrogen-fixing vegetation
- Livestock

Summarize #BR within a given range

Taxid	BedRooms	Well-id
4555112	4	1112
4577121	3	1113
4574461	5	1119
1298981	4	1201
3219884	5	1202
8188131	4	1210
7177234	6	1221
4534411	3	1319
4513871	4	1291
5164124	2	1228

Taxid	1000ft-SumBR	300ft-SumBR
4555112	104	14

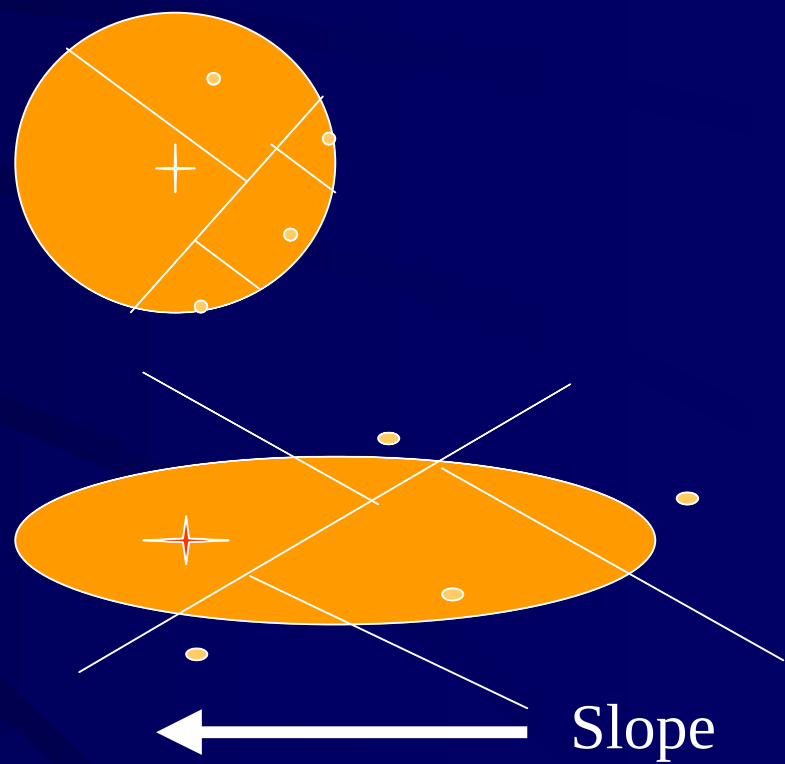


Development Density in Well Zone of Influence

Establish buffer digitally to aggregate data from nearby lots

Circular buffer for flat slopes

Elliptical buffer to capture upgradient influences



Can these factors be combined into a model of vulnerability?

- Use existing data to develop model for the Anchorage Hillside.
- Focus on pilot areas:
  - Dense NO3 representation.
  - Reasonable variation in NO3 values.
  - Existing mapping for geologic interpretation.
- Evaluate potential contributing factors for the pilot area.
- Extrapolate findings to other areas.

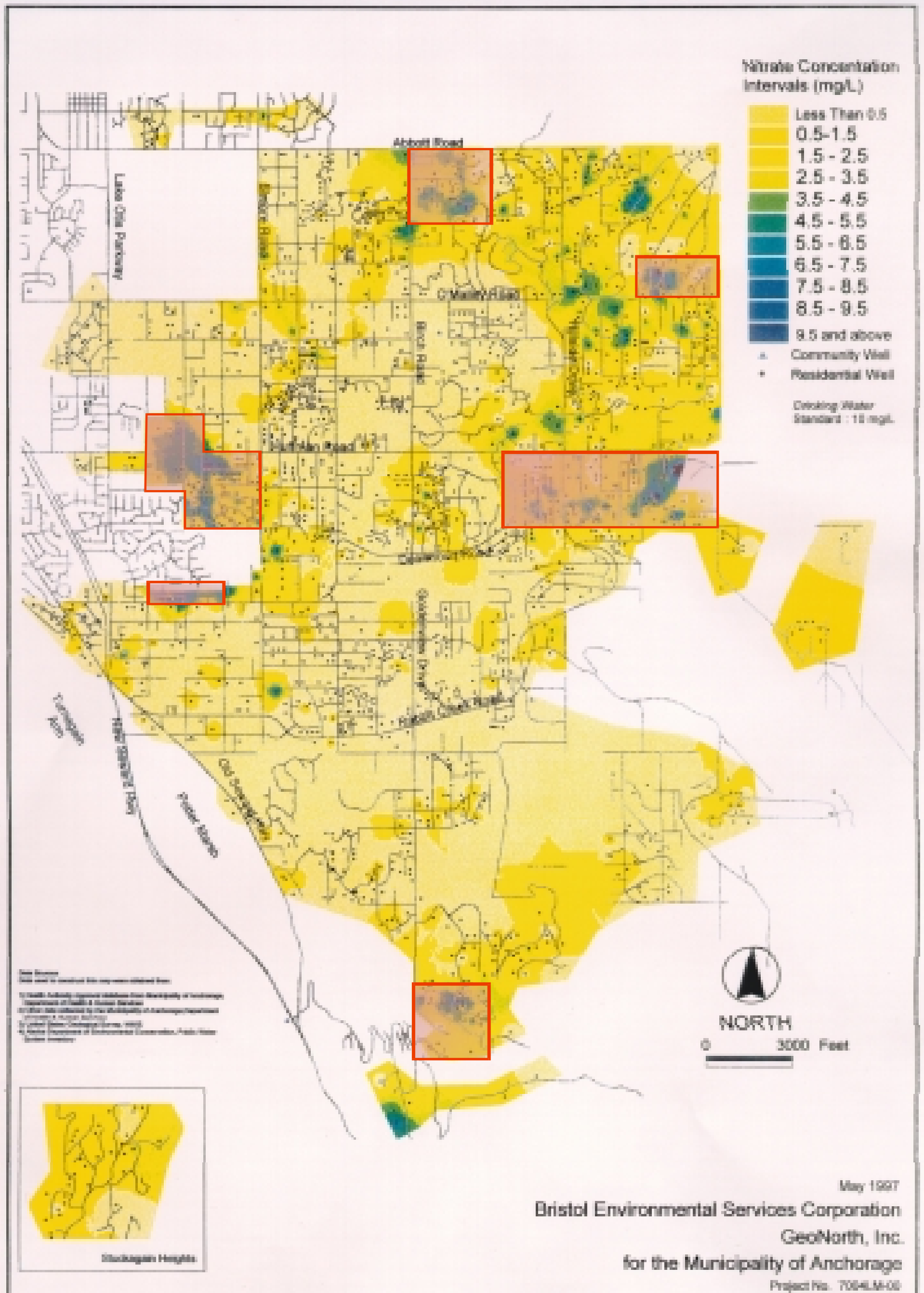


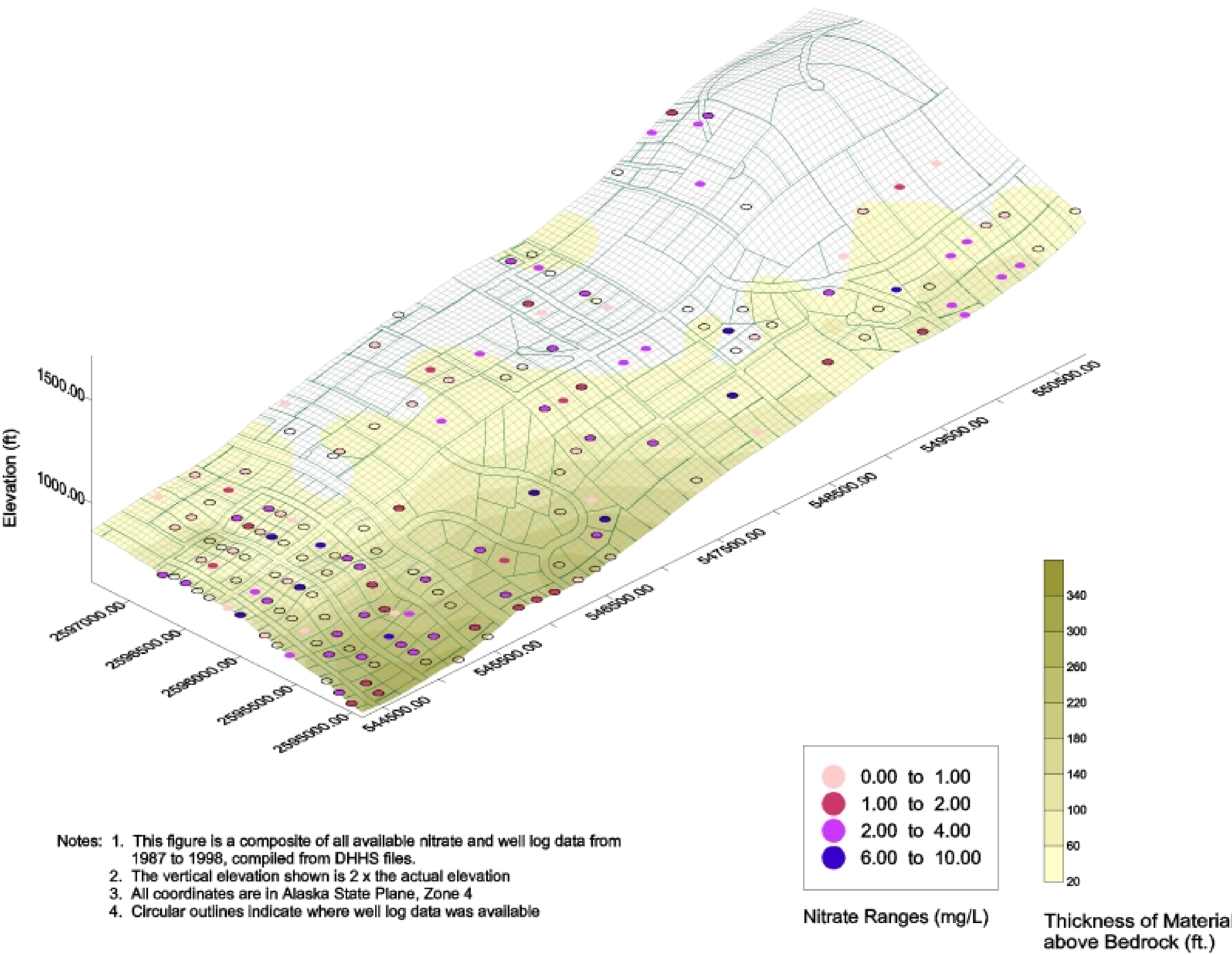
Figure 2. Interpolated Concentrations Of Nitrates In Well Water

Variables were researched from existing databases & well logs.

- Well Depth
- Case Depth
- Soil Absorption Rating
- Distance Between Well and Septic Field
- Water Yield from the Well
- Leach Field Sizing (HBR)
- Sum of Bedrooms
- Depth to Bedrock
- Terrain Units

Analysis focused on DeArmoun Pilot Area

- 120 acres
- 292 parcels
- Some data from over 100 wells.
- 23 sites had data available for all nine variables considered.


Elevation (ft)
1500.00
1000.00
2597000.00
2596500.00
2596000.00
2595500.00
2595000.00
544500.00
545500.00
546500.00
547500.00
548500.00
549500.00
550500.00
0.00 to 1.00
1.00 to 2.00
2.00 to 4.00
6.00 to 10.00
Nitrate Ranges (mg/L)
340
300
260
220
180
140
100
60
20
Thickness of Material above Bedrock (ft.)
Notes: 1. This figure is a composite of all available nitrate and well log data from 1987 to 1998, compiled from DHHS files.
2. The vertical elevation shown is 2 x the actual elevation
3. All coordinates are in Alaska State Plane, Zone 4
4. Circular outlines indicate where well log data was available

Hydrogeologic interpretation with existing data was limited.

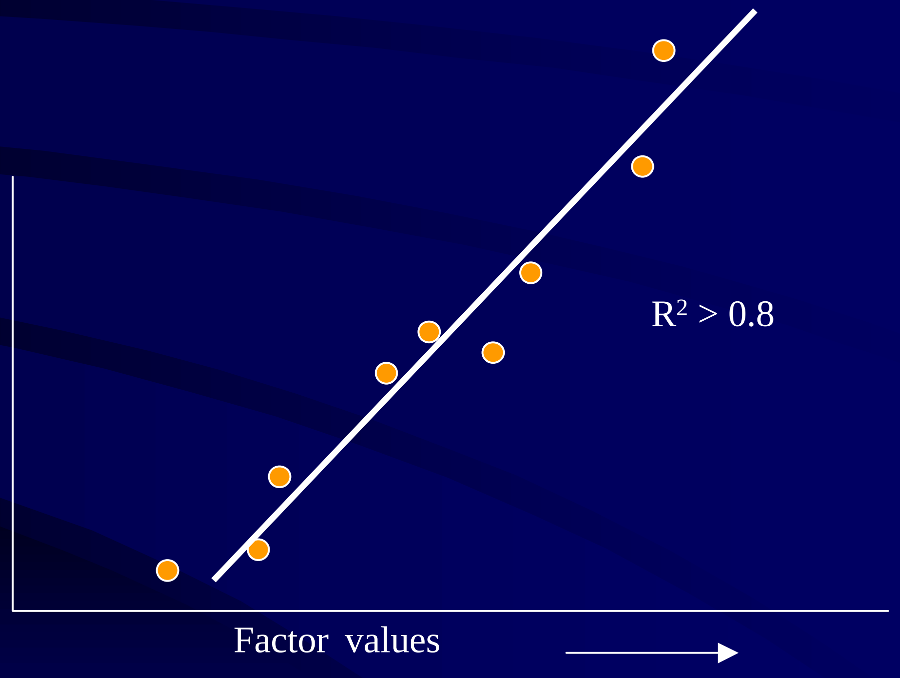
- Cross sections drawn with best available information, but:
  - Well logs too sparse to provide good correlation of strata;
  - Terrain Unit Mapping useful for surface features only;
  - Well construction data limited to depth.
- Conceptual model of groundwater movement shown for DeArmoun area

We applied a variety of statistical approaches seeking a reliable set of vulnerability factors:

- Correlation Analysis
- Regression Analysis
  - Linear
  - Multivariate Model
  - Others did not look promising
- No Non-Parametric Tests
- Nitrate Groupings

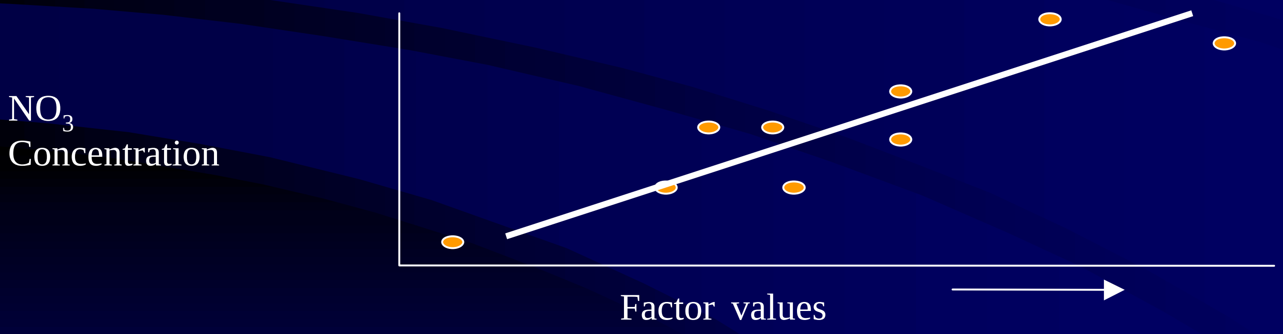
Our plan was to identify sensitive factors by visual and quantitative analysis

Strong Trend =
High Sensitivity



Significant factors would be derived from analysis of pilot area data.

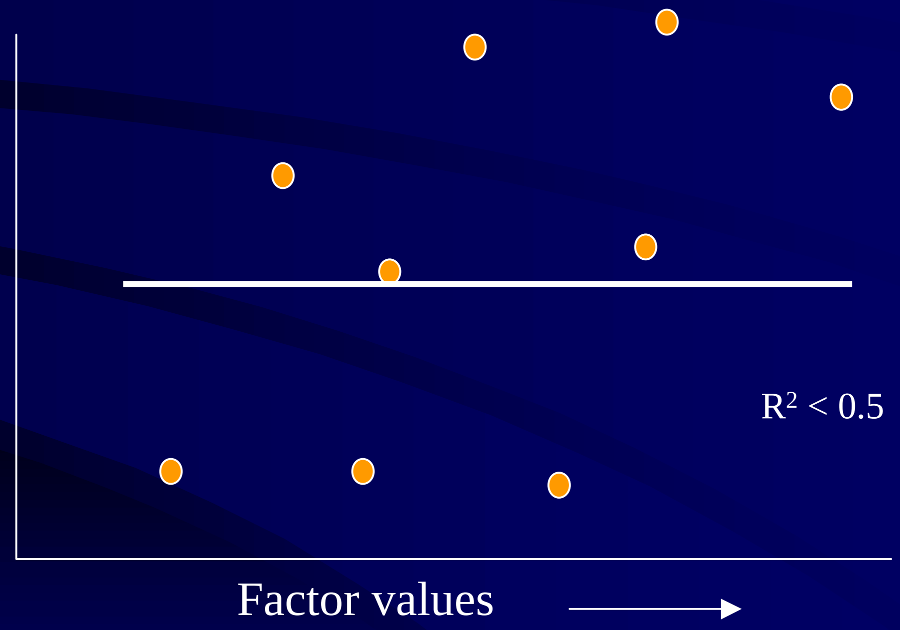
Plot histogram of values for each potential factor



Plot factor values versus nitrate concentration

Discount factors with weak trend or poor statistical correlation.

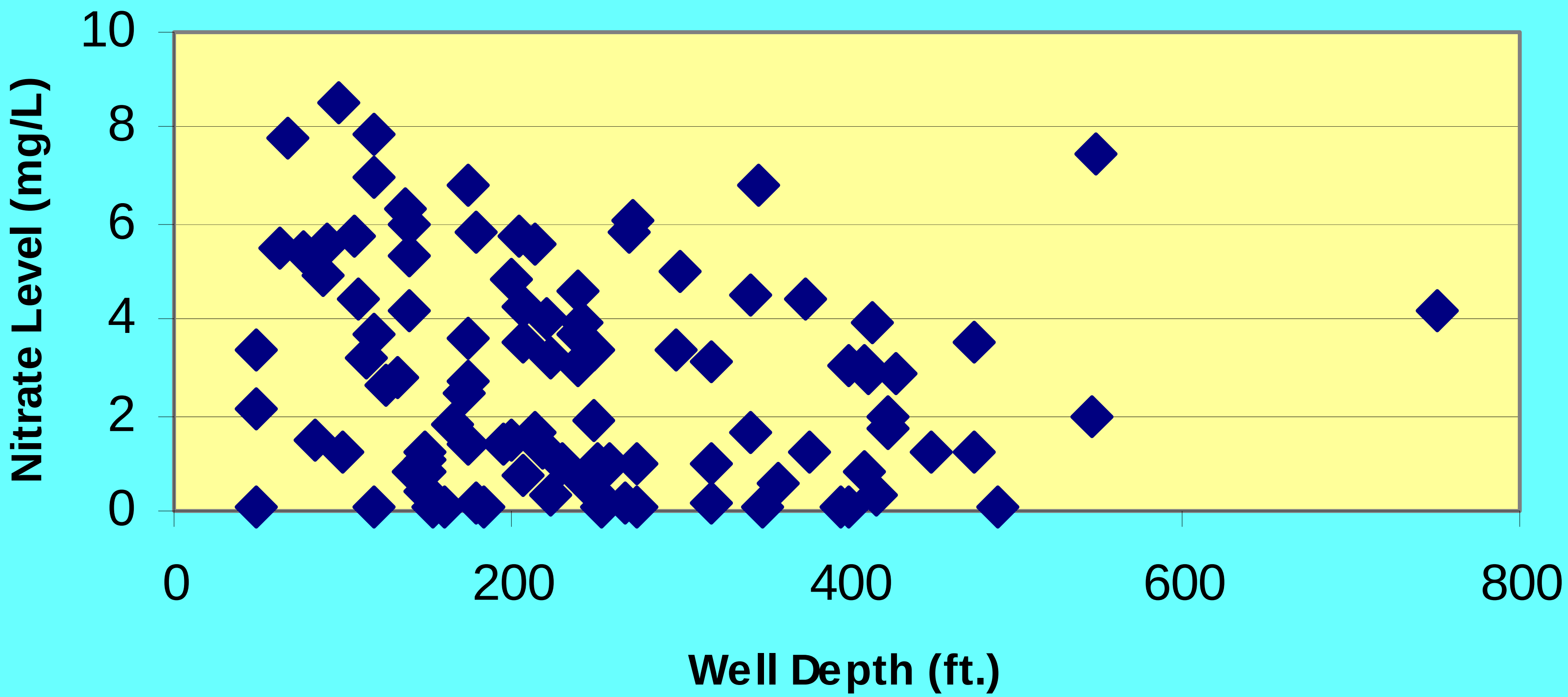
Weak Trend = Insensitive

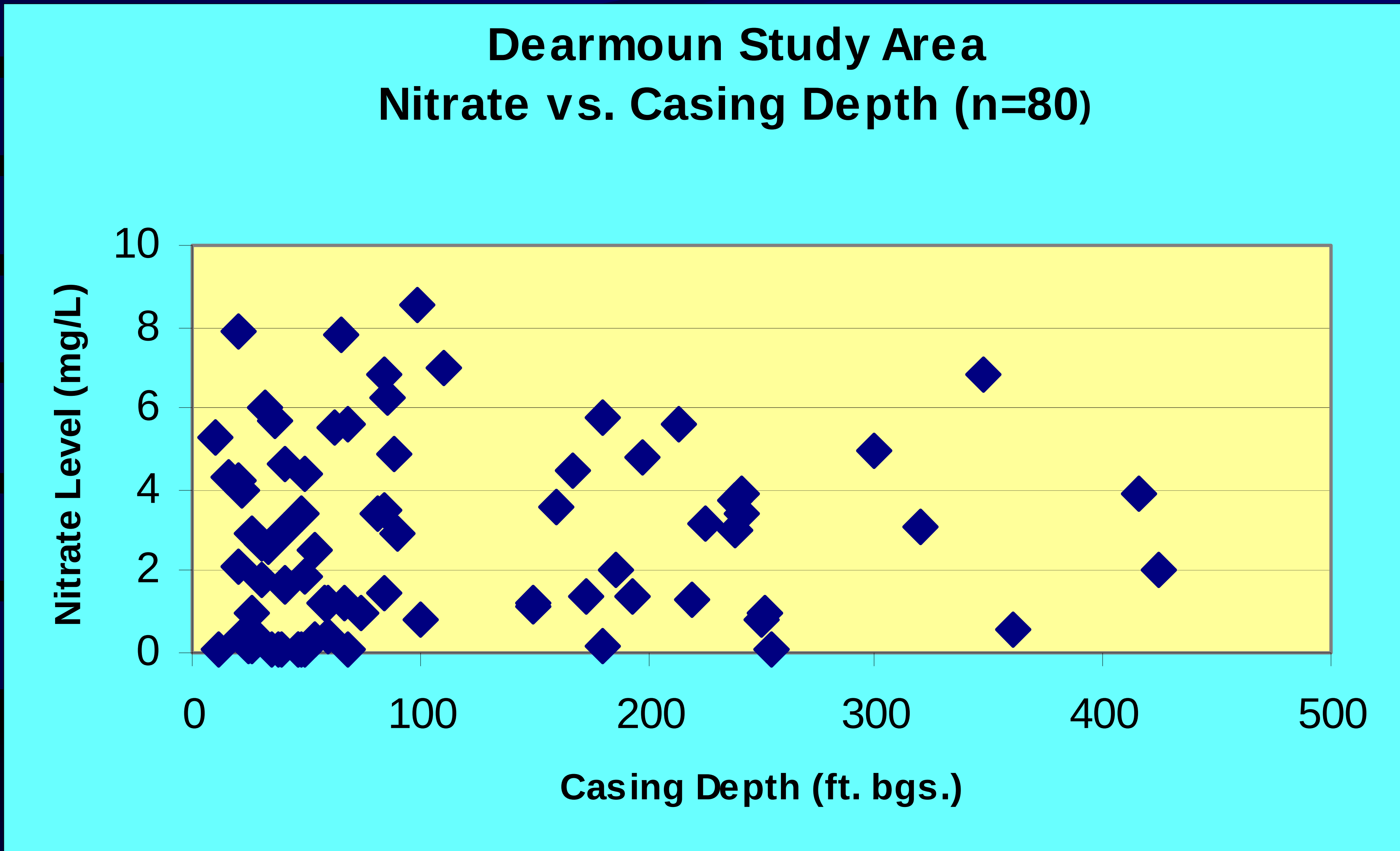


Regression Analysis

- Data set (23 samples)
- Poor correlations for single variables
- Multivariate analysis
  - Attempted for 9 variables
  - “Best” fit for 5 variables
  - R-squared <0.4
- Collinearity problems
- Non-normal data problems

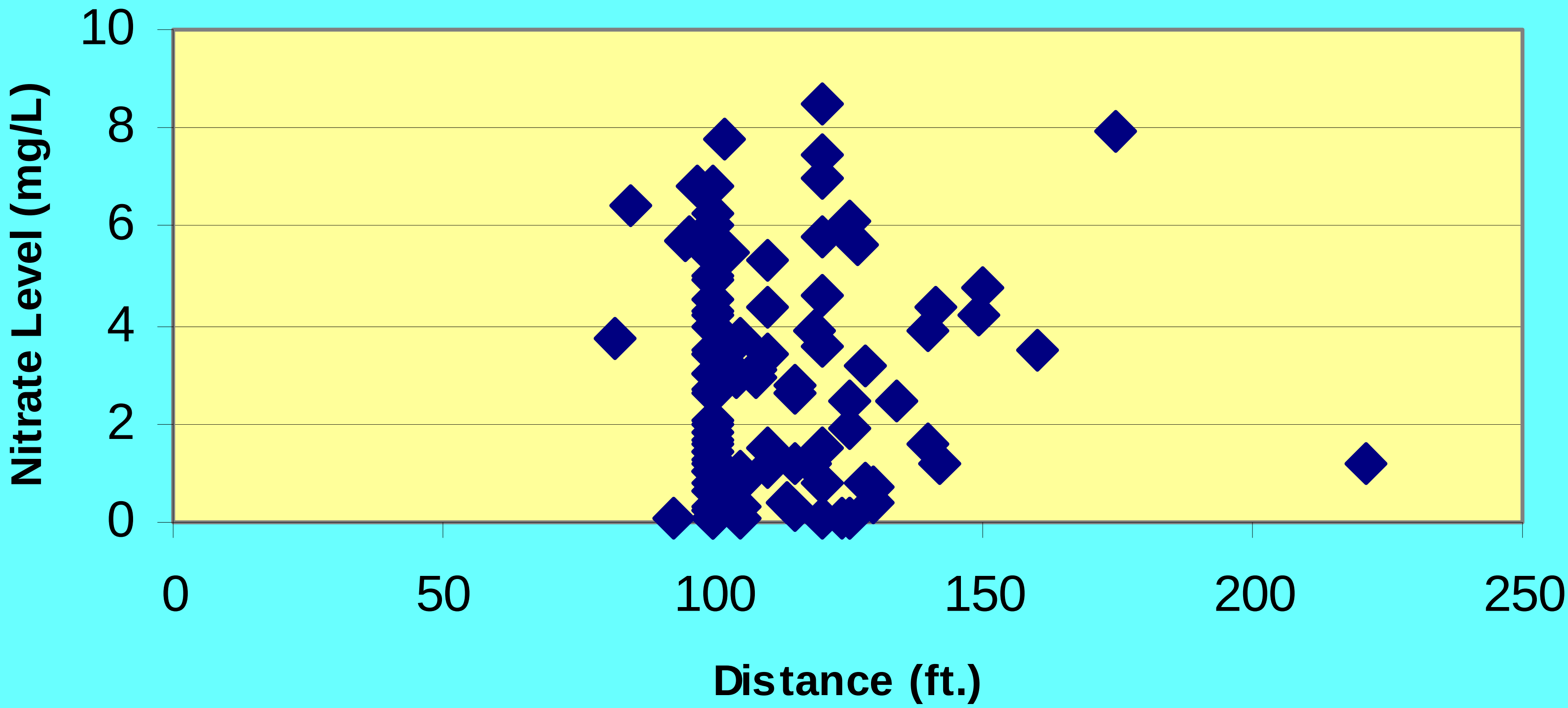
Dearmoun Study Area
Nitrate vs. Well Depth (n=101)



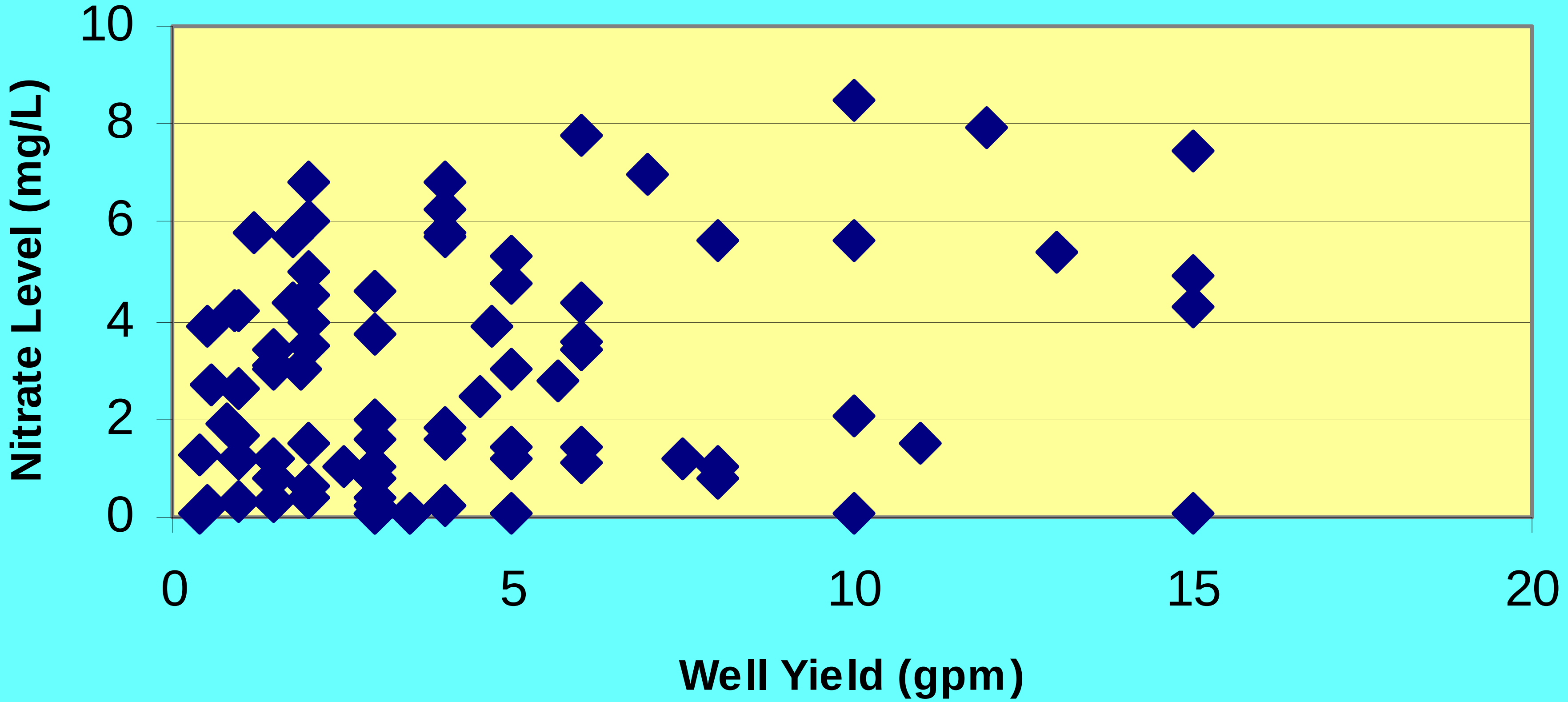


Dearmoun Study Area
Nitrate vs. Casing Depth (n=80)
Nitrate Level (mg/L)
10
8
6
4
2
0
0
100
200
300
400
500
Casing Depth (ft. bgs.)

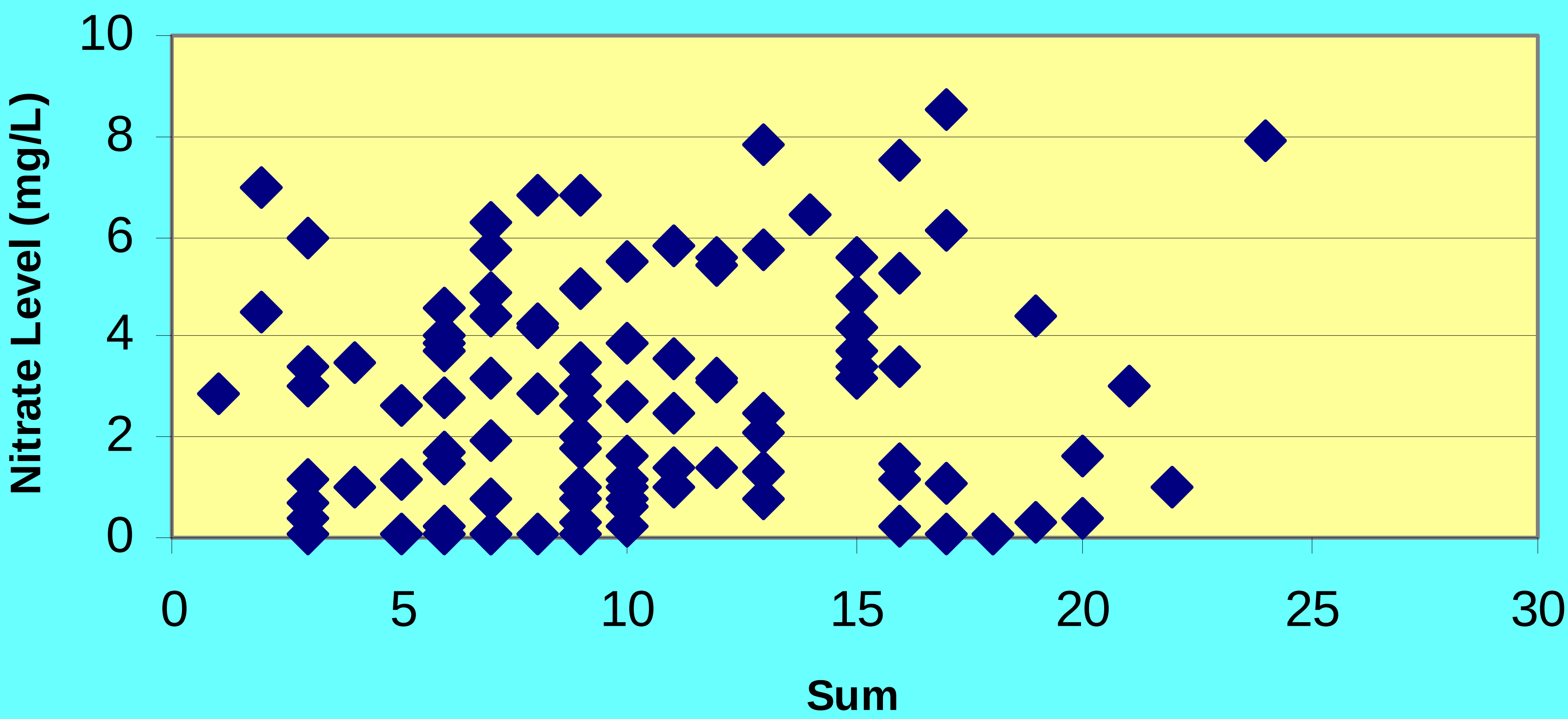
Dearmoun Study Area
Nitrate vs. Distance Well to Septic Field (n=104)

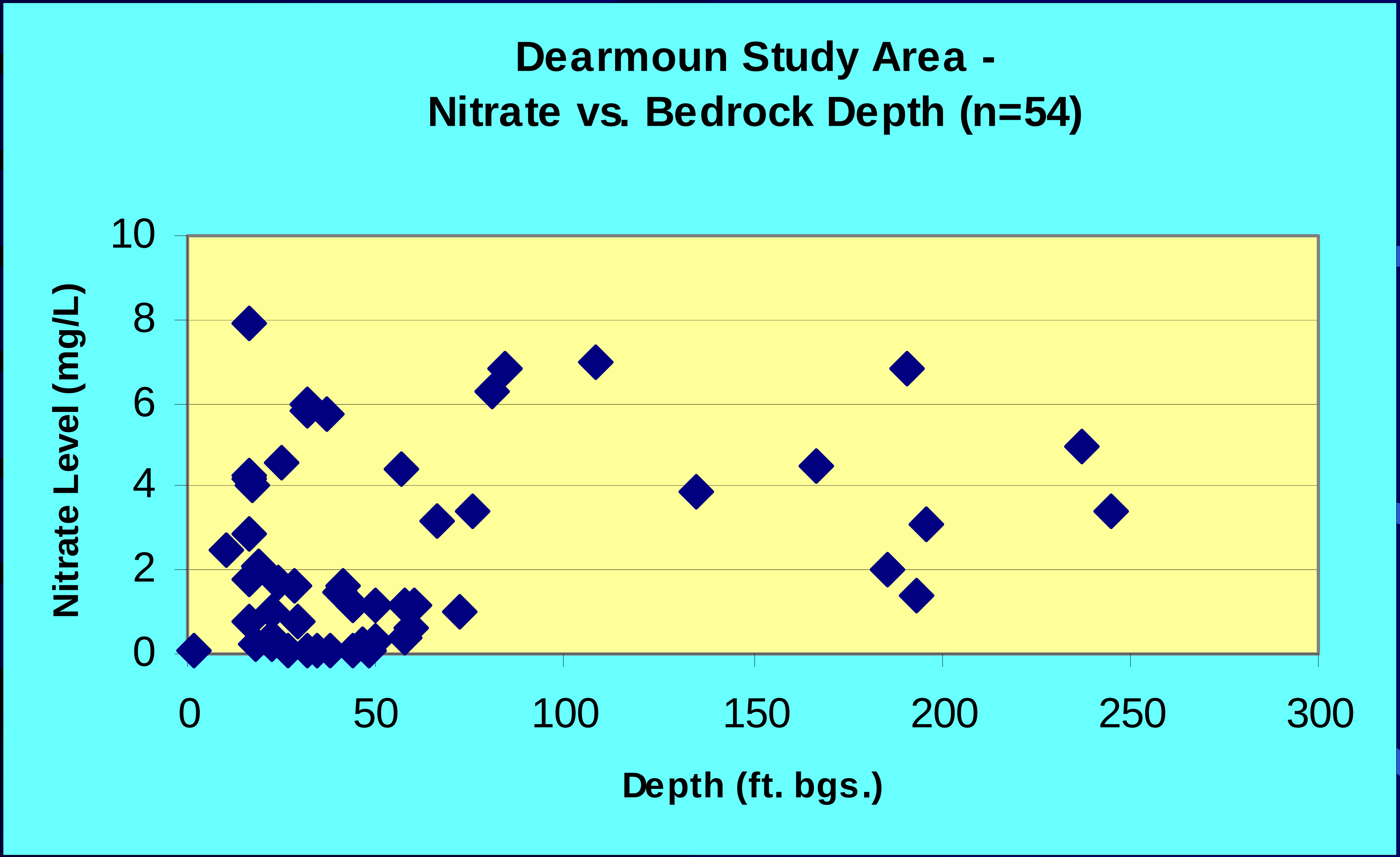


Dearmoun Study Area
Nitrate vs. Well Yield (n=84)

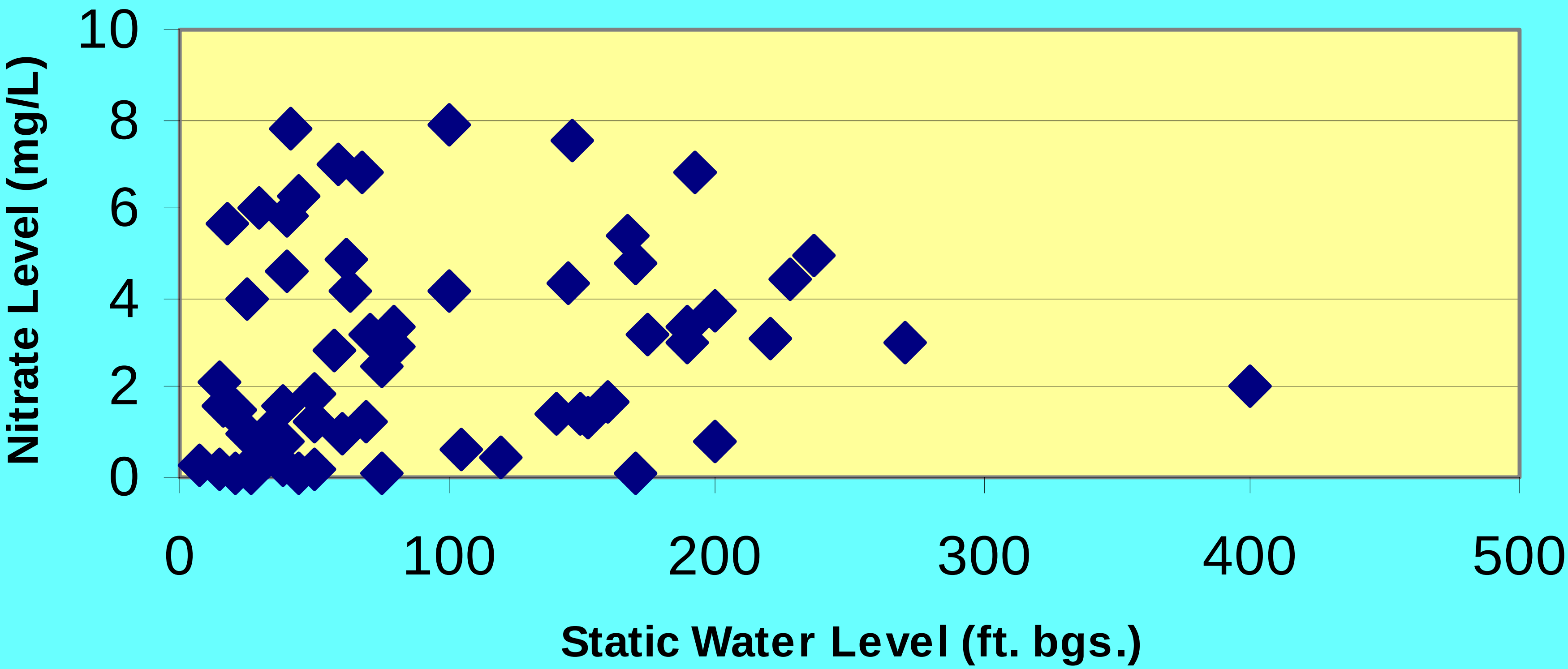


Dearmoun Study Area - Nitrate vs. Sum of Bedrooms (n=103)

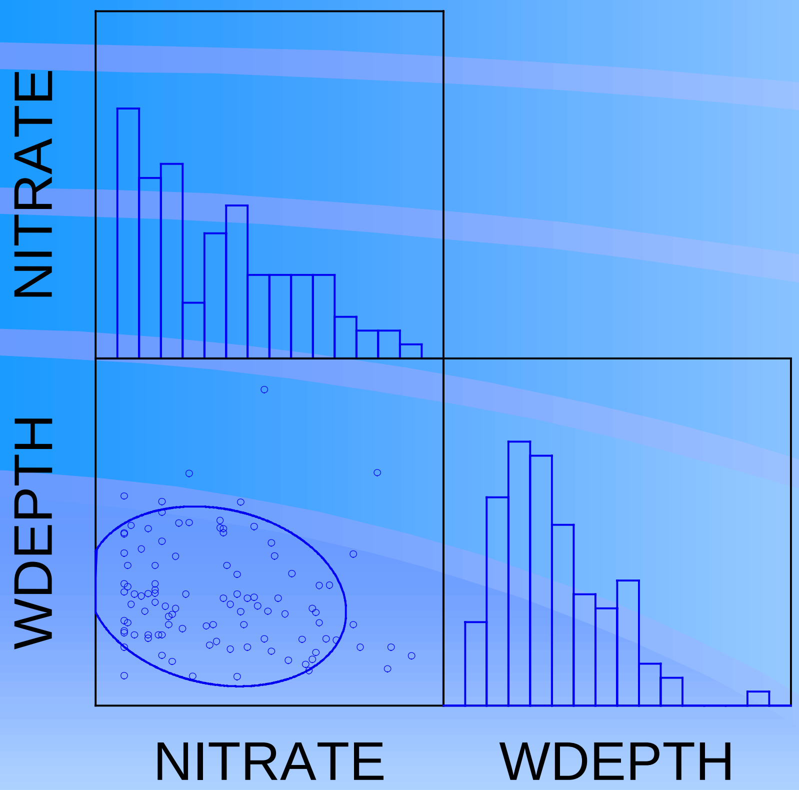


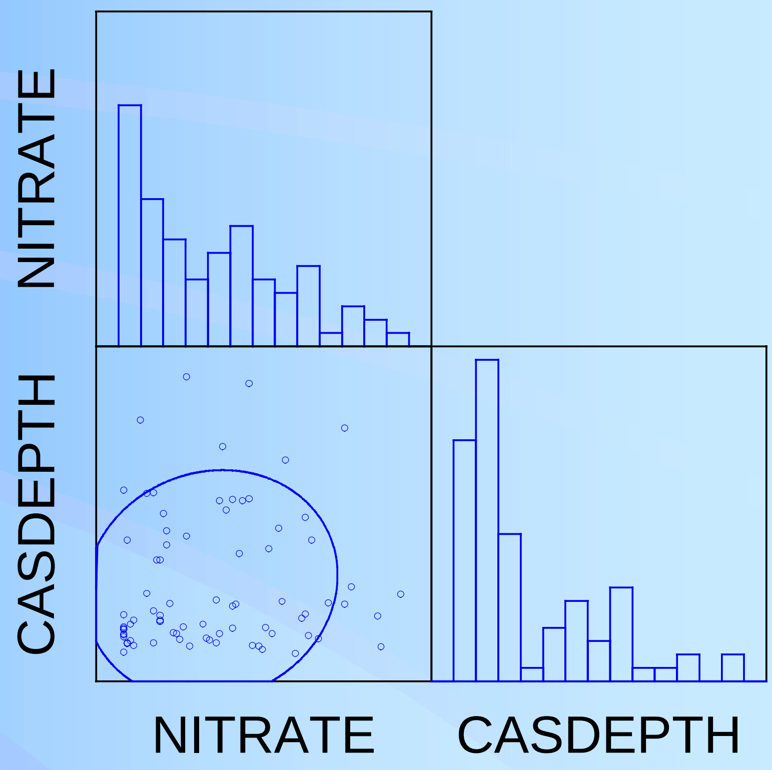

Dearmoun Study Area -
Nitrate vs. Bedrock Depth (n=54)
Nitrate Level (mg/L)
Depth (ft. bgs.)
0
2
4
6
8
10
0
50
100
150
200
250
300

Dearmoun Study Area
Nitrate vs. Static Water Level (n=62)



Other statistical views and quantification added little to our understanding





Failing useful linear correlations, we attempted to view the data by classes

- Divide NO3 findings into 4 ranges:

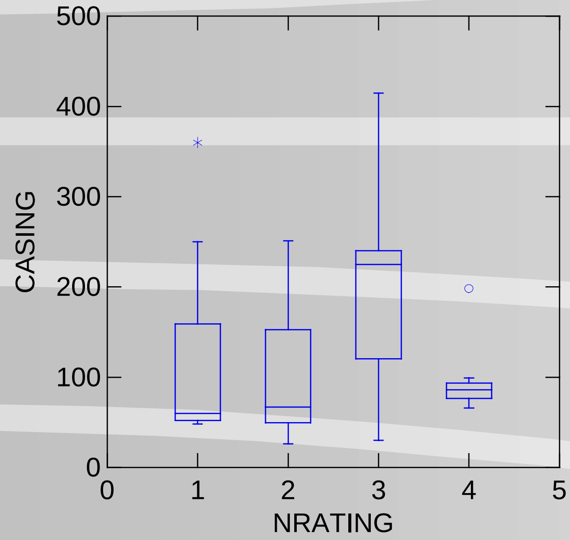
  0-1 mg/L   1-2 mg/L

  2-4 mg/L   >4 mg/L

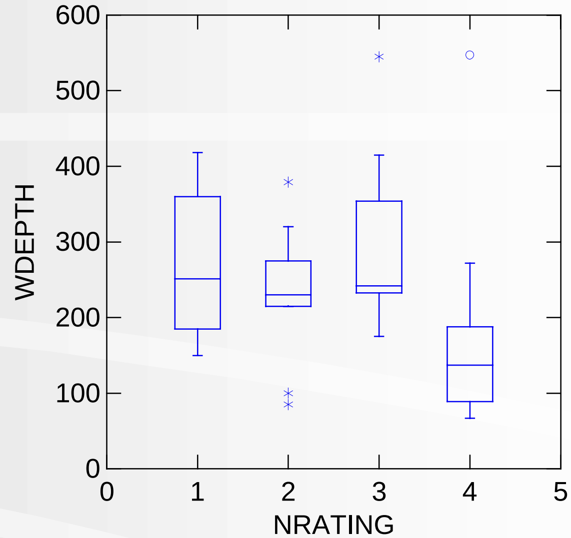
- Compare distribution of factor data by box and whisker plots

DeArmoun Data Sets

N=32



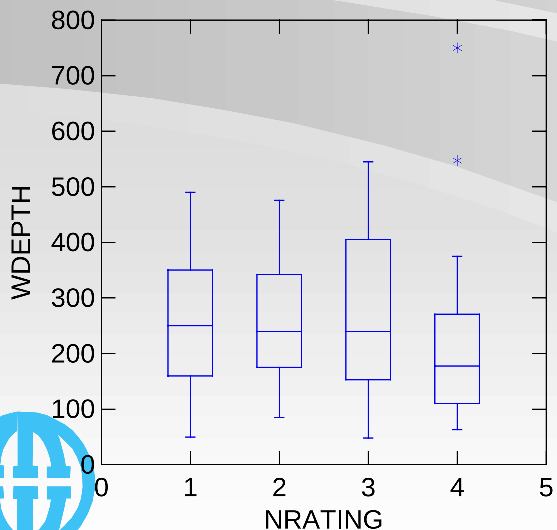
N=40



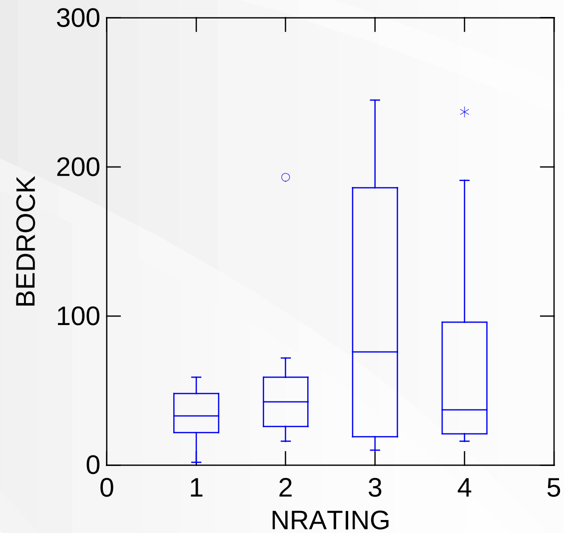
NRATING:

1) ≤ 1 mg/L
2) 1-2 mg/L
3) 2-4 mg/L
4) >4 mg/L

N=101

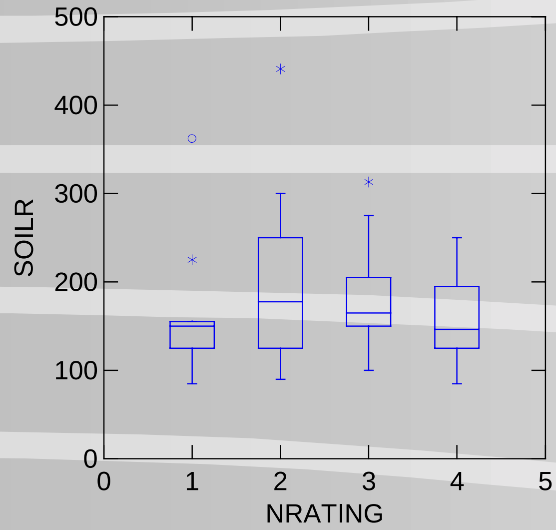


N= 54

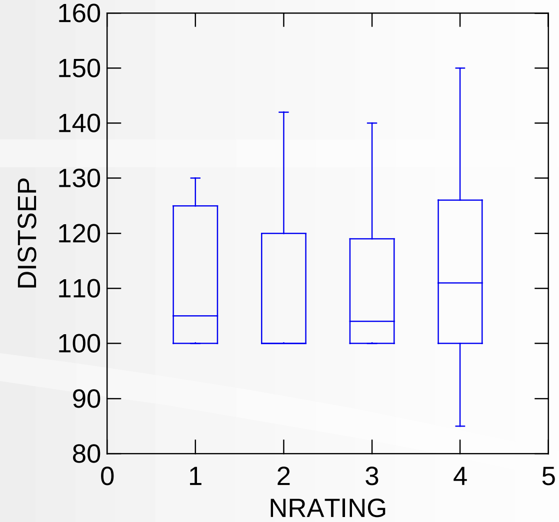


DeArmoun Data Sets

N=43



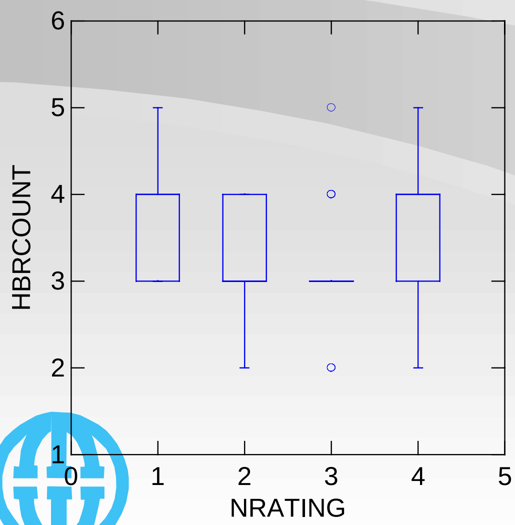
N=40



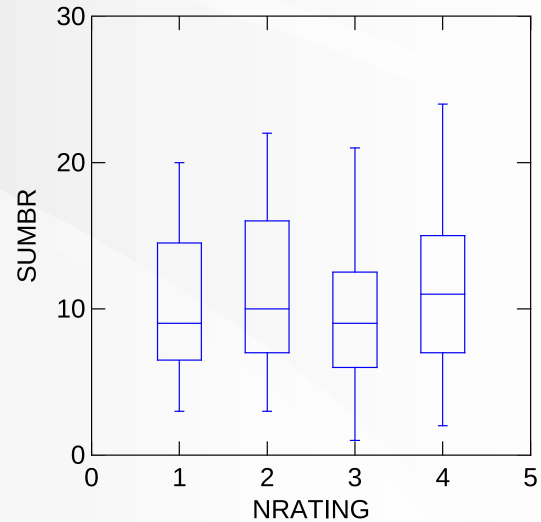
NRATING:

1) ≤ 1 mg/L
2) 1-2 mg/L
3) 2-4 mg/L
4) >4 mg/L

N=103



N=103

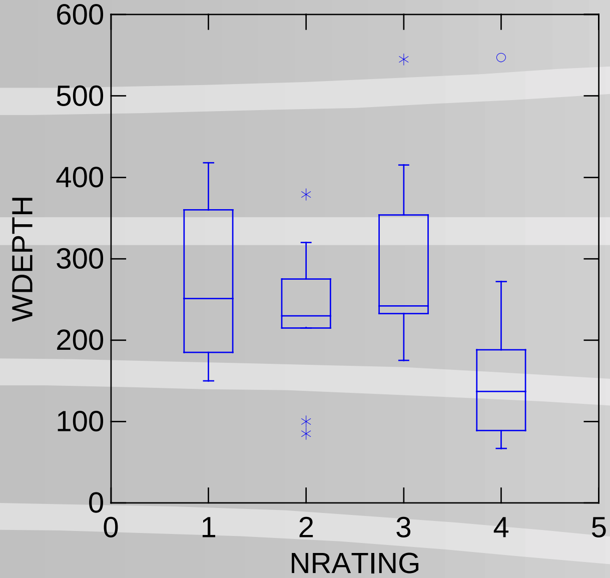


Results of DeArmoun Analysis

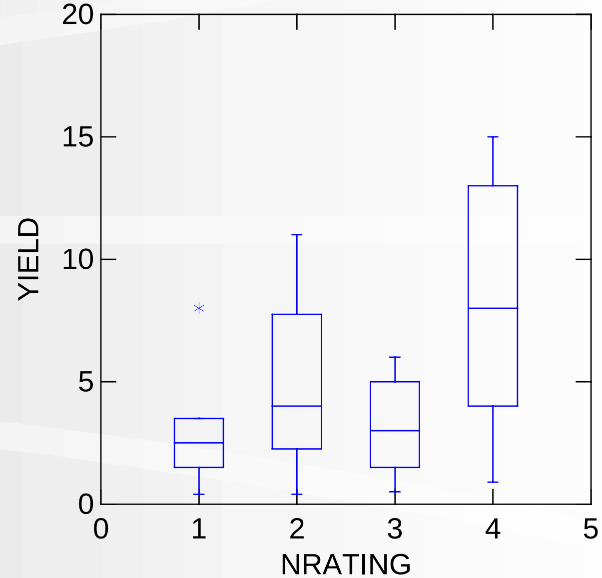
- Data suggests weak trend - higher nitrate values might be associated with:
  - Higher water yields
  - Low well depths
- But, there is no statistical significance associated with individual variables or their interactions
- Try similar analysis on independent subsets of the DeArmoun database.

Mountain Park

N=(40)



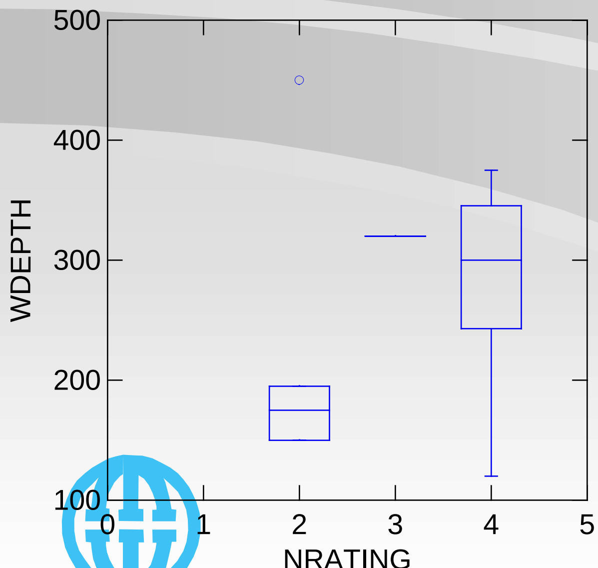
N=(32)



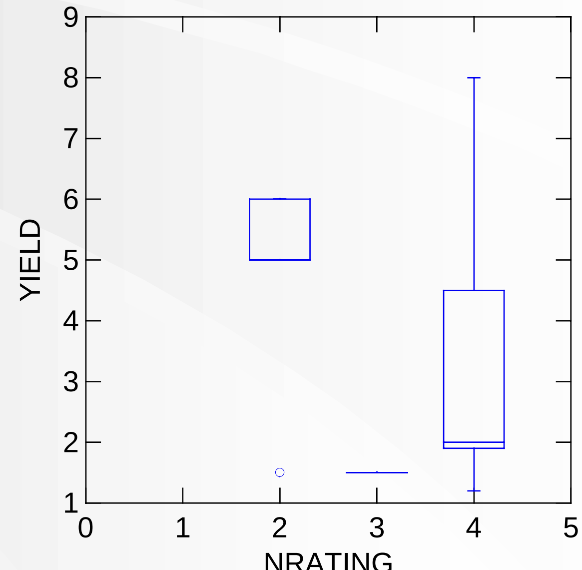
NRATING:

1) ≤ 1 mg/L
2) 1-2 mg/L
3) 2-4 mg/L
4) >4 mg/L

N=(13)



N=(13)



Aspen Highlands

Subset analysis confirms that we can't count on these relationships

- Mountain Park results corroborate DeArmoun findings that higher nitrate values may be associated with:
  - Higher water yields
  - Shallow well depths
- Aspen Highlands did not follow.
- Mountain Park subset may dominate DeArmoun.

Conclusions from statistical analysis

- No significant relationship between nitrate and any one of the proposed factors.
  - Poor correlations
  - Relationships change based on sample set
- No significant relationship between nitrate and any grouping of the proposed factors.
  - Collinearity issues
  - Data quality uncertain

Uncertainty and poor data quality cloud the findings

- Database is limited and hampered by lack of concurrent sampling and other controls.
- Unaccounted variables
  - Actual wastewater discharge volumes
  - Differences in development calculations
  - How well the water well was constructed
  - How well the septic field was constructed
  - Some other human-related variable

We looked for better data to support model development.

- Build localized cross section diagrams
- Compare stratigraphy and lithology
- Examine well construction
- Develop a localized conceptual model of groundwater movement

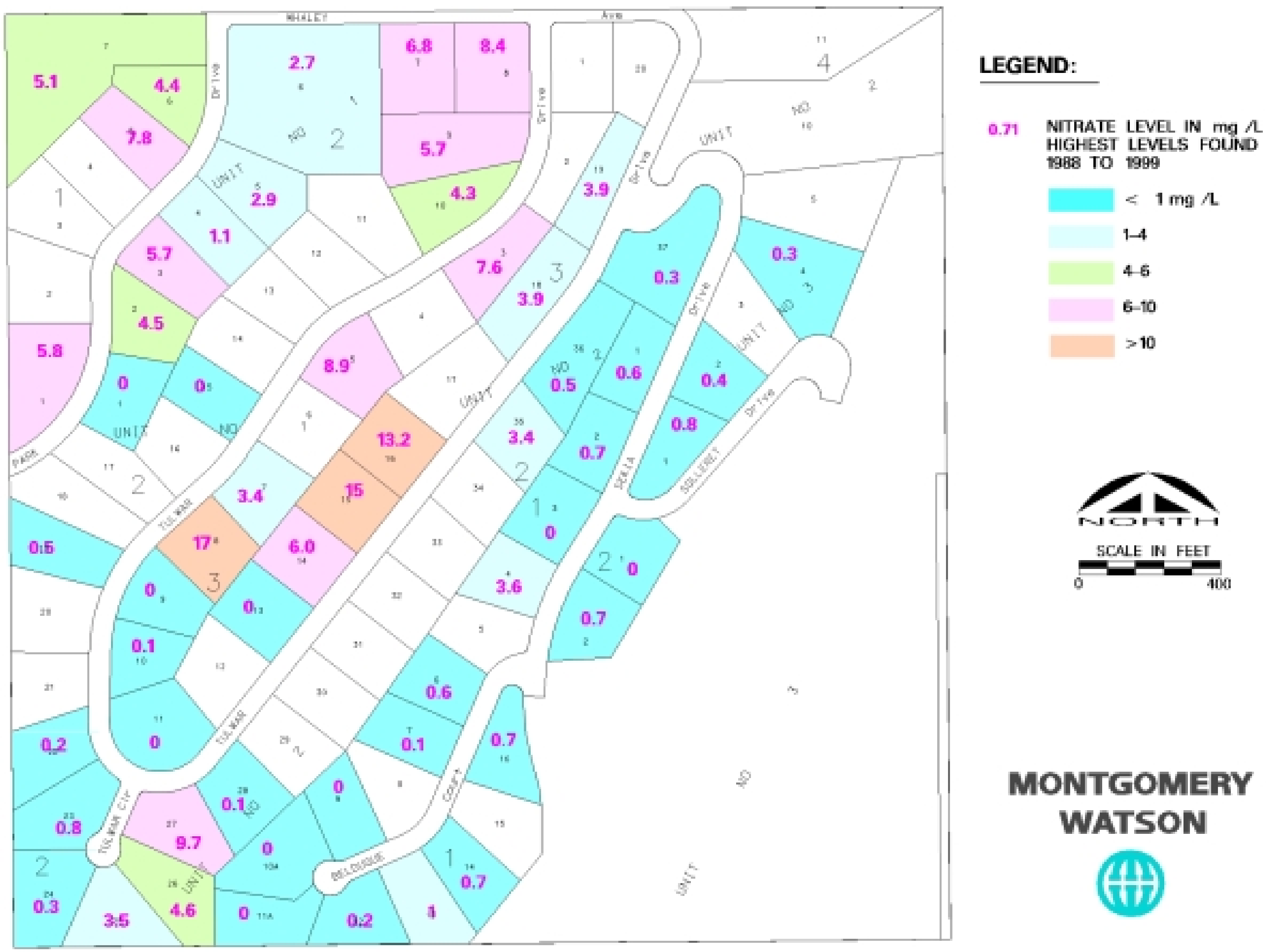
Model development focused on future utility

- Geologic factors can be used to identify development constraints.
- Geographic factors can be used to identify development limitations.
- Well construction factors can be used to improve existing construction guidelines.

Focus shifted to Field Study

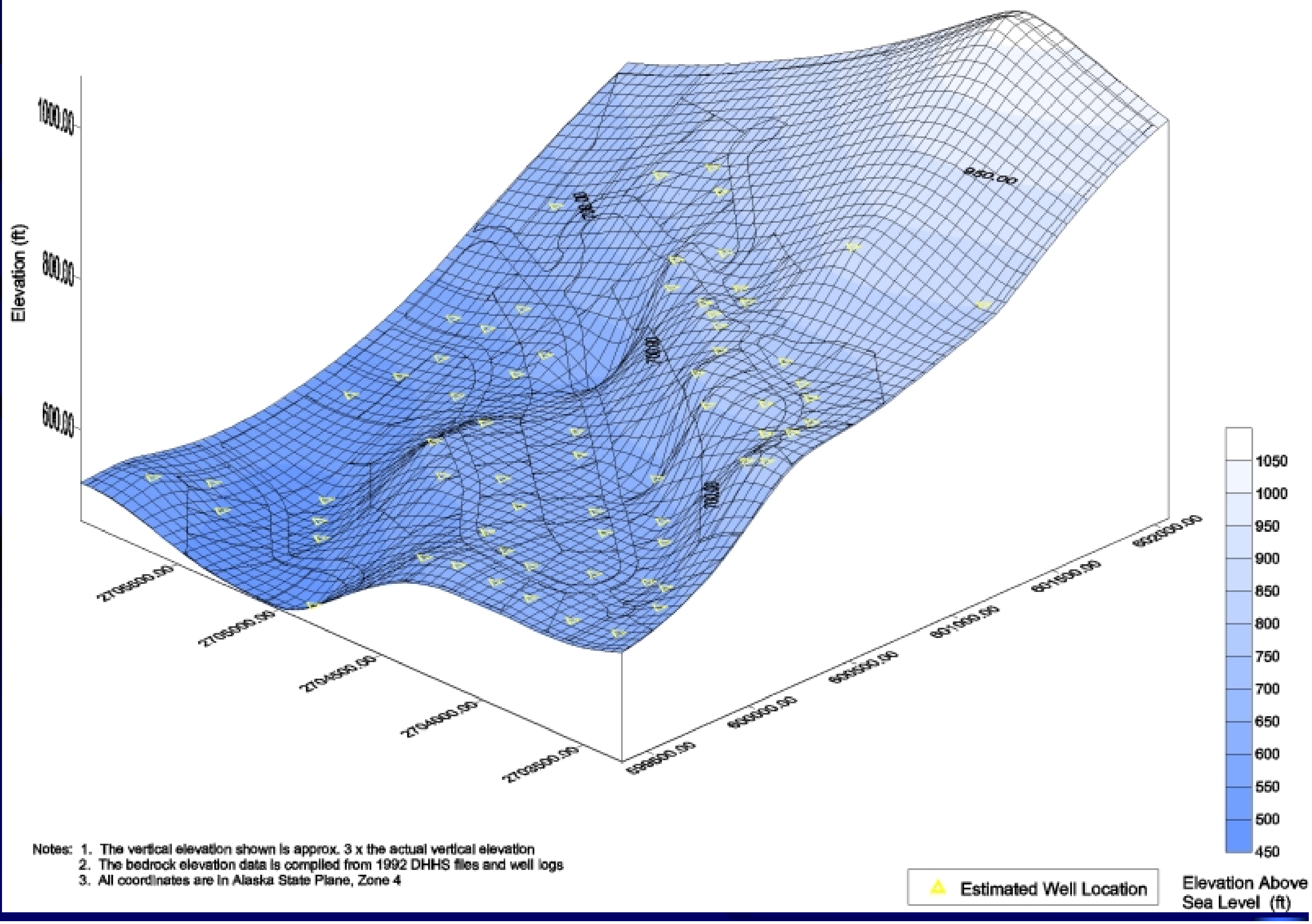
- Concurrent NO3 sampling and water tables
- Verification of well construction via CCTV
- High level of public interest and support
- Try to resolve existing concerns

Scimitar area has nitrate history

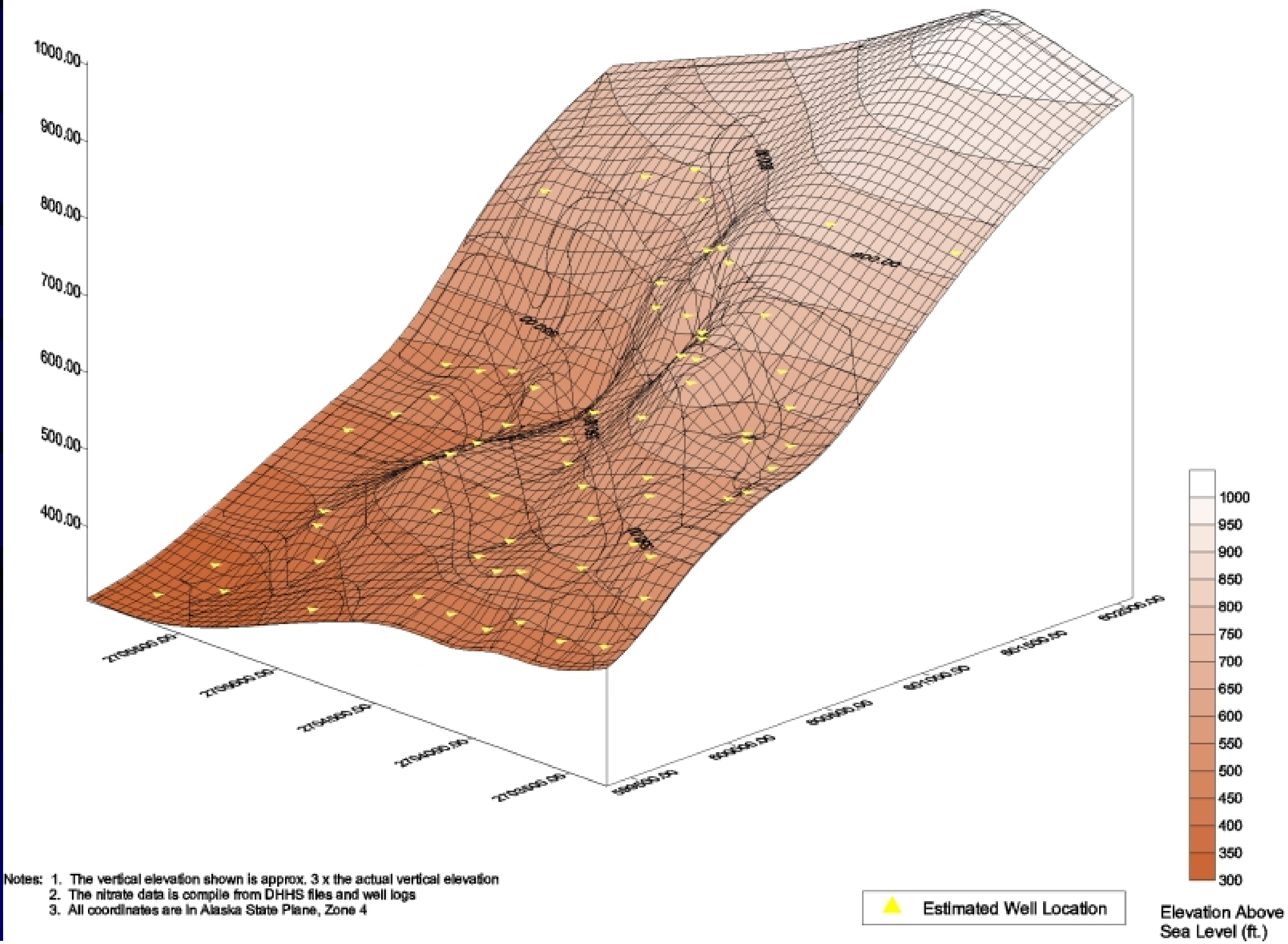


MONTGOMERY WATSON

Scimitar Surface Contours

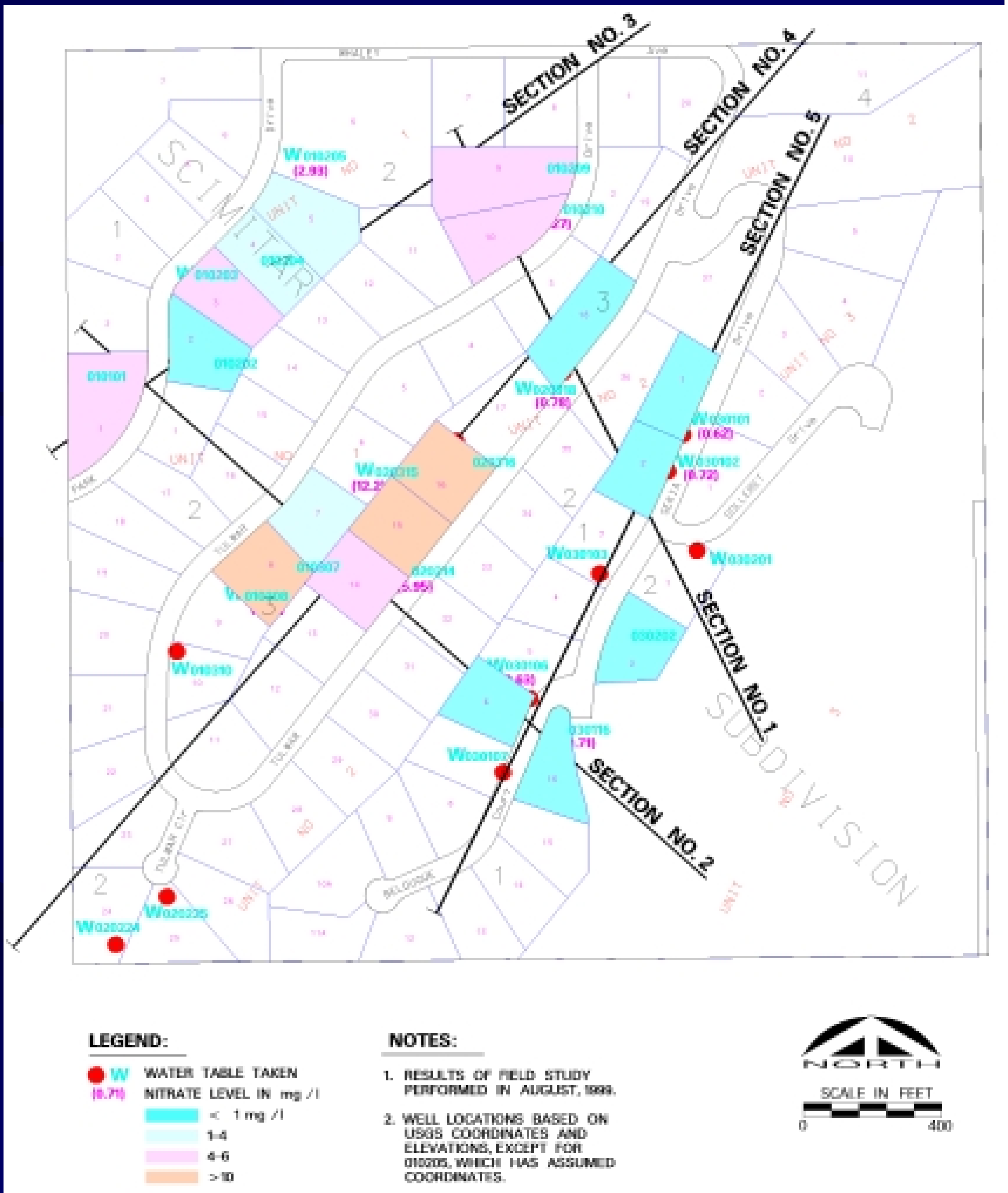


Scimitar Bedrock Contours

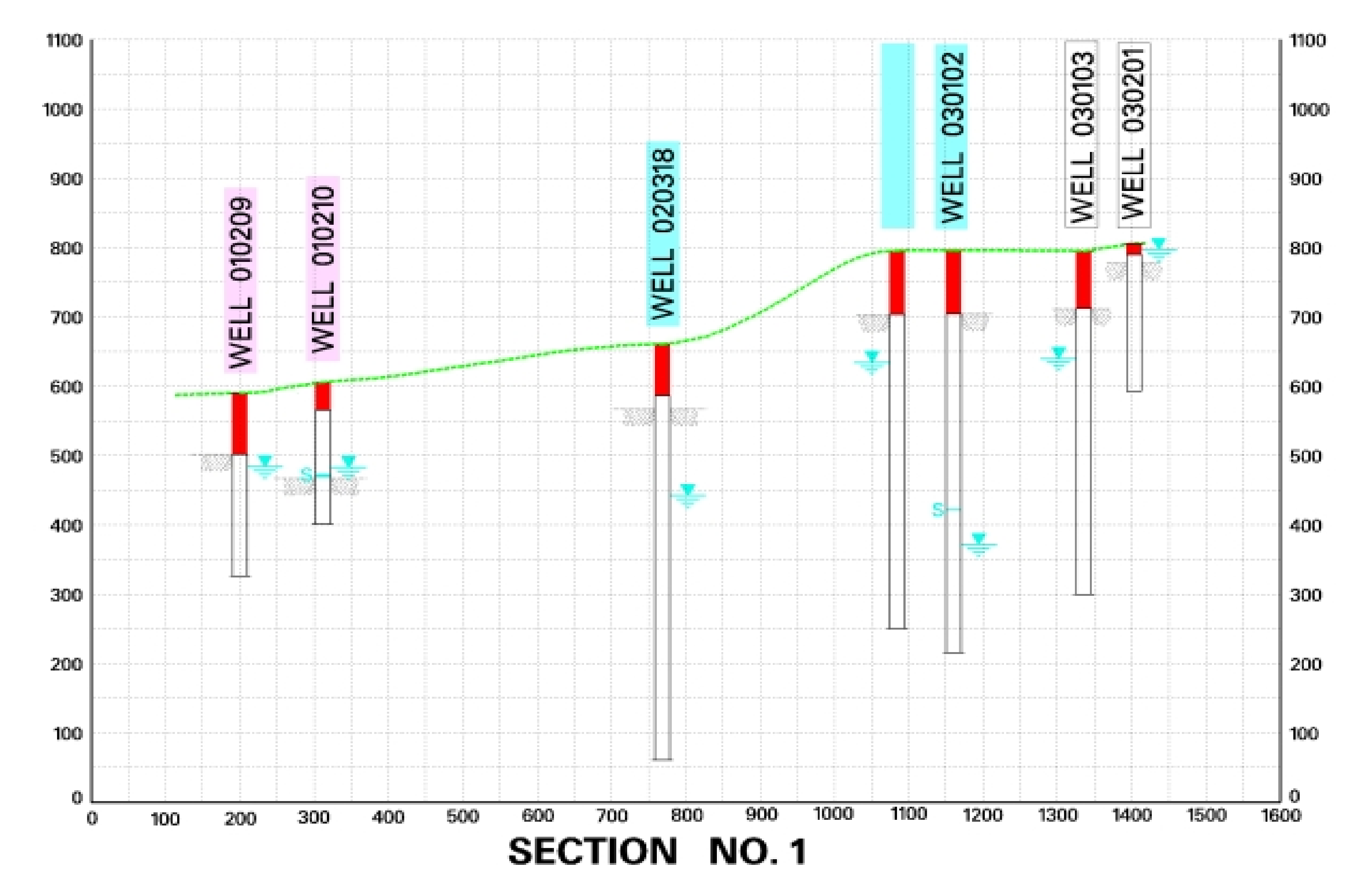


Field Study Findings

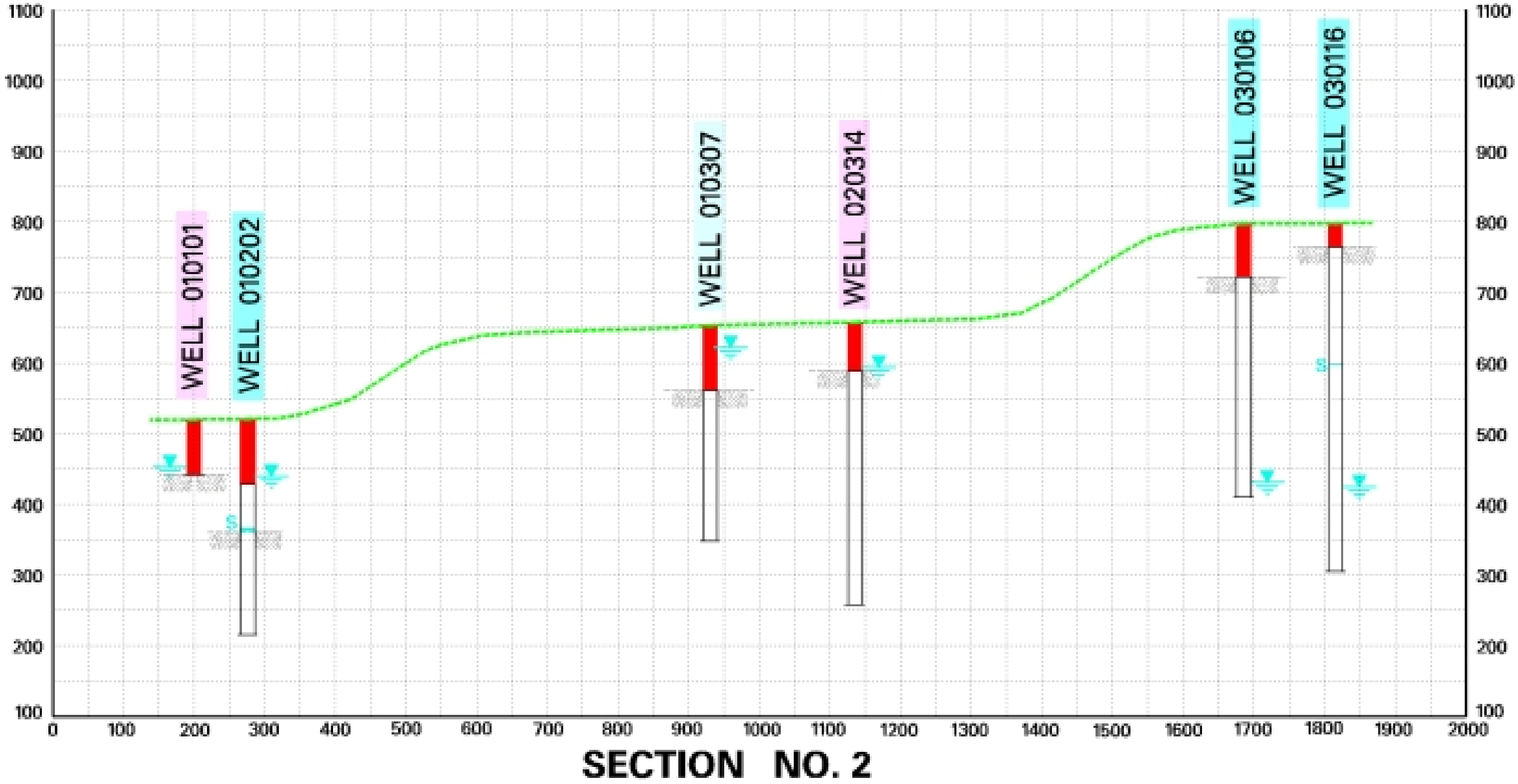
- 22 wells sounded for water table.
- 18 nitrate samples
- 16 CCTV inspection
- 9 samples for intensive chemical analysis



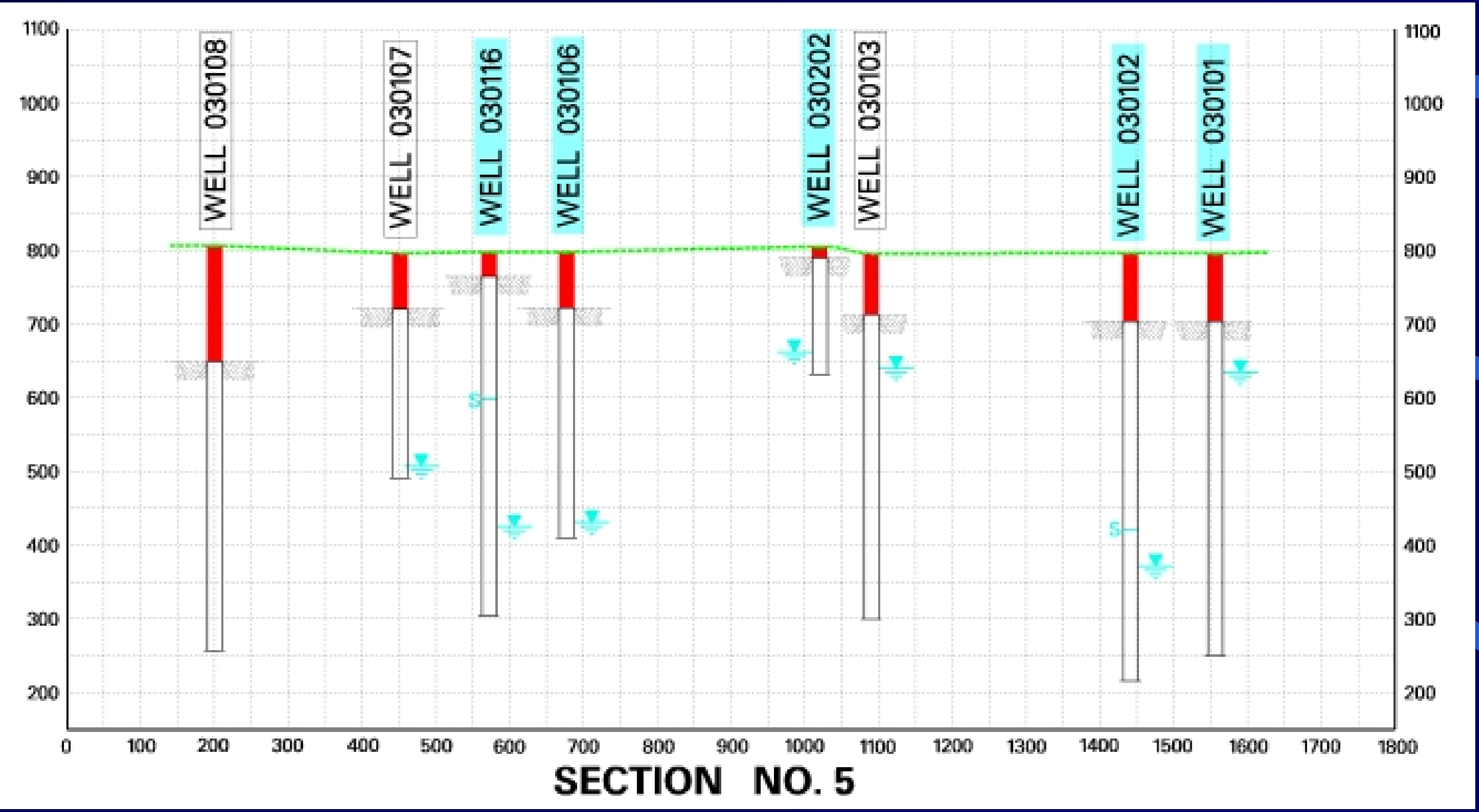
Scimitar NW-SE Section



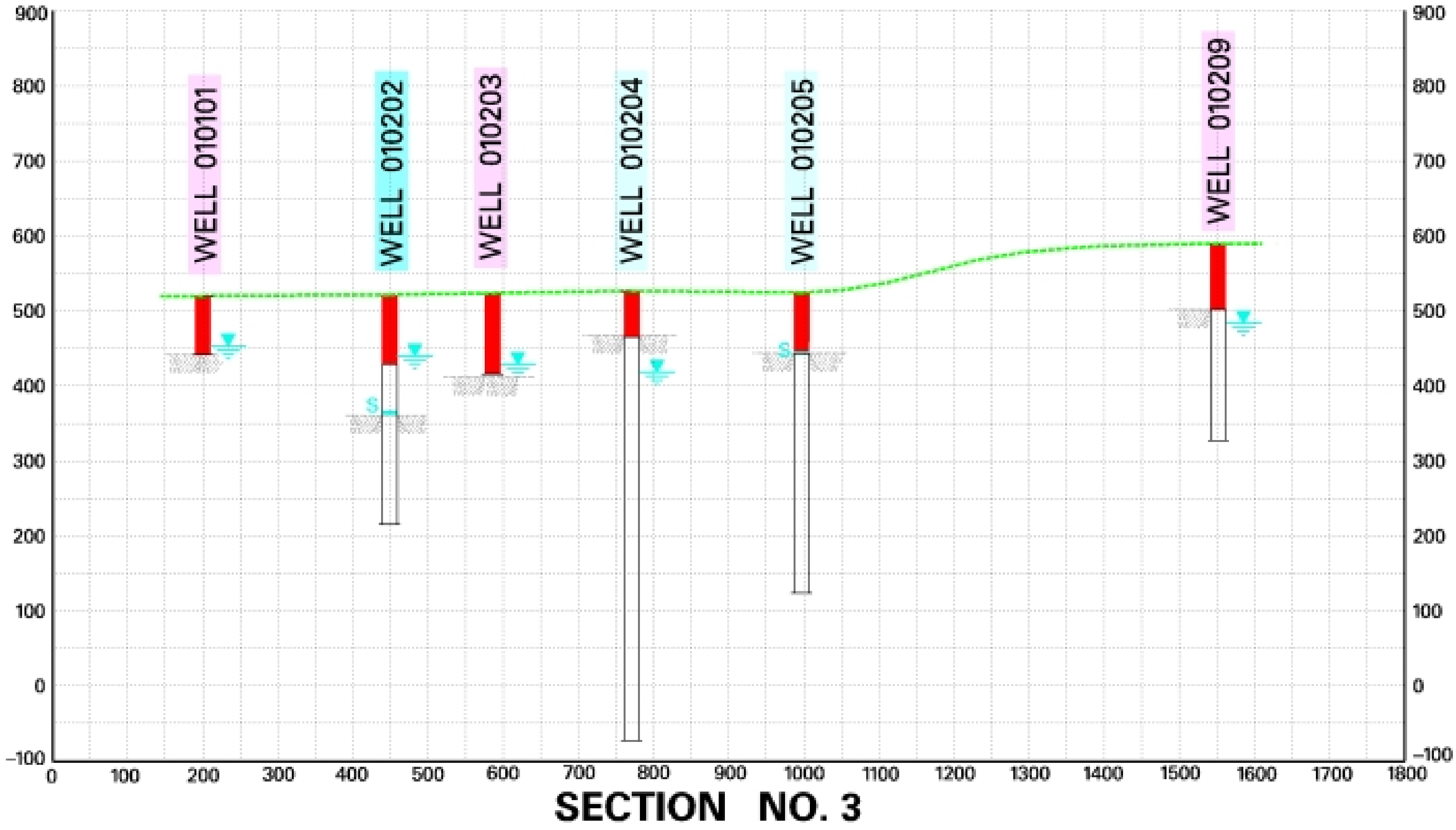
Scimitar WNW-ESE Section



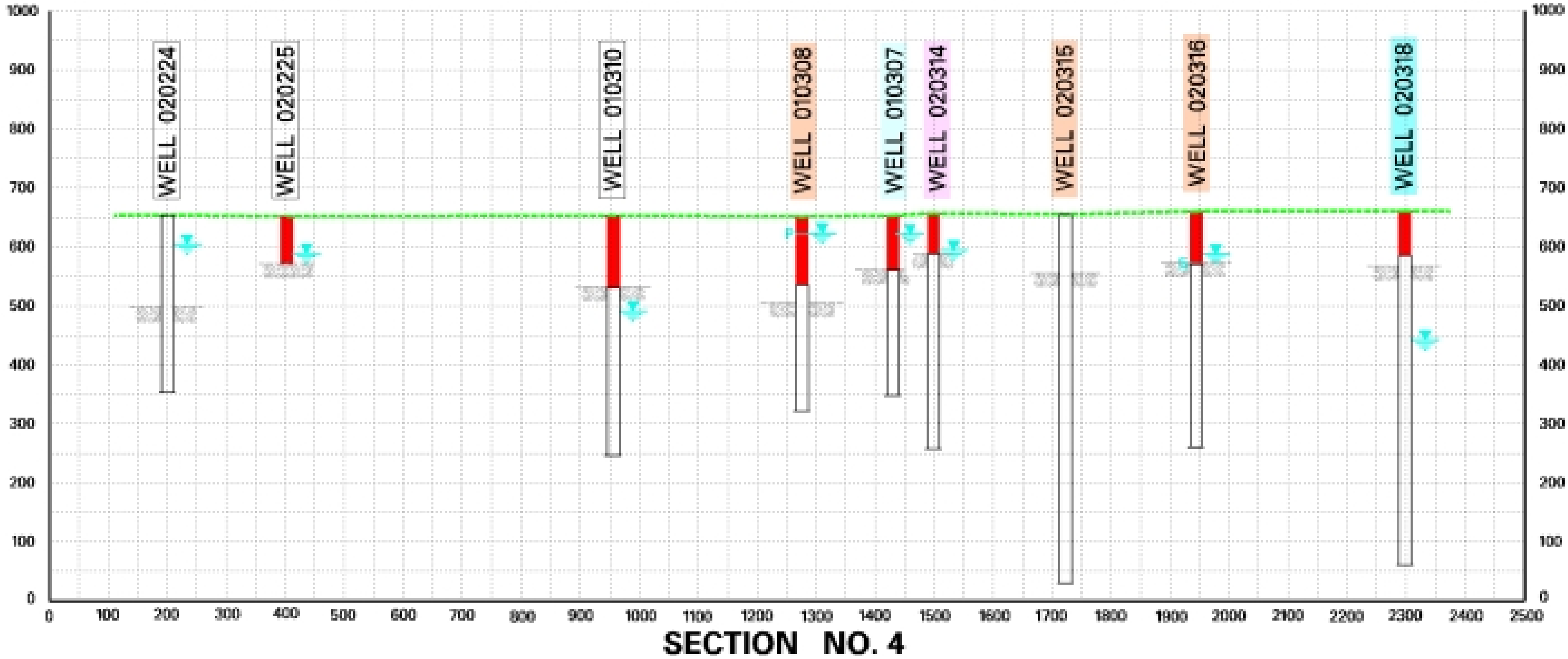
Scimitar Upper Transverse Section



Scimitar Lower Transverse Section

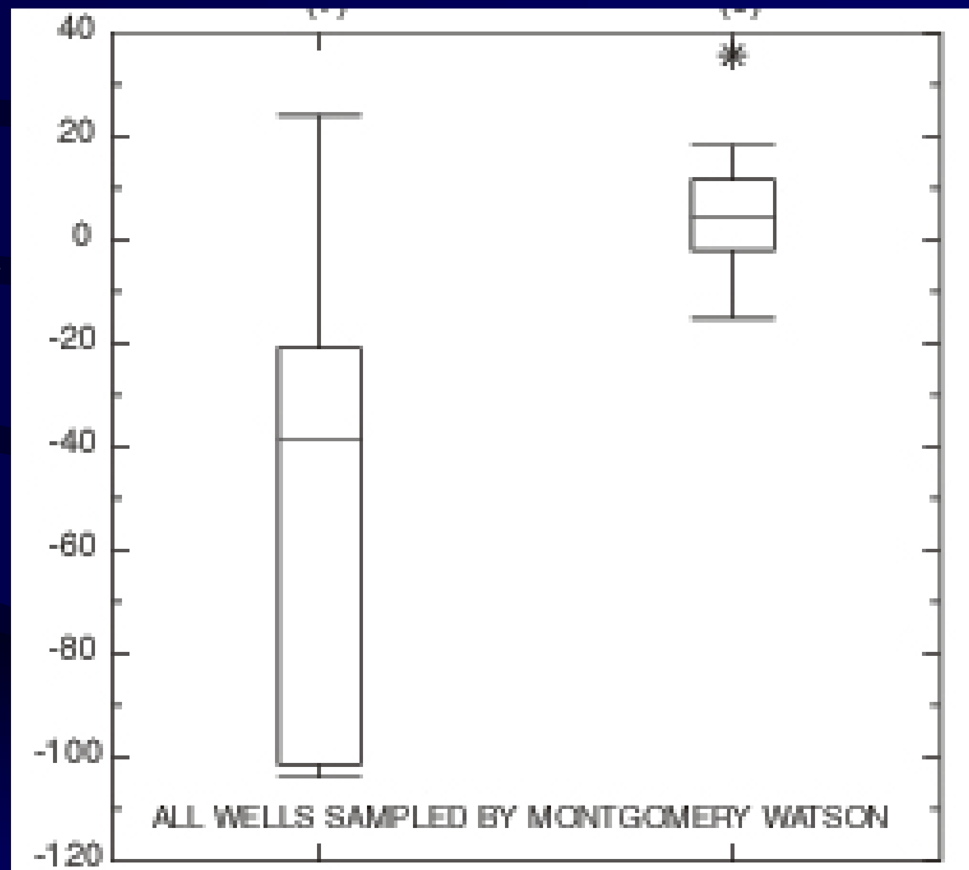


Scimitar Middle Transverse Section



Nitrate is higher in ground waters at or above the bedrock surface

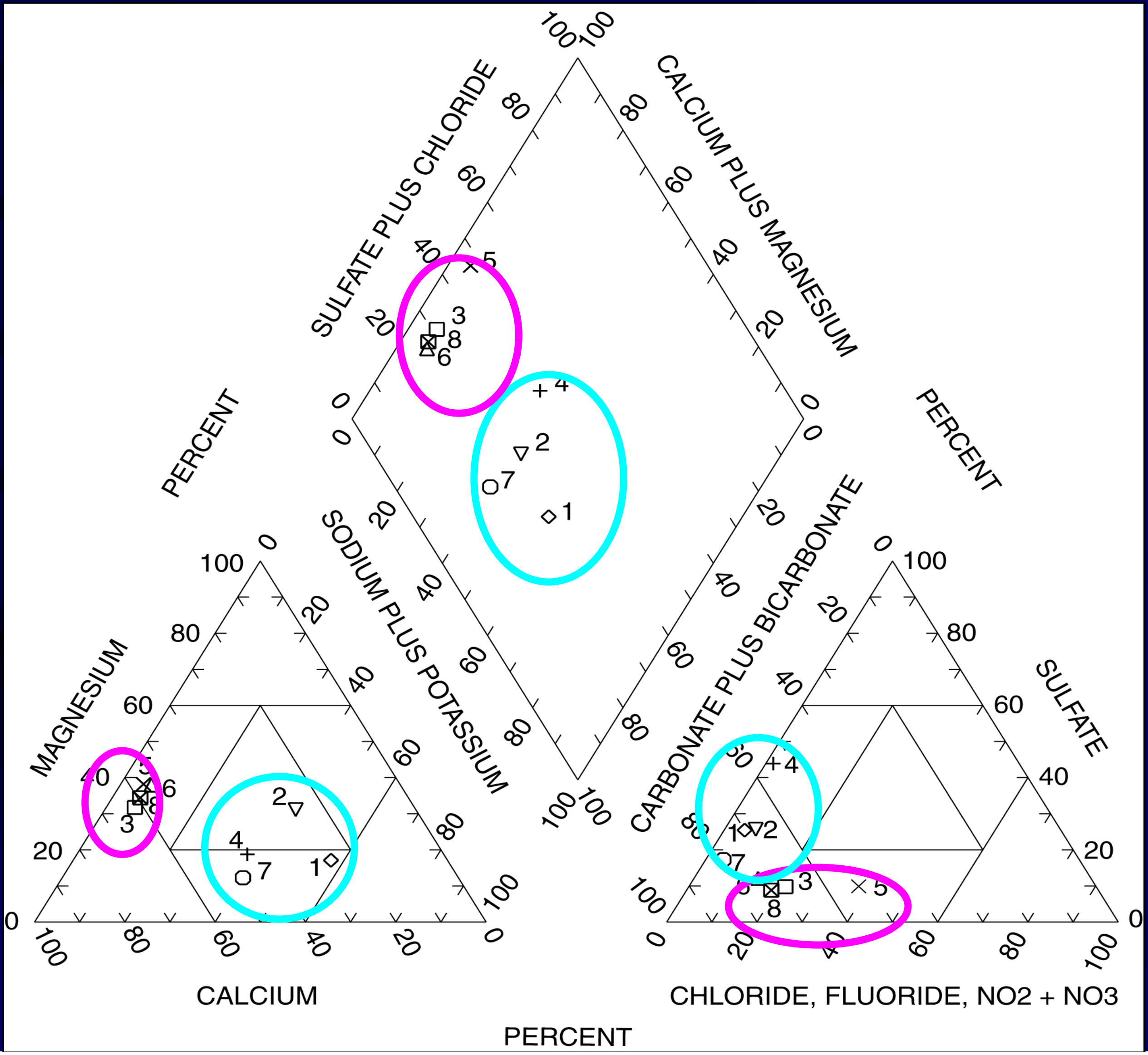
Distance from static water level to bedrock elevation



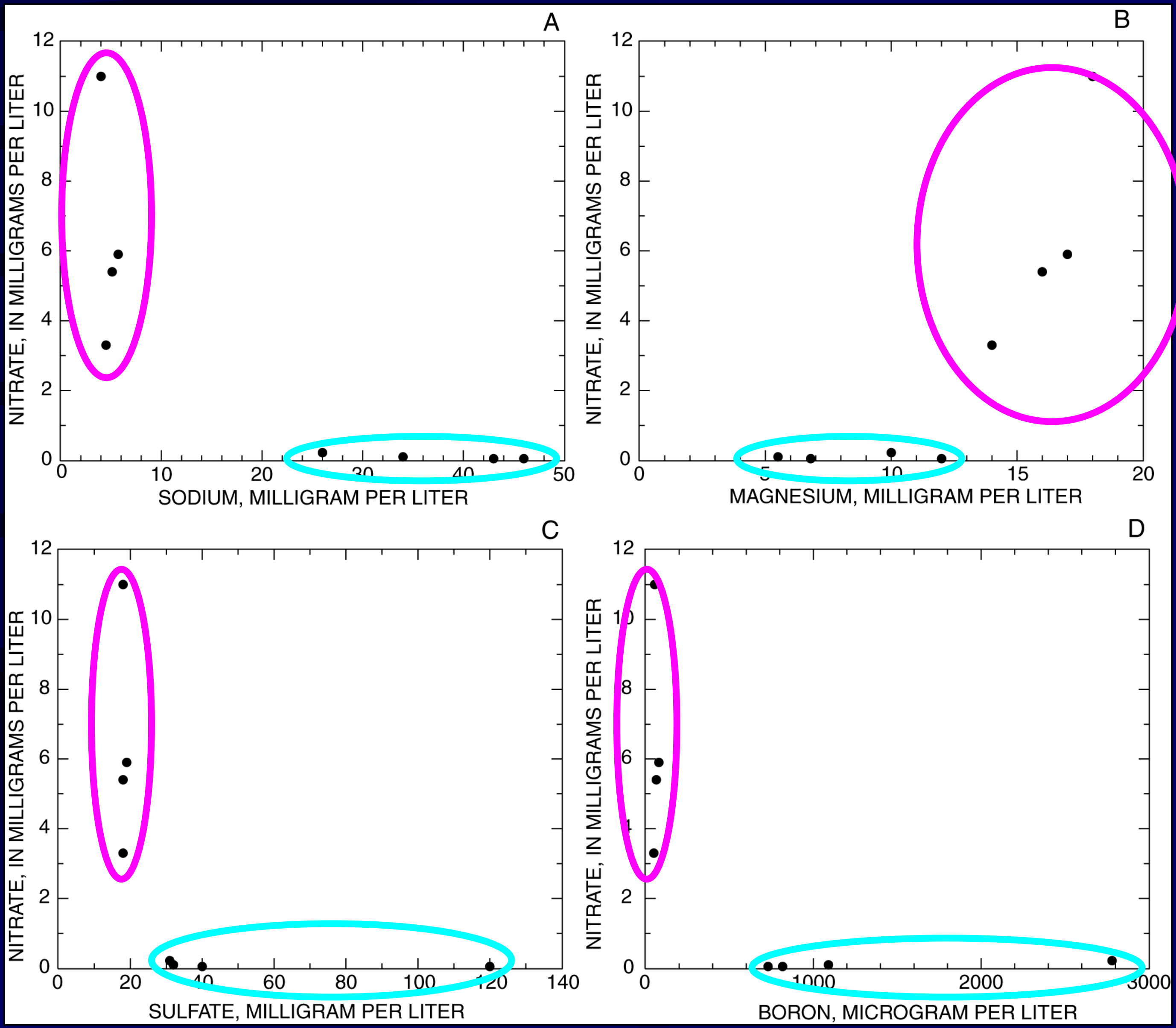
NO3 <1 mg/L

NO3 >1 mg/L

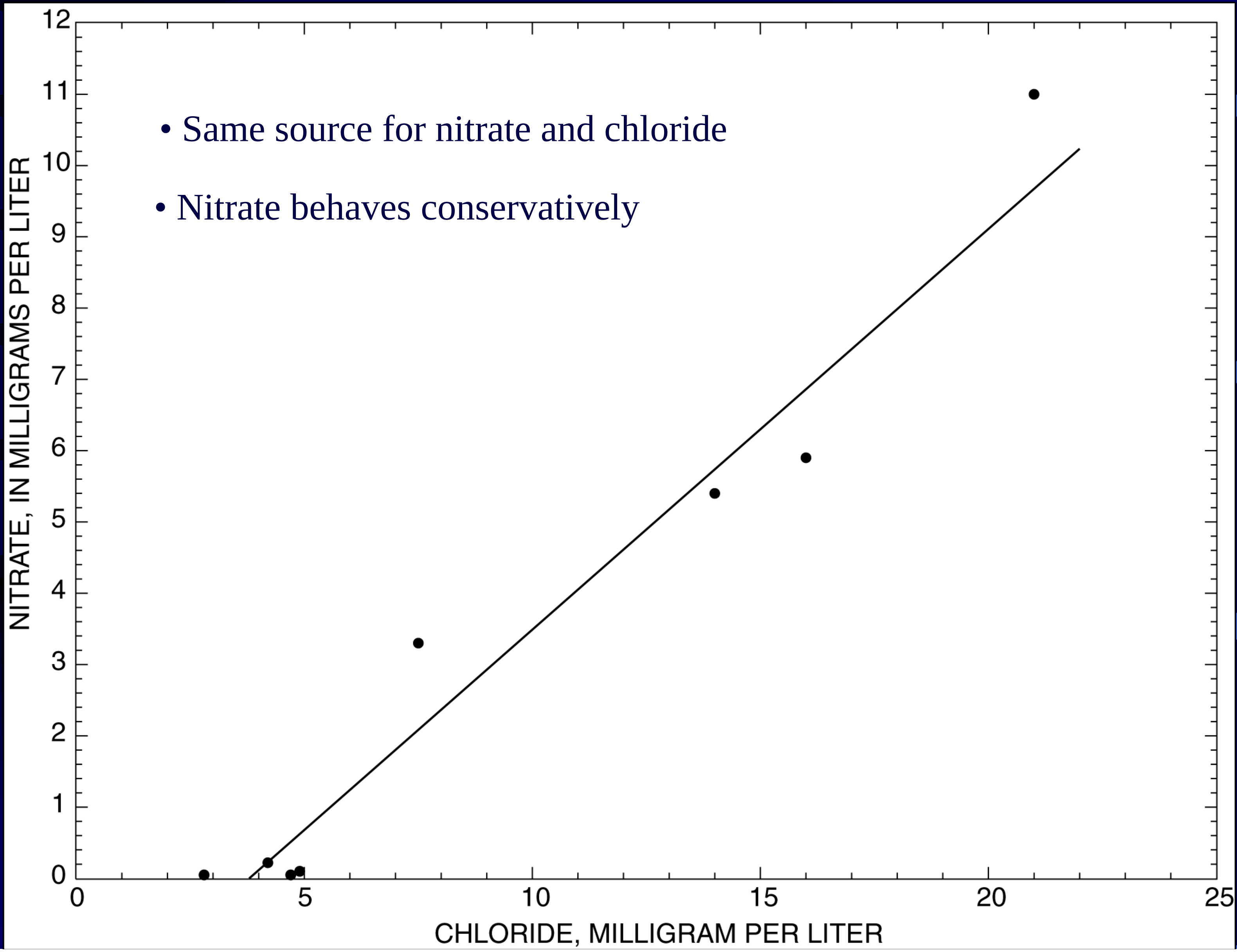
USGS analysis showed 2 distinct types of water chemistry



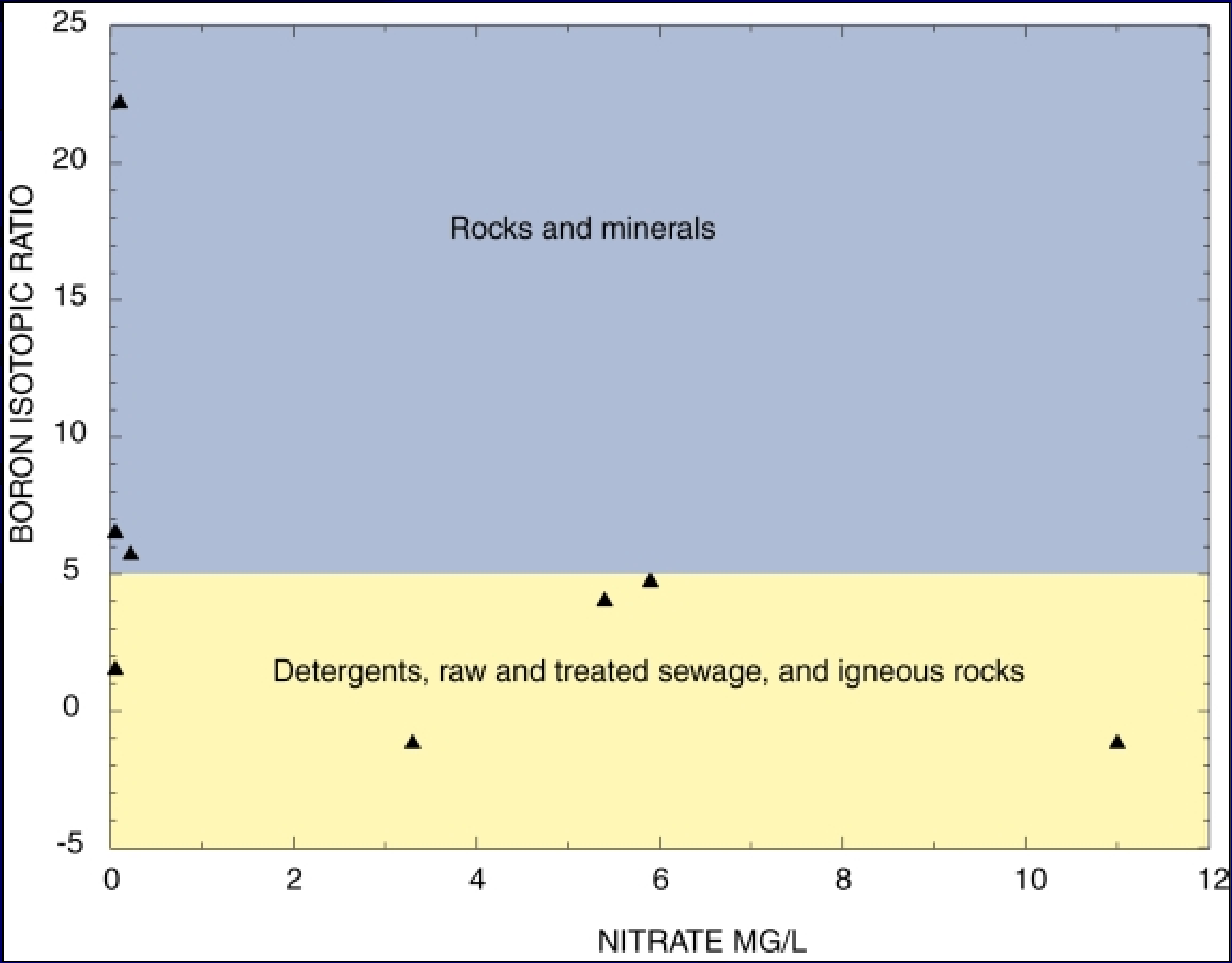
Nitrate occurrence is linked to certain other ions



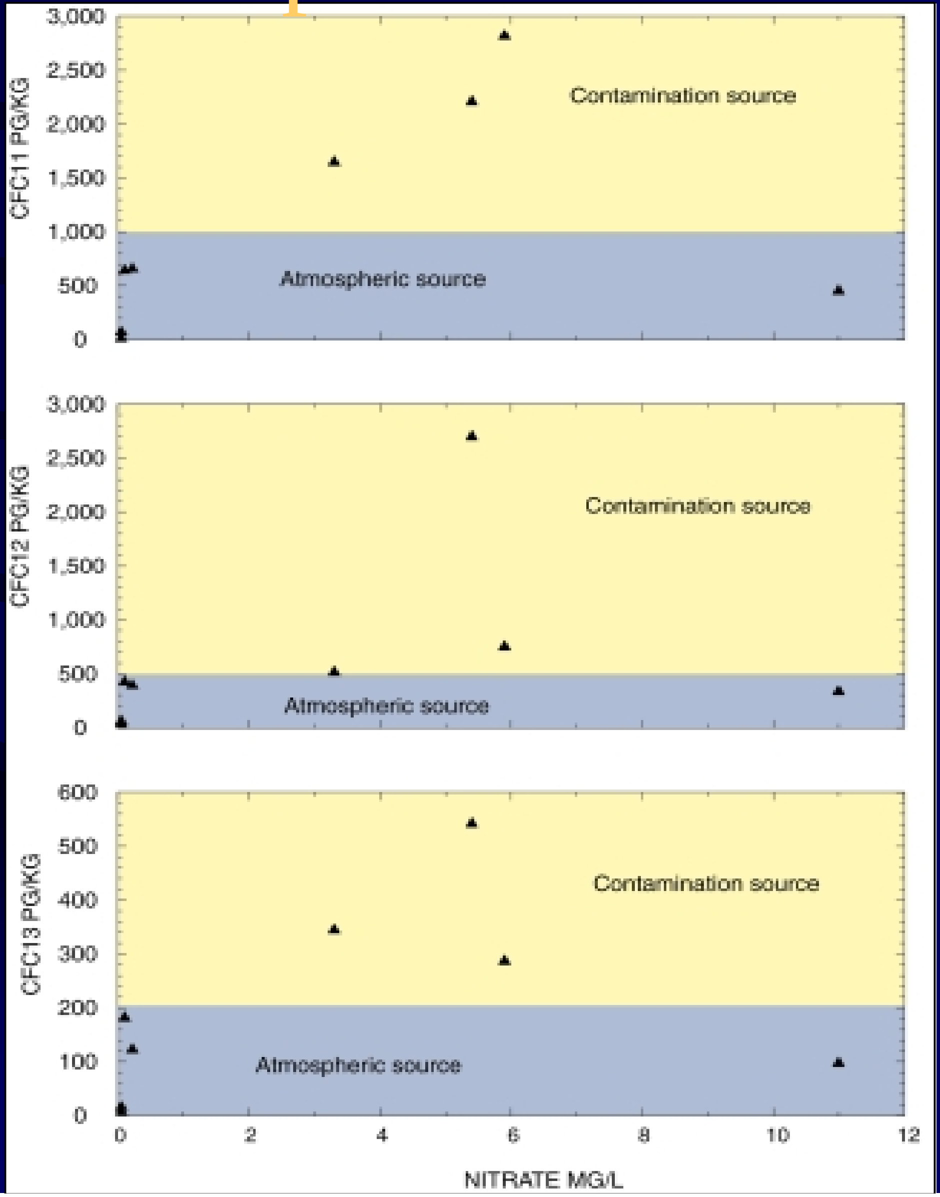
Nitrate and chloride are strongly correlated



Boron isotope ratios suggest human sources



Groundwater CFC's in "nitrate wells" are higher than atmospheric source levels



Conclusions from USGS Chemistry

- Two distinct water types in Scimitar
- Nitrate goes up with
  - increasing Chloride, Magnesium, and CFC
  - decreasing Sulfate, Sodium, and Boron
- Boron isotope ratios and CFC results suggest human influence with higher Nitrate
- Nitrate not reactive in shallow ground water

What we learned:

- Analysis of historic data was not very useful in determining vulnerability of particular sites.
- NO3 occurrence:
  - may be on the increase in certain areas.
  - varies depending on site-specific conditions.
  - is not necessarily related to “bad” conditions.
- In Scimitar Subdivision, NO3 is linked to shallow groundwater:
  - Strong correlation with other chemical signatures
  - Likely to have wastewater influence

What we should do:

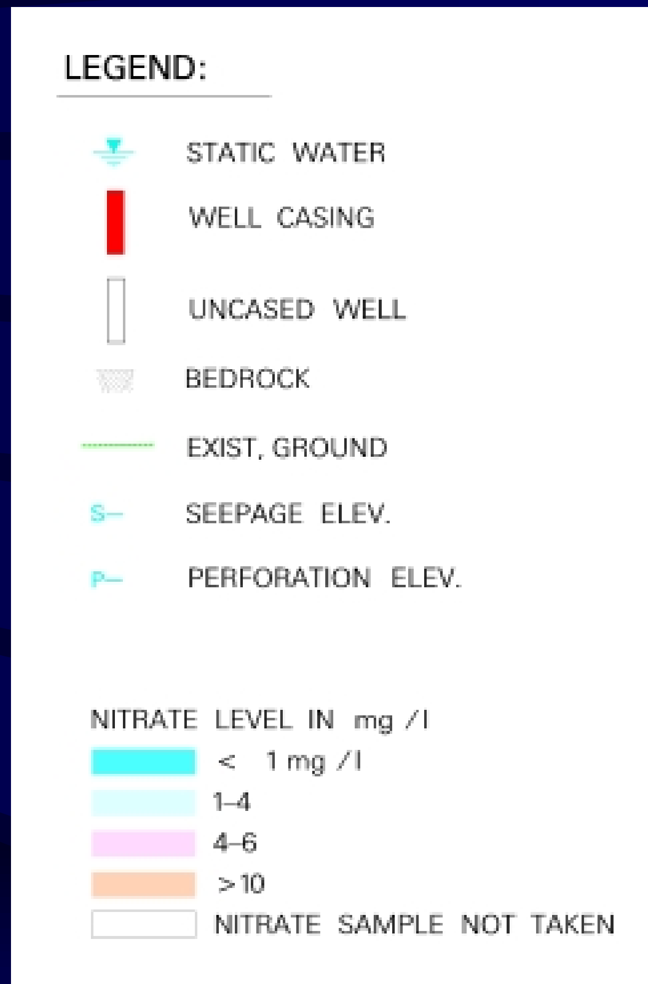
- Encourage development of deep bedrock aquifers.
- Reconsider the 100 foot setback.
- Control well construction:
  - Eliminate transport along casing annulus
  - Ensure isolation of clean aquifers

There are still a few things we don’t know:

- Do NO3 hotspots mean a general increasing trend?
- Are all shallow aquifers influenced by septic discharges?
- How deep do we have to go?
- Will improved well construction make a difference?
- Will well remediation eliminate NO3?

Thank you for your interest.

Stay tuned as the Municipality seeks additional funding for further investigations.


LEGEND:
STATIC WATER
WELL CASING
UNCASED WELL
BEDROCK
EXIST. GROUND
S—
SEEPAGE ELEV.
P—
PERFORATION ELEV.
NITRATE LEVEL IN mg /l
< 1 mg /l
1-4
4-6
>10
NITRATE SAMPLE NOT TAKEN