Plugging Wells With Bentonite Lab Trials

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Introduction

- Reason for doing this study
- Advantages of using bentonite as the plugging material
- Brine Salinity
- Fall 2011 Semester Testing
  - Plug Characteristics
  - Procedure

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Reason for doing the study

- The traditional method to plug and abandon wells is using cement to seal off pressure. The new technology of using bentonite to plug wells was developed recently. However, the application of the new technology is limited due to states' regulations.

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Advantages

- Using bentonite to plug wells is cheap.
- Using bentonite to plug wells is reliable.
- Other advantages

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Brine Salinity

- Bentontie performs well at low salinities.
- Saline solutions cause a decrease in plug integrity.
- The mechanism of saline solutions inhibit bentontie from swelling.

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Plug Characteristics

Granulated bentonite

Compressed bentonite

- Nodules
- Bullets

Plug Characteristics

Plug 1 – Freshwater
- 5 ft. granulated bentonite
- Breakthrough Pressure Testing from room temperature to 200 F

Plug 2 – 20,000 ppm
- 5 ft granulated bentonite
- Breakthrough Pressure Testing from room temperature to 200 F

Plug 3 – 20,000 ppm
- 5 ft compressed bentonite
- Breakthrough Pressure Testing at room temperature

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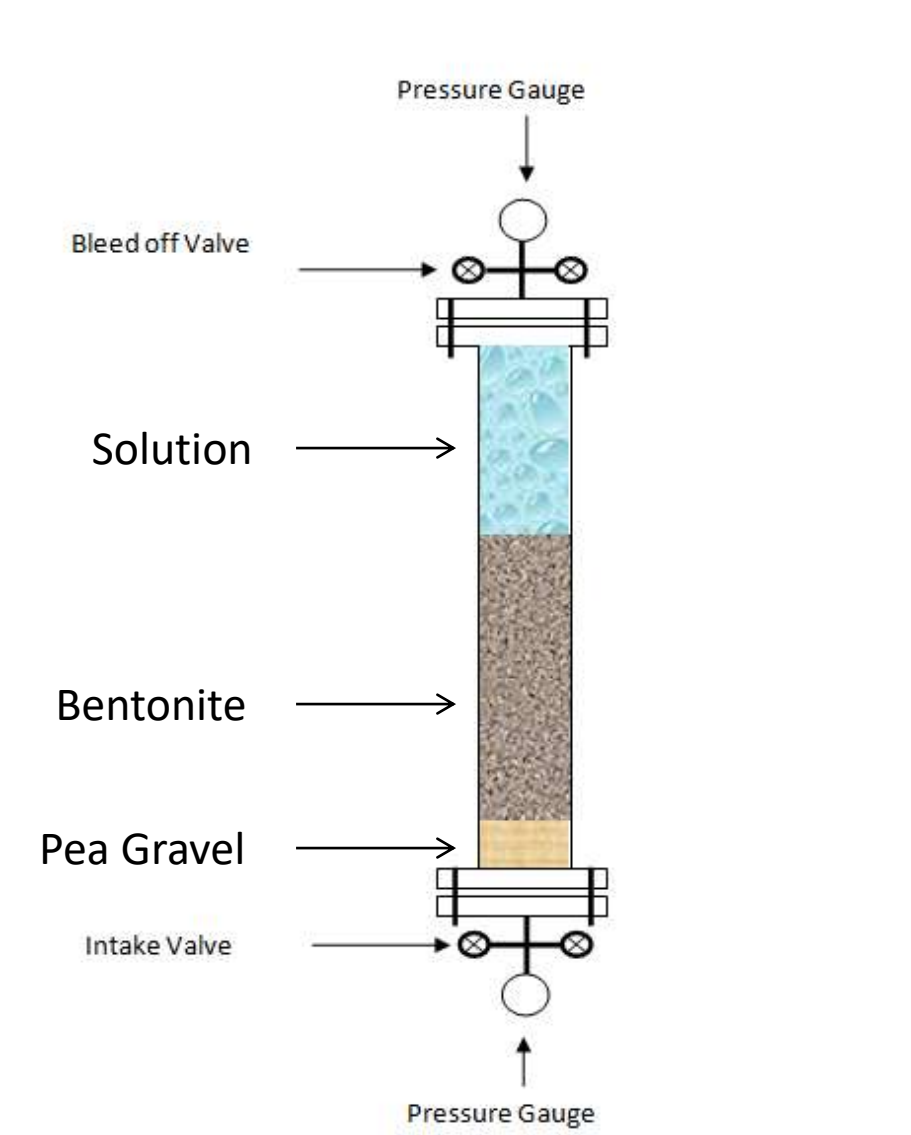
Casing Layout/Testing Procedure



Safety

Lab

- Hard hats and protective eye-wear while testing.
- Gloves during temperature testing and while handling bentonite and salt.
- Make sure lab and all equipment is safe, functional, and clean prior to any use.
- Be aware while releasing pressure.
- Always be aware of what others are doing and any impending danger.

Field

- Safety meeting upon entering field location.
- Hard hats, protective eye-wear, steel-toed boots, and FR's enforced upon entering the field.
- Methane monitoring device.
- Be aware of wildlife concerns.
- Always be aware of what others are doing and any impending danger.

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Ethics

- While testing the strength of bentonite plugs, it is important to test each apparatus in an efficient and similar manner.
- Must use accurate equipment.
- The results gathered in the lab may affect future regulations.
- Ethics and data integrity standards have been built as a whole collaborative group.

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Environment

- Wells must be properly abandoned when removed from service.
- The environment issue in the traditional well abandonment method.
- Using bentonite to abandon wells has no environment concerns.

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Economics

- Using cement to abandon wells is much more expensive than using bentonite.

- How does the bentonite Plug & Abandonment technology save money.

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Friction Factor

- Definition:

The friction factor refers to the ‘coefficient of friction’ or ‘frictional coefficient’.

$$friction\ factor = \frac{friction\ force}{swelling\ force}$$

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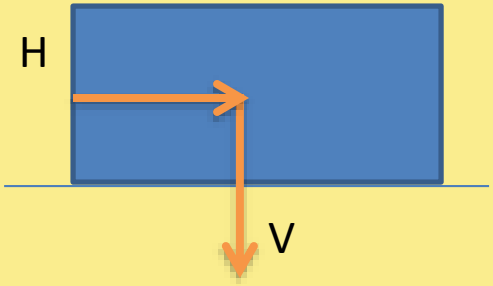
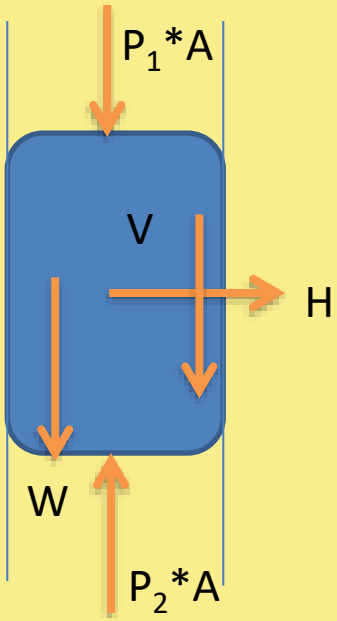
Friction Factor





$n=H/V$

$n=V/H$

$V=n*H > W$

$(P2-P1)A=W+V=W+n*H$

W – Weight of plug
P – Pressure exerted on plug
H – Horizontal expansion force
V – Frictional force
n – Friction factor
A – Cross sectional area

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Equation to Calculate Friction Factor

- Towler and Ehlers investigated the friction factor for bentonite pellets.
- Equation for Dislodgement Pressure of a Bentonite Plug:

$$P = K_b \rho_w \left(\frac{4 L_w H}{D} + \frac{2 \gamma_b H^2}{D} \right) + \rho_w (L_w + \gamma_b H)$$

- Where: K_b=coefficient of friction of the bentonite on the casing
  L_w=height of water above bentonite, ft
  γ_b=specific gravity of hydrated bentonite
  ρ_w=density of water, psi/ft
  H=height of bentonite plug, ft
  D=casing internal diameter, ft

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$$P - \rho_w(L_w + \gamma_b H)\ Versus\ \left(\frac{4L_w H}{D} + \frac{2\gamma_b H^2}{D}\right)$$

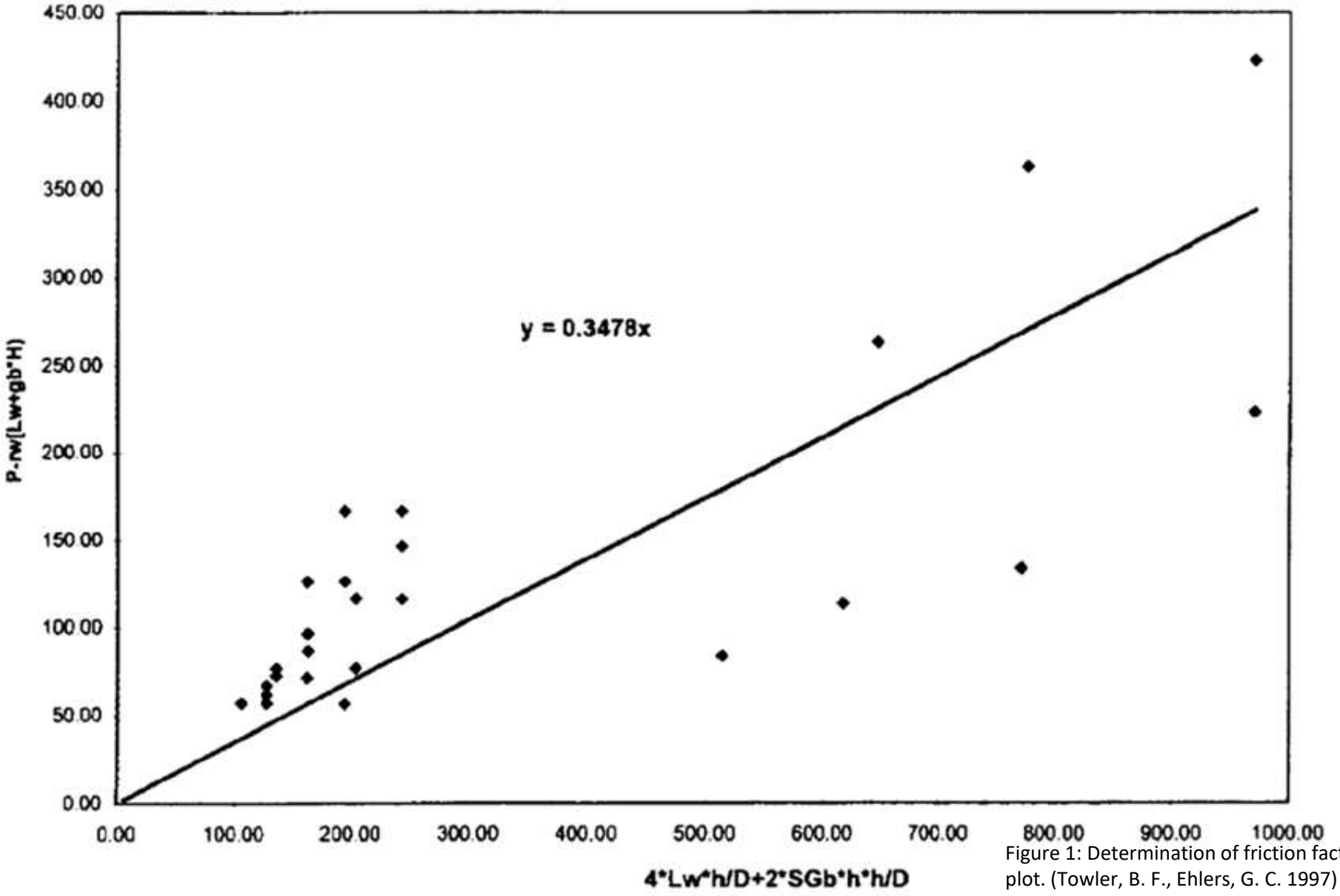
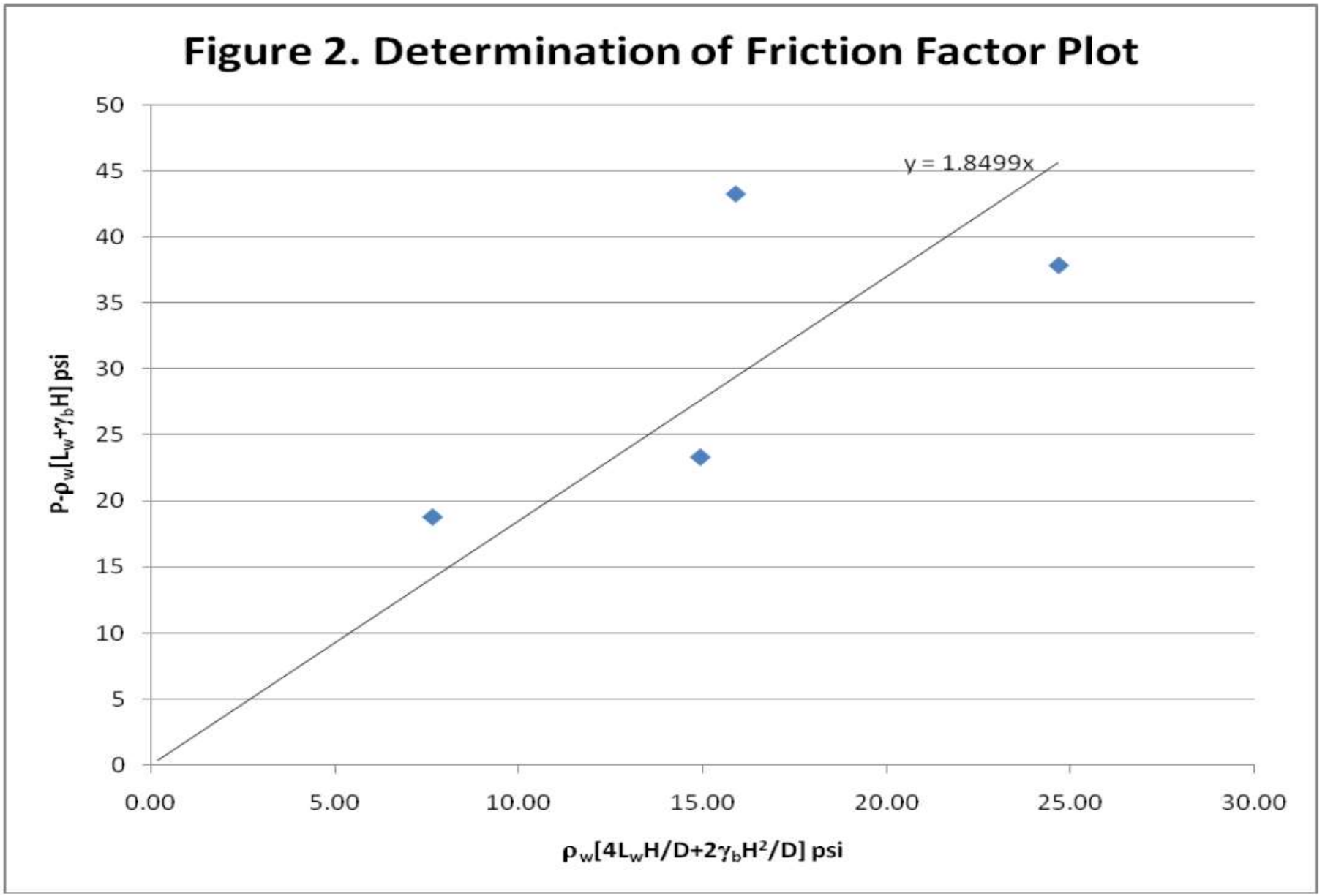


Figure 1: Determination of friction factor plot. (Towler, B. F., Ehlers, G. C. 1997)

$$P - \rho_w(L_w + \gamma_b H) \; Versus \; \rho_w\left(\frac{4L_w H}{D} + \frac{2\gamma_b H^2}{D}\right)$$



Last Year's Findings

Breakthrough Pressure Test of Bentonite Plugs: Previous Years						
Test Date	Hydration Time	Test	Salinity (ppm)	Plug Composition	Breakthrough Pressure (psig)	Plug Length (ft)
3/4/2011	7	1	Fresh Water	Granulated	**140**	5
3/22/2011	18	2	Fresh Water	Granulated	**160**	5
4/8/2011	17	3	Fresh Water	Granulated	**200**	5
4/26/2011	18	4	Fresh Water	Granulated	**210**	5
3/4/2011	7	1	20000	Granulated	**40**	5
3/22/2011	18	2	20000	Granulated	**40**	5
4/8/2011	17	3	20000	Granulated	**45**	5
4/26/2011	18	4	20000	Granulated	**70**	5
3/4/2011	7	1	20000	Bullets	**35**	5
3/22/2011	18	2	20000	Bullets	**35**	5
4/8/2011	17	3	20000	Bullets	**40**	5
4/26/2011	18	4	20000	Bullets	**55**	5

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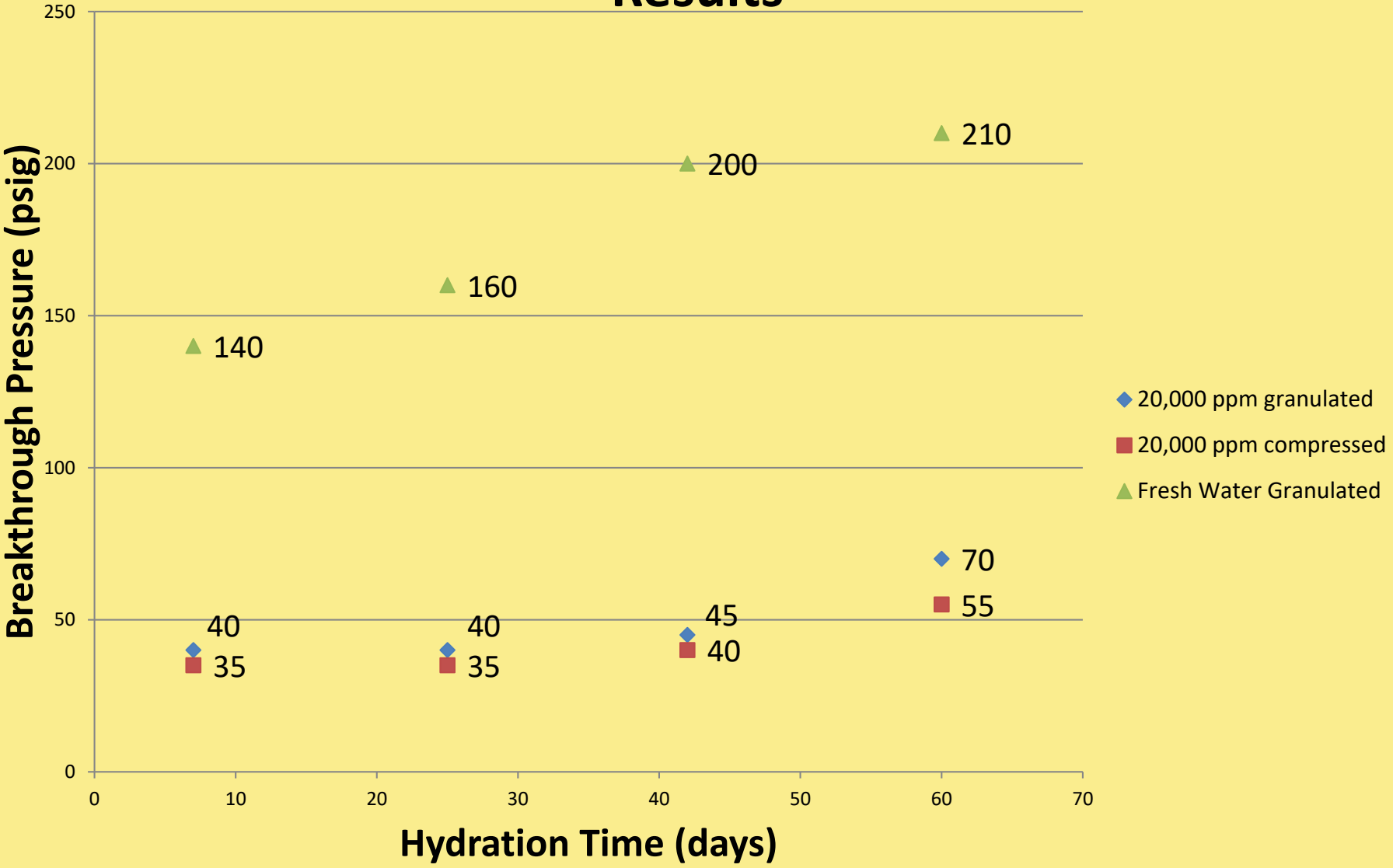
Breakthrough Pressure Testing: Previous Year Results



This Year's Results

Breakthrough Pressure Test of Bentonite Plugs: Current						
Test Date	Hydration Time	Test	Salinity (ppm)	Plug Composition	Breakthrough Pressure (psig)	Plug Length (ft)
9/23/2011	151	5	Fresh Water	Granulated	**215**	5
9/30/2011	7	6	Fresh Water	Granulated	**220**	5
10/10/2011	10	7	Fresh Water	Granulated	**219**	5
9/23/2011	151	5	20000	Granulated	**65**	5
9/30/2011	7	6	20000	Granulated	**55**	5
10/10/2011	10	7	20000	Granulated	**50**	5
10/20/2011	10	8	20000	Granulated	**51**	5
11/3/2011	14	9	20000	Granulated	**50**	5
11/11/2011	8	10	20000	Granulated	**N/A**	5
9/23/2011	151	5	20000	Bullets	**35**	5
9/30/2011	7	6	20000	Bullets	**35**	5
10/10/2011	10	7	20000	Bullets	**31**	5
10/20/2011	10	8	20000	Bullets	**32**	5
11/3/2011	14	9	20000	Bullets	**32**	5
11/11/2011	8	10	20000	Bullets	**N/A**	5

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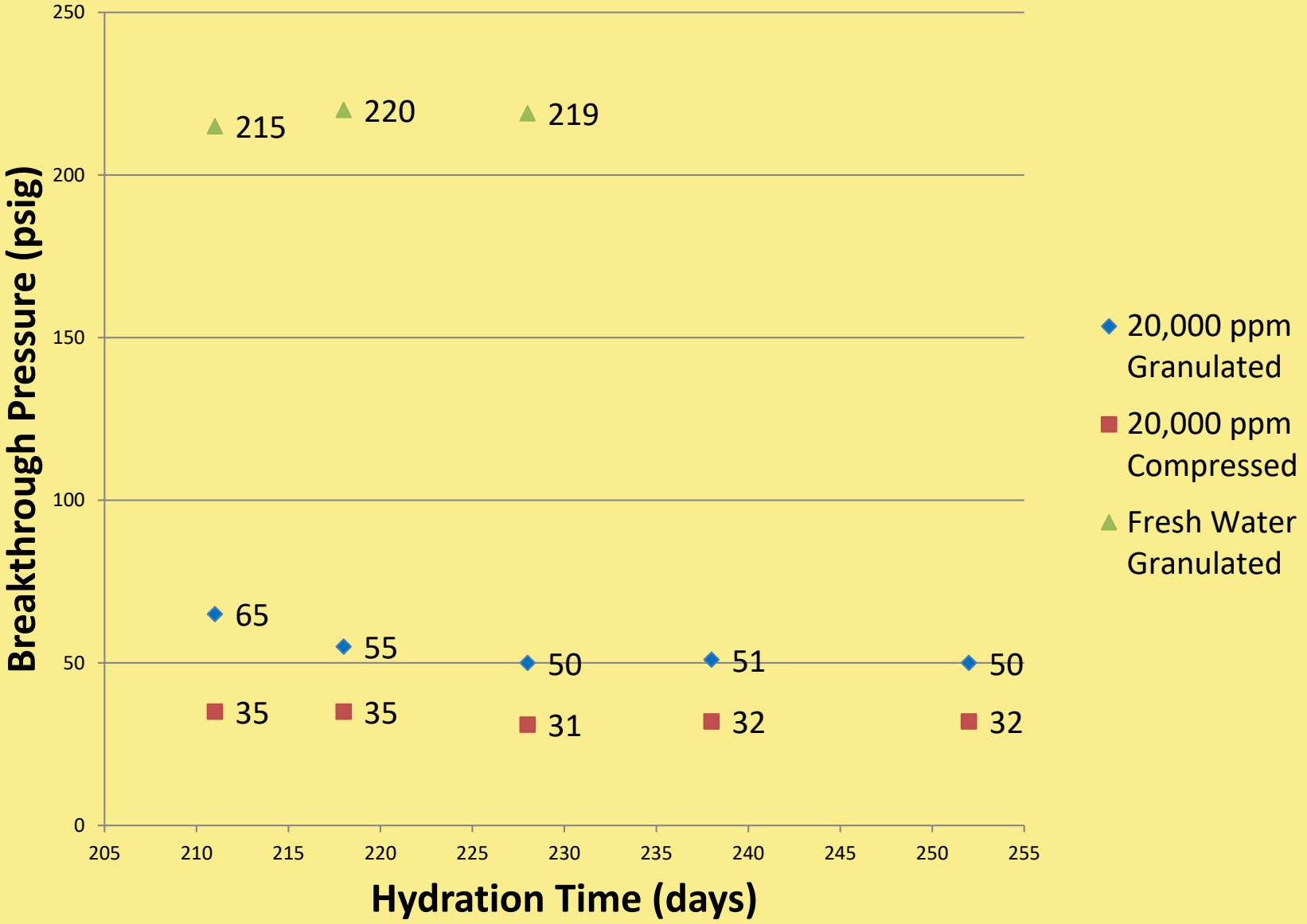
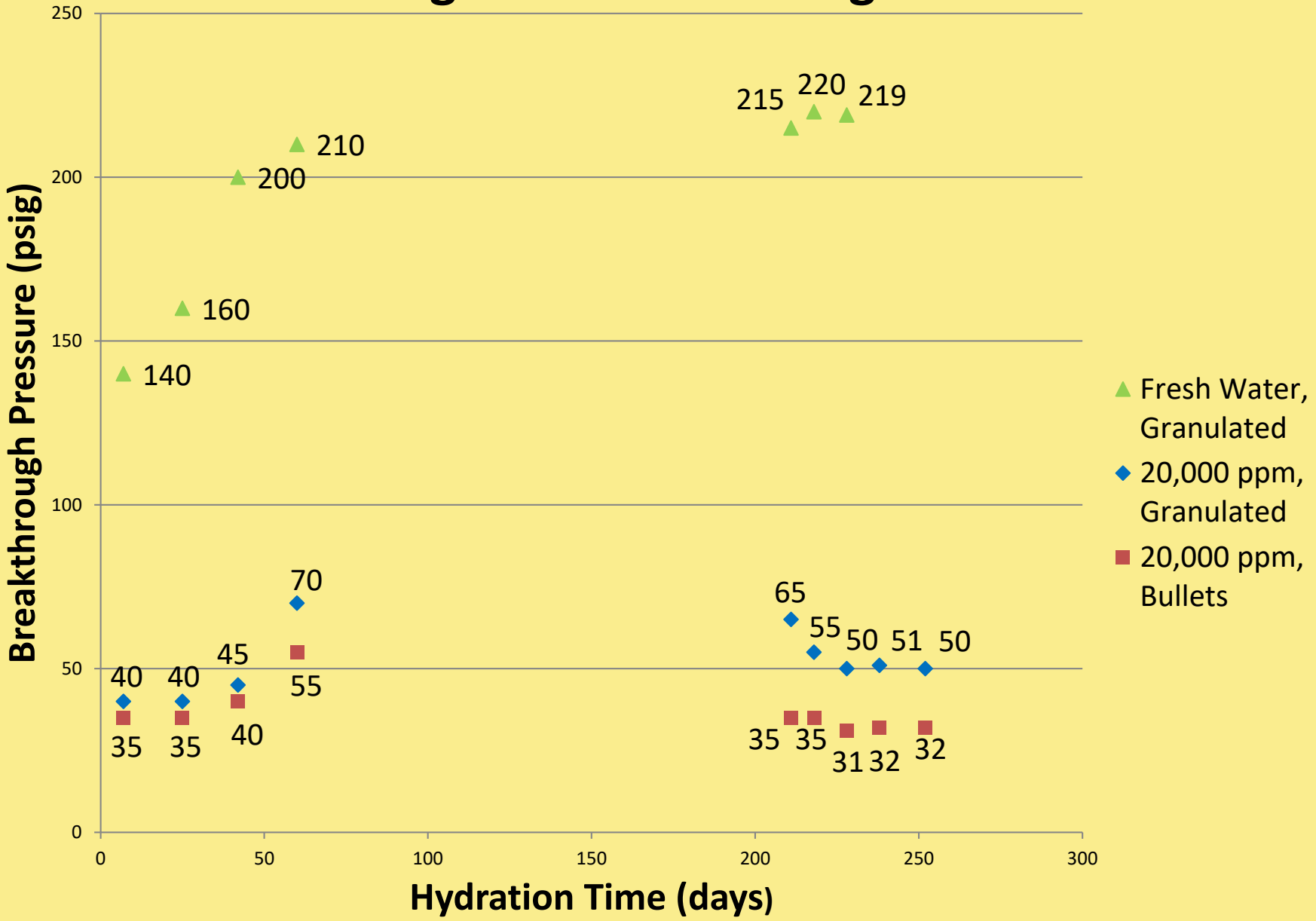
Breakthrough Pressure Testing: Current



Breakthrough Pressure Testing: Cumulative



Temperature Testing

Breakthrough Pressure Test of Freshwater Plug with Temperature							
Test Date	Hydration Time	Test	Salinity (ppm)	Plug Composition	Breakthrough Pressure (psig)	Temperature (F)	Plug Length (ft)
10/20/2011	0	1	Freshwater	Granulated	**230**	**100**	5
11/3/2011	14	2	Freshwater	Granulated	**145**	**125**	5
11/11/2011	8	3	Freshwater	Granulated	**N/A**	**150**	5
3/8/2012	111	4	Freshwater	Granulated	**115**	**150**	5
3/21/2012	13	5	Freshwater	Granulated	**35**	**175**	5
3/28/2012	7	6	Freshwater	Granulated	**5**	**200**	5

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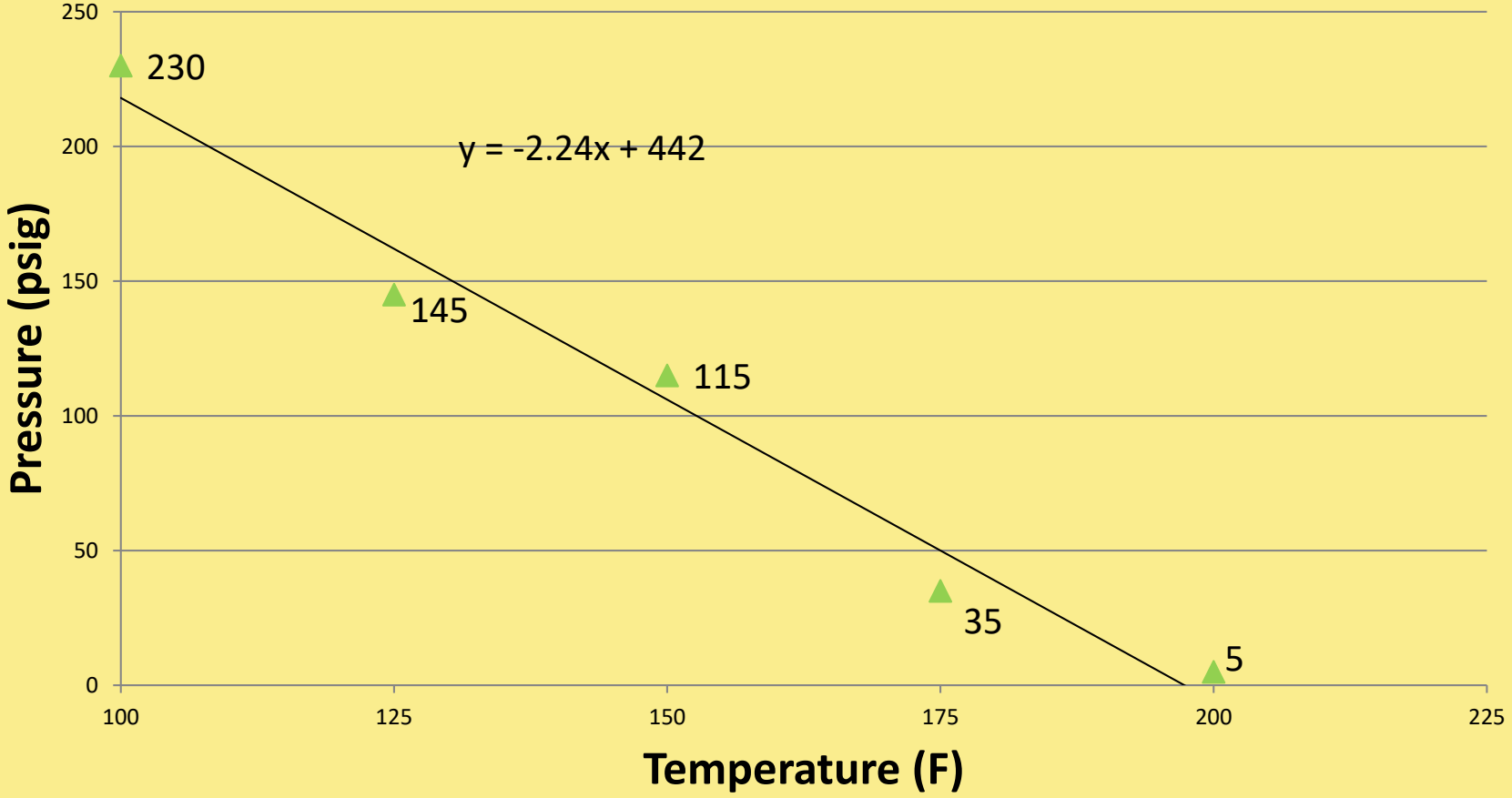
Freshwater Pressure Breakthrough with Temperature



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Temperature Testing

Breakthrough Pressure Test of Bentonite Plugs with Temperature							
Test Date	Hydration Time	Test	Salinity (ppm)	Plug Composition	Breakthrough Pressure (psig)	Temperature (F)	Plug Length (ft)
4/11/2012	0	1	20,000	Granulated	**50**	**100**	5
4/13/2012	2	2	20,000	Granulated	**43**	**125**	5
4/15/2012	2	3	20,000	Granulated	**48**	**150**	5
4/17/2012	2	4	20,000	Granulated	**18**	**175**	5
4/19/2012	2	5	20,000	Granulated	**8**	**200**	5

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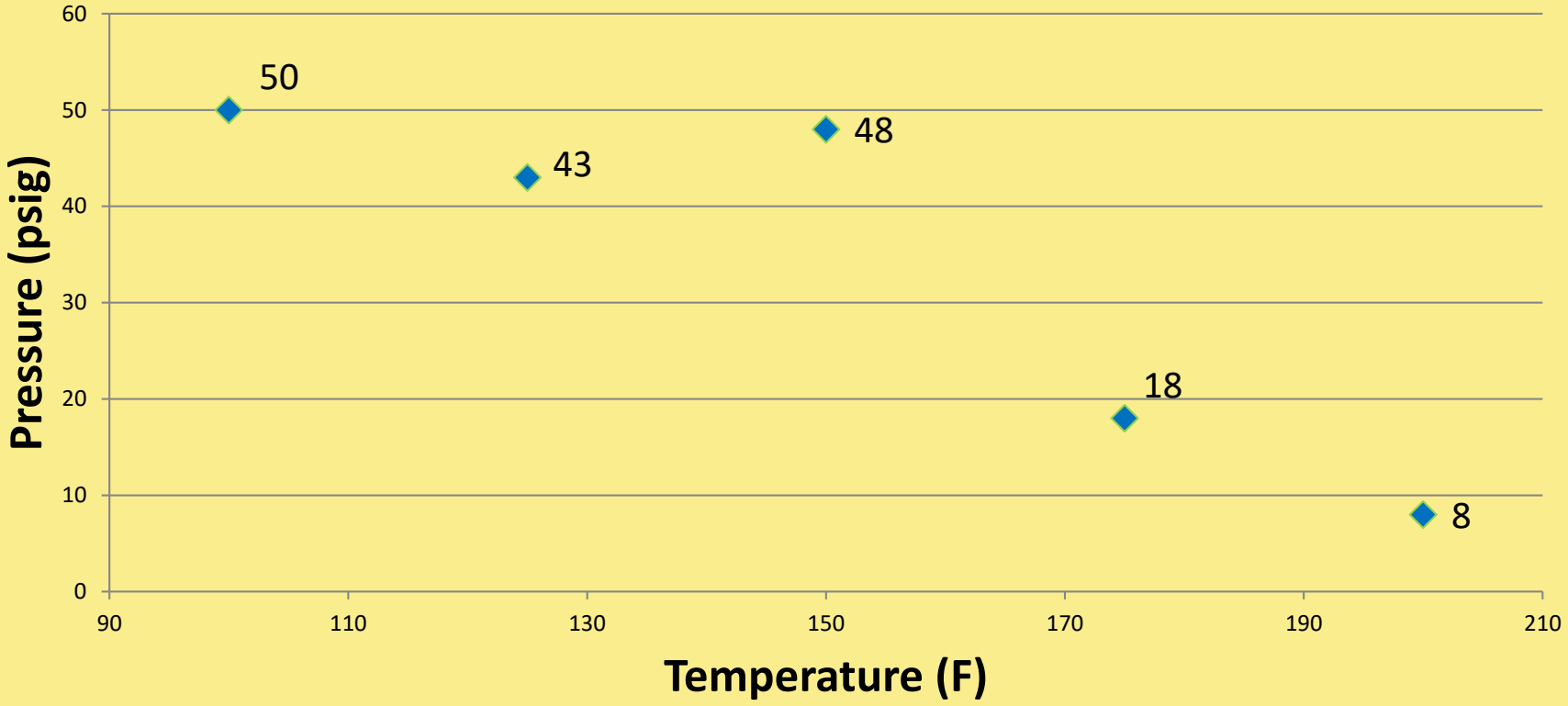
20,000 ppm Granulated Breakthrough Pressure with Temperature



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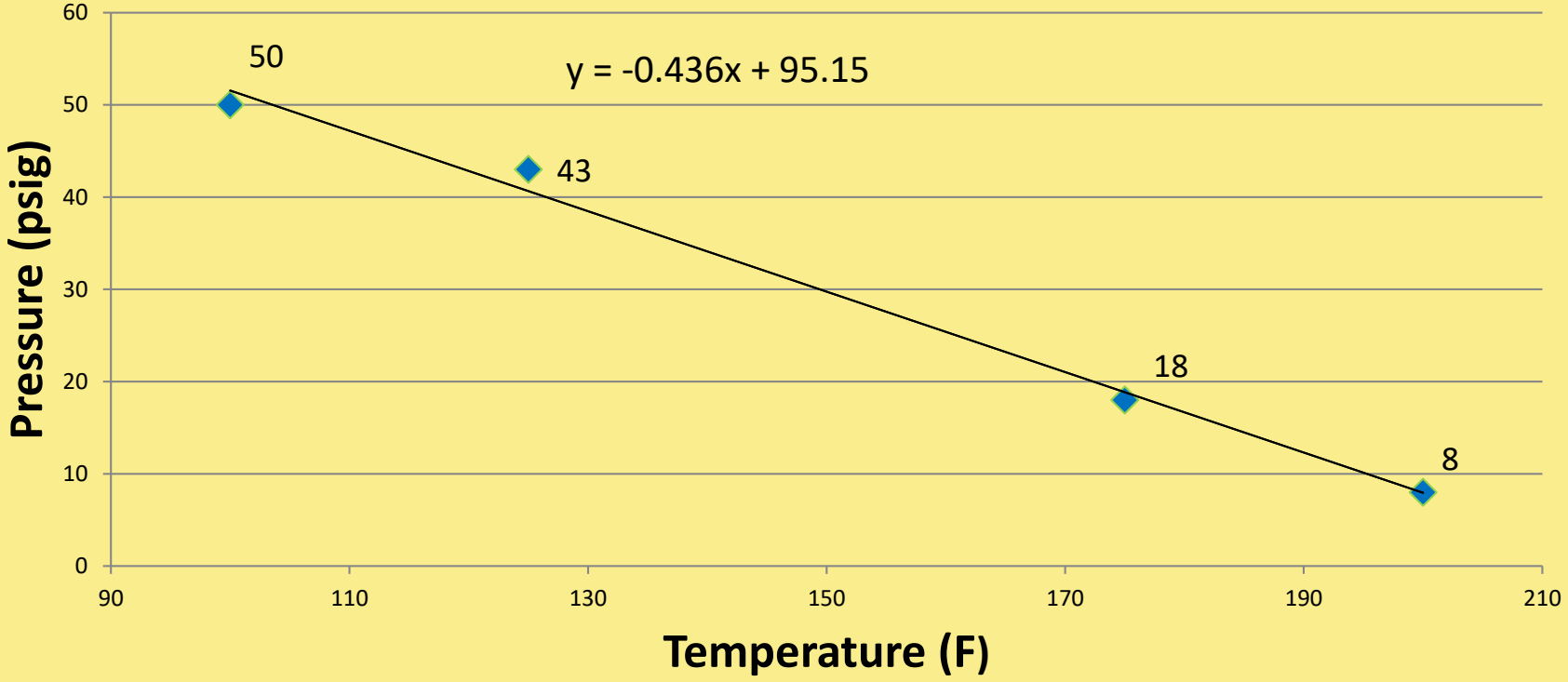
20,000 ppm Granulated Breakthrough Pressure with Temperature



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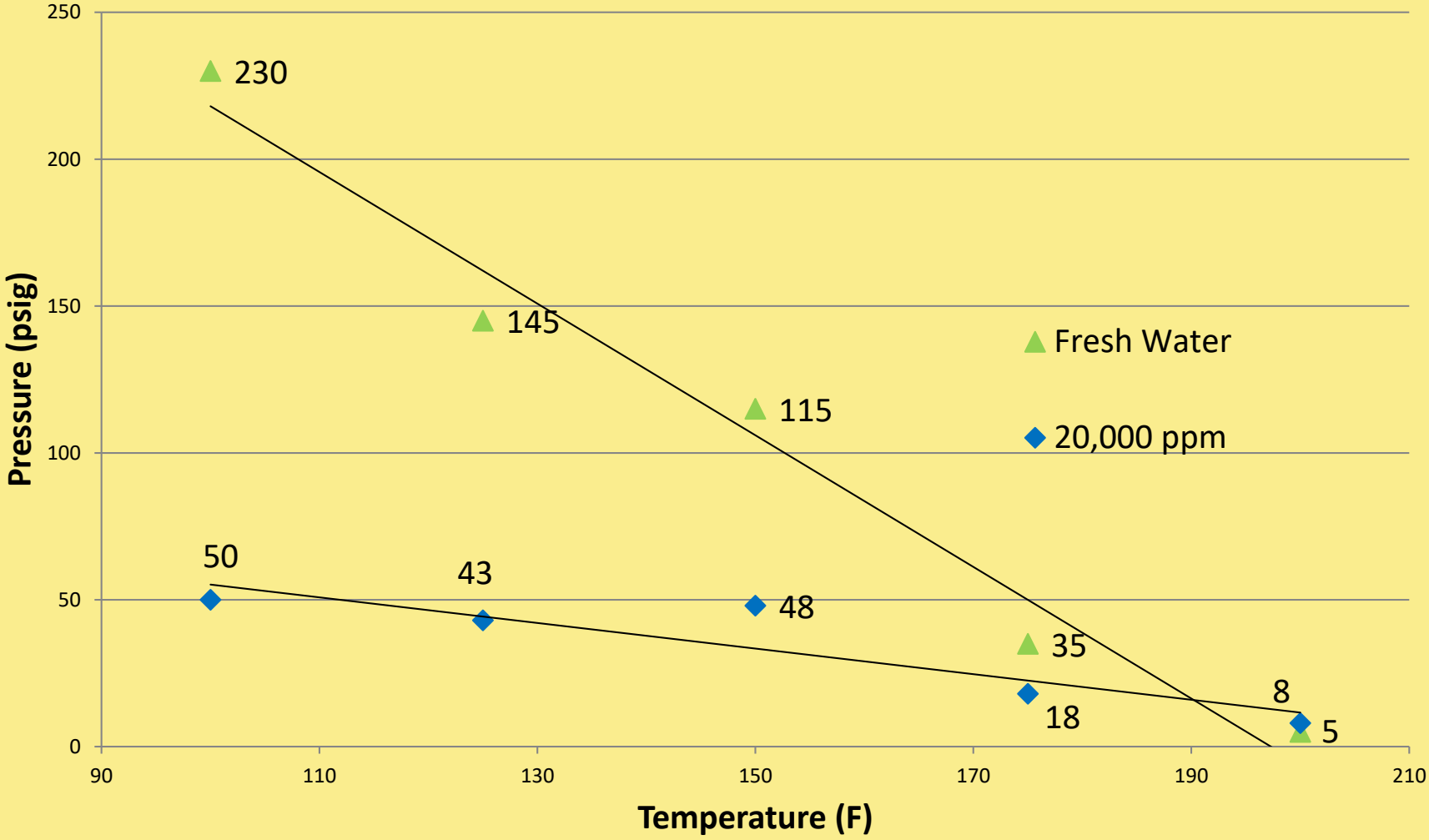
Temperature Comparison



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Conclusion

- Results
  - Granulated vs. Compressed
  - 20,000 ppm Discrepancies
  - Previous vs. Current Testing
  - Temperature Testing
- Issues
  - Bridging of compressed bentonite
  - Pressure gauge issues
  - Temperature control device
- Recommendations
  - All-in-one temperature device
  - Pressure release manifold
  - Longer thermocouple

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Questions?

A Special Thank You to:
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