ENGINEERING FOR A BETTER WORLD
FEEZOR
ENGINEERING, INC.

EXPANDED HEAT REMOVAL PILOT STUDY QUARTERLY REPORT

BRIDGETON LANDFILL

BRIDGETON, ST. LOUIS COUNTY, MISSOURI

October 2016

Prepared For:

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Expanded Heat Removal Pilot Study Quarterly Report

Bridgeton Landfill, LLC

APPENDICES

1 INTRODUCTION

This document is being submitted as a quarterly update for the Expanded Heat Removal Pilot Study underway in the South Quarry of the Bridgeton Landfill (BL) in Bridgeton, Missouri. This update was requested by the Missouri Department of Natural Resources (MDNR) in a letter dated September 4, 2014, and includes a summary of work and data collected during the Third Quarter 2016 operational period.

The following discussion includes a summary of activities and field data compiled during the Third Quarter 2016 operational period. This quarterly update provides a presentation of in-waste temperature measurements, heat removal results for each removal location, status of the current heat removal system, operating log for the reporting period, and a discussion of measurement results. Graphical presentations of data collected from in-place waste Temperature Monitoring Probes (TMPs) are presented in **Appendix A**. Graphical presentations of heat removal point data are provided in **Appendix B**. Plan views of the TMP locations and current heat removal system are provided as **Appendix C** and **Appendix D**, respectively. **Appendix E** provides entries made to the Heat Extraction System Operating Log during the Third Quarter 2016 operational period.

2 SYSTEM OPERATION

The heat extraction system has operated consistently during the Third Quarter 2016 operational period, with the following exceptions described below and presented in **Appendix E**:

- The cooling loop pump was observed to be in an inactive state on July 15th, 2016 and was restarted the same day;
- The flow meter at heat removal location GIW-7 was observed to be malfunctioning on July 18th, 2016. The flow meter was taken apart for troubleshooting on July 20th, 2016. Upon taking the meter apart, a clog in the meter was discovered. The clog was removed, the flow meter re-assembled, reinstalled, and returned to normal operation on July 20th, 2016;
- The temperature probe at location Temperature Monitoring Location 3 (TML-3), previously installed to measure cooling fluid temperature directly at a location along the system piping, was replaced on July 20th, 2016;
- On July 25th, 2016 the heat extraction system was observed to be off. Feezor Engineering, Inc. (FEI) restarted the system, but no temperature reading was able to be read at the main system control panel. The system vendor was contacted to come out to troubleshoot the temperature display. During troubleshooting by the vendor, a malfunctioning temperature transmitter was determined to be cause of the

malfunctioning panel temperature display. On July 26th, 2016, the system vendor replaced the temperature transmitter to restore the panel temperature display to working order; and

- On September 4th, 2016, the heat extraction system was observed to be shut off. The main system pump was determined to be inoperable and the system's propylene glycol exhausted. After troubleshooting the system, it was determined that U-tube cooling points in GIW-5 and GIW-10 were leaking, depleting the system's propylene glycol. The cooling fluid was presumably lost to the waste mass. GIW-5 was disconnected from the heat extraction system, a new main system pump was obtained, and the fluid supply tank was temporarily filled with water. Accordingly, the heat extraction system was able to be restarted later the same day, minus GIW-5. The leak in GIW-10 was determined to be fairly insignificant and allowed to remain online. GIW-5 and GIW-10 were retrofitted with the pipe-in-pipe design by the facility allowing for reconnection to the heat extraction system on September 30th, 2016.

Except as described above, the system has operated with minimal operational or physical changes since the expansion completed on June 26, 2015 (GIWs-08, -09, -11, -12 and -13). A review of **Appendix B** shows heat removal rates were generally consistent at each location during the Third Quarter 2016 operational period.

3 DATA SUMMARY

In-waste temperature measurements were collected on a weekly basis during the Third Quarter 2016 operational period as part of the on-going pilot study. Graphical presentations of in-waste temperature measurements are presented in **Appendix A**. The inflow temperature, outflow temperature, and flow rate are measured and recorded at each heat removal unit on a weekly basis. These measurements are utilized to calculate the heat extraction rate (in kilowatts) at each individual removal point. The heat extraction rates for each point are graphically presented with the respective flow rate (in gallons per minute) in **Appendix B**.

4 SUMMARY AND DISCUSSION OF RESULTS

The BL continued the generally successful operation of twelve (12) heat removal locations during the Third Quarter 2016 reporting period. Except as described in Section 2, the heat removal system has operated with only minor maintenance, since the expansion of the system during June 2015 except the above-referenced items in Section 2. The system generally continues to operate with minimal interruption.

Measurements collected during the reporting period are generally consistent with data recorded during previous quarters. A review of in-waste temperature measurements shows consistent temperatures during the reporting period, with the exception of TMPs in the

immediate vicinity of GIW-5 (5-5N, 5-5S, 5-9N, and 5-9S). The temperatures of the TMPs near GIW-5 were greater than temperatures observed in the recent past subsequent to the location's temporary disconnection from the heat extraction system during the period of September 4th through September 30th, 2016. The TMPs at approximately five (5) and nine (9) feet to the north of heat removal point GIW-10 continue to exhibit significant temperature reductions compared to measurements obtained prior to heat removal system initiation.

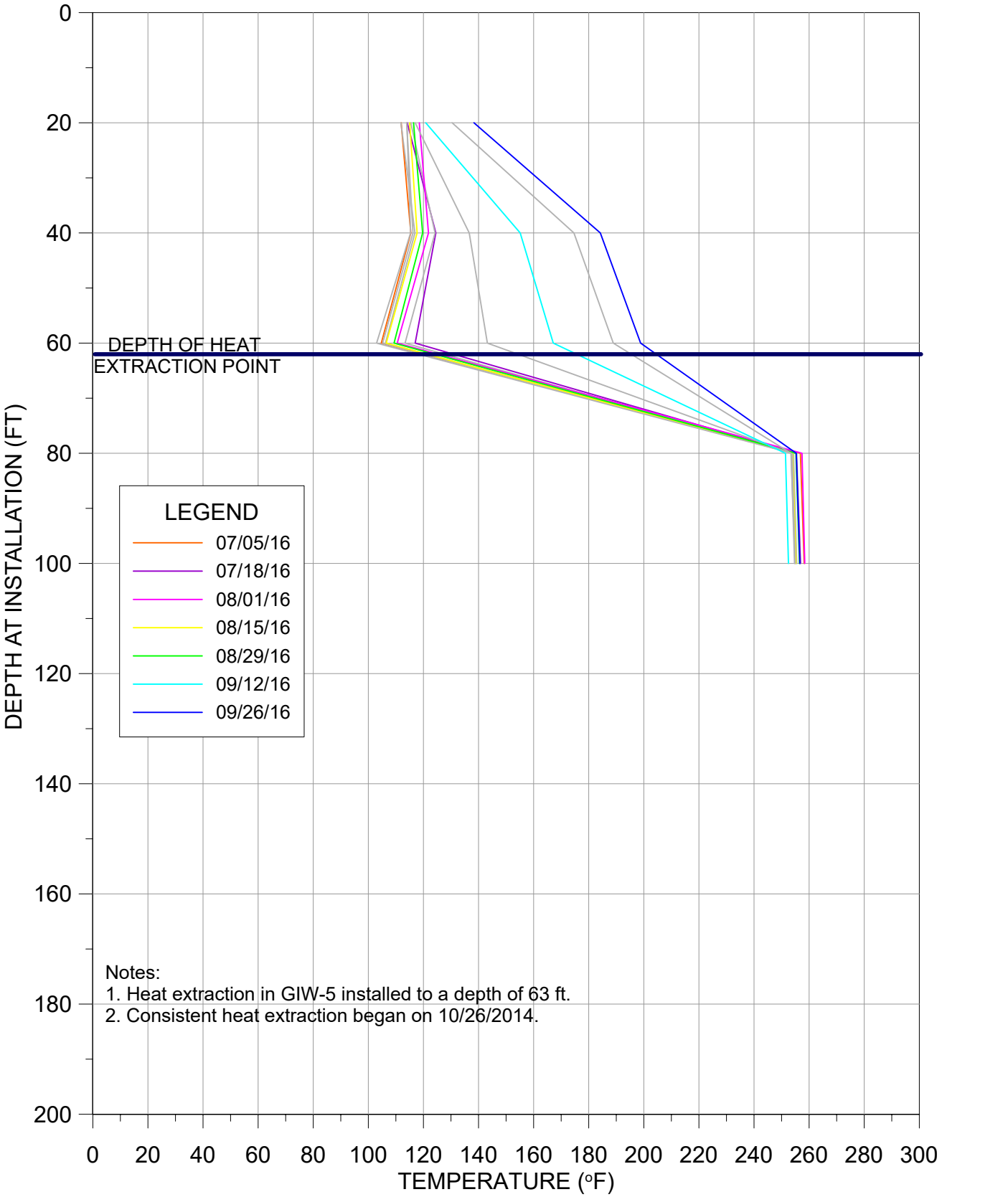
Subsurface temperatures on the north side of the heat removal locations continue to remain significantly lower compared to the south side. This suggests normal landfill heat generation in the waste to the north of the heat removal points.

A review of the heat removal point data for this reporting period has also been conducted. The initial (south line) heat removal locations (GIW-02, -03, -04, -05, -06, -07, and -10) have shown relatively steady rates of energy removal, with the exception of the heat removal rate of GIW-5, which appeared to be losing fluid on September 4th, 2016. Prior to September 4th GIW-05 exhibited a relatively steady rate of heat removal. The steady-state heat removal rates of the northern line of heat removal locations (GIW-08, -09, -11, -12, and -13) are generally greater than the steady-state heat removal rates of the southern line. This is expected and likely attributed to the greater depth of the heat removal locations on the northern line.

BL is continuing the operation of the expanded heat removal pilot study system at the facility, and has recently completed construction of and has commenced operation of the Heat Extraction Barrier as described in a November 2015 *Technical Evaluation of a Heat Extraction Barrier*, prepared by FEI and approved by MDNR correspondence dated December, 4 2015. As required by Comment No. 8 of the December 4, 2015 MDNR letter, incorporated by reference in Section VIII.35.c of the April 28, 2016 Administrative Settlement Agreement and Order on Consent for Removal Actions (ASAOC), system status summary reporting frequency is updated from a quarterly basis to a monthly basis. Accordingly, monthly reports will be submitted on the 20th of each month (or the first business day following the 20th if it falls on a weekend) going forward.

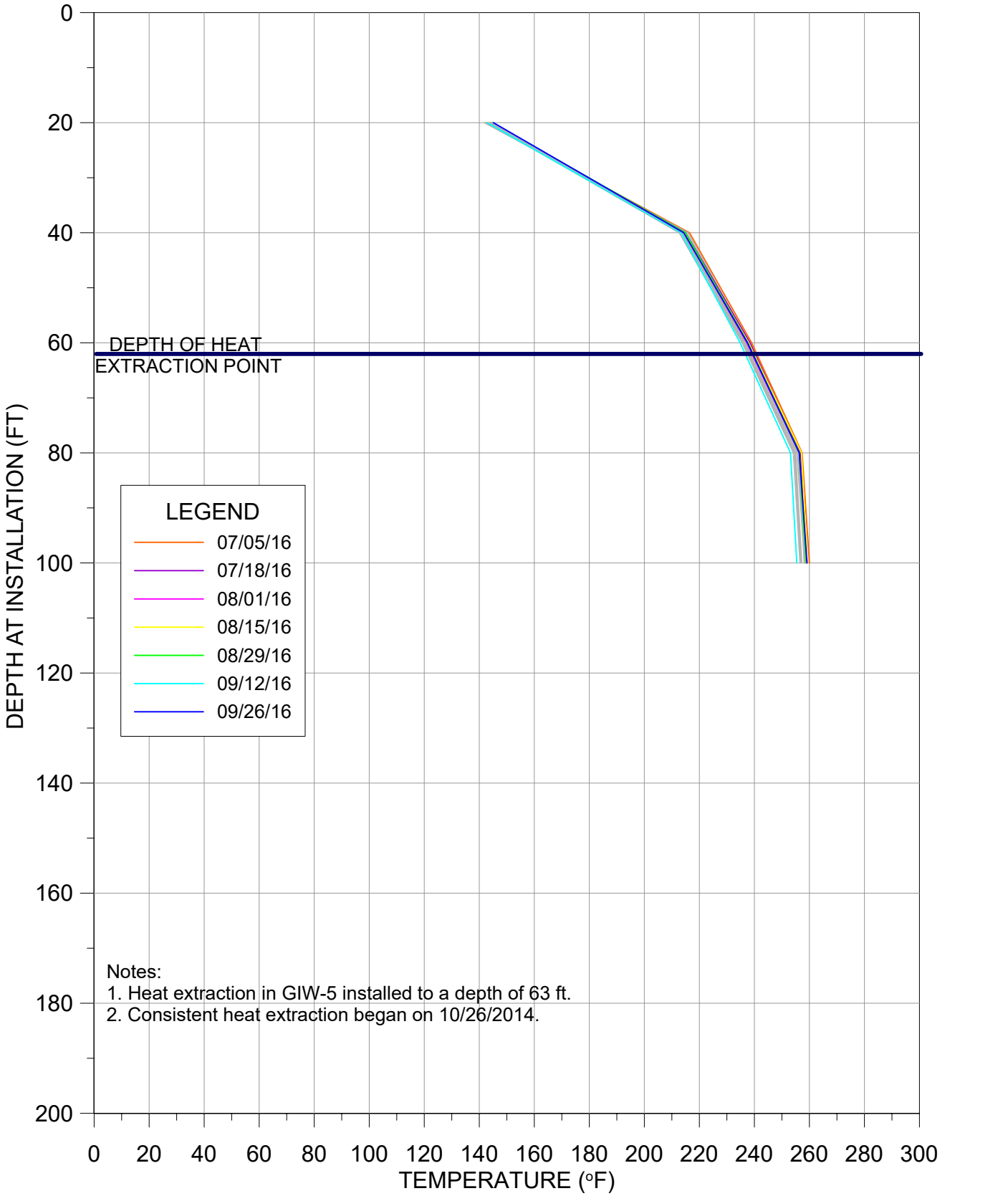
Appendix A – Temperature Monitoring Probe Graphs (Third Quarter 2016)

TMP-5-5N



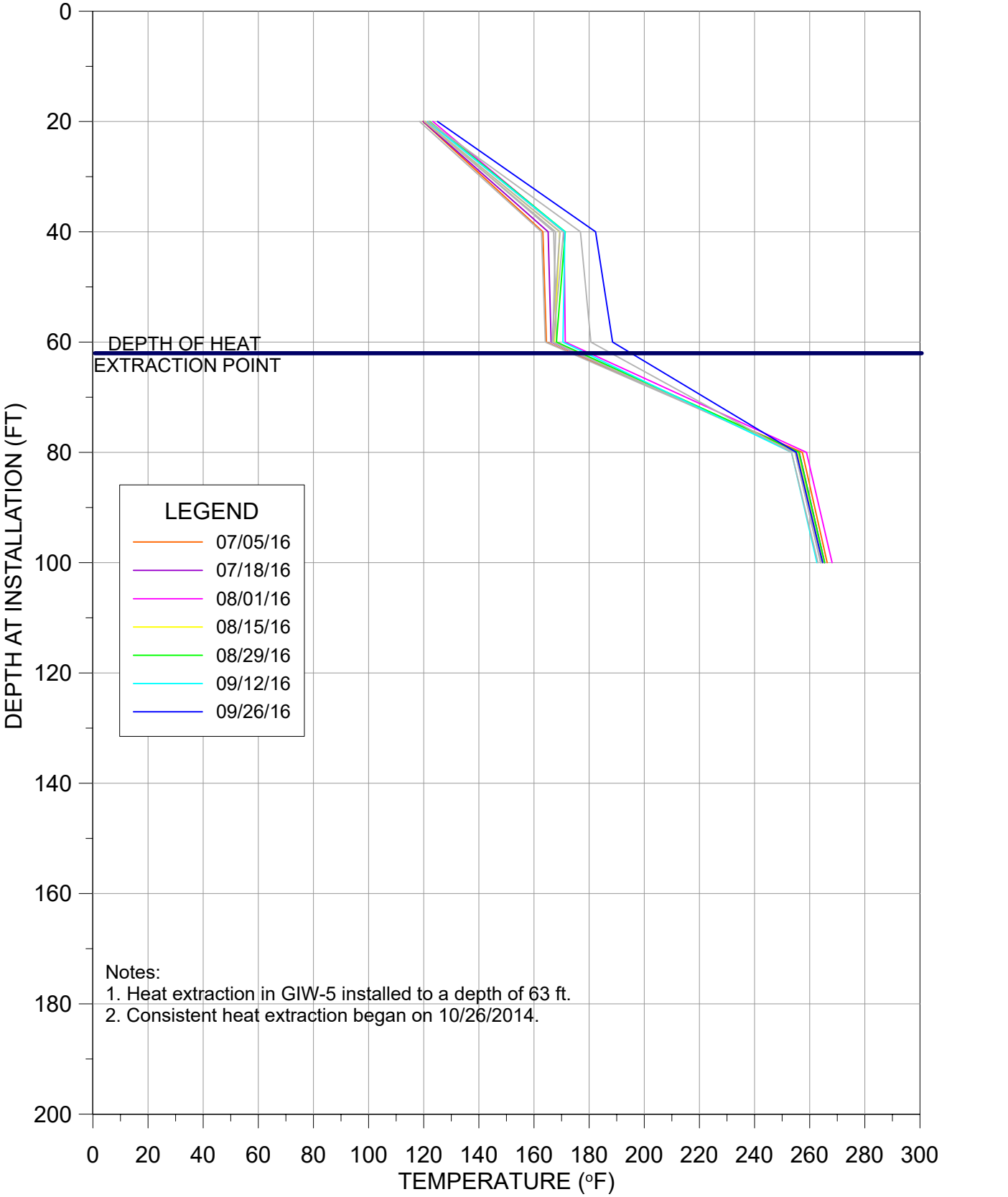
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-5-5S



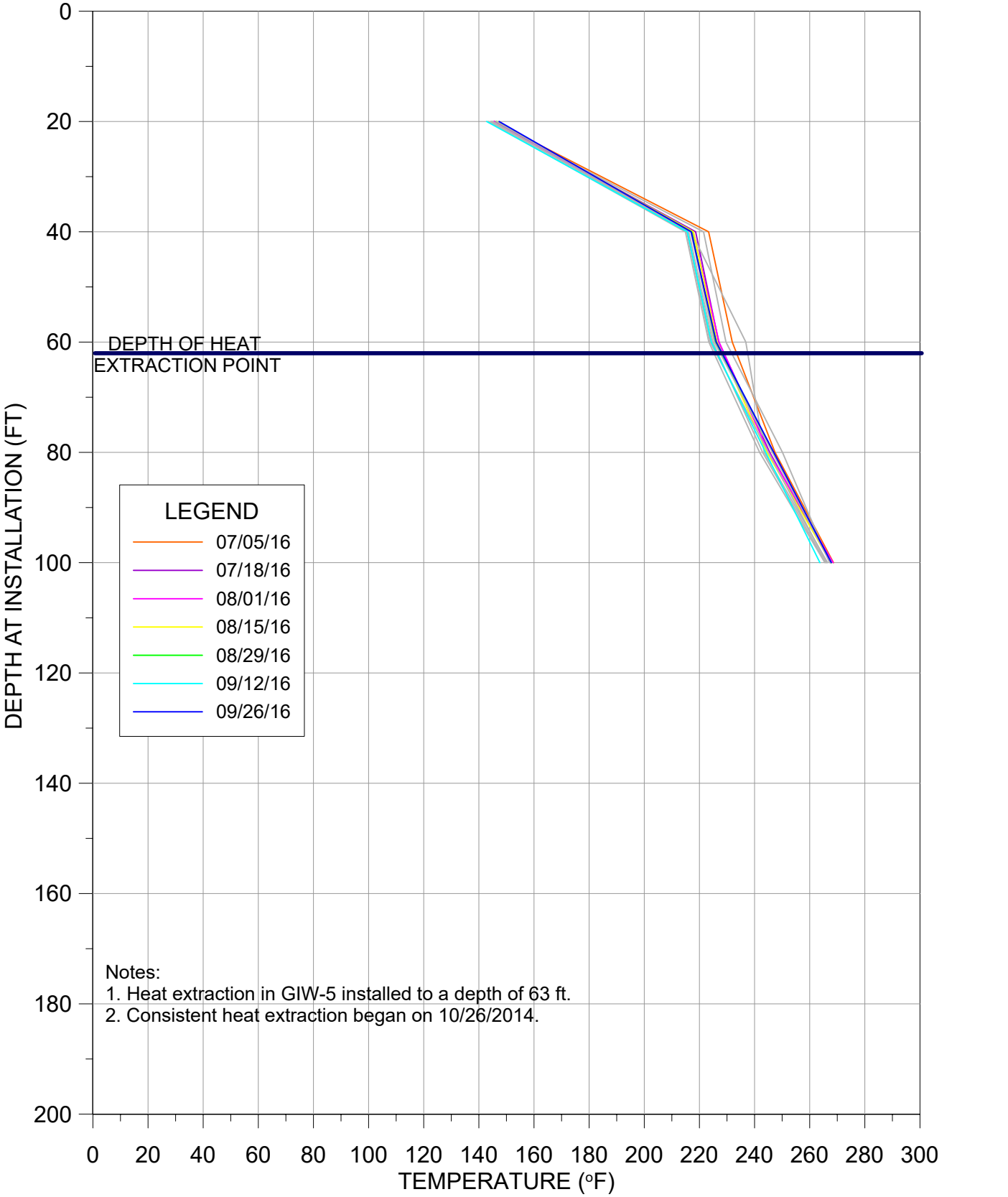
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-5-9N



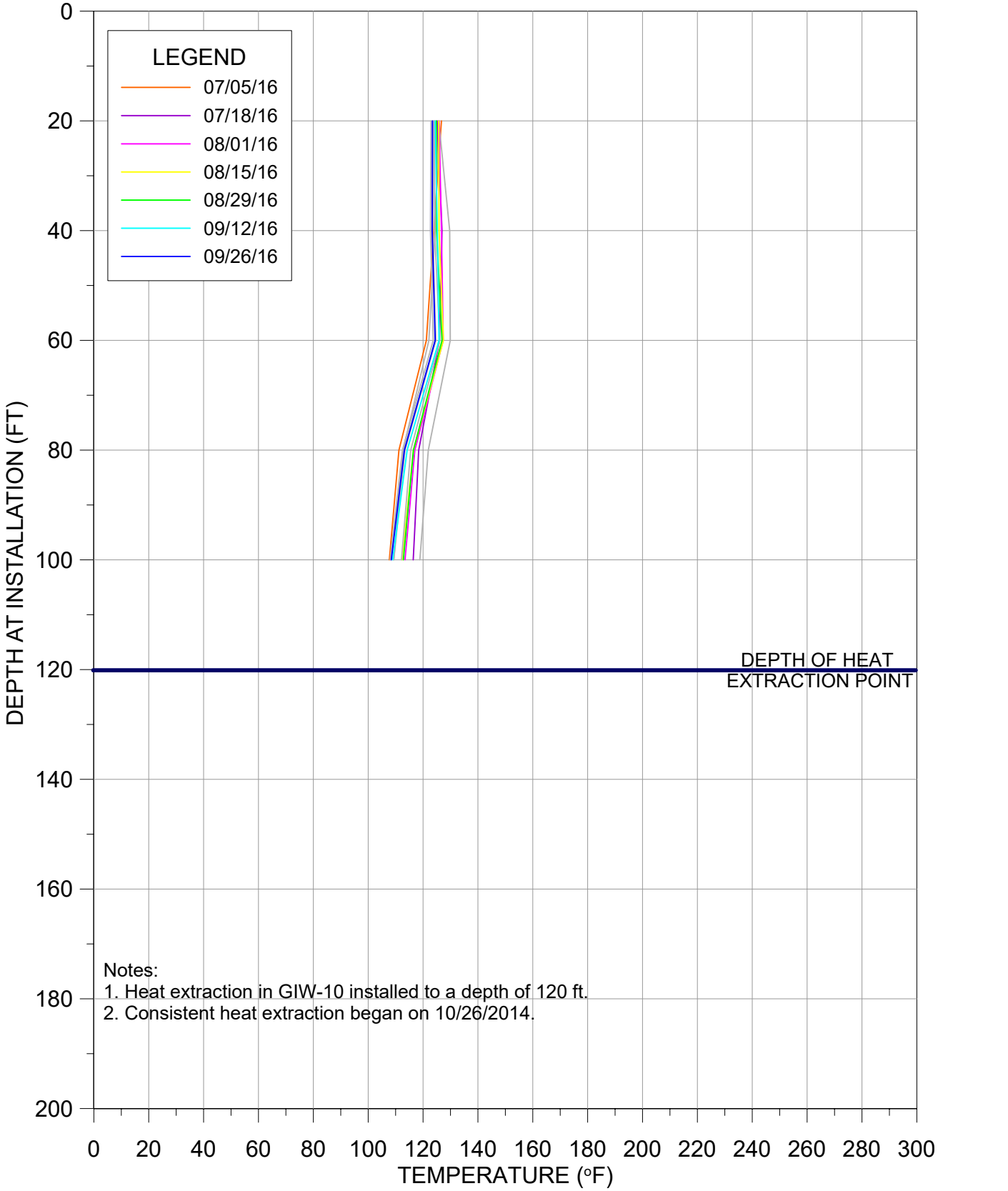
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-5-9S



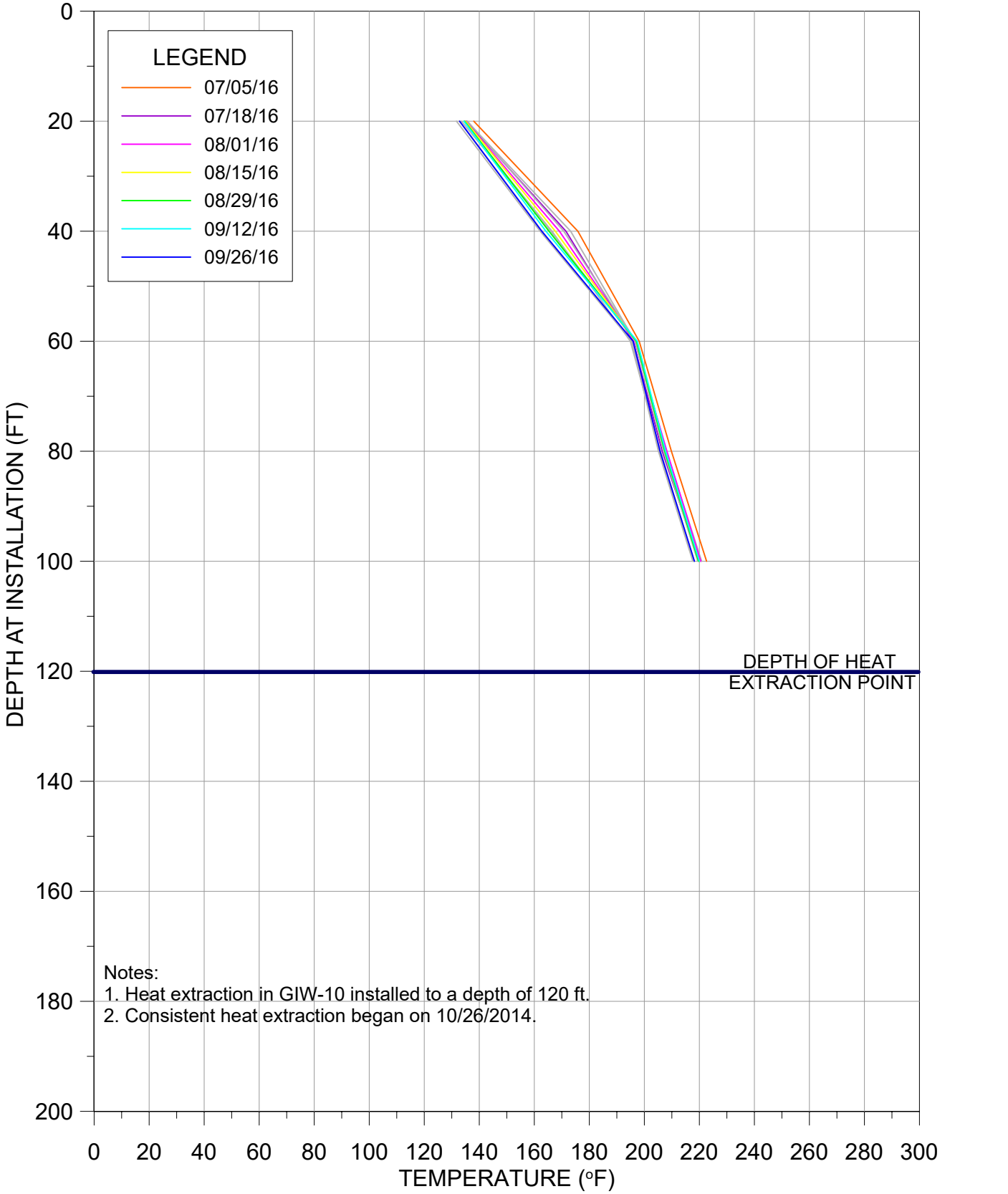
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-10-5N



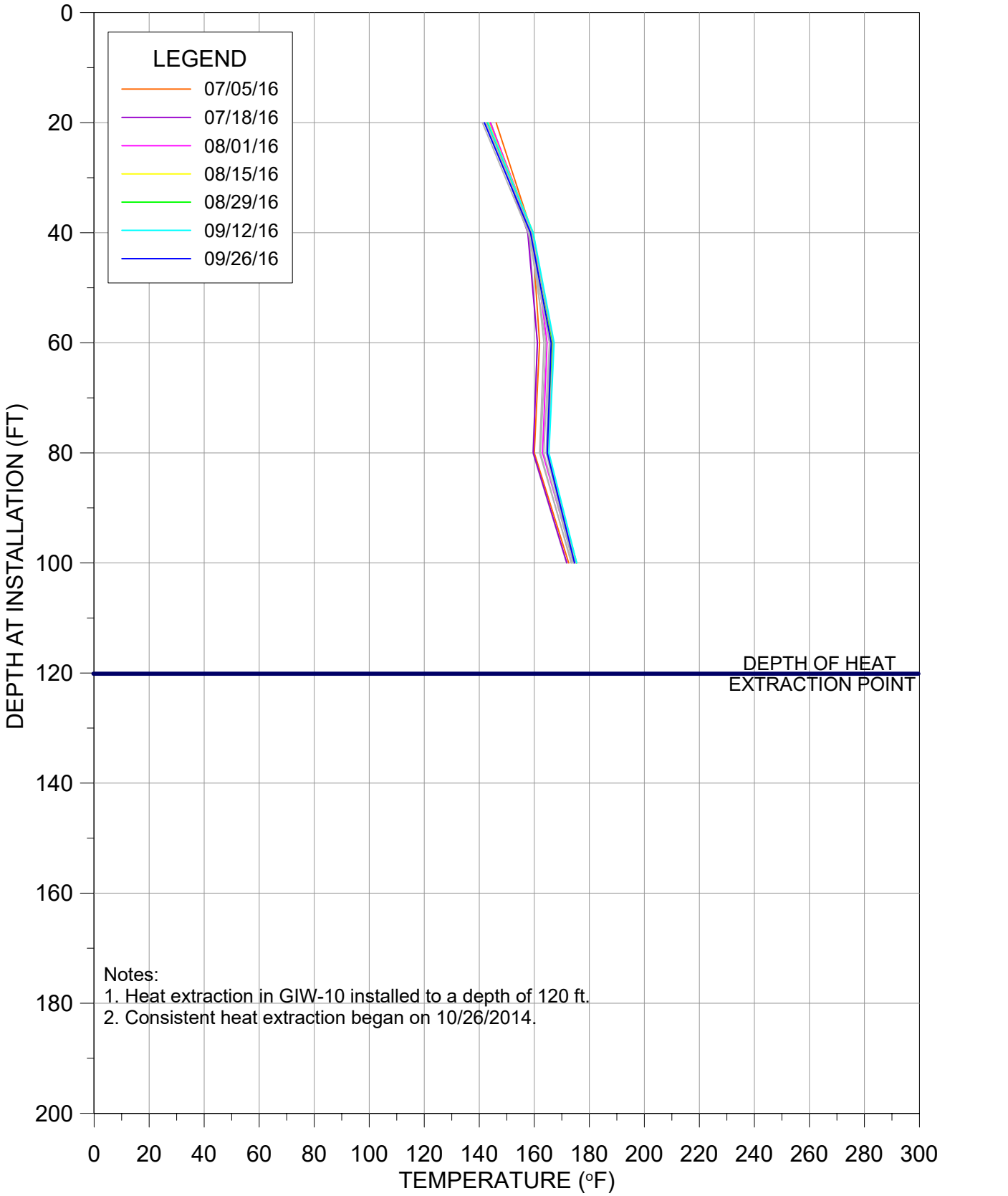
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-10-5S



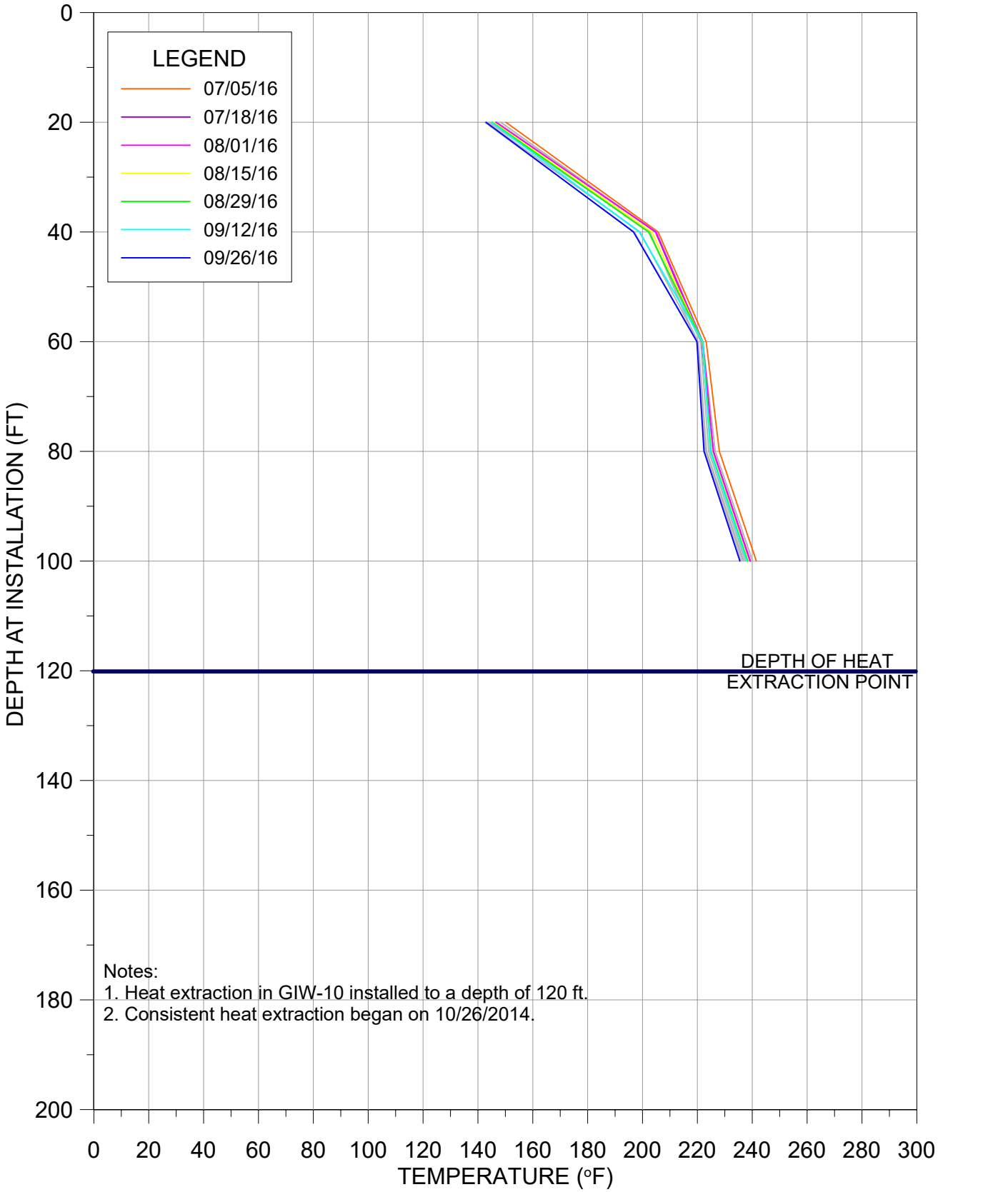
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-10-9N



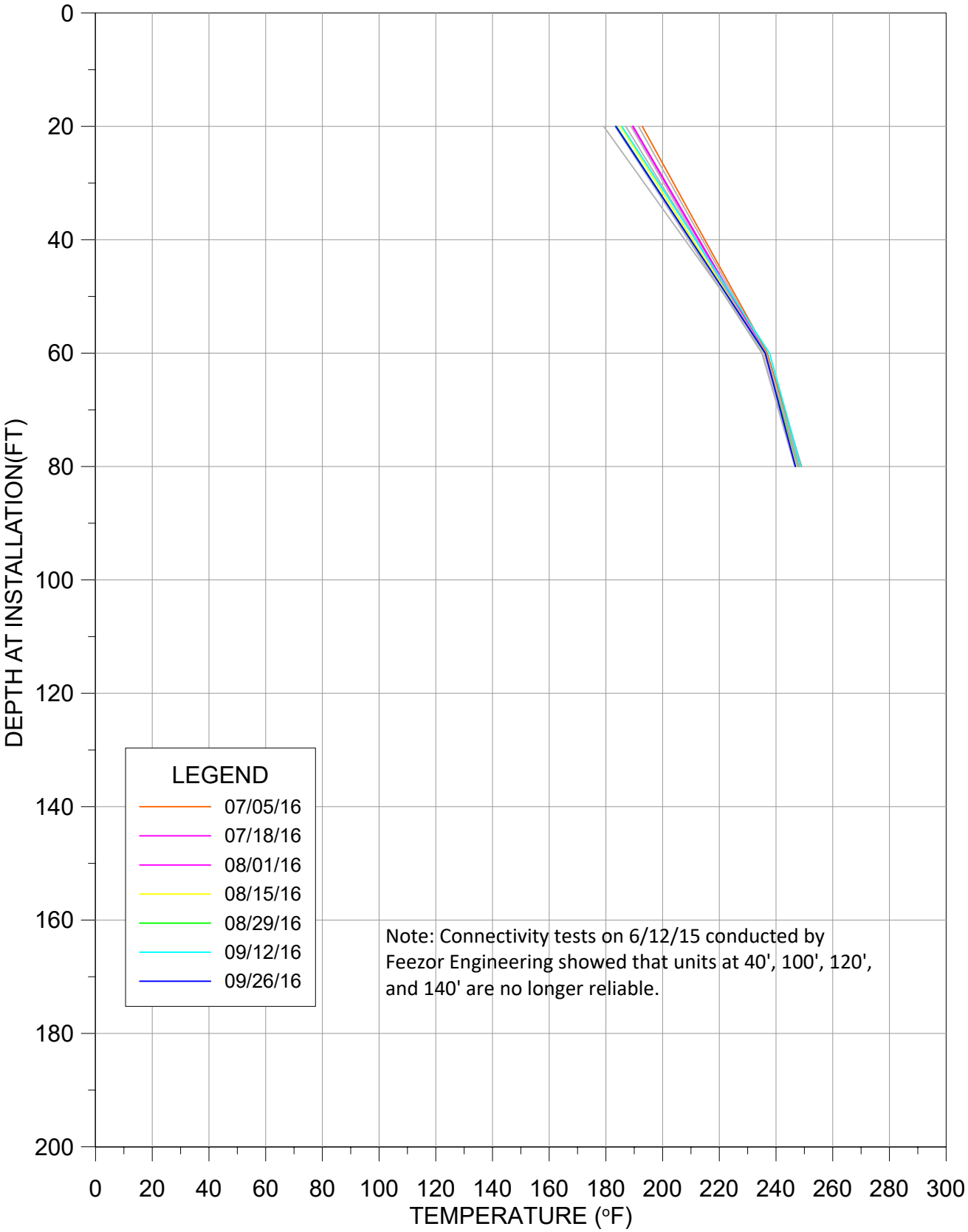
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-10-9S



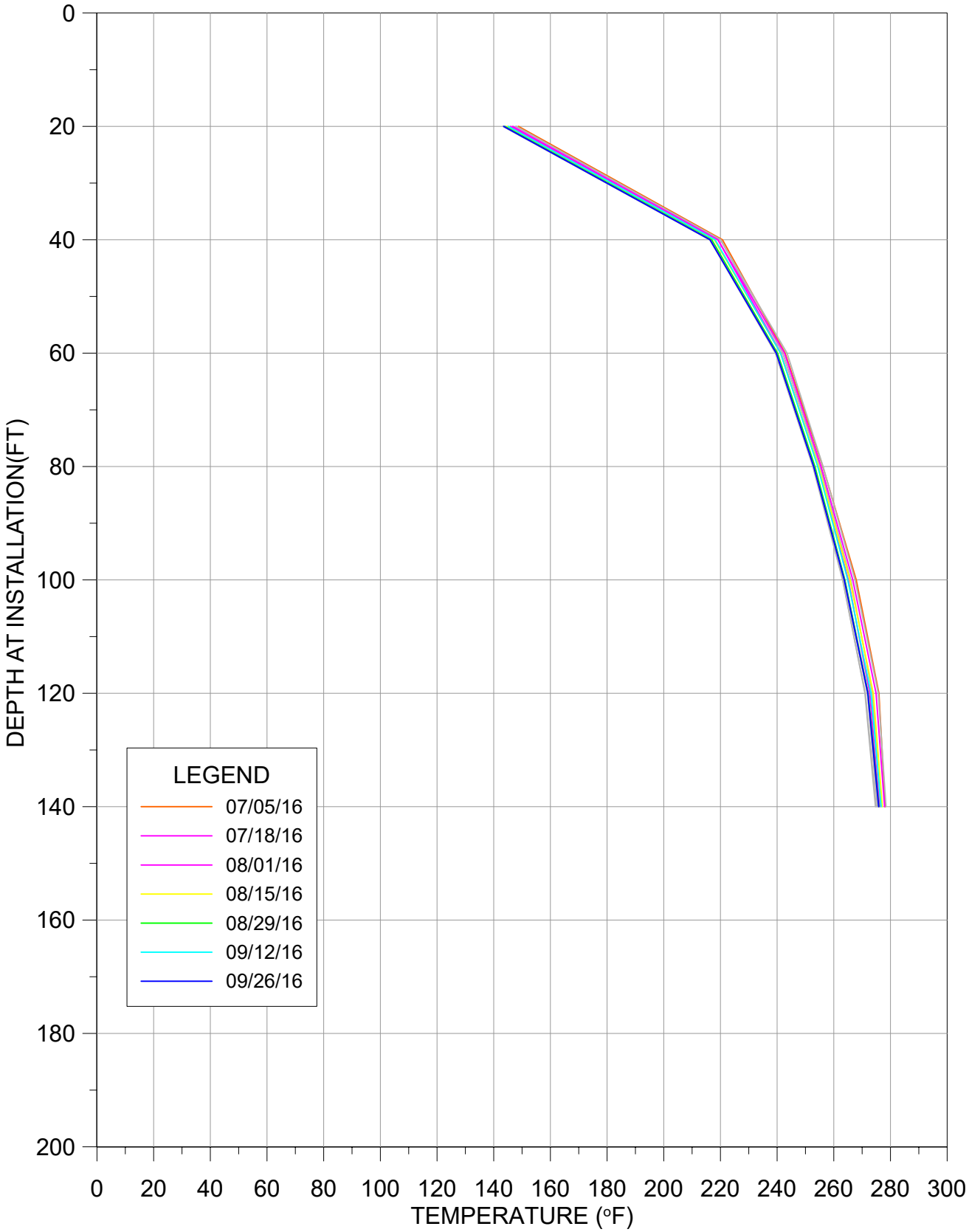
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-19



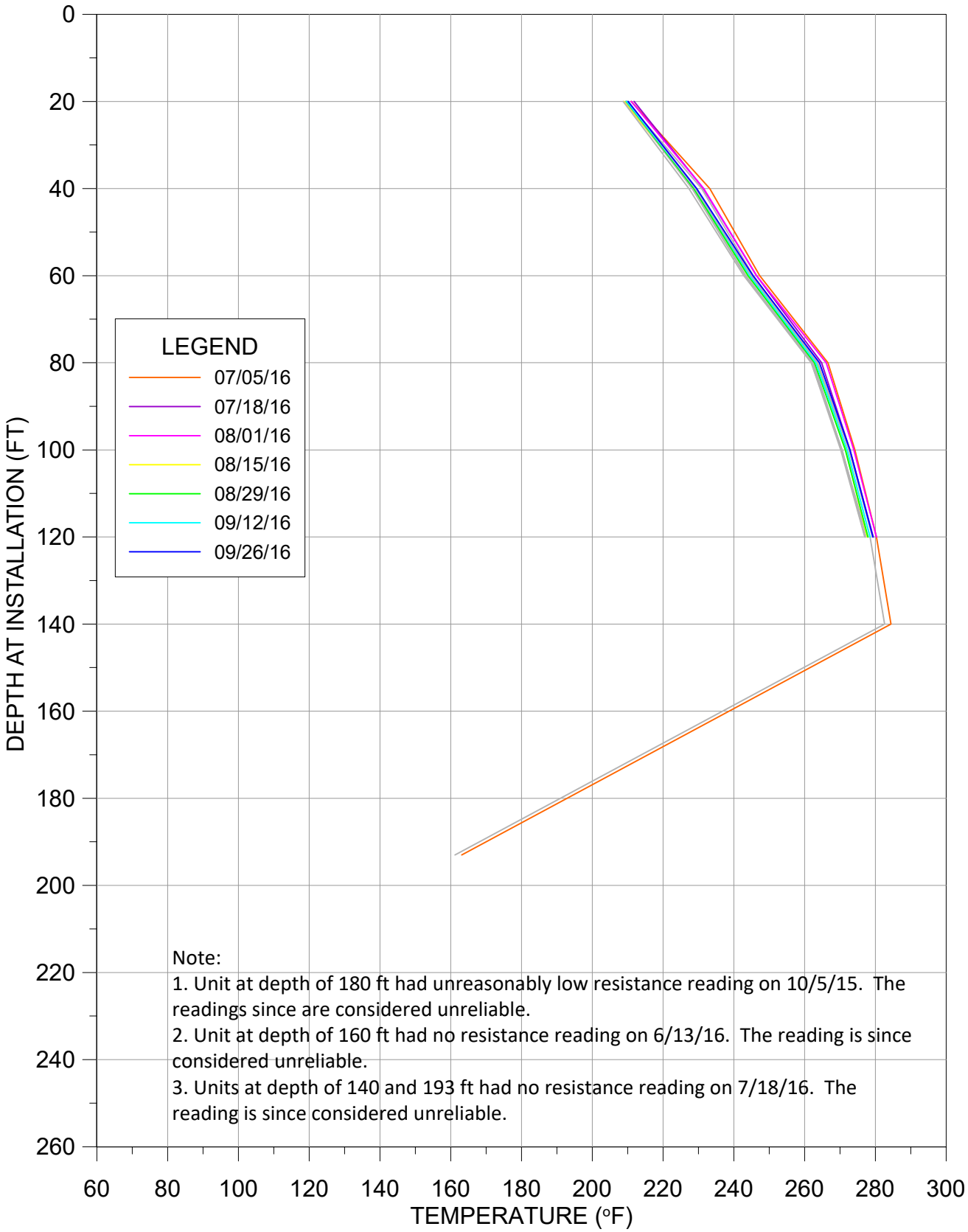
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-20



TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

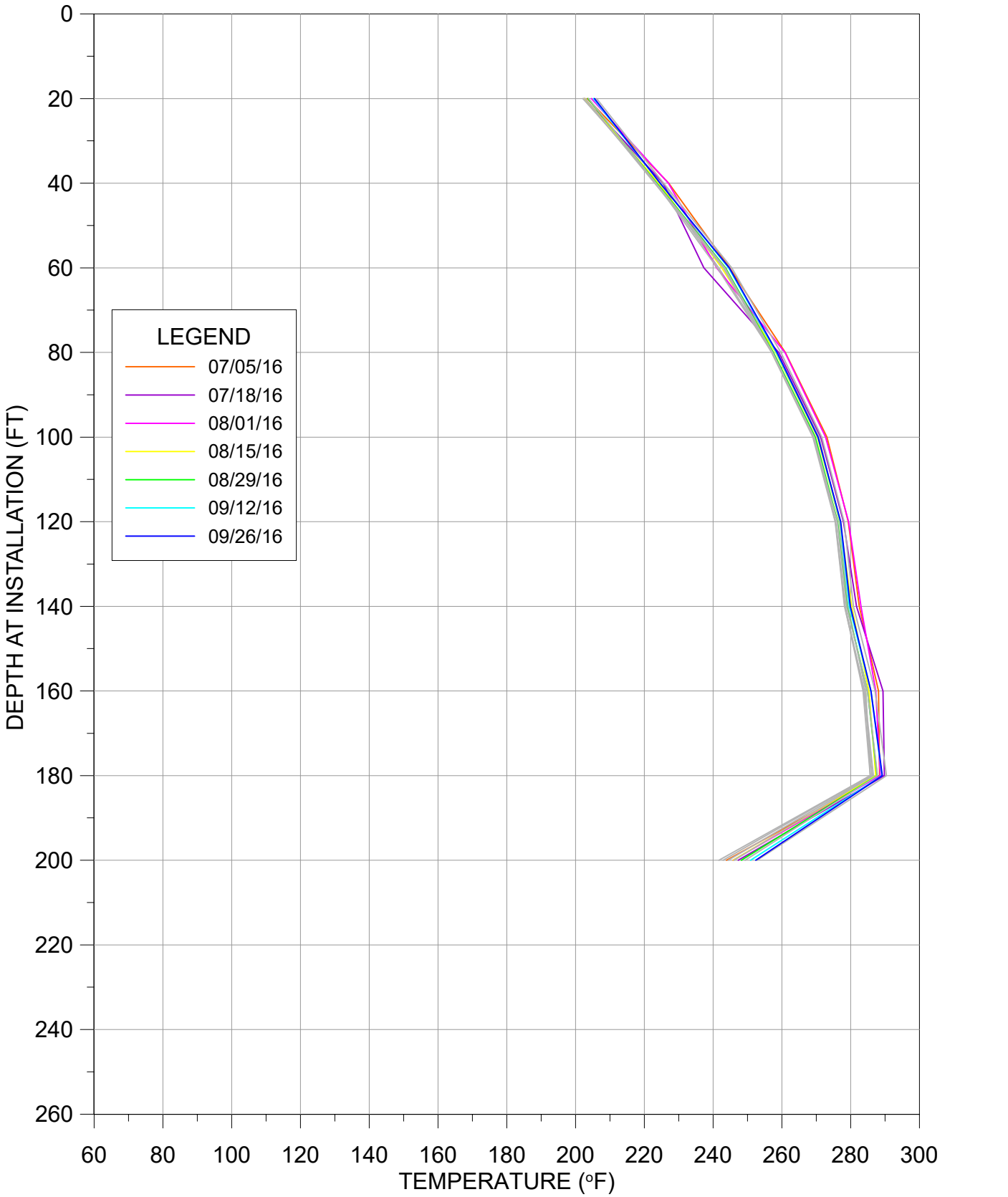
TMP-31



Note:
1. Unit at depth of 180 ft had unreasonably low resistance reading on 10/5/15. The readings since are considered unreliable.
2. Unit at depth of 160 ft had no resistance reading on 6/13/16. The reading is since considered unreliable.
3. Units at depth of 140 and 193 ft had no resistance reading on 7/18/16. The reading is since considered unreliable.

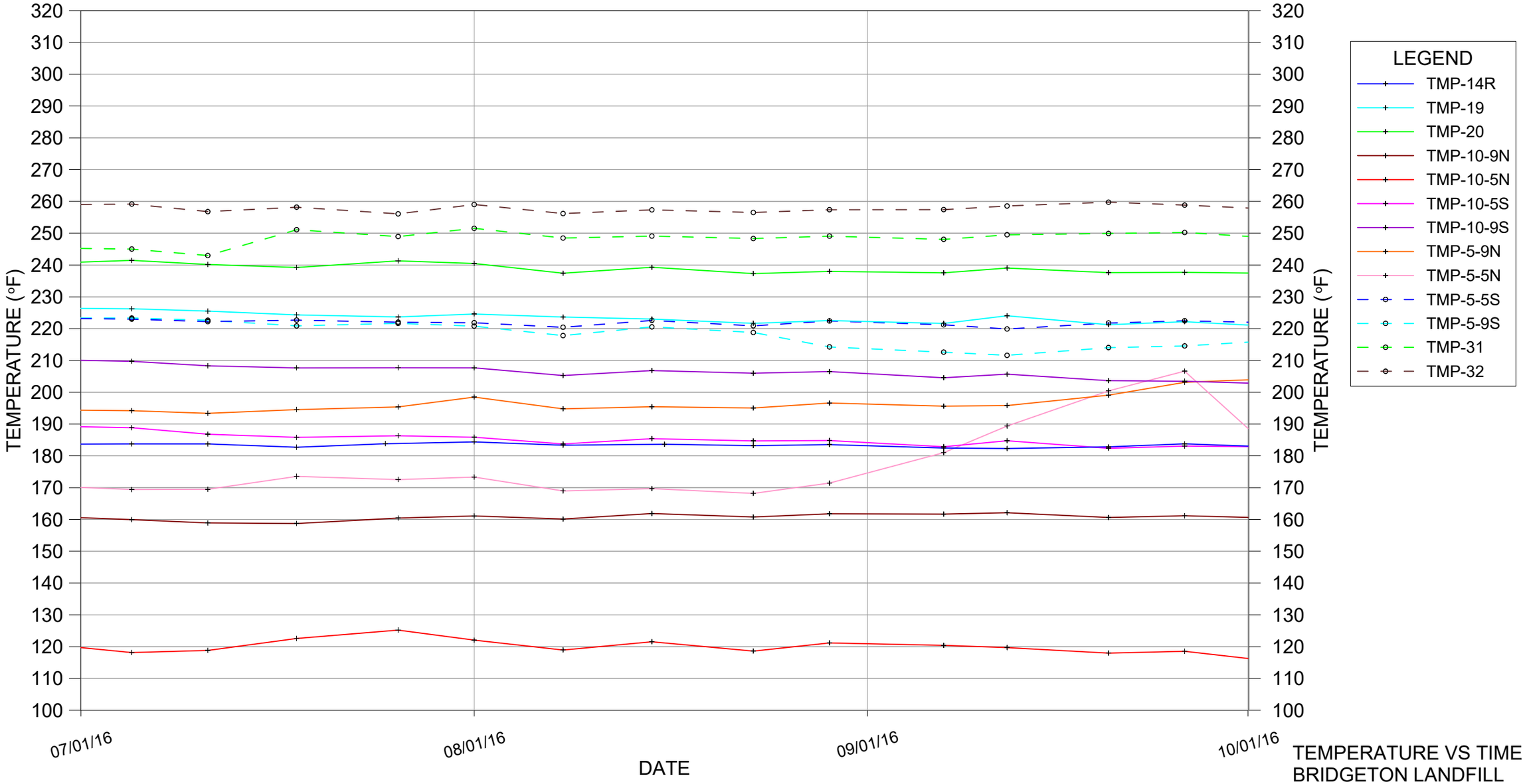
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

TMP-32



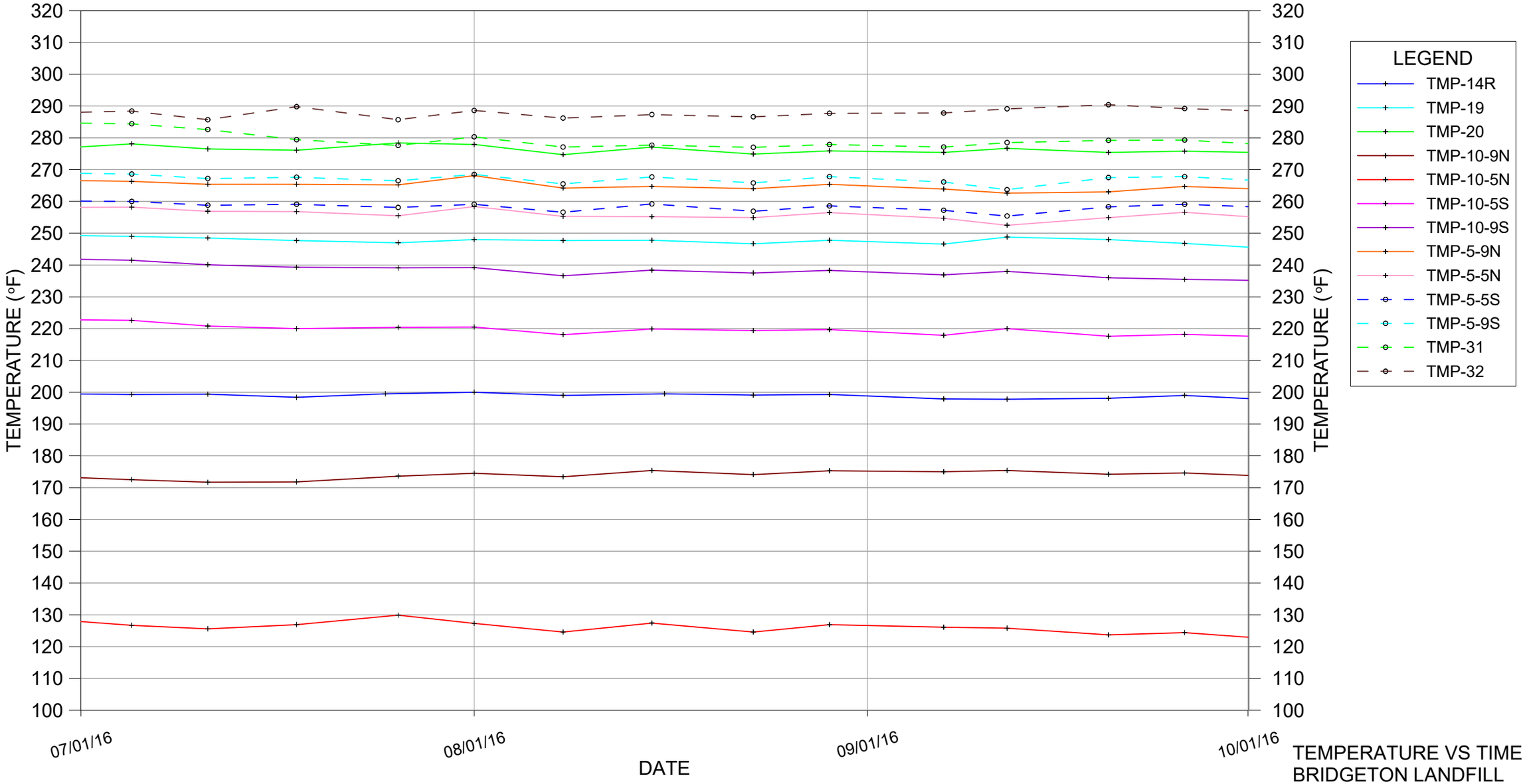
TEMPERATURE VS DEPTH
BRIDGETON LANDFILL

AVERAGE TEMPERATURES



TEMPERATURE VS TIME
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

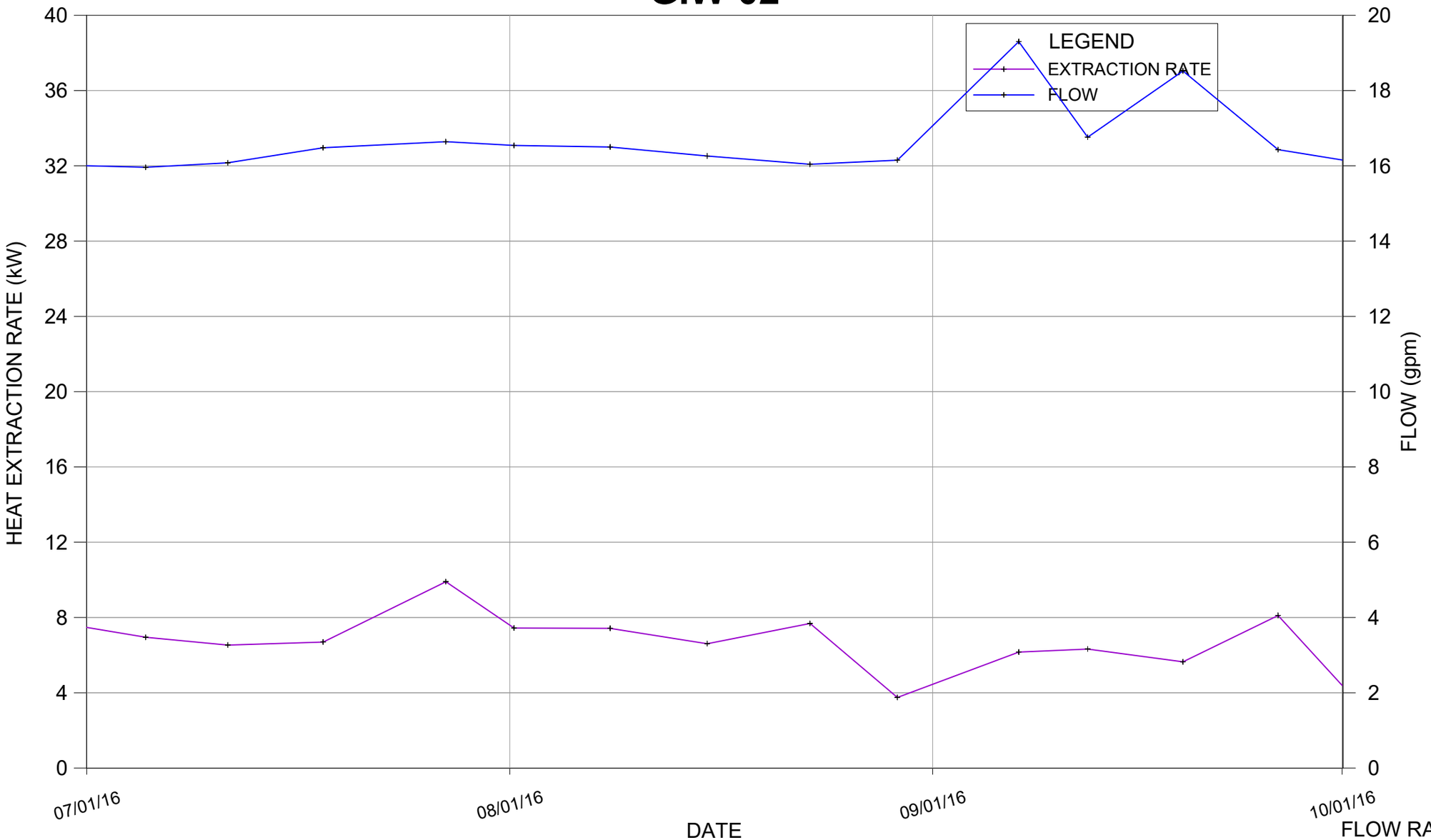
MAXIMUM TEMPERATURES



TEMPERATURE VS TIME
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

Appendix B – Heat Removal Point Data Graphs (Third Quarter 2016)

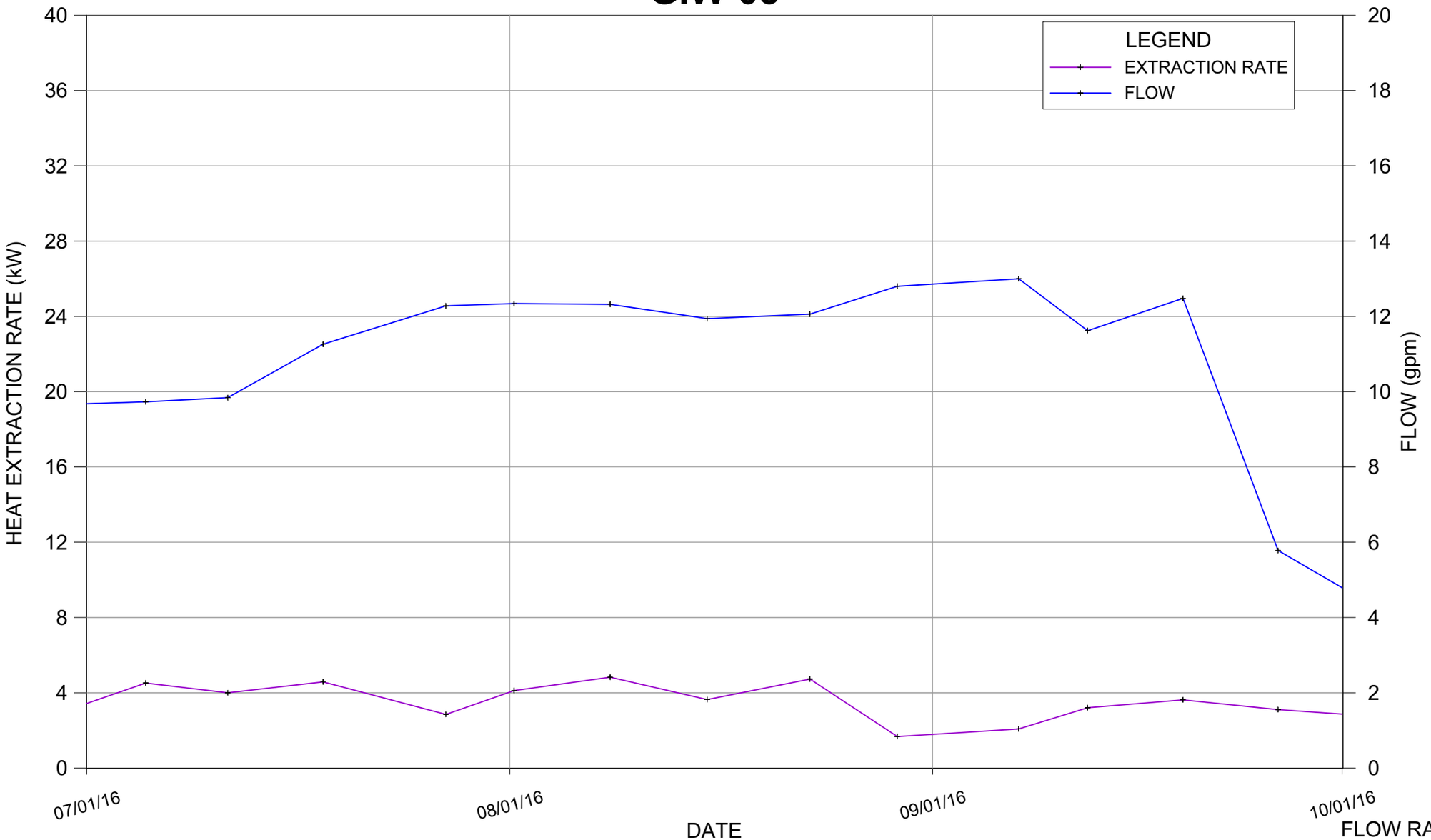
GIW-02



Note: Heat extraction rate data points are calculated based on instaneously measured input and output temperatures and provide an snapshot. Input and output temperatures fluctuate and the heat extraction rate varies inbetween data points from the connecting lines shown.

FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

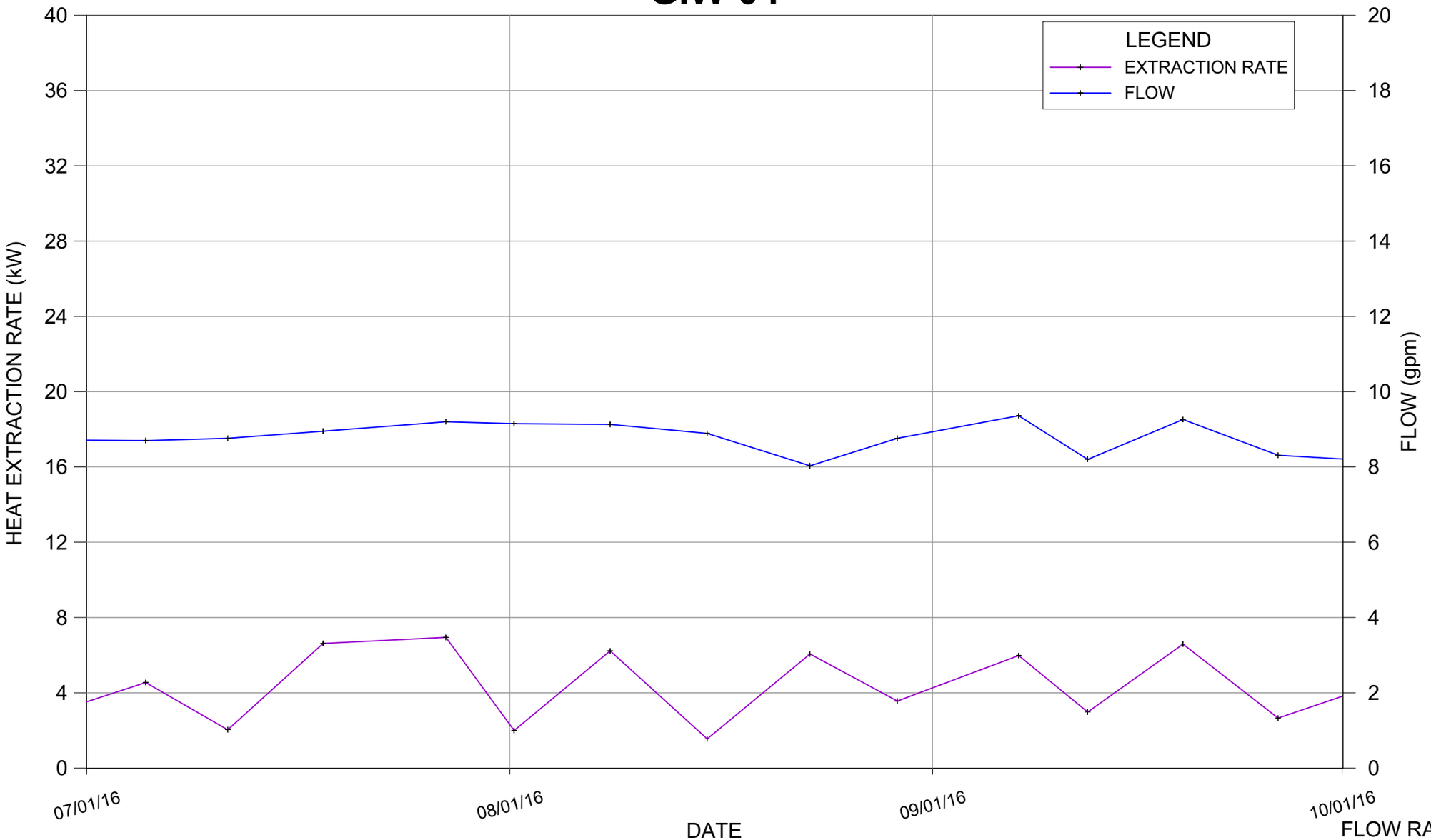
GIW-03



Note: Heat extraction rate data points are calculated based on instaneously measured input and output temperatures and provide an snapshot. Input and output temperatures fluctuate and the heat extraction rate varies inbetween data points from the connecting lines shown.

FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

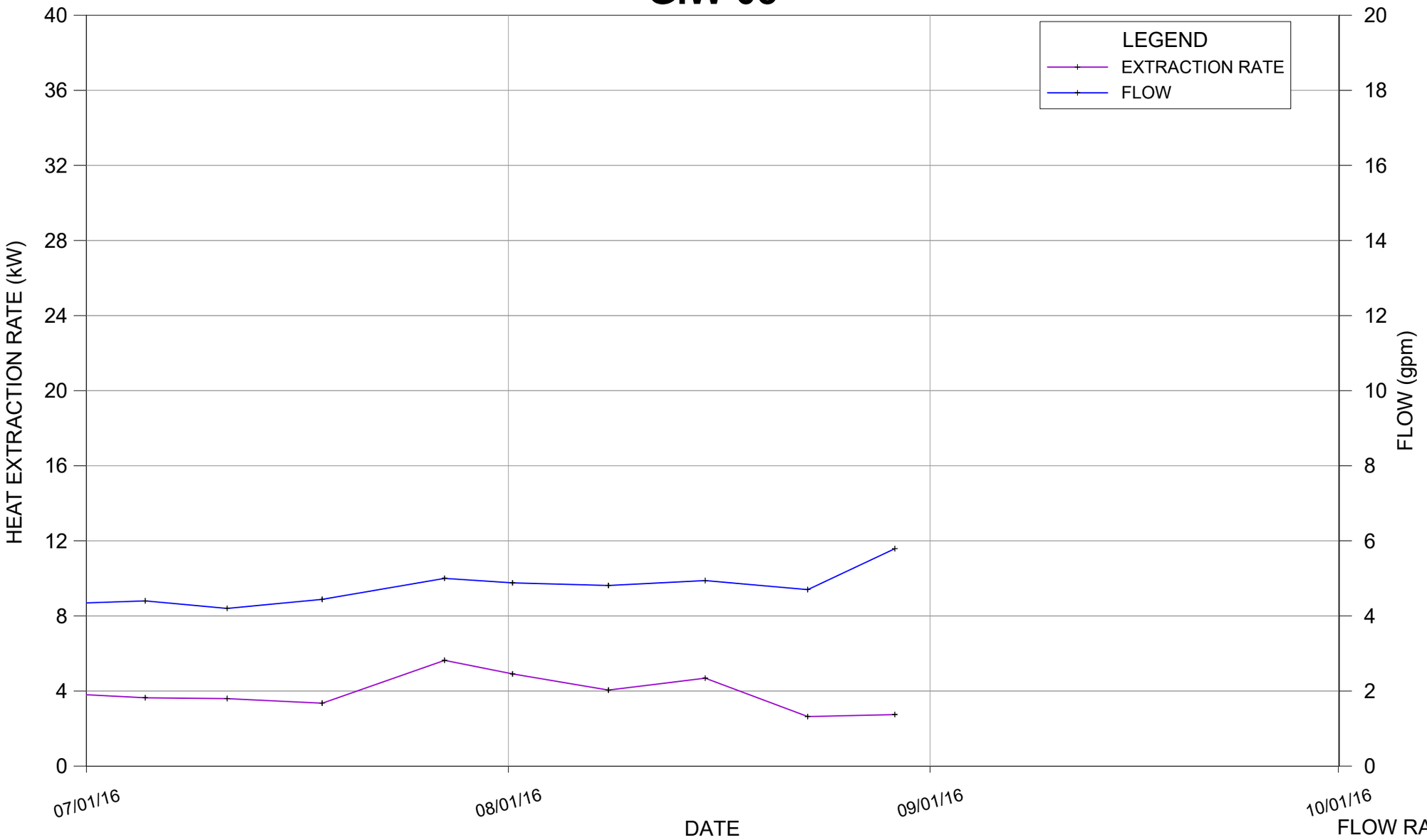
GIW-04



Note: Heat extraction rate data points are calculated based on instaneously measured input and output temperatures and provide an snapshot. Input and output temperatures fluctuate and the heat extraction rate varies inbetween data points from the connecting lines shown.

FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

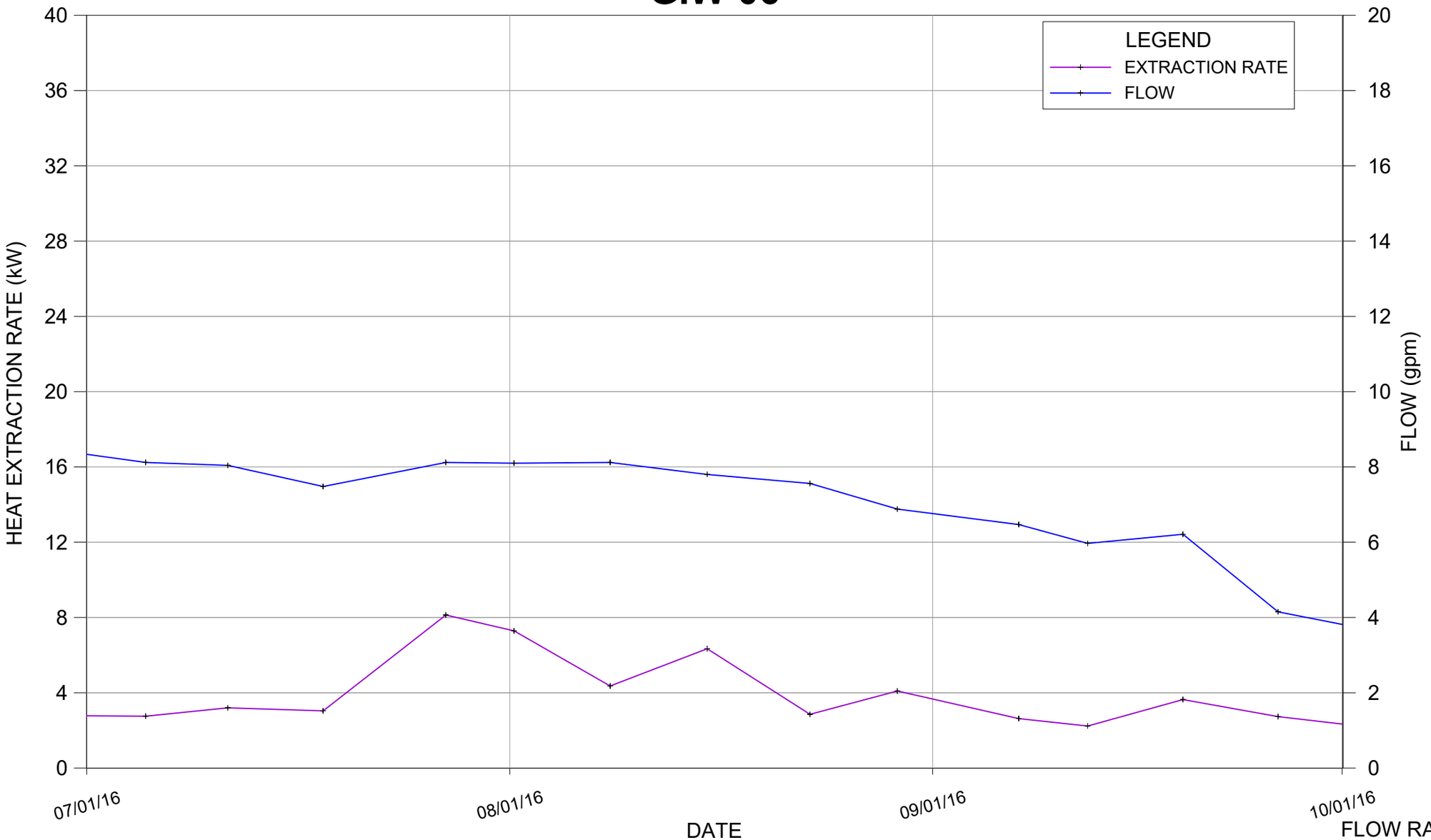
GIW-05



Note: Heat extraction rate data points are calculated based on instaneously measured input and output temperatures and provide an snapshot. Input and output temperatures fluctuate and the heat extraction rate varies inbetween data points from the connecting lines shown.

FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

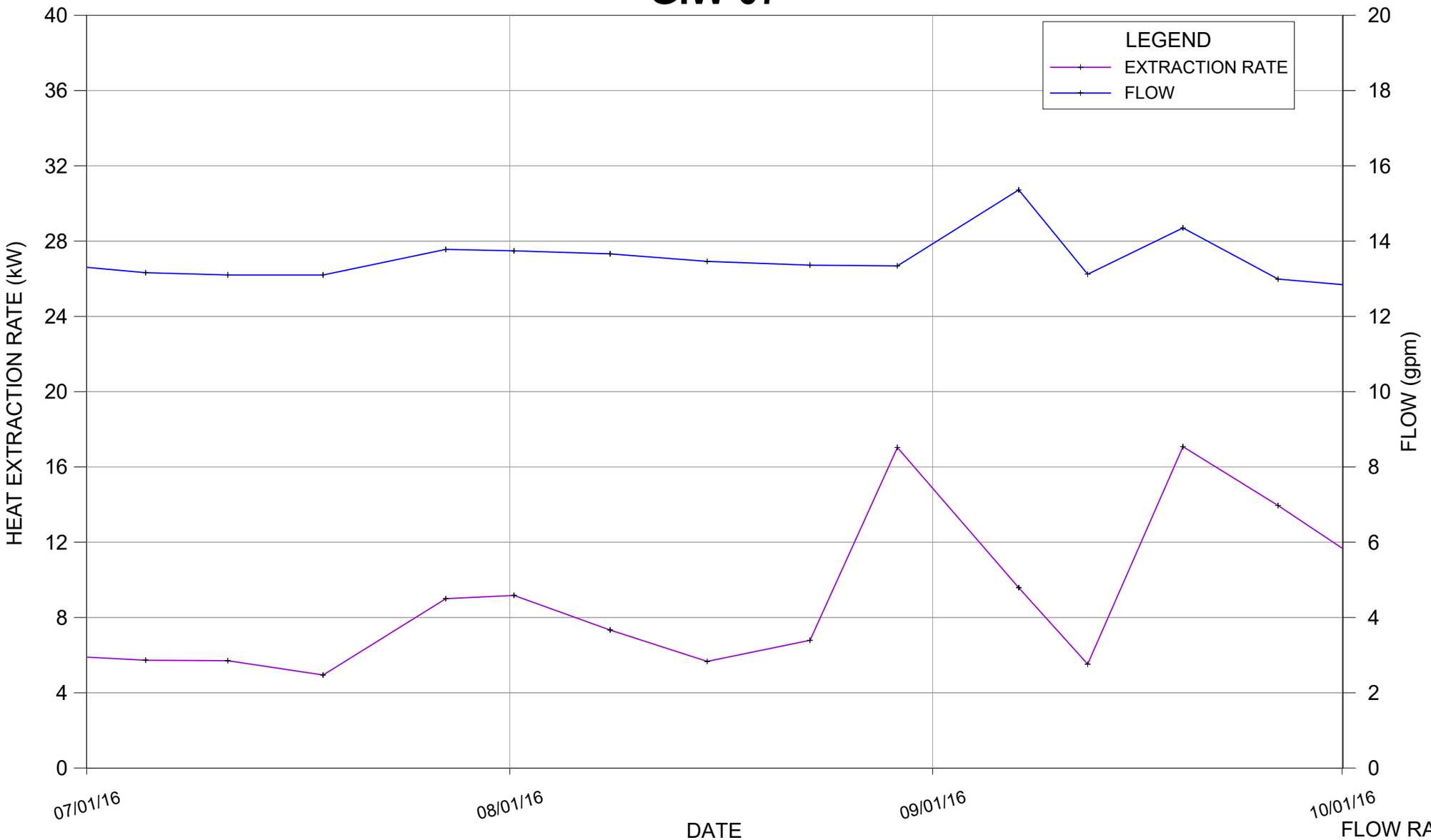
GIW-06



Note: Heat extraction rate data points are calculated based on instaneously measured input and output temperatures and provide an snapshot. Input and output temperatures fluctuate and the heat extraction rate varies inbetween data points from the connecting lines shown.

FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

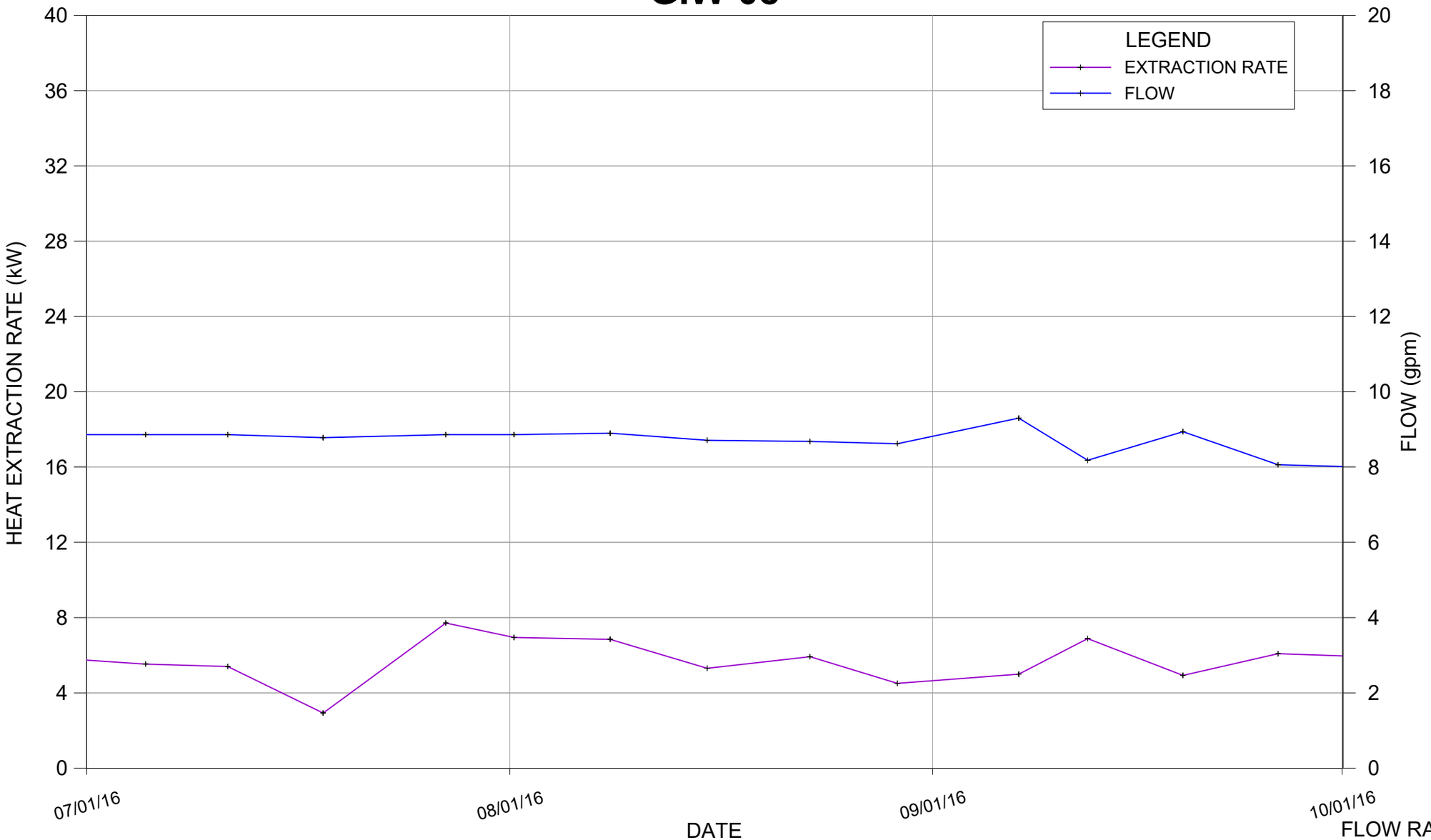
GIW-07



Note: Heat extraction rate data points are calculated based on instaneously measured input and output temperatures and provide an snapshot. Input and output temperatures fluctuate and the heat extraction rate varies inbetween data points from the connecting lines shown.

FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

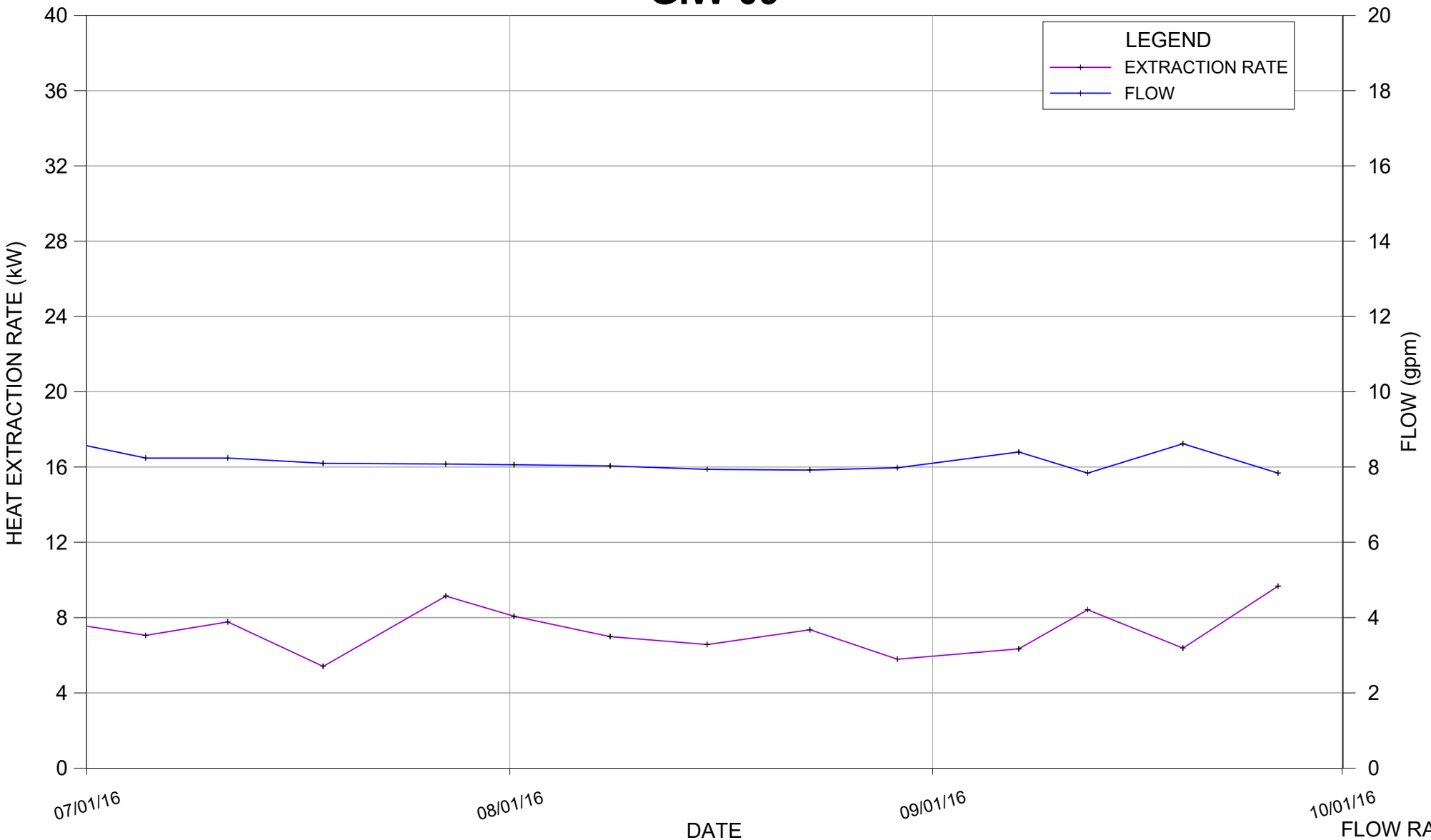
GIW-08



Note: Heat extraction rate data points are calculated based on instaneously measured input and output temperatures and provide an snapshot. Input and output temperatures fluctuate and the heat extraction rate varies inbetween data points from the connecting lines shown.

FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

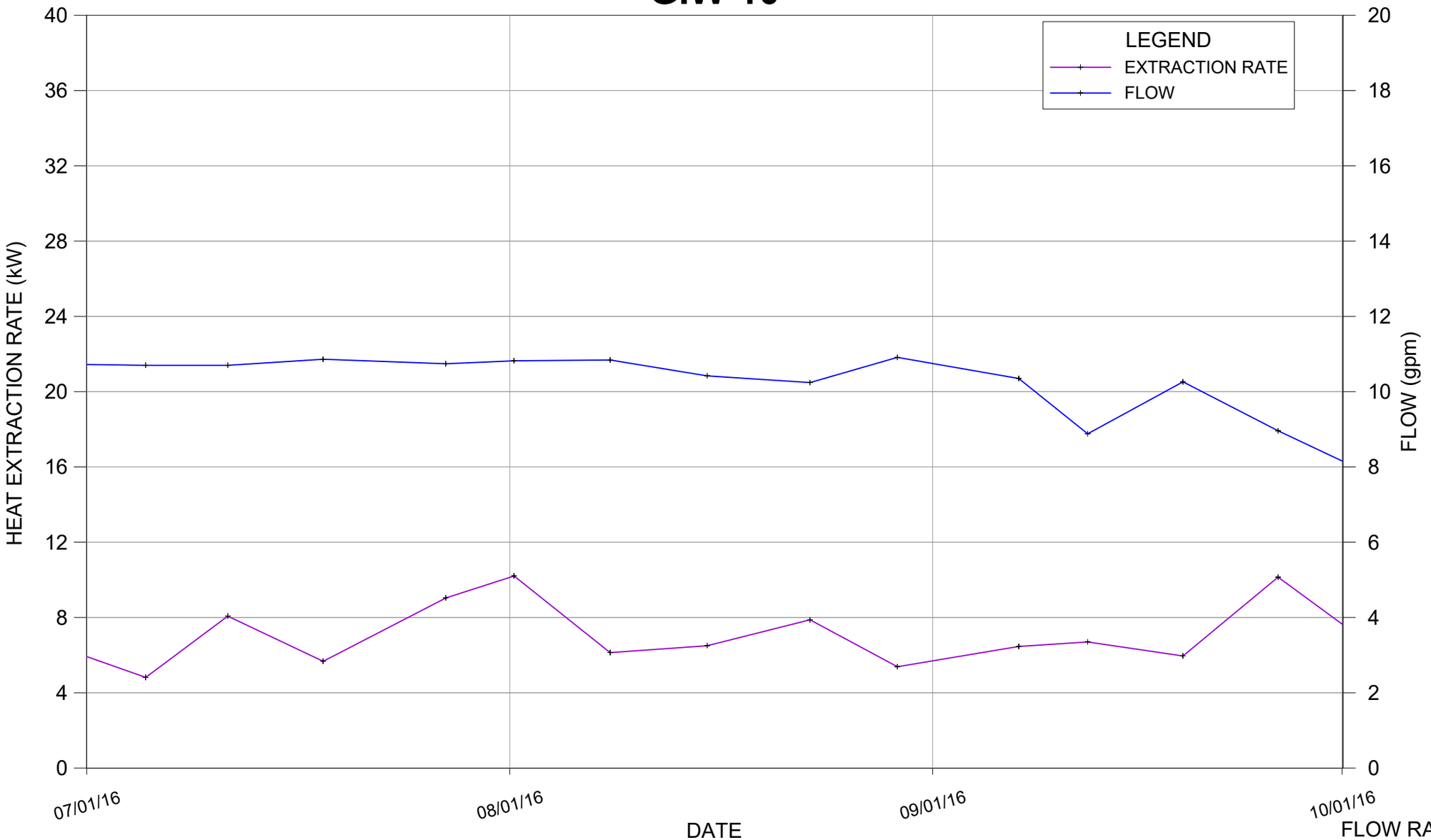
GIW-09



Note: Heat extraction rate data points are calculated based on instaneously measured input and output temperatures and provide an snapshot. Input and output temperatures fluctuate and the heat extraction rate varies inbetween data points from the connecting lines shown.

FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

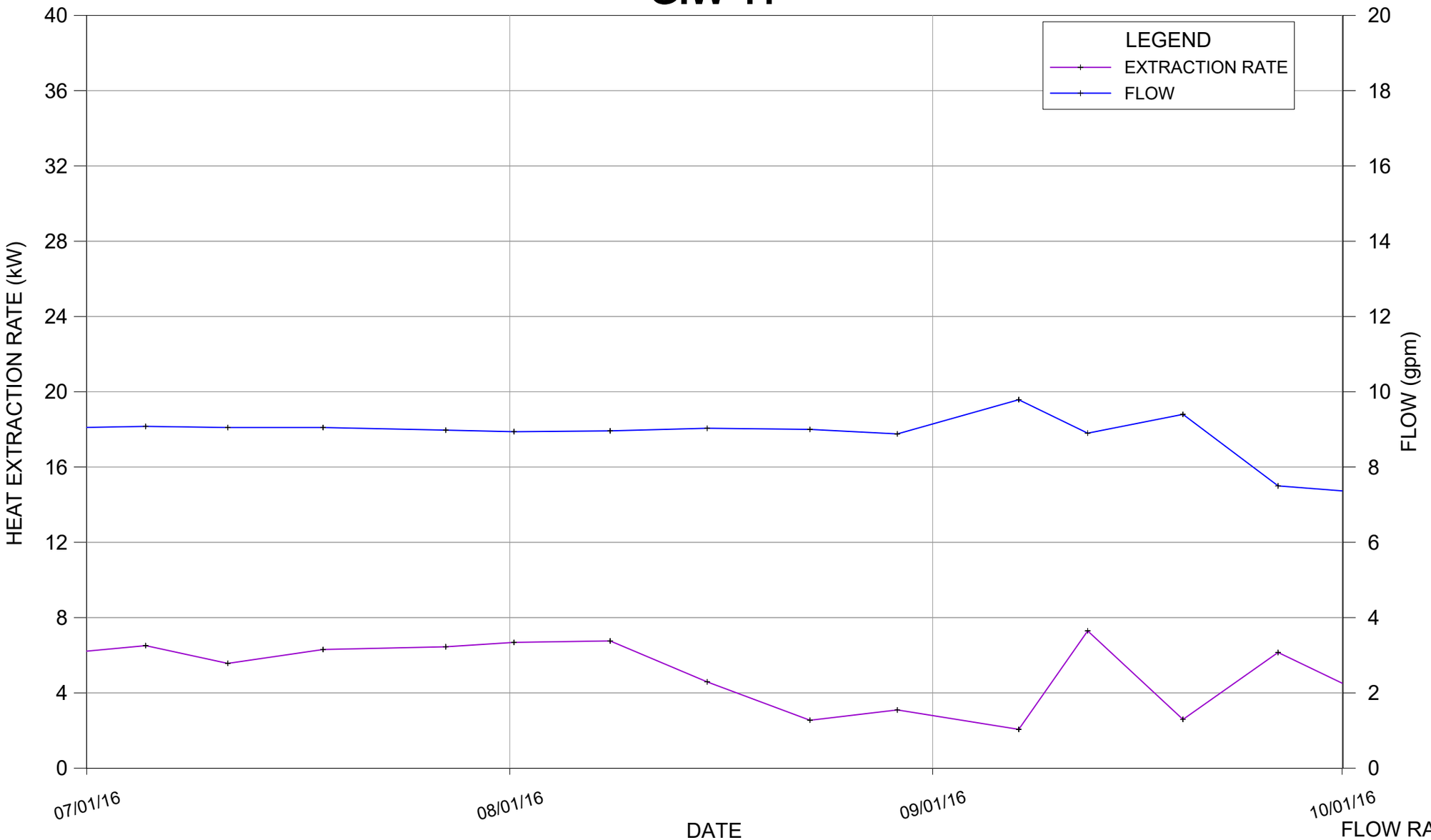
GIW-10



Note: Heat extraction rate data points are calculated based on instaneously measured input and output temperatures and provide an snapshot. Input and output temperatures fluctuate and the heat extraction rate varies inbetween data points from the connecting lines shown.

FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

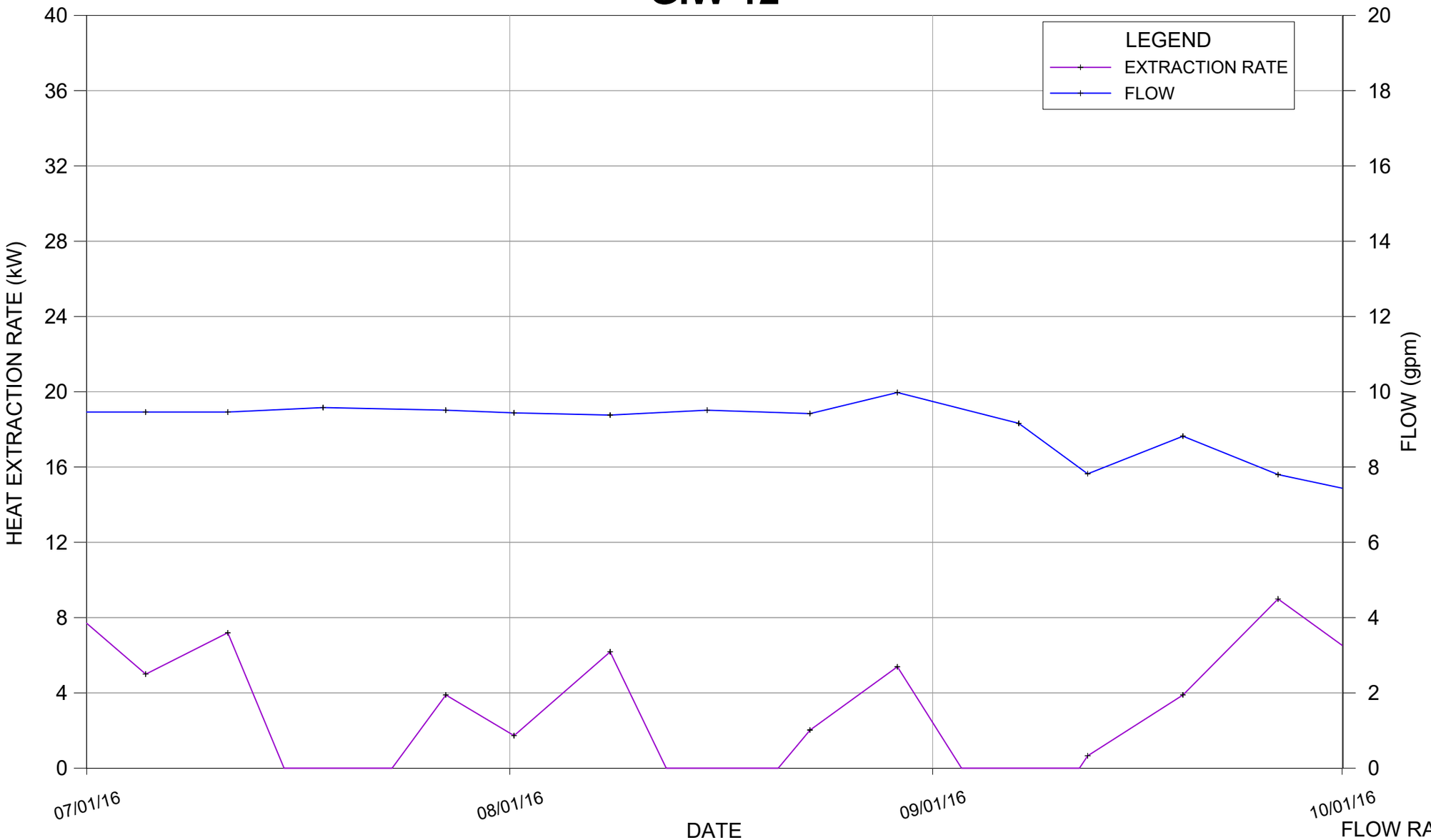
GIW-11



Note: Heat extraction rate data points are calculated based on instaneously measured input and output temperatures and provide an snapshot. Input and output temperatures fluctuate and the heat extraction rate varies inbetween data points from the connecting lines shown.

FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

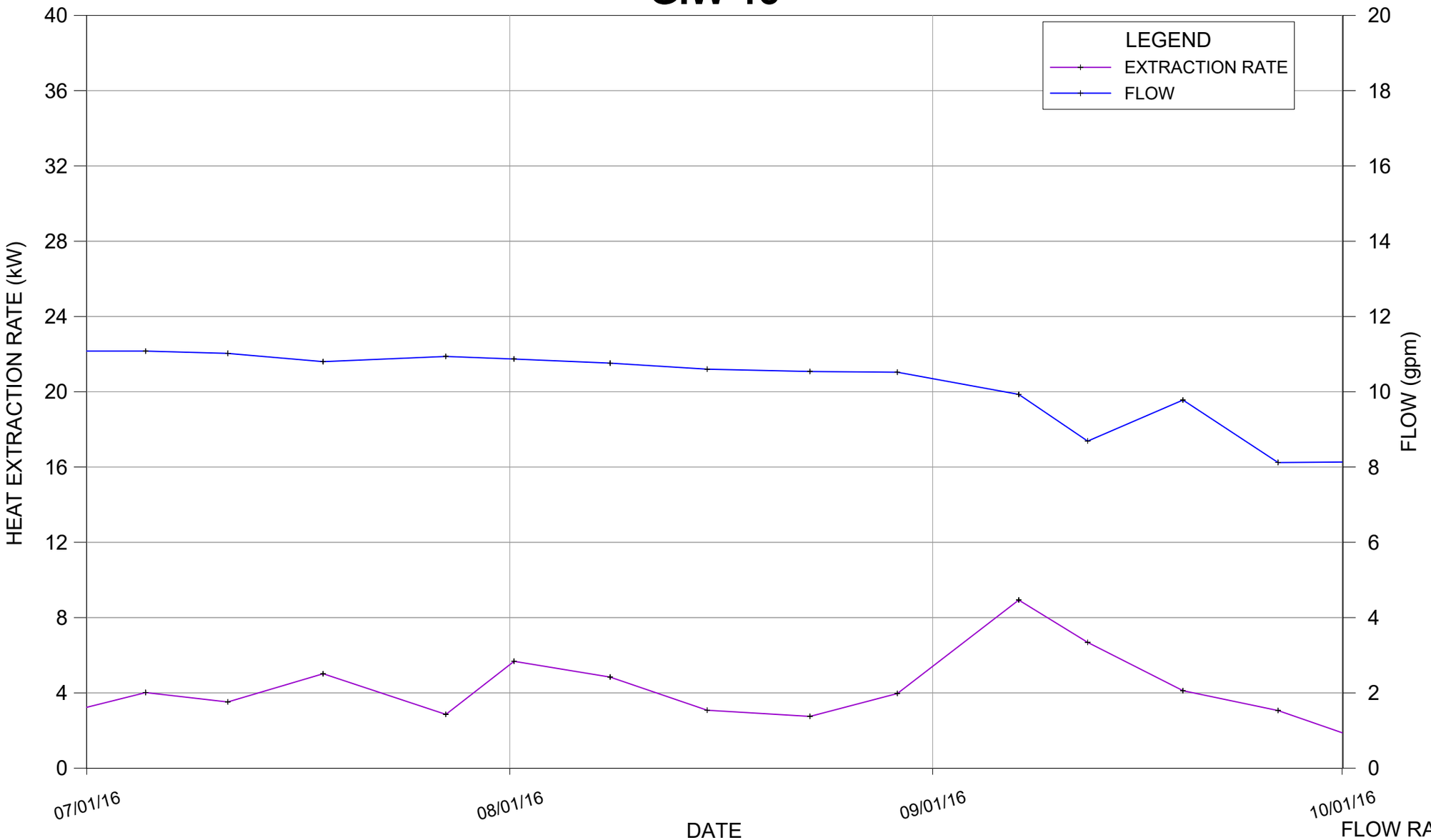
GIW-12



Note: Heat extraction rate data points are calculated based on instaneously measured input and output temperatures and provide an snapshot. Input and output temperatures fluctuate and the heat extraction rate varies inbetween data points from the connecting lines shown.

FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

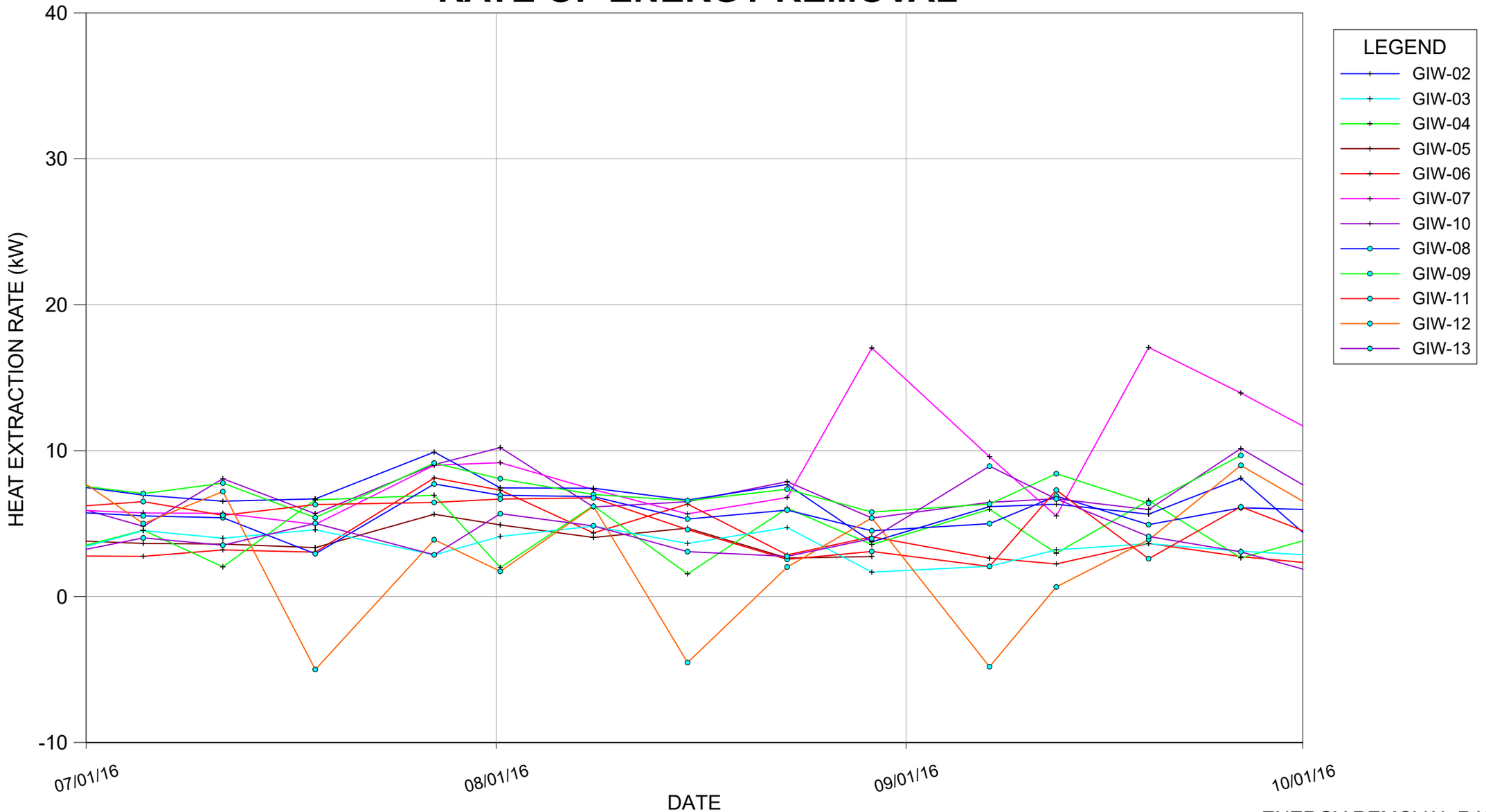
GIW-13



Note: Heat extraction rate data points are calculated based on instaneously measured input and output temperatures and provide an snapshot. Input and output temperatures fluctuate and the heat extraction rate varies inbetween data points from the connecting lines shown.

FLOW RATE AND HEAT EXTRACTION VS TIME
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

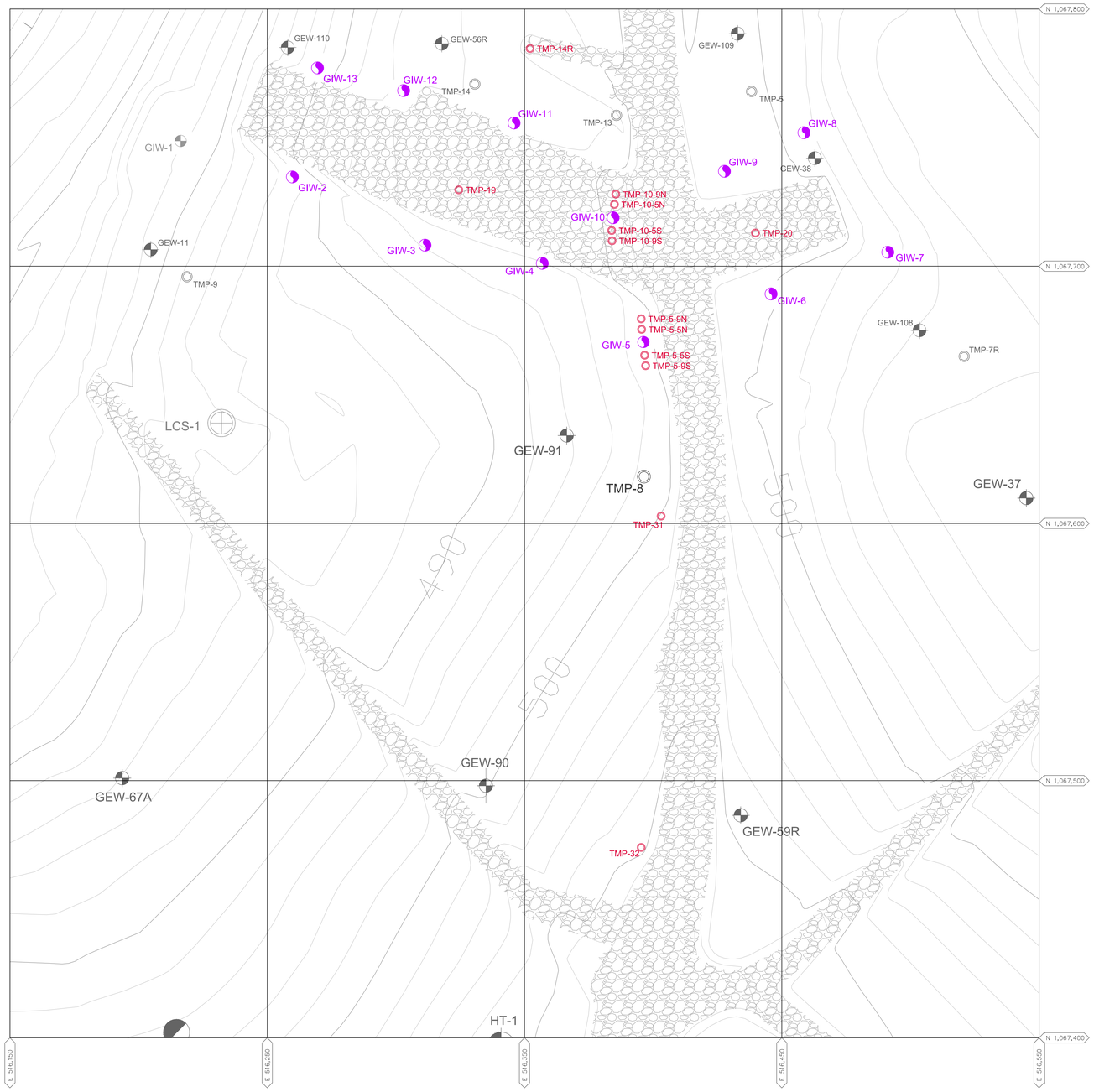
RATE OF ENERGY REMOVAL

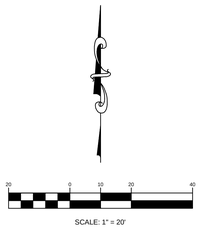


Note: Heat extraction rate data points are calculated based on instaneously measured input and output temperatures and provide an snapshot. Input and output temperatures fluctuate and the heat extraction rate varies inbetween data points from the connecting lines shown.

ENERGY REMOVAL RATE
BRIDGETON LANDFILL
(07/01/16 - 09/30/16)

Appendix C – Temperature Monitoring Probe Layout





LEGEND

- EXISTING GRADE (2' CONTOUR)
- 500 EXISTING GRADE (10' CONTOUR)
- EXISTING GAS EXTRACTION WELL
- EXISTING GAS INTERCEPTOR WELL
- EXISTING TEMPERATURE MONITORING PROBE
- HEAT REMOVAL POINT WITHIN GAS INTERCEPTOR WELL
- PILOT STUDY TEMPERATURE MONITORING PROBE

TMP INSTALLATION			
ID	Northing	Easting	Depth (ft)
TMP-19	1067729.43	516324.34	140
TMP-14R	1067784.62	516352.17	140
TMP-20	1067712.59	516439.87	140
TMP-5-9S	1067661.16	516397.18	100
TMP-5-5S	1067665.2	516396.79	100
TMP-5-5N	1067675.28	516395.69	100
TMP-5-9N	1067679.41	516395.37	100
TMP-10-9S	1067709.77	516384.13	100
TMP-10-5S	1067713.85	516384	100
TMP-10-5N	1067723.9	516384.95	100
TMP-10-9N	1067727.77	516385.53	100
TMP-31	1067602.84	516403.11	192.96
TMP-32	1067474.00	516395.36	205.2

NOTES:
1.) AERIAL TOPOGRAPHY WAS PROVIDED BY COOPER AERIAL SURVEYS CO. AND IS DATED MARCH 20, 2014.

BRIDGETON LANDFILL, LLC
13570 ST. CHARLES ROCK ROAD
BRIDGETON, MISSOURI 63044

TEMPERATURE MONITORING PROBE LAYOUT

TEMPERATURE MONITORING PROBE LAYOUT

Engineering for a Better World
FEEZOR ENGINEERING, INC.

PROJECT NUMBER: BT-045 | FILE PATH:

OCTOBER 2015
DESIGNED BY: AMR
APPROVED BY: ALK

REVISION	DATE

DRAWING NO.:
001

Appendix D – Heat Removal System Plan View

EQUALIZATION TANK

SYSTEM PUMP

CLOSED LOOP COOLING TOWER

SPRAY WATER TREATMENT

BLOWDOWN LINE TO MSD LIFT STATION

GEW-9
GEW-202
GEW-40R
GEW-40
TMP-1
TMP-2
TMP-3
TMP-3R
GEW-10
TMP-10
GEW-39
TMP-4R
TMP-4
TMP-11
TMP-12
TMP-6
GEW-96R
TMP-14R
GEW-110
GIW-13
GIW-12
TMP-14
GEW-109
TMP-13
TMP-5
GIW-11
GIW-8
GIW-1
GEW-38
GIW-9
GIW-2
TMP-19
GIW-10
TMP-10-9N
TMP-10-5N
TMP-10-5S
TMP-10-9S
TMP-20
GIW-7
GEW-11
GIW-4
GIW-3
TMP-9
GIW-6
GEW-108
TMP-5-9N
TMP-5-5N
TMP-7R
GIW-5
TMP-5-5S
TMP-5-9S
LCS-1
GEW-91
TMP-8
TMP-31
GEW-37
GEW-149
GEW-154
GEW-153
GEW-107
GEW-112
GEW-14A
GEW-13A
GEW-148
GEW-90
GEW-152
GEW-113
GEW-87A
GEW-59R
TMP-32
GEW-36
GC-5
GEW-151
GEW-106
AIT-1
AIT-2

460 470 480 490 500 510

LEGEND

- EXISTING GRADE (2' CONTOUR)
- 500 EXISTING GRADE (10' CONTOUR)
- EXISTING GAS EXTRACTION WELL
- EXISTING TEMPERATURE MONITOR PROBE
- EXISTING HEAT EXTRACTION POINT
- 4" COOLING LOOP INFLUENT PIPING (EXISTING)
- 2" COOLING LOOP INFLUENT PIPING (EXISTING)
- 4" COOLING LOOP EFFLUENT PIPING (EXISTING)
- 2" COOLING LOOP EFFLUENT PIPING (EXISTING)
- TEMPERATURE MONITORING LOCATION
- CHECK VALVE
- FLOW CONTROL VALVE
- FLOWMETERS
- EXISTING SOLID WASTE PERMIT BOUNDARY
- EXISTING QUARRY HIGHWALL

30 0 15 30 60

SCALE: 1" = 30'

NOTES:
1.) AERIAL TOPOGRAPHY WAS PROVIDED BY COOPER AERIAL SURVEYS CO. AND IS DATED MARCH 20, 2014.

BRIDGETON LANDFILL, LLC 13570 ST. CHARLES ROCK ROAD BRIDGETON, MISSOURI 63044	BRIDGETON LANDFILL EXPANDED HEAT EXTRACTION PILOT STUDY ADDITIONAL HEAT EXTRACTION PTS	FEEZOR ENGINEERING, INC. Engineering for a Better World	OCTOBER 2015 DESIGNED BY: DMK APPROVED BY: ALK
HEAT REMOVAL SYSTEM PLAN VIEW			DRAWING NO.: **001**
PROJECT NUMBER: BT-062	FILE PATH: C:\Users\aaron\Desktop\4Q Quarterly Report\BT-001A-Proposed Cooling Points- As Built\ Corporate Print 10-7-15.dwg		REVISION / DATE

Appendix E – Heat Extraction System Operating Log (Third Quarter 2016)

BRIDGETON LANDFILL

Heat Extraction System Operating Log

Name: Jon Wilkinson

Date: 7/15/2016

Time: 0705

Actions Taken or Observations:

Cooling loop pump observed to be deactivated.
Restart Cooling loop pump.

BRIDGETON LANDFILL

Heat Extraction System Operating Log

Name: Michael Spurgeon

Date: 7-18-16

Time: 0800

Actions Taken or Observations:

GIW-7 Flow meter not working

BRIDGETON LANDFILL

Heat Extraction System Operating Log

Name: Michael Spurgeon

Date: 7-20-16

Time: 0930

Actions Taken or Observations:

- Replaced TML-3 Temperature probe

BRIDGETON LANDFILL

Heat Extraction System Operating Log

Name: Michael

Date: 7-20-16

Time: 1130

Actions Taken or Observations:

Took apart GIV-7 flow meter. Flow meter was clogged. I removed accumulated matter. Flow meter back to normal

BRIDGETON LANDFILL

Heat Extraction System Operating Log

Name: Michael Spurgeon

Date: 7-25-16

Time: 0800

Actions Taken or Observations:

0800 - Heat Extraction System down
0810 → Turned System back on, but no temperature reading.
0900 → Called Rich @ BAC to come take a look at it.
1330 → Rich with BAC arrived and determine The temperture Transmitter was bad.
1500 → BAC will come replace Transmitter Tomorrow.

BRIDGETON LANDFILL

Heat Extraction System Operating Log

Name: Michael A. Spurgeon

Date: 7-26-16

Time: 1100

Actions Taken or Observations:

1100 - Joshua Smith More (BAC) came out and replaced Temperature Transmitter.

1200 - Checked system. Everything is working.

BRIDGETON LANDFILL

Heat Extraction System Operating Log

Name: Michael Spurgeon

Date: 9-4-16

Time:

Actions Taken or Observations:

1000 → Heat Extraction System down. needs new pump.

1100 → GIW 5 shut down, due to Construction

1600 → System is Turned back on. System is operational

BRIDGETON LANDFILL

Heat Extraction System Operating Log

Name: Brad Vits

Date: 9/30/2016

Time: 8:15-12:20

Actions Taken or Observations:

8:15 - GIW-10 taken offline

9:05 - Hayes Mechanical and Budrovich remove 120' of 1" stainless steel heat exchanger tubing. Install 120' of 2.5" stainless steel sch. 40 with full weld at seam. 119' of 1" stainless steel sch. 40 with threaded couplers previously installed inside of 2.5" and previously mounted to 6" blind flange with pass through 2.5" coupler. Follow revised heat exchanger piping installation. Hayes Mechanical installs wellhead consistent with GIW-8, 9, 11, 12 and 13. Wellhead is connected to existing cooling fluid distribution piping with monitoring and tuning fittings. Budrovich demobilizes from site and Hayes Mechanical begins cleanup.

12:20 GIW-10 brought back online.

BRIDGETON LANDFILL

Heat Extraction System Operating Log

Name: Brad Vits

Date: 9/30/2016

Time: 8:15-12:30

Actions Taken or Observations:

08:15 - GIW-5 taken offline previously by site personnel

9:05 - Hayes Mechanical and Budrovich remove 63' of 1" stainless steel heat exchanger tubing. Install 63' of 2.5" stainless steel sch. 40 with full weld at seam. 62' of 1" stainless steel sch. 40 with threaded couplers previously installed inside of 2.5" and previously mounted to 6" blind flange with pass through 2.5" coupler. Follow revised heat exchanger piping installation. Hayes Mechanical installs wellhead consistent with GIW-8, 9, 11, 12 and 13. Wellhead is connected to existing cooling fluid distribution piping with monitoring and tuning fittings. Budrovich demobilizes from site and Hayes Mechanical begins cleanup.

12:30 GIW-5 brought back online.