



DEPARTMENT

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September 20, 2011

HONORABLE MAYOR AND CITY COUNCIL  
City of Long Beach  
California**RECOMMENDATION:**

Receive and file the attached report, "Elevation Changes in the City of Long Beach, November 2010 through May 2011." (Citywide)

**DISCUSSION**

The City of Long Beach, through the Long Beach Gas and Oil Department (LBGO), supervises oil production and subsidence control operations in the Wilmington Oil Field. LBGO conducts elevation surveys every six months to monitor elevation changes in the oil fields and adjacent city areas. This report focuses on elevation changes that have occurred from November 2010 through May 2011. The LBGO survey includes the following areas: Civic Center, Central City, Alamitos Bay, Naples, Harbor District, and an offshore area encompassing the four offshore oil islands.

The results of the six-month survey show that elevations were stable in the Central City, Alamitos Bay, Naples, and the offshore areas. A portion of the Civic Center area experienced an elevation gain of up to 0.10 foot (1.2 inches). Elevations in the western portion of the Harbor District increase up to 0.12 foot (1.4 inches). The elevation increases appear to be the result of regional geologic factors and are not of concern.

The LBGO survey uses a series of benchmarks to determine elevation changes. Studies by the Department's engineers and geologists show that the benchmarks may rise and fall in such a manner as to make a survey either optimistic (slightly up in elevation) or pessimistic (slightly down in elevation). These changes in elevations may be associated with tidal cycles, temperature changes, and/or deep earth tectonic changes or re-pressuring operations. Surface elevations in a rebounded area can be expected to fluctuate under changing water flood conditions.

This matter was reviewed by Deputy City Attorney Richard Anthony on August 22, 2011 and Budget Management Officer Victoria Bell on August 19, 2011.

HONORABLE MAYOR AND CITY COUNCIL  
September 20, 2011  
Page 2

TIMING CONSIDERATIONS

City Council action on this matter is not time critical.

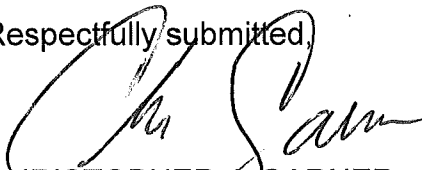
FISCAL IMPACT

There is no fiscal impact or local job impact associated with this action.

SUGGESTED ACTION:

Approve recommendation.

Respectfully submitted,



CHRISTOPHER J. GARNER  
DIRECTOR OF LONG BEACH GAS AND OIL

CJG:MH:lld  
09-20-11 Elevation Report

Attachment

APPROVED:

  
\_\_\_\_\_  
PATRICK H. WEST  
CITY MANAGER

**ELEVATION CHANGES  
IN THE  
CITY OF LONG BEACH**

**NOVEMBER 2010 THROUGH APRIL 2011**

**PREPARED**

**FOR**

**LONG BEACH CITY COUNCIL**

**BY THE**

**LONG BEACH GAS AND OIL  
DEPARTMENT**

## CONTENTS

		<u>Page</u>
I.	<b>ELEVATION SURVEY ANALYSIS</b>	
	Elevation Change – November 2010 through April 2011 .....	3
	Elevation Change – May 2010 through April 2011.....	4
	Use of Global Positioning System (GPS).....	5
II.	<b>APPENDIX</b>	
	Brief History of Long Beach Subsidence .....	6
	Survey Accuracy .....	7
	Elevation Change Map Construction .....	8
	Bench Mark Location Map .....	8
	Bench Mark and Net Injection Graphs, Harbor District .....	8
	Bench Mark and Net Injection Graphs, Ocean Boulevard and the Offshore Drilling Islands.....	9
III.	<b>ELEVATION CHANGE MAPS</b>	<u>Figures</u>
	November 2010 through April 2011 .....	1
	May 2010 through April 2011.....	2
	<b>BENCH MARK AND NET INJECTION GRAPHS</b>	
	Bench Mark Location Map .....	3
	Harbor District, Fault Blocks II-V .....	4-7
	Ocean Boulevard and Offshore Drilling Islands, Fault Blocks VI through 90S .....	8-13

## ELEVATION SURVEY ANALYSIS

The City of Long Beach semi-annual elevation survey of the Civic Center, Central City, Harbor District, Alamitos Bay, Naples, and offshore areas was conducted during May 2011. Changes in elevation that have occurred since the last two surveys, November 2010 and May 2010, are discussed in this report. The results in this report reflect elevation changes both within and beyond the scope of oilfield operations. Some changes are due to natural geologic factors.

### **Elevation Change – November 2010 through April 2011** (Figure 1)

Elevations throughout the Alamitos Bay, Naples and the offshore area were stable during the six-month period. A portion of the Civic Center area experienced an elevation gain of up to 0.10 foot (1.2 inches). The elevation gain was minor and is mainly attributed to regional geologic factors.

The eastern portion of the Harbor District, Piers B to H, remained stable during the six-month period. The western portion of the Harbor District, Piers A, S, and T, experienced an elevation increase of up to 0.12 foot (1.4 inches). The elevation increase appears to be the result of regional geologic factors.

Elevations in the City of Long Beach beyond the boundaries of the Wilmington Oil Field were stable. Minor elevation changes in geologically active areas outside the Wilmington Oil Field indicate that this six-month period was an “up” period semi-regionally.

**Elevation Change – May 2010 through April 2011** (Figure 2)

Elevations in the Central City and offshore areas near Island Grissom continued to increase during the 12-month period by as much as 0.12 foot (1.4 inches). The elevation change was minor and attributed to regional geologic factors. Elevations throughout the Central City, Alamos Bay, and Naples areas remained stable during the 12-month period.

The eastern portion of the Harbor District was stable during the 12-month period. The western portion of the Harbor District, Piers A, S, and T, experienced an elevation increase of up to 0.15 foot (1.8 inches). There is no reason for concern as the increase was minor. LBGO is continuing to analyze reservoir pressure data, water injection requirements, and elevation changes. The elevation increase is mainly attributed to regional geologic factors.

### **Use of Global Positioning System (GPS)**

This report is based solely upon computer processed data utilizing the Long Beach Deformation Network (LBDN). The LBDN consists of twelve (12) permanent, reference GPS base stations, communication equipment, computer server, monitoring software and five mobile GPS receivers. The Public Works Department's Bureau of Engineering surveyors utilize the mobile GPS receivers linked to the reference base stations to measure approximately 240 City and Harbor bench marks.

## APPENDIX

### **Brief History of Long Beach Subsidence**

Long Beach and the general vicinity have a history of regional subsidence (losses of elevation) since 1929. Elevation changes were minor amounting to an average of about -0.036 feet (-0.43 inches) per year until about 1939. Geologic movement such as the Long Beach Earthquake of March 1933 altered this average rate at times. Contributing causes of the subsidence were groundwater withdrawal from aquifers in the Long Beach area, regional basin sediment compaction, and tectonic effects of local faulting.

Development of the Wilmington Oil Field began in 1932. Oil operations accelerated subsidence and created a 29-foot deep subsidence bowl centered in the Wilmington-Long Beach Harbor area near Bench Mark 8772 (Figure 6). Development of the Ranger Zone west of Pine Avenue and its extension seaward in 1947 started the first definitive subsidence in the Central Business District that could be attributed to oil production.

Repressuring operations began in the 1950s. By 1965, subsidence stopped throughout the Long Beach portion of the Wilmington Oil Field. Several bench marks recovered over one foot in elevation, due to waterflood repressuring. As an example, from 1960 to 1970, Bench Mark 1735 near the corner of Ocean Boulevard and Magnolia Avenue recovered approximately one foot of elevation. The recovery of bench mark elevations is known as rebound.

In the 1990s, a large Harbor redevelopment project on Pier A destroyed several bench marks that overlaid the now curtailed steamflood project. Elevation losses in the area were suspected, and the destruction of these bench marks made it difficult to monitor any changes. In 1998, after the bench marks were replaced, additional well bore investigations determined that subsurface compaction of the deep shale intervals was occurring above the steam flooded zones due to high temperatures. The Fault Block II



Tar Zone Steamflood was terminated in 1999, and cold-water injection was initiated. The forced cooling of the deep formations has remedied the subsidence problem.

The Alamitos Bay and Naples area had losses in elevation prior to development of the adjacent oil operations. These original small losses were most likely due to the regional affects of basin sediment compaction and tectonic movements along the Newport-Inglewood Fault Zone. Later, the coastal strip from the Civic Center eastward to the Alamitos Bay Peninsula lost elevation due to oil and gas production from the West Wilmington Oil Field and possibly the adjacent oil fields. The coastal strip rebounded slightly due to water injection from the offshore Oil Islands that began in 1965.

### **Survey Accuracy**

The May 2002 Elevation Leveling Campaign marked the conversion from spirit, first and second order rod leveling, to GPS surveying of bench mark elevations.

Through statistical analysis of satellite, base station, mobile instrument geometries, a coincident spirit leveling and GPS bench mark elevation survey, City surveyors estimate the accuracy of GPS elevations to be 8 to 10 millimeters (0.025 feet or 0.30 inches). Areas are considered to be stable where elevation change is less than 0.025 feet (0.30 inches).

Studies by the City's subsidence control engineers, geologists, and consultants show that the bench marks may at times rise and fall somewhat rhythmically city-wide in such a manner as to make an entire survey either optimistic or pessimistic. These elevation changes are random and not well understood. Repressuring operations and the resulting rebound can mask the rise or fall pattern. Surface elevations in a rebounded area can be expected to fluctuate under changing water flood conditions. Because of these fluctuations, conclusions based upon short-term survey data should be viewed with caution. Short-term survey data are useful for possible early detection and confirmation of subsidence trends or relative elevation changes but should not be accepted without

consideration of the above factors. Annual survey data tend to average these fluctuations and depict a more dependable picture of the relative movements of bench marks.

### **Elevation Change Map Construction (Figures 1 and 2)**

All data are presented as contour lines showing the average change in surface elevation during a particular time period. For example, any point along a line reading 0.05 feet (0.60 inches) on an Elevation Change Map gained an elevation of one-twentieth of a foot or six-tenths of an inch during that period. The small hachures along contour lines point towards a loss in elevation.

### **Bench Mark Location Map (Figure 3)**

This map shows the location of bench marks used for the Bench Mark and Net Injection Graphs.

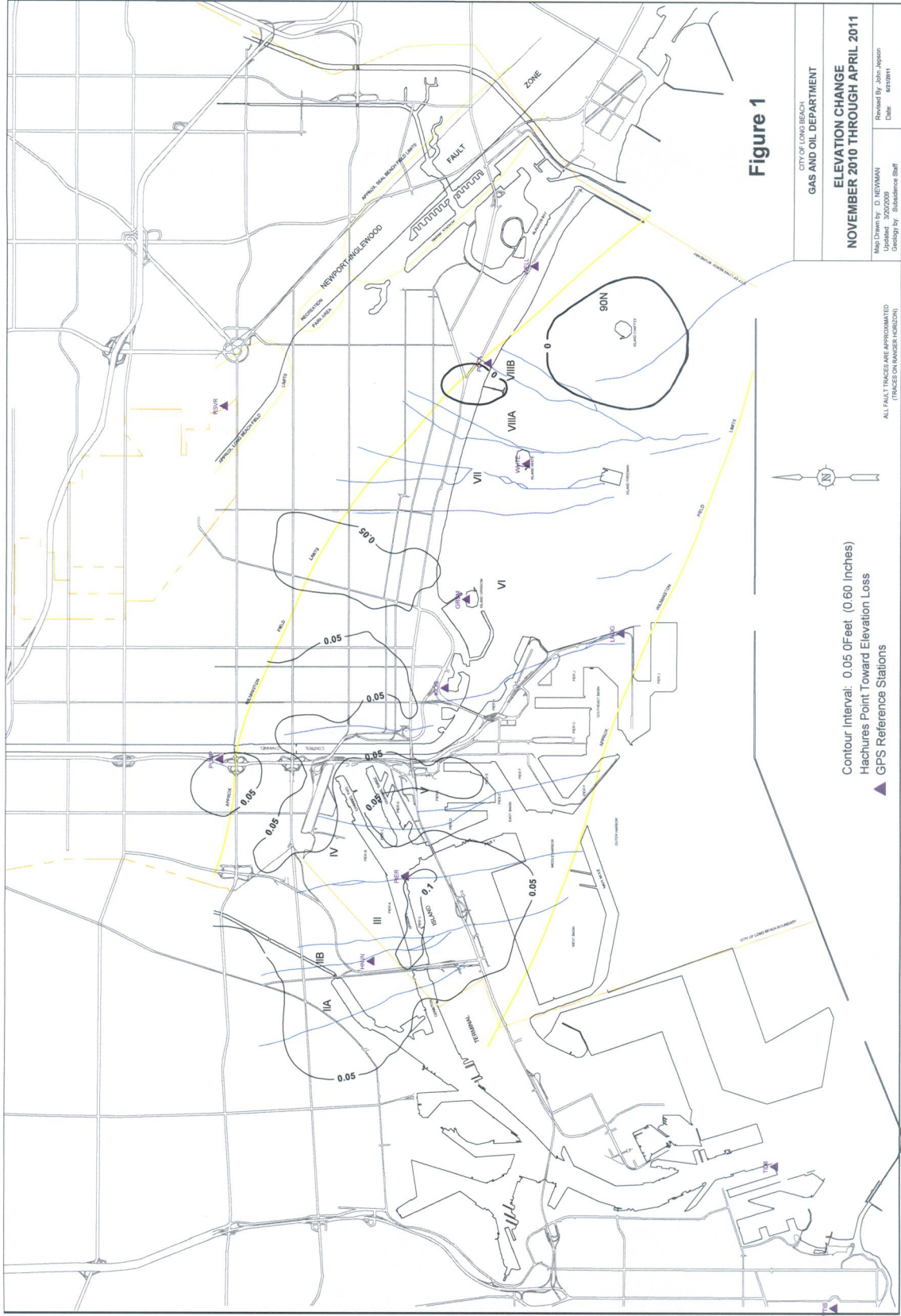
### **Bench Mark and Net Injection Graphs, Harbor District (Figures 4 – 7)**

The bench marks are normalized to mean sea level. Bench marks are plotted each time they are surveyed and are shown on a graph with a history of net injection for that same area and time. The net injection is the amount of water injected into the reservoirs that underlie that particular bench mark minus the gross fluid produced from the reservoirs in barrels per day. The graphs cover 20 years of net injection and bench mark monitoring.

In general, these graphs show a good correlation between the net injection and elevation change. For example, an increase in net injection is usually followed by an increase in elevation. There tends to be a lag time of months and sometimes years between the net injection change and the subsequent elevation change. The elevation plots of bench marks on Figures 4 through 7 in the Harbor District illustrate surface elevation fluctuations that can be expected to occur under the dynamic reservoir conditions experienced in extremely mature waterflooding operations.

**Bench Mark and Net Injection Graphs, Ocean Boulevard and the Offshore Drilling Islands (Figures 8 – 13)**

The last 20 years of elevation changes and accompanying net injection histories are shown on Figures 8 through 13 for bench marks located along Ocean Boulevard and on the offshore drilling islands. The elevation changes at Ocean Boulevard near Magnolia Avenue are shown by the graph of Bench Mark 1735 and Bench Mark 1215 on Figure 8. Permanent GPS Station WELL on Figure 12 shows surface elevation changes on the Alamitos Bay Peninsula. Bench Mark 938 monitors elevation on Naples Island.







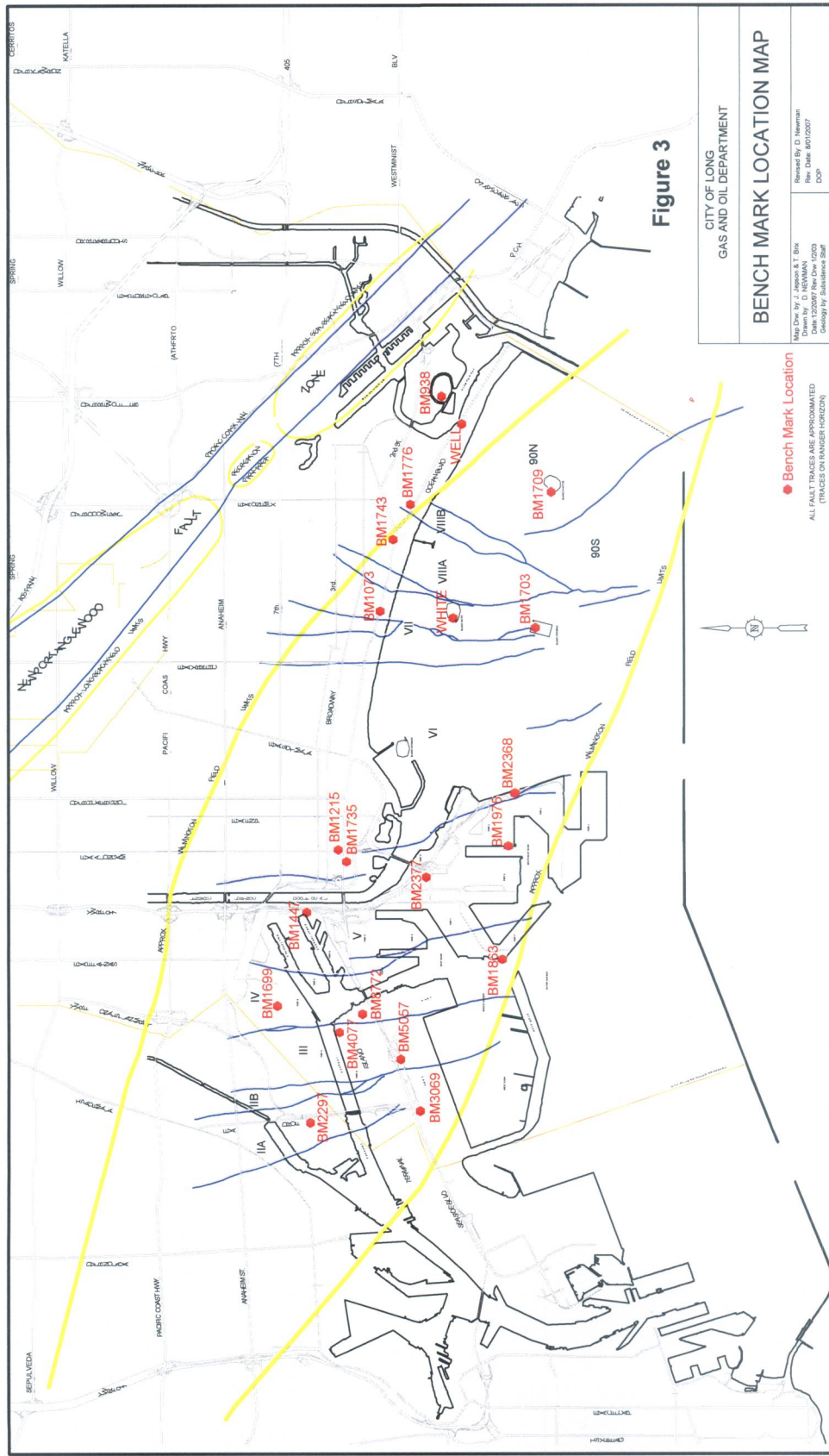


Figure 3

CITY OF LONG BEACH  
 GAS AND OIL DEPARTMENT

**BENCHMARK LOCATION MAP**

Map Date: 1/15/2007  
 Map Drawn By: D. Newman  
 Date: 1/20/07  
 Project: 0010007  
 DDP

● Benchmark Location

ALL FAULT TRACES ARE APPROXIMATED  
 (BASED ON NUMBERED SHEETS)

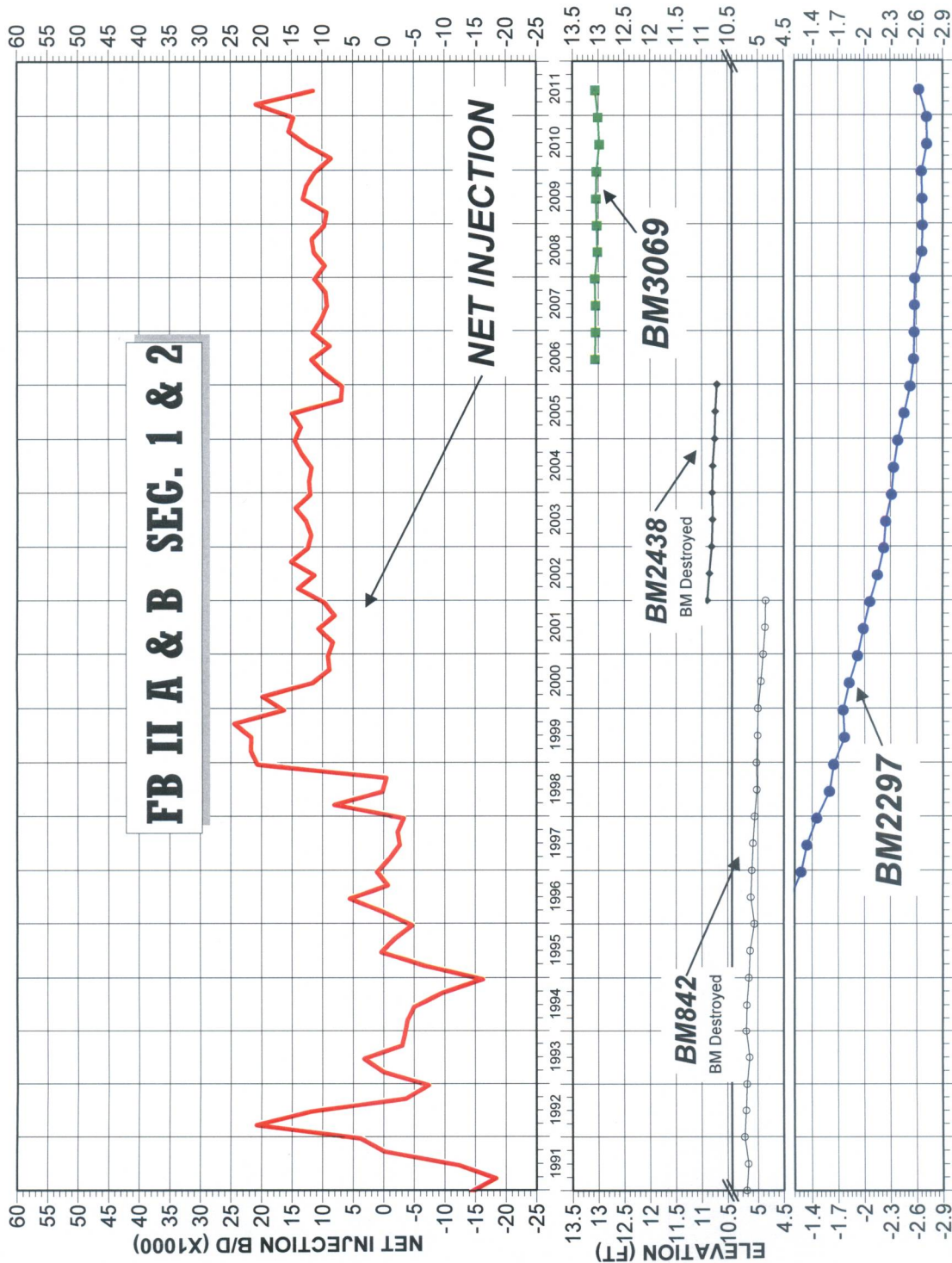


Figure 4

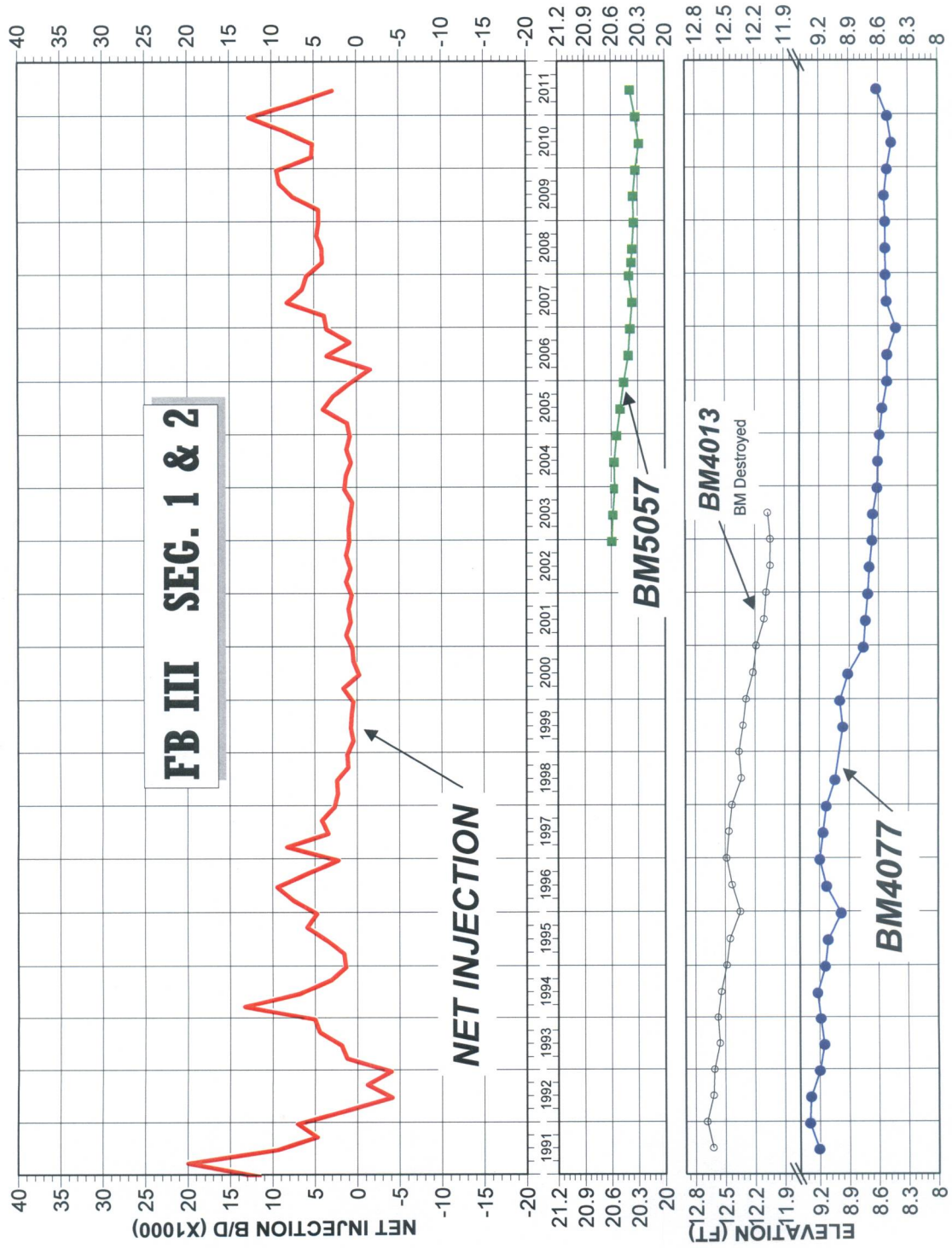


Figure 5



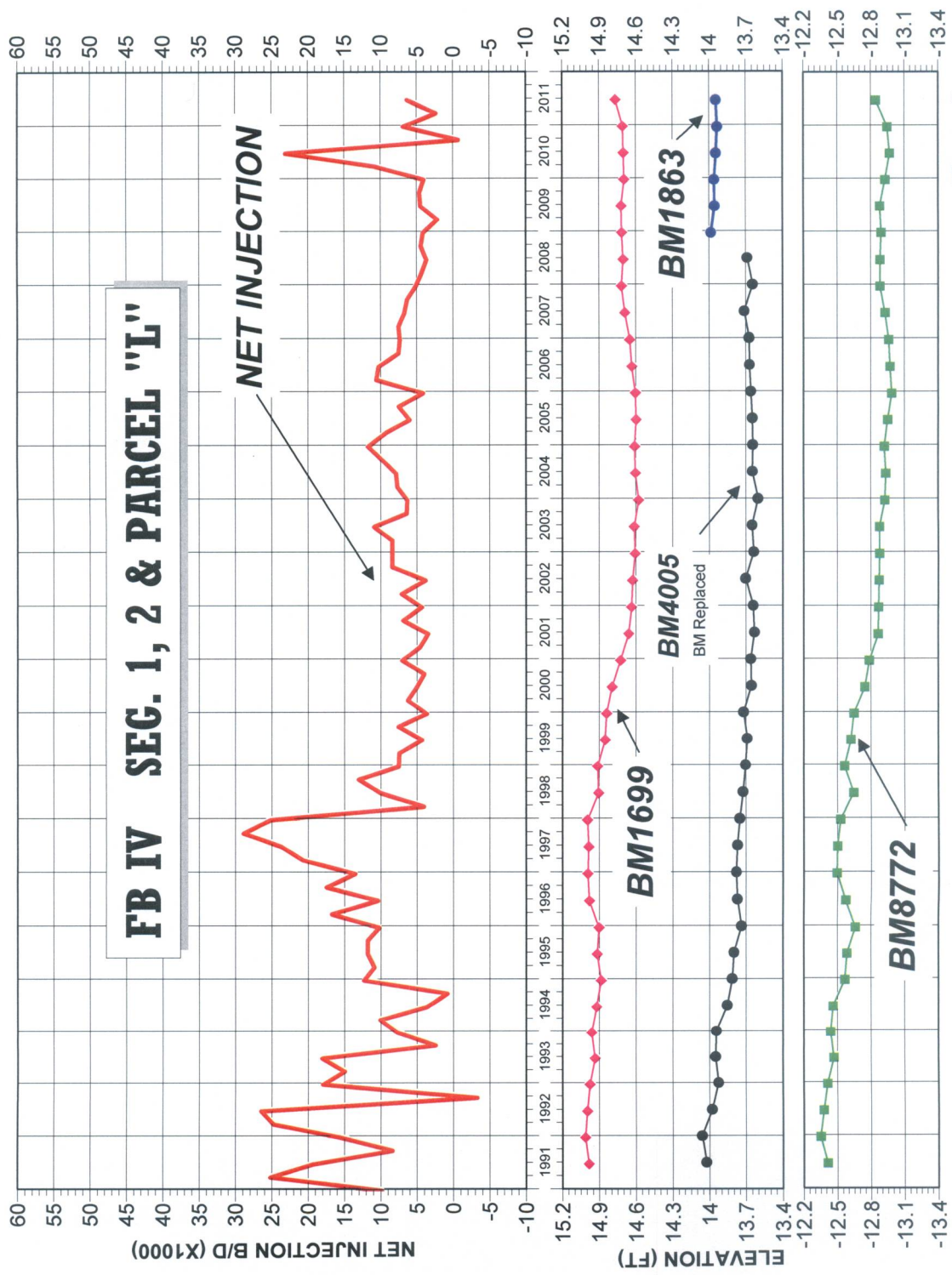
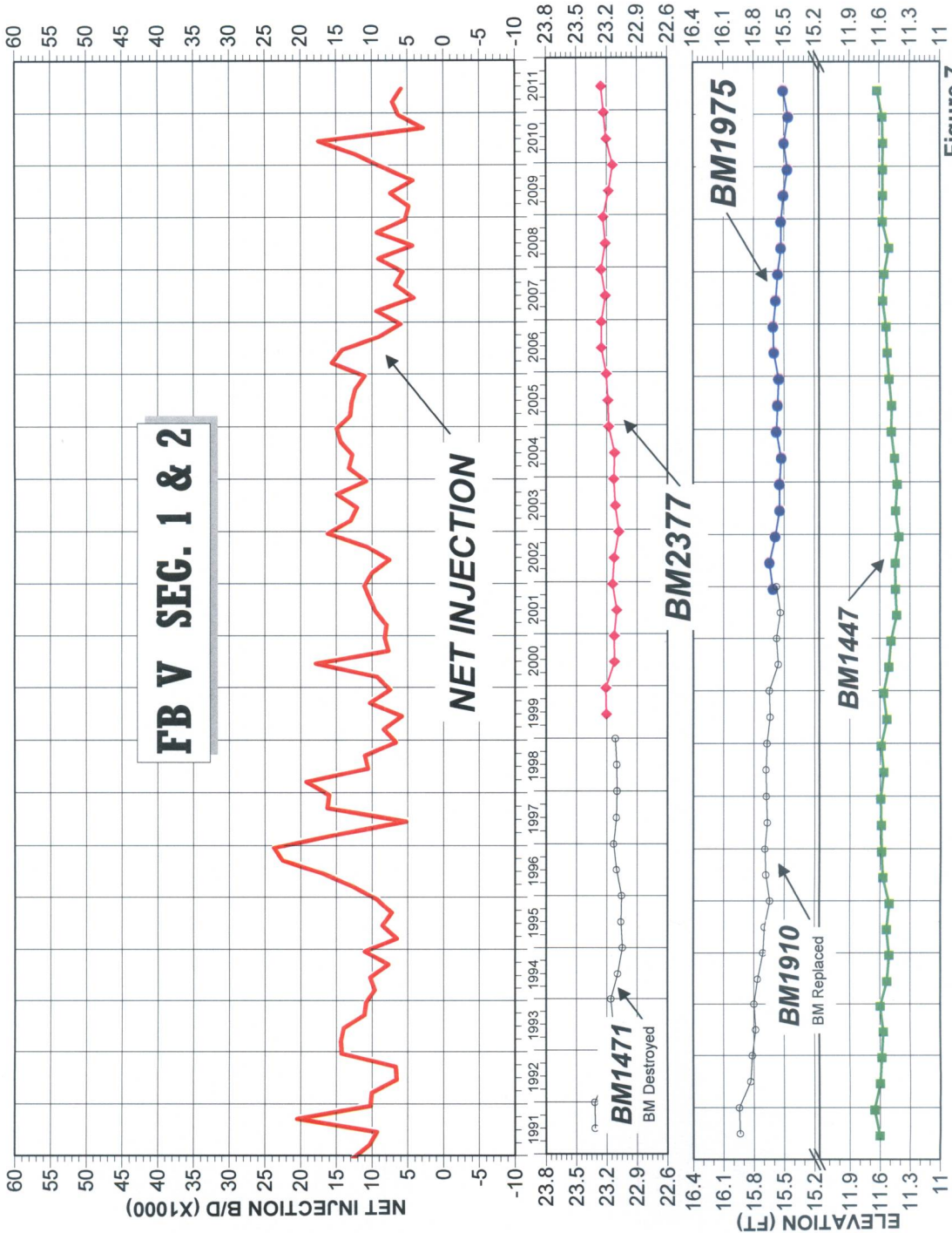
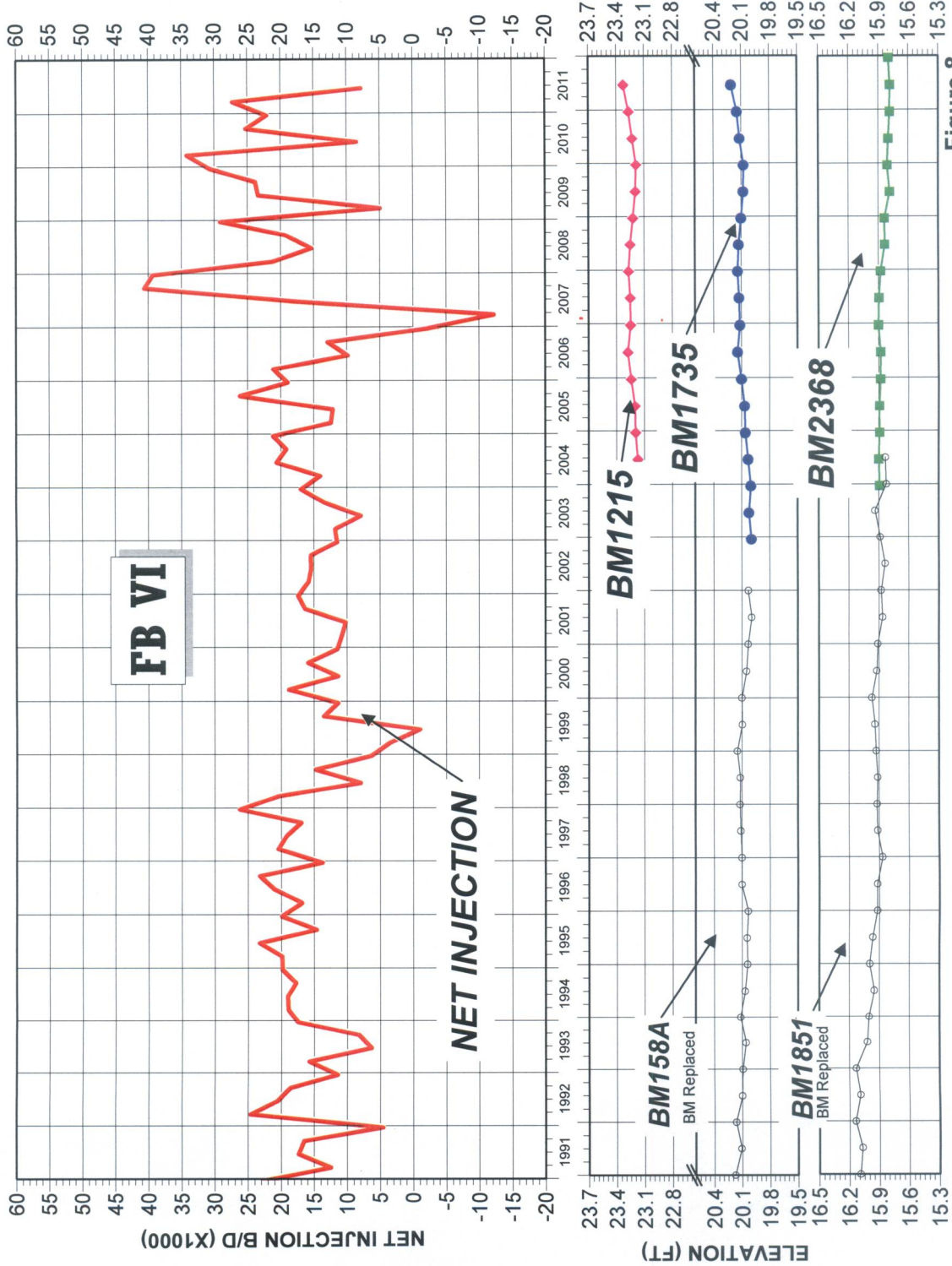


Figure 6





**Figure 8**



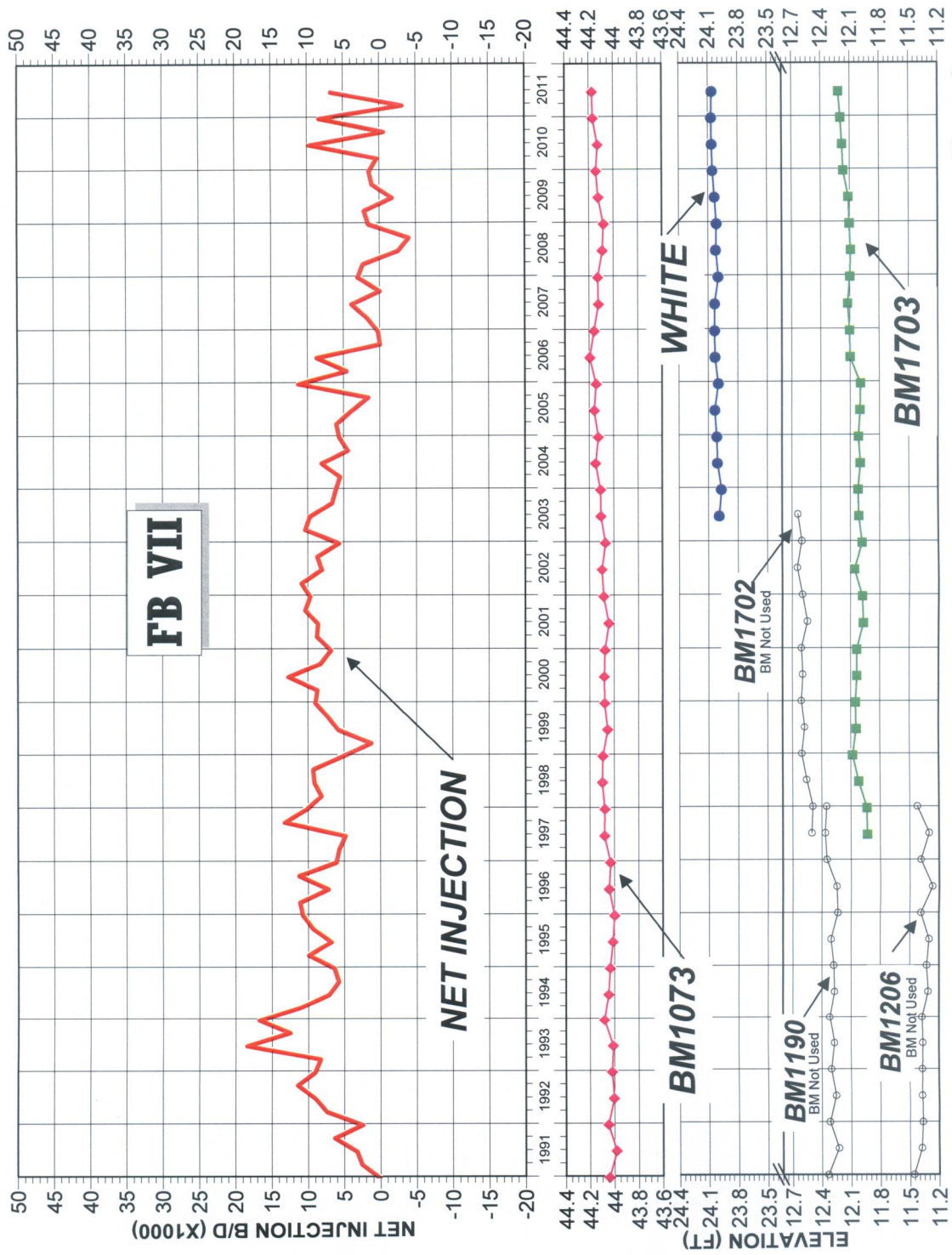


Figure 9

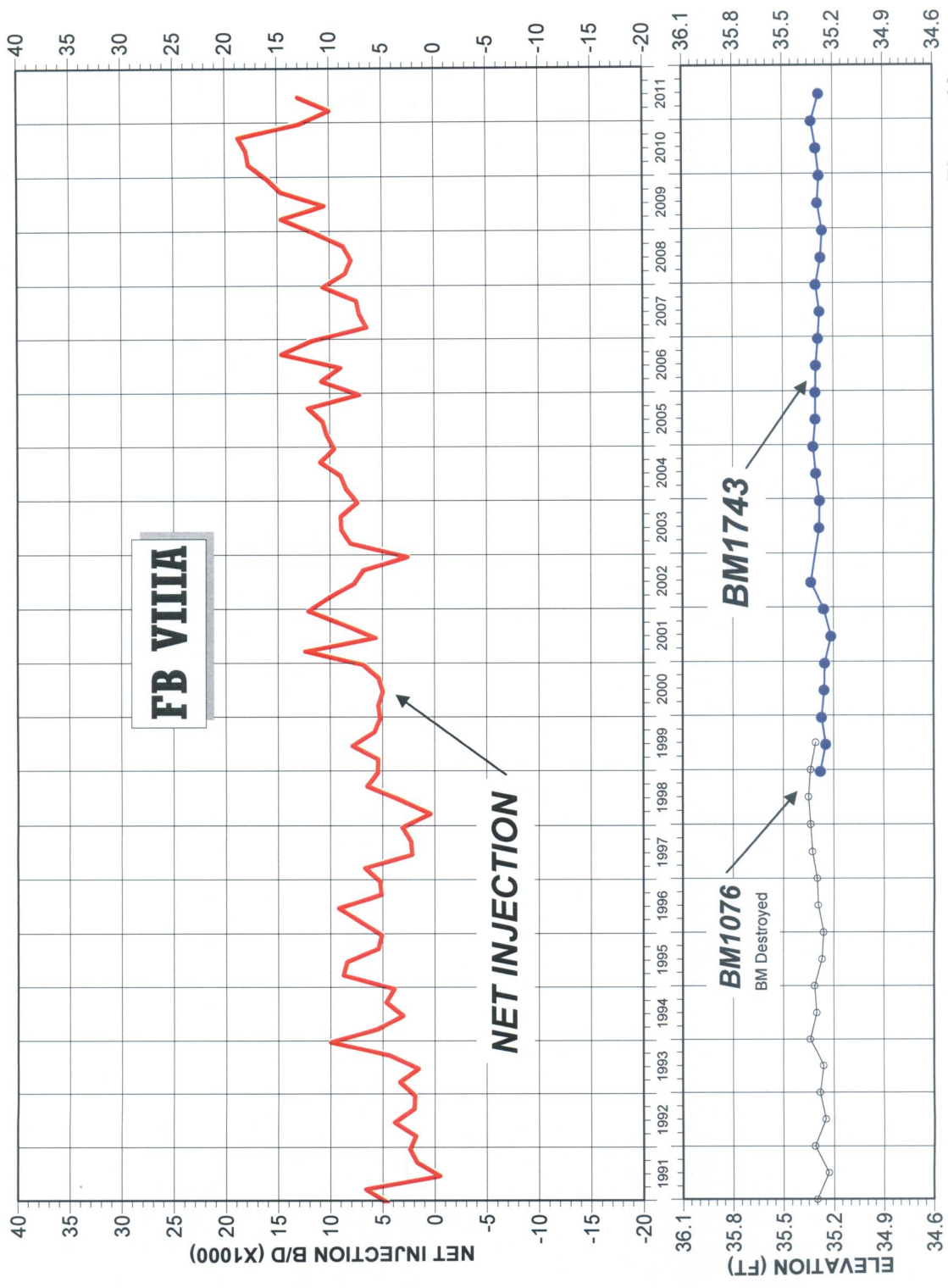


Figure 10

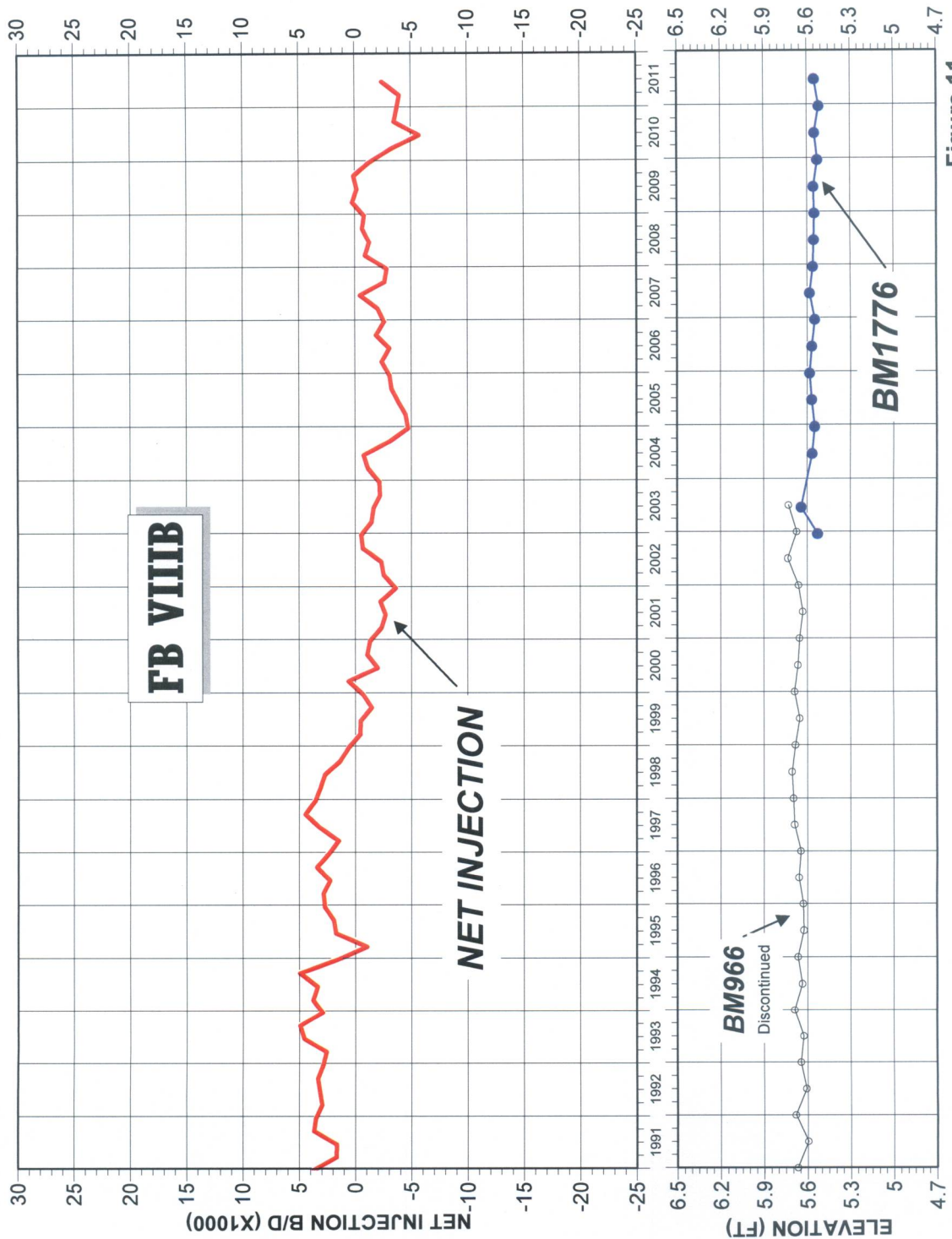


Figure 11

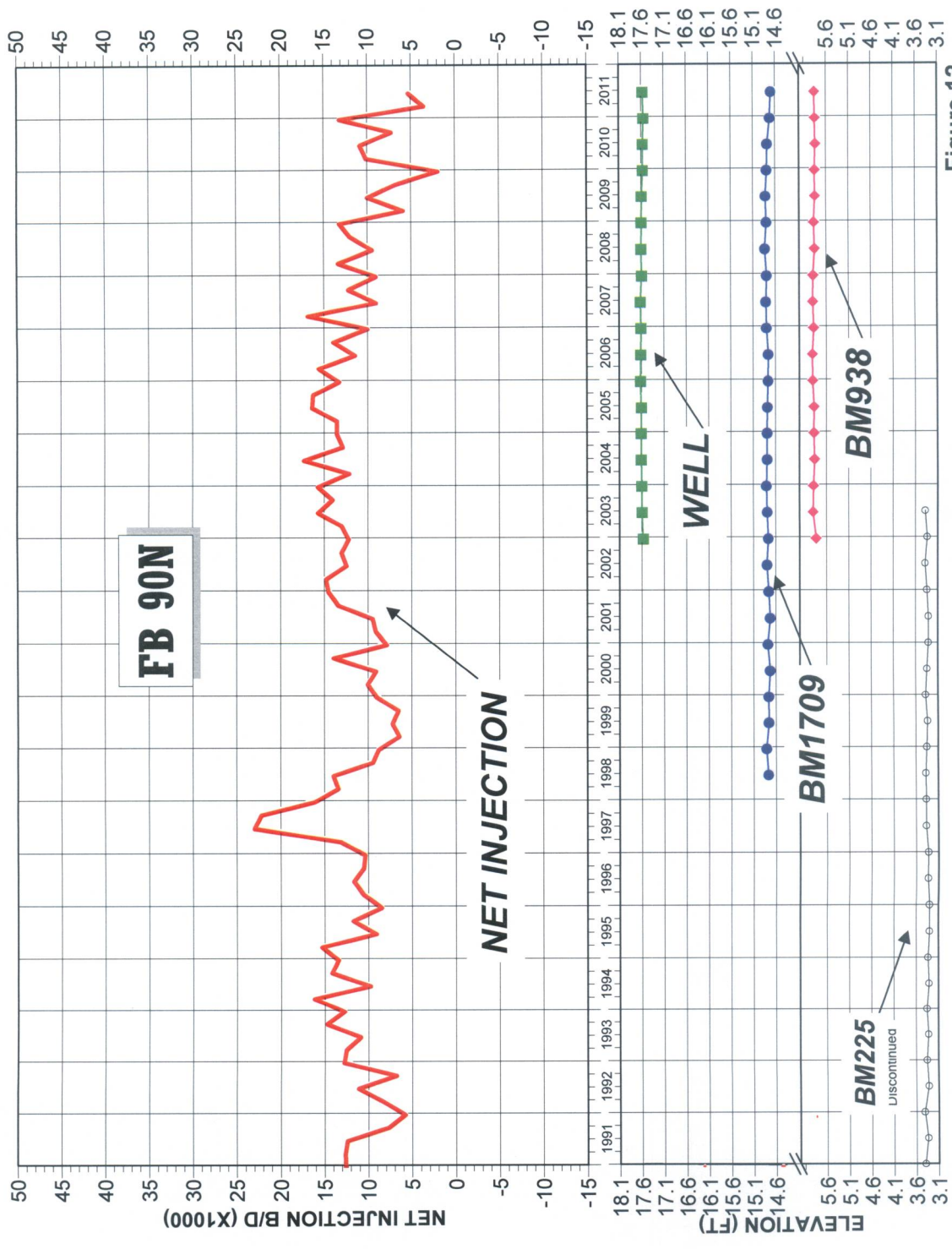


Figure 12



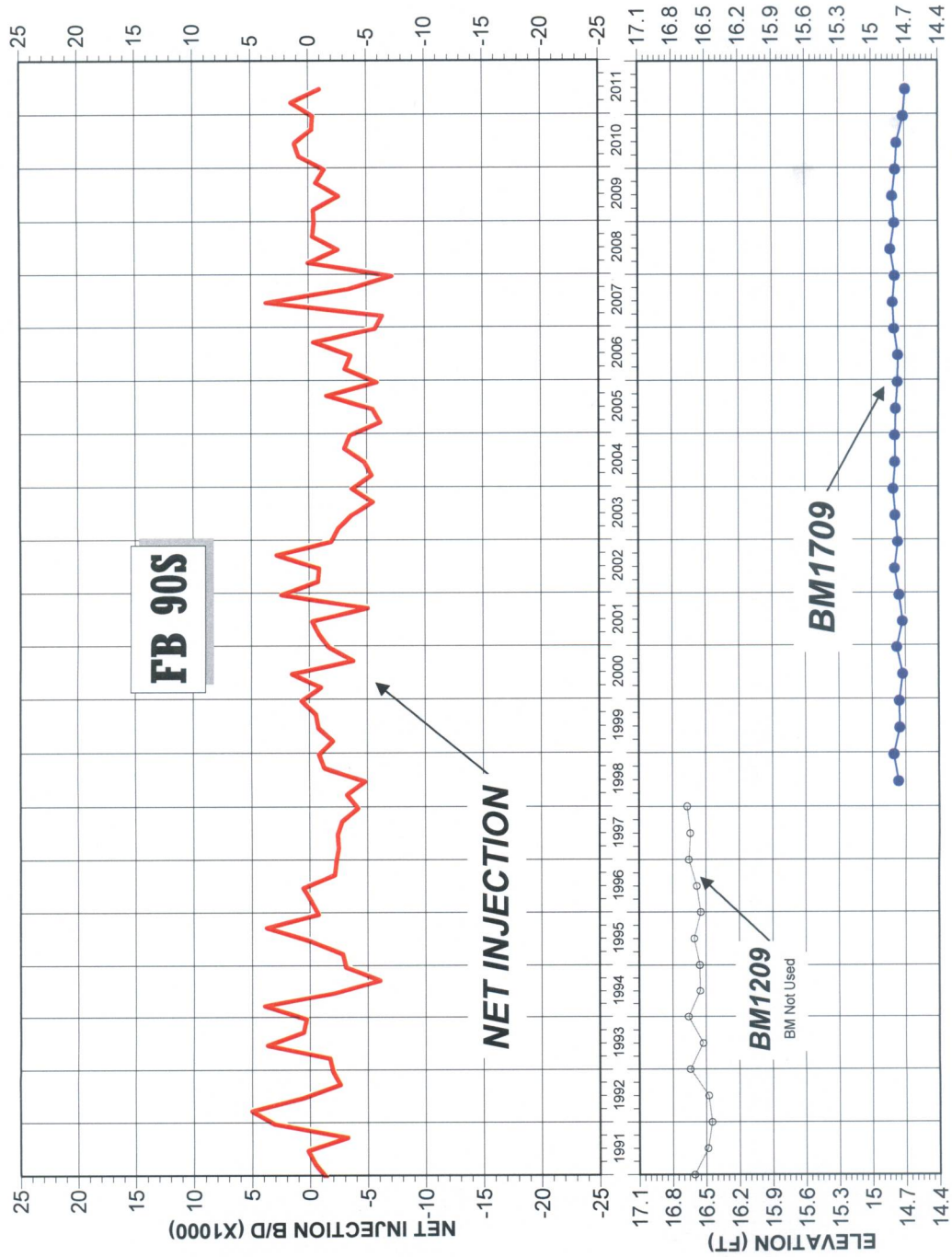


Figure 13