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January 30, 2017

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Re: *Results of Bedrock Production Well Optimization Test*
Bedrock Remediation Area (Operable Unit 2)
Former IBM East Fishkill Facility
NYSDEC Site No. 31454, EPA ID No. NYD000707901
East Fishkill, New York

Dear Mr. Czuhanich and Mr. Wilkie:

Enclosed, please find the Bedrock Production Well Optimization Testing Report for the former IBM East Fishkill Facility in East Fishkill, New York (Site). The report has been prepared by Groundwater Sciences Corporation on behalf of the IBM Corporation (IBM). This report is being submitted in accordance with the Site's New York State Part 373 permit, regulated by the New York State Department of Environmental Conservation (NYSDEC).

Should you have any questions, please contact Dean Chartrand of IBM at (703) 257-2583.

Very truly yours,
GROUNDWATER SCIENCES CORPORATION

C. Edward Stoner

C. Edward Stoner, P.G.
Project Manager

DABergmann for

Robert C. Watson, P.G.
President

Enclosure

BEDROCK PRODUCTION WELL OPTIMIZATION TEST REPORT

BEDROCK REMEDIATION AREA (OPERABLE UNIT 2)
FORMER IBM EAST FISHKILL FACILITY
TOWN OF EAST FISHKILL, DUTCHESS COUNTY, NEW YORK

Prepared for:

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January 30, 2017

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1 INTRODUCTION

On behalf of the IBM Corporation (IBM), Groundwater Sciences Corporation (GSC) has prepared this report providing the findings of an optimization test of active bedrock production wells PW-1, PW-2, PW-4, and PW-25 located within the main plant portion of the former IBM East Fishkill Facility (NYSDEC Site No. 314054, EPA ID No. NYD000707901) in East Fishkill, New York (Site). Extraction and treatment of groundwater from these four bedrock wells currently serves a dual-purpose of providing production water for GlobalFoundries manufacturing operations, while also providing hydraulic containment of volatile organic compound (VOC) plumes in bedrock groundwater within the Bedrock Remediation Area (Operable Unit #2 / OU2) of the Site.

The optimization test consisted of modifying bedrock production well withdrawals at the Site for a period of about 3.5 months. The purpose of the optimization test was to collect empirical data to assess the apparent hydraulic response in bedrock potentiometric levels under reduced and rebalanced production well withdrawals in anticipation of Site conditions where the purpose of the groundwater extraction is solely to maintain hydraulic containment of VOC plumes in Site bedrock. Results of this test have been reviewed in conjunction with historical operations data and groundwater modeling to develop targets for future production well withdrawals with the goal of optimizing hydraulic containment of VOC plumes in bedrock groundwater within the Bedrock Remediation Area of the Site. The optimization test was performed as part of IBM's groundwater Resource Conservation and Recovery Act (RCRA) Corrective Action (CA) program which is regulated by the New York State Department of Environmental Conservation (NYSDEC) under the Site's New York State Part 373 RCRA permit[1]. The Site is currently owned by GlobalFoundries but IBM maintains responsibility for implementation of the RCRA CA program.

[1] New York State Department of Environmental Conservation, November 2, 2011, *6NYCRR Part 373 Hazardous Waste Management Permit, IBM Corporation East Fishkill Facility*.

2 BACKGROUND

This section provides a description of background information pertinent to assess the reduction and rebalancing of the bedrock production well withdrawals.

2.1 Site Location

The Site consists of a semiconductor manufacturing and development facility located in south-central Dutchess County within the Town of East Fishkill, New York. A topographic base map showing the approximate location of the Site relative to regional ground surface topography and drainage features is provided as Figure 1. As shown on the figure, the Site consists of two tax parcels. The larger of the two parcels is bounded on the north by New York State Route 52, on the east by Lime Kiln Road, on the south by Interstate 84 (I-84) and the I-84 interchange at Lime Kiln Road, and on the west by high voltage power lines owned by Consolidated Edison Company of New York and natural gas lines owned by Central Hudson Gas & Electric Corporation. The smaller parcel is located east of Lime Kiln Road, south of Route 52 and west of Shenandoah Road. As indicated on Figure 1, the four active bedrock production wells are located in the central and northwestern portions of the larger tax parcel.

2.2 Regional Hydrogeologic Setting

According to regional surficial geologic mapping for the lower Hudson River Valley[2], the Site is located in an area of northeast and north-northeast trending ridges of glacial till and/or bedrock which are drained by valleys underlain by coarse-grained proglacial (near ice) outwash or kame sand and gravel deposits, glaciolacustrine silt and clay, and post-glacial alluvium. Bedrock in the area of the Site is mapped as the Cambrian to Lower Ordovician carbonate platform rocks of the Wappinger Group[3]. The Wappinger Group is mapped as dolostone and limestone interbedded with sandstone and shale. The bedrock of the Wappinger Group has a complex geologic history with

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[2] Cadwell, D.H., ed., 1989, *Surficial Geologic Map of New York, Lower Hudson Sheet*, New York Geological Survey, Map and Chart Series #40.

[3] Fisher, D.W., Isachsen, Y.W., and Rickard, L.V., eds., 1970, *Bedrock Geologic Map of New York, Lower Hudson Sheet*, New York State Geological Survey, Map and Chart Series #15.

multiple stages of folding and faulting, resulting in a series of northeasterly and northerly trending bedrock ridges and troughs.

As shown on the aerial photographic base map provided as Figure 2, surface water features within the Site include wetland areas within the southeastern, southern and western portions of the Site that are drained by Gildersleeve Brook and an unnamed tributary to Gildersleeve Brook referred to as the Central Drainage. The Central Drainage originates east of the Site and flows west through the central portion of the Site before discharging into Gildersleeve Brook. Gildersleeve Brook flows in a northwest direction near the western Site boundary and continues to flow outside the limits of the Site in a north to northwest direction before discharging into Fishkill Creek.

2.3 Site Hydrogeologic Conditions

Our understanding of Site hydrogeologic conditions is based on the review of the results of over fifty years of geotechnical engineering investigations and over thirty years of hydrogeologic and remedial investigations, including RCRA Facility Investigations and Corrective Measures Studies.

2.3.1 Surficial and Bedrock Geology

Overall, geologic conditions beneath the Site are in general conformance with regional surficial and bedrock geologic mapping. The topographic ridges in the southeastern portion of the Site consist of thin deposits of glacial till overlying bedrock, whereas, much of the developed portions of the Site are underlain by thick overburden deposits consisting of a descending sequence of post-glacial alluvium, glaciolacustrine silt & clay, glaciofluvial sand & gravel, and glacial till. Bedrock beneath the Site consists of a sequence of dolostone interbedded with lesser amounts of limestone, fine-grained sandstone, dolomitic siltstone, and shale. Structures within the Site bedrock are consistent with the region’s complex geologic history of folding and faulting.

2.3.2 Bedrock Surface Topography and Inferred Bedrock Structure

A map depicting bedrock surface topography superimposed with our conceptual model of bedrock fault structures is provided as Figure 3. As shown on the figure, the bedrock surface beneath the Site generally consists of a series of north-northeast trending ridges and troughs. Bedrock surface elevations range from about 310 feet above Mean Sea Level (ft amsl), at the crest of the bedrock ridge in the southeast portion of the Site, to less than 170 ft amsl in depressions located beneath Buildings 316, 334, and 323. Prominent ridges or mounds in the bedrock surface topography have been identified in the southeast undeveloped portion of the Site, beneath Buildings 330C and 338, beneath Buildings 300, 320B, and 310, beneath the northwestern portion of Building 323, and beneath much of Building 321. These relatively higher bedrock surface features generally correspond with areas or “blocks” of competent dolostone bedrock with limited amounts of weathering and fracturing.

Depressions in the bedrock surface that correspond to steeply dipping zones with moderately to highly weathered/fractured bedrock are shaded light brown on Figure 3. These weathered and fractured zones are separated by the blocks of relatively competent dolostone bedrock. These shaded areas are inferred to consist of ancient (inactive) “strike-slip” fault zones based on:

- The presence of thick zones of clay alteration minerals and iron-oxide staining, indicative of elevated pressure and temperature conditions consistent with faulting/shearing;
- The presence of mylonitic fabrics superimposing dolostone, limestone, and shale which is also indicative of faulting/shearing;
- The relatively abrupt change in bedrock surface topography near the margins of the weathered/fractured zones and the depth of penetration of the weathering/fracturing which are more likely to be reflective of a steeply dipping or vertical fault/shear zone rather than a low angle normal or thrust fault zone; and
- The apparent thickness of the weathered/fractured zone which is indicative of a wide transcurrent (strike-slip) fault rather than a more discrete (thinner) high angle normal fault.

2.3.3 Apparent Influences of Bedrock Structure on Site Hydrogeology

Based on predominant fracture orientations, areas of competent rock with limited discrete fracturing are expected to exhibit a greater magnitude of vertical hydraulic gradient, reflecting impeded vertical recharge of groundwater from soil. Areas of highly weathered and fractured bedrock are expected to exhibit lower vertical gradients, be more conducive to vertical recharge of groundwater, have highly variable directional hydraulic conductivity (conductivity that is much greater parallel to the predominant north-south fracture orientation, as compared to perpendicular to the predominant north-south fracture orientation), and have greater transmissivity.

As depicted on Figure 3, production wells PW-2, PW-4, and PW-25 are located within the area of a prominent zone of weathered/fractured bedrock that extends in a north-south direction through the central portion of the Site, whereas production well PW-1 is located in an area of competent bedrock proximate to separate areas of weathered/fractured bedrock. Consistent with the positions of these four active production wells with these inferred greater transmissivity fault zones, hydraulic responses to production well pumping indicate wells PW-2, PW-4, and PW-25 have greater interconnectivity as compared with well PW-1. In addition, the combined withdrawals of PW-2, PW-4, and PW-25 have a greater influence in bedrock potentiometric levels and hydraulic control in the central and southeastern portion of the Site, while withdrawals from PW-1 have a greater influence in bedrock potentiometric levels and hydraulic control in the northwestern portion of the Site and off-Site areas to the north and west.

2.4 VOC Plumes in Bedrock Groundwater

The Bedrock Remediation Area consists of portions of the bedrock aquifer underlying the Site where VOCs have been detected above applicable 6NYCRR Part 703 New York State Groundwater Quality Standards. The Bedrock Remediation Area is also referred to as Operable Unit 2 (OU2) in the Final Statement of Basis, dated September 2013 (effective date of April 16, 2014), that was developed by the NYSDEC in consultation with the New York State Department of Health (NYSDOH) under the authority of RCRA. The Bedrock Remediation Area results primarily from source areas within a former solvent storage area in the northeast portion of the Site (Area A/ OU5), a former landfill area in the southeast portion of the Site (Area C/OU9), the Building 330 Area of Concern (AOC) (B/330 AOC/OU8) in the southern portion of the Site, and the Building 322 AOC (B/322 AOC/OU7) in the northwestern portion of the Site. The primary VOCs in the bedrock groundwater consist of tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (CIS), vinyl chloride (VC), and Freon® TF. PCE and its transformation products TCE, CIS, and VC are collectively referred to as the PCE-Series compounds. As shown on Figure 4, PCE-Series compounds are present primarily in three bedrock groundwater plume areas, including:

- The Area A bedrock plume in the northeastern portion of the Site near Buildings 308 and 310;

- The Area C and B/330 AOC bedrock plume in the southeastern and southern portions of the Site beneath Buildings 300, 330C, 330D, 334, and 338; and
- The B/322 AOC bedrock plume in the northwestern portion of the Site, beneath the northern portion of Building 322, and portions of Buildings 320B and 321.

Based on the inferred limits of apparent hydraulic capture of the Site's bedrock production wells, the Bedrock Remediation Area groundwater plumes are hydraulically contained as follows:

- The Area A bedrock plume is captured by bedrock production well PW-2;
- The Area C and B/330 AOC bedrock plume is captured by bedrock production wells PW-4 and PW-25; and
- The B/322 AOC bedrock plume is captured by bedrock production well PW-1.

2.5 Bedrock Remediation Area (OU2) History and Status

IBM has been pumping and treating groundwater from on-Site production wells for over 35 years as an integral component of the groundwater CA program regulated by the NYSDEC under the Site's 6NYCRR Part 373 RCRA Permit. This program is in place to contain and remove chemicals present in groundwater at the Site. Historically, IBM treated the extracted groundwater in Building 316 and used the treated groundwater in other Site operations, ultimately discharging it through the Site's treatment plant (Building 325 Water Pollution Control Facility) under a State Pollutant Discharge Elimination System (SPDES) permit. The SPDES permit also authorized IBM to discharge the treated groundwater directly to the Gildersleeve Brook. Locations of the bedrock production wells, Building 316, and the Building 325 Water Pollution Control Facility are shown on Figure 2.

Bedrock production wells historically operating at the Site include wells PW-1, PW-2, PW-3, PW-4, PW-5, PW-5A (serving as a nearby backup well to PW-5), PW-6, PW-7, and PW-9. PW-3 was operated for a brief period of time, but was disconnected from the water supply system due to high turbidity and low yield. PW-8 was installed but was never connected to the overall water supply system as it did not yield sufficient quantities of water for water supply purposes. PW-9 has been rarely operated as it only serves as a backup well during water supply emergencies. These production wells were installed as water supply wells for Site manufacturing operations and began serving the dual-purpose of also providing hydraulic containment of bedrock groundwater plumes upon the discovery of VOCs in the water supply withdrawals in the late 1970s. The bedrock groundwater withdrawals are conveyed to Building 316, treated using granular activated carbon (GAC), and discharged to the deionized water plant or to the raw water storage tanks which feed the various process water systems. Treated water may also be discharged directly to a tributary to Gildersleeve Brook (referred to as the "Central Drainage") or the Site's Industrial Waste Treatment Plant.

In the late 1990s and early 2000s, investigations and corrective measures focused in the southeastern and southern portions of the Site resulted in the installation and operation of bedrock production/extraction wells PW-23 and PW-25. The PW-23 was installed and began operation in 2001 to capture and accelerate cleanup of a low concentration presence of VOCs in overburden and shallow bedrock in a former contractor staging area (Southeast Quadrant/OU9). PW-23 groundwater extraction operations were shut down in 2015 after successful removal of the VOC plume. A shut down test is currently underway in the area of PW-23 to assess for potential rebound of the VOC plume. PW-25 was installed and began extraction operations in 2003 as the result of a groundwater Corrective Measures Study (CMS) of the B/330 AOC. Similar to PW-2, withdrawals from PW-25 were initially treated using a separate GAC treatment train. As stated at the time of the B/330 AOC CMS, the goals of the well PW-25 extraction operations were as follows:

1. Segregating production well water with elevated (PW-25 concentrations are approximately 100x New York State Groundwater Quality Standards (NYSGQS)) concentrations of VOCs originating from the B/330 AOC from the potable water stream with exclusive use of the treated water for process needs.

2. Augmenting and supplementing existing groundwater containment measures, providing redundant containment capability closer to B/330 AOC sources, with the goal of shrinking the lateral and vertical extent of groundwater exceeding NYSGQS by capturing groundwater closer to the point of plume origination.

3. Enhancing mass removal operations by reducing mass cycling long distances through the Site's hydrologic system, reducing commingling of contaminated groundwater with clean water, and reducing the volume of VOC-containing groundwater that must be withdrawn for groundwater containment corrective action.

Initial operation of production well PW-25 was successful in meeting the above-listed goals. In a matter of a few years, significant reductions were observed in the overall extent of the VOC plumes in Site bedrock that originate in the B/330 AOC.

In 2007, the production well water supply was supplemented with municipal water from the Poughkeepsies' Water Treatment Facility via the Central Dutchess Water Transmission Line. Due to the availability of the municipal water, IBM implemented an on-Site production well withdrawal rebalancing plan whereby withdrawals from wells PW-5/5A, 6, and 7 were terminated and the Bedrock Remediation Area was monitored to confirm hydraulic containment of the VOC plumes in Site bedrock groundwater was maintained under the reduced production well withdrawals of about 1 million gallons per day (MGD).

At the present time, the remaining four active bedrock production wells at the Site (PW-1, PW-2, PW-4, and PW-25) continue to serve a dual-purpose of providing production water for GlobalFoundries manufacturing operations while also providing hydraulic containment of VOC plumes in bedrock groundwater within the Bedrock Remediation Area of the Site. The reuse of treated groundwater as production water in GlobalFoundries' operations is the subject of an existing three-year agreement between IBM and GlobalFoundries. However, if at some point GlobalFoundries no longer needs the water, IBM will need to continue to pump, treat and discharge the water as required by NYSDEC.

3 SCOPE OF WORK

The scope of the production well optimization test was developed with the goal of collecting empirical data to support minimizing the rate of main plant Site withdrawals while maintaining hydraulic containment of VOC plumes in bedrock groundwater. The optimization test work scope was developed based on: a review of 2013 and 2014 operating data for the Site's bedrock production wells; meetings with GlobalFoundries personnel to understand potential production water demands of manufacturing operations during the proposed test period; review of 2013 and 2014 potentiometric contour maps depicting apparent limits of hydraulic capture of the VOC plumes in bedrock groundwater; and groundwater modeling simulations to assess the sensitivity of possible adjustments in bedrock production well operations from baseline operating conditions in September 2014.

The groundwater modeling simulations were developed by GSC in consultation with Sanborn, Head & Associates, Inc. (SHA) of Concord, New Hampshire. In 1999, SHA developed a 10-layer, three-dimensional numerical groundwater model of the Site and relevant surrounding area. Wells are assigned a model layer based on the elevation of their screened interval as shown in Appendix A. Model layer 1 elevations range from 400 to 300 ft amsl, model layers 2 through 7 divide the 300 to 0 ft amsl range evenly into 50 ft intervals. Model layer 8 covers the interval from 0 to -100 ft amsl, model layer 9 from -100 to -200 ft amsl, and model layer 10 from -200 to -400 ft amsl. Overburden and shallow bedrock monitoring wells have screened intervals primarily corresponding to model layers 1 through 3, while deep overdurden and intermediate bedrock monitoring wells have screened intervals corresponding to model layer 4. Wells used in creating deep bedrock potentiometric contour maps of the Site correspond with model layer 5 (150 to 100 ft amsl) and model layer 6 (100 to 50 ft amsl). The PW-2 open bedrock borehole corresponds to model layers 5 through 7, while the primary productive zone for PW-4 corresponds to model layer 7. The majority of the open borehole for PW-1 and the screened interval for PW-25 is located in model layer 9.

The numerical model principally focuses on the bedrock aquifer and has been used over the past 15+ years to assist IBM in management of their bedrock groundwater remediation program and their on-Site and off-Site production well water supply withdrawals. For the purposes of the planning and work scope development of the optimization test, SHA completed seven groundwater model simulations that included:

- four steady-state simulations, designated #1A through #1D, with PW-4 shutdown and reduced or no withdrawals from PW-1;
- one steady-state simulation, designated #2, of Site production well withdrawals rebalanced using inactive production wells PW-5A, PW-6, and PW-7, rather than the off-Site well fields;
- one transient simulation, designated #3, using withdrawals of the steady-state simulation #1A to assess potentiometric changes at timeframes of one week, one month, three months, six months, one year, and five years; and
- one steady-state simulation, designated #4, using constant production well operating level target elevations rather than target withdrawals rates.

Simulations #1A and #1B most closely targeted the proposed optimization test withdrawals. Simulation #2 was used to predict the effects of rebalancing production well withdrawals using other on-Site bedrock production wells rather than increasing production well withdrawals from off-Site well fields. Simulation #3 was used to predict the minimum test duration that would be useful for collection of empirical data supporting reduced and rebalanced production well withdrawals. Simulation #4 was used to predict hydraulic capture operating the production wells using constant head (water level) controls rather than constant flow controls. The findings of the modeling were presented by SHA to IBM and GSC in a meeting on May 21, 2015. A June 2016 memorandum prepared by SHA that summarizes the scope and results of the groundwater modeling simulations is provided in Appendix A.

Recent operating data, 2013 and 2014 potentiometric contour maps, information/data obtained from GlobalFoundries, and groundwater modeling simulations were used to develop the following elements of the optimization test work scope:

1. Optimization test target withdrawal rates for on-Site and off-Site production wells;
2. A hierarchy of preferred production well withdrawal locations in case GlobalFoundries needed greater production water withdrawals during the test period; and
3. A schedule of groundwater monitoring locations and frequencies.

The proposed scope of the optimization test was described in a July 23, 2015 letter[4] to the NYSDEC that was prepared by GSC on behalf of IBM.

3.1 Optimization Test Withdrawal Rates

The optimization test was performed for a period of about 3.5 months, between August 17, 2015 and December 1, 2015. On the morning of August 17, GlobalFoundries operators adjusted on-Site bedrock production wells in an attempt to target the withdrawal rates listed in the July 23, 2015 optimization proposal. The target withdrawal rates for the three wells scheduled to continuously pump over the duration of the test were 70 gallons per minute (gpm) for PW-1, 120 gpm for PW-2, and 220 gpm for PW-25. Attempts were made to keep the active production wells pumping at or near each of the target rates for the entirety of the test. PW-4 was activated weekly at about 40 gpm for approximately one hour per week to test the pump since the well serves as the PW-2 backup in the event of an unplanned shutdown. Production wells PW-5/5A, 6, 7, and 9 were inactive throughout the test. PW-23 was inactive throughout the test except during the quarterly sampling event in October when approximately 240 gallons were purged from the well. Site process water needs were met by increasing groundwater withdrawals at the Wiccopee and RR Spur off-Site well fields (The general locations of the two off-Site production well fields relative to the Site are shown on Figure 2). The test concluded on December 1, 2015 when GlobalFoundries operators resumed PW-4 groundwater withdrawals and adjusted other well flows based on water supply needs for manufacturing.

Average 2015 production well withdrawal rates prior to the start of the optimization test are compared with withdrawal rates during the optimization test in the following table.

[4] Groundwater Sciences Corporation, July 23, 2015, letter from C. E. Stoner, P.G. to A. Czuhanich and H. Wilkie of NYSDEC, Re: Bedrock Production Well Optimization Testing, Bedrock Remediation Area (Operable Unit #2), Former IBM East Fishkill Facility/Hudson Valley Research Park.

PRODUCTION WELL(S)	AVERAGE WITHDRAWAL RATE IN 2015, Pre-Test		OPTIMIZATION TEST WITHDRAWAL RATE	
PW-1	162 gpm	0.23 MGD	70 gpm	0.10 MGD
PW-2	97 gpm	0.14 MGD	119 gpm	0.17 MGD
PW-4	99 gpm	0.14 MGD	<1 gpm	0.00 MGD
PW-25	181 gpm	0.26 MGD	215 gpm	0.31 MGD
*PW-5/5A, 6, 7, 9, 23	13 gpm	0.02 MGD	0 gpm	0.00 MGD
On-Site Subtotals	**552 gpm**	**0.79 MGD**	**404 gpm**	**0.58 MGD**
Wiccopee and RR Spur	687 gpm	0.99 MGD	840 gpm	1.2 MGD
Totals	**1,239 gpm**	**1.8 MGD**	**1,244 gpm**	**1.8 MGD**

*PW-5/5A and 7 pumped briefly in anticipation of storm related water supply emergencies in the first quarter of 2015 only. PW-6 and 9 were not pumped in 2015.

As indicated in the table, the average withdrawal rates during the test were 70 gpm for PW-1, 119 gpm for PW-2, and 215 gpm for PW-25. The total on-Site bedrock groundwater withdrawal rate during the test was 404 gpm (0.58 MGD). Graphs of withdrawal rates and groundwater elevations at the production wells are presented in Appendix B. The graphs show that withdrawal rates remained near the target rates for the entire test with no significant interruptions.

3.2 Optimization Test Groundwater Monitoring

Groundwater elevations were measured on a regular basis at eighty-five (85) groundwater monitoring wells and four production wells at the frequency shown on Table 1. The monitoring well locations were selected with the goal of measuring water levels in shallow, intermediate, and deep bedrock across different areas of the Site, along with measuring water levels in overburden in areas that could be influenced by changes in bedrock groundwater withdrawals.

The monitoring wells selected for the test were divided into three separate water level monitoring schedules, designated as A, B, and C. Schedule A includes 13 wells equipped with pressure transducers with dataloggers that were supplemented with manual measurements prior to the start of the test, at one week, two weeks, one month, two months, three months, and prior to test termination at about 3.5 months after the start. Schedule A also includes production wells PW-1, PW-2, PW-4 and PW-25, which have dedicated pressure transducers. Water levels were manually measured in Schedule B monitoring wells at the same frequency as Schedule A wells, but no pressure transducers were installed. Water levels were manually measured in Schedule C wells prior to the test, at one month, two months, three months, and prior to test termination. The locations of the 85 wells listed in Table 1 are shown on Plate 1. Monitoring wells screened in bedrock are labeled in blue and monitoring wells screened in overburden are labeled in purple. Monitoring wells with pressure transducers installed for the test period are highlighted in light blue. The initial baseline groundwater elevation monitoring round was completed on August 14, 2015, with subsequent water level rounds completed as shown on Table 1. Supplemental water level measurements were taken in an additional 81 bedrock monitoring wells at the end of the test on November 30, 2015. The supplemental wells are listed in Table 2 and shown on Plate C-1 in Appendix C.

Groundwater elevations recorded during the optimization test were tabulated, and are presented in Tables 1 and 2. Groundwater elevations versus time graphs were created for each monitoring well. Production well elevation and flow data were used to track weekly flow rates in comparison to target operating rates.

During the months of September 2015, October 2015, and November 2015 bimonthly samples were collected from production wells PW-1, PW-2, and PW-25 and submitted to Eurofins Lancaster Laboratories of Lancaster, PA for VOC analyses. Groundwater samples were also collected from the three production wells for VOC analysis at the time of test termination on December 1, 2015. The purpose of the sampling and VOC analyses was to assess for any significant changes in VOC mass removals during the optimization test period.

4 FINDINGS

This section presents the analysis and interpretation of physical and chemical data collected and reviewed as part of the Site bedrock production well optimization test. The findings of the test have been reviewed in conjunction with historical operations data and groundwater modeling to develop targets for future production well withdrawals that are reduced and rebalanced with the goal of optimizing hydraulic containment of VOC plumes in bedrock groundwater within the Bedrock Remediation Area of the Site.

4.1 Comparison of Optimization Test Withdrawals with Past Operations

As indicated in the tabular summary below, the average daily withdrawals from on-Site bedrock production wells ranged from about 0.96 to 1.04 MGD in the four years preceding the production well optimization test.

Groundwater Extraction Summary		
Year	**Average Daily MGD**	**Total Gallons Pumped**
2011	**0.961**	**350,787,788**
2012	**0.988**	**360,573,422**
2013	**1.036**	**378,176,556**
2014	**0.978**	**357,102,571**
2015 *	**0.714**	**260,740,994**

Notes:

*** Production Well Optimization Test completed from August 17, 2015, to December 1, 2015. During this period, only wells PW-1, PW-2 and PW-25 were operating; all other Production Wells on the main plant site were shut down.**

The average withdrawal rate over the four year period of 2011 through 2014 was 0.99 MGD. For comparison, the combined on-Site bedrock groundwater withdrawal rate of approximately 0.58 MGD during the optimization test, was 41% lower than the average on-Site bedrock production well withdrawal rate for the four years preceding the optimization test, 39% lower than the average on-Site bedrock groundwater withdrawal rate in 2014, and 27% lower than the average 2015 on-Site withdrawals for the seven and one-half month period prior to the optimization test.

4.2 Production Well Operating Levels

Time versus elevation graphs for PW-1, PW-2, PW-4, and PW-25 are in Appendix B. The graphs run from July 1, 2015, about six weeks prior to the start of the test, through December 1, 2015, at test termination. The graphs also include withdrawal rates in gpm on a secondary axis. A new transducer was installed in well PW-1 about one week prior to the test so the pre-test operating water level data were more limited for that well.

Overall, PW-1, PW-2, and PW-25 operating levels fluctuated prior to the test as adjustments were made by GlobalFoundries to withdrawal rates based on their water supply needs. During the test period the operating level for well PW-1 increased significantly from about 68 ft amsl to 129 ft amsl. The majority of the increase occurred during the initial few days of the test. The operating water level in well PW-2 gradually increased during the test from about 100 ft amsl to 113 ft amsl, consistent with the decline in withdrawals from well PW-1 and the shutdown of PW-4. The PW-4 operating level recovered quickly during the first one to two weeks of the test, followed by a more gradual rise that was similar to the water level rise observed at wells PW-1 and PW-2. The overall increase in water level elevation in well PW-4 was about 29 feet (elevation 107 ft amsl to elevation 136 ft amsl). The operating level for PW-25 initially declined about 20 feet during the first two weeks of the test (about elevation 57 amsl to about elevation 37 amsl), consistent with the increase in the PW-25 groundwater withdrawal rate, followed by a fairly similar operating level for the remainder of the test. Ground surface elevations in the vicinity of PW-1, PW-2, PW-4, and PW-25 generally range from approximately 240 ft amsl to 260 ft amsl.

4.3 Monitoring Well Groundwater Elevations

Wells where water levels were measured during the optimization test are shown on Plate C-1 of Appendix C. Yellow highlighting of a monitoring well indicates that PW-1 has the greatest apparent hydraulic influence on that monitoring well, with pink, green, and brown indicating the greatest apparent hydraulic influence from wells PW-2, PW-4, and PW-25, respectively. Plate C-1 also lists the SHA model layer associated with the screened or open interval of the wells listed in Table 1. Groundwater elevation versus time graphs for wells equipped with transducers and for wells where manual elevations were collected routinely, outlined in Table 1, are shown in Appendix C. The manual elevation graphs are grouped by production well and SHA model layer.

The automated (Appendix C, Graph C-1 through C-5) and manual (Appendix C, Graphs C-6 through C-26) water level measurements recorded during the optimization test indicate the following responses in potentiometric water levels:

- PW-1 Area Wells – A rapid potentiometric water level rise during the first week of the test, followed by a more gradual rise throughout the remainder of the test (Graphs C-1, C-6, C-7, and C-8). Potentiometric water levels were continuing to rise slowly at the time of the test termination. The highest potentiometric water level rises during the test were on the order of 10 to 20 feet.

- PW-2 Area – A rapid potentiometric water level rise during the first week of the test was followed by a more gradual rise throughout the remainder of the test in well GW-734 (Graph C-14) and well GW-737 (Graph C-13) to the west of PW-2 and well GW-732 (Graph C-3) to the northwest of PW-2. Potentiometric water levels increased slightly in transducer equipped wells GW-118 and GW-716 (Graph C-3) and in well GW-578 (Graph C-12), all located to the north of PW-2. Potentiometric water levels decreased during the test at well GW-012 (Graph C-10), well GW-711 (Graph C-11), well GW-722 (Graph C-11), well GW-777 (Graph C-9), and well GW-962 (Graph C-10), all located north of PW-2.

- Potentiometric water levels in overburden wells within the Area A (OU5) source area, north of PW-2, decreased during the test (Graph C-26). GW-074 and GW-731 remained dry throughout the test. Wells GW-621 and GW-714 had measurable water levels prior to the start of the test, and were dry at the end of the test. Groundwater elevations decreased throughout the test at well GW-748. Wells GW-763 and GW-010 elevations decreased through the first three months of the test followed by a slight increase in the last two weeks of the test. Groundwater elevations decreased at well GW-759 through the first two months of the test followed by a small increase. Groundwater elevations were lower at the end of the test than at the start of the test in wells GW-010, GW-763, and GW-759. Precipitation and recharge appears responsible for the inflection points observed at these locations.

- PW-2 and PW-4 Area Shallow Wells – Relatively shallow bedrock wells GW-109 and GW-965 (Graph C-2) in the PW-2 and PW-4 hydraulic response area responded rapidly to precipitation recharge events but did not appear to respond to the PW-4 shut down. A slight overall increase in potentiometric water levels was observed in well GW-106 (Graph C-2) and well GW-109, most likely due to seasonal recharge conditions in the latter half of the test period.

- PW-2 and PW-4 Area Deeper Wells – Potentiometric water levels for well GW-021 (Graph C-14) increased rapidly during the first two weeks of the test, leveled off during the middle of the test before rising for a second time during the last two to four weeks of the test. A rapid water level rise during the first two weeks of the test, followed a more gradual recovery was observed for well GW-609 (Graph C-4) and well GW-606 (Graph C-18). All three locations are screened in the fractured/weathered bedrock zone in the area between wells PW-2 and PW-4 and the area south of PW-4. The potentiometric water level rise was generally 5 to 10 feet near PW-2 and 15 to 20 feet near PW-4.

- PW-25 Area Wells – In the fractured/weathered bedrock zone south of PW-25, a steady decline in potentiometric water levels was observed during the first two months of the test followed by a slightly slower decline during the third month, and a slight increase in potentiometric water levels during the final two weeks of the test (Graphs C-5, C-20, and C-21). The overall decline in the potentiometric surface near B/330D is consistent with the increase in PW-25 withdrawals made by GlobalFoundries at the start of the test. Potentiometric water levels recorded in wells located southeast of PW-25 (wells screened in and around the weathered/fractured bedrock between B/330C and Area C) initially decreased, then rose so that by end of the test there was a net increase (Graphs C-22 and C-23). The seven wells shown on Graph C-24 and Graph C-25 are screened in deeper intervals than other wells in the PW-25 area. Potentiometric levels were higher at the end of the test in five locations, with the greatest change in GW-624, west of PW-25.

Overall, the results of groundwater monitoring indicated a hydraulic response consistent with the response predicted by the transient groundwater modeling simulation performed by SHA. The transient simulation of withdrawals similar to those used in the optimization test predicted about 75% of the fractured bedrock aquifer recovery would occur within about 3 months, but that equilibrium steady-state conditions would not be reached for about 4 to 5 years.

4.4 Inferred Lateral Potentiometric Contours, Flow Directions, and Capture Zones

Plate 2 and Plate 3 show the plan view potentiometric head distribution in the deep bedrock on August 14, 2015, prior to the start of the test on August 17, 2015 and at the end of the test on November 30, 2015. Wells with a screened or open hole interval elevation between approximately 50 and 120 ft amsl (equivalent to SHA model layers 6, 5, and the lower portion of 4) were used to define the potentiometric contours in Plate 2 and Plate 3. The approximately limits of the VOC plumes in bedrock groundwater, as defined by 5 microgram per liter PCE-Series isoconcentration contours are also shown on Plates 2 and 3 for reference. Descriptions of potentiometric water level conditions and bedrock groundwater flow directions inferred from the pre-test and near end of test water level measurements are provided in the following subsections.

4.4.1 Pre-Test Conditions (August 14, 2015)

Inferred bedrock potentiometric contours, flow directions, and hydraulic capture zones on Plate 2 are similar to those shown in annual reports from 2008 to 2014, after the shutdown of bedrock production wells PW-5/5A, PW-6, and PW-7. Inward lateral hydraulic gradients of about 0.2 to 0.02 feet per foot (ft/ft) extend around the perimeter of the Site. Bedrock groundwater flow directions are generally toward the production wells, with the steepest lateral hydraulic gradients in the vicinity of the production wells.

The PW-1 area of capture extends to the west onto the John Jay High School and former IBM West Complex properties, to the northeast beyond the intersection of West Drive and Route 52, to the east in the area east of Building 322 and beneath Building 320B, and to the south between inactive production wells PW-5/5A and PW-6. The eastern limit of the PW-1 capture zone is defined by a localized area of higher potentiometric head near well GW-130, and the northeastern limit by another localized area of higher potentiometric head in the vicinity of well GW-122. As shown on Plate 2, the approximate limits of the PCE-Series plume contained by groundwater extraction at PW-1 is located within a small fraction of the overall limits of PW-1 capture that extend off-site to the north and west.

The PW-2 area of capture is bounded to the west by a flow divide, defined by wells GW-130 and GW-122, separating it from the area of capture for well PW-1. The PW-2 capture zone extends to the north beyond Route 52 and to the east to Lime Kiln Road and possibly Shenandoah Road. The southern boundary of the PW-2 capture zone is defined by the generally east-west trending flow divide separating flow towards PW-2 from flow towards PW-4. The approximate limits of the PCE-Series plume contained by groundwater extraction at PW-2 is located well within the overall limits of PW-2 capture that extend off-Site to the north and east.

The PW-4 capture extends to the east to Lime Kiln Road, and is partly defined by the potentiometric high associated with the bedrock high that trends generally north-south in the vicinity of the Southeast Quadrant. The groundwater flow divide separating the PW-4 and PW-25 capture areas runs generally east from the potentiometric high near well GW-130, through Building 334 to the northern corner of Building 330C to the potentiometric high described previously near the Southeast Quadrant. As shown on Plate 2, the operation of PW-4 results in the northern extension of the PCE-Series plume originating in the area of the B330 complex.

The western boundary of the PW-25 capture zone extends from the southeastern corner of the former IBM West Complex to the potentiometric high at well GW-130. The PW-25 area of capture may extend as far south as I-84, with the eastern boundary extending to the potentiometric high east of Area C. The majority of the PCE-Series plume originating in the area of the Building 330 AOC is contained by groundwater extraction at PW-25. The plume associated with the Building 330 AOC is well within the overall limits of PW-25 capture that extend off-Site to the south.

4.4.2 Test Conditions at 3.5 Months (November 30, 2015)

Potentiometric contours and flow divides on Plate 3 were generated from data collected on November 30, 2015, approximately 3.5 months after shutdown of PW-4. As shown on Plate 3, bedrock groundwater flow directions are generally towards the center of the Site, with a strong inward gradient maintained by the operation of PW-1, PW-2, and PW-25. In general, the location and magnitude of the lateral hydraulic gradients on November 30, 2015 were similar to pre-test conditions on August 14, 2015. In particular, the range of inward lateral hydraulic gradients around the perimeter of the Site continued to be about 0.2 to 0.02 ft/ft. As expected, the largest observed changes in lateral gradient were observed in close proximity to production wells PW-1 and PW-4. Lateral gradients in the vicinity of production well PW-2 decreased slightly during the test period and lateral gradients near well PW-25 increased slightly during the test period.

The groundwater flow divide between PW-1 and PW-2 shifted slightly to the west near Building 320B during the course of the test. The flow divide between PW-1 and PW-25 shifted slightly to the north and to the west in the area of Buildings 300 and 323. The PW-1 capture zone at the end of the optimization test was largely unchanged from the start of the test. In the absence of extraction at PW-4, a flow divide for the 50 to 120 ft amsl interval contoured on Plate 3 runs from the localized potentiometric high near well GW-130 southeast through Building 334 to the potentiometric high associated with bedrock outcropping near the Southeast Quadrant. The PW-2 capture zone expanded to the south of PW-4 to include the parking lot area to the east of Building 334. The PW-25 capture zone expanded to the northeast of the well to include most of the area beneath Building 334 and former Buildings 332A and 332B near the northeast corner of Building 330C.

As shown on Plate 3, the approximate limits of the PCE-Series plumes continued to be contained under conditions of reduced PW-1 withdrawals and termination of PW-4 withdrawals. The small fraction of the PCE-Series presence formerly captured by well PW-4 would likely be reduced and ultimately removed by cutting off the source of the plume with PW-25 withdrawals.

4.5 Apparent Lateral Extent of Hydraulic Response

The apparent lateral extent of hydraulic response to the approximately 3.5 month production well optimization test is shown on Plate 4. The contours depict the inferred rise in potentiometric head as derived by cross-contouring the potentiometric head contours shown on Plates 2 and 3. As expected with the decline of PW-1 withdrawals and the shutdown of PW-4, the contours on Plate 4 show the greatest water level recovery and associated decline in lateral hydraulic gradient over a large area west and southwest of PW-1 and a much smaller area centered around PW-4. In the PW-4 area, greater than 10 feet of recovery was observed from Building 334 north to PW-2 and extending northwest towards Building 320B. In the PW-1 area, potentiometric water levels increased by more than 10 feet from the western property boundary to near the western edge of Building 320B, south to near Building 323, and north to Building 327. The broader rise in potentiometric levels in the area of PW-1, as compared to PW-4, is consistent with the results of groundwater model simulations #1A and #1B.

Potentiometric levels generally decreased in the vicinity of PW-25 due to an increase in the PW-25 pumping rate at the start of the optimization test. A decrease in potentiometric head of approximately 5 feet was observed in wells screened in and near the faulted, heavily weathered bedrock zone generally south of PW-25.

4.6 Inferred Vertical Potentiometric Contours, Flow Directions, and Capture Zones

Pre-test and near end of test potentiometric contours for cross-section A-A’ are shown on Plate 5. Pre-test and near end of test potentiometric contours for cross-section B-B’ are shown on Plate 6. Cross-section A-A’ runs roughly west to east from Route 52, through PW-1 and PW-2, and terminates near Lime Kiln Road. Cross-section B-B’ runs roughly north-south from Building 304, through PW-2, PW-4, and PW-25, terminating near the north side of Building 330D. Cross-section

A-A' is oriented roughly perpendicular to the predominant strike of bedrock structures and cross-section B-B' is oriented roughly parallel to the predominant strike of bedrock structures. Inferred bedrock faults and fault zones consisting of moderate to highly weathered and high hydraulic conductivity bedrock separated by areas of more competent bedrock with discrete fractures are shown on both cross-sections. In general, the shape and orientation of the potentiometric contours, the direction of groundwater flow, and the position and orientation of flow divides are inferred on the sections assuming asymmetrical hydraulic conductivity and connectivity due to the presence of the weathered/fractured bedrock fault zones. Pertinent inferences between the pre-test and near end of test conditions depicted on the cross-sections are provided in the following subsections.

4.6.1 Cross-Section A-A'

The broad capture zone of PW-1 associated with the western faulted/weathered bedrock is apparent in the pre-optimization potentiometric contours shown on cross-section A-A' of Plate 5. Although PW-1 is a deep well in relatively competent bedrock it's close proximity to bedrock weathered/fractured zones results in a broad area of capture that extends off-Site to the west, beyond Route 52. The inferred groundwater flow divide between PW-1 and PW-2 is shown in orange beneath Building 320B. As indicated by a comparison of the two cross-sections on Plate 5, the potentiometric contours around well PW-1 and the groundwater flow divide between PW-1 and PW-2 did not change significantly during the test period. A comparison of the pre-test and near end of test potentiometric contours in the area of PW-2 suggests a slightly narrowing of the west and east lateral extent of capture most likely reflecting greater capture of bedrock groundwater from the south due to the shutdown of PW-4.

4.6.2 Cross-Section B-B'

Production wells PW-2, PW-4, and PW-25 are inferred to be located within a generally north-south trending vertical fault zone that bisects the Site. As shown on Plate 6, wells PW-2 and PW-4 are screened in shallow bedrock and have different open-areas/screen lengths but they extend to similar depths, whereas, well PW-25 is screened in much deeper bedrock. Similar withdrawal rates from these wells in the nearly 13 years since the start of extraction at PW-25 has created a potentiometric low centered on the highly weathered fault zone, and shown on Plate 2 as the closed 140 ft amsl contour. The relatively steeper gradients in the potentiometric contours shown on the Plate 6 cross-sections in the area west of this potentiometric depression form as a result of the intersection of more discrete fracture zones in the more competent bedrock with the highly weathered/fractured, high hydraulic conductivity zone in the area of the three production wells. The more competent bedrock zone helps to define the flow divides between PW-1 and the remaining active production wells. A comparison of the two cross-sections on Plate 6 indicated the following changes between pre-test and near end of test potentiometric and groundwater flow conditions:

- The groundwater flow divides prior to the PW-4 shutdown between PW-2 and PW-4, and between PW-4 and PW-25, are replaced with a new flow divide between PW-2 and PW-25 that is located slightly north of B334, closer to PW-25 than to PW-2.
- The pre-test flow divide between PW-4 and PW-25 and the near end of test flow divide between PW-2 and PW-25 dips to the north due to the relative shallower elevations of the open-hole interval of PW-2 and the screen of PW-4, as compared to the screened interval elevations of PW-25.
- The lateral extent of PW-2 capture extends a much greater distance to the south during the PW-4 shutdown.
- The lateral extent of PW-25 capture extends to the north and south due to a combination of the PW-4 shutdown and the increase of PW-25 withdrawals at the start of the test.

4.7 Production Well Withdrawal Water Chemistry

Sampling dates and results for VOC analyses collected during the optimization test are summarized in Table 3. Results are consistent with sampling data generated in 2015 prior to the start of the test. Graphs in Appendix C show average daily flux in pounds per day for constituents of concern and flow rate for 2015. PW-1 daily flux decreased slightly after the start of optimization the test as a result of the decrease in flow rate. Flows before and after the start of the test were similar for both PW-2 and PW-25, and the daily flux graphs do not show an inflection point at the start of the test.

5 CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of the Site bedrock production well optimization test, GSC offers the following conclusions regarding optimization of the containment of VOC plumes in Bedrock Remediation Area (OU2) via reduced and rebalanced production well withdrawals.

1. The location and orientation of Site bedrock surface topography and bedrock structures results in significant asymmetry in Site bedrock potentiometric elevations, bedrock groundwater flow directions, bedrock groundwater flow divides, and associated bedrock production well capture zones.

2. The long-term nearly continuous operation of active bedrock production wells PW-1, PW-2, PW-4, and PW-25 has resulted in steep inward lateral hydraulic gradients in bedrock that extend beyond the limits of the Site.

3. The roughly 30 to 40% reduction in Site bedrock groundwater withdrawals during the optimization test, from recent annual average withdrawals of about 0.9 to 1 MGD to an average withdrawal rate of 0.6 MGD, did not significantly change bedrock potentiometric levels, groundwater flow directions, and the overall inward lateral hydraulic gradients in bedrock that extend beyond the limits of the Site.

4. The rapid recovery of potentiometric water levels during the first one to two weeks of the test followed by a more gradual water level recovery is consistent with results of groundwater modeling that predicted about 75% of the water level recovery would occur in the first three months of reduced on-Site bedrock groundwater withdrawals but that attainment of steady-state equilibrium conditions could take up to five years.

5. The VOC plumes in the Bedrock Remediation Area remain well within the limits of capture of the active bedrock production wells under the reduced bedrock groundwater withdrawal conditions used during the optimization test.

6. Changes in the VOC mass removal of individual production wells due to reduction and rebalancing of bedrock groundwater withdrawals are expected to be influenced primarily by changes in volumetric withdrawals while changes in VOC concentrations and speciation are likely to be much more gradual, occurring over a period of years rather than months.

7. Site bedrock production well withdrawal rates totaling about 0.6 MGD should provide an appropriate balance between reducing groundwater withdrawals while maintaining capture of VOC plumes in Site bedrock under current conditions. However, withdrawal rates necessary to maintain hydraulic capture could vary over time due to reasons outside of IBM’s control such as changes in recharge of precipitation due to on-Site and off-Site

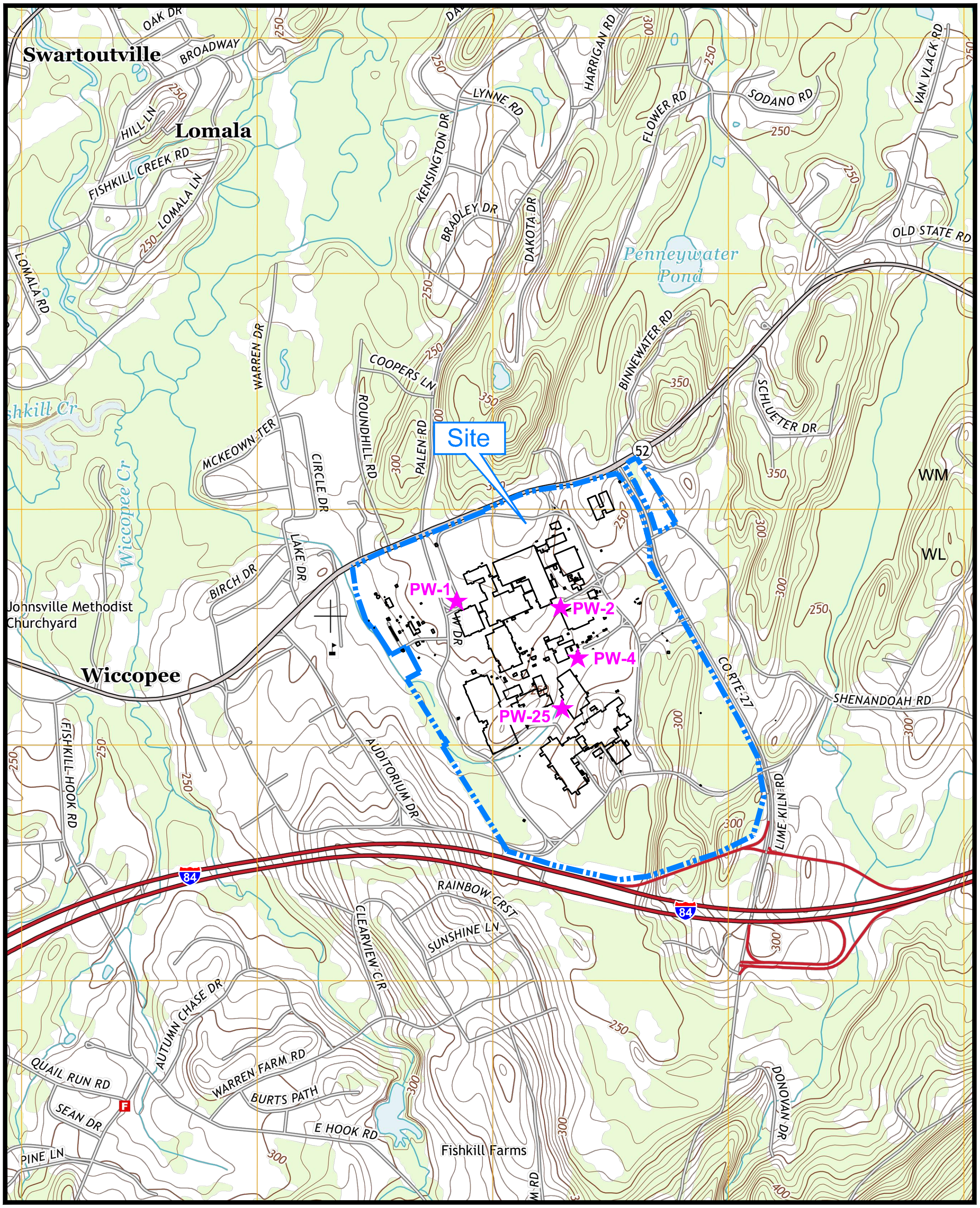
development, addition or subtraction of off-Site bedrock water supply withdrawals, and long-term wetter-than-average or drier-than-average climatic conditions.

In light of the above-listed conclusions, GSC recommends IBM consider the following as part of the on-going corrective measures implementation for Bedrock Remediation Area:

1. Reduction of production well withdrawals should focus on wells PW-1 and PW-4 while maintaining withdrawals for near-source production wells PW-2 and PW-25. The shutdown of well PW-4 and the operation of wells PW-1, PW-2, and PW-25 at the average groundwater withdrawal rates targeted during the optimization test, totaling about 0.6 MGD, are a recommended short-term operational goal.

2. Long-term production well operations should focus on maintaining potentiometric levels in bedrock rather than extraction rates to insure inward hydraulic gradients are maintained and VOC plumes in bedrock are contained within the Site. To account for the anticipated variability in future groundwater recharge conditions that could affect groundwater withdrawals, a maximum groundwater withdrawal rate of 1 MGD should be considered.

3. A groundwater monitoring program that is adequate to track changes in the apparent capture of the active on-Site bedrock production wells and changes in the nature and extent of the bedrock VOC plumes should remain as a component of the corrective measures implementation.



Portion of the Hopewell Junction, NY
7.5-minute USGS Quadrangle
(The National Map US Topo, 2013)
Latitude/Longitude: 41°32'27"N, 73°49'28"W (41.540714, -73.824185)

LEGEND
★ - Bedrock Production Well

Scale
0 1000' 2000'

Figure 1

Former IBM East Fishkill Facility

Site Location Map

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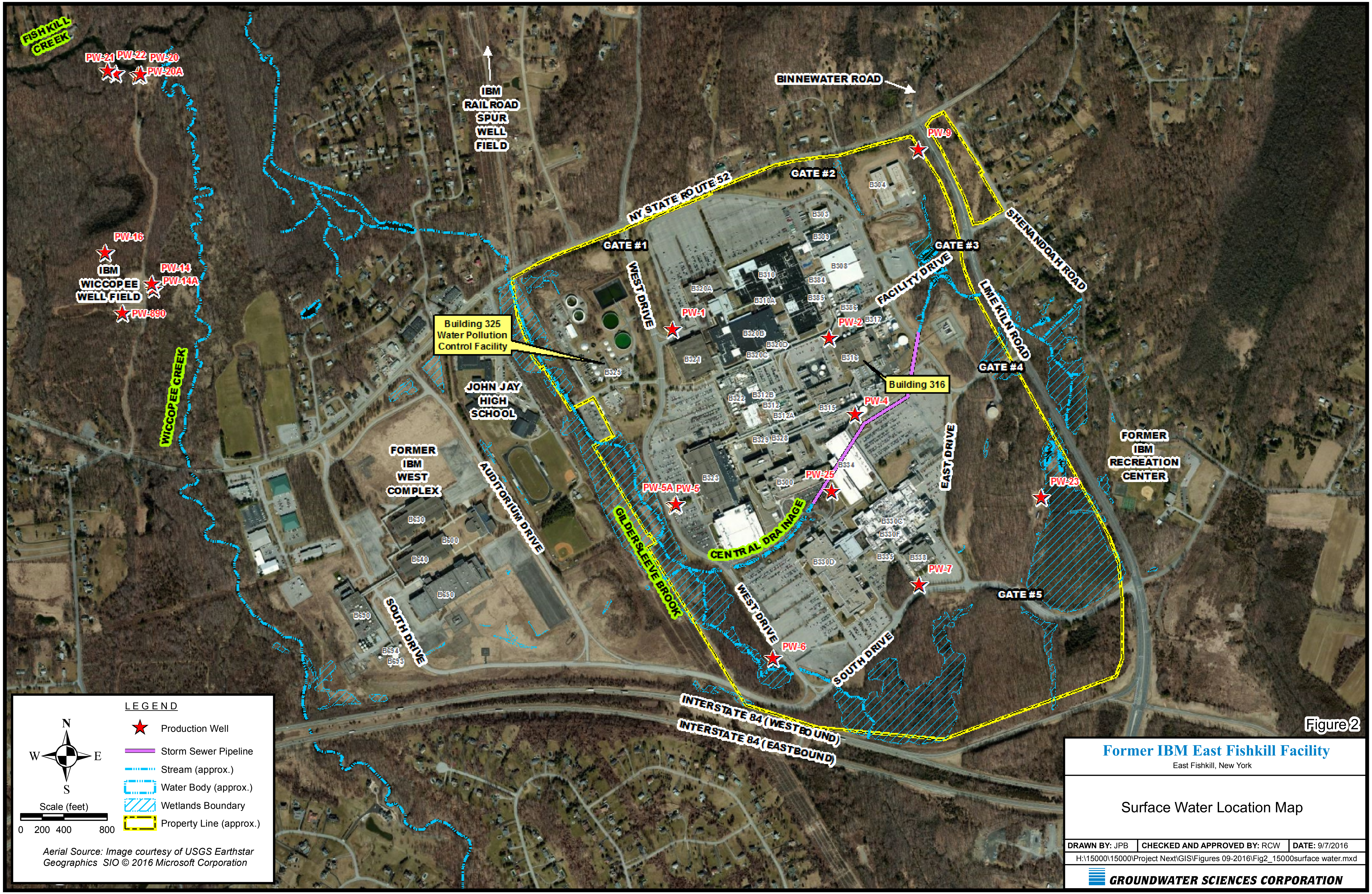
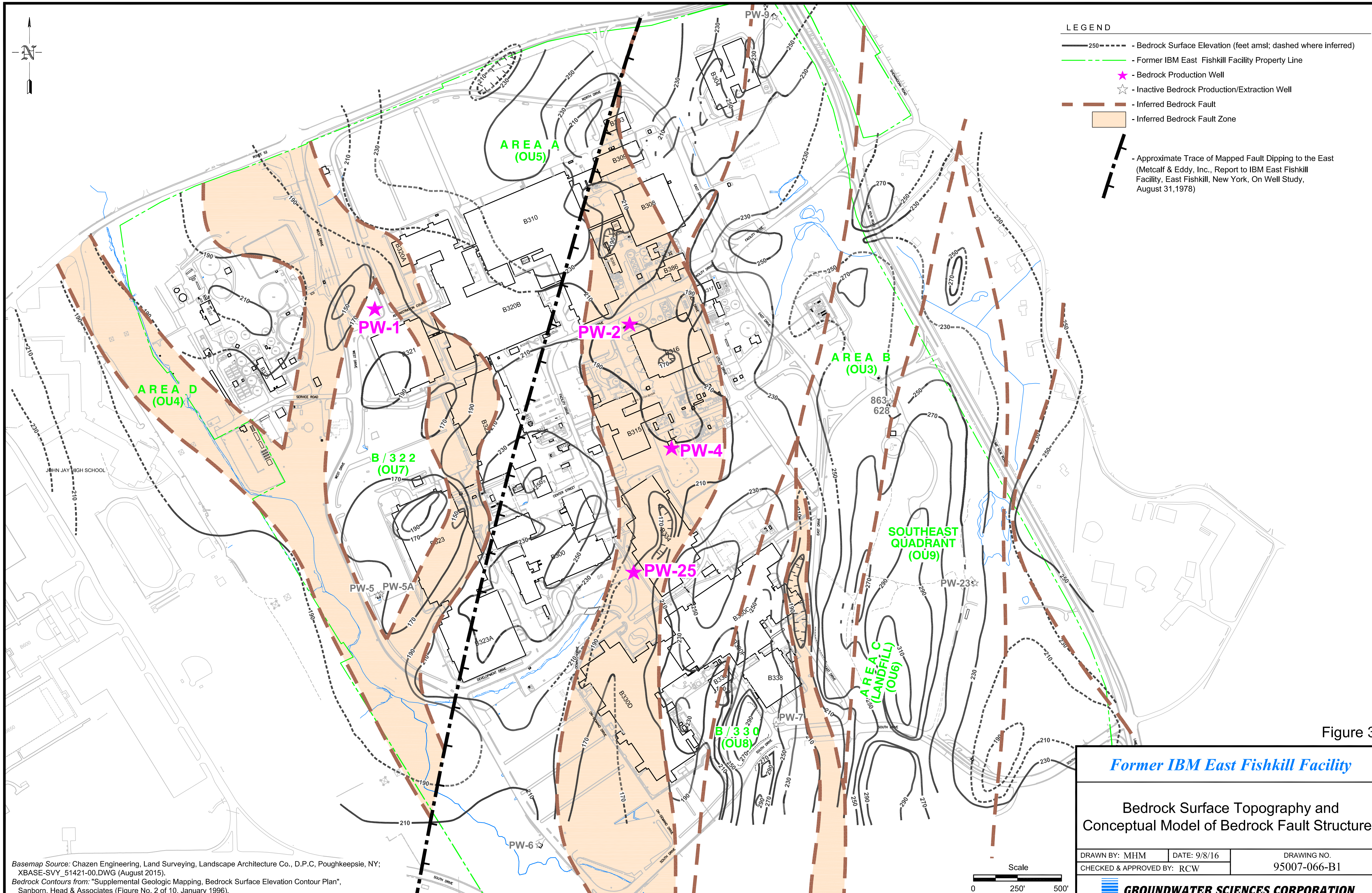
95007-044-E5 / 01-21-16


FISHKILL CREEK
PW-21
PW-22
PW-20
PW-20A
IBM RAIL ROAD SPUR WELL FIELD
BINNEWATER ROAD
PW-9
GATE #2
NY STATE ROUTE 52
SHENANDOAH ROAD
PW-16
IBM WICCOPEE WELL FIELD
PW-14
PW-14A
PW-890
GATE #1
WEST DRIVE
GATE #3
FACILITY DRIVE
LIME KILN ROAD
WICCOPEE CREEK
Building 325 Water Pollution Control Facility
PW-1
PW-2
GATE #4
Building 316
JOHN JAY HIGH SCHOOL
PW-4
FORMER IBM WEST COMPLEX
AUDITORIUM DRIVE
EAST DRIVE
FORMER IBM RECREATION CENTER
PW-5A
PW-5
PW-25
PW-23
GILDERSLEEVE BROOK
CENTRAL DRAINAGE
PW-7
GATE #5
SOUTH DRIVE
WEST DRIVE
PW-6
SOUTH DRIVE
INTERSTATE 84 (WESTBOUND)
INTERSTATE 84 (EASTBOUND)
LEGEND
Production Well
Storm Sewer Pipeline
Stream (approx.)
Water Body (approx.)
Wetlands Boundary
Property Line (approx.)
N
S
E
W
Scale (feet)
0 200 400 800
Aerial Source: Image courtesy of USGS Earthstar Geographics SIO © 2016 Microsoft Corporation
Figure 2
Former IBM East Fishkill Facility
East Fishkill, New York
Surface Water Location Map
DRAWN BY: JPB
CHECKED AND APPROVED BY: RCW
DATE: 9/7/2016
H:\15000\15000\Project Next\GIS\Figures 09-2016\Fig2_15000surface water.mxd
GROUNDWATER SCIENCES CORPORATION


LEGEND
250 - Bedrock Surface Elevation (feet amsl; dashed where inferred)
- Former IBM East Fishkill Facility Property Line
- Bedrock Production Well
- Inactive Bedrock Production/Extraction Well
- Inferred Bedrock Fault
- Inferred Bedrock Fault Zone
- Approximate Trace of Mapped Fault Dipping to the East (Metcalf & Eddy, Inc., Report to IBM East Fishkill Facility, East Fishkill, New York, On Well Study, August 31,1978)
N
AREA A (OU5)
AREA B (OU3)
AREA C (LANDFILL) (OU6)
AREA D (OU4)
B/322 (OU7)
B/330 (OU8)
SOUTHEAST QUADRANT (OU9)
PW-1
PW-2
PW-4
PW-25
PW-5
PW-5A
PW-6
PW-7
PW-9
PW-23
863
628
JOHN JAY HIGH SCHOOL
Scale
0 250' 500'
Figure 3
Former IBM East Fishkill Facility
Bedrock Surface Topography and Conceptual Model of Bedrock Fault Structures
DRAWN BY: MHM
DATE: 9/8/16
DRAWING NO. 95007-066-B1
CHECKED & APPROVED BY: RCW
GROUNDWATER SCIENCES CORPORATION
Basemap Source: Chazen Engineering, Land Surveying, Landscape Architecture Co., D.P.C, Poughkeepsie, NY; XBASE-SVY_51421-00.DWG (August 2015).
Bedrock Contours from: "Supplemental Geologic Mapping, Bedrock Surface Elevation Contour Plan", Sanborn, Head & Associates (Figure No. 2 of 10, January 1996).

LEGEND

- Former IBM East Fishkill Facility Property Line
- Former Structure
- Bedrock Production Well
- OU - Operable Unit
- 10 - PCE-Series Concentration Contour (ug/l)
- 5 - Approximate Limit of Plume as Defined by Median Concentration Equal to 5 ug/l of PCE-Series Compounds

Note: The PCE-series concentration is a calculated concentration that uses the weighted sum of four constituent VOC concentrations. In performing this calculation, compounds that were "not detected" are treated as zeroes.

Data from January through May 2015, median data used where appropriate (i.e. extraction locations, quarterly locations, etc.).

Scale 0 300' 600'

Figure 4

Former IBM East Fishkill Facility

Isoconcentration Contour Map
PCE-Series, Bedrock
January-May 2015

DRAWN BY: MHM	DATE: 9/7/16	DRAWING NO.
CHECKED & APPROVED BY: CES/RCW		95007-009-V3

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LEGEND

- Former IBM East Fishkill Facility Property Line
- Former Structure
- Bedrock Monitoring Well
- Soil Monitoring Well
- Bedrock Production Well
- Inactive Bedrock Production/Extraction Well
- OU - Operable Unit
- Transducer Installed in Well

Scale 0 150' 300'

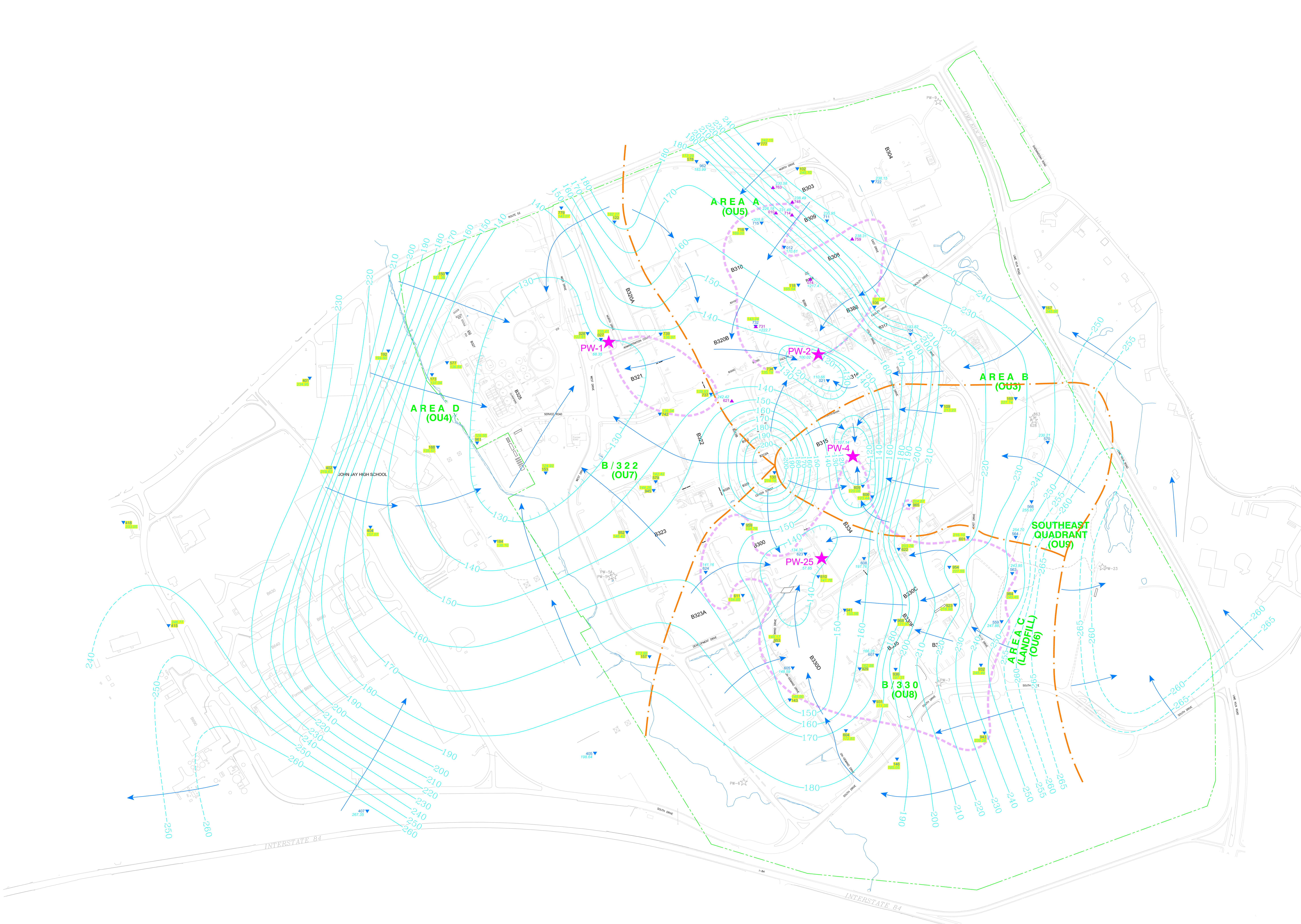
Plate 1

Former IBM East Fishkill Facility

Groundwater Monitoring Location Map
Production Well Optimization Test

DRAWN BY: MHM	DATE: 9/7/16	DRAWING NO. 95007-097-F3
CHECKED & APPROVED BY: CES/RCW		

GROUNDWATER SCIENCES CORPORATION



LEGEND

- Former IBM East Fishkill Facility Property Line
- Former Structure
- Bedrock Monitoring Well
- Soil Monitoring Well
- Bedrock Production Well
- Inactive Bedrock Production/Extraction Well
- OU - Operable Unit
- 200 - Contour of Constant Potentiometric Head (feet amsl)
- Generalized Direction of Groundwater Flow
- Groundwater Divide
- 170.61 - Groundwater Elevation (feet amsl)
- 169.00 - Groundwater Elevation Used for Contouring (feet amsl)
- Approximate Limit of PCE-Series Plume, 5 µg/l

The PCE-series concentration is a calculated concentration that uses the weighted sum of four constituent VOC concentrations. In performing this calculation, compounds that were "not detected" are treated as zeroes.

Note: Generally, the data used in contouring this plate is from the deepest of the bedrock wells in a well cluster and corresponds to a screened or open hole interval elevation between approximately 50 and 120 feet amsl (with the exception of PW-23). This elevation interval generally correlates with the principal water-bearing zones in the on-site deep bedrock production wells. (The principal water-bearing zone in PW-23 is at approximately 221 feet amsl, which is significantly higher than the elevation of the principal water-bearing zones in the other production wells.)

Average Pumping Rate 8/14/15 (gpm)	
PW-1	193
PW-2	96
PW-4	99
PW-25	196

Test Began 8/17/2015

Scale
0 150' 300'

Plate 2

Former IBM East Fishkill Facility

Groundwater Elevation Contour Map
August 14, 2015

DRAWN BY: MHM	DATE: 9/7/16	DRAWING NO. 95007-097-A3
CHECKED & APPROVED BY: CES		

GROUNDWATER SCIENCES CORPORATION

LEGEND

- Former IBM East Fishkill Facility Property Line
- Former Structure
- Bedrock Monitoring Well
- Soil Monitoring Well
- Bedrock Production Well
- Inactive Bedrock Production/Extraction Well

OU - Operable Unit

200 - Contour of Constant Potentiometric Head (feet amsl)

- Generalized Direction of Groundwater Flow
- Groundwater Divide

171.03 - Groundwater Elevation (feet amsl)

169.97 - Groundwater Elevation Used for Contouring (feet amsl)

- Approximate Limit of PCE-Series Plume, 5 µg/l

The PCE-series concentration is a calculated concentration that uses the weighted sum of four constituent VOC concentrations. In performing this calculation, compounds that were "not detected" are treated as zeroes.

Note: Generally, the data used in contouring this plate is from the deepest of the bedrock wells in a well cluster and corresponds to a screened or open hole interval elevation between approximately 50 and 120 feet amsl (with the exception of PW-23). This elevation interval generally correlates with the principal water-bearing zones in the on-site deep bedrock production wells. (The principal water-bearing zone in PW-23 is at approximately 221 feet amsl, which is significantly higher than the elevation of the principal water-bearing zones in the other production wells.)

Average Flow Rate 8/17/15 to 12/1/15 (gpm)	
PW-1	70
PW-2	119
PW-4	<1
PW-25	215

* Test Began 8/17/2015

Scale

0 150' 300'

Plate 3

Former IBM East Fishkill Facility

Groundwater Elevation Contour Map
November 30, 2015

DRAWN BY: MHM	DATE: 9/8/16	DRAWING NO.
CHECKED & APPROVED BY: CES/RCW		95007-097-E3

GROUNDWATER SCIENCES CORPORATION

LEGEND

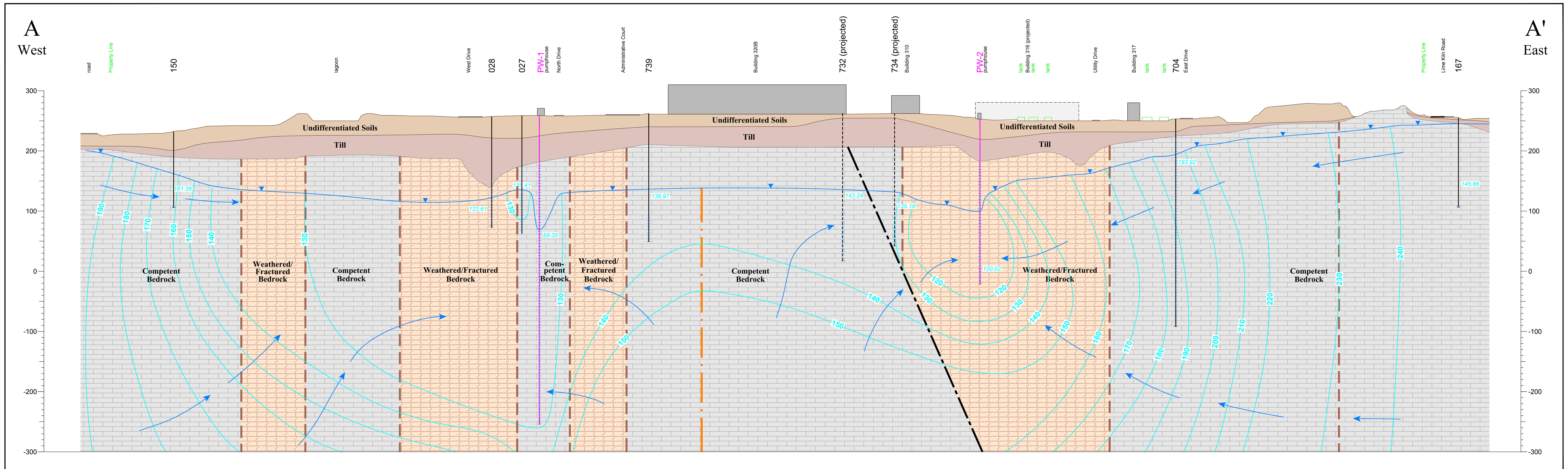
- Former IBM East Fishkill Facility Property Line
- Former Structure
- Bedrock Monitoring Well
- Soil Monitoring Well
- Bedrock Production Well
- Inactive Bedrock Production/Extraction Well
- OU - Operable Unit
- -5.76 - Change in Groundwater Elevation, 8/14/15 to 11/30/15 (feet amsl)
- 10 - Change in Constant Potentiometric Head Contour, August 14, 2015 through November 30, 2015 (feet amsl)
- Groundwater Divide

Gray wells are supplemental wells for November 30, 2015 elevation round,

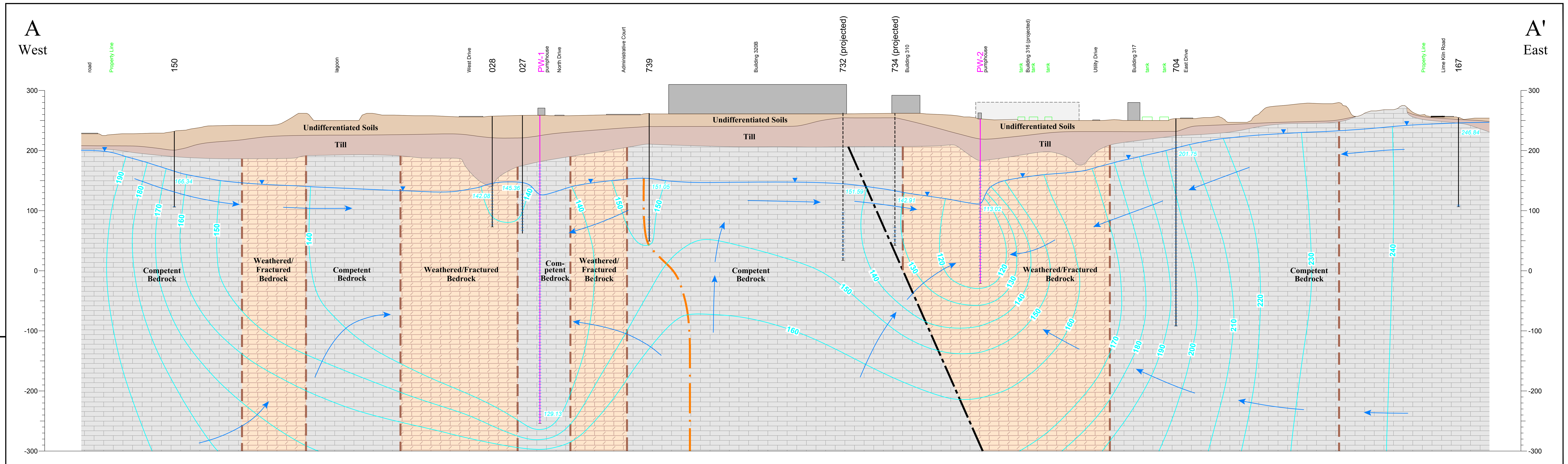
Scale
0 150' 300'

Plate 4

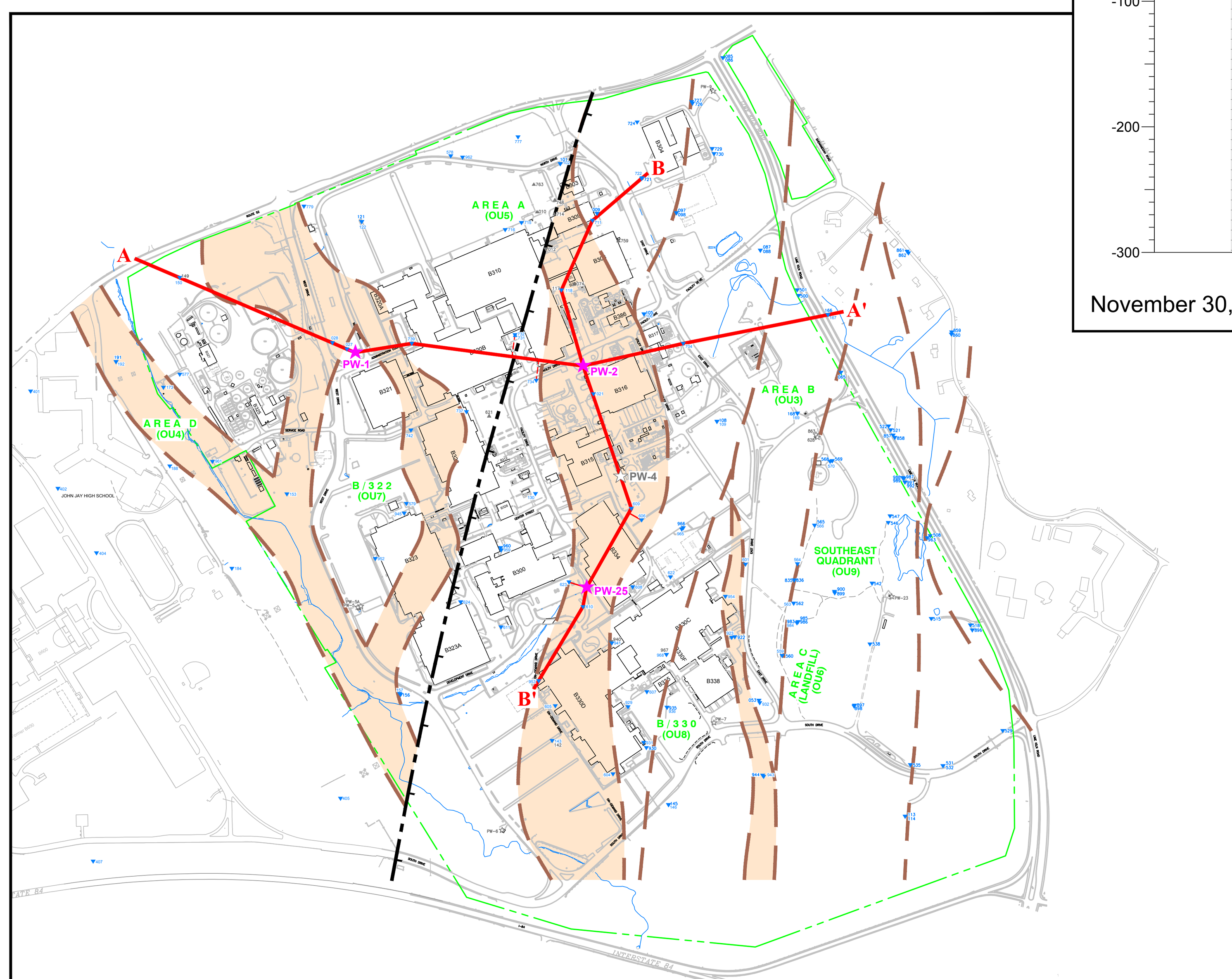
Former IBM East Fishkill Facility
Apparent Hydraulic Response to Production Well Optimization at About 3.5 months
DRAWN BY: MHM — DATE: 9/7/16 — DRAWING NO. 95007-101-B1
CHECKED & APPROVED BY: SF/RW/ES
GROUNDWATER SCIENCES CORPORATION



August 14, 2015



November 30, 2015



Cross Section Location Map

LOCATION MAP LEGEND

- Former IBM East Fishkill Facility Property Line
- Former Structure
- Bedrock Monitoring Well
- Bedrock Production Well
- Inactive Bedrock Production/Extraction Well
- OU - Operable Unit
- Cross Section Trace
- Inferred Bedrock Fault
- Inferred Bedrock Fault Zone
- Approximate Trace of Mapped Fault Dipping to the East (Metcalf & Eddy, Inc., Report to IBM East Fishkill Facility, East Fishkill, New York, On Well Study, August 31,1978)

Scale
0 400' 800'

CROSS SECTIONS LEGEND

- Ground Surface
- Till Contact
- Bedrock Contact
- Monitoring Well
- Screened or Open-Hole Interval
- Bottom of Well
- 141.76 - Groundwater Elevation (feet amsl)
- 200 - Contour of Constant Potentiometric Head (feet amsl)
- Inferred Direction of Groundwater Flow (schematic)
- Water Table
- Inferred Bedrock Fault
- Approximate Trace of Mapped Fault Dipping to the East (Metcalf & Eddy, Inc., Report to IBM East Fishkill Facility, East Fishkill, New York, On Well Study, August 31,1978)

Undifferentiated Soils

Till

Bedrock: characterized by moderate to highly weathered/fractured zones

Bedrock: characterized by discrete weathered/fractured zones

Horizontal Scale: 1"=200'
Vertical Scale: 1"=100'

Vertical Exaggeration = 2X

Scale
0 100' 200'

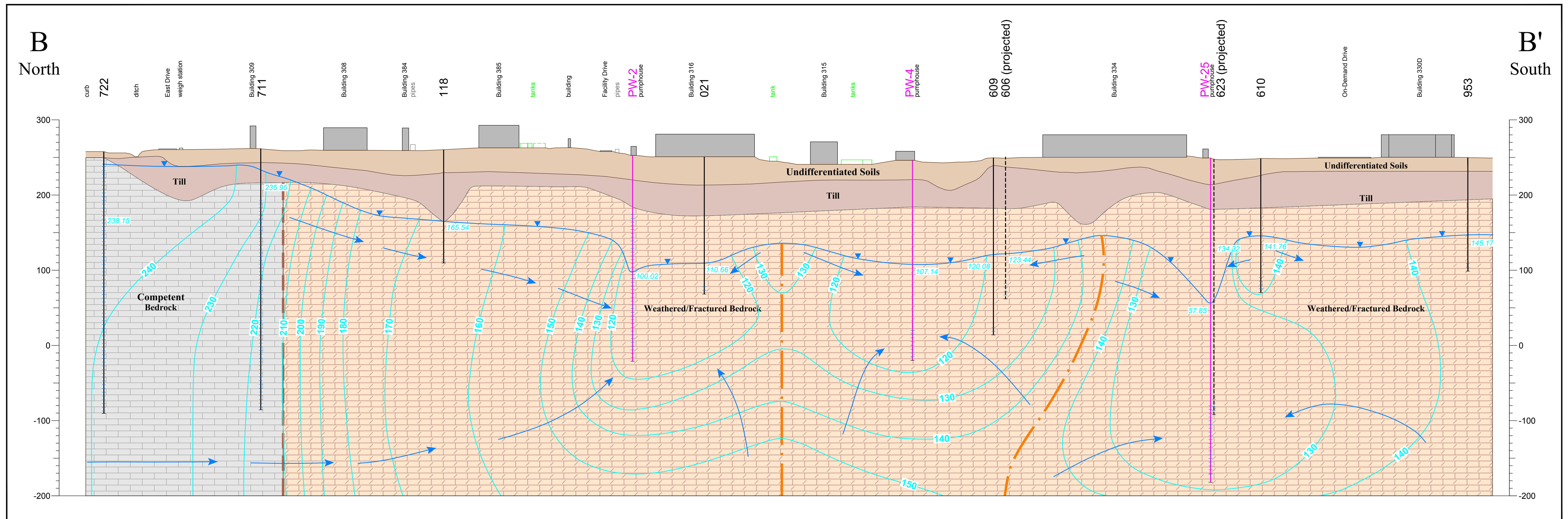
Plate 5

Former IBM East Fishkill Facility

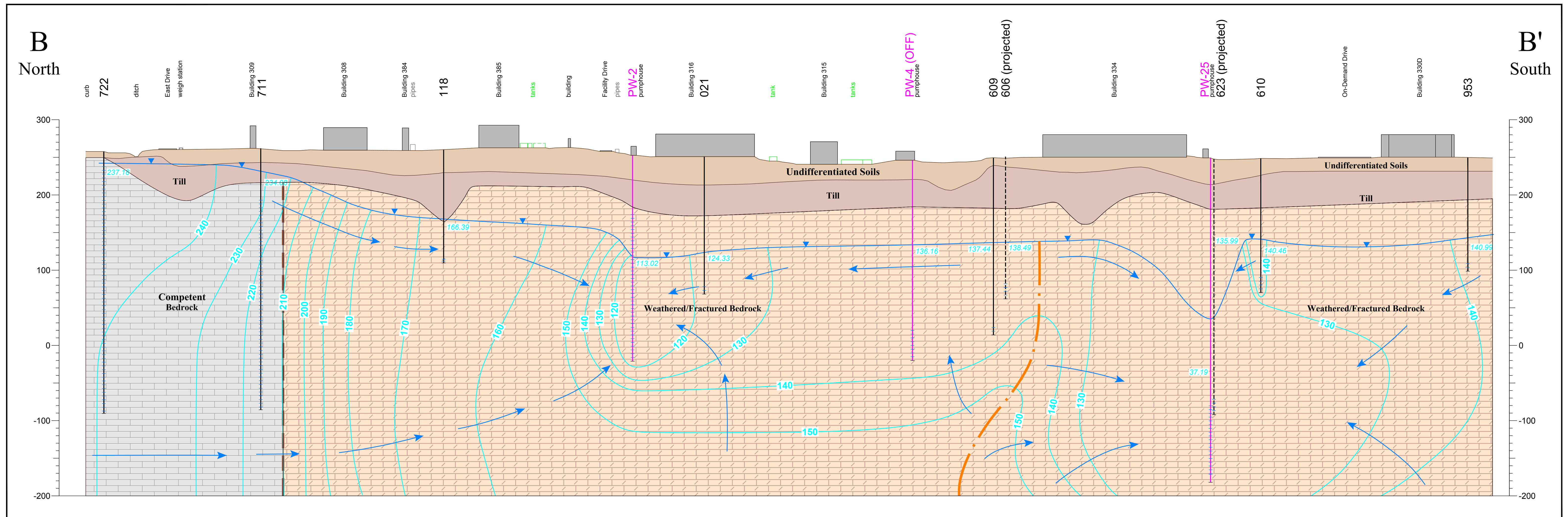
Hydrogeologic Cross-Section A-A'
Elevation Contour Map
August 14, 2015 and November 30, 2015

DRAWN BY: MHM	DATE: 12/7/16	DRAWING NO. 95007-CS05_1
CHECKED & APPROVED BY: CES/RCW		

GROUNDWATER SCIENCES CORPORATION



August 14, 2015



November 30, 2015

CROSS SECTIONS LEGEND

- Ground Surface
- Till Contact
- Bedrock Contact
- Monitoring Well
- Screened or Open-Hole Interval
- Bottom of Well

141.76 - Groundwater Elevation (feet amsl)

200 - Contour of Constant Potentiometric Head (feet amsl)

- Inferred Direction of Groundwater Flow (schematic)
- Water Table
- Inferred Bedrock Fault

Undifferentiated Soils

Till

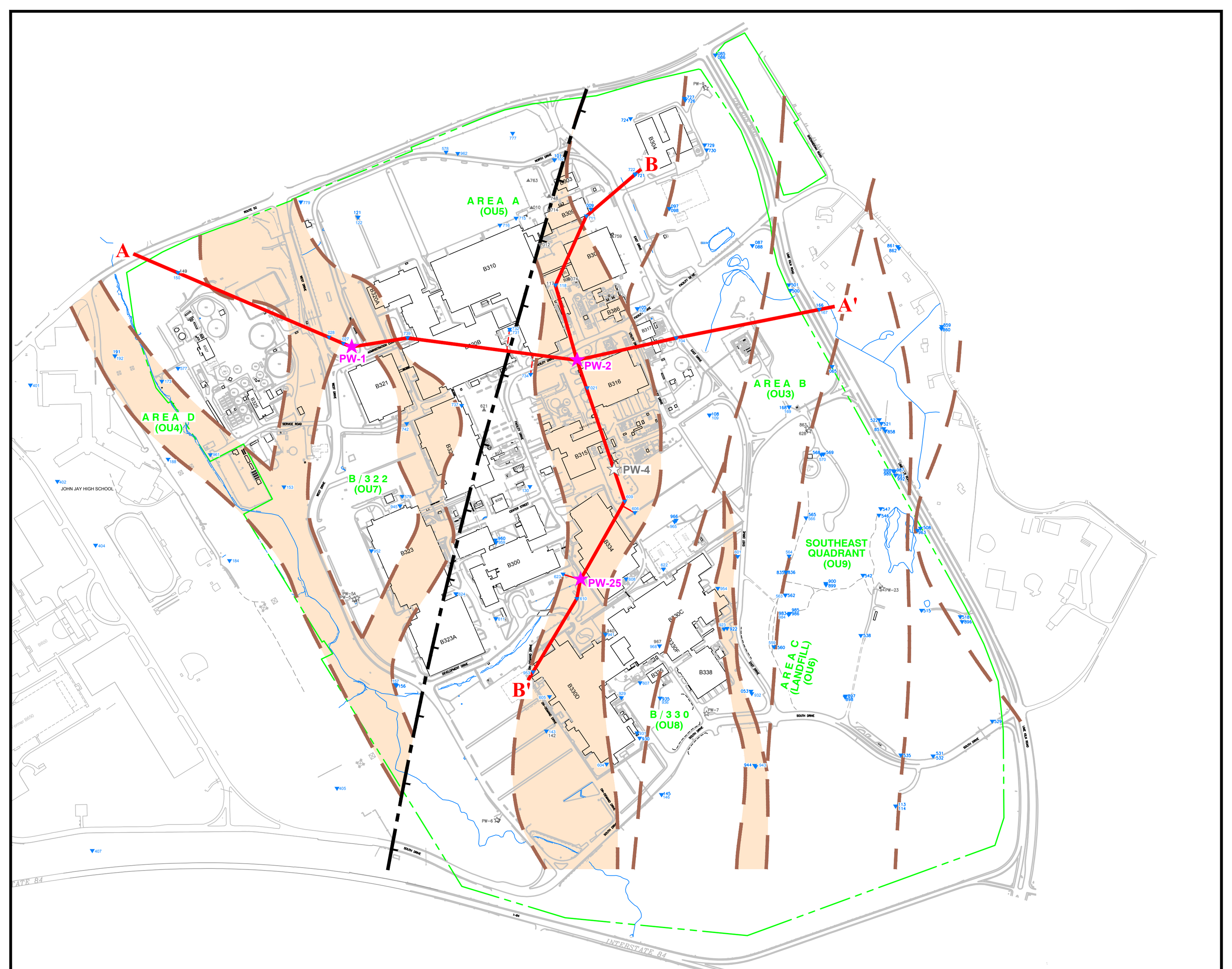
Bedrock: characterized by moderate to highly weathered/fractured zones

Bedrock: characterized by discrete weathered/fractured zones

Horizontal Scale: 1"=200'
Vertical Scale: 1"=100'

Vertical Exaggeration = 2X

Scale
0 100' 200'



Cross Section Location Map

LOCATION MAP LEGEND

- Former IBM East Fishkill Facility Property Line
- Former Structure
- Bedrock Monitoring Well
- Bedrock Production Well
- Inactive Bedrock Production/Extraction Well

OU - Operable Unit

- Cross Section Trace
- Inferred Bedrock Fault
- Inferred Bedrock Fault Zone
- Approximate Trace of Mapped Fault Dipping to the East (Metcalf & Eddy, Inc., Report to IBM East Fishkill Facility, East Fishkill, New York, On Well Study, August 31,1978)

Scale
0 400' 800'

Plate 6

Former IBM East Fishkill Facility

Hydrogeologic Cross-Section B-B'
Elevation Contour Map
August 14, 2015 and November 30, 2015

DRAWN BY: MHM	DATE: 12/7/16
CHECKED & APPROVED BY: CES/RCW	DRAWING NO. 95007-CS05_2

GROUNDWATER SCIENCES CORPORATION

Appendix A

SHA, June 2016 Memorandum, Re: Groundwater Model Simulations Summary

MEMORANDUM

To: Dean Chartrand (IBM Corporation)

From: Andrew Ashton

Brad Green

File: 2999.01

Date: June 2016

Re: Groundwater Model Simulations Summary -

Remedial Systems Separation/Groundwater Extraction Optimization Evaluation

cc: Robert Watson (Groundwater Sciences Corporation - GSC)
Ed Stoner (GSC)

This memorandum summarizes the findings of the application of a numerical model of groundwater flow to simulate various withdrawal scenarios from the dual purpose remediation and production wells within the bedrock aquifer at the former IBM East Fishkill (IBM-EF) facility (the Site). The groundwater model simulations were performed as part of the planning process for a proposed extraction well optimization test conducted at the Site during 2015. Sanborn, Head & Associates, Inc (Sanborn Head) conveyed the results of our assessment to IBM and Groundwater Sciences Corporation (GSC) at a meeting on May 21, 2015. The presentation from this meeting is included as Attachment A to this memorandum – figures and exhibits from this presentation are referenced herein.

BACKGROUND

In 1999, Sanborn Head was commissioned by IBM to develop a 10-layer, three-dimensional numerical groundwater model of the IBM-EF facility and relevant surrounding area. The available water level, groundwater withdrawal, and hydraulic property information were integrated into a numerical model principally focused on the bedrock aquifer, which the facility relies upon for groundwater remediation and water supply purposes. Exhibit 1 depicts the vertical layers used in the model compared to the well construction of the Main Site wells. The findings of the work were documented in a February 2002 report (2002 Report)[1]. Sanborn Head performed periodic updates to the model in 2005 to 2007; and in 2014, Sanborn Head initiated further groundwater modeling services to assist IBM with facility planning at the Site related to contaminated groundwater management and extraction. The 2014 services included calibration of the model to contemporaneous

[1] Described in "Report of Findings, Numerical Model – Bedrock Water Supply Aquifer, IBM East Fishkill Facility, East Fishkill, New York," prepared by Sanborn Head, dated February 1, 2002.

(2014) conditions of groundwater withdrawals and water levels, and the work is document in a June 2015 report[2].

The groundwater model originally developed in 1999 was updated and calibrated to steady state contemporaneous (2014) conditions, including recharge and withdrawal rates, which have occurred in the intervening period. The "baseline" condition shown in Figure 1 represents the final calibrated model that was used as a basis for comparison for the predictive modeling described below. The model was also calibrated to variable pumping and climatic conditions (transient conditions) over an approximately 6-year dataset for the period from 2009 to the fall of 2014. After completion of steady state and transient calibration, the 2014 model was used to simulate over 30 conditions that informed the potential consequences and potential mitigation strategies associated with failure of the well PW-2.

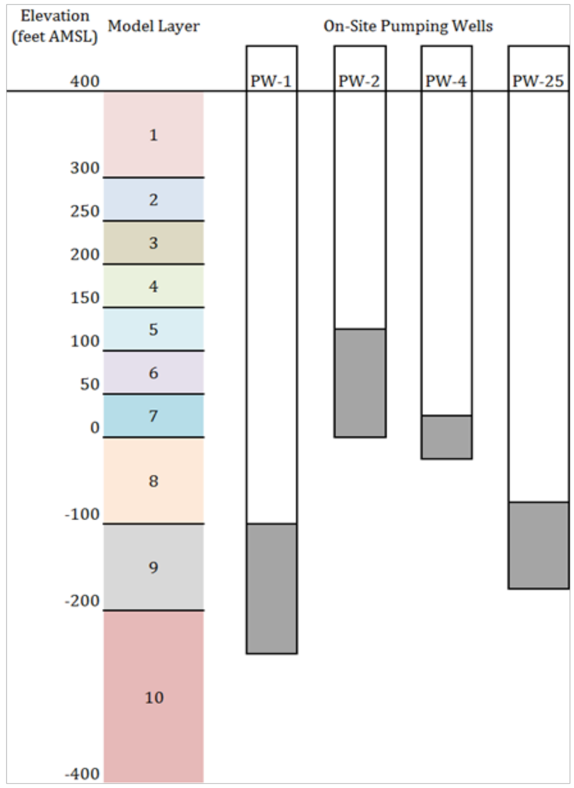


Exhibit 1 – Profile Illustration of Main Site Well Construction Relative to Model Layers - This exhibit shows the approximate elevation of the open or screened interval (grey boxes at base of each well) of the Main Site pumping wells in comparison to the layers defined in the groundwater model.

SCOPE

GLOBALFOUNDRIES acquired and began to operate the IBM-EFK site facility in mid-2015. As part of the transfer of the property, IBM initiated a review of the operation of existing water production wells that currently provide the dual benefit of water production and control of contaminated groundwater. IBM requested that Sanborn Head use the 2014 groundwater model to perform model simulations to inform planning for a proposed extraction well optimization test. Sanborn Head completed seven simulations, the conditions and rationale for which are described in Table 1. Each of these simulations involved modeling shut down of PW-4 and reduced pumping rates or shut down of PW-1. These simulations were grouped into four categories, including:

1. Increased pumping rates at off-site wells in Rail Road Spur or Wiccopee well fields to accommodate the reduction in on-site pumping (Simulations 1A -1D - steady state conditions);

2. Re-starting on-site wells PW-5A, PW-6, and PW-7 to accommodate the reduction in pumping from other on-site wells (Simulation 2 - steady state conditions);

[2] Updated Groundwater Model Report, IBM East Fishkill Facility, Hopewell Junction, New York, prepared by Sanborn Head, dated June 2015.

3. Temporal assessment of potentiometric level change under the proposed optimization test conditions (Simulation 3 – transient conditions); and

4. Alteration of pumping set points from fixed flow rates to fixed potentiometric levels (Simulation 4 - steady state conditions).

Results are presented in the following sections. As with previous modeling work, the ability to replicate hydraulic heads through the model domain is limited by incomplete knowledge of hydraulic properties, bedrock conditions, and model discretization. We note that the groundwater modeling as outlined in the above referenced reports represents an attempt to simulate complex interaction of natural system and human-induced input consistent with the present conceptual model of geologic, hydrologic, and water supply development conditions. As such, the groundwater simulation results summarized in this memorandum should be viewed as an approximate analog and a non-unique solution to groundwater flow. Other interpretations are possible.

RESULTS

<u>Simulations 1A – 1D</u>
This group of simulations includes assessment of a PW-4 shut-down, reduction in pumping rate or shutdown of PW-1 pumping rate, and increasing pumping rates at the off-site well fields (Railroad Spur and Wiccopee). As shown on Table 1, scenarios 1A to 1D reflect progressively lower pumping rates at PW-1, relatively consistent flows at the Wiccopee wells, and progressively greater pumping rates at the Rail Road Spur wells. Table 1 provides a summary of the simulation description, modeled production well withdrawal rates, and total groundwater withdrawal by well field area for each simulation 1A to 1D.

The figures depicted on pages 5-7 of Attachment A present results (for model layer 7) from simulation 1A to 1D compared to the baseline condition. The model predicts that inward gradients (towards the site) are maintained for each of the pumping scenarios contemplated in simulations 1A through 1D; such that, groundwater contamination is contained on-site without off-site migration. As shown on page 7 of Attachment A, the model predicts that the groundwater divide (or "saddle point") between the on-site and off-site cone of depressions moves in a southerly direction towards the site as increasing amounts of pumping are shifted to the Railroad Spur off-site wells, but none of the simulations predict a loss of capture from on-site.

With the reduction in flow rates or shut down of PW-1 and the shutdown of PW-4 on-site there is a reduction in hydraulic gradients and a predicted rise in potentiometric levels of about 60 to 70 feet in Area A (a key groundwater contamination source area). In addition, there is a slight increase in predicted flow of groundwater from Area A towards extraction well PW-25 in deepest model layer (i.e., layer 10).

<u>Simulation 2</u>
Simulation 2 was used to predict Main Site production well operating levels, potentiometric conditions, gradients, and apparent flow directions under conditions of reduced

withdrawals for PW-1 and shutdown of PW-4 with the balance of flow shifted to PW-5A, PW-6, and PW-7 (see Table 1).

Under the simulation 2 pumping conditions, the model predicts that flow and hydraulic gradients in shallow bedrock (i.e., model layer 7) would be relatively similar to that of the baseline 2014 condition with the exception of localized increases in potentiometric levels near PW-4, and decreases in potentiometric levels near the production wells 5A, 6, and 7. In deeper bedrock (i.e., model layer 10) there may be increased potential for transport from Area A toward PW-5A as shown on page 10 of Attachment A.

<u>Simulation 3</u>
Simulation 3 was performed to assess the timing of potentiometric level changes after alterations to pumping conditions in order to inform the optimization test monitoring frequency and overall test duration under the proposed test conditions presented in Table 1.

Page 13 of Attachment A shows potentiometric recovery after 1 week and 1 month. The charts presented in Attachment B and C show the timing of the change in potentiometric levels at key wells in the vicinity of production well PW-2.

Within 1 week, the model predicts significant rebound in potentiometric levels at PW-4 (i.e., up to 30 feet of recovery in near proximity to the well). During the first week following shutdown, the measurable change in water levels will likely be localized to PW-4 vicinity. After one-month, the model predicts measurable water level change throughout the PW-1/PW-2/PW-4/PW-25 catchment areas suggesting that a test duration greater than one month is appropriate to evaluate the influence in areas outside of the PW-4 vicinity. The model predicts that potentiometric level rise will reach steady-state in approximately 4 to 5 years assuming no other subsequent changes in pumping rates.

<u>Simulation 4</u>
Simulation 4 was used to assess steady-state production rates under constant head operating levels for Main Site production wells PW-1, PW-2, and PW-25. The simulation includes shut-down of PW-4 and withdrawals rates for off-site wells equal to those used in simulation 1A. We note that Simulation 4 included only a single model simulation to assess groundwater hydraulics and contaminant transport under constant head set-points, and as a result the sensitivity of the results presented for Simulation 4 has not been assessed.

PW-1 and PW-2 were fixed at an equal operating level of 70 ft AMSL while PW-25 was fixed at -30 ft AMSL. The model predicted production rates under steady-state conditions were 194 gpm, 156 gpm, and 314 gpm for PW-1, PW-2, and PW-25, respectively. The total estimated on-site withdrawal rate for PW-1, PW-2, and PW-25 combined under the fixed operating level scenario was 664gpm (fixed operating levels), which is comparable to the current total on-site withdrawal rates (646 gpm) simulated under the baseline condition with PW-1, PW-2, PW-4 and PW-25 operational.

Page 15 of Attachment A depicts the simulated potentiometric contours under fixed operating levels. The fixed operating level simulation suggests on-site gradients and potentiometric levels would be similar to the 2014 baseline condition (i.e., gradients are inward of the Site and capture of contaminated groundwater is maintained). Due to the increased pumping rate at PW-25 and with PW-4 off, potentiometric levels are lower in the southwest of the Site and particle track results indicate that a larger capture zone is induced by this well as compared to the baseline condition with flow-based set points.

AEA/BAG: aea

Encl. Table 1
Figure 1
Attachment A
Attachment B
Attachment C

P:\2900s\2999.01\Source Files\GW Model Sims Summary Memo\20160616 GW Model Sims Summary Memo.docx

TABLE

Table 1 - Groundwater Model Simulations Summary
Remedial Systems Separation - Groundwater Extraction Optimization
Hudson Valley Research Park (IBM East Fishkill Facility)
Town of East Fishkill, Dutchess County, New York

Simulation #	Description	Production Well Withdrawals (gpm)						Production Well Operating Level (ft. amsl)						Groundwater Withdrawal By Area	Rationale
		Main Site		RR Spur		Wiccopee		Main Site		RR Spur		Wiccopee			
Base Line	Steady-state simulation of September 2014 Pumping Conditions and including simulation of the John Jay High School well.	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	211 123 118 0 0 0 0 1 193	PW-10 PW-12	4 0	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	58 4 269 0 238 1	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	TBD by Model	PW-10 PW-12	TBD by Model	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	TBD by Model	Main Site: 646 gpm 0.93 MGD RR Spur: 4 gpm 0.01 MGD Wiccopee: 570 gpm 0.82 MGD	Provide baseline for comparison of subsequent simulations.
1A	Main Site Production Well Optimization: Steady-state simulation of reduced withdrawal conditions within the Main Site. Simulation maintains average 2014 withdrawals of 1190 gpm (1.7 MGD) while shifting about 270 gpm (0.39 MGD) from the Main Site to the off-site well fields. Area B, Area D, and B322 extraction well withdrawals are shutdown.	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	50 120 0 0 0 0 0 0 220	PW-10 PW-12	50 150	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	200 0 150 0 200 50	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	TBD by Model	PW-10 PW-12	TBD by Model	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	TBD by Model	Main Site: 390 gpm 0.56 MGD RR Spur: 200 gpm 0.29 MGD Wiccopee: 600 gpm 0.86 MGD	Predict Main Site production well operating levels, potentiometric conditions, gradients, and apparent flow directions under reduced withdrawals for PW-1 and shutdown of PW-4.
1B	Main Site Production Well Optimization: Steady-state simulation of reduced withdrawal conditions within the Main Site. Simulation maintains average 2014 withdrawals of 1190 gpm (1.7 MGD) while shifting about 270 gpm (0.39 MGD) from the Main Site to the off-site well fields. Area B, Area D, and B322 extraction well withdrawals are shutdown.	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	50 120 0 0 0 0 0 0 220	PW-10 PW-12	270 0	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	150 0 150 0 180 50	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	TBD by Model	PW-10 PW-12	TBD by Model	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	TBD by Model	Main Site: 390 gpm 0.56 MGD RR Spur: 270 gpm 0.39 MGD Wiccopee: 530 gpm 0.76 MGD	Predict Main Site production well operating levels, potentiometric conditions, gradients, and apparent flow directions under reduced withdrawals for PW-1 and shutdown of PW-4.
1C	Main Site Production Well Optimization: Steady-state simulation of reduced withdrawal conditions within the Main Site. Simulation maintains average 2014 withdrawals of 1190 gpm (1.7 MGD) while shifting about 270 gpm (0.39 MGD) from the Main Site to the off-site well fields. Area B, Area D, and B322 extraction well withdrawals are shutdown.	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	25 120 0 0 0 0 0 0 220	PW-10 PW-12	295 0	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	150 0 150 0 180 50	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	TBD by Model	PW-10 PW-12	TBD by Model	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	TBD by Model	Main Site: 365 gpm 0.53 MGD RR Spur: 295 gpm 0.42 MGD Wiccopee: 530 gpm 0.76 MGD	Predict Main Site production well operating levels, potentiometric conditions, gradients, and apparent flow directions under reduced withdrawals for PW-1 and shutdown of PW-4.
1D	Main Site Production Well Optimization: Steady-state simulation of reduced withdrawal conditions within the Main Site. Simulation maintains average 2014 withdrawals of 1190 gpm (1.7 MGD) while shifting about 270 gpm (0.39 MGD) from the Main Site to the off-site well fields. Area B, Area D, and B322 extraction well withdrawals are shutdown.	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	0 120 0 0 0 0 0 0 220	PW-10 PW-12	320 0	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	150 0 150 0 180 50	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	TBD by Model	PW-10 PW-12	TBD by Model	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	TBD by Model	Main Site: 340 gpm 0.49 MGD RR Spur: 320 gpm 0.46 MGD Wiccopee: 530 gpm 0.76 MGD	Predict Main Site production well operating levels, potentiometric conditions, gradients, and apparent flow directions under reduced withdrawals for PW-1 and shutdown of PW-4.

Simulation #	Description	Production Well Withdrawals (gpm)						Production Well Operating Level (ft. amsl)						Groundwater Withdrawal By Area	Rationale
		Main Site		RR Spur		Wiccopee		Main Site		RR Spur		Wiccopee			
2	Main Site Production Well Shift In Withdrawals: Steady-state simulation of shifting withdrawals within the Main Site from PW-1 and PW-4 to other Main Site wells. Off-site withdrawals maintain average withdrawals from 2014. Simulation maintains overall average 2014 withdrawals of 1190 gpm (1.7 MGD). Area B, Area D, and B322 extraction well withdrawals are shutdown.	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	50 120 0 170 50 50 0 0 220	PW-10 PW-12	20 60	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	25 10 155 0 205 55	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	TBD by Model	PW-10 PW-12	TBD by Model	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	TBD by Model	Main Site: 660 gpm 0.95 MGD RR Spur: 80 gpm 0.12 MGD Wiccopee: 450 gpm 0.65 MGD	Predict effects of using other Main Site production wells rather than the off-site well field wells to balance the declines in Main Site withdrawals due to reduced PW-1 withdrawals and shutdown of PW-4.
3	Main Site Production Well Optimization: Transient Simulation of decline in PW-1 withdrawal (from 210 to 50 gpm) and shutdown of PW-4 (from 110 to 0 gpm) with increases in off-site wellfield withdrawals to predict changes in Main Site potentiometric conditions and gradients at specific timeframes (1 week, 1 month, 3 months, 6 months, 1 year, and 5 years) using average recharge conditions. Results of simulation will assist in selection of optimization test monitoring frequency and overall test duration. Area B, Area D, and B322 extraction well withdrawals are shutdown.	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	211 to 50 123 to 120 118 to 0 0 0 0 0 0 193 to 220	PW-10 PW-12	4 to 50 0 to 150	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	58 to 200 4 to 0 269 to 150 0 to 0 238 to 200 1 to 50	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	TBD by Model	PW-10 PW-12	TBD by Model	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	TBD by Model	Main Site: 646 to 390 gpm 0.93 to 0.56 MGD RR Spur: 4 to 200 gpm 0.01 to 0.29 MGD Wiccopee: 570 to 600 gpm 0.82 to 0.86 MGD	Predict Main Site production well operating levels, potentiometric conditions, gradients, and apparent flow directions under reduced withdrawals from baseline conditions at timeframes of 1 week, 1 month, 3 months, 6 months, 1 year, and 5 years.
4	Main Site Production Well Optimization: Steady-state simulation using constant head operating levels for Main Site production wells using off-site wells withdrawals in simulation #1. Area B, Area D, and B322 extraction well withdrawals are shutdown.	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	TBD TBD 0 0 0 0 0 0 TBD	PW-10 PW-12	50 150	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	200 0 150 0 200 50	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	70 70 TBD TBD TBD TBD TBD TBD -30	PW-10 PW-12	TBD by Model	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	TBD by Model	Main Site: TBD gpm TBD MGD RR Spur: 200 gpm 0.29 MGD Wiccopee: 600 gpm 0.86 MGD	Predict Main Site production well withdrawals, potentiometric conditions, gradients, and apparent flow directions with target operating levels for PW-1, PW 2, and PW-25.

FIGURE

Figure 1

Steady-State Calibration

Baseline Conditions

Groundwater Model Simulations

Summary Memorandum
IBM East Fishkill Facility
Hopewell Junction, New York

Drawn By: E. Wright
Designed By: A. Ashton
Reviewed By: B. Green
Project No: 2999.01
Date: March 2016

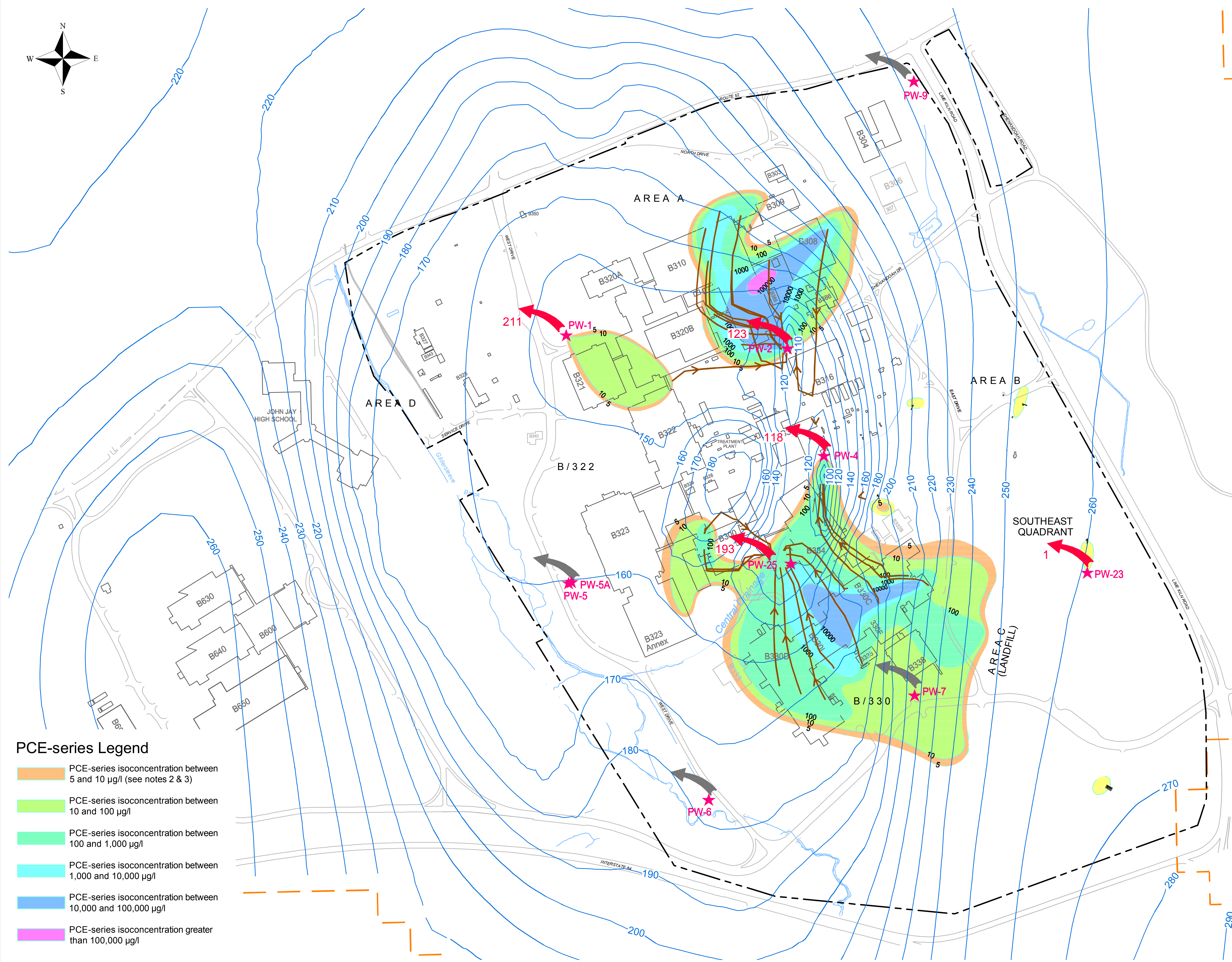


Figure Narrative

This figure shows model predicted groundwater potentiometric contours for the September 2014 average withdrawal and recharge conditions (steady-state, baseline model). In addition, model predicted particle track pathlines are shown to indicate groundwater flow direction from the periphery of bedrock groundwater plume. For comparison the figure also shows the January-June 2013 bedrock PCE-series iso-concentration contours (see notes below).

Notes

1. The potentiometric contours and groundwater flow pathlines were predicted using the three-dimensional numerical groundwater model developed by Sanborn Head as outlined in the report text and appendices. These outputs are shown for model layer 7 which represents an interval from 0 to 50 feet AMSL elevation. This layer was chosen as representative of main site bedrock aquifer conditions. The model outputs are based on post-processing of GIS shapefiles exported from the Visual MODFLOW model file named "Calibration 58.vmf".

2. The baseplan and PCE-series isoconcentration graphics are from a plate titled "Plate 6 - Isoconcentration Contour Map, PCE-Series, Bedrock, January-June 2013", included in the "2013 Annual Corrective Action Status Report", dated May 28, 2014 as prepared by Groundwater Sciences Corporation (GSC) of Harrisburg, Pennsylvania. The plate was provided to Sanborn Head electronically on October 15, 2014 as a file named "5007_PCE-BR-2009-2013.dwg".

3. The term "PCE-series" refers to concentrations for tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene, and vinyl chloride normalized as PCE, as discussed in the above referenced GSC report.

Legend

PW-4 Water supply production well

211 Active water supply production well and pumping rate (gpm) used for this simulation

In-active water supply production well

180 Model predicted groundwater potentiometric contour (feet AMSL) - see note 1

Model predicted groundwater flow pathlines (arrow indicates flow direction)

Model boundary

300' 150' 0 300' 600' Feet

SANBORN HEAD

ATTACHMENT A

IBM-EF Groundwater Modeling Simulations
Remedial Systems Separation - Groundwater Extraction Optimization

IBM East Fishkill Facility
East Fishkill, New York
May 21, 2015

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Agenda:

- Re-cap of Scope and Overview of Simulations Completed
- Simulation 1 – Optimization of Pumping Wells
  - Assess the consequences of shifting water balance
  - Assess options for PW-1 pumping optimization
  - Evaluate the influence of pumping conditions on plume control
- Simulation 2 – Shifting Balance of On-Site Pumping
- Insights from the Transient Model (Simulation 3)
- Review of Constant Head Operating Scenarios (Simulation 4) and Discussion of Recommendations/Additional Simulations

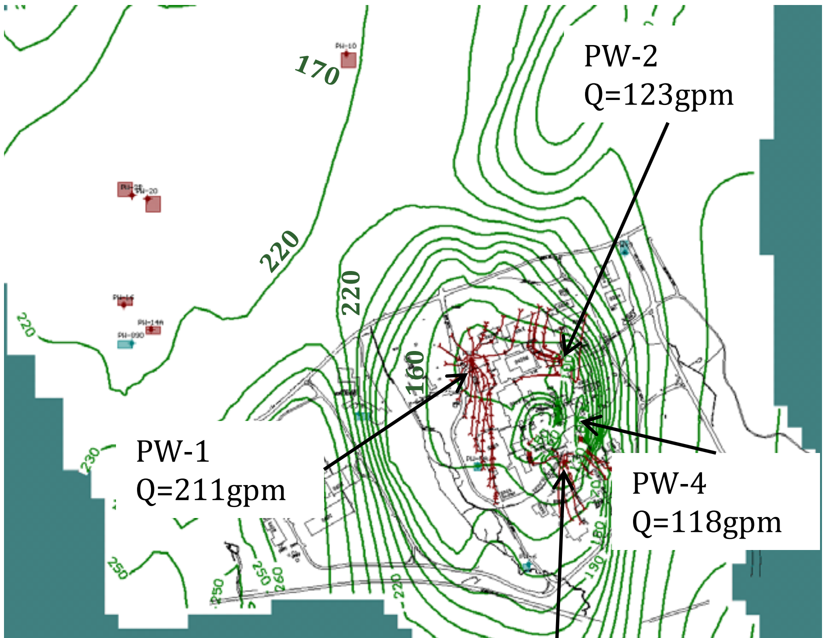
- Simulation 1 - Steady-State Simulation of Reduced Withdrawal Conditions within the Main Site
  - ➢ Where does water from PCE source areas travel?
  - ➢ How much do potentiometric levels change on-site?
  - ➢ Do existing wells capture the plumes?

Simulation #	Description	Production Well Withdrawals (gpm)						Rationale
		Main Site		RR Spur		Wiccopee		
1A	Steady-state simulation of reduced withdrawal conditions within the Main Site. Simulation maintains average 2014 withdrawals of 1190 gpm (1.7 MGD) while shifting about 270 gpm (0.39 MGD) from the Main Site to the off-site well fields.	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	50 120 0 0 0 0 0 0 220	PW-10 PW-12	50 150	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	200 0 150 0 200 50	Predict Main Site production well operating levels, potentiometric conditions, gradients, and apparent flow directions under reduced withdrawals for PW-1 and shutdown of PW-4.
1B	Similar to Simulation 1A with water production shifted primarily to PW-10.	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	50 120 0 0 0 0 0 0 220	PW-10 PW-12	270 0	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	150 0 150 0 200 50	Assess potential for off-site migration if production is shifted to southern Rail Road Spur well.
1C	Greatly reduced PW-1 pumping rate. Water production shifted to PW-10.	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	25 120 0 0 0 0 0 0 220	PW-10 PW-12	295 0	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	150 0 150 0 180 50	
1D	Complete shutdown of PW-1. Water production shifted to PW-10.	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	0 120 0 0 0 0 0 0 220	PW-10 PW-12	320 0	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	150 0 150 0 180 50	As Simulation 1C with complete shut-down of PW-1. Assess plume capture, gradients, potentiometric rise by PW-2 and PW-25 only.

What predictions does the model make about operating levels, potentiometric levels and gradients under reduced withdrawals for PW-1 and shutdown of PW-4?

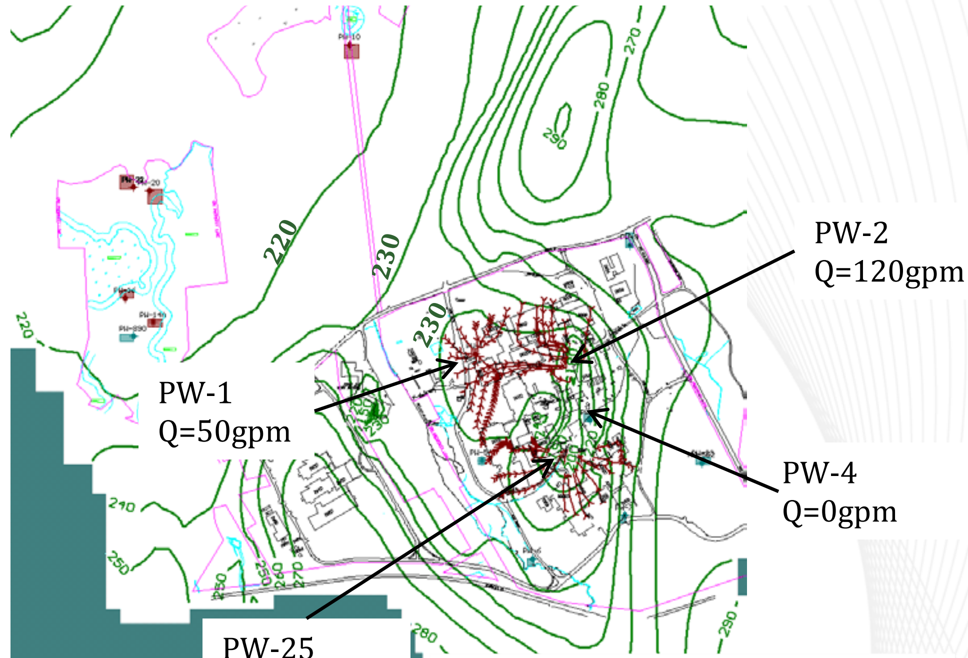
Plume is contained on-site. Potentiometric level rise of about 60 to 70 feet in Area A. Slight increase in predicted transport from Area A towards PW-25 in deepest model layer.

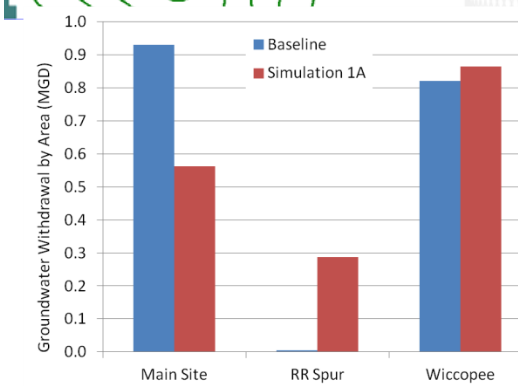
Baseline 2014 Condition



PW-25
Q=193gpm

Simulated flow paths after pumping rate changes (Simulation 1A)





Green contours represent potentiometric levels in model layer 7.

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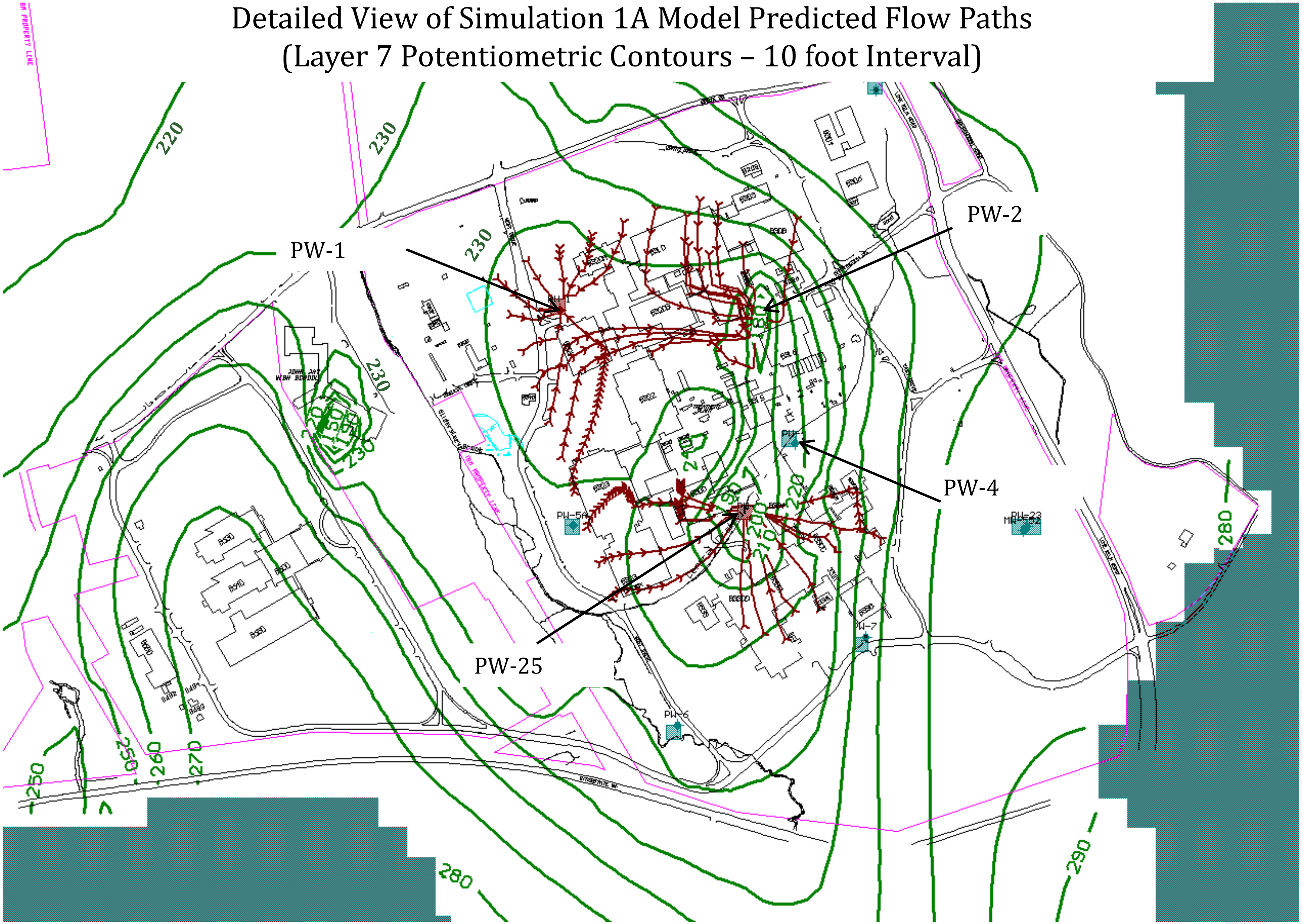
Detailed View of Simulation 1A Model Predicted Flow Paths
(Layer 7 Potentiometric Contours – 10 foot Interval)



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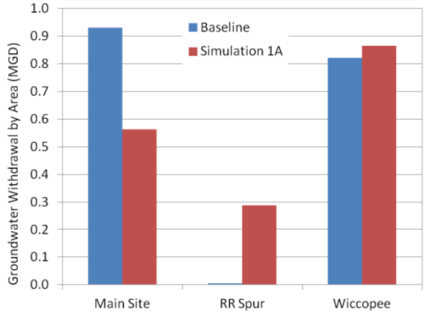
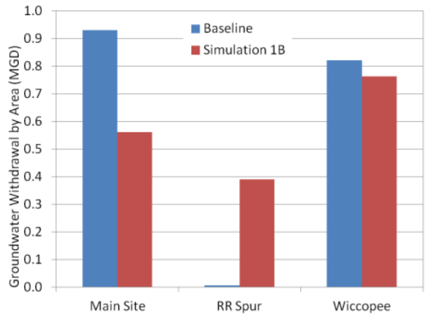
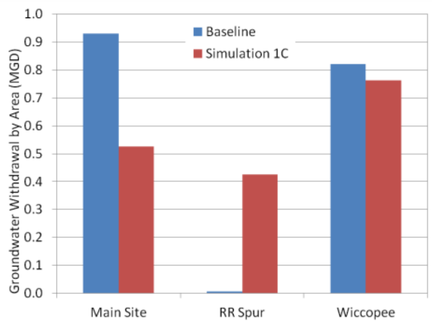
1A



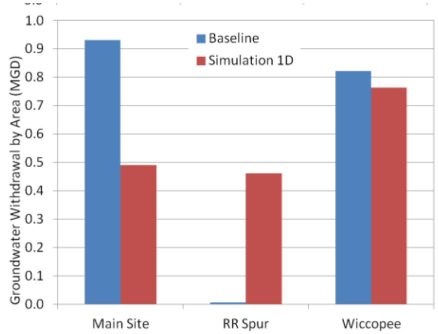
1B



1C

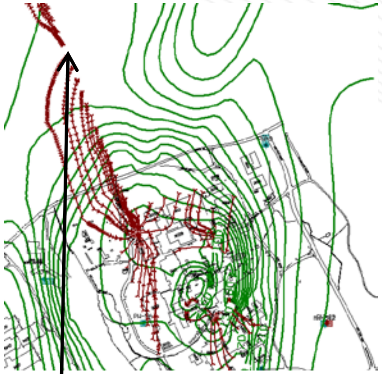


1D



Water Production Shifted to RR Spur
PW-1 Pumping Rate Reduced 50 to 0 gpm

Baseline



Saddle point under baseline condition

Simulations

Saddle point based on particle tracking

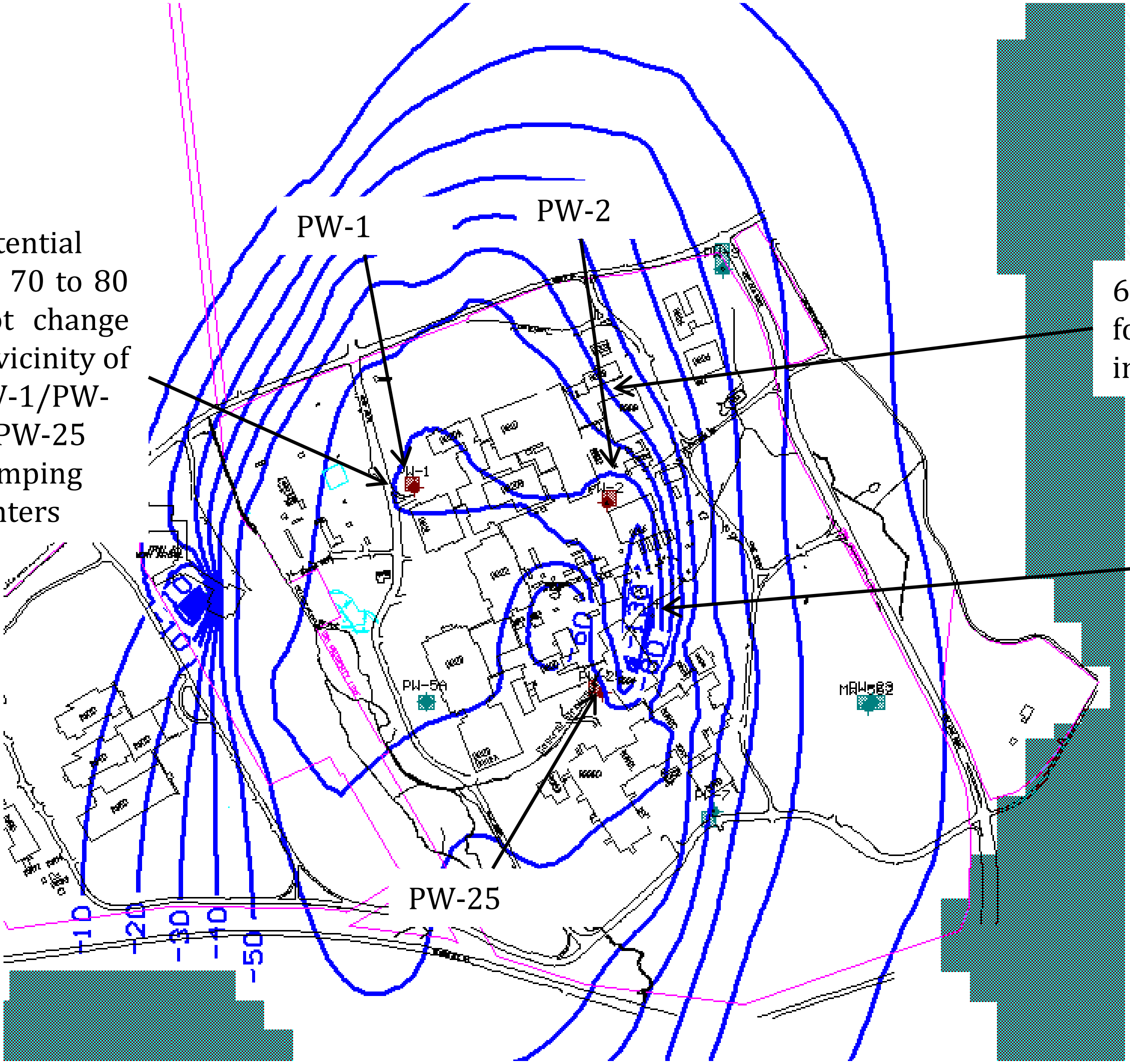
Saddle point based on particle tracking

Saddle point based on particle tracking

Saddle point based on particle tracking

Green contours represent potentiometric levels in model layer 7.

Simulation 1A Model Predicted Potentiometric Level Change Compared to 2014 Baseline Condition (Layer 7 Contours – 10 foot Interval)



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• Simulation 2 – Pumping Rate Summary

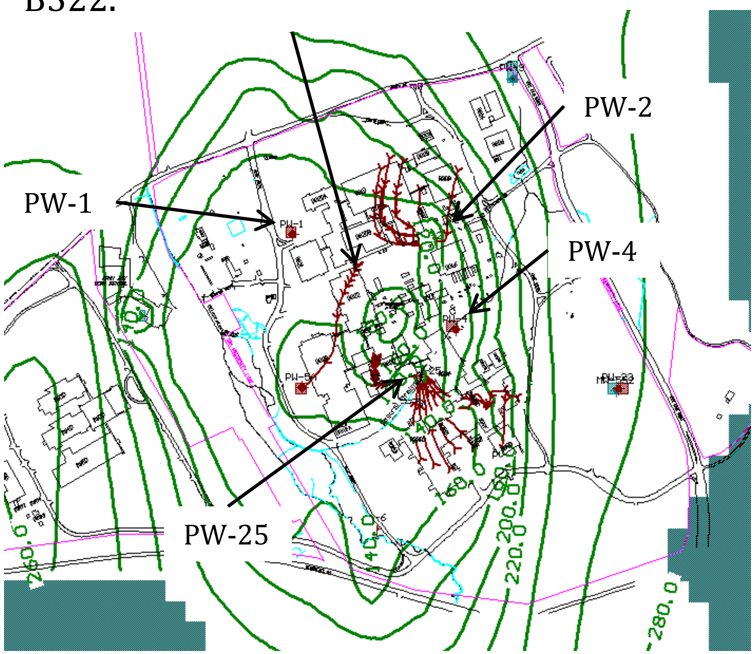
Simulation #	Description	Production Well Withdrawals (gpm)						Groundwater Withdrawal By Area	Rationale
		Main Site		RR Spur		Wiccopee			
Base Line	Steady-state simulation of September 2014 Pumping Conditions and including simulation of the John Jay High School well.	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	211 123 118 0 0 0 0 1 193	PW-10 PW-12	4 0	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	58 4 269 0 238 1	Main Site: 646 gpm 0.93 MGD RR Spur: 4 gpm 0.01 MGD Wiccopee: 570 gpm 0.82 MGD	Provide baseline for comparison of subsequent simulations.
2	Main Site Production Well Shift In Withdrawals: Steady-state simulation of shifting withdrawals within the Main Site from PW-1 and PW-4 to other Main Site wells. Off-site withdrawals maintain average withdrawals from 2014. Simulation maintains overall average 2014 withdrawals of 1190 gpm (1.7 MGD). Area B, Area D, and B322 extraction well withdrawals are shutdown.	PW-1 PW-2 PW-4 PW-5A PW-6 PW-7 PW-9 PW-23 PW-25	50 120 0 170 50 50 0 0 220	PW-10 PW-12	20 60	PW-14A PW-16 PW-20A PW-890 PW-21 PW-22	25 10 155 0 205 55	Main Site: 660 gpm 0.95 MGD RR Spur: 80 gpm 0.12 MGD Wiccopee: 450 gpm 0.65 MGD	Predict effects of using other Main Site production wells rather the off-site well field wells to balance the declines in Main Site withdrawals due to reduced PW-1 withdrawals and shutdown of PW-4.

• Simulation 2 – Water Production Shifted from PW-1/4 to PW-5A/6/7

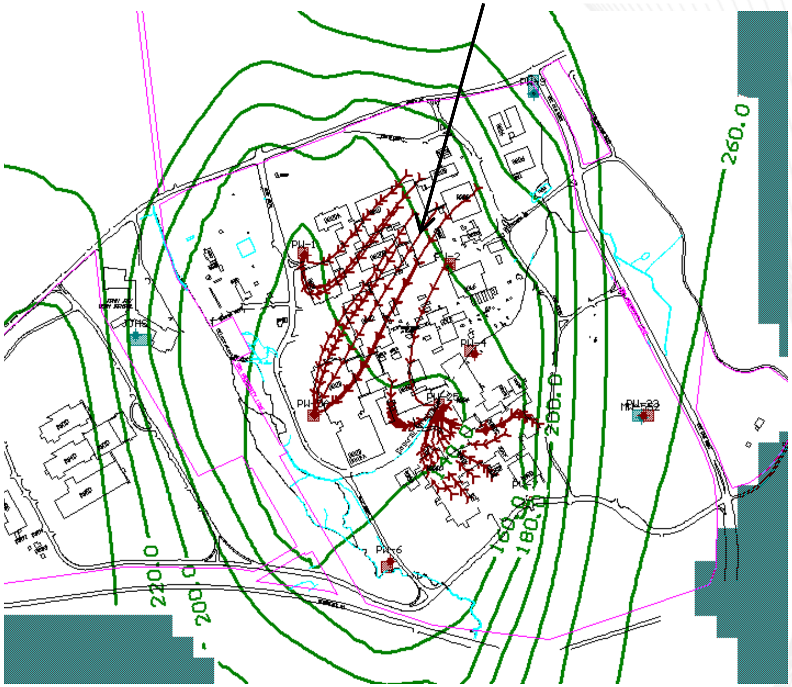
➢ Where does water from PCE source areas travel?

In shallow bedrock model predicts gradients that are similar to baseline 2014 conditions except in vicinity of B322.

In deeper bedrock the model predicts potential for transport from Area A toward PW-5A.



Sim2 Model results shown for layer 7

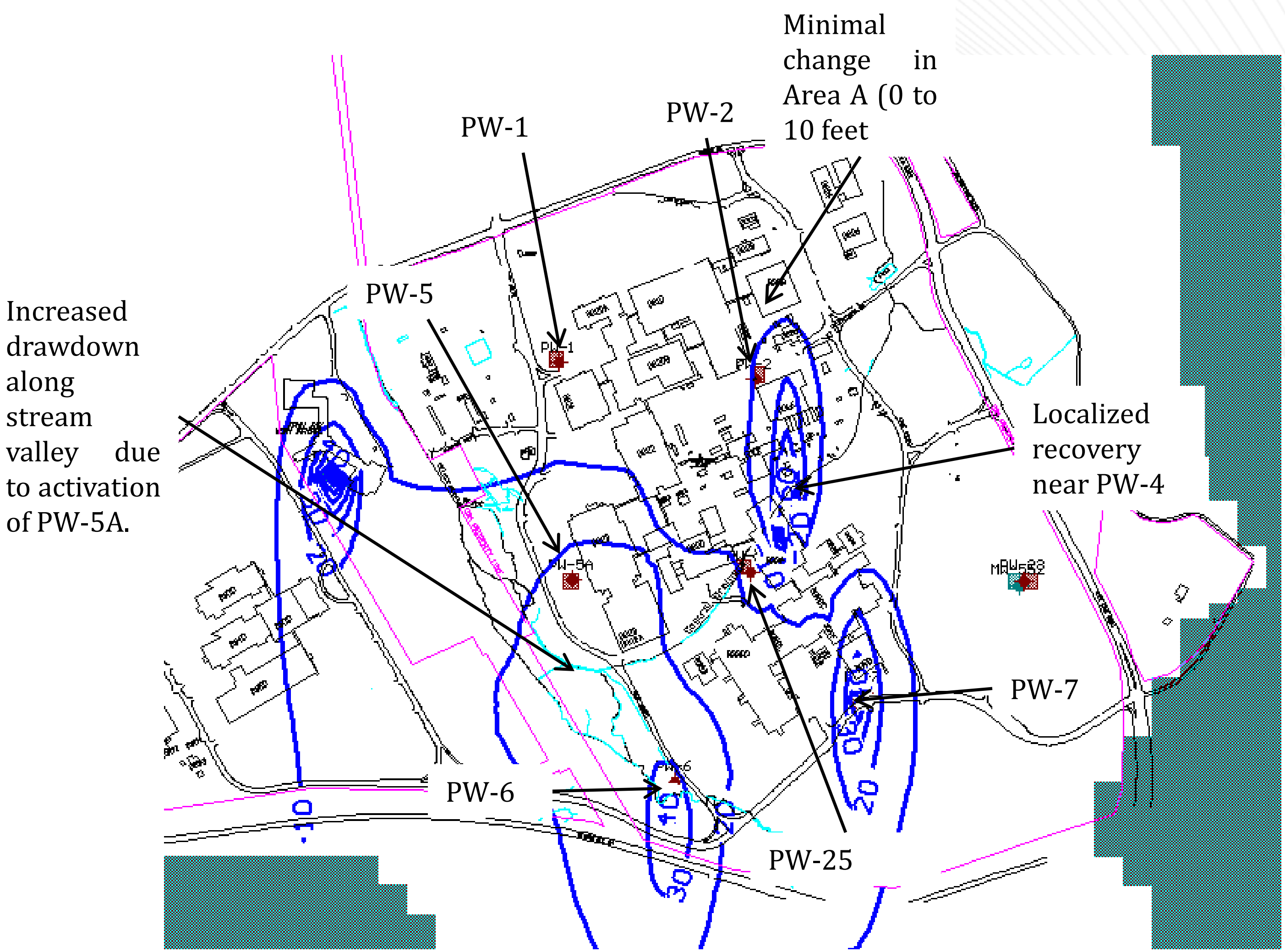


Sim2 Model results shown for layer 10

Green contours represent potentiometric levels in each respective model layer.

Simulation 2 – Water Production Shifted from PW-1/4 to PW-5A/6/7

- How much do on-site potentiometric levels change?



Model results shown for layer 7. Blue contours represent potentiometric level change.

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- Simulation 3: Goal - Assess the timing of potentiometric level changes after alterations to pumping conditions

- Observations

  - Within 1 week model predicts significant rebound in PW-4 – measurable change in water levels will likely be localized to PW-4 vicinity in this time frame.

  - Model predicts that a one month test duration allows significant measurable water level change through PW-1/PW-2/PW-4/PW-25 catchment areas.

  - Model predicts that potentiometric level rise will reach steady-state in 4 to 5 years.

- Proposed Deliverables

  - Potentiometric and recovery contours for 1 week/2 week/1 month timeframes that can be used to frame suitable monitoring locations.

  - Potentiometric level time series data and associated charts for individual monitoring locations to allow understanding of predicted water level change during the test period.

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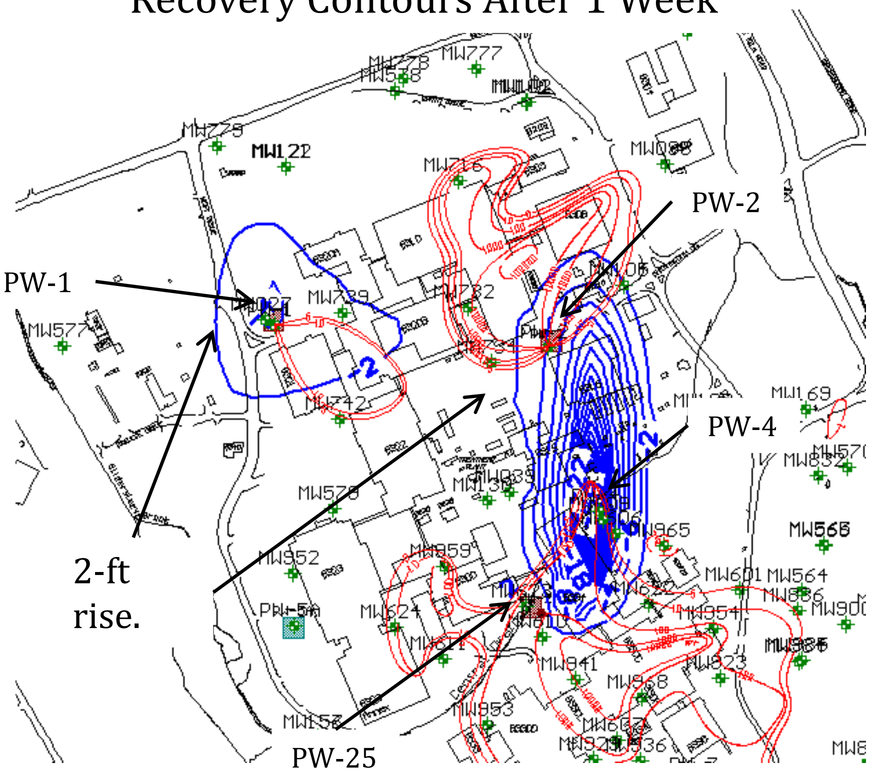
• Simulation 3

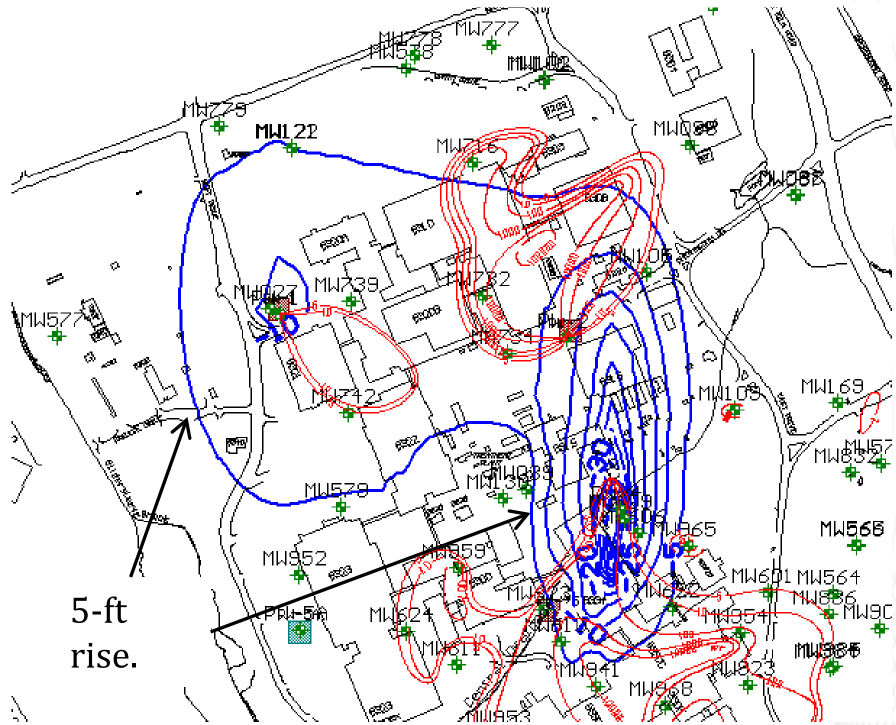
➢ What is the timing of on-site potentiometric level changes after shut-down of PW-4 and reduction in PW-1 pumping rate?

Recovery Contours After 1 Week



2 foot contour interval

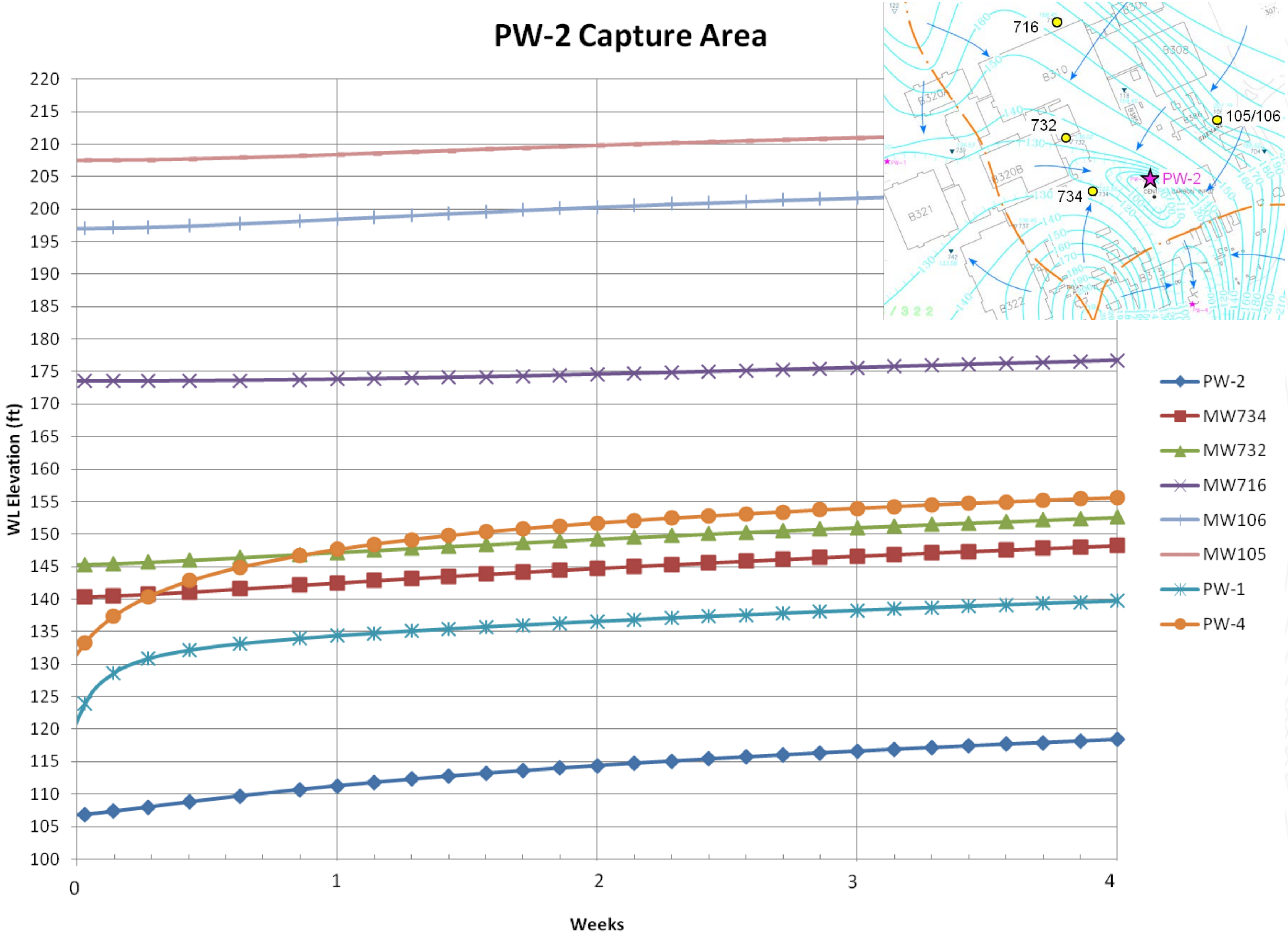
Recovery Contours After 1 Month



5 foot contour interval

Model results shown for layer 7. Blue contours represent potentiometric level change.
Red contours represent PCE-series isopleths (GSC 2013 Annual Report)

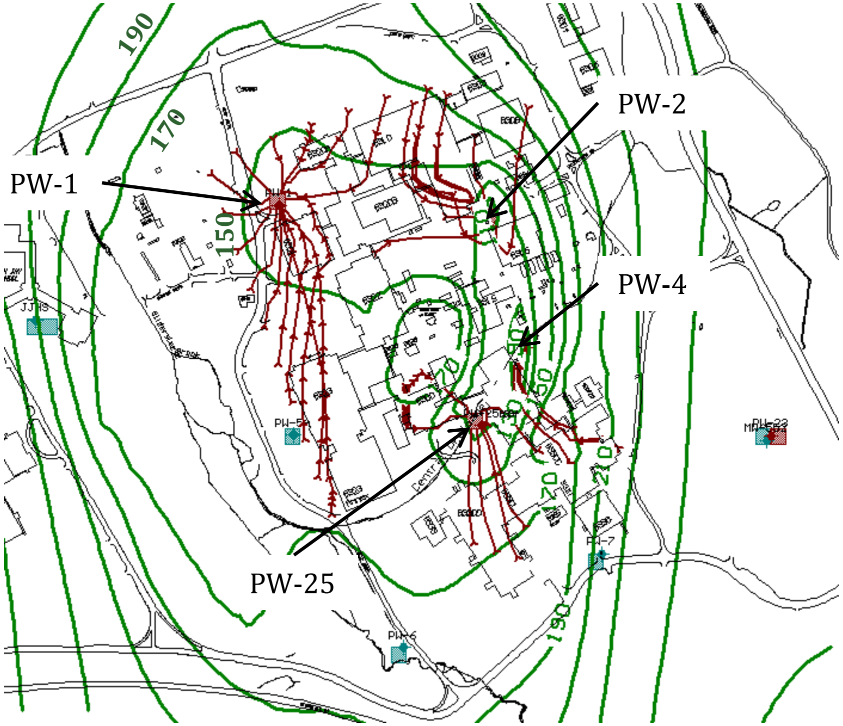
PW-2 Capture Area



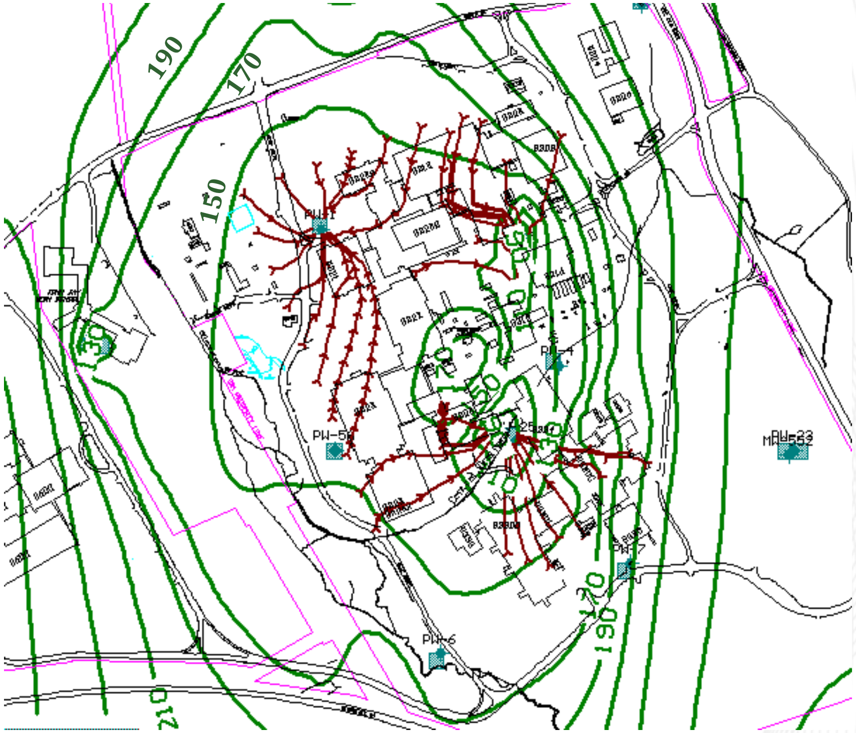
Simulation 4 – Assessment of Fixed Operating Levels for PW-1/2/25

Well	Modeled Operating Level (ft AMSL)	Model Predicted Pumping Rate (gpm)
PW-1	70	194 gpm
PW-2	70	156 gpm
PW-25	-30	314 gpm

Baseline 2014 Condition

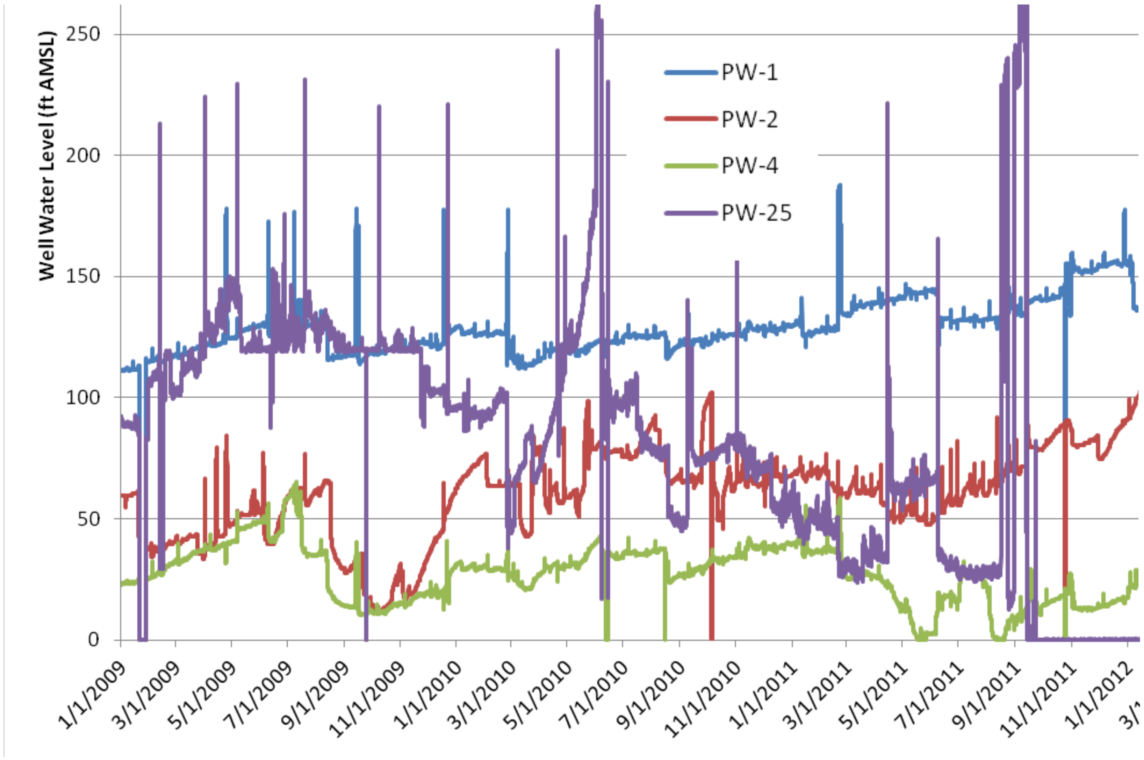


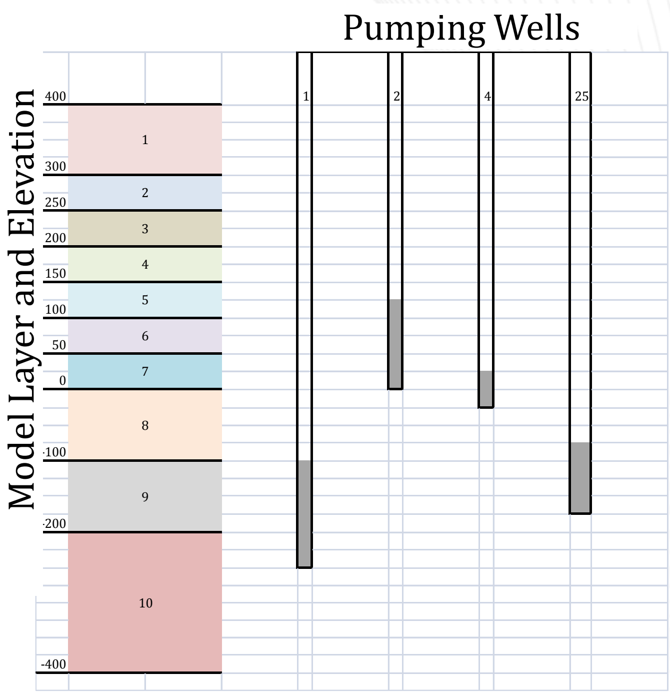
Simulated flow paths and pumping rates under fixed operating level scenario



Green contours represent potentiometric levels in model layer 7.

How have on-site production wells been operated in recent years and how might this influence decisions on future operating levels?





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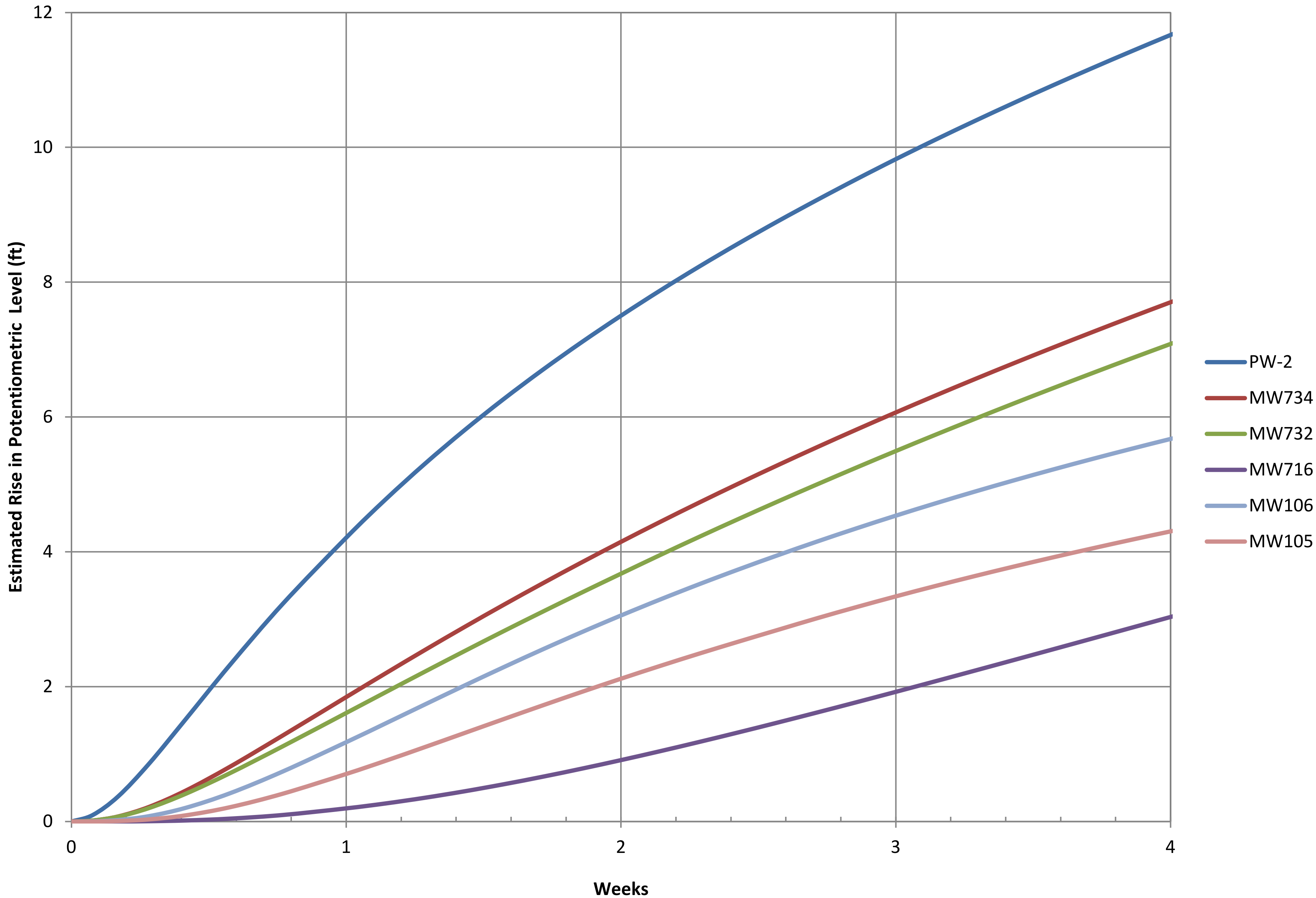
- Simulation 4: Goal - Assess fixed operating levels

- Discussion of Long-Term Operating Goals
  - Capture
  - Mass removal
  - Water production goals

- Simulation Approach and Assessment of Goals
  - Increase PW-1 operating level while maintaining capture.
  - Balance PW-2 and PW-25 to reduce potential for north-south migration.
  - Iteration of PW-1/2/25 operating levels to optimize mass removal .

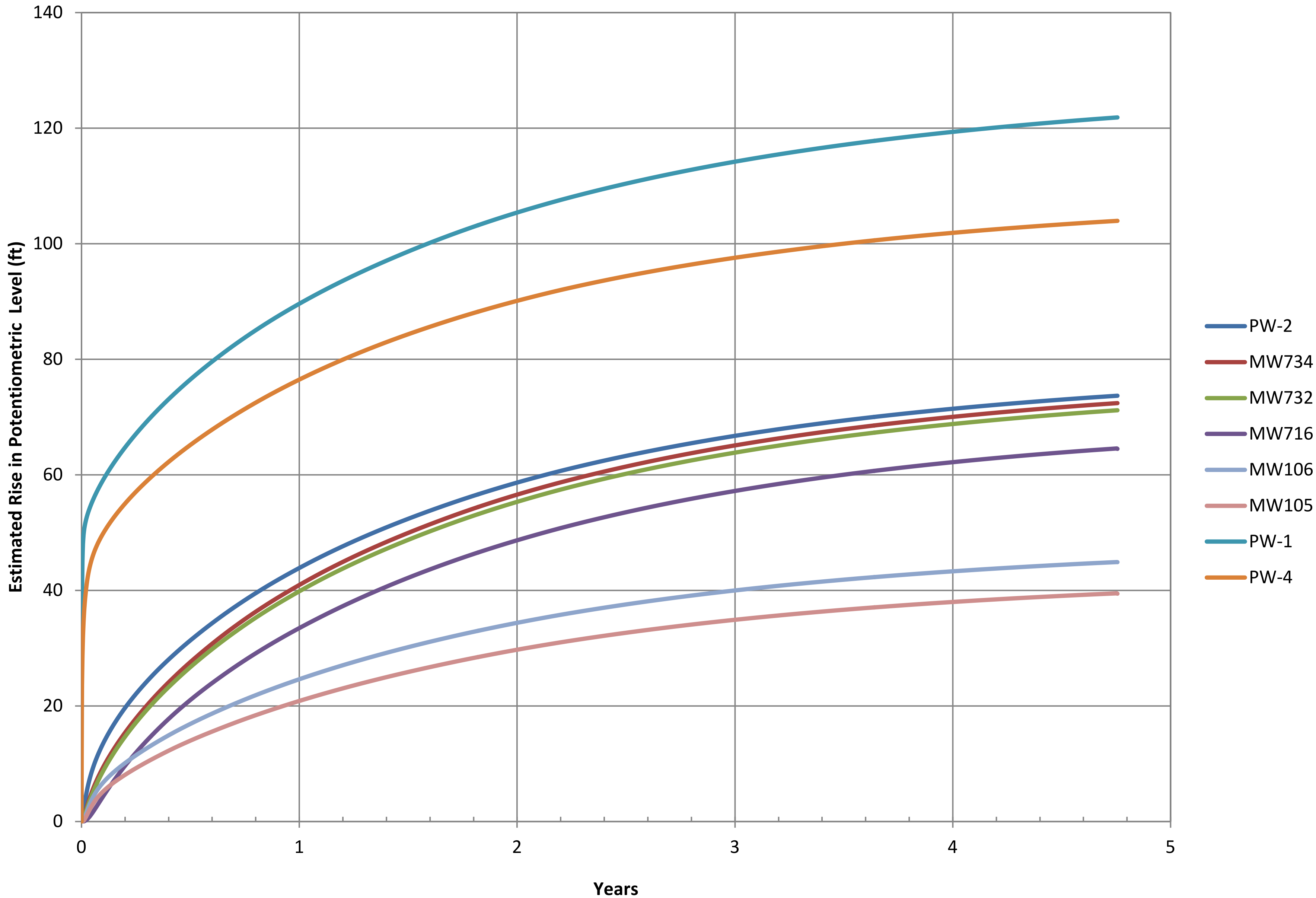
ATTACHMENT B

Attachment B - Simulation 3: Model Predicted Change to Potentiometric Levels During the First Four Weeks of Simulation for Wells Located in the PW-2 Capture Area



ATTACHMENT C

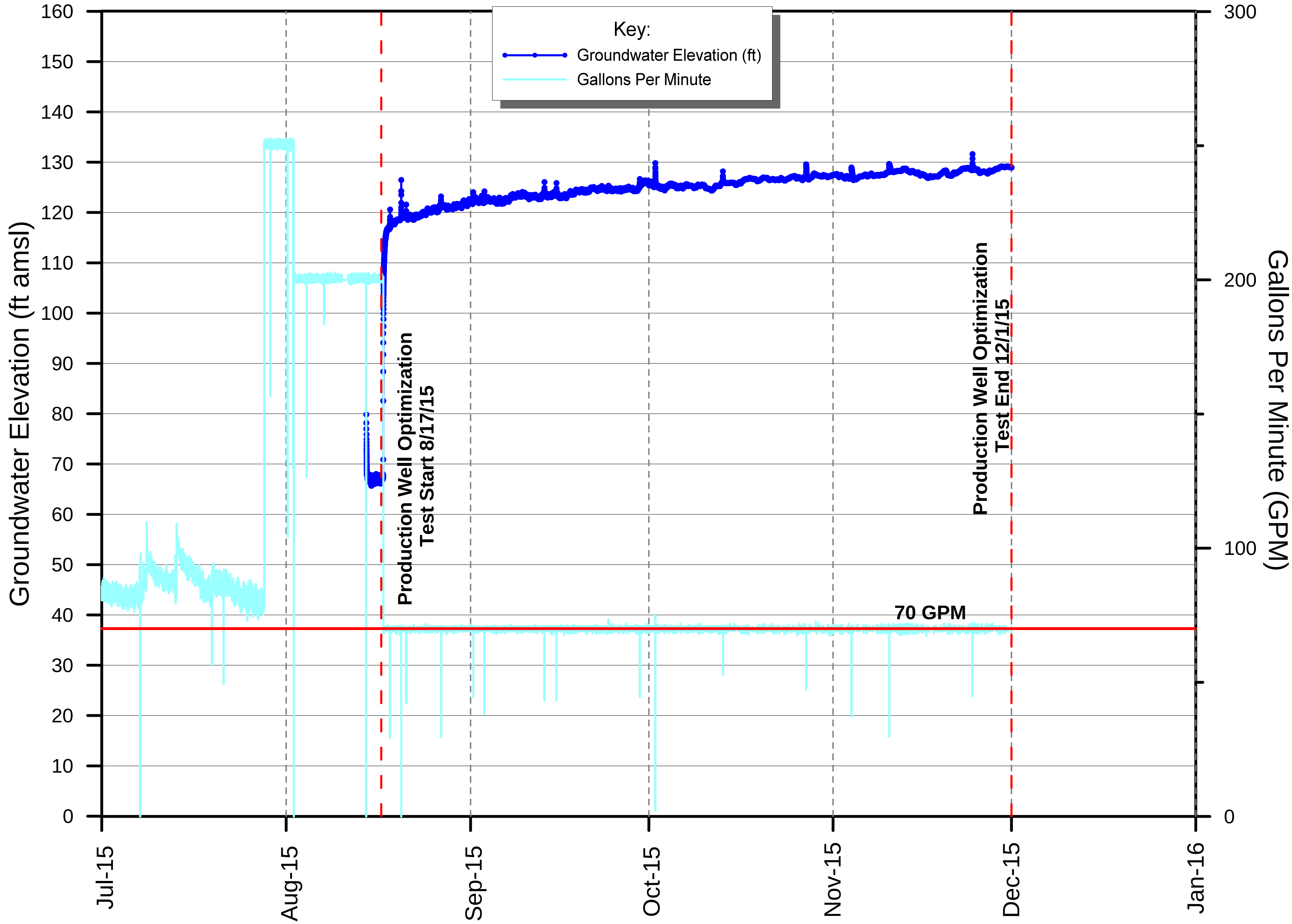
Attachment C - Simulation 3: Model Predicted Change to Potentiometric Levels During the First Five Years of Simulation for Wells Located in the PW-2 Capture Area

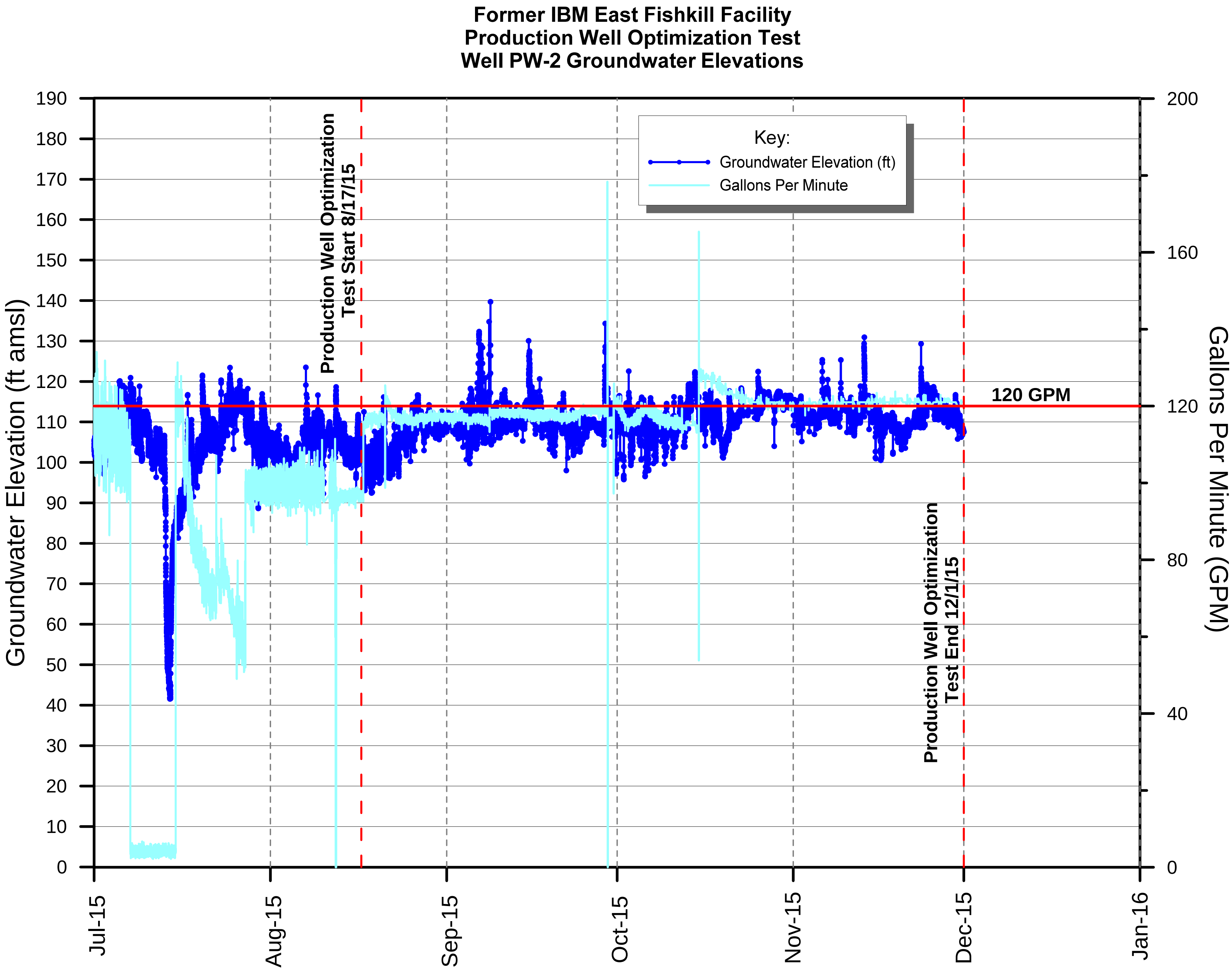


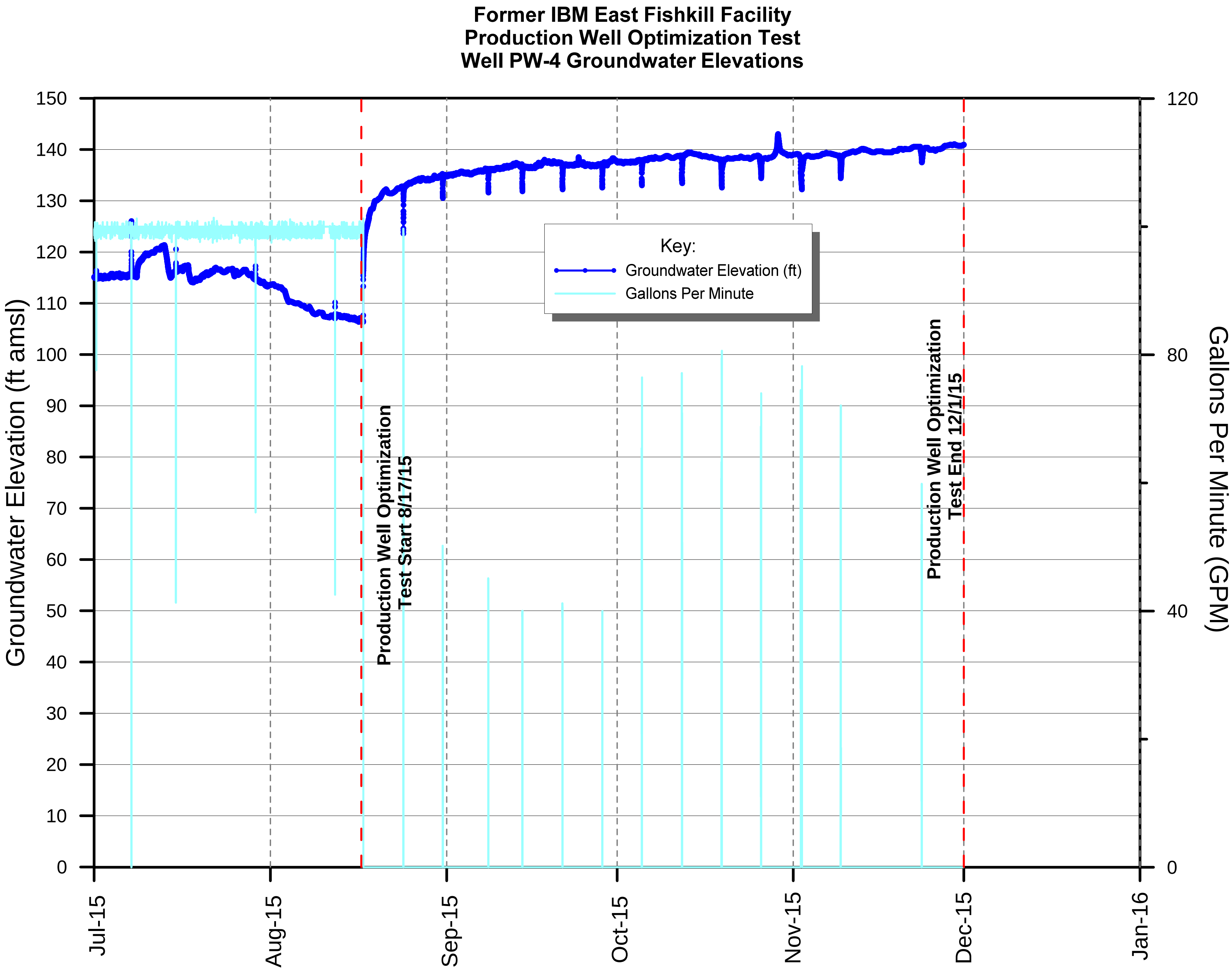
Appendix B

Production Well Operations Graphs

Former IBM East Fishkill Facility
Production Well Optimization Test
Well PW-1 Groundwater Elevations

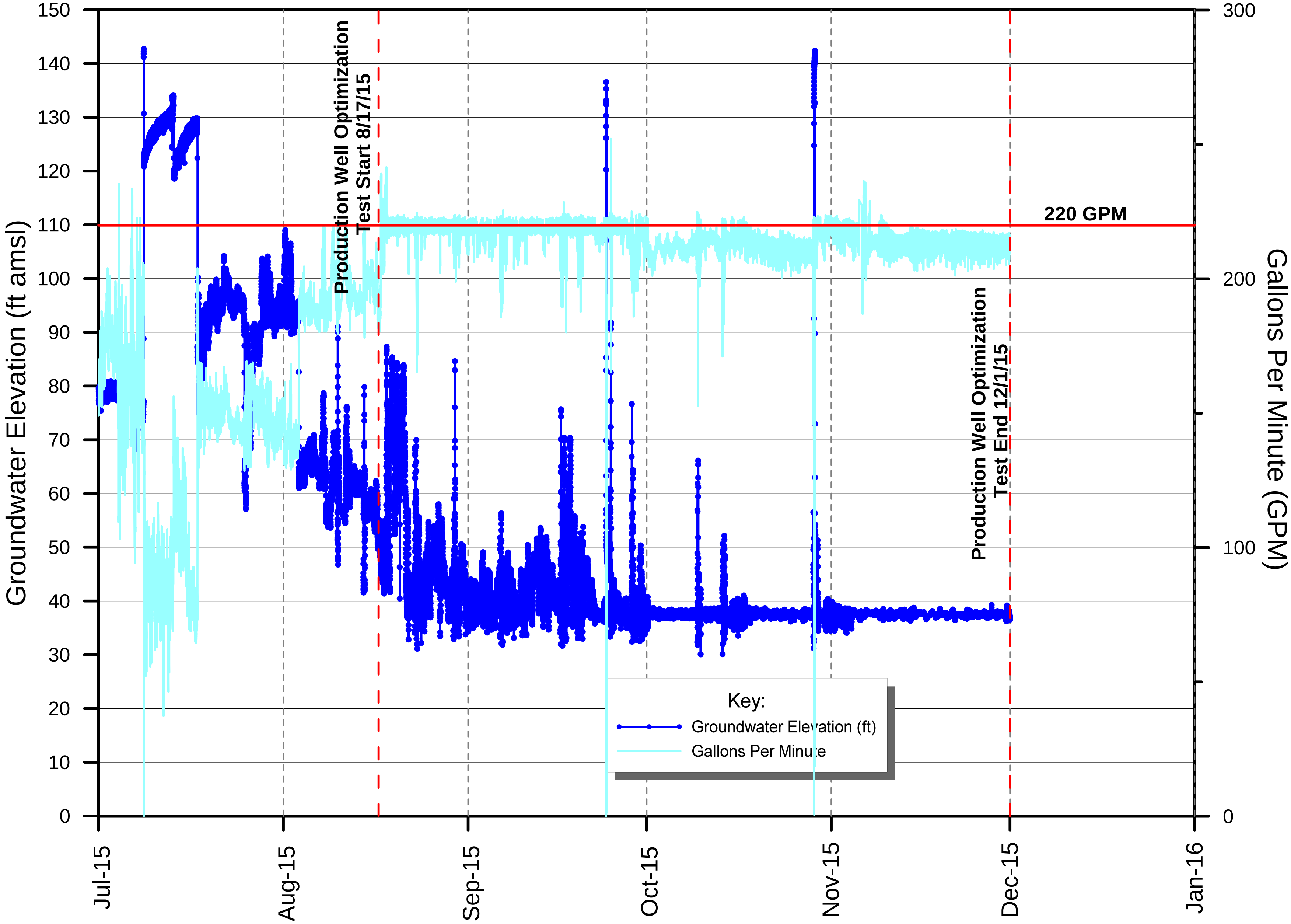



Former IBM East Fishkill Facility
Production Well Optimization Test
Well PW-2 Groundwater Elevations
Groundwater Elevation (ft amsl)
Gallons Per Minute (GPM)
Key:
Groundwater Elevation (ft)
Gallons Per Minute
120 GPM
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
200
160
120
80
40
0
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16



Former IBM East Fishkill Facility
Production Well Optimization Test
Well PW-4 Groundwater Elevations
Groundwater Elevation (ft amsl)
Gallons Per Minute (GPM)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
120
80
40
0
Key:
Groundwater Elevation (ft)
Gallons Per Minute
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16

Former IBM East Fishkill Facility
Production Well Optimization Test
Well PW-25 Groundwater Elevations



Appendix C

Groundwater Elevation versus Time Graphs

LEGEND

- Former IBM East Fishkill Facility Property Line
- Former Structure
- Bedrock Monitoring Well
- Soil Monitoring Well
- Bedrock Production Well
- Inactive Bedrock Production/Extraction Well

OU - Operable Unit

6 - Model Layer in Sanborn, Head & Associates, Inc. groundwater modeling simulations

- Associated with PW-1, Stacked Groundwater Elevation vs. Time Graphs in Appendix C
- Associated with PW-2, Stacked Groundwater Elevation vs. Time Graphs in Appendix C
- Associated with PW-4, Stacked Groundwater Elevation vs. Time Graphs in Appendix C
- Associated with PW-25, Stacked Groundwater Elevation vs. Time Graphs in Appendix C
- Not associated with any extraction well group
- Transducer Installed in Well, Groundwater Elevation vs. Time Graph in Appendix C

Green wells with no highlighting are supplemental wells for November 30, 2015 elevation round.

Plate C-1

Scale

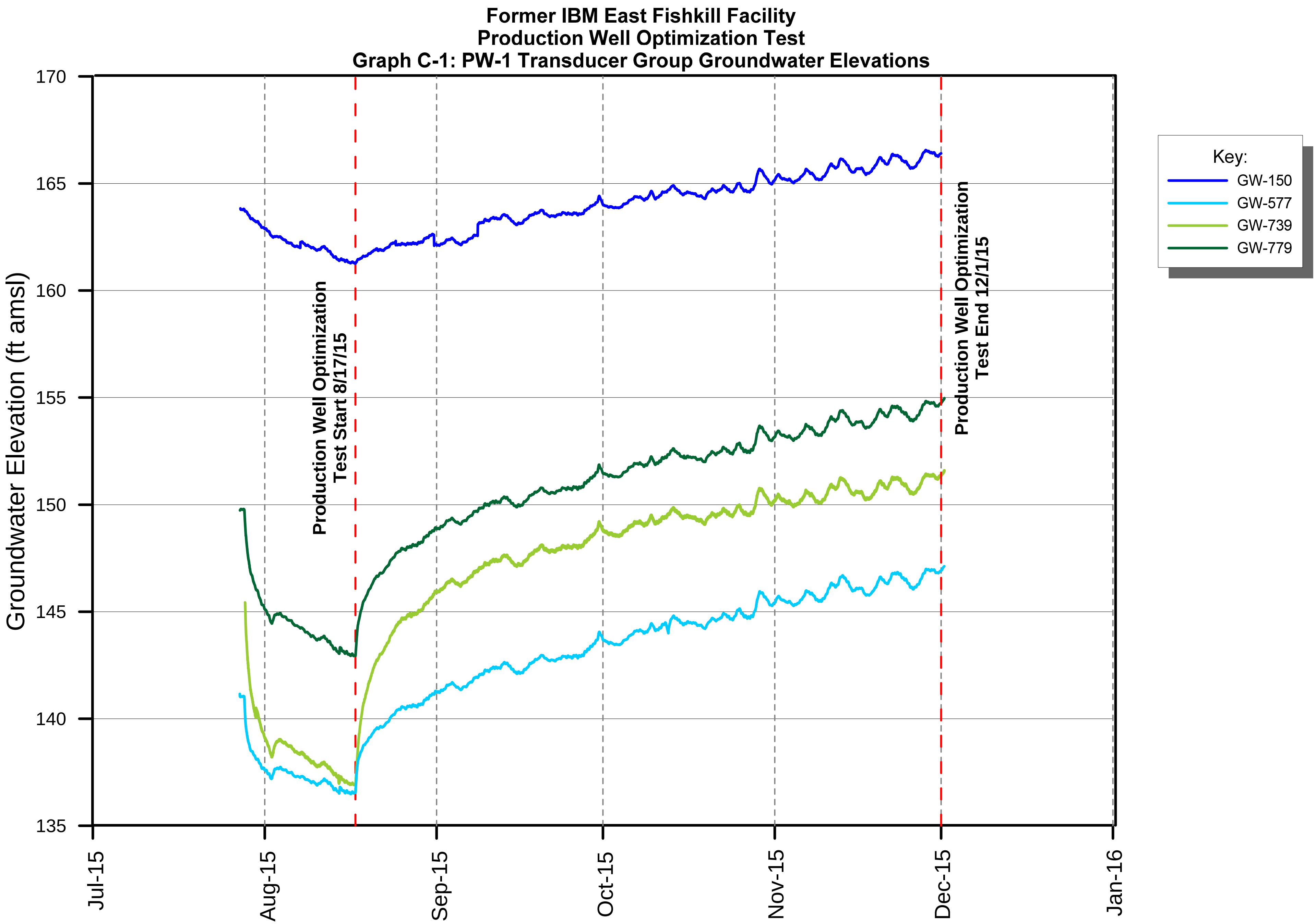
0 150' 300'

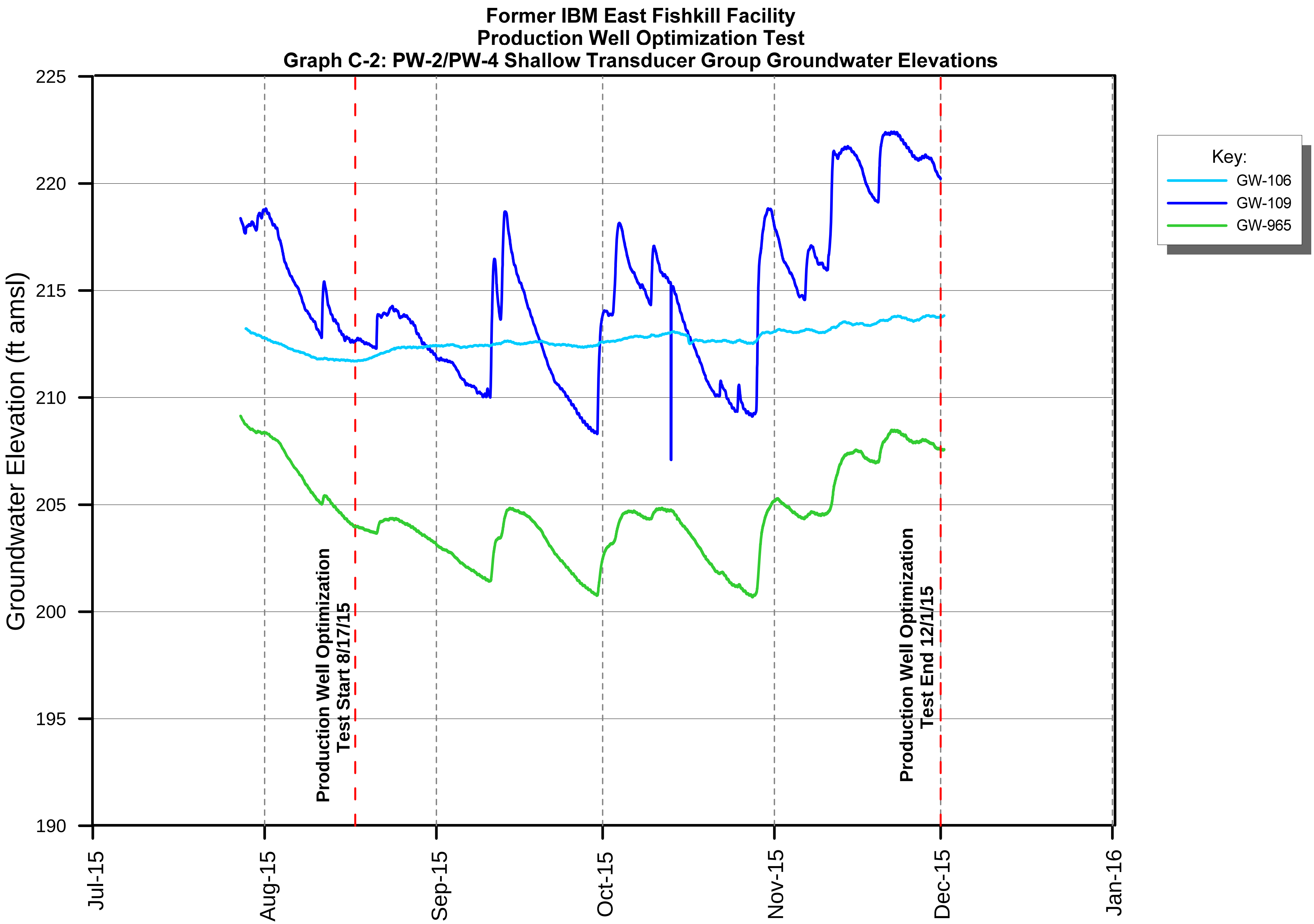
Former IBM East Fishkill Facility

Production Well Optimization Test
Groundwater Monitoring Group Location Map

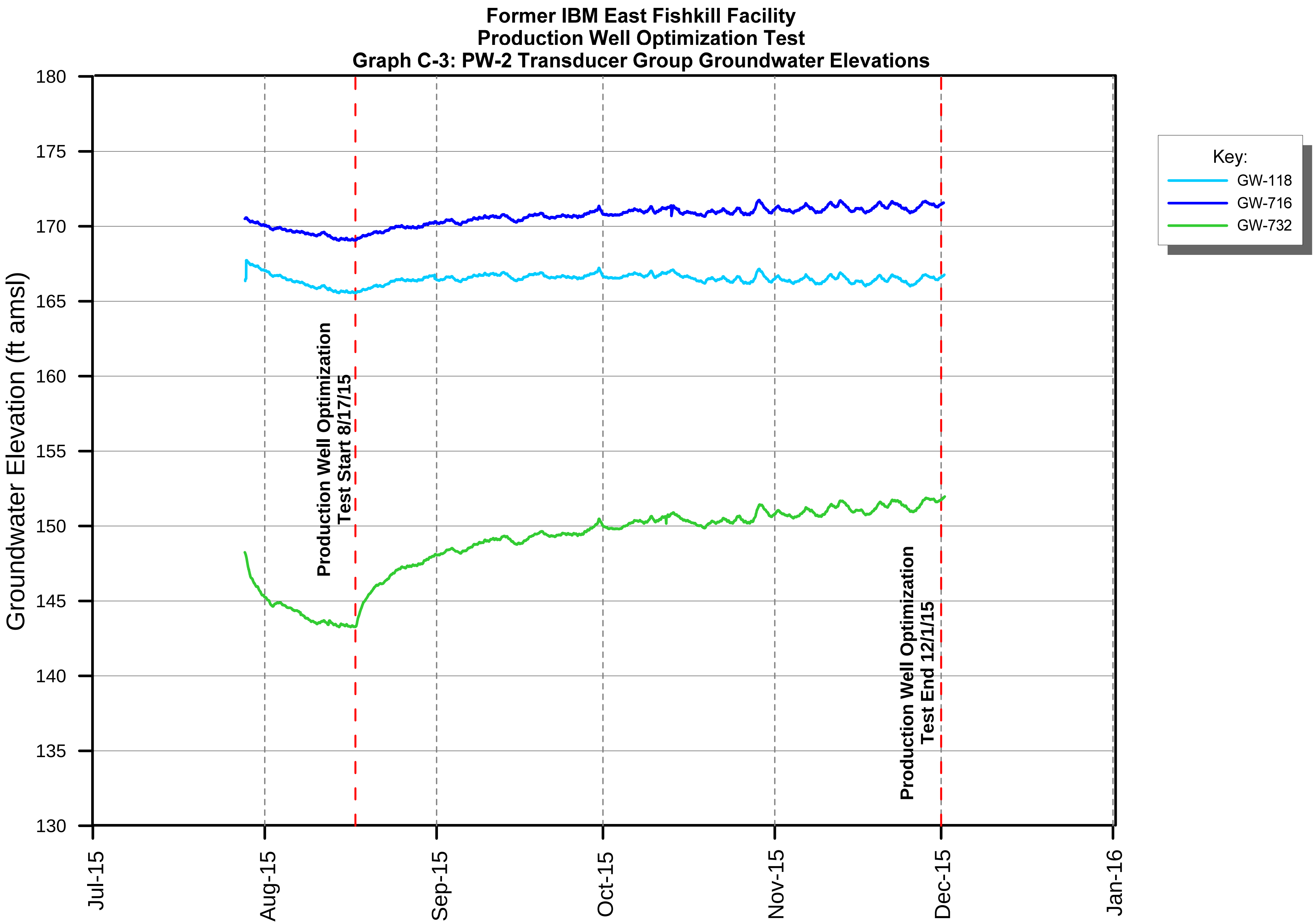
DRAWN BY: MHM	DATE: 1/13/16	DRAWING NO. 95007-097-F2
CHECKED & APPROVED BY: CES/RCW		

GROUNDWATER SCIENCES CORPORATION

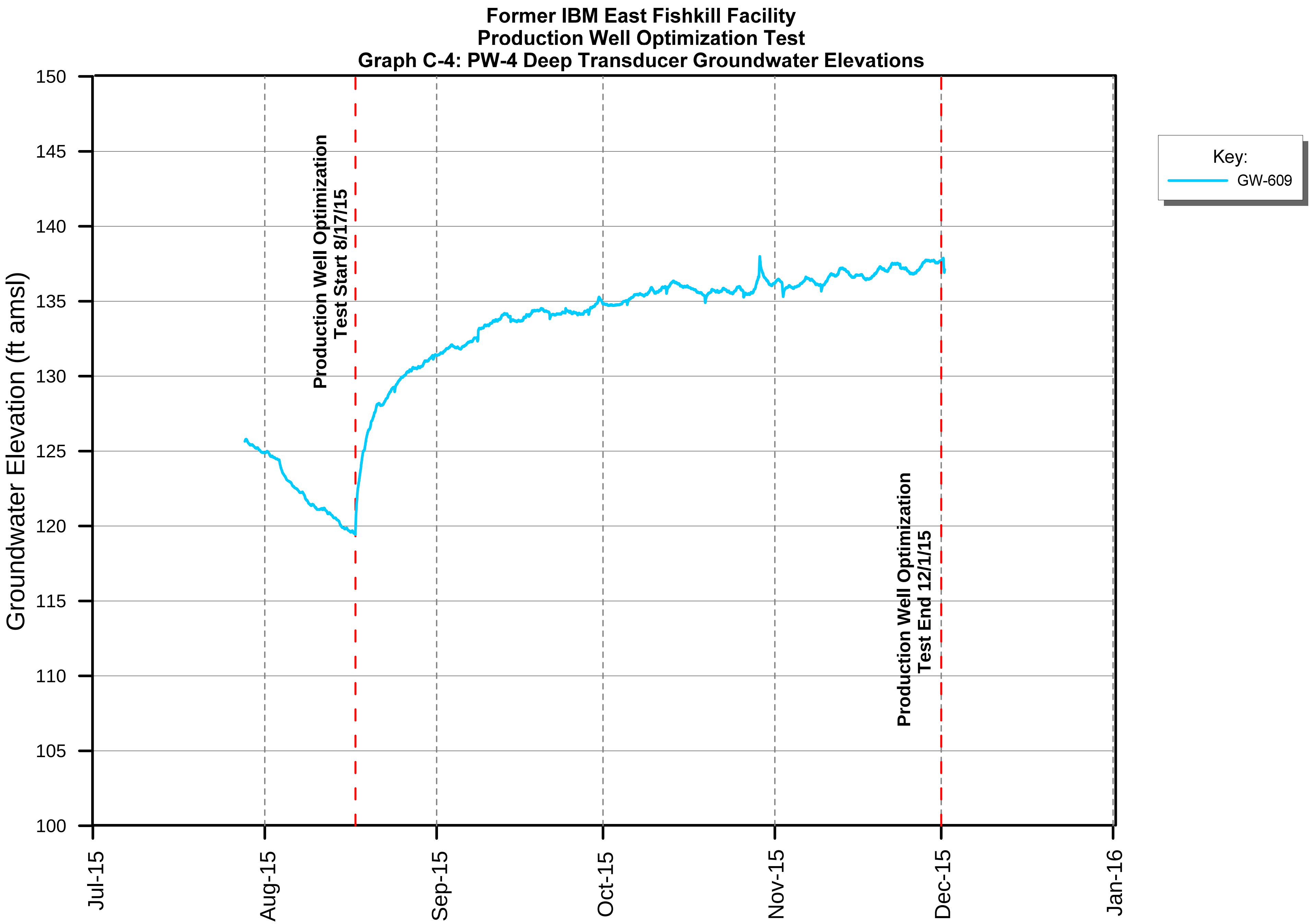

Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-1: PW-1 Transducer Group Groundwater Elevations
Groundwater Elevation (ft amsl)
170
165
160
155
150
145
140
135
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Key:
GW-150
GW-577
GW-739
GW-779

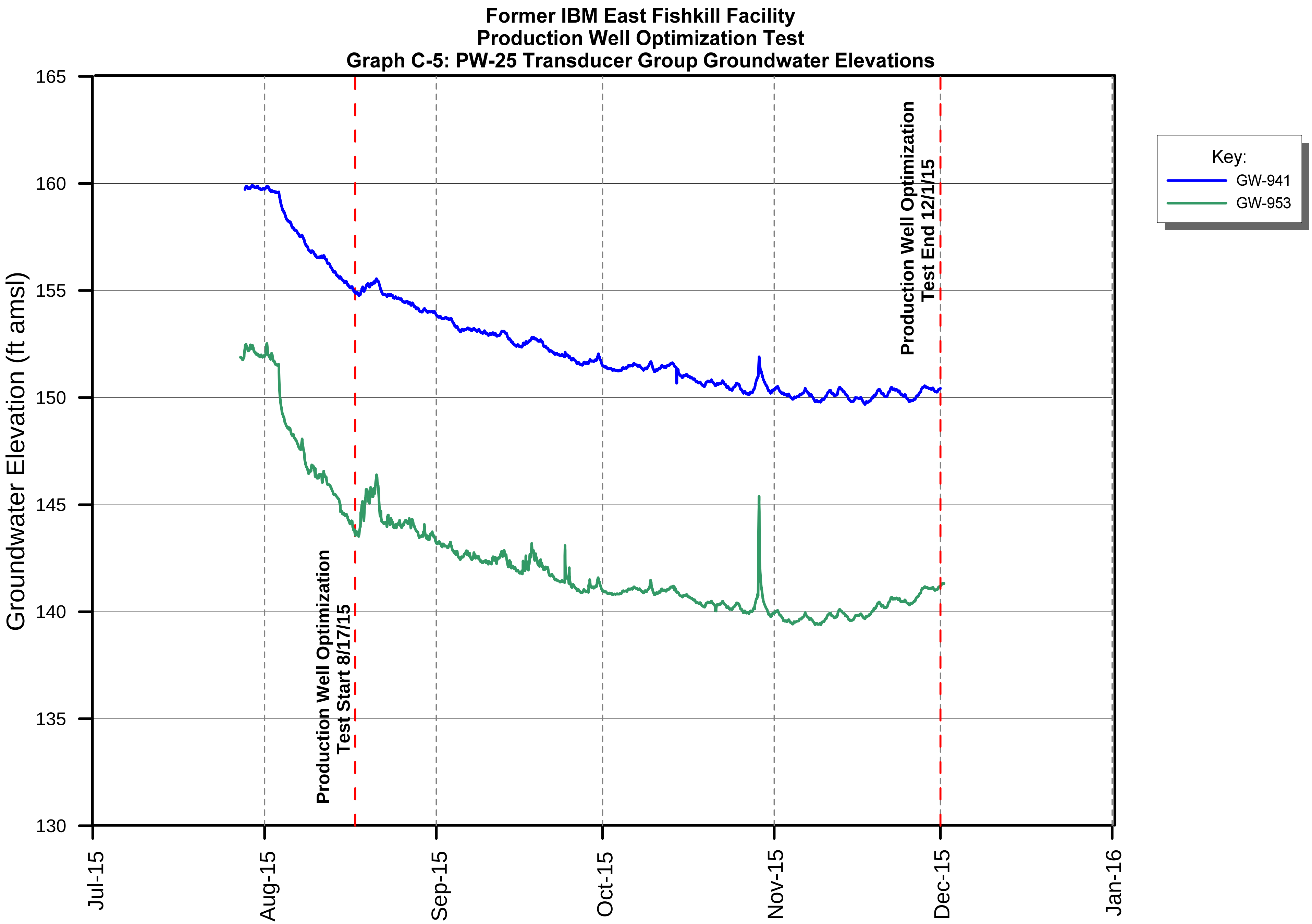


Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-2: PW-2/PW-4 Shallow Transducer Group Groundwater Elevations
Groundwater Elevation (ft amsl)
225
220
215
210
205
200
195
190
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Key:
GW-106
GW-109
GW-965

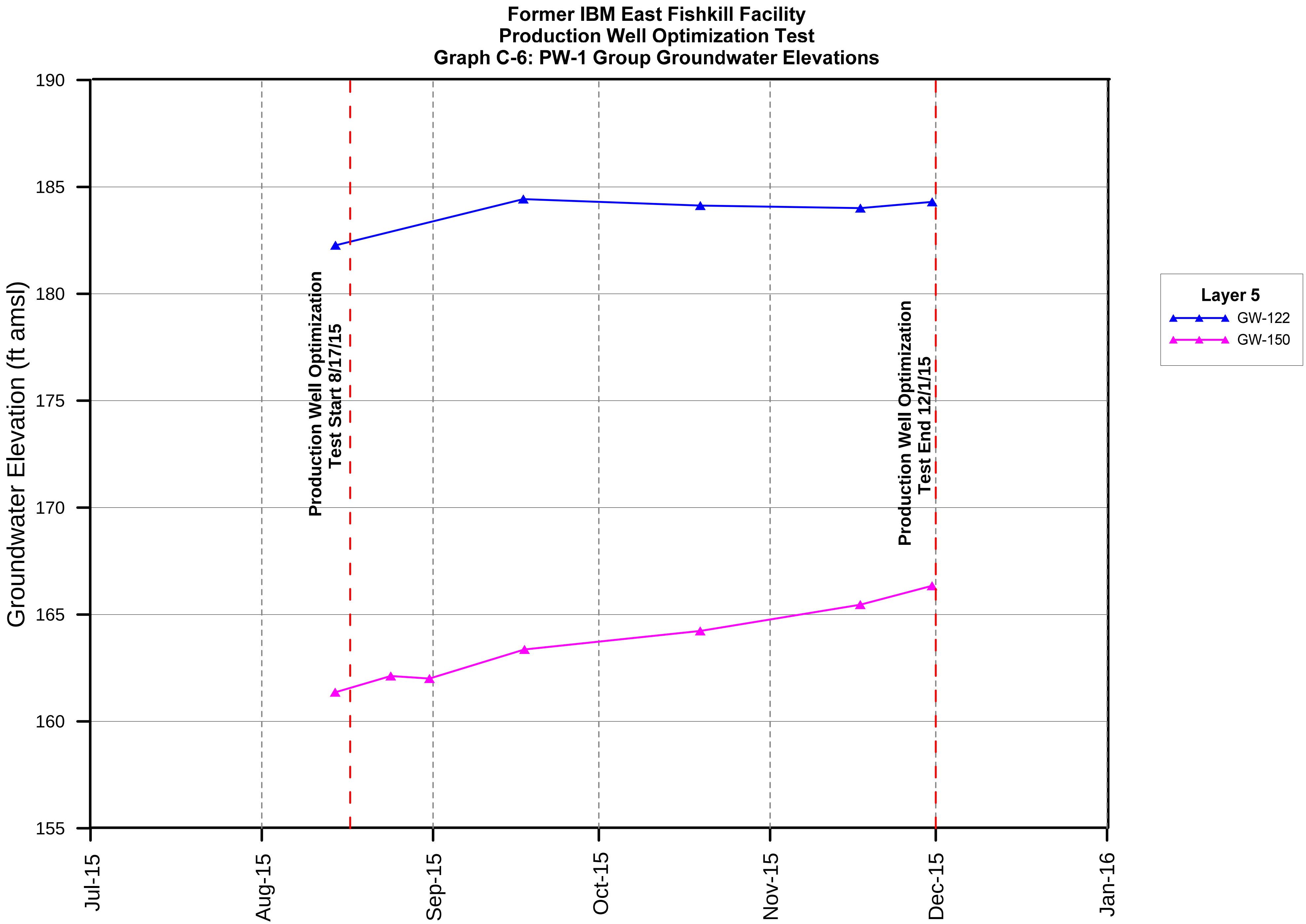


Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-3: PW-2 Transducer Group Groundwater Elevations
Groundwater Elevation (ft amsl)
180
175
170
165
160
155
150
145
140
135
130
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Key:
GW-118
GW-716
GW-732

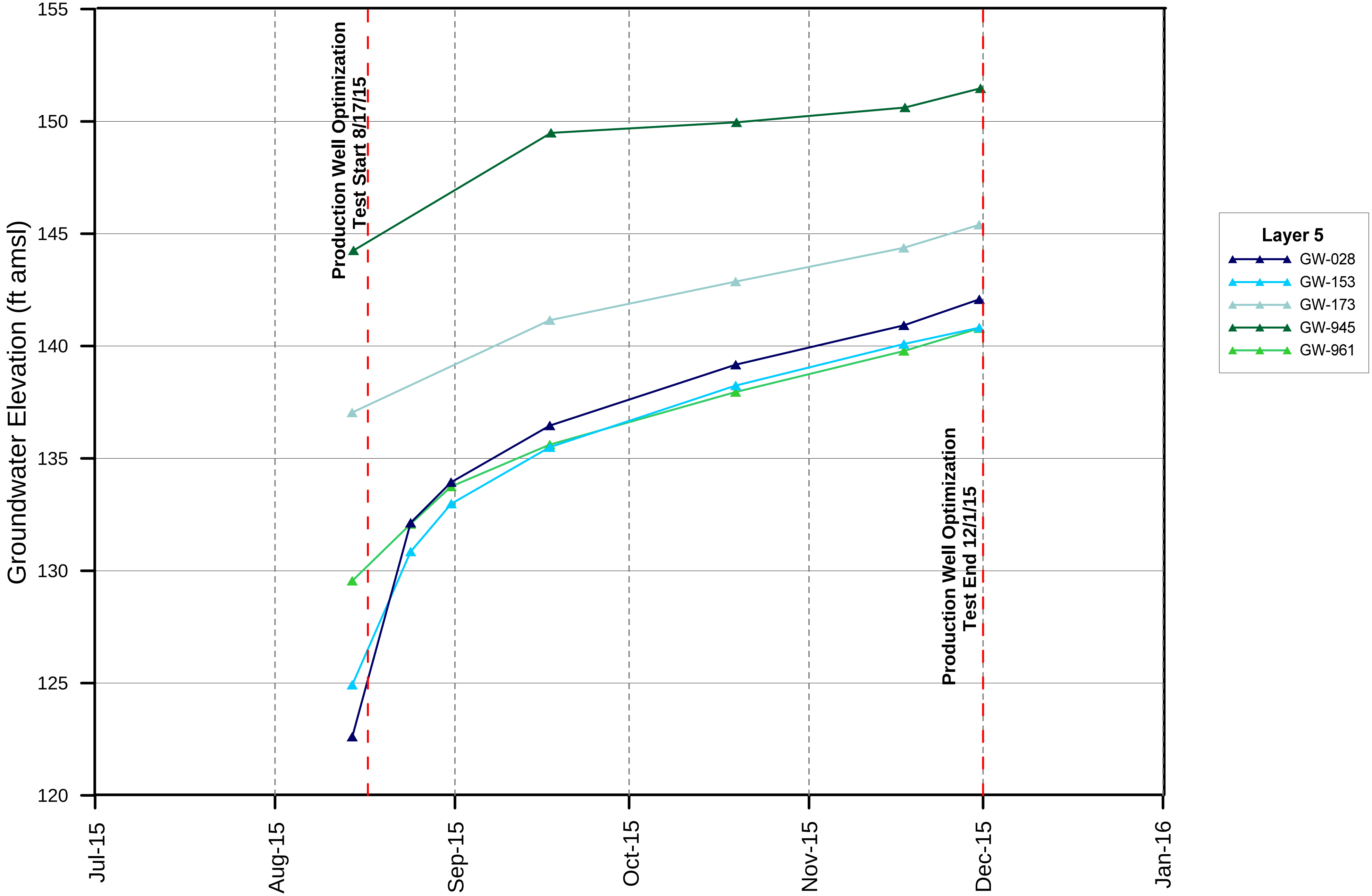

Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-4: PW-4 Deep Transducer Groundwater Elevations
Groundwater Elevation (ft amsl)
150
145
140
135
130
125
120
115
110
105
100
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Key:
GW-609

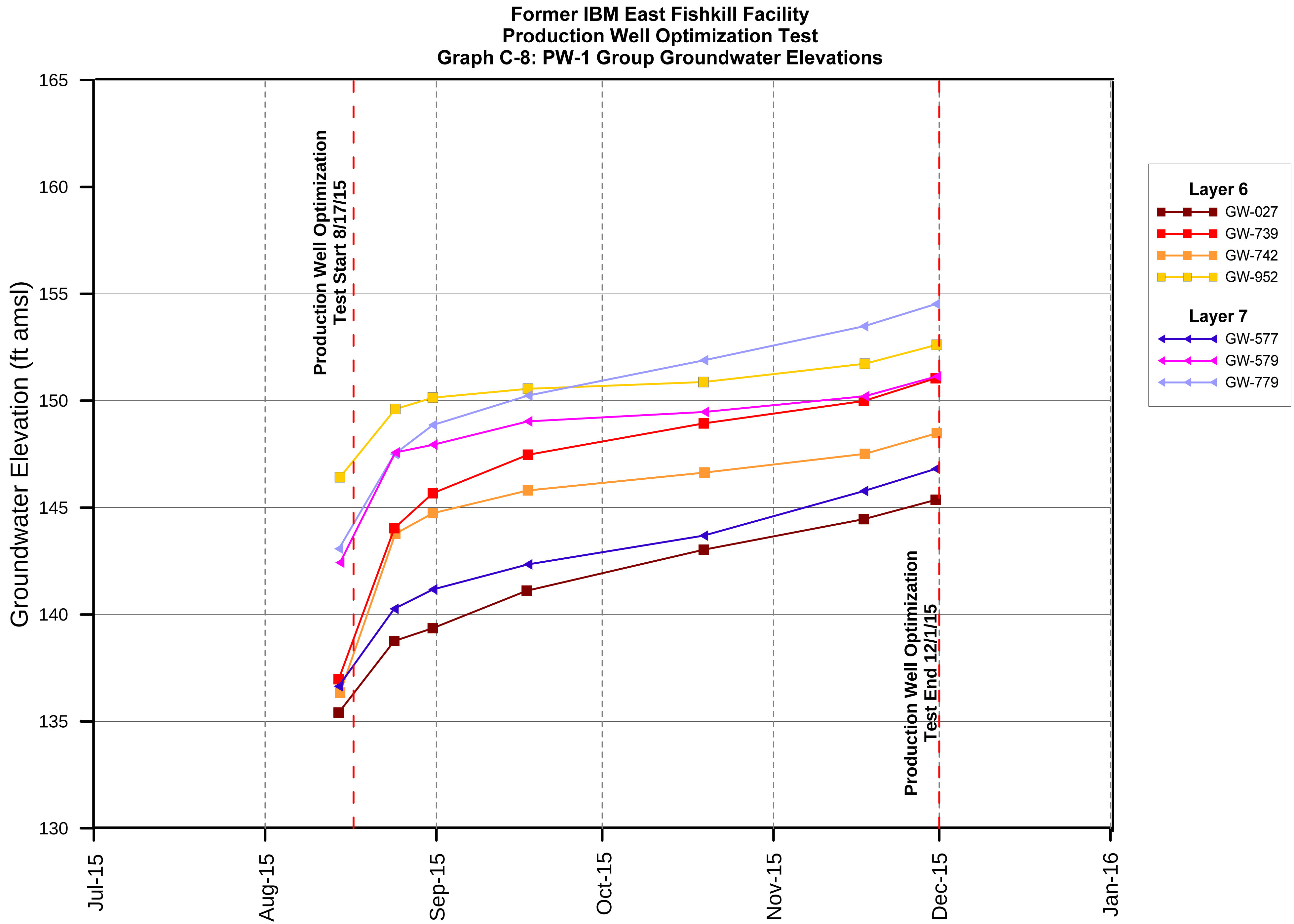


Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-5: PW-25 Transducer Group Groundwater Elevations
Groundwater Elevation (ft amsl)
165
160
155
150
145
140
135
130
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Key:
GW-941
GW-953


Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-6: PW-1 Group Groundwater Elevations
Groundwater Elevation (ft amsl)
190
185
180
175
170
165
160
155
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Layer 5
GW-122
GW-150

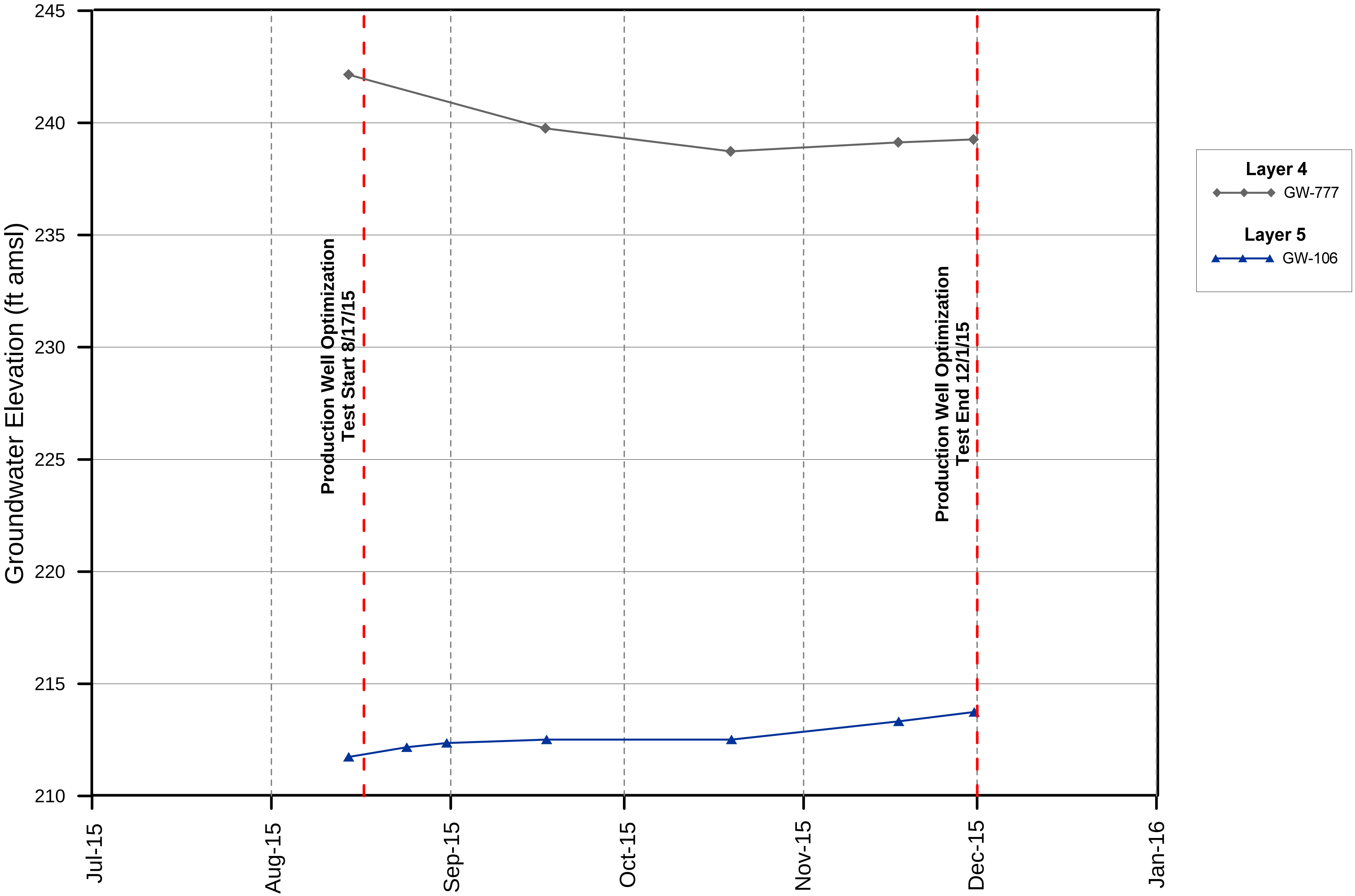
Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-7: PW-1 Group Groundwater Elevations



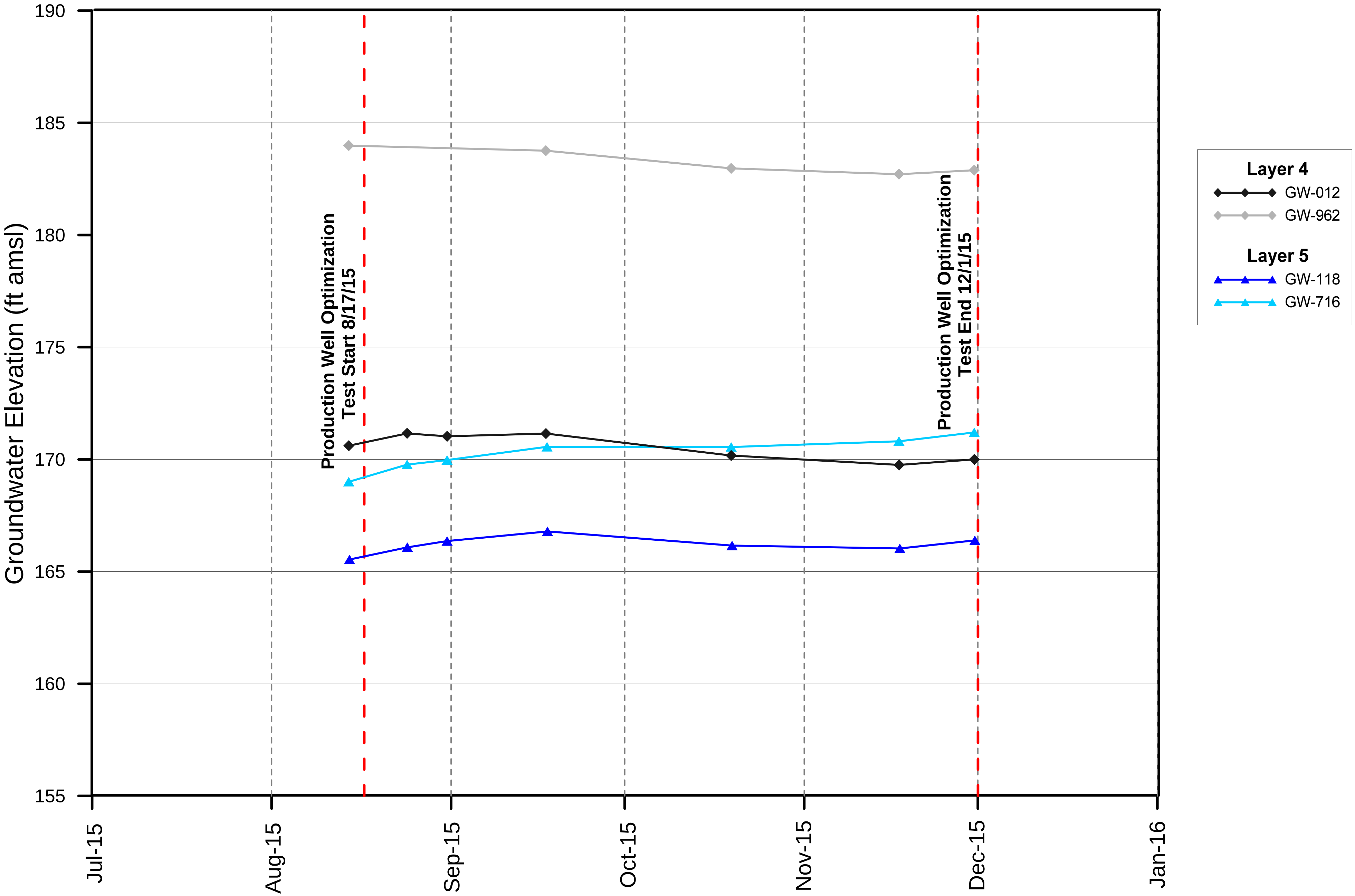


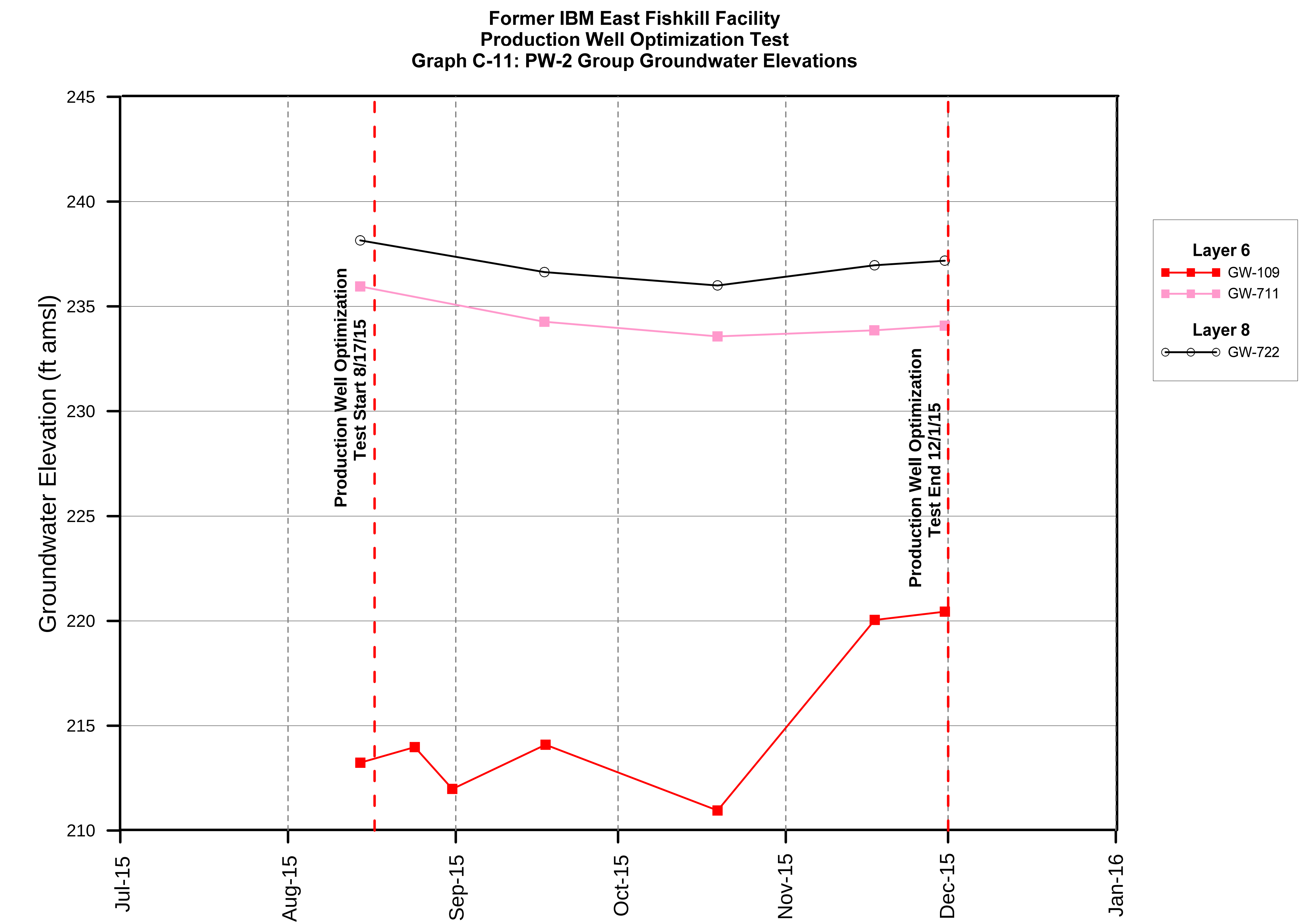
Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-8: PW-1 Group Groundwater Elevations
Groundwater Elevation (ft amsl)
165
160
155
150
145
140
135
130
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Layer 6
GW-027
GW-739
GW-742
GW-952
Layer 7
GW-577
GW-579
GW-779

Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-9: PW-2 Group Groundwater Elevations

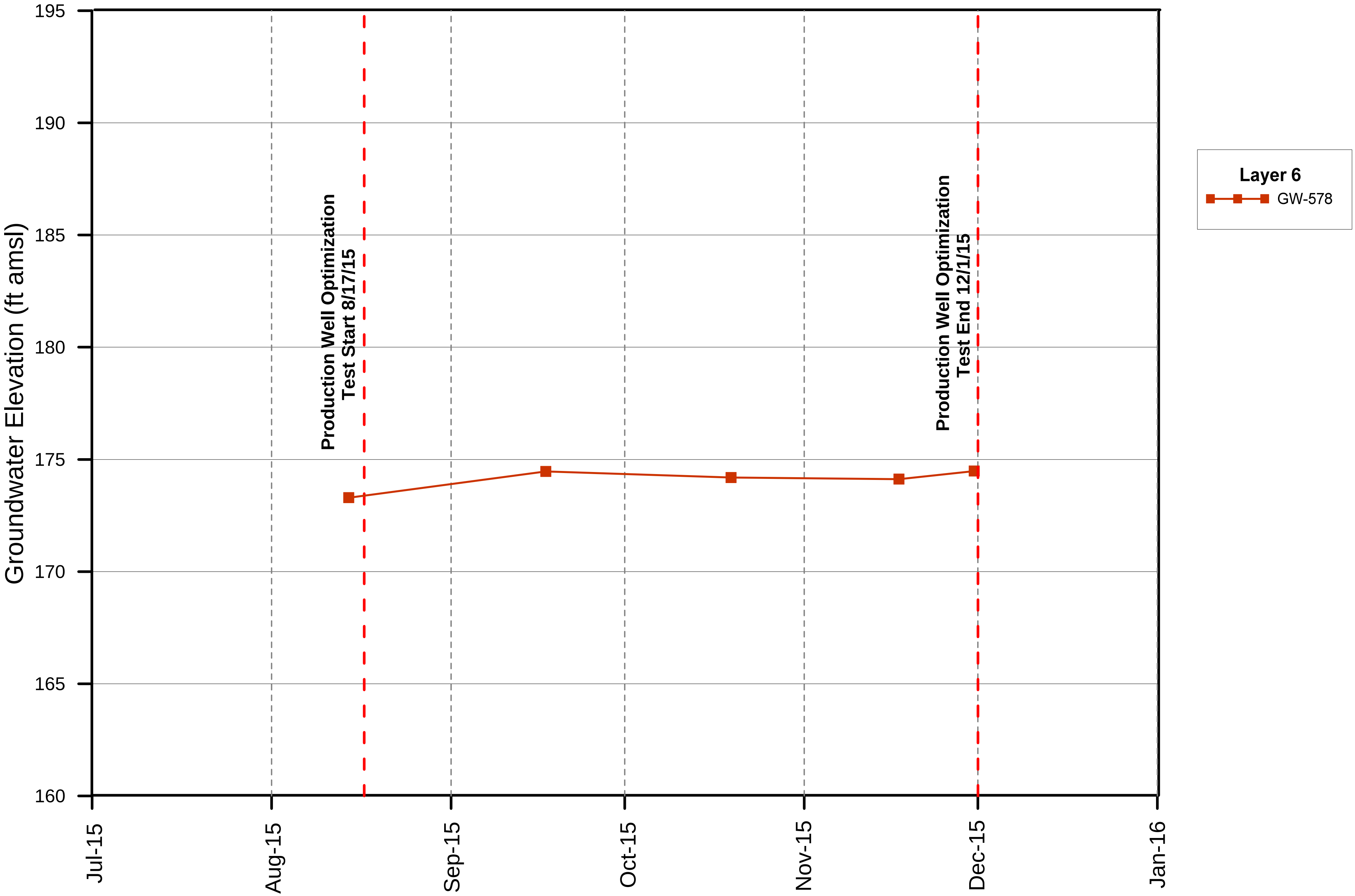


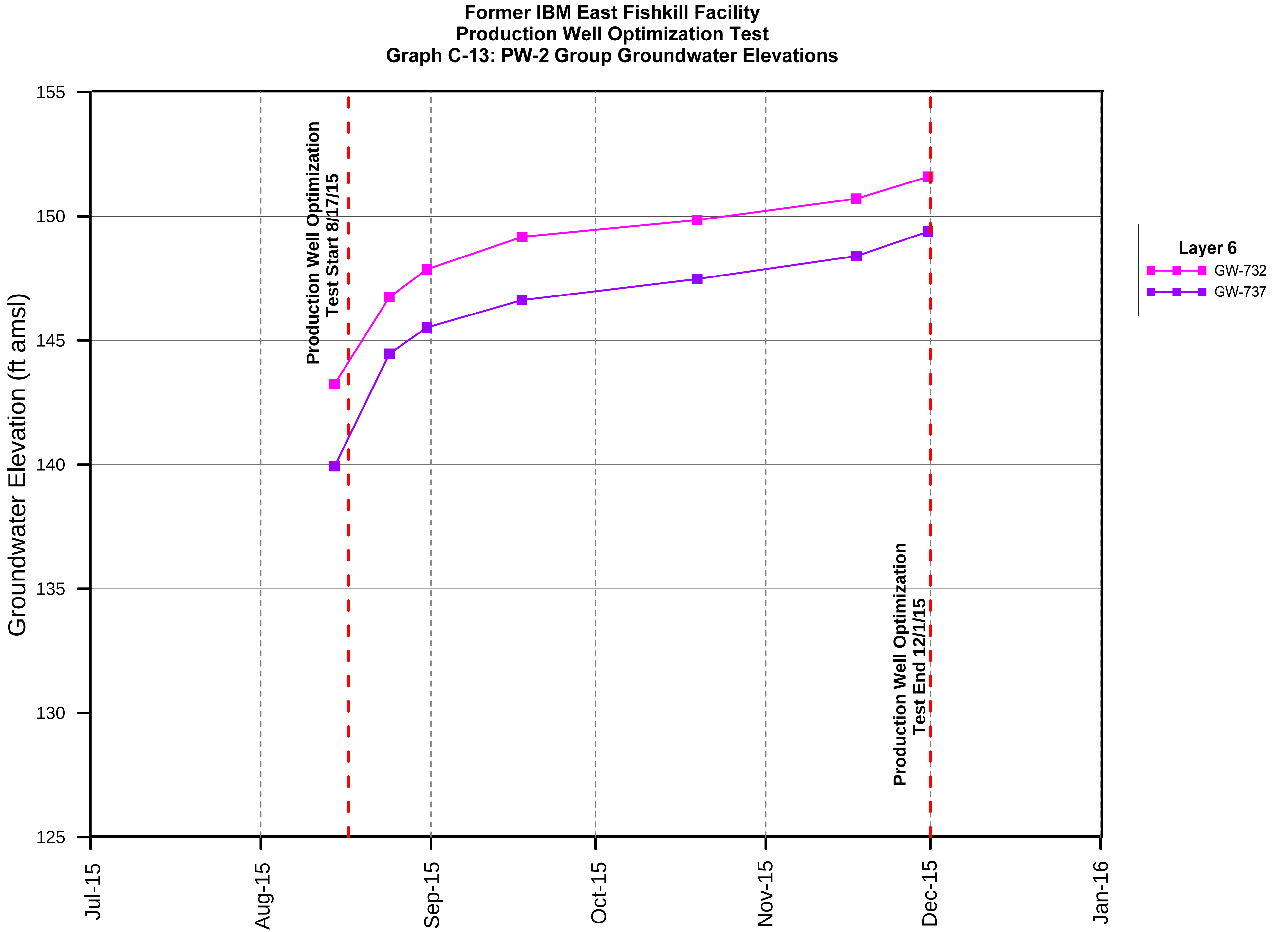
Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-10: PW-2 Group Groundwater Elevations



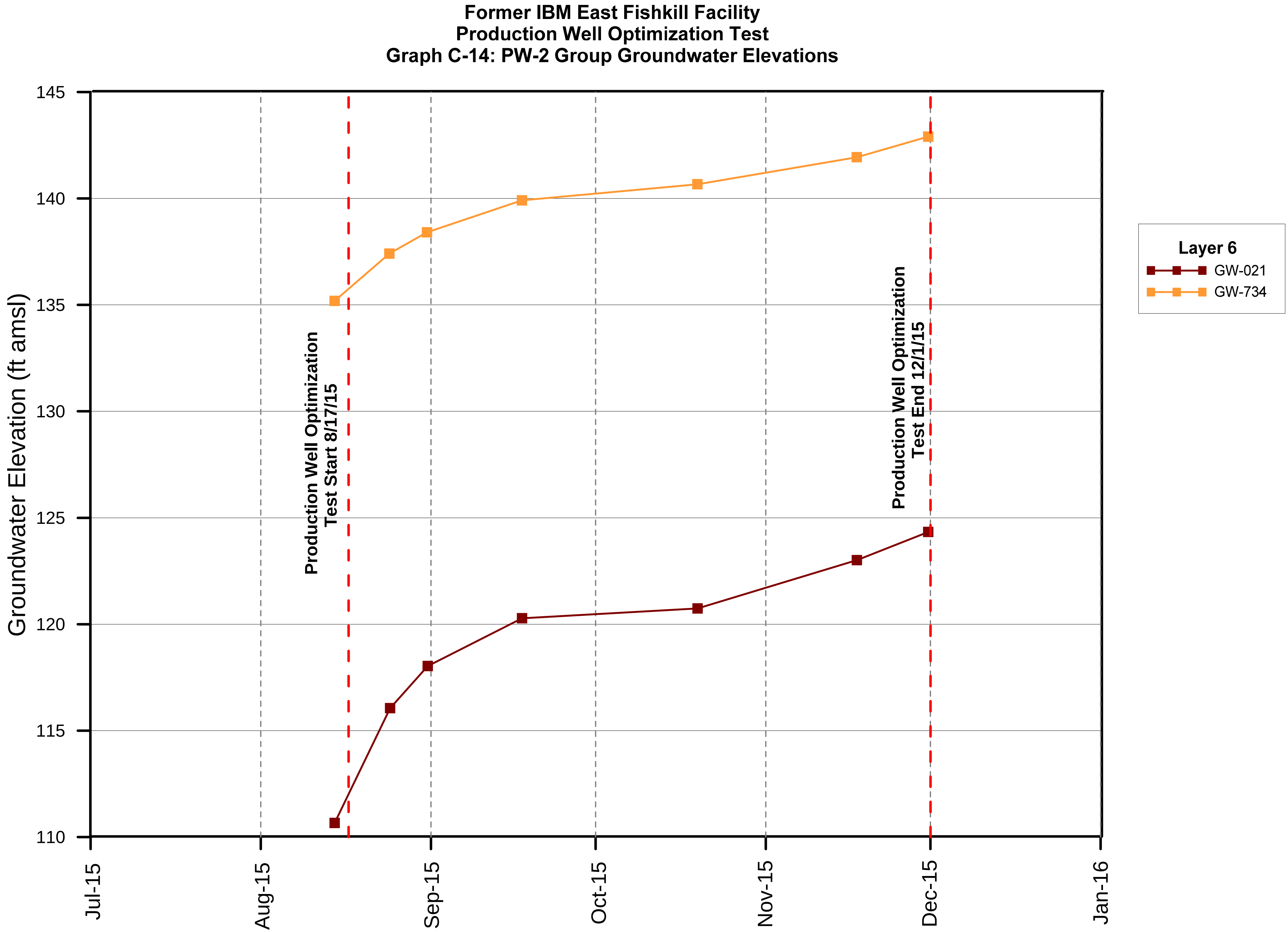

Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-11: PW-2 Group Groundwater Elevations
Groundwater Elevation (ft amsl)
245
240
235
230
225
220
215
210
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Layer 6
GW-109
GW-711
Layer 8
GW-722

Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-12: PW-2 Group Groundwater Elevations



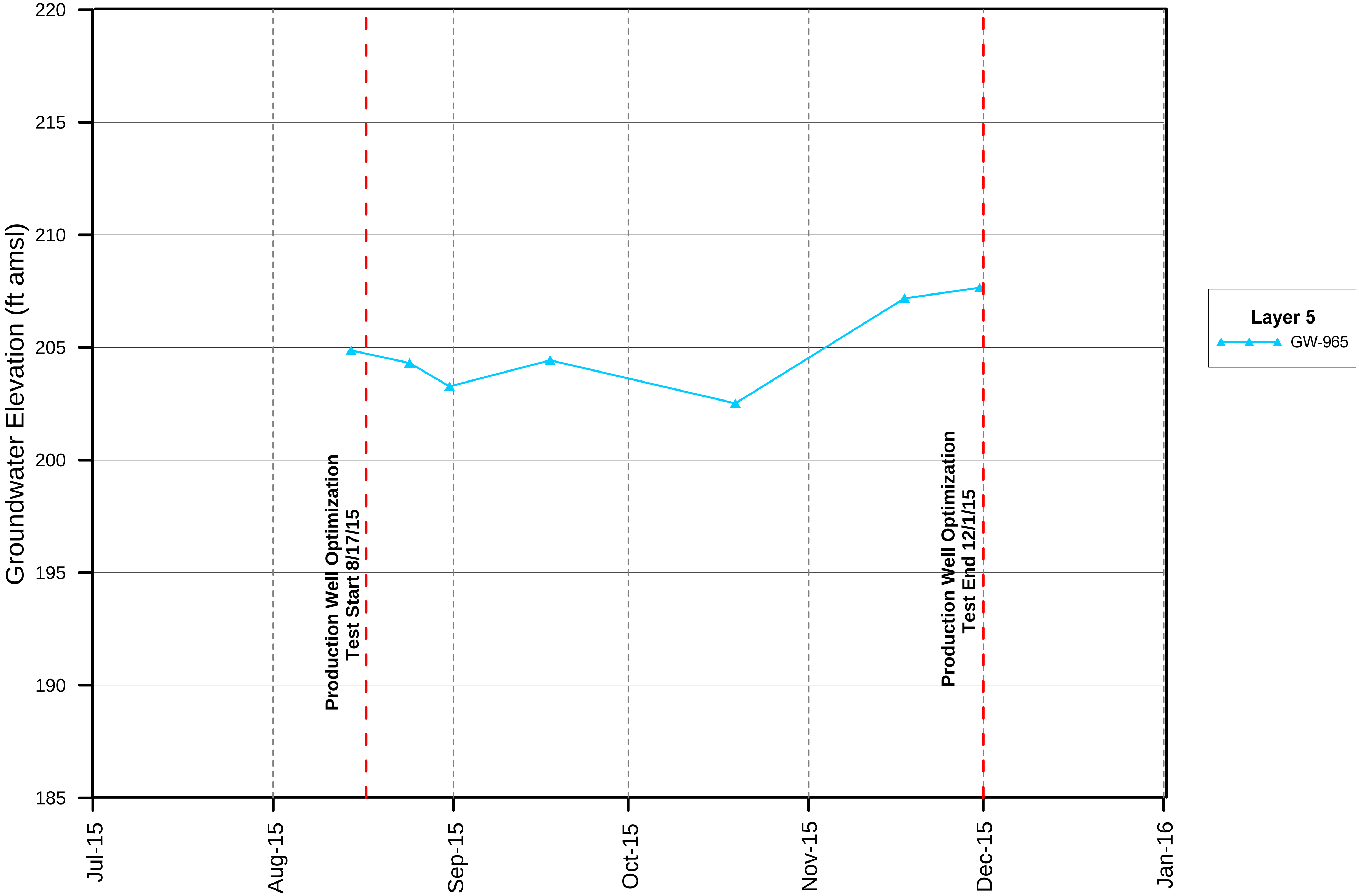


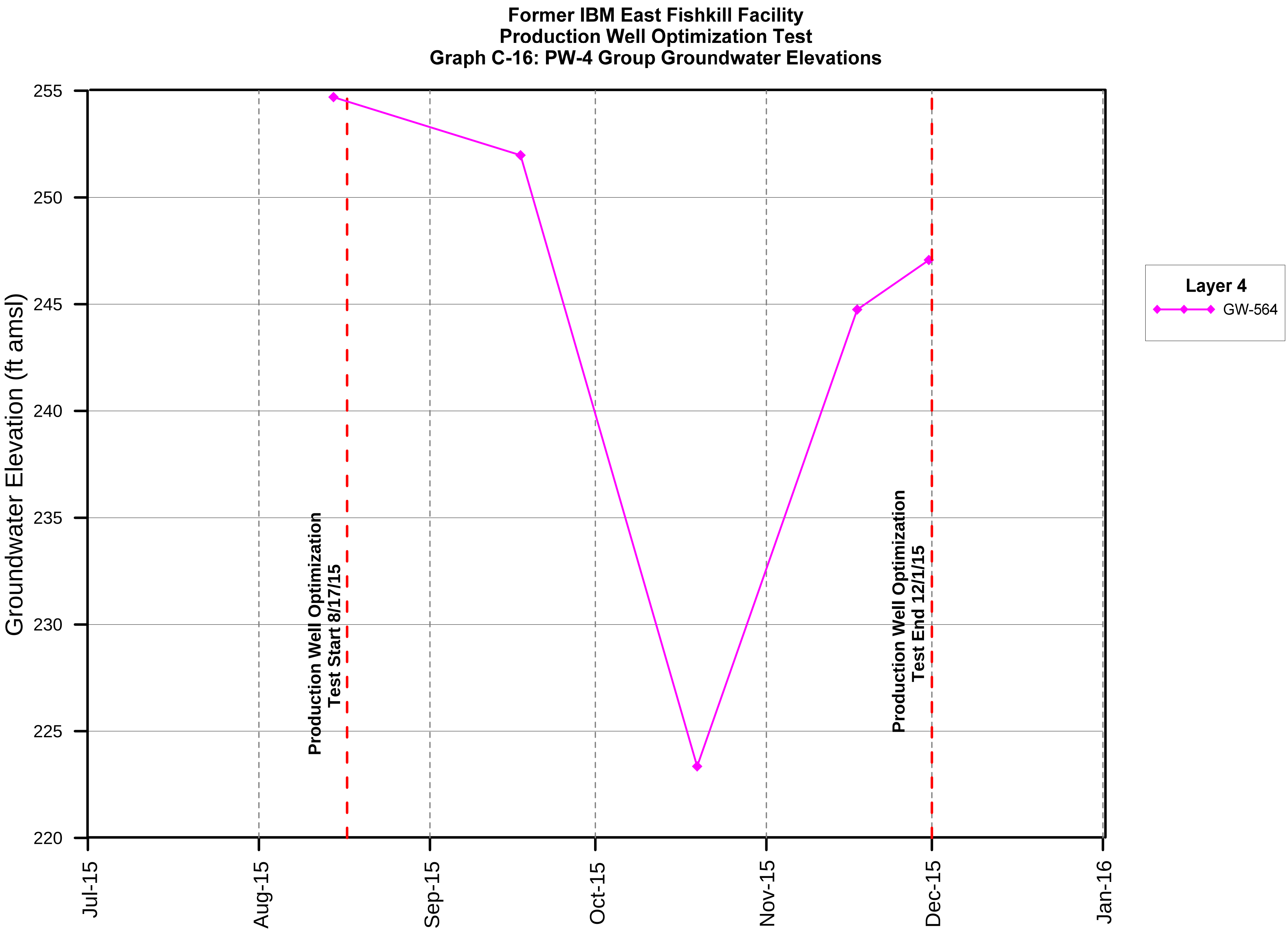
Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-13: PW-2 Group Groundwater Elevations
Groundwater Elevation (ft amsl)
155
150
145
140
135
130
125
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Layer 6
GW-732
GW-737



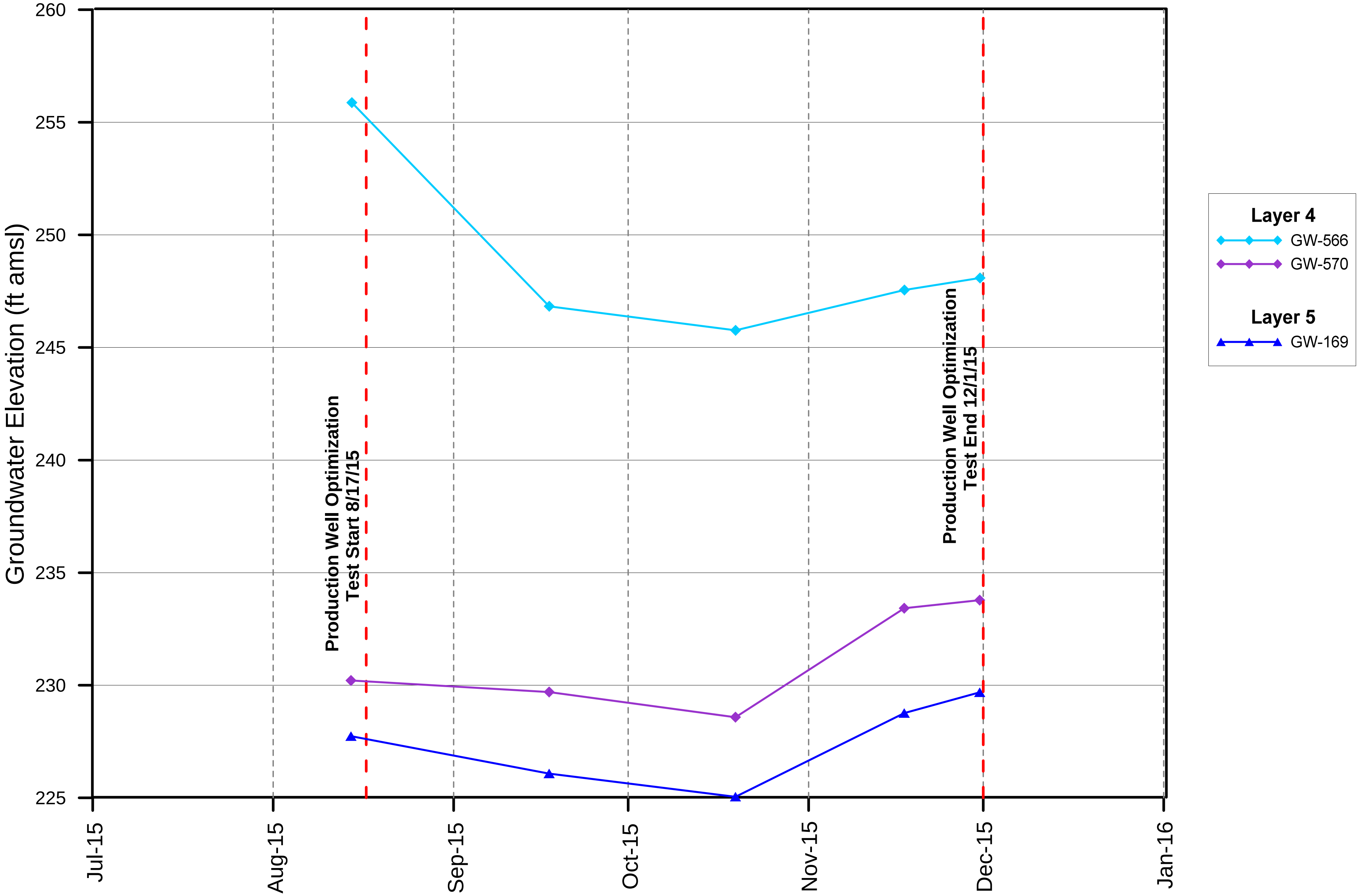
Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-14: PW-2 Group Groundwater Elevations
Groundwater Elevation (ft amsl)
145
140
135
130
125
120
115
110
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Layer 6
GW-021
GW-734

Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-15: PW-4 Group Groundwater Elevations

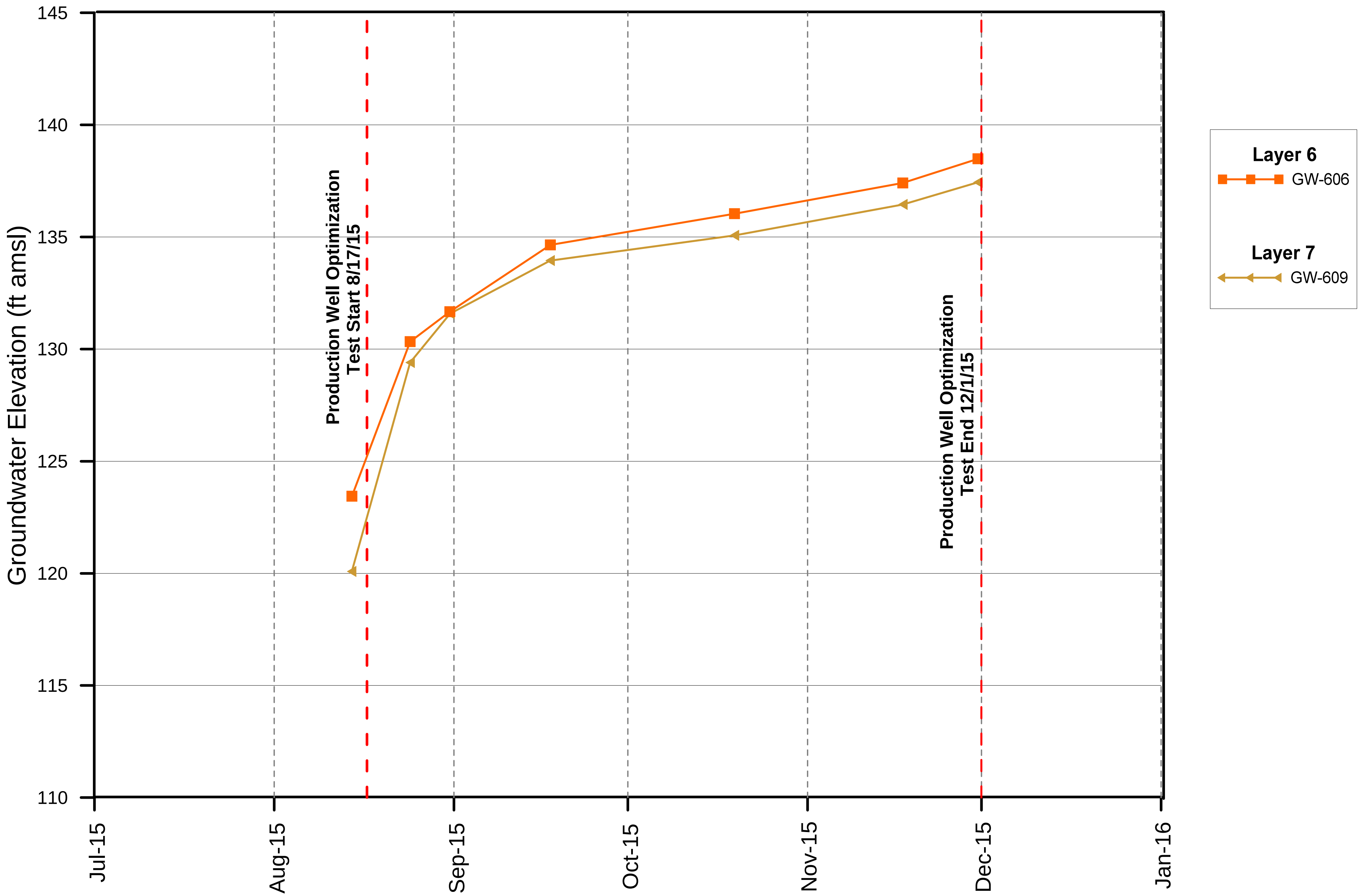



Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-16: PW-4 Group Groundwater Elevations
Groundwater Elevation (ft amsl)
255
250
245
240
235
230
225
220
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Layer 4
GW-564

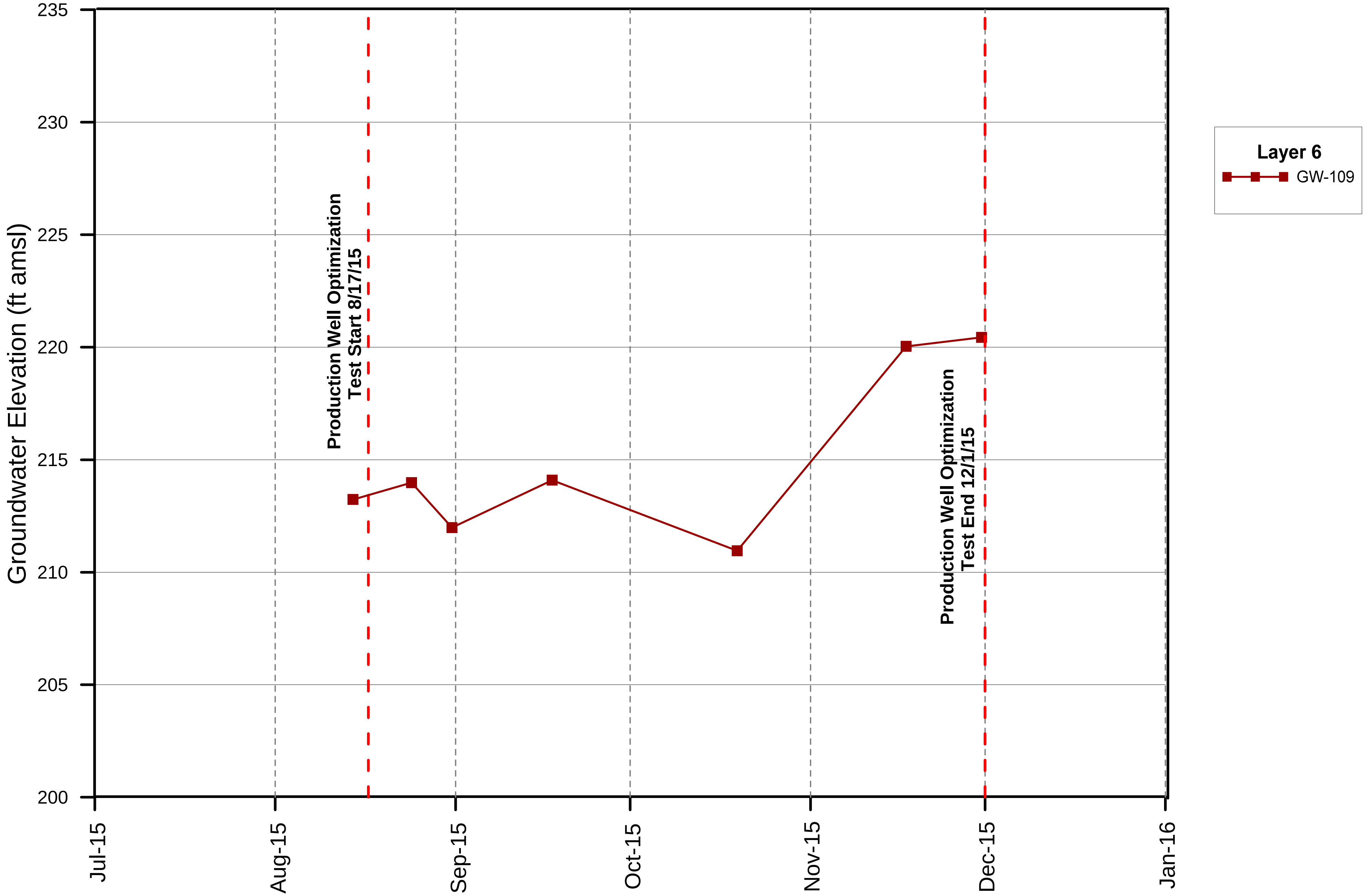
Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-17: PW-4 Group Groundwater Elevations



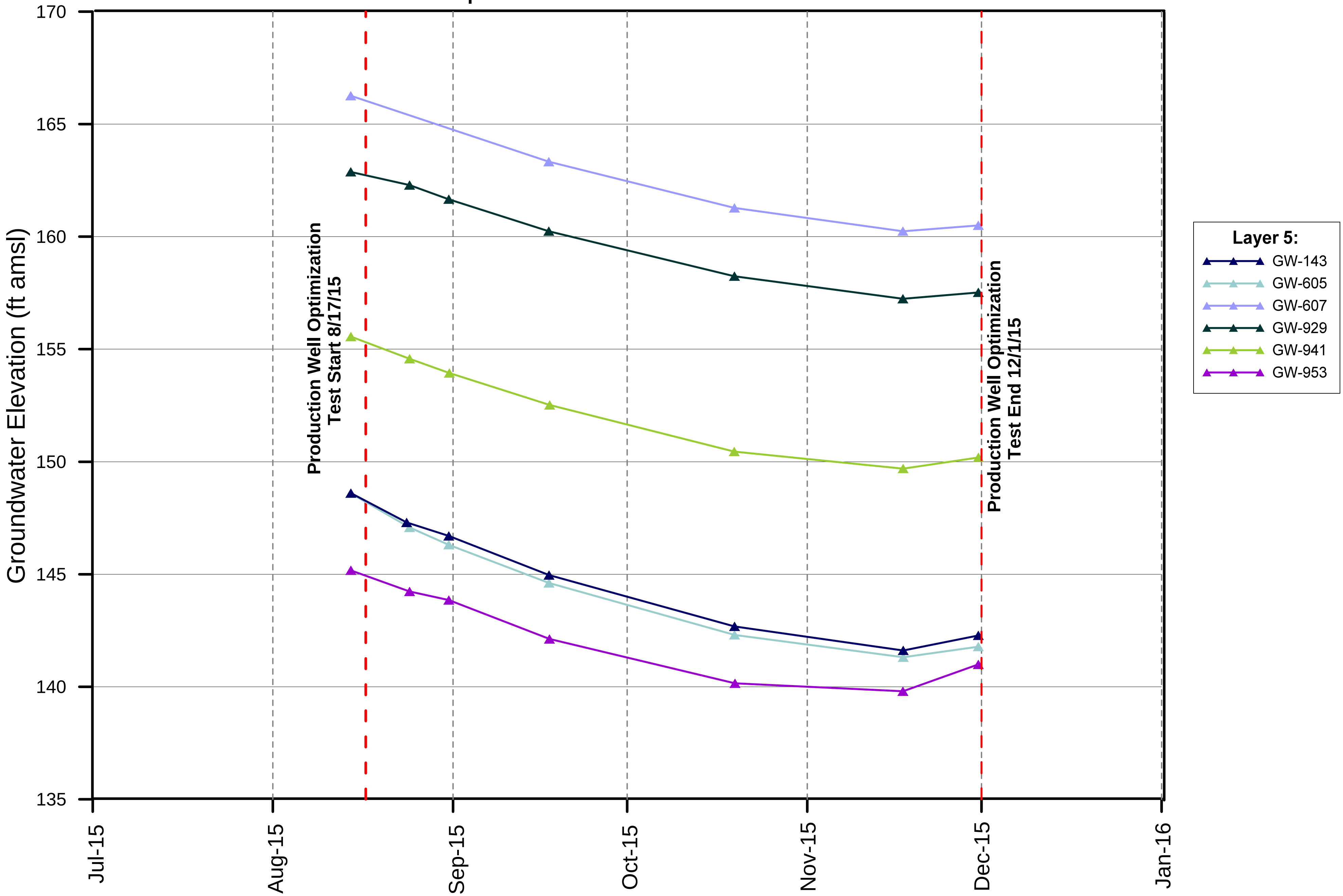
Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-18: PW-4 Group Groundwater Elevations

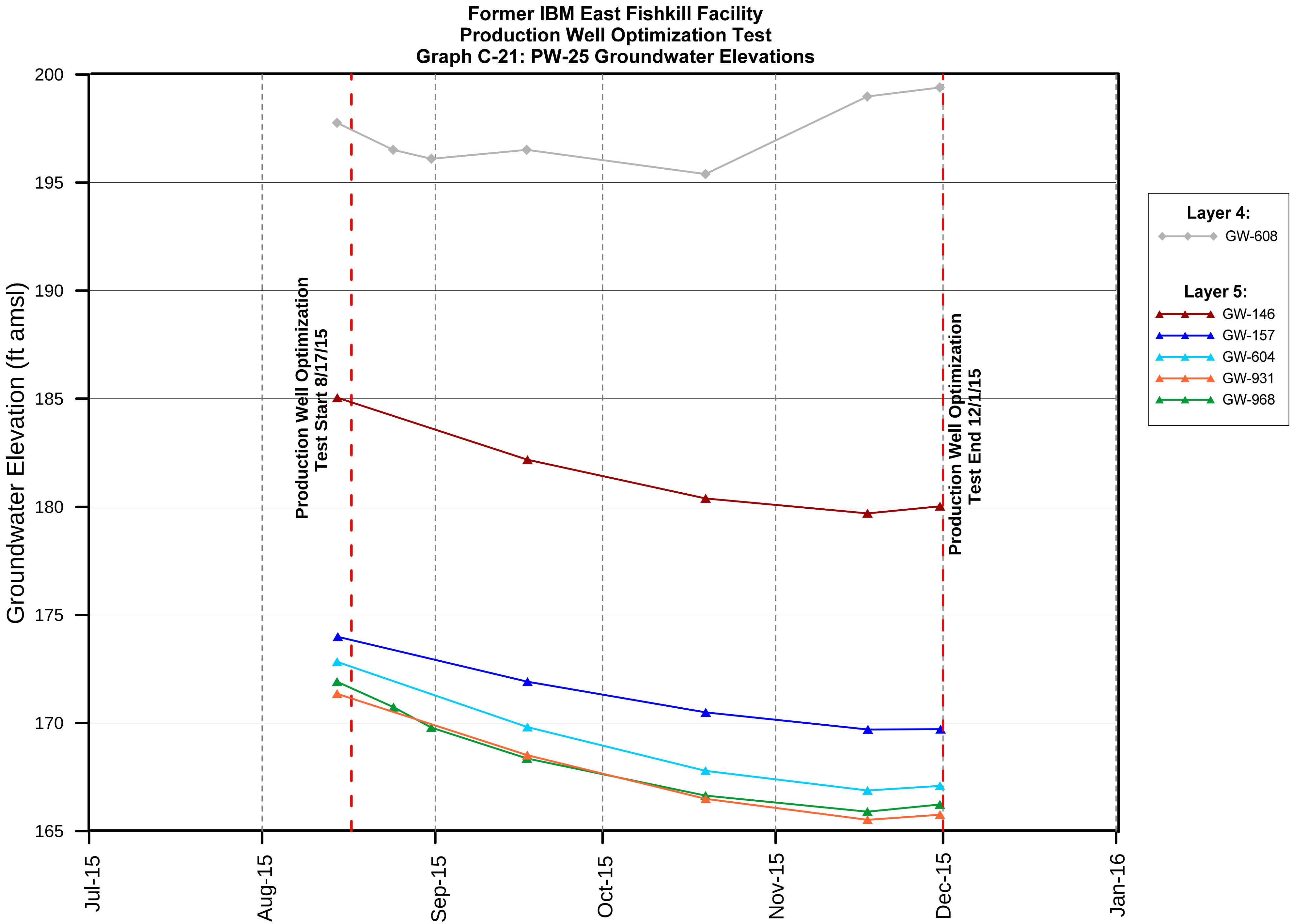


Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-19: PW-4 Group Groundwater Elevations

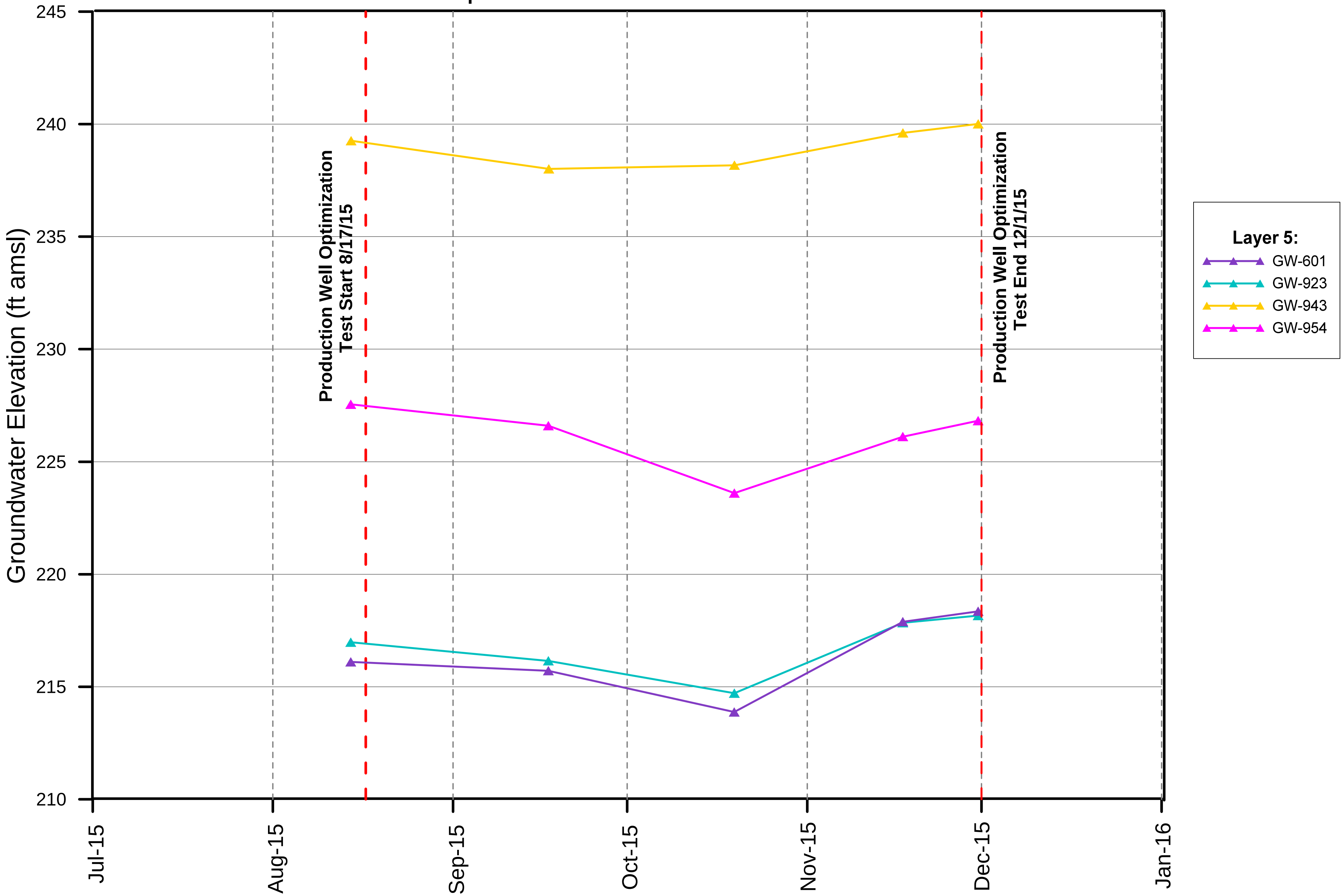


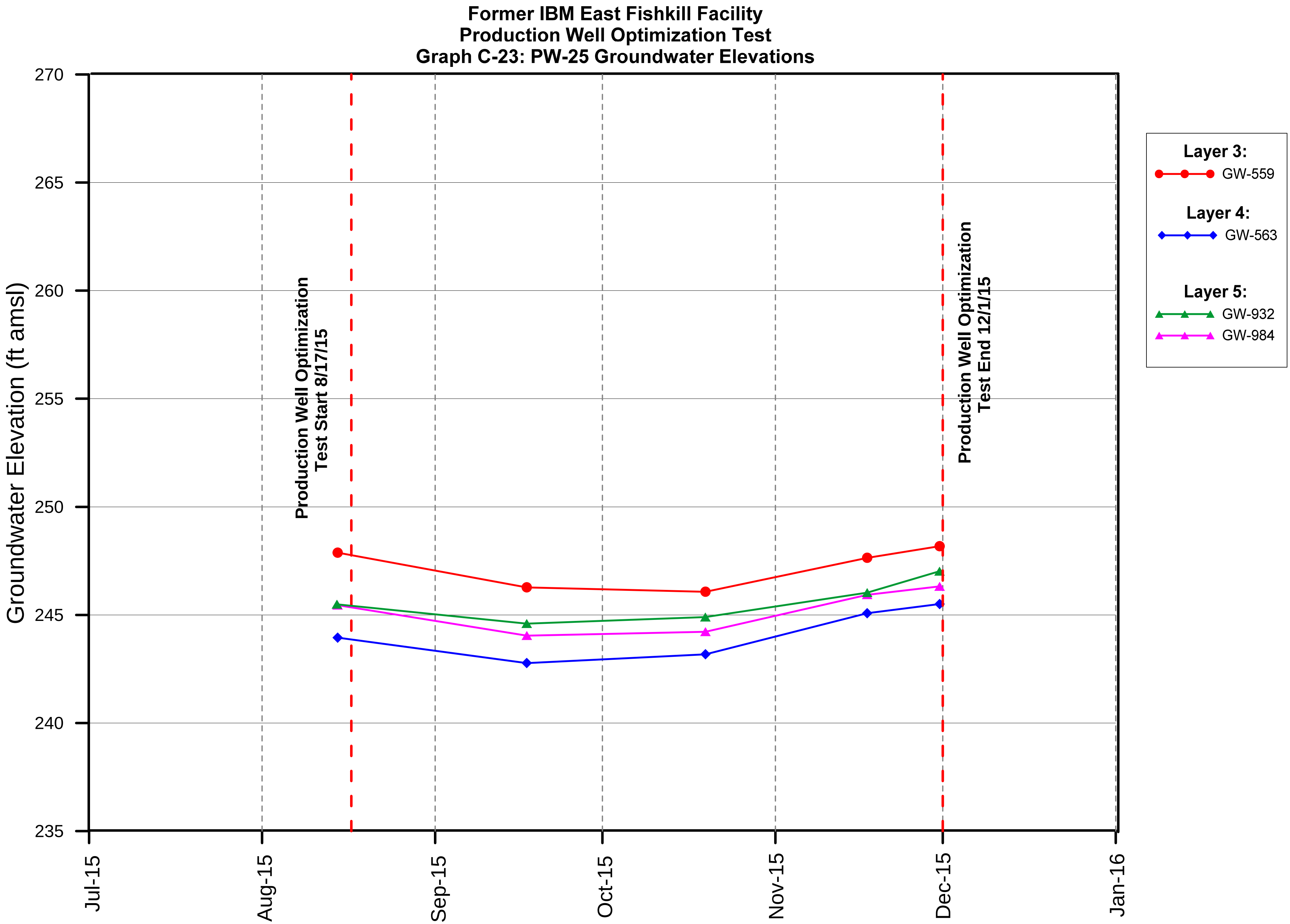
Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-20: PW-25 Groundwater Elevations



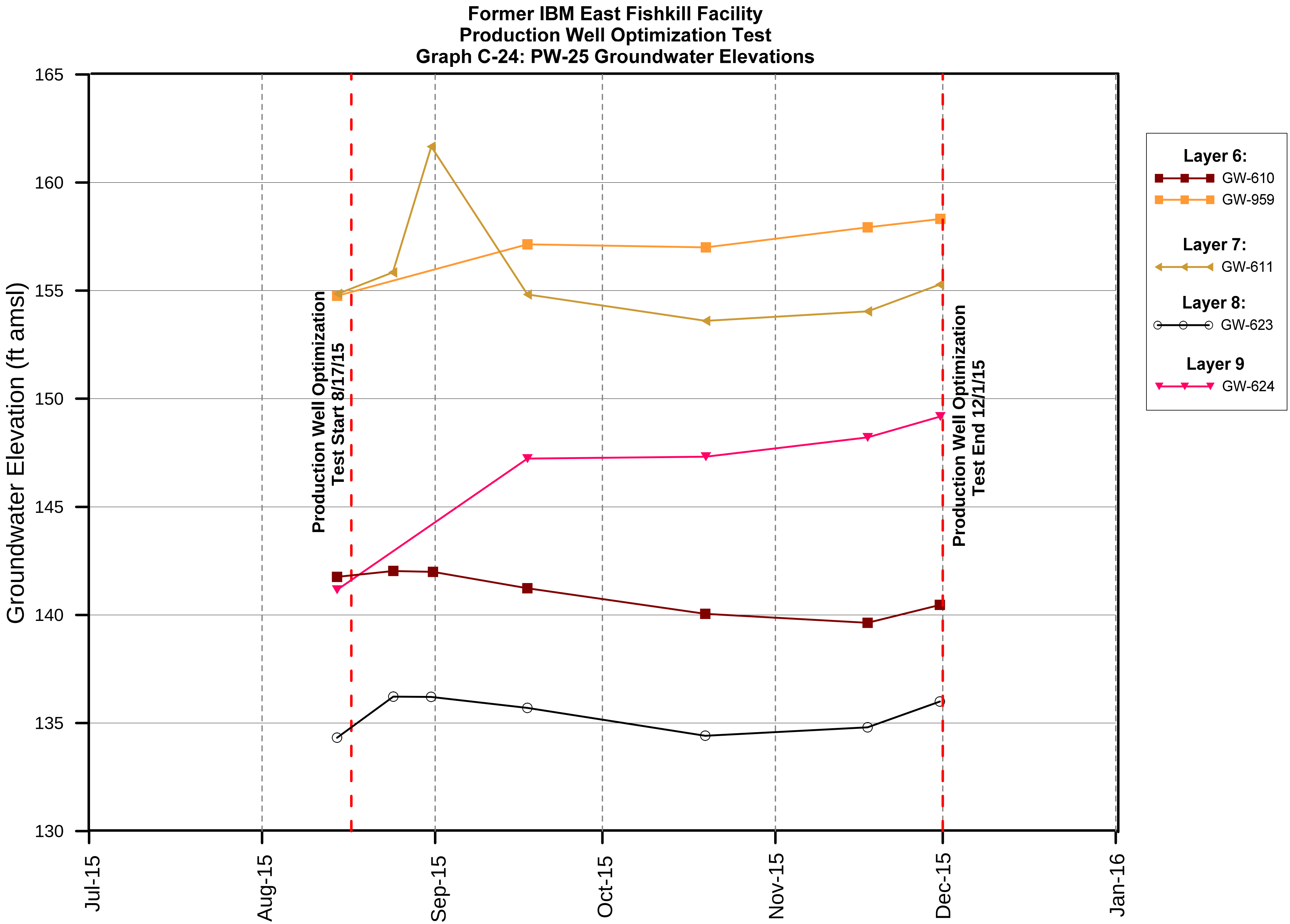

Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-21: PW-25 Groundwater Elevations
Groundwater Elevation (ft amsl)
200
195
190
185
180
175
170
165
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Layer 4:
GW-608
Layer 5:
GW-146
GW-157
GW-604
GW-931
GW-968

Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-22: PW-25 Groundwater Elevations

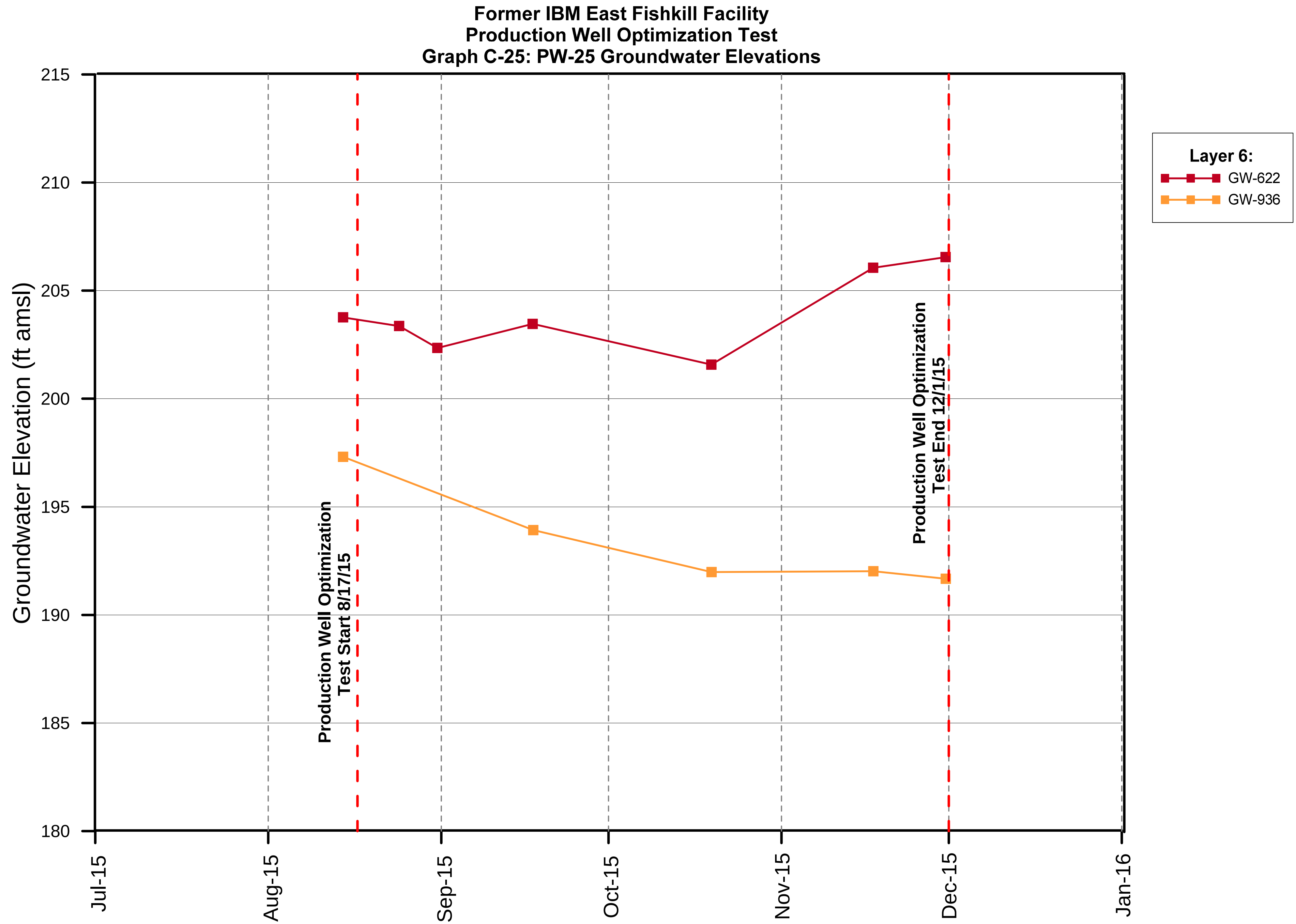


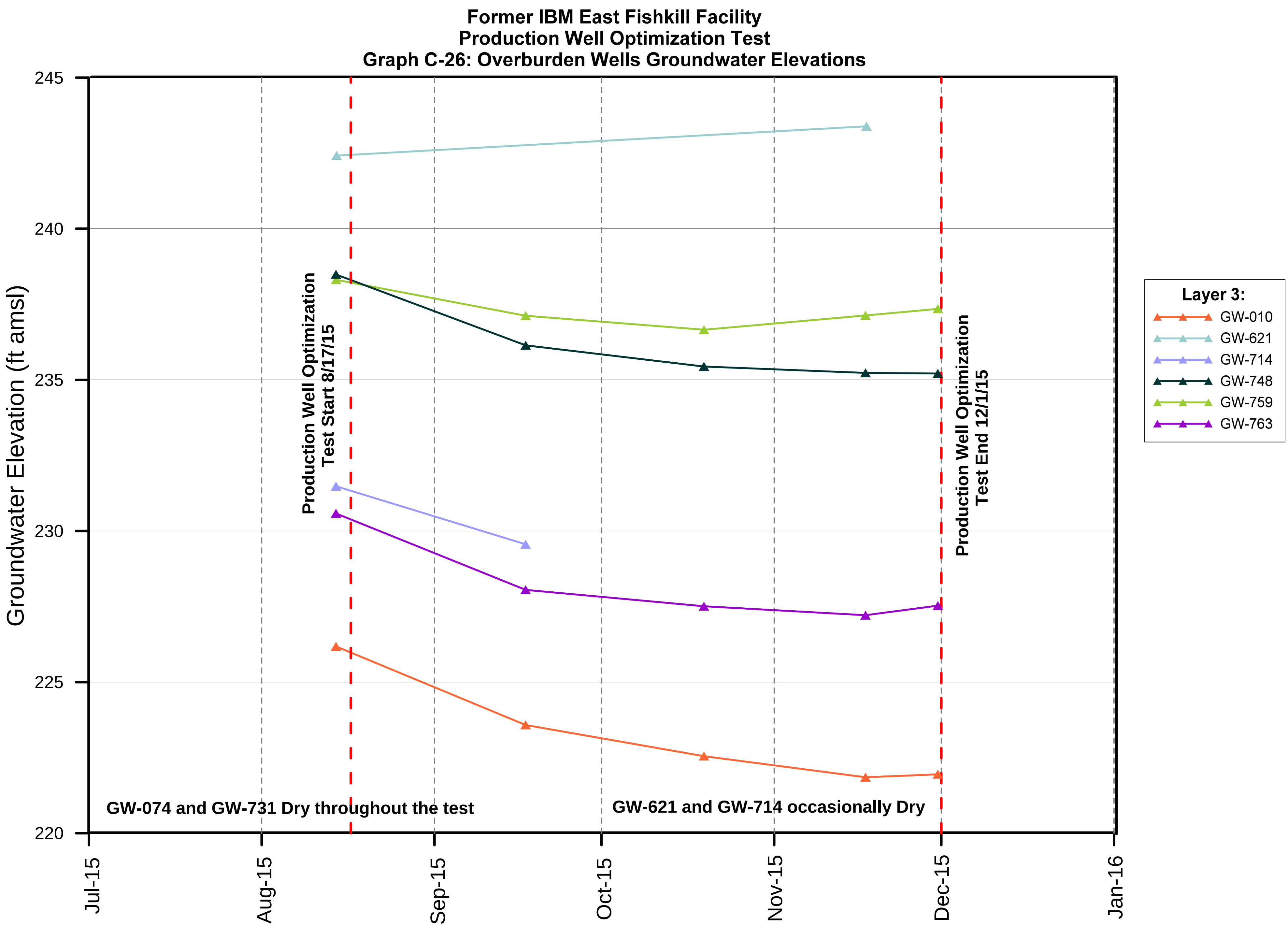


Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-23: PW-25 Groundwater Elevations
Groundwater Elevation (ft amsl)
270
265
260
255
250
245
240
235
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization
Test Start 8/17/15
Production Well Optimization
Test End 12/1/15
Layer 3:
GW-559
Layer 4:
GW-563
Layer 5:
GW-932
GW-984



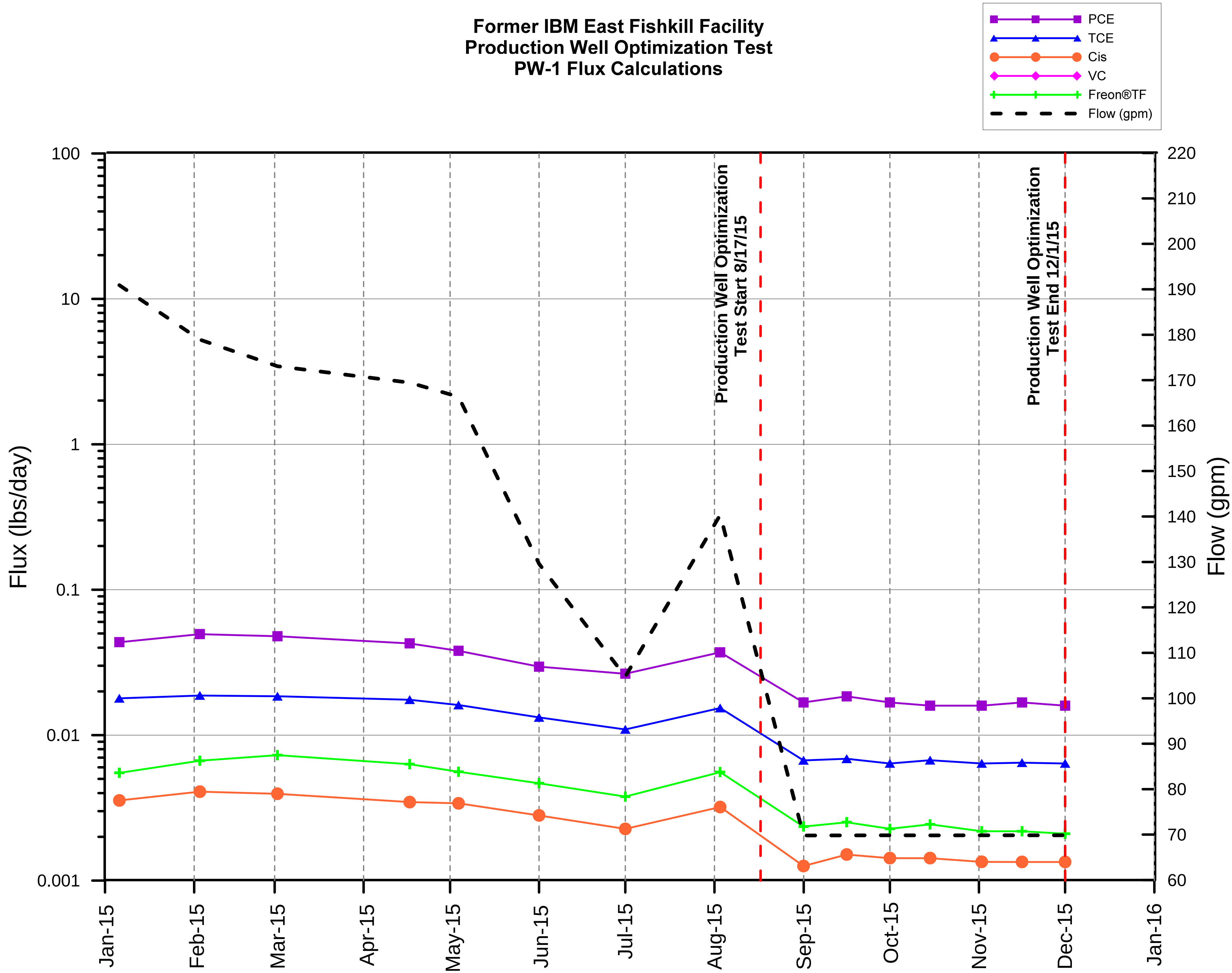
Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-24: PW-25 Groundwater Elevations
Groundwater Elevation (ft amsl)
165
160
155
150
145
140
135
130
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Layer 6:
GW-610
GW-959
Layer 7:
GW-611
Layer 8:
GW-623
Layer 9
GW-624


Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-25: PW-25 Groundwater Elevations
Groundwater Elevation (ft amsl)
215
210
205
200
195
190
185
180
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Layer 6:
GW-622
GW-936

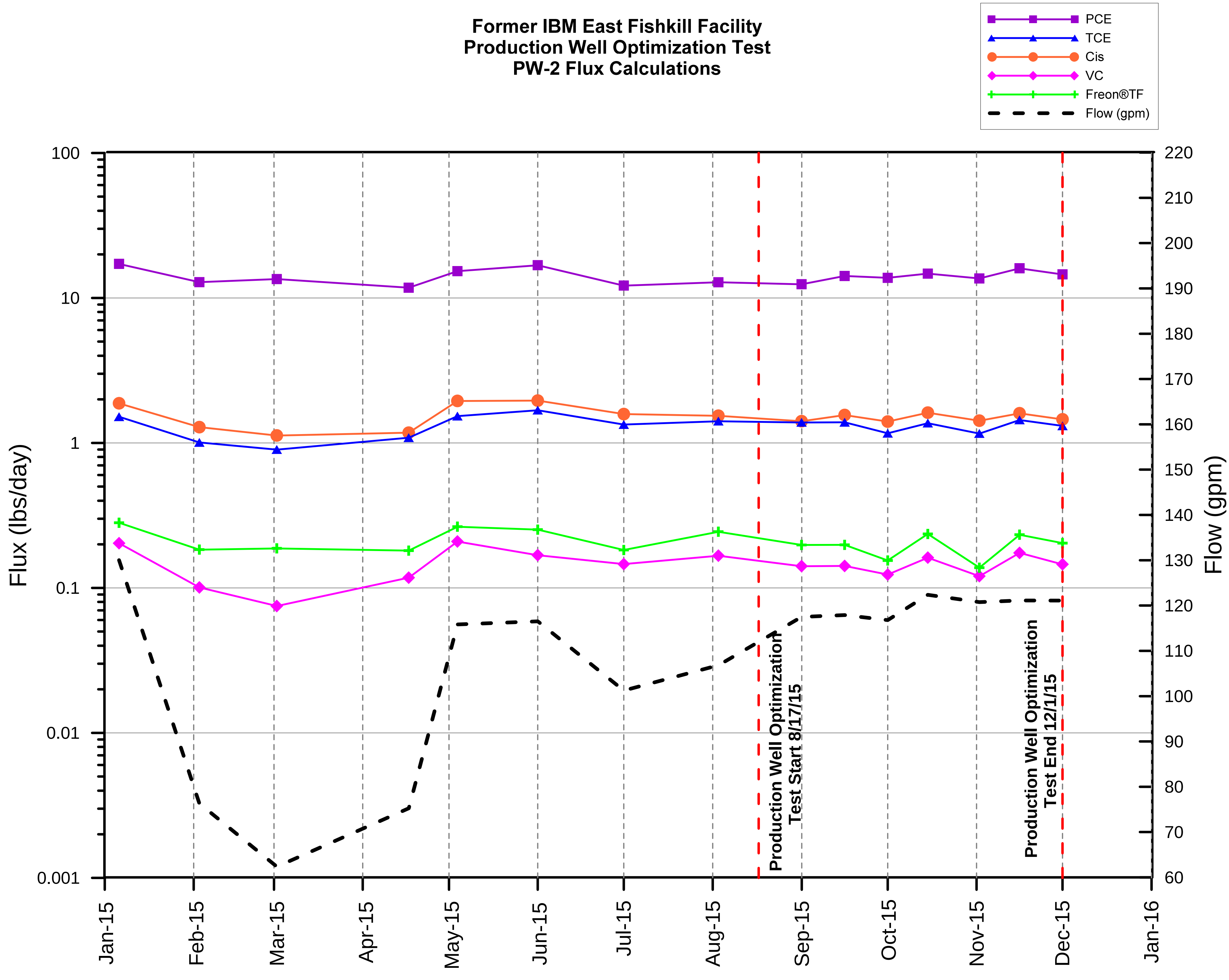

Former IBM East Fishkill Facility
Production Well Optimization Test
Graph C-26: Overburden Wells Groundwater Elevations
Groundwater Elevation (ft amsl)
245
240
235
230
225
220
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
GW-074 and GW-731 Dry throughout the test
GW-621 and GW-714 occasionally Dry
Layer 3:
GW-010
GW-621
GW-714
GW-748
GW-759
GW-763

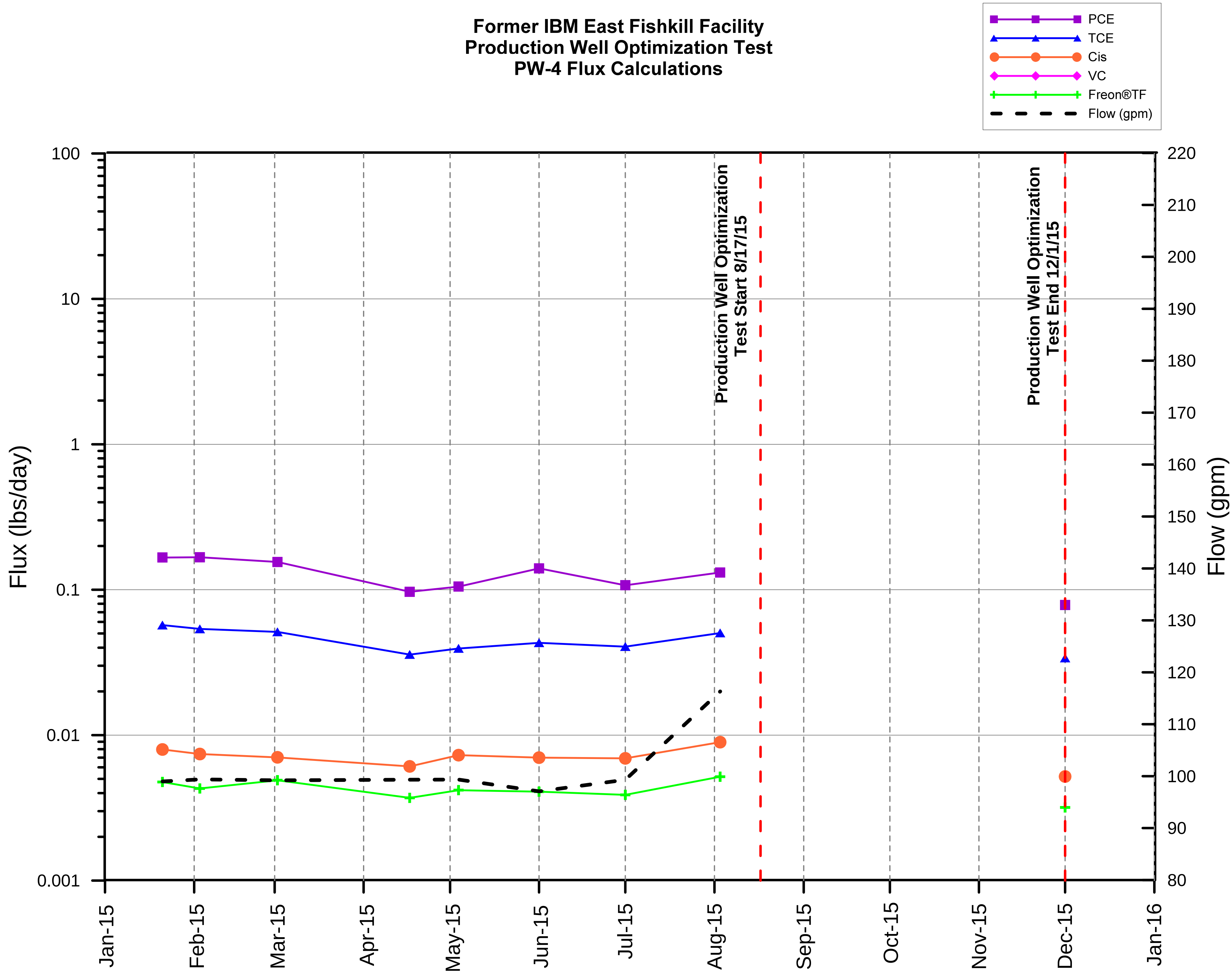
Appendix D

Production Well Flux Calculations

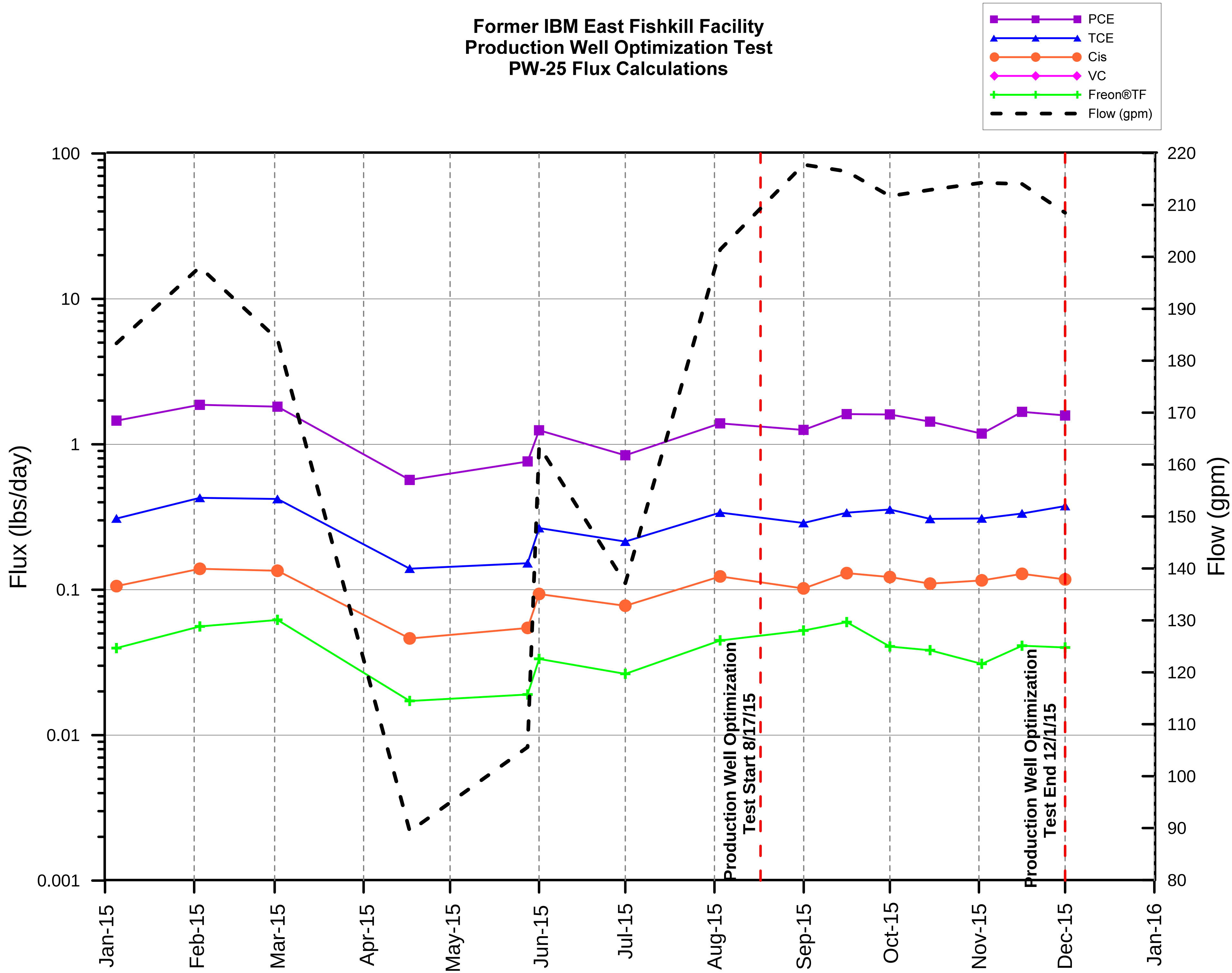


Former IBM East Fishkill Facility
Production Well Optimization Test
PW-1 Flux Calculations
PCE
TCE
Cis
VC
Freon®TF
Flow (gpm)
Flux (lbs/day)
Flow (gpm)
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
100
10
1
0.1
0.01
0.001
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
Jan-15
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16


Former IBM East Fishkill Facility
Production Well Optimization Test
PW-2 Flux Calculations
PCE
TCE
Cis
VC
Freon®TF
Flow (gpm)
Flux (lbs/day)
Flow (gpm)
100
10
1
0.1
0.01
0.001
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Jan-15
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16



Former IBM East Fishkill Facility
Production Well Optimization Test
PW-4 Flux Calculations
PCE
TCE
Cis
VC
Freon®TF
Flow (gpm)
Flux (lbs/day)
Flow (gpm)
100
10
1
0.1
0.01
0.001
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Jan-15
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16



Former IBM East Fishkill Facility
Production Well Optimization Test
PW-25 Flux Calculations
PCE
TCE
Cis
VC
Freon®TF
Flow (gpm)
Flux (lbs/day)
Flow (gpm)
100
10
1
0.1
0.01
0.001
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
Production Well Optimization Test Start 8/17/15
Production Well Optimization Test End 12/1/15
Jan-15
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16

Table 1

Production Well Optimization Test - Manual Water Level Elevations

Hudson Valley Research Park (Former IBM East Fishkill Facility)

Town of East Fishkill, Dutchess County, New York

Well ID	WL Mon Sch	Screen Location	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)
012	B	Bedrock	8/14/2015	94.10	170.61	8/24/2015	93.55	171.16	8/31/2015	93.68	171.03	9/17/2015	93.56	171.15	10/19/2015	94.54	170.17	11/17/2015	94.96	169.75	11/30/2015	94.71	170.00
021	B	Bedrock	8/14/2015	140.22	110.66	8/24/2015	134.83	116.05	8/31/2015	132.85	118.03	9/17/2015	130.60	120.28	10/19/2015	130.14	120.74	11/17/2015	127.87	123.01	11/30/2015	126.55	124.33
027	B	Bedrock	8/14/2015	124.83	135.41	8/24/2015	121.48	138.76	8/31/2015	120.88	139.36	9/17/2015	119.13	141.11	10/19/2015	117.21	143.03	11/17/2015	115.78	144.46	11/30/2015	114.88	145.36
028	B	Bedrock	8/14/2015	136.61	122.61	8/24/2015	127.09	132.13	8/31/2015	125.28	133.94	9/17/2015	122.76	136.46	10/19/2015	120.05	139.17	11/17/2015	118.30	140.92	11/30/2015	117.14	142.08
102	C	Bedrock	8/14/2015	21.39	245.70							9/17/2015	23.99	243.10	10/19/2015	25.74	241.35	11/17/2015	26.67	240.42	11/30/2015	26.76	240.33
106	A	Bedrock	8/14/2015	46.00	211.74	8/24/2015	45.57	212.17	8/31/2015	45.38	212.36	9/17/2015	45.23	212.51	10/19/2015	45.23	212.51	11/17/2015	44.42	213.32	11/30/2015	44.00	213.74
109	A	Bedrock	8/14/2015	42.22	213.23	8/24/2015	41.47	213.98	8/31/2015	43.47	211.98	9/17/2015	41.36	214.09	10/19/2015	44.50	210.95	11/17/2015	35.41	220.04	11/30/2015	35.01	220.44
118	A	Bedrock	8/14/2015	97.52	165.54	8/24/2015	96.98	166.08	8/31/2015	96.70	166.36	9/17/2015	96.27	166.79	10/19/2015	96.90	166.16	11/17/2015	97.03	166.03	11/30/2015	96.67	166.39
122	C	Bedrock	8/14/2015	80.91	182.27							9/17/2015	78.75	184.43	10/19/2015	79.05	184.13	11/17/2015	79.17	184.01	11/30/2015	78.88	184.30
130	C	Bedrock	8/14/2015	38.19	214.18							9/17/2015	38.96	213.41	10/19/2015	39.12	213.25	11/17/2015	38.97	213.40	11/30/2015	38.74	213.63
143	B	Bedrock	8/14/2015	102.48	148.60	8/24/2015	103.78	147.30	8/31/2015	104.38	146.70	9/17/2015	106.12	144.96	10/19/2015	108.40	142.68	11/17/2015	109.47	141.61	11/30/2015	108.80	142.28
146	C	Bedrock	8/14/2015	68.85	185.05							9/17/2015	71.72	182.18	10/19/2015	73.51	180.39	11/17/2015	74.20	179.70	11/30/2015	73.88	180.02
150	A	Bedrock	8/14/2015	73.42	161.36	8/24/2015	72.66	162.12	8/31/2015	72.78	162.00	9/17/2015	71.42	163.36	10/19/2015	70.55	164.23	11/17/2015	69.32	165.46	11/30/2015	68.44	166.34
153	B	Bedrock	8/14/2015	116.06	124.92	8/24/2015	110.13	130.85	8/31/2015	108.00	132.98	9/17/2015	105.48	135.50	10/19/2015	102.74	138.24	11/17/2015	100.89	140.09	11/30/2015	100.16	140.82
157	C	Bedrock	8/14/2015	69.10	173.99							9/17/2015	71.18	171.91	10/19/2015	72.60	170.49	11/17/2015	73.39	169.70	11/30/2015	73.38	169.71
167	C	Bedrock	8/14/2015	8.72	245.86							9/17/2015	9.60	244.98	10/19/2015	9.39	245.19	11/17/2015	7.97	246.61	11/30/2015	7.74	246.84
169	C	Bedrock	8/14/2015	37.38	227.74							9/17/2015	39.04	226.08	10/19/2015	40.07	225.05	11/17/2015	36.36	228.76	11/30/2015	35.43	229.69
173	C	Bedrock	8/14/2015	92.67	137.04							9/17/2015	88.56	141.15	10/19/2015	86.84	142.87	11/17/2015	85.34	144.37	11/30/2015	84.31	145.40
184	C	Bedrock	8/14/2015	98.31	136.10							9/17/2015	94.37	140.04	10/19/2015	92.60	141.81	11/17/2015	91.43	142.98	11/30/2015	90.44	143.97
188	C	Bedrock	8/14/2015	102.00	135.57							9/17/2015	98.44	139.13	10/19/2015	96.54	141.03	11/17/2015	95.28	142.29	11/30/2015	94.21	143.36
192	C	Bedrock	8/14/2015	34.58	194.60							9/17/2015	37.32	191.86	10/19/2015	35.37	193.81	11/17/2015	34.84	194.34	11/30/2015	33.68	195.50
401	C	Bedrock	8/14/2015	7.27	234.95							9/17/2015	20.58	221.64	10/19/2015	20.32	221.90	11/17/2015	19.03	223.19	11/30/2015	18.44	223.78
402	C	Bedrock	8/14/2015	28.99	219.67							9/17/2015	60.64	188.02	10/19/2015	56.60	192.06	11/17/2015	56.09	192.57	11/30/2015	54.22	194.44
404	C	Bedrock	8/14/2015	91.38	157.07							9/17/2015	91.23	157.22	10/19/2015	90.84	157.61	11/17/2015	90.51	157.94	11/30/2015	89.81	158.64
405	C	Bedrock	8/14/2015	59.37	198.64							9/17/2015	61.78	196.23	10/19/2015	63.32	194.69	11/17/2015	64.03	193.98	11/30/2015	63.57	194.44
407	C	Bedrock	8/14/2015	78.36	267.35							9/17/2015	88.07	257.64	10/19/2015	89.21	256.50	11/17/2015	89.59	256.12	11/30/2015	89.46	256.25
415	C	Bedrock	8/14/2015	18.96	246.77							9/17/2015	21.28	244.45	10/19/2015	21.48	244.25	11/17/2015	20.53	245.20	11/30/2015	20.55	245.18
418	C	Bedrock	8/14/2015	20.35	233.05							9/17/2015	21.27	232.13	10/19/2015	21.83	231.57	11/17/2015	20.69	232.71	11/30/2015	20.01	233.39
559	C	Bedrock	8/14/2015	34.87	247.88							9/17/2015	36.48	246.27	10/19/2015	36.68	246.07	11/17/2015	35.11	247.64	11/30/2015	34.57	248.18
563	C	Bedrock	8/14/2015	41.68	243.95							9/17/2015	42.86	242.77	10/19/2015	42.45	243.18	11/17/2015	40.55	245.08	11/30/2015	40.13	245.50
564	C	Bedrock	8/14/2015	34.89	254.70							9/17/2015	37.61	251.98	10/19/2015	66.24	223.35	11/17/2015	44.84	244.75	11/30/2015	42.52	247.07
566	C	Bedrock	8/14/2015	29.82	255.87							9/17/2015	38.86	246.83	10/19/2015	39.93	245.76	11/17/2015	38.14	247.55	11/30/2015	37.60	248.09
570	C	Bedrock	8/14/2015	49.78	230.21							9/17/2015	50.29	229.70	10/19/2015	51.41	228.58	11/17/2015	46.57	233.42	11/30/2015	46.21	233.78
577	A	Bedrock	8/14/2015	93.78	136.64	8/24/2015	90.16	140.26	8/31/2015	89.25	141.17	9/17/2015	88.08	142.34	10/19/2015	86.73	143.69	11/17/2015	84.65	145.77	11/30/2015	83.61	146.81
578	C	Bedrock	8/14/2015	99.06	173.29							9/17/2015	97.89	174.46	10/19/2015	98.16	174.19	11/17/2015	98.23	174.12	11/30/2015	97.87	174.48
579	B	Bedrock	8/14/2015	105.12	142.42	8/24/2015	99.96	147.58	8/31/2015	99.60	147.94	9/17/2015	98.51	149.03	10/19/2015	98.07	149.47	11/17/2015	97.33	150.21	11/30/2015	96.40	151.14
601	C	Bedrock	8/14/2015	49.98	216.10							9/17/2015	50.37	215.71	10/19/2015	52.20	213.88	11/17/2015	48.19	217.89	11/30/2015	47.73	218.35
604	C	Bedrock	8/14/2015	79.83	172.83							9/17/2015	82.85	169.81	10/19/2015	84.87	167.79	11/17/2015	85.78	166.88	11/30/2015	85.57	167.09
605	B	Bedrock	8/14/2015	104.42	148.59	8/24/2015	105.93	147.08	8/31/2015	106.70	146.31	9/17/2015	108.40	144.61	10/19/2015	110.71	142.30	11/17/2015	111.70	141.31	11/30/2015	111.23	141.78
606	B	Bedrock	8/14/2015	129.83	123.44	8/24/2015	122.94	130.33	8/31/2015	121.60	131.67	9/17/2015	118.62	134.65	10/19/2015	117.23	136.04	11/17/2015	115.86	137.41	11/30/2015	114.78	138.49
607	C	Bedrock	8/14/2015	87.51	166.26							9/17/2015	90.44	163.33	10/19/2015	92.49	161.28	11/17/2015	93.53	160.24	11/30/2015	93.27	160.50
608	B	Bedrock	8/14/2015	57.75	197.76	8/24/2015	59.00	196.51	8/31/2015	59.41	196.10	9/17/2015	59.00	196.51	10/19/2015	60.12	195.39	11/17/2015	56.53	198.98	11/30/2015	56.11	199.40
609	A	Bedrock	8/14/2015	129.10	120.08	8/24/2015	119.78	129.40	8/31/2015	117.60	131.58	9/17/2015	115.23	133.95	10/19/2015	114.11	135.07	11/17/2015	112.73	136.45	11/30/2015	111.74	137.44
610	B	Bedrock	8/14/2015	109.11	141.76	8/24/2015	108.84	142.03	8/31/2015	108.88	141.99	9/17/2015	109.64	141.23	10/19/2015	110.82	140.05	11/17/2015	111.24	139.63	11/30/2015	110.41	140.46
611	B	Bedrock	8/14/2015	95.93	154.85	8/24/2015	94.94	155.84	8/31/2015	89.12	161.66	9/17/2015	95.96	154.82	10/19/2015	97.18	153.60	11/17/2015	96.74	154.04	11/30/2015	95.50	155.28
622	B	Bedrock	8/14/2015	64.32	203.76	8/24/2015	64.72	203.36	8/31/2015	65.73	202.35	9/17/2015	64.62	203.46	10/19/2015	66.50	201.58	11/17/2015	62.02	206.06	11/30/2015	61.53	206.55
623	B	Bedrock	8/14/2015	112.42	134.32	8/24/2015	110.52	136.22	8/31/2015	110.53	136.21	9/17/2015	111.04	135.70	10/19/2015	112.33	134.41	11/17/2015	111.94	134.80	11/30/2015	110.75	135.99
624	C	Bedrock	8/14/2015	105.15	141.16							9/17/2015	99.08	147.23	10/19/2015	98.99	147.32	11/17/2015	98.10	148.21	11/30/2015	97.13	149.18
704	C	Bedrock	8/14/2015	61.18	193.82							9/17/2015	57.55	197.45	10/19/2015	58.40	196.60	11/17/2015	54.00	201.00	11/30/2015	53.25	201.75
711	C	Bedrock	8/14/2015	27.74	235.95							9/17/2015	29.42	234.27	10/19/2015	30.12	233.57	11/17/2015	29.83	233.86	11/30/2015	29.61	234.08

Table 1
Production Well Optimization Test - Manual Water Level Elevations
Hudson Valley Research Park (Former IBM East Fishkill Facility)
Town of East Fishkill, Dutchess County, New York

Well ID	WL Mon Sch	Screen Location	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)
715	B	Bedrock	8/14/2015	DRY	DRY	8/24/2015	DRY	DRY	8/31/2015	DRY	DRY	9/17/2015	DRY	DRY	10/19/2015	DRY	DRY	11/17/2015	DRY	DRY	11/30/2015	DRY	DRY
716	A	Bedrock	8/14/2015	103.14	169.00	8/24/2015	102.37	169.77	8/31/2015	102.17	169.97	9/17/2015	101.58	170.56	10/19/2015	101.59	170.55	11/17/2015	101.33	170.81	11/30/2015	100.94	171.20
722	C	Bedrock	8/14/2015	22.00	238.15							9/17/2015	23.51	236.64	10/19/2015	24.15	236.00	11/17/2015	23.19	236.96	11/30/2015	22.97	237.18
732	A	Bedrock	8/14/2015	121.93	143.24	8/24/2015	118.43	146.74	8/31/2015	117.31	147.86	9/17/2015	116.00	149.17	10/19/2015	115.32	149.85	11/17/2015	114.46	150.71	11/30/2015	113.58	151.59
734	B	Bedrock	8/14/2015	126.60	135.19	8/24/2015	124.38	137.41	8/31/2015	123.38	138.41	9/17/2015	121.88	139.91	10/19/2015	121.12	140.67	11/17/2015	119.85	141.94	11/30/2015	118.88	142.91
737	B	Bedrock	8/14/2015	121.27	139.93	8/24/2015	116.73	144.47	8/31/2015	115.68	145.52	9/17/2015	114.58	146.62	10/19/2015	113.73	147.47	11/17/2015	112.80	148.40	11/30/2015	111.82	149.38
739	A	Bedrock	8/14/2015	124.38	136.97	8/24/2015	117.31	144.04	8/31/2015	115.68	145.67	9/17/2015	113.88	147.47	10/19/2015	112.41	148.94	11/17/2015	111.36	149.99	11/30/2015	110.30	151.05
742	B	Bedrock	8/14/2015	124.12	136.34	8/24/2015	116.69	143.77	8/31/2015	115.72	144.74	9/17/2015	114.66	145.80	10/19/2015	113.82	146.64	11/17/2015	112.95	147.51	11/30/2015	111.98	148.48
777	C	Bedrock	8/14/2015	33.88	242.15							9/17/2015	36.27	239.76	10/19/2015	37.30	238.73	11/17/2015	36.90	239.13	11/30/2015	36.77	239.26
779	A	Bedrock	8/14/2015	120.27	143.07	8/24/2015	115.84	147.50	8/31/2015	114.48	148.86	9/17/2015	113.10	150.24	10/19/2015	111.45	151.89	11/17/2015	109.86	153.48	11/30/2015	108.82	154.52
923	C	Bedrock	8/14/2015	45.78	216.98							9/17/2015	46.61	216.15	10/19/2015	48.05	214.71	11/17/2015	44.92	217.84	11/30/2015	44.60	218.16
929	B	Bedrock	8/14/2015	89.28	162.88	8/24/2015	89.87	162.29	8/31/2015	90.50	161.66	9/17/2015	91.92	160.24	10/19/2015	93.92	158.24	11/17/2015	94.92	157.24	11/30/2015	94.64	157.52
931	C	Bedrock	8/14/2015	80.75	171.35							9/17/2015	83.59	168.51	10/19/2015	85.61	166.49	11/17/2015	86.58	165.52	11/30/2015	86.34	165.76
932	C	Bedrock	8/14/2015	21.62	245.49							9/17/2015	22.51	244.60	10/19/2015	22.21	244.90	11/17/2015	21.08	246.03	11/30/2015	20.09	247.02
936	C	Bedrock	8/14/2015	56.83	197.31							9/17/2015	60.22	193.92	10/19/2015	62.16	191.98	11/17/2015	62.12	192.02	11/30/2015	62.47	191.67
941	A	Bedrock	8/14/2015	98.96	155.56	8/24/2015	99.95	154.57	8/31/2015	100.58	153.94	9/17/2015	102.00	152.52	10/19/2015	104.07	150.45	11/17/2015	104.83	149.69	11/30/2015	104.33	150.19
943	C	Bedrock	8/14/2015	14.97	239.26							9/17/2015	16.22	238.01	10/19/2015	16.06	238.17	11/17/2015	14.62	239.61	11/30/2015	14.22	240.01
945	C	Bedrock	8/14/2015	105.10	144.26							9/17/2015	99.87	149.49	10/19/2015	99.40	149.96	11/17/2015	98.74	150.62	11/30/2015	97.89	151.47
952	B	Bedrock	8/14/2015	98.92	146.42	8/24/2015	95.73	149.61	8/31/2015	95.20	150.14	9/17/2015	94.78	150.56	10/19/2015	94.47	150.87	11/17/2015	93.61	151.73	11/30/2015	92.73	152.61
953	A	Bedrock	8/14/2015	106.60	145.17	8/24/2015	107.54	144.23	8/31/2015	107.92	143.85	9/17/2015	109.65	142.12	10/19/2015	111.62	140.15	11/17/2015	111.97	139.80	11/30/2015	110.78	140.99
954	C	Bedrock	8/14/2015	40.65	227.55							9/17/2015	41.60	226.60	10/19/2015	44.60	223.60	11/17/2015	42.09	226.11	11/30/2015	41.38	226.82
959	C	Bedrock	8/14/2015	96.69	154.76							9/17/2015	94.31	157.14	10/19/2015	94.45	157.00	11/17/2015	93.52	157.93	11/30/2015	93.13	158.32
961	B	Bedrock	8/14/2015	104.18	129.55	8/24/2015	101.66	132.07	8/31/2015	99.98	133.75	9/17/2015	98.12	135.61	10/19/2015	95.78	137.95	11/17/2015	93.95	139.78	11/30/2015	92.94	140.79
962	C	Bedrock	8/14/2015	87.83	183.99							9/17/2015	88.06	183.76	10/19/2015	88.85	182.97	11/17/2015	89.11	182.71	11/30/2015	88.93	182.89
965	A	Bedrock	8/14/2015	50.53	204.87	8/24/2015	51.09	204.31	8/31/2015	52.13	203.27	9/17/2015	50.97	204.43	10/19/2015	52.88	202.52	11/17/2015	48.22	207.18	11/30/2015	47.74	207.66
968	B	Bedrock	8/14/2015	99.38	171.91	8/24/2015	100.56	170.73	8/31/2015	101.50	169.79	9/17/2015	102.93	168.36	10/19/2015	104.65	166.64	11/17/2015	105.39	165.90	11/30/2015	105.06	166.23
984	C	Bedrock	8/14/2015	60.00	245.45							9/17/2015	61.41	244.04	10/19/2015	61.23	244.22	11/17/2015	59.52	245.93	11/30/2015	59.13	246.32
PW-1	A	Bedrock	8/14/2015	193.89	68.35	8/24/2015	142.33	119.91	8/31/2015	140.20	122.04	9/17/2015	139.05	123.19	10/19/2015	136.15	126.09	11/17/2015	135.15	127.09	11/30/2015	133.11	129.13
PW-2	A	Bedrock	8/14/2015	155.32	100.02	8/24/2015	149.55	105.79	8/31/2015	147.82	107.52	9/17/2015	146.15	109.19	10/19/2015	146.63	108.71	11/17/2015	143.40	111.94	11/30/2015	142.32	113.02
PW-4	A	Bedrock	8/14/2015	141.59	107.14	8/24/2015	120.35	128.38	8/31/2015	117.90	130.83	9/17/2015	115.85	132.88	10/19/2015	119.38	129.35	11/17/2015	113.73	135.00	11/30/2015	112.57	136.16
PW-25	A	Bedrock	8/14/2015	192.68	57.85	8/24/2015	206.50	44.03	8/31/2015	208.20	42.33	9/17/2015	213.50	37.03	10/19/2015	213.34	37.19	11/17/2015	213.15	37.38	11/30/2015	213.34	37.19
010	C	Overburden	8/14/2015	44.58	226.18							9/17/2015	47.18	223.58	10/19/2015	48.21	222.55	11/17/2015	48.91	221.85	11/30/2015	48.81	221.95
074	C	Overburden	8/14/2015	DRY	DRY							9/17/2015	DRY	DRY	10/19/2015	DRY	DRY	11/17/2015	DRY	DRY	11/30/2015	DRY	DRY
621	C	Overburden	8/14/2015	13.38	242.42							9/17/2015	DRY	DRY	10/19/2015	DRY	DRY	11/17/2015	12.41	243.39	11/30/2015	DRY	DRY
714	C	Overburden	8/14/2015	34.78	231.48							9/17/2015	36.70	229.56	10/19/2015	DRY	DRY	11/17/2015	DRY	DRY	11/30/2015	DRY	DRY
731	C	Overburden	8/14/2015	DRY	DRY							9/17/2015	DRY	DRY	10/19/2015	DRY	DRY	11/17/2015	DRY	DRY	11/30/2015	DRY	DRY
748	C	Overburden	8/14/2015	29.46	238.49							9/17/2015	31.81	236.14	10/19/2015	32.51	235.44	11/17/2015	32.72	235.23	11/30/2015	32.74	235.21
759	C	Overburden	8/14/2015	22.89	238.31							9/17/2015	24.08	237.12	10/19/2015	24.54	236.66	11/17/2015	24.07	237.13	11/30/2015	23.85	237.35
763	C	Overburden	8/14/2015	38.10	230.58							9/17/2015	40.63	228.05	10/19/2015	41.17	227.51	11/17/2015	41.47	227.21	11/30/2015	41.15	227.53

Water level monitoring conducted as follows:

A Automated water level recorder supplemented by manual measurements prior to the start of the test, at one week, two weeks, one month, two months, three months,and prior to test termination.

B Manual measurements prior to the start of the test, at one week, two weeks, one month, two months, three months, and prior to test termination.

C Manual measurements prior to the start of the test, at one month, two months, three months, and prior to test termination.

Table 2

Production Well Optimization Test - Supplemental Manual Water Level Elevations

11/30/2015, End of Test - Bedrock Monitoring Wells

Hudson Valley Research Park (Former IBM East Fishkill Facility)

Town of East Fishkill, Dutchess County, New York

Well ID	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)
009	11/30/2015	25.51	239.84
053	11/30/2015	18.84	247.74
065	11/30/2015	5.80	252.96
085	11/30/2015	30.87	245.47
086	11/30/2015	29.26	247.08
087	11/30/2015	11.21	244.79
088	11/30/2015	10.93	245.07
097	11/30/2015	34.22	243.47
098	11/30/2015	33.90	243.79
101	11/30/2015	27.43	239.66
105	11/30/2015	34.89	222.85
108	11/30/2015	28.15	227.30
113	11/30/2015	1.87	267.14
114	11/30/2015	4.60	264.41
117	11/30/2015	92.40	170.66
121	11/30/2015	61.38	201.80
142	11/30/2015	94.61	156.75
145	11/30/2015	72.13	181.77
149	11/30/2015	69.12	165.66
156	11/30/2015	47.25	195.33
166	11/30/2015	6.27	248.31
168	11/30/2015	34.37	230.75
191	11/30/2015	27.53	201.65
500	11/30/2015	12.17	247.72
501	11/30/2015	9.75	248.01
508	11/30/2015	4.89	257.91
515	11/30/2015	2.78	258.03
518	11/30/2015	4.12	258.46
521	11/30/2015	5.66	256.58
522	11/30/2015	4.05	258.40
529	11/30/2015	2.24	268.30
531	11/30/2015	0.90	265.20
532	11/30/2015	2.12	263.98
535	11/30/2015	4.23	262.11
538	11/30/2015	13.80	255.17
542	11/30/2015	22.32	257.66
546	11/30/2015	9.16	257.76
547	11/30/2015	8.20	257.91
560	11/30/2015	35.08	247.65
562	11/30/2015	33.50	252.13
565	11/30/2015	31.55	254.14

Well ID	Date	Depth to Water Below TOC (ft.)	GW Elevation (ft)
568	11/30/2015	23.10	256.40
569	11/30/2015	23.66	256.33
721	11/30/2015	16.54	243.38
722	11/30/2015	22.91	237.24
724	11/30/2015	26.72	242.98
726	11/30/2015	16.87	246.06
727	11/30/2015	17.50	245.99
729	11/30/2015	13.77	246.52
730	11/30/2015	25.09	234.32
835	11/30/2015	25.88	261.44
836	11/30/2015	30.38	256.94
857	11/30/2015	3.83	257.58
858	11/30/2015	4.73	256.12
859	11/30/2015	6.63	256.17
860	11/30/2015	6.99	255.84
861	11/30/2015	17.64	249.42
862	11/30/2015	17.66	248.47
896	11/30/2015	3.61	258.43
897	11/30/2015	9.48	260.58
898	11/30/2015	3.92	266.20
899	11/30/2015	49.18	253.84
900	11/30/2015	35.12	267.57
922	11/30/2015	33.69	229.02
930	11/30/2015	84.78	167.06
935	11/30/2015	59.98	194.16
940	11/30/2015	104.34	150.03
944	11/30/2015	10.24	243.87
960	11/30/2015	36.65	214.75
962	11/30/2015	88.85	182.97
963	11/30/2015	6.38	258.17
966	11/30/2015	47.48	207.80
967	11/30/2015	102.85	168.44
983	11/30/2015	59.20	246.32
985	11/30/2015	52.73	252.13
986	11/30/2015	54.50	250.20
987	11/30/2015	4.07	256.13
988	11/30/2015	4.31	256.25
989	11/30/2015	0.21	260.36
991	11/30/2015	3.66	256.44
992	11/30/2015	5.03	255.09

Table 3

Production Well Optimization Test - Production Well Chemistry Data

Hudson Valley Research Park (Former IBM East Fishkill Facility)

Town of East Fishkill, Dutchess County, New York

Location Date Lab ID	PW-1 9/1/2015 80323364	PW-1 9/16/2015 8051321	PW-1 10/1/2015 8074154	PW-1 10/15/2015 8092444	PW-1 11/2/2015 8116148	PW-1 11/16/2016 8136985	PW-1 12/1/2015 8156578
1,1,1-Trichloroethane	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5
Freon 113 (Freon TF)	2.8	3.0	2.7	2.9	2.6	2.6	2.5
Freon 123a	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5
1,2-Dichlorobenzene	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5
Acetone	ND@5.0	ND@5.0	ND@5.0	ND@5.0	ND@5.0	ND@5.0	ND@5.0
Chlorobenzene	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5
cis-1,2-Dichloroethene	1.5	1.8	1.7	1.7	1.6	1.6	1.6
Dichlorodifluoromethane	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5
Ethylbenzene	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5
m,p-Xylene	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5
o-Xylene	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5
Tetrachloroethene	20	22	20	19	19	20	19
Trichloroethene	8.0	8.2	7.6	8.0	7.6	7.7	7.6
Trichlorofluoromethane	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5
Vinyl Chloride	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5	ND@0.5

Location Date Lab ID	PW-2 9/1/2015 80323365	PW-2 9/16/2015 8051323	PW-2 10/1/2015 8074156	PW-2 10/15/2015 8092445	PW-2 11/2/2015 8116149	PW-2 11/16/2016 8136986	PW-2 12/1/2015 8156579
1,1,1-Trichloroethane	ND@25	ND@10	ND@25	ND@50	ND@50	ND@50	ND@50
Freon 113 (Freon TF)	140	140	110	160	95	160	140
Freon 123a	ND@25	9.6J	ND@25	ND@50	ND@50	ND@50	ND@50
1,2-Dichlorobenzene	ND@25	ND@10	ND@25	ND@50	ND@50	ND@50	ND@50
Acetone	ND@250	ND@100	ND@250	ND@500	ND@500	ND@500	ND@500
Chlorobenzene	ND@25	ND@10	ND@25	ND@50	ND@50	ND@50	ND@50
cis-1,2-Dichloroethene	1000	1100	1000	1100	980	1100	1000
Dichlorodifluoromethane	ND@25	ND@10	ND@25	ND@50	ND@50	ND@50	ND@50
Ethylbenzene	ND@25	4.6J	ND@25	ND@50	ND@50	ND@50	ND@50
m,p-Xylene	ND@25	2.6J	ND@25	ND@50	ND@50	ND@50	ND@50
o-Xylene	ND@25	5.2J	ND@25	ND@50	ND@50	ND@50	ND@50
Tetrachloroethene	8800	10000	9800	10000	9400	11000	10000
Trichloroethene	980	980	830	930	800	990	900
Trichlorofluoromethane	ND@25	ND@10	ND@25	ND@50	ND@50	ND@50	ND@50
Vinyl Chloride	100	100	88	110	83	120	100

Location Date Lab ID	PW-25 9/1/2015 80323366	PW-25 9/16/2015 8051322	PW-25 10/1/2015 8074158	PW-25 10/15/2015 8092446	PW-25 11/2/2015 8116150	PW-25 11/16/2016 8136987	PW-25 12/1/2015 8156580
1,1,1-Trichloroethane	ND@0.5	ND@0.5	ND@2.5	ND@5.0	ND@5.0	ND@5.0	ND@2.5
Freon 113 (Freon TF)	20	23	16	15	12	16	16
Freon 123a	0.6	0.6	ND@2.5	ND@5.0	ND@5.0	ND@5.0	ND@2.5
1,2-Dichlorobenzene	ND@0.5	ND@0.5	ND@2.5	ND@5.0	ND@5.0	ND@5.0	ND@2.5
Acetone	ND@5.0	ND@5.0	ND@25	ND@50	ND@50	ND@50	ND@25
Chlorobenzene	ND@0.5	ND@0.5	ND@2.5	ND@5.0	ND@5.0	ND@5.0	ND@2.5
cis-1,2-Dichloroethene	39	50	48	43	45	50	47
Dichlorodifluoromethane	ND@0.5	ND@0.5	ND@2.5	ND@5.0	ND@5.0	ND@5.0	ND@2.5
Ethylbenzene	ND@0.5	ND@0.5	ND@2.5	ND@5.0	ND@5.0	ND@5.0	ND@2.5
m,p-Xylene	ND@0.5	ND@0.5	ND@2.5	ND@5.0	ND@5.0	ND@5.0	ND@2.5
o-Xylene	ND@0.5	ND@0.5	ND@2.5	ND@5.0	ND@5.0	ND@5.0	ND@2.5
Tetrachloroethene	480	620	630	560	460	650	630
Trichloroethene	110	130	140	120	120	130	150
Trichlorofluoromethane	0.2J	0.2J	ND@2.5	ND@5.0	ND@5.0	ND@5.0	ND@2.5
Vinyl Chloride	0.2J	0.2J	ND@2.5	ND@5.0	ND@5.0	ND@5.0	ND@2.5

Table 3

Production Well Optimization Test - Production Well Chemistry Data

Hudson Valley Research Park (Former IBM East Fishkill Facility)

Town of East Fishkill, Dutchess County, New York

Location Date Lab ID	PW-4 9/1/2015	PW-4 9/16/2015	PW-4 10/1/2015	PW-4 10/15/2015	PW-4 11/2/2015	PW-4 11/16/2016	PW-4 12/1/2015 8156585
1,1,1-Trichloroethane	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	ND@0.5
Freon 113 (Freon TF)	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	3.0
Freon 123a	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	ND@0.5
1,2-Dichlorobenzene	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	ND@0.5
Acetone	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	ND@5.0
Chlorobenzene	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	ND@0.5
cis-1,2-Dichloroethene	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	4.9
Dichlorodifluoromethane	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	ND@0.5
Ethylbenzene	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	ND@0.5
m,p-Xylene	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	ND@0.5
o-Xylene	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	ND@0.5
Tetrachloroethene	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	74
Trichloroethene	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	ND@0.5
Trichlorofluoromethane	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	ND@0.5
Vinyl Chloride	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	OFF LINE	ND@0.5