CORRECTIVE ACTION PLAN
POTENTIAL NORTHWARD PROGRESSION OF SUBSURFACE SMOLDERING EVENT
BRIDGETON LANDFILL

Prepared for:

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CEC Project 131-178

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1.0 INTRODUCTION

Bridgeton Landfill, in coordination with the Missouri Department of Natural Resources (MDNR), has developed and implemented an extensive monitoring network to document the extent and conditions of the subsurface smoldering event (SSE), and specifically, any migration of the event. A key focus on this ongoing evaluation for the last two years has been the careful monitoring of the northward extent of the SSE.

Additionally, throughout the past two years, Bridgeton Landfill has developed and implemented numerous mitigation measures to control the extent and impact of the ongoing SSE within the South Quarry area of the Bridgeton Landfill.

As documented by several recent evaluations, the data continues to demonstrate a stability of the event in the northward extent and the lack of movement to the north, into the neck and North Quarry areas of the landfill. However, some of the earliest installed temperature monitoring probe (TMP) intervals have failed and ongoing monitoring shows a slow warming trend of some of the gas extraction wells (GEWs) in the neck area. As a result, on October 7, 2014, the MDNR issued a letter requesting that additional TMPs be installed in the North Quarry and that Bridgeton Landfill perform a corrective action assessment and prepare a corrective action plan for addressing certain elevated temperatures in the vicinity.

At the request of Bridgeton Landfill, Civil & Environmental Consultants, Inc. (CEC) has prepared this Corrective Action Plan (Plan) for the Potential Northward Progression of the SSE. This Plan is comprised of the following main sections:

2.0 Assessment of Current Conditions – Provides a summary of the temperature and gas quality conditions in the neck area and presents interpretations of data relative to the potential northward movement of the SSE.

3.0 Existing Corrective Measures – Describes efforts made to date in the neck area in attempt to prevent northward movement of the SSE.

4.0 Potential Contingent Corrective Measures – Presents measures that may be taken in the event that monitoring detects temperatures higher than the temperatures of concern expressed by the MDNR.

A separate document is being prepared to address the specifics of the request for installation of additional TMPs in the North Quarry.

It should be noted that a Corrective Action Plan is typically developed following the development and preparation of a Corrective Action Assessment. In this case, as discussed below, a full corrective action assessment would need to consider the impact of numerous mitigative measures including the newly implemented expanded heat removal pilot study. In order to continue the cooperative and proactive planning process, Bridgeton Landfill is submitting this Corrective Action Plan for current planning purposes. This Plan will be updated as appropriate based upon ongoing evaluations.

2.0 ASSESSMENT OF CURRENT CONDITIONS

2.1 SOUTH QUARRY

2.1.1 Conditions in the South Quarry

CEC conducted a detailed review of data and reported our findings in a 107 page letter which is dated September 16, 2014 and included herein as Appendix A. The resulting assessment of current conditions is that:

- *"The SSE is confined to the South Quarry;*
- *The active SSE is not expanding, but is moving to the south;*
- *While temperatures in the neck area are warming slowly, this is not an indication that the SSE is moving into the neck area, let alone through the neck area;*
- *The SSE is not prone to "daylighting under the flexible membrane cap."*

> *While some gas extraction wells (GEWs) in the vicinity of the Gas Interceptor Wells (GIWs) have indicated higher carbon monoxide (CO) levels and temperatures, CEC believes that this is due to transient conditions and/or improvements in gas collection efficiency as well as conduction and convection of heat as explained later in this letter."*

Based on experience at other facilities undergoing SSEs, it is likely that it will take many years for temperatures in affected areas to cool noticeably, even without the presence of any proximate exothermic SSE activity. However, the neck area will benefit from a favorable geometric and geologic setting due to the sharply angled near-vertical limestone faces that impinge into the area, forming the narrow opening referred to as the "neck." These limestone faces act as large "heat sinks" allowing conduction of heat into the quarry walls which is then conveyed to millions of tons of cool limestone rock.

In addition, Bridgeton Landfill voluntarily developed and has recently implemented an expanded heat extraction system in the Gas Interceptor Wells; this series of heat extraction wells was implemented in October 2014. Bridgeton Landfill will be monitoring numerous temperature measurements regularly and will submit the first quarterly assessment of the performance and results of the system with the January 20, 2015 Monthly Data Submittal. This ongoing assessment will be used to assess the effectiveness of the heat extraction system for potential long term corrective action.

2.1.2 Rate of SSE Movement

Two analyses of rate of movement of an advancing SSE have been performed in the South Quarry at the Bridgeton Landfill. The first was performed in 2013 as the SSE was moving to the north (as indicated by location of an advancing settlement front); that analysis indicated an average movement rate of 0.49 feet per day (see Appendix B) prior to movement to the north appearing to cease in October 2013. A similar analysis was performed for the period late-2013 to mid-2014 for the southward movement; this analysis resulted in a maximum average movement of 0.48 feet per day (see Appendix B). Based on these analyses, it is concluded that an advancing SSE moves at a maximum rate of approximately 0.50 feet per day for conditions within the Bridgeton Landfill. This rate of movement would allow sufficient time to plan and install virtually any potential corrective measure.

2.2 NORTH QUARRY

Several GEWs in the North Quarry (GEW-43R, -53, -54, and -55) consistently operate at higher-than-typical gas temperatures with readings in the 140°F range. However, these, and all North Quarry wells exhibit carbon monoxide levels that are either below detection levels or at very low levels that are not of concern. Other gas indicators such as methane and carbon dioxide are present at normal levels for aged waste material. Altogether, the North Quarry data suggest no presence of SSE at the current time.

New TMPs (TMP-16, -17, and -18) were installed in the North Quarry in August 2014 and indicate maximum in situ waste temperatures in the range of 152-162°F. These temperatures are within the 20-40°F difference that normally exists between gas wellhead temperature and surrounding in situ waste temperature.

3.0 EXISTING CORRECTIVE MEASURES

3.1 SOUTH QUARRY CORRECTIVE MEASURES

Since the time that a subsurface reaction was confirmed to be occurring in the South Quarry, Bridgeton Landfill has made isolation of the SSE to the South Quarry a primary objective. In late 2012, Bridgeton Landfill had comprehensive evaluations of potential measures prepared; the results of which were submitted to MDNR in early 2013 as listed below:

- North Quarry Heat Barrier System, dated January 4, 2013;
- Gas Interceptor Well Design, dated January 10, 2013;
- Gas Interceptor Well Expanded Design, submitted February 6, 2013; and
- Letter to Charlene Fitch date March 29, 2013 presenting a summary of potential isolation measures (included with this report as Appendix C).

In early 2013, Bridgeton Landfill moved forward quickly with the installation of Gas Interceptor Wells (GIWs) to remove heat from the northern extent of the SSE. The GIW system was fully operational by April 8, 2013. With the addition of the GIWs, 23 gas removal points were located within a two-acre area—this is more than five times the normal density of gas removal and indicative of the great measures to which Bridgeton Landfill has gone to effect heat removal.

Accelerated surface settlement—demonstrated to be a strong indicator of the movement of an SSE—continued north until October 2013 with the leading edge reaching as far north as the area between the two lines of GIWs (see Figure 1). Since October 2013, no further northward progression of accelerated settlement has occurred; in fact, the zone of accelerated settlement has moved to the far southern portion of the South Quarry. It is possible that the GIW system, together with the favorable geometry and geology of the neck area, effectively arrested the northward advance of the SSE. Based upon ongoing temperature monitoring in the GIWs and recent measurement of CO levels, it is apparent that the GIWs and surrounding gas wells are extracting reaction-impacted gas, as was intended by their placement and operation. Meanwhile, ongoing monitoring north of the GIWs in the North Quarry continues to show the absence of reaction-impacted gas.

Even with these measures, temperatures in some of the TMPs and GEWs in the neck area have continued to slowly increase. CEC believes that these slow increases are due to conduction and convection of heat that was left in the area after the SSE was active in the vicinity. However, CEC and Bridgeton Landfill believe that the optimum condition in the neck area would be to observe declining temperature profiles. While the GIWs may have arrested northward movement of the SSE, it appears that it may take quite some time to produce the desired declining temperatures.

Therefore, Bridgeton Landfill voluntarily developed and implemented a pilot study to evaluate another possible means for removing heat from the neck area. This pilot study was first implemented in one GIW and has since been expanded to more of the GIW system, in concert with an expanded in situ waste temperature monitoring network. The plans for Alternative Heat Extraction Pilot Study were submitted on July 23, 2014 and have since been approved by the MDNR. These plans propose equipping seven of the GIWs with closed-loop circulated water to remove heat from the waste mass that is adjacent to these GIWs. The alternative heat extraction water circulation was started on October 24, 2014. As of this writing, it is too early to tell if this method will remove enough heat to offset the ongoing conduction and convection of heat from the south.

Temperature data from the pilot heat extraction area is collected on a regular basis. At the request of MDNR, compiled data sets and discussion of performance will be prepared and submitted on a quarterly basis. Over time, this expanded temperature monitoring network will be used to assess energy and heat removal in order to evaluate the local and extended effectiveness of the heat removal.

CEC continues to conclude that—even with some slight, gradual warming of temperatures in the neck area—the SSE will likely not resume a northward progression due to the natural heat removal that occurs at the neck as described in Section 2.1.1 and due to the measures installed by Bridgeton Landfill. However, this expanded heat extraction study together with the expanded monitoring network will provide additional data in order to continue comprehensive assessment.

3.2 NORTH QUARRY CORRECTIVE MEASURES

In 2013, per the First Agreed Order, Bridgeton Landfill worked diligently with the MDNR to develop a North Quarry Contingency Plan (NQCP) which prescribed measures to be taken in the North Quarry in the event that certain "trigger" criteria were met. Before completion of the NQCP, Bridgeton Landfill elected to voluntarily undertake <u>all</u> corrective measures which were being contemplated in the DRAFTS of the NQCP.

A final version of the North Quarry Action Plan (NQAP) was submitted on January 28, 2014 and approved by the MDNR on April 14, 2014. Much of the work required by the NQAP has been completed, including: 4.35 acres of EVOH capping, installation of 23 new/replacement steel GEWs, installation of three new TMPs and construction of 12 perimeter sumps. This work is in hiatus at this time until approval is received for construction of the Isolation Barrier between the North Quarry and Westlake OU-1.

4.0 POTENTIAL CONTINGENT CORRECTIVE MEASURES

The October 7, 2014 letter from the MDNR specified a "corrective action zone" to be addressed by the corrective action assessment and plan. This zone has been indicated on Figure 1. The MDNR letter also specified target temperatures to be maintained within the corrective action zone as less than 185°F for gas extraction wells (GEWs) and less than 200°F for temperature monitoring probes (TMPs).

Potential corrective measures have been considered for a number of scenarios within the corrective action zone as described in the following sections.

<u>Scenario 1 – Isolated Subsurface Oxidation (SSO) Event</u>

Due to the presence of temporary FML cap over much of the corrective action zone and the careful management of the wellfield, occurrence of a typical deep, oxygenated subsurface fire (SSO) is unlikely. If one were to occur, it would be recognized by a sharp increase in temperature in one gas well without a similar increase in adjacent wells. Smoke, and melted (plastic) wellhead components would also accompany an SSO. If this were to occur, the procedures specified in the Local Subsurface Oxidation procedure (provided in Appendix D and also included with Volume 2 of the Operation, Maintenance and Monitoring Plan) would be implemented.

<u>Scenario 2 – South Quarry - Advancing Settlement Front Near GIWs</u>

If monthly settlement surveys once again indicate the presence of a settlement front (defined as 1.35 vertical feet per month in a 30 day period) within 100 feet of the south row of GIWs, it will be assumed (although may not be fact) that the SSE has reemerged in the vicinity. In this case, Bridgeton Landfill will evaluate the potential efficacy of providing additional heat extraction to the GIWs or elsewhere in the neck or south of the neck. Since the pilot study for heat extraction in seven GIWs only began recently, it is not possible to say whether adding heat extraction in the area would impact any possible northward SSE movement.

<u>Scenario 3 –Presumed SSE Beyond GIWs</u>

If a settlement front advances through or occurs beyond the GIWs, or if two or more adjacent monitoring points indicate greater than 185°F for a GEW or 200°F for a TMP (except TMP-12 which is compromised) within the corrective action zone, then it will be presumed (although may not be fact) that an SSE is occurring in the vicinity. Because Bridgeton Landfill voluntarily implemented proactive contingency measures as part of the 2013 North Quarry Action Plan, the North Quarry already has features in place to promote effective management and mitigation of SSE conditions. Therefore, the proposed corrective measures will include the following:

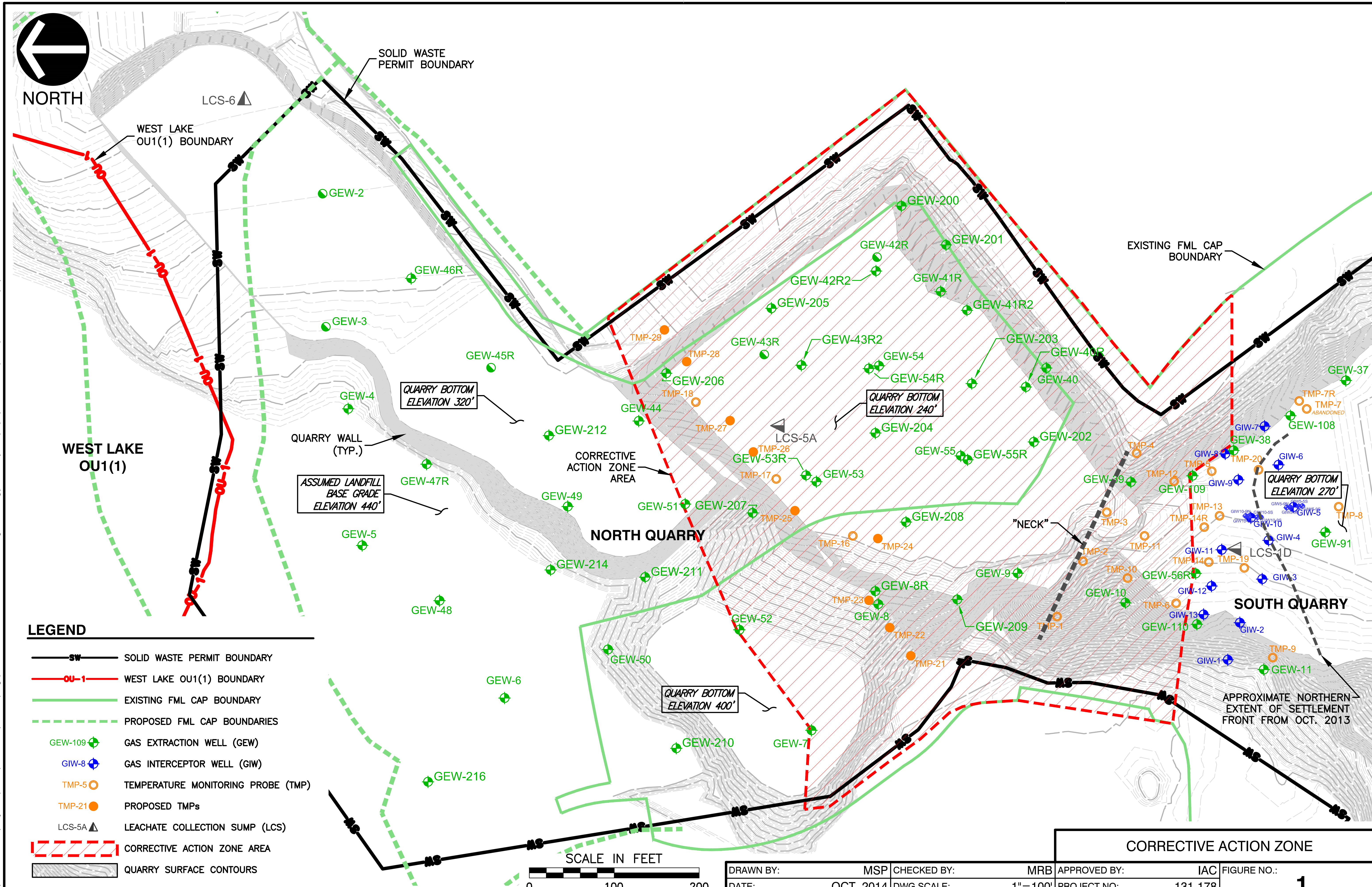
1. Expand ongoing monthly settlement surveys to include the North Quarry area;
2. Complete the remaining area of North Quarry EVOH cap up to the area needed for the isolation barrier; and
3. Connect the already installed new North Quarry (steel) gas wells to the gas extraction system to manage potential reaction-impacted gas.

After the results of the GIW heat extraction pilot study are known, it may be possible to consider well-specific, area-specific, or linear heat extraction features to contain or isolate propagation of the SSE.

Scenario 4 – Presumed SSE beyond GIWs after Receipt of USEPA and ACoE Approval for Isolation Barrier

If the Isolation Barrier between the North Quarry and OU-1 is approved prior to the presumed presence of an SSE beyond the GIWs, then it may be implemented in addition to, or lieu of, the Scenario 3 corrective measure.

FIGURES



CORRECTIVE ACTION ZONE

DRAWN BY: MSP	CHECKED BY: MRB	APPROVED BY: IAC	FIGURE NO.:
DATE: OCT. 2014	DWG SCALE: 1"=100'	PROJECT NO: 131-178	1

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APPENDIX A

SEPTEMBER 16, 2014 LETTER TO MDNR, COMMENTS ON THALHAMER DATA REVIEW MEMO

September 16, 2014

Mr. Brian Power
Bridgeton Landfill, LLC
13570 St. Charles Rock Road
Bridgeton, MO 63044

Dear Mr. Power:

Subject: Comments on Thalhamer Data Review Memo
Bridgeton Landfill, Bridgeton, Missouri
CEC Project 131-178

Bridgeton Landfill, LLC (Bridgeton Landfill) has requested that Civil & Environmental Consultants, Inc. (CEC) review and provide comment on the August 29, 2014 Memorandum from Todd Thalhamer, P.E. to Brenda Ardrey of the MDNR. As you know, CEC personnel have experience at Bridgeton Landfill as well as four other landfills which are undergoing similar subsurface reactions. The experience at these other facilities allows events at the Bridgeton Landfill to be put into context and understood relative to trends and observations at the other similar facilities.

In CEC's opinion, the latest data does not change the following conclusions which were made in the July 17, 2014 letter from Bridgeton Landfill (the July 17 letter supporting Bridgeton Landfill' position is include with this letter as Attachment A):

- The SSE is confined to the South Quarry;
- The active SSE is not expanding, but is moving to the south;
- While temperatures in the neck area are warming slowly, this is not an indication that the SSE is moving into the neck area, let alone through the neck area;
- The SSE is not prone to "daylighting under the flexible membrane cap."

While some gas extraction wells (GEWs) in the vicinity of the Gas Interceptor Wells (GIWs) have indicated higher carbon monoxide (CO) levels and temperatures, CEC believes that this is due to transient conditions and/or improvements in gas collection efficiency as well as conduction and convection of heat as explained later in this letter.

Mr. Thalhamer's memo was divided into five different sections, each of which is addressed in the subsequent portions of this letter.

Smolder Event Movement Data

Based on observations at other facilities, and supported by observations at the Bridgeton Landfill, CEC believes that all three of the following things need to be present to indicate the presence and movement of an active SSE:

- Substantial levels of carbon monoxide (CO);
- Elevated subsurface temperatures; and
- Higher-than-normal settlement with movement of a settlement "front."

A detailed description of the relationship of these three parameters is included as Attachment B of this letter (this document was submitted to the MDNR in August 2013 as part of a North Quarry Contingency Plan submittal).

As recently as October 2013 the "settlement front" included a northward advancement. Since that time, the settlement front has pulled away from the neck area indicating that the advancement of the SSE is currently entirely to the south (see the Map with Direction of SSE Movement included in Attachment A). Therefore, since only two of the three necessary indicators are present, CEC believes that the SSE is not active in the neck area and is not moving northward in the neck area.

Elevated CO and temperatures do exist in the vicinity of the neck area and these are further discussed below.

Elevated CO in the Neck Area

The GIWs were put into operation in February 15, 2013 to supplement the existing gas collection in the South Quarry neck area and to improve removal of heat being conducted from the SSE, which was—at the time—active in the northern portion of the South Quarry. The GIWs were deliberately positioned through an area that already had elevated temperatures and high levels of CO; in fact, elevated temperatures and CO were present north of the GIW locations prior to operation of the GIWs. Examples are given below:

Gas Well Number	Pre-GIW CO Jan. 23-Feb. 13, 2013	Current CO Aug. 11, 2014
GEW-10	340 ppm	33 ppm
GEW-38	3200 ppm	3300 ppm
GEW-109	2800 ppm	2500 ppm

As shown, CO in the area north of the GIWs has been present for a long time, fluctuates significantly, and does not indicate SSE currently moving into or through the area.

Elevated Temperature in the Neck Area

In its July 17, 2014 letter, Bridgeton Landfill correctly noted that "temperature in the neck area is gradually warming" and "the warming in the area is likely the result of conduction and convection of heat." The GIWs remain at elevated temperatures even in absence of an active, proximate SSE because the process of pulling heat out of the former SSE front is a slow one. CEC believes that continued operation of the GIWs and neck area wells, together with further retreat and diminishing of the SSE in the South Quarry, will eventually result in temperature drop in the neck area.

Data Variability in the Neck Area

In a typical landfill, gas extraction wells are spaced approximately 150-200 feet apart—usually one to two wells per acre. In the neck area at Bridgeton Landfill there are 23 gas extraction wells (including the GIWs) within a two-acre area resulting in over 11 wells per acre. This extremely high density of wells facilitates removal of SSE-affected (low-methane, high-CO) gas and heat out of the northern portion of the South Quarry.

The large number of closely-spaced gas extraction wells in the neck area makes uniform operation and resulting consistent gas well quality difficult to achieve. For instance, GIW-8 is only 10 feet from GEW-38, and GIW-12 is only 23 feet from GEW-56R. As a result, these wells compete for the same gas and—based on the transient vacuum or exposed perforation conditions that exist—exhibit larger-than-normal fluctuations in gas temperature and carbon monoxide levels. Month-to-month comparisons of values in these wells need to be undertaken with caution, and an emphasis should be placed on trends observed over many months to provide meaningful interpretations. Attachment C presents graphs showing wellhead temperature for the GEW wells referenced in Mr. Thalhamer's letter. The variability caused by the interference between the closely-spaced wells and by the transient operating conditions in the wells is evident.

Carbon Monoxide at the Flare Inlet

Mr. Thalhamer notes that CO levels have increased at the flare inlet. He does not note, however, that flow volume at the flare compound has increased from approximately 7,000 cfm to 9,000 cfm since April 2014 as shown on Attachment D. This increase in flow is the result of continuing efforts to improve vacuum distribution and expose gas well perforations where the SSE is most active and where CO levels are the highest. Therefore, a significant increase in CO level at the flare inlet is expected. In fact, rather than being an indicator of concern, this reflects successful operation of the gas extraction system to collect the heated reaction gases.

Temperature Readings in GEW and GIW for the Period July to August 2014

Neck Area

Elevated and variable gas well temperatures in the neck area were discussed in the previous section of this letter as due to the conduction and convection of heat from the south, slow process of heat removal, and the extremely dense well spacing.

North Quarry

The North Quarry wells GEW-53, and -54 have a long history of temperatures over 131°F; there is no evidence of a changing temperature trend in these wells or any association with the SSE in the South Quarry. In fact, when these same concerns were raised about these wells in June 2013, due to temperatures greater than the current temperatures, Bridgeton Landfill performed CO testing as an added confirmation of the lack of impact. GEW-54 was monitored for CO until its temperature dropped below 140°F. Subsequent CO testing events have continued to confirm the absence of CO at levels of concern; a key indicator relied upon by Mr. Thalhamer.

South Quarry

Mr. Thalhamer's point here is unclear. All of the listed wells are located in the South Quarry; far south of the neck area and are expected to be in the indicated temperature range. General temperature and carbon monoxide increases in the South Quarry appear to be related to improvements such as the late June installation of ten additional GEW liquid pumps which helped increase gas flow in the reaction area.

CO Readings for the Period of April 2014 to July 2014

Neck Area

See discussion in previous section "Smolder Event Movement Data." Elevated CO was present in the neck area even before installation of the GIWs and is expected to remain elevated due to the extremely high density of gas wells in the neck area pulling SSE-impacted gas toward them. The CO in neck area wells fluctuates but does not yet exhibit a strong, confirmed upward trend.

North Quarry

We agree that the low levels detected in these wells **are not** of concern.

South Quarry

Improvements in gas removal volume and efficiency (see previous discussion on CO levels at the flare inlet) may increase CO levels in the South Quarry wells.

Flare Inlet

See previous discussion on CO levels at the flare inlet. Increased CO levels at the flare inlet are attributed to significant improvement gas collection volume from the South Quarry which has increased the volume of gas containing elevated CO.

Oxygen Readings for July 2014

Mr. Thalhamer identifies wells that exhibit maximum oxygen readings over 5% at the wellhead. These oxygen levels do not represent elevated oxygen in the waste mass, but are due to well operational issues that result in zero landfill gas flow so that the readings are not obtained on flowing gas removed from the waste mass. Such a condition is referred to in the industry as a “deadheaded” gas well. A deadheaded gas well can result from a collapsed gas well, or a gas well casing which has been “watered in” and has no perforations available from which to extract gas out of the waste mass, or a well that had been completely turned off by closing the valve connecting it to the header system. The Bridgeton Landfill technicians are instructed to restore flow to deadheaded gas wells, but this often requires placement or repair of a pump, or possibly redrilling the gas well—both of which may take some time.

When a gas well is deadheaded, the vacuum that is applied to the top of the gas well cannot remove gas from the landfill but may pull in very minor amount of ambient air through fittings, joints, connections, and sampling ports that exist in the wellhead. This ambient air contains up to 20% oxygen, so when no landfill gas is flowing, a wellhead may exhibit up to 20% oxygen depending on the nature of the pathways that allow the minor amounts of air to be drawn into the wellhead. All of the wells that exhibit oxygen at the wellhead over 5% are fully- or partially-deadheaded. In addition, all of these wells are in the South Quarry that is covered by a flexible membrane liner which prevents oxygen from being pulled into the waste mass. Therefore, these oxygen levels do not represent elevated oxygen in the waste mass.

TMP Concerns

As Mr. Thalhamer notes, many of the TMP intervals have been adversely affected by the landfill conditions. Thermocouples and their fragile wire leads were not intended and are not suited to survive on a long-term basis buried in solid waste material that settles and shifts and contains gas and liquid.

Temperatures of some of the shallower TMP intervals have increased in recent months. This is likely due to shallow migration of warm gas that is moving through the upper waste layer – which is the most gas permeable waste layer. CEC believes that the SSE is not expanding or moving into the neck and that the SSE is not a fire. It has been our experience that the SSE requires an adjacent high temperature zone to propagate; therefore, the natural cooling sink of the landfill surface will mitigate the possibility of the SSE coming to the surface or the surface down to the SSE. Experience at other sites with similar reactions has shown that this has never occurred.

Mr. Thalhamer specifically mentions TMP-2, -8, -9, -12, and -14 in his letter. Attachment E contains the most recent graph illustrating the long-term trend of maximum TMP temperature. Although some of the intervals may be warming gradually, we do not agree that there is a dramatic increase that suggests SSE activity in the area. Rather, any warming in the area is likely the result of conduction and convection of heat from the active reacting area further south in the South Quarry. Further, the warming in this area has been gradual over time – very different from sudden and larger temperature increases observed in areas affected by the active SSE (see Attachment A).

Due to MDNRs concern with the number of invalid TMP intervals, Bridgeton Landfill and MDNR have agreed in principle to implement weekly wellhead temperature monitoring in the 10 designated neck area GEWs. CEC believes that this will provide sufficient data to evaluate conditions—together with CO and settlement data—even of all if the TMP intervals fail.

<u>Comments on Thalhamer's Recommendations</u>

1. CEC supports Bridgeton Landfill's Expanded Heat Removal Pilot Study. Although there is no evidence that additional heat removal is necessary, the testing of another potential heat removal technology is considered potentially beneficial.

2. CO testing of the GIW wells in the South Quarry is not necessary because there are already 10 gas wells sampled in the same two-acre area. A clearer understanding of conditions in the South Quarry neck area will not result from this additional testing.

3. CEC understands that the chains-of-custody and final lab reports, including all data, are always available for MDNR inspection on site.

4. CEC does not support replacement of any of the compromised TMPs. The original purpose of the TMPs was to allow proper placement of the GIW system and to augment wellhead and settlement data for determining progression of the active SSE. The TMP data is no longer needed as conditions in the neck area are now well documented and a very large database of wellhead and settlement data exists—allowing detailed assessment of conditions without the TMP data. In addition, Bridgeton Landfill and MDNR have agreed in principle to implement weekly wellhead temperature monitoring in the 10 designated neck area GEWs. CEC believes that this will provide sufficient data in to evaluate conditions—together with CO data and settlement data—even if all of the TMP intervals fail.

CEC recommends that the observations made by Mr. Thalhamer be noted, and that they should be evaluated relative to new data collected in upcoming events. Based on experience at other similar reactions at other facilities, it is our belief that it may take years for temperature and CO levels to drop in the neck area, even without active, proximate SSE activity.

If you have any further questions, please call Michael R. Beaudoin at (248) 374-8610.

Sincerely,

CIVIL & ENVIRONMENTAL CONSULTANTS, INC.

Michael R. Beaudoin, P.E.
Principal

Kevin T. Kamp, P.E.
Senior Project Manager

Enclosures

ATTACHMENT A

JULY 17, 2014 RESPONSE LETTER

Bridgeton Landfill, LLC
13570 St. Charles Rock Road
Bridgeton, Missouri 63044

Mr. Chris Nagel
Missouri Department of Natural Resources
1738 East Elm Street
Jefferson City, Missouri 65101

July 17, 2014

Dear Mr. Nagel:

Thalhamer Data Review
Bridgeton Landfill, Bridgeton, Missouri
Permit No. 0118912

On June 20, 2014, you provided Bridgeton Landfill with a memo from Todd Thalhamer which was dated June 15, 2014. The memo summarized Mr. Thalhamer's interpretation of data (from the June 10, 2014 Weekly Data Submittal and the May and June 2014 Monthly Data Submittals) relative to the location and movement of the SSE. Bridgeton Landfill believes that it is necessary to provide a response to Mr. Thalhamer's interpretations and concerns because we believe them to be misleading and incorrect.

For more than a year and a half Bridgeton Landfill has collected and reported an extensive volume of data in order to carefully and comprehensively assess the location, extent and impact of the reaction occurring deep within the South Quarry. We have worked with MDNR to develop this monitoring and reporting protocol, and to update it as appropriate to ensure that we are able to work together utilizing the best available information. That extensive data continues to show that the reaction remains a subsurface reaction, contained in the South Quarry, and that it is not progressing into the North Quarry. We are discouraged that MDNR or any consultant working for MDNR would issue findings and conclusions that do not properly account for all available data. We are providing this response in order to supplement the limited data relied upon by Mr. Thalhamer with the additional data that should be included as part of any assessment.

The following paragraphs attempt to address his observations, conclusions, and concerns.

<u>"Subsurface Fire/Smoldering Event Continues to Expand in the South Quarry"</u>
The reaction is not a subsurface fire, but rather an exothermic reaction occurring in the absence of oxygen (a necessary component for fire). The term SSE (subsurface smoldering event) was developed by MDNR and adopted in the May 2013 Agreed Order, and that term will be used to refer to the reaction that is occurring.

We disagree that the active SSE is expanding, but believe that it is moving. The direction of movement of the active SSE is indicated by the movement of the areas exhibiting large settlement. While settlement may not be a good early indicator of the genesis of an SSE—an ongoing SSE does result in volume reduction which is reflected as settlement at the ground surface. When the SSE moves, areas with accelerated settlement (previously defined as greater than 1.35 feet per month) are observed over or adjacent to the area of the active SSE. The map provided in Attachment A shows locations for the areas within which accelerated settlement is occurring. It can be seen that the total area affected by accelerated settlement is shrinking and that the location of the accelerated settlement (and—correspondingly—the active SSE) is moving away from the North Quarry and further south into the South Quarry.

Evidence that the SSE is not expanding, enlarging, or intensifying is provided by the rate of settlement that is occurring. The rate of settlement—expressed as cubic yards per day—is an indicator of the size and activity level of the SSE. As shown on the graph in Attachment B, the rate of settlement in the past seven months has been very steady. This suggests that the SSE is not expanding.

<u>"Subsurface Fire/Smoldering Event is Past the Last Line of Gas Interceptor Wells/Temperature Concerns"</u>
We agree that temperature in the neck is gradually warming. We do not agree that the SSE is moving toward the neck, let alone "through the neck." The warming in the area is likely the result of conduction and convection of heat from the active reacting area in the southern portion of the South Quarry. As we have noted in earlier reports, the compact waste material is a good insulator and maintains and transfers heat very slowly to surrounding waste. Even if the SSE were to cease reacting today, temperatures in the neck area—well removed from the SSE—would increase for some period of time before they started to drop. Further, the warming in this area has been gradual over time – very different from sudden and larger temperature increases observed in areas affected by the active SSE.

Specific examples referenced by Mr. Thalhamer as "Temperature of Concerns":

<u>Neck Area:</u>
"GEW-38 above 190° F." Bridgeton Landfill notes that this well temperature has been pretty steady with minor fluctuations and a gradual maximum temperature rise from 184° F in October 2013 to 192° F in May 2014 (eight months). See table in Attachment C.

"GEW-109 above 165° F." Bridgeton Landfill notes that this well temperature has been pretty steady with minor fluctuations and a maximum temperature decrease from 172° F in October 2013 to 166° F in May 2014 (eight months). See table in Attachment C.

"GIW-1, -2, -3, -9, -10, -11, -12, and -13 temperatures above 165° F to 200° F." Bridgeton Landfill has observed gradually rising temperatures in these GIWs; however, many of these wells have had elevated temperatures since early 2013. We believe that the gradual warming is due to the conduction of heat as explained prior in this letter. Higher gas temperatures at a given gas flow rate result in more heat being removed from the landfill in the area of the GIWs—this is the proper function and operation of these wells. Graphs for these GIWs are provided in Attachment D.

<u>North Quarry</u>
"GEW-53 and GEW-54 above NSPS temperature threshold of 131° F." These gas wells have historically operated at temperatures greater than 131° F. This condition exists at many landfills that do not have an SSE or reaction occurring. The temperatures in these wells have been pretty steady with minor fluctuations and a gradual maximum temperature decreases from 142° F in October 2013 to 137° F in May 2014 (eight months) for GEW-53, and from 144° F in October 2013 to 138° F in May 2014 (eight months) for GEW-54. See table in Attachment C.

South Quarry

"GEW-15, -16R, -18R, -21A, -34A, -57A, -58, -65A, -71, -72RR, -77, -81, -86, and –100. SEW 13, 63, 74 temperatures over 190° F." Bridgeton Landfill does not understand the nature of the concern with these wells. They are all located in the South Quarry, south of the neck area and are most definitely impacted by the SSE. Wellhead temperatures over 190° F have existed in many of these wells for many months as would be expected based on their location.

Oxygen Readings

Mr. Thalhamer notes several wells that exhibit maximum oxygen readings over 5% at the wellhead. All of the wells noted by Mr. Thalhamer are in the South Quarry.

On June 24, 2013, Bridgeton Landfill replied in a letter to MDNR regarding Mr. Thalhamer's previous concern on this issue (included with this letter as Attachment E). As explained in that letter, these oxygen levels do not represent elevated oxygen in the waste mass, but are due to well operational issues that result in zero landfill gas flow so that the readings obtained are affected by ambient air in the wellhead. It should be noted that all of the gas wells referenced by Mr. Thalhamer are in the South Quarry which is covered by a flexible membrane liner which prevents air from being pulled into the waste mass. The Monthly Data Submittals reviewed by Mr. Thalhamer contain these explanations for such oxygen readings, again stating that they are not representative of oxygen present in the waste mass.

TMP Concerns

As noted in the Weekly Data Submittals and ongoing discussions with MDNR, many of the TMP intervals have been adversely affected by the landfill conditions. Thermocouples and their fragile wire leads were not intended and are not suited to survive on a long-term basis buried in solid waste material that settles and shifts and contains gas and liquid. In fact TMP-13 that Mr. Thalhamer is "most concerned about" has experienced compromised intervals all year, as noted in the weekly reports provided to MDNR. By the time of the June 10, 2014, weekly report, no TMP graph was even included for TMP-13 since it was determined that all intervals had become compromised. Even without these documented data issues, it is not proper to rely on any one monitoring point alone given the expansive monitoring network in place at the Bridgeton Landfill.

It is true that reported temperatures of some of the shallower TMP intervals have increased in recent months. This may be due to compromised or failing units, or may be due to shallow migration of warm gas that is moving through the upper waste layer – which is the most gas permeable waste layer. Bridgeton Landfill does not believe, as stated by Mr. Thalhamer in Item 4 of this portion of his letter, that the SSE is migrating vertically and will result in a "subsurface fire/smoldering event daylighting under the flexible membrane cap." Even if this unlikely event were to occur, the facility has developed an Incident Management Plan that specifically addresses adequate means for responding, controlling, and rapidly extinguishing such a surface fire; the IMP was developed in concert with first responders and with Mr. Thalhamer. MDNR acknowledged the sufficiency of these surface fire response procedures in its June 20, 2014, letter.

Recent Data Not Available to Mr. Thalhamer

The second paragraph of Mr. Thalhamer's memo states "until additional carbon monoxide sampling is performed in the neck, I am not able to conclusively state that the subsurface fire/smoldering event is past the GIW system." Mr. Thalhamer makes this statement even though three rounds of site-wide carbon monoxide testing during this calendar year have each confirmed the absence of carbon monoxide in the North Quarry – including the neck wells in the North Quarry – and reflected the consistency of current North Quarry conditions with those documented in June 2013 sampling.

Since the time of Mr. Thalhamer's review, Bridgeton Landfill has received the results of carbon monoxide sampling on ten gas extraction wells in the "neck area." Some of these wells are in the North Quarry and others in the South Quarry. The results continue to indicate very steady levels of carbon monoxide in the South Quarry neck area, while no carbon monoxide is detected in the North Quarry neck area wells. See Attachment F for a table with these results.

In conclusion, the data, facility observations, and experience with similar reactions support the following conclusions:

1. The SSE is confined to the South Quarry.
2. The active SSE is not expanding, but is moving to the south.
3. While temperatures in the neck area are warming slowly, this is not an indication that the SSE is moving into the neck area, let alone through the neck area.
4. The SSE is not prone to "daylighting under the flexible membrane cap." However, Bridgeton Landfill has an Incident Management Plan—developed in concert with the first responders and Mr. Thalhamer—that specifically addresses adequate means for responding, controlling, and rapidly extinguishing a surface fire.
5. The most recent carbon monoxide testing data in the neck area (not available for review by Mr. Thalhamer before his memo was prepared) indicates that the neck area results are stable.

If you need additional information, please contact me at (314) 744-8165.

Sincerely,
Bridgeton Landfill, LLC

Brian J. Power

Brian Power
Environmental Manager

Attachments:

A – Map with Direction of SSE Movement
B – Graph of Settlement Volume
C – Table with Maximum Monthly Wellhead Temperatures
D – GIW Wellhead Temperature Graphs
E – June 13, 2013 Letter Response to Thalhamer Data Review
F – North Quarry and Neck Area Carbon Monoxide Results

ATTACHMENT A

MAP WITH DIRECTION OF SSE MOVEMENT

LEGEND

- TOPOGRAPHY (2' CONTOUR)
- 500 — TOPOGRAPHY (10' CONTOUR)
- SEPTEMBER 23, 2013 SETTLEMENT FRONT
- JUNE 15, 2014 SETTLEMENT FRONT

GENERAL NOTES:

1.) TOPOGRAPHY SHOWN BASED ON PHOTOGRAPHY DATED 3-20-2014.

SETTLEMENT NOTES:

1.) DRAWING DEPICTS THE LOCATION OF SETTLEMENT ACTIVITY THAT IS 1.35 FT PER 30 DAYS - INDICATIVE OF THE SETTLEMENT FRONT BASED ON THE ANALYSIS OF SURVEY DATA IN 2012.

2.) THE SEPTEMBER 23, 2013 SETTLEMENT FRONT WAS DEVELOPED BY COMPARING THE SURVEY FROM AUGUST 17, 2013 TO THE SURVEY FROM SEPTEMBER 23, 2013 AND PLACING A BOUNDARY AROUND THE AREA THAT SHOWED SETTLEMENT OF 1.35 FT OR GREATER PER 30 DAYS.

3.) THE JUNE 15, 2014 SETTLEMENT FRONT WAS DEVELOPED BY COMPARING THE SURVEY FROM MAY 15, 2014 TO THE SURVEY FROM JUNE 15, 2014 AND PLACING A BOUNDARY AROUND THE AREA THAT SHOWED SETTLEMENT OF 1.35 FT OR GREATER PER 30 DAYS.

BRIDGETON LANDFILL, LLC
13570 SAINT CHARLES ROCK ROAD
BRIDGETON, MISSOURI 63044

BRIDGETON LANDFILL
SETTLEMENT MONITORING

SETTLEMENT FRONTS
SEPTEMBER 2013 AND JUNE 2014

Engineering for a Better World
FEEZOR ENGINEERING, INC.

DATE: JULY 2014
DESIGNED BY: DMK
APPROVED BY: ALK

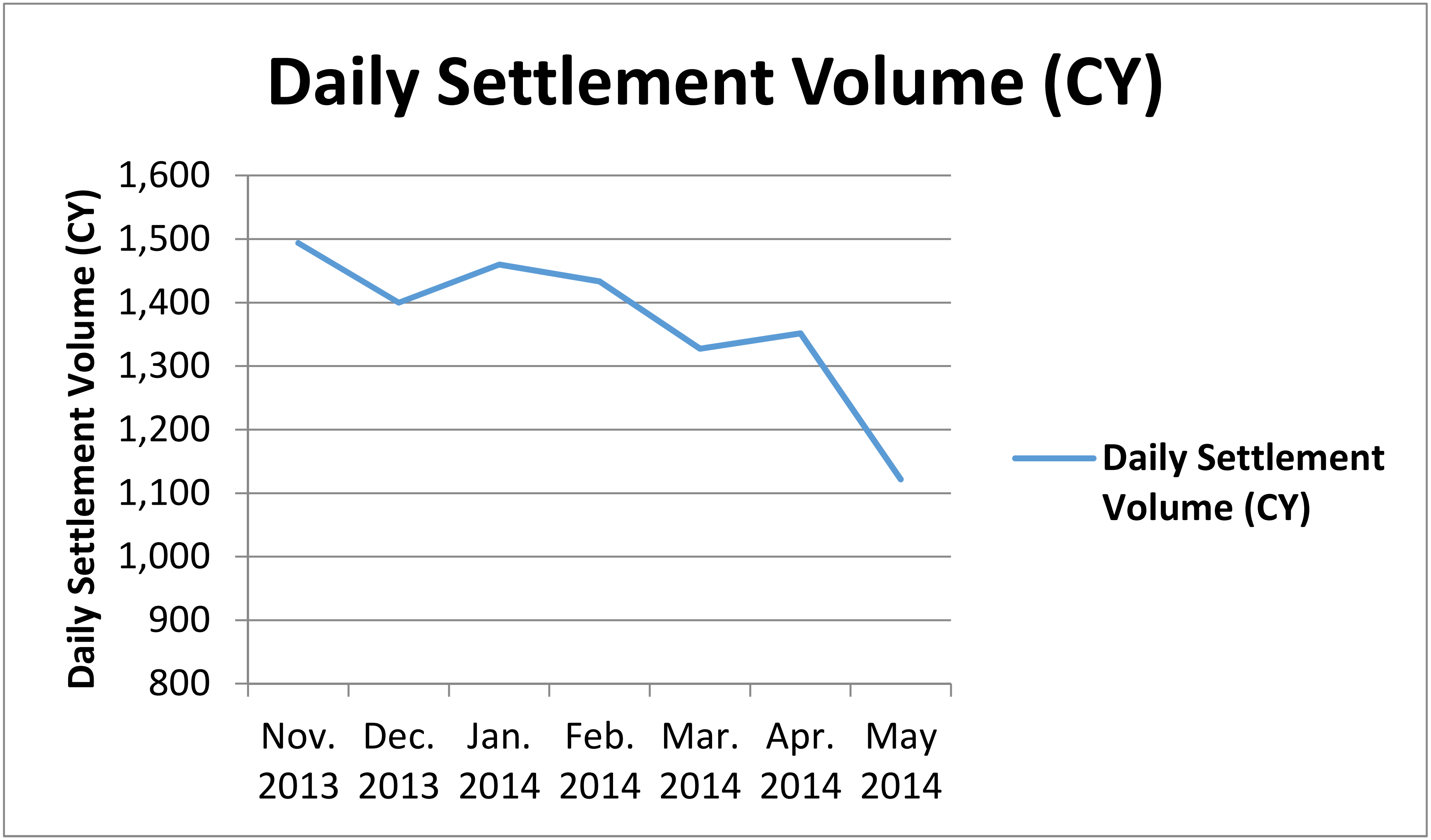
REVISION	DATE

DRAWING NO.: **001**

PROJECT NUMBER: BT-021 | FILE PATH: S:\BRIDGETON LANDFILL\BT-021\SETTLEMENT FRONT VECTORS.DWG

ATTACHMENT B

GRAPH OF SETTLEMENT VOLUME



Daily Settlement Volume (CY)
Daily Settlement Volume (CY)
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
Nov. 2013
Dec. 2013
Jan. 2014
Feb. 2014
Mar. 2014
Apr. 2014
May 2014
Daily Settlement Volume (CY)

ATTACHMENT C

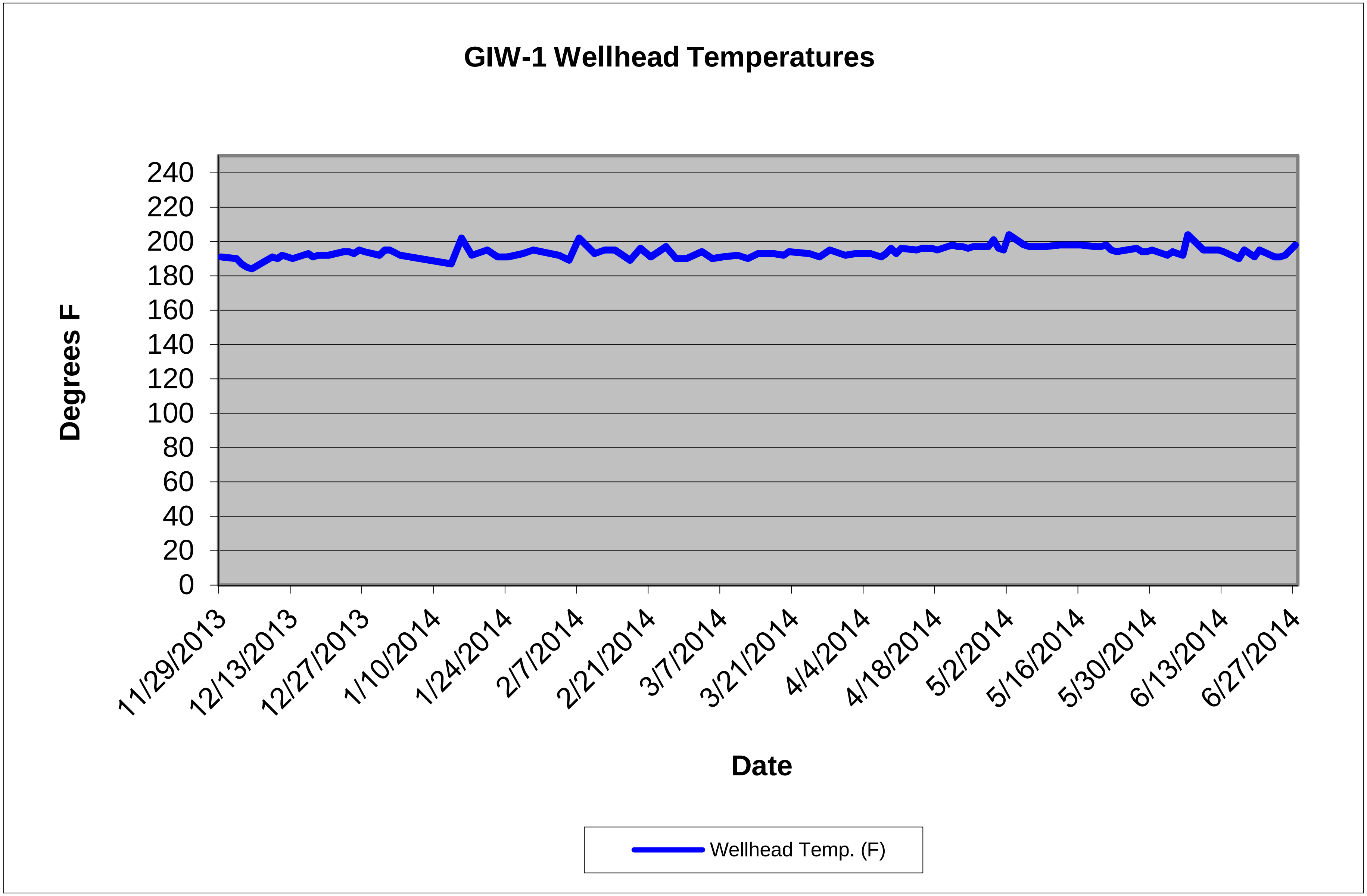
TABLE WITH MAXIMUM MONTHLY WELLHEAD TEMPERATURES

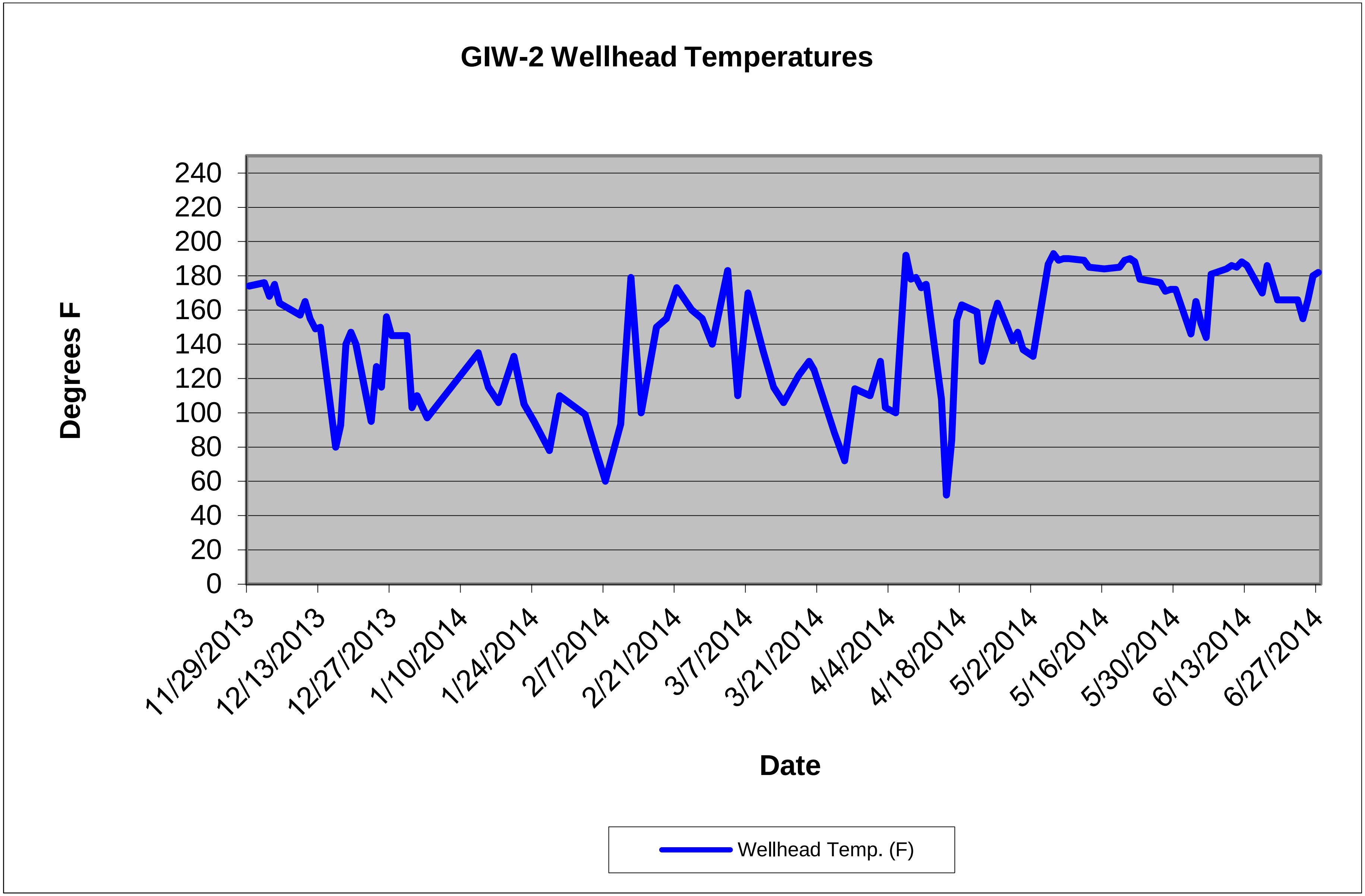
BRIDGETON LANDFILL
SELECT GAS EXTRACTION WELL TEMPERATURE DATA

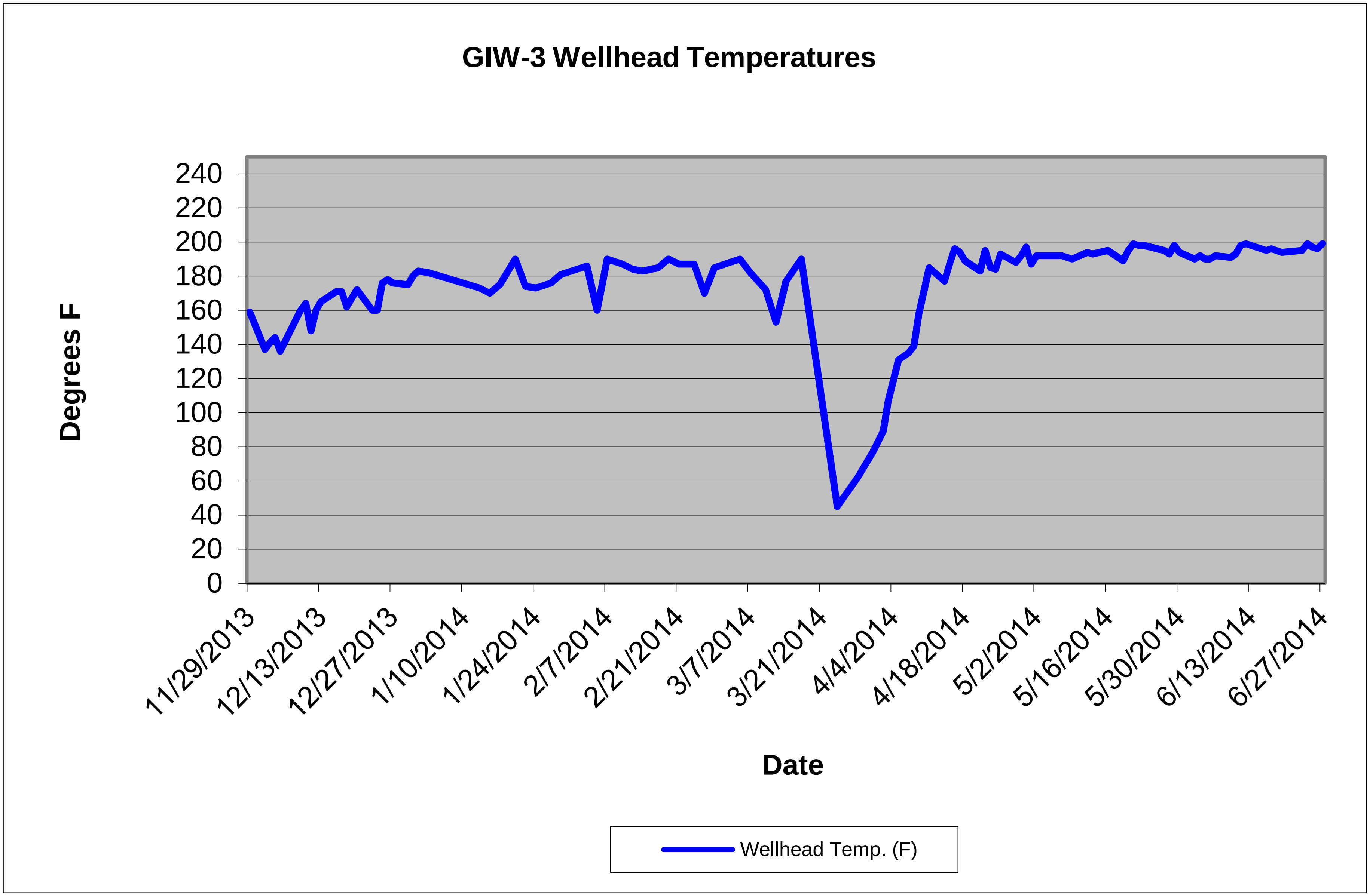
	Maximum Initial Wellhead Temperature (deg. F)							
Well Name	**Oct. 2013**	**Nov. 2013**	**Dec. 2013**	**Jan. 2014**	**Feb. 2014**	**Mar. 2014**	**Apr. 2014**	**May 2014**
Neck Area								
GEW-38	184	179	181	181	186	190	189	192
GEW-109	172	170	174	162	167	170	122	166
North Quarry								
GEW-53	142	133	128	137	132	138	139	137
GEW-54	144	148	136	142	140	138	138	138

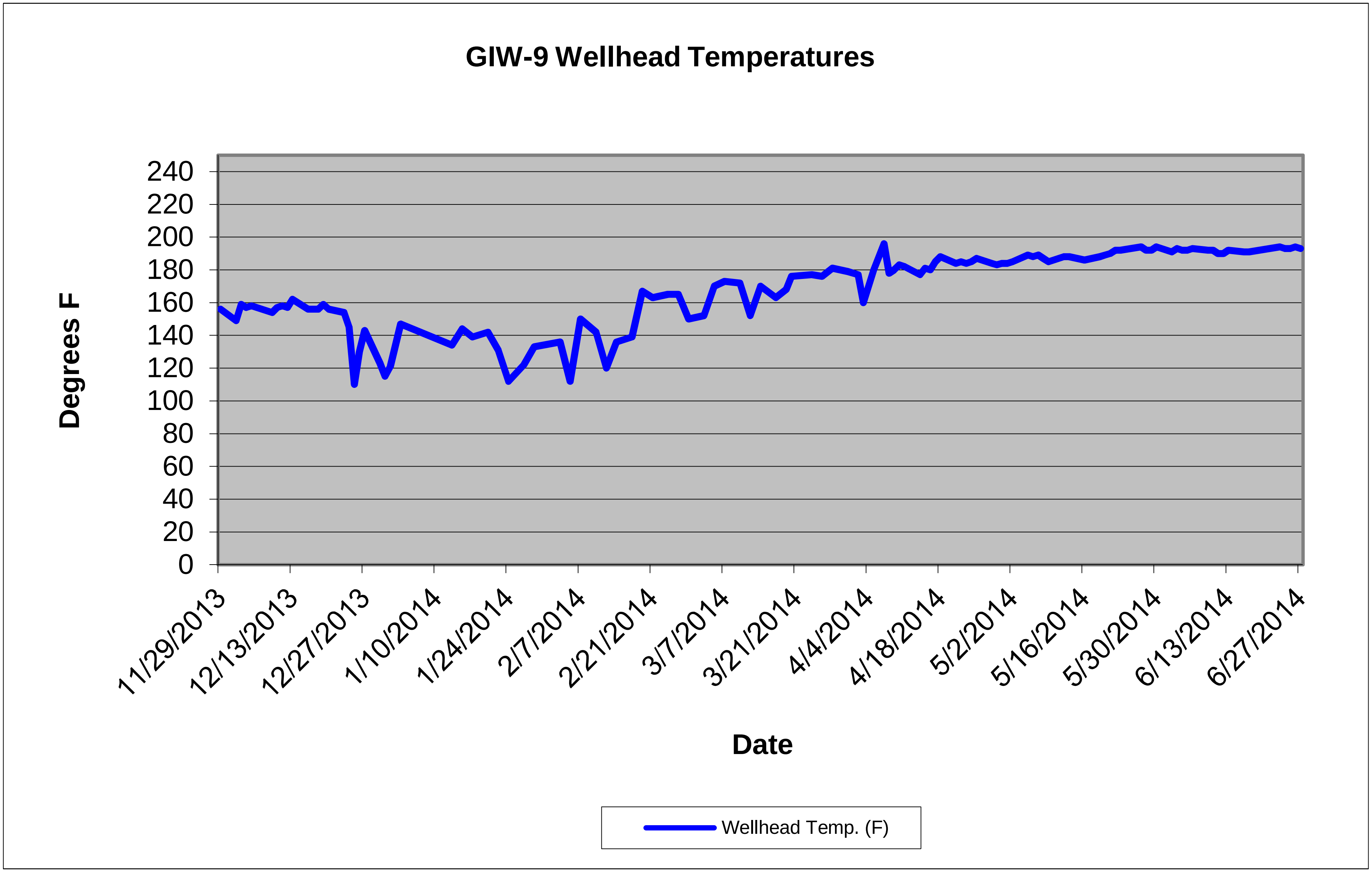
ATTACHMENT D

GIW WELLHEAD TEMPERATURE GRAPHS

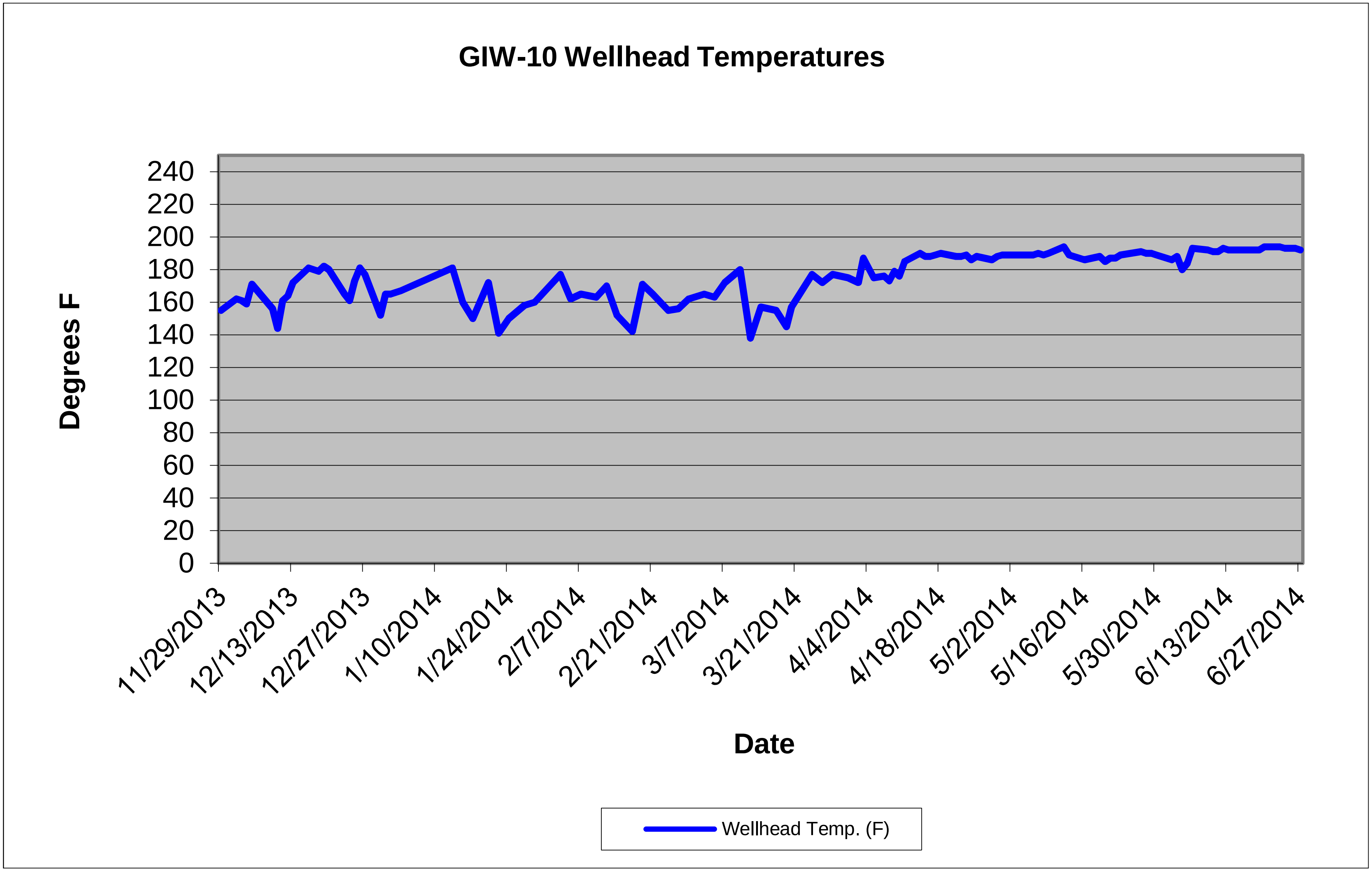

GIW-1 Wellhead Temperatures
Degrees F
240
220
200
180
160
140
120
100
80
60
40
20
0
11/29/2013
12/13/2013
12/27/2013
1/10/2014
1/24/2014
2/7/2014
2/21/2014
3/7/2014
3/21/2014
4/4/2014
4/18/2014
5/2/2014
5/16/2014
5/30/2014
6/13/2014
6/27/2014
Date
Wellhead Temp. (F)


GIW-2 Wellhead Temperatures
Degrees F
0
20
40
60
80
100
120
140
160
180
200
220
240
11/29/2013
12/13/2013
12/27/2013
1/10/2014
1/24/2014
2/7/2014
2/21/2014
3/7/2014
3/21/2014
4/4/2014
4/18/2014
5/2/2014
5/16/2014
5/30/2014
6/13/2014
6/27/2014
Date
Wellhead Temp. (F)

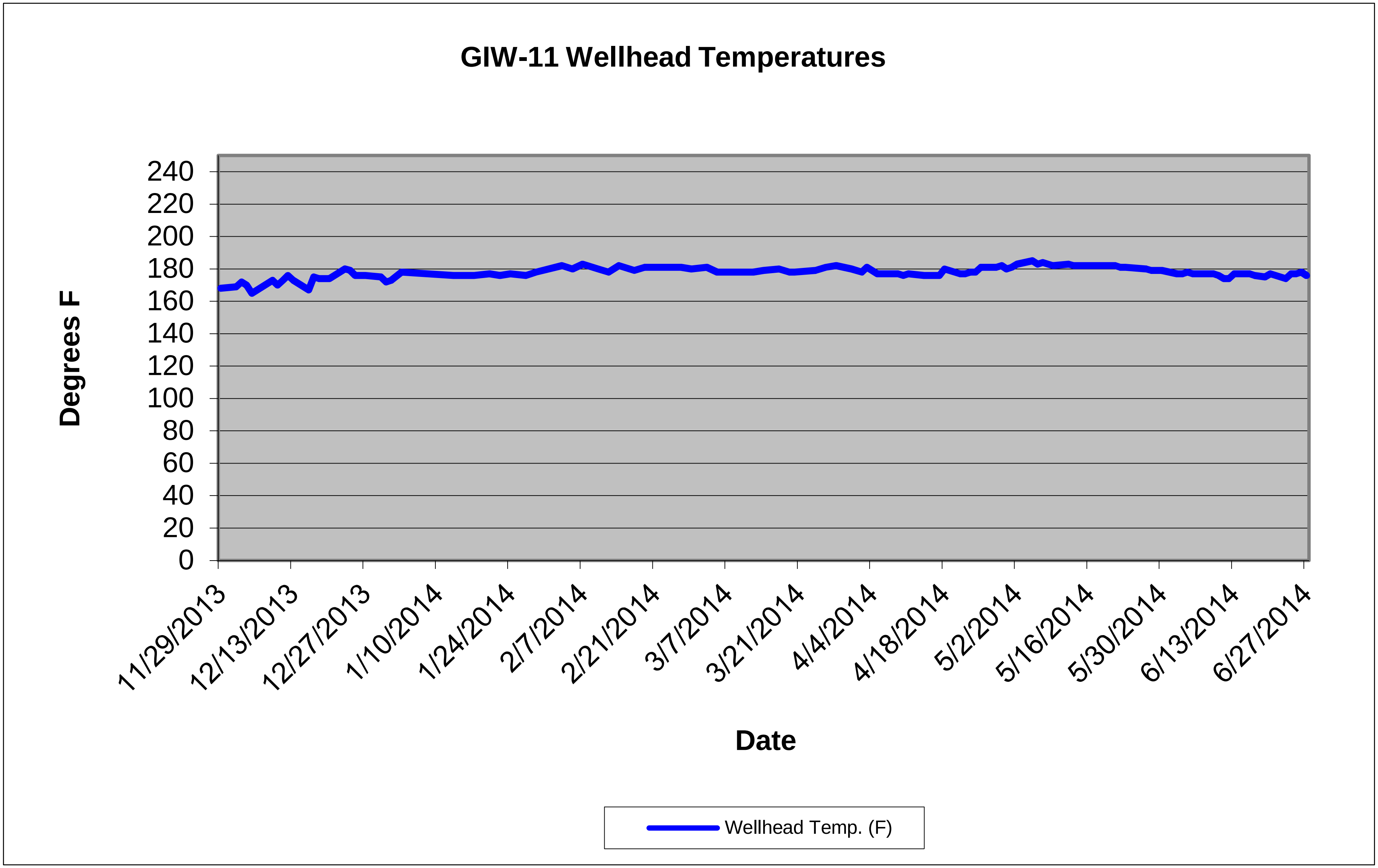

GIW-3 Wellhead Temperatures
Degrees F
240
220
200
180
160
140
120
100
80
60
40
20
0
11/29/2013
12/13/2013
12/27/2013
1/10/2014
1/24/2014
2/7/2014
2/21/2014
3/7/2014
3/21/2014
4/4/2014
4/18/2014
5/2/2014
5/16/2014
5/30/2014
6/13/2014
6/27/2014
Date
Wellhead Temp. (F)



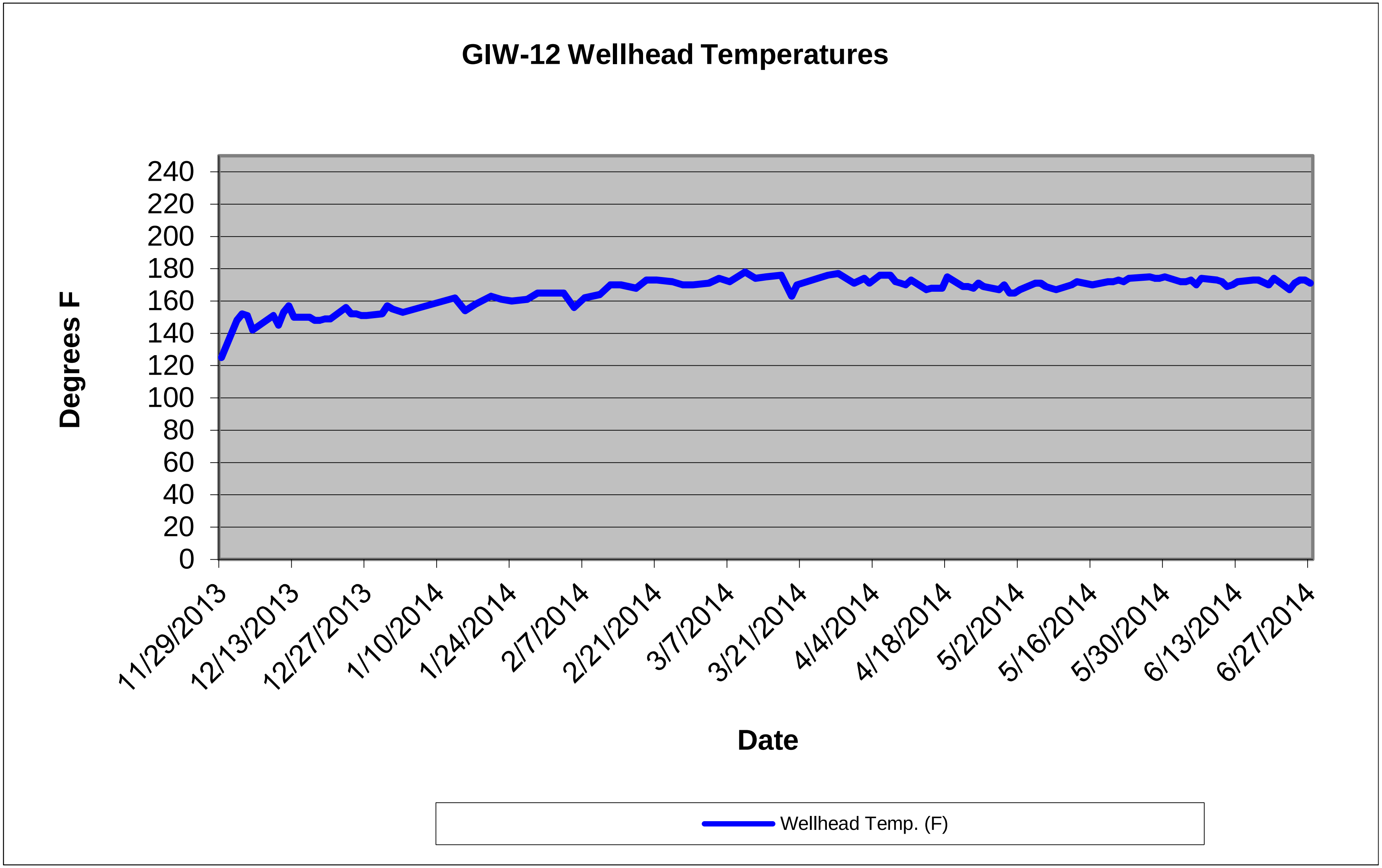
GIW-9 Wellhead Temperatures
Degrees F
240
220
200
180
160
140
120
100
80
60
40
20
0
11/29/2013
12/13/2013
12/27/2013
1/10/2014
1/24/2014
2/7/2014
2/21/2014
3/7/2014
3/21/2014
4/4/2014
4/18/2014
5/2/2014
5/16/2014
5/30/2014
6/13/2014
6/27/2014
Date
Wellhead Temp. (F)



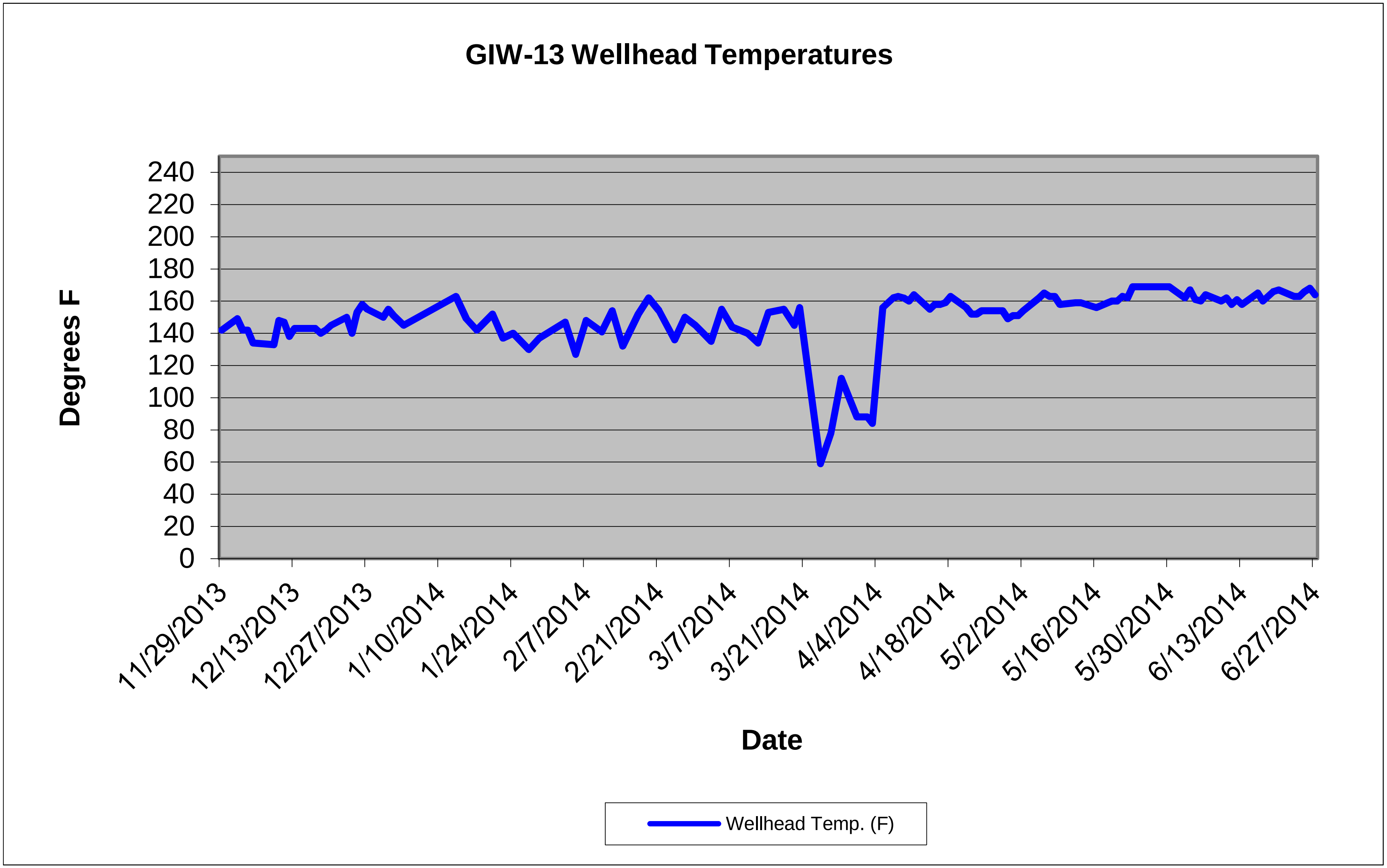
GIW-10 Wellhead Temperatures
Degrees F
240
220
200
180
160
140
120
100
80
60
40
20
0
11/29/2013
12/13/2013
12/27/2013
1/10/2014
1/24/2014
2/7/2014
2/21/2014
3/7/2014
3/21/2014
4/4/2014
4/18/2014
5/2/2014
5/16/2014
5/30/2014
6/13/2014
6/27/2014
Date
Wellhead Temp. (F)



GIW-11 Wellhead Temperatures
Degrees F
240
220
200
180
160
140
120
100
80
60
40
20
0
11/29/2013
12/13/2013
12/27/2013
1/10/2014
1/24/2014
2/7/2014
2/21/2014
3/7/2014
3/21/2014
4/4/2014
4/18/2014
5/2/2014
5/16/2014
5/30/2014
6/13/2014
6/27/2014
Date
Wellhead Temp. (F)



GIW-12 Wellhead Temperatures
Degrees F
0
20
40
60
80
100
120
140
160
180
200
220
240
11/29/2013
12/13/2013
12/27/2013
1/10/2014
1/24/2014
2/7/2014
2/21/2014
3/7/2014
3/21/2014
4/4/2014
4/18/2014
5/2/2014
5/16/2014
5/30/2014
6/13/2014
6/27/2014
Date
Wellhead Temp. (F)



GIW-13 Wellhead Temperatures
Degrees F
240
220
200
180
160
140
120
100
80
60
40
20
0
11/29/2013
12/13/2013
12/27/2013
1/10/2014
1/24/2014
2/7/2014
2/21/2014
3/7/2014
3/21/2014
4/4/2014
4/18/2014
5/2/2014
5/16/2014
5/30/2014
6/13/2014
6/27/2014
Date
Wellhead Temp. (F)

ATTACHMENT E

JUNE 13, 2013 LETTER RESPONSE TO THALHAMER DATA REVIEW

Bridgeton Landfill, LLC
13570 St. Charles Rock Road
Bridgeton, Missouri 63044

Mr. Aaron Schmidt
Missouri Department of Natural Resources
1738 East Elm Street
Jefferson City, Missouri 65101

June 24, 2013

Dear Mr. Schmidt:

Gas Wellfield Management
Bridgeton Landfill, Bridgeton, Missouri
Permit No. 0118912

At the June 18, 2013 Team Bridgeton meeting, you referred to comments in the report "Data Evaluation of the Subsurface Smoldering Event at the Bridgeton Landfill" prepared by Todd Thalhammer, P.E. dated June 17, 2013. The referenced comments are found in the "General Comments and Concerns on the Landfill Data" section of the report and deal with Mr. Thalhamer's concern with what he sees as "overpull" of the gas extraction wellfield.

We do not believe that a systemic condition of overpull exists in the wellfield, but remain open to discussing this further to answer any questions and offer the following comments in response to the concerns raised in Mr. Thalhamer's report:

1. The report references several incidents where inlet gas to the flare contained more than 5% oxygen and cites that as evidence that the "facility is overdrawing the gas collection and control system." However, it should be noted that the gas collected at the flare includes gas from many locations other than the GEW and GIW wells in the wellfield. About 50 PEW (perimeter extraction wells) are installed outside the limits of waste in soil and rock materials for the purpose of limiting methane migration. These wells draw primarily ambient air with high oxygen levels but do not draw oxygen into the waste material. Also, there are a number of "odor control" devices that contribute gas to the flare inlet, such as "bubblesuckers" (features that remove shallow gas from under sections of synthetic liner material), sump collectors, shallow horizontal trenches, and leachate vessels; each of these allow ambient air into the gas collection system, without pulling oxygen into waste material.

2. Table 4 of the report lists gas wells from April that had peak oxygen level over 5%. There are many reasons that this can occur, and the details of these specific incidents can be investigated. Generally speaking, the presence of a high water level in a gas well can limit or prevent landfill gas from reaching the wellhead where oxygen is measured. In such cases, the field instrument pulls a vacuum on the wellhead which may allow air to infiltrate the wellhead causing oxygen readings that are not representative of oxygen levels in the waste mass. In other cases, It is

possible that settlement causes the solid casing portion of the gas well to pull away from the soil creating a "short-circuit" of air to migrate down along the casing and to enter the top of the well screen (which is usually shallow and well above the reaction area); again, this would not be representative of the oxygen content in the waste mass.

We agree with MDNR and Mr. Thalhammer regarding the importance of minimizing oxygen intrusion into the waste mass, and will continue to remain diligent while also exerting efforts to maximize gas removal in an attempt to control odor. We have reinforced our procedures to assure follow-up and trouble-shooting for GEW and GIW wells that indicate presence of oxygen; these may result in earlier introduction of a pump into a well, greater attention to surface seals, etc. Addition of the EVOH cap should allow better surface seal eliminating one of the above-mentioned variables.

If you need additional information, please contact Michael R. Beaudoin of CEC at 248-804-8022 or myself at 314-744-8195.

Sincerely,

Bridgeton Landfill, LLC

Michael R. Beaudoin FOR

Craig Almanza
Area Environmental Manager

cc: Mr. Chris Nagel, Chief, MDNR-SWMP

ATTACHMENT F

NORTH QUARRY AND NECK AREA CARBON MONOXIDE RESULTS

BRIDGETON LANDFILL NORTH QUARRY AND NECK AREA CARBON MONOXIDE ANALYSES

Gas Well	*June 6, 2013 Sample*	*January 24, 2014 Sample*	*March 25, 2014 Sample*	*May 22-23, 2014 Sample*	*June 25, 2014 Sample, Neck*
	ppm	ppm	ppm	ppm	ppm

North Quarry Gas Extraction Wells

GEW-1	ND	ND	ND	ND	
GEW-2	ND	180	ND	ND	
GEW-3	ND	ND	ND	ND	
GEW-4	ND	ND	ND	ND	
GEW-5	ND	ND	ND	ND	
GEW-6	ND	ND	ND	ND	
GEW-7	ND	ND	ND	ND	
GEW-8	ND	ND	ND	ND	ND
GEW-9	ND	ND	ND	ND	ND
GEW-40	ND	ND	ND	ND	ND
GEW-41R	ND	ND	ND	ND	
GEW-42R	ND	ND	ND	ND	
GEW-43R	ND	ND	ND	ND	
GEW-44	ND	ND	ND	ND	
GEW-45R	ND	ND	ND	ND	
GEW-46R	ND	ND	ND	ND	
GEW-47R	100	36	ND	ND	
GEW-48	ND	ND	ND	ND	
GEW-49	ND	ND	ND	ND	
GEW-50	ND	ND	ND	ND	
GEW-51	ND	120	120	ND	
GEW-52	ND	ND	ND	ND	
GEW-53	44	120	150	ND	
GEW-54	44	24	ND	ND	
GEW-55	ND	32	30	ND	ND

South Quarry/Neck Area (closest sampling date to North Quarry event possible)

GEW-10	370	180	300	63	ND
GEW-38	2700	2400	2000	2400	2300
GEW-39	630	260	280	280	260
GEW-56R	230	2900	690	440	ND
GEW-109	1500	1300	1900	1700	1500
GEW-110	920	460	NA	NA	880

(yellow) = Neck Area Well designated June 2014

ATTACHMENT B

CORRELATION OF SITE METRICS WITH REACTION PREDICTION

APPENDIX E

CORRELATIONS OF SITE METRICS WITH REACTION PREDICTION

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ATTACHMENT E-1

1 INTRODUCTION

1.1 PURPOSE

The purpose of the work presented in this Appendix was to identify those metrics that can be obtained at the site on a normal basis to predict the location and rate of movement of the reaction at the Bridgeton Landfill. Data that has been and will be gathered at the landfill and could potentially be used to monitor the location and progress of the reaction was examined in detail to determine how well it predicted behavior to date and how those data could be used for the purpose of triggering actions in the future.

1.2 SCOPE

The following data was examined:

- Temperature Monitoring Probe Readings (available since late fall 2012)
- Gas wellhead field monitoring data (available for wells since 2009 and earlier)
- Laboratory Gas Analysis from individual gas wells (available for some wells at dates starting as early as 2011 but monthly for most south quarry wells beginning in August 2012)
- Settlement rate data (grid survey comparisons beginning in January 31, 2013 and GPS digital terrain models back to early 2011 on a monthly basis)

The data used and the analyses and predictive capacity and relationships identified are presented and described in the subsequent sections of this appendix.

2 GENERAL DATA PRESENTATION

2.1 TMP MEASUREMENTS

TMP data has been gathered on weekly basis for each of the TMP units once they were installed. In some cases, most notably TMP-8, some of the thermocouple units have become inoperable with time. TMP data has been plotted with time along with the settlement rates for grid based surveys and gas well data (gas wellhead temperature) to identify correlations between these conditions and in-ground temperature. The maximum and average values for the TMP plotted were chosen to represent the TMP readings in the simplest fashion. TMP plots with settlement rate at the TMP are presented in Figures E-1 through E-14 and TMP plots with gas wellhead temperatures, for gas wells that are proximate to TMPs, are presented in Figures E-15 through E-22. TMP maximum temperatures were also included in plots for gas well constituents where they were proximate to gas wells as described in Section 2.2 of this Appendix. These figures are referred to in subsequent sections of this Appendix.

2.2 GAS WELL DATA

Gas wellhead data, i.e. well head temperature, and field analyzer measured CO_2, and CH_4, have been plotted along with laboratory gas analysis of CO, CO_2, H_2 and CH_4 with time. Nearby TMP maximum temperature and settlement rate values at the gas wells have also been included. Figures E-23 through E-47 present plots of gas wells selected to cover a range of behaviors, locations relative to the reaction, and wells that are proximate to settlement fronts and TMP readings. These figures are referred to in subsequent sections of this Appendix.

3 ANALYSIS OF DATA

3.1 TMP DATA

The TMP data was analyzed to look at what in-ground temperatures were consistent with other signs of the reaction. The main indicators of the reaction are typically settlement at the ground surface, gas wellhead temperatures and CO.

3.1.1 COMPARISON TO SETTLEMENT RATE

Comparison of settlement and maximum temperature measured at a TMP location is illustrated in Figures E-1 through E-14. Three of the TMP's, TMP-7R, TMP-8, and TMP-9, as shown on Figures E-7 through E-9, respectively, have exhibited maximum temperatures in excess of 220 °F. As can be seen in Figures E-7 and Figure E-8, maximum TMP temperature and settlement rate are closely linked to the settlement rate having exceeded a value in the range of -0.04 to -0.045 ft per day. Figure 9, depicting TMP-9, does not show this correlation, but is located where the waste thickness is approximately 0.4 times the thickness of the other locations, so it is possible the similar rate of settlement at the location of TMP-9 is on the order of -0.016 to -0.018 ft per day, which appears to have been exceeded in December or January of this year. It should be noted that settlement at the TMP-9 location has been limited since those dates and temperatures of late have been falling. When looking at the Figures it should be noted that the survey data for settlement rate prior to December 12 was not done on a grid basis so actual settlement rates reported in December are considered less accurate than those reported on or after January 31, 2013, when all data was compared to a common grid location point to point.

The remaining TMPs have experienced a maximum temperature of 180 °F, as can be seen in the corresponding Figures.

It is not surprising that local settlement is related to exceedence of temperatures in excess of 220 °F. At this temperature, paper and other cellulose based materials can begin to pyrolyze, resulting in volume reduction. It can also be seen looking at Figure 8 that temperatures continued to rise after the onset of achieving 220 °F, which suggests that pyrolysis-related settlement behind the front is greater. As described in the March 29, 2013, letter to Mrs. Fitch of MDNR from Craig Almanza of Bridgeton Landfill[1] under the heading "Analysis of the Shape of the Zone of Accelerated Settlement", the settlement at any point in the area of advancing settlement includes settlement associated with volume reduction from areas as far away as 150 ft. This may well explain why there is apparently no substantive time delay between the achievement of the maximum TMP values of 220 °F and a settlement rate of -0.04 to -0.045 ft/day. This is consistent with mapping of

[1] Referred to hereinafter as Reference 1 and included in Appendix A of the North Quarry Contingency Plan Part 1.

the settlement front as a measure of the reaction advance using the -0.045 ft/day value that has been presented thus far in the project.

At shallower sections of the quarry it may be appropriate to reduce the level of settlement per day deemed as accelerated settlement to a value that is consistent with the heated zone in the shallower area compared to full quarry height locations. This would reflect the fact that settlement rate associated with the reaction is actually associated with the thickness of the waste being heated to a level that results in volume destruction, based on the TMP charts of temperature with depth.

3.1.2 Comparison to Gas WellHead Temperature

Gas wellhead temperature reflects the average temperature of the waste the gas has passed through for the zone around the well. In areas where the temperature varies significantly with direction and distance from the well, such as near a temperature front, the gas wellhead temperature can be very different than the waste temperature at any depth around the well. In areas that are not experiencing temperature changes in lateral directions, the gas wellhead value reflects the average temperature typically of the upper 75 feet of waste column, which in a decomposing landfill is cooler than landfill waste temperatures at greater depths but still well above the landfill bottom (>40 or 50'above bottom). As such the temperature difference between maximum and average TMP values compared to the gas wellhead temperature seen in Figures E-15 through E-22 is not unexpected.

For gas wells more than 100 feet from the Settlement Front or apparent heat front, such as GEW-10, GEW-39, GEW-56R and GEW-109, the wellhead temperature was found to be as much as 30 °F lower than the average nearby TMP value (GEW-10 and TMP10 – Figure E-15) but more typically 10 to 15 °F lower. Maximum TMP values for these same wells were 12 to 45 °F higher than the wellhead temperature of nearby wells. No correlation between temperature difference and distance from the TMP to the well were identified, given the greater differences were observed at GEW-10 which is within only 10 feet away from TMP-10. Differences between the TMP max and average values were typically greater if the well was north of the TMP (further from the advancing heat front) than south of the TMP (closer to the heat front). One could generally conclude that typically wellhead temperatures removed from the heat fronts could be in the range of 40 °F below the maximum temperature in the waste, but the data is limited. The significant difference between the TMP-10 and GEW-10 suggests that the TMP data represents a relatively small distance close to the TMP.

For gas wells closer than 100 feet from the Settlement Front (or heat front), such as GEW11, GIW7, and GIW-11 the variation between gas wellhead temperature and the TMP average values was typically less than was observed in the wells further away from the front. But the variation from the maximum TMP value was consistently close to thirty degrees. The only observed exception was GIW-7 which, being 51 feet away from TMP-7R, did not show a rise in temperature during the beginning of June 2013, when TMP-7R increased nearly 60 degrees in maximum and 20 degrees in average. GIW-7 is the only well near the heat front that is also within any proximity of a TMP. A plot for GIW12 is also included (Figure E-22) just to complete the set of wells close to TMPs.

However, GIW-12 has yet to reach a stable operating condition and therefore no conclusions can be drawn from it.

Generally speaking, the gas wellhead temperature can be shown not to directly reflect the maximum temperatures in the waste mass. In general it would be reasonable to suggest that in areas not within 100 feet of more of a settlement front, the wellhead temperature is likely within 40 to 45 °F of the maximum waste temperature. This would suggest that in the absence of settlement occurring at an elevated rate or significant CO concentrations, a wellhead temperature of up to 175 °F could, in the absence of other indicators, be acceptable and would indicate maximum waste temperatures in the vicinity of that well less than 220 °F. A gas wellhead temperature of 175 °F or higher could indicate the area had been likely been warmed by processes not consistent with biological degradation processes and would reflect maximum temperatures within the waste in the area of influence of the well that would exceed 220 °F.

3.1.3 Ability to Predict Location and Rate

TMP data is not able to predict rate or location that is closer than the spacing between TMP points. For example, if one looks at Figures E-7 and E-8, it is clear that the change in temperature from 180 to 190 to 220 was a gradual change that was consistent with the slope of the temperature line in advance of the change. It is apparent that some energy consuming activity is associated with this temperature rise that makes the transition faster, once the temperature transition to 220 °F is achieved the temperature continues to rise higher. Based on the behavior of TMP-7R and TMP-8 it appears that all one can conclude is that the front is either at a location or not. The rate of travel is not apparent from the TMP data alone. Review of data associated with TMP-13 does not indicate the rate the front may be advancing toward it based on measured temperature. All that could possibly be concluded is TMP-13 is warming at a very slow rate (See Figure E-13).

3.2 GAS WELL DATA

Gas well data was examined to determine what, if any, information was predictive of location and rate of movement of the reaction. Figures E-23 through E-47 contain gas well measurements and TMP data, when a TMP is nearby, along with settlement rate data based on the surveys performed at the site. In addition, a summary of gas well location relative to the settlement front, as currently defined by rate of settlement of -0.45 ft per day (1.35ft per 30 day month). Settlement rate data prior to January 31, 2013 is considered less accurate given the surveying methods used.

As explained in Section 3.1.2, the gas well data is influenced by proximity to the heat front, but not in an easily definable way. To explore the relationship, the locations of gas wells relative to the settlement front or in proximity to the front were identified. These are summarized in Table E-1 for settlement front locations as of July 2012 and later. Earlier settlement fronts have not been determined.

As can be seen in Table E-1, many of the gas wells that are within 50 feet of the settlement front as of April 15, 2013 have been inside of the gas front or within a limited distance of the settlement front since September 2012 or July 2012. It is also possible to examine wellhead temperatures within the settlement zone, as well as other gas make up.

Gas well constituents represent gas being collected at any time, not gas being produced at any specific location. When the gas being produced is constant with time, the gas collected should be similar to the gas being produced. When the gas being produced is changing with time, the gas being collected represents a mixture of gasses produced with gasses that are stored in pore spaces or diffusing from solids within the area of influence. In addition, as was mentioned in Section 3.1.2, the gas collected comes from an unknown tributary area and would be expected to include the gasses from any nearby heat affected zone prior to the heat of the reaction actually causing volume reduction at the well. Further, since the gas constituents are tracked as percent volume (dry) constituents not related to methanogenesis are amplified in concentration by the reduction in methane production that occurs when the waste mass is warmed over 160 °F. Once methane production is halted to temperature rise, the major gas constituents are typically CO_2, H_2. CO is also present but is not a major gas constituent (typically less than 1% or 10,000 ppm). Based on experience at other sites, CO concentrations are likely to remain elevated for some time even after temperatures begin to fall and settlement rates reduce. For this reason it is appropriate to examine well gas concentrations by looking at wells that have been inside or near the reaction area at times in the past, wells that have only recently been in or near the reaction area and wells that have never been proximate to the reaction area as separate sets of data. Screening for wells that have never been in the reaction area has been approximated by those wells not currently within 150 ft of any of the settlement fronts and wells that, since 2011, are not located in areas that have settled more than 5 feet, which excludes wells GEW 14a, GEW-18R, GEW-19A ,GEW-112 and GEW-45R possibly from the wells not within 150 feet of settlement fronts. GEW -24a, through 30 R in the southeast corner of the South Quarry were also eliminated from this set given their proximity to the reaction and the likelihood that added fill placed in this area had masked settlements.

Laboratory of gas analysis is available for only south quarry wells and most of that is for periods following August of 2012. Therefore, only gas wells in the south quarry were included in the analysis of gas well constituents. Field measurements of gas well constituents were not utilized for analysis of wells within the vicinity of the reaction area since they do not include any information on CO or H_2.

3.2.1 *GAS WELLHEAD TEMPERATURE*

3.2.1.1.1 Wells Inside or Proximate to the Settlement Fronts

Gas wellhead temperature inside or proximate to the settlement fronts was analyzed by looking at all data and filtering for CO values higher than a fixed value. The following presents the wellhead temperatures as they related to CO values. Gas wellhead temperatures below 100 °F were manually excluded from the analysis as being not representative of gas wells with any flow. It should be noted that some reported temperatures were as low as 0 °F.

CO Minimum	Average	Median	Standard Deviation	Sample Count
5000 ppm	171.5	180	24.7	109
4000 ppm	170	179	24.8	174
3000 ppm	162	170	26	270
2000 ppm	156	152	25.8	384

The results indicate that a gas well temperature above 170 is identified with CO values on average of more than 4000 ppm. Gas wellhead temperatures in excess of this value would suggest that significant waste alteration via heat is occurring. As represented in Figures E-24 through E-47, the data does have significant scatter, as would be expected given that each data point is a composite of gas produced from waste within the zone of influence of the well. The significant reduction in median temperature from CO concentration of 3000 ppm to 2000 ppm indicates that the threshold indicator is at least 3000 ppm. The minimal change between 4000 and 5000 ppm suggests that 4000 ppm could be used as a threshold for clearly being in the elevated head zone and gas wellhead temperatures in the range of 170 to 175, which could be considered indication of waste temperatures having reached 220 °F temperatures. Consistent with the comparisons of TMP values and wellhead temperatures discussed in Section 3.1.2, CO in excess of this value would suggest that significant waste alteration via heat is occurring.

3.2.1.1.2 Wells more than 150 feet from Any Settlement Front

An evaluation of the gas wellhead temperatures measured routinely at the site was performed for all the wells outside the settlement areas. The evaluation is reported in Table E-2. The average value of wellhead temperature was 107 °F with a maximum value of 155 °F associated with GEW-54 located in the south end of the North Quarry. Minimum readings of 19 °F were reported. These low readings bias downward the average value and are certainly not representative of the gas in the wells but likely a measurement taken with no or little flow in the well. Ignoring temperatures below 90 °F raises the average temperature to 113 °F. This suggests a temperature of 135 °F (the average plus 1 standard deviation) would represent a temperature at which nothing is occurring. Higher wellhead temperatures may warrant further scrutiny if other indicators of reaction are present.

TABLE E-2
FIELD MEASUREMENTS OF
OF GAS WELLS > 150 FT FROM SETTLEMENT
FRONTS

	CH4	CO2	O2	CH2/CO2	Init Temp
Average	40.62092	40.11428	0.452371	1.052027	105.0662
Median	43.6	38.9	0	1.131016	110
Std Dev	12.88234	10.44071	2.018484	0.31617	22.67967
Min	0.1	0.2	0	0.012422	19
Max	66.9	86.2	21.5	2.167857	155
Count	7749	7753	7753	7749	4395
Average Using only t>90deg					113.2069

3.2.2 Gas Constituents

3.2.2.1 CO

3.2.2.1.1 Wells Inside or Proximate to the Settlement Fronts

Laboratory gas well sampling data was analyzed for wells inside the settlement front as of March 20, 2013, which represented the largest settlement front area to date. The statistical evaluation of the CO levels in the wells for gas samples obtained in February through April 2013, is presented in Table E-3. The CO levels averaged 3300 ppm but ranged from 170 to 6700 ppm. The median value was 2900 ppm. When compared to the sample set that includes all the data from the same wells back to August 2012, the average value of the time within the front was lower than the overall average value, shown in Table E-3, of 4460 ppm with approximately the same minimum value and 8900 maximum value. This clearly did not indicate any significant change with being within the reaction zone of high heat and not. It suggests either the area was already reacting for the full period or that wells proximate to the front have quite variable CO concentrations. This would suggest that CO values in excess of 4000 ppm are indicative, but not definitive of being within the settlement or heat front zone.

TABLE E-3A
ANALYSIS OF WELL INSIDE MARCH 20, 2013
SETTLEMENT FRONT - SAMPLE DATES 2/13 TO 5/13

	CO	CO2	H2	CH4	CO2/CO	CH4/CO2
Average	0.332	62.226	20.484	6.845	507.150	0.114
Min	0.017	43.000	0.000	0.150	103.125	0.002
Max	0.670	72.000	34.000	26.000	3176.471	0.433
STD Deviation	0.211	6.220	9.452	8.061	760.966	0.138
MEDIAN	0.290	63.000	23.000	3.700	206.897	0.056

TABLE E-3B
ANALYSIS OF WELLS INSIDE MARCH 20. 2013
SETTLEMENT FRONT - SAMPLE DATES 8/12 TO 5/13

	CO	CO2	H2	CH4	CO2/CO	CH4/CO2
Average	0.446	61.319	21.304	5.502	276.275	0.100
Min	0.015	35.000	0.000	0.150	78.652	0.002
Max	0.890	73.000	32.000	32.000	3176.471	0.627
STD Deviation	0.209	7.746	7.262	6.532	507.410	0.129
MEDIAN	0.450	64.000	23.000	2.800	132.653	.041

3.2.2.1.2 Wells more than 150 feet from Any Settlement Front

The laboratory gas well sampling data for the wells that had not been within a 150 of settlement front are presented in Table E-4, shown below.

TABLE E-4
LABORATORY GAS ANALYSIS
GAS WELL NOT WITHIN 150 FT OF
SETTLEMENT FRONTS

STATISTICS	C02	METHANE	HYDROGEN	CO	CO2/CO	METH/CO2
Count	46	46	47	68.00	46	46
Average	54.74	22.90	6.40	0.07	3034	0.478
Maximum	76.00	46.00	28.00	0.33	16296	1.212
Minimum	21.00	3.10	0.00	0.00	185	0.051
Median	56.50	24.00	0.00	0.01	1135	0.450
Standard Deviation	14.25	14.17	8.51	0.09	3799	0.350

The data shows that CO values within the areas that have not been within or near settlement front limits in the past are on average approximately 700 ppm, but do have numerous values in excess of this value. The average plus one standard deviation of data range could be adopted as a reasonable indication that some heating of the waste, worthy of exploration, is warranted. This would correspond to a CO value of 1600 ppm. The complete set of well samples used is provided in Attachment E-1.

3.2.2.2 H_2

3.2.2.2.1 Wells Inside or Proximate to the Settlement Fronts

The laboratory gas well sampling data for wells within or proximate to settlement fronts indicates a wide range of H_2 partial volumes, as can be seen in Table E-3. The data is so variable that it cannot be used an indicator, other than to suggest that higher than 20 percent hydrogen seems to be strongly related with significant warming. However, it does not, as is apparent in Figure E-41 (GEW-38), relate to settlement rate, maximum TMP temperature, CO level, or wellhead temperature. GEW-38 is within 100 feet of the settlement front. Figure E-34 (GEW 63) also depicts a well proximate to the settlement front. It is approximately 57 feet from the location of the front as of May 2013. It does indicate an increase in H_2, but it occurred in 2011, well in advance of any significant increase in well temperature or CO level. This can be compared to Figure E-37 (GEW-69R) which has been within the settlement front for a significant time and exhibited H_2 levels comparable to the previous two wells mentioned. Wells that have moved in and out of settlement fronts, such as GEW-12A and GEW-32R (Figures E-24 and E-27, respectively), show that H_2 values are not related to settlement rate or wellhead temperature.

Average values of H_2 within the heat front or proximate to, as reported in Tables E-3A and E-3B, are 20% to 21%. but as described above, significant variation exists. A median value of 23% was found in both the post January 2013 sample subset and the full sample of wells within the March 2013 settlement front limits. A median value of 26% was found for wells within the settlement front limits as of February through April samples. However no definitive value is apparent.

3.2.2.2.2 Wells more than 150 feet from Any Settlement Front

The laboratory gas well sampling data for the wells that had not been within a 150 of settlement front are presented in Table E-4. The data shows that H_2 values within the areas that have not been within or near settlement front limits in the past are on average approximately 6.4%, but do have numerous values in excess of this value. The median plus one standard deviation of data range is 8.5%. This is significant and is not recommended as a target for an indication that no heating is likely to occur. It is likely that the values of hydrogen are reflective of the ease in which it migrates within the waste mass and the fact that values are heavily weighted to samples only taken in the south quarry.

3.2.2.3 CH_4

3.2.2.3.1 Wells Inside or Proximate to the Settlement Fronts

Wells near, or within, the settlement fronts exhibit reduced Methane concentrations as the waste is warmed, which is to be expected given the relatively low temperature at which methanogenesis is impeded. All of the wells that eventually are in warmed areas exhibit low methane levels. While this would be predictive of the area eventually being warmed, it does not indicate when that may occur or if it would eventually be warmed to a temperature that would result in significant volume reduction of the waste. This is evident in Figures E-31 and E-33, all near but not within settlement fronts. Methane concentrations in GEW-38 (Fig.E-31) have fallen to less than 5%, while in GEW-56R (Figure E-33), located about the same distance from the front and exhibiting similar maximum TMP temperatures, the methane contractions are in excess of 20% at present. The wells have markedly different behavior and either may or may not be warmed to a maximum waste temperature of 220 °F.

Laboratory analysis of gas well samples for methane of the same well and date sets described in Section 3.2.2.1.1 shows the methane content averaged between 4% and 6%, but had significant deviations from average, with maximum values of 32% and minimum values of 0.15%. The median value was less than 4%. The data shows no specific trend other than it diminishes with time as the well spends more time in the heated zone, which, as noted above, is expected given the negative impact of increased temperature on methanogenesis. The statistical results are presented in Tables E-3A and E-3B.

3.2.2.3.2 Wells more than 150 feet from Any Settlement Front

The analysis of wells for methane concentration from laboratory gas samples indicated the average methane content was 23%, with significant variability, as can be seen in Table E-4. The standard minimum and maximum values were 3% and 46%, respectively. This suggests that methane content is not a reliable measure for determining if no reaction processes are ongoing. Field measurements of methane indicated a higher average, 40.6%, but a large range (0.1% to 67%) suggesting that field measures of methane are not definitive.

3.2.2.4 Gas Ratios

3.2.2.4.1 Wells Inside or Proximate to the Settlement Fronts

As can be seen in Tables E-3A and E-3B, the gas ratios of CO_2/CO and CH_4/ CO_2, are consistently lower than those for areas outside any reaction affected areas. However, there is still no clear value that can be identified. Other screening suggested that CO_2/CO below 115 were definitely associated with wells within the settlement fronts, but wide variation exists inside the fronts. This is apparent with the lack of significant difference between the well data sets for the periods containing the full range of data and only the months near or within the March 20. 2013 fronts.

The CH_4/ CO_2 ratio shows similar noisiness with no clear difference between sample sets.

3.2.2.4.2 Wells more than 150 feet from Any Settlement Front

The minimum ratio of CO_2/CO, using laboratory gas samples, was 165 and the median value was 480. Average and maximum values were very high given the very low levels of CO measured and the number of Non Detects (which were assigned 10000 as a ratio). Ratios of less than 115 were found to be indicative of substantial heating. The geometric mean of the values was 825 suggestive of a CO value of 700 ppm which is lower than the median 900 ppm measured. It is suggested that the median ratio of 480 would be more appropriate which suggests a CO value of greater than 1300 ppm would be present.

The ratio of Methane to CO_2 was also calculated utilizing the field measured values. As can be seen in Table E-4, the ratio varied from greater than 1.2 to a minimum of 0.045. The average less one standard deviation would be approximately 0.13. It should be noted that this metric is very noisy as far as data is concerned, as can be seen in the Figures E-24 through E-47. It is not recommended for use for any decisions.

Given the noisy nature of the field data and the fact that no field measurement of CO is possible, field data for gas ratios was not analyzed statistically.

3.3 SETTLEMENT RATE DATA

Settlement rate data has been collected at the site on approximately a monthly basis since 2012. The data collected prior to December 2012 was analyzed and reported in the January 3, 2013 submittal to the MDNR. This report identified a rate of -0.045 ft per day of elevation change as the likely measure of accelerated settlement for the site. Changes in the survey method to improve the comparison month to month were made starting in December 2012 for a portion of the South Quarry and completed by the January 31, 2013 survey. From that date on, settlement maps have been prepared on a monthly basis and the settlement front identified as the location of the boundary between areas settling faster and slower than the aforementioned rate. The demarcation has been seen to be useful in tracking the expansion of the reaction-affected areas, that is, expansion of elevated temperature into areas previously not warmed to above 220 °F.

The correlation between the settlement front and temperature is apparent in Figure E-7 and E-8. It does not appear that there is any significant time lag between the onset of maximum TMP temperatures of 220 °F and settlement rate increase above the threshold of 0.04 to 0.045 ft per day, or an equivalent rate at TMP 9 corrected for depth, as described in Section 3.1.1. In addition, while the data correlating the settlement rate to a TMP maximum temperatures is limited to the three points where the settlement front has encountered a TMP, it is consistent at all three. At the same time the TMPs not indicating temperatures above 220 °F have not experienced high settlement rates since the use of the more accurate grid survey, which is further support for the correlation at all TMP locations.

At the present time there are 14 TMPs, of which only three have reached a maximum temperature of 220 °F. The remaining 11 TMPS are between the North Quarry and the area that has reached temperatures of 220 °F. The relationship between settlement rate and TMP maximum temperature will, if the reaction continues to progress to the north, be able to be tested and refined as needed. The relationship can continued to be tested as a timely indicator of the reaction by the insertion of TMPs in the apparent path of the progress of the reaction as appropriate based upon progression.

4 CONCLUSIONS

4.1 DETERMINATION OF THE LOCATION OF THE REACTION FRONT

The measurements that best indicate the zone of the reaction front are those measurements of temperature from the TMPs considered together with the monitoring of surface settlement. Together, identifying the rate of surface settlement relative to TMPs which have reached 220 degrees Fahrenheit, we can best identify the location of the reaction front. The current data available identifies the settlement rate for areas that are full depth of the quarry, as an elevation drop of approximately -0.45 ft per day or -1.35 ft per 30 day period. If the reaction moves into areas with waste thicknesses that are significantly less than the current 220 to 260 feet, the value should be adjusted downward to reflect the portion of the waste mass between 50 and 150 feet that is less than 60 feet above the quarry floor. These above measures are useful in identify advancing fronts and so have been proposed for the purpose of developing trigger lines for contingent future actions on site. However it should be noted that these are not relevant for identifying retreating fronts, because the heat stays in the waste long after the elevated temperatures are reached.

Following review of the extensive data available from gas wells, it appears these values are highly variable and should be considered useful as general temporal indicators. As an indicator parameter, the gas well data can be evaluated in conjunction with other relevant data. The best gas well indicators appear to be CO and wellhead temperatures. It would appear that CO values of above 4000 ppm and gas wellhead temperatures higher than 175 degrees Fahrenheit are likely good indicators that wells are within or proximate (within 50 feet of) the heat front.

Other data can be used as indications of trends, such as rising hydrogen concentrations or falling methane concentrations, but the data does not support any specific values that would be useful as a trigger mechanism.

In conclusion, the extensive data collected at Bridgeton Landfill throughout the progression of the SSE has allowed for a site-specific detailed evaluation of predictive, responsive, and trend reflecting conditions related to the SSE. Based upon this evaluation, a firm basis has been established for the selection of trigger points for identification of the location and movement of the SSE, as well as information for the assessment of general trends within the waste mass.

4.2 AREAS <u>Not</u> INVOLVED IN THE REACTION FRONT OR PROXIMATE TO THE FRONT

Analysis of the available data suggests that gas well CO levels under 1600 and wellhead temperatures of under 135 are indicative of the conditions at the site that are far removed from the areas that have been heated to 220 °F. If isolated wells are higher than these values they should be monitored for trends. If they are within 200 feet or less of the settlement front, then exceeding these values can be expected.

GAS WELL LOCATION in or PROXIMATE to SETTLEMENT FRONTS

	September 2012	March 2013	May 2013	February 2013	July 2012	October 2012	February 2013	April	April	November 2012	March	February 2013	March
Name	within 25 ft	inside front	inside front	within 25 ft	within 25 ft	within 25 ft	inside front	inside front, plus 50 ft	inside front	inside front	between front and 25 ft	between 25 and 50 ft of front	between 25 and 50 ft of front
Name	September 2012 - within 25 ft	March 2013 - inside front	May 2013 - inside front	February 2013 - within 25 ft	July 2012 - within 25 ft	October 2012 - within 25 ft	February 2013 - inside front	April - inside front, plus 50 ft	April - inside front	November 2012 - inside front	March - between front and 25 ft	February 2013 - between 25 and 50	March - between 25 and 50 ft of front
GEW-104				X				X	X		X	X	
GEW-12a	X					X	X			X			
GEW-15								X					X
GEW-31R					X	X							
GEW-32R					X	X	X	X		X			
GEW-33R				X		X	X	X		X	X	X	
GEW-36								X			X		
GEW-37								X			X		
GEW-38								X					
GEW-57B	X	X		X	X	X	X	X	X	X			
GEW-57R	X	X		X	X	X	X	X	X	X			
GEW-58	X	X	X	X	X	X	X	X	X	X		X	
GEW-59R	X	X	X		X	X	X	X	X	X			
GEW-60R	X			X	X	X	X	X		X			X
GEW-61R	X	X			X	X	X	X	X	X			
GEW-62R	X				X	X	X	X		X	X		
GEW-64				X	X	X		X	X		X		
GEW-65A	X	X		X	X	X	X	X	X	X		X	
GEW-66	X	X			X	X	X	X	X	X			
GEW-67	X	X			X	X	X	X		X		X	
GEW-68								X					
GEW-69R		X					X	X	X				
GEW-70R	X	X				X	X	X	X	X			
GEW-71	X	X				X	X	X	X	X			
GEW-72R		X					X	X					
GEW-74	X	X				X	X	X	X				
GEW-75	X	X				X	X	X	X	X			
GEW-76R		X					X	X	X				
GEW-79R		X					X	X	X				
GEW-82R				X				X	X		X		
GEW-83	X	X			X	X	X	X	X	X			
GEW-84	X	X				X	X	X	X	X			
GEW-85	X	X		X	X	X	X	X	X	X			
GEW-90	X	X	X			X	X	X	X	X			
GIW-5								X				X	X
GIW-6								X					
GIW-7								X					
GIW-8								X					
GIW-9								X					
HT-1	X				X	X	X	X		X	X		
TMP-15		X	X			X	X	X	X				
TMP-7R								X					
TMP-8		X	X				X	X	X				

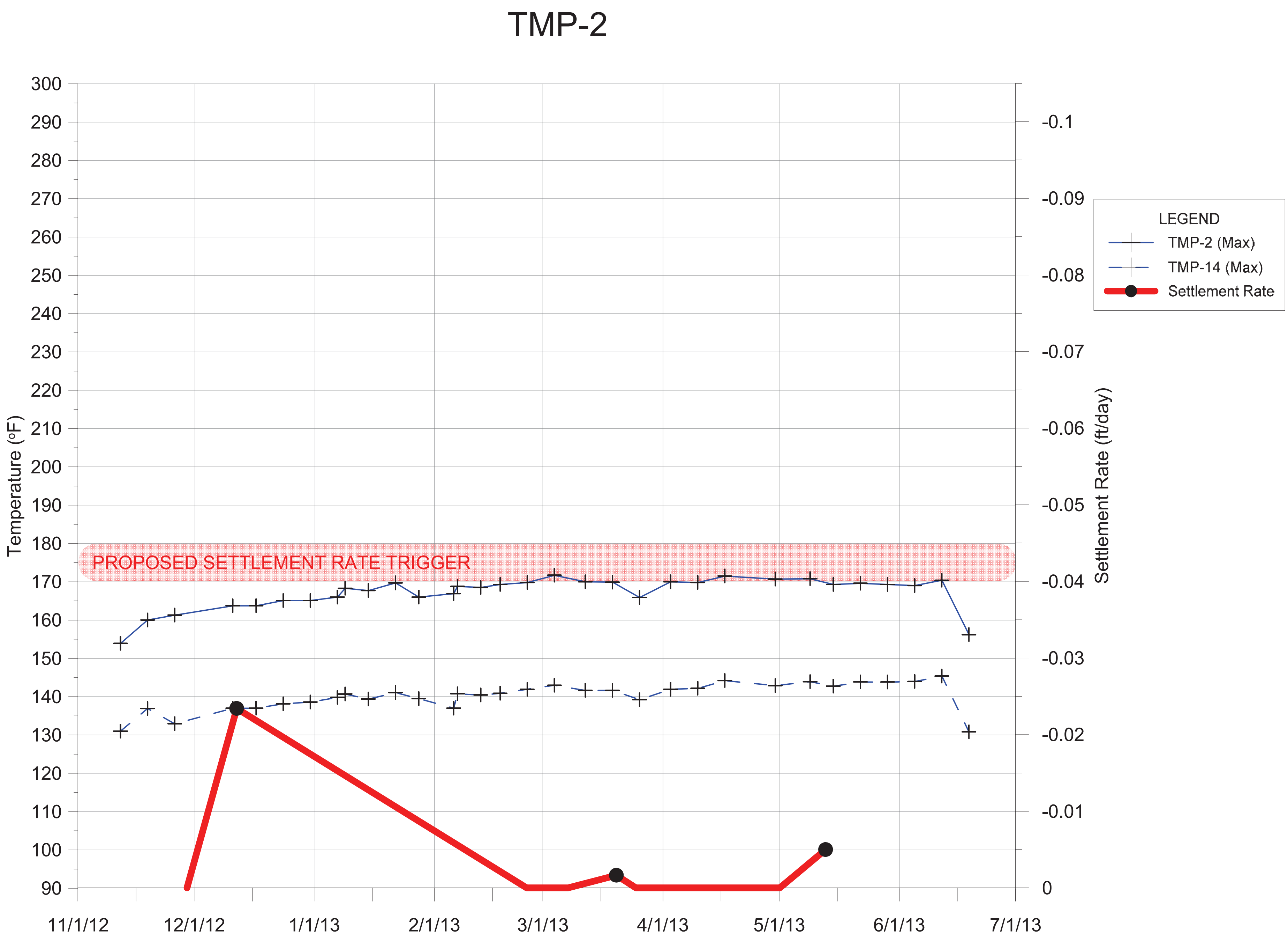
TABLE E-1

FIGURES

TMP-1

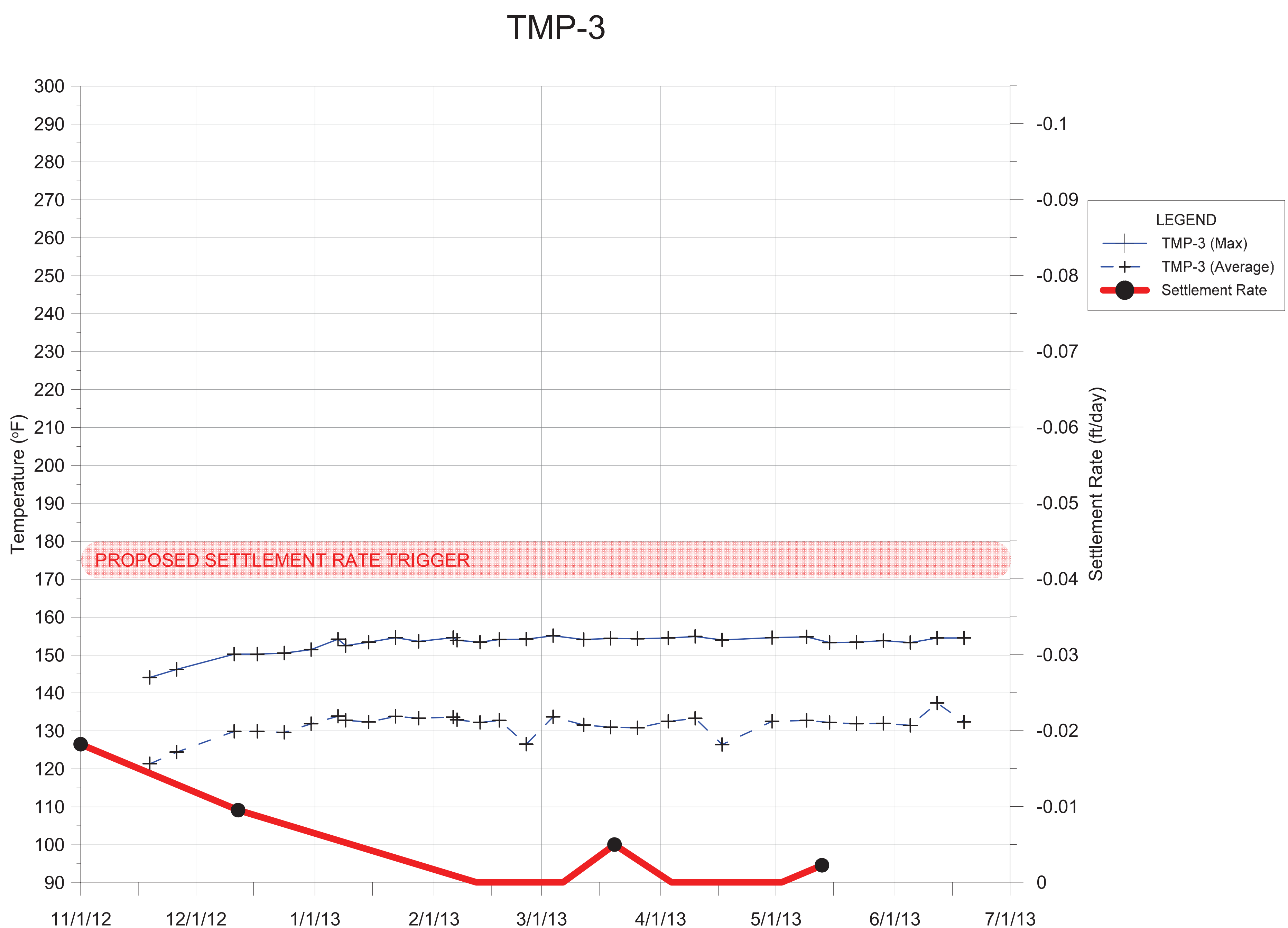
TMP TEMPERATURE AND SETTLEMENT RATE BRIDGETON LANDFILL

FIGURE E-1



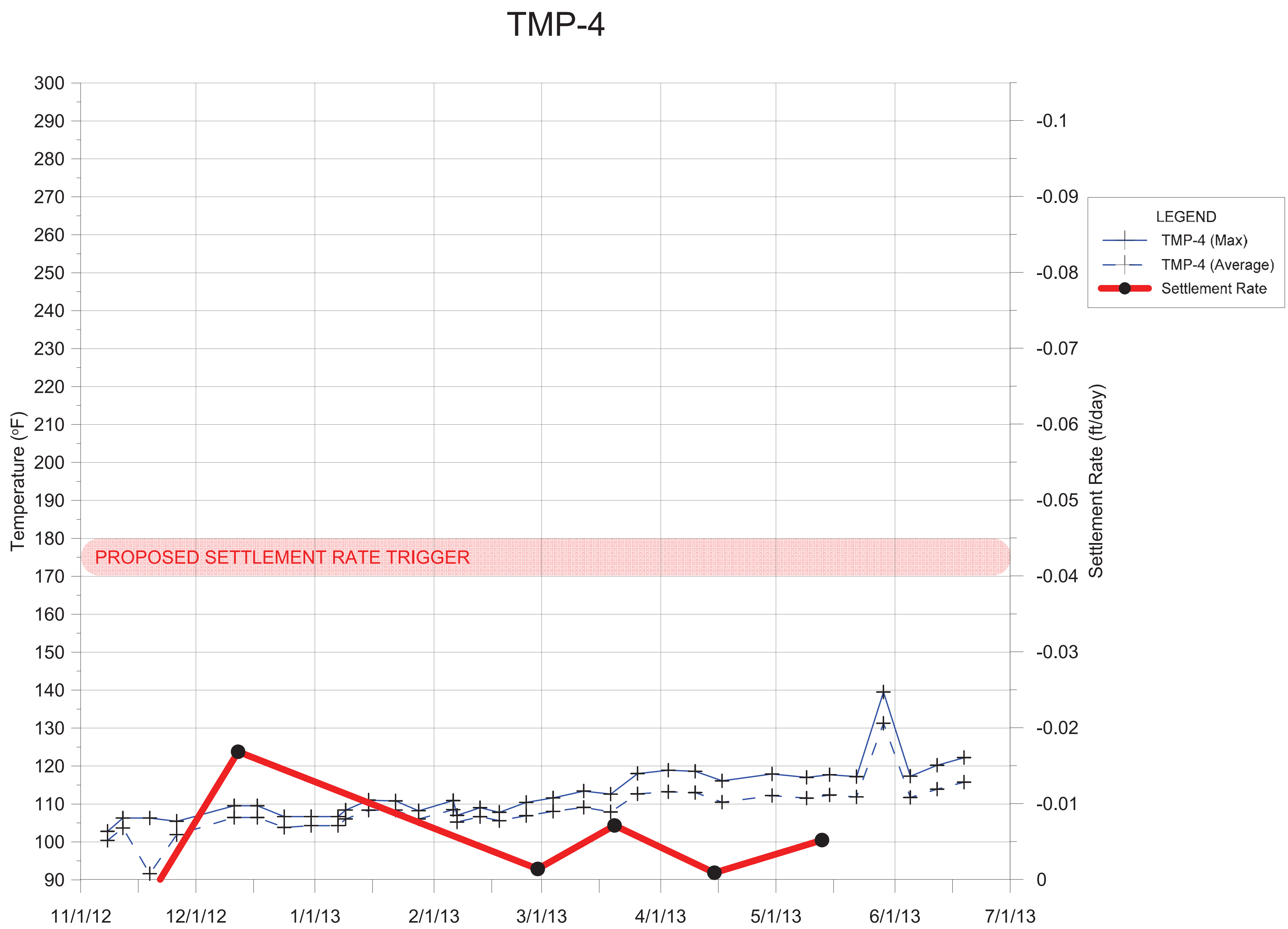
TMP TEMPERATURE AND
SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-2



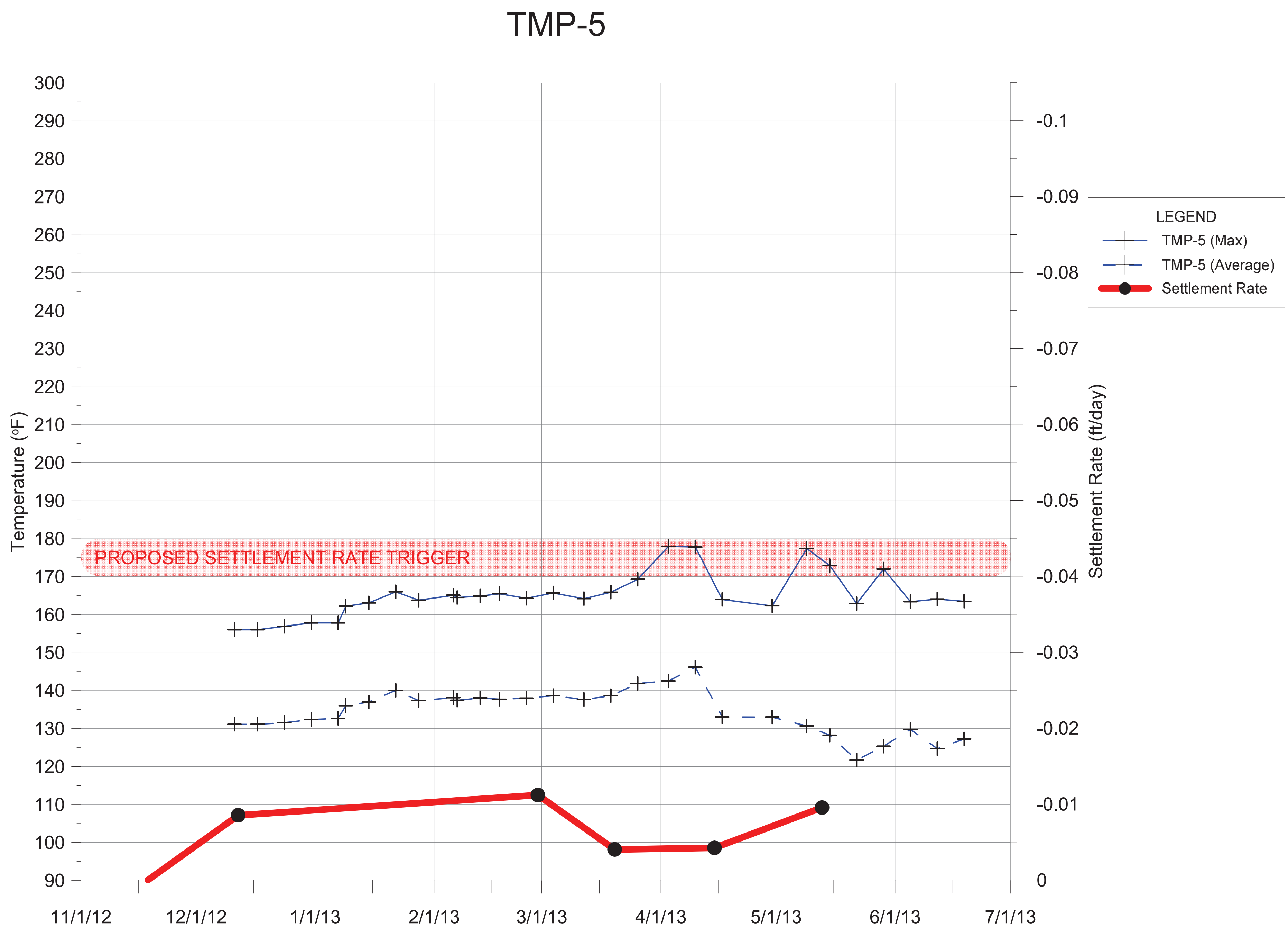
TMP TEMPERATURE AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-3



TMP TEMPERATURE AND
SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-4



TMP TEMPERATURE AND
SETTLEMENT RATE
BRIDGETON LANDFILL

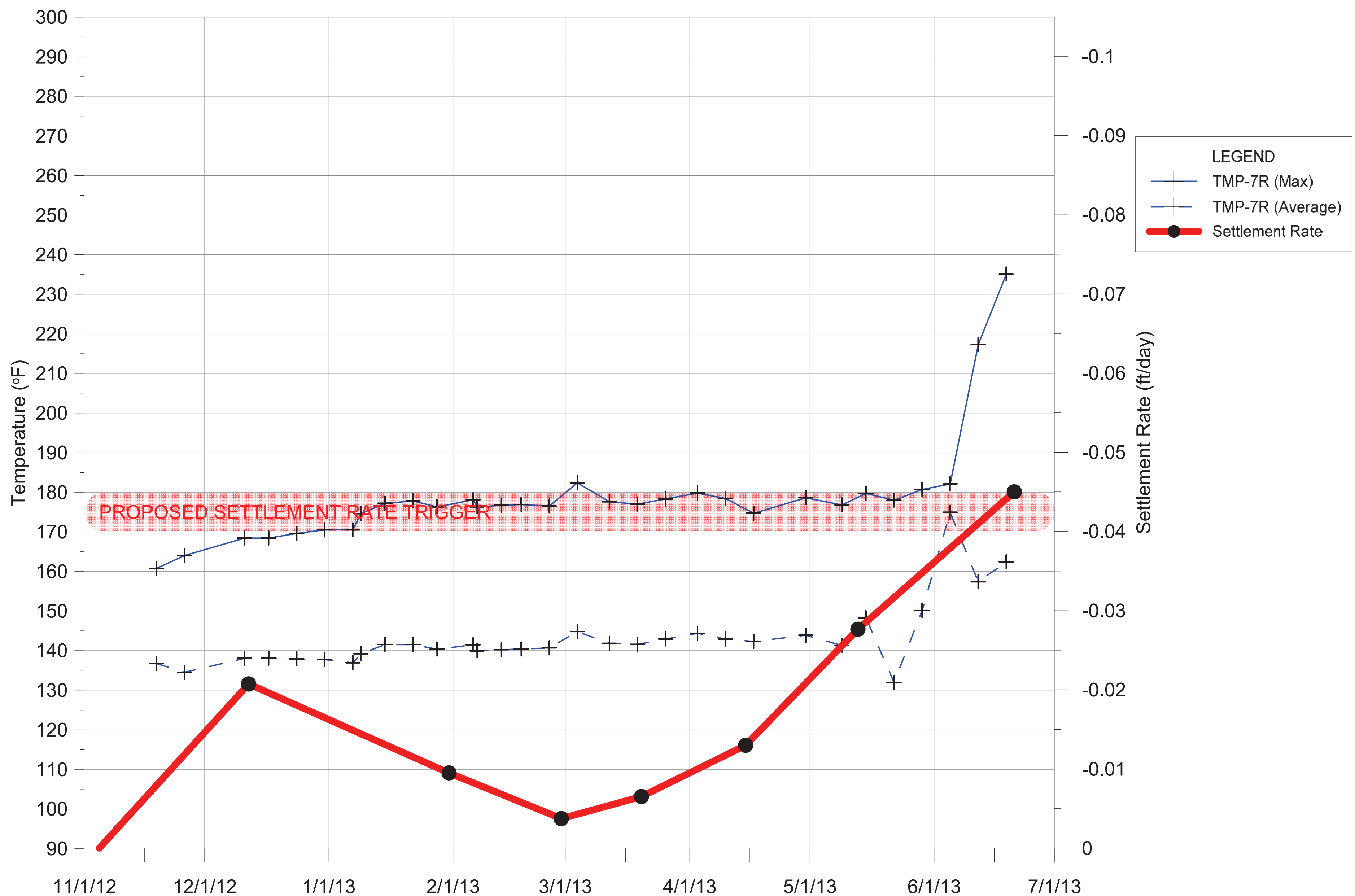
FIGURE E-5

TMP-6

TMP TEMPERATURE AND
SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-6

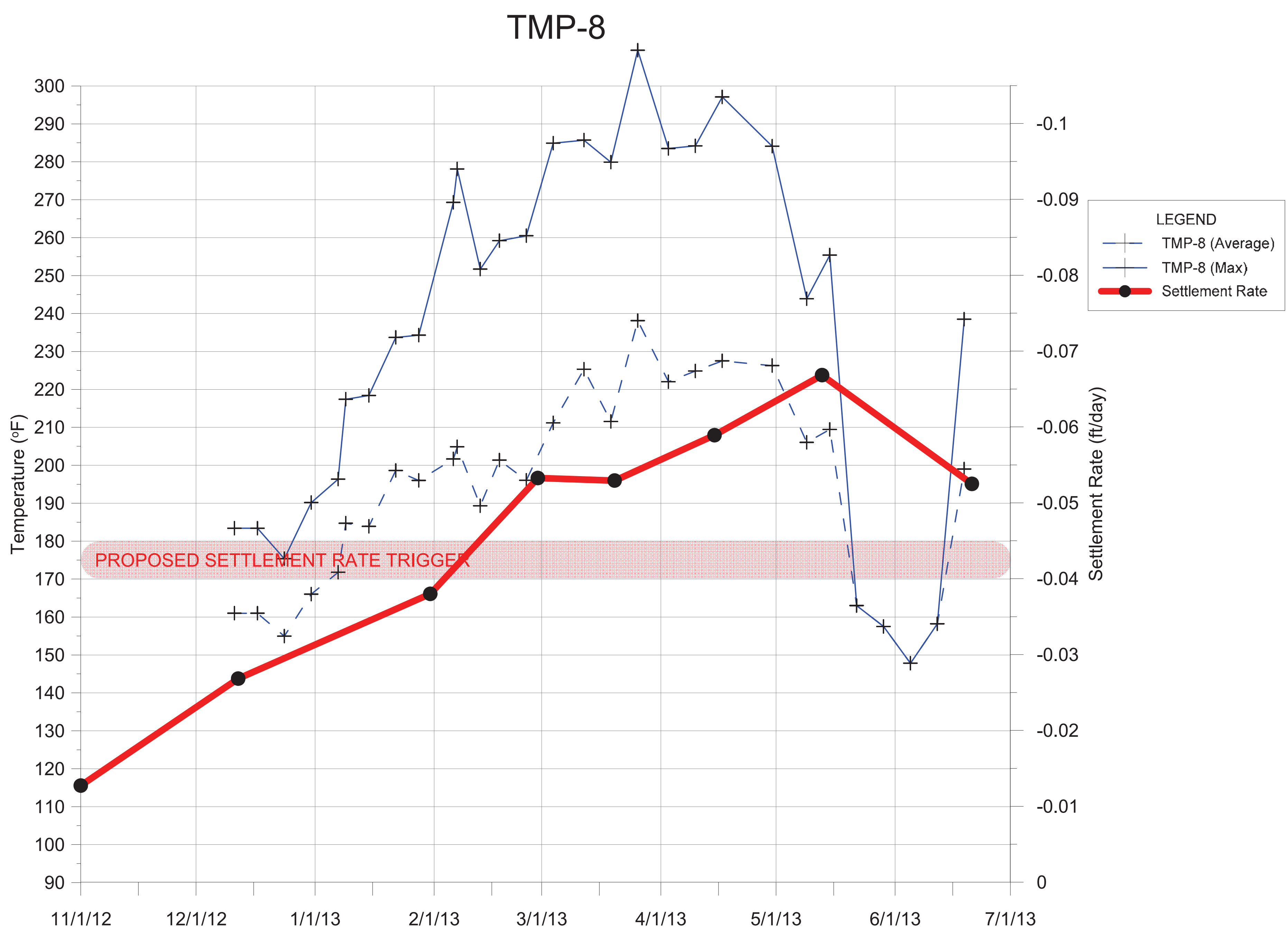
TMP-7R



TMP TEMPERATURE AND
SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-7

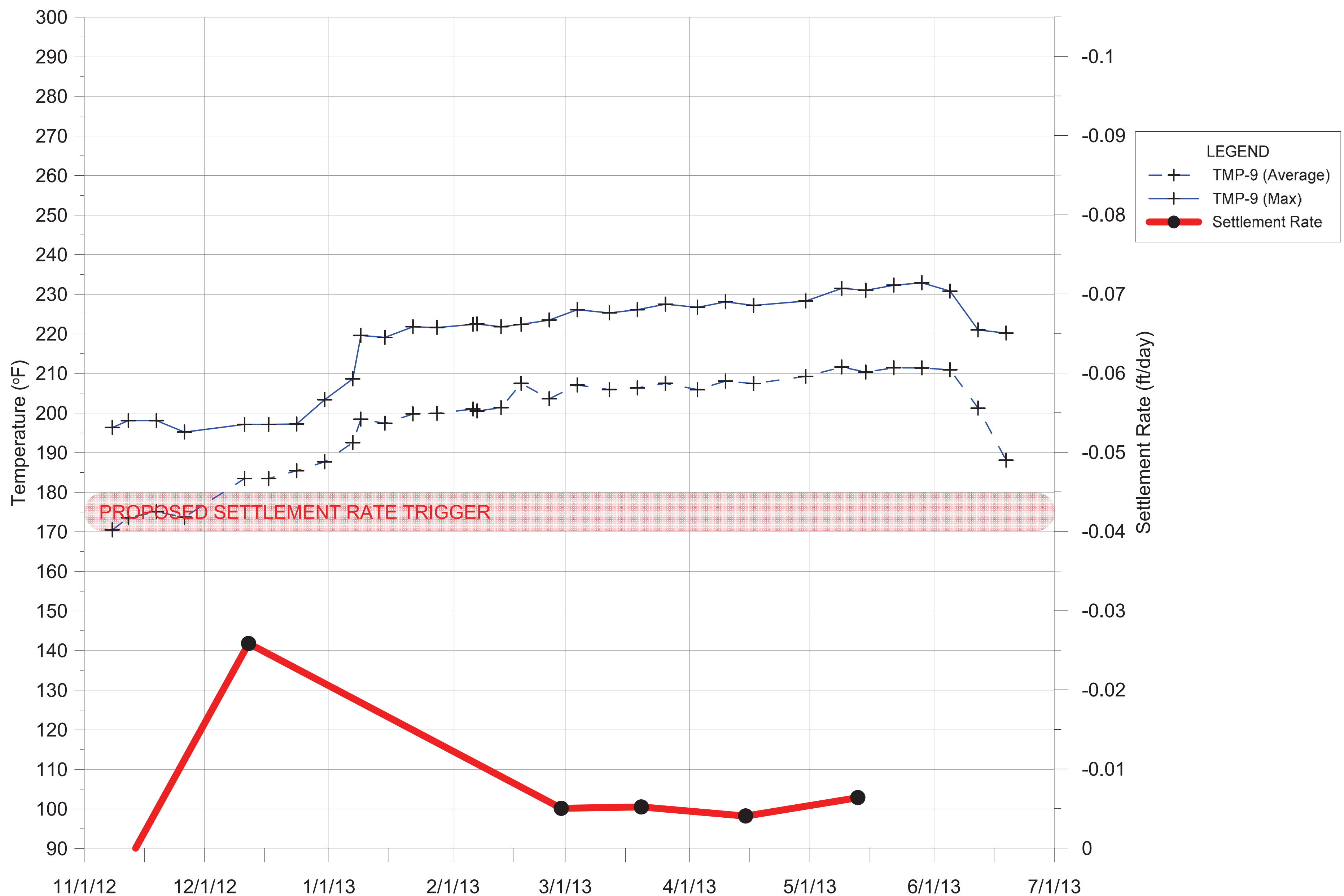
TMP-8



TMP TEMPERATURE AND
SETTLEMENT RATE
BRIDGETON LANDFILL

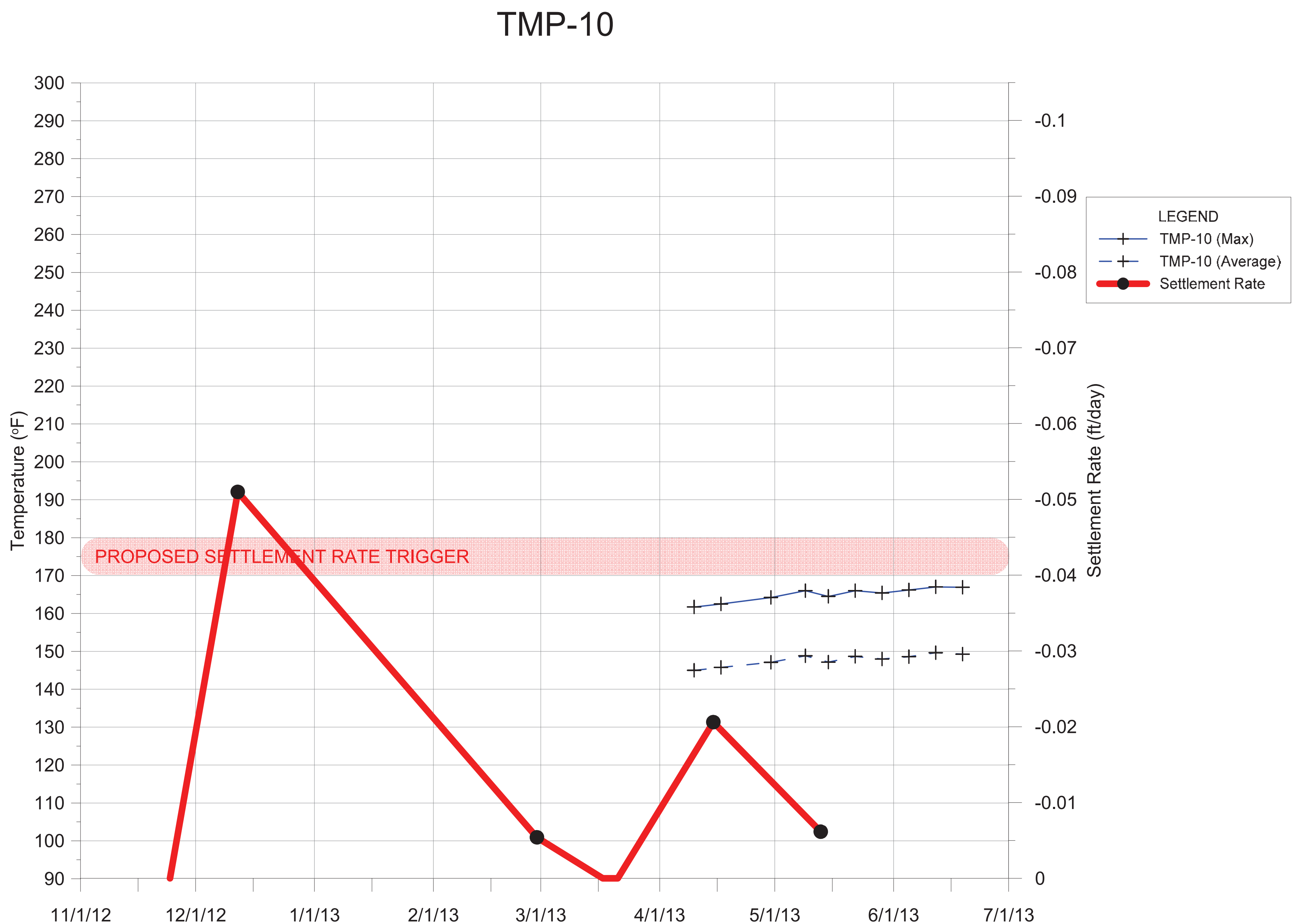
FIGURE E-8

TMP-9



TMP TEMPERATURE AND
SETTLEMENT RATE
BRIDGETON LANDFILL

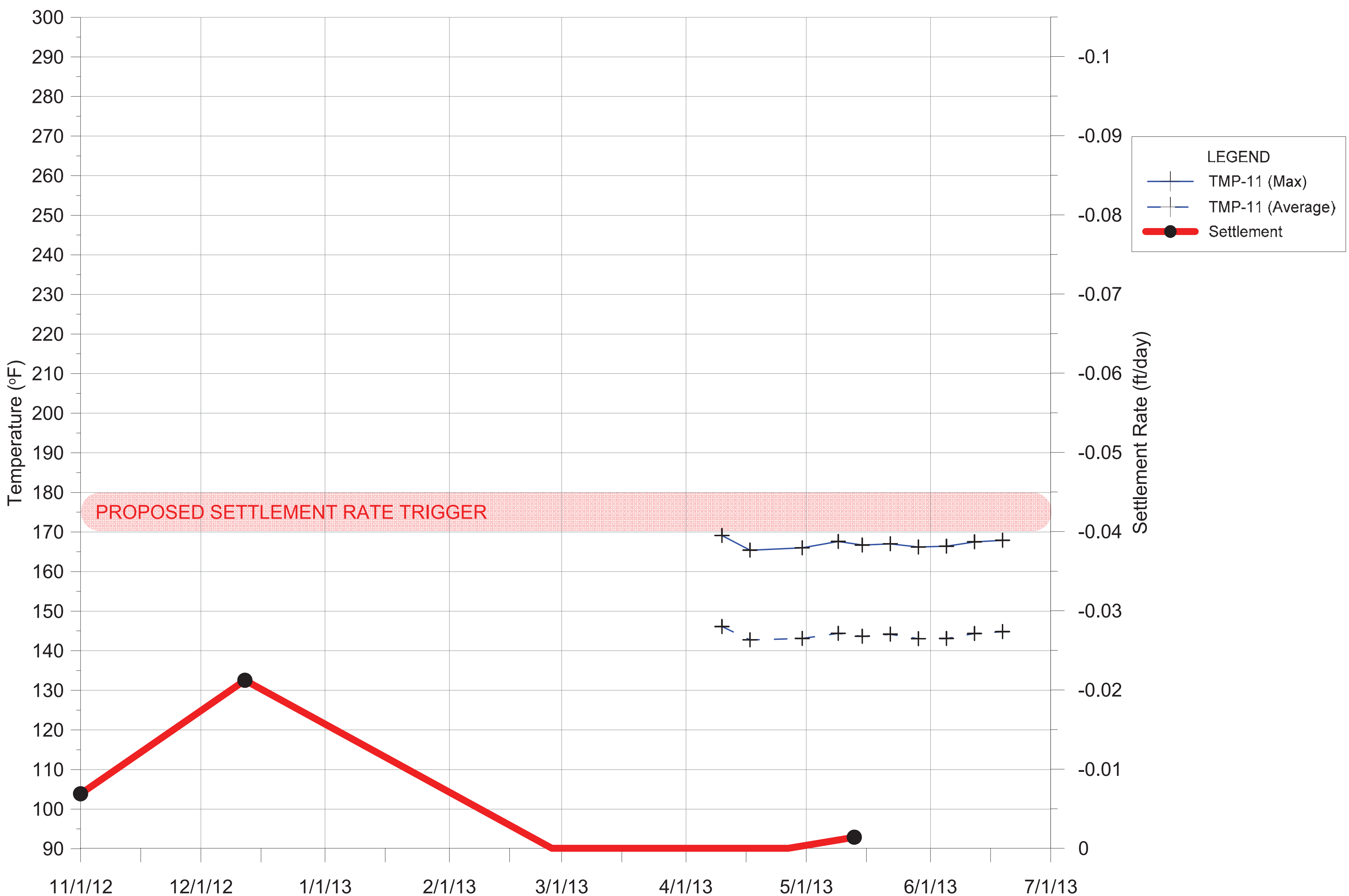
FIGURE E-9



TMP TEMPERATURE AND
SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-10

TMP-11



TMP TEMPERATURE AND
SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-11

TMP-12

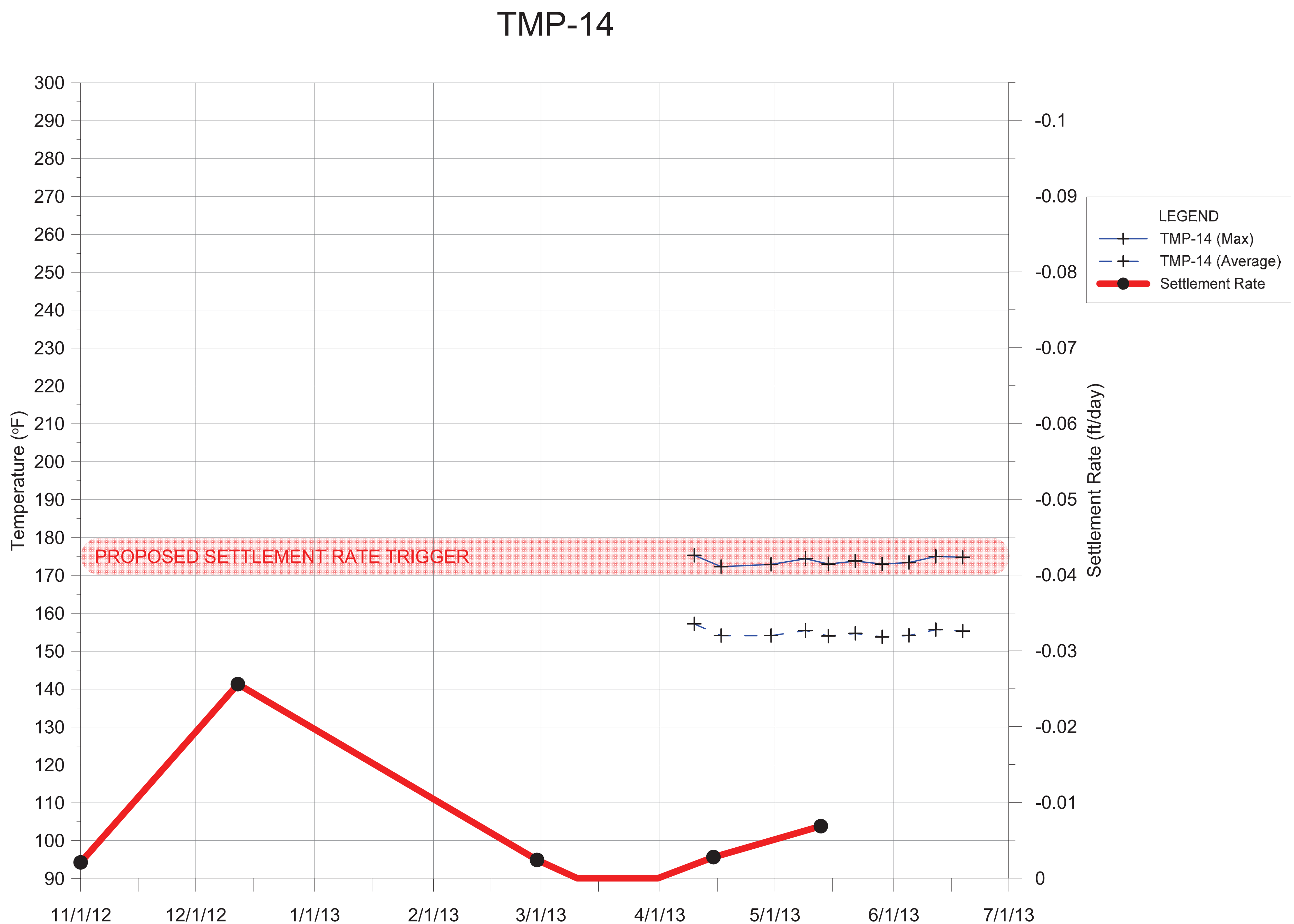
TMP TEMPERATURE AND
SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-12

TMP-13

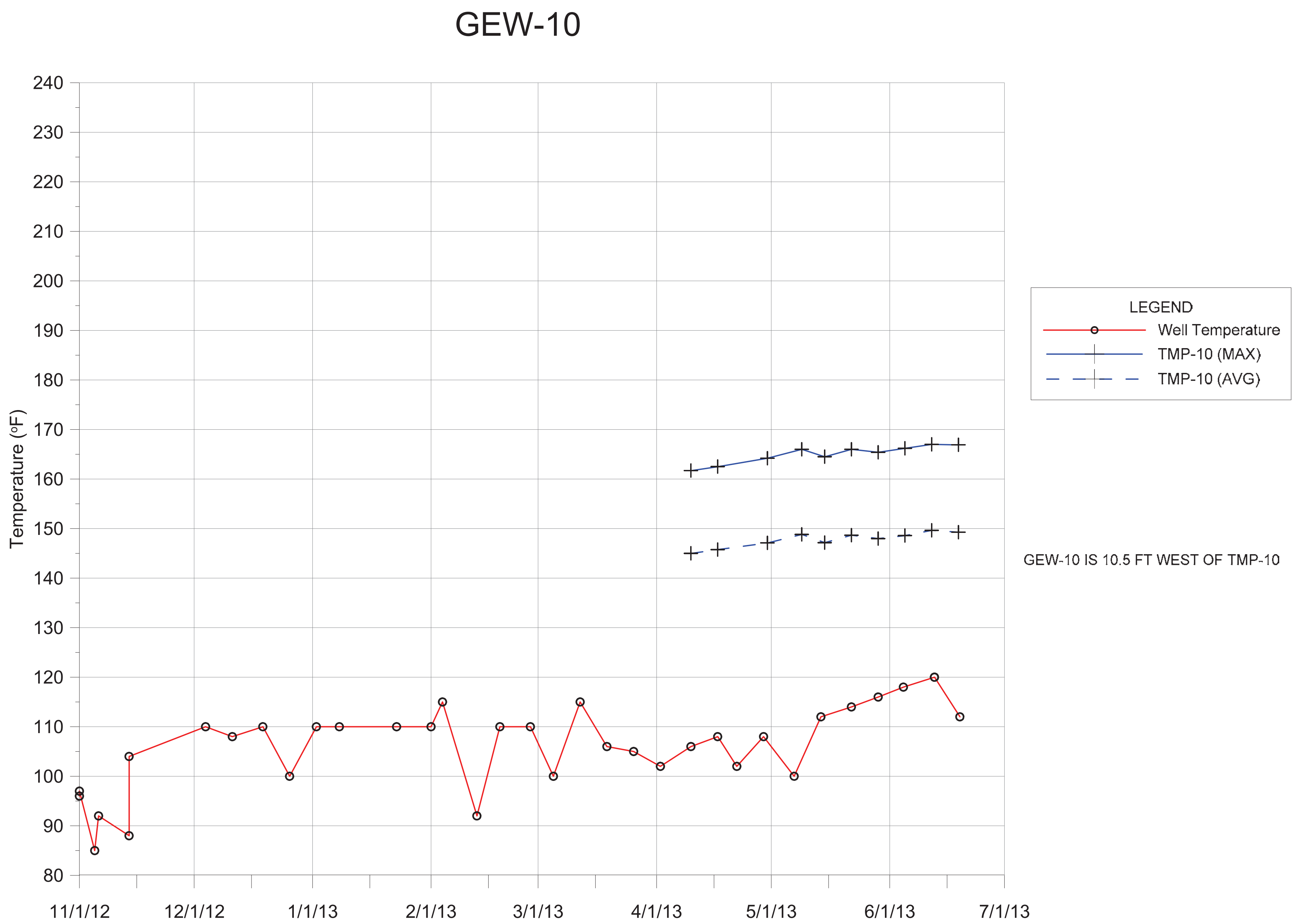
TMP TEMPERATURE AND
SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-13



TMP TEMPERATURE AND
SETTLEMENT RATE
BRIDGETON LANDFILL

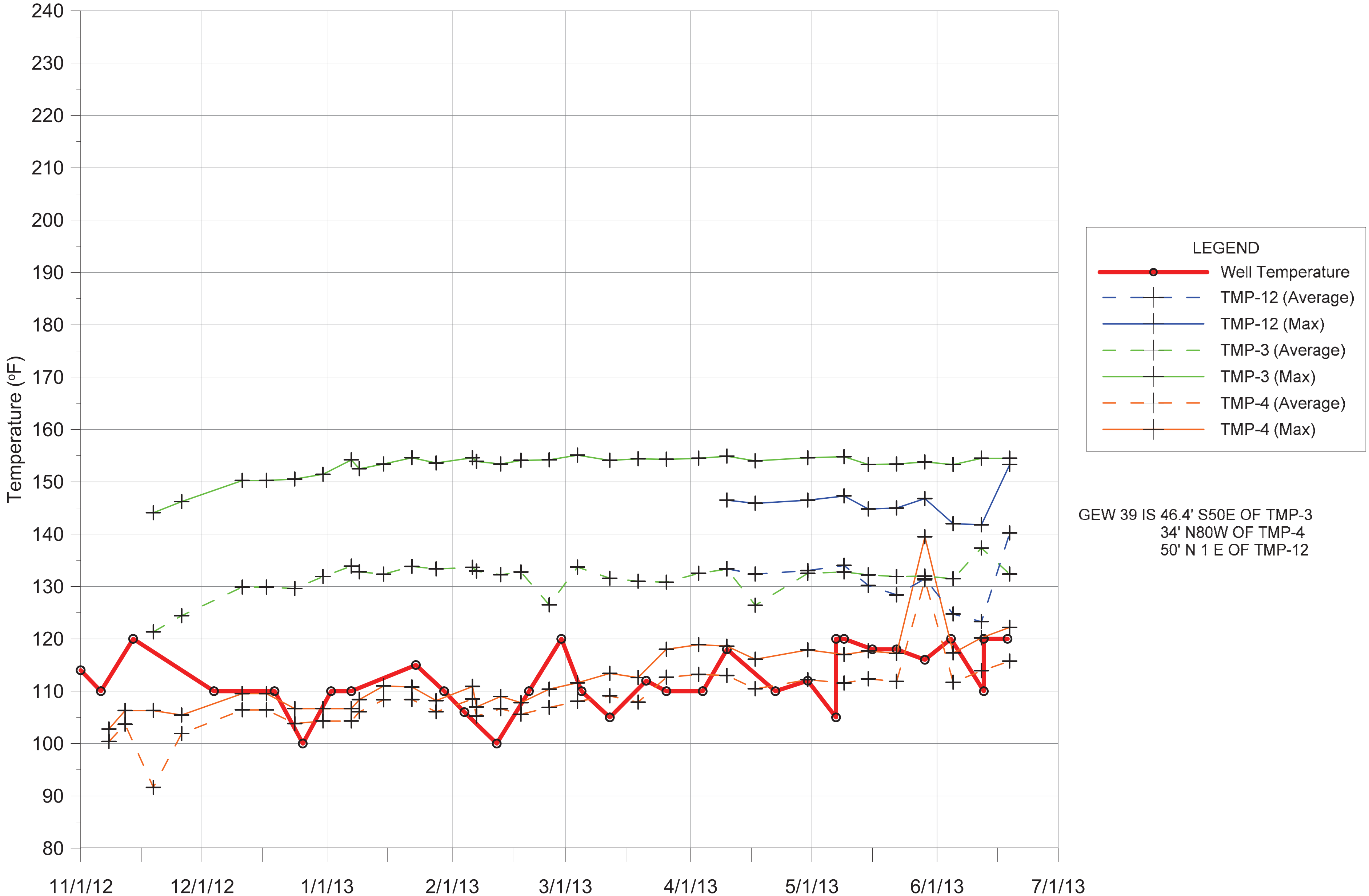
FIGURE E-14



TEMPERATURE COMPARISON
BRIDGETON LANDFILL

FIGURE E-15

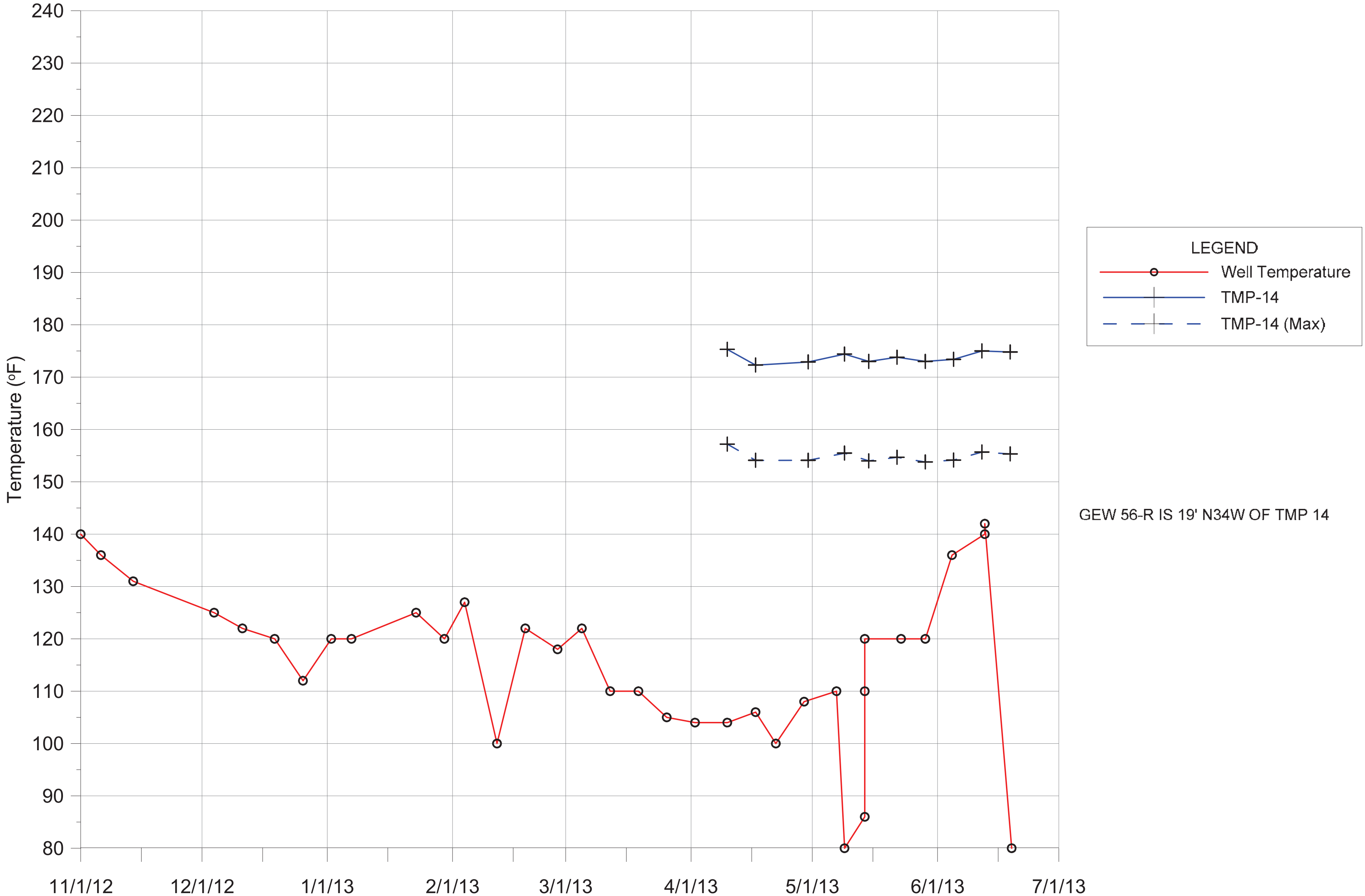
GEW-39



TEMPERATURE COMPARISON
BRIDGETON LANDFILL

FIGURE E-16

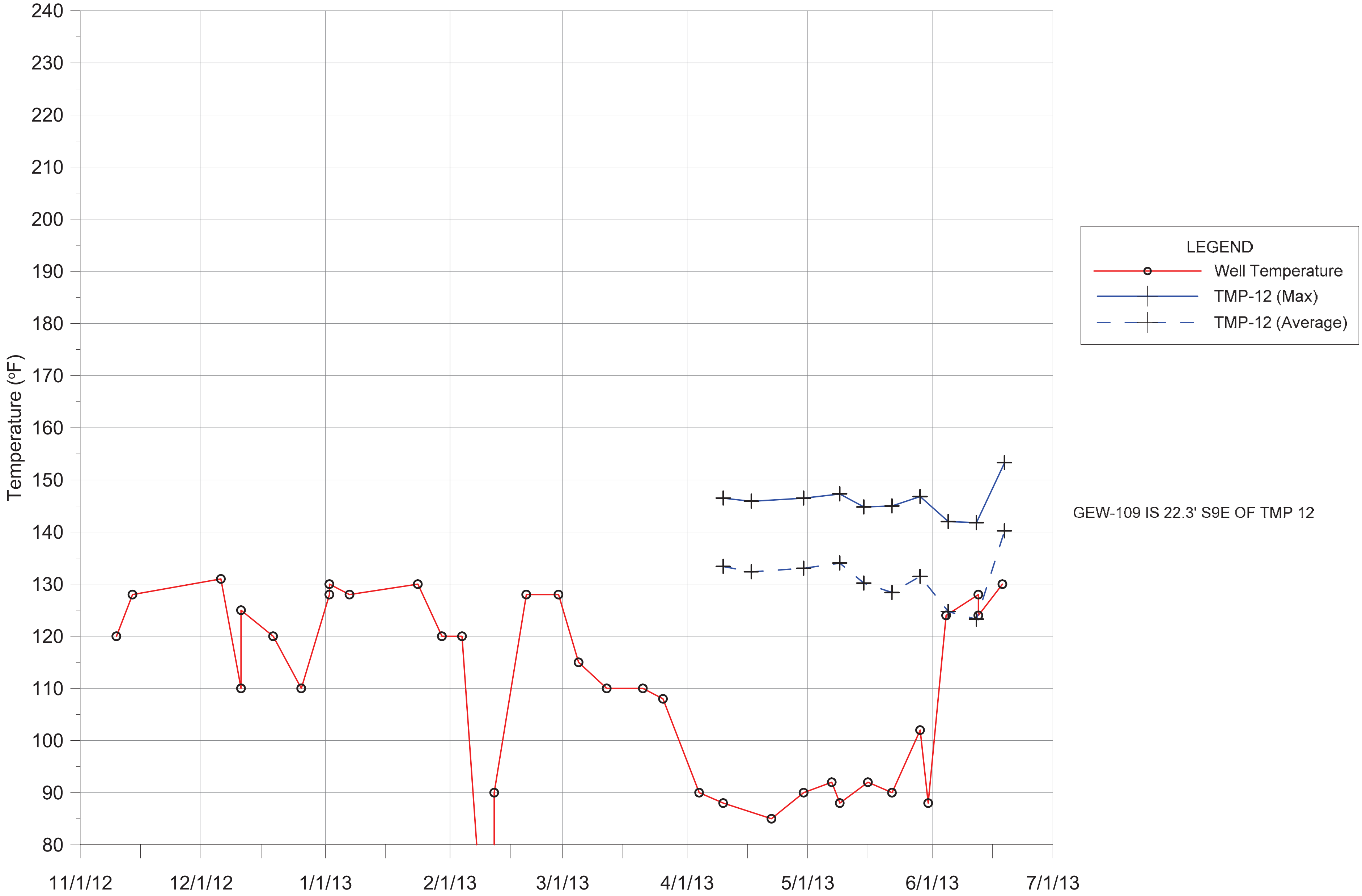
GEW-56R



TEMPERATURE COMPARISON
BRIDGETON LANDFILL

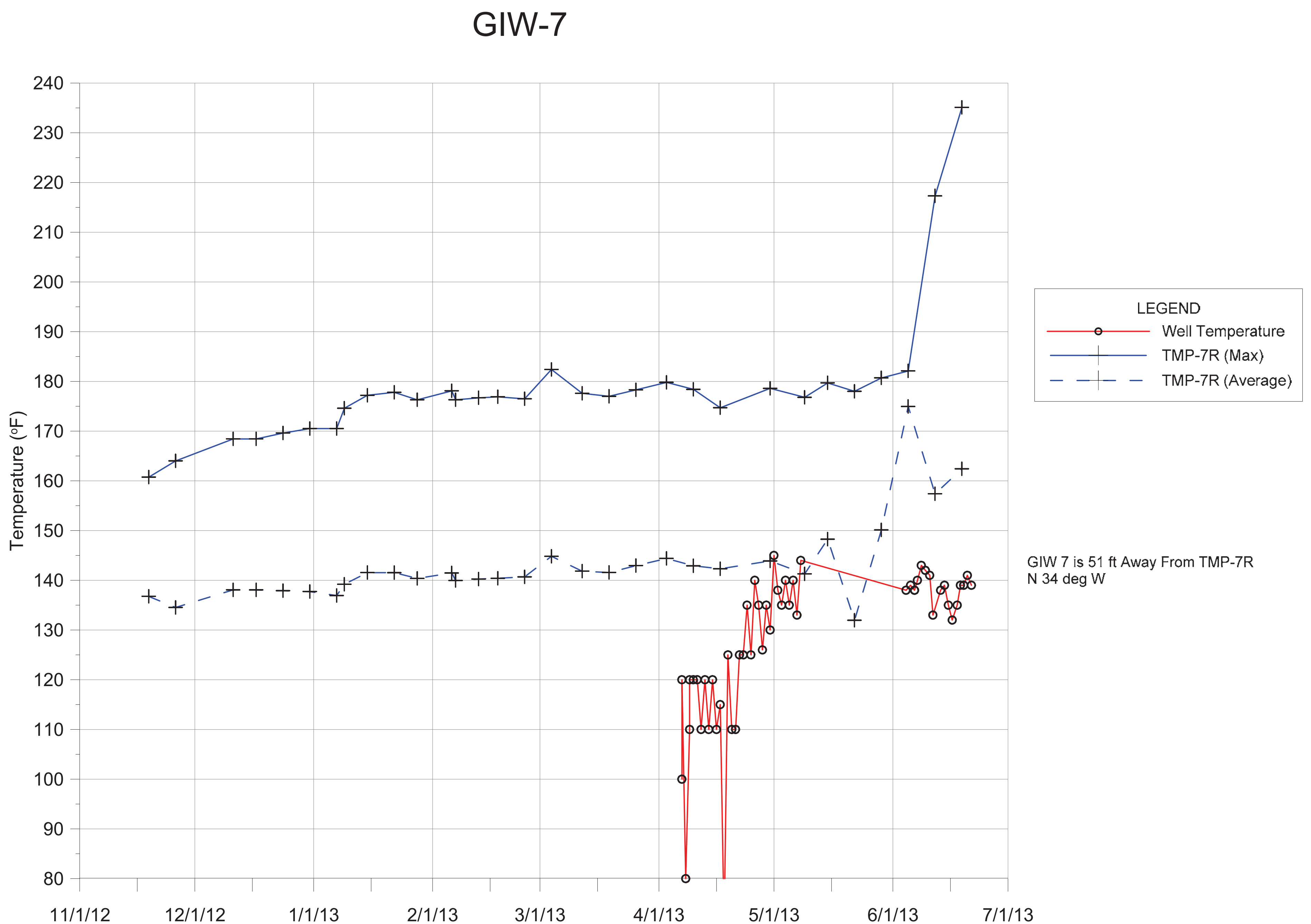
FIGURE E-17

GEW-109



TEMPERATURE COMPARISON
BRIDGETON LANDFILL

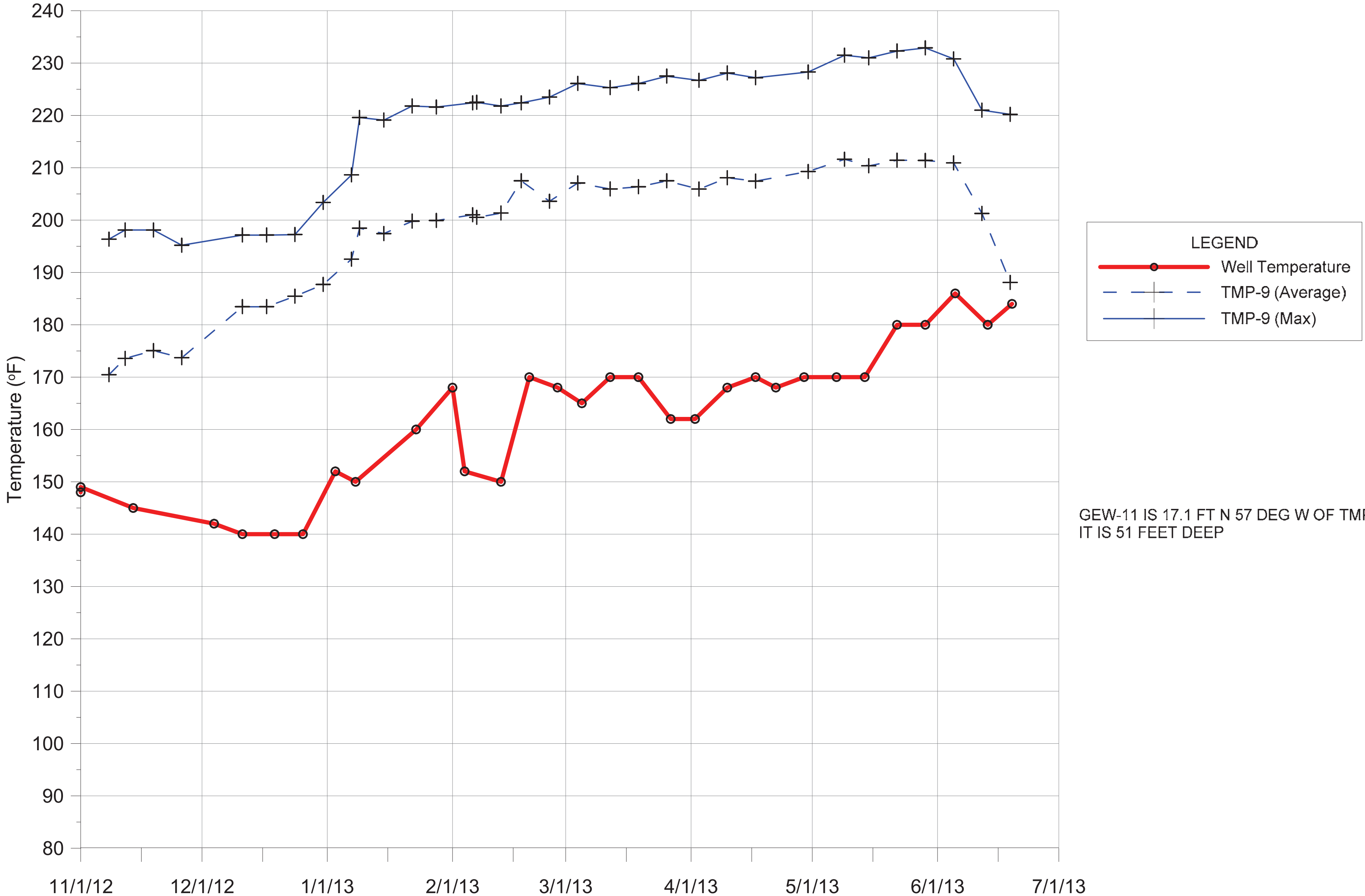
FIGURE E-18



TEMPERATURE COMPARISON
BRIDGETON LANDFILL

FIGURE E-19

GEW-11



GEW-11 IS 17.1 FT N 57 DEG W OF TMP 9
IT IS 51 FEET DEEP

TEMPERATURE COMPARISON
BRIDGETON LANDFILL

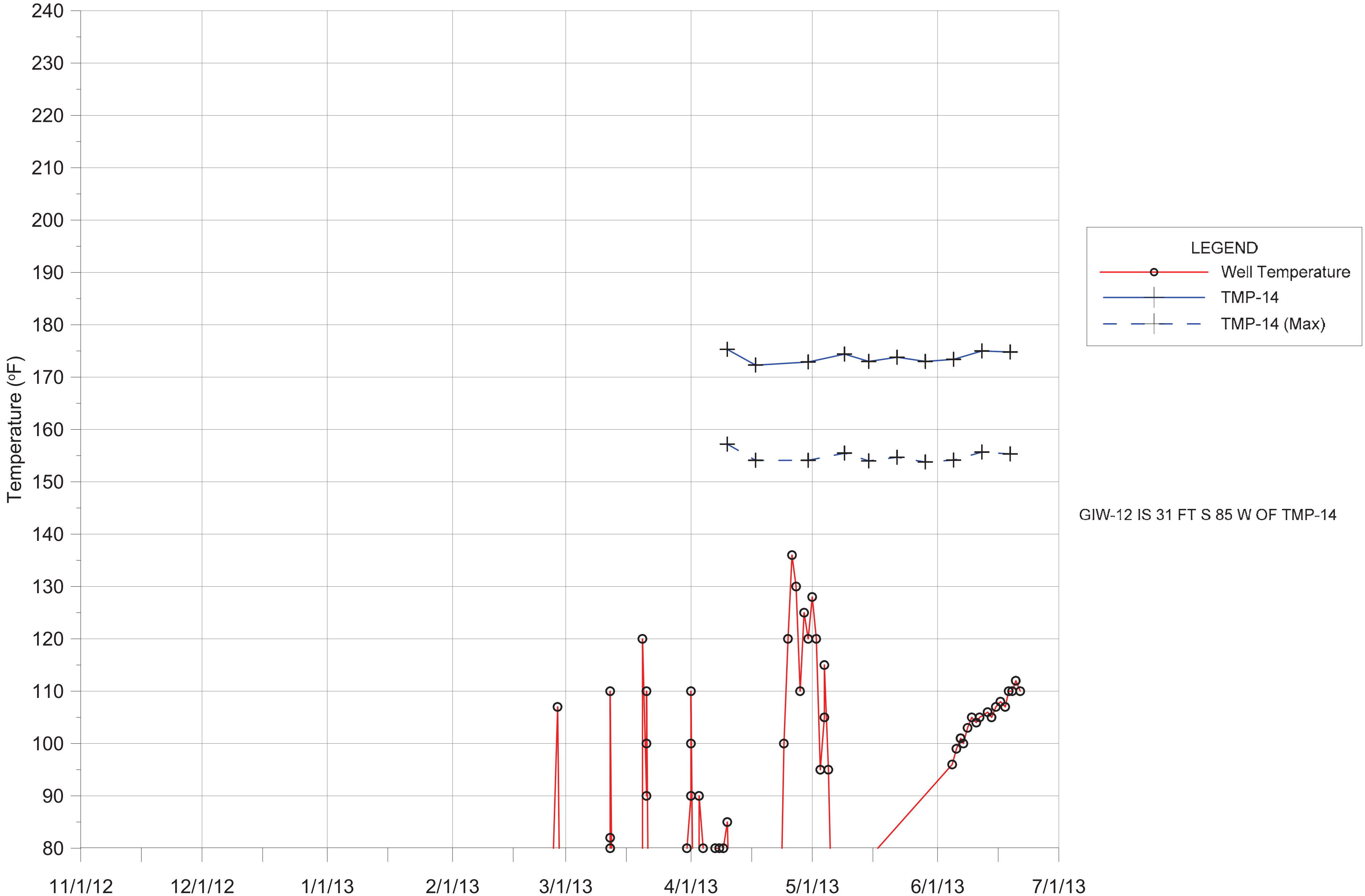
FIGURE E-20

GIW-11

TEMPERATURE COMPARISON
BRIDGETON LANDFILL

FIGURE E-21

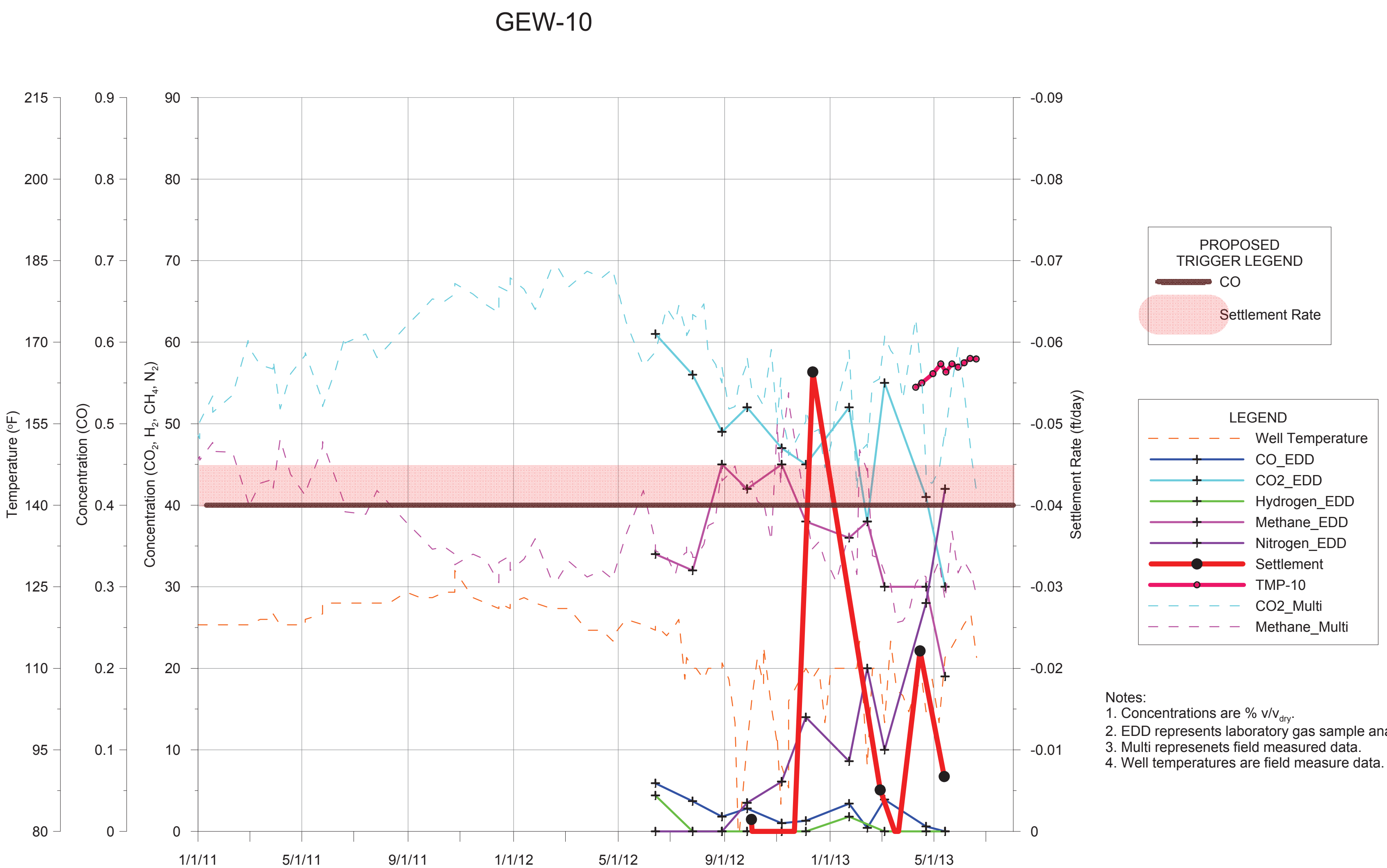
GIW-12



GIW-12 IS 31 FT S 85 W OF TMP-14

TEMPERATURE COMPARISON
BRIDGETON LANDFILL

FIGURE E-22

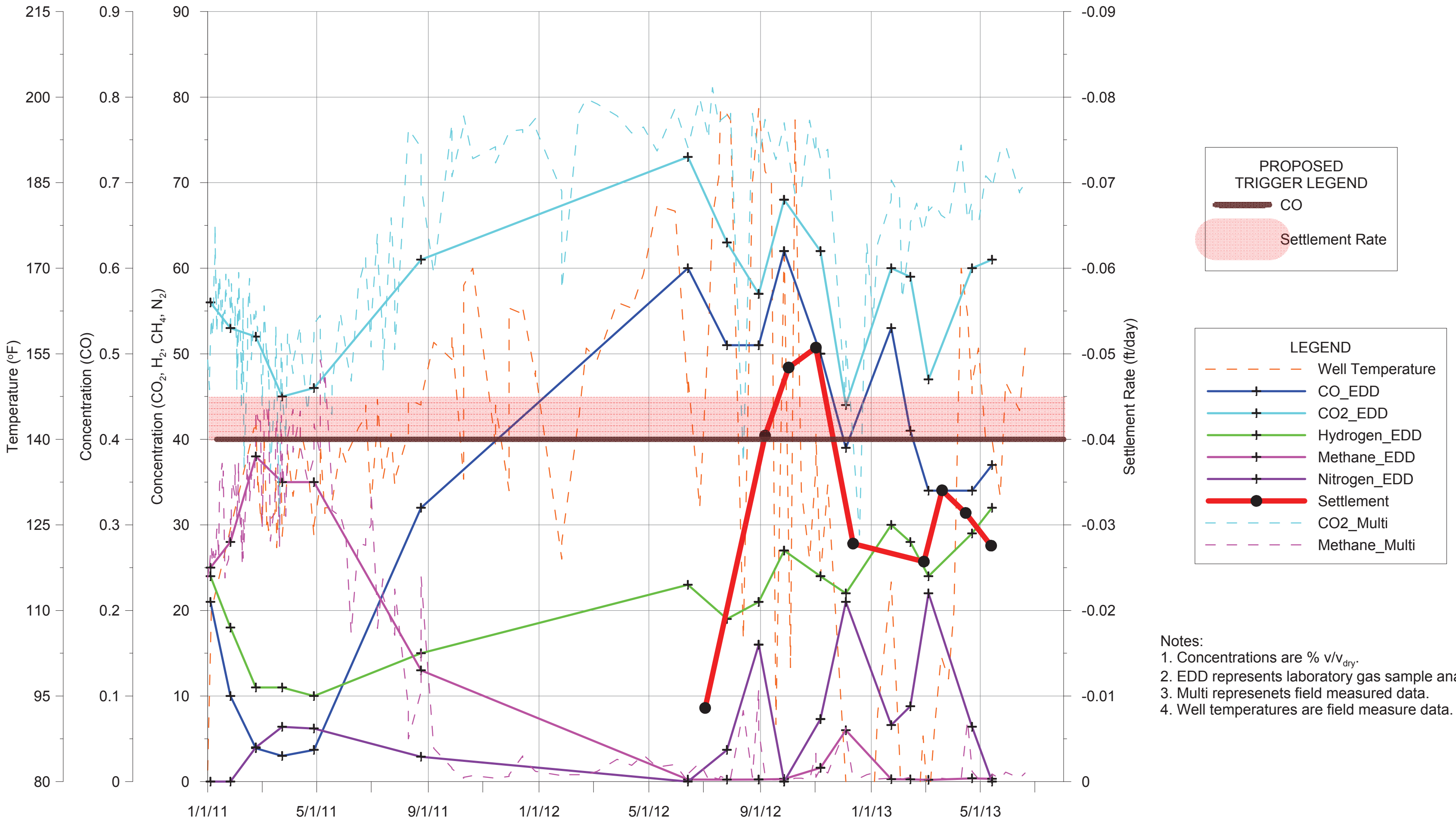


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-23

GEW-12A

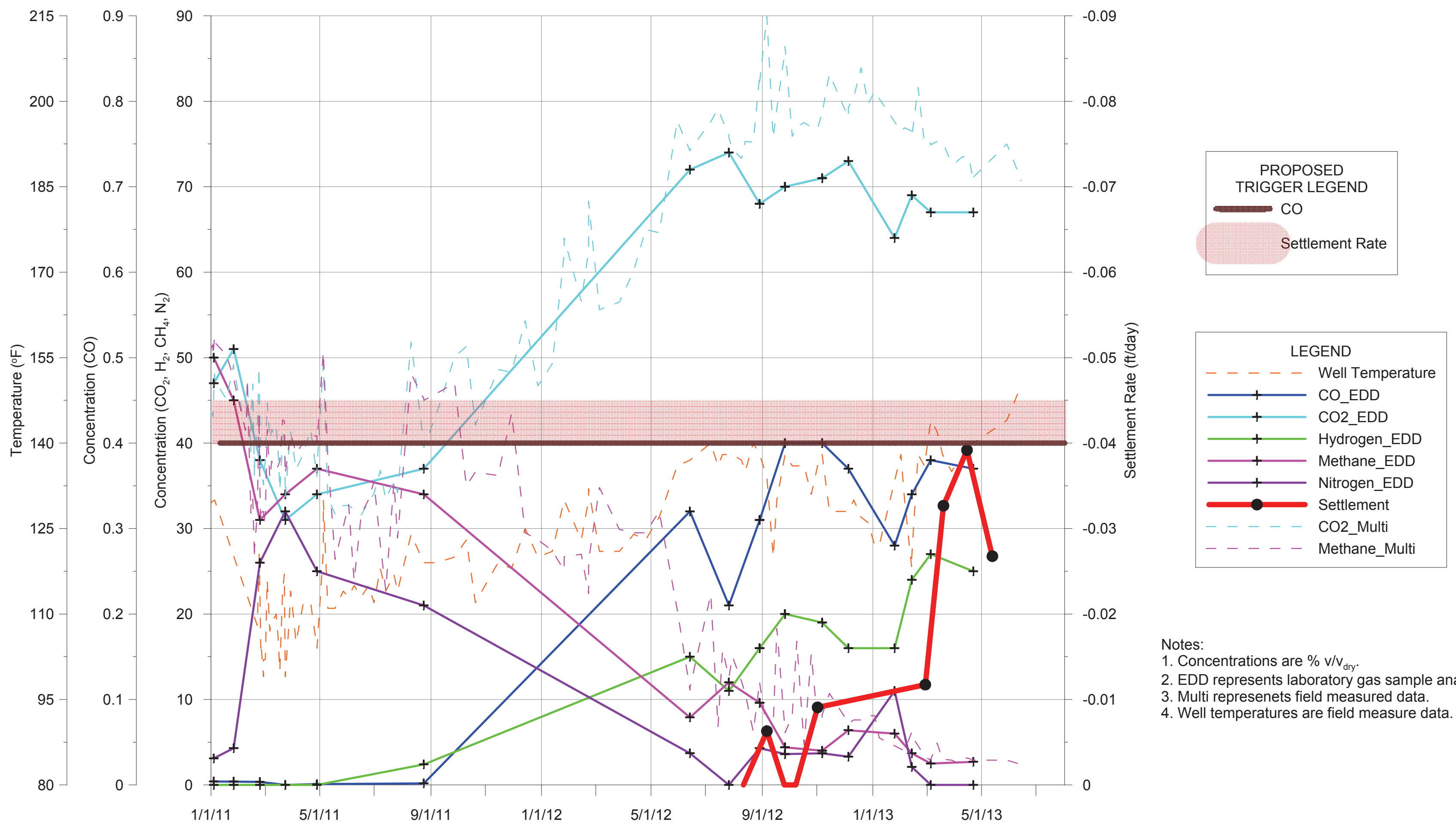


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-24

GEW-15

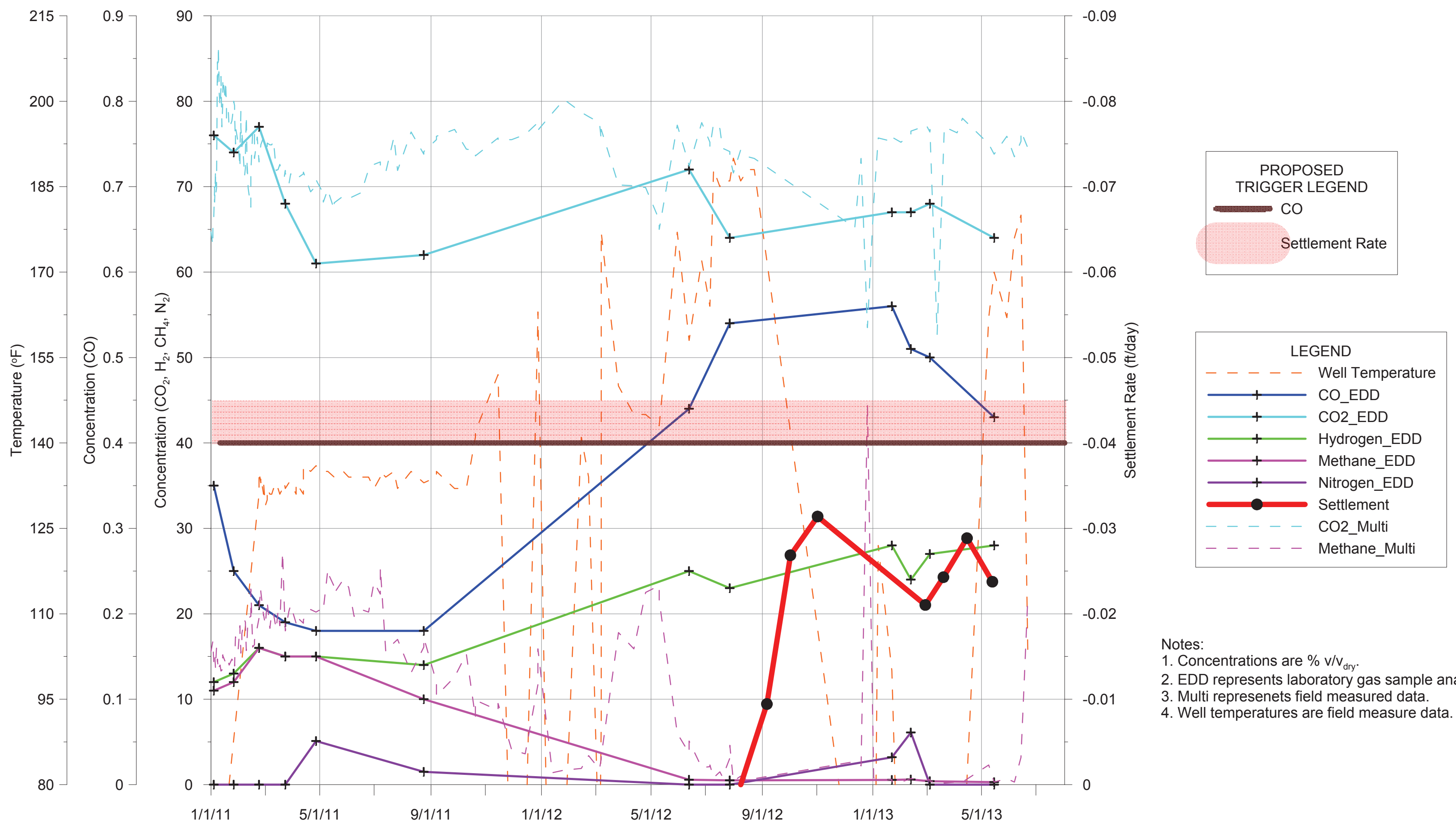


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-25

GEW-31R

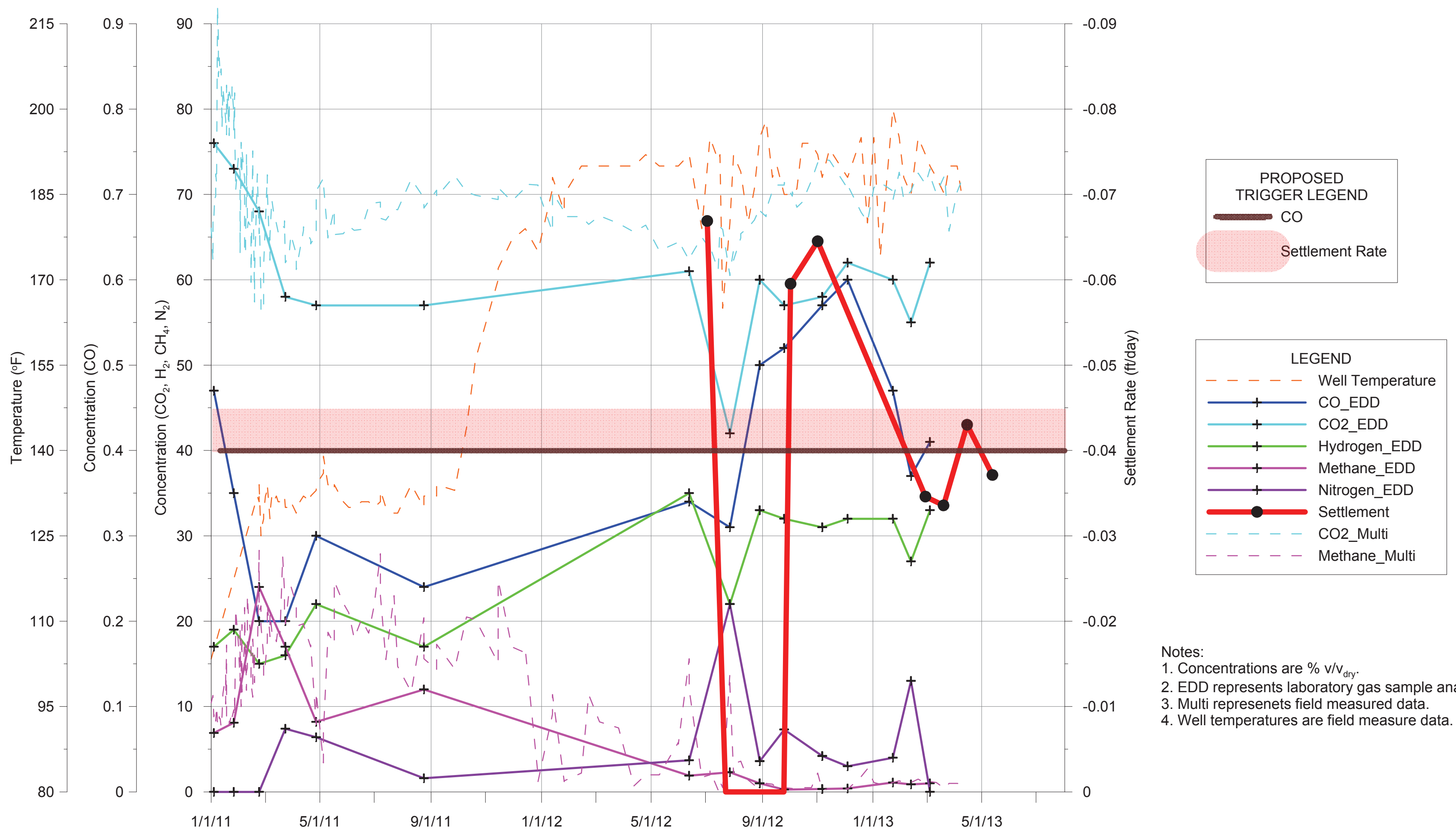


Notes:
1. Concentrations are % v/v$_{dry}$.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-26

GEW-32R

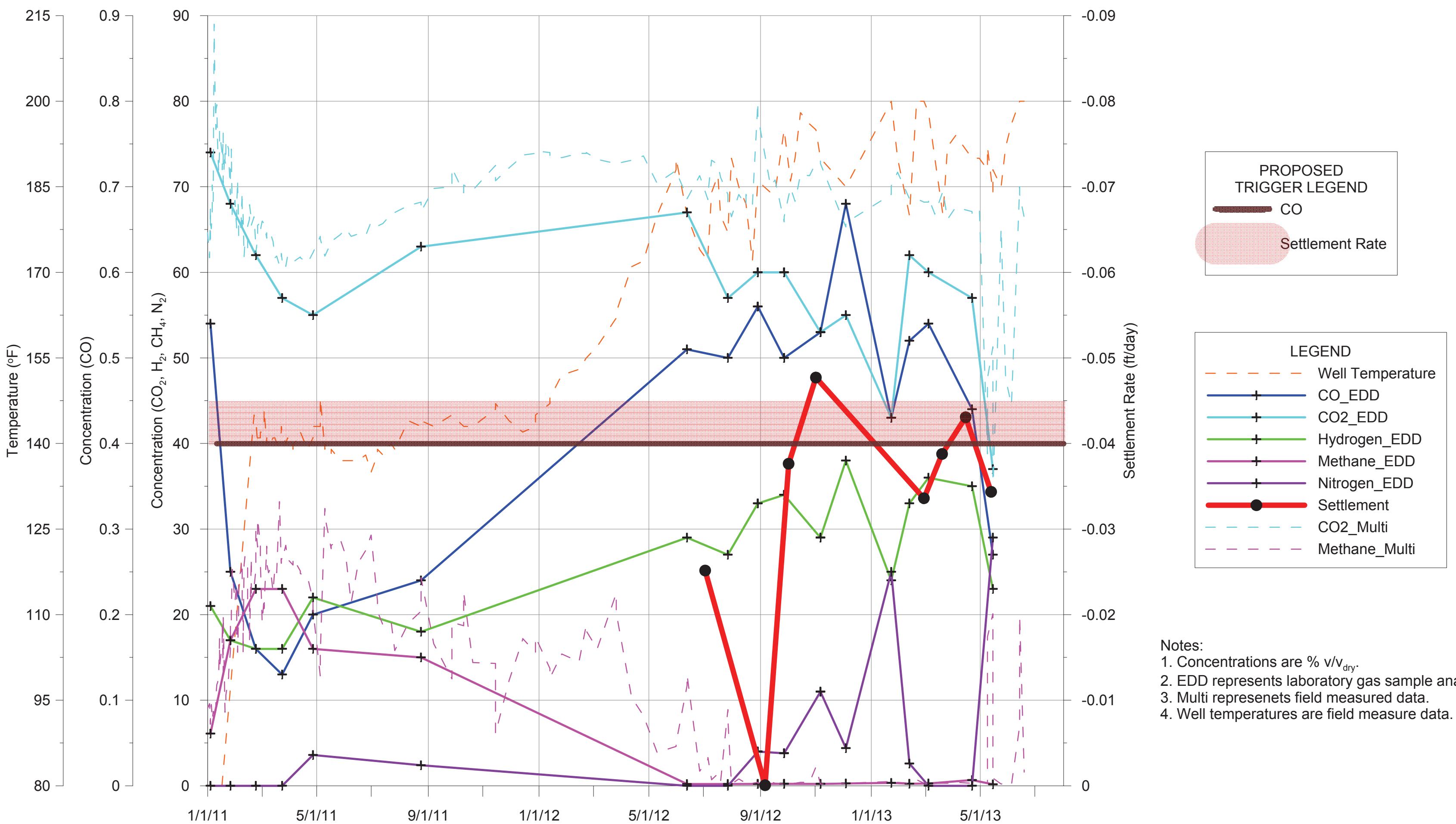


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-27

GEW-33R

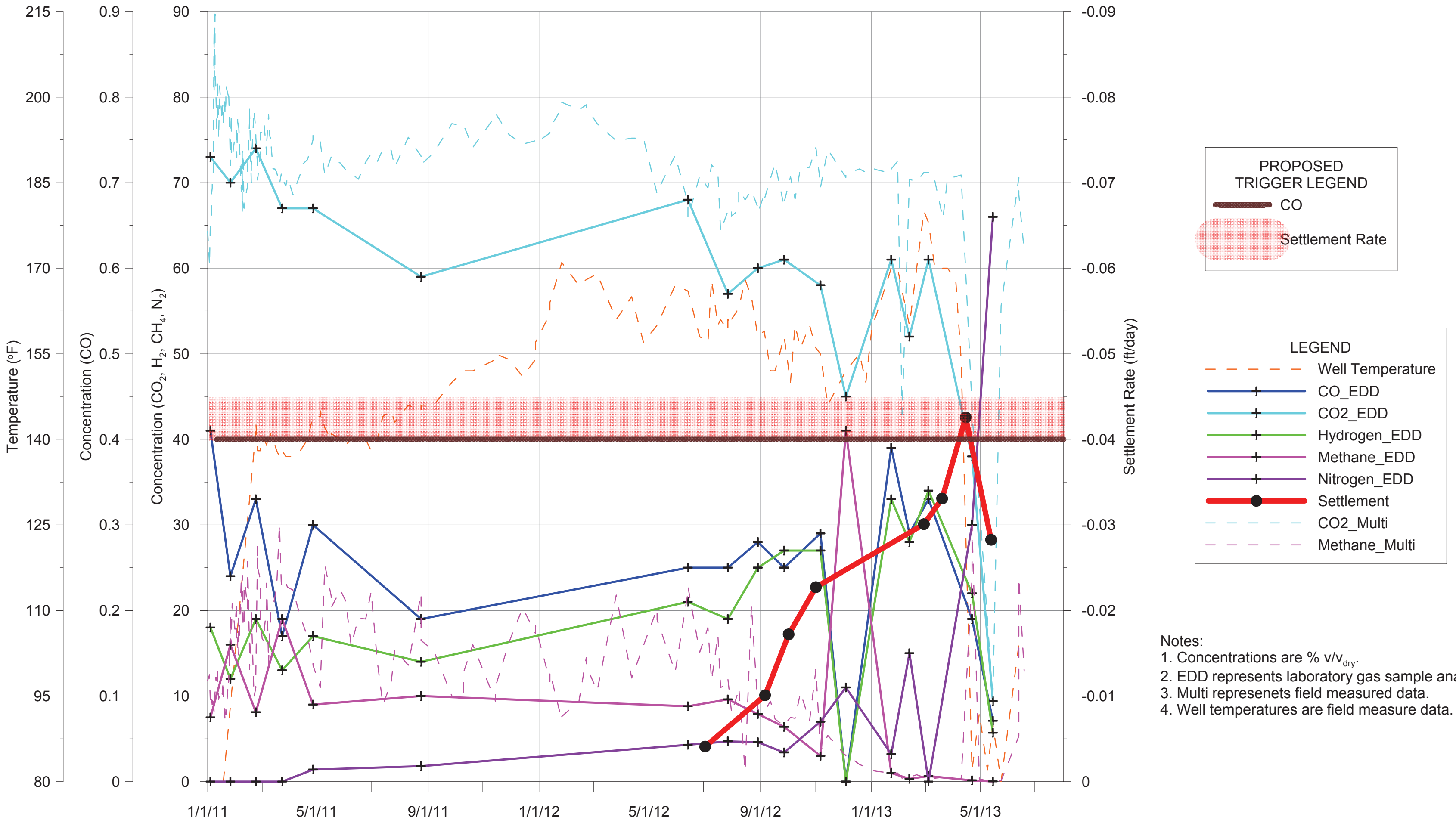


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-28

GEW-36

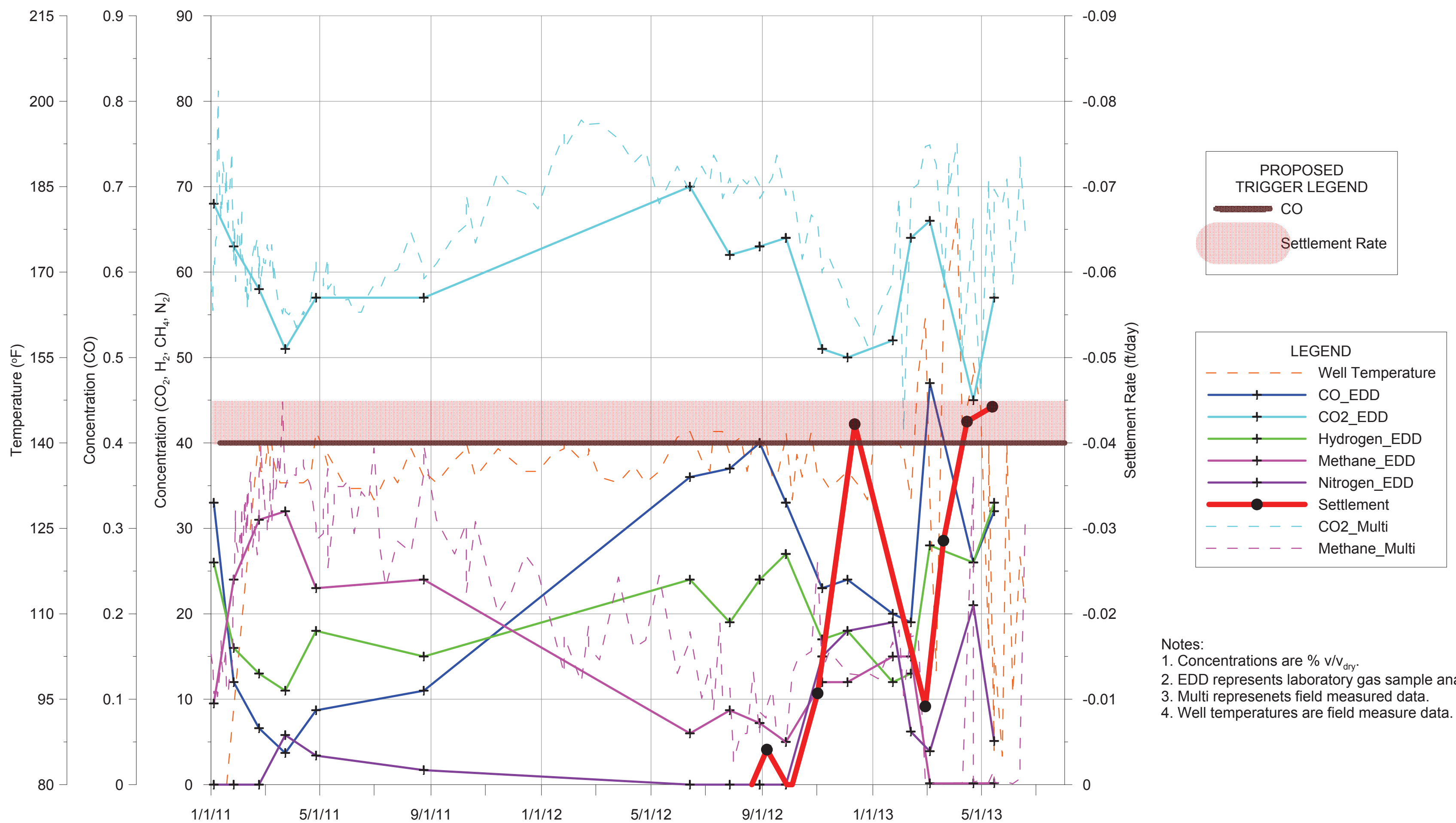


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-29

GEW-37

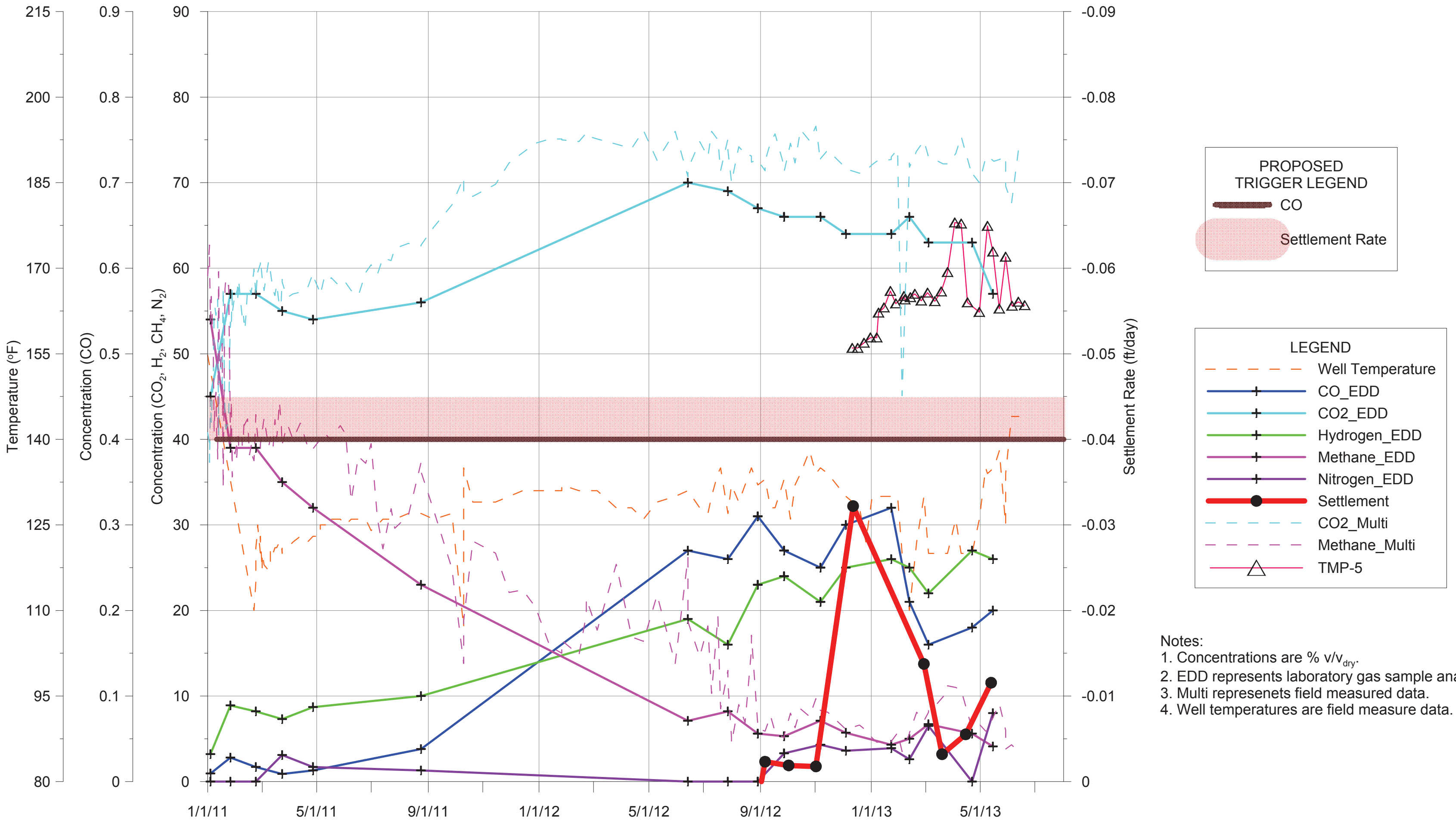


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS, TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-30

GEW-38

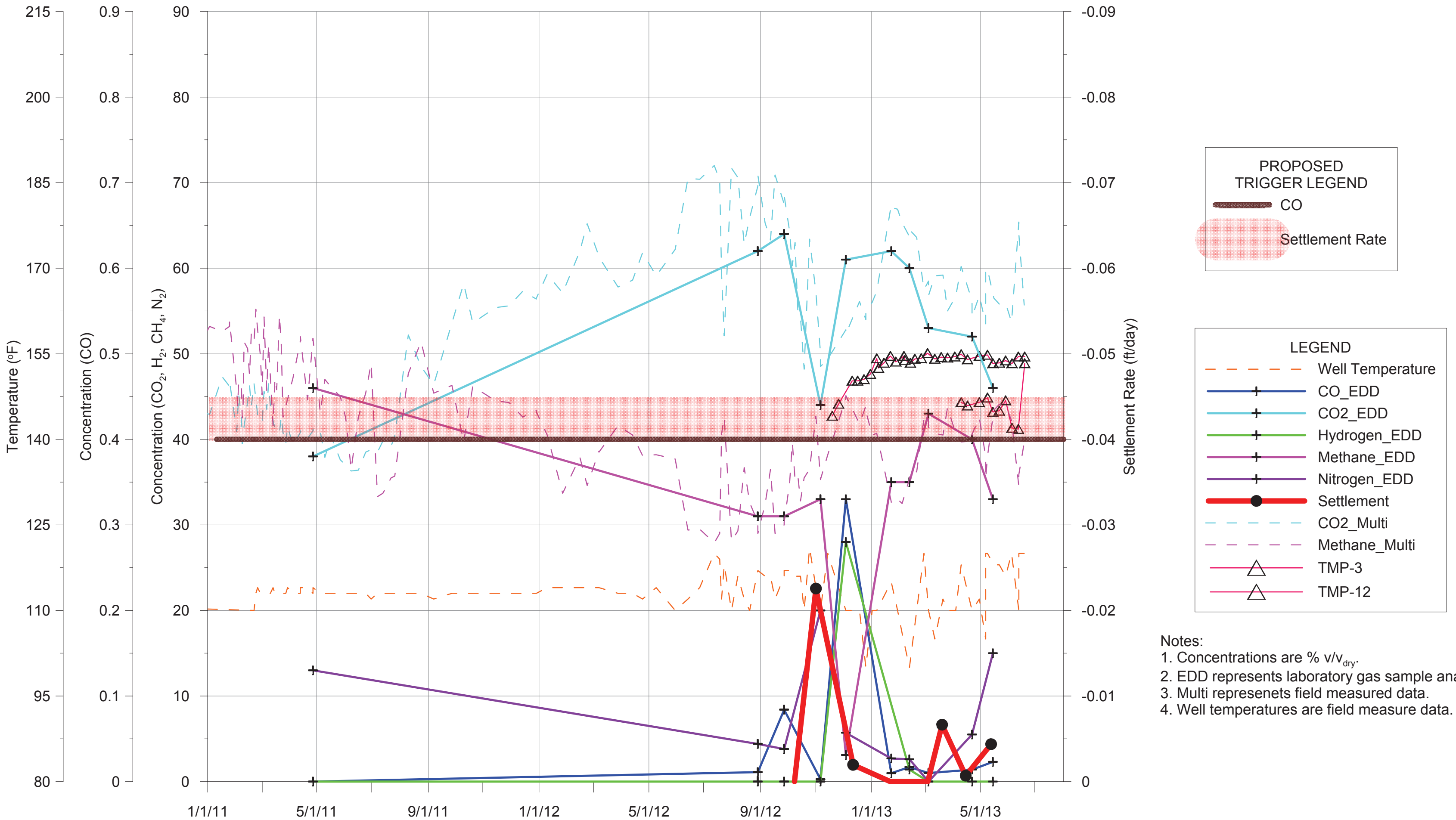


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS, TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-31

GEW-39

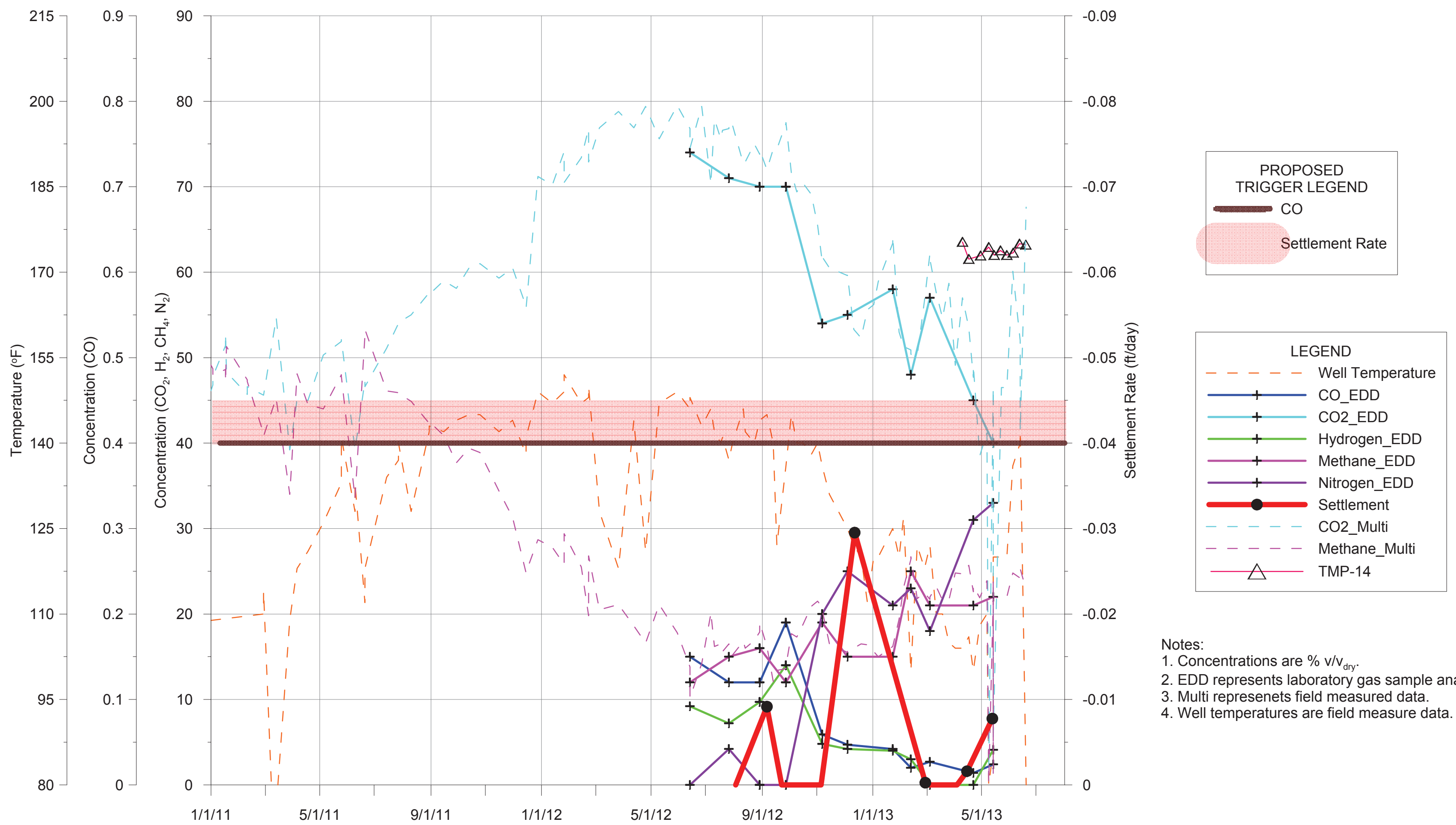


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS, TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-32

GEW-56R

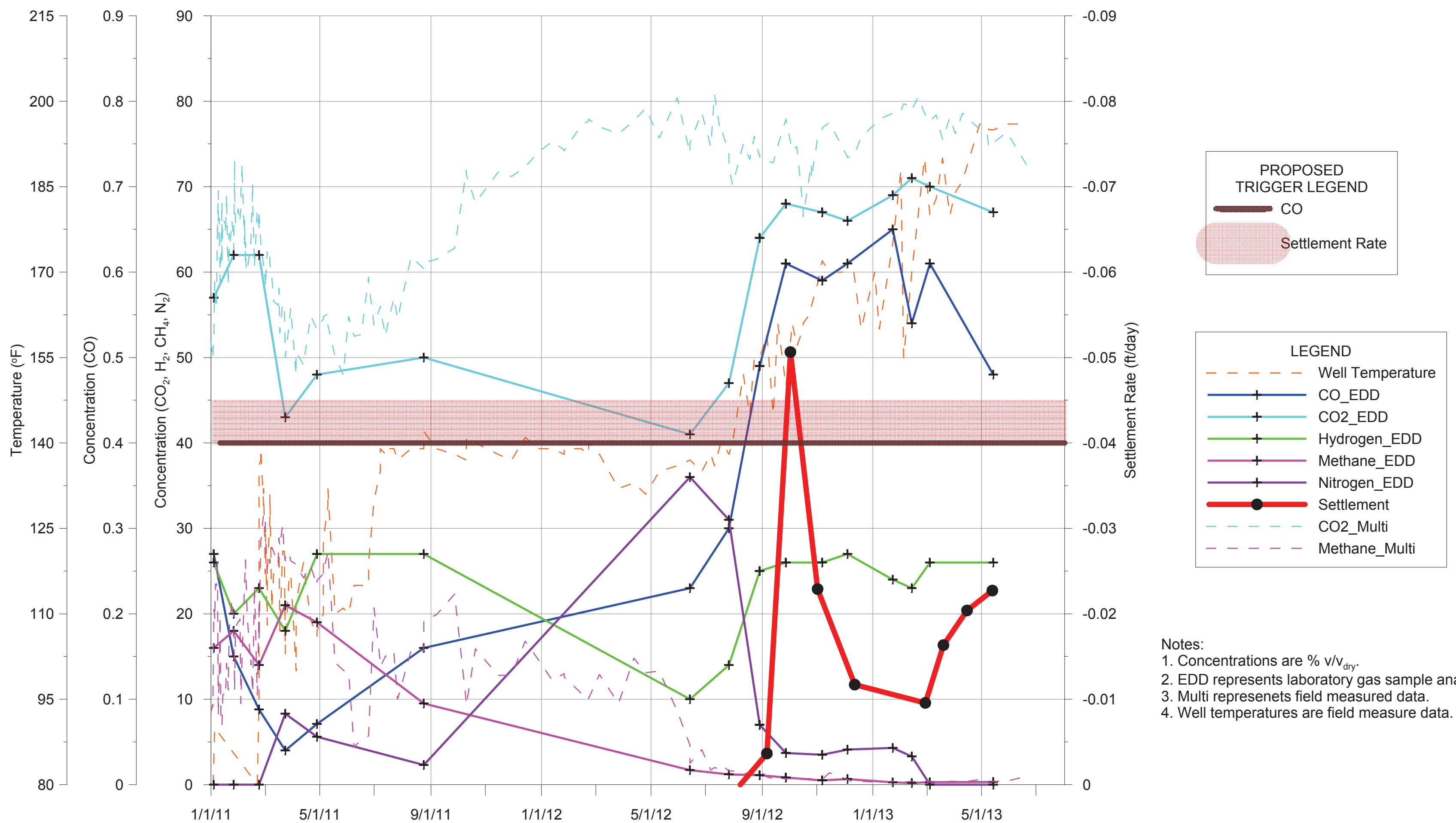


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-33

GEW-63

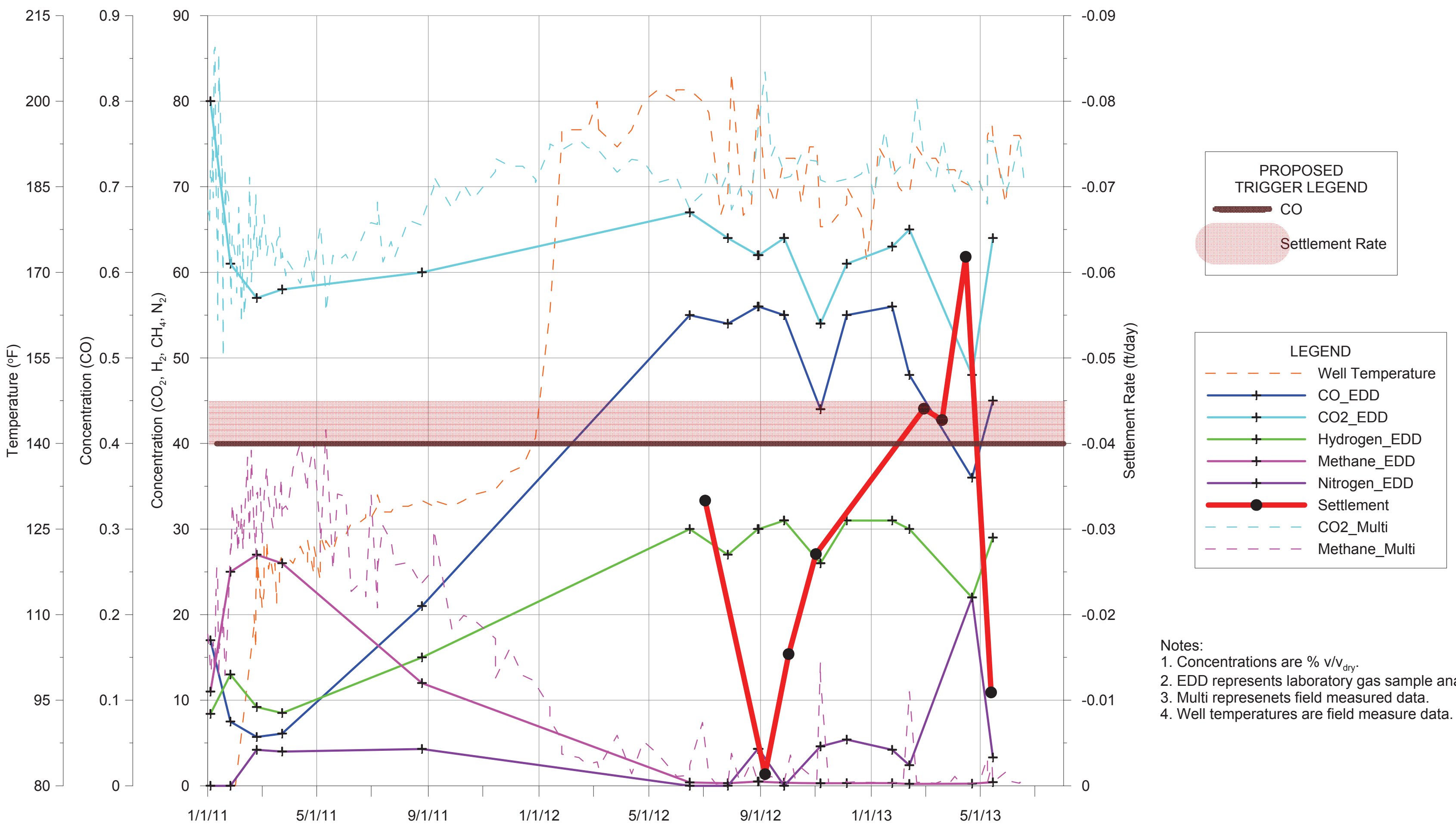


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-34

GEW-64

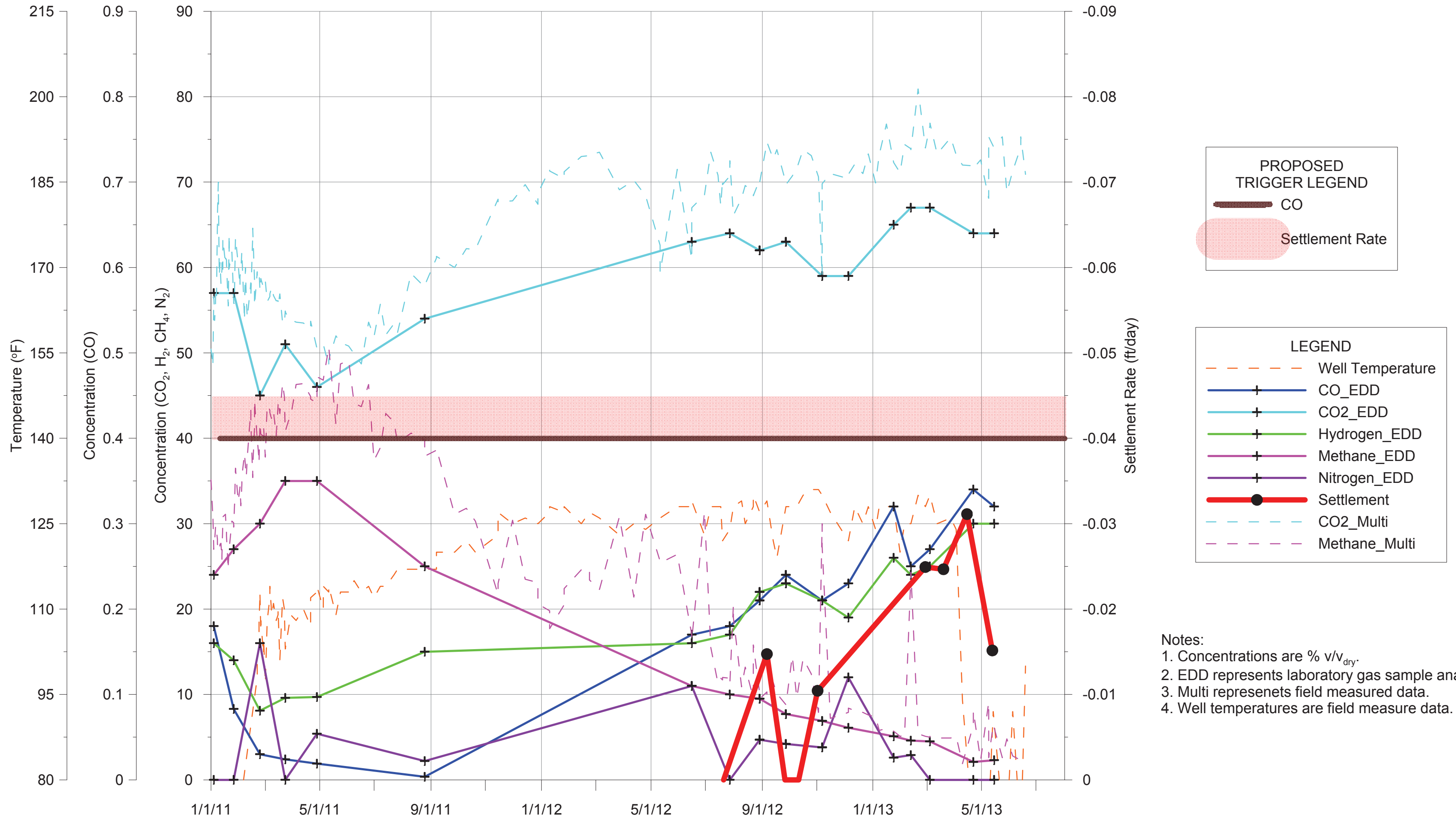


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-35

GEW-68

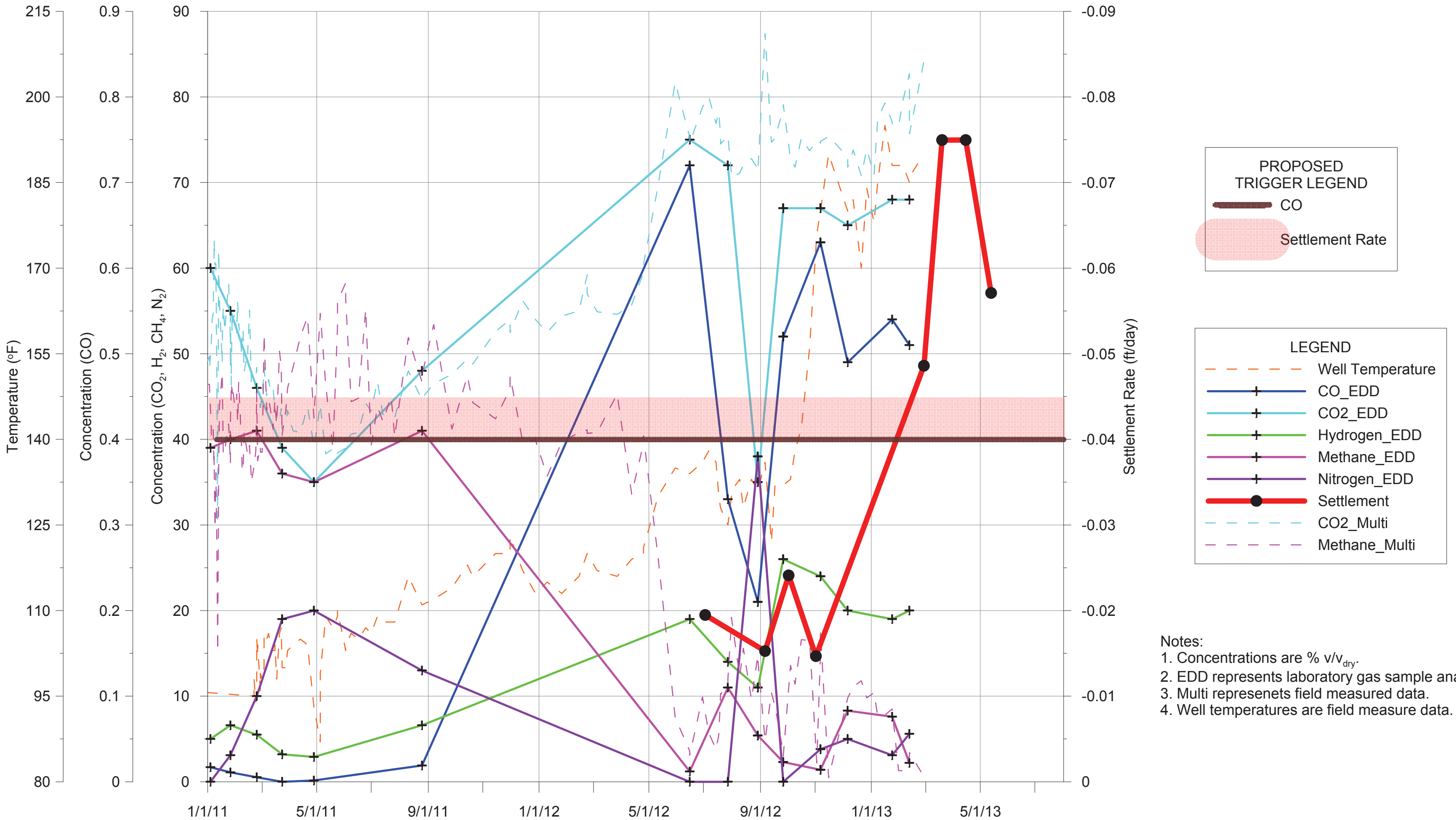


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-36

GEW-69R

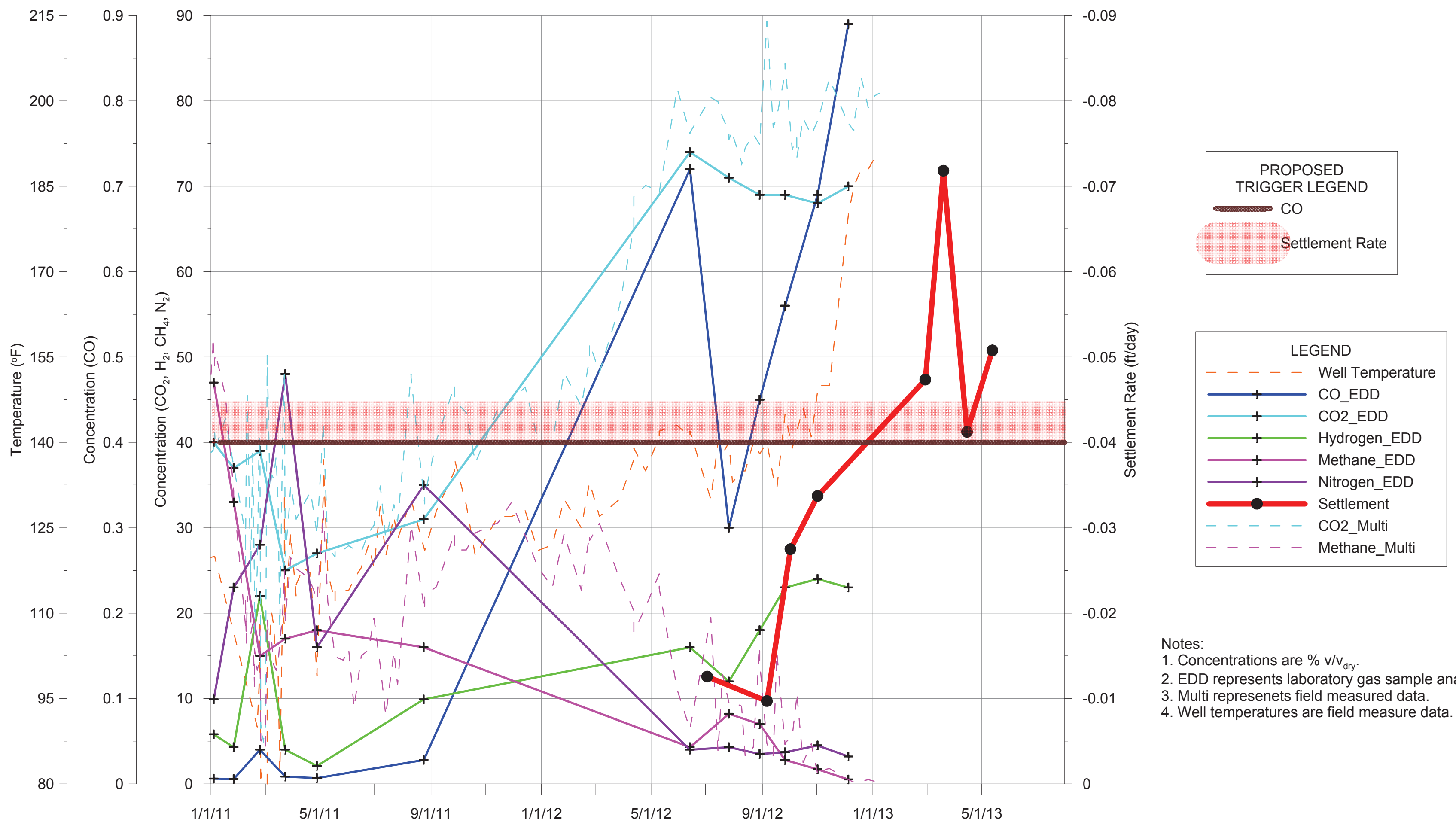


Notes:
1. Concentrations are % v/v$_{dry}$.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-37

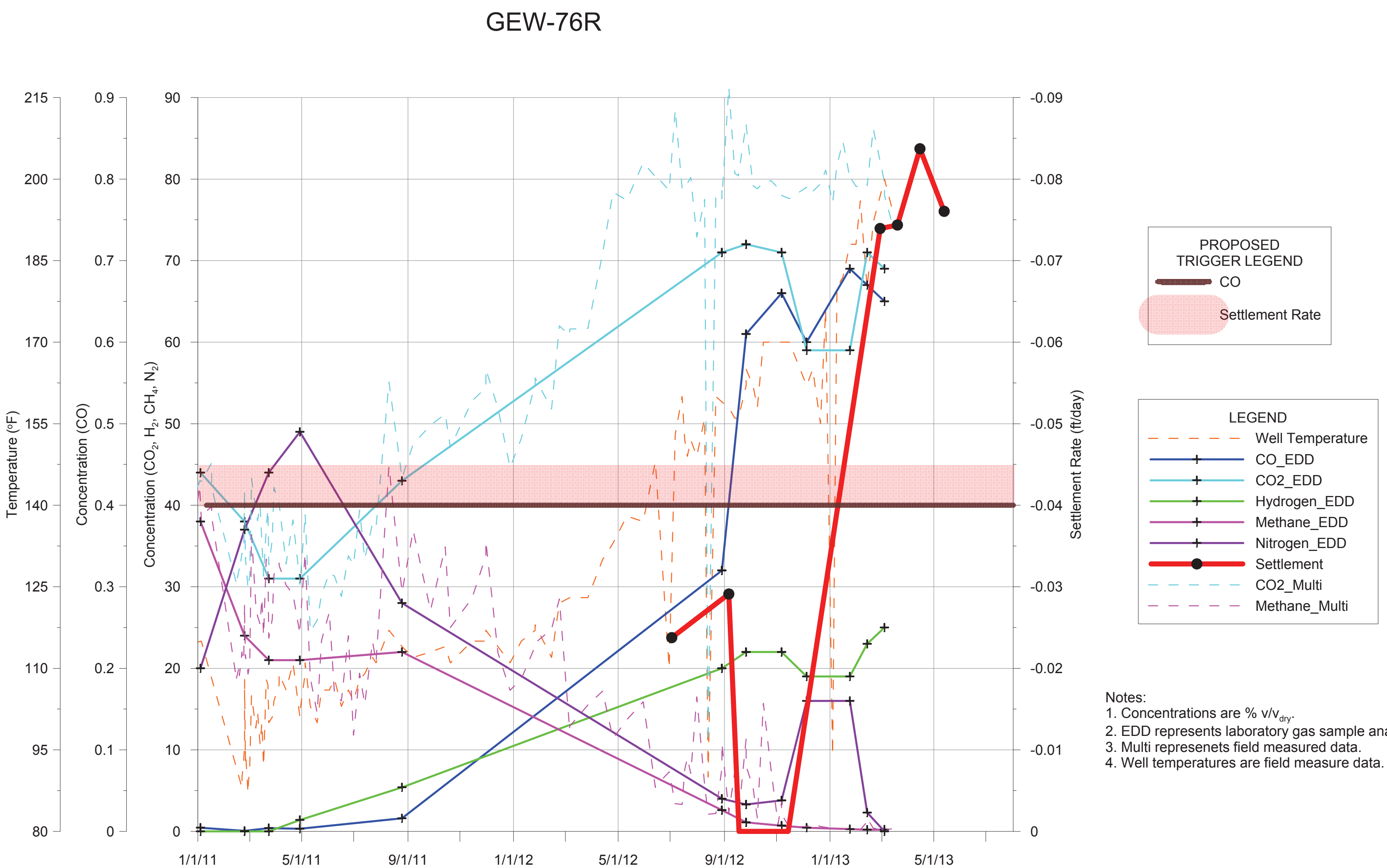
GEW-72R



Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS, TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

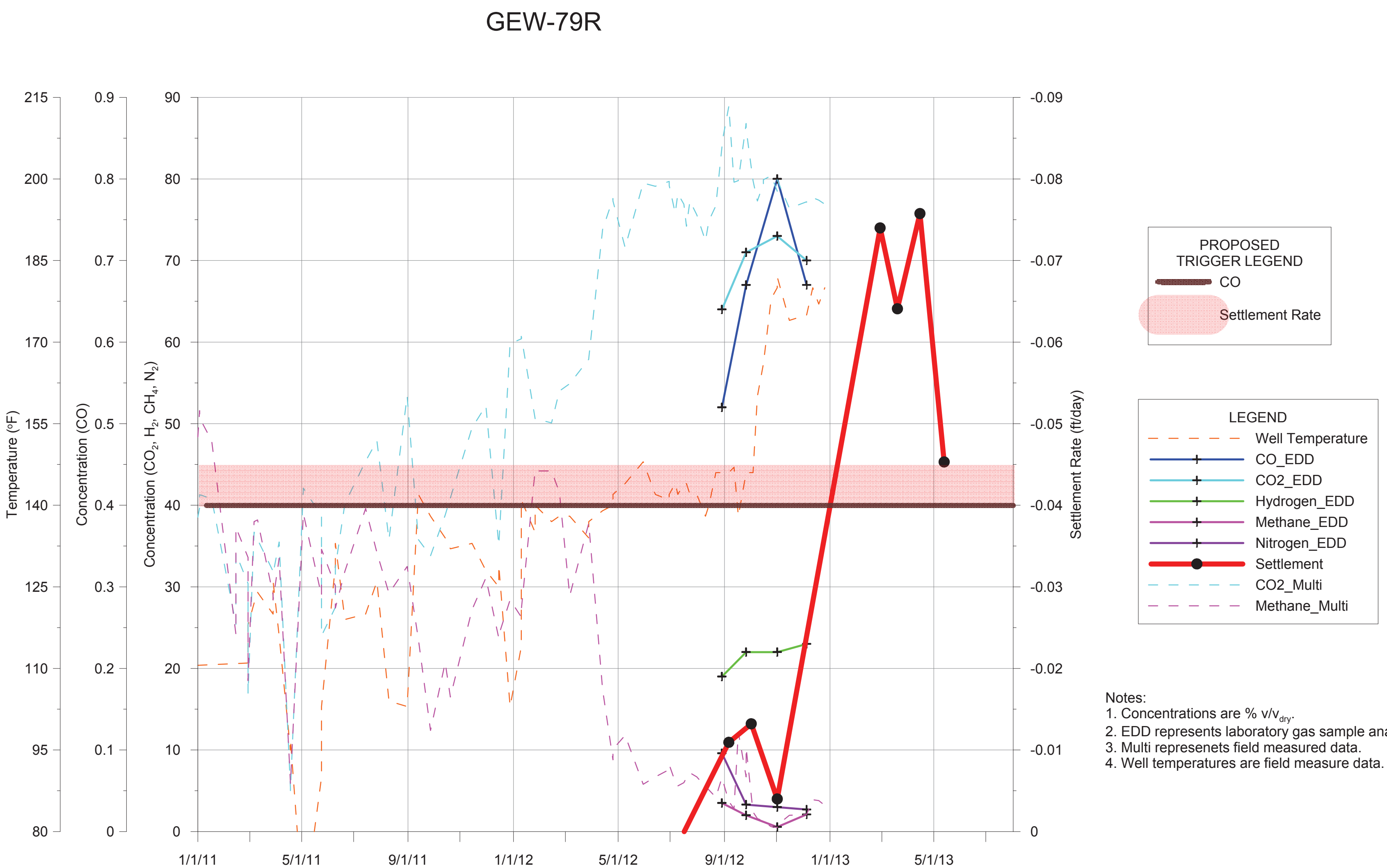
FIGURE E-38



Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

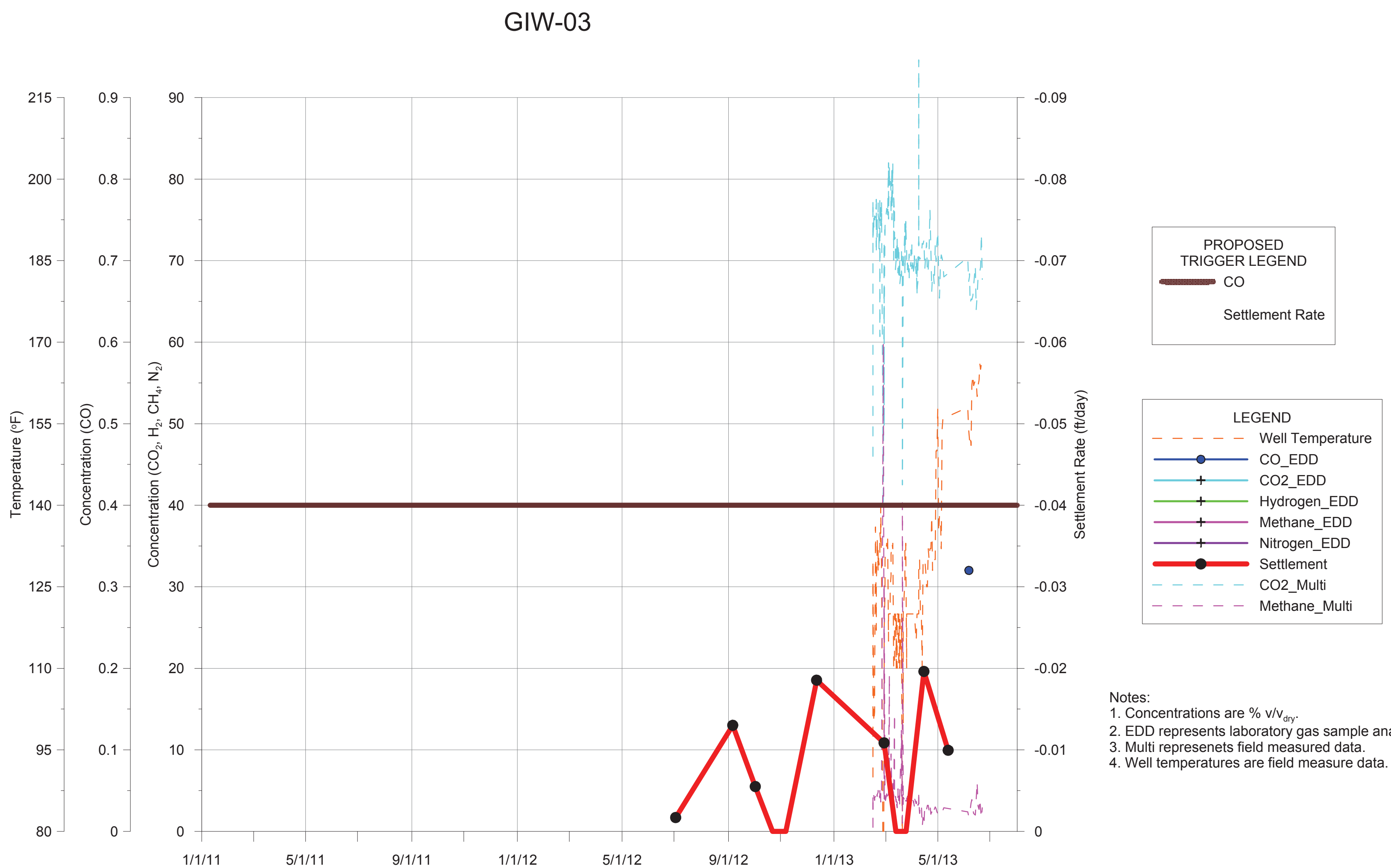
FIGURE E-39



Notes:
1. Concentrations are % v/v$_{dry}$.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

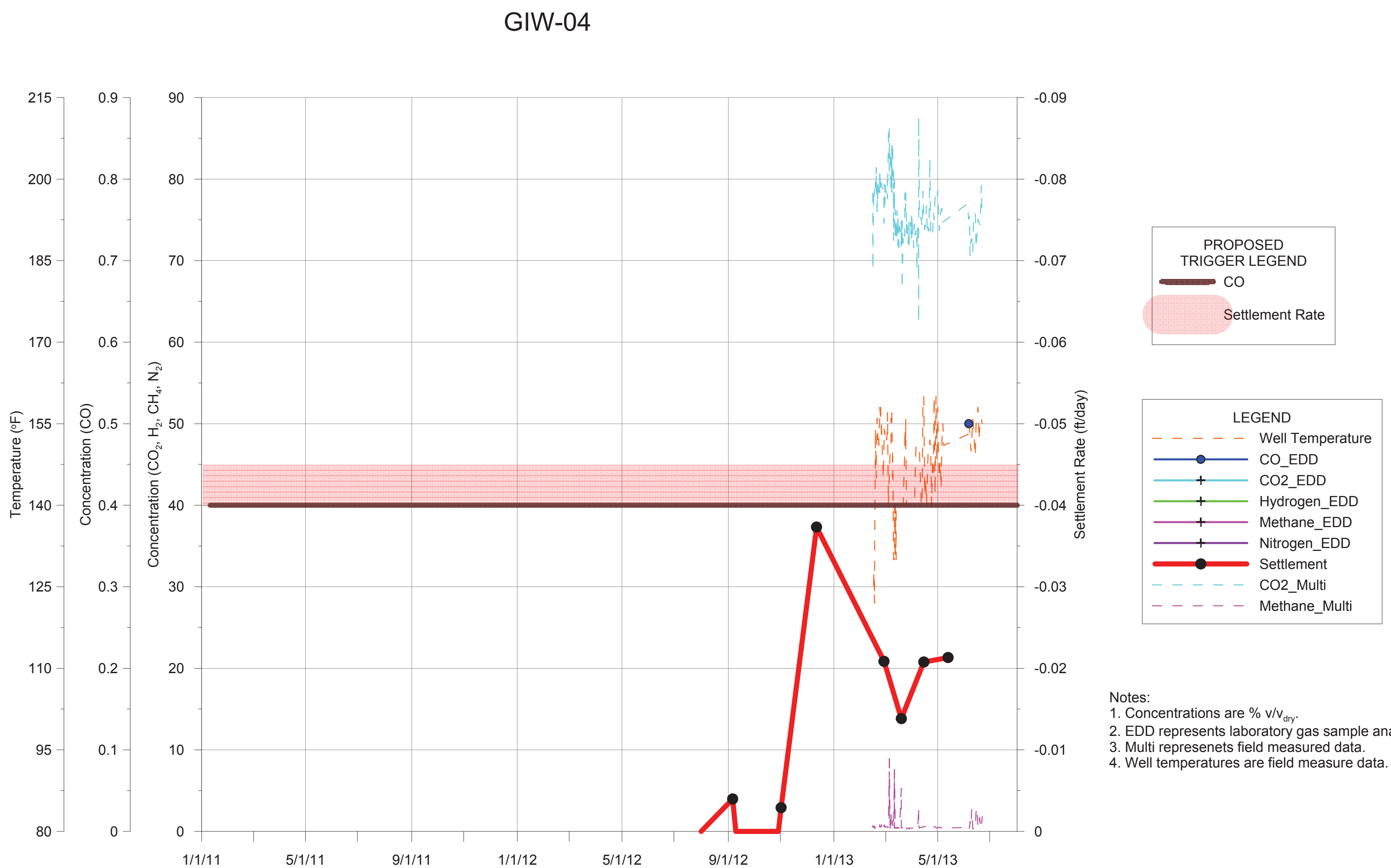
FIGURE E-40



Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

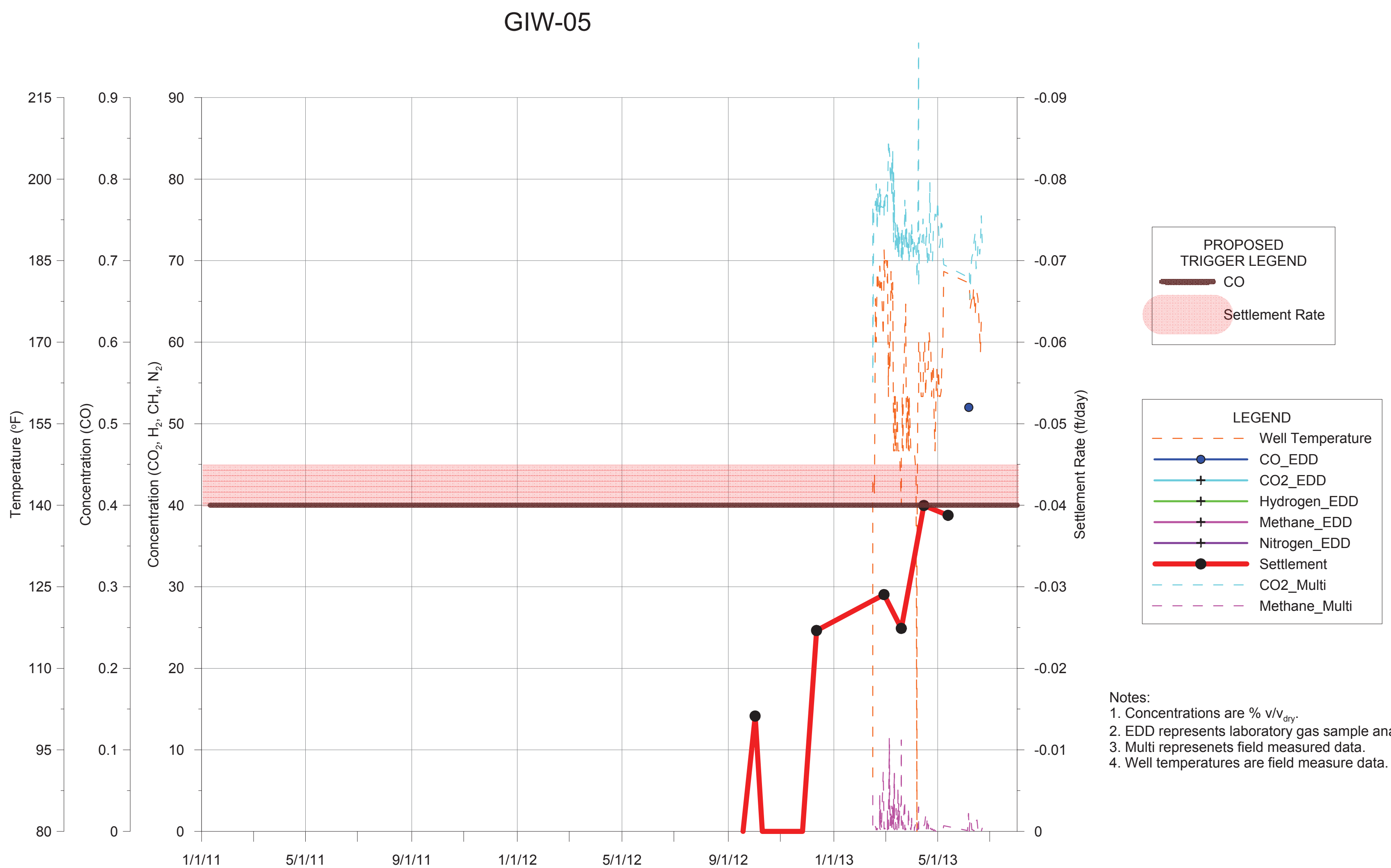
FIGURE E-41



Notes:
1. Concentrations are % v/v$_{dry}$.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-42

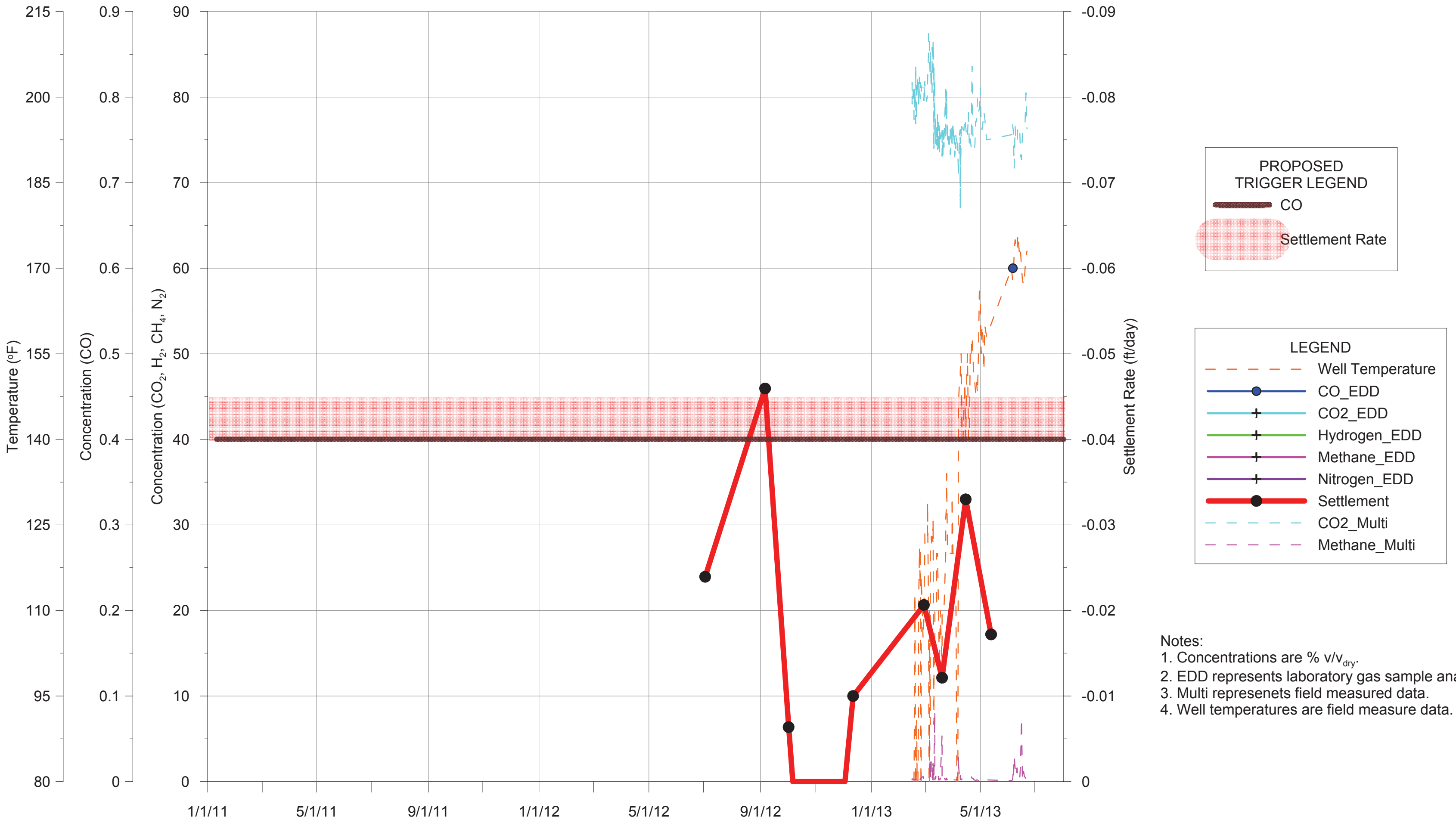


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-43

GIW-06

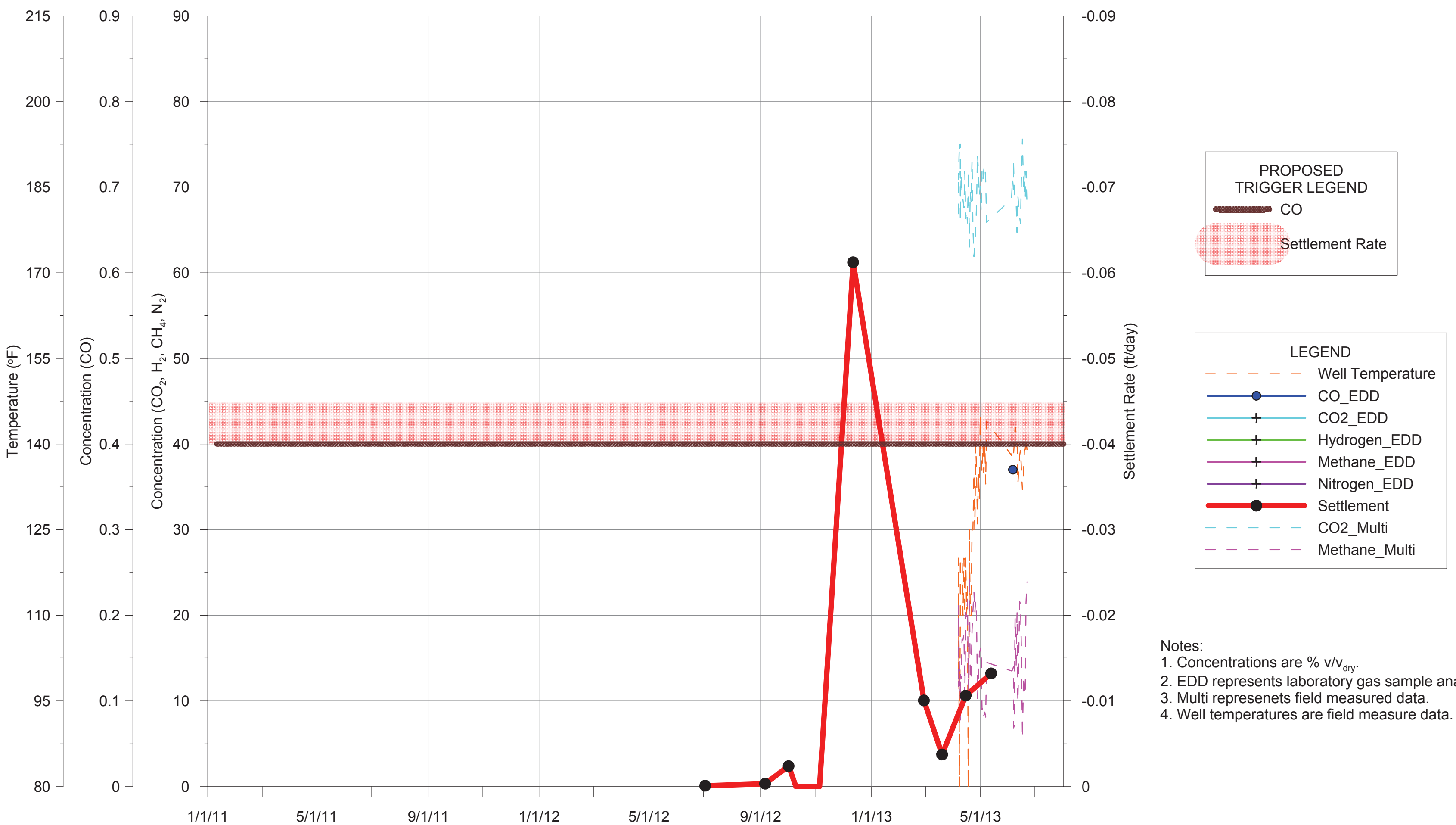


Notes:
1. Concentrations are % v/v$_{dry}$.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS, TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-44

GIW-07

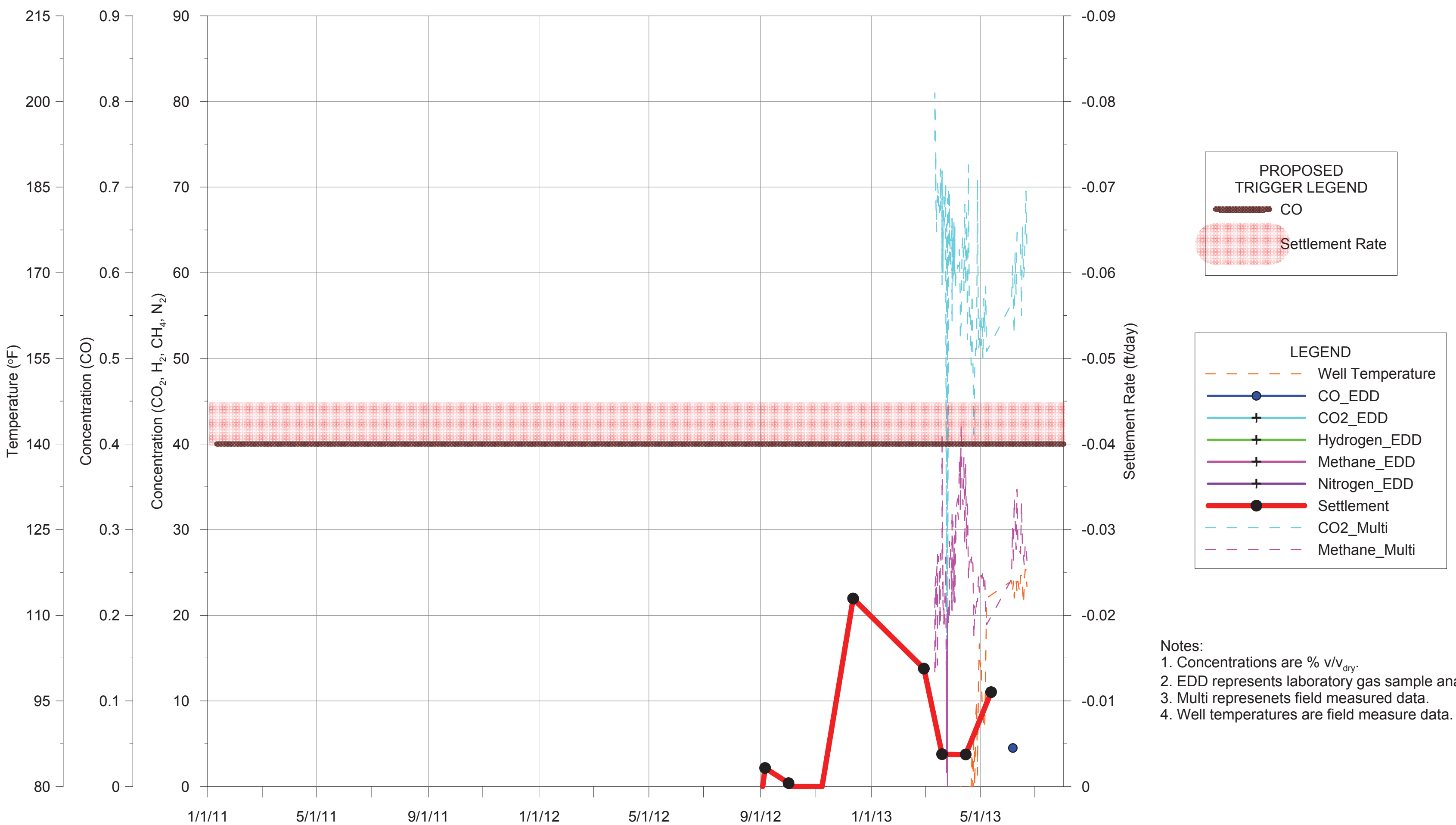


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-45

GIW-08

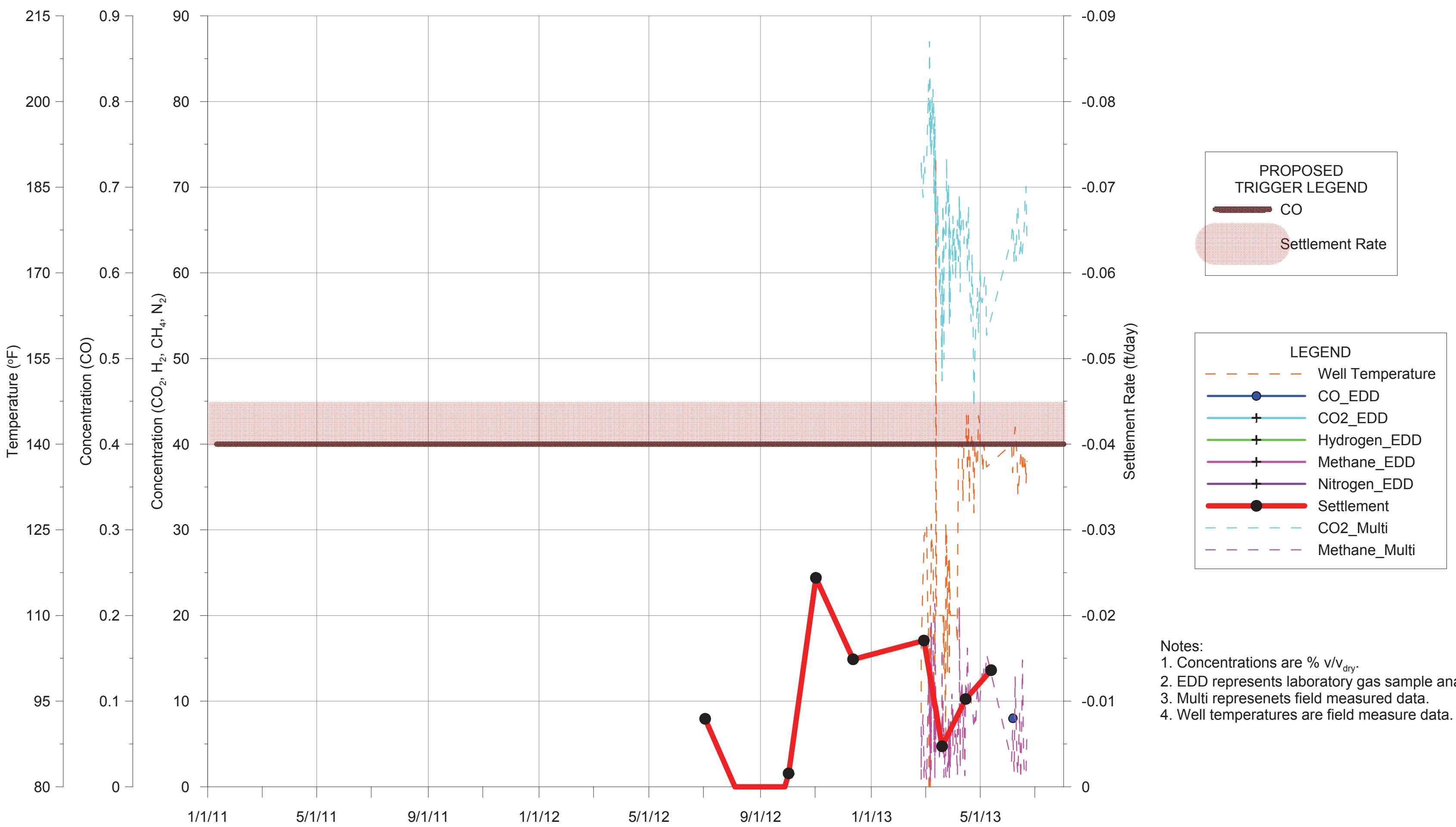


Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-46

GIW-09



Notes:
1. Concentrations are % v/v_{dry}.
2. EDD represents laboratory gas sample analysis.
3. Multi represenets field measured data.
4. Well temperatures are field measure data.

GAS CONCENTRATIONS,
TEMPERATURE, AND SETTLEMENT RATE
BRIDGETON LANDFILL

FIGURE E-47

ATTACHMENT E-1

		Wells used for Lab Gas Analysis of GAS WELLS not within 150 ft of a reaction						
	Row Labels	Max of Carb	Max of Meth	Max of Hydr	Max of Nitrog	Max of Oxygen/A	Max of Ca	co2/co	Meth/CO2
6/7/2013	GEW-01						0		
6/7/2013	GEW-02						0		
6/6/2013	GEW-03						0		
6/7/2013	GEW-04						0		
6/7/2013	GEW-05						0		
6/7/2013	GEW-06						0		
6/7/2013	GEW-07						0		
6/7/2013	GEW-08						0		
6/6/2013	GEW-09						0		
6/13/2012	GEW-10	61	34	4.4	0	0	0.059	1033.9	0.557377
7/26/2012	GEW-10	56	32	0	0	0	0.037	1513.5	0.571429
8/29/2012	GEW-10	49	45	0	0	0	0.018	2722.2	0.918367
9/27/2012	GEW-10	52	42	0	3.5	0	0.028	1857.1	0.807692
11/6/2012	GEW-10	47	45	0	6.1	1.7	0.01	4700	0.957447
12/4/2012	GEW-10	45	38	0	14	1.7	0.013	3461.5	0.844444
1/23/2013	GEW-10	52	36	1.8	8.6	0.92	0.034	1529.4	0.692308
2/13/2013	GEW-10	38	38	0	20	3.5	0.0042	9047.6	1
3/5/2013	GEW-10	55	30	0	10	1.5	0.039	1410.3	0.545455
4/22/2013	GEW-10	41	30	0	28	0	0.006	6833.3	0.731707
5/14/2013	GEW-10	30	19	0	42	8.3	0	10000	0.633333
4/22/2013	GEW-110	62	8.8	19	8.8	0	0.094	659.57	0.141935
5/14/2013	GEW-110	67	5.3	21	4.4	0	0.17	394.12	0.079104
2/12/2013	GEW-20a	41	17	0	33	8.5	0.02	2050	0.414634
3/6/2013	GEW-20a	21	6.7	0	57	16	0.017	1235.3	0.319048
4/25/2013	GEW-20a	36	4.3	3.7	43	12	0.092	391.3	0.119444
5/14/2013	GEW-20a	37	6.3	0	42	11	0.084	440.48	0.17027
2/12/2013	GEW-22R	76	14	7.6	2	0.53	0.15	506.67	0.184211
3/6/2013	GEW-22R	73	13	8.3	4	0	0.17	429.41	0.178082
4/25/2013	GEW-22R	53	5.9	8.8	25	7	0.16	331.25	0.111321
5/14/2013	GEW-22R	74	8.1	14	0	0	0.19	389.47	0.109459
2/12/2013	GEW-23a	65	25	6.6	3.2	0.64	0.084	773.81	0.384615
3/6/2013	GEW-23a	65	23	6.9	3.9	0	0.089	730.34	0.353846

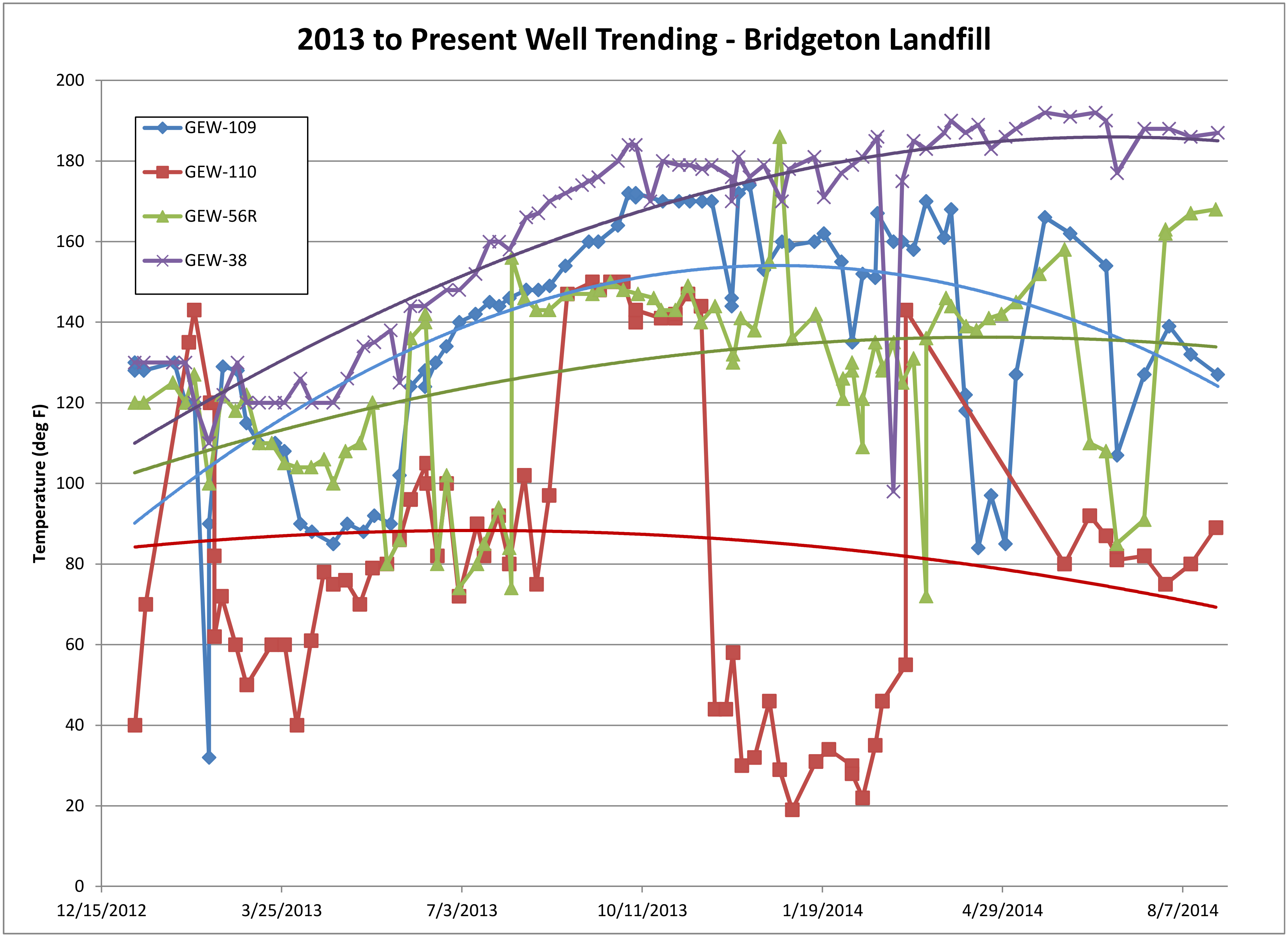
4/25/2013	GEW-23a	70	16	10	0	0	0.15	466.67	0.228571
5/14/2013	GEW-23a	57	14	8.5	16	4.3	0.091	626.37	0.245614
4/27/2011	GEW-39	38	46	0	13	0.83	0	10000	1.210526
8/29/2012	GEW-39	62	31	0	4.4	0	0.011	5636.4	0.5
9/27/2012	GEW-39	64	31	0	3.8	0	0.084	761.9	0.484375
11/6/2012	GEW-39	44	33	0	20	1.4	0.0027	16296	0.75
12/4/2012	GEW-39	61	3.1	28	5.7	1.6	0.33	184.85	0.05082
1/23/2013	GEW-39	62	35	0	2.7	0.69	0.0098	6326.5	0.564516
2/12/2013	GEW-39	60	35	1.4	2.6	0.6	0.017	3529.4	0.583333
3/5/2013	GEW-39	53	43	0	0	0	0.01	5300	0.811321
4/22/2013	GEW-39	52	40	0	5.5	0	0.014	3714.3	0.769231
5/15/2013	GEW-39	46	33	0	15	3.1	0.023	2000	0.717391
4/27/2011	GEW-40	33	40	0	22	0.98	0	10000	1.212121
6/6/2013	GEW-40						0		
4/27/2011	GEW-41R	29	32	0	33	1.1	0	10000	1.103448
6/1/2013	GEW-41R			0	0	0	0		
4/27/2011	GEW-42R	33	35	0	32	1.2	0	10000	1.060606
6/7/2013	GEW-44						0		
6/7/2013	GEW-47R						0.01		
6/7/2013	GEW-48						0		
6/7/2013	GEW-49						0		
6/7/2013	GEW-50						0		
6/7/2013	GEW-51						0		
6/7/2013	GEW-52						0		
6/7/2013	GEW-53						0.0044		
6/7/2013	GEW-54						0.0044		
6/6/2013	GEW-55						0		
2/12/2013	GEW-77	68	6.9	20	3.4	0.95	0.29	234.48	0.101471
3/6/2013	GEW-77	68	6.4	23	0	0	0.31	219.35	0.094118
4/25/2013	GEW-77	67	4.9	25	0	0	0.31	216.13	0.073134
5/14/2013	GEW-77	66	4.7	25	0	0	0.29	227.59	0.071212
2/12/2013	GEW-80	73	11	11	3	0.85	0.18	405.56	0.150685
3/6/2013	GEW-80	74	10	13	0	0	0.21	352.38	0.135135
4/25/2013	GEW-80	71	8.1	17	0	0	0.23	308.7	0.114085
5/14/2013	GEW-80	71	7.9	17	0	0	0.21	338.1	0.111268

6/6/2013	GIW-13						0.086		

wells used for analysis of lab. gas for GAS Wells not within 150 ft of settlement fronts

ATTACHMENT C

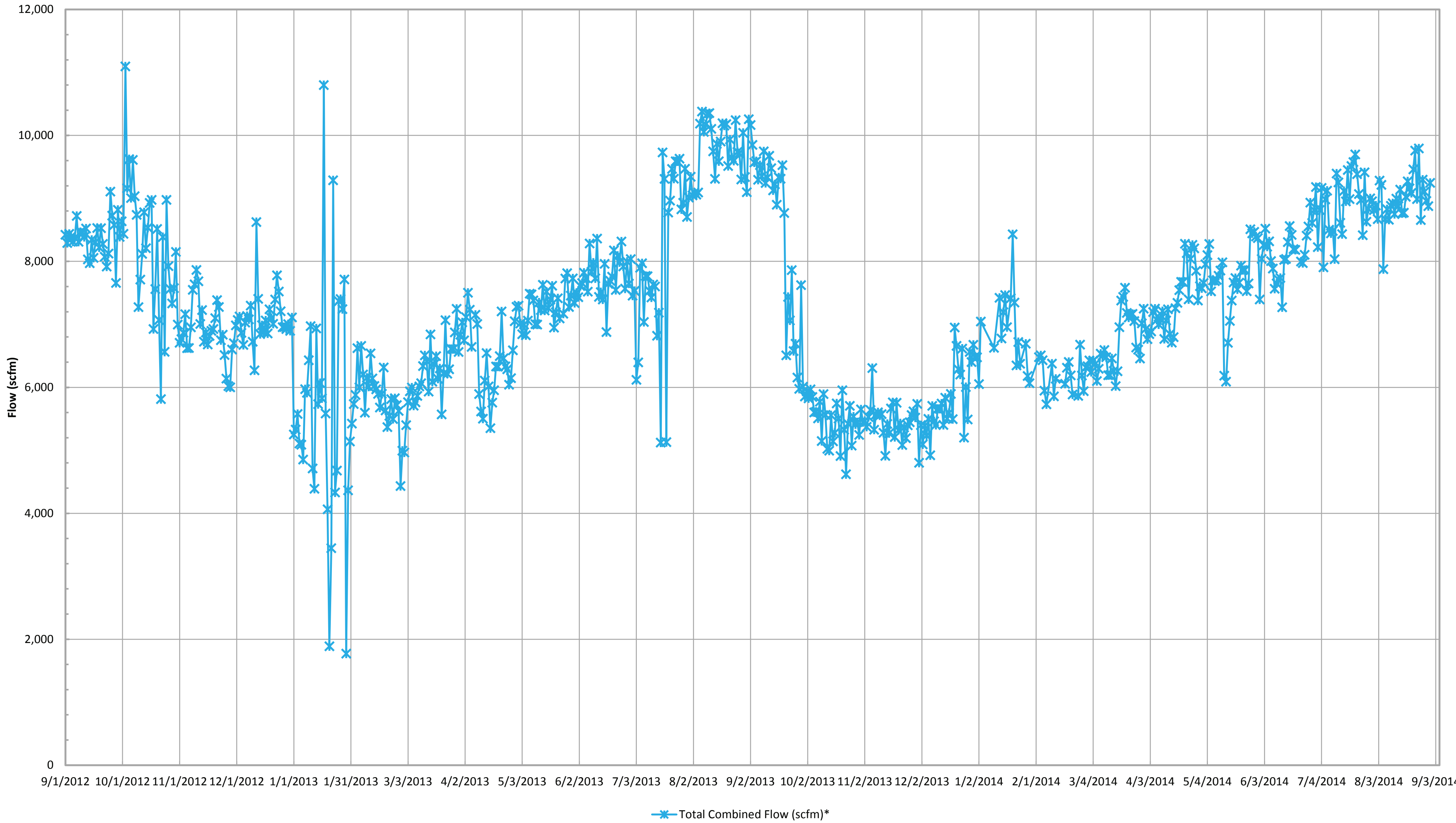
WELLHEAD TEMPERATURE IN SELECTED NECK AREA WELLS


2013 to Present Well Trending - Bridgeton Landfill
GEW-109
GEW-110
GEW-56R
GEW-38
Temperature (deg F)
0
20
40
60
80
100
120
140
160
180
200
12/15/2012
3/25/2013
7/3/2013
10/11/2013
1/19/2014
4/29/2014
8/7/2014

ATTACHMENT D

TOTAL COMBINED FLARE FLOW

Total Combined Flow (scfm)*



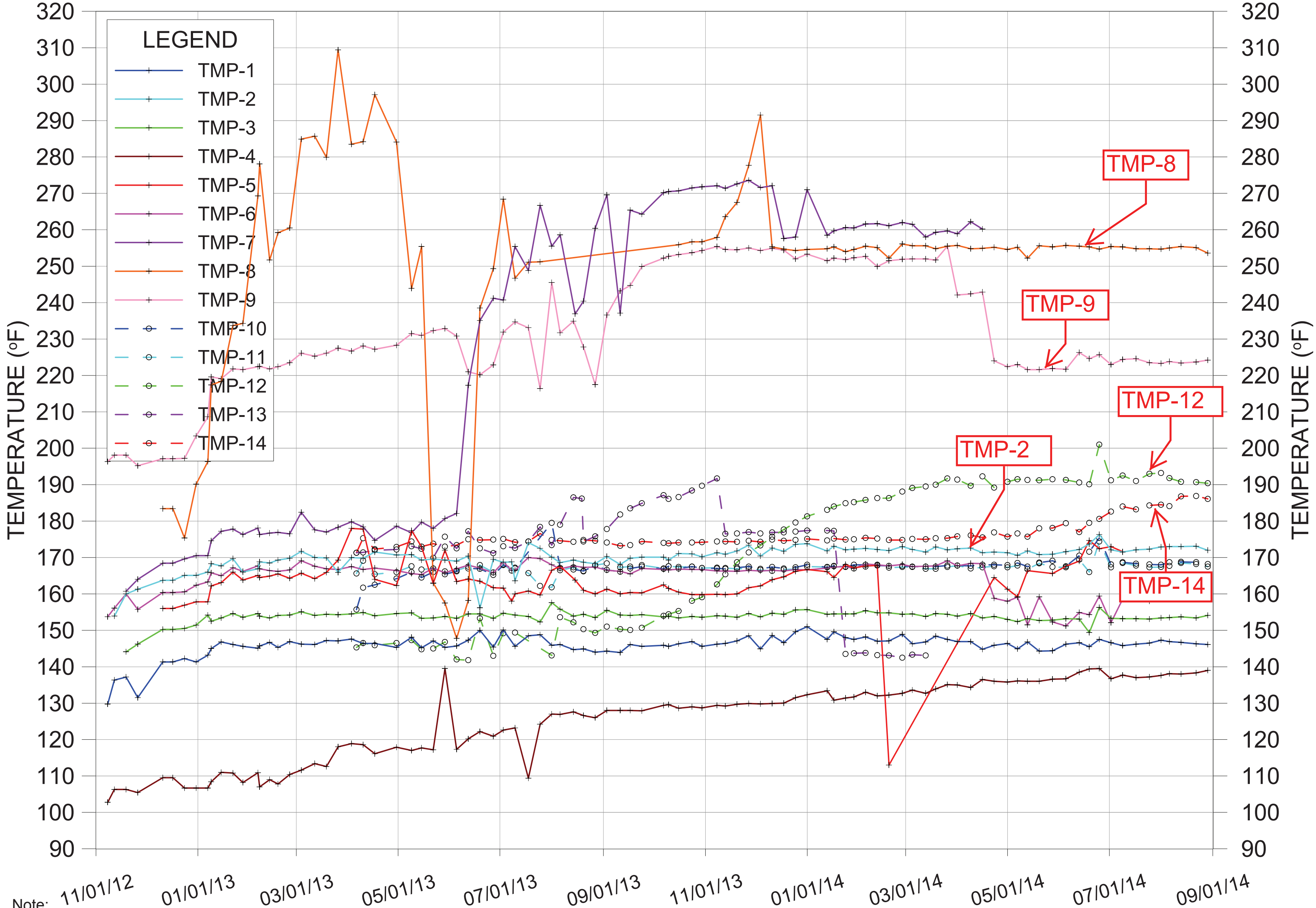
*Combined flow is based on tabulated flow data collected daily from each device.

SCS ENGINEERS

ATTACHMENT E

TMP MAXIMUM TEMPERATURE GRAPHS

MAXIMUM TEMPERATURES

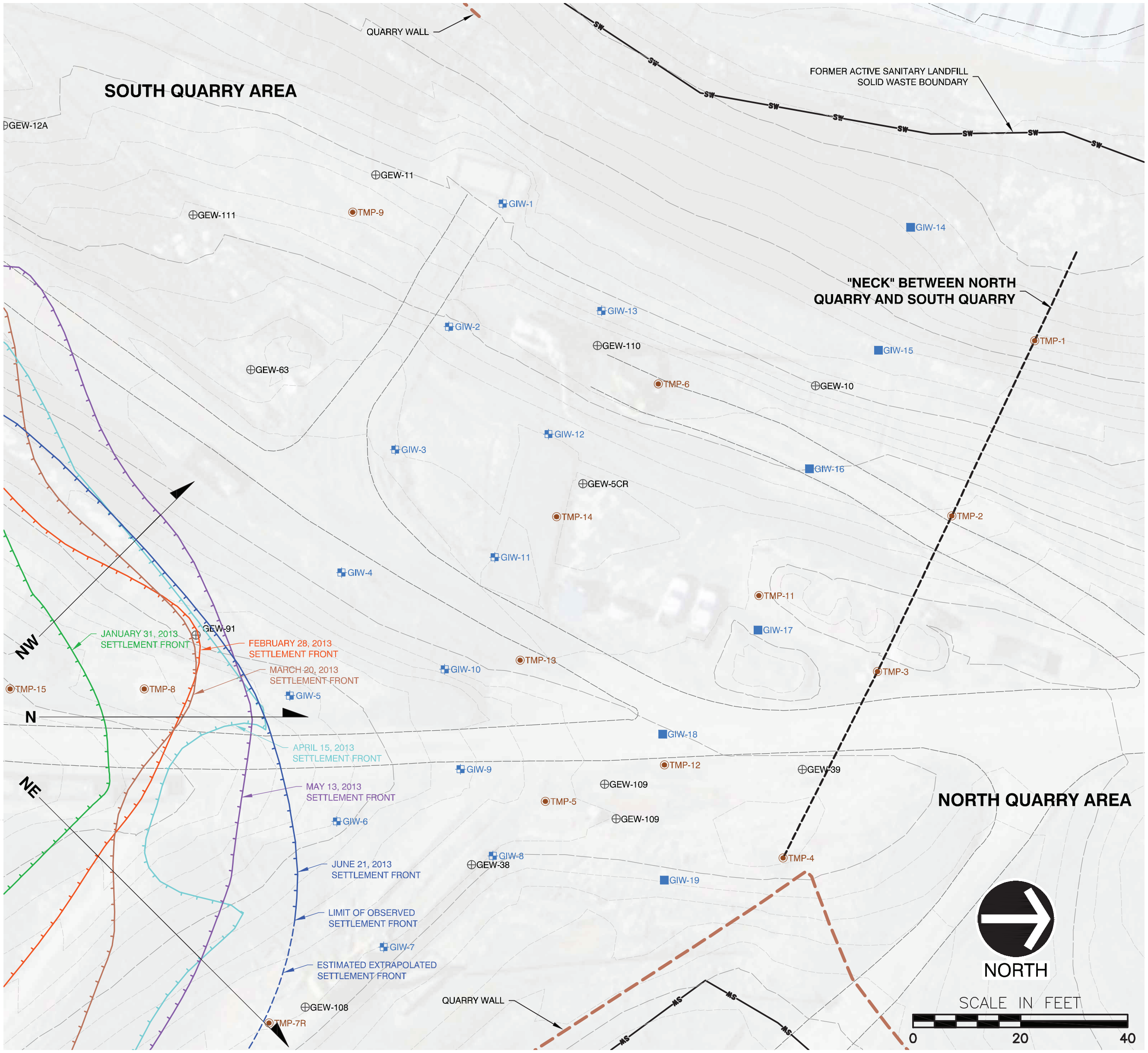


Note:
1. From 5/22 - 6/12/13, only the TMP-8 reading at 20' depth was operational.
No valid readings were obtained for TMP-8 from 8/1 to 10/10/2013. Valid readings from 20' to 40' resumed on 10/16/2013.
2. A new OMEGA dial was installed at TMP-7R on 6/12/2013 enabling more vaild readings.
3. No valid readings were obtained for TMP-10 and TMP-12 on 7/18/2013 or 7/25/2013.
4. End terminals were replaced just prior to the 8/6/2013 readings with type T Omega connectors (part # SMPW-CC-T-M) on all TMPs except for TMP-8.

TEMPERATURE VS TIME
BRIDGETON LANDFILL

APPENDIX B

SSE (SETTLEMENT FRONT) MOVEMENT RATE MAPS



VECTOR DATA

DATE RANGE (ALL 2013)	1/31-2/28	2/28-3/20	3/20-4/15	4/15-5/13	5/13-6/21	TOTAL	AVERAGE MOVEMENT (FEET/DAY)
NO. OF DAYS	28	20	26	28	38	140	
NE VECTOR (FT)	15	8	46	0	33	102	0.73
N VECTOR (FT)	28	1	30	-5	5	59	0.42
NW VECTOR (FT)	29	6	8	14	-13	44	0.31
OVERALL AVERAGE							0.49

NOTE

1. SETTLEMENT FRONT DEFINED AS LINE OF EQUAL RATE OF SETTLEMENT 1.35 FEET PER 30 DAY PERIOD.

LEGEND

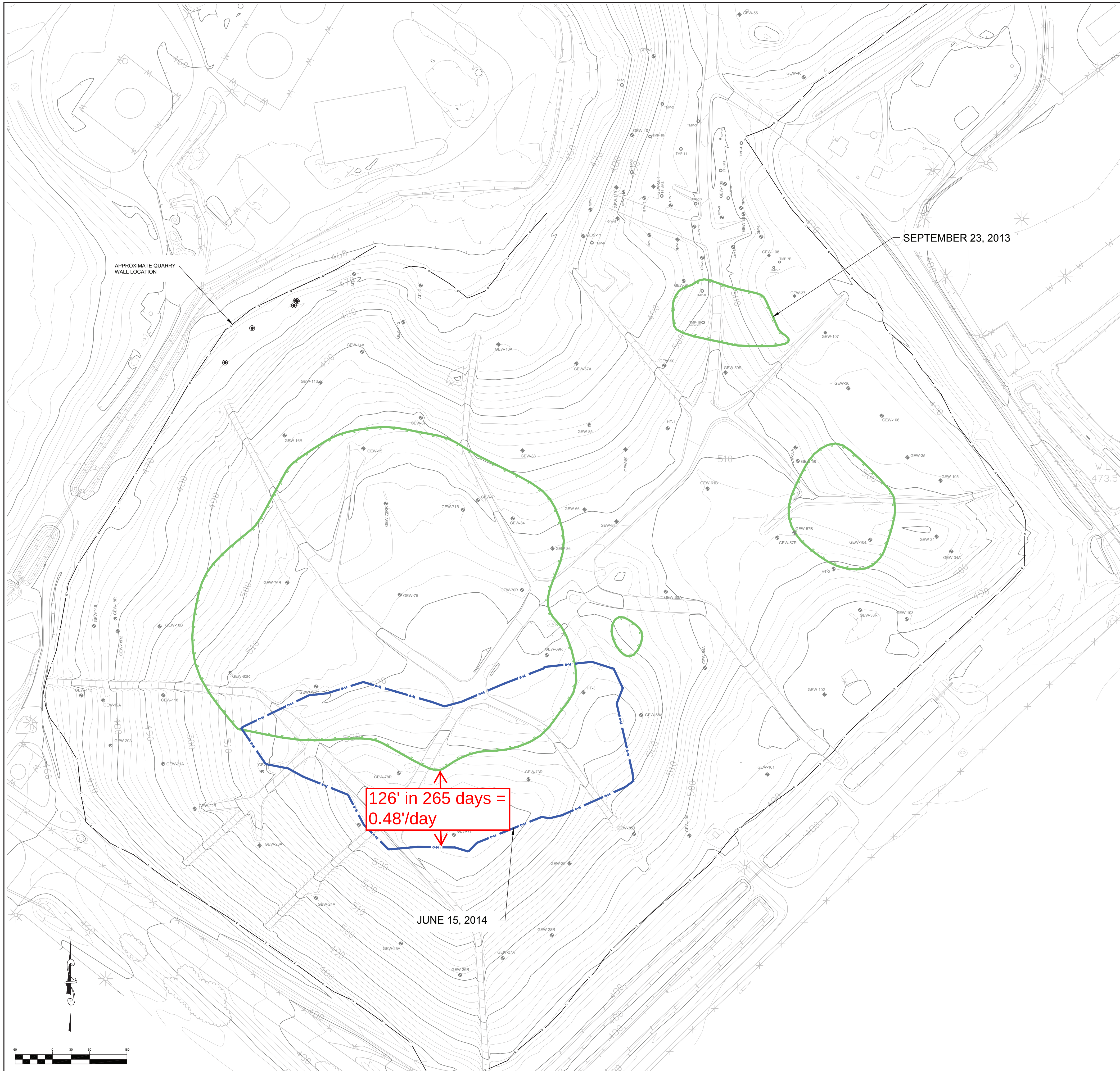
GEW-81	EXISTING LFG EXTRACTION WELL (GEW)
GEW-2	EXISTING LFG EXTRACTION WELL (WITH PUMP)
TMP-6	EXISTING TEMPERATURE MONITORING PROBE (TMP)
GIW-10	GAS INTERCEPTOR WELL (GIW)
TMP-16	CONTINGENT TEMPERATURE MONITORING PROBE (TMP)
GIW-14	EXISTING SOLID WASTE BOUNDARY
SW	EXISTING SOLID WASTE BOUNDARY
	EXISTING QUARRY HIGHWALL
	VECTOR DATA LINE

REFERENCE

1. TOPOGRAPHIC INFORMATION BASED UPON BRIDGETON LANDFILL– DTM.DWG PROVIDED BY COOPER AERIAL SURVEYS CO., DATED FEB. 2013. SURVEY FIELD SUPPLEMENTED BY WEAVER BOOS CONSULTANTS.
2. AERIAL IMAGERY PROVIDED BY EAST WEST GATEWAY COORDINATING COUNCIL OF MISSOURI AND ILLINOIS, COLLECTED IN LATE FEBRUARY AND EARLY MARCH OF 2012.

SETTLEMENT MOVEMENT MAP

DRAWN BY: MSP	CHECKED BY: MRB	APPROVED BY: DRAFT	FIGURE NO.: --
DATE: JUL. 2013	DWG SCALE: 1"=20'	PROJECT NO: 131-178.0001	



LEGEND

- TOPOGRAPHY (2' CONTOUR)
- 500 TOPOGRAPHY (10' CONTOUR)
- SEPTEMBER 23, 2013 SETTLEMENT FRONT
- JUNE 15, 2014 SETTLEMENT FRONT

GENERAL NOTES:

1.) TOPOGRAPHY SHOWN BASED ON PHOTOGRAPHY DATED 3-20-2014.

SETTLEMENT NOTES:

1.) DRAWING DEPICTS THE LOCATION OF SETTLEMENT ACTIVITY THAT IS 1.35 FT PER 30 DAYS - INDICATIVE OF THE SETTLEMENT FRONT BASED ON THE ANALYSIS OF SURVEY DATA IN 2012.

2.) THE SEPTEMBER 23, 2013 SETTLEMENT FRONT WAS DEVELOPED BY COMPARING THE SURVEY FROM AUGUST 17, 2013 TO THE SURVEY FROM SEPTEMBER 23, 2013 AND PLACING A BOUNDARY AROUND THE AREA THAT SHOWED SETTLEMENT OF 1.35 FT OR GREATER PER 30 DAYS.

3.) THE JUNE 15, 2014 SETTLEMENT FRONT WAS DEVELOPED BY COMPARING THE SURVEY FROM MAY 15, 2014 TO THE SURVEY FROM JUNE 15, 2014 AND PLACING A BOUNDARY AROUND THE AREA THAT SHOWED SETTLEMENT OF 1.35 FT OR GREATER PER 30 DAYS.

BRIDGETON LANDFILL, LLC 13570 SAINT CHARLES ROCK ROAD BRIDGETON, MISSOURI 63044	BRIDGETON LANDFILL SETTLEMENT MONITORING	FEEZOR ENGINEERING, INC. Engineering for a Better World	DATE: JULY 2014 DESIGNED BY: DMK APPROVED BY: ALK
SETTLEMENT FRONTS **SEPTEMBER 2013 AND JUNE 2014**			REVISION / DATE
PROJECT NUMBER: BT-021	FILE PATH: S:\BRIDGETON LANDFILL\BT-021\SETTLEMENT FRONT VECTORS.DWG		DRAWING NO.: **001**

APPENDIX C

MARCH 29, 2013 LETTER TO CHARLENE FITCH, BARRIER EVALUATIONS

March 29, 2013

Ms. Charlene S. Fitch, Chief, Engineering Section
Missouri Department of Natural Resources
P.O. Box 176
Jefferson City, Missouri 65102-0176

SUBJECT: BRIDGETON LANDFILL, LLC
SW PERMIT NUMBER 0118912
BRIDGETON LANDFILL FACILITY
BRIDGETON, MISSOURI 63044

Dear Ms. Fitch:

This Letter Report has been prepared in support of Solid Waste Permit Number 0118912 issued to Bridgeton Landfill, LLC by the Missouri Department of Natural Resources (MDNR), and in follow up to the *February 27, 2013* meeting between Bridgeton Landfill, LLC representatives and MDNR, the *February 8, 2013* "Gas Interceptor Well Expanded Design Conditional Approval" letter, the *February 6, 2013* "2013 Gas Interceptor Well System-Expanded Design Bridgeton Landfill", the *January 11, 2013* "Gas Interceptor Well Design Approval" letter, the *January 4, 2013* "North Quarry Heat Barrier System" report, and the *September 14, 2012* "Temperature Monitoring Point Installation Plan". Specifically, the work is related to subsurface smoldering event (SSE) at Bridgeton Landfill in Bridgeton, Missouri.

We appreciate your consideration of the enclosed materials and look forward to continuing working with MDNR regarding the management plan and systematic monitoring, response and planning activities for the Bridgeton Landfill. Specifically, we are available at your convenience to review the updated data and discuss the technical merits of the potential contingencies with representatives from MDNR.

As you are aware from our ongoing work on this matter since the SSE began, this is a complex event that has required careful evaluation and management. Our continuing investigation and evaluation of the SSE have revealed a wealth of information about the event, and will provide a solid basis for assessing contingency options now and in the future. We look forward to continue working with MDNR to gather additional data and prepare plans that are appropriate and responsive to the situation, while ensuring ongoing protection of human health and the environment.

Executive Summary

This Letter Report is intended to provide an update of the subsurface smoldering event, together with an engineering feasibility evaluation of existing and potential future contingency containment systems. The report will address the following key elements:

1. Overview of the Current Management and Monitoring System

Bridgeton Landfill installed and proposed to expand its temperature monitoring system, per the approved *September 14, 2012* "TMP Installation Plan." Utilizing the temperature monitoring system, Bridgeton Landfill can monitor the effectiveness of the interceptor well system and continue to develop data regarding the extent and migration of the SSE.

Bridgeton Landfill has also installed the gas interceptor well system. This system is intended to facilitate more rapid heat removal, limiting the progression of heat past the interceptor well system. While we expect the interceptor well system to be an effective, permanent first line of defense, we have created and continue to refine contingency strategies to ensure that the radiologically impacted materials in the West Lake OU-1 are not impacted by the SSE.

We agree with MDNR that this evaluation of appropriate contingency planning is of critical importance, but the available data indicates that continued monitoring and study is appropriate before undertaking the invasive work of any barrier system, which carries risk. If this event follows the current pattern of development, as witnessed at other similar hydrogen gas producing sites, the reaction will not spread to shallower portions of the landfill. In these shallower zones, significant losses of energy occur and lead to rapid cooling. Additionally, energy can be lost to the underlying ground surface (i.e. rock surfaces or other native material).

Currently, the limited northward migration of the event is moving primarily east - towards the quarry wall, rather than the neck at the northwest. However, even if the current rate of migration is presumed to not only be directly in the direction of the radiologically impacted materials, but also continue migration in that direction at that rate consistently moving forward (neither of which is an assumption supported by current facts), it would take more than seven years to reach the buffer area outside of the radiologically impacted materials. Based on the data, it is clear that there is sufficient time to monitor the effectiveness of the interceptor well system, when activated, while improving upon our existing understanding of the SSE extent and impact.

2. Update on the Evaluation of the Extent of the Settlement and Heat Impact

Bridgton Landfill implemented an improved system for detecting settlement in a way that can accurately document the rate, extent and direction of settlement movement. The new additional data reveals that settlement is focused in a relatively localized location beneath the wells GEW-60R, GEW-61R, and GEW-62R. Visual settlement on the surface is primarily a product of the lateral spreading of settlement due to the depth at which volume is reducing. The energy spreads laterally from this localized reaction spot, resulting in settlement in areas beyond the location of the actual SSE. Any remedial measures must take this type of settlement into account, since settlement in one location is not necessarily indicative of an ongoing reaction at that location or of a spreading heat event

The modest rates of heat rise and lack of movement of heat fronts support the concept that hydrogen liberation is the only significant heat producing event ongoing at the Bridgeton Landfill. This is based on temperature evaluation and heat calculations. If other waste oxidation events were occurring and responsible for any significant amount of the volume reduction at the Bridgeton Landfill, they would add a large amount of energy to the Bridgeton Landfill and temperature rises would be much greater than those seen to date.

3. Evaluation of Additional Containment Contingencies

This Letter Report revisited several physical barrier evaluations reviewed in depth as part of the January 4, 2013 "North Quarry Heat Barrier System" heat dissipation approach. Evaluating potential displacement and resulting settlement issues makes it clear that many alternative barrier systems are not feasible. Thin barrier systems would all rely on some heat removing component to function. Additionally, and depending on the type physical barrier, construction timelines range from one to two years. Lengthy construction obviously makes rapid deployment difficult, and it also increases the challenges relative to managing odors, nuisance issues like vectors and truck traffic. Physical barrier construction in the "neck area of the landfill" is also complicated by the need to abide by certain airport covenants. Therefore, the heat removal identified by Bridgeton Landfill in the "North Quarry Heat Barrier System" report is preferable to other physical barrier systems located in the "neck area of the landfill" because it offers superior protection with reduced construction time that can be organized to possibly comply with the airport easement and covenants.

In response to MDNR's direction, this Letter Report also considered the viability of an injection system. There are no reported uses of inert gas in landfills other than at fires that are quite shallow (less than 50 feet) and isolated in nature. There is no evidence that such injections could occur at the depths of this SSE. Since there is currently no evidence of free oxygen at depth, the only possible purpose of gas injection is to remove heat. This is much more efficiently accomplished by the proposed heat barrier system presented in the January 4 "North Quarry Heat Barrier System" report.

Finally, Bridgeton Landfill has evaluated other possible contingencies to prevent the heat reaction from advancing into the West Lake OU-1 area. This Letter Report evaluates the excavation of waste to create an isolation barrier south of the southern limit of where no radioactive material above background was found. The shallower depth and ability to anchor the barrier prevents many of the feasibility concerns seen in deeper excavations. Such an approach would also limit the volume of waste excavation, consistent with concerns raised by the Airport Authority. Finally the relative speed of construction, just three months, allows such a system to be implemented quickly. This isolation barrier located south of the southern limit of where no radioactive material will provide the physical barrier that MDNR has requested, it just requires that we must locate it further north of the requested "neck area of the landfill" in order to make it technically competent should it need to arrest an advancement of heat, and make it constructable.

4. **Conclusion**

The onsite monitoring systems continues to reveal that any detectable rate of movement toward the north is relatively slight and is slowing over time. Bridgeton Landfill requests that data from the monitoring systems that MDNR and Bridgeton Landfill mutually established should continue to be watched closely in order to keep current data and expand understanding of the extent and impact of the SSE. This data can be monitored while the first line of defense gas interceptor well system is activated and used to effectively and efficiently remove energy from the SSE. The data and monitored performance of the gas interceptor well system can be utilized to more effectively evaluate and plan any contingency to ensure that there is no impact to the radiologically impacted materials at the West Lake OU-1 site without undue increases in odor and complications with the airport easement and covenants.

Summary Table of Containment Evaluation:

The following summary table was created in effort to help Bridgeton Landfill and MDNR track the various systems and broadly compare and contrast their relative strengths and weaknesses.

		Current Systems			**Contingency Barrier Approaches at Neck**			**Contingency Barrier Approaches at North Limits of the North Quarry Fill**
Criteria		Interceptor Wells – First Line of Defense	Temperature Monitoring Probes (TMPs)	Settlement Assessment	North Quarry Heat Barrier System	Alternative Barrier Plan	Alternative Injection System	North Excavation and Barrier
	Technically feasible	Yes	Yes	Yes	Yes	No	Yes	Yes
	Previously proven technology	Yes	Yes	Yes	No	No	No	Yes
	Secure approval from MDNR	Yes	Yes	Yes	Not currently approved	Suggested by MDNR	Suggested by MDNR	Pending
	Complies with Airport restrictions and covenants	Yes	Yes	Yes	Yes	No	Yes	Pending
	Reasonable timeline	Yes	Yes	Yes	Yes	No	Yes	Yes
	Length of construction implementation	Current	Current	Current	1 year	2 years	2 years	3 months

Through the implementation and expansion of our temperature monitoring system and improvements in our settlement data collection, Bridgeton Landfill has developed, when coupled with landfill gas collection wellhead temperatures, strong, reliable data which can be used to analyze and understand the subsurface smoldering event (SSE). Further, this data, which is collected weekly and monthly, respectively, provides us with a system to promptly detect any changes in the SSE (including both the direction and the rate of movement) and provide an early warning system as any changes might arise. Based on a review of the most recent data available, it appears that to the extent the SSE is moving, it is moving for the most part in a southwestern direction, away from the radiologically impacted materials.

While these data indicates that the progression of the reaction may not necessitate any physical barrier, we have nonetheless continued evaluation of potential contingency plans. In response to MDNR's request, this Letter Report provides an updated assessment of potential physical barrier systems installed at the neck. Unfortunately, similar to the conclusions reached in the January 4, 2013, North Quarry Heat Barrier System report, we have not identified any physical systems for the "neck area of the landfill" that will adequately meet the mutual needs of the MDNR and Bridgeton Landfill due to technical inadequacies and unsuitable construction schedules.

Finally, this Letter Report presents an additional contingency plan that would create a physical barrier between the Bridgeton Sanitary Landfill and the West Lake site where radiological wastes are located. We welcome the opportunity to meet with MDNR to discuss this additional contingency plan and the findings and evaluations using the most current data detailed in this Letter Report.

Update on Current Management and Monitoring System

MDNR has requested that Bridgeton Landfill design a system to prevent the spread of the SSE to the northern section of the quarry fill. Bridgeton Landfill provided MDNR an evaluation of possible measures of achieving this goal in the North Quarry Heat Barrier System report (dated January 4, 2013). In that report a heat removal system was identified as being most suitable for achieving the goal. Other means of arresting the spread of heat were assessed and rated as unfeasible, with the exception of a wide cementious barrier fill placed under slurry conditions and reinforced. This system was identified as technically feasible but not able to be constructed in short enough time periods and still susceptible to failure due to uncertainty as to how much settlement may occur.

Subsequent to the submittal of the North Quarry Heat Barrier System report, Bridgeton Landfill requested approval to install a series of interceptor wells along with additional TMPs. MDNR provided approval of the proposed installation but required that Bridgeton Landfill begin designing and installing a system at the quarry narrow point "neck" that would act as a temporary barrier to resist thermal transfer of heat from one side to the other. The February 8, 2013 letter required *"that the design must include a rationale for and calculations supporting the thickness of the barrier, depth of the barrier and thermal modeling for heat transfer. The goal is for the barrier to maintain its integrity for a 3-6 month window of time once the reaction reaches the barrier."*

In the same letter the Solid Waste Management Program (SWMP) requested *"that Bridgeton begin designing and selecting an injection system backup plan for the barrier system in case the gas interceptor well system and the barrier systems do not stop the advance of the SSE."*

Bridgeton Landfill does not believe that measures designed to only last a few months of performance are reasonable to install given the time and effort required to install any barrier system at all. It is the opinion of Bridgeton Landfill that a suitable system was presented, along with the rationale for design, in the aforementioned report dated January 4, 2013. In that report the heat barrier system based on heat removal was identified as the most feasible system. A rationale for design was presented.

MDNR cited the increased temperatures at the southernmost TMPs (8 and 9) as part of the basis for the demand for immediate action. It should be mentioned that Bridgeton Landfill specifically placed the southernmost row of TMPs, including TMPs 8 and 9, in areas they expected to have the heat front pass through, for the purpose of gaining information. These were not intended to act as a trigger mechanism for additional action. Based on the March 11th measurements at the Bridgeton Landfill and an evaluation by our Consultants of progression rates, the expected arrival date for the heat/settlement front is further away than earlier estimated (approximately 16 months) from reaching the TMP 1-4 line where the North Quarry Heat Barrier System report identified the trigger. This is based on a 13 ft/month advance rate (February 2013) versus the 18 ft/month (November 2012) in the report. This slowing of the advance rate will allow for more time for evaluation and to let the impact of the gas interceptor well system be assessed.

In an effort to minimize or stop movement of subsurface heat from the south quarry to the north quarry, additional special purpose, gas interceptor wells were installed, consistent with MDNR approved plans. The gas interceptor well system consists of two rows of wells. The first row of wells was installed approximately 50 feet north of the first line of temperature monitoring probes (TMPs 7R, 8, and 9). The second row of wells was installed 50 feet north of the first row of wells, and staggered in between the first row of wells. The gas interceptor well system is designed to allow for more rapid removal of heated gas allowing a release point for heat generated by and emanating from the SSE, which will effectively and efficiently remove energy.. The gas interceptor wells are spaced more closely together than traditional gas extraction wells to allow for more heat removal from any heat front. When activated, it is expected that the gas interceptor wells will initially draw the heat towards them. But the combined rows of wells will remove heat, reducing the energy and heat, limiting the migration of heat past the gas interceptor well system, as has been effectively used at other similar sites experiencing subsurface smoldering events. Additionally, because these wells are relatively fast to install, this system can continue to be added upon as needed in order to increase its effectiveness. These wells also conform to the existing airport easements and covenants, and are installed with methods that manage construction-generated odors better than can be managed in other forms of invasive construction.

Building upon the current TMP system, six additional TMPs are currently being installed in between the gas interceptor well system and the TMPs located at the narrow point "neck" of the landfill. This will allow for more extensive monitoring of any heat that might move past the gas interceptor well system in order to evaluate the effectiveness of the system on a more timely basis and provide us the ability to respond with additional and precisely targeted gas interceptor wells.

Additionally, continued monitoring of the expanded TMP system will improve any design rationale of a heat removal barrier, or selected barrier approach, should MDNR continue to believe that such a barrier is warranted. The added data will be useful in the determination of heat energy flowing toward the proposed heat removal and/or barrier location that needs to be removed. Our Consultants' estimated heat energy rate, as presented in the North Quarry Heat Barrier System report, was 12 watts per square meter. Using the information currently available this appears to be an overestimate, meaning that the heat front would actually place less demand on the heat removal system than previously calculated.

Update on the Extent of Reaction and Associated Characteristics

Bridgeton Landfill engineers have implemented an extensive monitoring systems (TMP and settlement assessment) to more accurately, when coupled with landfill gas collection wellhead temperatures, document and monitor the extent of the heat and settlement impact from the SSE. A robust system for settlement assessment was developed by creating a more detailed grid in order to consistently gather equivalent data during each monitoring event. Over the last several months the Bridgeton Landfill has expanded the TMP system to include the installation of probes directly into the center of the reaction, the installation of probes proximate to the reaction, and installation of probes both in advance of and beyond the installed gas interceptor well system. These expanded monitoring systems have provided significantly more data regarding the SSE, its extent, and its changes. As of February 2013, two complete monthly settlement monitoring events using the grid method have been completed and a third will occur at the end of March 2013. The results have been, and will continue to be, shared with MDNR.

Settlement (Volume Reduction / Zone of Accelerated Settlement)

Analysis of the waste settlement data by our Consultants indicates that the volume reduction associated with the SSE continues. Settlement continues to occur at an elevated rate in the areas that have already settled substantially. For example, in locations where the total settlement since March 2011 is approximately 30 feet, the rate of settlement was 1.0 ft/month or more. This indicates that the waste in this area is still actively settling. The North Quarry Heat Barrier System report) identified a vertical settlement rate of 1.35 ft/month as indicative of accelerated, as compared to typical, settlement. The location of the vertical settlement rate of 1.35 ft/month has continued to expand outwardly. This expansion is referred to as the zone of accelerated settlement and is shown on Drawing 1.

The northern movement of the zone of accelerated settlement has slowed from the average rate of 18 ft/month in November 2012, to 13 ft/month in February 2013 (assuming a 30 day month). However, the expansion of the zone of accelerated settlement in the southern direction, defined by the same current rate of 13 ft/month, has increased during this same time period. Also evident in the zone of the accelerated settlement is that the northern movement is more towards the east at present, instead of heading toward the narrow point (neck) of the quarry. The southern acceleration combined with this eastern movement on the north part results in an overall rounding of the zone of accelerated settlement, which is discussed in greater detail below.

Analysis of the Shape of the Zone of Accelerated Settlement

Analysis of settlement shapes, by our Consultants, based on the settlement that has occurred since March 2011 suggests that settlement shape to the east from the low area near GEW-60R is consistent with the subsidence shape associated with volume reduction of the waste occurring only under the zone of accelerated settlement, as revealed in Drawing 1.

The surface manifestation of reduction in waste volume occurring centered at depths of 140 feet, which is consistent with elevated temperatures measured in TMP-8, was used by our Consultant to analyze the extent of the zone of accelerated settlement. Our Consultant's comparative analysis suggests a volume reduction of approximately 38 feet has occurred near points of maximum observed settlement since March, 2011. (Note that we acknowledge that certain quantities of soil were placed across many portions of the landfill prior to March 2011. The shape manifested by the settlement that has occurred since March 2011 is still valid for purposes of this particular evaluation, however Bridgeton Landfill can investigate soil depths in interest of continued full cooperation if MDNR prefers to incorporate settlement that could be masked by the soil placed prior to March 2011.) Based on mine subsidence literature, (reported settlements associated with tunnel collapse and finite element simulations) volume reduction sufficient to cause 30 feet or more of surface settlement would have wide spread effects. This is the case near GEW-61R and GEW-62R, as illustrated in Drawing 2

Based on the analysis by our Consultants of the settlement shapes and predictions using either mine subsidence, tunnel collapse or finite element simulation methods, settlements occurring at depths of 135 feet bgs will result in settlement at locations greater than 150 feet laterally. The vertical settlement at a distance of 150 feet laterally from a significant settlement event occurring at 135 feet below the ground surface (bgs) is still 5% of the total vertical settlement of the event. The settlement directly over the event is approximately 85% of the volume reduction. This suggests an "angle of draw", to use a mine subsidence term, approximately equivalent to slightly more than 50 degrees measured from the vertical, or 40 degrees or less measured from the horizontal. Significant ground motions toward the settlement locations occur at a significant distance from the SSE, since the settlement from this reaction appears to be occurring at depths that average more than 135 ft bgs.

As a result of the analysis of the zone of accelerated settlement, it is clear that volume reduction of the waste at depth results in very significant lateral spreading of settlement. Therefore, settlement at any given location is not, by itself, indicative that a volume reducing activity is occurring directly underneath that location, thus accelerated rate of settlement alone cannot be used as indicative of the extent of the SSE. This needs to be included in the conclusions drawn about the ongoing reactions at the Bridgeton Landfill and the design of any remedial measures.

TMP Observations

Since the fall of 2012, the Bridgeton Landfill has installed and monitored nine temperature monitoring points (TMP). These TMPs collect data spanning the full vertical depth of the waste at 85 points using thermocouples. Seventy five of the original thermocouples are functioning to date. In addition, six more TMPs are being installed south of the quarry narrow point to allow further definition of temperature gradients in both the vertical and horizontal directions.

As of March 19, 2013, the temperature front has moved north of TMP 8 and 9. This front is characterized by the increase in temperature from < 185 °F to temperatures > 210 °F. Examination of the TMPs that have experienced temperature rise shows the temperatures are typically elevated within a certain depth range, and that above and below this depth range the temperature is reducing. Using the average value with the range that is elevated, and not dissipating in the upward or downward direction, provides some detail as to how the heat front is progressing. These average temperatures, depicted in the attached Average Temperature plots generated by our Consultant, show increases in temperature typically into January 2013, followed by a period of nearly constant temperatures or slight rises in temperature. The more rapid rises in temperature associated with the heat front are apparent in TMP 8 and TMP 9, presented in the attached Average Temperature plots. TMPs 1, 3 and 4 showed no upward trends as is apparent in the weekly temperature readings. It should be noted that in the above presentation, the non-functioning thermocouplings were not used in the average calculation. Given the depth of the zones used for the temperature average, the behavior is not affected significantly by ambient temperature trends. Based on the average temperature values the heat front is progressing at a slowing rate to the north.

Additional information on gradients of temperature surrounding TMPs will be provided to MDNR in subsequent reports on TMP results as evidence of SSE.

Overall Heat Balance and Correlation to Collected Hydrogen

An overall approximate heat balance calculation was performed by our Consultants. This analysis utilized the premise that the hydrogen being generated at the Bridgeton Landfill is indicative of a metal oxidation process, whether from metal hydroxides, or metal oxides, and whereby the hydrogen is liberated from water molecules as a product of the reaction with metals. At present, Bridgeton Landfill has not identified other sources of hydrogen generation at the temperature ranges measured within the landfill.

The elevated temperature of the landfill results in heat losses to the landfill surface, heat removal in the form of landfill gas, heat removal in the form of water vapor in the landfill gas (originating as liquid and being vaporized), heat being used to warm the waste as the heat front advances, general warming of the waste and liquid, and heat losses to the ground at the perimeter and bottom of the landfill.

Using the temperature gradients measured at the TMPs, total hydrogen collected at the flare station, flow rates and temperatures of the gasses, estimates of water vapor generated contained in the gas, and the zone of accelerated settlement rate in February 2013; an approximate heat accounting was performed by our Consultants. A total heat energy rate of 2.16×10^6W was determined, based on the calculations ignoring the average rise in temperature of the landfill that has occurred in general. This calculated value should be considered a lower range estimate, given that some of the warm wells in the south quarry area do not have measured flow rates which results in the underestimation the energy used in vaporizing water. This is contrasted with a heat energy value of approximately 4.58×10^6W indicated by the 11% of the average flow rate of 3800 scfm of gas processed at the flare. The excess rate of energy production would account for raising the average temperature of the waste. A rough calculation shows the excess energy would raise the temperature of a waste mass 200 ft thick over twenty acres approximately 20 °F per year.

Based on our Consultants' calculations, and acknowledging the total hydrogen is likely higher than being collected, it does not appear that rates of heat rise or movement of heat fronts support the concept that significant heat producing events (i.e. a combustion event) are ongoing at the Bridgeton Landfill, other than those associated with the hydrogen liberation. If such waste oxidation events were occurring and responsible for any significant amount of the volume reduction at the Bridgeton Landfill, they would add a large amount of energy to the Bridgeton Landfill and temperature rises would be much greater than those seen to date. This is consistent with Bridgeton Landfill's data that do not indicate free oxygen at depth, where the volume reduction is occurring, and the overall lack of any fire type behavior or residues encountered in the sampled TMPs. At the present time the pyrolyzation of the waste, occurring at low temperature was assumed to be energy neutral so no energy loss or gain is associated with the volume reduction in the calculations.

According to our Consultants, this suggests that current energy production (assuming just metal oxide reactions are occurring) accounts for all the excess temperature at the Bridgeton Landfill and that remedial measures should be focused on the behaviors associated with this type of heat producing event.

Conclusions Based on Data Gathered to Date

The current monitoring systems at the Bridgeton Landfill show the settlement and temperature fronts continue to expand from a centralized deep settlement point. However, this is not revealing since the spreading of both settlement and elevated temperature would be expected to continue even if the actual heat generation was declining, given the significant storage of heat energy in the landfill.

As addressed in the discussion of Settlement, the rate of the expansion of the zone of accelerated settlement to the north is slowing, even without the installed first line of defense of gas interceptor wells being activated and in a state of full operation whereby they will remove heat energy from the SSE.

Settlement at any location is influenced by settlements occurring at depth in other locations. As this Letter Report has demonstrated, the temperature levels and rates of advance are consistent with a non-combustion based metal oxidation reaction that liberates hydrogen. The rates of hydrogen collection would account for all elevated temperature behaviors seen at the landfill

Notably, no evidence of smolder has been observed in the samples from the TMP borings, including those installed in the warmest area of the Bridgeton Landfill.

Evaluation of Contingency Options

Evaluation of Physical Thermal Barriers

Notwithstanding the slowing of the zone of accelerated settlement northward or the mounting evidence that the reaction causing heat at the Bridgeton Landfill is not related to the combustion of waste, Bridgeton Landfill has evaluated physical barriers that could be installed at the entry to the north quarry to prevent advancement of the temperature front. The types of barriers evaluated were identified in Table 1 of the North Quarry Heat Barrier System report. They included some of those that MDNR or its advisors have proposed as well as others. In response to the request of MDNR, Bridgeton Landfill has further considered physical barriers beyond the level presented in the North Quarry Heat Barrier System report.

Structural Barriers

Conductivity

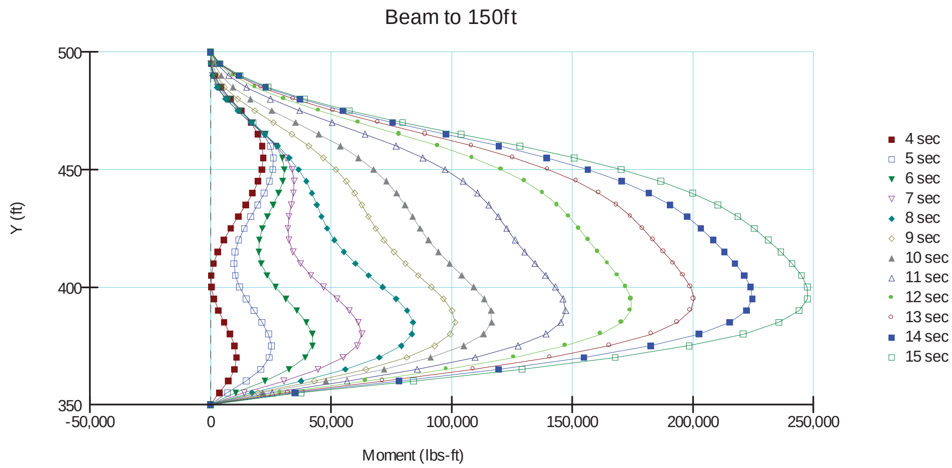
Specifically, non-open space barriers structurally supported barriers, which included tangent pile walls, sheet barriers and structural slurry walls were considered. The thinner barriers, e.g. tangent piles, sheet pile, thin structural slurry walls, were identified as being technically unfeasible due to the uncertainty as to the development of bending moments and shear forces associated with advance of settlement fronts. In addition these thinner type systems are thermally more conductive than waste material. Heat energy arriving at a concrete barrier will pass directly through it, thus, the system composed of concrete would require it be made of insulating concrete, which is too weak, or that heat exchanging devices be embedded in the concrete to remove the heat, which makes this type of barrier a very expensive version of the heat removal system already proposed but with additional problems because it is has structural issues as well.

Stiffness

Approximation of the lower limit of settlement induced stresses was performed using finite element methods (FEM). A settlement varying from 2 to 10 ft/month occurring at 135 feet bgs and at a distance 75 foot in south of the barrier was simulated. The waste was assumed to be a homogeneous elastic/plastic media. It was found that significant displacements were predicted and bending moments were, as expected, a function of the stiffness of the wall section used. Ideally the design moment for vertical barrier wall of minimal stiffness would still be in excess of 250,000 ft lbs (unfactored) even with the settlement front 75 feet away. As the settlement front approached the barrier this would worsen. In addition, moments were based on the assumption that a rectangular wall section was used. If a tangent pile system was used, and steel included in the piles, the overall stiffness of the cracked sections would increase and the moments would be higher. It should be noted that the deflections at the wall were on the order of feet and the depth of the wall stopped at 150 feet below grade.

Bending moments

A bending moment diagram is presented below from the simulation. The settlement at each time step to 10 sec is 0.5 ft, after 10 sec the step was increased to 1 ft sec. The total settlement at 75 foot away is 10 foot at 135 feet and 8.5 feet at the ground surface over the maximum settlement. The original ground surface is at elevation 500 in the simulation. Surface settlement at the barrier beam were only 1.5 ft for the 15 sec time step. (note the times are not material in the duration but just a calculation step)



The required reinforcing to remain intact for this type of installation is approximately 3 square inches per foot of wall length for the depth of the wall if the average distance of the reinforcing steel is 3 feet from the average wall face. This requires large diameter wall elements if concrete tangent piles were used and a double structural row. This type of system would also need follow up jetting and grouting to remove all waste between piles or initial special low strength caisson filler piles with large diameter 48 inch piles and a single row of structural caissons nearly touching to create a seal. In any case the number of piles would be approximately equivalent of 1 -36 inch diameter pile every 24 inches. Given the width of the quarry at the narrowest point this would result in approximately 140 piles to a depth of 150 feet. Holes would have to be drilled under slurry or cased in order to remain open and alignment would be challenging, likely requiring additional piles. The result of such work would not reduce the need to install thermal extraction units. These could presumably be included in the design. This system would take significant time to install and have little to no advantage over the heat removal barrier system. The system could also be done using a narrow structural slurry wall with the same issues relative to the time and uncertainty in performance as well as also requiring heat removal elements.

Insulating Barrier

Barrier systems that would be non-structural in nature, for example creating a continuous or nearly continuous disruption in the waste mass and filling it with an insulation material, such as a urethane based mineral grout, are technically possible. It should be mentioned that all insulating systems would use some gas entraining method within a cementious matrix and mineral fillers for strength. As such they are all subject to crushing and possess limited shear strengths. Increasing the strength is done at the expense of the insulation quality.

The placement of the material would require a large number of holes be drilled (approximately 200) to depths of greater than 150 foot and filled with a mixture of urethane foam and inert mineral to act as insulation. This would require a greater drilling period than for a structural barrier or a similar slurry excavation period. In addition, the grout is subject to crushing and displacement, making it doubtful that it would remain intact since settlements and subgrade movements would be non-uniform. It is possible that insulating materials could be installed between or behind structural elements, such as a structural slurry wall with an insulation zone on the warm or cool face. Combining structural and insulating materials complicates the barrier construction, significantly increasing the time. Insertion of insulating panels in the slurry filled trench is not possible given their light weight relative to the slurry. For the depths being considered the buoyancy force per 1 foot wide panel 2 feet thick and 150 foot deep is approximately 8 tons. This would require a steel case approximately 1.25 inches thick fully encasing the foam panel to sink it in the slurry. It also requires panels of this dimension to pre-assembled over the trench and inserted. This is not practically feasible and identifies that insulation construction in the ground would require a second excavation, doubling the time of construction. This would also be true of tangent pile systems.

Conclusions on Barriers

The evaluation of displacements and forces resulting from settlement events occurring at depth and distance from a barrier show the forces generated by structural requirements are significant even when the event is 75 feet away from the wall and with favorable assumptions concerning homogeneity. The barriers of this type can be made wide enough to resist forces but, as noted in the North Quarry Heat Barrier System report (see Sec. 5.4.4) they would take approximately 1 year to construct and would still require heat removal systems to be installed.

Structural systems do not represent thermal barriers as they are made of materials that are no less than 2 to 5 times more conductive than the solid waste. As such, all require heat removal elements that are equivalent to those needed for the system Bridgeton Landfill has already identified as feasible in the North Quarry Heat Barrier System report.

Insulation systems could be constructed but would take significantly more time since they would require a structural component to prevent crushing or the loss of integrity. The increase in construction time is approximately twice the time associated with a structural system.

Thin barrier systems in the end would all rely on some heat removing component to function. Therefore, they do not offer any improvement over the system of heat removal identified in the North Quarry Heat Barrier System report while at the same time increasing the time of construction.

Injection Systems

Bridgeton Landfill is not aware of any injection systems that would have any significant impact on the advance of a heat front. It is our understanding that MDNR is referring to systems that would inject cool inert gasses into the waste, although the request does not provide any reference to the types of systems MDNR would like to consider. Other possible injection materials may include water.

The injection of gasses into the landfill at depth is theoretically possible. However, the injection of gas at depths of interest, 80 to 150 ft or deeper, is problematic. At these depths the average pore spaces in the waste are small, as is evidenced by the specific yield of or drainable porosity dropping to only a few at 60 ft (200kPa) and zero at 120 ft (400 kPa). This is based upon the unit weight of waste. At these low pore space sizes and in the presence of a moist environment, the liquid within the waste is continuous and injection of gas is controlled by the permeability of waste for a liquid permeant. The permeability of solid waste at vertical stresses of 200 to 400 kPa are reported in the literature to be in the range of the low 1E-6 to 1E-7 cm/sec (Beaven et al ASCE GSP #209, 2008). Under these conditions the rate of injection would be similar to the rate of injection into a clay of water in piezometer, very low. The only method of injection that would yield a significant injection volume would involve hydro-fracture. As hydro-fracturing occurred the gas flow would increase, but only in narrow zones and along unknown pathways. The gas fracturing would propagate upward, as the minor principal stresses would decrease in this direction. Flow would exit at the surface or possibly be collected partially in nearby wells. If a significant number of wells in an area were to be injected simultaneously along a line or within a limited area, the fracture systems would likely combine and increase the gas flow within a limited fracture system.

The cooling impact of gas is limited to the heat capacity of gas injected. For example CO_2 has a heat capacity of approximately 860 joules per kilogram per degree K. Across the narrow of the quarry this would require injecting approximately 550 to 1000 cu ft per minute equivalent scfm of gas continuously just to hold the temperature constant at 130 degrees or 100,000 to 180,000 lbs per day of gas, depending on the heat flux rate assumed. This is not a feasible method for controlling temperatures.

There are no reported uses of inert gas in landfills other than at fires that are quite shallow (less than 50 feet) and isolated in nature. There is no evidence that such injections could occur at the depths at issue here. Further, if it were possible to inject that amount of dry gas through the waste it would dehydrate the existing waste creating a dry waste mass and conditions that are favorable to combustion, presenting an additional risk not currently present.

Since there is currently no evidence of free oxygen at depth, the only possible purpose of gas injection is to remove heat. This is much more efficiently accomplished by the proposed heat barrier system presented in the North Quarry Heat Barrier System report.

Other Possible Location Actions

Bridgeton Landfill has evaluated other possible actions that may be taken to prevent the heat SSE from advancing into the areas where the radioactive materials have been documented at above background levels. The studies that have been performed for the West Lake facility have identified a southern limit of where no radioactive material above background was found. Excavation of waste south of this limit to create an isolation barrier was evaluated on a conceptual basis. The results of the evaluation are described subsequently.

Conceptual Barrier Types at the North Limits of the North Quarry Fill

The barrier types at the North Limits of the North Quarry Fill for the isolation barrier all involve the removal of waste material and replacement with inert materials to the base of the waste. The removal methods considered included: open excavation without support; partial open excavation down to within 15 feet of the bottom of waste where a digging box could be used to finish the waste removal; and a slurry wall excavation with vertical sides to the bottom of waste.

The inert material would consist of earthen, cementious backfill. All barrier systems would include the installation of heat removing devices that would prevent elevated temperatures from passing through the barrier. All open excavations at the North Limits of the North Quarry Fill would be backfilled to near existing grade so that drainage patterns could be maintained.

With the exception of the slurry wall sections, a significant portion of the excavated waste is placed back in the excavation area, with the inert barrier on the north side. This significantly reduces the amount of material that will have to be taken off site which should improve the construction time for the operation, while having no impact on the performance of the barrier.

Excavation Location and Quantities

The approximate bottom of waste materials was estimated by our Consultants utilizing results of the WL series borings from the West Lake Area 1 evaluation, along with the quarry mapping dated 1979 provided by Aquaterra. The depth to waste varies in the area with location and ground surface elevation. The approximate bottom of waste and quarry bottom contours are depicted in Drawing C-0, along with the ground surface base and WL boring locations. This information demonstrates that the average depth to the bottom of waste materials is between 25 to 70 feet in the area of interest, as opposed to more than 200 feet at the quarry narrow point to the south. This decreased excavation depth allows for faster construction time, and minimizes the volume of excavated materials, which is relevant to concerns raised by the Airport Authority regarding the excavation of waste materials.

In general the thickness of waste material is lower the further north the excavation is. However, it is critical to ensure that the extent of the excavation can occur outside the boundary previously identified as having no radiological material. Along the east side the quarry bottom is encountered and the waste becomes deeper as the quarry deepens and the existing grades increase. This places practical limits on moving the barrier to the south to increase the buffer from waste that contains radioactive materials above background levels. Therefore, it is beneficial to insert the barrier as far north as possible without encountering radioactive materials.

Excavations on the shallow side (north) were assumed to be at 1H:1V, for open excavations down to the bottom of waste. This temporary slope of limited depth is considered safe for short periods. The longer excavations on the south, where possible leachate seepage may be encountered were assigned a 1.5H:1V slope.

When a digging box was assumed to be used, the slopes on both sides of the excavation were assumed to be 1.5H:1V to reflect the fact that the excavation and backfilling would require more personnel time outside the excavation vehicles and the free open areas at the bottom of the excavation would be of limited size. The digging box was assumed to have a minimum width of 4 feet.

Slurry wall excavations were assumed to be near vertical.

Three alignments for excavation were analyzed as part of the work. They are shown in plan and profile views on drawing C-0 through C-4.

The excavation volumes are summarized below.

Alignment	Excavation Section	Volume of Excavation
		(cubic yards)
NE-1	Open Excavation to Waste Bottom	140,600
NE-1	Excavation with 15 ft Digging box	97,300
NE-2	Excavation with 15 ft Digging box to Sta 6+00 then Slurry wall to end (Sta 11+39)	38900 of which 4000 is within slurry wall
NE-3	Excavation with 15 ft Digging Box	119,000
NE-3	Open Excavation to Waste Bottom	180,750

As can be seen on drawings C-2 through C-4 the NE-1 alignment resulted in some incursion beyond the southern limit of the defined non-radiological area. Alignment NE-2 is essentially the same as NE-1 but curves were introduced to allow slurry wall type construction. The limits of the slurry wall section were selected to maintain a significant buffer from the aforementioned southern limit (approximately 50 foot). No assessment of the other options was made along this alignment. However the volume associated with open cut to waste to Sta. 6+00 is 66,600 yd^3 so the total would be 70,000 if the open excavation and slurry wall combination were chosen along NE-2.

The NE-3 alignment provides a minimum buffer of 40 feet from the southern limit and the option with the 15 foot digging box reduces the minimum buffer to approximately 20 feet.

Engineering Features of the Possible Barriers at the North Limits of the North Quarry Fill

The open excavation with and without the digging box utilize earth or cementious backfill materials to create a non-combustible barrier. The thermal isolation is provided by the heat extraction system that is installed as the backfill material is placed and possibly drilled in once the barrier is finished. Because the proposed backfills are inclined against the north side of the excavation or cementious at the base, they do not have stability issues associated with settlement of the waste on the south side. Backfilling the entire system to grade removes surface water management and long term stability issues.

The slurry wall sections can be designed assuming complete elimination of material support on the south side. The placement of permanent anchorage into the upper section of the barrier wall and pinning some amount of reinforcing tendons into the underlying bedrock or alluvium allows a stable wall section to be made. The wall sections could be done in panels using standard slurry panel construction techniques but with weaker concrete and low levels of reinforcement. Thicker wall sections are imagined (approximately 10 feet) to create a better thermal mass and to counteract stresses. Calculations at this conceptual stage have shown that stability can be achieved for a 65 foot high wall with no waste on the south side.

Conclusions Concerning Barrier Feasibility at the North Limits of the North Quarry Fill

All of these options are technically feasible, within the confines of the airport easements and covenants and are quickly implemented for odor and vector control, but would require further definition and approval/agreement of parties involved at the Bridgeton Landfill or with whom the Bridgeton Landfill has pre-existing agreements.

It should be noted that at the present time the heat front is more than 1200 feet south of the closest point along the limit of excavation depicted in Drawing C-4. At current rates of progress, even if it were assumed that the heat even would migrate into the North Quarry, this distance would require more than 7 years for the heat front to traverse.

In order to monitor any movement of an SSE heat front across the north quarry, a continued system of TMPs could be deployed. The final set of TMPS that would trigger the start of construction of this barrier north of the north quarry should be selected at a distance approximately one year away from the limit of excavation on the south side. This would be a sufficient distance for completion of construction. The location of this is dependent on the rate of front advance and whether or not it appears to be increasing in rate of slowing, all of which can be observed through on-going monitoring of settlement and temperature monitoring. .

It should be pointed out that if the SSE follows the current pattern of development, and as witnessed at other hydrogen gas producing site, it will not spread to the shallower portions of the fill to the west. It is also possible the SSE would not be able to supply heat sufficiently after the fill elevations drop to below 480 feet to the northwest side, given the fill depth is only heat losses occur along the top and bottom surfaces with an average width of quarry of only 200 feet.

An agreed upon location where gas well temperatures would exceed 170 °F measured at the well head or TMP temperatures would exceed 185 °F could be determined based on the history of movement that would be observable in the monitoring systems along with overall heat balance considerations and collected hydrogen amounts. Because gas monitoring wells are already present within the North Quarry and because TMPs may be installed quickly, the monitoring systems can continue to be expanded as appropriate if the reaction reaches the North Quarry.

A work plan has been prepared that identifies the steps for designing permitting and procuring the contractors needed for the barrierwork at the North Limits of the North Quarry Fill. The plan is provided in Attachment A. Included in the plan are steps to identify permitting issues, fully define the bottom of waste along proposed alignment areas, verification of the absence of radioactive materials in the excavation areas, and documentation of liquid levels along the proposed alignment areas. The outline contains a listing of all tasks.

The time to perform the work as outlined is dependent on several triggers but should be able to be completed in approximately 3 months, following agreement to proceed, to finished documents for procurement purposes. The intended field work is likely to consist of use of piezocone soundings coupled with gamma detectors as opposed to borings in order to confirm that the locations for excavation are not impacted by radiological materials above background.

In addition to the field work associated with the design and construction of the barrier system at the North Limits of the North Quarry Fill, settlement monitoring data would be gathered at grid locations across the northern quarry zone to represent baseline elevation data. Baseline hydrogen content readings should be obtained from gas wells in the northern area also to identify any SSE activity in the area north of the entry to the north quarry section. In the event that isolated hydrogen generation is detected, it may be appropriate to install heat removal systems, like the gas interceptor well system, in the area to prevent the initiation of larger events.

Conclusion

In conclusion, Bridgeton Landfill, LLC continues to develop and refine contingency strategies to ensure that the radiologically impacted materials in the West Lake OU-1 are not impacted by the SSE. While we agree with MDNR that this evaluation is of critical importance, the available data indicates that more monitoring and study is appropriate before undertaking the invasive work of any barrier system.

It should be pointed out that if the SSE follows the current pattern of development, and as witnessed at other hydrogen gas producing site, it will not spread to the shallower portions of the fill to the west. It is also possible the SSE would not be able to supply heat sufficiently after the fill elevations drop to below 480 to the northwest side, given the fill depth is only heat losses occur along the top and bottom surfaces with an average width of quarry of only 200 feet.

Further, even if the current rate of migration is presumed toward the radiologically impacted material, , it would take seven years to reach the outer limit of the proposed barrier system at the North Limits of the North Quarry Fill, several hundred feet outside the radiologically impacted materials.

It is clear that there is sufficient time to gather results from the monitoring systems in place and improve upon our collective understanding of the SSE's extent and impact, while evaluating the effect of the interceptor well system.

If you have any questions or comments regarding this Letter Report, please contact me at 314-744-8195 or calmanza@republicservices.com.

Sincerely,

Craig
Almanza

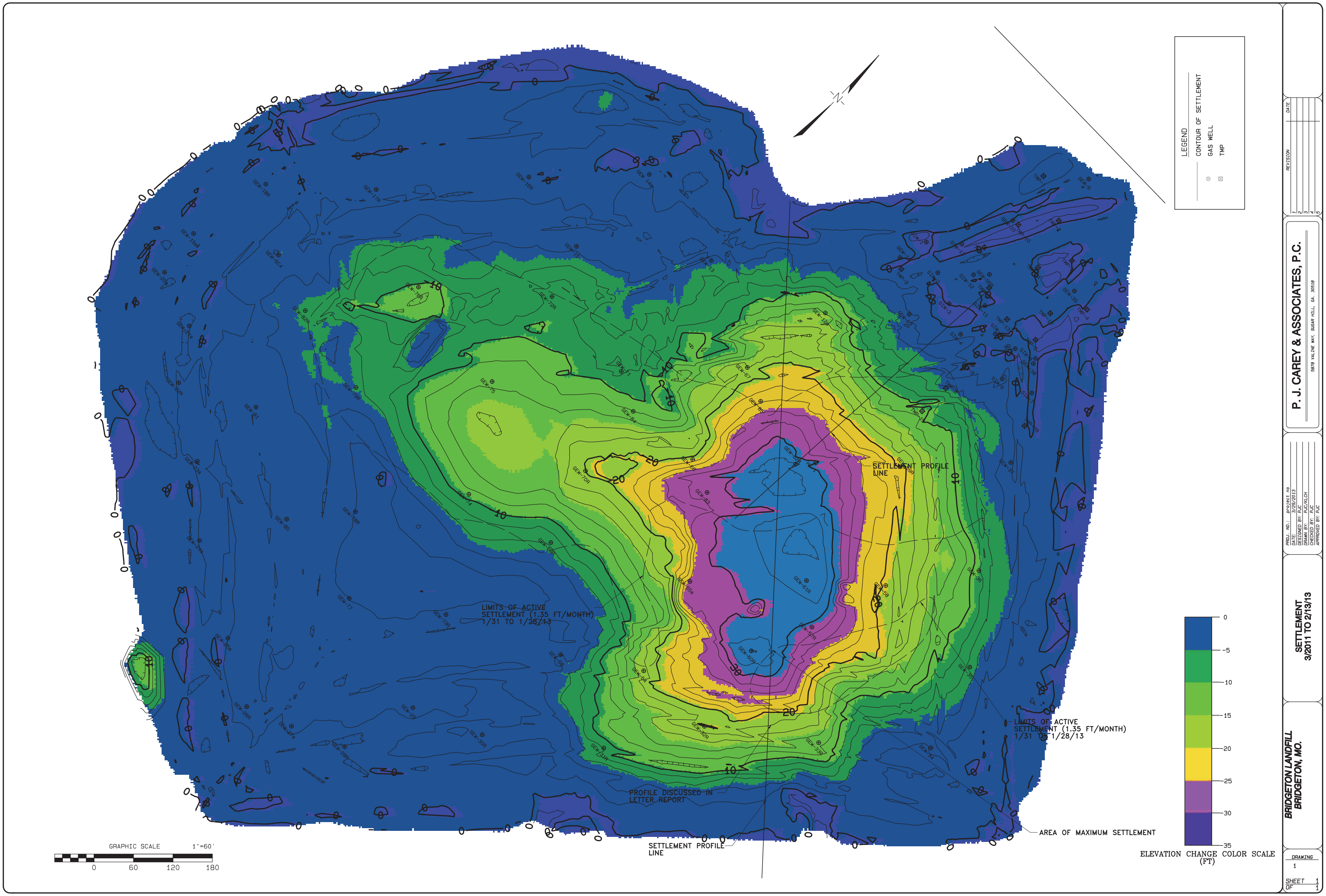
Digitally signed by Craig Almanza
DN: dc=com, dc=repsrv,
ou=Corporate, ou=Users,
cn=Craig Almanza
Date: 2013.03.29 16:54:59 -05'00'

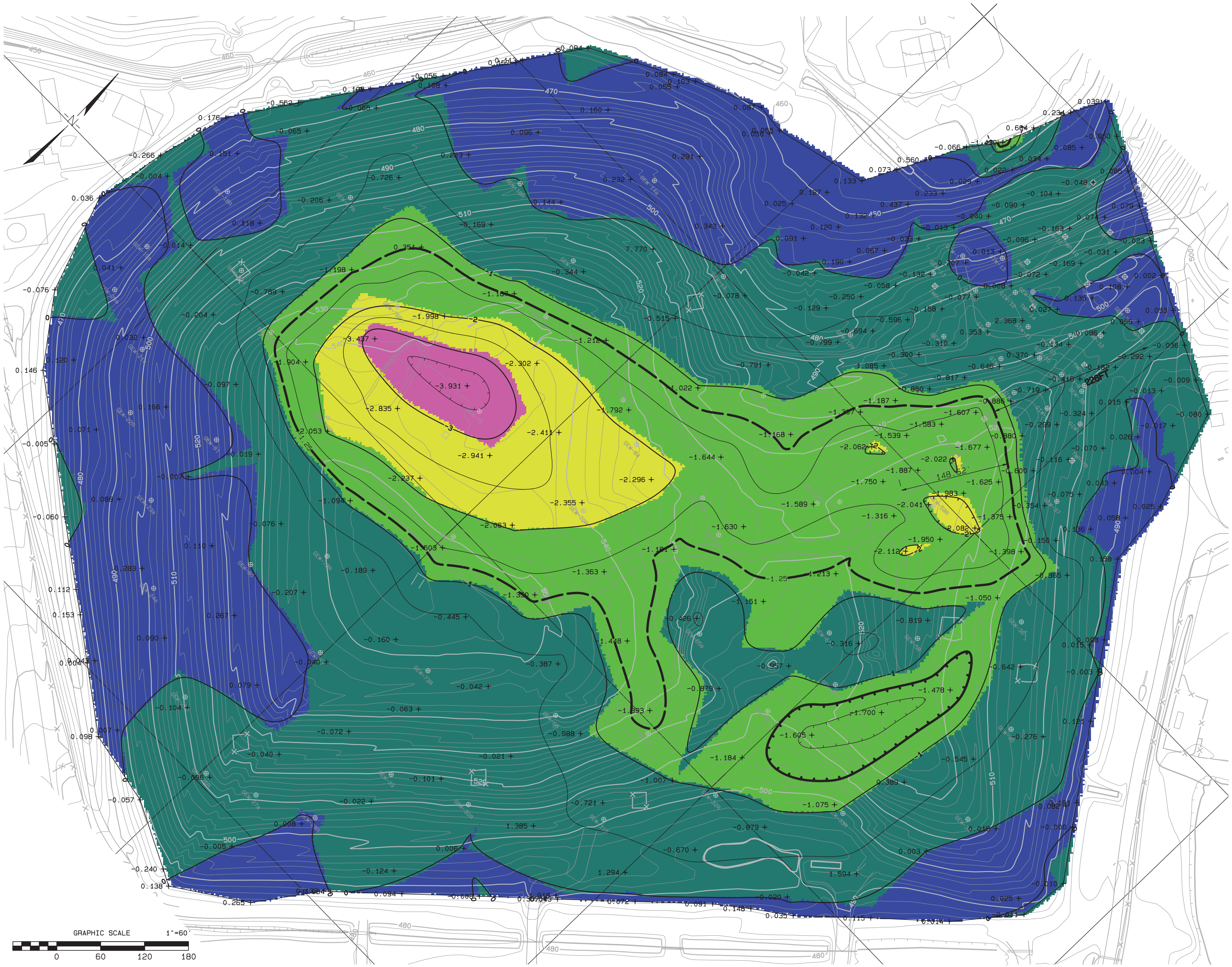
Craig Almanza
Area Environmental Manager
Bridgeton Landfill, LLC

Attachment A – Scope of Work
Enclosures:

- Drawing 1 – Zone of accelerated settlement
- Drawing 2 – Surface elevation change
- Hydrogen Data Map February 2013
- Average Temperature Plots (TMP 2, 5, 6, 7, 8, 9)
- Drawing C0-C5 – Plan and profile views

Attachment A


LEGEND
CONTOUR OF SETTLEMENT
GAS WELL
TMP
SETTLEMENT PROFILE LINE
LIMITS OF ACTIVE SETTLEMENT (1.35 FT/MONTH) 1/31 TO 1/28/13
PROFILE DISCUSSED IN LETTER REPORT
AREA OF MAXIMUM SETTLEMENT
GRAPHIC SCALE 1"=60'
0 60 120 180
0 -5 -10 -15 -20 -25 -30 -35
ELEVATION CHANGE COLOR SCALE (FT)
REVISION DATE
P. J. CAREY & ASSOCIATES, P.C.
5878 VALINE WAY, SUGAR HILL, GA. 30518
PROJ. NO.: project no
DATE: 3/29/2013
DESIGNED BY: PJC
DRAWN BY: PJC/KLCH
CHECKED BY: PJC
APPROVED BY: PJC
SETTLEMENT 3/2011 TO 2/13/13
BRIDGETON LANDFILL BRIDGETON, MO.
DRAWING 1
SHEET 1 OF 1



GRAPHIC SCALE 1"=60'

0 60 120 180

LEGEND

EXISTING TOPOGRAPHIC CONTOUR

GAS WELL

TMP

SETTLEMENT GRID SURVEY POINT

GENERAL NOTES

TOPOGRAPHY SHOWN BASED ON PHOTOGRAPHY DATED 2-23-2013

SETTLEMENT NOTES

CONTOURS ARE OF CHANGE IN ELEVATION FROM 1-31-2013 TO 2-28 & 3-1 2013 PERFORMED AT GRID POINTS USING GPS METHODS

POINTS HAVING POSITIVE ELEVATION CHANGES >0.3 FT WERE EXCLUDED FROM CONTOURING AS THEY REFLECT SOIL PLACEMENT

SETTLEMENT IS REPORTED AS A NEGATIVE CHANGE IN ELEVATION

COUNTOUR AT -1.25 FT IS SHOWN AS APPROXIMATE BOUNDARY OF SETTLEMENT FRONT AS OF 2/28/2013

ELEVATION CHANGE COLOR SCALE (FT)

REVISION	DATE
1	
2	
3	
4	
5	

BRIDGETON LANDFILL, LLC

P. J. CAREY & ASSOCIATES, P.C.

5878 VALINE WAY, SUGAR HILL, GA. 30518

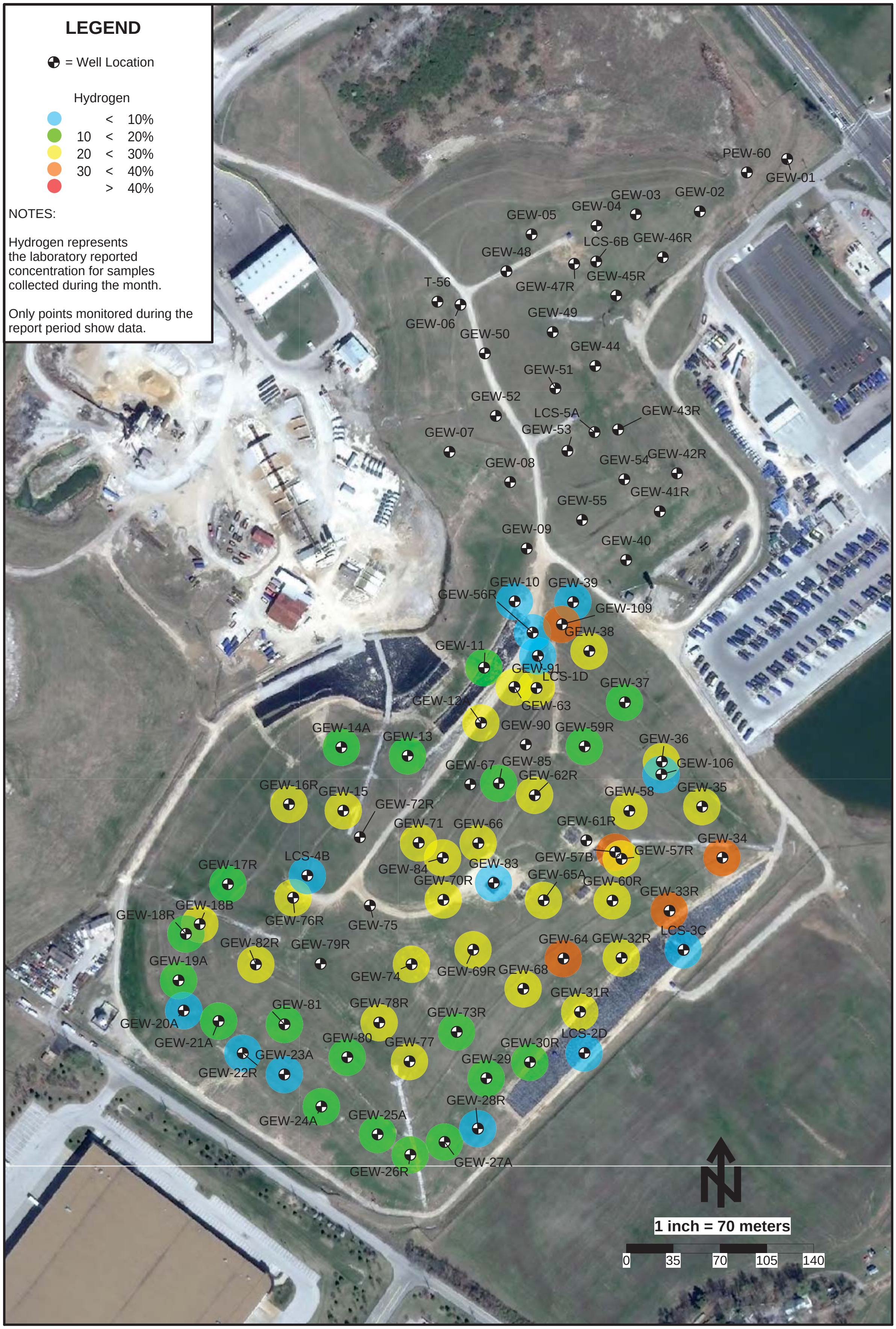
PROJ. NO.: 179.002
DATE: 3/29/2013
DESIGNED BY: PJC
DRAWN BY: PJC/KLCH
CHECKED BY: PJC
APPROVED BY: PJC

PLOT OF ELEVATION CHANGE BETWEEN 1/31/13 & 2/28/13

BRIDGETON LANDFILL
SETTLEMONITORING

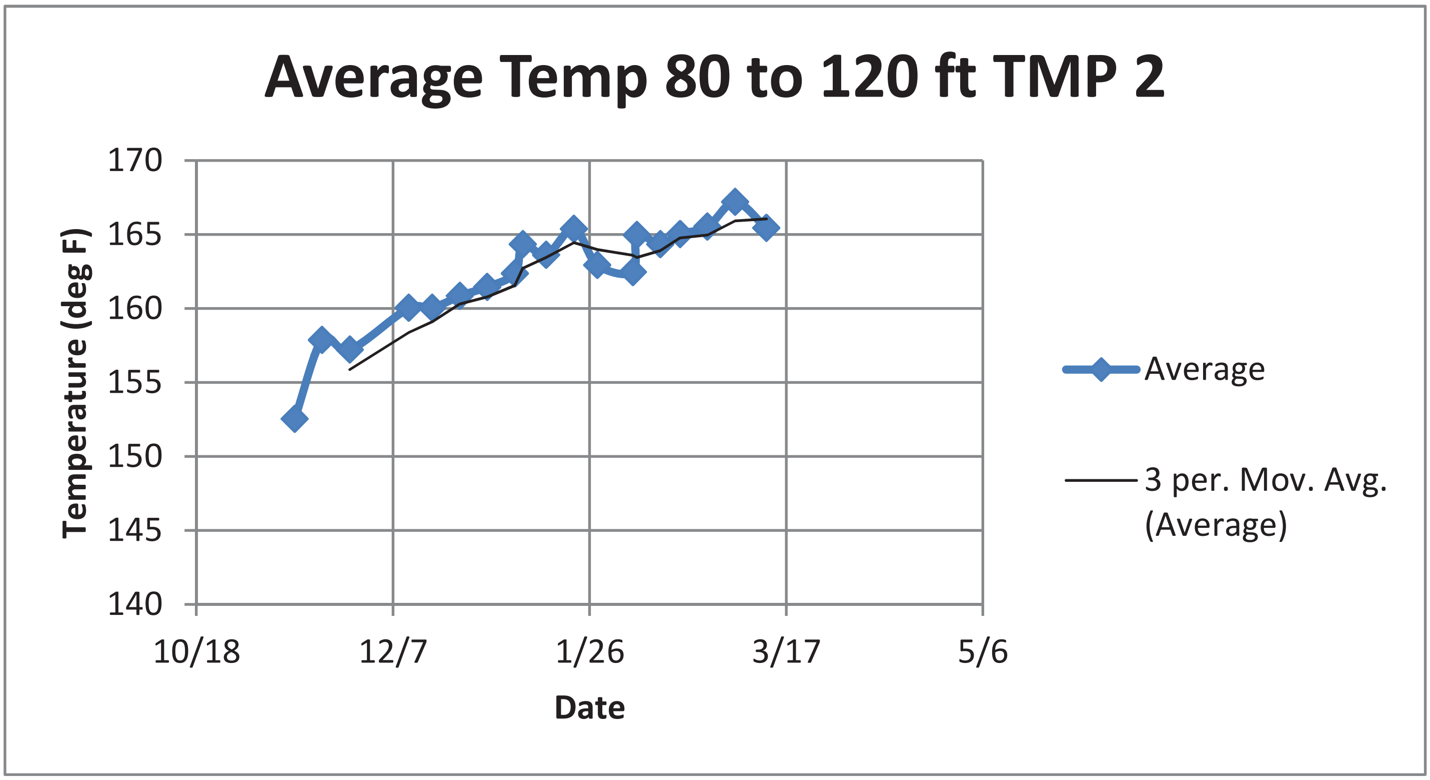
DRAWING 2

SHEET 2 OF 3

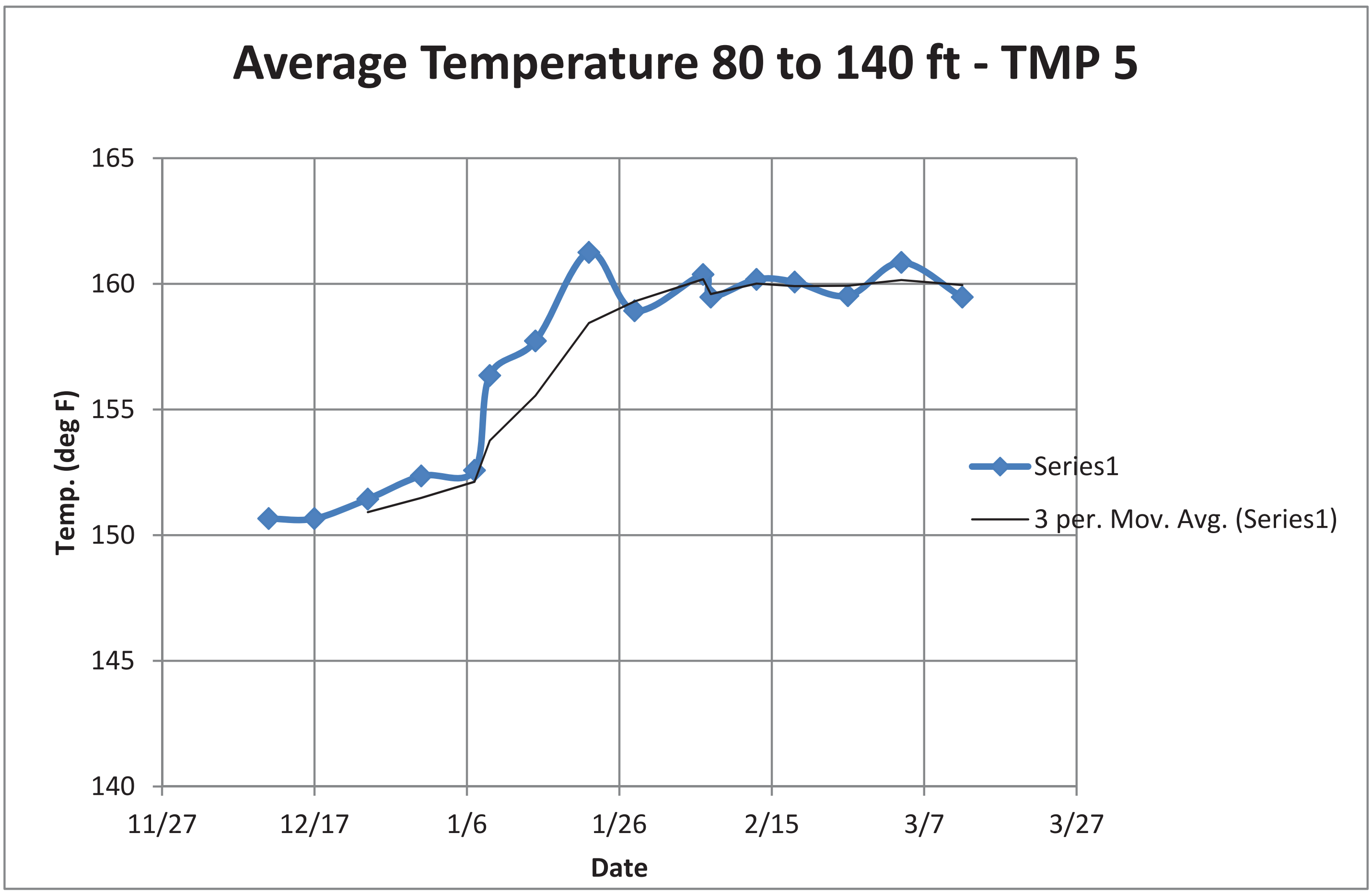


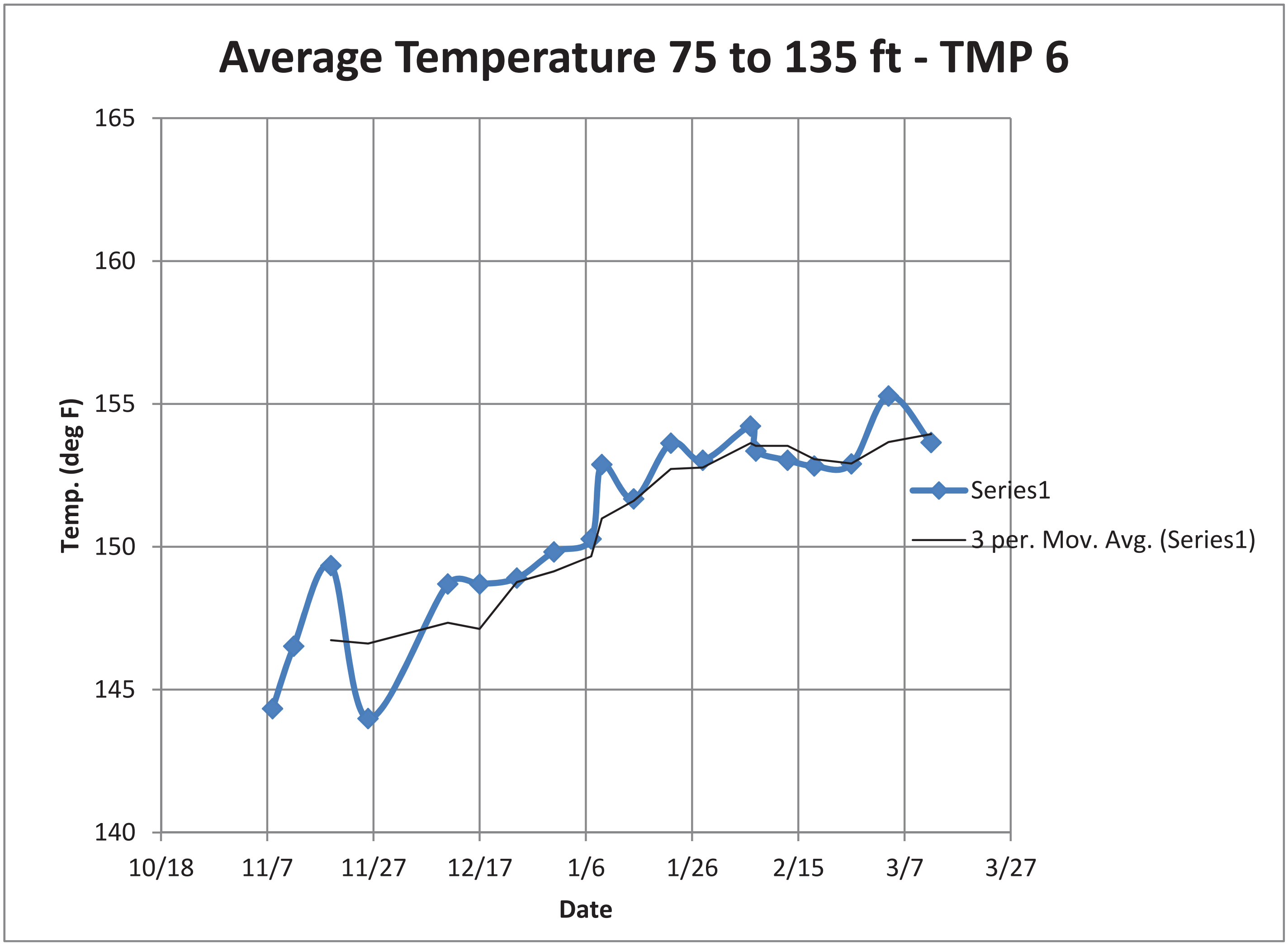
Hydrogen Data Map - February 2013 - Bridgeton Landfill

SCS ENGINEERS

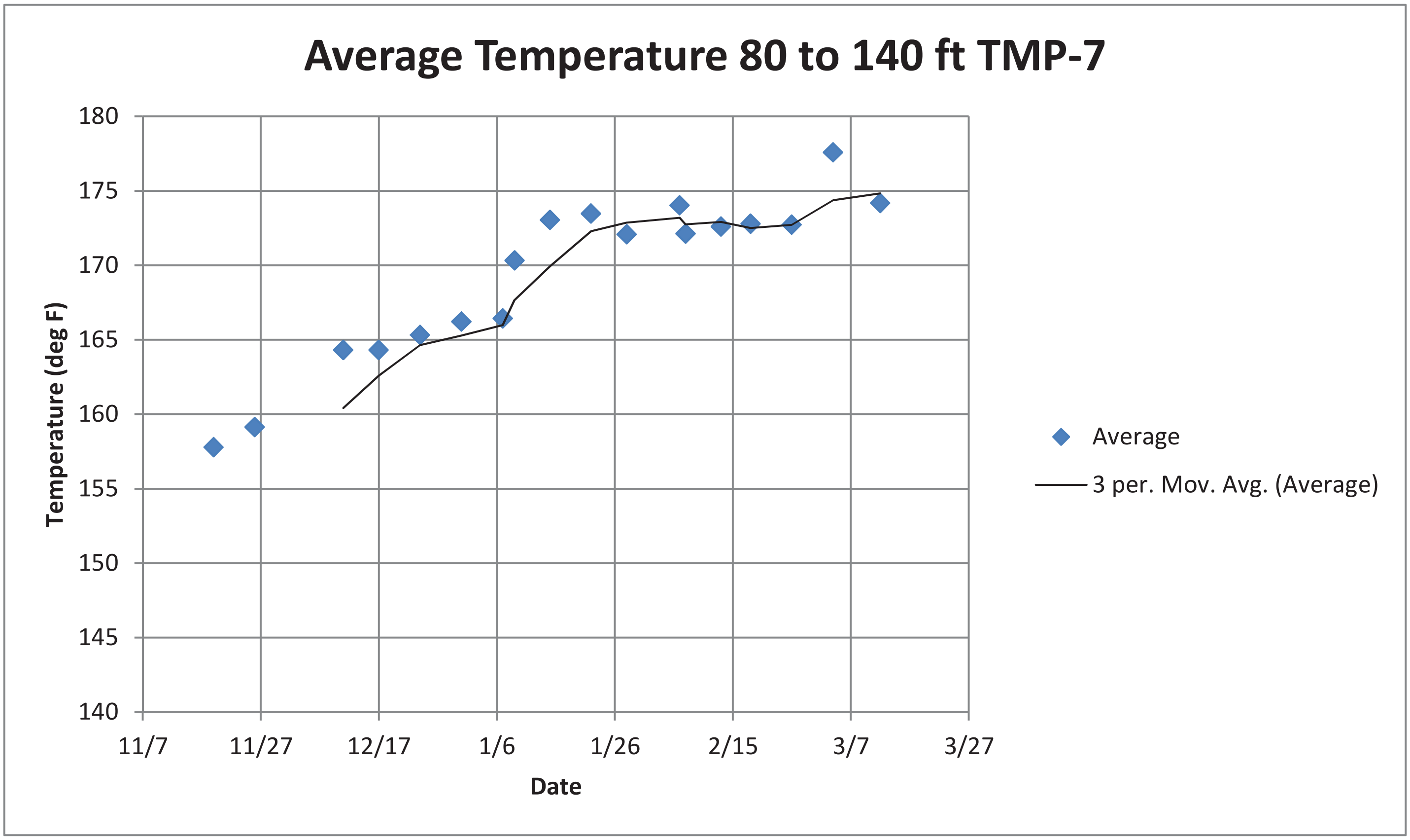


Average Temp 80 to 120 ft TMP 2
170
165
160
155
150
145
140
Temperature (deg F)
10/18
12/7
1/26
3/17
5/6
Date
Average
3 per. Mov. Avg. (Average)

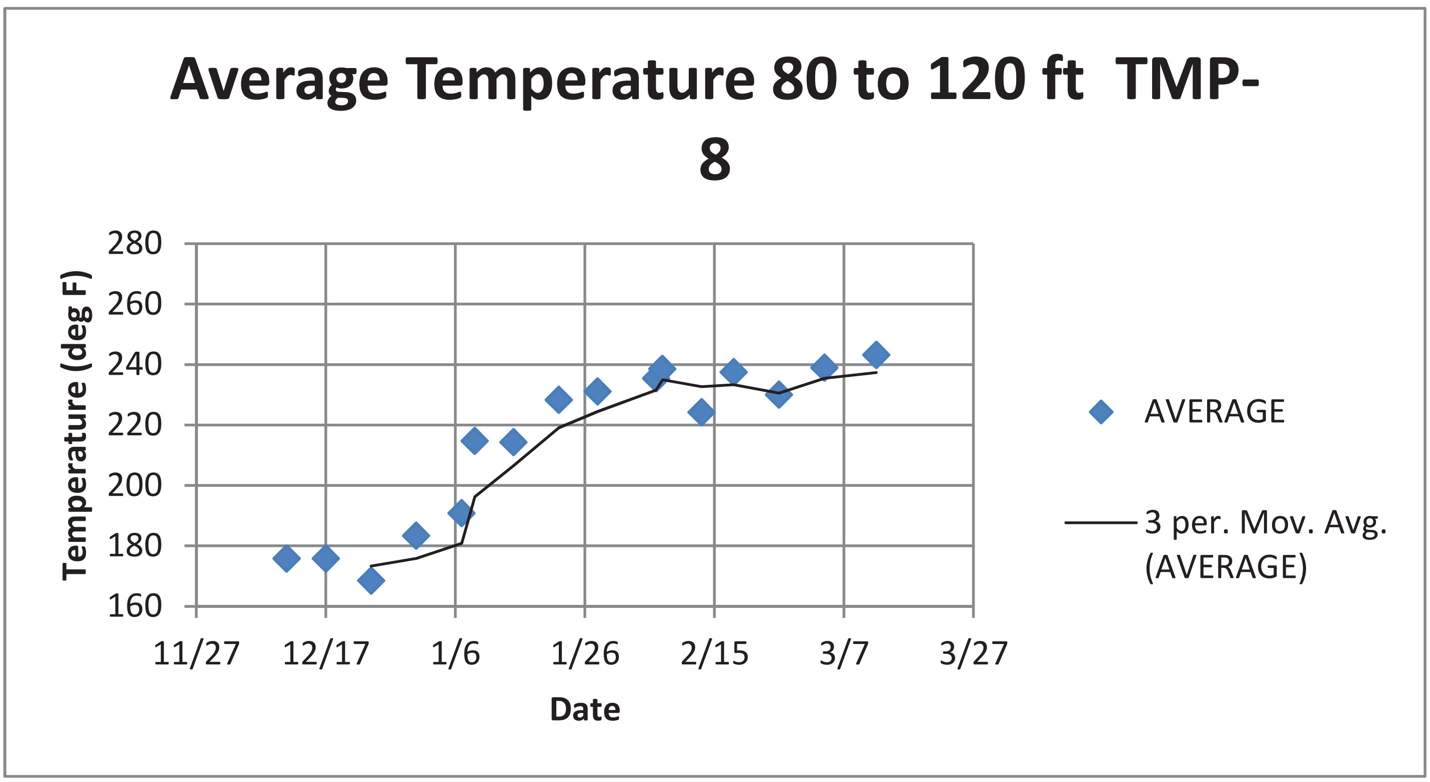

Average Temperature 80 to 140 ft - TMP 5
165
160
155
150
145
140
Temp. (deg F)
11/27
12/17
1/6
1/26
2/15
3/7
3/27
Date
Series1
3 per. Mov. Avg. (Series1)

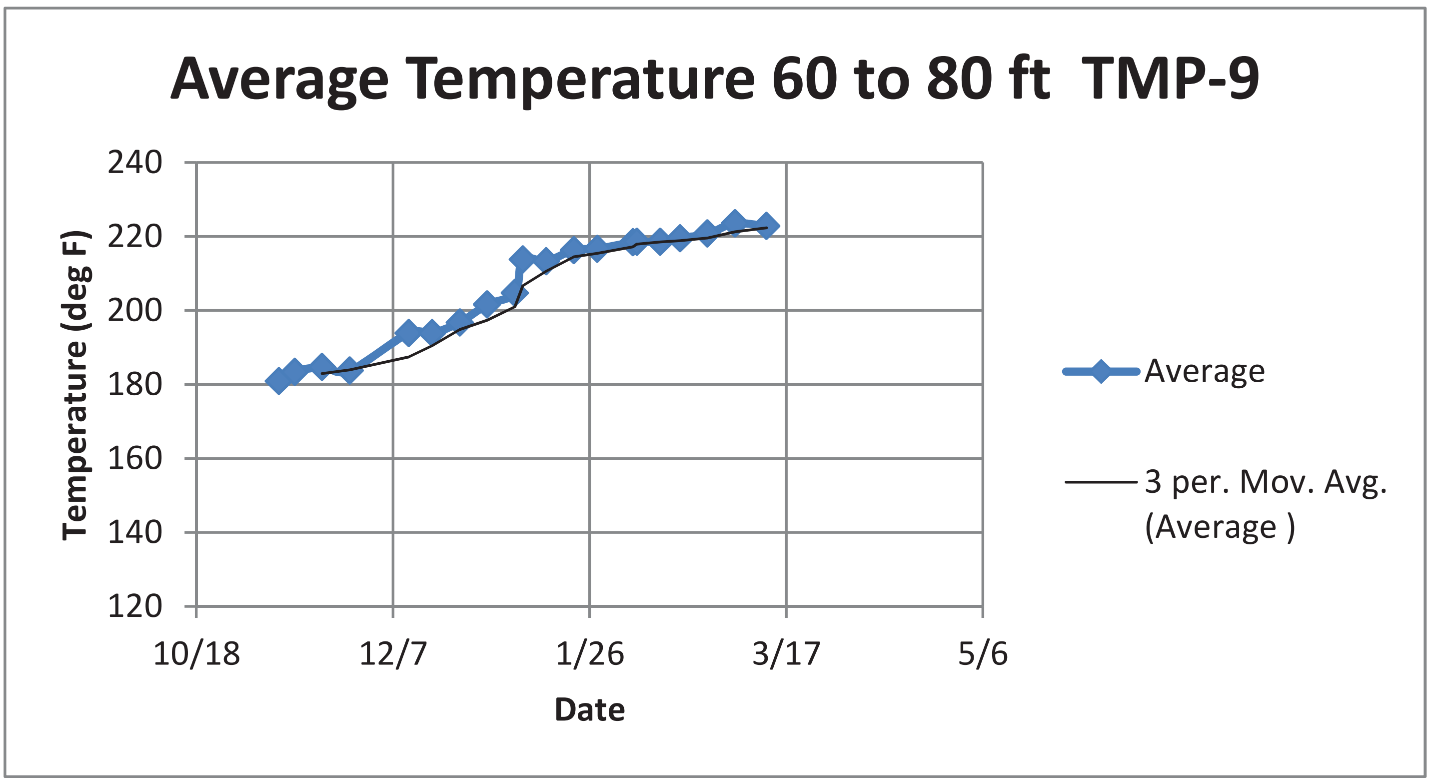


Average Temperature 75 to 135 ft - TMP 6
Temp. (deg F)
165
160
155
150
145
140
10/18
11/7
11/27
12/17
1/6
1/26
2/15
3/7
3/27
Date
Series1
3 per. Mov. Avg. (Series1)

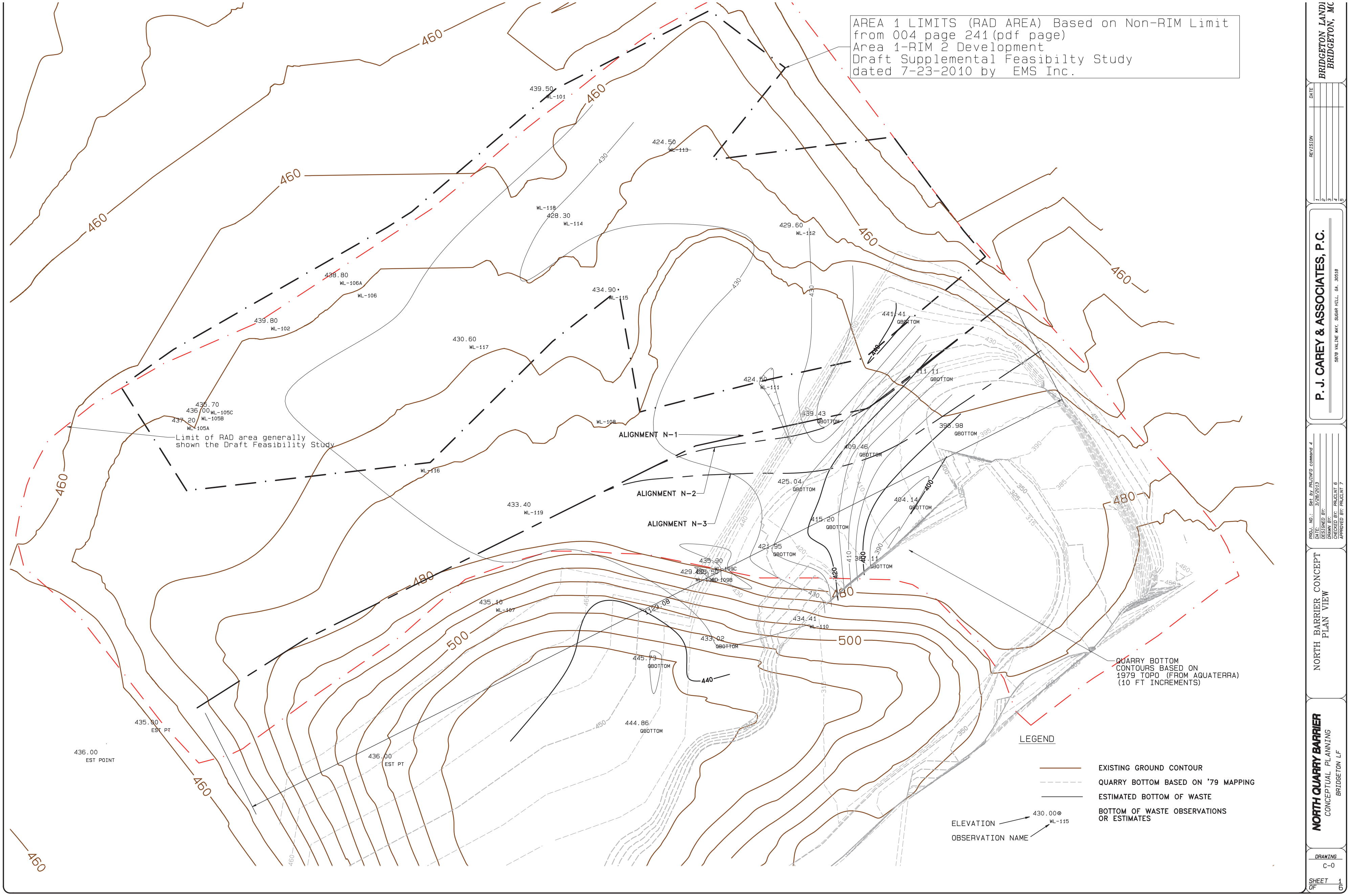


Average Temperature 80 to 140 ft TMP-7
Temperature (deg F)
180
175
170
165
160
155
150
145
140
11/7
11/27
12/17
1/6
1/26
2/15
3/7
3/27
Date
Average
3 per. Mov. Avg. (Average)

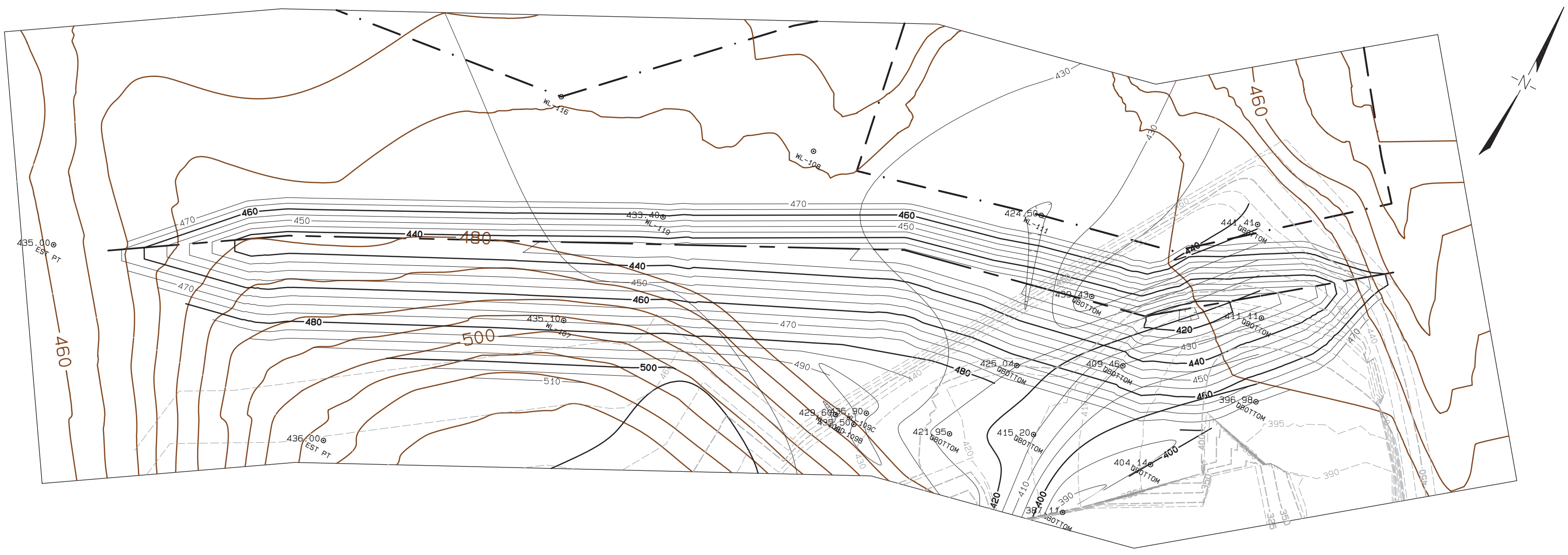

Average Temperature 80 to 120 ft TMP-8
Temperature (deg F)
280
260
240
220
200
180
160
11/27
12/17
1/6
1/26
2/15
3/7
3/27
Date
AVERAGE
3 per. Mov. Avg. (AVERAGE)



Average Temperature 60 to 80 ft TMP-9
240
220
200
180
160
140
120
Temperature (deg F)
10/18
12/7
1/26
3/17
5/6
Date
Average
3 per. Mov. Avg. (Average)



Plot Date/Time: Thu Mar 28,2013 / 15:47:00

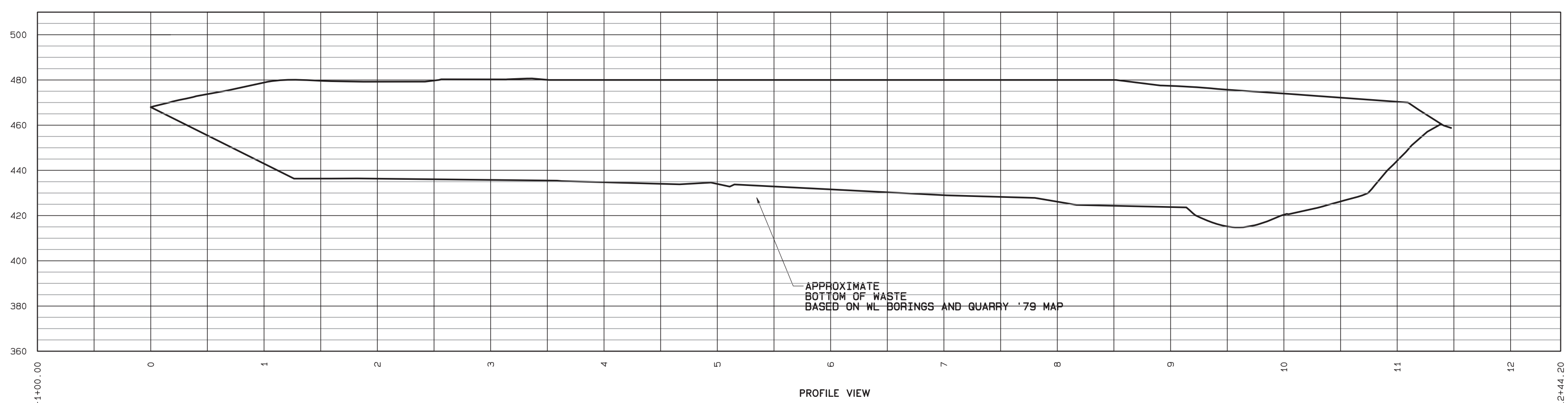


EXCAVATION QUANTITY FOR GRADING SHOWN IS 140,600 CU YDS

ALIGNMENT N-1

PLAN VIEW

Scale: 1" = 50'



PROFILE VIEW

Horz. Scale: 1" = 50'

BRIDGETON LANDI
BRIDGETON, MC

REVISION | DATE

P. J. CAREY & ASSOCIATES, P.C.
5878 VALINE WAY, SUGAR HILL, GA. 30518

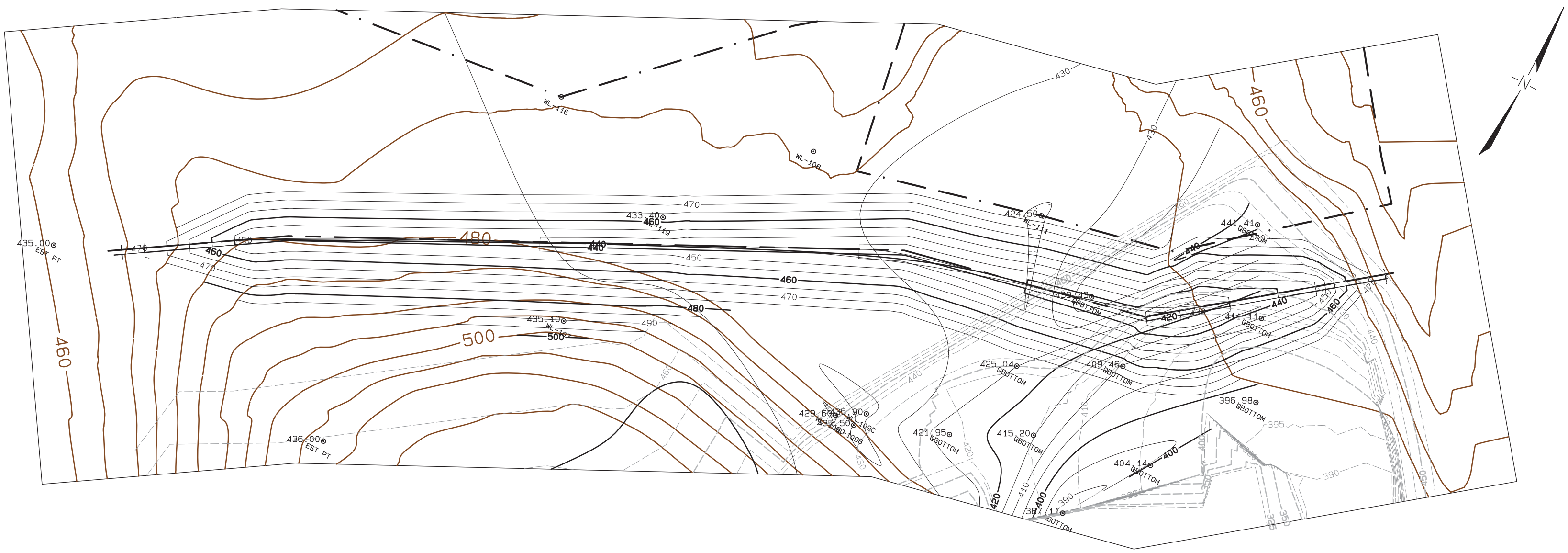
PROJ. NO.: Set by PRJINFO command 4
DATE: 3/28/2013
DESIGNED BY:
DRAWN BY:
CHECKED BY: PRJCLNT 6
APPROVED BY: PRJCLNT 7

EXCAVATION TO BOTTOM OF WASTE
1:1 ON NORTH, 1.5:1 ON SOUTH

NORTH QUARRY BARRIER
CONCEPTUAL PLANNING
BRIDGETON LF

DRAWING C-1
SHEET 2 OF 6

Project Desc.: Path: N:\RADW\Barrier\bridgeton nbarrier1.prd Plot Date/Time: Thu Mar 28,2013 / 15:47:25



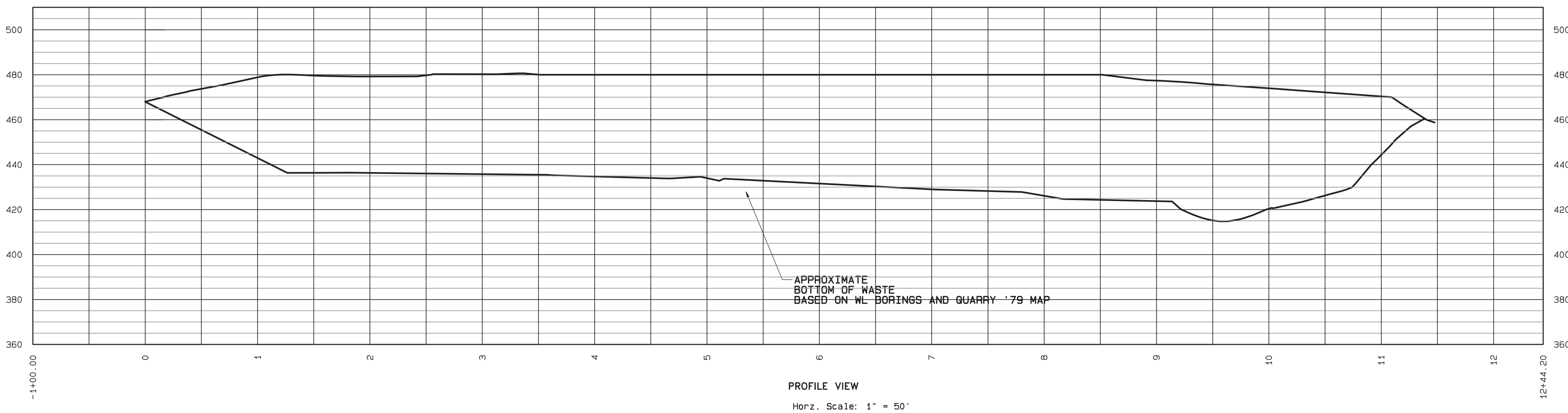
EXCAVATION QUANTITY FOR GRADING SHOWN
IS 97,300 CU YDS

ALIGNMENT N-1

PLAN VIEW

Scale: 1" = 50'

GRAPHIC SCALE 1"=50'
0 50 100 150



PROFILE VIEW

Horz. Scale: 1" = 50'

BRIDGETON LANDFILL
BRIDGETON, MO

REVISION	DATE
1	
2	
3	
4	
5	

P. J. CAREY & ASSOCIATES, P.C.
5878 VALINE WAY, SUGAR HILL, GA. 30518

PROJ. NO.: Set by PRJINFO command 4
DATE: 3/28/2013
DESIGNED BY:
DRAWN BY:
CHECKED BY: PRJCLNT 6
APPROVED BY: PRJCLNT 7

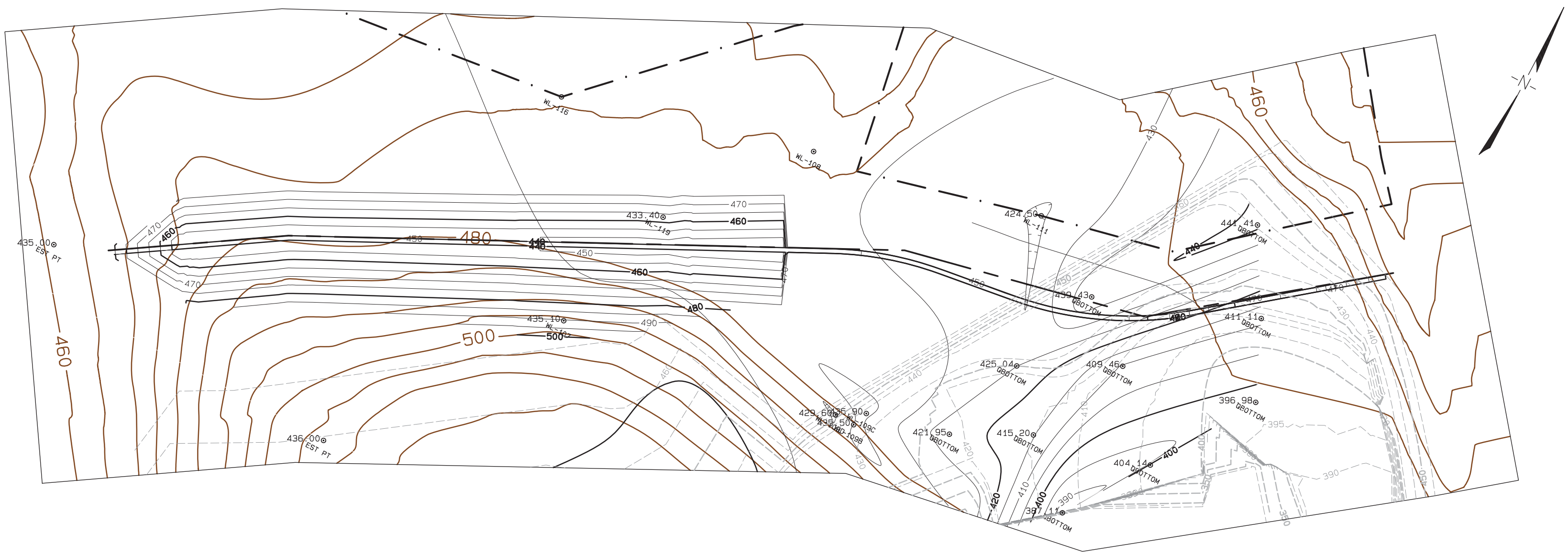
EXCAVATION ON N-1
USING 15 FT D. BOX
1.5:1 SLOPES

NORTH QUARRY BARRIER
CONCEPTUAL PLANNING
BRIDGETON LF

DRAWING
C-2

SHEET 3
OF 6

Project Desc.: Path: N:\RADW\Barrier\bridgeton nbarrier1.pro Plot Date/Time: Thu Mar 28,2013 / 15:47:32



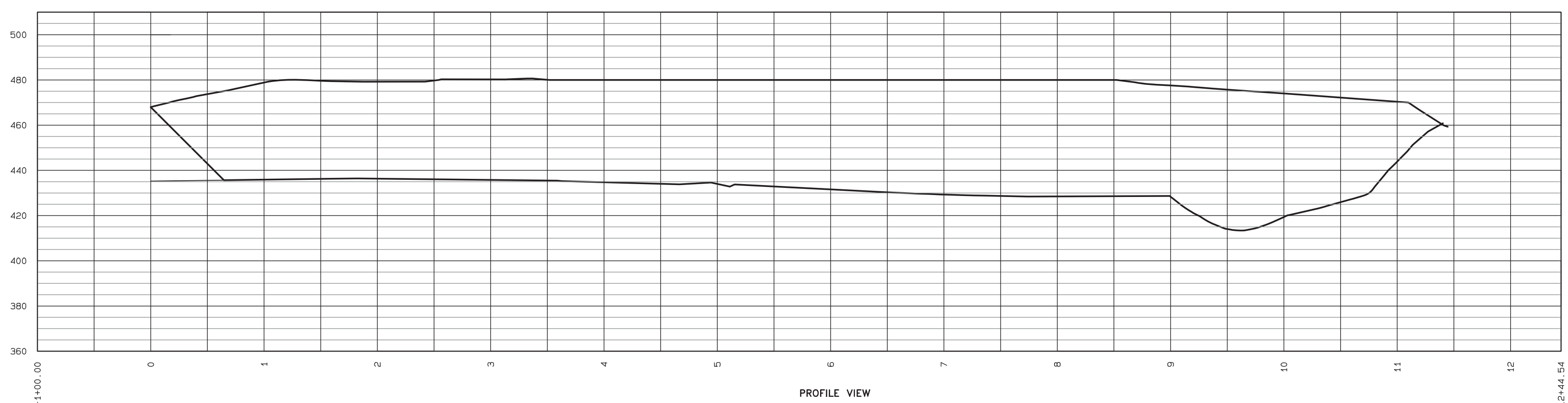
EXCAVATION QUANTITY FOR GRADING SHOWN
IS 38,900 CU YDS

ALIGNMENT N-2

PLAN VIEW

Scale: 1" = 50'

GRAPHIC SCALE 1"=50'
0 50 100 150



PROFILE VIEW

Horz. Scale: 1" = 50'

BRIDGETON LANDFILL
BRIDGETON, MO

REVISION DATE

P. J. CAREY & ASSOCIATES, P.C.
5878 VALINE WAY, SUGAR HILL, GA. 30518

PROJ. NO.: Set by PRJINFO command 4
DATE: 3/28/2013
DESIGNED BY:
DRAWN BY:
CHECKED BY: PRJCLNT 6
APPROVED BY: PRJCLNT 7

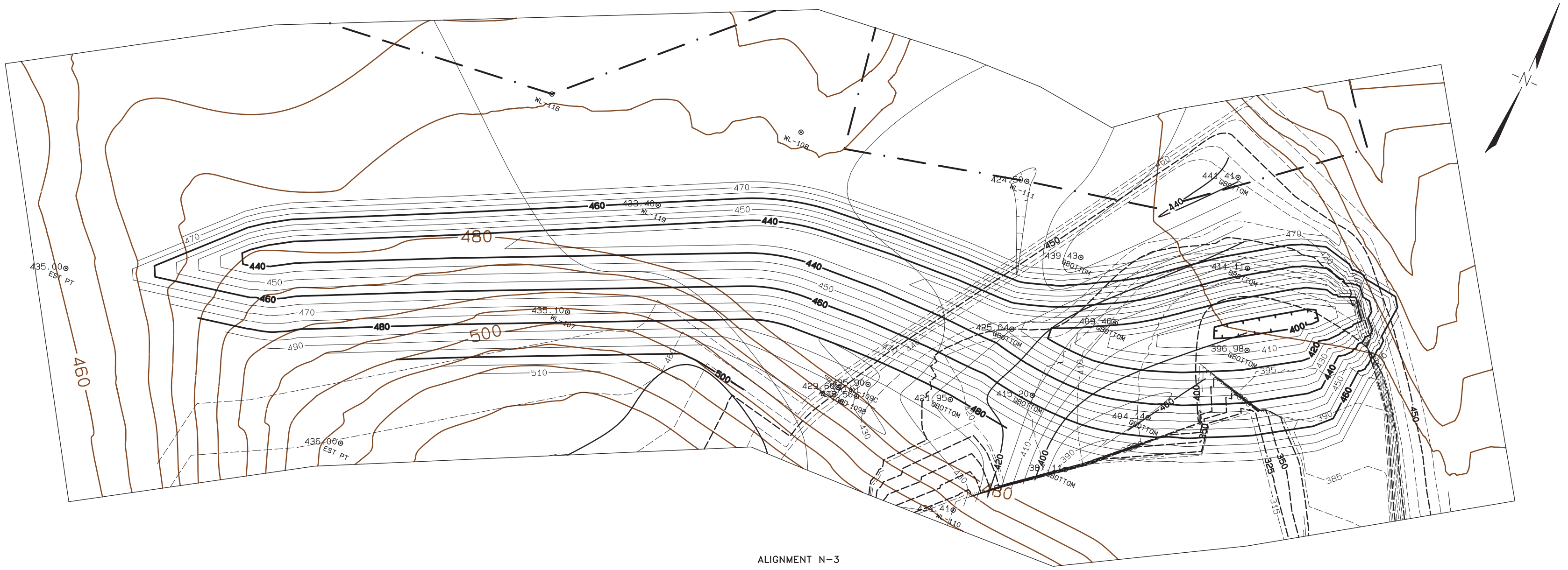
EXCAVATION TO BOTTOM
OF WASTE
USING 15 FT D.BOX TO STA 6
THEN SLURRY WALL

NORTH QUARRY BARRIER
CONCEPTUAL PLANNING
BRIDGETON LF

DRAWING C-3

SHEET 4 OF 6

Project Desc.: Path: N:\RADW\Barrier\bridgeton nbarrier1.pro Plot Date/Time: Thu Mar 28, 2013 / 15:47:41



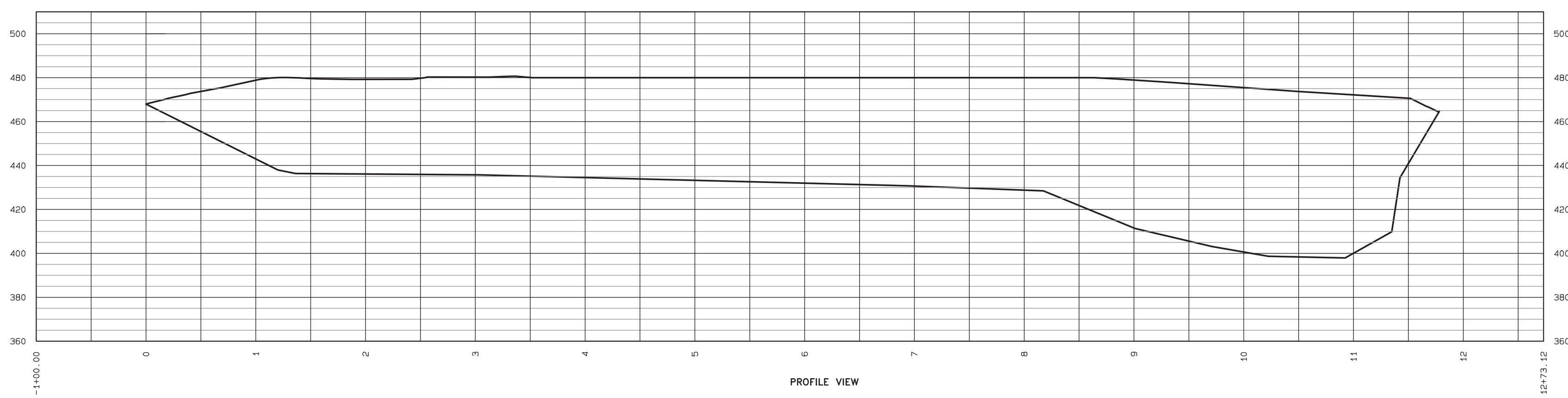
ALIGNMENT N-3

EXCAVATION QUANTITY FOR GRADING SHOWN
IS 180,750 CU YDS

PLAN VIEW

Scale: 1" = 50'

GRAPHIC SCALE 1"=50'
0 50 100 150



PROFILE VIEW

Horz. Scale: 1" = 50'

BRIDGETON LANDF…
BRIDGETON, MO

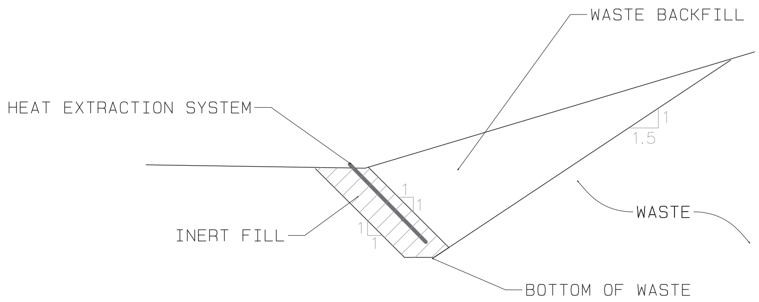
P. J. CAREY & ASSOCIATES, P.C.
5878 VALINE WAY, SUGAR HILL, GA. 30518

EXCAVATION N-3
1:1 ON NORTH
15:1 ON SOUTH

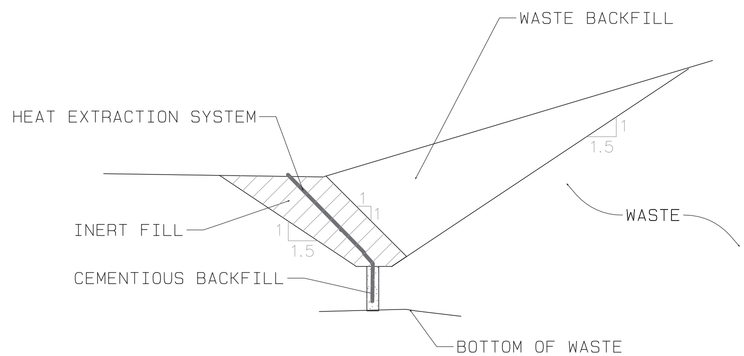
NORTH QUARRY BARRIER
CONCEPTUAL PLANNING
BRIDGETON LF

DRAWING C-4

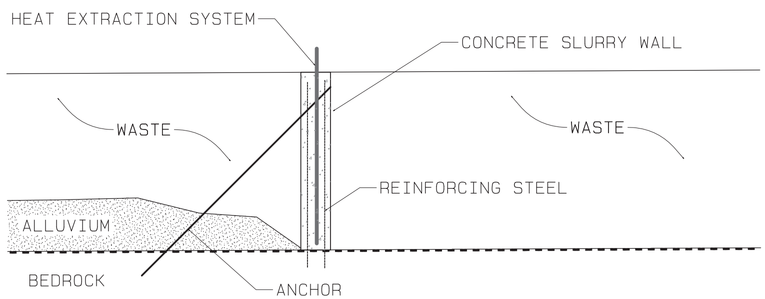
SHEET 5 OF 6



OPEN EXCAVATION



OPEN EXCAVATION
WITH 15 FOOT TRENCH BOX



SLURRY WALL
AT MAXIMUM DEPTH

BRIDGETON LANDFILL
BRIDGETON, MO

DATE | REVISION

P. J. CAREY & ASSOCIATES, P.C.
5878 VALINE WAY, SUGAR HILL, GA. 30518

PROJ. NO.: Set by PRJINFO command 4
DATE: 3/28/2013
DESIGNED BY:
DRAWN BY:
CHECKED BY: PRJCLNT 6
APPROVED BY: PRJCLNT 7

CONCEPTUAL
CROSS SECTIONS

NORTH QUARRY BARRIER
CONCEPTUAL PLANNING
BRIDGETON LF

DRAWING
C-5
SHEET 6
OF 6

Project Desc.: Path: N:\RADW\Barrier\bridgeton nbarrier1.pro Plot Date/Time: Thu Mar 28,2013 / 15:47:55

Work Plan for the Barrier at the North Limits of the North Quarry Fill

1 Tasks

1.1 Preliminary Layout and Concept

1.2 Confirmation of No Rad Waste in Excavation Area –

1.2.1 Evaluate current knowledge base

1.2.2 Determine if added information is needed to insure no RIM is encountered in the excavation

1.2.3 Develop plan (if required) for Gathering Supplemental RIM information

1.2.4 Perform Supplemental RIM Identification Field Work (if needed)

1.2.5 Finalize southernmost Limits of RIM waste to use for project

1.2.6 Perform any Field work needed to finalize concept (borings, test pits etc)

1.3 Finalization of Alignment and Concept

1.3.1 Modify Alignment and Concept to Avoid All RAD waste

1.3.1.1 Adjust alignment and slopes/excavation methods as required

1.3.1.2 Identify locations for access, staging and stormwater management

1.3.1.3 Deposition of waste materials (on site of off site)

1.3.1.4 Identification of permits required and time frames needed for approvals from regulatory agencies

1.3.2 Obtain Approval of Finalized Concept

1.4 Detailed Design

1.4.1 Preliminary Design Work

1.4.1.1 Develop design details for anticipated support system on NE end of work

1.4.1.2 Develop sequence of operations

1.4.1.3 Stormwater management integration for temporary excavation work

1.4.1.4 Air(dust and odor) management practices

1.4.1.5 Decon Area requirements

1.4.1.6 Heat Exchange System and Earthen fill requirements

1.4.1.7 Excavated waste disposition

1.4.1.8 Preparation of permit packages if needed

1.4.2 Final Design

1.4.2.1 Plans clearly identifying work need

1.4.2.2 Finalize Analyses

1.4.2.3 Finalize Monitoring and QA/QC requirements

1.4.2.4 Complete permit application packages

1.5 Construction Package Development

1.5.1 Plans

1.5.2 Specifications

1.5.3 Quantities

1.5.4 Bid Documents

APPENDIX D

LOCAL SUBSURFACE OXIDATION PROCEDURE

Appendix D

Local Subsurface Oxidation (SSO – Potential Landfill Fires)

Subsurface Oxidation Events (SSO) are common events that occur at many landfills that have active gas collection systems. These are local subsurface fires that are caused by a combination of subsurface conditions and well management. Unlike large subsurface reactions (which are extremely rare, do not require oxygen to propagate, and are quite different in nature), SSOs usually only involve a small area and a minimal number of gas wells.

In the North Quarry of the Bridgeton Landfill, it is important to distinguish between an isolated, readily-contained and easily-extinguished SSO from the advancement or initiation of a large subsurface reaction.

Typical Symptoms

- Dramatic localized landfill settlement.
- Charred or cracked surface cover.
- Stressed or dead vegetation in an area that is otherwise properly vegetated.
- Smoke or smoky odor emanating from the landfill surface or wellhead.
- Drastic or unusual increase in flowing gas temperature.
- Abnormal discoloration of wellhead/riser assembly.
- Abnormally high CO concentration in LFG.
- Deformed riser pipes.

Initial Notification and Investigation

Notify Environmental Manager immediately after visually identifying any potential SSO. An initial investigation shall be started within 12 hours after visual identification of a potential SSO.

1) Do not change the condition of the well during the initial investigation.

2) Health and Safety Considerations

   - Consult HASP for procedures related to landfill fires.
   - Under no circumstances shall an initial investigation be conducted without first consulting the HASP and implementing appropriate controls and procedures.
   - Do not breathe landfill gas or smoke. Stand upwind of emissions.
   - Wear appropriate PPE. Burns may be caused by hot PVC / HDPE / steel.
   - Do not drive heavy equipment / vehicles near well or depression until ground stability has been verified. *The burned waste mass may give way and equipment/personnel may fall into sinkhole.*

3) Conduct physical inspection

   a) Inspect the nearest extraction well to the potential SSO location.
   b) Inspect all wells within 500 feet of nearest extraction well to the potential SSO location.
   c) Inspect the landfill surface within 500 feet of nearest extraction well to the potential SSO location.

d) Visibly inspect for large localized settlement, cracks, holes, collapse, missing components, and areas that could be sources of air intrusion into the waste mass including:

- Monitoring ports
- Well casing
- Hoses
- Erosion ruts
- Dry soil cracks
- Manways
- Lift stations
- Sumps
- Leachate cleanout risers

4) Measure gas quality, pressure and temperature, at all wells within 500 feet of nearest extraction well to the potential SSO location. *Special precautions may be necessary to address high gas temperatures.*

5) Measure CO concentrations with colorimetric tubes (Draeger tubes) at all wells within 500 feet of nearest extraction well to the potential fire location, and obtain summa canister samples for laboratory CO analyses at all wells that indicate CO detections >500 ppm by colorimetric tube. *Gas temperature and other interference gasses can affect the accuracy of the measurement; therefore, the results of any CO field monitoring should be expressed qualitatively only.*

6) Infrared Thermometer Survey

- Use an IR laser thermometer to measure the temperature of the ground surface in the area of the suspected SSO. *Shallow fires or fires that have consumed large amounts of refuse will produce elevated surface temperatures. Extreme caution must be taken in these areas due to the possibility of the ground giving way.*

SSOs are often caused by "overpulling" a gas well or wells in a certain area. Oxygen is drawn into the waste mass which can generate heat and provide the necessary oxygen for combustion. Since oxygen readings are collected as part of normal Title V, New Source Performance Standards (NSPS) monitoring, a review of the collected historical data from surrounding wells should be made. The data review should trend oxygen readings in from the wells in the general area of the SSO to determine if there was an overpull situation. Temperature should also be historically trended as heat; along with CO data (see below) is a good indicator of an SSO in the area.

Gas quality in wells adjacent to the SSO *may* be affected. In particular, carbon monoxide levels could elevate based on wellfield operation issues and preferred pathways within the waste mass. It is important to determine if the SSO is constrained to a single gas well and / or a single isolated area. Therefore, laboratory CO analyses will be expedited with results received within seven days of detection by colorimetric tube.

If the above investigation suggests that more than one gas well may be actively involved in an SSO area, then the investigation shall be expanded to include the wells within 500 feet of the SSO area.

Formal Notifications

The Environmental Manager shall notify the MDNR (SWMP Engineering Section Chief or Program Director at (573) 751-5401) within one business day of determination. The notification will include the gas well identification, date of initial detection, approximate area of the SSO, and results of initial investigation. The MDNR may observe or conduct confirmatory sampling.

Data Analysis

Determine the state of the SSO

- Analyze temperature gradient between monitored wells.
- Analyze oxygen gradient between monitored wells.
- Analyze nitrogen to oxygen ratio gradient between monitored wells. *If nitrogen is not measured directly, assume balance gas of nitrogen.*
- Analyze pressure gradient between monitored wells.
- Analyze methane to CO_2 ratio gradient between monitored wells.

Removing the Oxygen from the Fire

The key to stopping a SSO once it has begun is to completely restrict oxygen from entering the smoldering waste mass (snuff out the fire). Once the initial investigation has been performed and a general sense of the extent of the SSO has been determined, safely begin to restrict further oxygen intrusion using the following method:

1) Shutdown well(s) that is believed to have been the cause of the SSO.

2) Shutdown all wells in surrounding area (within the approximately 300 feet of suspect well(s)).

3) Cap or repair any item identified during the physical inspection that may be contributing to oxygen intrusion.

4) Carefully add additional cover to areas that show cap integrity issues if necessary. Work slowly and pay special attention to the ground surface as material placement commences.

    - During cover placement activities, there should be a minimum of two people available; the equipment operator, and a line-of-sight person on the ground that is responsible for watching the ground surface as the equipment operator places the soil.
    - Use a low ground pressure (LGP) machine, if available. If LGP machine is not available, use the lightest machine with the widest tracks available. Do not use rubber tired machine to place cover material.
    - Slowly push soil into the area and compact with the bucket or tracks of the equipment.

Note: Closing wellhead valves to minimize vacuum in the area of concern may cause vacuum levels to increase within the main header. This will redistribute the overall vacuum applied to the wellfield and may cause higher vacuums to other wells in the GCCS. Carefully watch for redistribution of vacuum, and adjust prime mover vacuum set-point accordingly. If greater than 10 percent of the total wells in the wellfield are closed to remediate the SSO, a complete retune of the wellfield may be warranted.

Things to Avoid

- *Flushing the well with water* – Flushing the well with water can potentially clog the well.
- *Excavating soil in the SSO area* – Do not excavate in the SSO area. Excavation will allow additional oxygen to enter the already smoldering waste mass and can potentially auto-ignite.
- Venting – Do not remove the wellhead to vent the well. Wellfields are typically under negative pressure. Residual vacuum exists in the waste mass for a period of time when wells are closed. If the wellhead is removed to vent, it is highly possible that the residual vacuum in the area will pull ambient air into the waste mass adding oxygen to the SSO.
- *Introduction of water into open cap fissures* – Applying water to open fissures in the cap where an SSO exists can create a plume of highly odorous stream. It is also dangerous to bring a heavy, rubber tired water truck to the area to apply water. The steam created can be dangerous to workers in the immediate area. If an open cap fissure exists in an SSO area, is shall be safely filled with soil. Removing the pathway for oxygen intrusion is the most effective way to put out the SSO.

Continued Monitoring

Monitor the wells closest to the suspected SSO area and adjacent wells at least once a day for at least two weeks.

- Monitor for gas quality, temperature, and CO. *As the SSO subsides, residual CO will remain in the waste mass for weeks and possibly months. Elevated CO levels are not a reliable indicator that an SSO is still in progress. However, CO levels should generally decline with time if the fire has been extinguished.*
- Once SSO indicators are no longer noted, monitor the well and adjacent wells once a week for at least 4 months before returning to normal monitoring schedule.

It is important that during these monitoring events the valve on the wellhead is opened for a prescribed time at a prescribed vacuum. This must be performed consistently form event to event to pull stagnant LFG form the well and fill the casing with fresh LFG form the Landfill formation. Analysis of this fresh LFG will provide the most realistic picture of the status of the SSO. Once readings are collected, the well must be returned to its closed position.

Repairs

Repairs should be made to the SSO area, as necessary

- Visual Inspection
- O&M Provider shall visually inspect the following:
  - Wellheads and lateral piping,
  - Cover soil and geosynthetics, and
  - Other items within SSO area.

- Provide findings to, and generate repair options for OM&M Manager.
- OM&M Manager shall facilitate repairs, as required.

Timeline for Local SSO Resolution

It is important that a structured SSO monitoring plan and diligent adherence to the plan be carried out to return the wellfield to normal operation as soon as possible. However, it is advisable to take time and slowly ensure the SSO is fully extinguished and that the bacteria population in the area has recovered and is consistently producing gas.

The severity of the SSO, the age of the waste, moisture content, and a number of other variables will all determine how long it takes the wellfield to regain compliance with NSPS. Experience has shown that the timeline form the point when the SSO is identified and extinguished to the point when the wellfield resumes normal operation can vary from 2 to 3 weeks up to (in some serious SSO situations) 1 year or more.

Classification of the Event

The Environmental Manager and the MDNR will actively collaborate to verify and classify the SSO event. Such determination will be made within four weeks of the Initial Notification.

The event will be classified as a local SSO if monitoring indicates that combustion is constrained to one gas well and that there is no evidence that the SSO is enlarging.

If the event is not classified as a local SSO and may, instead, be considered a triggerable action per the North Quarry Contingency Plan, then Bridgeton Landfill and the MDNR will discuss and reach agreement on the appropriate action which may include further monitoring or entering into the path of actions provided in Table 1 of the North Quarry Contingency Plan – Part 1.