Assessment of Water Level Trends in Bedrock Wells in NH

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Acknowledgements

- Joseph Ayotte, Denise Argue, Thomas Mack USGS-NH
- David Wunsch, NHGS & State Geologist
- Derek Bennett, NHDES
- Stephen Roy, NHDES

USGS Open-File Report 2010–1189

Project Objectives

1) Assess groundwater level trends in bedrock in NH (statewide and regionally)
2) Assess if trends are significant and reason for trends
   - Water use
   - Climatic
   - Well construction practices
   - Local effects (geology, topography, density of development etc.)
3) Make recommendations regarding groundwater level monitoring

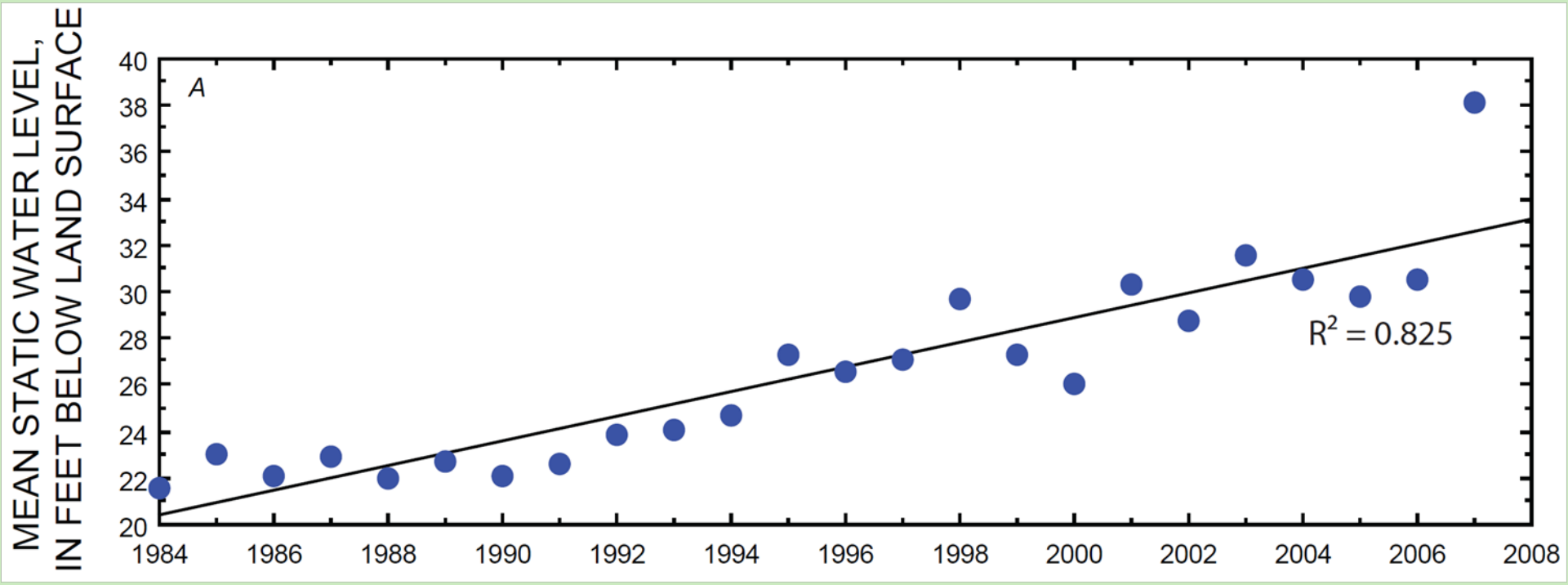
Why??

- Frequent statements from drillers and the public about “running out of water”
- Documented changes in New England Hydrology

  (growing season increase, stream flow, ice out/spring run-off, increased water use, land development)
- 2005 Groundwater model of the seacoast bedrock aquifers predicted impacts to water levels due to:
  1) Climate change
  2) Water use
  3) Impervious surfaces
  4) Sewering

  USGS SIR 2008–5222
- Known trouble spots for private and public wells

Annual Mean Static Water Level (SWL) in New Bedrock Wells in NH



Background Information

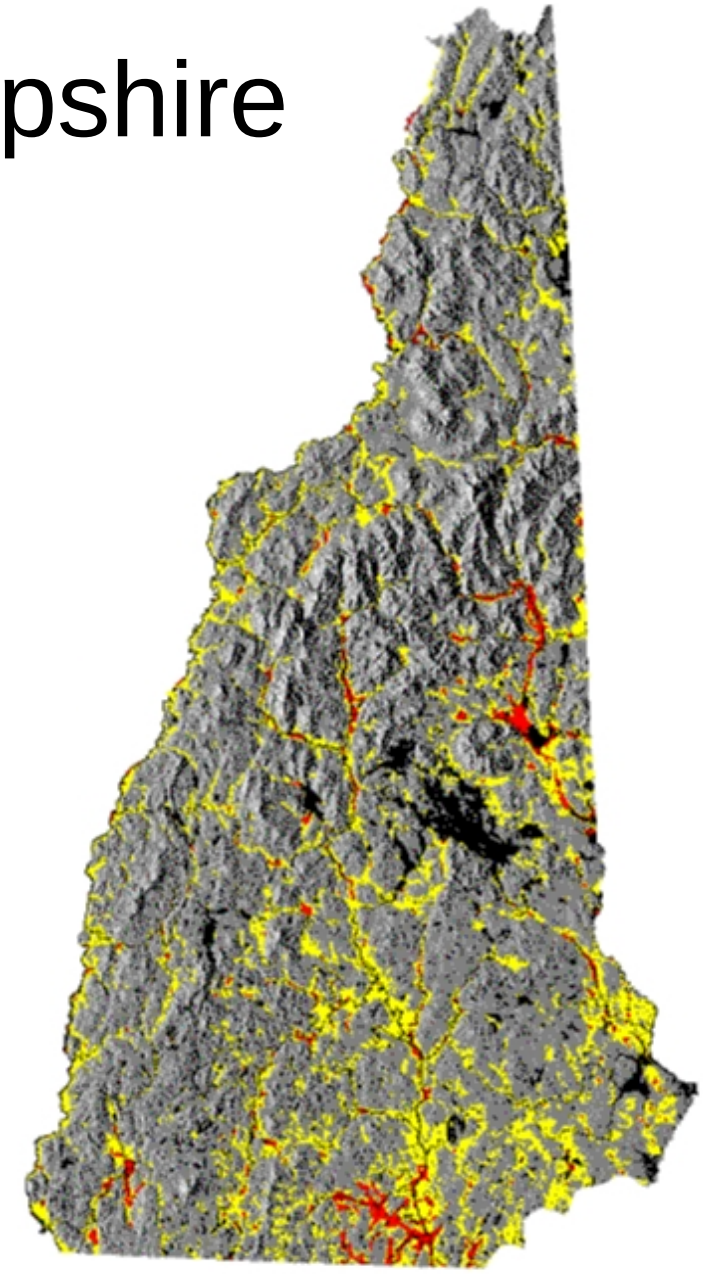
- 50% of NH residents obtains their drinking water from bedrock wells
  - 40% Private wells
  - 10% Public water supply
- Approximately 220,000 bedrock wells in NH
- Well construction reports have been submitted to the state since 1984
- Population of NH has doubled since 1984

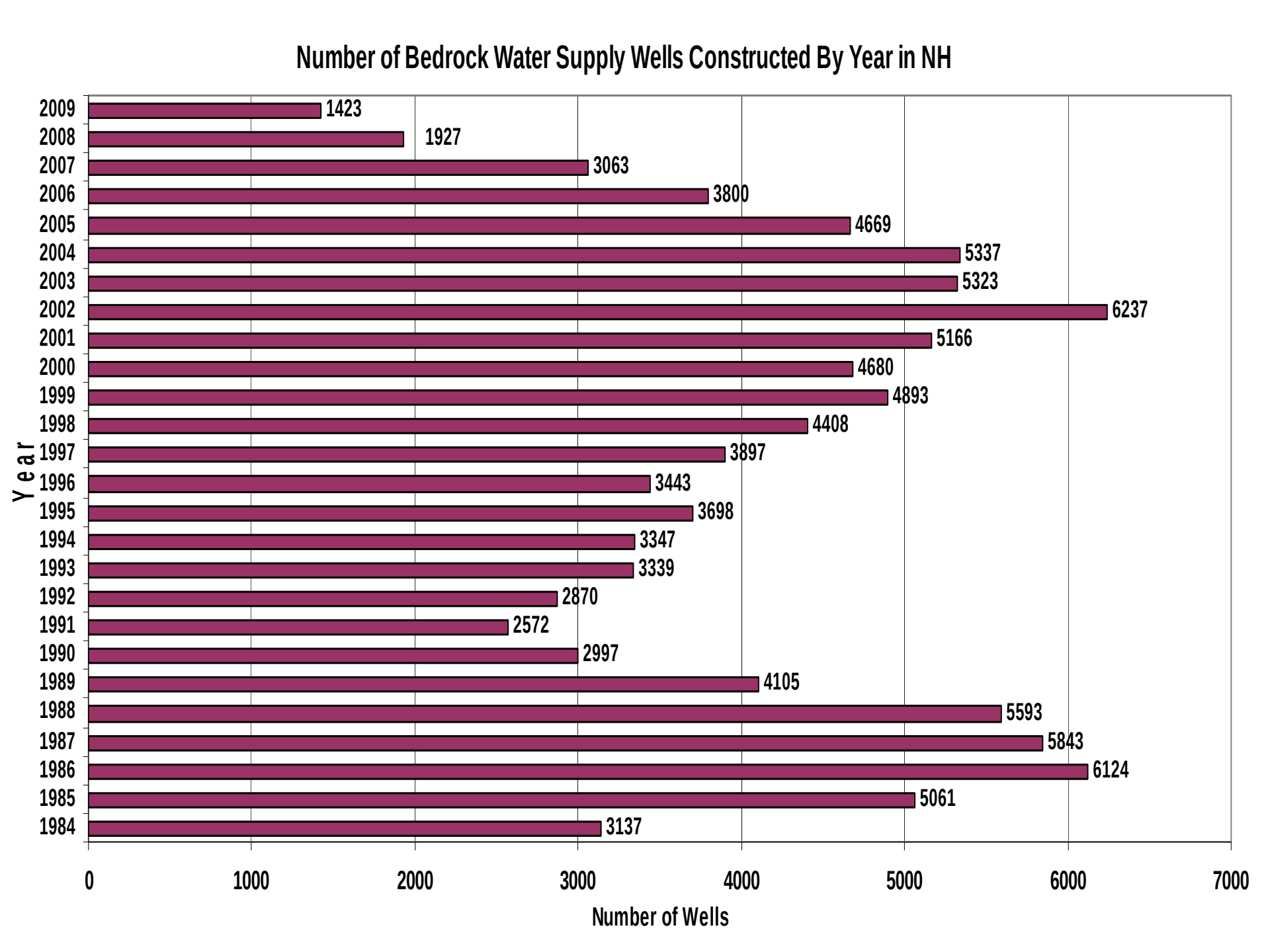
Aquifers in New Hampshire

Only 14% of the state is covered by stratified drift aquifers.

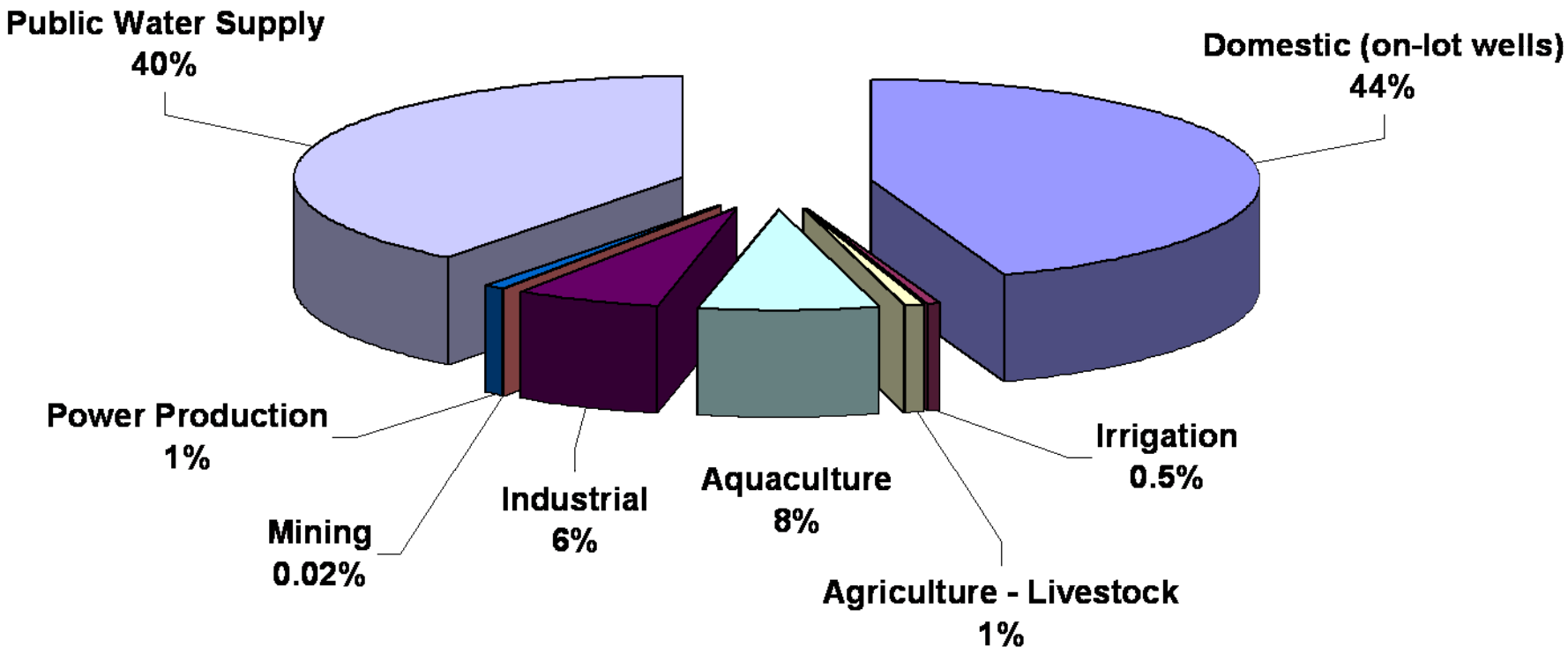
Transmissivity less than or equal to 2,000 ft^2/day

Transmissivity greater than 2,000 ft^2/day

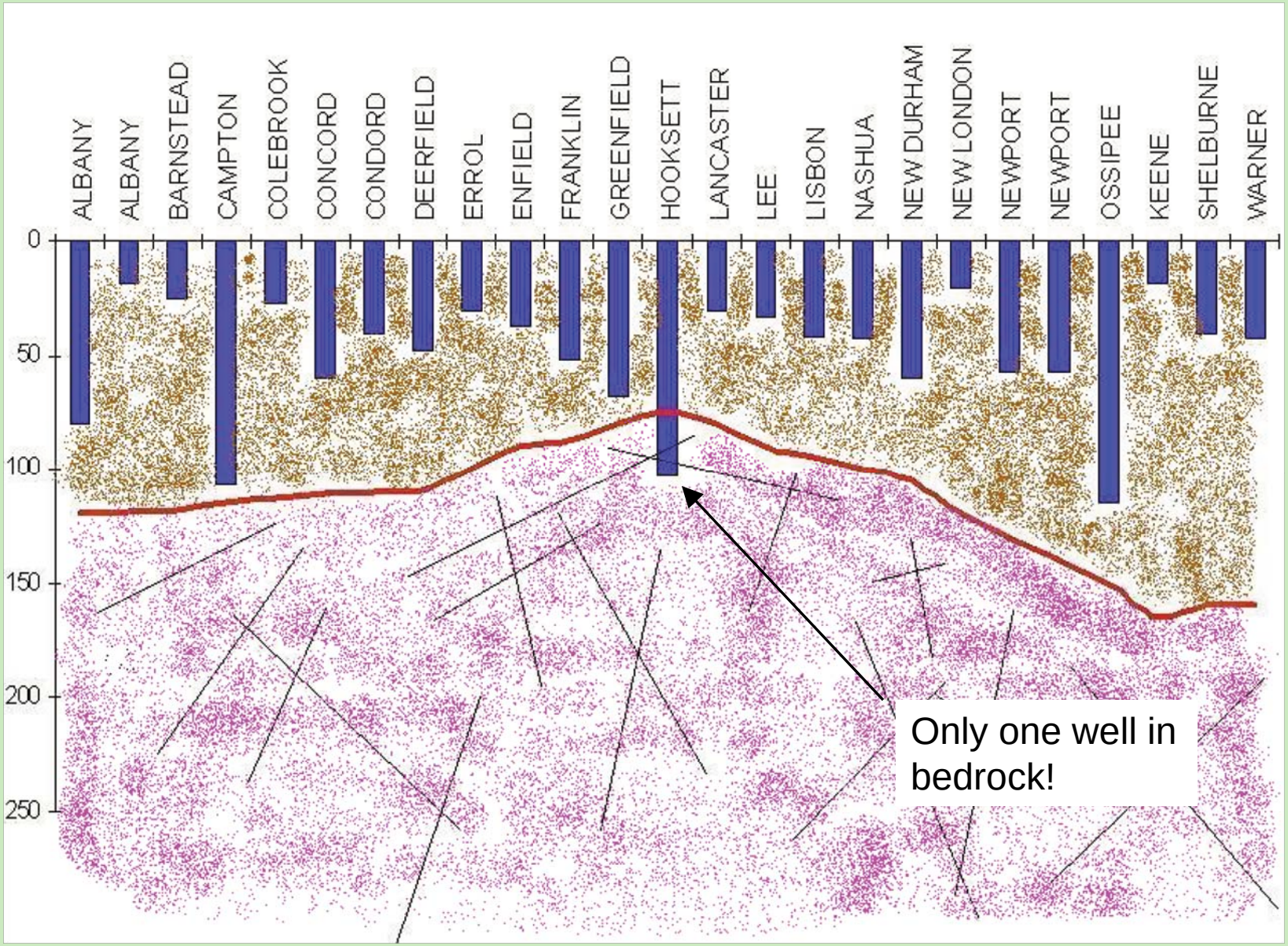



Number of Bedrock Water Supply Wells Constructed By Year in NH
Year
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997
1996
1995
1994
1993
1992
1991
1990
1989
1988
1987
1986
1985
1984
1423
1927
3063
3800
4669
5337
5323
6237
5166
4680
4893
4408
3897
3443
3698
3347
3339
2870
2572
2997
4105
5593
5843
6124
5061
3137
0
1000
2000
3000
4000
5000
6000
7000
Number of Wells

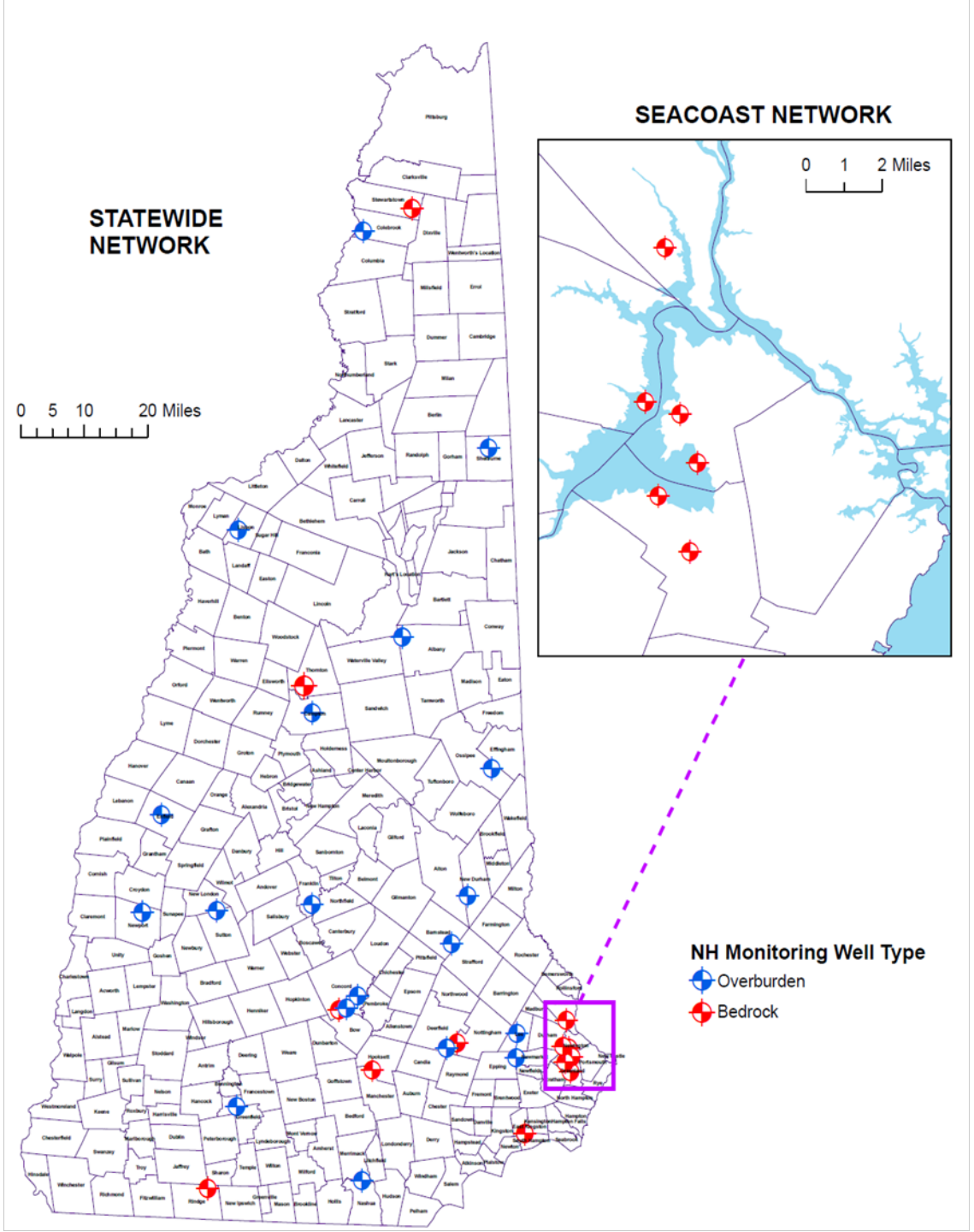
Average Daily Groundwater Use in NH - 93,000,000 gallons per day



NH Monitoring Well Network Prior to 2007



NH's Post 2007 Bedrock Well Monitoring Network includes 33 bedrock wells at 11 sites.



Existing SWL Data Sets Reviewed

- Contamination Sites – (pump and treat effects, shallow bedrock, well integrity)
- Canada – Quebec Province established and quickly unfunded water level monitoring sites
- Nova Scotia – Good data but different geology
- Maine's Monitoring Network
- Massachusetts – 3 bedrock monitoring wells
- Water levels at large groundwater withdrawals sites in NH (30-40 wells)
- Well construction records in NH

Majority of bedrock well monitoring sites initiated within the last 7-10 years

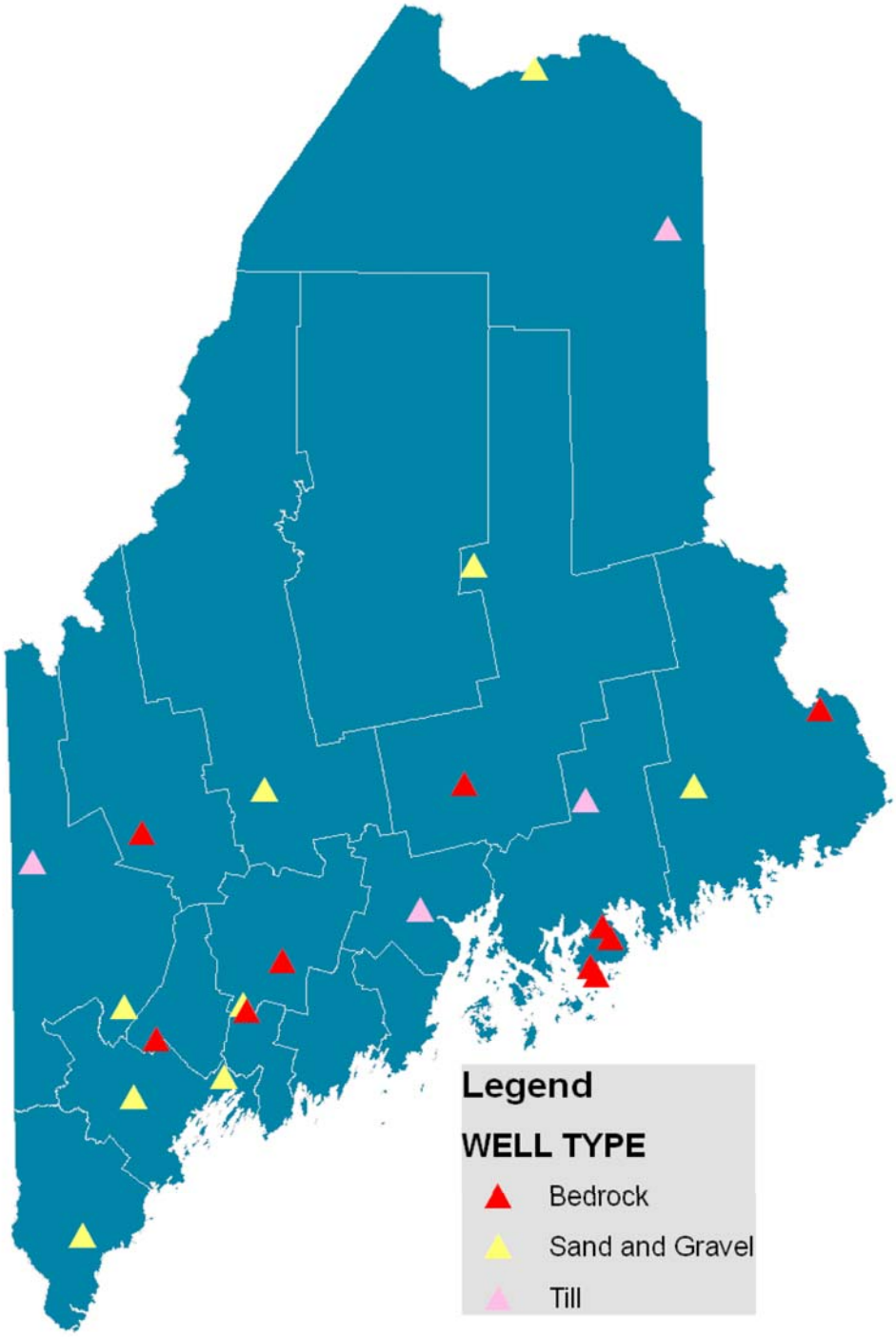
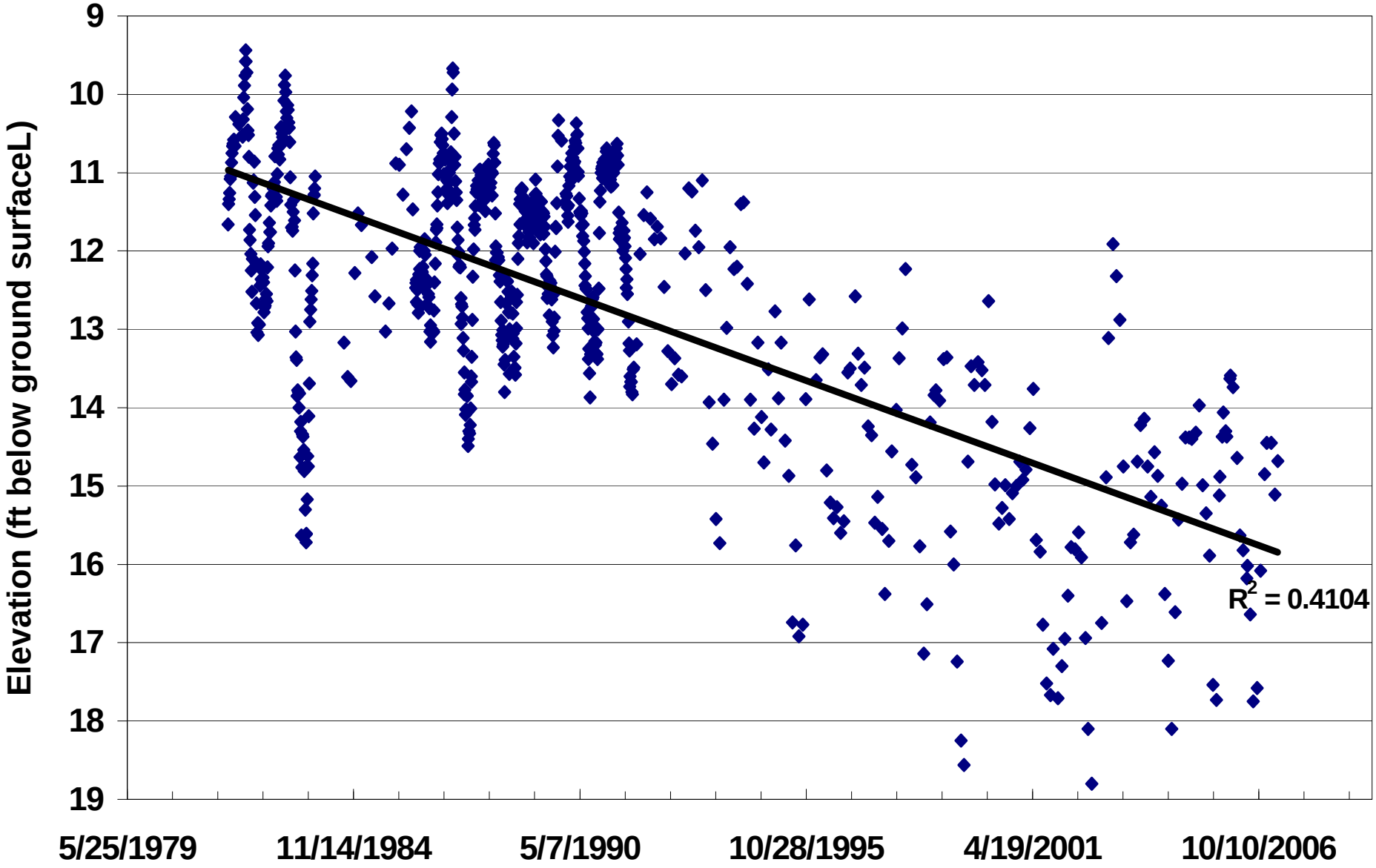
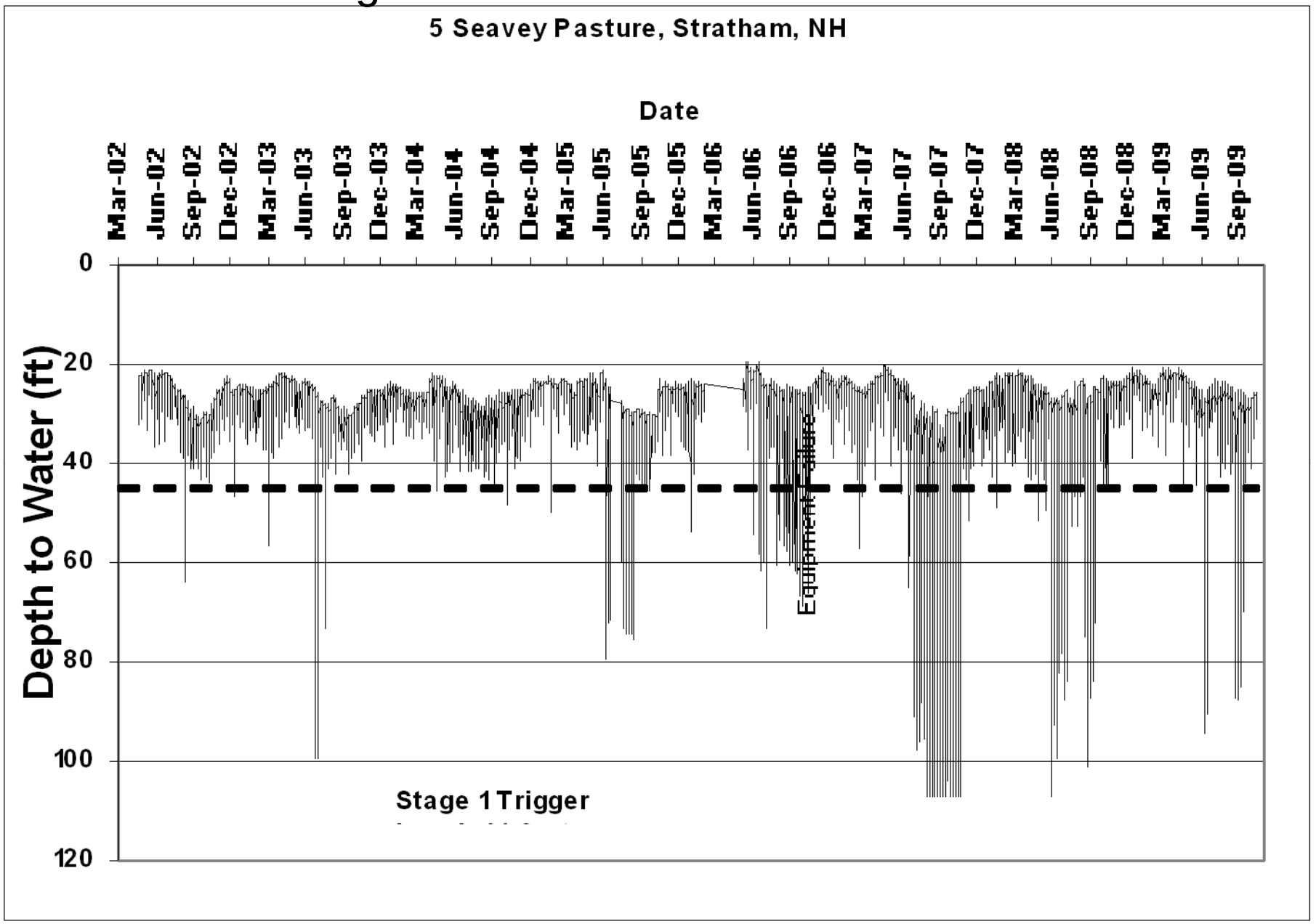


Figure 1b: Water Level Elevation in Pelham, MA [MA-PDW (740 ft Deep)]



Typical Water Level Trend in Residential Bedrock Wells Near Large Groundwater Withdrawal Sites in NH



Well Completion Reports in NH

Well Number

_____
(FOR CONTRACTOR'S USE)

This report must be submitted to the N.H. Water Well Board no later than **90 days** after the completion of the well.

State of New Hampshire
Water Well Board
PO Box 95
Concord, NH 03302-0095

Well Completion Report

Special Notes on Back

Staff Use Only

WRB# _____

LOCACC _____

1. **Well Owner/Home Owner:** _____
and/or Name Permanent Mailing Address

Building Contractor: _____
Name Permanent Mailing Address

2. **Location of Well:** Town _____ Address _____
Street No Road Name

Town: Tax Map No._____Lot No._____

Latitude N_____ °_____._____ GPS Manufacturer: ☐ Garmin ☐ Magellan

Longitude W_____ °_____._____ ☐ Other _____

Please Report Coordinates in: Map Datum: WGS 84 Position Format: hddd°mm.mmm

3. **Non-Conforming Well Location Form Required:** ☐ Yes ☐ No
If Yes, please attach form to this report.

4. **Date Well was Completed:** _____

5. **Proposed Use of Well:** ☐ Domestic ☐ Monitoring Well ☐ Other (Explain) _____

6. **Reason for Constructing Well:** ☐ New Supply ☐ Replace Existing Supply ☐ Other _____

7. **Type of Well:** ☐ Drilled in Bedrock ☐ Drilled in Gravel ☐ Dug ☐ Driven Point ☐ Wash Well ☐ Other_____

8. **Total Depth of Well** _____ feet below land surface.

9. **Depth to Bedrock** _____ feet below land surface.

10. **Casing Details:** Length _____ft., Dia. _____in., Material _____, Wt. _____lb./ft.

11. **Method(s) of Sealing Casing to Bedrock:** ☐ Drive Shoe ☐ Drillings ☐ Grout ☐ Other _____

12. **Measured Yield:** ☐ Bailed ☐ Pumped ☐ Compressed Air, for _____ Hours, at _____GPM

13. **Static Water Level:** _____ feet below land surface. Date Measured_____

14. **Water Analysis:** Has the water been analyzed? ☐ Yes ☐ No If yes, where_____

15. **Stratigraphic and Lithologic Log:**

Depth in Feet From	To	Water Bearing	Surficial Material Description	Texture	Type
Ground Surface			☐ Sand ☐ Gravel ☐ Till ☐ Clay/Silt ☐ Weathered Bedrock		
			☐ Sand ☐ Gravel ☐ Till ☐ Clay/Silt ☐ Weathered Bedrock		
			☐ Sand ☐ Gravel ☐ Till ☐ Clay/Silt ☐ Weathered Bedrock		
			☐ Sand ☐ Gravel ☐ Till ☐ Clay/Silt ☐ Weathered Bedrock		
			☐ Sand ☐ Gravel ☐ Till ☐ Clay/Silt ☐ Weathered Bedrock		
Competent Bedrock			Bedrock Type	Texture	Color(s)
			☐ Granite ☐ Basalt ☐ Schist ☐ Gneiss ☐ Other		
			☐ Granite ☐ Basalt ☐ Schist ☐ Gneiss ☐ Other		
			☐ Granite ☐ Basalt ☐ Schist ☐ Gneiss ☐ Other		
			☐ Granite ☐ Basalt ☐ Schist ☐ Gneiss ☐ Other		

Suggested Descriptors: Texture: Fine Medium Coarse
Color: White = 1, Gray = 2, Black = 3, Blue = 4, Green = 5, Yellow = 6, Brown = 7, Pink = 8

Please Complete Additional Information on Reverse Side

16. **Yield Log:** If the yield was tested at different depths during drilling, list below.

Feet	GPM	Feet	GPM	Feet	GPM

17. **Additional Well Development Methods Used:**

Hydro-Fracturing Information: ☐ Standard ☐ Zone No. of Settings _____

Packer Settings (Ft) 1st Set_____ 2nd Set _____ 3rd Set _____ 4th Set _____

High Pressure (PSI) _____ _____ _____ _____

Low Pressure (PSI) _____ _____ _____ _____

Surging Depths: 1st Set_____ 2nd Set _____ 3rd Set _____ 4th Set _____

Other Methods (Explain) _____

18. **Measured Yield After Development** _____ GPM, Before Development _____ GPM

19. **Additional Well Seals Installed Inside of Well:**

☐ Jaswell Type Seal ☐ Shale Packer Depth Setting _____ feet below land surface.

☐ Other (Explain) _____

Drop Pipe Used: ☐ Steel ☐ PVC ☐ Grouted Between Liner and Outer Casing

20. **Screen Details:** Make & Type _____, Material _____, Length _____ft.

Diameter _____ in., Slot Size _____, Depth to top of screen from land surface _____ft.

Gravel Pack, if used: Gravel Size or Type _____

21. A water well contractor must provide a drawing indicating the position of each well, if more than one well is located within the lot, relative to significant permanent man-made features. Provide this information in the space below, or as an attachment to this form. Additional information attached: ☐ Yes ☐ No

22. A technical driller must submit a separate well completion report for every monitoring well installed into bedrock at a single property or place of business. A technical driller also must submit a well completion report for the deepest monitoring well it installs at a property or place of business. If the technical driller has not completed a separate well completion form for each monitoring well they installed in unconsolidated material at a single property or place of business, then it must prepare and submit a map showing the location of each monitoring well installed by the technical driller relative to significant man-made or natural features at a given site, and relative to well(s) located with GPS. Please provide this sketch below, or as an attachment to this Well Completion Form. Additional information attached: ☐ Yes ☐ No

23. Please attach results of drawdown test if performed.

24. Please provide any additional or unusual information about the well in the space below, or as an attachment to this form.

Additional Notes:

Doing Business as _____
Company or Business Name

Report Filed by _____
Licensee Signature

This form is also available on line at www.des.nh.gov/wwb

Date of Report _____ License No. _____

Information Contained on New Well Construction Records

- Well driller info.
- Address/tax map
- Location coordinates (varies/sometimes)
- Well owner name
- Date of well installation
- Purpose of well
- Reason for well
- Type of well
- Depth of well
- Depth to bedrock
- Casing length
- Yield test info
- Static water level
- Static water level date
- Overburden material description
- Hydrofracture info
- Casing/grout information

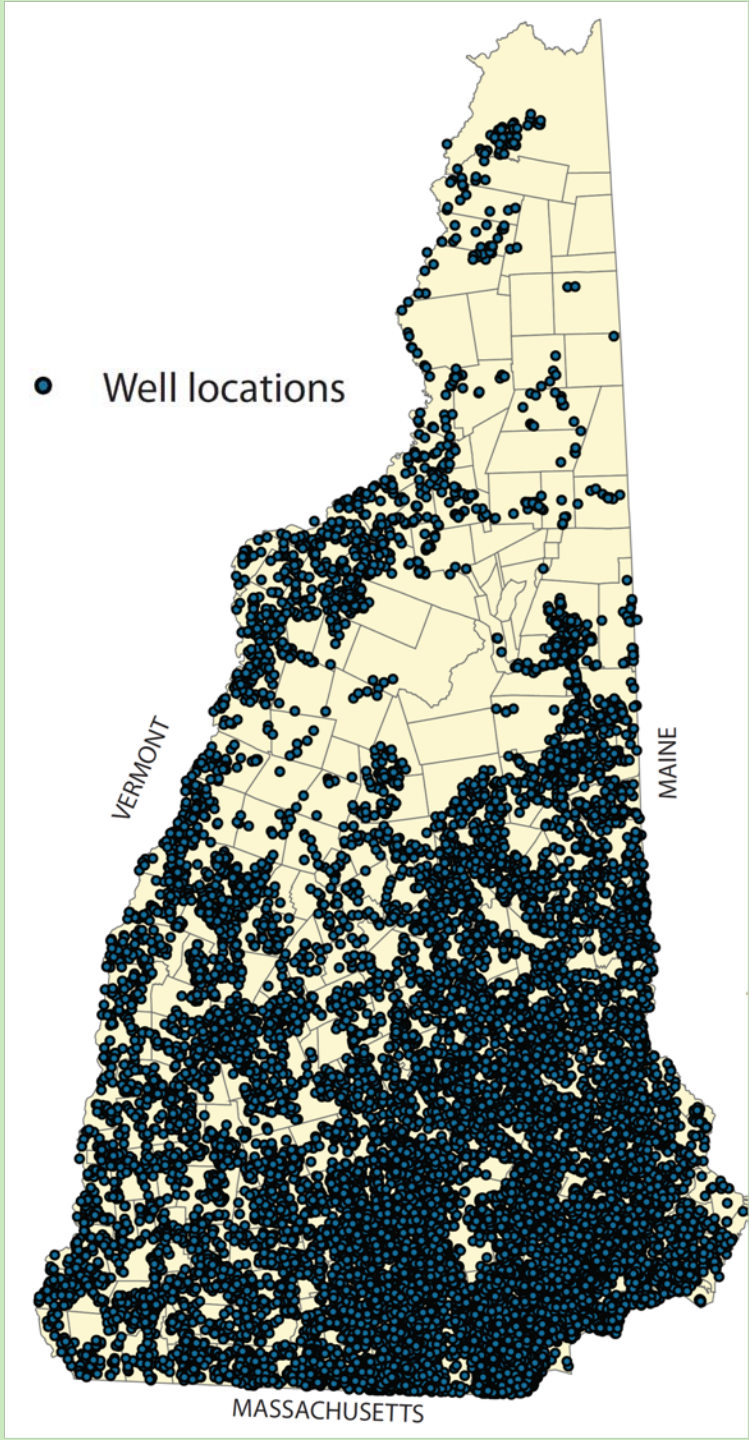
Accuracy and completeness of information varies and has improved over time due to enforcement efforts.

What We Did

- Analyzed 60,000 reported values of water levels over the period of 1984-2007 reported on well construction logs
- 50% wells geolocated (gps, E-911, digital tax maps)
- Also analyzed other well characteristics
  - Total well depth
  - Length of well casing
  - Well yield
  - Depth to bedrock
  - Elevation
  - Proximity to topographic relief
  - Hillside orientation
  - Geology
  - Deepened and replacement well trends
  - Population density

Location of Wells Constructed Since 1984 with Reported Water Levels

Records provide a high quantity of relatively low quality data for statistical analyses (64% of water levels measured end in a “0” or “5”)



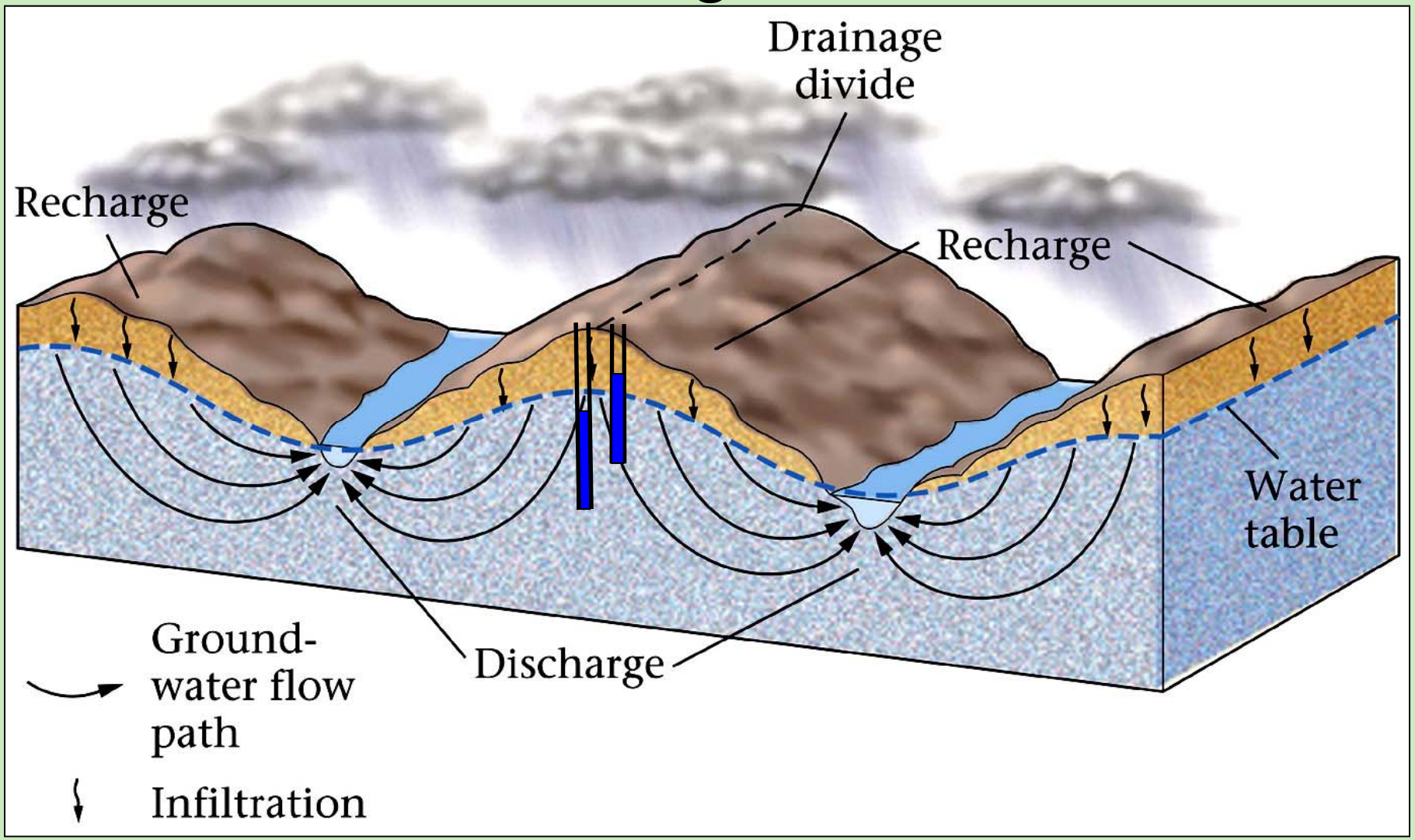
Summary of Findings

- Apparent deepening of static water levels of about 14 feet in newly constructed wells from 1984-2007 (the rate is double in some areas)
- Depth of wells, length of casing, length of casing into bedrock also increased in this time period
- Wells on hill slopes or higher elevation generally have deeper water levels, lower yields and tend to fail more often
- Water levels in wells located on high areas on south facing slopes are generally deeper than north facing slopes
- Deepening of SWL in some towns is twice the rate of deepening in other towns
- Not able to statistically determine if increases in water use is a cause for lower static water levels (too many changing variables with similar trends).

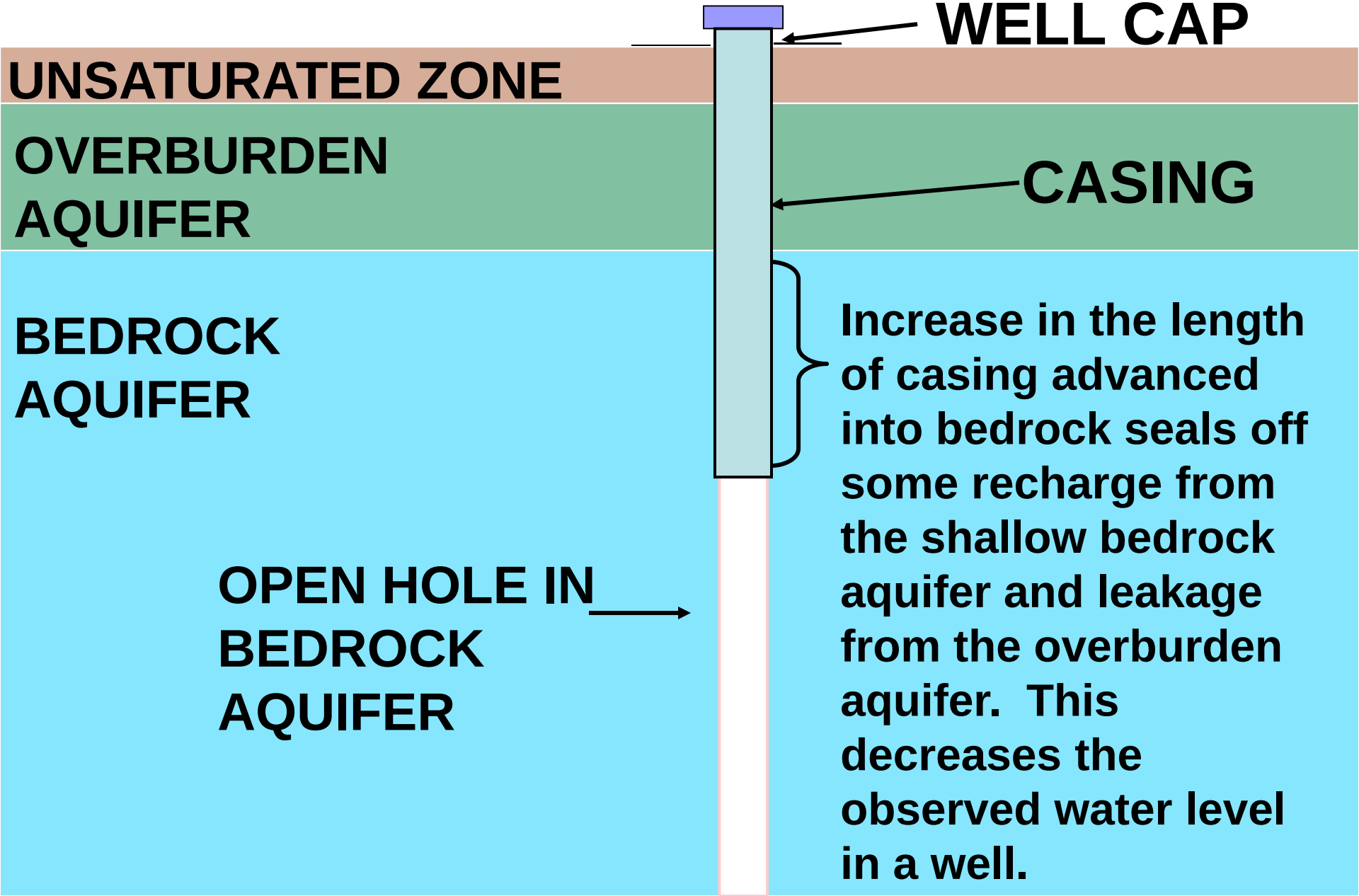
Probable Primary Cause of Lower SWL in Newly Constructed Wells

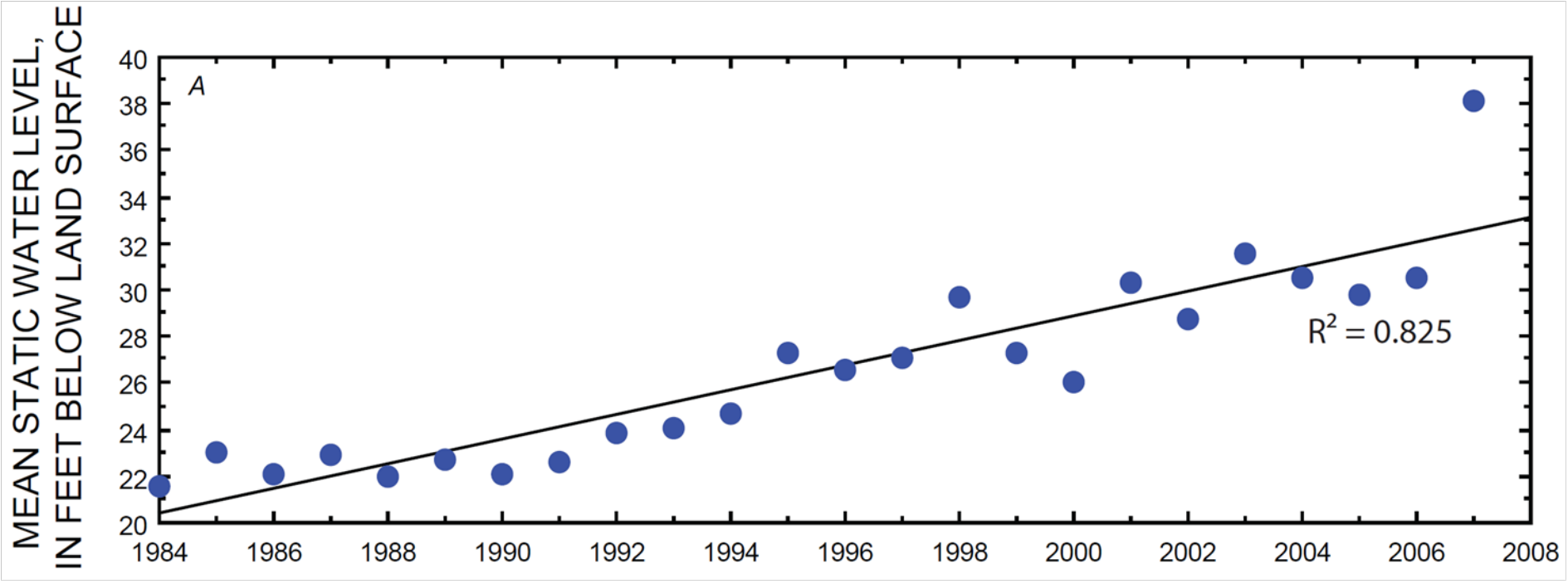
Lower heads in deeper wells coupled with increase casing length in bedrock diminish contribution of water from the overburden/shallow fractures result in deeper bedrock water levels

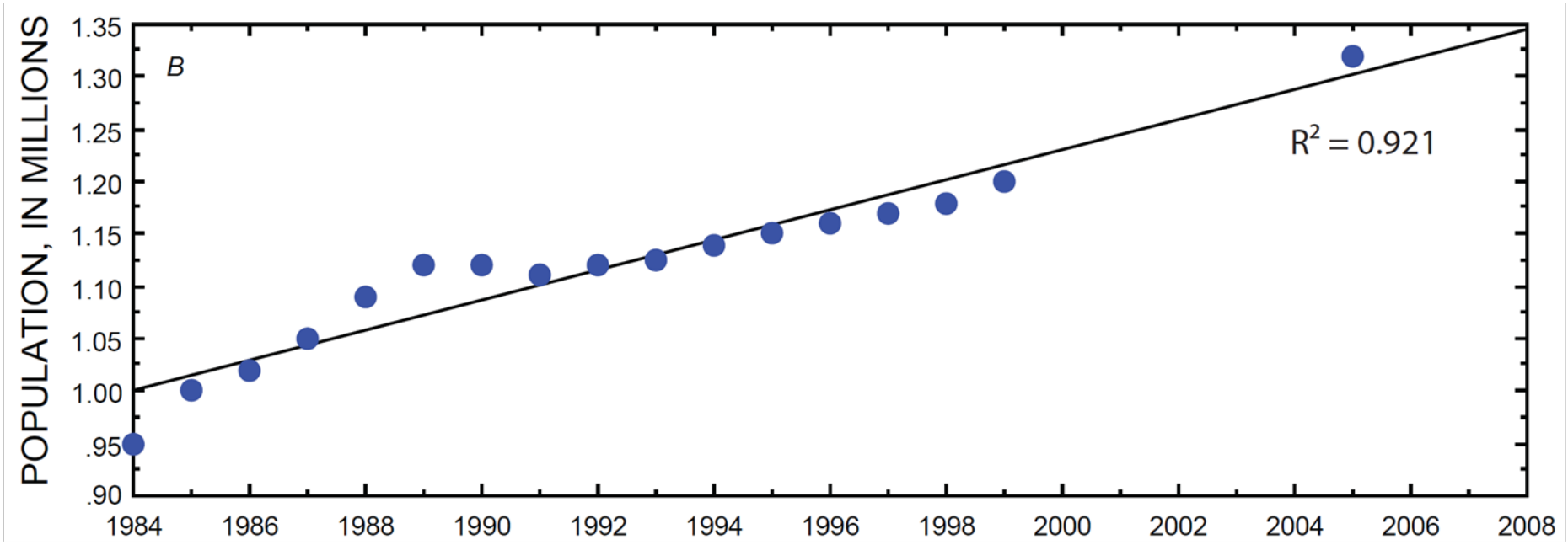
Typical Potentiometric Surface in Recharge Areas



Bedrock Well

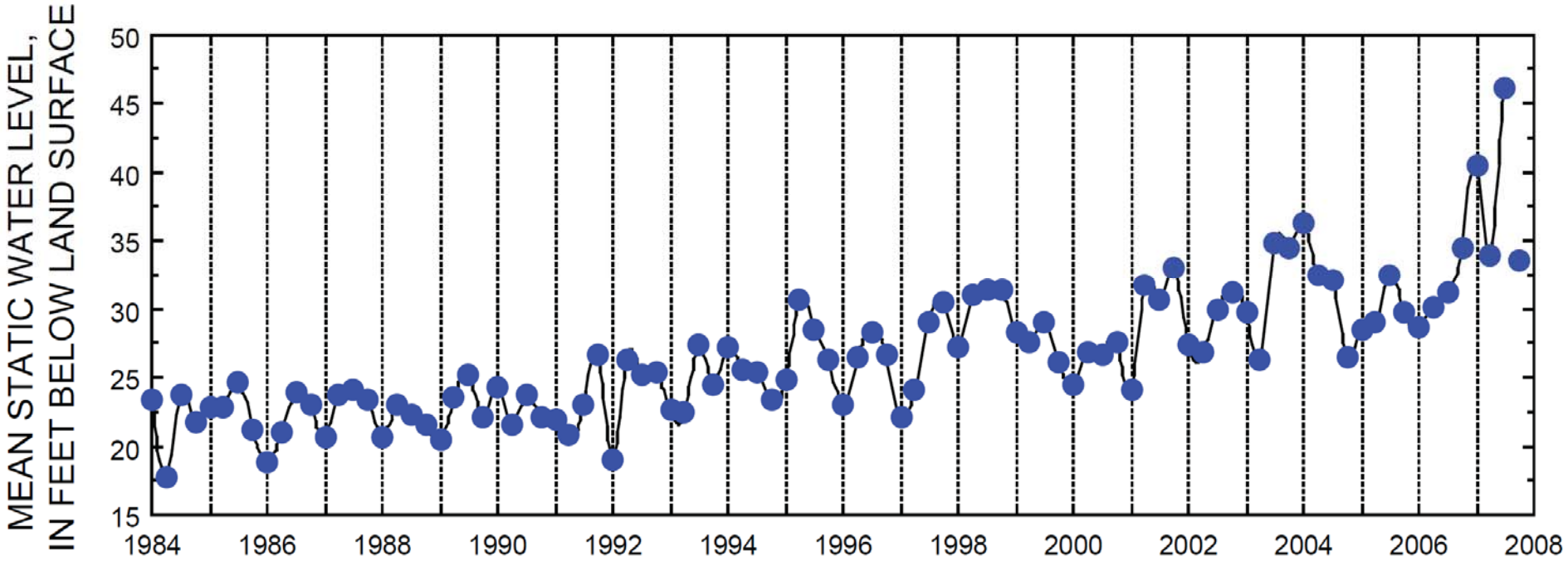


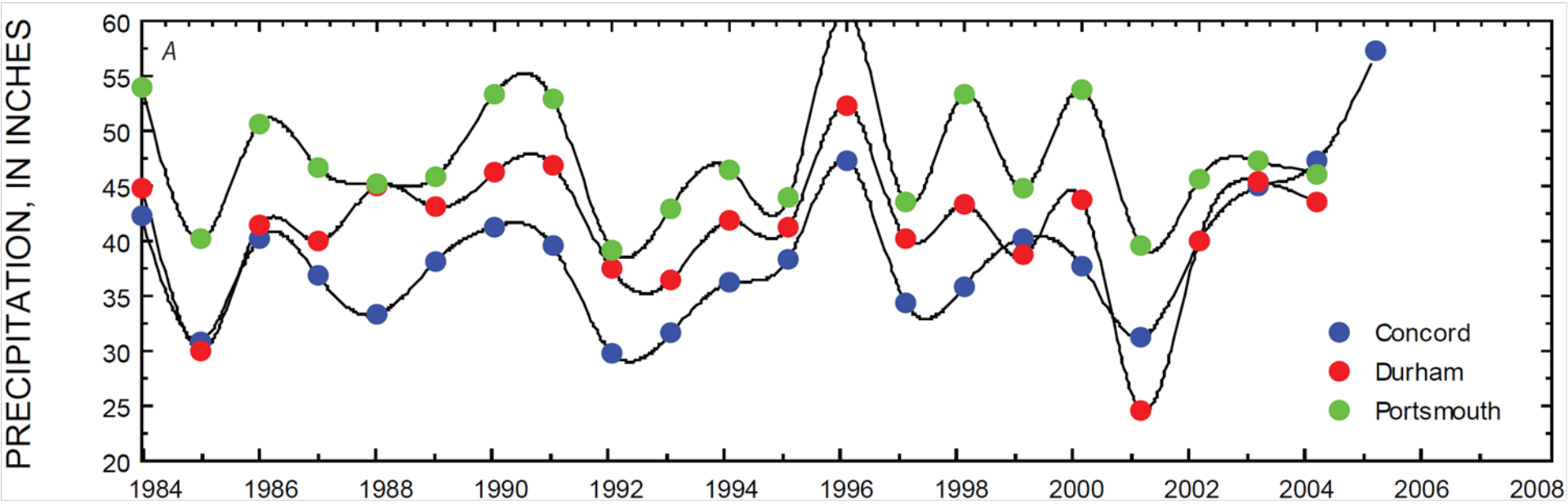

A
MEAN STATIC WATER LEVEL, IN FEET BELOW LAND SURFACE
40
38
36
34
32
30
28
26
24
22
20
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
R² = 0.825

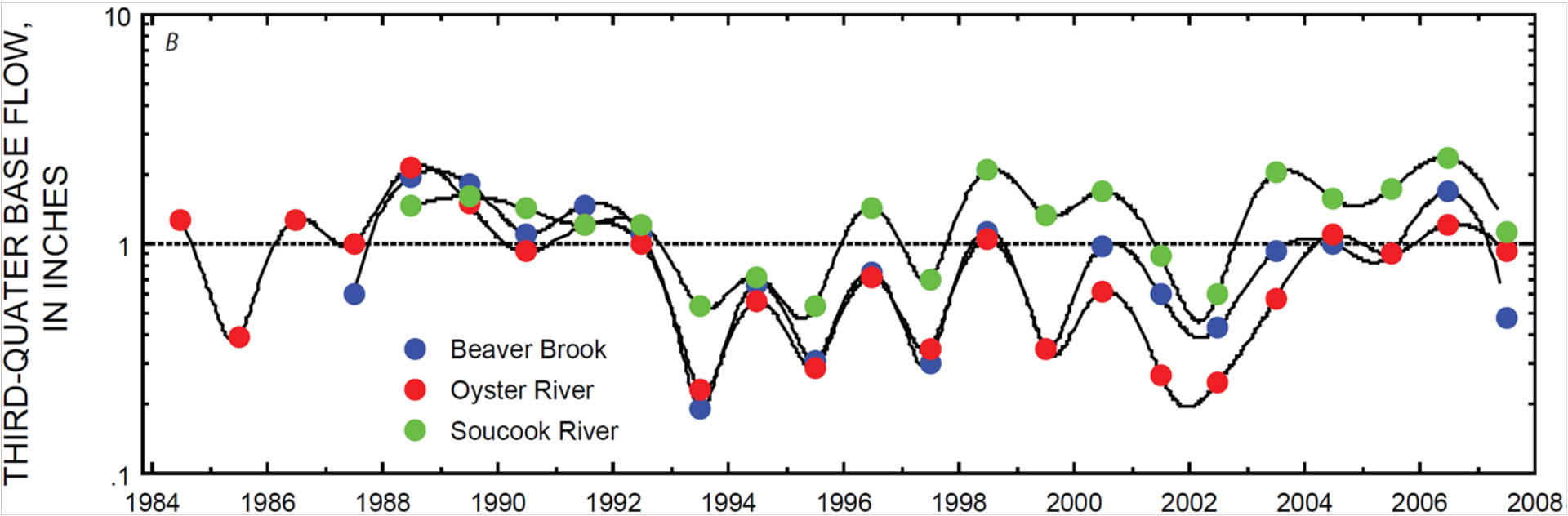

B
POPULATION, IN MILLIONS
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
.95
.90
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
R² = 0.921

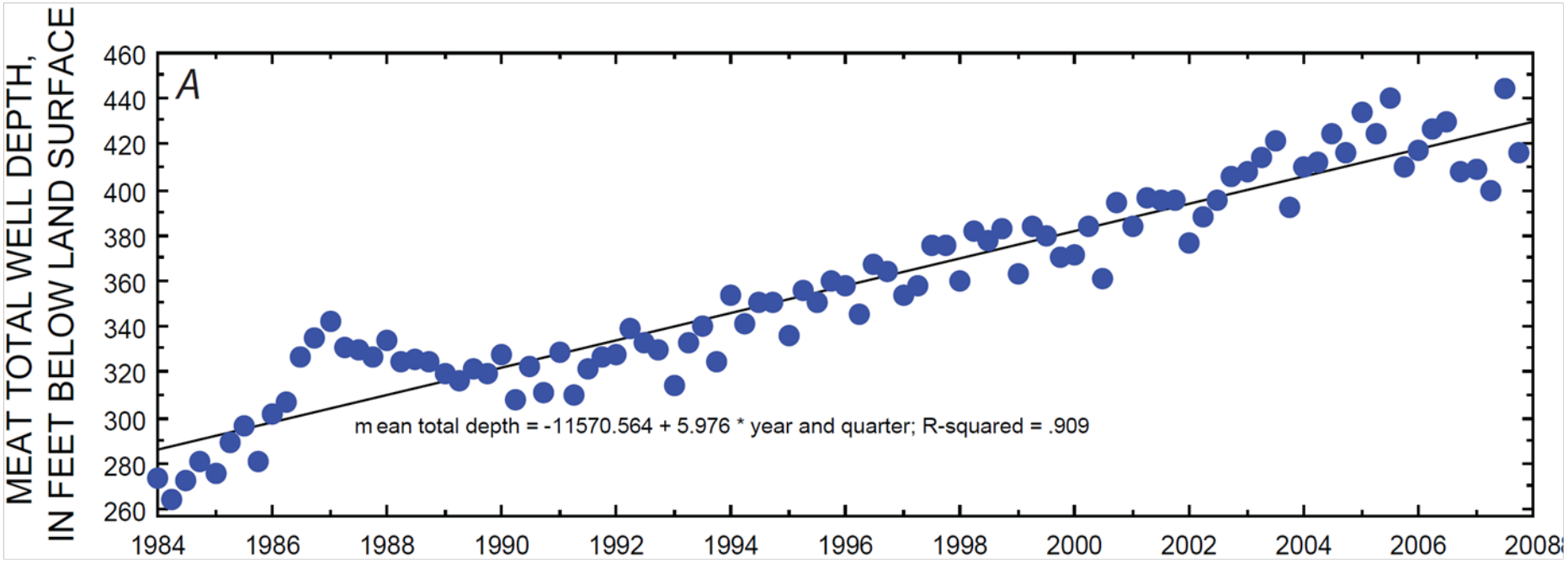
Mean Quarterly Static Water Levels

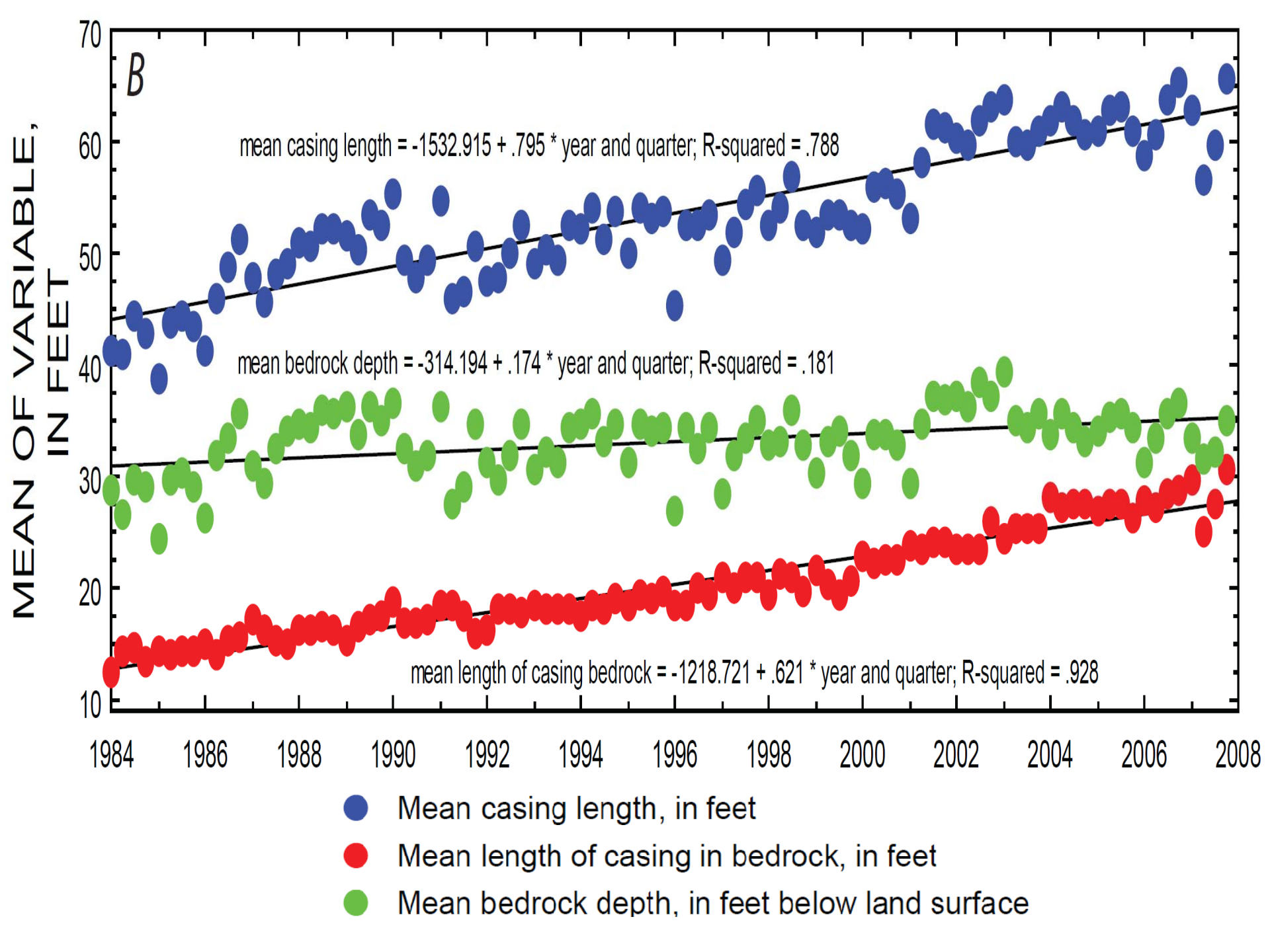
(1984-2007)

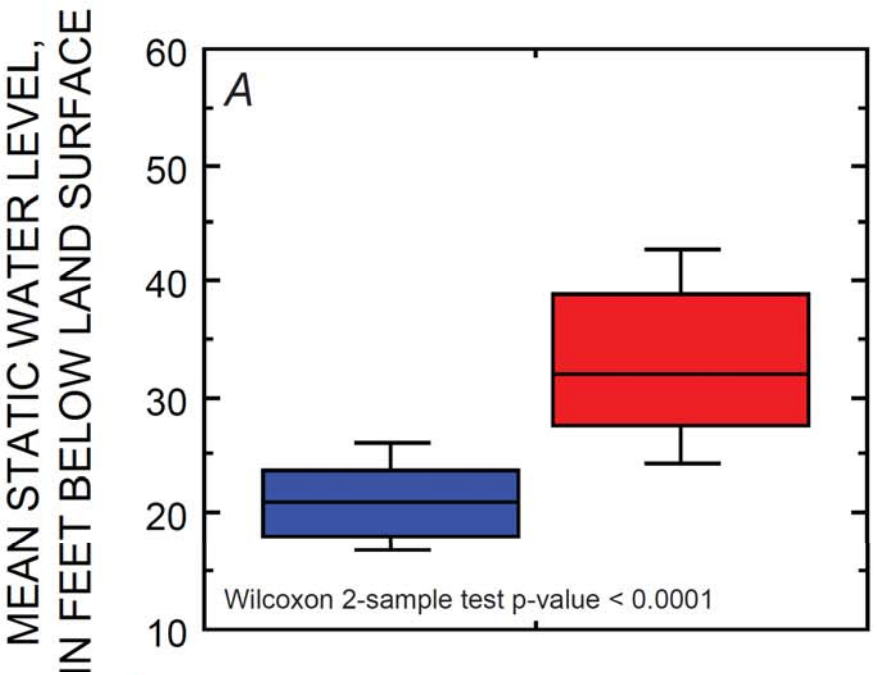


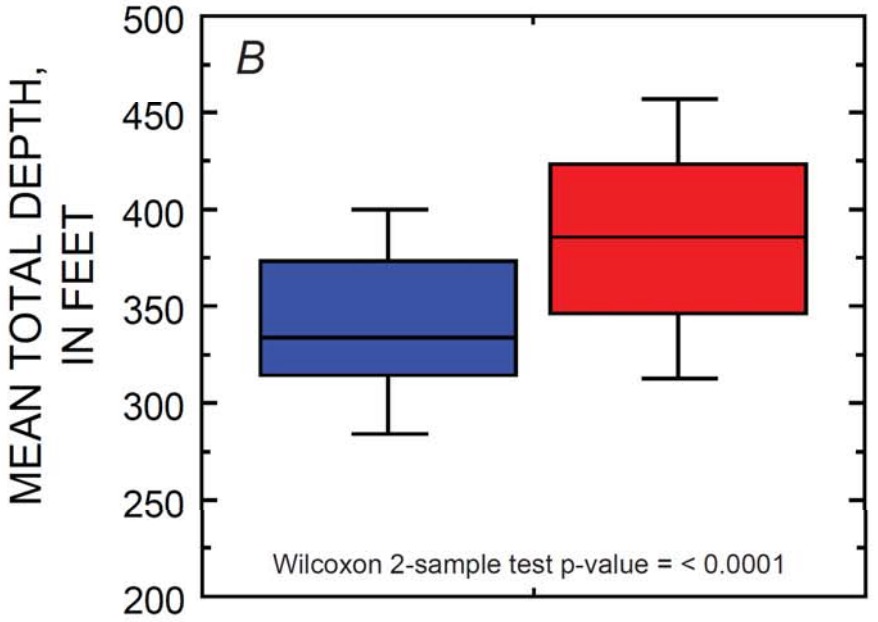

A
PRECIPITATION, IN INCHES
60
55
50
45
40
35
30
25
20
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Concord
Durham
Portsmouth

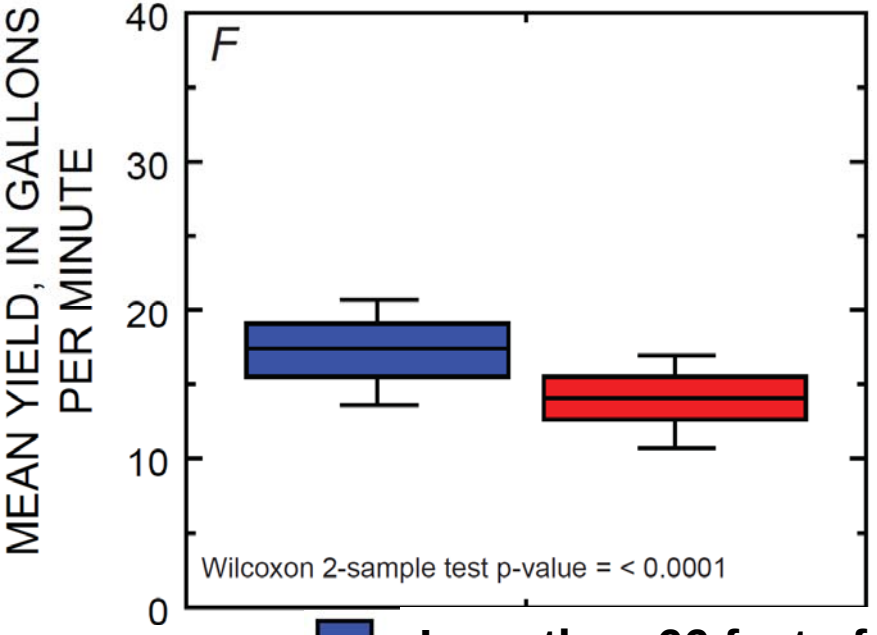

B
THIRD-QUATER BASE FLOW, IN INCHES
10
1
.1
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Beaver Brook
Oyster River
Soucook River


MEAT TOTAL WELL DEPTH, IN FEET BELOW LAND SURFACE
A
460
440
420
400
380
360
340
320
300
280
260
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
mean total depth = -11570.564 + 5.976 * year and quarter; R-squared = .909


B
mean casing length = -1532.915 + .795 * year and quarter; R-squared = .788
mean bedrock depth = -314.194 + .174 * year and quarter; R-squared = .181
mean length of casing bedrock = -1218.721 + .621 * year and quarter; R-squared = .928
MEAN OF VARIABLE, IN FEET
70
60
50
40
30
20
10
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Mean casing length, in feet
Mean length of casing in bedrock, in feet
Mean bedrock depth, in feet below land surface







Box plots nearly identical for:

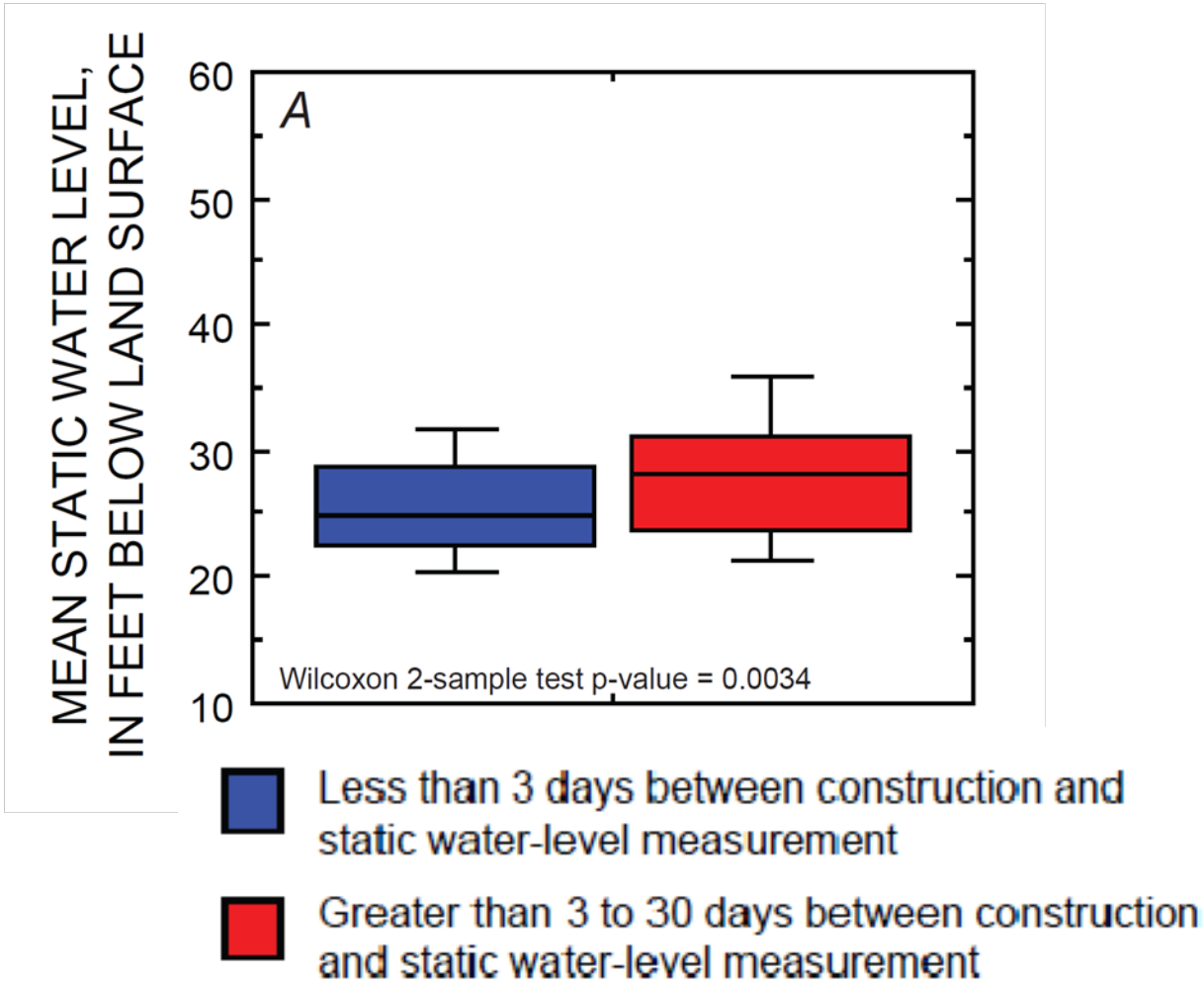
- Length of casing
- Bedrock depth
- Length of casing in bedrock

Less than 66 feet of vertical relief within 1,640 feet of the well

More than 66 feet of vertical relief within 1,640 feet of the well

Other Variables Considered

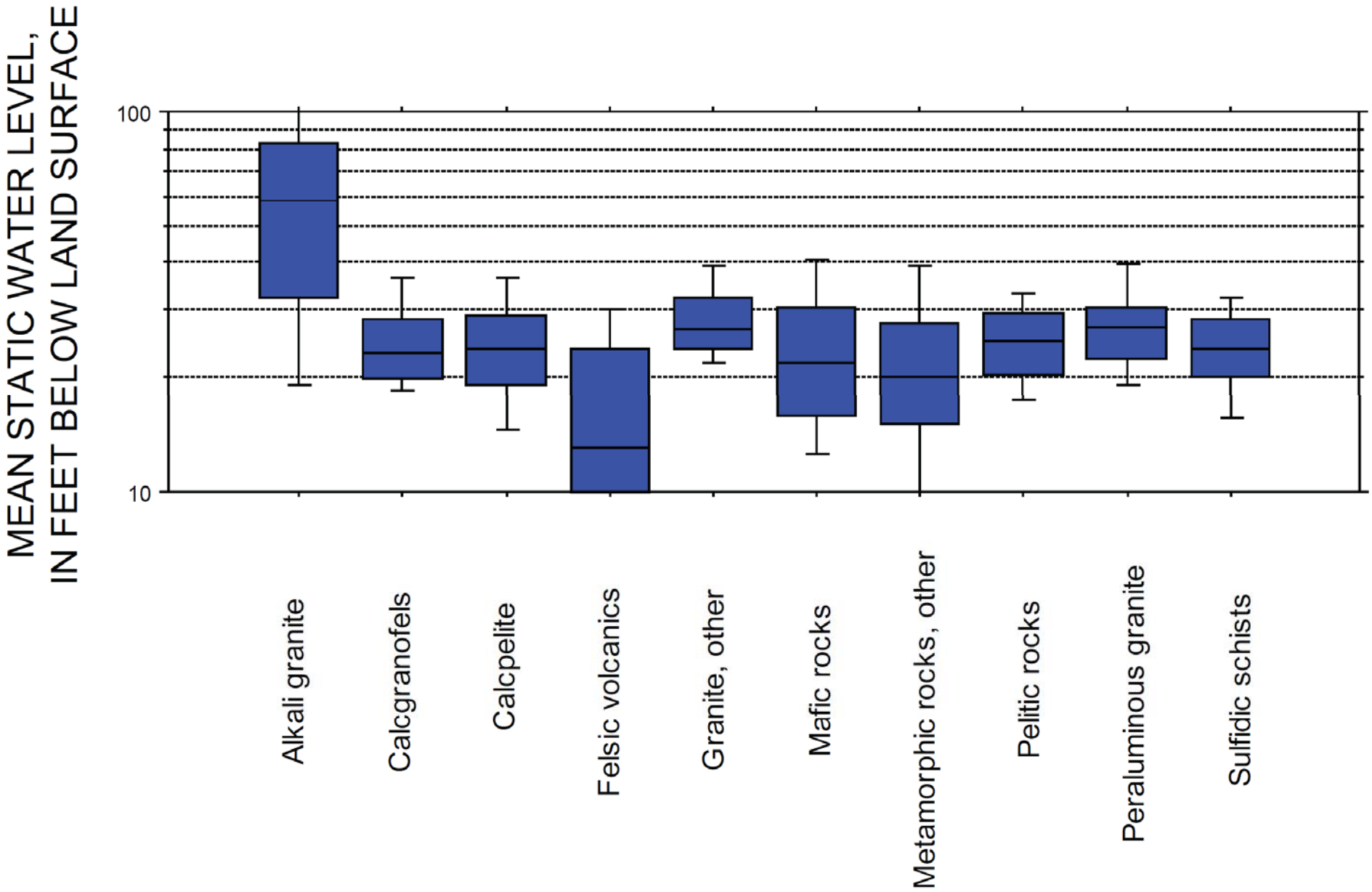
Length of time of SWL Measurement from Time of Well Construction

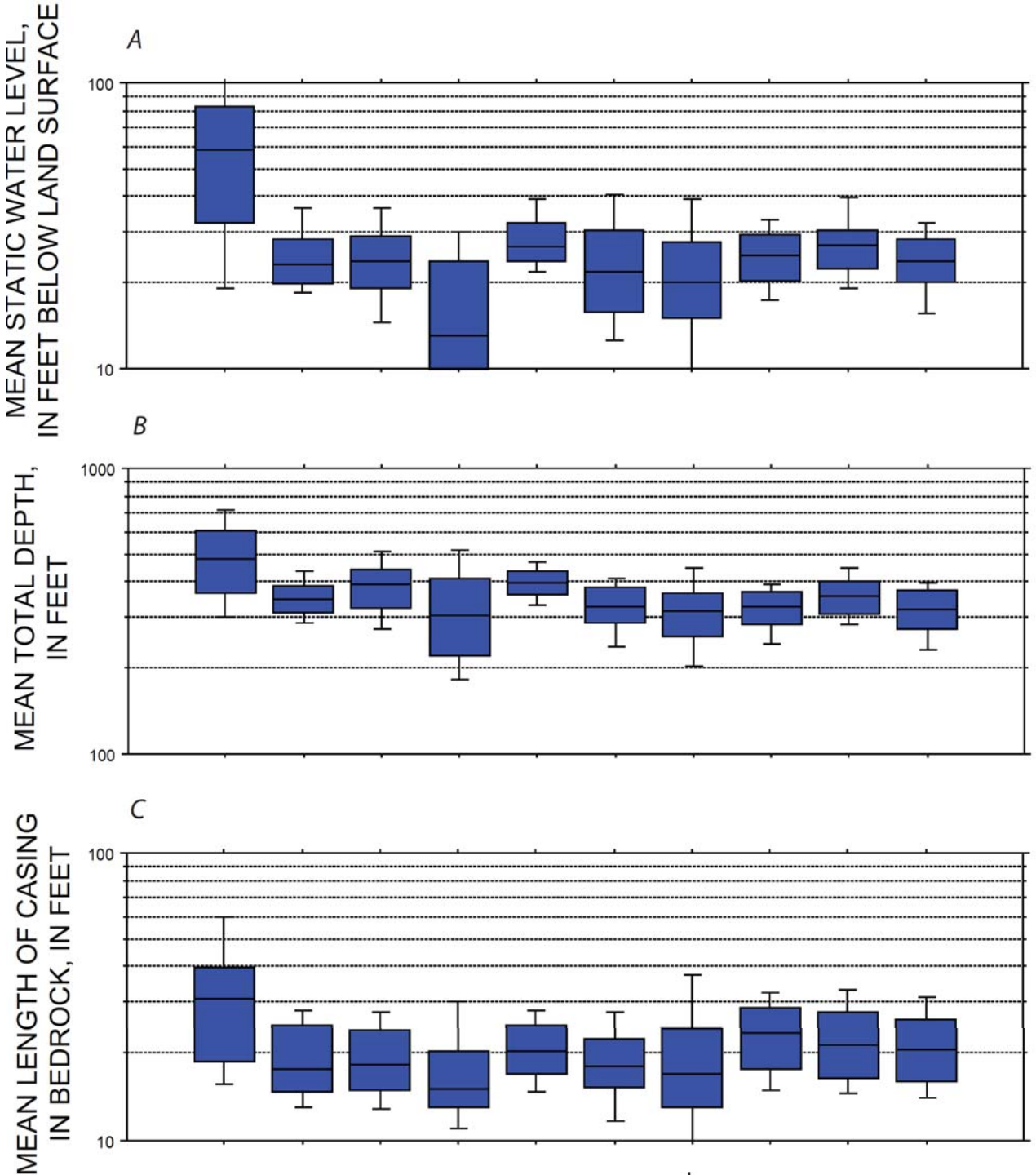


Relation of SWL to Local Scale Factors

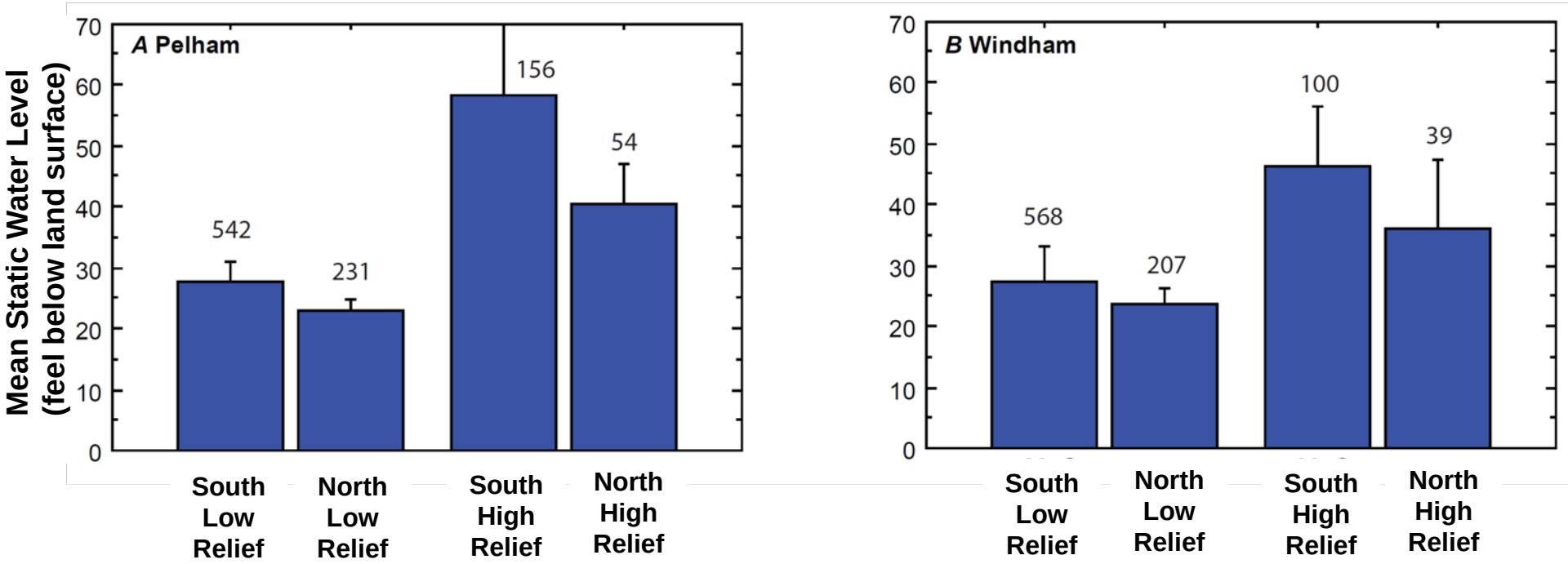
- Geology
- Local Topography/Orientation
- Local hydraulics
- Density of wells

Static Water Level in Lithologic Groups



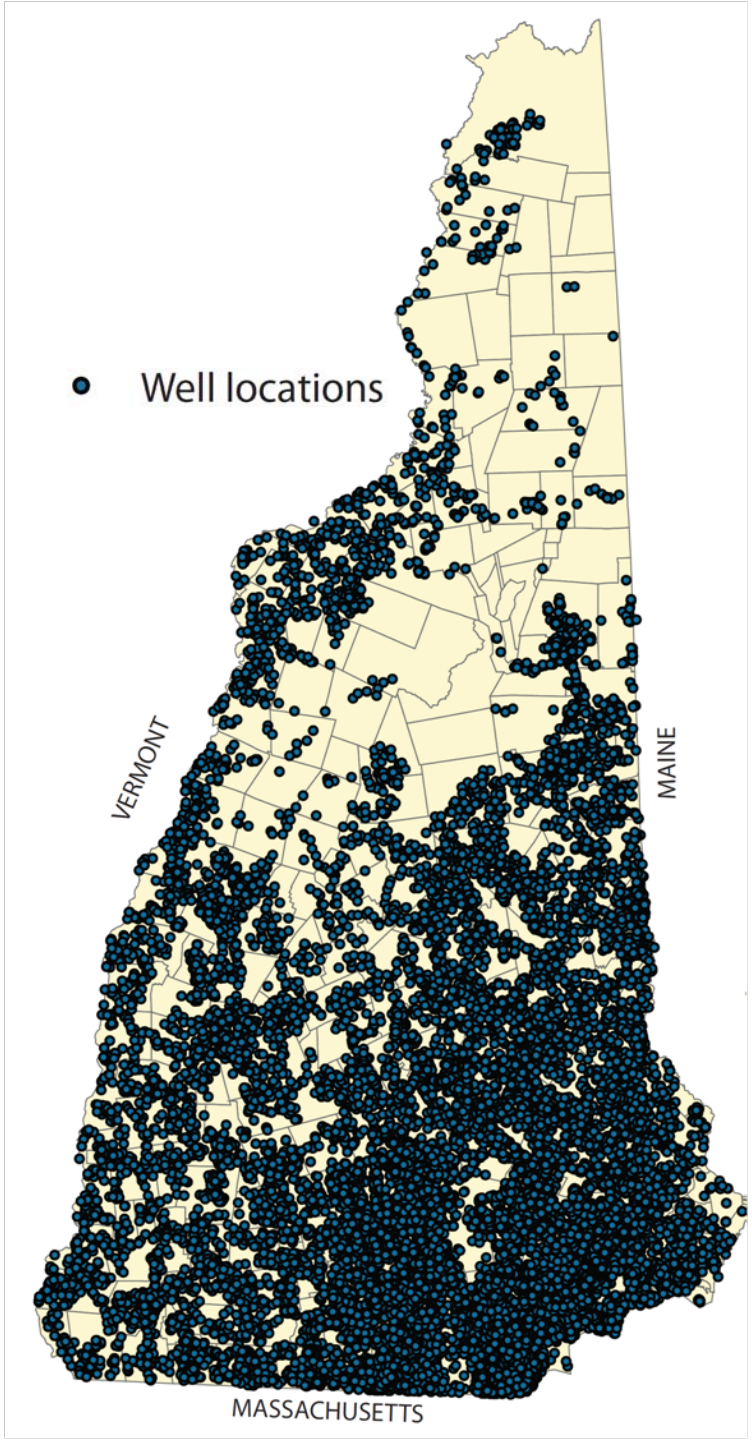

A
MEAN STATIC WATER LEVEL, IN FEET BELOW LAND SURFACE
100
10
B
MEAN TOTAL DEPTH, IN FEET
1000
100
C
MEAN LENGTH OF CASING IN BEDROCK, IN FEET
100
10

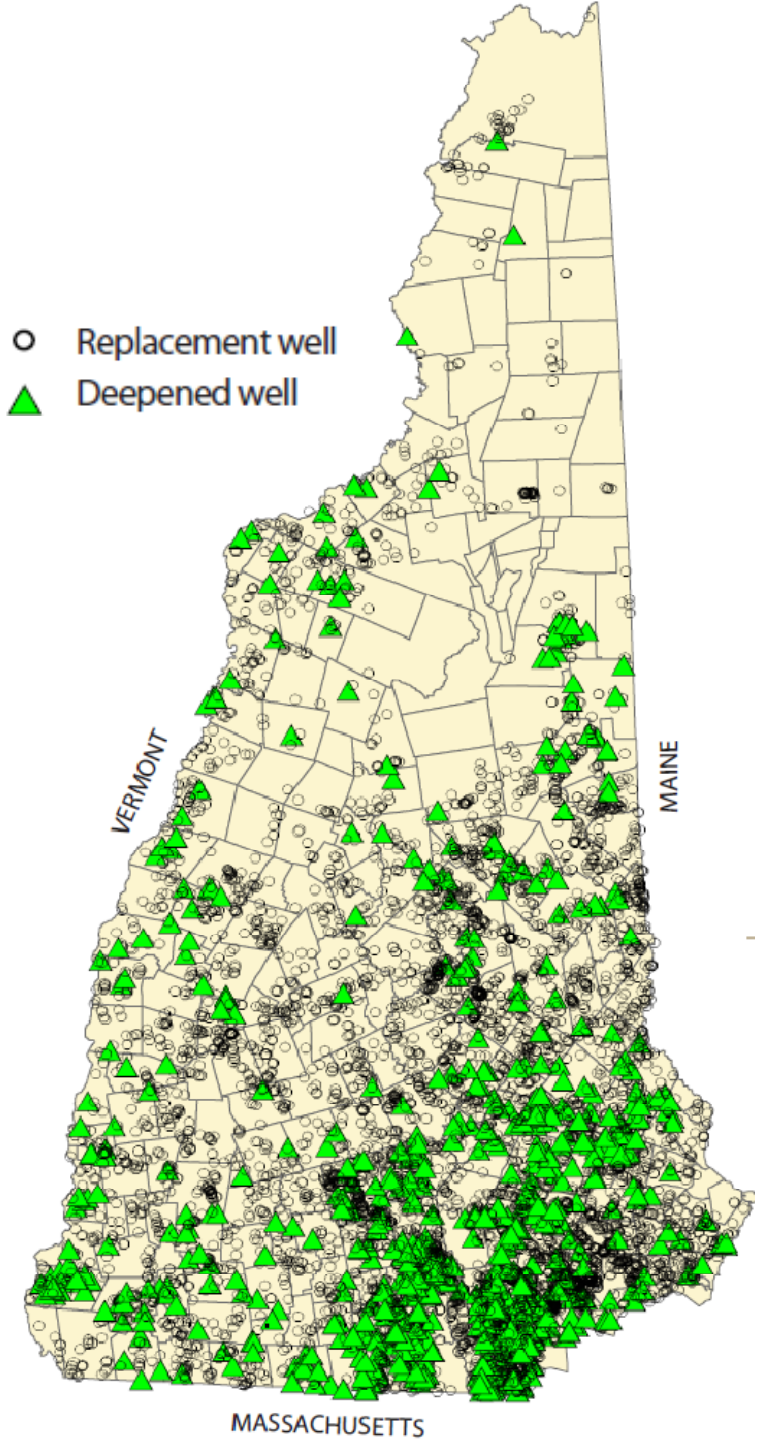
SWL are Generally Deeper on South Facing Hillsides

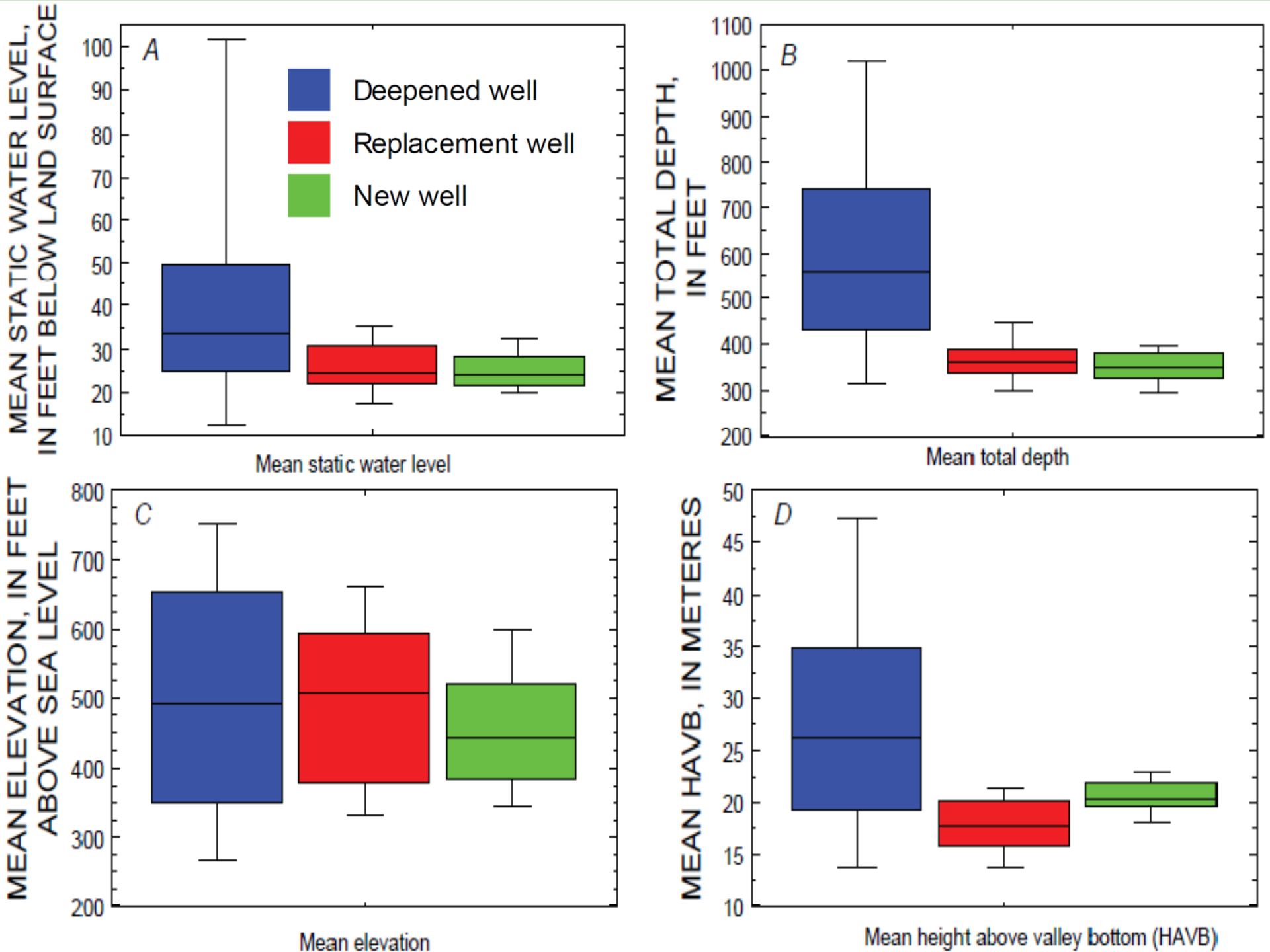


Potential Reasons

- Slopes in the southerly direction are commonly steeper in NH
- Increased evaporation and transpiration
- Slight differences in rainfall/temperature


Well locations
VERMONT
MAINE
MASSACHUSETTS


Replacement well
Deepened well
VERMONT
MAINE
MASSACHUSETTS


A
Deepened well
Replacement well
New well
MEAN STATIC WATER LEVEL, IN FEET BELOW LAND SURFACE
100
90
80
70
60
50
40
30
20
10
Mean static water level
B
MEAN TOTAL DEPTH, IN FEET
1100
1000
900
800
700
600
500
400
300
200
Mean total depth
C
MEAN ELEVATION, IN FEET ABOVE SEA LEVEL
800
700
600
500
400
300
200
Mean elevation
D
MEAN HAVB, IN METERES
50
45
40
35
30
25
20
15
10
Mean height above valley bottom (HAVB)

How this Information Can Be Used

- Determine if we have adequate water level monitoring data
- Assess if our well construction regulations are impacting the viability of new wells
- Determine if well yields reported by well drillers are reliable
- Develop guidance/model regulations to ensure adequate well yield based on:
  - Local conditions (geology, topography, hillside orientation)
  - Site specific well construction and testing recommendations
  - Density of Development
- Raises the question – Do our current well construction guidelines/regulations inadvertently adversely affect water quality & quantity sometimes?

Proposed Groundwater Monitoring Network in NH

See NH Groundwater.com

Goals of the Network

1) **Water level trends in bedrock in high use areas**
2) **Drought monitoring**
3) **Understand recharge/discharge relationships better**
4) **Climate change trends**