Prepared for:
**Tronox LLC**
**Henderson, Nevada**

# Revised Work Plan to Evaluate Effective Groundwater Capture at Tronox Extraction Systems, Tronox LLC, Henderson, Nevada

ENSR Corporation
August 2007
Document No.: 4020-023-160

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August 29, 2007

Ms. Shannon Harbour, P.E.
Nevada Division of Environmental Protection
2030 East Flamingo Road, Suite 230
Las Vegas, Nevada 89119-0818

**Subject: Revised Work Plan to Evaluate Effective Groundwater Capture at Tronox LLC, Henderson, Nevada**

Dear Ms. Harbour:

Tronox LLC (Tronox) has undertaken an Environmental Conditions Assessment (ECA) as directed by the Nevada Division of Environmental Protection (NDEP). In response to the comments contained in the NDEP June 26, 2007 letter, Tronox has revised the enclosed Work Plan to Evaluate Effective Groundwater Capture. The NDEP letter and Tronox's annotated response to the comments are also included.

Please contact me at (702) 651-2234 if you have any comments or questions concerning this correspondence.

Sincerely,

SM Crowley

Susan M. Crowley
Staff Environmental Specialist

Overnight Mail

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Revised Work Plan to Evaluate Effective Groundwater Capture
at Tronox Extraction Systems
Tronox LLC
Henderson, Nevada

**Responsible CEM for this project**

*I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state and local statutes, regulations and ordinances.*

SMCrowley

Susan M. Crowley, CEM 1428 Exp.:03/08/09
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## APPENDIX

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# 1.0 Introduction

In commenting on the Tronox LLC (Tronox) Semi-annual Performance Report (February 28, 2007), the Nevada Division of Environmental Protection NDEP (2007a) requested that Tronox evaluate the effectiveness of its groundwater capture systems by utilizing at least three of six United States Environmental Protection Agency (USEPA) "lines of evidence" (USEPA 2002, 2005). In response to that request, a draft work plan was provided to NDEP on May 30, 2007. Comments to that work plan were provided by NDEP on June 26, and responses to those comments are included as **Appendix A** of this report. The responses are also included in the *Annual Performance Report for Chromium and Perchlorate, July 2006-June 2007* (ENSR 2007b). Subsequent to the NDEP (2007b) comments, McGinley and Associates (2007) provided a report June 30, 2007 describing the results of capture analysis using both an analog approach and a numerical groundwater model constructed for the Athens Road well field. In their report, McGinley evaluated well field capture efficiency using both the analog and numerical methods and provided recommendations to further evaluate the capture zone at Athens Road.

In consideration of the NDEP (2006b) comments and recommendations provided by McGinley (2007), Tronox has revised the May 30, 2007 work plan to evaluate the effectiveness of its groundwater capture systems. The revised work plan provides both:

- a discussion of the existing lines of evidence for capture and a data gap analysis; and,
- a scope of work to improve and strengthen the evidence that hydraulic capture is adequate for each of the facilities.

Enhancements to the monitoring well field and extraction program are recommended, along with other methods to evaluate the hydraulic data in support of converging lines of evidence that hydraulic capture is occurring at each location.

## 1.1 Operational History

Tronox operates three primary groundwater containment and extraction systems associated with its Henderson Facility **(Figure 1)**:

- <u>On-Site Slurry Wall and Interceptor Well Field</u> – A slurry wall constructed as a barrier to groundwater flow extends 1600 feet in length, is about 60 feet deep, and is combined with an upgradient series of 23 extraction wells. The upgradient well field pumps about 65 gallons per minute (gpm) of impacted water, effectively dewatering the alluvial aquifer in the vicinity of the barrier.
- <u>Athens Road Well Field</u> – Located approximately 8,200 feet north of the On-Site collection system, the Athens Road Well Field includes a series of 14 extraction wells at seven paired well locations. The wells span roughly 1200 feet of the alluvial paleochannel and pump at a combined rate of about 260 gpm.
- <u>Seep Area Collection System</u> – Located near Las Vegas Wash, approximately 4,500 feet north of the Athens Road Well Field, the system includes a surface capture pump for the intermittent

surface stream (Seep) flow and 10 wells in the Seep well field to capture subsurface flow. The Seep Area Collection System pumps at a combined rate of about 670 gpm.

All groundwater from the hydraulic containment systems is routed for treatment to the Tronox facility and is discharged under an NPDES permit (ENSR 2007b).

## 1.2 NDEP Comments to Tronox Quarterly Reports

NDEP requires verification that the Tronox systems are effectively removing contaminants passing through the capture zone. The evaluation of the containment must consider a three-dimensional capture including flow contributions from both the alluvium in the paleochannels and the upper portion of the Muddy Creek Formation (NDEP 2007a).

At least three of the six possible lines of evidence are required by the USEPA (2002, 2005) to demonstrate adequate capture. The possible lines of evidence include the following:

1. Capture zone estimated through calculations of flow-budget or analytical modeling
2. Demonstration of overlapping cones of depression via flow nets both in plan view and vertical cross section
3. Demonstration of inward flow from a compliance boundary using groundwater elevations at two or more locations perpendicular to the boundary
4. Concentration trends over time at sentinel wells located downgradient of the containment
5. Particle tracking using a calibrated numerical model
6. Tracer testing

# 2.0 PROPOSED APPROACH FOR FURTHER CAPTURE ZONE EVALUATION

Section 2 discusses each of the three groundwater capture systems and provides a performance evaluation based on recent data (ENSR 2007b). Data gaps in demonstrating effective capture are identified, and a scope of work to address those gaps is presented. Tronox proposes to install several new wells in each well field and to address those data gaps and further evaluate groundwater capture based on results from those wells. **Figures 2 through 4** show the locations of the proposed additional monitor and extraction wells, and **Table 1** presents the proposed rationale and well completion information.

## 2.1 On-Site Slurry Wall and Interceptor Wells

There is a significant interaction between the perchlorate and hexavalent chromium plumes and the total dissolved solids plume, which affect plume geometry at the groundwater capture systems off the site. The location and extent of the perchlorate, chromium and total dissolved solids (TDS) plumes interpreted from groundwater samples collected in April and May 2007 are shown on Plates 6, 7 and 8, respectively, of the *Annual Performance Report for Chromium and Perchlorate, July 2006-June 2007* (ENSR 2007b). Plate 8 shows that very high TDS, up to 51,000 milligrams per liter (mg/L), exists west of the Tronox facility and that this plume of high TDS enters the Main Channel beneath the northwestern corner of Tronox property. Likewise, east of the facility a high TDS area, up to 17,600 mg/L, exists beneath the northern portion of the Timet property. South of the Tronox slurry wall the highest TDS encountered is in the immediate area of the Interceptor well field; all concentrations south of the well field are significantly lower. This is an indication that the area beneath the process plants is cleaning up over time. North of the slurry wall TDS concentrations are in the 2,800-8,000 mg/L range due to the effective groundwater capture at the collection system and the recharge of low-TDS Lake Mead water.

It is interesting to note the plume configuration along the Tronox-Timet boundary (Insert B on Plate 8, ENSR 2007b). Here TDS less than 5,000 mg/L is mapped extending north to M-19 and that the highest TDS at the eastern end of the barrier wall is only 5,610 mg/L. Note also that a re-entrant of high TDS extends from the Timet side (well CLD2-R) onto the Tronox side (wells M-74 and M-88).

Plates 6 and 7 (ENSR 2007b) show the configuration of the chromium and perchlorate plumes, respectively through their length from the site to the Las Vegas Wash. As mapped both plumes occupy the inter-fluvial area east of the Main Channel from south of Warm Springs Road to Sunset Road where they begin to enter the channel. This is due to the higher density high TDS-bearing groundwater in the channel prohibiting the chromium and perchlorate plumes from entering the channel until the density difference dissipates down-gradient. Both chromium and perchlorate behave as soluble ions and migrate at the rate of groundwater flow.

### 2.1.1 Performance Evaluation

The current lines of evidence for effective groundwater capture include:

<u>Capture Zone:</u> The 1,600-foot wide slurry wall was designed to provide a physical barrier to groundwater migration across most of the identified perchlorate plume. As mapped on Plate 7 (ENSR 2007b) the wall is stopping the downgradient flow of perchlorate above 10 mg/L on the east end and 25 mg/L on the west end. At

an average plume concentration of 1,089 mg/L perchlorate upgradient of the slurry wall, this equates to an effective capture rate of about 98 percent [(1,089-25)/1,089=0.977]).

Flow Budget: The slurry wall, installed in 2001, has dramatically improved groundwater capture. Current capture rates of about 65 gpm are double those before the wall was installed. Water level data indicate the alluvial aquifer has been mined and is effectively dewatered behind the barrier. The wall is keyed into at least 30 feet of the Muddy Creek Formation. The presumed upward flow of groundwater is further enhanced by the pumping upgradient of the barrier. Given this enhancement to upward flow, it would be anticipated that perchlorate mass if present within the upper portion of the Muddy would be locally influenced in the vicinity of the barrier and interceptor well field.

A preliminary estimate of the groundwater flow at the Interceptor well line and slurry wall was developed based on a solution of Darcy's Law assuming three main sources of groundwater potentially available for capture:

- Groundwater in the alluvium, subsequently "dammed up" behind the slurry wall;
- Groundwater in the Muddy Creek, subsequently "dammed up" behind the groundwater barrier wall, and
- Groundwater flowing vertically and "daylighting" from the Muddy Creek upwards into the incised alluvial channels up-gradient from the slurry wall. The third flow element is included in the budget, since the estimates of flow from the alluvium and Muddy Creek dammed behind the barrier do not adequately account for the water being pumped at the interceptor well field. The calculations and input parameters are provided in **Appendix B**.

Using these variables the calculated groundwater flow to the well field is estimated to be 67.0 gpm; 5.7 gpm from the Muddy Creek dammed behind the barrier, 23.5 gpm in the alluvium behind the barrier and 37.8 gpm from groundwater daylighting from the Muddy Creek to the alluvium upgradient of the barrier. This estimated flow is about two gpm higher than what is currently being pumped at the interceptor well field and suggests that a small flow may not being captured by the barrier well field, possibly at the ends of the wall. Further evaluation of the flow west and east of the barrier will be completed upon installation of the additional piezometers proposed in Section 2.1.2.

Downgradient Concentration Declines over Time: Perchlorate itself is an effective tracer, since it migrates advectively, and is not readily adsorbed to soils. Plume maps (ENSR 2007b) indicate expansion of a zone containing less than 100 mg/L perchlorate downgradient of the recharge trenches where stabilized lake water is added to offset extracted groundwater and maintain groundwater flow. As the recharge water flow is slightly less than the water volume being extracted upgradient of the slurry wall, the rapidly expanding area containing less than 100 mg/L perchlorate indicates perchlorate capture. Comparison of the current plume map with previous maps shows a continuing trend moving the 100 mg/L perchlorate contour lines eastward. Tronox expects that the trend will continue as discussed below in Section 2.1.2.

The expansion of the less than 100 mg/L perchlorate zone is occurring in an area that has historically contained greater than 1,000 mg/L perchlorate. This is a 10:1 (90 percent) decrease. If the infiltration of about 60 gpm of clean (<5 ug/L perchlorate) Lake Mead water in the recharge trenches is totally responsible for this 10:1 decrease then no more than 6 gpm (60 gpm X 10 percent remaining) can be leaking around the barrier wall to keep the downgradient perchlorate plume at about 100 mg/L. The Interceptor well field was pumping

64.2 gpm in June 2007 (ENSR 2007b). The flow budget at the well field is therefore no more than 70.2 gpm (64.2 + 6), which demonstrates a greater than 91 percent capture efficiency [(70.2-6)/70.2=0.914].

#### 2.1.2 Evaluation of Groundwater Velocity Downgradient of the Barrier

As suggested by NDEP (2007b) Tronox has completed a qualitative evaluation to determine the times at which perchlorate and chromium plumes might reach the Athens Road well field (**Appendix C**). The evaluation was done through an analysis of "break over", wherein the effect of the recharged Lake Mead water was used to approximate the groundwater velocity south of the barrier. The resulting groundwater velocity was used to approximate the travel time to the Athens Road well field for both the perchlorate and chromium plumes. The calculations indicate that the mitigating effects of the on-site slurry wall will reach the Athens Road well field between the years 2010 and 2015, depending on velocity.

### 2.1.3 Data Gaps and Proposed Additional Evaluation

The physical barrier wall on the Tronox Site simplifies evaluation of capture and is additive to the criteria established by USEPA. To strengthen the lines of evidence for capture, Tronox has identified several data gaps and corresponding proposals to address them:

- **Data Gap**: Demonstrate the slurry wall is continuous and does not leak significantly along its length.

  **Proposal:** Pump wells M-70 and M-71 on the downgradient side of the slurry wall and monitor the perchlorate concentrations over time. Concentrations of perchlorate are expected to decrease over time indicating that the slurry wall is functioning as designed. Tronox proposes to pump these two wells north of the slurry wall at a rate of about one gpm each or as formation transmissivity permits. Capacity to handle the water in the Groundwater Treatment Plant (GWTP) will be made available by routing the discharge from selected wells connected to the west header and containing very low chromium concentrations, directly to the GW-11 pond.

- **Data Gap:** Demonstrate the upward gradient from the Muddy Creek to the alluvium.

  **Proposal:** Install two new nested monitoring wells at the west and east end of the barrier, and compare water levels to determine the head differential between the Muddy Creek and the alluvium. Proposed well locations (IM-5 and IM-6) are shown on **Figure 2**. The proposed nested wells will consist of two wells each completed in the Muddy Creek adjacent to shallow wells that will be used to evaluate horizontal flow around the west and east end of the slurry wall. The proposed well completions are provided on **Table 1**.

- **Data Gap:** Reconcile the flow budget around the west and east end of the slurry wall.

  **Proposal:** To evaluate the movement of groundwater around the west and east ends of the barrier wall, Tronox proposes to install monitor wells IM-2 and IM-4 and wells IM-1 and IM-3, respectively **(Figure 2)**. Proposed well completion data for these wells are provided on **Table 1**.

- **Data Gap:** Demonstrate that there are overlapping cones of depression for the interceptor extraction wells.

**Proposal:** Conduct short-term shutdowns of up to four interceptor wells with low pumping rates in areas lacking monitoring coverage within the well field in order to obtain water elevation data to aid in contouring cones of depression. Perform distance drawdown plots following procedures outlined in Driscoll (1986) to evaluate pumping well drawdown and efficiency.

Though not a data gap, in response to trends in perchlorate concentrations in monitor wells on the west end of the barrier, and to improve capture near the terminus of the barrier, an additional groundwater extraction well (IEX-1) is proposed in this area **(Figure 2)**. Performance of this well will be monitored by the proposed monitor wells IM-2 and IM-4. This well is proposed in addition to the increased pumping of well IAR as described in the annual report (ENSR 2007b).

## 2.2 Athens Road Well Field

In their assessment of the Athens Road well field, McGinley (2007) compared both analog methods and numerical groundwater modeling to USEPA guidance for determining capture effectiveness and mass recovery efficiency.

Results of the numerical groundwater model showed:

- Two-hundred and sixty (260) particles released at the southern boundary of the model were all captured by the well field along Athens Road; and,
- A mass flux evaluation indicated the well field was over 99 percent efficient in mass recovery along Athens Road.

Results of the analog assessment showed:

- Flow vectors using triangulated extraction wells (ART) and down-gradient monitor wells (ARP) did not show inward flow, suggesting capture might not be achieved using the ARP wells as the compliance boundary.

McGinley concluded that the numerical groundwater model provided some use in showing the well field had a high degree of efficiency, but that existing well pairs did not exist that could validate model predictions. They recommended that:

- Analog capture analysis be considered using a standard procedure,
- Additional nested monitor wells be located to evaluate inward flow and to provide vertical definition across the extraction well field,
- Pumping tests conducted on the proposed new wells and that the data gathered be used in expanding the site conceptual model and for possible updating of the numerical groundwater model.

The McGinley groundwater modeling results fairly match the results from a model previously constructed by Tronox that was used in designing the Athens Road well field. In both cases, calibrated numerical models, constructed independently, demonstrated complete particle capture, one of the USEPA criteria required to demonstrate capture. Further, McGinley's 99+ percent mass recovery is also a significant result that would support the demonstration of effective well field capture.

Tronox agrees, as discussed below, that additional wells are needed to demonstrate inward flow from the ARP well compliance boundary. However, Tronox believes there is sufficient hydraulic data from pumping tests conducted on the ART wells making additional pumping tests unnecessary.

### 2.2.1 Performance Evaluation

Capture Zone: The Athens Road well field was designed to provide a hydraulic barrier spanning the approximately 1,200-foot width of the identified perchlorate plume in this area. Perchlorate is an effective tracer to assess groundwater capture. As mapped on Plate 7 (ENSR 2007b) the well field is stopping the down-gradient flow of perchlorate above about 1 mg/L perchlorate on the west end and about 5 mg/L on the east end. At an average concentration of 225 mg/L perchlorate approaching the well field, this equates to an effective capture rate of about 98 percent (225-5)/225=0.978). This means that the capture zone is defined as extending from 50 feet west of ART-2 to 50 feet east of PC-122.

Flow Budget: The Athens Road wells are extracting about 260 gallons of groundwater per minute and perchlorate at a rate of approximately 700 pounds per day. This volume of groundwater and perchlorate removal compares favorably with the flow budget and mass flux calculated from the May 2007 flow budget calculations at Sunset Road, 1,375 feet up-gradient of the well field **(Appendix B)**. The results indicate that about 196 gpm and 495 lbs/day perchlorate were present at Sunset Road in May 2007. This calculation is the result of using hydraulic conductivity data from slug tests performed on the Sunset Road wells.

Overlapping Cones of Depression: Overlapping cones of depression are evident from data collected from adjacent piezometers and monitoring wells, indicating that the well field has developed a capture zone sufficient to encompass the width of the plume in this area. In fact, the entire 1,200 feet length of the target capture zone is within an area of overlapping cones of depression and significant drawdown of as much as 11.1 feet in ART-3 (see Plate 4, ENSR 2007b).

Numerical Modeling: A numerical evaluation by an NDEP contractor (McGinley 2007) using MODFLOW showed that particles released in the model were completely captured by the Athens Road well field and that mass flux within the model showed greater than 99 percent capture efficiency.

Downgradient Concentration Declines over Time: *Figure 20*, the *COH WRF Well Line Perchlorate Trend* graph (ENSR 2007b) shows that downgradient wells PC-98R and MW-K5 have exhibited consistent decreasing trends of perchlorate concentrations with time. Since full-scale system operation of the Athens Road well field in October 2002, perchlorate concentrations in groundwater samples from well PC-98C and MW-K5 have been reduced 88 and 95 percent respectively. These wells are located about 2,000 feet down-gradient of the Athens Road well field.

### 2.2.2 Data Gaps and Proposed Additional Evaluation

To further evaluate the capture zone at Athens Road, Tronox has identified several data gaps and has developed proposals to address them:

- **Data Gaps:** In contrast to numerical modeling results, McGinley (2007) was not able to demonstrate inward flow using water level data from the second half of 2006 due to the absence of sufficient monitor wells. Also, there is insufficient data to demonstrate influence from pumping of the Athens Road well field on water within the underlying Muddy Creek.

**Proposal:** In order to demonstrate upward vertical head and inward flow, two additional nested piezometers, AM-1 and AM-2 will be completed 100 feet down-gradient of recovery wells ART-3 and ART-9 in the western and eastern sub-channels, respectively. Proposed well locations are shown on **Figure 3**. The new wells will allow calculation of flow vectors and vertical head to confirm capture.

Additionally, the three recently abandoned ARP-series piezometers, ARP-4R, ARP-5R and ARP-6R downgradient of the well field will be re-established nearby their former locations **(Figure 3)**. Proposed well completion data are provided on **Table 1**.

## 2.3 Seep Area Well Field and Seep Stream Collection System

### 2.3.1 Performance Evaluation

The goal of the Seep Area Collection System is to provide a hydraulic containment along the approximately 800-foot width of the perchlorate plume and to reduce the concentration in the surface water of the Las Vegas Wash to below 100 µg/L at Northshore Road. The Seep Area system is less than 1,000 feet from the Las Vegas Wash and multiple lines of evidence such as decreasing analyte concentrations in downgradient monitor wells (Plate 7, ENSR 2007b) indicate that the Las Vegas Wash underflow is encroaching on the well field. Because of this complex situation the Seep well field capture zone is defined as that area influenced by the current overlapping drawdown cone (Plate 5, ENSR 2007b).

<u>Flow Budget</u>: A flow budget calculation was prepared and input parameters are presented in **Appendix B**. The cross sectional area used in the calculations is shown on the Seep well field hydrogeologic cross-section (Figure 4, ENSR 2007b). The area extends from 50 feet west of PC-120 to 175 feet east of PC-133. The System, which was installed beginning in 2001, is currently extracting about 670 gpm of groundwater at an average concentration of 12.7 mg/L perchlorate. This equates to about 102 lbs/day of perchlorate that would otherwise discharge into the adjacent Las Vegas Wash. The estimate derived from the Seep well field pump tests show that 561 gpm and 88 lbs/day perchlorate are flowing toward the well field and that the extra water being pumped is probably Las Vegas Wash underflow. The mass flux calculation suggests that the well field demonstrates significant capture efficiency.

<u>Overlapping Cones of Depression</u>: Plate 5, the *Net Drawdown Map, Seep Well Field* (ENSR 2007b) shows a greater than 2,000-foot wide zone where there are overlapping cones of depression.

<u>Inward Flow</u>: Partial inward flow is demonstrated by potentiometric surface maps (Plate 2, ENSR 2007b) created with groundwater level data from monitoring wells in the area. Additional monitor wells are required to close data gaps in areas where there is insufficient well coverage to adequately evaluate drawdown in the pumping wells, and thus confirm inward flow.

<u>Down-gradient Concentration Declines over Time:</u> Perchlorate loading in the SNWA irrigation wells in Las Vegas Wash downstream of the Seep Area Collection System shows significant decreasing trends (Plate 7, ENSR 2007b). Additionally, Las Vegas Wash surface water sampling shows a 91.5 percent decrease between May 1999 (950 µg/L) and May 2007 (80 µg/L).

### 2.3.2 Data Gaps and Proposed Additional Evaluation

To further evaluate the capture zone at the Seep Area Collection System, the following data gaps have been identified and measures to address them are proposed:

- **Data Gap:** Demonstrate inward flow within the overlapping cones of depression.

  **Proposal:** Install three additional piezometers (SM-1, SM-2 and SM-3) near recovery wells PC-117, PC-118 and PC-133 to support the understanding of drawdown in these wells and the delineation of the capture zone **(Figure 4)**. Proposed well completions are provided on **Table 1**.

  Additionally, use the water level data from the new wells and the current well field to construct plan-view and cross-sectional view flow nets from which to demonstrate the inward flow of groundwater and to calculate capture zone width.

  Lastly, develop distance drawdown plots following procedures outlined in Driscoll (1986) to evaluate pumping well drawdown and efficiency supporting the evaluation of inward flow at the Seep Well Field.

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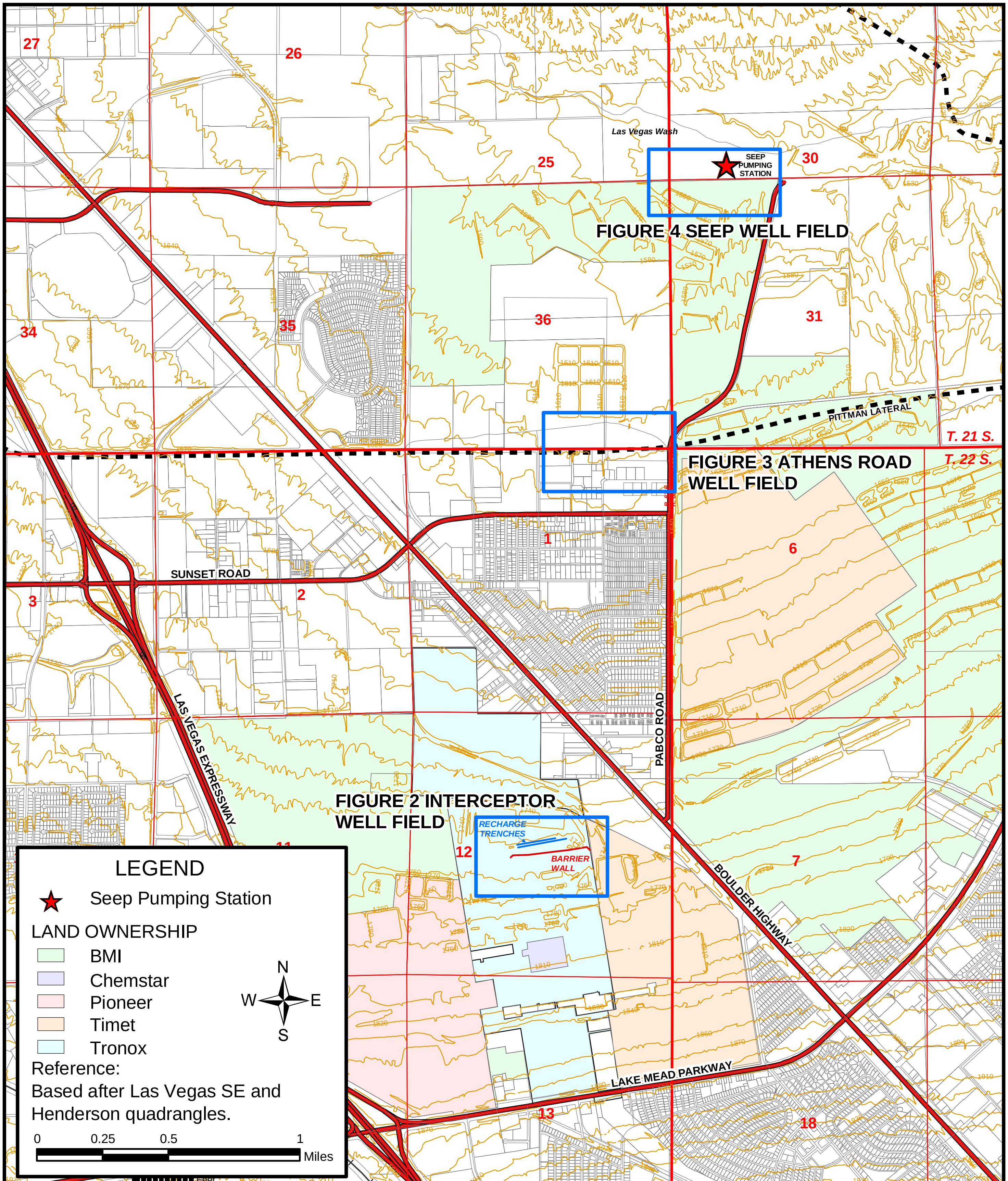


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**LOCATION MAP**

Capture Zone Workplan
Tronox Facility
Henderson, Nevada

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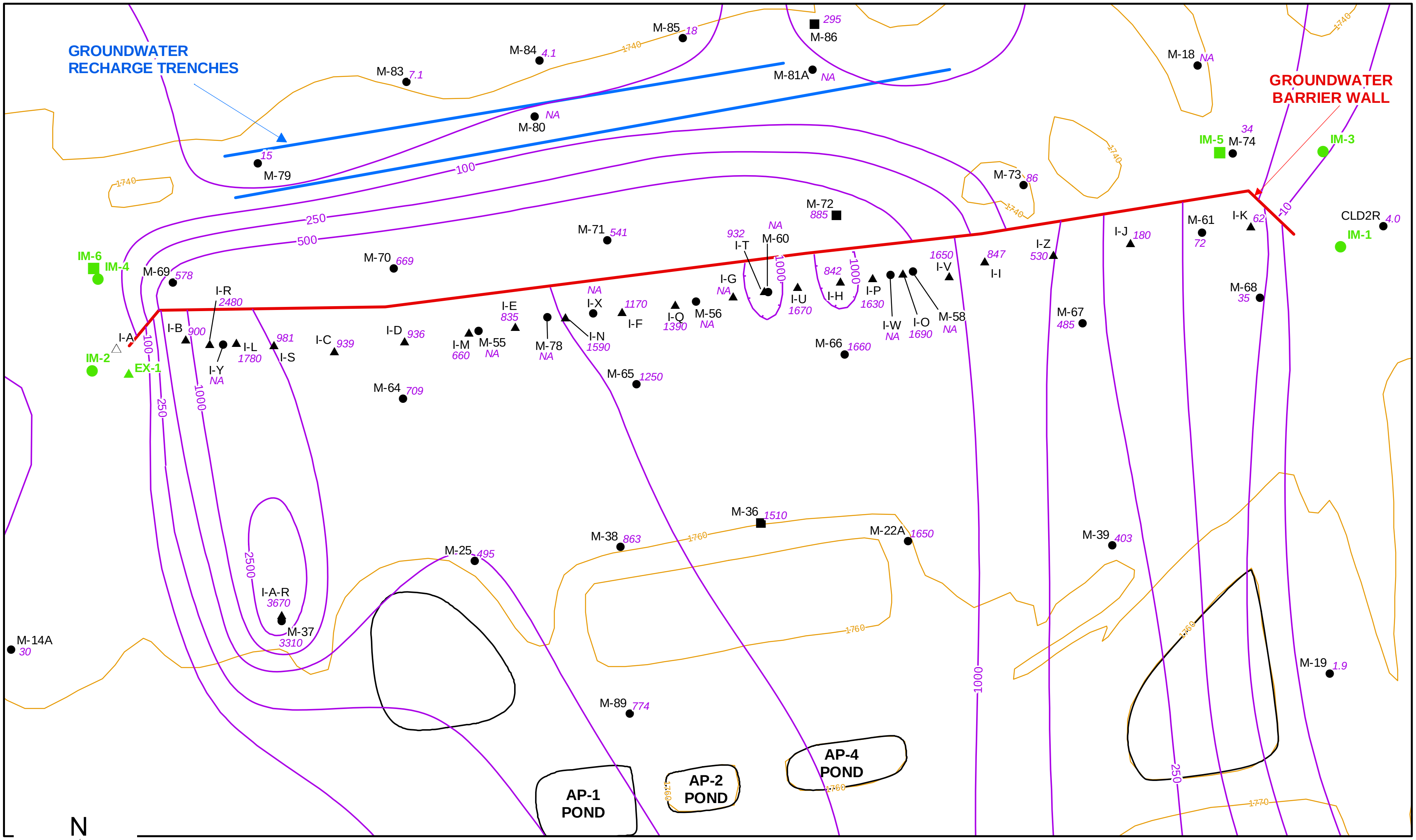


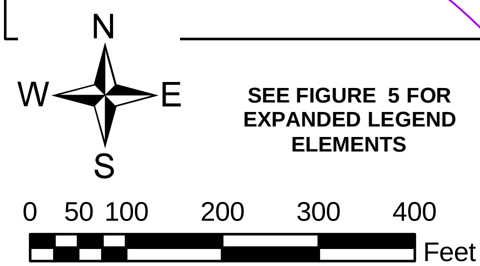


**SEE FIGURE 5 FOR EXPANDED LEGEND ELEMENTS**

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CAMARILLO, CALIFORNIA 93012
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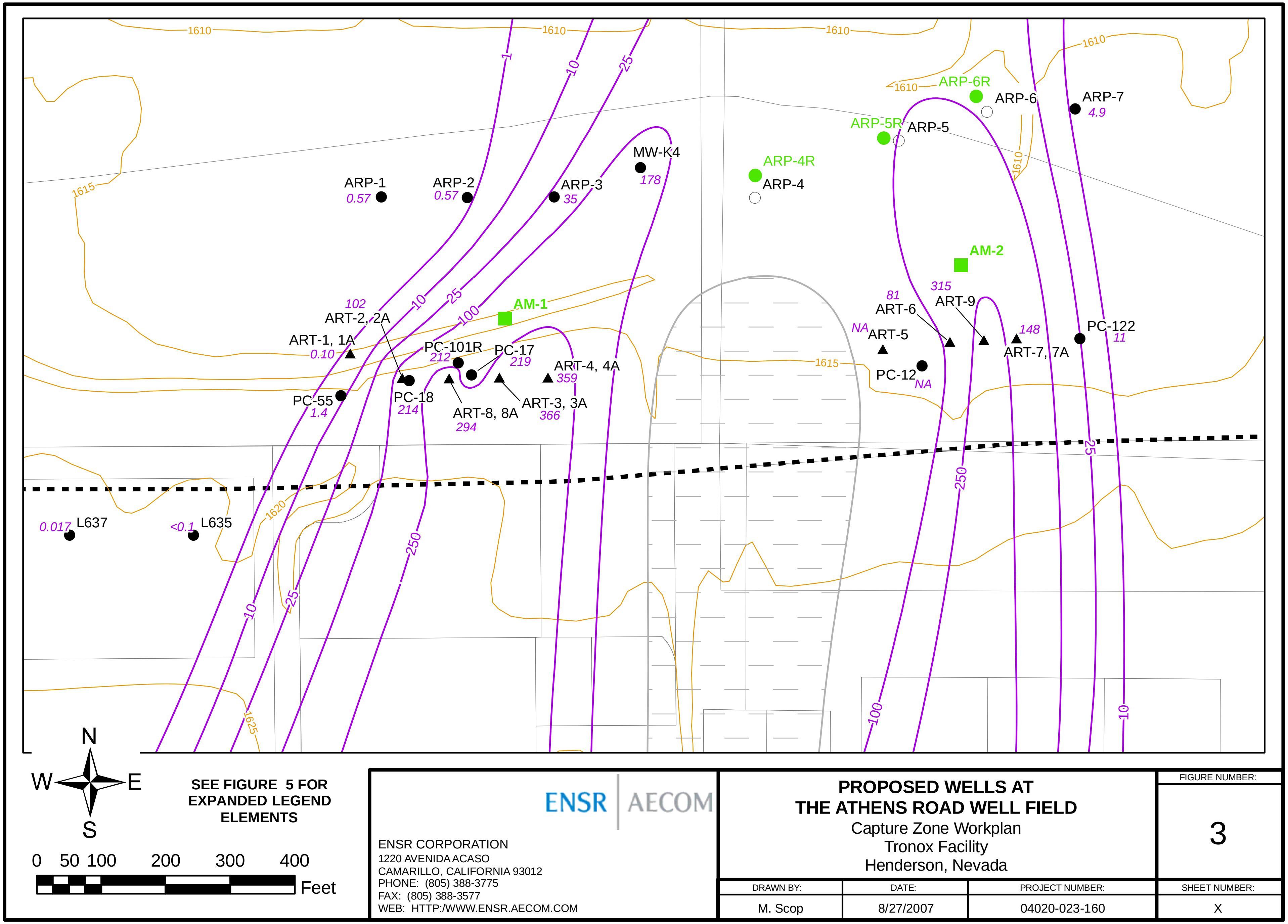
**PROPOSED WELLS AT THE INTERCEPTOR WELL FIELD**
Capture Zone Workplan
Tronox Facility
Henderson, Nevada

| FIGURE NUMBER: |
|---|
| 2 |

| DRAWN BY: | DATE: | PROJECT NUMBER: | SHEET NUMBER: |
|---|---|---|---|
| M. Scop | 8/27/2007 | 04020-023-160 | X |

J:\TronoxGIS\mxd\task-160\Interceptor_WF.mxd




SEE FIGURE 5 FOR EXPANDED LEGEND ELEMENTS

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**PROPOSED WELLS AT THE ATHENS ROAD WELL FIELD**

Capture Zone Workplan
Tronox Facility
Henderson, Nevada

| FIGURE NUMBER: |
|---|
| 3 |

| DRAWN BY: | DATE: | PROJECT NUMBER: | SHEET NUMBER: |
|---|---|---|---|
| M. Scop | 8/27/2007 | 04020-023-160 | X |

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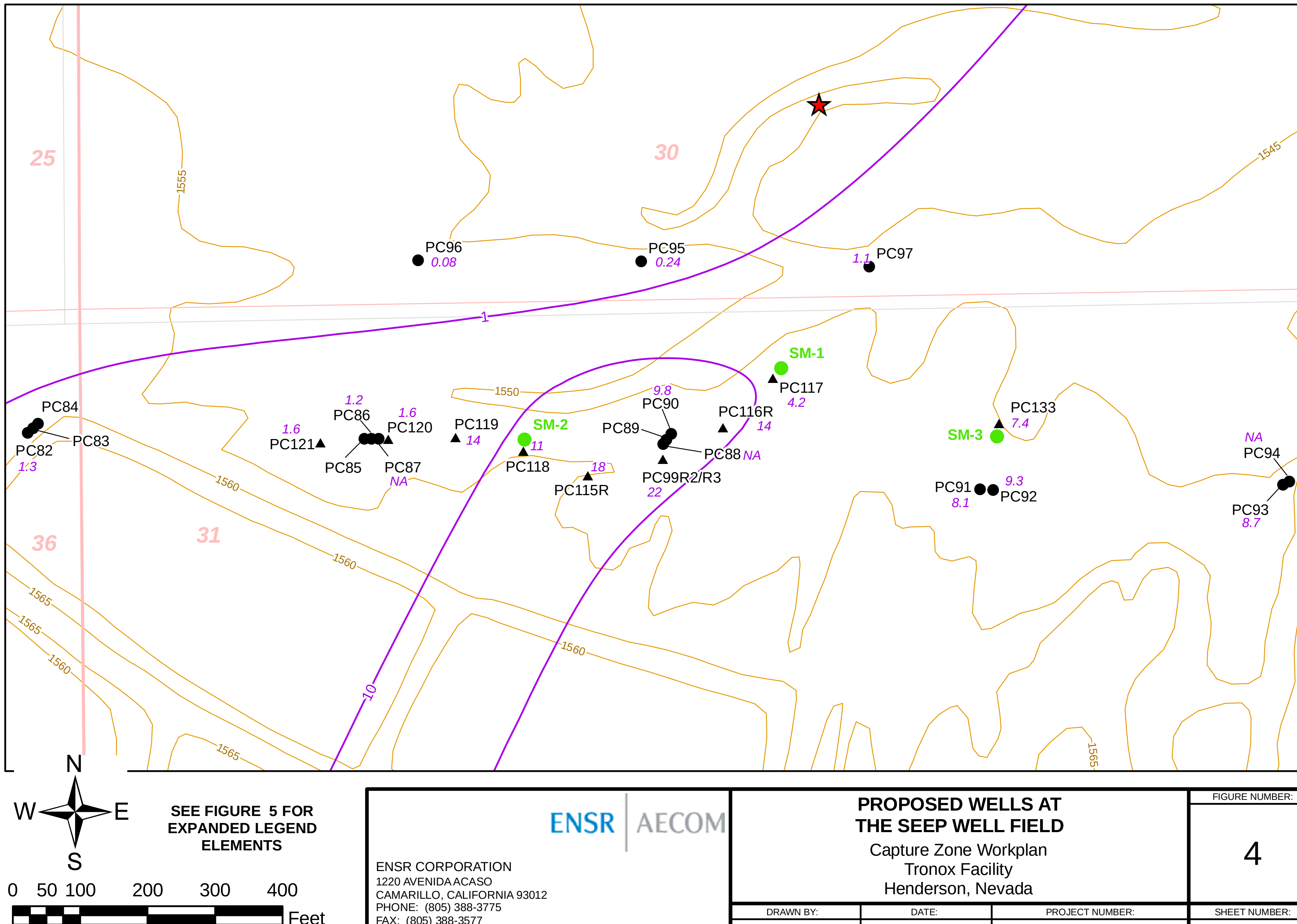


SEE FIGURE 5 FOR EXPANDED LEGEND ELEMENTS

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**PROPOSED WELLS AT THE SEEP WELL FIELD**

Capture Zone Workplan
Tronox Facility
Henderson, Nevada

| FIGURE NUMBER: |
|---|
| 4 |

| DRAWN BY: | DATE: | PROJECT NUMBER: | SHEET NUMBER: |
|---|---|---|---|
| M. Scop | 8/27/2007 | 04020-023-160 | X |

## LEGEND

Monitoring Well

Appendix J Monitoring Well

Recovery Well

Abandoned Monitoring Well

Abandoned Recovery Well

Proposed Monitor Well

Proposed Nested Monitoring Well
Wells will be installed either one bore hole or in seperate boreholes at in close proximity to one another.

Proposed Recovery Well

Seep Pumping Station

15 — Perchlorate Concentration (mg/L) May (ENSR 2007b Plate 7)

Perchlorate Contour (mg/L) (Dashed where approximate) May (ENSR 2007b Plate 7)

Closed Perchlorate Contour (mg/L) Concentrations are lower inside relative to surrounding values May (ENSR 2007b Plate 7)

Unsaturated Alluvium

1760 — Topographic Contour Line

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**EXPANDED LEGEND ELEMENTS**

Capture Zone Workplan
Tronox Facility
Henderson, Nevada

| FIGURE NUMBER: | DRAWN BY: | DATE: | PROJECT NUMBER: | SHEET NUMBER: |
|---|---|---|---|---|
| 5 | M. Scop | 8/27/2007 | 04020-023-160 | X |

## TABLE -1
### PROPOSED MONITOR AND RECOVERY WELLS
### WORK PLAN TO EVALUATE EFFECTIVE CAPTURE
### AT TRONOX EXTRACTION SYSTEMS, HENDERSON, NEVADA

| Proposed Well[1] | LOCATION[2] | WELL CONSTRUCTION[3] | CASING DIAMETER | COMPLETION[4] | Screen Interval[6] | Depth to Water[7] | RATIONALE[8] |
|---|---|---|---|---|---|---|---|
| | | | inches | | feet-bgs | feet-bgs | |
| **INTERCEPTOR WELL FIELD** | | | | | | | |
| IM-1 | East end of the barrier wall. | Single | 2 | (Alluvium) Muddy Creek[5] | 20-40 | 27 | Proposed in response to NDEP Comment 10 (June 26) to evaluate flow around the east end of the barrier wall. |
| IM-2 | West end of the barrier wall. | Single | 2 | (Alluvium) Muddy Creek[5] | 20-40 | 25 | Proposed to evaluate flow around the west end of the barrier wall, and as companion monitor well to IEX-1. Also in response to NDEP Comment 10. |
| IM-3 | East end of barrier wall. | Single | 2 | (Alluvium) Muddy Creek[5] | 20-45 | 29 | Proposed in response to NDEP Comment 10 (June 26) to evaluate flow around the east end of the barrier wall. |
| IM-4 | West end of barrier wall. | Single | 2 | (Alluvium) Muddy Creek[5] | 20-45 | 25 | Proposed to evaluate flow around the west end of the barrier wall and as companion monitor wells to IEX-1. Also in response to NDEP Comment 10. |
| IM-5 | A nested well north of the barrier adjacent to well M74. | Nested (2) | 2/2 | Muddy Creek | 60-70 and 80-90 | 30 | Proposed to evaluate underflow below barrier wall and vertical gradient in Muddy Creek. Response to NDEP Comment 8 (June 26). |
| IM-6 | A nested well north of the barrier adjacent to well IM-4. | Nested (2) | 2/2 | Muddy Creek | 60-70 and 80-90 | 30 | Proposed to evaluate underflow below barrier wall and vertical gradient in Muddy Creek. Response to NDEP Comment 8 (June 26). |
| IEX-1 | Extraction well at the west end of barrier wall. | Single | 6 | (Alluvium) Muddy Creek[5] | 25-45 | 25 | Proposed in the May 30 Work Plan to enhance capture around west end of the barrier. Proposed north-northwest of well IAR. |
| **ATHENS ROAD WELL FIELD** | | | | | | | |
| AM-1 | 100 feet north of Extraction Well ART-3. | Nested (2) | 2 | Alluvium and Muddy Creek | 25-40 and 55-65 | 30 | Response to NDEP Comment 21 (June 26) and McGinley (June 30) recommendation for additional wells to demonstrate inward flow. |
| AM-2 | 100 feet north of Extraction Well ART-9. | Nested (2) | 2 | Alluvium and Muddy Creek | 25-40 and 55-65 | 30 | Response to NDEP Comment 21 (June 26) and McGinley (June 30) recommendation for additional wells to demonstrate inward flow. |
| ARP-4R | Replacement for Monitor Well ARP-4. | Single | 2 | Alluvium | 15-30 | 24 | Replacement well. Proposed to demonstrated inward flow in response to NDEP Comment 21 (June 26) and McGinley (June 30) recommendation. |
| ARP-5R | Replacement for Monitor Well ARP-5. | Single | 2 | Alluvium | 20-40 | 30 | Replacement well. Proposed to demonstrated inward flow in response to NDEP Comment 21 (June 26) and McGinley (June 30) recommendation. |
| ARP-6R | Replacement for Monitor Well ARP-5. | Single | 2 | Alluvium | 20-40 | 30 | Replacement well. Proposed to demonstrated inward flow in response to NDEP Comment 21 (June 26) and McGinley (June 30) recommendation. |

# TABLE -1
## PROPOSED MONITOR AND RECOVERY WELLS
## WORK PLAN TO EVALUATE EFFECTIVE CAPTURE
## AT TRONOX EXTRACTION SYSTEMS, HENDERSON, NEVADA

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **SEEP WELL FIELD** | | | | | | | |
| **SM-1** | **Monitor well for Extraction Well 117.** | **Single** | **2** | **Muddy Creek** | 5-35 | 9 | Proposed in the May 30 work plan and in response to NDEP Comment 25 (June 26) for additional wells to support mapping of the cone of depression. |
| **SM-2** | **Monitor well for Extraction Well 118.** | **Single** | **2** | **Muddy Creek** | 5-25 | 6 | Proposed in the May 30 work plan and in response to NDEP Comment 25 (June 26) for additional wells to support mapping of the cone of depression. |
| **SM-3** | **Monitor well for Extraction Well 133.** | **Single** | **2** | **Muddy Creek** | 5-30 | 10 | Proposed in the May 30 work plan and in response to NDEP Comment 25 (June 26) for additional wells to support mapping of the cone of depression. |

**TOTALS** **15 wells**

**14 of the wells will be monitor/piezometer wells (4 of which will be nested (2 screens per single well boring or two wells in close proximity))**

**1 of the wells willl be an extraction well**

**NOTES**

1 Wells proposed in the ENSR (May 30, 2007) Draft Work Plan and in response to comments from NDEP (June 26, 2007) and McGinley and Associates Groundwater Modeling Report (June 30, 2007).
2 Locations for the proposed wells are shown on **Figures 2, 3 and 4**.
3 Wells will be constructed of PVC casing and screen. Single, equates to one PVC well screen per borehole; Nested (2) indicates two screens will be placed in one single borehole or in separate borings in clo
4 The well completion will depend upon conditions encountered during the boring. Wells will be installed in either the Alluvium and Muddy Creek or in some cases across the contact.
5 Indicates that the well may be installed across the contact between the Alluvium and Muddy Creek. Interval will depend on lithology and moisture content encountered during drilling.
6 The screen interval and slot size will depend upon formation conditions encountered during drilling. What is proposed is based on adjacent well lithology and recent water levels.
7 Depth to groundwater is from May 2007 and from wells adjacent to the proposed well location as shown on Cross Sections A, B and C in the Annual Performance Report (ENSR 2007b).
8 Rationale as proposed in the draft work plan (May 30, 2007) and in response to comments received from NDEP (June 26) and McGinley and Associates (June 30).

**DEFINITIONS**

feet-bgs feet below ground surface

**REFERENCES**

**ENSR 2007a (May 30, 2007)**, Draft Work Plan to Evaluate the Effective Groundwater Capture at TRONOX Extraction Systems, Henderson, Nevada: ENSR, Camarillo, California.

**ENSR 2007b**, Annual Performance Report for Chromium and Perchlorate, July 2006-June 2007, Submitted in Accordance with Chromium Mitigation Program and Perchlorate Performance Consent Orders: ENSR, Camarillo, California, August 29, 2007, 4020-023-110.

N**DEP June 26, 2007**, Response to NDEP Comments of the Tronox Semi-Annual Performance Report Dated February 28, 2007 and the Required Work Plan to Evaluated effective Groundwater Capture at Tronox Extraction Systems, Henderson, Nevadata, dated May 30, 2007: Nevada Division of Enviornmental Protection, Las Vegas, Nevada.

**McGinley June 30, 2007**, Athens Road Well Field Modeling Report - Near BMI Industrical Complex, Henderson, Nevada: McGinley and Associates, Reno Nevada.

# Appendix A

# Response to NDEP (June 26) Comments to the May 30, 2007 Draft Work Plan

**Tronox Response to NDEP June 26, 2007 Comments**
**on the Draft Groundwater Capture Work Plan dated May 30, 2007**

**1. NDEP Comment**
The subject work plan must be signed by a CEM per NAC 459.9719.

**Tronox Response**
*The revised work plan will have a CEM jurat and signature.*

**2. NDEP Comment**
The Flow Budgets presented herein could be improved by calculating the estimated groundwater flow at one or more cross sectional areas and comparing these values to the volume of groundwater extracted at the respective well field.

**Tronox Response**
*The Flow Budgets will be evaluated as suggested and provided in the revised work plan.*

**3. NDEP Comment**
TRX must discuss the relationship between perchlorate, hexavalent chromium and other Site-related chemicals. Some portions of the plume which contain high TDS water may migrate in a fashion that is atypical (due to density gradients or other reasons).

**Tronox Response**
*TRX will include a generalized discussion of the relationship of perchlorate, total chromium, and other specific site-related chemicals to TDS and how the plume(s) relate to the various recovery areas.*

**4. NDEP Comment**
TRX must include a map(s) illustrating the proposed locations of piezometers and groundwater monitoring wells.

**Tronox Response**
*Maps illustrating the proposed locations of piezometers and groundwater monitoring wells will be provided in the revised work plan.*

**5. NDEP Comment**
Section I, page 1 of 7, footnote #1, the NDEP recommends adding the following reference: Capture Zone Analysis for Pump-and-Treat Systems, EPA NARPM Conference May 24, 2005.

**Tronox Response**
*The reference will be added.*

**6. NDEP Comment**
Section I, page 2 of 7, 2$^{nd}$ paragraph, 2$^{nd}$ bullet, "Demonstration of overlapping cones of depression via flow nets both in plan view and vertical cross section." This is not included in EPA (2002) reference as a line of evidence. The EPA (2005) clearly indicates that drawdown (cone of depression) and capture zone are not the same. The capture zone and cone of depression will only be the same if background hydraulic gradient is zero. However, given the geometry of the line of extraction wells within and extending across a mapped paleochannel, the NDEP acknowledges that overlapping cones of depression can be a line of evidence. This comment is applied to a number of Sections of the report and will not be repeated.

**Tronox Response**
*TRX generally agrees with the information discussed in this comment. TRX also believes that the presence of the slurry wall plays a major role in the capture of the onsite plume. TRX will endeavor to better define the impact of the wall on the USEPA's capture zone line of evidence.*

**7. NDEP Comment**
Section II, page 2 of 7, Capture Zone, TRX indicates that the barrier wall was designed "to provide a physical barrier to groundwater migration across the width of the identified perchlorate plume." It is important to frame this discussion in terms of concentration because it is obvious that the lower concentration portions of the perchlorate plume are not being captured.

**Tronox Response**
*The length of the slurry wall was limited by physical barriers both to the east and the west at the time of installation. The discussion of the wall can be revised to be more accurate by saying it is a physical barrier across the higher concentration portion of the perchlorate plume.*

**8. NDEP Comment**
Section II, page 2 of 7, Flow Budget, TRX needs to support the argument about upward hydraulic gradient with on-site data including both water level elevation and water quality. In addition, TRX states "Current capture rates (70 gpm) are double those before the wall was installed." Please note that the rate of capture is irrelevant when the upgradient flow rate is unknown.

**Tronox Response**
*TRX will be installing two nested piezometers to demonstrate the vertical component of the groundwater regime under the facility. These piezometers will be installed at appropriate multiple depths and will be located in an area outside the main groundwater impact plume to minimize potential cross contamination. The groundwater will also be sampled for appropriate water quality parameters*

**9. NDEP Comment**
Section II, page 3 of 7, 1$^{st}$ paragraph 2$^{nd}$ sentence, Flow Budget, please provide the calculations and input parameters.

**Tronox Response**
*TRX will provide calculations in the revised work plan based on known and estimated input parameters for the flow budget at the onsite recovery area.*

**10. NDEP Comment**
Section II, page 3 of 7, 2$^{nd}$ and 3$^{rd}$ paragraphs, last sentences, Flow Budget, the NDEP has the following comments:

a. The NDEP requests that this statement be supported with the installation of at least two monitoring wells at both locations as illustrated in Figure 1 (see following comment) to measure gradient. Flow may then be calculated using these newly installed monitoring wells and M69 (west side) and M74 (east side).
b. Please note that the NDEP is including Figure 1 as example of possible well locations for comment clarity. TRX may propose different well locations.
c. TRX should include a map illustrating the proposed locations of the monitoring wells. This comment applies to other portions of the work plan as well.
d. TRX states "the volume of groundwater migrating around the…end of the barrier wall is estimated to be less than 1 gpm." It is not evident how this number was derived and what concentration applies to the 1 gpm number. Based on the data provided by TRX and others, the NDEP believes that a >1 mg/l plume impacts the northern 50 percent of the TIMET property. The source of this plume appears to be TRX.

**Tronox Response**
*a. /b. /c. TRX will install groundwater monitor wells at each end of the barrier wall at locations shown in Figure 2 of the Revised Work Plan to Evaluate Effective Capture at Tronox Extraction Systems (August 2007). TRX will provide a map showing the proposed well locations along with any other proposed monitor wells,, piezometers, or additional recovery wells in the revised work plan.*
*d. TRX will be reevaluating the eastern edge of the plume boundaries following installation of the proposed monitor wells. Whether the chromium and perchlorate plumes on TIMET property are residual (prior to slurry wall installation) or ongoing has yet to be determined. Based on second quarter 2007 data, it is unclear why the total chromium and perchlorate concentrations are higher in well CLD-1R further away from the TRX boundary than those in well CLD-2R, adjacent to TRX property. Also, the TDS value for CLD-2R is more than three times higher than the groundwater values on adjacent TRX property and the TDS concentration in CLD-1R.*

**11. NDEP Comment**
Section II, page 3 of 7, 4$^{th}$ paragraph, Flow Budget, TRX must provide basis for this evaluation, i.e., calculations and input parameters.

**Tronox Response**
*TRX will provide the requested information in the revised work plan. We intend to further refine this estimate using the additional data from the proposed east and west monitor wells.*

**12. NDEP Comment**
Section II, page 3 of 7, Downgradient Concentration Declines over Time, water from Lake Mead is likely 0.010 mg/L or less based on historical analysis. Thus, the expansion of a zone containing less than 100 mg/L could occur through dilution alone by the addition of low perchlorate concentration water regardless whether the extraction wells were achieving capture at the rate in which TRX describes.

**Tronox Response**
*The expansion of the less than 100 mg/L perchlorate zone is occurring in an area that historically contained perchlorate concentrations exceeding 1,000 mg/L (see Plate 6, Phase II Groundwater Perchlorate Investigation Report, July 15, 1998). If ~60 gpm recharge of stabilized Lake Mead water with less than 4 µg/L perchlorate (3/17/07 value from April 26, 2007 UIC Permit report) is capable of a ten to one reduction of perchlorate by simple dilution only, then the groundwater flow in this area would have to be ~6 gpm or less. If this is true, then based on the current capture rate, the extraction wells must be capturing more than 90 percent of the flow as we now perceive it.*

**13. NDEP Comment**
Section II, page 3 of 7, Downgradient Concentration Declines over Time, please delete the last two sentences from this paragraph because the addition of low perchlorate concentration water invalidates the analysis.

**Tronox Response**
*Based on the analysis presented under #12 above, there is some rationale for the statements, however, TRX will evaluate the sentences and revise or eliminate them if appropriate.*

**14. NDEP Comment**
Section II, page 4 of 7, Proposed Additional Evaluation, 1$^{st}$ bullet, as noted above, the NDEP is not sure what this will prove because low perchlorate concentration water from Lake Mead is being injected downgradient of these wells.

**Tronox Response**
*Wells M-71 and M-72 are two of the wells in the "dead zone" immediately downgradient from the slurry wall but upgradient from the recharge trenches. TRX believes that the impacted groundwater in this area is trapped between the slurry wall and the recharge trenches in an area of essentially no groundwater flow. There is recent evidence that this area is beginning to "drain" downgradient to the northeast towards monitor well M-86. TRX has noted that well M-72 has declined in concentration while well M-86 has correspondingly increased.*

*TRX is planning to pump these wells to extract (or "mine") much of the impacted groundwater from this area in an attempt to clean it out. In response to the groundwater extraction, injected Lake Mead water could migrate further into this area and assist in lowering the groundwater concentrations via flushing or dilution.*

**15. NDEP Comment**
Section II, page 4 of 7, Proposed Additional Evaluation, 3rd bullet, the NDEP requests three shallow (water table) monitoring wells at each end of the barrier wall to evaluate effectiveness of the barrier. (See also comment above.)

**Tronox Response**
*TRX has proposed the installation of groundwater monitor wells and/or piezometers on the east end of the barrier wall (see RTC 10 a/b/c), and plans to install at least one new recovery well with attendant monitor wells or piezometers on the west end. This request for three shallow monitor wells at each end of the barrier wall will be reviewed in conjunction with the planned well installation proposals.*

**16. NDEP Comment**
Section II, page 4 of 7, Proposed Additional Evaluation, 5th bullet, the NDEP requires contouring water level elevation excluding the use of pumping water levels from extraction wells. TRX may propose a method to estimate water levels for pumping wells taking into account well losses (inefficiency). Alternately, TRX could install piezometers in this area.

**Tronox Response**
*TRX will base water level contouring on existing monitor wells and non-pumping extraction wells along the Interceptor well line and may add additional piezometer(s) in areas with minimal coverage. Further, data from the monitor and non-pumping wells may be used to estimate well efficiency such that the pumping wells can be included in the contouring. A method to estimate well efficiency will be considered and may be included in the revised work plan.*

**17. NDEP Comment**
Section II, page 4 of 7, Proposed Additional Evaluation, the NDEP suggests that TRX consider installation of monitoring wells in a north south line along the TIMET-TRX border to delineate the extent of the plume in this area. Alternately, TRX could utilize some existing TIMET wells if they are adequate. Based upon the recently completed TIMET CSM the concentrations of perchlorate at TIMET range from 0.069 mg/l (along Lake Mead Parkway) to a high of 4.3 mg/l on the western side of the TIMET property (well CLD1-R).

**Tronox Response**
*TRX will consider this well placement proposal in conjunction with the monitor well installation already proposed in this area (see RTC 10 a/b/c). TRX will utilize Timet wells CLD1-R, 2-R and 4-R to delineate the plume.*

**18. NDEP Comment**
Section II, page 4 of 7, Performance Evaluation, TRX should examine the concentration versus time trend graphs for the Athens Road well field. The NDEP notes that no appreciable change can be discerned from September 2001 to the most current quarterly report. The NDEP acknowledges that some of the declines may be obscured by the scale of the Figure. In any case, TRX should discuss these trends specifically and present Figures which are legible and appropriately scaled. In addition, TRX should discuss these concentrations versus time trend graphs in relation to the estimated travel times of the remedial system. For example, discuss the concentrations in the Athens Road well field from the time of the installation of the slurry wall until the present time and then explain why the concentrations are not declining. It appears to the NDEP that some portion of the 100 mg/l perchlorate plume is not being captured on-Site.

**Tronox Response**
*There is no appreciable change in the concentrations at the Athens Road well field because the mitigating effect of the slurry wall has yet to reach the well field. If perchlorate is moving at approximately the same velocity as the groundwater, then the break-over point, the point at which steady concentration decline begins to occur in a given well due to the influence of the slurry wall and the recharge trenches, is still several years*

*away from reaching Athens Road. TRX will discuss the breakover analyses for several key wells downgradient from the onsite system and will present approximate time frames for expected declines in the perchlorate concentrations at the Athens Road well field.*

**19. NDEP Comment**
Section II, page 5 of 7, Athens Road Extraction Gallery, Flow Budget, the NDEP requires TRX to provide the calculations and input parameters before the NDEP will comment on the results of the calculations.

**Tronox Response**
*Calculations and input parameters will be provided in the revised work plan.*

**20. NDEP Comment**
Section II, page 5 of 7, Athens Road Extraction Gallery, Overlapping Cones of Depression, see comment above regarding overlapping cones of depression. The 11 foot drawdown reported for ART-3 in the *Semi-Annual Performance Report for Chromium and Perchlorate* dated February 6, 2007 may be the result of well inefficiency.

**Tronox Response**
*Plate 3 of the Semi-Annual Performance Report for Chromium and Perchlorate dated February 6, 2007 shows that the drawdown in ART-3 is 9.0 feet, not 11.0 feet. This drawdown is valid because at the time of calculation adjacent buddy well ART-3A was the pumping well whereas ART-3 was the monitor well.*

**21. NDEP Comment**
Section II, page 5 of 7, Athens Road Extraction Gallery, Inward Flow, the NDEP does not agree that inward flow is demonstrated by the Potentiometric Surface Map, Fourth Quarter 2006. West of the Tertiary Muddy Creek Formation(TMCf) high the groundwater elevation contours and data as posted on the map show a gradient south to north, *i.e.*, towards the wash. East of the TMCf high there is insufficient data to support the closed (depression) contour as drawn on the map. No groundwater elevation data have been reported between the closed 1590 contour and the 1590 contour to the north to indicate a higher water level. An alternative way to map this data could include connecting the 1590 depression contour with the same 1590 contour to the north.

**Tronox Response**
*Groundwater elevation data to be presented in the July 2006 – June 2007 Annual Performance Report show that a closed contour (depression) is mapped encircling Athens Road WF drawdown on both sides of the Muddy Creek Formation high. To test the validity of this interpretation of the potentiometric data TRX will install additional nested piezometer wells downgradient of the ART wells to demonstrate inward flow.*

**22. NDEP Comment**
Section II, page 5 of 7, Athens Road Extraction Gallery, Proposed Additional Evaluation, 2$^{nd}$ bullet, unless the “available and accessible monitor wells along the width of Athens Road” lie between the ART-series and ARP-series wells there may still not be adequate groundwater level data to demonstrate inward flow. It may be necessary to install one or more well pairs to the ART “buddy” wells to achieve this purpose. If well pairs are installed NDEP should review and approve the location for these wells.

**Tronox Response**
*The available and accessible monitor wells are currently being monitored. TRX will install additional nested piezometer wells downgradient of the ART wells at locations agreeable to the NDEP.*

**23. NDEP Comment**
Section II, page 5 of 7, Numerical Modeling, this discussion has no references and hence cannot be verified by the NDEP. In addition, the NDEP noted that the numerical modeling completed previously (but not referenced in this report) does not demonstrate the 97.5 percent capture purported by TRX.

**Tronox Response**
*TRX will reference the numerical modeling report in the revised work plan. Under direction of NDEP McGinley [June 30, 2007] has recently completed a particle-tracking model indicating over 99 percent capture. The McGinley report identifies several data gaps which will need resolution to confirm capture. Tronox is working to address those data gaps which will allow a more robust demonstration of capture. .*

**24. NDEP Comment**
Section II, page 6 of 7, Seep Area Collection System, Flow Budget, no flow budget is presented or referenced in this section. The NDEP requires a flow budget calculation to be presented or referenced.

**Tronox Response**
*A flow budget calculation will be presented in the revised work plan.*

**25. NDEP Comment**
Section II, page 6 of 7, Seep Area Collection System, Overlapping Cones of Depression, see comment above. In addition, the NDEP does not believe that overlapping cones of depression have been demonstrated to exist in this area.

**Tronox Response**
*Up to five additional piezometer wells were proposed by TNX in the Seep well field in order to map cones of depression. Plate 5 (ENSR, 2007b) shows an overlapping cone of depression based solely on monitoring well data. Considering the proximity of the well field to Las Vegas Wash it is unlikely that full capture can expected.*

**26. NDEP Comment**
Section II, page 6 of 7, Seep Area Collection System, it is not clear to the NDEP that full capture in the Seep Area is warranted or feasible. The goals for this area should be discussed and a capture zone should be agreed upon. It is evident that the remedial system can be optimized in this well field and others.

**Tronox Response**
*The goals for the Seep well field will be discussed in the revised work plan and a capture zone agreed upon.*

# Appendix B

# Flow Budget Estimates – Interceptor, Athens Road and Seep Well Fields

# APPENDIX B

# FLOW BUDGET ESTIMATES
# INTERCEPTOR, ATHENS ROAD AND SEEP WELL FIELDS

## INTERCEPTOR WELL AREA FLOW BUDGET ESTIMATE

An initial estimate of the groundwater flow available for capture at the On-Site Interceptor well line and groundwater barrier wall is necessary to determine in a more quantitative sense the quantity of groundwater that is being captured. This initial estimate is based on a solution of Darcy's Law assuming three main sources of groundwater potentially available for capture at the barrier wall: 1) groundwater in the alluvium, and subsequently "dammed up" behind the barrier wall; 2) groundwater in the Muddy Creek, and subsequently "dammed up" behind the groundwater barrier wall, and 3) groundwater flowing vertically and "daylighting" from the Muddy Creek upwards into the incised alluvial channels upgradient from the barrier wall. The third flow element was included in the budget, since the estimates of flow from the alluvium and Muddy Creek dammed behind the barrier do not adequately account for the water being pumped at the interceptor well field. Estimates of available groundwater from the three main areas are described below. These data are summarized in **Table B-1**.

### 1) Alluvial groundwater dammed up behind the barrier wall

The amount of saturated alluvium upgradient from the interceptor wells was estimated using a west-east traverse of monitor wells along the Interceptor well line shown on Figure 2 – Cross Section A-A' (ENSR 2007b). The maximum average cell saturation (based on May 2007 water elevation data) noted along this line was 4.25 feet. The estimate utilizes a horizontal gradient of 0.02 (from Plate 2, ENSR, 2007b) and a hydraulic conductivity from a monitor well (M-2) drawdown test for the alluvium of 453 gallons per day per foot squared (gpd/ft$^2$). As shown on **Table B-1**, the calculated flow for the dammed saturated alluvium is 23.5 gallons per minute (gpm).

### 2) Muddy Creek groundwater dammed up behind the barrier wall

The barrier wall is approximately 1600 feet long and was installed approximately 60 feet below grade. Based on an average thickness of 30 feet for the alluvium in the area of the wall, approximately 30 feet of upper Muddy Creek is blocked by the barrier wall. The underflow for this portion of the Muddy Creek was estimated using a length of 1600 feet, a depth of 30 feet, and a hydraulic conductivity of 8.5 gpd/ft$^2$. The hydraulic conductivity was estimated from a pumping test in well M-11 which is completed within the Muddy Creek formation. As shown on **Table B-1** the calculated flow for the dammed portion of the Muddy Creek is 5.7 gpm.

### 3) Muddy Creek groundwater daylighting into the alluvium upgradient from the barrier wall

The bulk of the monitor wells upgradient from the slurry wall have groundwater levels in the upper Muddy Creek formation. Because there is an upward vertical gradient, groundwater from the Muddy Creek will discharge into the incised alluvial channels, and thus contribute to flow upgradient of the barrier. An estimate of this volume of groundwater was made as an additional source of groundwater within the alluvium behind the barrier wall. In order to account for this near vertical upflow, a cross-sectional area 1600 feet long (the west-east length of the barrier wall) by 200 feet width (south-north) was utilized to account for the area of the incised alluvial channels. This 200 foot width represents an estimate of the area that Muddy Creek groundwater is first daylighting into the alluvium upgradient from the barrier wall and takes into consideration the upgradient reach of alluvial channels cut into the Muddy Creek. It was assumed that water discharging to the alluvium would flow under the same conditions as estimated for the alluvium dammed behind the barrier. As shown on **Table B-1** the calculated flow for the daylighting Muddy Creek is 37.8 gpm.

Adding up the available groundwater estimates presented in **Table B-1** yields a calculated flow budget of about 66.9 gpm. Evaluations from planned additional monitor well and recovery well installations will be necessary to fine tune this figure.

**TABLE B-1**
**GROUNDWATER UNDERFLOW - MAY 2007**
**INTERCEPTOR WELL FIELD**

| ALLUVIUM - DAMMED | | | | | | | |
|---|---|---|---|---|---|---|---|
| **CELL ID (1)** | **I-Y** | **M-55** | **I-X** | **I-G** | **I-U** | **I-Z** | **TRAVERSE TOTAL** |
| Cell Width (ft) | 230 | 180 | 200 | 100 | 100 | 550 | **1,360** |
| Cell Height (ft) (2) | 2.25 | 1.25 | 4.25 | 2.25 | 1.25 | 3.25 | |
| Cell Area (A) ($ft^2$) | 517.5 | 225 | 850 | 225 | 125 | 1787.5 | **3,730** |
| K (gpd/ft2) (3) | 453 | 453 | 453 | 453 | 453 | 453 | |
| Q (gpd) (Q = KiA) (4) | 4,689 | 2,039 | 7,701 | 2,039 | 1,133 | 16,195 | **33,794** |
| **Q (gpm)** | 3.3 | 1.4 | 5.3 | 1.4 | 0.8 | 11.2 | **23.5** |

| MUDDY CREEK - DAMMED | | | | | | | |
|---|---|---|---|---|---|---|---|
| **CELL ID** | **MCD** | | | | | | **TRAVERSE TOTAL** |
| Cell Width (ft) | 1,600 | | | | | | **1,600** |
| Cell Height (ft) | 30 | | | | | | |
| Cell Area (A) ($ft^2$) | 48,000 | | | | | | **48,000** |
| K (gpd/ft2) (5) | 8.5 | | | | | | |
| Q (gpd) (Q = KiA) (4) | 8,160 | | | | | | **8,160** |
| **Q (gpm)** | 5.7 | | | | | | **5.7** |

| MUDDY CREEK - UPFLOW | | | | | | | |
|---|---|---|---|---|---|---|---|
| **CELL ID** | **MCU** | | | | | | **TRAVERSE TOTAL** |
| Cell Width (ft) | 1,600 | | | | | | **1,600** |
| Cell Height/Width (ft) (6) | 200 | | | | | | |
| Cell Area (A) ($ft^2$) | 320,000 | | | | | | **320,000** |
| K (gpd/ft2) (5) | 8.5 | | | | | | |
| Q (gpd) (Q = KiA) (4) | 54,400 | | | | | | **54,400** |
| **Q (gpm)** | 37.8 | | | | | | **37.8** |
| **TOTAL GPM** | | | | | | | **67.0** |

**NOTES**

(1) Cell ID is well name in center of cell - locations shown on Figure 2 (this document) and Figure 2 (ENSR 2007b)
Cell width was centered on these borings/wells.
(2) Cell height is saturated thickness of alluvium (ENSR 2007b, Figure 2)
(3) Hydraulic conductivity from well M-2 drawdown test
(4) Hydraulic Gradient (i) is 0.02 ft/ft
(5) Hydraulic conductivity from well M-11 drawdown test
(6) Since Muddy Creek upflow is near vertical the horizontal dimension = vertical dimension

**DEFINITIONS**

| | |
|---|---|
| A | Area |
| ClO4 | Perchlorate |
| ft | feet |
| $ft^2$ | feet squared |
| gpd | gallons per day |
| gpd/$ft^2$ | gallons per day per foot squared |
| gpm | gallons per minute |
| i | gradient |
| K | hydraulic conductivity |
| lbs/day | pounds per day |
| MCD | Muddy Creek "dammed" groundwater |
| MCU | Muddy Creek "upward flow" groundwater (water from the Muddy Creek to Alluvium) |
| mg/L | milligrams per liter |
| Q | flow |

**REFERENCES**

**ENSR 2007b**, Annual Performance Report for Chromium and Perchlorate, July 2006-June 2007, Submitted in Accordance with Chromium Mitigation Program and Perchlorate Performance Consent Orders: ENSR, Camarillo, California, August 29, 2007, 4020-023-110.

## TABLE B-2
## GROUNDWATER UNDERFLOW AND MASS FLUX - MAY 2007
## SUNSET ROAD TRAVERSE - USING SUNSET ROAD SLUG TEST PARAMETERS

| SLUG TEST PARAMETERS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **CELL ID [1]** | **PC132** | **PC131** | **PC50** | **PC130** | **PC129** | **PC128** | **PC25** | **PC127** | **PC24** | **PC126** | **TRAVERSE TOTAL** |
| Cell Width (ft) | 175 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | **1,975** |
| Cell Height (ft) [2] | 22 | 29 | 29.9 | 28.6 | 20.2e | 13.2 | 2.7e | 13.9 | 7.0 | 13.5e | |
| Cell Area (A) ($ft^2$) | 3850 | 5800 | 5980 | 5720 | 4040 | 2640 | 540 | 2780 | 1400 | 2700 | **35,450** |
| Aquifer parameters (K) from well …….. | **PC132** | **PC131** | **PC50** | **PC130** | **PC129** | **PC128** | **PC127 & PC128(Av)** | **PC127** | **PC24** | **PC126** | |
| K ($gpd/ft^2$) [3] | 670 | 577 | 594 | 390 | 731 | 235 | 581 | 926 | 473 | 473 | |
| Q (gpd) (Q = KiA) [4] | 36113 | 46852 | 49730 | 31231 | 41345 | 8686 | 4392 | 36040 | 9271 | 17879 | **281,540** |
| **Q (gpm)** | 25 | 33 | 35 | 22 | 29 | 6 | 3 | 25 | 6 | 12 | **196** |
| **ClO4 mg/L (May 2007)** | 3.7 | 14.4 | 324 | 445 | 373 | 172 | 100e* | 305 | 13* | 9.0 | |
| **ClO4 lbs/day** | 1 | 6 | 134 | 116 | 129 | 12 | 4 | 92 | 0.5 | 1 | **495** |

**NOTES**

(1) Cell ID is well or soil boring name - locations shown on Plate 7 (ENSR 2007b). Cell width was centered on these borings/wells.
(2) Cell height is saturated thickness of alluvium (ENSR 2007b).
(3) Hydraulic conducitivity is from slug test data.
(4) Hydraulic gradient (i) is 0.014 ft/ft.

**DEFINITIONS**

| | |
|---|---|
| A | Area |
| ClO4 | Perchlorate |
| e | estimate |
| e* | estimate from April 1998 |
| ft | feet |
| $ft^2$ | feet squared |
| gpd | gallons per day |
| $gpd/ft^2$ | gallons per day per foot squared |
| gpm | gallons per minute |
| i | gradient |
| K | hydraulic conductivity |
| lbs/day | pounds per day |
| mg/L | milligrams per liter |
| Q | flow |
| * | concentration from May 2006 |

**REFERENCES**

**ENSR 2007b**, Annual Performance Report for Chromium and Perchlorate, July 2006-June 2007, Submitted in Accordance with Chromium Mitigation Program and Perchlorate Performance Consent Orders: ENSR, Camarillo, California, August 29, 2007, 4020-023-110.

**TABLE B-3**
**GROUNDWATER UNDERFLOW AND MASS FLUX - MAY 2007**
**SEEP TRAVERSE - USING SEEP WELLS PUMP TEST PARAMETERS**

| CELL ID (1) | PC120 | PC119 | PC118 | PC115R | PC99R | PC116R | PC117 | PC133 | TRAVERSE TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| Cell Width (ft) | 100 | 100 | 100 | 110 | 85 | 80 | 200 | 350 | 1,125 |
| Cell Height (ft) (2) | 40 | 41 | 42.5 | 44.5 | 45.5 | 43 | 41 | 31 | |
| Cell Area (A) ($ft^2$) | 4,000 | 4,100 | 4,250 | 4,895 | 3,868 | 3,440 | 8,200 | 10,850 | 43,603 |
| Aquifer parameters (K) from well …….. | PC120 | PC119 | PC118 | PC115R | PC99 | PC116R | PC117 | PC133 | |
| K ($gpd/ft^2$) (3) | 6,768 | 34,112 | 1,052 | 128 | 5,000 | 5,000 | 207 | 95 | |
| Q (gpd) (Q = KiA) (4) | 103,550 | 534,961 | 17,102 | 2,397 | 73,966 | 65,790 | 6,493 | 3,943 | 808,201 |
| **Q (gpm)** | 72 | 372 | 12 | 2 | 51 | 46 | 5 | 3 | **561** |
| **ClO4 mg/L (ENSR 2007b)** | 1.6 | 14.0 | 10.8 | 17.9 | 22.3 | 13.9 | 4.2 | 7.4 | |
| **ClO4 lbs/day** | 1 | 62 | 2 | 0.4 | 14 | 8 | 0.2 | 0.2 | **88** |

**NOTES:**

(1) Cell ID is well name in center of cell - locations shown on Figure 4 (this document) and Figure 4 (ENSR 2007b). Cell width was centered on these borings/wells.
(2) Cell height is saturated thickness of alluvium (ENSR 2007b, Figure 4).
(3) Hydraulic Conducitivity was from pumping test data.
(4) Hydraulic Gradient (i) is 0.003825 ft/ft.

**DEFINITIONS**

| | |
|---|---|
| A | Area |
| ClO4 | Perchlorate |
| ft | feet |
| $ft^2$ | feet squared |
| gpd | gallons per day |
| $gpd/ft^2$ | gallons per day per foot squared |
| gpm | gallons per minute |
| i | gradient |
| K | hydraulic conductivity |
| lbs/day | pounds per day |
| mg/L | milligrams per liter |
| Q | flow |

**REFERENCES**

**ENSR 2007b**, Annual Performance Report for Chromium and Perchlorate, July 2006-June 2007, Submitted in Accordance with Chromium Mitigation Program and Perchlorate Performance Consent Orders: ENSR, Camarillo, California, August 29, 2007, 4020-023-110.

# Appendix C

# Groundwater Velocity Estimates, North of the Interceptor Well Field and Barrier Wall

# APPENDIX C
## Evaluation of Groundwater Velocity Downgradient of the Barrier

An evaluation of the estimated groundwater velocity downgradient from the onsite slurry wall and recharge trenches was conducted to determine approximate travel times for the perchlorate and chromium plumes to reach the Athens Road well field. This evaluation was based on qualitative assessments of concentration versus time decline curves for monitor wells downgradient from the onsite recharge trenches.

The basis for the curve examinations was the determination of a “break-over point”. This break-over point represents the approximate point in time when recharged Lake Mead water containing very low concentrations of total chromium and perchlorate has moved a sufficient distance in the groundwater to a monitor well and is recognized as the beginning of a fairly consistent decline in concentrations of these constituents. For this evaluation, the break-over point is defined as that point halfway between the last high concentration point and the next sample point of a consistent decline. This is related back to the time of installation of the slurry wall (October 2001) and must therefore be chosen at a time after installation of the wall. **Figure C-1** is a time-series graph that illustrates the break-over point interpreted for perchlorate in monitor well PC-54. The time of the break-over point, July 2005, is compared back to the slurry wall date (October 2001) and represents a time period of 1368 days. For the calculation of estimated groundwater velocity, the distance from the recharge trenches to the well (2,000 feet) is divided by the break-over point time, giving a velocity in feet per day at that well (1.5 ft/d). **Table C-1** contains the estimated break-over time, distance from the recharge trenches, and estimated groundwater velocity for monitor wells down-gradient from the recharge trenches that show declines in constituent concentrations over time. **Attachment CA** to this appendix contains the time versus concentration graphs with plotted break over points for monitor wells down-gradient from the recharge trenches. Total chromium graphs for wells PC-64 and PC-65 were not prepared because too few total chromium analyses have been collected to date to create a meaningful graph.

**Figures C-2 and C-3** are graphical presentations of the number of estimated groundwater velocities calculated for each constituent graph per well that fall within a given velocity range. The highest and lowest velocities from **Table C-1** were not included in the graphs, as these values were observed to be outliers to the majority of the perchlorate and chromium transport velocity estimates. An evaluation of **Figures C-2 and C-3** reveals that the bulk of the estimated groundwater velocities generated from both the perchlorate and chromium decline curves fall within the 1 to 4 ft/d intervals, however, the most common velocity noted in the estimations was between 1 and 2 ft/d. It is interesting to note the similarity between the predicted perchlorate and chromium transport velocities. It would be assumed that chromium in groundwater would be retarded more than perchlorate. However, this does not appear to be the case, and may reflect absorption characteristics of the aquifer matrix and general absence of organic material.

From this spread of values, a representative velocity of 1.5 ft/d can be utilized as an estimate to determine the approximate time for the on-site slurry wall and recharge trench effects to reach downgradient locations. For example, the downgradient distance from the on-site recharge trenches to the monitor well array at Sunset Road is approximately 6,600 feet. Based on the 1.5 feet per day estimate of groundwater velocity, the effects of the onsite barrier wall / recharge trenches could be noted in the Sunset Road monitor wells in 4400 days from October 2001 (barrier wall emplacement), or roughly by or before fourth quarter 2013. The same calculation for the Athens Road well field (8,000 feet downgradient) would be 14.6 years, or second quarter 2015.

Even though the bulk of the groundwater velocities from the qualitative break-over point estimations fall roughly in the 1.5 ft/d interval, there were a significant number of velocities in the 2 to 3 ft/d range. Utilizing an average groundwater velocity of 2.5 ft/d for these estimates, the above time frames for Sunset Road and Athens Road would be reduced to 7.2 years (fourth quarter 2008) and third quarter 2010), respectively.

Because of the variable nature of the alluvium, multiple groundwater velocities are to be expected both within alluvial channels and in inter-channel areas. The estimated 1.5 ft/d velocity could very easily represent an overall average for the alluvial system with the understanding that channel areas may display greater velocities. Of note is an additional review of the perchlorate time versus concentration graphs for wells PC-64, -65, -66, and -67 in **Attachment CA**. The break-over point for both PC-64 and PC-65 is based on a minimal number of values and will require additional data from future sampling to confirm the timeframe. The perchlorate graphs for wells PC-66 and PC-67 tell a different story. In both cases, perchlorate values are still increasing, which would indicate that the break-over point has not as yet reached these wells. If this is the case, then the reduced concentration “front” in the alluvium in this down-gradient area is between PC-64 / -65 and PC-66 / -67, approximately 3,700 feet down-gradient from the recharge trenches.

This groundwater velocity evaluation based on a break-over point of declining groundwater constituent concentrations serves as an adequate, qualitative method for determining approximate time frames for the onsite remediation activities to impact down-gradient areas. The subjective determination of break-over points is “evergreen” in the sense that changes and adjustments can occur as additional groundwater data are collected.

**FIGURE C-1**
**Well PC-54**
**Perchlorate**

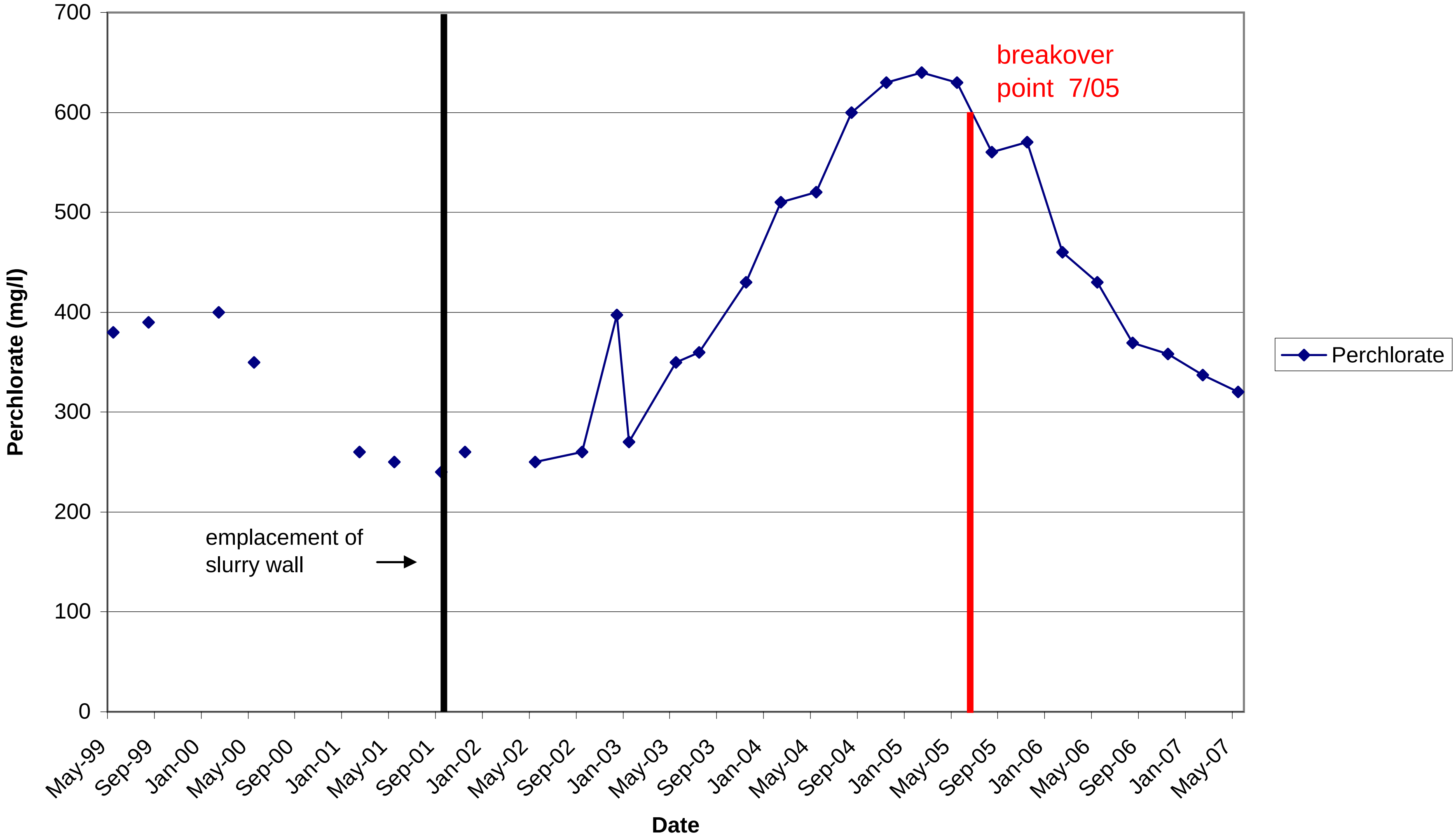


**Figure C-2**
**Groundwater velocities from perchlorate trends**

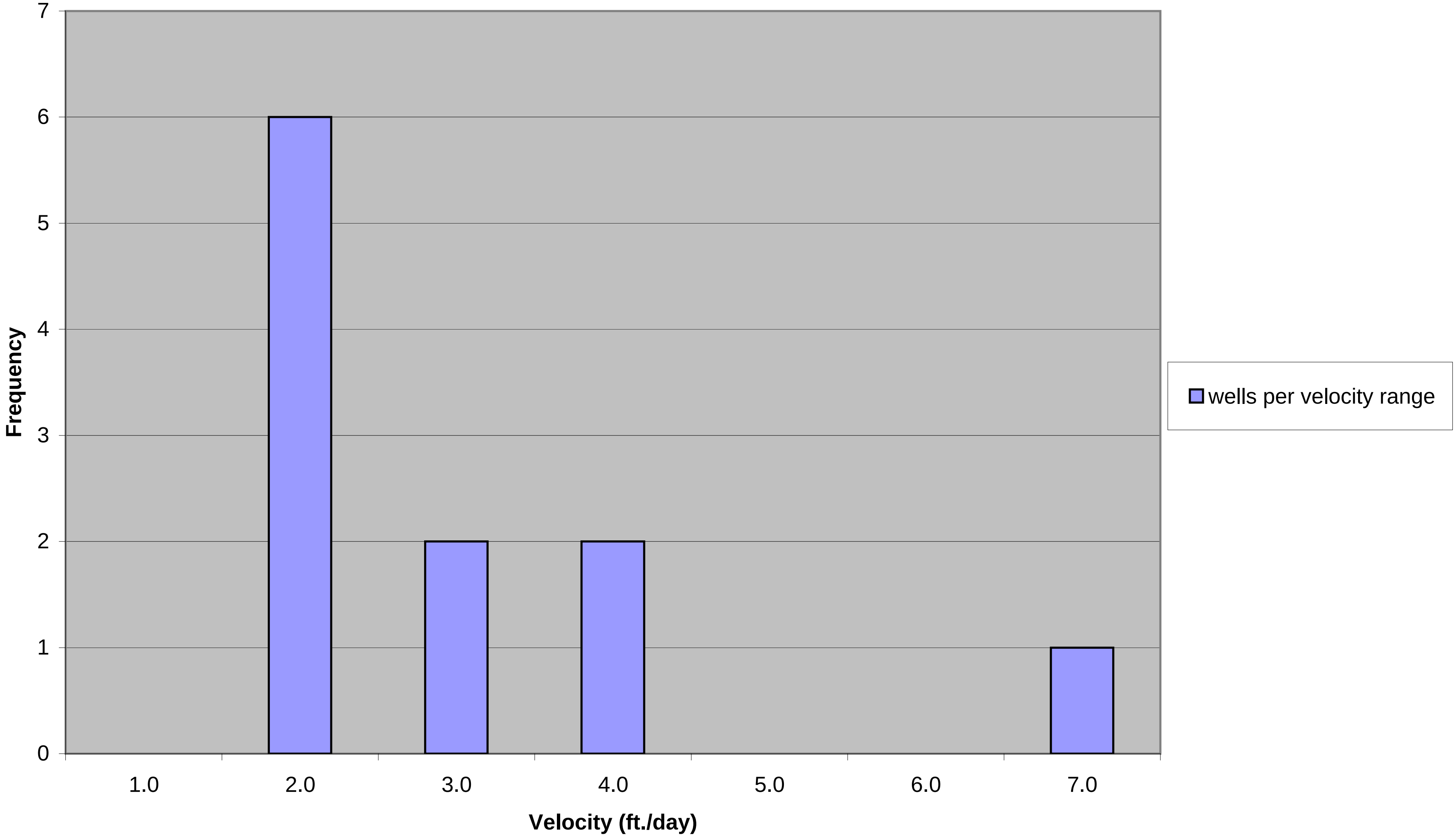


**Figure C-3**
**Groundwater velocities from total chromium trends**

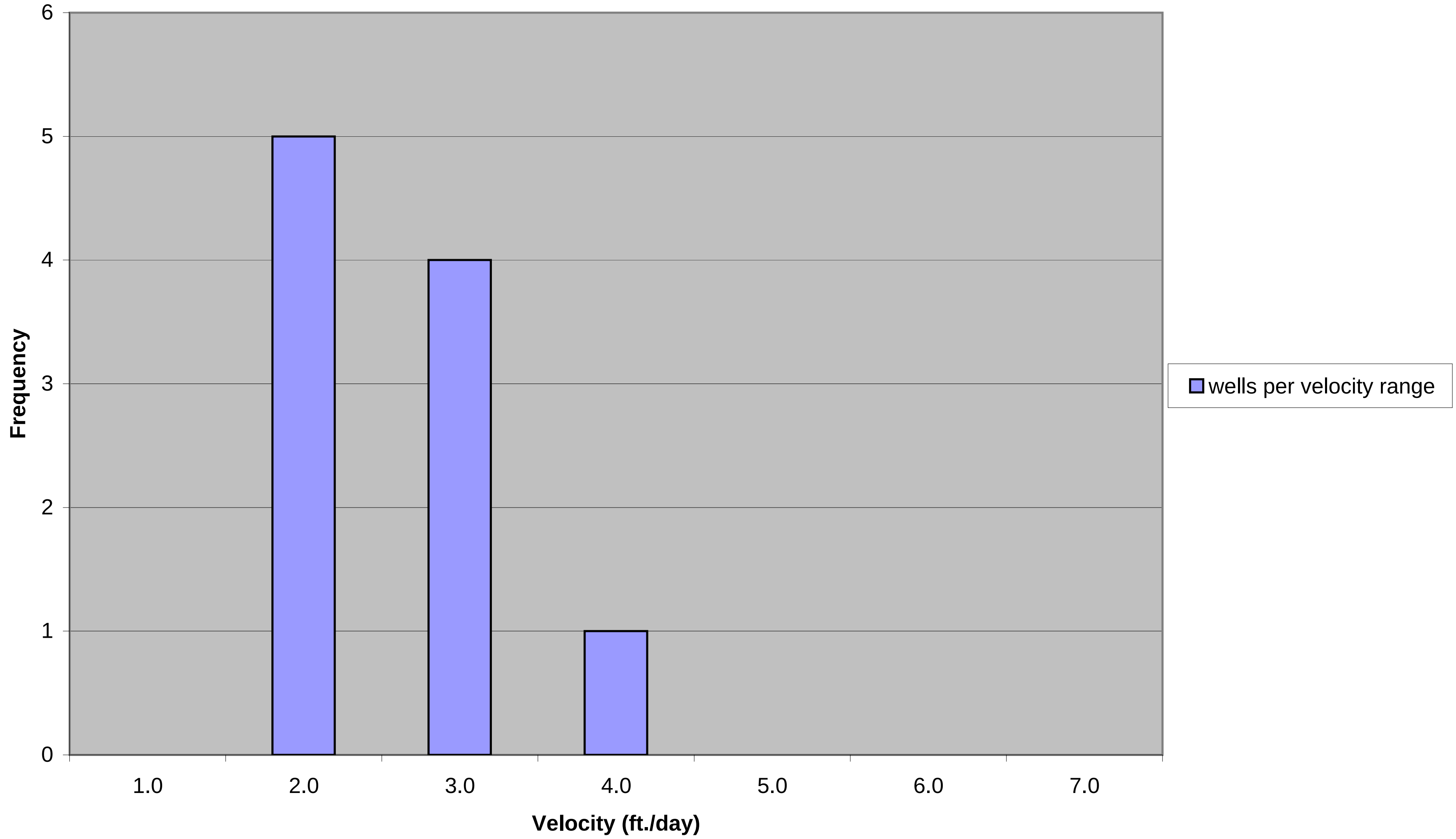


**TABLE C-1**
**GROUNDWATER VELOCITY DATA**

| Well number | Distance (ft) from recharge trenches | Breakover point time (days) | Calculated groundwater velocity (ft/d) |
|---|---|---|---|
| M-23 - P (1) | 1400 | 123 | 11.4 |
| M-23 - C | 1400 | 426 | 3.3 |
| M-48 - P | 1300 | 457 | 2.8 |
| M-48 - C | 1300 | 638 | 2 |
| M-87 - P (1) | 500 | 547 | 0.9 |
| M-87 - C | 500 | 426 | 1.2 |
| M-95 - P | 2600 | 761 | 3.4 |
| M-95 - C | 2600 | 1126 | 2.3 |
| M-96 - P | 2600 | 822 | 3.2 |
| M-96 - C | 2600 | 912 | 2.9 |
| M-100 - P | 750 | 123 | 6.1 |
| M-100 - C (1) | 750 | 61 | 12.3 |
| M-101 - P | 700 | 547 | 1.3 |
| M-101 - C | 700 | 547 | 1.3 |
| M-102 - P | 800 | 638 | 1.3 |
| M-102 - C | 800 | 700 | 1.1 |
| PC-37 - P | 2400 | 1460 | 1.6 |
| PC-37 - C | 2400 | 1368 | 1.8 |
| PC-54 - P | 2000 | 1368 | 1.5 |
| PC-54 - C | 2000 | 1277 | 1.6 |
| PC-64 - P | 3600 | 1856 | 1.9 |
| PC-65 - P | 3600 | 1856 | 1.9 |
| PC-72 - P | 2900 | 1187 | 2.4 |
| PC-72 - C | 2900 | 1187 | 2.4 |

**Notes**

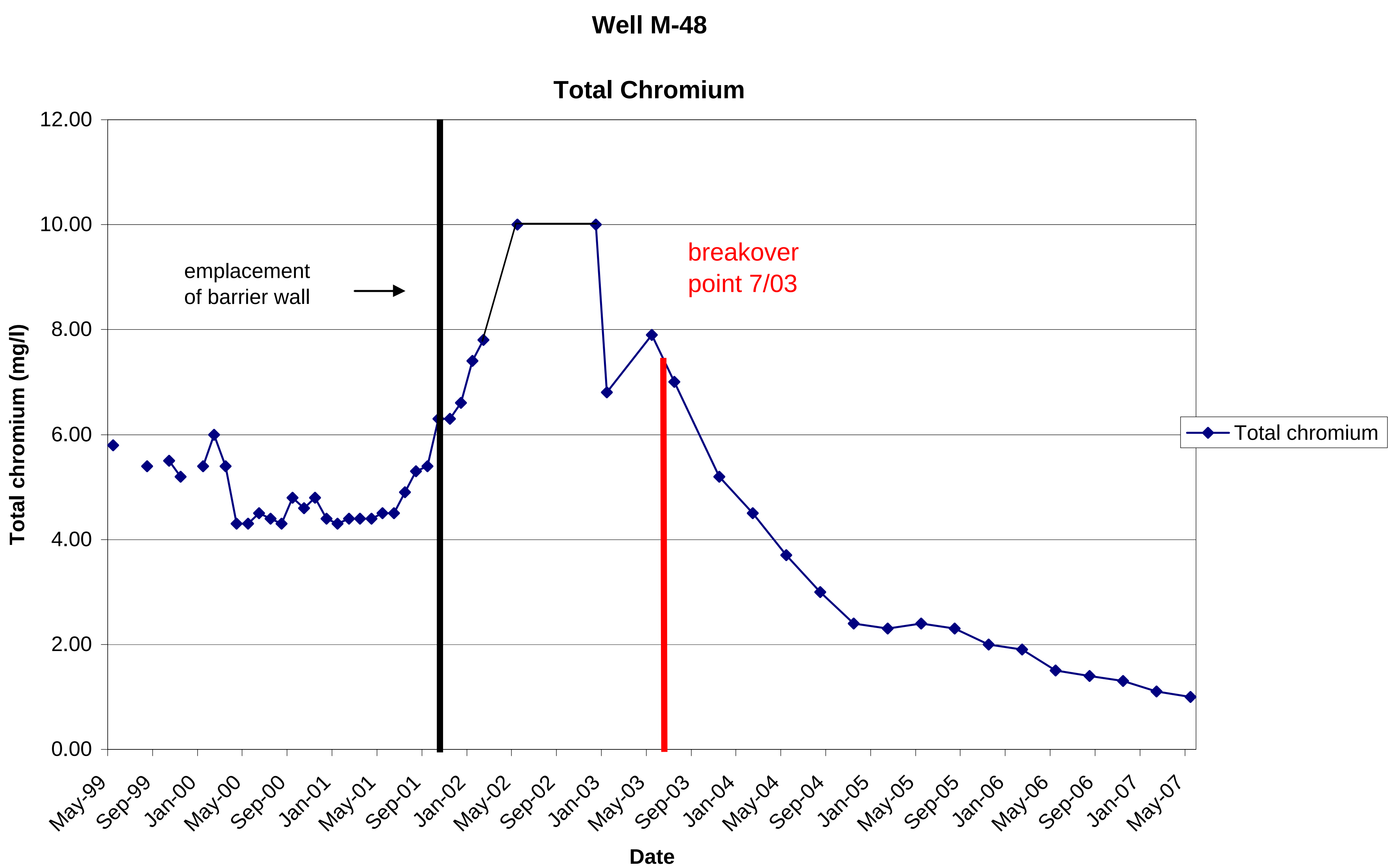
**(1)** **Not included in Figures C-2 and C-3.**

**Definitions**

**P** **Velocity estimate from perchlorate time series**
**C** **Velocity estimate from total chromium time series**
**ft** **feet**
**ft/d** **feet per day**

# Attachment CA

## Perchlorate and Chromium Time-Series Graphs for Wells North of the Recharge Trenches


Well M-48
Total Chromium
Total chromium (mg/l)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
emplacement
of barrier wall
breakover
point 7/03
Total chromium
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
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Jan-05
May-05
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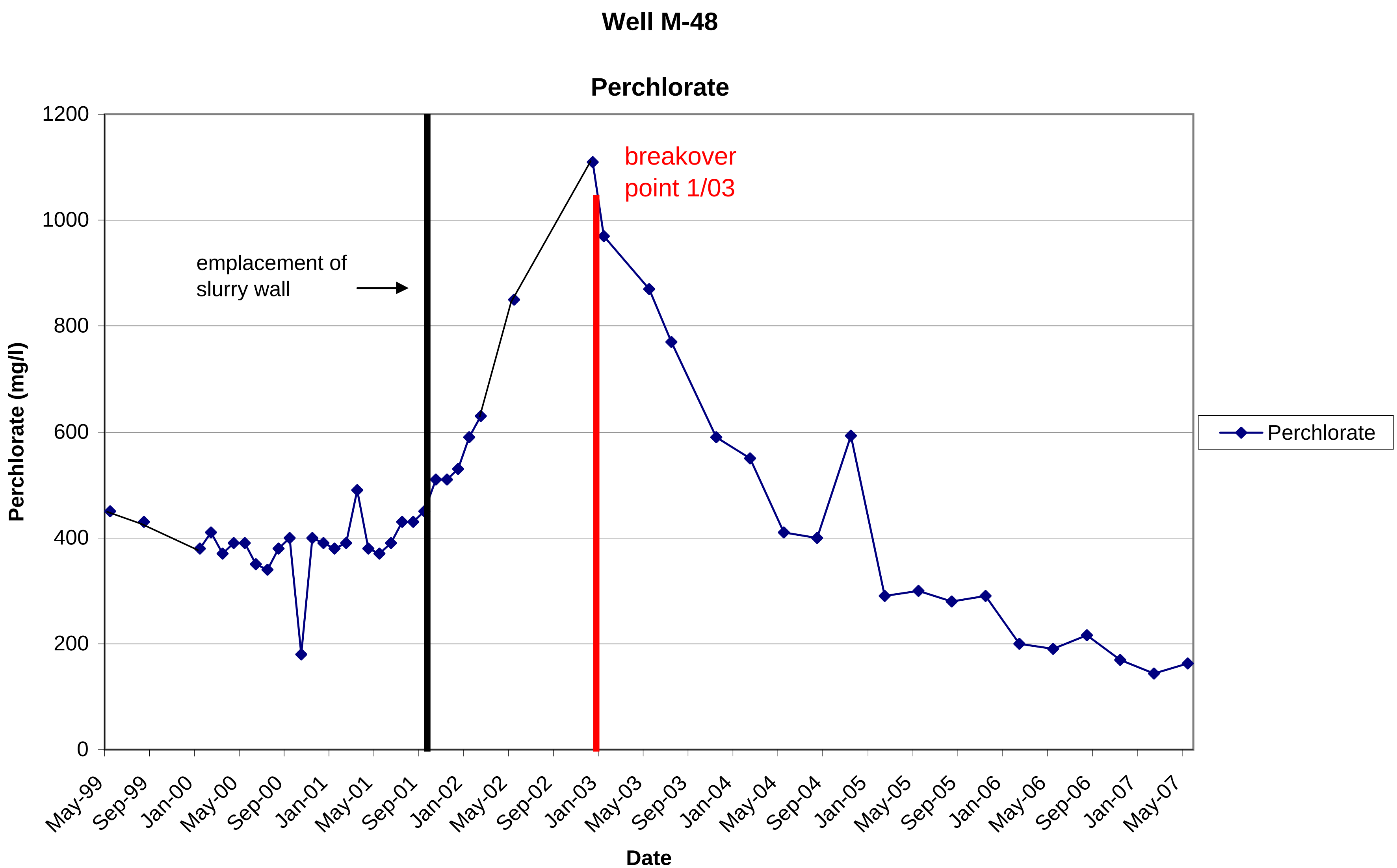
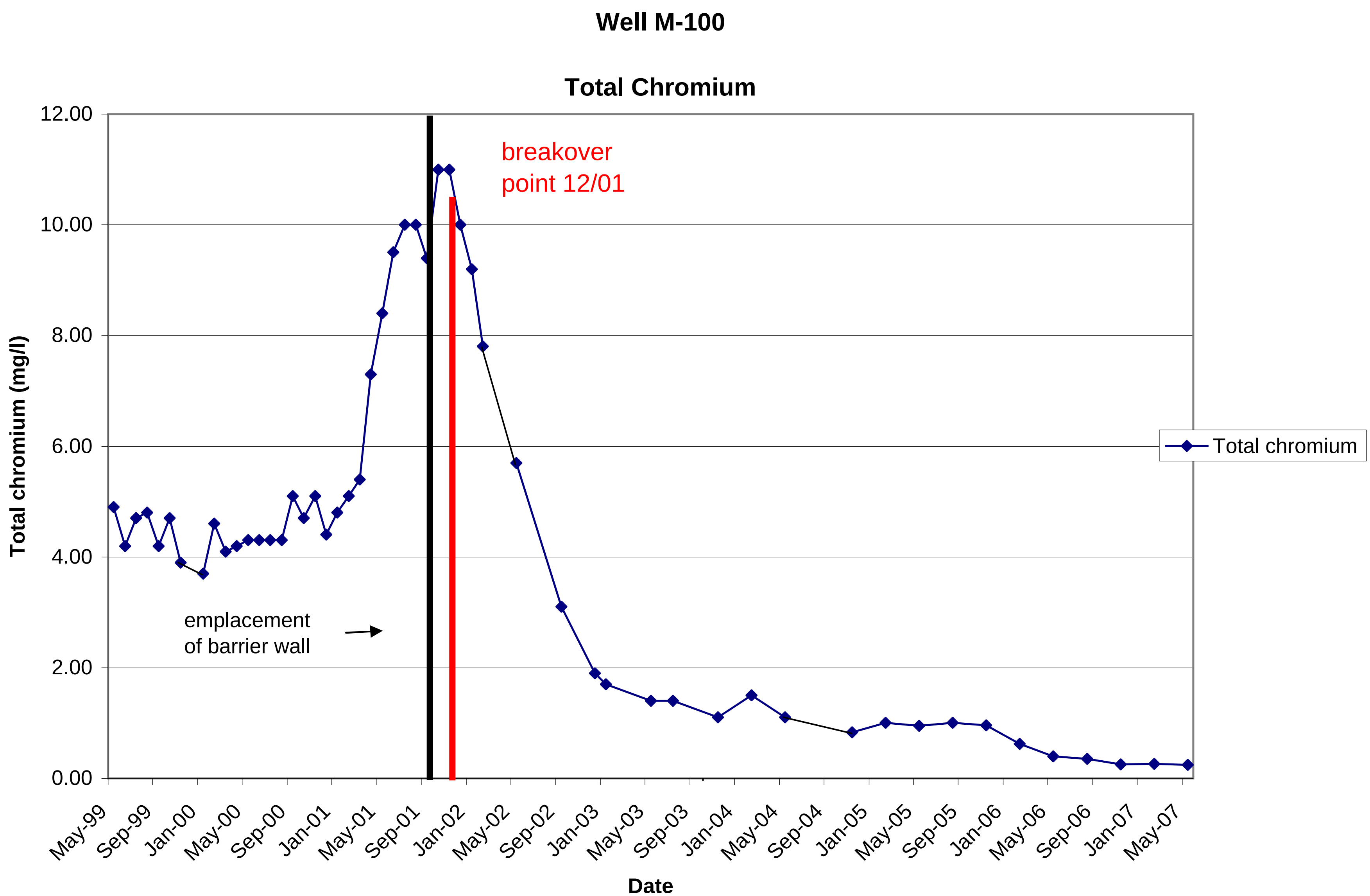
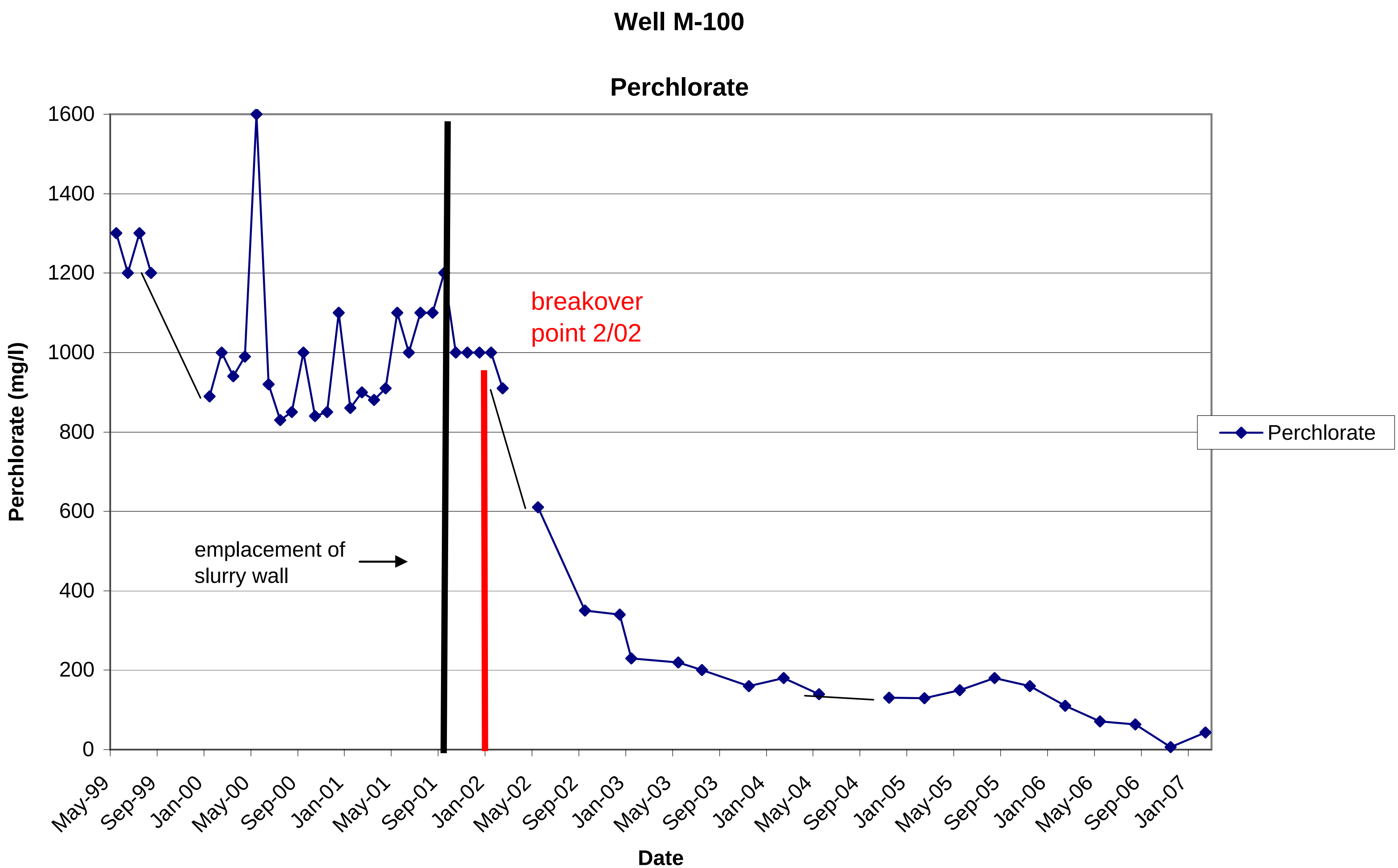
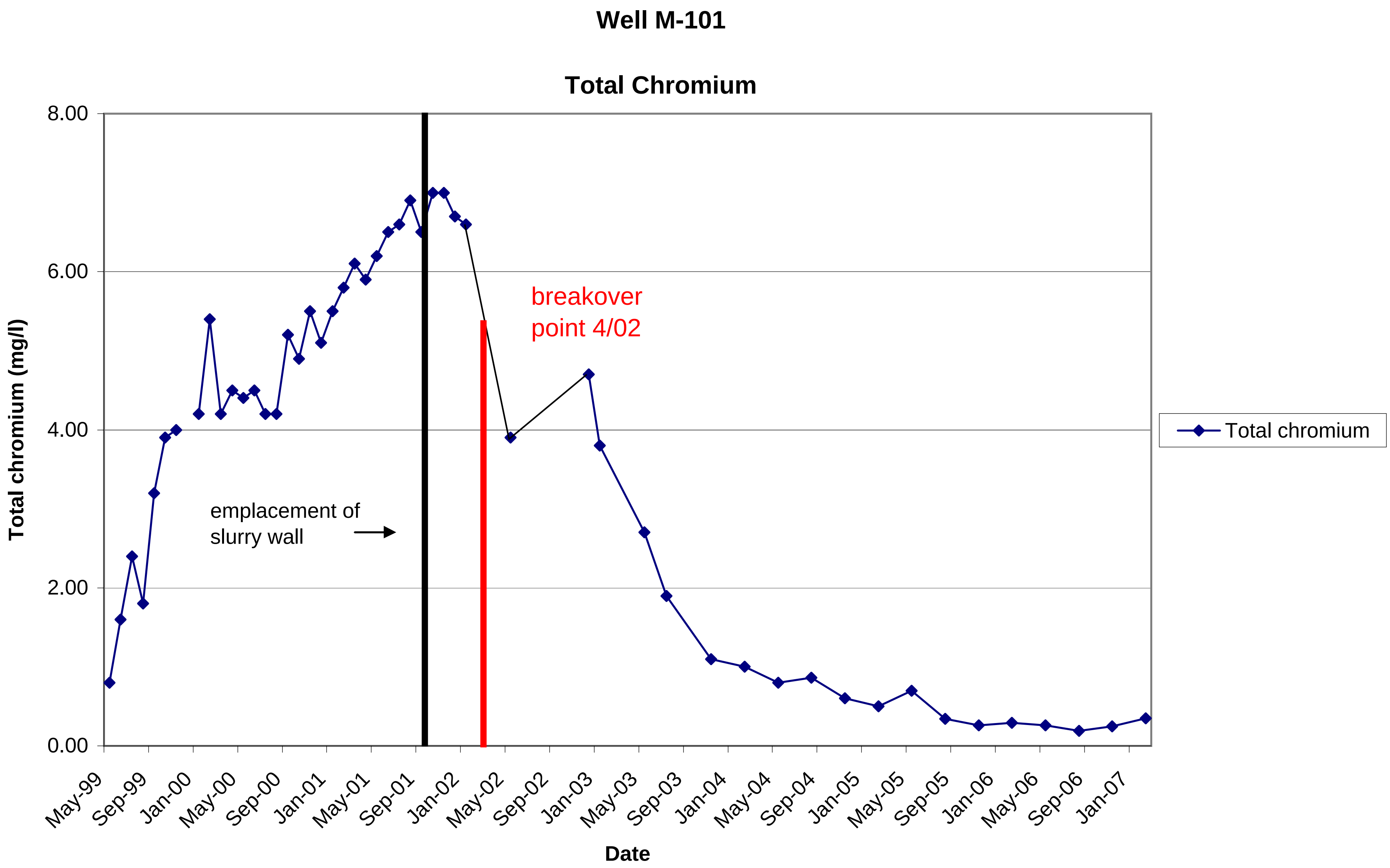
Jan-06
May-06
Sep-06
Jan-07
May-07
Date



Well M-48
Perchlorate
Perchlorate (mg/l)
1200
1000
800
600
400
200
0
emplacement of
slurry wall
breakover
point 1/03
Perchlorate
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date


Well M-100
Total Chromium
breakover
point 12/01
emplacement
of barrier wall
Total chromium (mg/l)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date
Total chromium


Well M-100
Perchlorate
1600
1400
1200
1000
800
600
400
200
0
Perchlorate (mg/l)
breakover
point 2/02
emplacement of
slurry wall
Perchlorate
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
Date



Well M-101
Total Chromium
Total chromium (mg/l)
8.00
6.00
4.00
2.00
0.00
breakover
point 4/02
emplacement of
slurry wall
Total chromium
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
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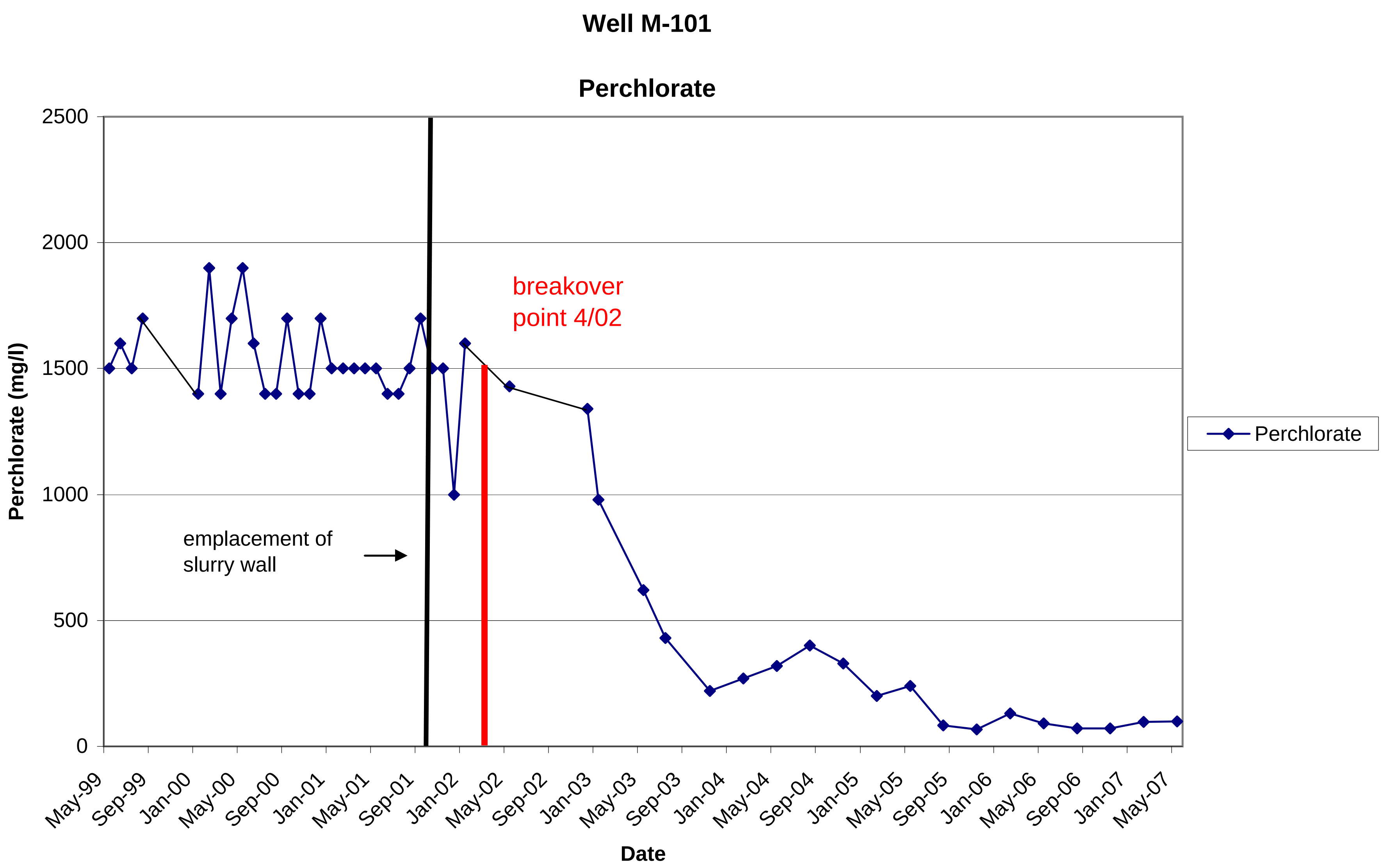
May-06
Sep-06
Jan-07
Date



Well M-101
Perchlorate
Perchlorate (mg/l)
2500
2000
1500
1000
500
0
breakover
point 4/02
emplacement of
slurry wall
Perchlorate
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
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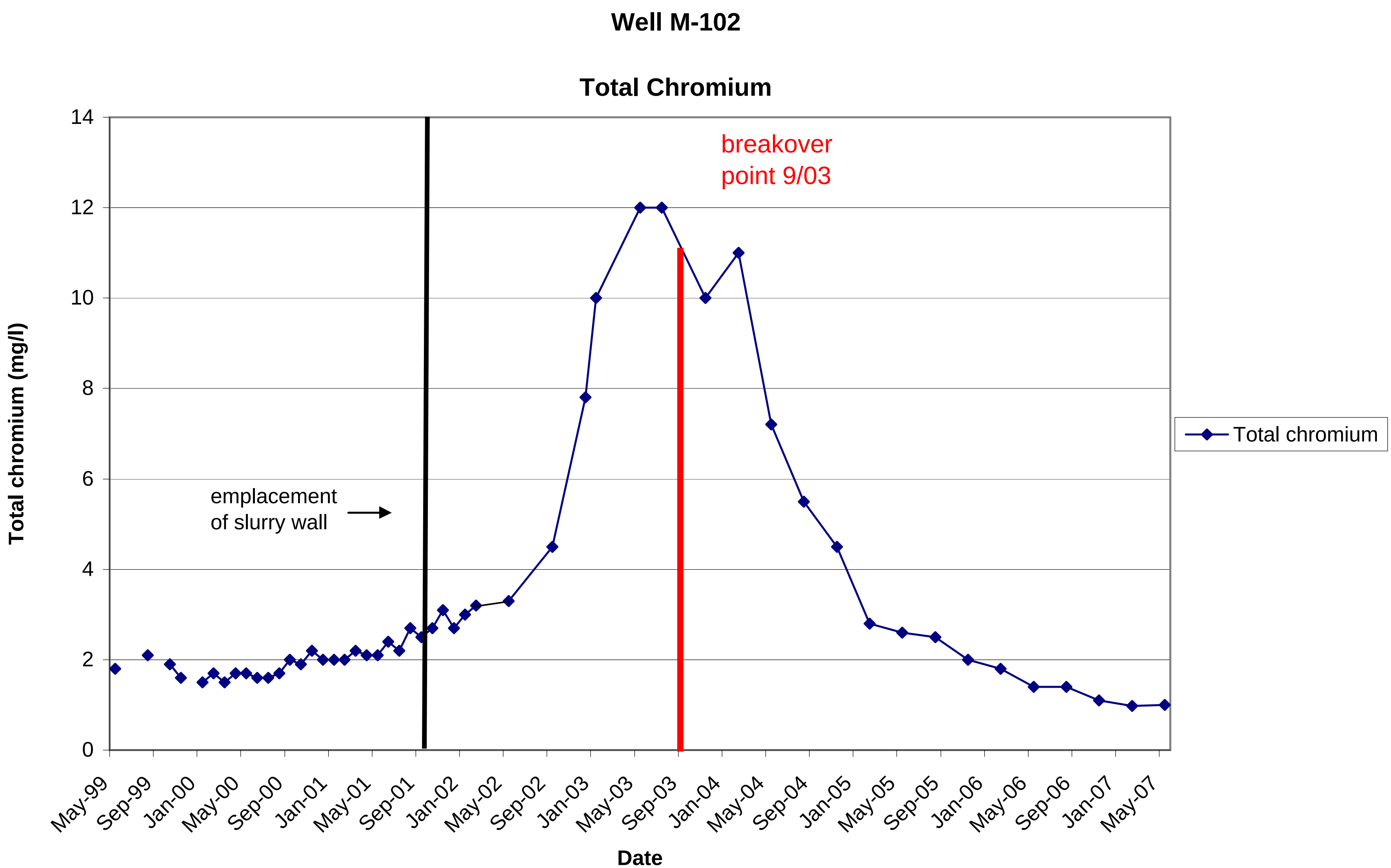
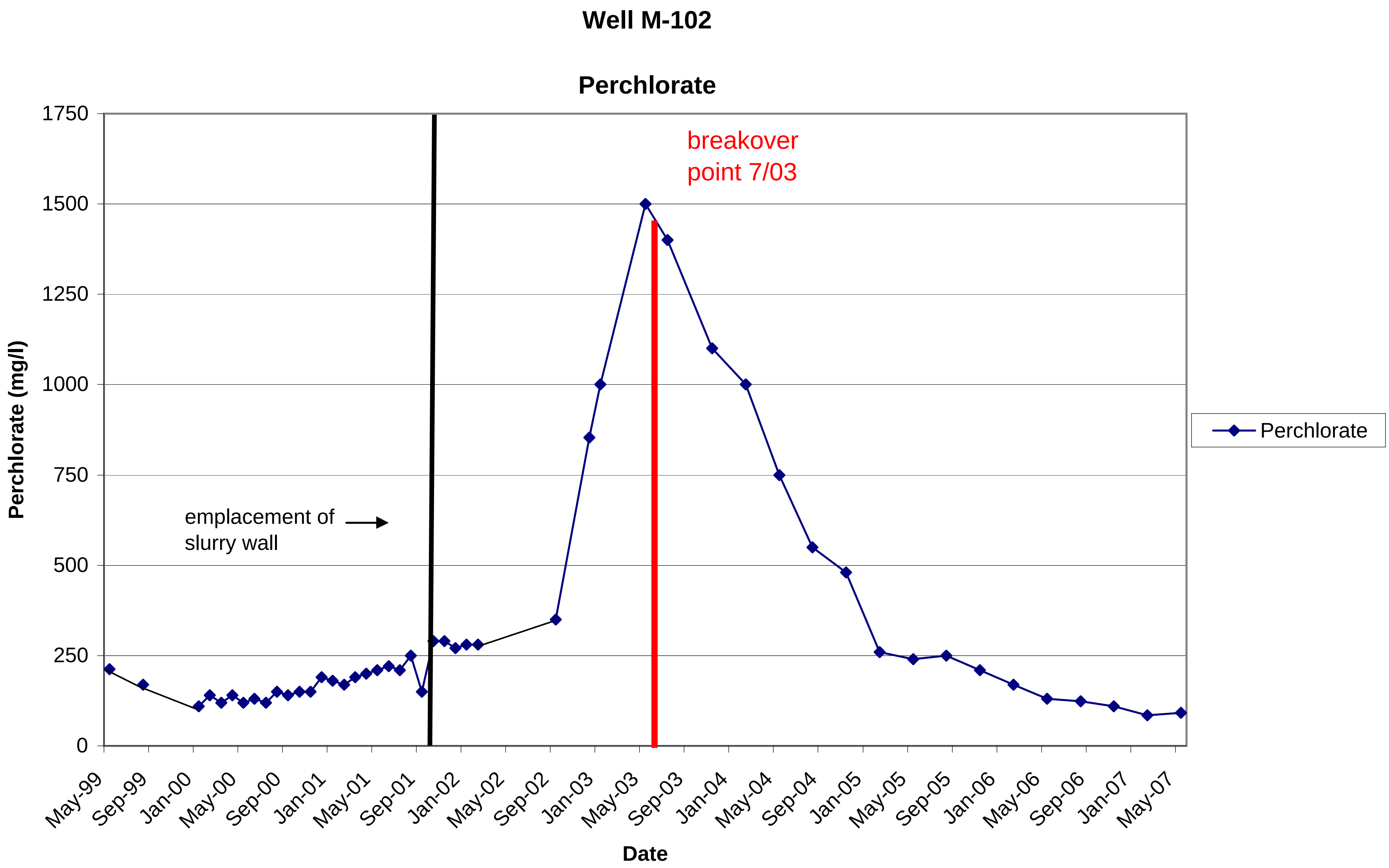
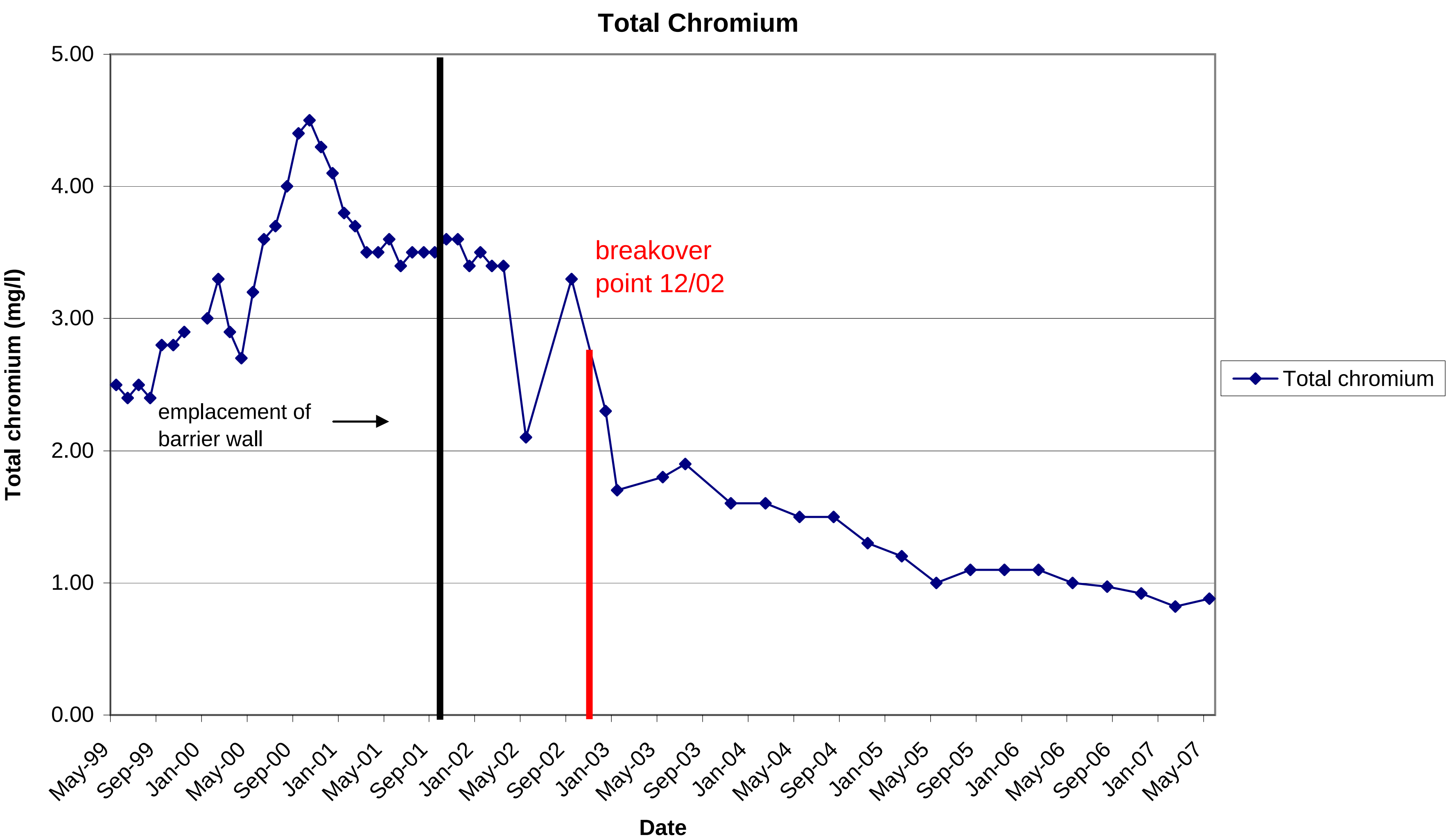
Jan-07
May-07
Date



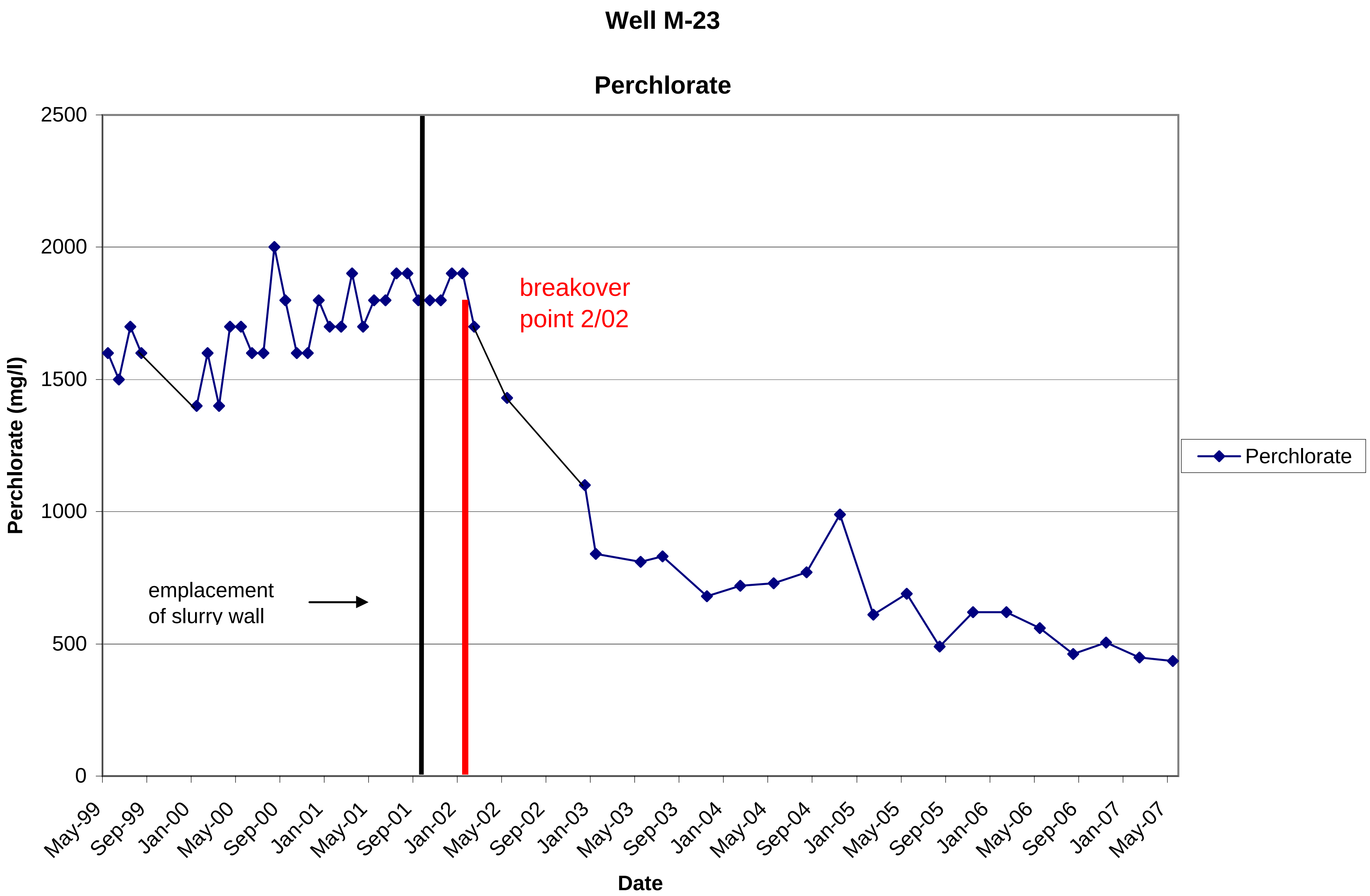
Well M-102
Total Chromium
breakover point 9/03
emplacement of slurry wall
Total chromium
Total chromium (mg/l)
Date
0
2
4
6
8
10
12
14
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07

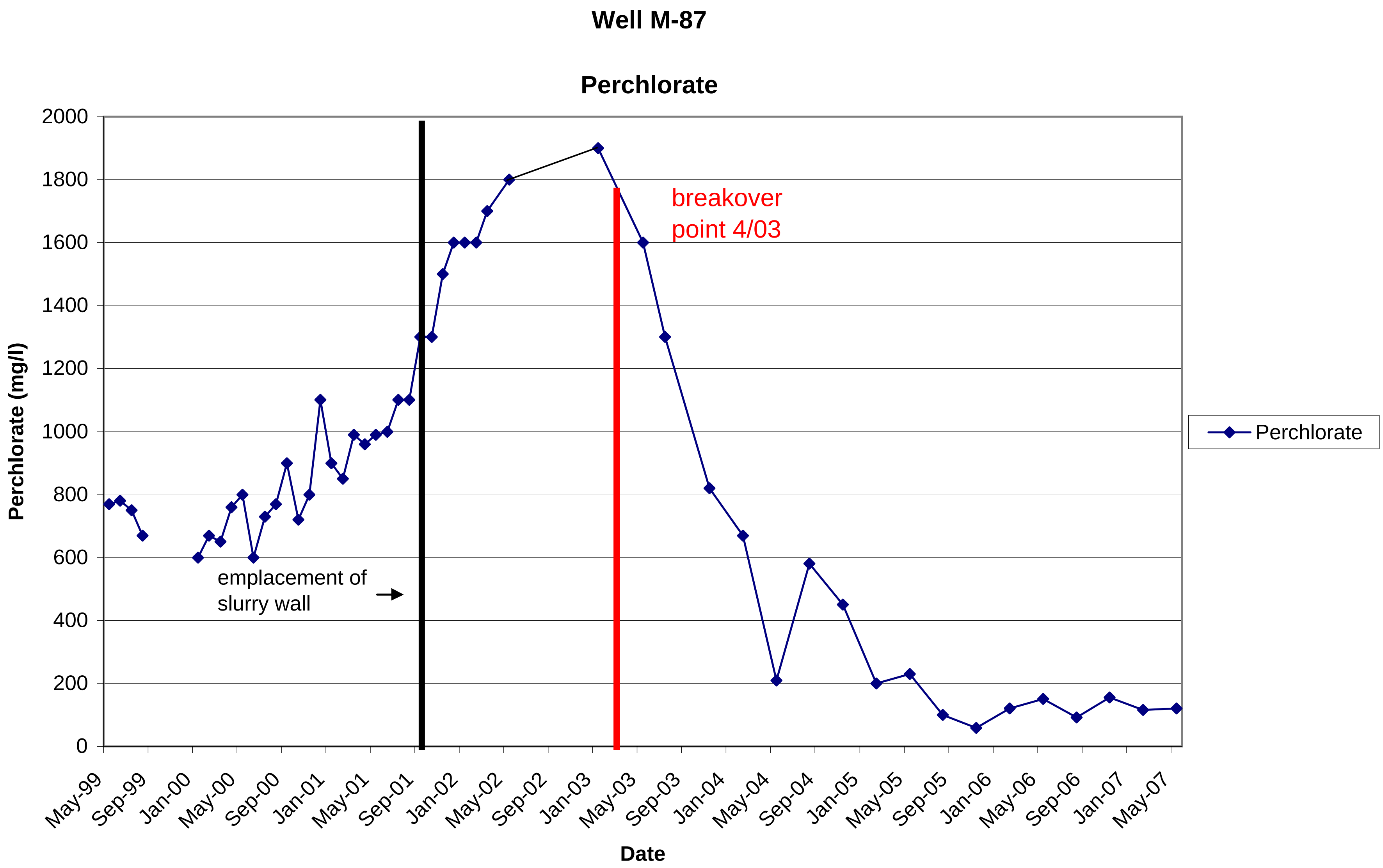

Well M-102
Perchlorate
Perchlorate (mg/l)
1750
1500
1250
1000
750
500
250
0
breakover
point 7/03
emplacement of
slurry wall
Perchlorate
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date

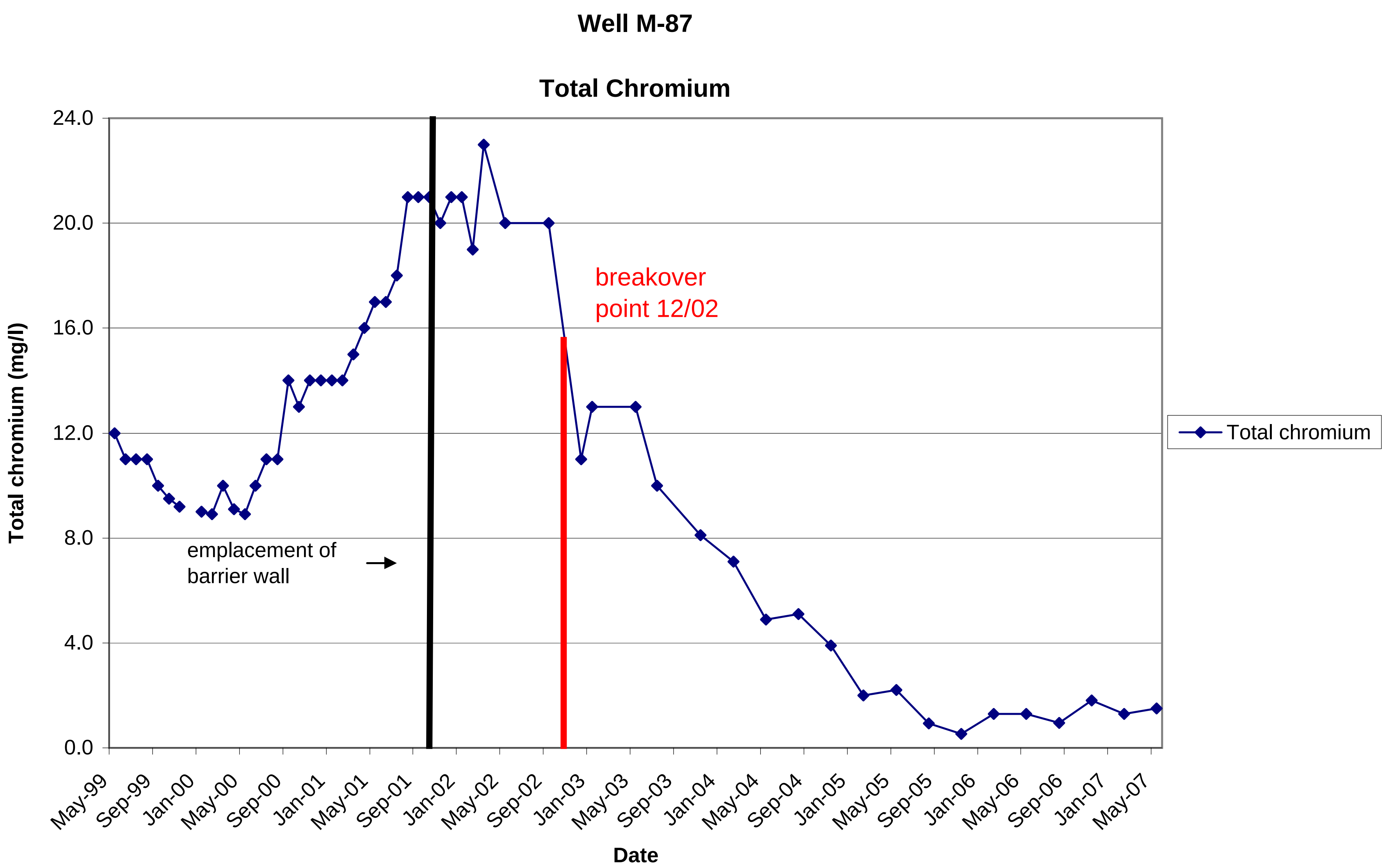
## Well M-23



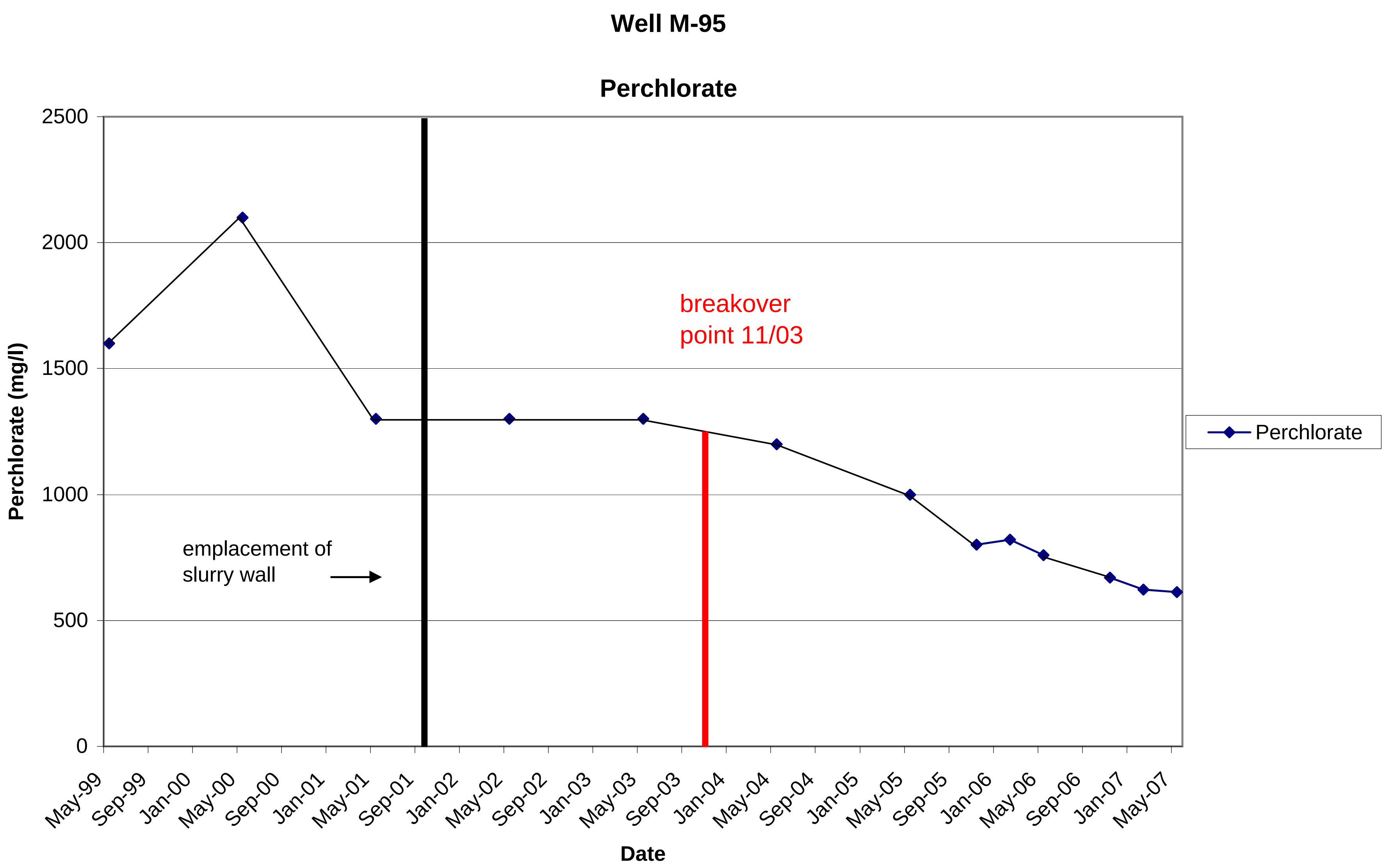
Total Chromium
5.00
4.00
3.00
2.00
1.00
0.00
Total chromium (mg/l)
emplacement of
barrier wall
breakover
point 12/02
Total chromium
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date


Well M-23
Perchlorate
Perchlorate (mg/l)
2500
2000
1500
1000
500
0
breakover
point 2/02
emplacement
of slurry wall
Perchlorate
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date

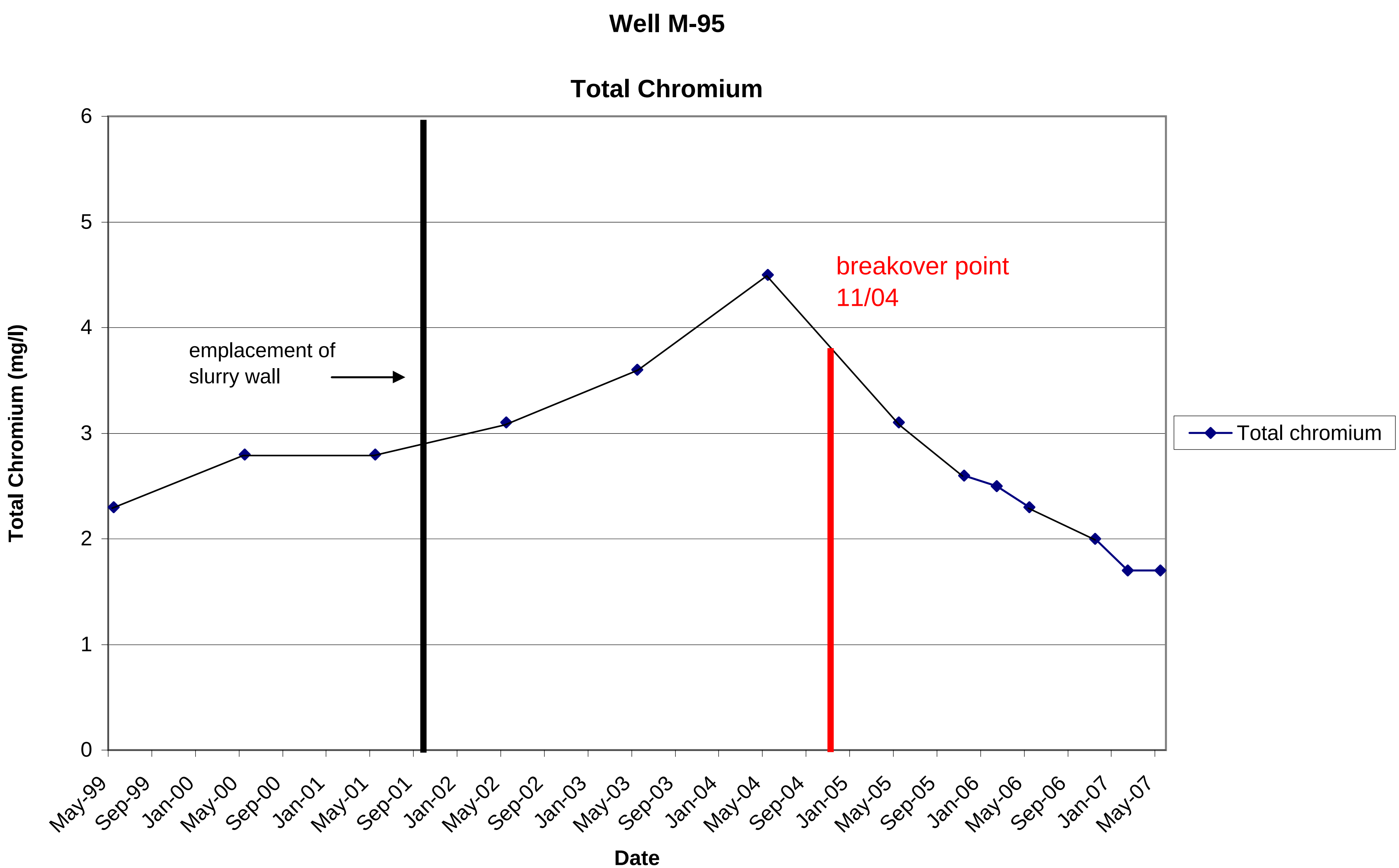

Well M-87
Perchlorate
Perchlorate (mg/l)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
emplacement of
slurry wall
breakover
point 4/03
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date
Perchlorate

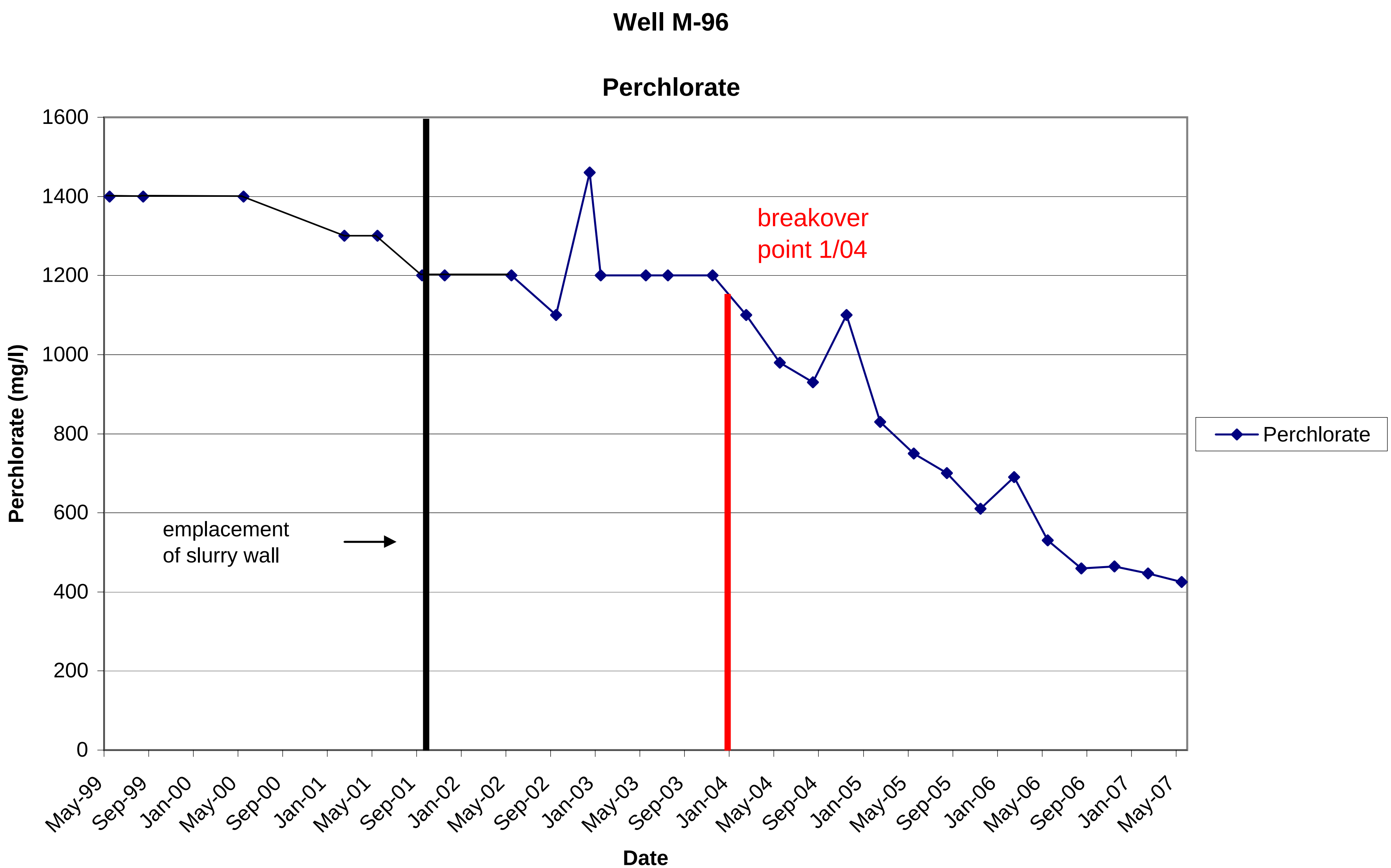


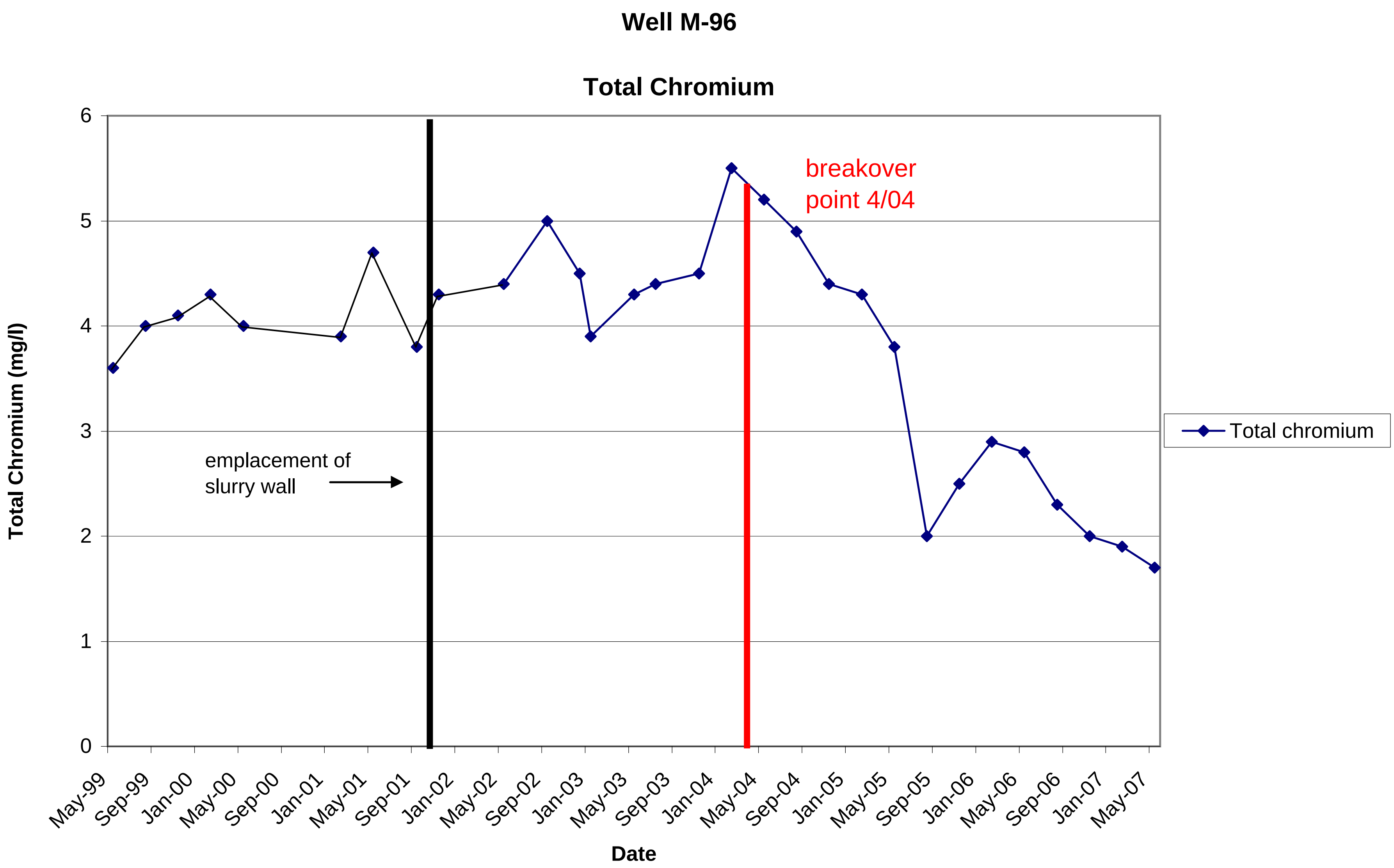
Well M-87
Total Chromium
Total chromium (mg/l)
24.0
20.0
16.0
12.0
8.0
4.0
0.0
breakover
point 12/02
emplacement of
barrier wall
Total chromium
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date

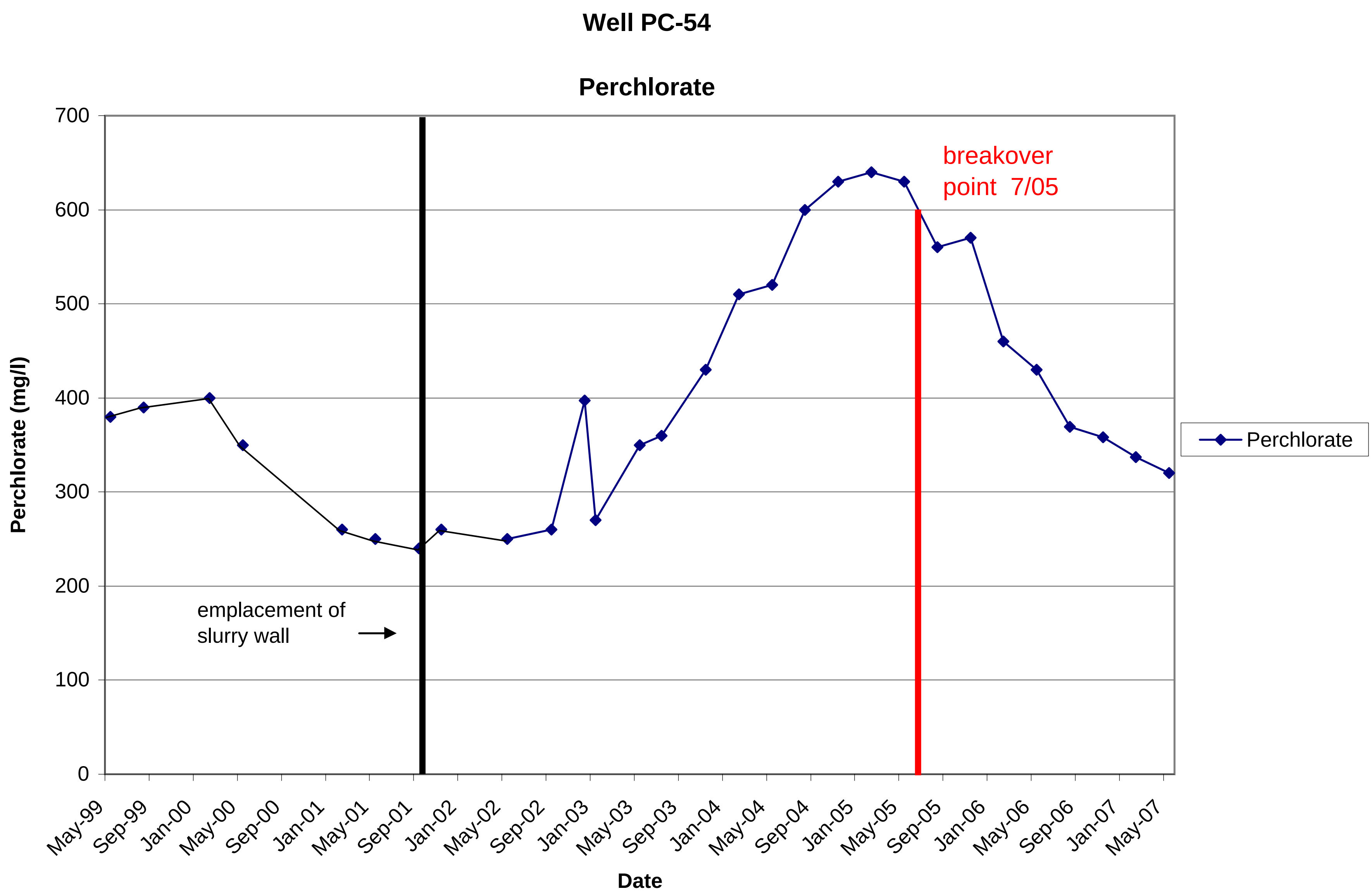


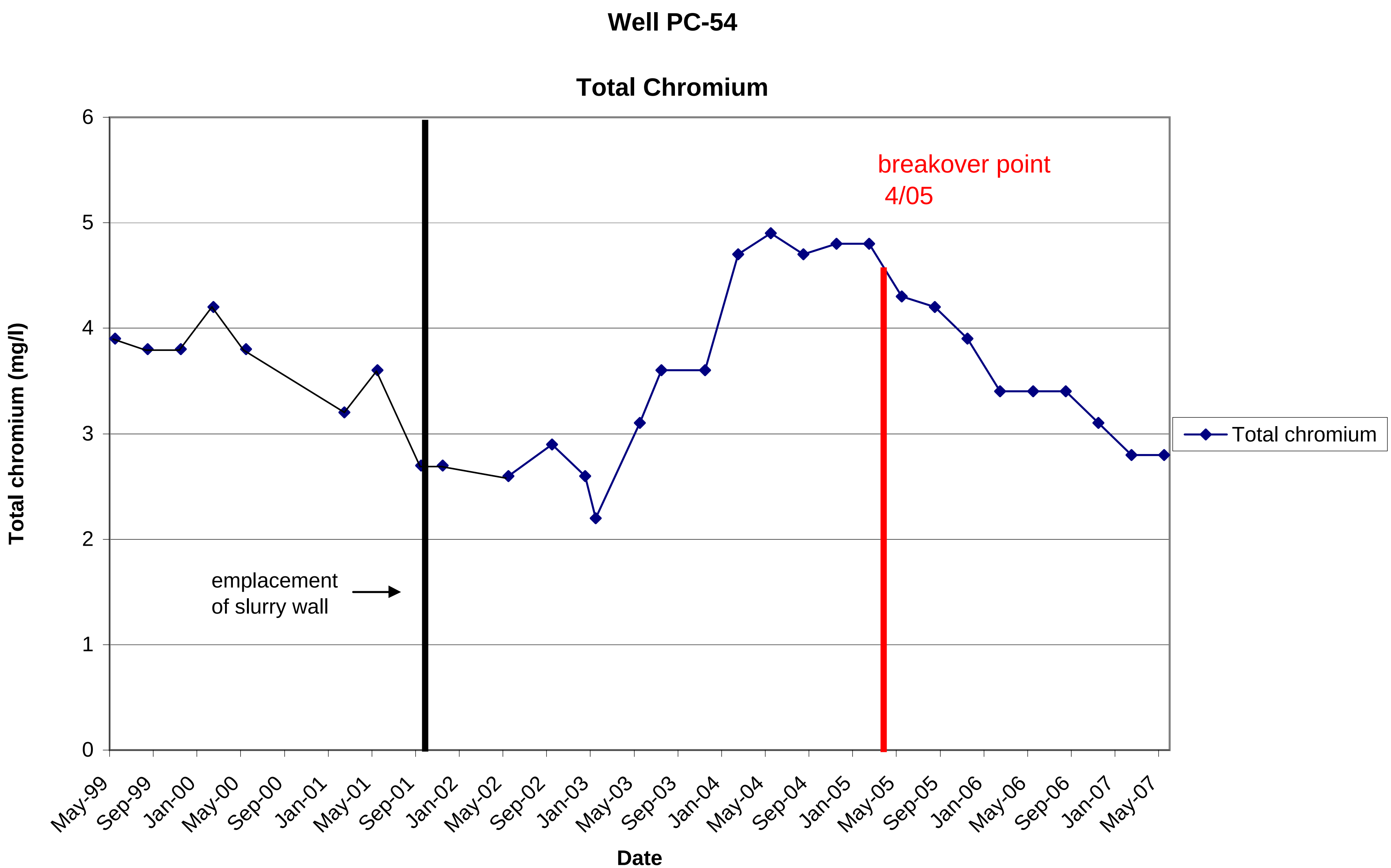
Well M-95
Perchlorate
2500
2000
1500
1000
500
0
Perchlorate (mg/l)
breakover
point 11/03
emplacement of
slurry wall
Perchlorate
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date


Well M-95
Total Chromium
Total Chromium (mg/l)
6
5
4
3
2
1
0
emplacement of
slurry wall
breakover point
11/04
Total chromium
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date

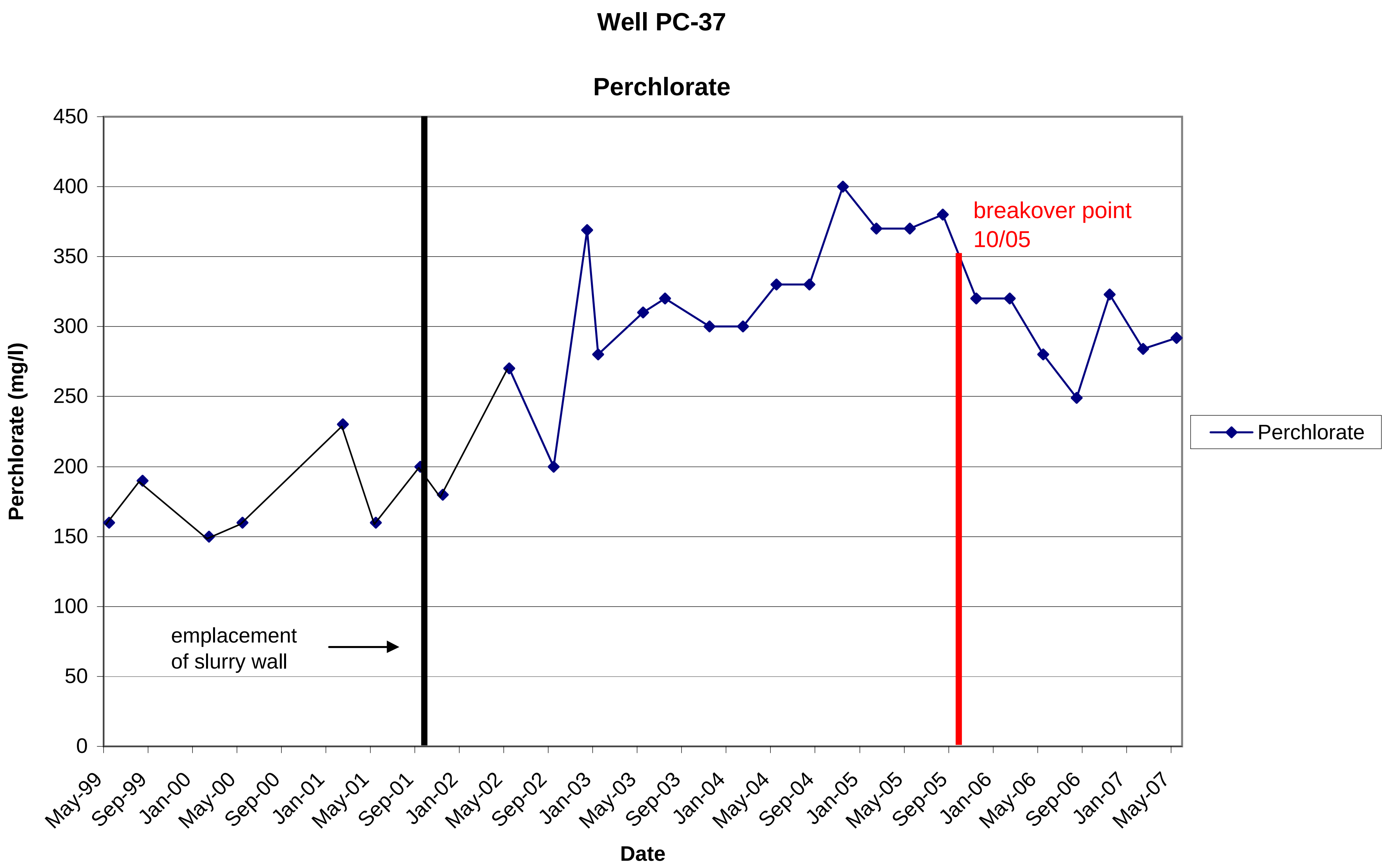

Well M-96
Perchlorate
Perchlorate (mg/l)
1600
1400
1200
1000
800
600
400
200
0
breakover
point 1/04
emplacement
of slurry wall
Perchlorate
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date


Well M-96
Total Chromium
Total Chromium (mg/l)
0
1
2
3
4
5
6
emplacement of
slurry wall
breakover
point 4/04
Total chromium
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date

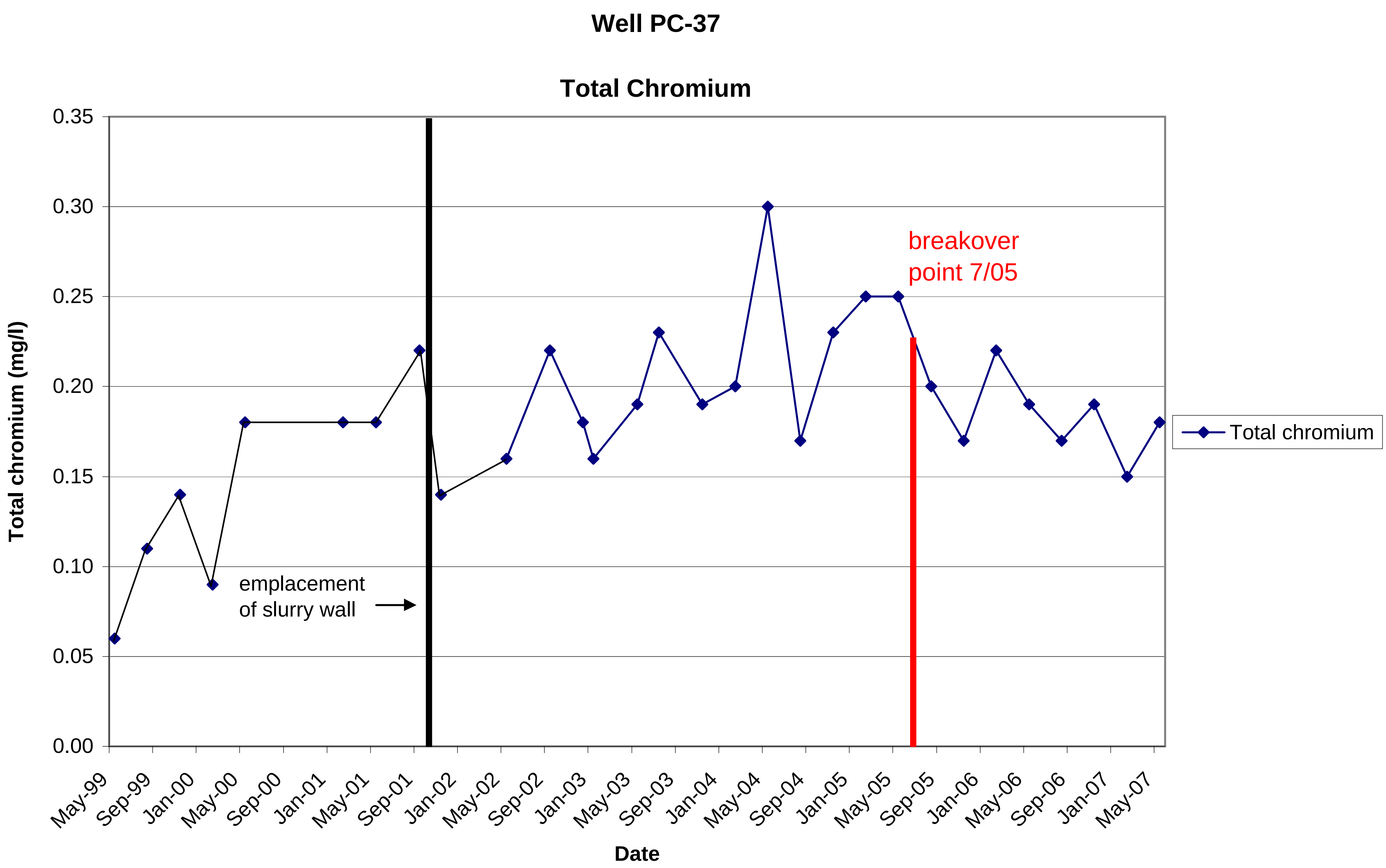

Well PC-54
Perchlorate
700
600
500
400
300
200
100
0
Perchlorate (mg/l)
breakover
point 7/05
emplacement of
slurry wall
Perchlorate
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date

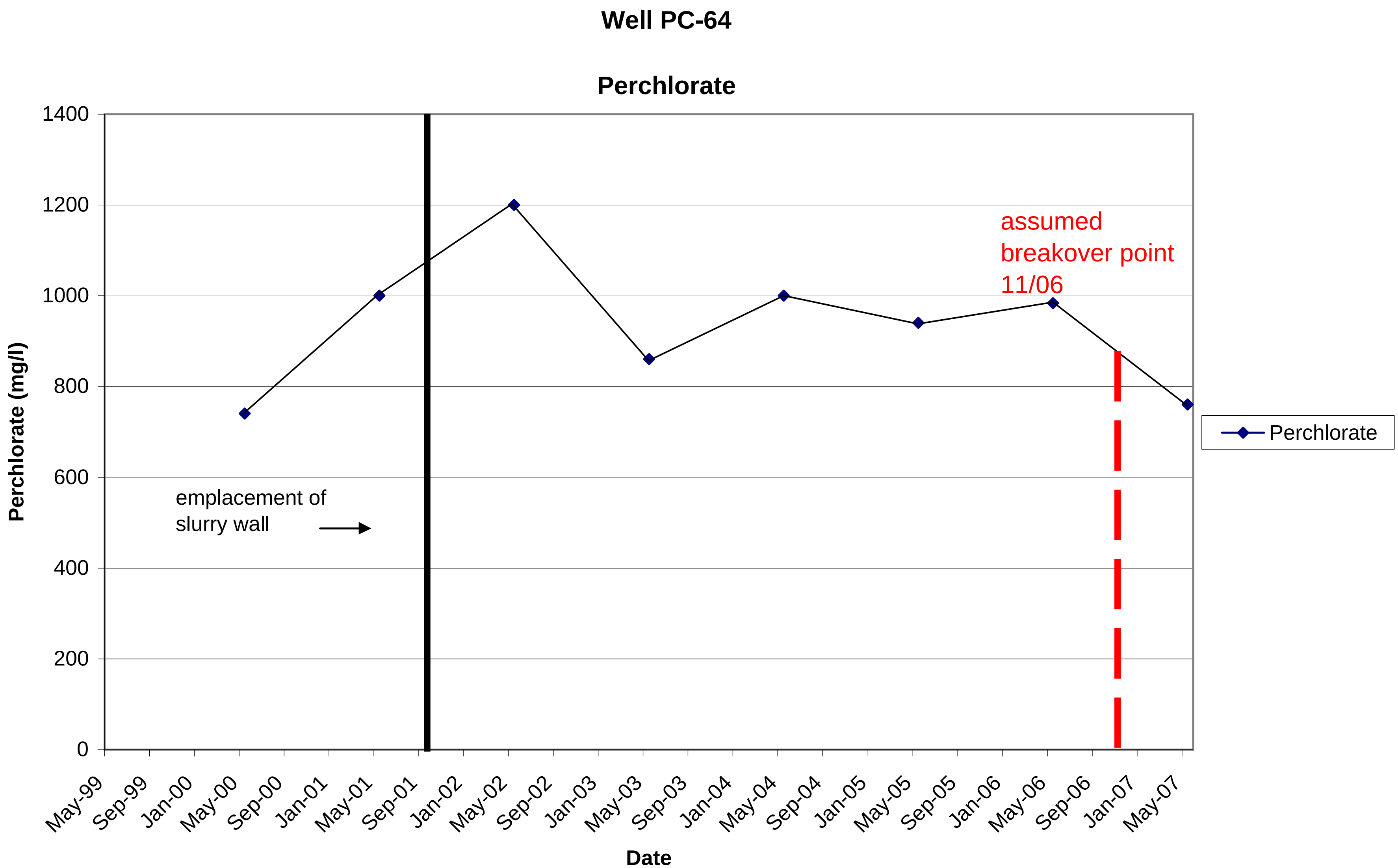


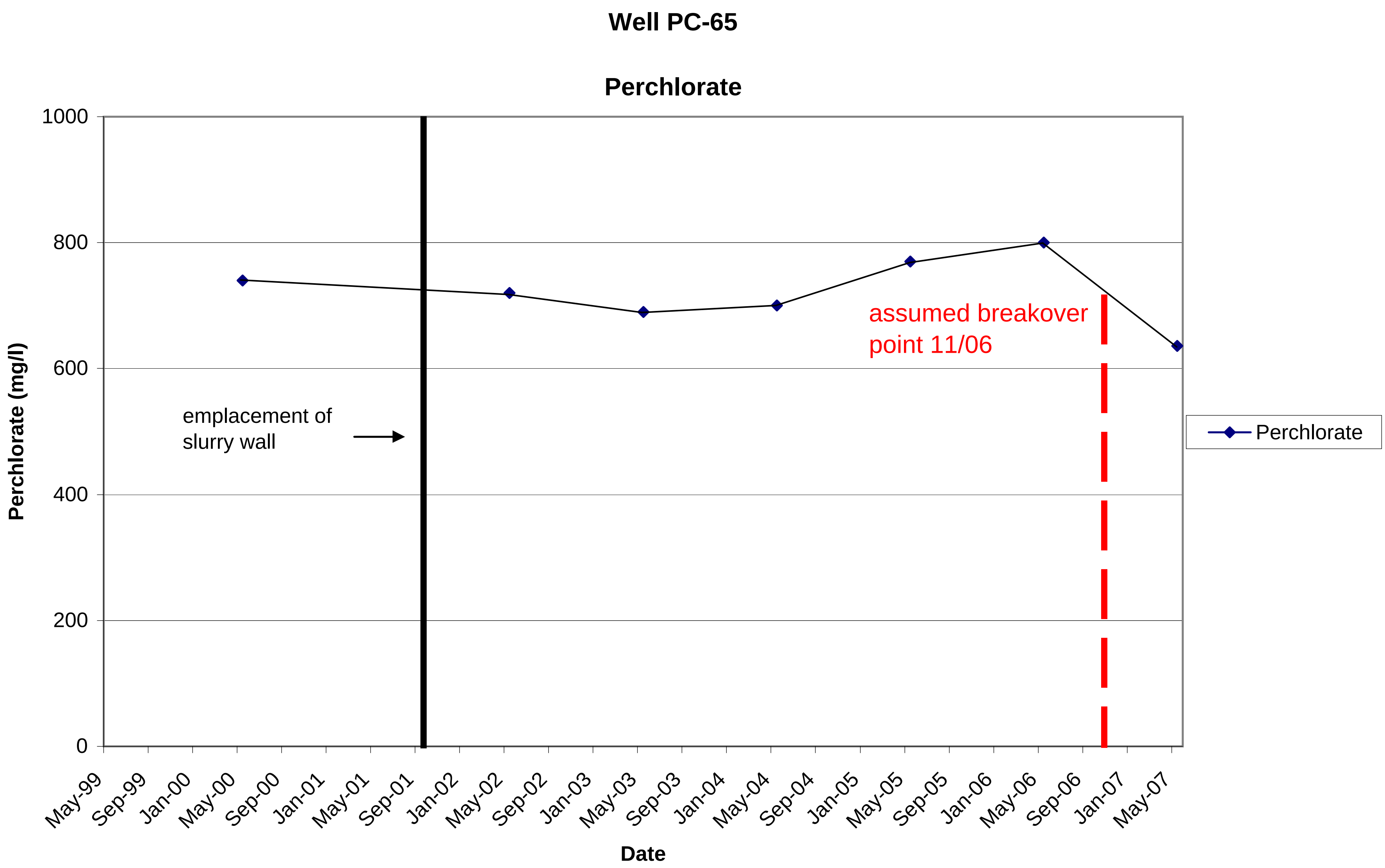
Well PC-54
Total Chromium
Total chromium (mg/l)
0
1
2
3
4
5
6
breakover point
4/05
emplacement
of slurry wall
Total chromium
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date



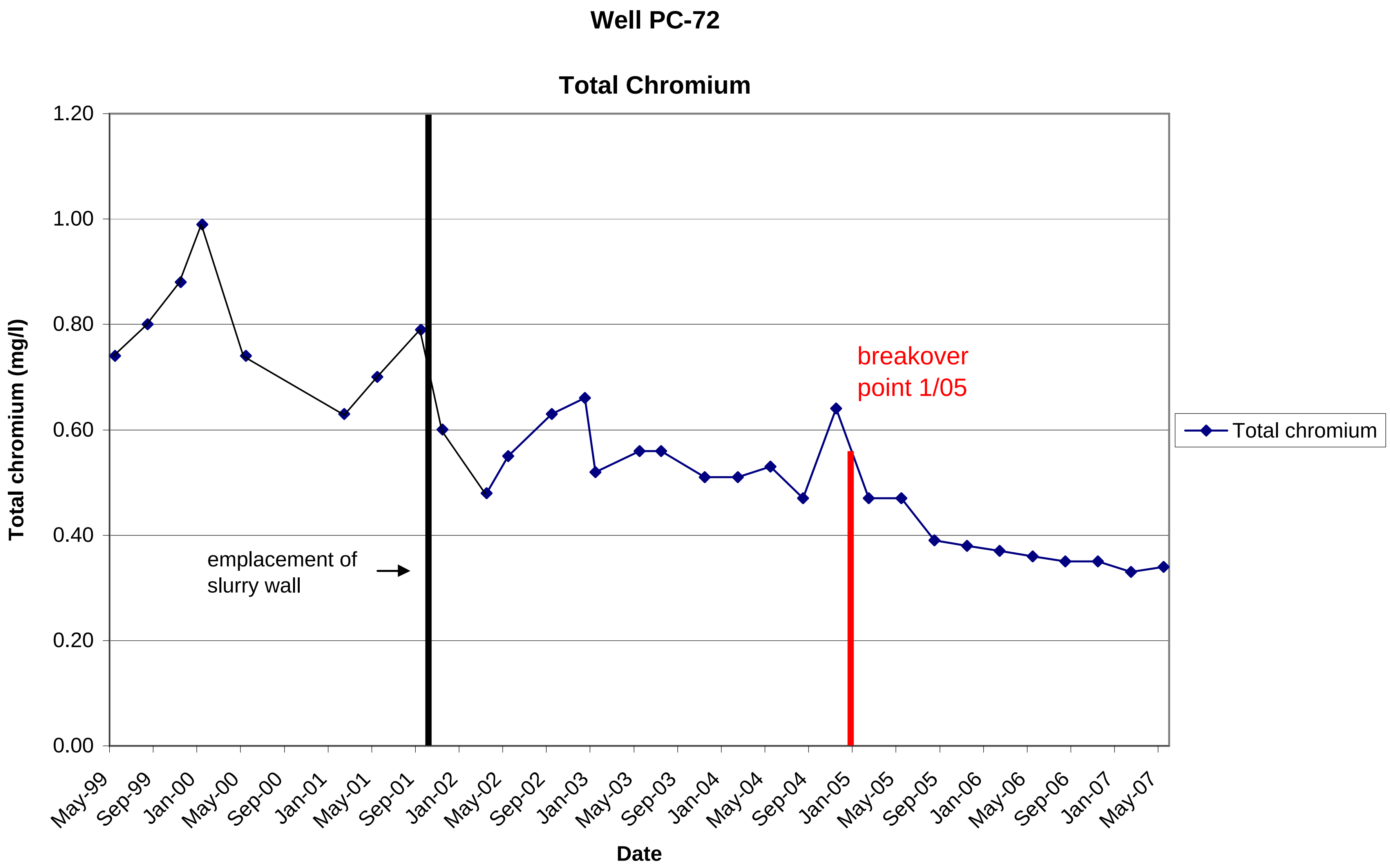
Well PC-37
Perchlorate
Perchlorate (mg/l)
450
400
350
300
250
200
150
100
50
0
breakover point
10/05
emplacement
of slurry wall
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date
Perchlorate


Well PC-37
Total Chromium
Total chromium (mg/l)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
emplacement
of slurry wall
breakover
point 7/05
Total chromium
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date

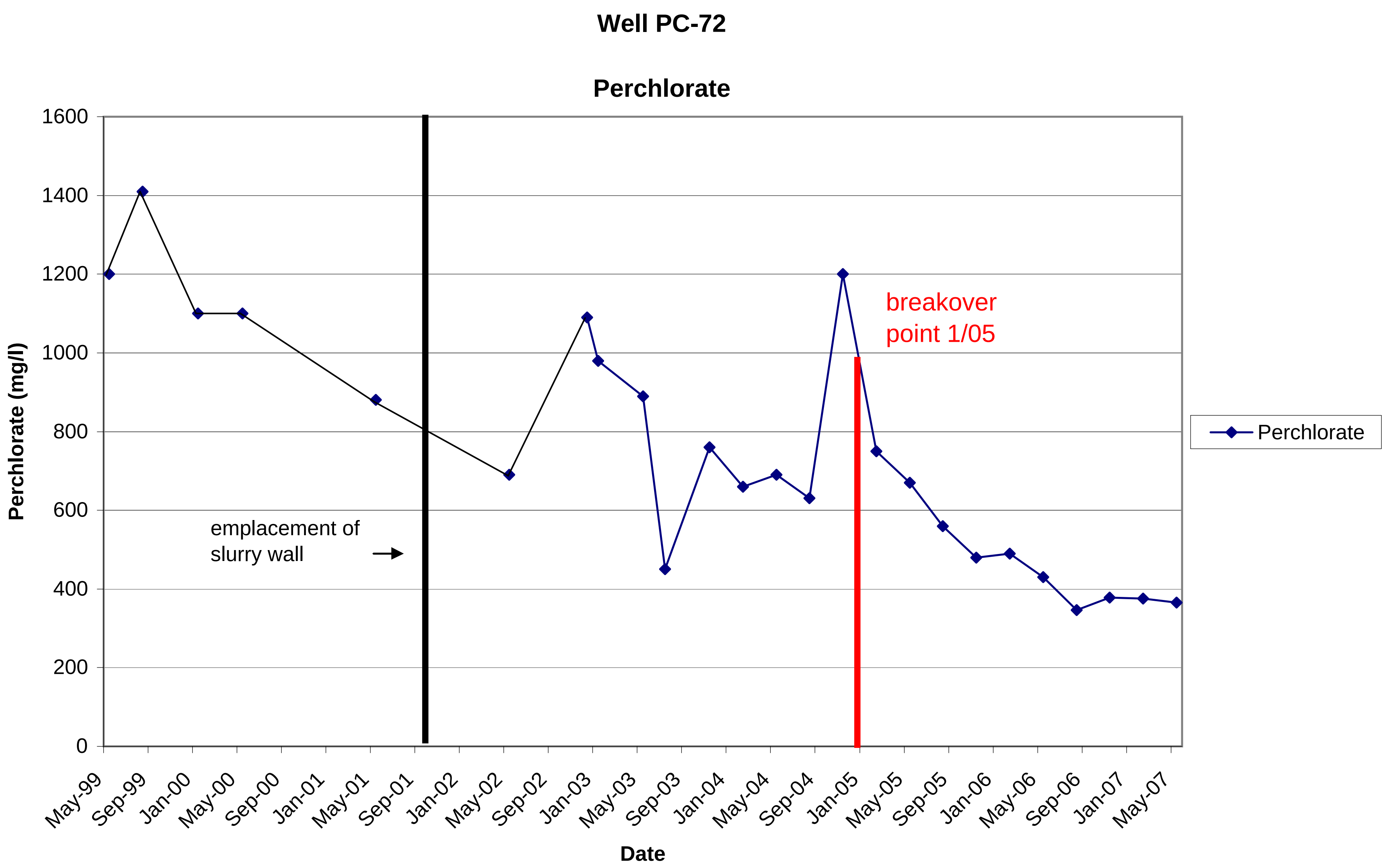

Well PC-64
Perchlorate
Perchlorate (mg/l)
1400
1200
1000
800
600
400
200
0
emplacement of
slurry wall
assumed
breakover point
11/06
Perchlorate
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date



Well PC-65
Perchlorate
1000
800
600
400
200
0
Perchlorate (mg/l)
emplacement of
slurry wall
assumed breakover
point 11/06
Perchlorate
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date



Well PC-72
Total Chromium
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Total chromium (mg/l)
breakover
point 1/05
emplacement of
slurry wall
Total chromium
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date



Well PC-72
Perchlorate
Perchlorate (mg/l)
1600
1400
1200
1000
800
600
400
200
0
emplacement of slurry wall
breakover point 1/05
Perchlorate
May-99
Sep-99
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Date

**APPENDIX C**
**DATA TABLE**
**PRECHLORATE AND TOTAL CHROMIUM TIME SERIES PLOTS**
**REVISED CAPTURE ZONE ANALYSIS - INTERCEPTOR WELL FIELD AND BARRIER**
**(all values are in mg/L)**

| DATE | M-23 | | | M-87 | | | M-100 | | | M-101 | | | M-102 | | | M-95 | | | M-96 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lab S.C. | Cr | ClO4 | Lab S.C. | Cr | ClO4 | Lab S.C. | Cr | ClO4 | Lab S.C. | Cr | ClO4 | Lab S.C. | Cr | ClO4 | Lab S.C. | Cr | CLO4 | Lab S.C. | Cr | ClO4 |
| May-99 | 14600 | 2.50 | 1600 | 12800 | 12.0 | 770 | 12900 | 4.90 | 1300 | 13800 | 0.80 | 1500 | 9120 | 1.8 | 212 | | 2.3 | 1600 | 14300 | 3.6 | 1400 |
| Jun-99 | 14300 | 2.40 | 1500 | 12200 | 11.0 | 780 | 12800 | 4.20 | 1200 | 14100 | 1.60 | 1600 | | | | | | | | | |
| Jul-99 | 14400 | 2.50 | 1700 | 11900 | 11.0 | 750 | 12400 | 4.70 | 1300 | 14100 | 2.40 | 1500 | | | | | | | | | |
| Aug-99 | 14400 | 2.40 | 1600 | 11800 | 11.0 | 670 | 12400 | 4.80 | 1200 | 14300 | 1.80 | 1700 | 8870 | 2.1 | 170 | | | | 14400 | 4.0 | 1400 |
| Sep-99 | 14000 | 2.80 | | 11100 | 10.0 | | 11700 | 4.20 | | 14400 | 3.20 | | | | | | | | | | |
| Oct-99 | 14100 | 2.80 | | 11200 | 9.5 | | 11400 | 4.70 | | 14500 | 3.90 | | 8790 | 1.9 | | | | | | | |
| Nov-99 | 14400 | 2.90 | | 11100 | 9.2 | | 10800 | 3.90 | | 14400 | 4.00 | | 8680 | 1.6 | | | | | 14400 | 4.1 | |
| Dec-99 | | | | 10800 | | | | | | | | | | | | | | | | | |
| Jan-00 | 14000 | 3.00 | 1400 | 11100 | 9.0 | 600 | 10100 | 3.70 | 890 | 14200 | 4.20 | 1400 | 5540 | 1.5 | 110 | | | | | | |
| Feb-00 | 13800 | 3.30 | 1600 | 11200 | 8.9 | 670 | 9800 | 4.60 | 1000 | 14100 | 5.40 | 1900 | 8500 | 1.7 | 140 | | | | 14200 | 4.3 | |
| Mar-00 | 13800 | 2.90 | 1400 | 11100 | 10.0 | 650 | 9900 | 4.10 | 940 | 13100 | 4.20 | 1400 | 8400 | 1.5 | 120 | | | | | | |
| Apr-00 | 13600 | 2.70 | 1700 | 11200 | 9.1 | 760 | 9600 | 4.20 | 990 | 14000 | 4.50 | 1700 | 8400 | 1.7 | 140 | | | | | | |
| May-00 | 11200 | 3.20 | 1700 | 11200 | 8.9 | 800 | 9000 | 4.30 | 1600 | 13300 | 4.40 | 1900 | 8050 | 1.7 | 120 | | 2.8 | 2100 | 14000 | 4.0 | 1400 |
| Jun-00 | 13600 | 3.60 | 1600 | 11200 | 10.0 | 600 | 8700 | 4.30 | 920 | 12800 | 4.50 | 1600 | 8580 | 1.6 | 130 | | | | | | |
| Jul-00 | 10300 | 3.70 | 1600 | 8300 | 11.0 | 730 | 6700 | 4.30 | 830 | 10000 | 4.20 | 1400 | 6020 | 1.6 | 120 | | | | | | |
| Aug-00 | 12300 | 4.00 | 2000 | 11100 | 11.0 | 770 | 8300 | 4.30 | 850 | 12500 | 4.20 | 1400 | 7760 | 1.7 | 150 | | | | | | |
| Sep-00 | 14100 | 4.40 | 1800 | 12200 | 14.0 | 900 | 9000 | 5.10 | 1000 | 13600 | 5.20 | 1700 | 8380 | 2.0 | 140 | | | | | | |
| Oct-00 | 12200 | 4.50 | 1600 | 11100 | 13.0 | 720 | 8100 | 4.70 | 840 | 11900 | 4.90 | 1400 | 7510 | 1.9 | 150 | | | | | | |
| Nov-00 | 13000 | 4.30 | 1600 | 10100 | 14.0 | 800 | 8700 | 5.10 | 850 | 12900 | 5.50 | 1400 | 8000 | 2.2 | 150 | | | | | | |
| Dec-00 | 12700 | 4.10 | 1800 | 12200 | 14.0 | 1100 | 8800 | 4.40 | 1100 | 12600 | 5.10 | 1700 | 8100 | 2.0 | 190 | | | | | | |
| Jan-01 | 12800 | 3.80 | 1700 | 12800 | 14.0 | 900 | 8800 | 4.80 | 860 | 12800 | 5.50 | 1500 | 8090 | 2.0 | 180 | | | | | | |
| Feb-01 | 12800 | 3.70 | 1700 | 12600 | 14.0 | 850 | 8800 | 5.10 | 900 | 12600 | 5.80 | 1500 | 7950 | 2.0 | 170 | | | | 13600 | 3.9 | 1300 |
| Mar-01 | 12500 | 3.50 | 1900 | 13400 | 15.0 | 990 | 9700 | 5.40 | 880 | 12900 | 6.10 | 1500 | 8160 | 2.2 | 190 | | | | | | |
| Apr-01 | 12900 | 3.50 | 1700 | 13900 | 16.0 | 960 | 10800 | 7.30 | 910 | 12800 | 5.90 | 1500 | 8250 | 2.1 | 200 | | | | | | |
| May-01 | 12800 | 3.60 | 1800 | 13700 | 17.0 | 990 | 11300 | 8.40 | 1100 | 12600 | 6.20 | 1500 | 8250 | 2.1 | 210 | | 2.8 | 1300 | 13300 | 4.7 | 1300 |
| Jun-01 | 13200 | 3.40 | 1800 | 14200 | 17.0 | 1000 | 12200 | 9.50 | 1000 | 13200 | 6.50 | 1400 | 8520 | 2.4 | 220 | | | | | | |
| Jul-01 | 12000 | 3.50 | 1900 | 13500 | 18.0 | 1100 | 11300 | 10.00 | 1100 | 12100 | 6.60 | 1400 | 7950 | 2.2 | 210 | | | | | | |
| Aug-01 | 11900 | 3.50 | 1900 | 14000 | 21.0 | 1100 | 11200 | 10.00 | 1100 | 12200 | 6.90 | 1500 | 7890 | 2.7 | 250 | | | | | | |
| Sep-01 | 11600 | 3.50 | 1800 | 14200 | 21.0 | 1300 | 11200 | 9.40 | 1200 | 11900 | 6.50 | 1700 | 7930 | 2.5 | 150 | | | | 12710 | 3.8 | 1200 |
| Oct-01 | 11500 | 3.60 | 1800 | 14400 | 21.0 | 1300 | 11100 | 11.00 | 1000 | 11800 | 7.00 | 1500 | 7950 | 2.7 | 290 | | | | | | |
| Nov-01 | 11500 | 3.60 | 1800 | 14200 | 20.0 | 1500 | 11100 | 11.00 | 1000 | 11800 | 7.00 | 1500 | 8010 | 3.1 | 290 | | | | 14000 | 4.3 | 1200 |
| Dec-01 | 12900 | 3.40 | 1900 | 16400 | 21.0 | 1600 | 12700 | 10.00 | 1000 | | 6.70 | 1000 | 8520 | 2.7 | 270 | | | | | | |
| Jan-02 | 11600 | 3.50 | 1900 | 14700 | 21.0 | 1600 | 10000 | 9.20 | 1000 | | 6.60 | 1600 | 8250 | 3.0 | 280 | | | | | | |
| Feb-02 | 11230 | 3.40 | 1700 | 14700 | 19.0 | 1600 | 9990 | 7.80 | 910 | | | | 8210 | 3.2 | 280 | | | | | | |
| Mar-02 | 12500 | 3.40 | | 14100 | 23.0 | 1700 | | | | | | | | | | | | | | | |
| May-02 | 11600 | 2.10 | 1430 | 15800 | 20.0 | 1800 | 8820 | 5.70 | 610 | 12200 | 3.90 | 1430 | 8000 | 3.3 | | | 3.1 | 1300 | 14400 | 4.4 | 1200 |
| Sep-02 | 9440 | 3.30 | | 15080 | 20.0 | | 5570 | 3.10 | 350 | | | | 9180 | 4.5 | 350 | | | | 12030 | 5.0 | 1100 |
| Dec-02 | 8510 | 2.30 | 1100 | 14300 | 11.0 | | 4740 | 1.90 | 340 | 10900 | 4.70 | 1340 | 11100 | 7.8 | 853 | | | | 13100 | 4.5 | 1460 |
| Jan-03 | 7680 | 1.70 | 840 | 14800 | 13.0 | 1900 | 4200 | 1.70 | 230 | 9650 | 3.80 | 980 | 11500 | 10.0 | 1000 | | | | 12340 | 3.9 | 1200 |
| May-03 | 7700 | 1.80 | 810 | 13350 | 13.0 | 1600 | 4230 | 1.40 | 220 | 7920 | 2.70 | 620 | 13200 | 12.0 | 1500 | | 3.6 | 1300 | 12820 | 4.3 | 1200 |
| Jul-03 | 7630 | 1.90 | 830 | 10670 | 10.0 | 1300 | 3840 | 1.40 | 200 | 6720 | 1.90 | 430 | 12200 | 12.0 | 1400 | | | | 12460 | 4.4 | 1200 |
| Nov-03 | 7200 | 1.60 | 680 | 8590 | 8.1 | 820 | 3670 | 1.10 | 160 | 5150 | 1.10 | 220 | 10620 | 10.0 | 1100 | | | | 12950 | 4.5 | 1200 |
| Feb-04 | 7030 | 1.60 | 720 | 7020 | 7.1 | 670 | 3670 | 1.50 | 180 | 6510 | 1.00 | 270 | 9680 | 11.0 | 1000 | | | | 12270 | 5.5 | 1100 |
| May-04 | 6730 | 1.50 | 730 | 5630 | 4.9 | 210 | 3150 | 1.10 | 140 | 6350 | 0.80 | 320 | 7780 | 7.2 | 750 | | 4.5 | 1200 | 11700 | 5.2 | 980 |
| Aug-04 | 6590 | 1.50 | 770 | 5900 | 5.1 | 580 | | | | 6630 | 0.86 | 400 | 6300 | 5.5 | 550 | | | | 11200 | 4.9 | 930 |
| Nov-04 | 6140 | 1.30 | 990 | 4060 | 3.9 | 450 | 2660 | 0.83 | 131 | 5410 | 0.60 | 330 | 5320 | 4.5 | 480 | | | | 10600 | 4.4 | 1100 |
| Feb-05 | 5000 | 1.20 | 610 | 2960 | 2.0 | 200 | 2780 | 1.00 | 130 | 5360 | 0.50 | 200 | 4280 | 2.8 | 260 | | | | 8840 | 4.3 | 830 |
| May-05 | 4440 | 1.00 | 690 | 3370 | 2.2 | 230 | 3170 | 0.95 | 150 | 5840 | 0.70 | 240 | 4220 | 2.6 | 240 | | 3.1 | 1000 | 8610 | 3.8 | 750 |
| Aug-05 | 4940 | 1.10 | 490 | 2080 | 0.9 | 100 | 3210 | 1.00 | 180 | 4270 | 0.34 | 84 | 3830 | 2.5 | 250 | | | | 7780 | 2.0 | 700 |
| Nov-05 | 5750 | 1.10 | 620 | 1510 | 0.5 | 58 | 2850 | 0.96 | 160 | 3600 | 0.26 | 68 | 2870 | 2.0 | 210 | | 2.6 | 800 | 8530 | 2.5 | 610 |
| Feb-06 | 6400 | 1.10 | 620 | 2390 | 1.3 | 120 | 2910 | 0.62 | 110 | 5200 | 0.29 | 130 | 3290 | 1.8 | 170 | | 2.5 | 820 | 9380 | 2.9 | 690 |
| May-06 | 6280 | 1.00 | 560 | 2520 | 1.3 | 150 | 2350 | 0.40 | 71 | 5160 | 0.26 | 92 | 3000 | 1.4 | 130 | | 2.3 | 760 | 9360 | 2.8 | 530 |
| Aug-06 | | 0.97 | 462 | | 1.0 | 92 | | 0.35 | 63 | | 0.19 | 72 | | 1.4 | 123 | | | | | 2.3 | 459 |
| Nov-06 | | 0.92 | 505 | | 1.8 | 155 | | 0.25 | 6 | | 0.25 | 71 | | 1.1 | 110 | | 2 | 670 | | 2.0 | 464 |
| Feb-07 | | 0.82 | 449 | | 1.3 | 116 | | 0.26 | 43 | | 0.35 | 98 | | 0.98 | 85 | | 1.7 | 623 | | 1.9 | 446 |
| May-07 | | 0.88 | 436 | | 1.5 | 121 | | 0.24 | 13 | | 0.54 | 100 | | 1.00 | 92 | | 1.7 | 612 | | 1.7 | 425 |

**Definitions**

| | |
|---|---|
| **Lab S.C.** | **Specific Conductivity from Laboratory Analysis** |
| **Cr** | **Total Chromium** |
| **ClO4** | **Perchlorate** |
| **mg/L** | **milligrams per liter** |

**APPENDIX C**
**DATA TABLE**
**PRECHLORATE AND TOTAL CHROMIUM TIME SERIES PLOTS**
**REVISED CAPTURE ZONE ANALYSIS - INTERCEPTOR WELL FIELD AND BARRIER**
**(all values are in mg/L)**

| DATE | PC-54 | | | PC-37 | | | M-48 | | | PC-64 | | | PC-65 | | | PC-72 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lab S.C. | Cr | ClO4 | Lab S.C. | Cr | ClO4 | Lab S.C. | Cr | ClO4 | Lab S.C. | Cr | ClO4 | Lab S.C. | Cr | ClO4 | Lab S.C. | Cr | ClO4 |
| May-99 | 10600 | 3.9 | 380 | 9350 | 0.06 | 160 | 10200 | 5.80 | 450 | | | | | | | | 0.74 | 1200 |
| Jun-99 | | | | | | | | | | | | | | | | | | |
| Jul-99 | | | | | | | | | | | | | | | | | | |
| Aug-99 | 10700 | 3.8 | 390 | 9400 | 0.11 | 190 | 9488 | 5.40 | 430 | | | | | | | | 0.80 | 1410 |
| Sep-99 | | | | | | | | | | | | | | | | | | |
| Oct-99 | | | | | | | 9240 | 5.50 | | | | | | | | | | |
| Nov-99 | 10600 | 3.8 | | 9100 | 0.14 | | 9330 | 5.20 | | | | | | | | | 0.88 | |
| Dec-99 | | | | | | | | | | | | | | | | | | |
| Jan-00 | | | | | | | 9260 | 5.40 | 380 | | | | | | | | 0.99 | 1100 |
| Feb-00 | 10500 | 4.2 | 400 | 9210 | 0.09 | 150 | 9340 | 6.00 | 410 | | | | | | | | | |
| Mar-00 | | | | | | | 9250 | 5.40 | 370 | | | | | | | | | |
| Apr-00 | | | | | | | 9200 | 4.30 | 390 | | | | | | | | | |
| May-00 | 10300 | 3.8 | 350 | 8940 | 0.18 | 160 | 9200 | 4.30 | 390 | 10870 | | 740 | 10780 | | 740 | | 0.74 | 1100 |
| Jun-00 | | | | | | | 8930 | 4.50 | 350 | | | | | | | | | |
| Jul-00 | | | | | | | 6890 | 4.40 | 340 | | | | | | | | | |
| Aug-00 | | | | | | | 8630 | 4.30 | 380 | | | | | | | | | |
| Sep-00 | | | | | | | 9880 | 4.80 | 400 | | | | | | | | | |
| Oct-00 | | | | | | | 8510 | 4.60 | 180 | | | | | | | | | |
| Nov-00 | | | | | | | 9230 | 4.80 | 400 | | | | | | | | | |
| Dec-00 | | | | | | | 9090 | 4.40 | 390 | | | | | | | | | |
| Jan-01 | | | | | | | 9190 | 4.30 | 380 | | | | | | | | | |
| Feb-01 | 9520 | 3.2 | 260 | 8930 | 0.18 | 230 | 9120 | 4.40 | 390 | | | | | | | | 0.63 | |
| Mar-01 | | | | | | | 9220 | 4.40 | 490 | | | | | | | | | |
| Apr-01 | | | | | | | 9440 | 4.40 | 380 | | | | | | | | | |
| May-01 | 9380 | 3.6 | 250 | 8940 | 0.18 | 160 | 9420 | 4.50 | 370 | 10720 | | 1000 | | | | | 0.70 | 880 |
| Jun-01 | | | | | | | 9690 | 4.50 | 390 | | | | | | | | | |
| Jul-01 | | | | | | | 9060 | 4.90 | 430 | | | | | | | | | |
| Aug-01 | | | | | | | 9120 | 5.30 | 430 | | | | | | | | | |
| Sep-01 | 8950 | 2.7 | 240 | 8460 | 0.22 | 200 | 9170 | 5.40 | 450 | | | | | | | | 0.79 | |
| Oct-01 | | | | | | | 9230 | 6.30 | 510 | | | | | | | | | |
| Nov-01 | 9190 | 2.7 | 260 | 8740 | 0.14 | 180 | 9230 | 6.30 | 510 | | | | | | | | 0.60 | |
| Dec-01 | | | | | | | 9370 | 6.60 | 530 | | | | | | | | | |
| Jan-02 | | | | | | | 9370 | 7.40 | 590 | | | | | | | | | |
| Feb-02 | | | | | | | 9960 | 7.80 | 630 | | | | | | | | | |
| Mar-02 | | | | | | | | | | | | | | | | | 0.48 | |
| May-02 | 9650 | 2.6 | 250 | 9370 | 0.16 | 270 | 12000 | 10.00 | 850 | 13500 | | 1200 | 10800 | | 720 | | 0.55 | 690 |
| Sep-02 | 8800 | 2.9 | 260 | 8460 | 0.22 | 200 | | | | | | | | | | | 0.63 | |
| Dec-02 | 9600 | 2.6 | 397 | 9340 | 0.18 | 369 | 10600 | 10.00 | 1110 | | | | | | | | 0.66 | 1090 |
| Jan-03 | 8990 | 2.2 | 270 | 8850 | 0.16 | 280 | 9750 | 6.80 | 970 | | | | | | | | 0.52 | 980 |
| May-03 | 9530 | 3.1 | 350 | 9320 | 0.19 | 310 | 8900 | 7.90 | 870 | 11400 | | 860 | 9920 | | 690 | | 0.56 | 890 |
| Jul-03 | 9520 | 3.6 | 360 | 9230 | 0.23 | 320 | 8170 | 7.00 | 770 | | | | | | | | 0.56 | 450 |
| Nov-03 | 9960 | 3.6 | 430 | 9510 | 0.19 | 300 | 7430 | 5.20 | 590 | | | | | | | | 0.51 | 760 |
| Feb-04 | 9620 | 4.7 | 510 | 9080 | 0.20 | 300 | 6440 | 4.50 | 550 | | | | | | | | 0.51 | 660 |
| May-04 | 9390 | 4.9 | 520 | 9020 | 0.30 | 330 | 5760 | 3.70 | 410 | 11760 | | 1000 | 9090 | | 700 | | 0.53 | 690 |
| Aug-04 | 9340 | 4.7 | 600 | 8760 | 0.17 | 330 | 5220 | 3.00 | 400 | | | | | | | | 0.47 | 630 |
| Nov-04 | 9050 | 4.8 | 630 | 8780 | 0.23 | 400 | 4760 | 2.40 | 593 | | | | | | | | 0.64 | 1200 |
| Feb-05 | 7830 | 4.8 | 640 | 7770 | 0.25 | 370 | 3950 | 2.30 | 290 | | | | | | | | 0.47 | 750 |
| May-05 | 7560 | 4.3 | 630 | 7850 | 0.25 | 370 | 4120 | 2.40 | 300 | 9790 | 2.7 | 940 | 7800 | 6.4 | 770 | | 0.47 | 670 |
| Aug-05 | 7580 | 4.2 | 560 | 7770 | 0.20 | 380 | 4250 | 2.30 | 280 | | | | | | | | 0.39 | 560 |
| Nov-05 | 7880 | 3.9 | 570 | 8240 | 0.17 | 320 | 4470 | 2.00 | 290 | | | | | | | | 0.38 | 480 |
| Feb-06 | 8360 | 3.4 | 460 | 6400 | 0.22 | 320 | 4610 | 1.90 | 200 | | | | | | | | 0.37 | 490 |
| May-06 | 8430 | 3.4 | 430 | 9300 | 0.19 | 280 | 4520 | 1.50 | 190 | 10000 | 3.4 | 984 | 9510 | 4.2 | 800 | | 0.36 | 430 |
| Aug-06 | | 3.4 | 369 | | 0.17 | 249 | | 1.40 | 216 | | | | | | | | 0.35 | 347 |
| Nov-06 | | 3.1 | 358 | | 0.19 | 323 | | 1.30 | 169 | | | | | | | | 0.35 | 378 |
| Feb-07 | | 2.8 | 337 | | 0.15 | 284 | | 1.10 | 144 | | | | | | | | 0.33 | 376 |
| May-07 | | 2.8 | 320 | | 0.18 | 292 | | 1.00 | 163 | | 2.9 | 760 | | 3.6 | 636 | | 0.34 | 365 |

**Definitions**

| | |
|---|---|
| **Lab S.C.** | **Specific Conductivity from Laboratory Analysis** |
| **Cr** | **Total Chromium** |
| **ClO4** | **Perchlorate** |
| **mg/L** | **milligrams per liter** |