
FRESH KILLS LANDFILL

LEACHATE CONTROLS AT LANDFILL SECTION 2/8 AND LANDFILL SECTION 3/4 REPORT

Submitted to:

New York State

Department of Environmental Conservation

Prepared by:

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Under the Direction of:

New York City Department of Sanitation

Waste Management Engineering

44 Beaver Street, 9th Floor

New York, NY 10004



Date: July 30, 2015

Document No. 151771-000-GN-RP-00033

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Executive Summary

In 1990, the New York City Department of Sanitation (DSNY) and the New York State Department of Environmental Conservation (NYSDEC) entered into an Order on Consent (Consent Order). The 1990 Order on Consent was negotiated with the intent to obtain an operating permit for Sections 1/9 and 6/7 and develop an interim plan to operate Sections 2/8 and 3/4 while developing and implementing the final closure plan for Sections 2/8 and 3/4.

In October 1998, DSNY and NYSDEC agreed to Order on Consent Modification No. 6. This modification consisted of the revision to Appendix A-4 – Fresh Kills Leachate Mitigation Report and the addition of Appendix A-14 – Landfill Leachate Mitigation of Sections 2/8 and 3/4. Appendix A-14 set forth the requirements and milestones for leachate controls at Sections 2/8 and 3/4.

ES1.0 Leachate Control Systems

The Leachate Control Systems at Sections 2/8 and 3/4 consist of the following components: final cover and drainage, perimeter leachate collection drains both original and supplemental, and center leachate recovery wells. There are three types of final cover in each of Sections 2/8 and 3/4. Types I and II final cover include geosynthetics, and Type III final cover consists of low permeable soils. Drainage swales divert surface water runoff from the landfill cover to stormwater basins installed outside the limits of final cover throughout Sections 2/8 and 3/4.

Both the original and supplemental leachate collection drains are an open system, as they are located outside the limits of the final cover. As such, they are influenced by leachate, groundwater, and precipitation into the drain, as well as overland precipitation runoff and final cover seepage flow. The supplemental drains are also influenced by surface water flow because of their proximity to Main and Richmond Creeks.

The overall length of the original leachate collection drains is 4,950 linear feet. Of this total, 2,150 linear feet are located in Section 2/8, and 2,800 linear feet are located in Section 3/4. The overall length of the Supplemental Drains is 5,465 linear feet. Of this total, 3,965 linear feet are in Section 2/8 and 2,500 linear feet are in Section 3/4.

The design of the original leachate collection drains consists of a 3-foot wide trench with a bottom elevation of -0.5 to +1.5 feet as measured by the Richmond High Water Datum (RHWD). There is a 6-inch diameter slotted high density polyethylene (HDPE) pipe approximately 6 inches off the bottom of the trench. The trench is filled with New York State Department of Transportation (NYSDOT) No. 2 stone. Leachate is removed from the collection drain using a

pumping station. The pumping station consists of a 24-inch diameter collection well located inside a collection well vault with the pump regulated by an electric control panel. The design of the supplement drains is similar with the exception that the bottom elevation of the drains is at an elevation -2 feet RHWD.

The Center Leachate Recovery Well program consisted of six center recovery wells installed in Sections 2/8 and 3/4 between late 1996 to early 1997 and began operating in 1998. No well averaged more than one gallon per minute (gpm), which equates to less than 1,440 gpd. Because of the low leachate collection rates, problems with structural integrity and operations, and cost to install compared to the amount of leachate collected by the leachate recovery wells, it was recommended that the leachate recovery well program be abandoned. NYSDEC approved the abandonment of the leachate recovery wells on May 15, 2013. Well abandonment and appurtenance removal was performed in June 2013.

ES2.0 Evaluation of Systems Operations

An evaluation of the leachate collection rates based on totalizer readings and SCADA-recorded data demonstrates that leachate collection rates are impacted by the following:

- Horizontal leachate flow from refuse mound;
- Groundwater flow;
- Surface water bodies;
- Precipitation runoff and seepage;
- Duration of operation of pump in collection well; and
- Pump off elevations.

Leachate collection rates at the treatment plant are obtained through the use of two methods, SCADA (continuous electronic) and totalizers (manual). The monthly totalizer readings were summed to provide annual leachate collection rates. For the Section 2/8 original drain, a significant decrease in the leachate collection rate is observed between 2001 and 2002 and a decrease in the leachate collection rate is seen from 2003 to 2014. In the Section 3/4 original drain, a decrease in the annual leachate collection rate is seen between the 2006 and 2007 annual periods. The Sections 2/8 and 3/4 supplemental drain annual leachate collections show an overall decreasing trend in the collection rates.

The annual, monthly and daily leachate collection rate graphs clearly show the effect of precipitation on the collection rates. The periods of lowest collection rates are used to evaluate for base flow conditions. The base flow condition occurs when leachate is primarily being collected in the drain (i.e., horizontal leachate flux from the refuse mound) without contribution from precipitation. The precipitation from runoff and seepage, duration of the operation of the

pump in the collection well, and pump on and pump off elevations is determined by evaluation of the SCADA- recorded leachate elevation and flow rate data.

The groundwater flow component in the original drains and the groundwater and surface water (i.e., Main and Richmond Creeks) components in the supplemental drains are difficult if not impossible to determine; therefore, these components are conservatively counted as leachate in this evaluation.

ES3.0 Evaluation of Environmental Data

To determine the effect of the leachate control systems environmental monitoring data are evaluated including chemistry data for groundwater and surface water and groundwater elevations. Groundwater chemistry data is evaluated from shallow/refuse monitoring wells at Landfill Section 2/8 and Landfill Section 3/4 as they relate to the original collection drains, the supplemental collection drains, or the areas of each section for which there are no drains. Water level elevation data is presented and evaluated for select shallow/refuse monitoring wells contiguous to the original drains at Landfill Section 2/8 and Landfill Section 3/4 as well as piezometer sets installed as part of the supplemental drains. Surface water chemistry data is evaluated for the creeks that border the landfill sections at Fresh Kills Landfill as well as for the smaller tributaries of those creeks.

Groundwater quality monitoring analytical data are evaluated in several manners:

- Piper and Stiff diagrams
- Time series plots for select leachate indicator parameters
- Statistical trend analysis

The proportions of many dissolved solutes in leachate and natural groundwater should be different because the composition of landfill waste and its associated geochemical relations are different than the mineral-water reactions in the underlying geologic materials. In general, groundwater that has mixed with seawater has a very typical sodium-chloride composition that is clearly discernible on the Piper and Stiff diagrams. Groundwater that shows evidence of leachate mixing has a distinctive sodium-bicarbonate composition which is also evident on the Piper and Stiff diagrams.

A Stiff diagram is a type of plot that depicts water composition by shape recognition. The anions chloride, bicarbonate, and sulfate (Cl^- , HCO_3^- , and SO_4^{2-}) are plotted on the right side of the diagram, and the cations sodium, potassium, calcium, and magnesium (Na^+ , K^+ , Ca^{2+} , and Mg^{2+}) are plotted on the left side of the diagram. Piper diagrams are useful for interpreting individual water compositions and mixtures of compositions. The Piper and Stiff diagrams show changes from leachate-influence composition to non-leachate influenced composition as well as seawater-influenced composition.

Ammonia, boron, and total dissolved solids are three parameters that are used to indicate leachate influence at Fresh Kills Landfill. Time series plots for these parameters are evaluated for each of the shallow/refuse zone monitoring wells in Landfill Sections 2/8 and 3/4. These plots generally show decreasing trends in concentration for these parameters.

Trends in groundwater chemistry data for other parameters analyzed for at Fresh Kills Landfill are evaluated by the Mann-Kendall test for trend. The Mann-Kendall test for trend was used to determine if an analyte shows a statistically significant trend in concentration or value at a specific well location.

Water level measurements collected from select shallow/refuse monitoring wells as well as piezometer sets along the drains are evaluated in this section on a monthly basis. The water levels show the effect that the operation of the drains. In general a decrease in water level is seen when the original drains began operating and over time a general increase in water level elevations is seen since operation began. The water levels from the piezometer sets show a gradient towards the drains, both on the landfill and outboard sides.

Surface water quality, monitoring began with the surface water and sediment investigation performed in 1991-1992 to determine the potential for leachate in shallow groundwater to affect. Long-term monitoring of surface water and sediment began in 1994 and continues under the EMP. The concentrations of ammonia measured in the Landfill creeks include loadings attributable to the Landfill as well as loading from upstream sources, from adjacent wetlands and from the Arthur Kill; therefore, the in-situ concentrations are likely to be higher than that which would result from the Landfill alone. The model-predicted decreasing surface water ammonia concentrations has been verified by the annual monitoring results even though there are multiple sources of ammonia to the Fresh Kills Landfill tidal creeks, The ammonia concentrations have not exceed applicable NYSDEC acute criteria in recent years of the monitoring program.

ES4.0 Summary and Conclusions

The evaluation of the leachate controls at Landfill Sections 2/8 and 3/4 shows that the components of leachate collection rates include:

- Horizontal leachate flow from refuse mounds;
- Groundwater flow from outside of collection drains;
- Surface water (Richmond and Main Creeks) flow towards drains (Supplemental Drains);
- Precipitation – directly into over drains, surface runoff and seepage through final cover;
- Operation of collection well pumps (operational down time);
- Collection well pump off elevation.

Precipitation has the largest effect on the leachate collection rates. The contribution of groundwater flow into the drains is more difficult to determine but likely is not significant in the original drains based on groundwater elevations in the groundwater monitoring wells that are proximate to the original drains.

Taking into account the above influences on the collection rates, base flows were determined for each of the four drains for each annual period. These base flows were used to determine the total amount of leachate collected in a year and graphs of these data show a decreasing trend in the base flows. Calculations show that leachate accounts for between 34% and 50% of the total volume collected.

The calculated base flow rates show a reduction in flow rate in the original drains from 1998 to 2015 of approximately 90% in Landfill Section 2/8 and approximately 70% in Landfill Section 3/4. In comparison, the model predicted total leachate discharge to decrease by approximately 80% at Landfill Section 2/8 and approximately 65% at Landfill Section 3/4 from 2000 to 2015 model output period. The model also predicted that flow in both Landfill Section 2/8 and Landfill Section 3/4 would be reduced to less than 80% of the 1993 baseline flow by or before 2012; the decreases in estimated base flows in the collection drains agrees with the model-predicted decreases. Estimates also show only a one to two percent difference in the 2015 model year between final cover only and final cover with the partial perimeter drains. This would indicate that there is no marginal benefit to additional collection, and that within the accuracy of the model, leachate flows have been controlled to the maximum extent practicable.

Lower leachate flow and consistent runoff has changed the groundwater composition at the toe of slope. Factors contributing to the change in groundwater composition include the following:

- Final cover installation precluding additional leachate generation.
- With no leachate generation horizontal leachate flow is reduced over time due to the lack of leachate generation.
- Drainage swales that control the amount of runoff at the toe of slope.
- While horizontal leachate flow reduces, precipitation runoff remains relatively consistent based on annual precipitation rates.

This is clearly supported by the change in groundwater composition seen in the groundwater monitoring wells which began prior to the initiation of the operation of the drains.

ES5.0 Recommendation

Based on the evaluation of the leachate collection rates and groundwater analytical data the objectives of the leachate control systems at Sections 2/8 and 3/4 have been met. This evaluation shows that final cover is effective in controlling leachate generation as supported by the base flow leachate collection rates having decreased over time. The final cover and drainage components of the leachate control system also affect the groundwater composition at the perimeter of the landfill sections, with reduced-leachate to non-leachate compositions being observed. The evaluation also shows that precipitation runoff accounts for a majority of the volume of water collected at the four drains along with surface water in the supplemental leachate collection drains at Landfill Sections 2/8 and 3/4.

Therefore, it is recommended that the operation of the drains be terminated. The drains may be left in-place, but the associated aboveground appurtenances can be removed.

Table of Contents

Executive Summary.....	ES-1
ES1.0 Leachate Control Systems	ES-1
ES2.0 Evaluation of Systems Operations	ES-2
ES3.0 Evaluation of Environmental Data	ES-3
ES4.0 Summary and Conclusions	ES-4
ES5.0 Recommendation	ES-6
Table of Contents	i
List of Tables	iii
List of Figures	iv
List of Appendices	xi
List of Acronyms and Abbreviations.....	xii
1.0 Introduction	1-1
1.1 Historical Perspective and Regulatory Requirements.....	1-1
1.2 Leachate Control Objectives and Requirements	1-3
1.3 Objective of Report.....	1-5
1.4 Report Organization	1-6
2.0 Description of Leachate Control Systems	2-1
2.1 Final Cover and Drainage.....	2-1
2.2 Original Leachate Collection Drains	2-4
2.3 Center Leachate Recovery Wells	2-7
2.4 Supplemental Leachate Collection Drains.....	2-7
3.0 Evaluation of Systems Operational Data	3-1
3.1 Leachate Collection Rates.....	3-1
3.2 Precipitation and Seasonality Effects Evaluation.....	3-3
3.3 Base Flow Evaluation	3-7
4.0 Evaluation of Environmental Data.....	4-1
4.1 Groundwater Chemistry.....	4-1
4.1.1 Groundwater Chemistry Evaluation Approach.....	4-2
4.1.1.1 Piper and Stiff Diagrams	4-3
4.1.1.2 Time-Series Plots.....	4-5

Table of Contents (continued)

4.1.1.3	Statistical Trend Analysis	4-5
4.1.2	Landfill Section 2/8	4-5
4.1.2.1	Landfill Section 2/8 – Original Leachate Collection Drain.....	4-6
4.1.2.2	Landfill Section 2/8 – Supplemental Leachate Collection Drain	4-9
4.1.2.3	Landfill Section 2/8 – Small Mound (North Mound) – No Drains	4-11
4.1.3	Landfill Section 3/4	4-12
4.1.3.1	Landfill Section 3/4 – Original Leachate Collection Drain.....	4-13
4.1.3.2	Landfill Section 3/4 – Supplemental Leachate Collection Drain	4-15
4.1.3.3	Landfill Section 3/4 – Southern Perimeter (No Drains).....	4-17
4.2	Water Levels	4-19
4.2.1	Monitoring Wells	4-19
4.2.2	Piezometer Sets	4-20
4.3	Surface Water Chemistry	4-22
5.0	Summary and Conclusions	5-1
5.1	Leachate Control Objectives	5-1
5.2	Data Evaluation	5-2
5.3	Summary of Evaluation	5-3
5.4	Conclusions.....	5-4
6.0	Recommendations	6-1
7.0	References	7-1

List of Tables

Table	Title
3.1-1	SCADA-Recorded and Monthly Totalizer Readings – Section 2/8 Original Drain
3.1-2	SCADA-Recorded and Monthly Totalizer Readings – Section 3/4 Original Drain
3.1-3	SCADA-Recorded and Monthly Totalizer Readings – Section 2/8 Supplemental Drain
3.1-4	SCADA-Recorded and Monthly Totalizer Readings – Section 3/4 Supplemental Drain
4.1-1	Results of Mann-Kendall Tests for Trend Landfill Section 2/8 – Original Collection Drain
4.1-2	Results of Mann-Kendall Tests for Trend Landfill Section 2/8 – Supplemental Collection Drain
4.1-3	Results of Mann-Kendall Tests for Trend Landfill Section 2/8 – Small Mound (No Drains)
4.1-4	Results of Mann-Kendall Tests for Trend Landfill Section 3/4 – Original Collection Drain
4.1-5	Results of Mann-Kendall Tests for Trend Landfill Section 3/4 – Supplemental Collection Drain
4.1-6	Results of Mann-Kendall Tests for Trend Landfill Section 3/4 – No Drains
4.2-1	Evaluation of Seasonality of Groundwater Elevations – Groundwater Monitoring Wells Contiguous to Original Drain – Landfill Section 2/8
4.2-2	Evaluation of Seasonality of Groundwater Elevations – Groundwater Monitoring Wells Contiguous to Original Drain – Landfill Section 3/4

List of Figures

Figure	Title
3.1-1	Annual Leachate Collection Rates – Original Leachate Collection Drain – Landfill Section 2/8
3.1-2	Annual Period Leachate Collection Rates – Original Leachate Collection Drain – Landfill Section 2/8
3.1-3	Annual Leachate Collection Rates – Original Leachate Collection Drain – Landfill Section 3/4
3.1-4	Annual Period Leachate Collection Rates – Original Leachate Collection Drain – Landfill Section 3/4
3.1-5	Annual Period Leachate Collection Rates – Supplemental Leachate Collection Drain – Landfill Section 2/8
3.1-6	Annual Leachate Collection Rates – Supplemental Leachate Collection Drain – Landfill Section 3/4
3.1-7	Monthly Leachate Collection Rates - Original Leachate Collection Drain – Landfill Section 2/8
3.1-8	Monthly Leachate Collection Rates - Original Leachate Collection Drain – Landfill Section 3/4
3.1-9	Monthly Leachate Collection Rates - Supplemental Leachate Collection Drain – Landfill Section 2/8
3.1-10	Monthly Leachate Collection Rates - Supplemental Leachate Collection Drain – Landfill Section 3/4
3.1-11	Daily Leachate Collection Rate - Original Drain – Landfill Section 2/8
3.1-12	Daily Leachate Collection Rate - Original Drain – Landfill Section 3/4
3.1-13	Daily Leachate Collection Rate - Supplemental Drain – Landfill Section 2/8
3.1-14	Daily Leachate Collection Rate - Supplemental Drain – Landfill Section 3/4
3.2-1	January Collection Rate and Precipitation – Original Drain – Landfill Section 2/8
3.2-2	February Collection Rate and Precipitation – Original Drain – Landfill Section 2/8
3.2-3	March Collection Rate and Precipitation – Original Drain – Landfill Section 2/8
3.2-4	April Collection Rate and Precipitation – Original Drain – Landfill Section 2/8
3.2-5	May Collection Rate and Precipitation – Original Drain – Landfill Section 2/8
3.2-6	June Collection Rate and Precipitation – Original Drain – Landfill Section 2/8
3.2-7	July Collection Rate and Precipitation – Original Drain – Landfill Section 2/8
3.2-8	August Collection Rate and Precipitation – Original Drain – Landfill Section 2/8
3.2-9	September Collection Rate and Precipitation – Original Drain – Landfill Section 2/8
3.2-10	October Collection Rate and Precipitation – Original Drain – Landfill Section 2/8
3.2-11	November Collection Rate and Precipitation – Original Drain – Landfill Section 2/8
3.2-12	December Collection Rate and Precipitation – Original Drain – Landfill Section 2/8
3.2-13	January Collection Rate and Precipitation – Original Drain – Landfill Section 3/4
3.2-14	February Collection Rate and Precipitation – Original Drain – Landfill Section 3/4

List of Figures (continued)

Figure	Title
3.2-15	March Collection Rate and Precipitation – Original Drain – Landfill Section 3/4
3.2-16	April Collection Rate and Precipitation – Original Drain – Landfill Section 3/4
3.2-17	May Collection Rate and Precipitation – Original Drain – Landfill Section 3/4
3.2-18	June Collection Rate and Precipitation – Original Drain – Landfill Section 3/4
3.2-19	July Collection Rate and Precipitation – Original Drain – Landfill Section 3/4
3.2-20	August Collection Rate and Precipitation – Original Drain – Landfill Section 3/4
3.2-21	September Collection Rate and Precipitation – Original Drain – Landfill Section 3/4
3.2-22	October Collection Rate and Precipitation – Original Drain – Landfill Section 3/4
3.2-23	November Collection Rate and Precipitation – Original Drain – Landfill Section 3/4
3.2-24	December Collection Rate and Precipitation – Original Drain – Landfill Section 3/4
3.2-25	January Collection Rate and Precipitation - Supplemental Drain - Landfill Section 2/8
3.2-26	February Collection Rate and Precipitation - Supplemental Drain - Landfill Section 2/8
3.2-27	March Collection Rate and Precipitation - Supplemental Drain - Landfill Section 2/8
3.2-28	April Collection Rate and Precipitation - Supplemental Drain - Landfill Section 2/8
3.2-29	May Collection Rate and Precipitation - Supplemental Drain - Landfill Section 2/8
3.2-30	June Collection Rate and Precipitation - Supplemental Drain - Landfill Section 2/8
3.2-31	July Collection Rate and Precipitation - Supplemental Drain - Landfill Section 2/8
3.2-32	August Collection Rate and Precipitation - Supplemental Drain - Landfill Section 2/8
3.2-33	September Collection Rate and Precipitation - Supplemental Drain - Landfill Section 2/8
3.2-34	October Collection Rate and Precipitation - Supplemental Drain - Landfill Section 2/8
3.2-35	November Collection Rate and Precipitation - Supplemental Drain - Landfill Section 2/8
3.2-36	December Collection Rate and Precipitation - Supplemental Drain - Landfill Section 2/8
3.2-37	January Collection Rate and Precipitation – Supplemental Drain – Landfill Section 3/4
3.2-38	February Collection Rate and Precipitation – Supplemental Drain – Landfill Section 3/4
3.2-39	March Collection Rate and Precipitation – Supplemental Drain – Landfill Section 3/4
3.2-40	April Collection Rate and Precipitation – Supplemental Drain – Landfill Section 3/4
3.2-41	May Collection Rate and Precipitation – Supplemental Drain – Landfill Section 3/4
3.2-42	June Collection Rate and Precipitation – Supplemental Drain – Landfill Section 3/4

List of Figures (continued)

Figure	Title
3.2-43	July Collection Rate and Precipitation – Supplemental Drain – Landfill Section 3/4
3.2-44	August Collection Rate and Precipitation – Supplemental Drain – Landfill Section 3/4
3.2-45	September Collection Rate and Precipitation – Supplemental Drain – Landfill Section 3/4
3.2-46	October Collection Rate and Precipitation – Supplemental Drain – Landfill Section 3/4
3.2-47	November Collection Rate and Precipitation – Supplemental Drain – Landfill Section 3/4
3.2-48	December Collection Rate and Precipitation – Supplemental Drain – Landfill Section 3/4
3.2-49	Daily Collection Rates – Seasonality Evaluation – Original Leachate Collection Drain – Landfill Section 2/8
3.2-50	Daily Collection Rates – Seasonality Evaluation – Original Leachate Collection Drain – Landfill Section 3/4
3.2-51	Daily Collection Rates – Seasonality Evaluation – Supplemental Leachate Collection Drain – Landfill Section 2/8
3.2-52	Daily Collection Rates – Seasonality Evaluation – Supplemental Leachate Collection Drain – Landfill Section 3/4
3.3-1	Operational Data – September 1998 – Original Leachate Collection Drain – Landfill Section 2/8
3.3-2	Operation Data – October 1998 – Original Leachate Collection Drain – Landfill Section 2/8
3.3-3	Operation Data – November 1998 – Original Leachate Collection Drain – Landfill Section 2/8
3.3-4	Operation Data – December 1998 – Original Leachate Collection Drain – Landfill Section 2/8
3.3-5	Operational Data – September 1998 – Original Leachate Collection Drain – Landfill Section 3/4
3.3-6	Operational Data – October 1998 – Original Leachate Collection Drain – Landfill Section 3/4
3.3-7	Operational Data – November 1998 – Original Leachate Collection Drain – Landfill Section 3/4
3.3-8	Operational Data – December 1998 – Original Leachate Collection Drain – Landfill Section 3/4
3.3-9	Adjusted Leachate Collection Rates Based on Estimated Base Flows – Original Leachate Collection Drain – Landfill Section 2/8
3.3-10	Precipitation – 1998 through 2002
3.3-11	Change in Flow Rate – Original Drain – Landfill Section 2/8
3.3-12	Daily Operation – October 2003 – Original Leachate Collection Drain – Landfill Section 2/8
3.3-13	Operation and Base Flow – Original Drain – Landfill Section 2/8
3.3-14	Base Flow Evaluation – Daily Collection Rates - Supplemental Leachate Collection Drain – Landfill Section 2/8
3.3-15	Base Flow Evaluation – Daily Collection Rates - Supplemental Leachate Collection Drain – Landfill Section 3/4

List of Figures (continued)

Figure	Title
3.3-16	Leachate Collection Rates – October 2012 – Supplemental Collection Drain – Landfill Section 2/8
3.3-17	Leachate Collection Rates – July 2011 – Supplemental Collection Drain – Landfill Section 3/4
4.1-1	Shallow/Refuse Groundwater Monitoring Well Array
4.1-2A & B	Piper and Stiff Diagrams – Well IT324S
4.1-3A & B	Piper and Stiff Diagrams – Well IT320S
4.1-4A & B	Piper and Stiff Diagrams – Well IT322S
4.1-5A & B	Piper and Stiff Diagrams – Well IT323S
4.1-6A & B	Piper and Stiff Diagrams – Well IT321S
4.1-7A & B	Piper and Stiff Diagrams – Well IT308S
4.1-8A & B	Piper and Stiff Diagrams – Well IT306S
4.1-9A & B	Piper and Stiff Diagrams – Well IT319S
4.1-10	Ammonia Concentrations – Landfill Section 2/8 – Original Drain
4.1-11	Boron Concentrations – Landfill Section 2/8 – Original Drain
4.1-12	Total Dissolved Solids Concentrations – Landfill Section 2/8 – Original Drain
4.1-13A & B	Piper and Stiff Diagrams – Well IT315S
4.1-14A & B	Piper and Stiff Diagrams – Well IT317S
4.1-15A & B	Piper and Stiff Diagrams – Well IT318S
4.1-16A & B	Piper and Stiff Diagrams – Well IT303S
4.1-17A & B	Piper and Stiff Diagrams – Well IT316S
4.1-18	Ammonia Concentrations – Landfill Section 2/8 – Supplemental Drain
4.1-19	Boron Concentrations – Landfill Section 2/8 – Supplemental Drain
4.1-20	Total Dissolved Solids Concentrations – Landfill Section 2/8 – Supplemental Drain
4.1-21A & B	Piper and Stiff Diagrams – Well IT301S
4.1-22A & B	Piper and Stiff Diagrams – Well IT312S
4.1-23A & B	Piper and Stiff Diagrams – Well IT313S
4.1-124A & B	Piper and Stiff Diagrams – Well IT325S
4.1-25A & B	Piper and Stiff Diagrams – Well IT302S
4.1-26	Ammonia Concentrations – Landfill Section 2/8 – Small Mound (No Drains)

List of Figures (continued)

Figure	Title
4.1-27	Boron Concentrations – Landfill Section 2/8 – Small Mound (No Drains)
4.1-28	Total Dissolved Solids Concentrations – Landfill Section 2/8 – Small Mound (No Drains)
4.1-29A & B	Piper and Stiff Diagrams – Well IT427S
4.1-30	Piper and Stiff Diagrams – Well IT413S
4.1-31A & B	Piper and Stiff Diagrams – Well IT428S
4.1-32A & B	Piper and Stiff Diagrams – Well IT408S
4.1-33A & B	Piper and Stiff Diagrams – Well IT401S
4.1-34A & B	Piper and Stiff Diagrams – Well IT411S
4.1-35A & B	Piper and Stiff Diagrams – Well IT412S
4.1-36	Ammonia Concentrations – Landfill Section 3/4 – Original Drain
4.1-37	Boron Concentrations – Landfill Section 3/4 – Original Drain
4.1-38	Total Dissolved Solids Concentrations – Landfill Section 3/4 – Original Drain
4.1-39A & B	Piper and Stiff Diagrams – Well IT404S
4.1-40A & B	Piper and Stiff Diagrams – Well IT422S
4.1-41A & B	Piper and Stiff Diagrams – Well IT403S
4.1-42A & B	Piper and Stiff Diagrams – Well IT419S
4.1-43A & B	Piper and Stiff Diagrams – Well IT420S
4.1-44A & B	Piper and Stiff Diagrams – Well IT421S
4.1-45A & B	Piper and Stiff Diagrams – Well IT433S
4.1-46	Ammonia Concentrations – Landfill Section 3/4 – Supplemental Drain
4.1-47	Boron Concentrations – Landfill Section 3/4 – Supplemental Drain
4.1-48	Total Dissolved Solids Concentrations – Landfill Section 3/4 – Supplemental Drain
4.1-49A & B	Piper and Stiff Diagrams – Well IT426S
4.1-50A & B	Piper and Stiff Diagrams – Well IT407S
4.1-51A & B	Piper and Stiff Diagrams – Well IT406S
4.1-52A & B	Piper and Stiff Diagrams – Well IT425S
4.1-53A & B	Piper and Stiff Diagrams – Well IT423S
4.1-54A & B	Piper and Stiff Diagrams – Well IT424S

List of Figures (continued)

Figure	Title
4.1-55A & B	Piper and Stiff Diagrams – Well IT405S
4.1-56	Ammonia Concentrations – Landfill Section 3/4 – Southern Perimeter (No Drains)
4.1-57	Boron Concentrations – Landfill Section 3/4 – Southern Perimeter (No Drains)
4.1-58	Total Dissolved Solids Concentrations – Landfill Section 3/4 – Southern Perimeter (No Drains)
4.2-1	Water Level Elevations – Monitoring Well IT306S – Landfill Section 2/8
4.2-2	Water Level Elevations – Monitoring Well IT319S – Landfill Section 2/8
4.2-3	Water Level Elevations – Monitoring Well IT320S – Landfill Section 2/8
4.2-4	Water Level Elevations – Monitoring Well IT321S – Landfill Section 2/8
4.2-5	Water Level Elevations – Monitoring Well IT401S – Landfill Section 3/4
4.2-6	Water Level Elevations – Monitoring Well IT408S – Landfill Section 3/4
4.2-7	Water Level Elevations – Monitoring Well IT412S – Landfill Section 3/4
4.2-8	Water Level Elevations – Monitoring Well IT417S – Landfill Section 3/4
4.2-9	Water Level Elevations – Monitoring Well IT428S – Landfill Section 3/4
4.2-10	Monthly Average Water Level Elevations – Landfill Section 2/8 – Original Drain
4.2-11	Monthly Average Water Level Elevations – Landfill Section 3/4 – Original Drain
4.2-12	Water Level Elevations – Monitoring Piezometer Set MP281 – Supplemental Leachate Collection Drain – Landfill Section 2/8
4.2-13	Water Level Elevations – Monitoring Piezometer Set MP282 – Supplemental Leachate Collection Drain – Landfill Section 2/8
4.2-14	Water Level Elevations – Monitoring Piezometer Set MP283 – Supplemental Leachate Collection Drain – Landfill Section 2/8
4.2-15	Water Level Elevations – Monitoring Piezometer Set MP284 – Supplemental Leachate Collection Drain – Landfill Section 2/8
4.2-16	Water Level Elevations – Monitoring Piezometer Set MP341 – Supplemental Leachate Collection Drain – Landfill Section 3/4
4.2-17	Water Level Elevations – Monitoring Piezometer Set MP342 – Supplemental Leachate Collection Drain – Landfill Section 3/4
4.2-18	Water Level Elevations – Monitoring Piezometer Set MP343 – Supplemental Leachate Collection Drain – Landfill Section 3/4
4.2-19	Water Level Elevations – Monitoring Piezometer Set MP344 – Supplemental Leachate Collection Drain – Landfill Section 3/4

List of Figures (continued)

Figure	Title
4.2-20	Monthly Average Water Level Elevations – MP342 – Landfill Section 3/4 – Supplemental Drain
4.3-1	Monitoring Stations and Shallow Groundwater Monitoring Well Array
5.1-1	Annual Leachate Collection Rates – Original Leachate Collection Drain – Landfill Section 2/8
5.1-2	Annual Leachate Collection Rates – Original Leachate Collection Drain – Landfill Section 3/4
5.1-3	Annual Leachate Collection Rates – Supplemental Leachate Collection Drain – Landfill Section 3/4
5.1-4	Leachate Collection Rates – Original Collection Drain – Landfill Section 2/8
5.1-5	Leachate Collection Rates – Original Collection Drain – Landfill Section 3/4
5.1-6	Leachate Collection Rates – Supplemental Collection Drain – Landfill Section 2/8
5.1-7	Leachate Collection Rates – Supplemental Collection Drain – Landfill Section 3/4
5.1-8	Piper and Stiff Diagrams – Well IT316S – Landfill Section 2/8
5.1-9	Piper and Stiff Diagrams – Well IT407S – Landfill Section 3/4

List of Appendices

Appendix	Title
A	Plate 1 – Small Tributary Study Sampling Locations

List of Acronyms and Abbreviations

Ca ²⁺	Calcium ion
CFR	Code of Federal Register
cfs	Cubic feet per second
CJO	Consent Judgment and Order
Cl ⁻	Chloride ion
CMR	Corrective Measures Report
DSNY	New York City Department of Sanitation
FHR	Final Hydrogeology Report
FLMR	Fresh Kills Leachate Mitigation Report
FSWSR	Final Surface Water and Sediment Report
gpd	Gallons per day
gpm	Gallons per minute
HCO ₃ ⁻	Bicarbonate ion
HDPE	High density polyethylene
K ⁺	Potassium ion
meq/L	Milliequivalents per liter
Mg ²⁺	Magnesium ion
Na ⁺	Sodium ion
NOMD	Notice of Milestone Deficiency
NYCDOS	New York City Department of Sanitation
NYSDEC	New York State Department of Environmental Conservation
NYSDOT	New York State Department of Transportation
RCRA	Resource Conservation and Recovery Act
RHWD	Richmond High Water Datum
SCADA	Supervisory Control and Data Acquisition
SO ₄ ²⁻	Sulfate ion
TDS	Total dissolved solids

1.0 Introduction

The background of the leachate control program at Landfill Sections 2/8 and 3/4 including the historical perspective of the development of the program as well as regulatory requirements is presented in this chapter. The objective of this report as well as the report structure are also provided in this chapter.

1.1 Historical Perspective and Regulatory Requirements

In April 1990, the New York City Department of Sanitation (DSNY) and the New York State Department of Environmental Conservation (NYSDEC) entered into an Order on Consent (Consent Order). The 1990 Order on Consent (NYSDEC, 1990) was negotiated with the intent to obtain an operating permit for Sections 1/9 and 6/7 and develop an interim plan to operate Sections 2/8 and 3/4 while developing and implementing the final closure plan for Sections 2/8 and 3/4.

In October 1998, DSNY and NYSDEC agreed to Order on Consent Modification No. 6 (NYSDEC, 1998). This modification consisted of the revision to Appendix A-4 – Fresh Kills Landfill Leachate Mitigation of Sections 1/9 and 6/7, Subjects 17, 18 and 19, and the establishment of Compliance Schedule A-14 – Landfill Leachate Mitigation of Sections 2/8 and 3/4. Compliance Schedule A-14 set forth the requirements and milestones for leachate controls at Sections 2/8 and 3/4.

The following investigation reports related to the Consent Order were prepared under the direction of DSNY and submitted to NYSDEC:

- *Fresh Kills Leachate Mitigation Report (IT 1993c)* – Consent Order Appendix A-4; October 1993.
- *Final Surface Water and Sediment Report (IT, 1993a)* – Consent Order Appendix A-7; November 1993.
- *Final Hydrogeological Report (IT, 1993b)* - Consent Order Appendix A-6; December 1993.
- *Draft Section 2/8 and 3/4 Leachate Mitigation Report (IT 1994a)* - January 1994.
- *Fresh Kills Leachate Mitigation Report and Corrective Measures Assessment Report (IT, 1994)* - Consent Order Appendix A-4; March 1994.

The following reports related to leachate mitigation were prepared under the direction of DSNY and submitted to NYSDEC but were not Consent Order required reports:

- *Draft Section 2/8 and 3/4 Leachate Mitigation Report (IT 1994a)* - January 1994.

- *Response to NYSDEC Comments on Draft Section 2/8 and 3/4 Report*; May 1994.
- *Final Technical Report Small Tributary Study* (IT, 1995b); May 1995.

The *Final Hydrogeological Report* (IT, 1993b) (FHR) presented the results of the hydrogeological investigation that was performed between 1990 and 1992. The *Final Surface Water and Sediment Report* (IT, 1993a) (FSWSR) presented the results of the surface water and sediment investigation that was performed between 1991 and 1992. The FHR and FSWSR were basis for the Sections 2/8 and 3/4 Final Closure Report that was submitted in May 1992 and the evaluation of the leachate mitigation system alternatives that was performed as part of the *Fresh Kills Leachate Mitigation Report and Corrective Measures Assessment Report* (IT, 1994).

In 1994, DSNY submitted the *Fresh Kills Leachate Mitigation Report* (FLMR) and *Corrective Measures Assessment Report* (CMR) (IT, 1994). The objectives of FLMR & CMR were to:

- Develop and recommend a plan for controlling leachate discharge to the maximum extent practicable and a minimum 80% at Landfill Sections 1/9 and 6/7, and
- Define the impact of any leachate discharge not amenable to control under the recommended plan.

The Corrective Measures Report portion of the report was completed under Resource Conservation and Recovery Act (RCRA) compliance and 6 NYCRR Part 360-2.20 which had become effective October 9, 1993.

Leachate Mitigation System Alternative Development was completed under the FLMR & CMR. The report included preliminary data screening of mitigation alternatives (Chapter 7), refinement and evaluation of mitigation alternatives (Chapter 8), development and evaluation of five (5) site-wide alternatives (Chapter 9). Site-Wide Alternative 1 was recommended as the Preferred Site-Wide Corrective Measure Alternative. Site-Wide Alternative 1 included final cover at Sections 2/8 and 3/4, leachate collection drains and a cutoff wall at Sections 1/9 and 6/7, and leachate treatment. This alternative was in compliance with 40 Code of Federal Register (CFR) Subtitle D and Part 360-2.20.

The Draft Leachate Mitigation Evaluation for Sections 2/8 and 3/4 was submitted to NYSDEC in January 1994 but was not a Consent Order-required report. This report was prepared concurrent with the *Final Leachate Mitigation Report and Corrective Measures Report* (FLMR & CMR). The Sections 2/8 and 3/4 evaluation used the Preferred Site-Wide Alternative-1 developed in FLMR & CMR, as the basis to develop alternatives for Sections 2/8 and 3/4. The alternatives for developed for Sections 2/8 and 3/4 included:

- Final cover only – preferred method based on site-wide evaluation;
- Final cover and complete containment and collection;

- Final cover and leachate pumping;
- Final cover and leachate pumping (2/8 north mound) and final cover and complete containment and collection (2/8 south mound and 3/4);
- Final cover only (2/8 north mound) and final cover and complete containment and collection (2/8 south mound and 3/4).

The Draft Leachate Mitigation Evaluation for Sections 2/8 and 3/4 concluded that implementation of mitigation measures other than placement of final cover provides only marginal environmental benefit at significant additional costs.

1.2 Leachate Control Objectives and Requirements

The overall leachate control prescribed in the Consent Order was related to Sections 1/9 and 6/7 and required:

- A minimum of 80% or
- The maximum extent practicable.

Leachate discharge during the 1993 baseline period as determined by the model developed as part of the FLMR was established as the basis for determining the 80% goal. The model assumed the leachate control systems as recommended in the FLMR to be operating by 1997; actual operation in 1998. Based on the model results, site-wide leachate control was predicted to exceed 80% by 2000, with a leachate control efficiency of 85%. The predicted Section 6/7 leachate control efficiency was 100% and the predicted Section 1/9 leachate control efficiency was 90% in 2000; whereas, the predicted leachate control efficiencies for Sections 2/8 and 3/4 were 70% and 60%, respectively. The Leachate Control Efficiency for site wide Alternative 1 for the 1993 baseline period and model output Years 2000 to 2015 is summarized below:

Leachate Control Efficiency
Site-Wide Alternative 1^a
Table 9.3-1 FLMR & CMR^b - March 1994

Landfill Section	Uncontrolled Leachate Flux (gal/day) ^c			Leachate Control Efficiency ^d		
	Model Output Year			Model Output Year		
	1993 - Baseline	2000	2015	1993 - Baseline	2000	2015
6/7	328,641	22	0	100%	100%	
1/9	592,049	60,745	45,665	90%	92%	
3/4	200,172	79,348	27,444	60%	86%	
2/8	176,917	52,314	11,078	70%	94%	
Total	1,297,779	192,429	84,187	85%	94%	

Notes: ^a Containment, Collection and Treatment at Sections 1/9 and 6/7, Final Cover only at Sections 2/8 and 3/4

^b Fresh Kills Leachate Mitigation Report & Corrective Measures Report

^c Total of horizontal and vertical flux

^d As a percentage of total uncontrolled leachate from in the 1993 baseline period

Based on the model output of uncontrolled leachate flux under Site-Wide Alternative 1 – Final Cover Only at Sections 2/8 and 3/4, 80% leachate control efficiency was projected to occur in 2006 at Section 2/8 and 2012 at Section 6/7.

Site-Wide Alternative 1 - Final Cover

Landfill Section 2/8

Year	Uncontrolled Leachate Flux (gpd) ^b			Leachate Control Efficiency ^d
	Horizontal	Vertical	Total	
2000^a	48,627	3,687	52,314	70%
2001	46,000	3,565	49,565	72%
2002	43,373	3,443	46,816	74%
2003	40,746	3,321	44,067	75%
2004	38,119	3,198	41,318	77%
2005	35,492	3,076	38,569	78%
2006	32,865	2,954	35,820	80%
2007	30,238	2,832	33,071	81%
2008	27,612	2,710	30,321	83%
2009	24,985	2,588	27,572	84%
2010	22,358	2,466	24,823	86%
2011	19,731	2,344	22,074	88%
2012	17,104	2,221	19,325	89%
2013	14,477	2,099	16,576	91%
2014	11,850	1,977	13,827	92%
2015^a	9,223	1,855	11,078	94%

Landfill Section 3/4

Year	Uncontrolled Leachate Flux (gpd) ^b			Leachate Control Efficiency ^d
	Horizontal	Vertical	Total	
2000^a	65,278	14,070	79,348	60%
2001	62,279	13,609	75,888	62%
2002	59,280	13,147	72,427	64%
2003	56,281	12,686	68,967	66%
2004	53,282	12,225	65,507	67%
2005	50,283	11,764	62,047	69%
2006	47,284	11,302	58,586	71%
2007	44,285	10,841	55,126	72%
2008	41,286	10,380	51,666	74%
2009	38,287	9,919	48,206	76%
2010	35,288	9,457	44,745	78%
2011	32,289	8,996	41,285	79%
2012	29,290	8,535	37,825	81%
2013	26,291	8,074	34,365	83%
2014	23,292	7,612	30,904	85%
2015^a	20,293	7,151	27,444	86%

Notes: ^a Model output year

^b Linear interpolation between model output years

^c Based on Year 2000 model boundary fluxes; 27% controlled by drain

^d As a percentage of total uncontrolled leachate from in the 1993 baseline period

 Year 80% leachate control efficiency achieved

In March 1995, NYSDEC issued a Notice of Milestone Deficiency (NOMD) related to Sections 2/8 and 3/4 leachate control (NYSDEC, 1995). In April 1995, NYSDEC proposed that 100,000 gallons per day (gpd) from each of Sections 2/8 and 3/4 could practicably be collected for 5 years to address the NOMD through the use of pumping wells. DSNY demonstrated that based on data provided in the Final Hydrogeological Report, adequate amounts of drainable leachate was not available to achieve the proposed 100,000 gpd rate for 5 years.

The *Final Technical Report – Small Tributary Study* (IT, 1995) was submitted May 1995. The small tributary investigation was performed under the direction of DSNY to obtain a water quality perspective for implementing leachate controls at Sections 2/8 and 3/4. The main objective of this study was to characterize on-site surface drainages at Fresh Kills Landfill. The investigation consisted of the collection of surface water and sediment samples at 8 stations, T-1 through T-8, during 4 sampling events performed in 1994. The small tributary study evaluated water quality in each tributary within Fresh Kills Landfill with regard to NYSDEC surface water quality standards or guidance values. The NYSDEC water class was based on proximity to existing downstream water classifications and whether or not the tributary was tidally-influenced. The investigation concluded that the tributaries were receiving leachate influence ranging from 2 to 50 percent of stream volume at worst case low flow conditions. The final cover design, planned leachate controls, basins, etc. were expected to result in a reduction of leachate influence to the small tributaries.

As part of an implementation agreement between DSNY and NYSDEC for leachate control at Sections 2/8 and 3/4 DSNY proposed to install either:

- Center leachate recovery wells, as a means of source reduction, or
- Partial perimeter drains to intercept potential leachate migration to the small tributaries.

Ultimately DSNY implemented both systems with considerations. These considerations included a replacement schedule for center leachate recovery wells and restricted flows to the leachate treatment plant.

An additional legal requirement facing DSNY was the Consent and Judgment Order (CJO) – Civil No. 95-1259 (JBW), which was related to a Clean Water Act citizen's suit. Data evaluation and report preparation related to this Consent and Judgment Order was performed between 1999 and 2000. This Judgment order required installation of supplemental leachate controls to collect additional leachate and to control potential migration of leachate to surface water bodies adjacent to the landfill sections. The objective of the CJO was to reach the 80% abatement of leachate flow more quickly.

1.3 Objective of Report

The objective of this report is to present and evaluate leachate collection system operational data (1998 to 2015) and historical environmental data (1991 to 2015) to demonstrate that the objectives of the leachate control systems have been met in support of terminating the operation of the leachate collection drains in Sections 2/8 and 3/4.

This report is a follow up to a meeting that held on October 29, 2014. Descriptions of the leachate systems, leachate collection data, and environmental data presented during the October 29, 2015 meeting are included in the report. The evaluation of leachate collection data is

expanded in this report to include detailed seasonality and base flow determinations. The environmental data has been expanded in this report to include each of the groundwater monitoring wells, as well as additional analytical parameters.

1.4 Report Organization

This report is organized into seven chapters:

Section 1.0 includes the Introduction and presents an overview of the regulatory requirements and historical perspective, the leachate control requirements, and the objectives of this report.

Section 2.0 presents a summary and description of the leachate control systems including final cover and drainage, partial perimeter original drains, center leachate recovery wells and the supplemental drains.

Section 3.0 presents a summary and evaluation of leachate systems operational data. Specifically, annual, monthly and daily leachate collection rates based on data obtained from totalizers and the Supervisory Control and Data Acquisition (SCADA) system recorded-information are presented and evaluated. Leachate elevations recorded by the SCADA system as they relate to the operation of the drains are evaluated. The effect of precipitation as it relates to the leachate collection system operations is also evaluated.

Section 4.0 presents an evaluation of environmental data for Fresh Kills Landfill and its relation to the leachate collection system. Groundwater and surface water chemistry and groundwater levels are presented in this section.

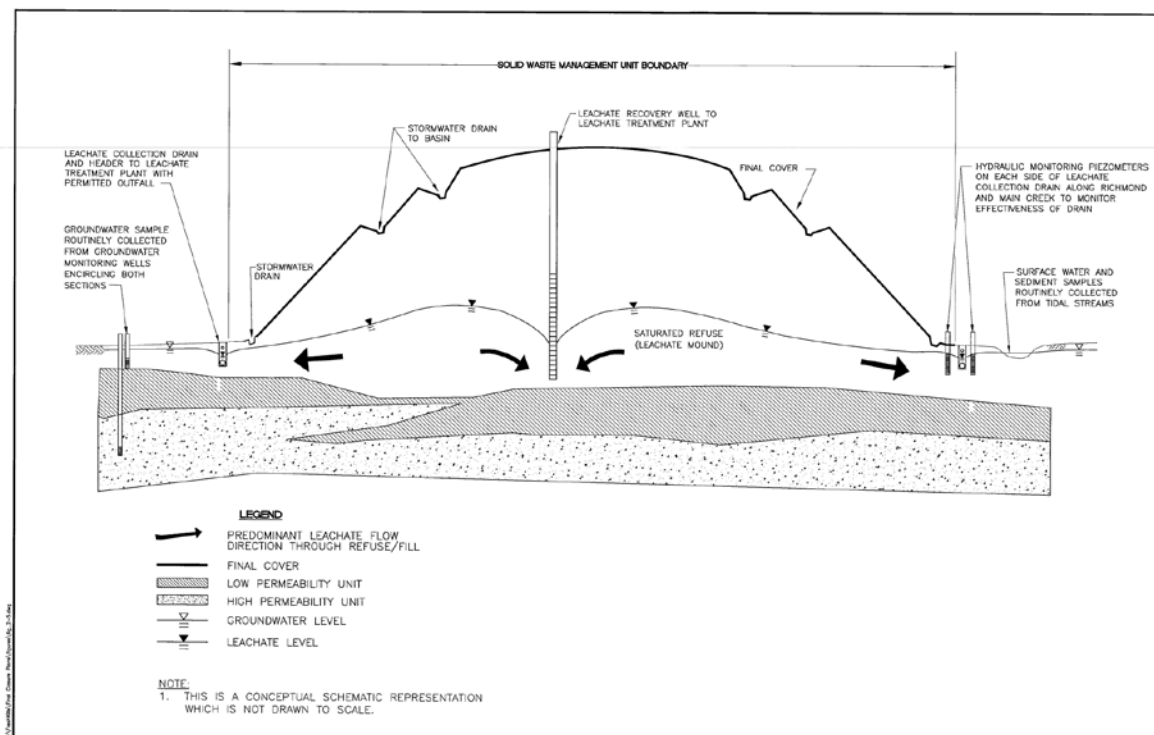
Section 5.0 provides a summary of the data and conclusions drawn from the evaluation of the data presented in this report.

Section 6.0 presents the recommendations for the future operation of the leachate collection system.

Section 7.0 includes a list of references used to summarize and evaluate the data presented in this report.

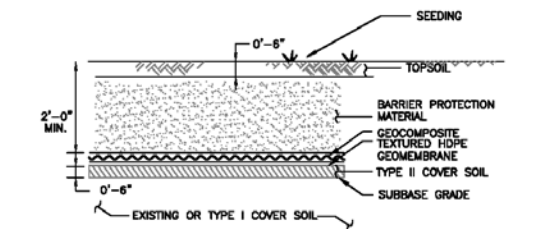
2.0 Description of Leachate Control Systems

The Leachate Control Systems at Sections 2/8 and 3/4 consist of the following components: final cover and drainage, perimeter leachate collection drains both original and supplemental, and center leachate recovery wells. A general schematic of the leachate control systems at Sections 2/8 and 3/4 is presented below:

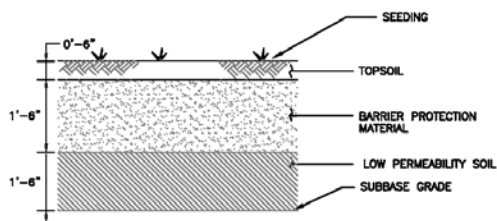


2.1 Final Cover and Drainage

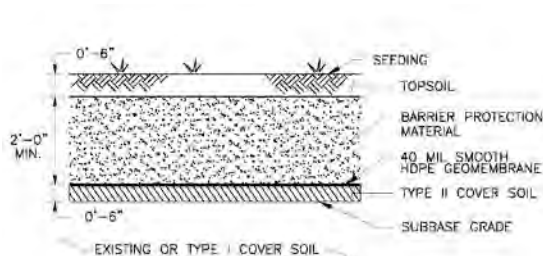
There are three types of final cover in Sections 2/8 and 3/4 as shown in the figures below. Types I and II final cover include geosynthetics, with Type I installed on slopes greater than 15 degrees and Type II on slopes less than 15 degrees. Type III final cover consists of low permeable soils; this type of cover was installed on the lower slopes in portions of southern and eastern of Section 2/8 and the lower slopes in portions of Section 3/4. There are two types of Type III final cover; Type IIIA which has 1 foot of low permeability soil and Type IIIB which has 1.5 feet of low permeability soil.

**FINAL COVER SECTION — TYPE I**

N.T.S.

**FINAL COVER SECTION — TYPE III**

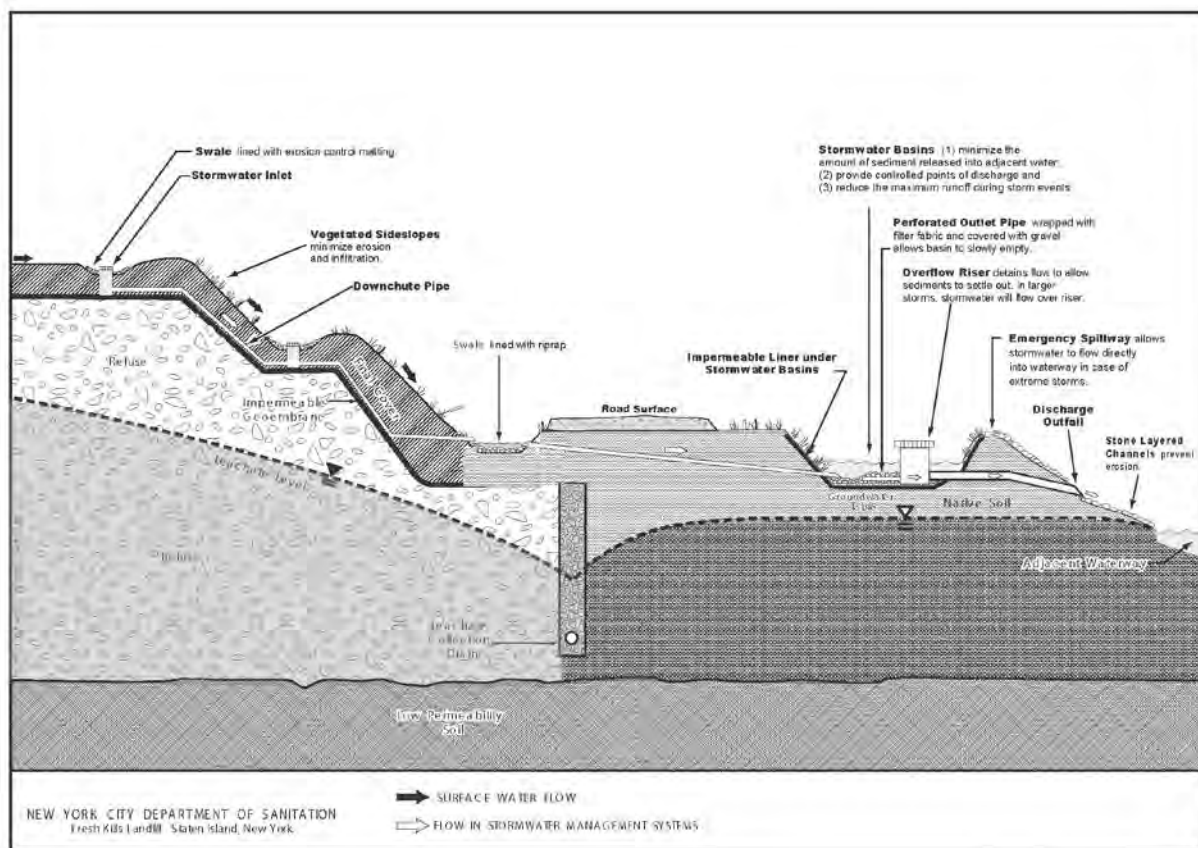
N.T.S.

**FINAL COVER SECTION — TYPE II**

NO SCALE

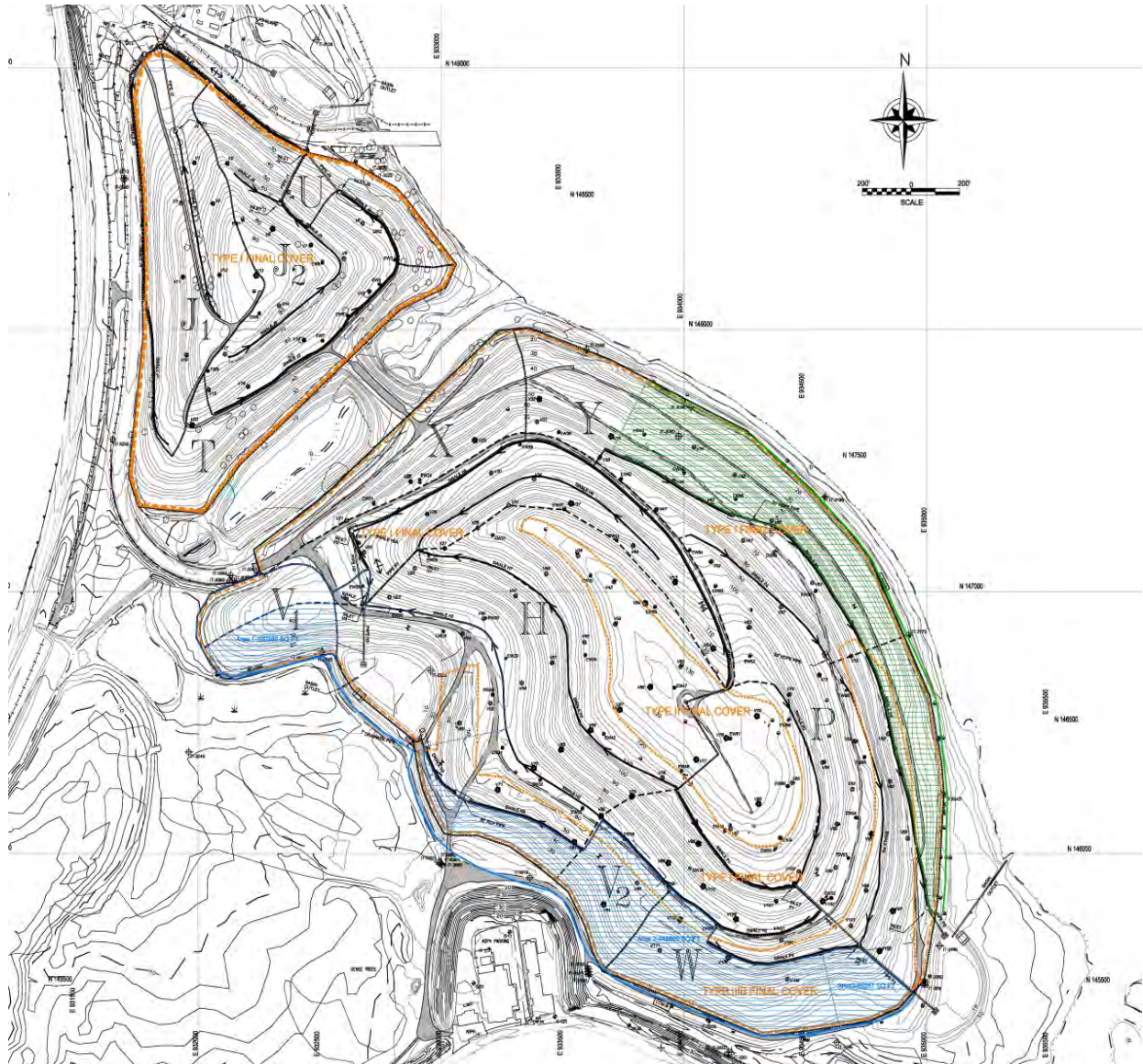
Drainage swales divert surface water runoff from the landfill cover to stormwater basins installed outside the limits of final cover throughout Sections 2/8 and 3/4. Overland flow of surface water runoff occurs from the lower most drainage swale to the toe of slope of the refuse mound.

A schematic of surface water flow is shown below:



The limits of final cover and the locations of the drainage swales and stormwater basins are shown in the following figures for Sections 2/8 and 3/4.

Section 2/8 Final Cover and Drainage – Type I, Type II and Type III



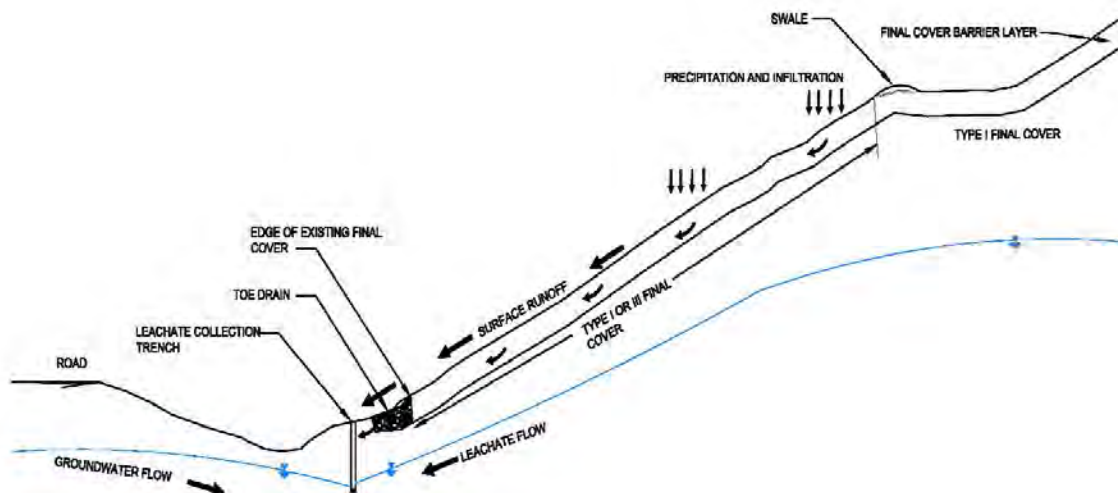
In the above and following figures, blue shading represents drainage to the original drain and green shading represents drainage to the supplemental drain.

Topographic map showing proposed final cover types (Type I, Type II, Type III) and Main Creek. The map includes contour lines, spot elevations, and a north arrow. Key features include:

- TYPE I FINAL COVER** (shaded area)
- TYPE II FINAL COVER** (dashed line)
- TYPE III FINAL COVER** (solid line)
- MAIN CREEK**
- LEACHATE COLLECTION SYSTEM**
- LEACHATE PUMP HOUSE**

Spot elevations and coordinates are provided for various points on the map. A scale bar indicates 200 feet. A north arrow is located in the upper right corner. A legend in the lower right corner defines the cover types: Type I (shaded area), Type II (dashed line), and Type III (solid line).

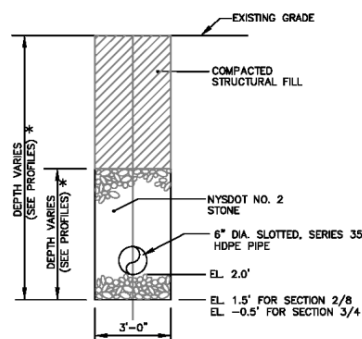
The original leachate collection drains are an open system, as they are located outside the limits of the final cover. As such, they are influenced by leachate, groundwater, and precipitation into the drain, as well as overland precipitation runoff and final cover seepage flow. The original drain design is depicted in the schematic presented below:



The overall length of the original leachate collection drains is 4,950 linear ft. Of this total, 2,150 linear ft. are located in Section 2/8, and 2,800 linear ft. are located in Section 3/4. As shown in the following figure, the original collection drains are shown in yellow and the Section 2/8 original drain extensions and the supplemental leachate collection drains are shown in green.



The design of the original leachate collection drains consists of a 3-foot wide trench with a bottom elevation of -0.5 to +1.5 feet as measured by the Richmond High Water Datum (RHWD). There is a 6-inch diameter slotted high density polyethylene (HDPE) pipe approximately 6 inches off the bottom of the trench. The trench is filled with New York State Department of Transportation (NYSDOT) No. 2 stone. The typical trench construction detail is shown below:



SECTION 2/8 AND 3/4 LEACHATE
COLLECTION TRENCH DETAIL
N.T.S.

Leachate is removed from the collection drain using a pumping station. The pumping station consists of a 24-in. diameter collection well located inside a collection well vault with the pump regulated by an electric control panel. The control panel limits the leachate collection rate as it's related to hydraulic loading at the treatment plant (65,000 gpd from each Landfill Section). Leachate is pumped to the Fresh Kills Leachate Treatment plant. This facility has a capacity to treat 1.05 million gpd. Pumping and flow rates to the treatment plant are controlled by the SCADA system. The Section 2/8 collection well vault and electric control panel is shown below:



2.3 Center Leachate Recovery Wells

The Center Leachate Recovery Well program consisted of six center recovery wells installed in Sections 2/8 and 3/4 between late 1996 to early 1997. Pump tests were performed in 1997 on the six wells to determine operational capacity. Wells RC1 and RC2 were located in Section 2/8 and wells RC3R, RC3S, RC4R and RC4S were located in Section 3/4. Each well was constructed with 6-in. diameter stainless steel. Over time these wells experienced structural problems in the form of well shear due to pressures from the subsiding mound. Three replacement wells were installed in 2000. Two wells were installed in Section 2/8: RC6 as a replacement for RC1 and RC7 as a replacement for RC2. Well RC5 was installed as a replacement for RC4R in Section 3/4. In 2001, well RC8 was installed as a replacement for RC6 in Section 2/8. Average leachate collection rate at these wells was generally less than 1 gpm.

RC2 was the highest producing center leachate recovery well, producing up to 6,700 gpd with an average of 1,160 gpd. However, RC2 sheared due to the pressures from the subsiding mound and was replaced by RC7. RC7 was installed about 20 ft. from RC2. RC7 produced up to an average of 100 gpd with a peak of 400 gpd, despite its proximity to RC2.

In February 2003, DSNY submitted the *Leachate Controls at Sections 2/8 and 3/4 Report* (Shaw, 2003) to NYSDEC, which provided a summary status of the leachate collection program as of the submittal date. The recommendation presented in the report included a request to decommission the center leachate recovery well system. NYSDEC approved the abandonment of the leachate recovery wells on May 15, 2013. Well abandonment and appurtenance removal was performed in June 2013.

2.4 Supplemental Leachate Collection Drains

The Supplemental Leachate Collection drains are also an open system as they are located outside of the limits of the final cover. These drains are influenced by leachate, groundwater, and precipitation into the drain, as well as overland precipitation runoff, final cover seepage flow. Because of their proximity to Main and Richmond Creeks, the supplemental drains are also influenced by surface water flow. The overall length of the Supplemental Drains is 5,465 linear feet. Of this total, 3,965 linear feet are in Section 2/8 and 2,500 linear feet are in Section 3/4.

The Supplemental Leachate Collection Drains consist of a 3-foot wide trench lined with filter fabric. A 6-inch diameter slotted HDPE pipe is located about six-inches off the bottom of the trench and the trench is backfilled with 1-inch diameter stone. A 6-inch diameter dual-walled transfer force main is located within the trench. The bottom elevation of the drains is at an elevation -2 feet RHWD. In addition, the system contains a 24-inch diameter collection well, a valve chamber housing and an electric control panel. The control panel regulates the pump, flow transmitter and water level transmitter. These appurtenances are shown in the picture below:



Hydraulic monitoring piezometer sets (four sets of three piezometers at each drain) are located along the length of the drain with each set having a piezometer inside, within and outside the drain (see picture below). In addition to water level measurements, samples are collected from the piezometer sets to test for parameters that indicate an increase in salinity, namely specific conductance and chloride. The water levels and sample collection and testing is performed by the operator of the Fresh Kills Landfill Leachate Treatment Plant on a routine basis. Water level and specific conductance measurements are made monthly and chloride measurements are made quarterly.

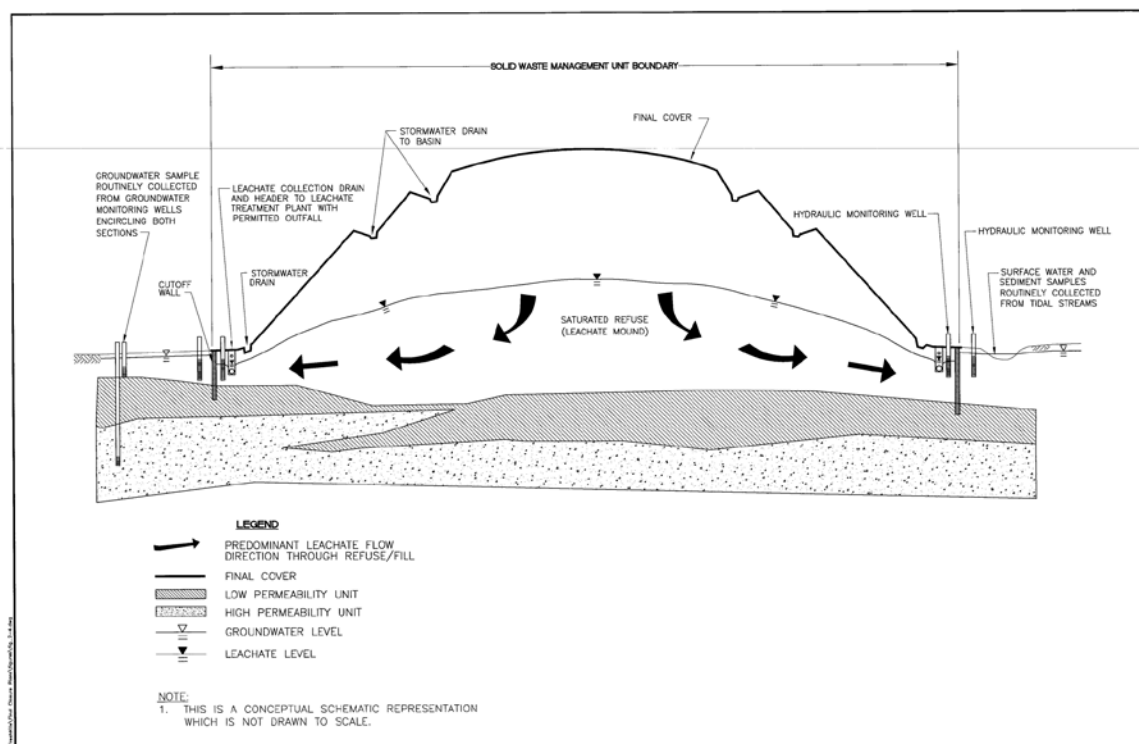


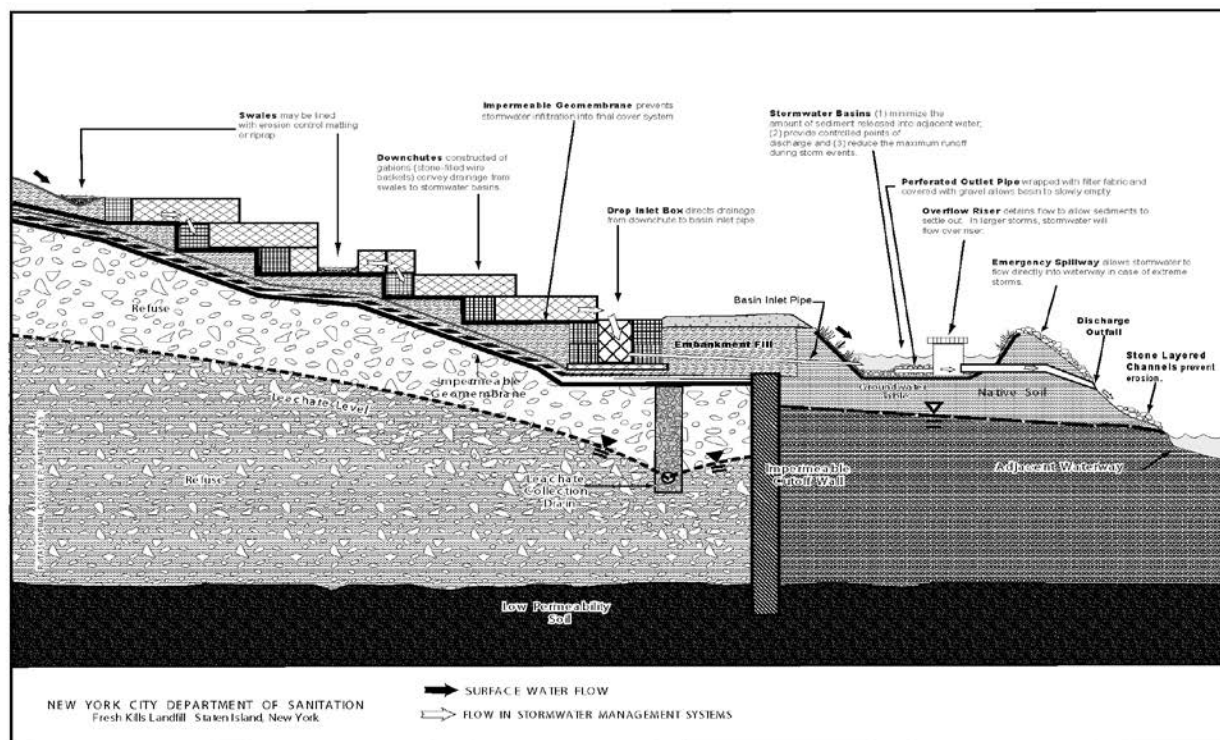
Leachate is pumped to the Fresh Kills Landfill Leachate Treatment Plant. Pumping and flow rates to the treatment plant are controlled by the SCADA system.

Open to Partially Closed to Closed Leachate Control System

As a basis for evaluating the leachate collection data for the Sections 2/8 and 3/4 the leachate collection and containment systems at Landfill Sections 1/9 and 6/7 were reviewed. There was no leachate control systems in place at Landfill Sections 1/9 and 6/7 during the 1993 baseline period other than about 20 acres of Type III final cover on the lower eastern slope of Section 1/9. The leachate control systems became partially closed systems in both Section 1/9 and 6/7 with the construction of the cutoff wall and collection drain in 1998. Final cover was installed over the leachate collection drain and cutoff wall to tie in the final cover to be constructed on the refuse mounds at Sections 1/9 and 6/7. In Section 6/7, leachate control became a closed system with the construction of the final cover and drainage systems between 2007 and 2011. The final cover on the Section 6/7 mound ties into the final cover over the leachate collection drain, thus precluding entry of precipitation, surface water runoff, and final cover seepage flow. The construction of final cover began at Section 1/9 in 2014, which will convert leachate control into a closed system at Section 1/9. Below are general schematics of the closed leachate control systems at Sections 1/9 and 6/7.

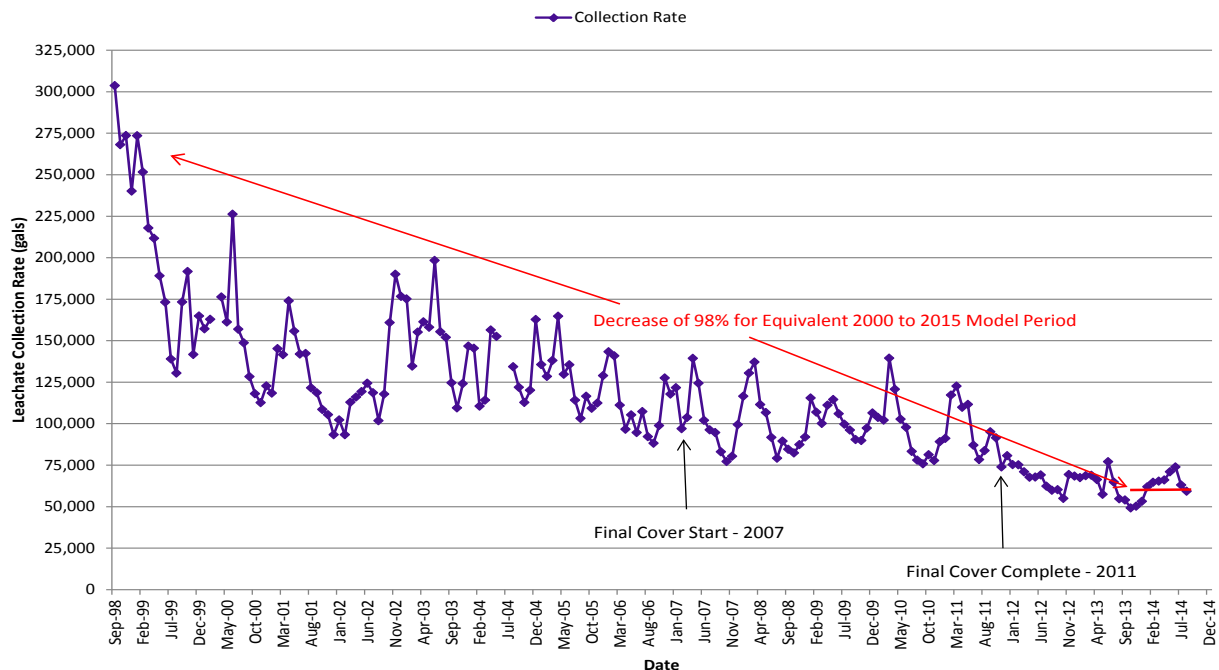
Landfill Schematic – Sections 1/9 and 6/7





As shown in the following figure, the leachate collection rate has decreased by approximately 98 percent from 1998 to 2014 with the completion of a closed leachate control system at Section 6/7. This is the system that was modelled as part of the recommended Site-Wide Alternate 1.

Average Daily Leachate Collection Rate - Section 6/7



3.0 *Evaluation of Systems Operational Data*

This chapter provides an evaluation of the leachate collection rates based on totalizer readings and SCADA-recorded data. Based on this evaluation it is demonstrated that leachate collection rates are impacted by the following:

- Horizontal leachate flow from refuse mound
- Groundwater flow
- Surface water bodies
- Precipitation runoff and seepage
- Duration of operation of pump in collection well
- Pump off elevations

3.1 *Leachate Collection Rates*

Leachate collection rates at the treatment plant are obtained through the use of two methods, Supervisory Control and Data Acquisition (SCADA) (continuous electronic) and totalizers (manual). Totalizer readings are obtained on a monthly basis by the operator of the Fresh Kills Landfill Leachate Treatment Plant. These totalizer readings are presented in the Monthly Operating Report prepared by the operator of the Fresh Kills Landfill Leachate Treatment Plant under the direction of DSNY. Operational notes regarding the flow meters are indicated in the monthly reports. The totalizer readings for each of the four drain segments have been compiled and are provided in Tables 3.1-1 through 3.1-4.

The SCADA system continuously records operational data for the leachate collection drains. The data relevant to this evaluation are flow rates at each collection well and leachate elevations in the drain as recorded at the leachate collection drain. The SCADA-recorded flow rates are used to determine daily leachate collections rates, which are then summed to calculate monthly and annual collection rates. The monthly and annual leachate collection rates based on the SCADA data are also shown graphically. The SCADA-recorded data are relatively consistent with the totalizer data as seen on the graphs, providing confidence in the detailed evaluations based on the SCADA data included in this report.

The monthly totalizer readings were summed to provide annual leachate collection rates. Since the Sections 2/8 and 3/4 original drains did not start operating until September 1998 running 12-month period leachate collection rates were also determined. The supplemental drains in Section 2/8 and 3/4 began operating in mid-November 2001 so only annual leachate collection rate graphs were prepared for these drain segments. Graphs presenting the annual data are provided in the figures listed below; precipitation rates are also included on the figures:

- Figure 3.1-1 – Annual Leachate Collection Rate Section 2/8 Original Drain
- Figure 3.1-2 – 12-Month Leachate Collection Rate Section 2/8 Original Drain
- Figure 3.1-3 – Annual Leachate Collection Rate Section 3/4 Original Drain
- Figure 3.1-4 – 12-Month Leachate Collection Rate Section 3/4 Original Drain
- Figure 3.1-5 – Annual Leachate Collection Rate Section 2/8 Supplemental Drain
- Figure 3.1-6 – Annual Leachate Collection Rate Section 3/4 Supplemental Drain

Graphs presenting the monthly leachate collection rates for each of the four drain segments are presented in the following figures:

- Figure 3.1-7 – Monthly Leachate Collection Rate Section 2/8 Original Drain
- Figure 3.1-8 – Monthly Leachate Collection Rate Section 3/4 Original Drain
- Figure 3.1-9 – Monthly Leachate Collection Rate Section 2/8 Supplemental Drain
- Figure 3.1-10 – Monthly Leachate Collection Rate Section 3/4 Supplemental Drain

For the Section 2/8 original drain, a significant decrease in the leachate collection rate is shown on each of the figures between 2001 and 2002. From 2003 to 2014, a decrease in the leachate collection rate is also seen. The effect of precipitation on the leachate collection rate is observed for 2011; with an increase in the leachate collection rate associated with approximately 70 inches of precipitation occurring in 2011. This increase in the leachate collection rate is not as obvious on the 12-month period graph as two large rain events occurred at the change-over in the periods (i.e., August and September).

In the Section 3/4 original drain, a decrease in the annual leachate collection rate is seen between the 2006 and 2007 annual periods. A pronounced increase in leachate collection is seen in the Section 3/4 original drain in 2011, coinciding with approximately 70 inches of precipitation. Similar to the Section 2/8 original drain, this increase in the leachate collection rate is not as obvious on the 12-month period graph.

The monthly graphs for the Sections 2/8 and 3/4 original drains (Figures 3.1-7 and 3.1-8) show fluctuations in the collection rates which are related to seasonal effects.

The Sections 2/8 and 3/4 supplemental drain annual leachate collection graphs show an overall decreasing trend in the collection rates. Similar to the monthly graphs for the Sections 2/8 and 3/4 original drains, the monthly graphs for the supplemental drains show fluctuations in the collection rates which are related to seasonal effects (Figures 3.1-9 and 3.1-10). Consistent with the annual data for the original drains, the effect of precipitation on the leachate collection rate in the supplemental drains is also observed in 2011.

Both the precipitation and seasonal effects will be evaluated in greater detail in subsequent report sections.

The daily leachate collection rates based on the SCADA-recorded flow rates are also plotted for each drain segment. Graphs of the daily collection rates are presented on the following figures:

- Figure 3.1-11 – Daily Leachate Collection Rate Section 2/8 Original Drain
- Figure 3.1-12 – Daily Leachate Collection Rate Section 3/4 Original Drain
- Figure 3.1-13 – Daily Leachate Collection Rate Section 2/8 Supplemental Drain
- Figure 3.1-14 – Daily Leachate Collection Rate Section 3/4 Supplemental Drain

The significant decrease in the leachate collection rate for the Section 2/8 original drain is observed on the daily collection rate graph (Figure 3.1-11) as it was on the monthly and annual leachate collection rate charts (Figures 3.1-1 and 3.1-7). A change in collection rate occurred mid-May 2001; a detailed evaluation of this period is provided in a following report section. Similar to the monthly and annual period graphs, precipitation effects are evident with fluctuations in the daily collection rates. The periods of low daily collection rates generally occur in the summer months and generally show a decreasing trend over time.

The low daily collection rates are interpreted as representing base flow conditions where leachate is primarily being collected in the drain (i.e., horizontal leachate flux from the refuse mound) without effects of precipitation.

There is no discernable change in the daily collection rates for the Section 3/4 original drain (see Figure 3.1-12). However, similar to the Section 2/8 original drain, the precipitation effects are evident, along with a general decrease in the low daily collection rates.

As shown on Figure 3.1-13, the daily leachate collection rate graph for the Section 2/8 supplemental drain shows a change in daily collection rate pattern in 2010. This may represent a change in the base flow. There is an obvious decrease in the maximum daily leachate collection rates which likely reflects a change in base flow conditions as annual precipitation rates are relatively consistent.

Similar to the Section 3/4 original drain, there is no discernable change in the daily collection rates for the Section 3/4 supplemental drain (Figure 3.1-14). Maximum daily leachate collection rates tend to decrease in starting in 2011. As noted above for the Section 2/8 supplemental drain, this decrease in the maximum daily collection rates may reflect a change in base flow conditions based on relatively consistent annual precipitation rates.

3.2 *Precipitation and Seasonality Effects Evaluation*

To evaluate the seasonal effect on the leachate collection rates the daily collection rates were plotted by monthly period. For example, the January daily collection rates for the Section 2/8

original drain for 1999 through 2015 (Figure 3.2-1). An additional plot of daily precipitation and monthly precipitation is presented below the daily collection rate graph.

These graphs are presented in the following Figures:

- Figures 3.2-1 through 3.2-12 Section 2/8 original drain January through December
- Figures 3.2-13 through 3.2-24 Section 3/4 original drain January through December
- Figures 3.2-25 through 3.2-36 Section 2/8 supplemental drain January through December
- Figures 3.2-37 through 3.2-48 Section 3/4 supplemental drain January through December

In general, these graphs clearly show the effect of precipitation on the collection rates. Precipitation is as recorded for the date and if a precipitation event occurs at the end of a month, the daily collections rates may not be affected until the following month. The months of lowest collection rates can also be determined based on these plots. The lowest collection rates are generally observed in July through October.

To further demonstrate the seasonality effects, the daily collection rates were plotted from minimum to maximum by monthly period over the full operational period (e.g., 1999 through 2014 for the Section 2/8 original drain). These graphs are shown in the following figures:

- Figure 3.2-49 Section 2/8 original drain
- Figure 3.2-50 Section 3/4 original drain
- Figure 3.2-51 Section 2/8 supplemental drain
- Figure 3.2-52 Section 3/4 supplemental drain

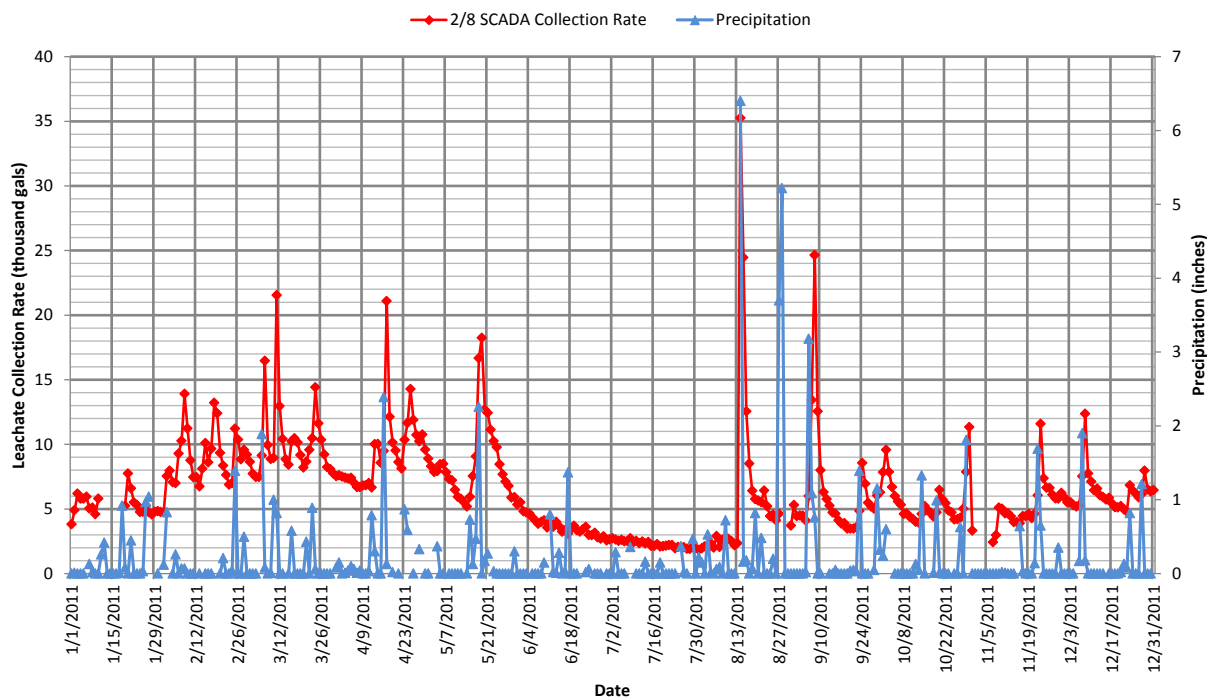
As shown on Figure 3.2-49, there is no observable difference in the periods of lowest collection rates at the scale presented. A reduced scale is required to observe these differences and a portion is provided as an insert on the main plot. On Figure 3.2-50 for the Section 3/4 original drain, the lowest collection rates occur in the months of July through November, and the highest collection rates tend to occur in January through May. For the Section 2/8 supplemental drain (Figure 3.2-51) the lowest collection rates occur in July through October and the highest collection rates clearly occur in December and January. At the Section 3/4 supplemental drain (Figure 3.2-52), the lowest collection rates are indicated in the months of July through October, and the highest collection rates tend to occur in December, January, April and May.

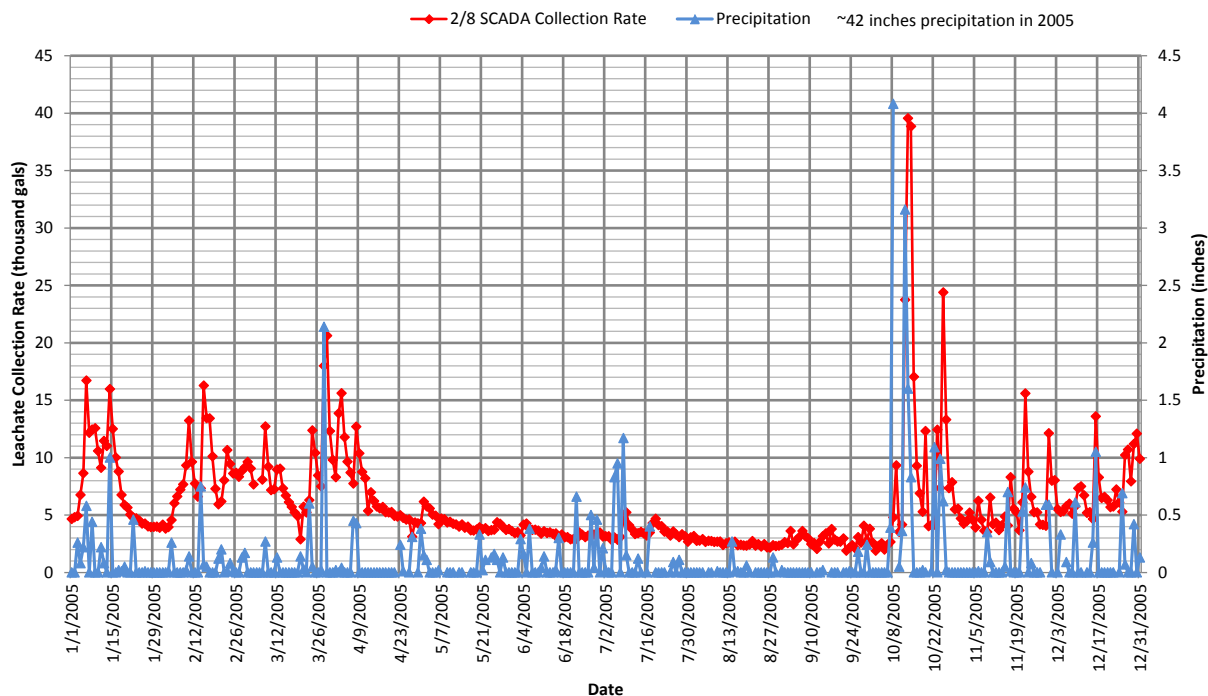
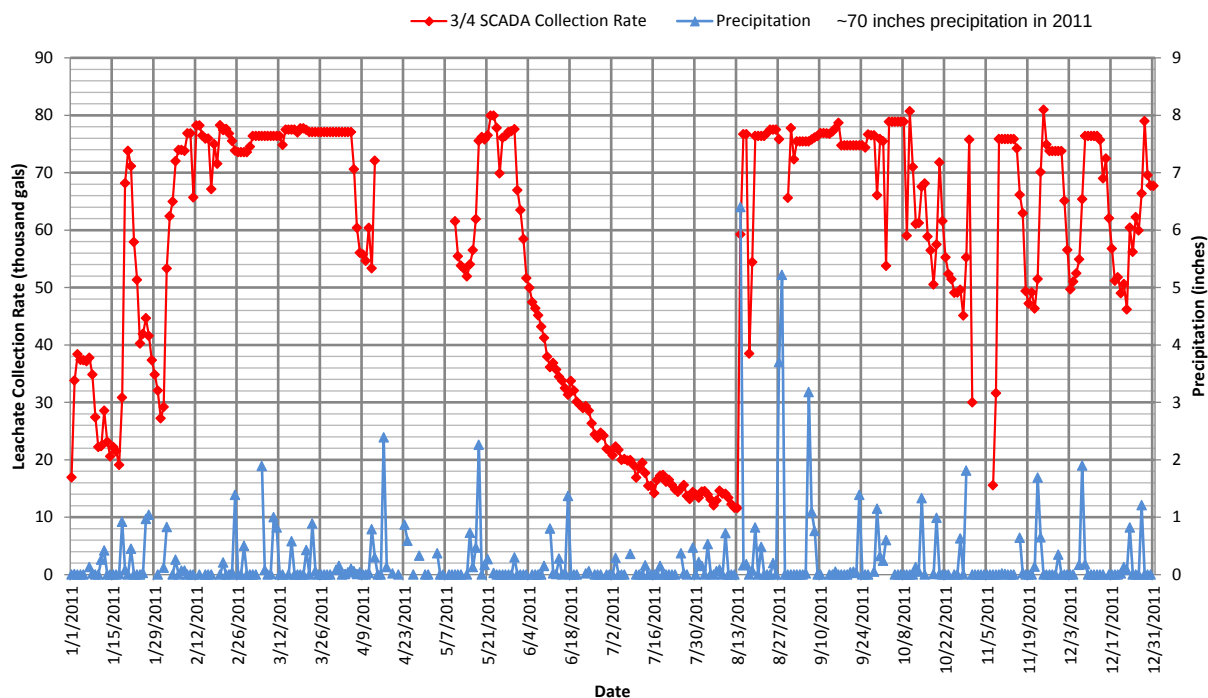
Specific examples showing that precipitation effects on leachate collection rates for the Sections 2/8 and 3/4 original collection drains are most pronounced during the winter and spring periods (December through May) are provided below. During the summer and early fall periods it generally takes a precipitation event of greater than an inch to have an influence on the collection rates. As shown in the graph for the Section 2/8 original drain for Year 2011 the leachate

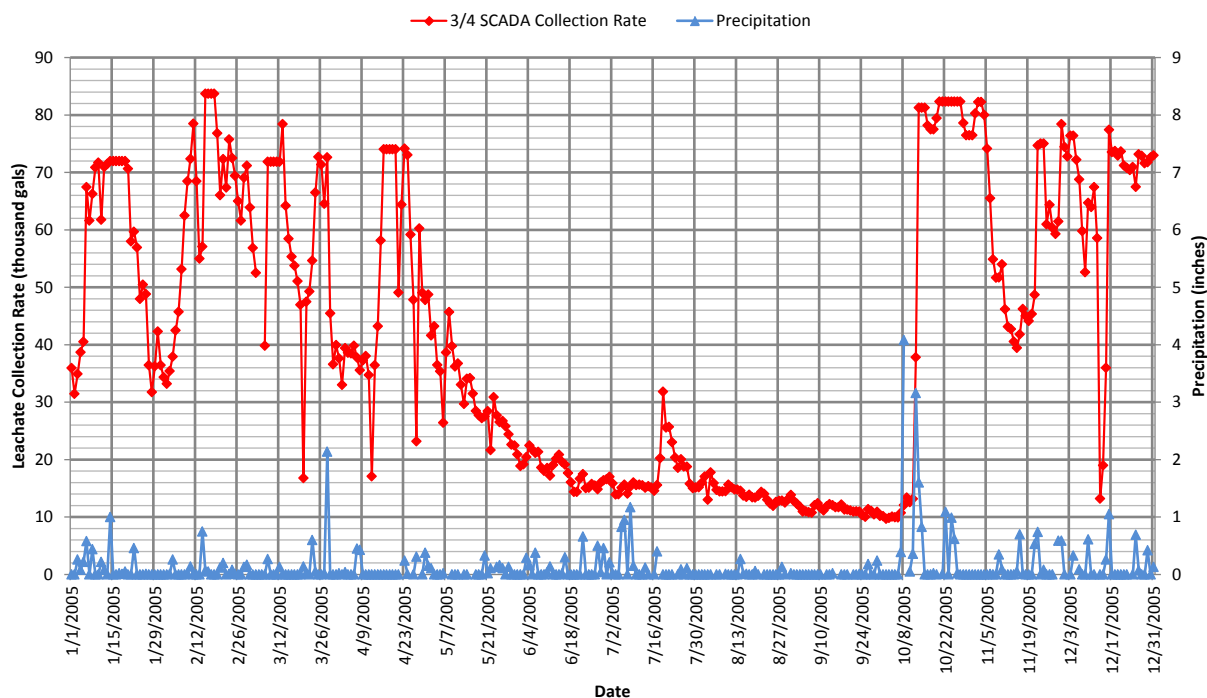
collection rate through July and August was in the 2,000 to 3,000 gpd range. After a precipitation event of more than 6 inches on August 14, 2011, the collection rate increased to more than 35,000 gpd. Two additional precipitation events exceeding 4-inches each followed on August 27 and September 6, 2011. At the Section 3/4 original collection drain, the leachate collection rate was approaching approximately 10,000 gpd prior to the precipitation events. The collection rate increased to more than 75,000 gpd and remained at that rate for about 25 days.

Landfill Section 2/8 Original Drain

Precipitation Effects on Leachate Collection Rates - Year 2011



Precipitation Effects on Leachate Collection Rates - Year 2005Landfill Section 3/4 Original Drain**Precipitation Effects on Leachate Collection Rates - Year 2011**

Precipitation Effects on Leachate Collection Rates - Year 2005

The periods of lowest collection rates as described above are used to select distinct periods to evaluate for base flow conditions. The base flow condition occurs when leachate is primarily being collected in the drain (i.e., horizontal leachate flux from the refuse mound) without contribution from precipitation. This evaluation provides an estimate of the percentage of the total collection rate that is attributable to only leachate.

3.3 *Base Flow Evaluation*

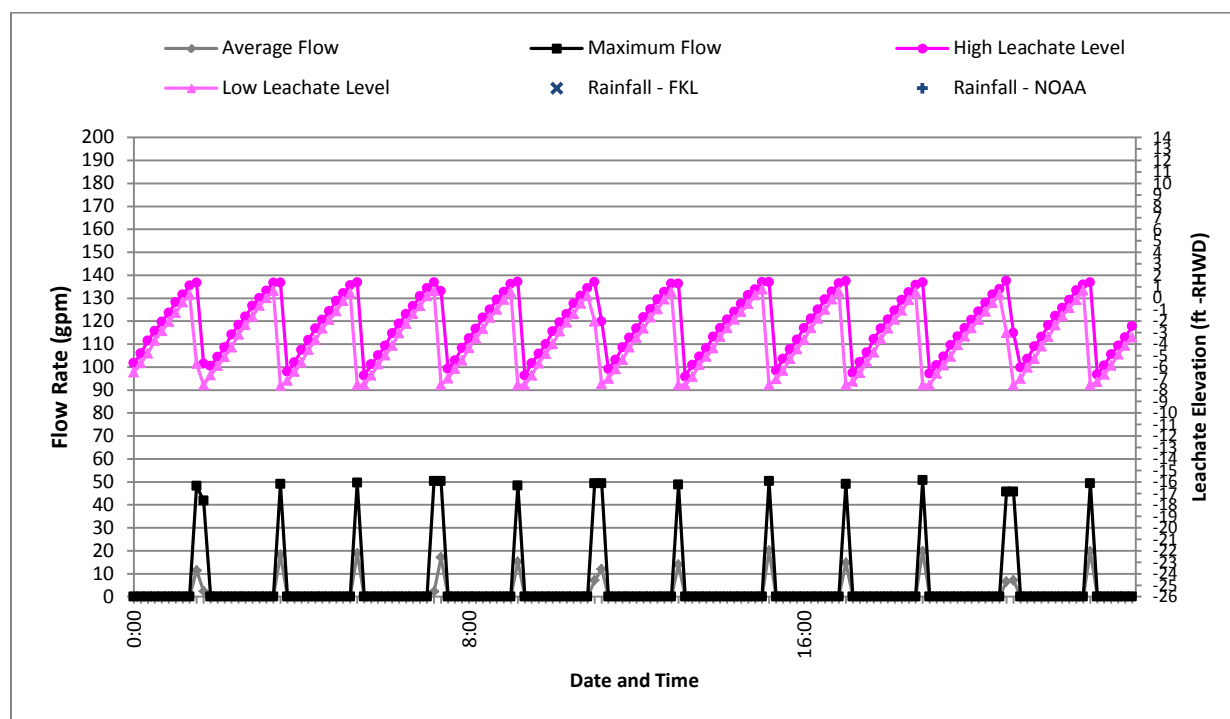
Based on the evaluation of operational data, the following have an effect on leachate collection rates and impact base flow conditions:

- Horizontal leachate flow from mound
- Groundwater flow
- Precipitation runoff and seepage
- Duration of operation of pump in collection well
- Pump off elevations

The precipitation from runoff and seepage, duration of the operation of the pump in the collection well, and pump off elevations can be determined by evaluation of the SCADA-recorded leachate elevation and flow rate data. The groundwater flow component in the original drains and the groundwater and surface water (i.e., Main and Richmond Creeks) components in

the supplemental drains are difficult if not impossible to determine; therefore, these components are conservatively counted as leachate in this analysis. In general, the pump off elevation is set to the bottom elevation of the collection drain. Leachate collection rates can be influenced if these settings vary. Specifically, a daily collection rate may be biased low if the pump off elevation is set to a higher level. This is important to consider when evaluating leachate collection rates for base flow conditions.

The initial evaluation performed was to determine base flow conditions when the original drain segments began operating in September 1998. The flow rates are plotted against the leachate elevations to demonstrate system operation. For example, as shown in the figure below, the system is cycling because the pump is removing leachate from the drain faster than the recharge.



The operational data for the Section 2/8 original drain are provided in Figures 3.3-1 through 3.3-4 for the months of September through December 1998. The operation data for September 1998 (Figure 3.3-1) is not useful as the leachate elevations and pumping rates are not representative of system operation. Based on the totalizer reading for September 1998 of 556,790 gallons the daily average was about 18,560 gallons. An evaluation of the operational data for October 1998 (Figure 3.3-2) indicates that the pump was off approximately 6 days. Adjusting the totalizer reading of 541,800 gallons for the time the pump was not operating, the average daily collection rate for October 1998 was 21,830 gallons. The operational data for November 1998 indicates that the average daily collection rate was about 12,193 gallons (see Figure 3.3-3). Figure 3.3-3 also includes a time series graph showing a daily collection rate of about 10,000 gallons per day

(gpd). Figure 3.3-4 shows the operational data for December 1998. The pump in the Section 2/8 original drain was not operating for about 14 days during the month of December 1998. The totalizer reading for this period was 177,773 gallons, and adjusting for the time the pump was not operating the average collection rate in December 1998 was about 10,613 gpd. The time series graph included on Figure 3.3-4 shows daily collection rates of about 10,000 gpd decreasing to about 8,000 gpd. A summary of the adjusted daily collection rates are presented below:

Period	Section 2/8 Totalizer Readings	Totalizer Average Daily Collection Rate (gal)	Adjusted Average Daily Collection Rate (gal)
September 1998	556,790	18,560	***
October 1998	541,800	17,477	21,830
November 1998	320,585	10,686	12,193
December 1998	177,773	5,926	11,282

Note: *** Pumping rate and leachate elevation data not sufficient to perform evaluation

A similar evaluation was performed for the Section 3/4 original drain. The operation data for the Section 3/4 original drain are provided in Figures 3.3-5 through 3.3-8 for the months of September through December 1998. As shown on these figures, the operational data for the Section 3/4 original drain are more consistent than the Section 2/8 original drain data. The operation data for September 1998 (Figure 3.3-5) indicates that pumping as controlled by the SCADA system began at approximately 15:50 on September 1, 1998. The totalizer reading for September 1998 was 835,950 gallons which is an average of about 31,703 gpd. An evaluation of the operational data for October 1998 (Figure 3.3-6) indicates that the pump was off approximately 5 days. Adjusting the totalizer reading of 715,292 gallons for the time the pump was not operating, the average collection rate for October 1998 was about 27,063 gpd. The operational data for November 1998 indicates that the average daily collection rate was about 20,397 gallons based on a totalizer reading of 482,171 gallons and adjusted for the time the pump was not operating (see Figure 3.3-7). Figure 3.3-8 provides the operational data for December 1998 and shows that the pump in the Section 3/4 original drain was operating nearly the entire month with just one obvious period of shutdown. The totalizer reading was 523,400 gallons and adjusting for the time the pump was not operating the average collection rate in December 1998 was about 17,992 gpd. A summary of the adjusted daily collection rates for the first four months of operation are presented below:

Period	Totalizer Reading	Average Daily Collection Rate Based on Totalizer (gpd)	Adjusted Average Daily Collection Rate (gpd)
September 1998	835,950	27,865	31,703
October 1998	715,292	23,074	27,063
November 1998	482,171	16,072	20,397
December 1998	523,400	16,884	17,992

Precipitation was relatively low during the period of September through December 1998, with the highest precipitation occurring in September with about 2.5 inches; October precipitation was just under 2 inches and November and December less than 1 inch. Only two rain events of approximately one inch were recorded. Consequently, during initial operation, precipitation likely did not have an effect on the leachate collection rates. Therefore, the adjusted average collection rates likely represent initial base flow.

Using the periods of low collection rates based on the precipitation and seasonality evaluation as presented previously, the daily collection rates were sorted for 12-month periods from minimum to maximum collection rates. Representative collection rates for a specific month were used to determine the average estimated base flow for a period. An example based on the Section 3/4 original drain is provided below:

Date	Daily Rate (1,000 gal)	Date	Daily Rate (1,000 gal)	Date	Daily Rate (1,000 gal)	Date	Daily Rate (1,000 gal)
4/18/2008	5.347	9/19/2008	9.580	8/29/2010	9.416	9/6/2010	8.843
8/14/2008	7.808	10/23/2008	9.610	8/28/2010	9.485	9/15/2010	9.013
8/10/2008	8.124	9/17/2008	9.746	8/24/2010	9.853	9/5/2010	9.067
8/31/2008	9.168	10/19/2008	9.892	8/21/2010	9.854	11/1/2010	9.275
8/9/2008	9.357	9/16/2008	9.922	8/31/2010	9.919	9/11/2010	9.331
8/22/2008	9.784	9/1/2008	9.940	8/30/2010	10.014	11/19/2010	9.340
8/21/2008	9.839	9/5/2008	9.984	8/13/2010	10.040	9/7/2010	9.342
10/29/2007	9.839	9/4/2008	10.020	8/26/2010	10.075	9/13/2010	9.349
11/18/2007	9.933	9/11/2008	10.085	8/25/2010	10.169	11/11/2010	9.356
10/25/2007	10.005	9/23/2008	10.094	8/14/2010	10.170	11/21/2010	9.369
11/19/2007	10.021	9/2/2008	10.144	8/15/2010	10.183	9/10/2010	9.372
11/24/2007	10.037	9/24/2008	10.229	8/17/2010	10.220	9/12/2010	9.427
8/27/2008	10.047	10/24/2008	10.267	8/27/2010	10.222	9/14/2010	9.487
8/20/2008	10.068	9/22/2008	10.324	8/23/2010	10.231	11/22/2010	9.496
8/23/2008	10.070	9/8/2008	10.413	8/20/2010	10.265	11/12/2010	9.517
8/29/2008	10.272	9/20/2008	10.476	8/18/2010	10.365	9/29/2010	9.529
8/26/2008	10.301	9/25/2008	10.540	7/5/2010	10.412	11/7/2010	9.546
8/15/2008	10.339	9/10/2008	10.569	8/19/2010	10.547	11/18/2010	9.662
8/30/2008	10.437	9/3/2008	10.641	8/8/2010	10.624	9/8/2010	9.690
8/28/2008	10.457	9/18/2008	10.679	8/22/2010	10.678	11/6/2010	9.802
10/26/2007	10.574	10/22/2008	10.690	8/16/2010	10.811	9/27/2010	9.802
11/25/2007	10.787	10/11/2008	10.940	8/7/2010	10.902	9/26/2010	9.866
10/22/2007	10.791	7/29/2009	10.963	10/20/2009	10.939	11/30/2010	9.876
11/17/2007	10.872	9/9/2008	10.996	10/26/2009	11.016	11/29/2010	9.939
11/20/2007	10.881	9/12/2008	11.020	10/21/2009	11.023	9/9/2010	9.957

Note: The shaded values are representative collection rates for the specific periods.

Using the data for the entire operating period, a period average base flow was calculated based on the selected representative daily flows. The period used and the calculated average for the Section 3/4 original drain are presented below. These calculated averages were then used to determine an estimated base flow for a calendar year. The estimated annual base flows are also shown in the table below:

Period	Period Average (1,000 gpd)	Year	Estimated Base Flow (gpd)
Nov-99	18.415	1999	19,000
Aug-00	19.188	2000	17,000
Nov-00	13.022		
		2001	13,000
Aug-02	13.200	2002	13,000
Sep-02	13.868		
Oct-03	12.510	2003	13,000
Feb-04	13.154	2004	13,000
Aug-05	12.929	2005	12,000
Oct-05	10.050		
Oct-06	12.769	2006	10,000
Oct-07	9.967	2007	10,000
Aug-08	10.012	2008	10,000
Sep-08	9.974		
		2009	10,000
Aug-10	10.030	2010	9,500
Sep-10	9.276		
		2011	9,500
Aug-12	11.169	2012	9,500
Oct-12	9.496		
Oct-13	6.368	2013	9,500
Oct-14	9.580	2014	9,500

Note: The period averages shaded orange indicate values that are higher or lower than surrounding values.

The period used, the calculated average, and the estimated base flow for a calendar year based on these calculated averages for the Section 2/8 original drain are presented below:

Period	Period Average (1,000 gpd)	Year	Estimated Base Flow (gpd)
Aug-99	4.866	1999	7,000
Sep-99	6.810		
Jun-00	5.230	2000	5,000
May-01	3.125	2001	3,000
Aug-01	2.798		
Aug-02	1.863	2002	2,500
Sep-02	2.047		
Oct-03	3.020	2003	2,500
		2004	2,500
Aug-05	2.426	2005	2,500
Sep-05	2.310		
Sep-06	2.992	2006	2,500
Oct-06	2.917		
Oct-07	2.251	2007	2,500
Oct-08	2.551	2008	2,500
Jul-09	2.376	2009	2,500
Aug-10	1.931	2010	2,000
Sep-10	1.838		
Jul-11	1.917	2011	2,000
Aug-12	2.428	2012	2,000
Sep-12	2.343		
Nov-13	1.408	2013	1,500
Oct-14	1.520	2014	1,500

To substantiate the validity of this method for estimating base flow, the actual totalizer readings were compared to the estimated collection rates based the estimated base flows for September 1998 through December 2002, the first several years of operation. This comparison is shown in Figure 3.3-9. The increases in totalizer collection rates correspond to higher precipitation rates as shown on Figure 3.3-10.

A more detailed evaluation of the operational data was performed for May 2001, when the collection rate appears to be stabilizing as shown on Figure 3.3-9. A time series graph of the collection rates for May 2001 is presented in the lower half of the figure and shows a steady decrease. The operational data for May 16, 2001 is presented in the upper portion of Figure 3.3-11 which demonstrates the system is operating as designed, with the changes in leachate elevations showing the pump on and pump off elevations and the flow rate showing the rate at which the pump is operating. An obvious change in collection rate and recharge rate is noted at

about 14:40 on May 16, 2015. With the decreasing collection rates, a 1.3 inch precipitation event on May 22, 2001 was observed to have an effect on the collection rate about noon of that day, with a corresponding increase in the collection rate for that day. As indicated on Figure 3.3-11, the pump rates starting at about 14:10 on May 29 are not valid, thus the inconsistent collection rates for May 29 through May 31, 2001.

Additional evaluations were performed for the Section 2/8 original drain for October 2003 and September 2014. The daily operation data for October 2003 is presented in Figure 3.3-12. The totalizer reading for this month was 114,210 and the average collection rate adjusted for when collection well was not pumping is 3,855 gpd. The SCADA recorded collection rate for October 2003 was 116,336 gallons and the average is 3,753 gpd. A time series graph of the daily collection rates is included as an insert on the primary graph. This shows a relatively consistent collection rate of about 3,150 gpd from October 9 through October 23, and a minimum rate of about 2,700 gpd on October 24 and 25. The increase in collection rates at the end of the month are related to precipitation events.

The daily operation data for September 2014 is presented in Figure 3.3-13. The totalizer reading for this month was 48,755 gallons and the average collection rate adjusted for when the collection well was not pumping is 1,625 gpd. The SCADA-recorded collection rate for September 2014 was 54,441 gallons and the average is 1,815 gpd. The time series graph on Figure 3.3-13 shows a relatively consistent collection rate of about 1,600 gpd from September 22 to 27, 2014, which represents base flow conditions.

The base flow conditions for the supplemental drains are more difficult to determine; however, a decrease in the collection rates is evident over time. To demonstrate the change in collection rates over time in the supplemental drains, the daily leachate collection rates for each operating year were plotted from minimum to maximum. Low collection rates that are not representative of operating conditions were not included. These plots are shown on Figures 3.3-14 and 3.3-15 for Sections 2/8 and 3/4, respectively. The lowest 8 through 21 and lowest 2 through 26 collection rates for each operating year were plotted and are included as insert graphs on Figures 3.3-14 and 3.3-15. These ranges of rates were selected based on a review of the overall and were determined to represent base flow conditions. Both graphs show a decrease in collection rates over time.

For verification, the operating data for the Section 2/8 supplemental drain for October 2012 was evaluated. The collection rates for October 2012 are provided in a time series graph in the upper portion of Figure 3.3-16 and show that the lowest collection rates are approximately 15,000 gpd. The operating data for October 13, 2012, which is provided in the lower portion of Figure 3.3-16, shows that the system was operating as designed. The 15,000 gpd is consistent with estimated base flow for Year 11 (2012) shown on the insert time series graph on Figure 3.3-14.

The operating data for the Section 3/4 supplemental drain for July 2011 was also evaluated for verification. The collection rates for July 2011 are provided in a time series graph in the upper portion of Figure 3.3-17 and show that the lowest collection rate is approximately 18,000 gpd on July 23, 2011. The operating data for July 23, 2011, which is provided in the lower portion of Figure 3.3-17, shows that the system was operating as designed. The 18,000 gpd when projected on the insert time series graph on Figure 3.3-15 is consistent with estimated decrease in base flow over time.

Table 3.1-1
SCADA-Recorded and Monthly Totalizer Readings
Section 2/8 Original Drain
Sections 2/8 and 3/4 Leachate Controls Report
Fresh Kills Landfill

Period	SCADA	Totalizer
	(1,000 gal)	
September-98	548.26	556.79
October-98	291.36	541.80
November-98	297.46	320.59
December-98	181.21	177.77
January-99	1727.88	1677.50
February-99	949.57	950.26
March-99	1571.68	1565.84
April-99	737.23	746.65
May-99	566.71	573.33
June-99	377.16	369.57
July-99	225.27	221.07
August-99	198.15	218.05
September-99	891.15	500.59
October-99	634.00	652.34
November-99	487.67	513.57
December-99	1039.57	1042.41
January-00	639.36	639.36
February-00	1021.84	1056.87
March-00	1139.64	1142.23
April-00	1098.74	1094.97
May-00	326.67	292.81
June-00	6.63	41.49
July-00	62.31	27.44
August-00	263.60	275.82
September-00	278.84	276.05
October-00	143.94	134.51
November-00	127.62	150.16
December-00	613.88	605.78
January-01	979.60	979.60
February-01	1046.32	1046.32
March-01	1347.93	1347.93
April-01	887.83	887.83
May-01	303.99	303.99
June-01	512.99	512.99
July-01	211.77	211.77
August-01	175.68	175.68
September-01	115.14	115.14
October-01	160.39	113.49
November-01	172.68	92.46
December-01	180.64	120.12
January-02	114.20	107.08
February-02	87.21	83.64
March-02	175.76	168.14
April-02	144.61	144.18
May-02	194.74	186.32
June-02	101.24	93.41
July-02	75.02	69.80
August-02	71.59	69.56
September-02	86.79	75.96

Period	SCADA	Totalizer
	(1,000 gal)	
October-02	181.59	172.50
November-02	172.47	157.95
December-02	217.37	208.78
January-03	202.84	196.17
February-03	126.79	117.93
March-03	272.67	265.50
April-03	251.49	245.76
May-03	185.38	172.12
June-03	291.97	265.41
July-03	117.53	111.99
August-03	150.47	137.88
September-03	117.51	117.04
October-03	117.08	114.21
November-03	178.54	173.52
December-03	256.87	249.90
January-04	156.07	159.36
February-04	165.31	158.34
March-04	254.74	244.42
April-04	268.10	260.48
May-04	161.51	137.74
June-04	120.31	55.88
July-04	174.95	140.53
August-04	124.26	521.01
September-04	124.88	75.93
October-04	114.20	102.83
November-04	126.78	123.70
December-04	183.21	178.48
January-05	234.76	215.22
February-05	233.01	212.93
March-05	253.45	247.72
April-05	211.73	205.95
May-05	131.51	116.54
June-05	101.45	96.47
July-05	108.82	102.39
August-05	78.28	73.98
September-05	85.50	60.61
October-05	291.82	258.66
November-05	166.87	143.49
December-05	224.65	228.68
January-06	321.57	301.46
February-06	258.44	231.37
March-06	169.91	140.76
April-06	171.82	173.43
May-06	158.66	150.59
June-06	169.93	162.91
July-06	133.69	124.93
August-06	95.34	89.57
September-06	151.22	145.75

Table 3.1-1
SCADA-Recorded and Monthly Totalizer Readings
Section 2/8 Original Drain
Sections 2/8 and 3/4 Leachate Controls Report
Fresh Kills Landfill

Period	SCADA	Totalizer
	(1,000 gal)	
October-06	158.95	156.85
November-06	228.07	219.09
December-06	170.93	169.67
January-07	127.15	119.05
February-07	113.02	106.98
March-07	253.08	244.15
April-07	358.30	350.97
May-07	197.06	186.48
June-07	129.96	123.24
July-07	124.90	120.32
August-07	140.01	133.24
September-07	86.75	82.72
October-07	83.11	79.02
November-07	88.97	87.37
December-07	141.48	139.85
January-08	176.50	184.49
February-08	201.77	213.71
March-08	241.27	254.53
April-08	186.77	181.90
May-08	202.31	201.52
June-08	79.61	117.48
July-08	99.25	94.49
August-08	106.74	99.96
September-08	122.37	146.13
October-08	116.56	136.52
November-08	135.12	154.73
December-08	217.55	231.60
January-09	173.70	171.53
February-09	156.24	149.68
March-09	172.64	155.91
April-09	251.35	246.71
May-09	165.93	233.67
June-09	129.27	184.90
July-09	95.83	137.23
August-09	12.99	112.37
September-09	34.11	90.48
October-09	104.57	98.55
November-09	106.59	100.32
December-09	191.61	186.64
January-10	159.12	164.76
February-10	192.04	192.18
March-10	239.03	315.65
April-10	244.30	207.89
May-10	172.98	162.20
June-10	114.74	109.82
July-10	79.75	74.78
August-10	65.55	61.91
September-10	63.77	64.89

Period	SCADA	Totalizer
	(1,000 gal)	
October-10	111.03	101.80
November-10	85.68	83.28
December-10	127.67	114.51
January-11	118.17	150.62
February-11	250.71	239.84
March-11	310.19	294.90
April-11	282.29	269.27
May-11	262.11	244.92
June-11	109.32	99.79
July-11	70.54	66.90
August-11	167.69	171.02
September-11	188.37	185.69
October-11	170.78	157.01
November-11	125.71	125.94
December-11	193.46	184.40
January-12	178.81	185.12
February-12	141.22	147.47
March-12	149.15	155.09
April-12	127.21	123.22
May-12	178.12	170.84
June-12	133.67	126.01
July-12	104.00	81.91
August-12	82.69	78.56
September-12	80.91	83.72
October-12	80.00	82.93
November-12	97.08	91.62
December-12	144.48	132.33
January-13	154.31	159.38
February-13	181.54	181.54
March-13	231.20	217.49
April-13	173.78	163.97
May-13	120.26	116.84
June-13	234.98	220.43
July-13	127.15	101.75
August-13	97.47	104.16
September-13	82.02	74.86
October-13	65.33	55.04
November-13	53.35	49.07
December-13	92.85	89.77
January-14	148.94	147.04
February-14	216.49	211.78
March-14	200.12	202.37
April-14	221.84	238.04
May-14	237.95	226.61
June-14	134.88	137.04
July-14	107.06	109.77
August-14	74.90	74.47
September-14	54.45	48.76
October-14	57.30	67.62
November-14	90.62	93.12
December-14	178.85	171.97

Table 3.1-2
SCADA-Recorded and Monthly Totalizer Readings
Section 3/4 Original Drain
Sections 2/8 and 3/4 Leachate Controls Report
Fresh Kills Landfill

Period	SCADA	Totalizer
	(1,000 gal)	
September-98	67.21	835.95
October-98	9.97	715.29
November-98	425.13	482.17
December-98	513.38	523.40
January-99	1428.81	1480.69
February-99	1453.96	1468.27
March-99	1941.68	1940.57
April-99	1093.53	1095.67
May-99	809.22	809.06
June-99	605.71	608.22
July-99	549.82	515.01
August-99	96.04	91.14
September-99	641.43	603.20
October-99	0.00	996.06
November-99	0.00	463.92
December-99	0.00	1303.51
January-00	938.24	938.24
February-00	1316.04	1375.68
March-00	1646.00	1636.96
April-00	1402.21	1400.02
May-00	1273.32	1268.35
June-00	814.02	770.58
July-00		
August-00	995.15	1013.95
September-00	516.14	512.91
October-00	445.53	443.41
November-00	410.91	412.84
December-00	886.74	871.22
January-01	1282.81	1282.81
February-01	1588.19	1588.19
March-01	1596.31	1596.31
April-01	1642.53	1642.53
May-01	1102.33	1102.33
June-01	766.03	766.03
July-01	573.76	573.76
August-01	486.44	486.44
September-01	478.41	478.41
October-01	679.32	666.36
November-01	1884.55	1953.30
December-01	2192.22	1149.33
January-02	2121.31	2062.06
February-02	1815.03	1761.38
March-02	1592.08	1550.96
April-02	1100.82	1092.99
May-02	1263.53	1202.08
June-02	787.78	745.79
July-02	533.82	504.19
August-02	416.65	392.94
September-02	478.44	442.28

Period	SCADA	Totalizer
	(1,000 gal)	
October-02	1582.11	1565.03
November-02	1790.15	1722.12
December-02	2185.47	2201.23
January-03	2015.00	2014.61
February-03	1114.03	1026.44
March-03	2311.18	2375.20
April-03	2118.98	2081.54
May-03	1264.35	1244.51
June-03	2051.61	2016.40
July-03	1525.18	1451.02
August-03	1380.17	1300.49
September-03	608.49	911.01
October-03	513.13	319.05
November-03	1054.37	411.95
December-03	1374.77	566.52
January-04	1135.20	480.87
February-04	718.18	571.24
March-04	1885.15	1848.39
April-04	1924.06	2060.14
May-04	1866.30	3076.61
June-04	1330.62	185.48
July-04	1742.73	161.40
August-04	2036.88	663.45
September-04	1345.59	1368.86
October-04	1287.96	1170.18
November-04	775.33	777.43
December-04	1693.77	1678.97
January-05	1694.74	1615.20
February-05	1775.40	1639.09
March-05	1698.35	1719.12
April-05	1483.15	1574.55
May-05	980.29	874.81
June-05	538.15	515.26
July-05	543.35	515.85
August-05	437.76	416.43
September-05	340.25	329.95
October-05	1682.43	1650.03
November-05	1769.50	1730.43
December-05	2033.41	2095.41
January-06	2020.16	2154.17
February-06	1846.56	1797.44
March-06	1529.04	1262.05
April-06	1496.70	1229.36
May-06	1423.79	1735.52
June-06	1682.36	1316.77
July-06	858.94	763.04
August-06	444.09	429.53
September-06	448.94	438.66

Table 3.1-2
SCADA-Recorded and Monthly Totalizer Readings
Section 3/4 Original Drain
Sections 2/8 and 3/4 Leachate Controls Report
Fresh Kills Landfill

Period	SCADA	Totalizer
	(1,000 gal)	
October-06	988.99	995.92
November-06	1952.50	1910.11
December-06	1499.47	1499.50
January-07	1773.89	1739.62
February-07	677.19	652.57
March-07	1681.65	1652.46
April-07	1867.48	1837.77
May-07	1743.07	1669.32
June-07	766.80	734.02
July-07	549.77	533.71
August-07	840.26	819.03
September-07	505.96	496.18
October-07	384.44	378.68
November-07	371.45	390.84
December-07	1226.43	1298.93
January-08	1786.88	1818.72
February-08	1704.77	1776.96
March-08	1861.88	1861.92
April-08	807.00	777.44
May-08	1207.46	1155.66
June-08	657.63	601.67
July-08	383.15	365.17
August-08	368.82	346.27
September-08	351.56	352.80
October-08	405.39	408.96
November-08	661.79	668.16
December-08	1420.92	1424.16
January-09	1238.65	1195.69
February-09	766.07	727.61
March-09	600.25	532.67
April-09	1107.14	1090.27
May-09	1221.57	1200.98
June-09	718.58	966.07
July-09	818.54	821.40
August-09	722.09	653.59
September-09	428.37	416.59
October-09	505.48	520.47
November-09	678.44	634.31
December-09	1609.44	1642.13
January-10	1395.23	1442.62
February-10	1221.28	1224.68
March-10	2236.42	2304.71
April-10	1931.42	1919.37
May-10	1304.47	1185.03
June-10	625.58	601.43
July-10	424.37	410.60
August-10	330.91	320.05
September-10	265.09	259.59

Period	SCADA	Totalizer
	(1,000 gal)	
October-10	383.36	372.00
November-10	318.85	302.77
December-10	699.64	631.53
January-11	1106.54	1086.76
February-11	2001.89	1993.67
March-11	2377.69	2377.64
April-11	896.34	2134.63
May-11	1536.53	2150.11
June-11	1083.24	1005.68
July-11	530.75	513.09
August-11	1312.79	1338.24
September-11	2263.03	2266.86
October-11	1940.83	1909.91
November-11	1544.11	1491.69
December-11	1951.01	1892.41
January-12	1528.89	1585.51
February-12	950.13	985.52
March-12	819.18	831.82
April-12	594.11	581.79
May-12	861.59	836.28
June-12	670.44	639.60
July-12	448.75	432.47
August-12	368.52	357.91
September-12	328.36	340.00
October-12	300.23	289.54
November-12	432.33	420.55
December-12	940.11	944.37
January-13	1168.97	1244.01
February-13	1407.30	1423.46
March-13	1783.67	1717.23
April-13	949.09	946.21
May-13	783.17	758.49
June-13	1070.96	1082.07
July-13	820.25	764.46
August-13	451.26	442.34
September-13	325.71	314.99
October-13	262.21	260.42
November-13	228.90	227.15
December-13	573.05	625.19
January-14	1627.31	1626.50
February-14	1754.87	1825.38
March-14	1819.93	1820.52
April-14	1964.91	1961.89
May-14	1919.20	1817.49
June-14	988.45	941.27
July-14	1030.49	1085.03
August-14	557.32	547.66
September-14	367.41	697.50
October-14	331.98	333.03
November-14	634.74	359.50
December-14	2175.38	2072.04

Table 3.1-3
SCADA-Recorded and Monthly Totalizer Readings
Section 2/8 Supplemental Drain
Sections 2/8 and 3/4 Leachate Controls Report
Fresh Kills Landfill

Period	SCADA	Totalizer
	(million gal)	
November-01	0.00	0.16
December-01	0.00	1.16
January-02	1.18	1.26
February-02	0.92	0.93
March-02	1.67	1.70
April-02	1.21	1.29
May-02	1.94	1.91
June-02	0.81	0.16
July-02	0.60	0.60
August-02	0.57	0.64
September-02	1.02	1.01
October-02	2.22	2.27
November-02	1.49	1.35
December-02	1.96	1.55
January-03	2.20	2.25
February-03	1.16	1.27
March-03	1.93	2.02
April-03	1.27	1.31
May-03	0.35	0.37
June-03	0.58	0.59
July-03	2.14	1.97
August-03	1.89	1.77
September-03	1.26	1.45
October-03	1.37	1.45
November-03	2.25	2.25
December-03	2.35	2.41
January-04	1.96	1.97
February-04	1.71	2.06
March-04	2.00	2.00
April-04	2.27	2.27
May-04	1.61	0.51
June-04	1.22	1.09
July-04	1.83	0.16
August-04	2.02	3.51
September-04	1.59	1.63
October-04	1.70	1.68
November-04	1.41	1.44
December-04	2.30	2.50
January-05	2.15	2.05
February-05	1.86	1.82
March-05	1.78	1.86

Period	SCADA	Totalizer
	(million gal)	
April-05	1.02	1.14
May-05	1.77	1.72
June-05	0.90	0.89
July-05	1.02	1.05
August-05	0.80	0.81
September-05	0.23	0.23
October-05	0.00	0.00
November-05	0.00	0.00
December-05	1.13	1.23
January-06	1.65	1.68
February-06	2.03	2.08
March-06	1.67	1.64
April-06	1.39	1.48
May-06	1.84	1.85
June-06	1.65	0.26
July-06	1.43	1.39
August-06	0.52	0.53
September-06	1.52	1.50
October-06	1.26	1.36
November-06	2.06	2.10
December-06	2.14	2.15
January-07	1.20	1.11
February-07	1.50	1.48
March-07	2.00	2.05
April-07	2.04	2.06
May-07	2.04	2.06
June-07	1.22	1.17
July-07	0.96	0.95
August-07	1.47	1.46
September-07	0.74	0.73
October-07	0.82	0.50
November-07	1.03	1.05
December-07	1.99	2.06
January-08	2.20	2.20
February-08	1.96	1.96
March-08	1.82	1.81
April-08	1.19	1.24
May-08	0.90	0.85
June-08	0.18	0.19

Table 3.1-3
SCADA-Recorded and Monthly Totalizer Readings
Section 2/8 Supplemental Drain
Sections 2/8 and 3/4 Leachate Controls Report
Fresh Kills Landfill

Period	SCADA	Totalizer
	(million gal)	
July-08	0.29	0.31
August-08	0.76	0.77
September-08	0.95	0.97
October-08	1.31	1.32
November-08	1.59	1.61
December-08	1.98	1.98
January-09	1.94	1.96
February-09	1.14	1.14
March-09	1.07	1.02
April-09	1.82	1.91
May-09	1.88	1.89
June-09	1.47	1.52
July-09	1.26	1.30
August-09	0.80	0.95
September-09	0.40	0.76
October-09	1.25	1.25
November-09	1.79	1.74
December-09	2.02	2.08
January-10	1.87	1.87
February-10	1.31	1.31
March-10	1.68	1.76
April-10	1.66	1.71
May-10	1.66	1.63
June-10	0.81	0.79
July-10	0.52	0.50
August-10	0.64	0.63
September-10	0.56	0.55
October-10	1.11	1.08
November-10	0.91	0.88
December-10	1.34	0.85
January-11	1.47	1.56
February-11	1.73	1.80
March-11	1.94	1.99
April-11	1.87	1.91
May-11	1.91	1.96
June-11	1.35	1.31
July-11	0.72	0.69
August-11	0.80	0.79
September-11	1.90	1.95

Period	SCADA	Totalizer
	(million gal)	
October-11	1.93	1.89
November-11	1.46	1.56
December-11	1.95	2.00
January-12	1.82	1.82
February-12	1.21	1.21
March-12	1.12	1.12
April-12	0.93	1.09
May-12	1.37	1.36
June-12	1.23	1.19
July-12	0.74	0.71
August-12	0.56	0.54
September-12	0.49	0.49
October-12	0.63	0.62
November-12	1.74	1.75
December-12	1.58	1.60
January-13	1.80	1.80
February-13	1.55	1.55
March-13	1.72	1.76
April-13	1.45	1.42
May-13	1.05	1.04
June-13	1.49	1.53
July-13	0.95	0.95
August-13	0.76	0.74
September-13	0.53	0.51
October-13	0.57	0.55
November-13	0.49	0.47
December-13	1.07	1.14
January-14	1.87	1.96
February-14	1.63	1.70
March-14	1.86	1.88
April-14	1.77	1.89
May-14	1.76	1.76
June-14	1.28	1.27
July-14	0.85	0.89
August-14	0.74	0.73
September-14	0.61	0.58
October-14	0.63	0.62
November-14	1.03	1.06
December-14	1.83	1.88

Table 3.1-4
SCADA-Recorded and Monthly Totalizer Readings
Section 3/4 Supplemental Drain
Sections 2/8 and 3/4 Leachate Controls Report
Fresh Kills Landfill

Period	SCADA	Totalizer
	(million gal)	
November-01		0.149
December-01		1.376
January-02	1.380	1.435
February-02	1.289	1.269
March-02	1.676	1.653
April-02	0.960	1.027
May-02	1.390	1.307
June-02	0.956	0.945
July-02	0.606	0.607
August-02	0.916	1.035
September-02	0.944	0.831
October-02	1.911	1.895
November-02	1.832	1.052
December-02	1.225	1.117
January-03	1.020	0.874
February-03	0.206	0.074
March-03	1.191	1.113
April-03	2.233	2.034
May-03	0.183	1.826
June-03	0.570	1.748
July-03	0.663	0.566
August-03	1.770	1.776
September-03	1.416	1.471
October-03	1.252	1.306
November-03	1.775	2.732
December-03	2.026	2.123
January-04	1.911	0.733
February-04	1.655	1.069
March-04	2.012	2.593
April-04	1.965	2.079
May-04	2.015	1.868
June-04	1.768	1.513
July-04	1.847	1.523
August-04	1.706	3.114
September-04	1.916	1.938
October-04	2.170	2.168
November-04	0.569	0.535
December-04	1.516	1.664
January-05	2.175	1.984
February-05	1.110	1.019

Period	SCADA	Totalizer
	(million gal)	
March-05	1.317	1.325
April-05	0.000	0.010
May-05	0.871	0.857
June-05	0.194	0.206
July-05	0.345	0.336
August-05	0.363	0.293
September-05	0.000	0.000
October-05	0.085	0.086
November-05	0.029	0.146
December-05	1.855	1.890
January-06	1.551	1.510
February-06	1.583	1.560
March-06	0.594	0.549
April-06	0.868	0.857
May-06	1.501	1.471
June-06	1.287	0.110
July-06	0.848	0.911
August-06	1.159	1.169
September-06	1.850	1.829
October-06	2.050	2.086
November-06	2.032	2.008
December-06	2.095	2.095
January-07	1.944	1.917
February-07	1.282	1.139
March-07	1.880	1.864
April-07	1.935	1.892
May-07	1.938	1.928
June-07	1.568	0.849
July-07	1.250	1.301
August-07	1.716	1.701
September-07	1.217	1.253
October-07	1.357	1.387
November-07	1.161	1.240
December-07	1.732	1.776
January-08	1.972	1.974
February-08	1.694	1.709
March-08	1.712	1.712
April-08	1.761	1.770
May-08	2.071	2.076
June-08	1.346	1.274

Table 3.1-4
SCADA-Recorded and Monthly Totalizer Readings
Section 3/4 Supplemental Drain
Sections 2/8 and 3/4 Leachate Controls Report
Fresh Kills Landfill

Period	SCADA	Totalizer
	(million gal)	
July-08	0.945	0.973
August-08	0.634	0.618
September-08	0.923	0.920
October-08	1.548	1.560
November-08	1.747	1.767
December-08	1.730	1.731
January-09	1.546	1.531
February-09	1.073	1.035
March-09	1.439	1.391
April-09	1.950	1.971
May-09	2.046	2.028
June-09	1.613	1.611
July-09	1.657	1.562
August-09	1.442	1.559
September-09	1.346	1.356
October-09	1.600	1.656
November-09	1.610	1.615
December-09	2.013	2.011
January-10	1.927	1.928
February-10	1.477	1.480
March-10	1.703	1.874
April-10	1.433	1.484
May-10	1.699	1.702
June-10	1.147	1.133
July-10	0.978	0.953
August-10	1.170	1.224
September-10	1.047	1.083
October-10	1.289	1.309
November-10	1.292	1.157
December-10	1.632	1.605
January-11	1.756	1.887
February-11	1.708	1.678
March-11	1.890	1.875
April-11	0.846	1.854
May-11	1.389	1.919
June-11	1.780	1.284
July-11	1.219	1.230
August-11	1.509	1.551
September-11	1.811	1.796
October-11	1.916	1.932

Period	SCADA	Totalizer
	(million gal)	
November-11	1.417	1.358
December-11	1.957	1.962
January-12	2.023	2.023
February-12	1.486	1.486
March-12	1.337	1.342
April-12	1.330	1.359
May-12	1.372	1.396
June-12	1.514	1.527
July-12	1.129	1.128
August-12	0.952	0.955
September-12	1.011	1.008
October-12	0.969	0.985
November-12		
December-12		
January-13	2.089	1.863
February-13	1.314	1.328
March-13	1.806	1.801
April-13	1.685	1.742
May-13	1.358	1.376
June-13	1.896	1.068
July-13	1.528	1.426
August-13	1.030	0.896
September-13	0.818	0.807
October-13	1.085	1.097
November-13	0.727	0.745
December-13	1.322	1.368
January-14	1.993	2.001
February-14	1.714	1.722
March-14	2.006	2.117
April-14	1.859	1.882
May-14	1.940	1.880
June-14	1.469	1.478
July-14	1.291	1.352
August-14	1.076	1.075
September-14	1.016	1.046
October-14	0.720	0.676
November-14	1.092	1.141
December-14	1.954	1.949

Chapter 3.0 Figures

Explanation of Figures in Chapter 3.0

Figures 3.1-1, 3.1-3, 3.1-5 and 3.1-6 - Time Series Graphs of calendar year (annual) leachate collection rates and annual precipitation

Leachate collection rates related to each of the four drains for data reported through the Supervisory Control and Data Acquisition (SCADA) system (continuous electronic) and through the totalizers (manual). Precipitation rates are also included on the figures.

Figures 3.1-2 and 3.1-4 - Time Series Graphs of 12-month period leachate collection rates and annual precipitation

Leachate collection rates reported through the SCADA system and totalizer readings beginning with the start of the operation of the original drains in September 1998 at Sections 2/8 and 3/4.

Figures 3.1-7 through 3.1-10 - Time Series Graphs of monthly leachate collection rates

Leachate collection rates reported through the SCADA system and totalizer leachate collection rates for each month for each of the four drains.

Figures 3.1-11 through 3.1-14 - Time Series Graphs of daily leachate collection rates

Leachate collection rates reported through the SCADA system

Figures 3.2-1 through 3.2-48 - Time Series Graphs by monthly period (e.g., all January data) of daily collection rates and precipitation

Demonstrate the seasonal effect on the leachate collection rates by plotting the daily collection rates and precipitation by monthly period by showing the effect of precipitation on the collection rates. These graphs are arranged as follows:

- Figures 3.2-1 through 3.2-12 Section 2/8 original drain January through December
- Figures 3.2-13 through 3.2-24 Section 3/4 original drain January through December
- Figures 3.2-25 through 3.2-36 Section 2/8 supplemental drain January through December
- Figures 3.2-37 through 3.2-48 Section 3/4 supplemental drain January through December

Figures 3.2-49 through 3.2-52 – Plot of daily collection rates to demonstrate seasonal variation

Daily collection rates plotted from minimum to maximum over the full operational period (e.g., 1998 through 2014 for the Section 2/8 original drain) to show the variation in collection rates during the different months. Figures are presented for each of the four drains in Landfill Sections 2/8 and 3/4.

Figures 3.3-1 through 3.3-8 – Time series plots of operational data during the initial four months of operation (September 1998 through December 1998) of the original drains in Sections 2/8 and 3/4.

Plots present the leachate flow rates and leachate elevations as recorded by the SCADA system at the leachate collection well in the original drains; 10 minute intervals are utilized. The following are plotted:

- Dark mauve line shows the high leachate elevations; shows the pump on elevation and maximum elevation of leachate in the drain. Also shows the maximum elevation of leachate in the drain if the pump is not operating and if there is a precipitation effect.
- Light mauve line shows the low leachate elevations; shows the pump off elevation and maximum elevation of leachate in the drain
- Black shows the maximum pumping rate during the 10 minute interval; shows the rate at which the pump operated
- Gray shows the average pumping rate over the 10 minute interval; is used to calculate volume of leachate collected

These data were used in determining initial operating conditions and base flow rates.

Figure 3.3-9 - Time Series Plot of monthly collection rates and adjusted monthly collection rates based on estimated base flows.

The monthly collection rates based on totalizer readings are presented along with the adjusted monthly collection rates based on estimated base flows. The adjusted monthly collection rates remove the precipitation and operational effects.

Figure 3.3-10 - Time Series Plot of precipitation from September 1998 through December 2002

Plot of daily precipitation recorded by weather station at Fresh Kills Landfill and by NOAA at Newark Liberty Airport with annual cumulative shown on secondary vertical axis. and is presented for comparison to the increases in totalizer collection rates which correspond to higher precipitation rates.

Figure 3.3-11 – Upper plot is a time series plot of operational data for the Section 2/8 original drain for May 16, 2001 and the lower plot is a time series plot of collection rates for May 2001.

The upper plot shows a change in the flow rate in the original drain at Section 2/8 on May 16, 2001 with a change in the cycling pattern. The upper plot also shows that the drain was operating as designed on May 16, 2001. The lower plot shows a decline in the collection rate through May 2001. An example of a 1.3 inch precipitation event on the leachate collection rate on May 22, 2001 is observed to affect flow rates at about noon of that day.

Figure 3.3-12 - Time series plots of operational data for original leachate collection drain in Section 2/8 presents for October 2003

Plot provides an example of the evaluation of the operational data performed for the Section 2/8 original drain for October 2003 to show the system was operating as designed and to determine the daily collection rates and base flow conditions.

Figure 3.3-13 – Upper graph is a time series plots of daily leachate collection rates and precipitation for the original leachate collection drain in Section 2/8 presents for September 2014. The lower graph shows the operational data for this period.

Plot provides an example of the evaluation of the operational data performed for the Section 2/8 original drain for September 2014 to show the system was operating as designed and to determine the daily collection rates and base flow conditions.

Figures 3.3-14 and 3.3-15 - Plot of daily collection rates to determine base flows in the Sections 2/8 and 3/4 supplemental drains

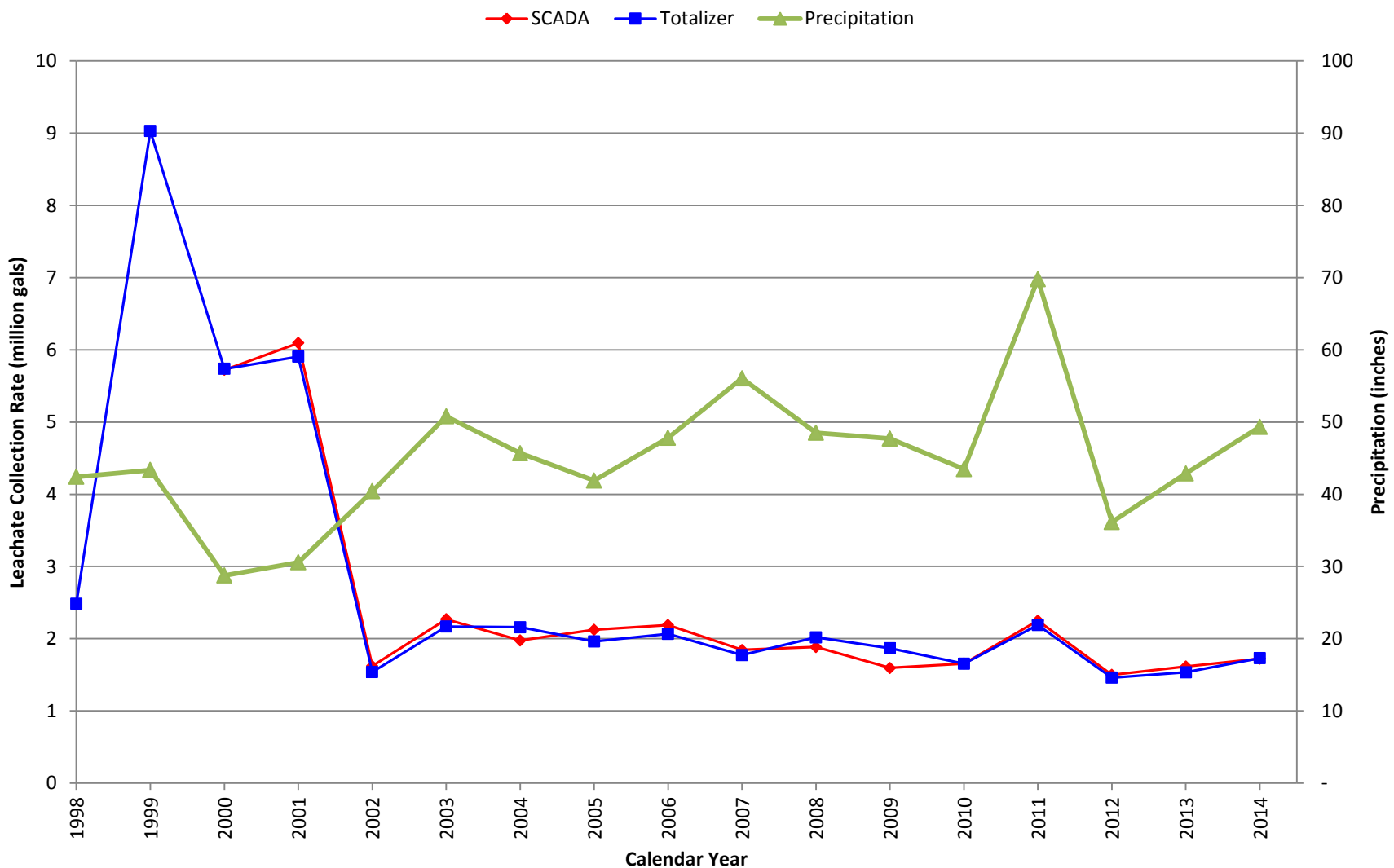
The daily leachate collection rates over the operating period were plotted from minimum to maximum. The change in collection rates is obvious over-time; that is, from Year 1 to Year 13. The lowest 8 through 21 and lowest 2 through 26 collection rates were plotted and are included in an insert graph. These ranges of rates were selected based on a review of the daily collection rates by annual period and were determined to be best representative of base flow conditions. The estimate base flow line is fit to the lowest 8 through 21 and lowest 2 through 26 collection rates lines.

Figure 3.3-16 - Upper plot is a time series plot of collection rates for October 2012 and the lower plot is a time series plot of operational data for October 13, 2012 for the Section 2/8 supplemental drain.

The upper plot shows a decline in the collection rate through mid-October 2012, with an estimated base flow of about 15,000 gallons per day (gpd). The lower plot shows that the drain was operating as designed on October 13, 2012. The estimated base flow of about 15,000 gpd is consistent with the estimated base flow rate previously presented in Figure 3.3-14.

Figure 3.3-17 - Upper plot is a time series plot of collection rates for July 2011 and the lower plot is a time series plot of operational data for July 23, 2011 for the Section 3/4 supplemental drain.

The upper plot shows a decline in the collection rate through July 2011, with an estimated lowest collection rate of about 18,000 gallons per day (gpd). The lower plot shows that the drain was operating as designed on July 23, 2011. The estimated base flow of about 18,000 gpd is consistent with the estimated base flow rate previously presented in Figure 3.3-15.



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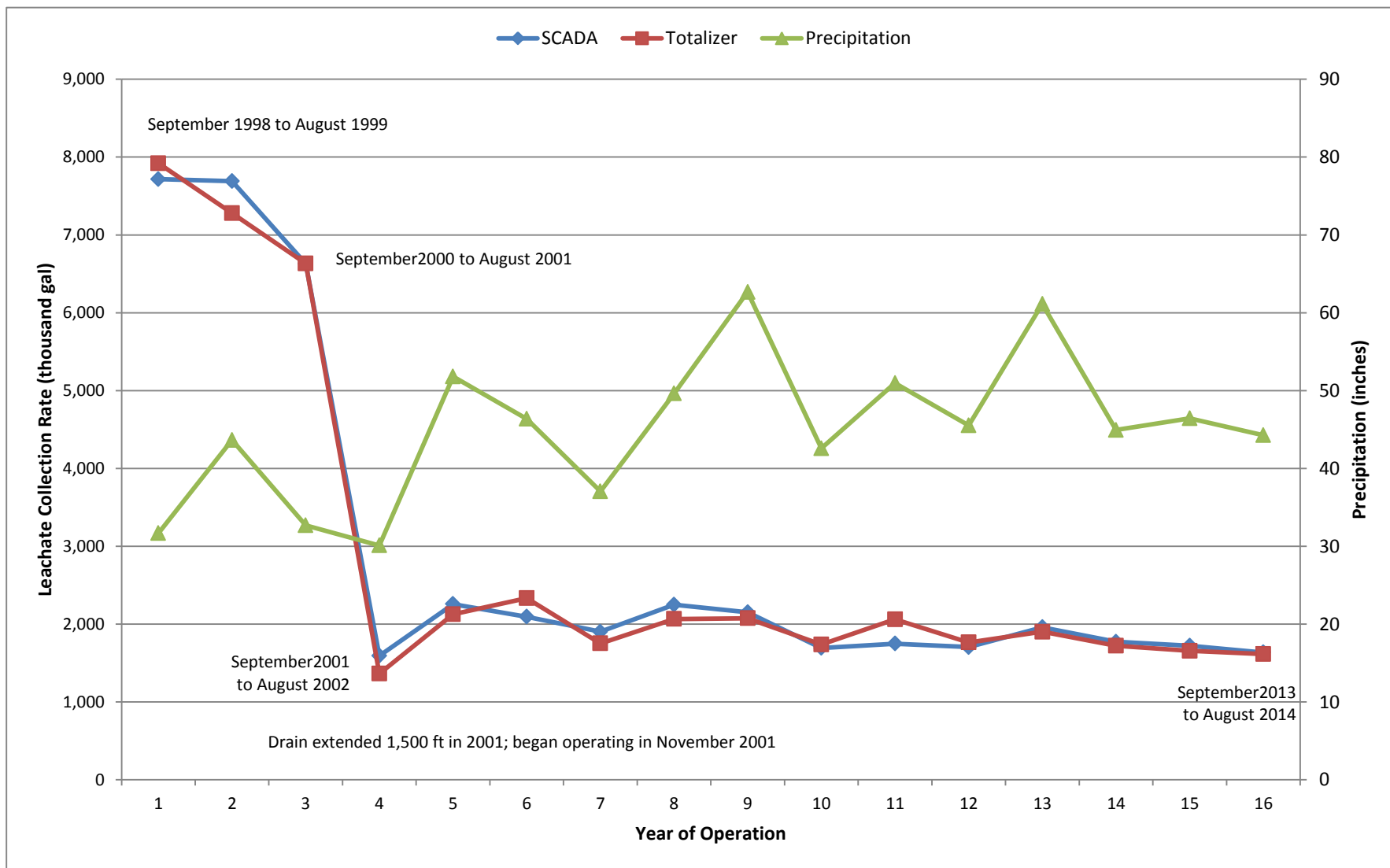
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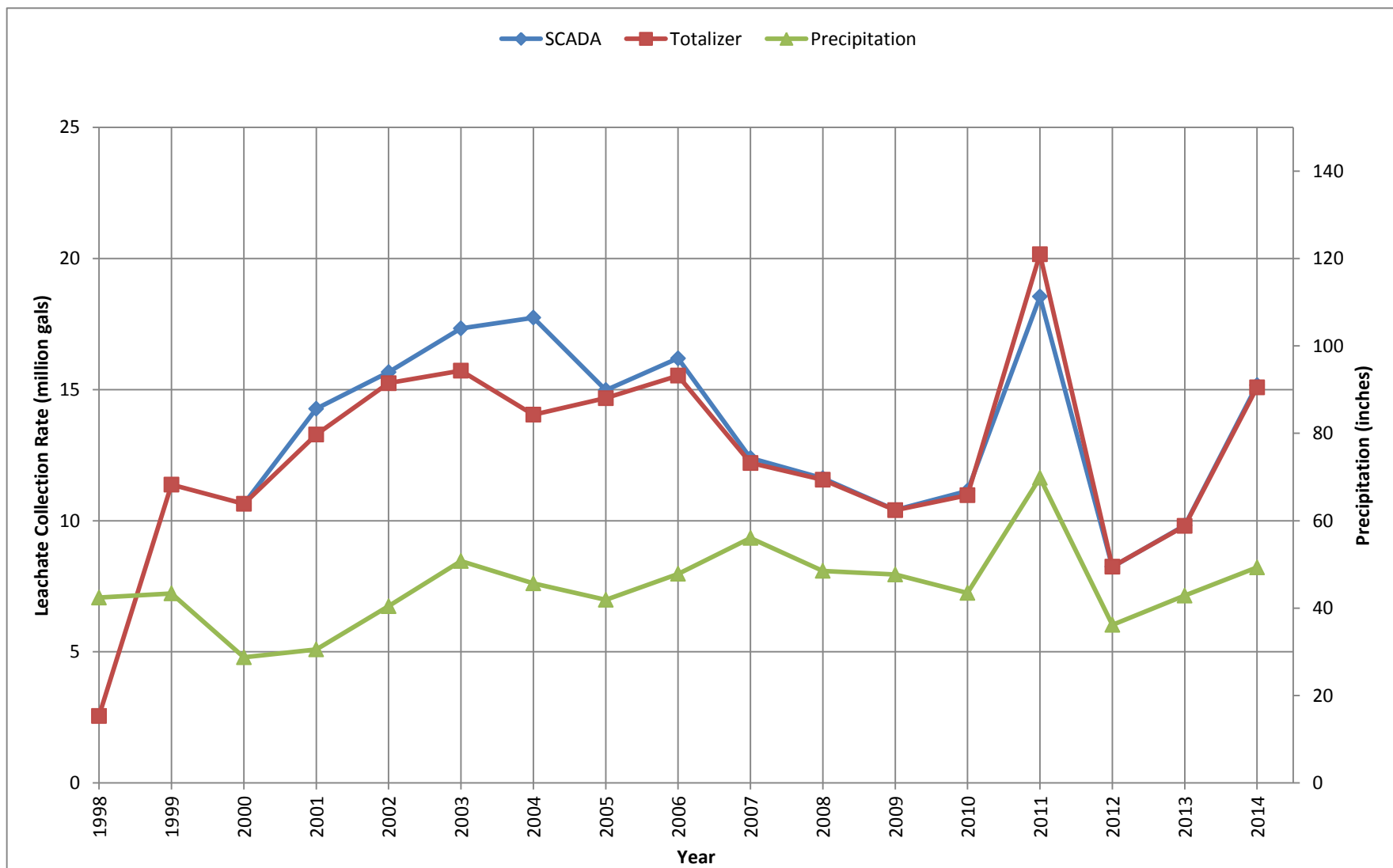
Leachate Controls at Landfill
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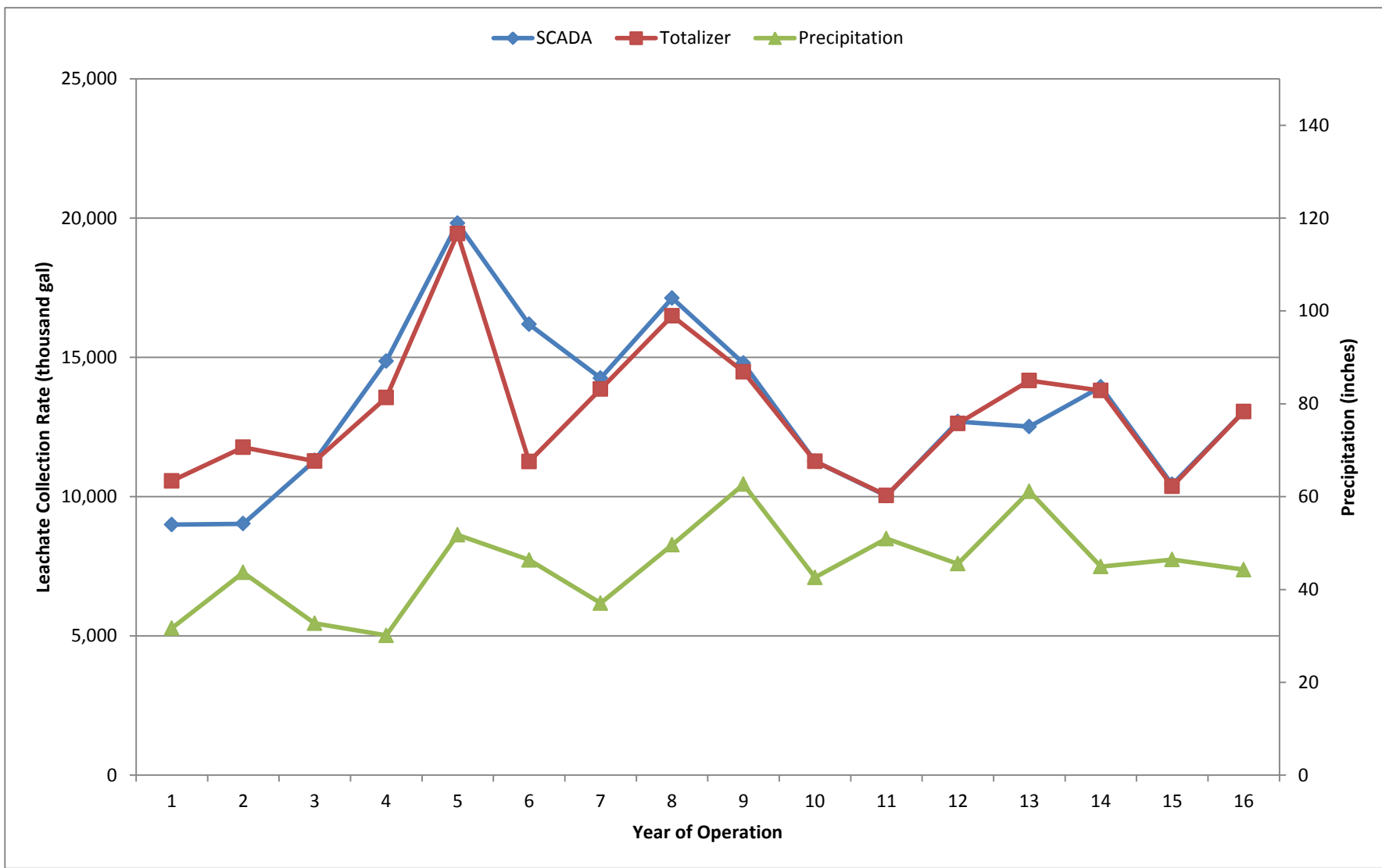
Figure 3.1.1
Annual Leachate Collection Rates
Original Leachate Collection Drain
Landfill Section 2/8



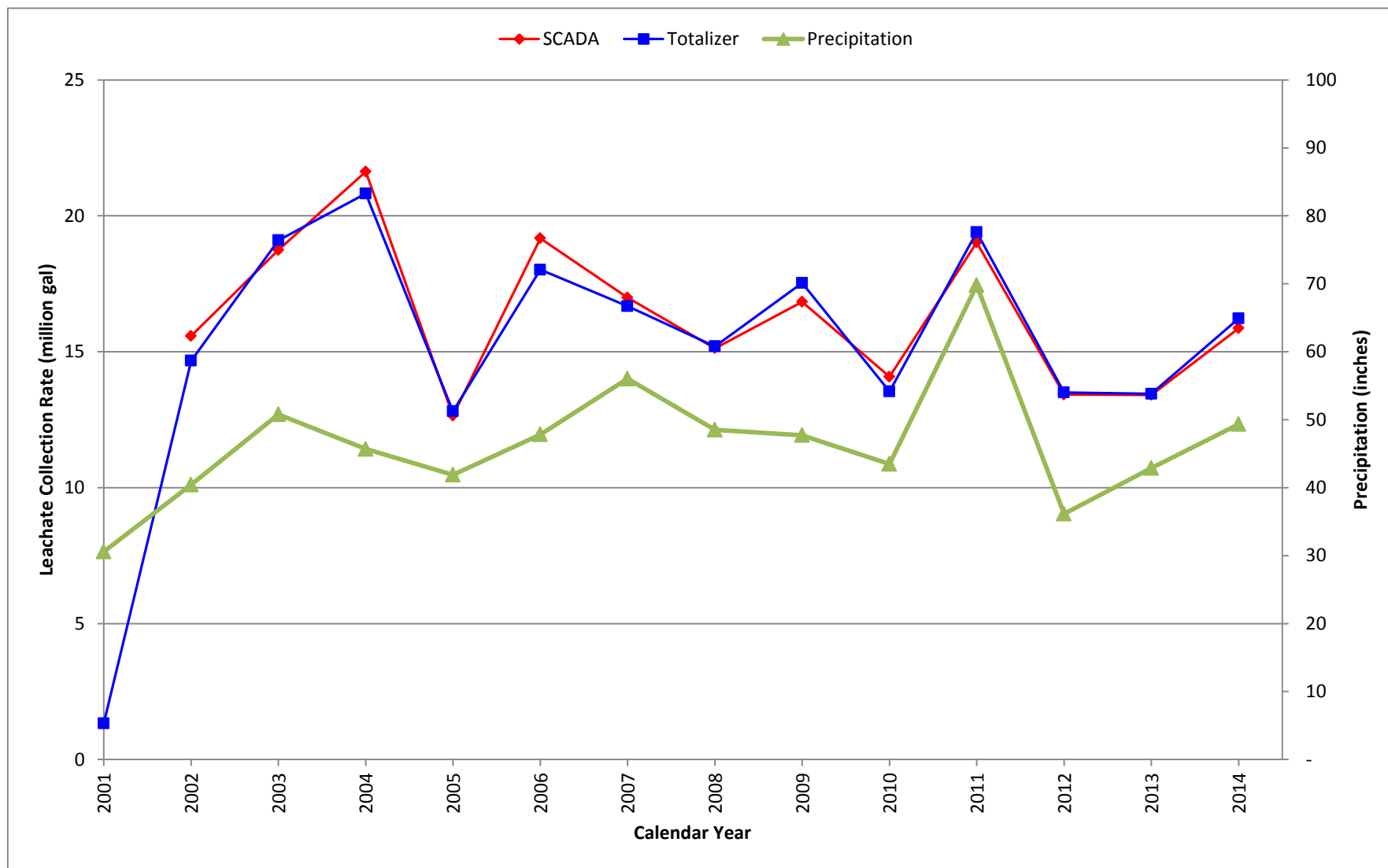
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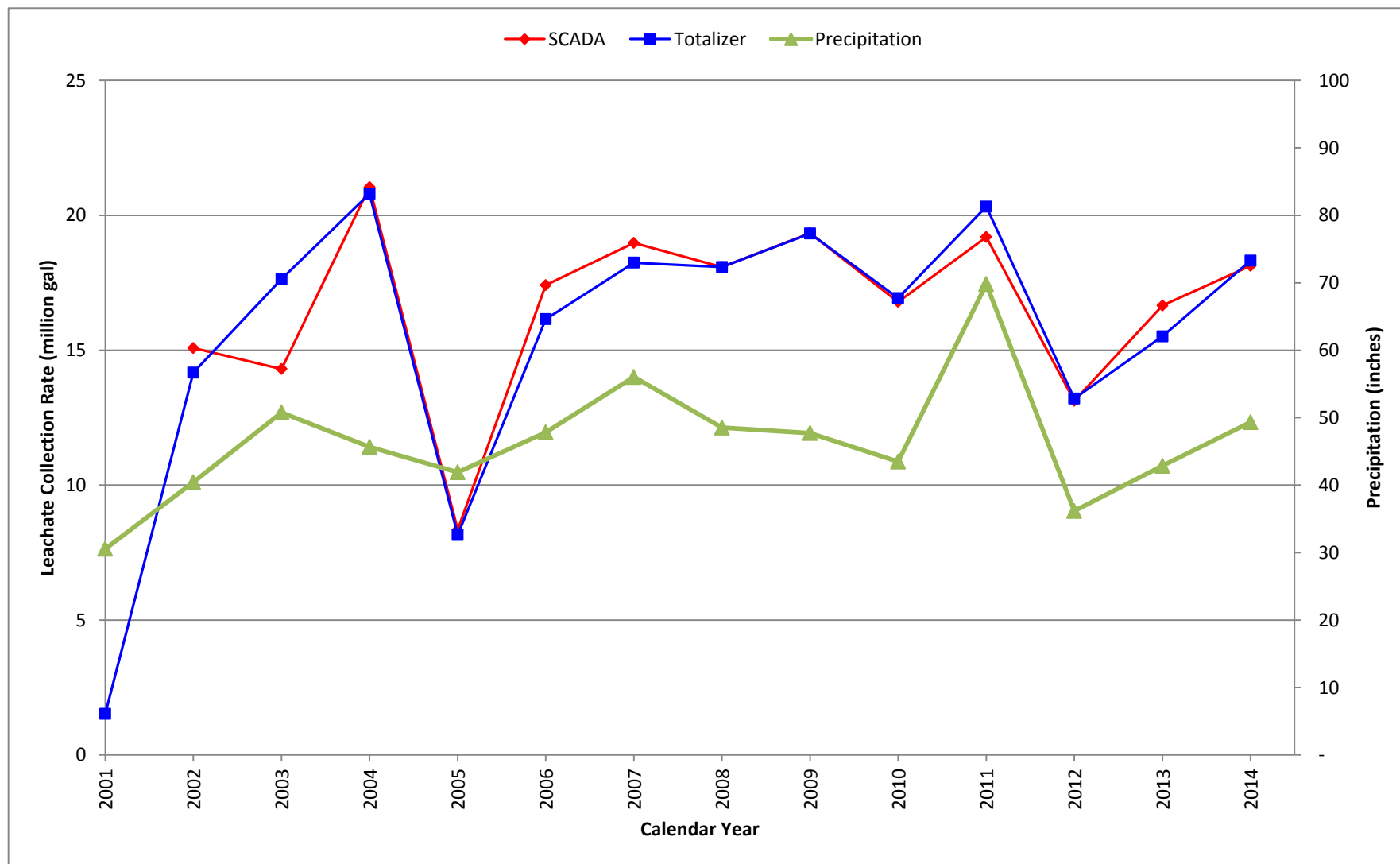
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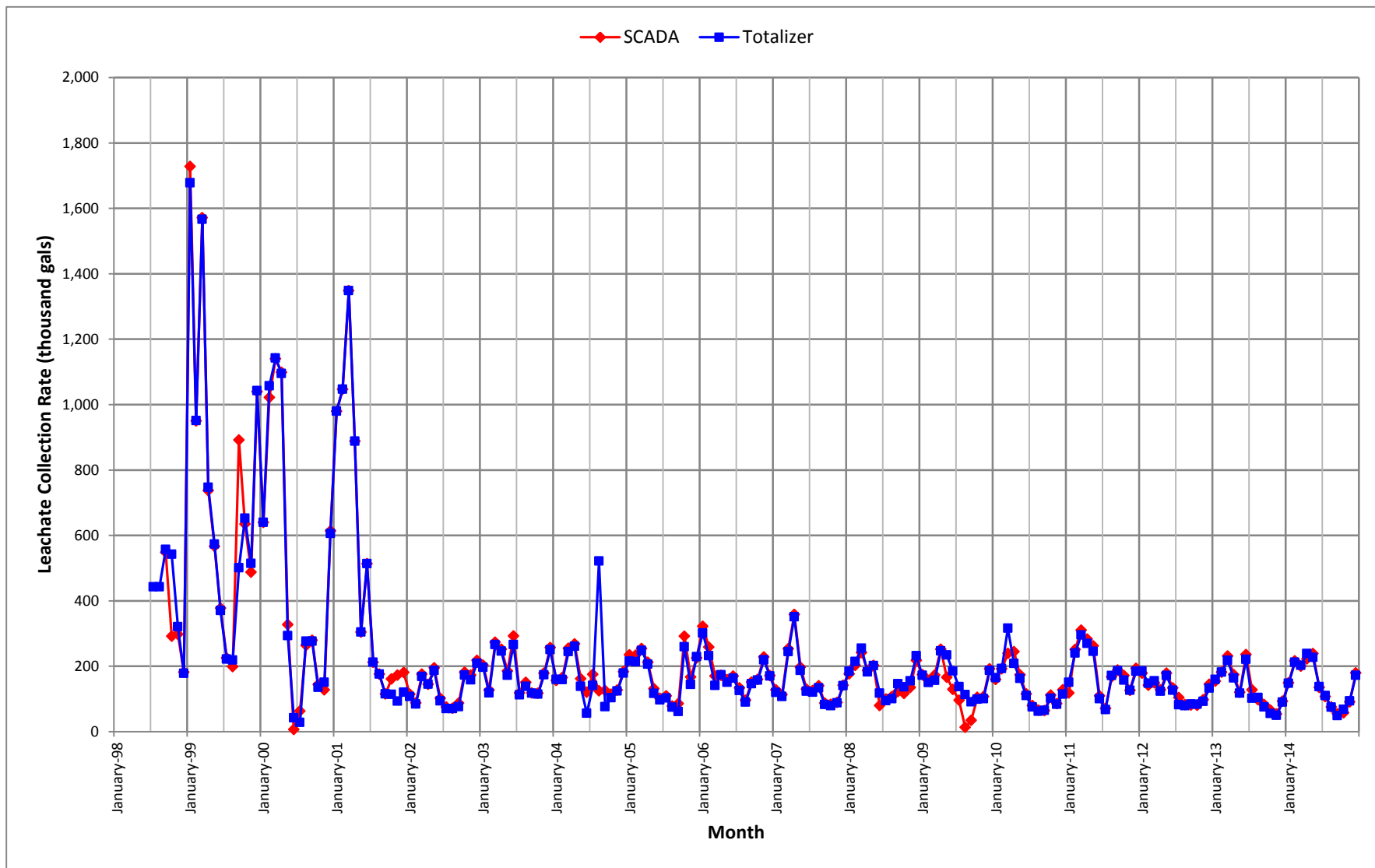
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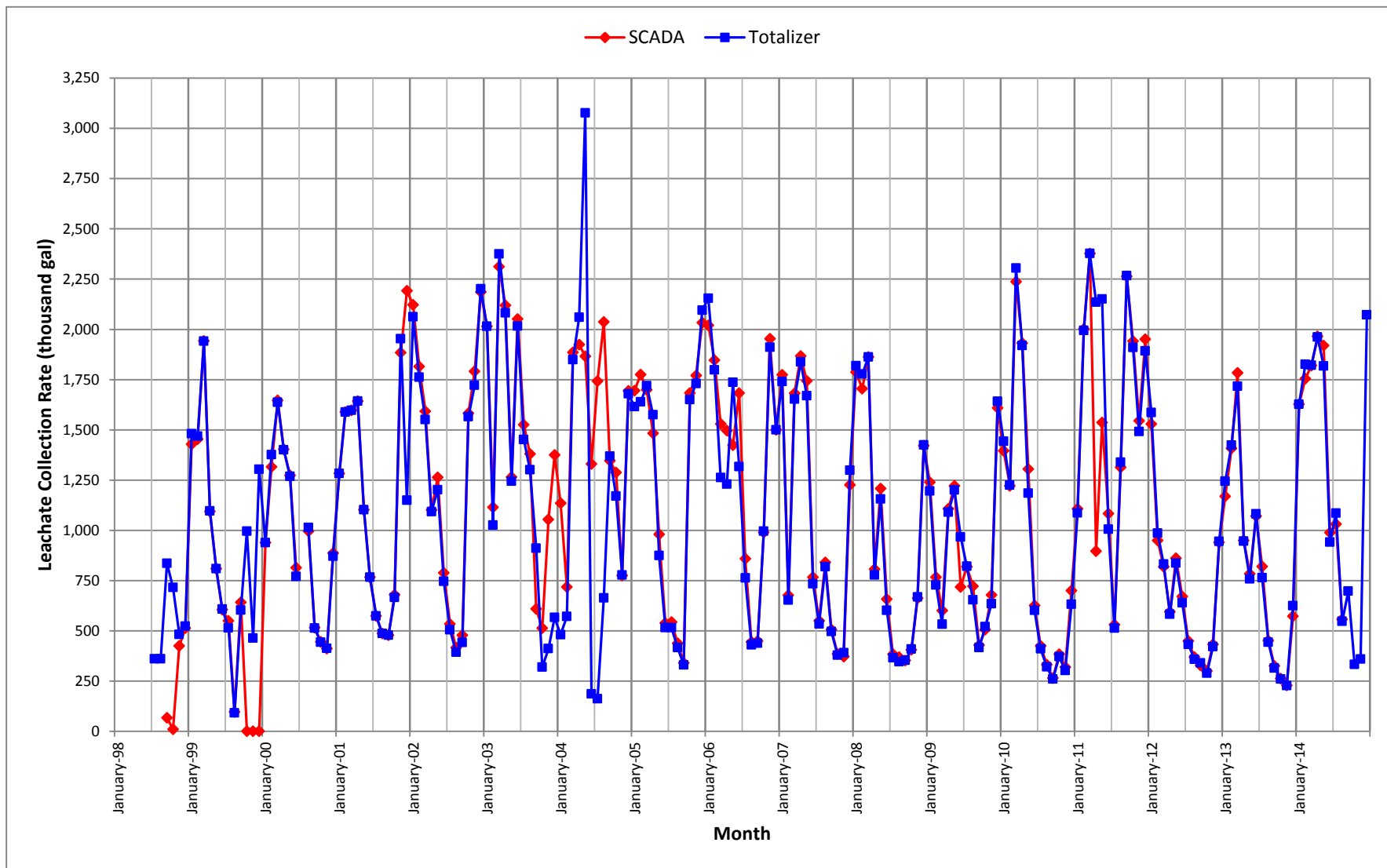
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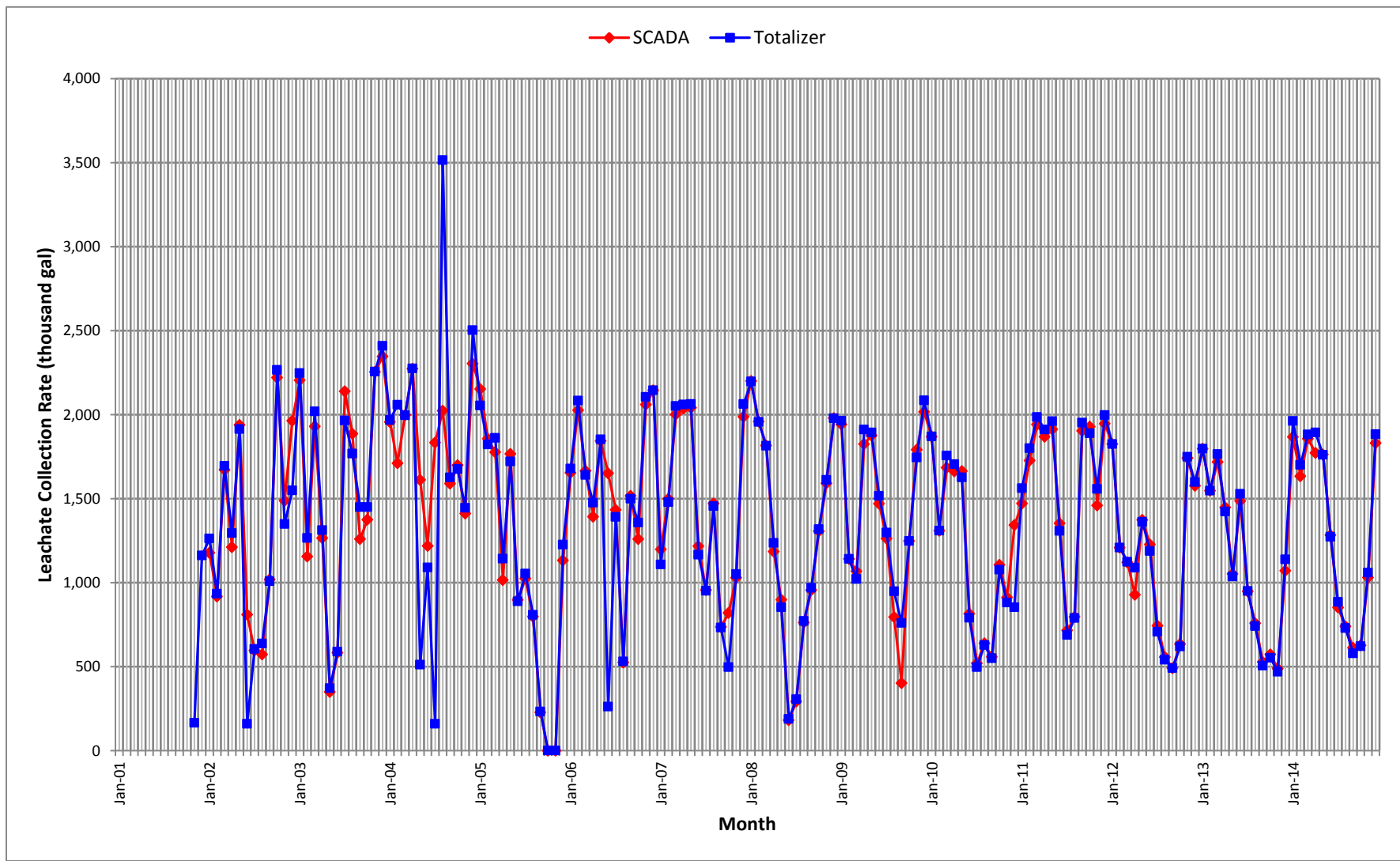
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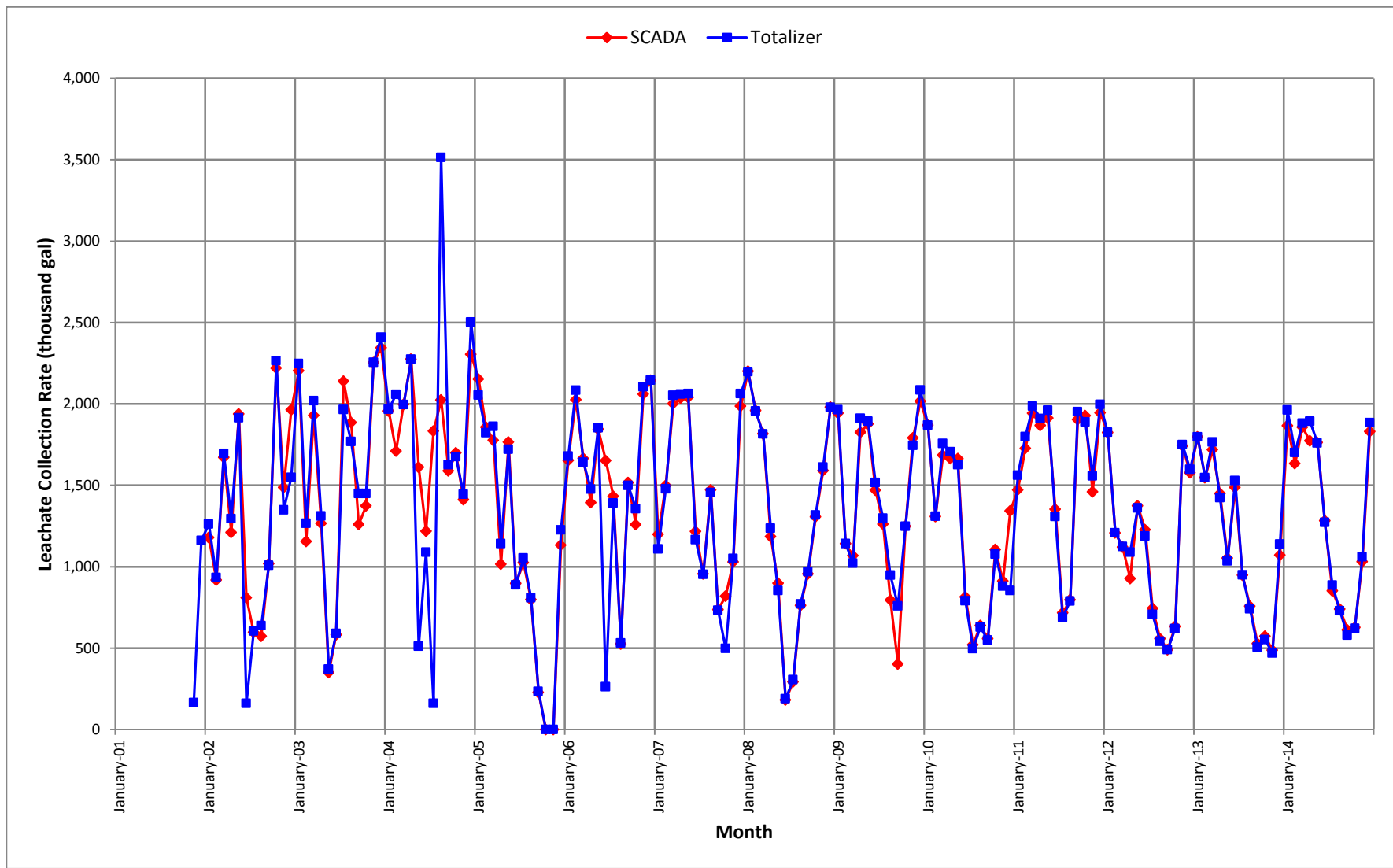
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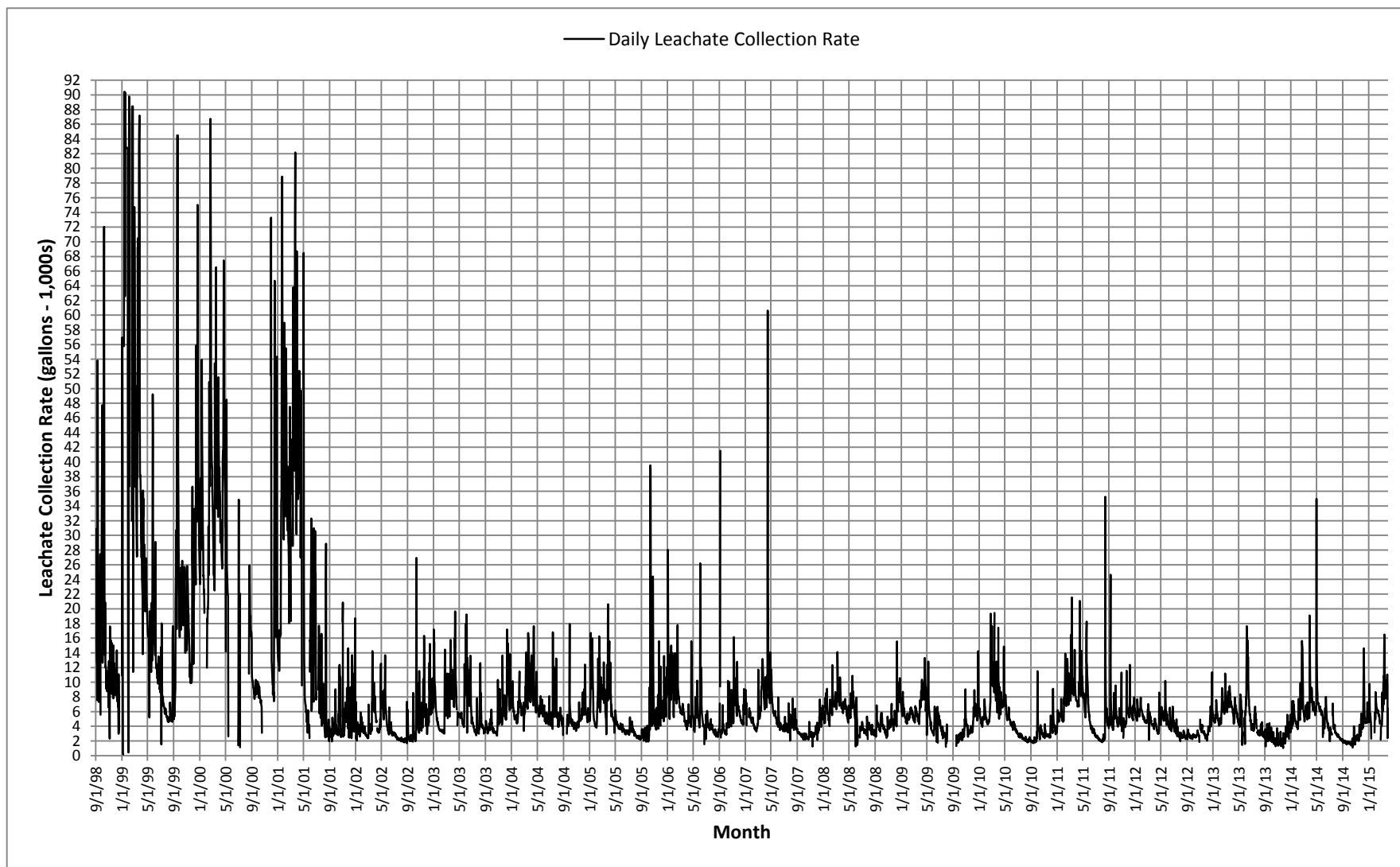
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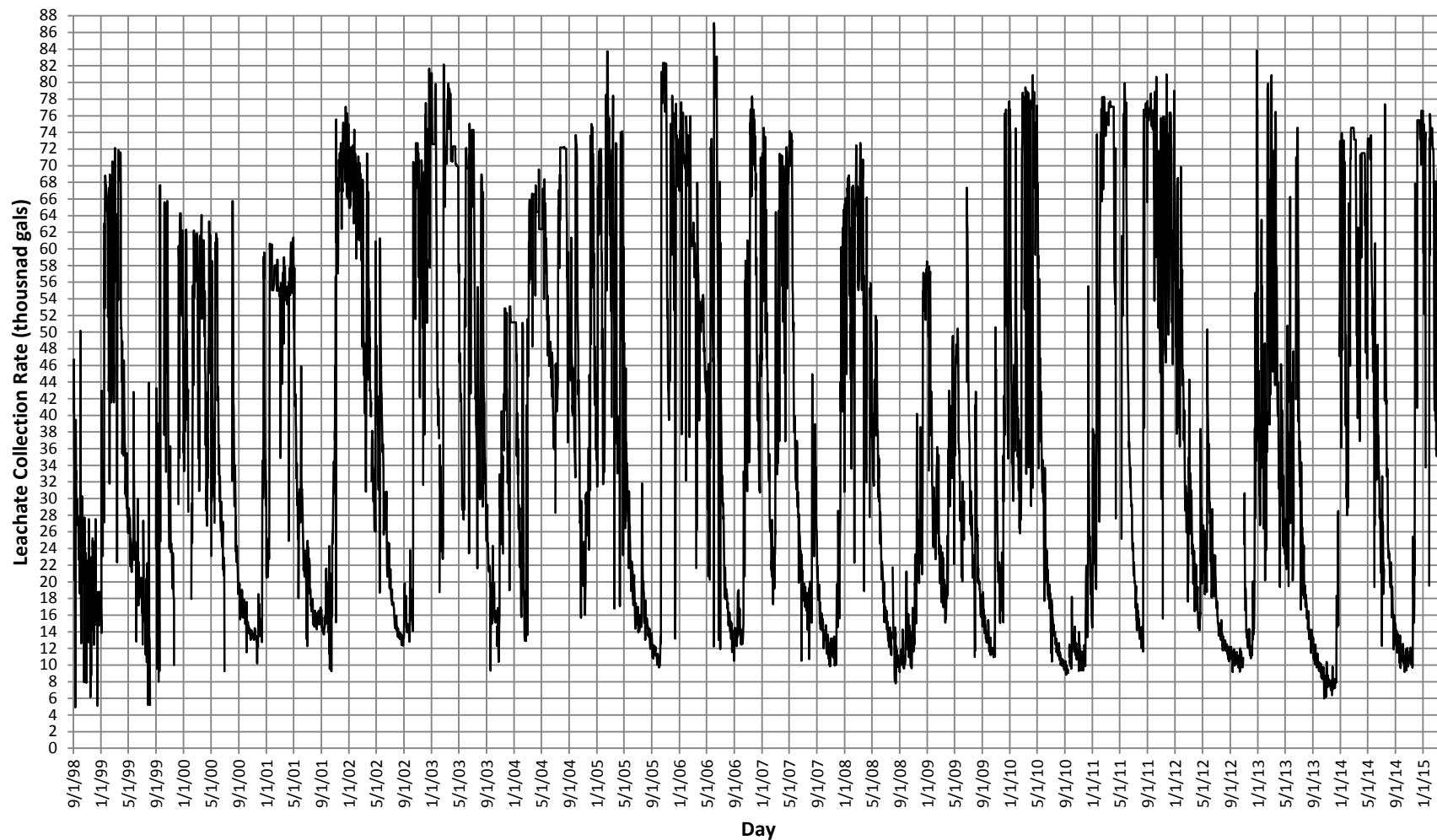


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— Daily Leachate Collection Rate



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Figure 3.1-12
Daily Leachate Collection Rate
Original Drain
Landfill Section 3/4

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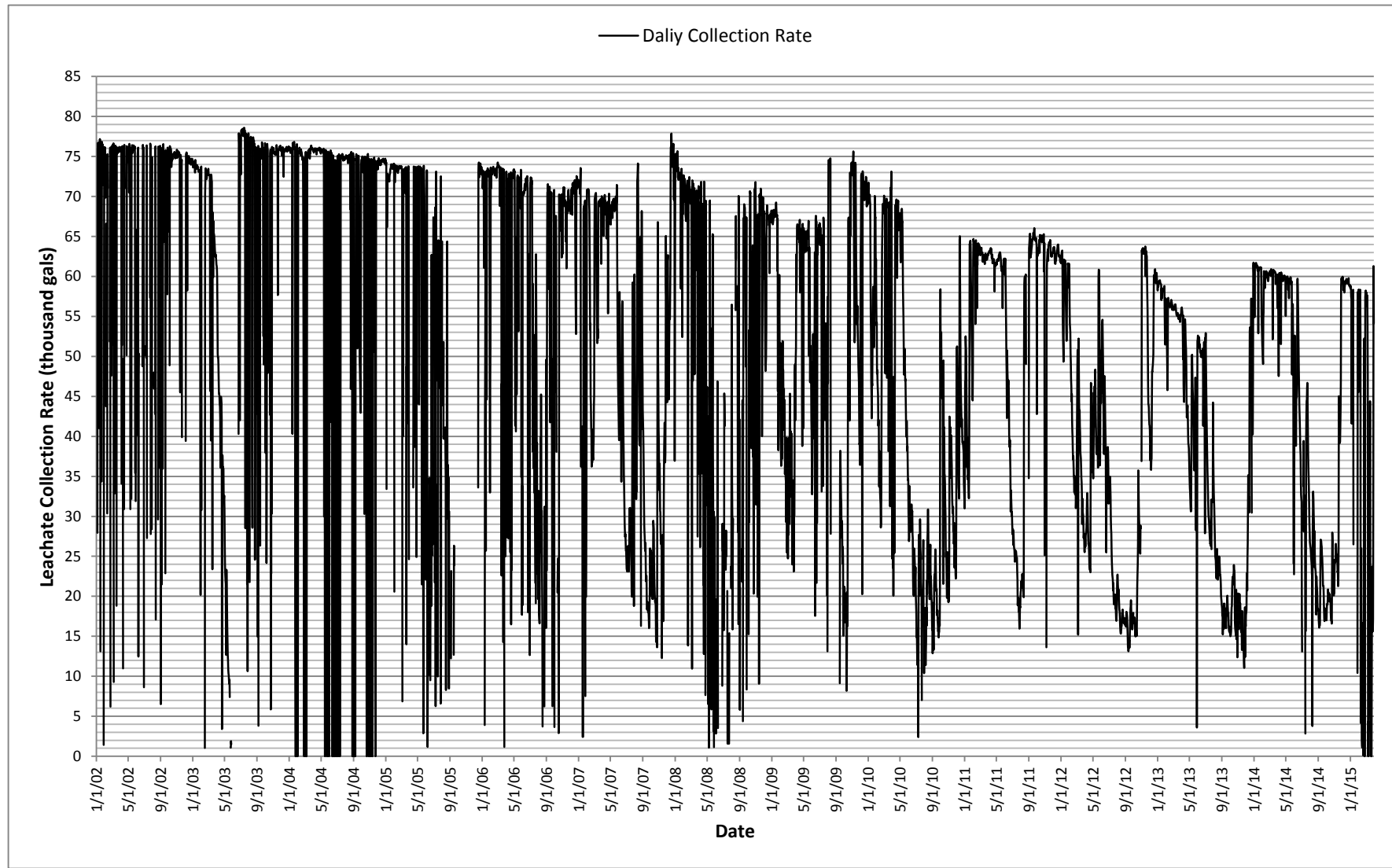
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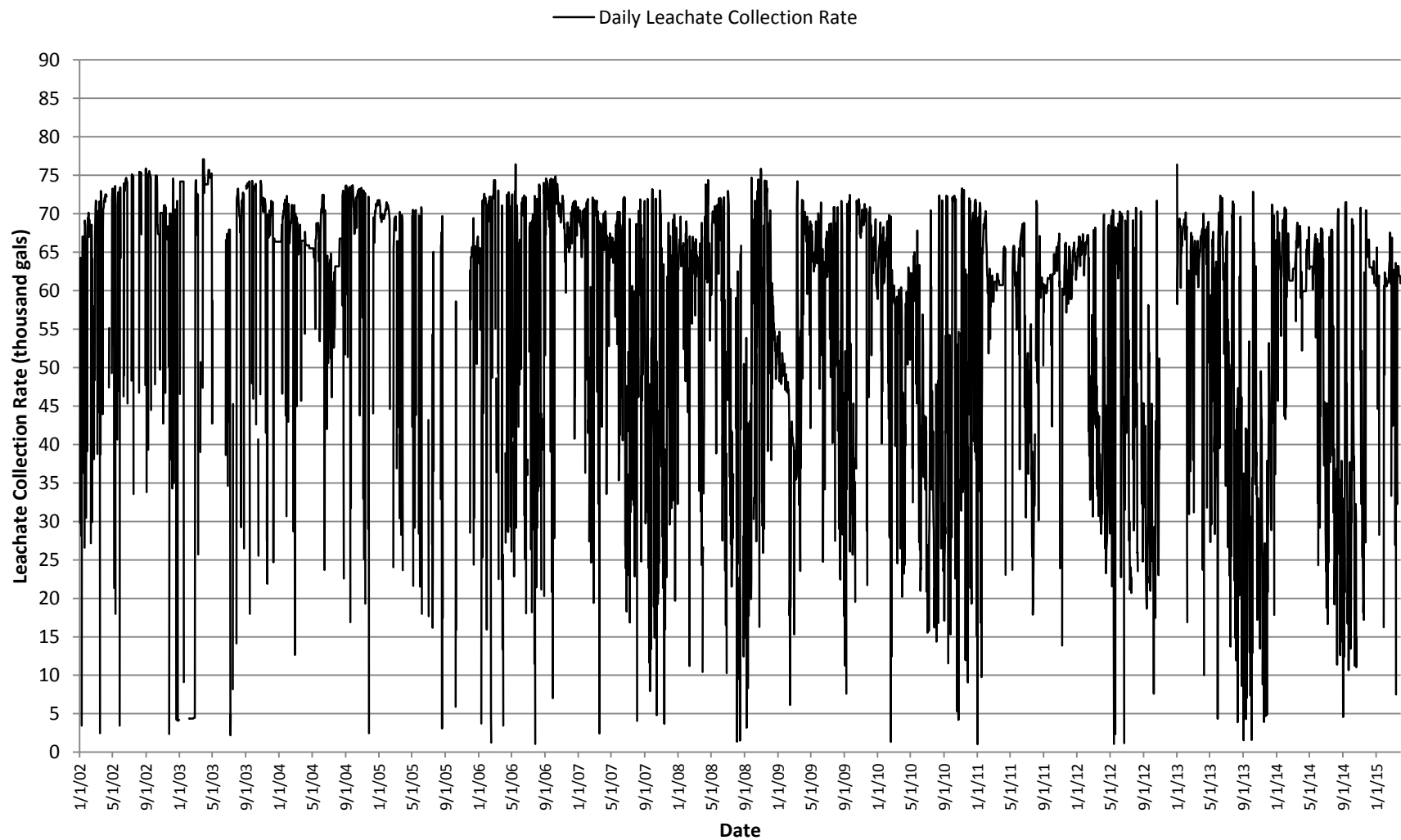
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Figure 3.1-14
Daily Leachate Collection Rate
Supplemental Drain
Landfill Section 34

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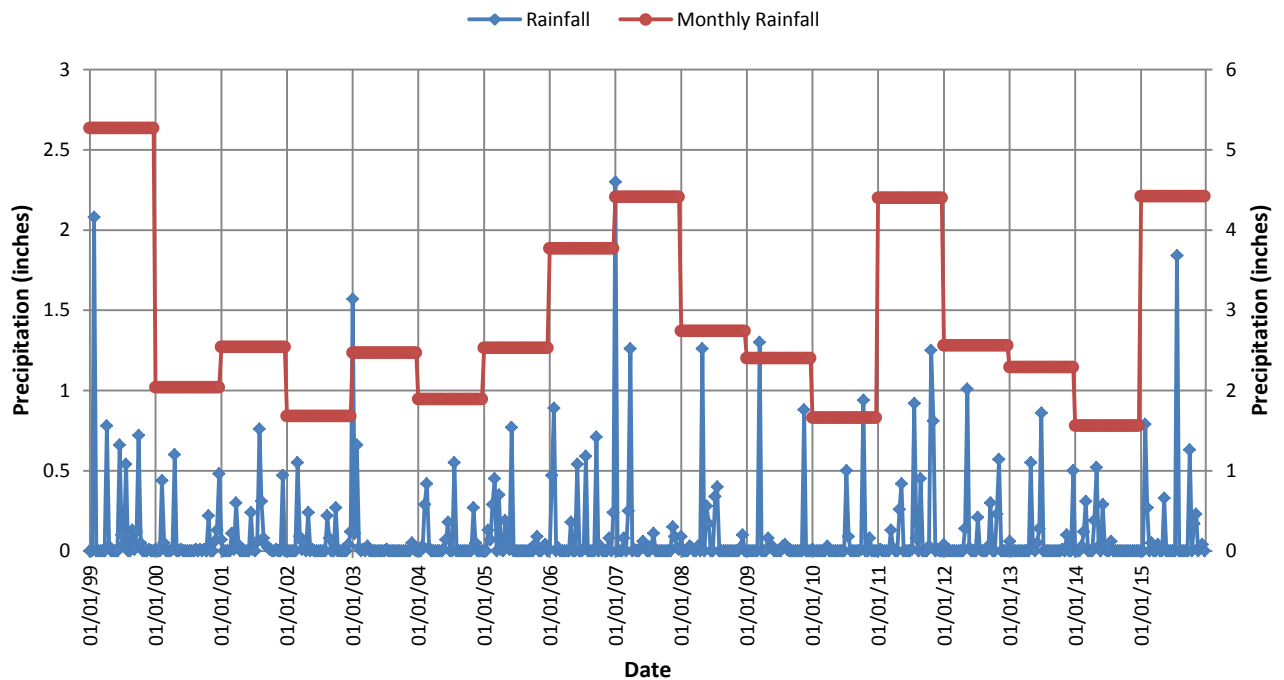
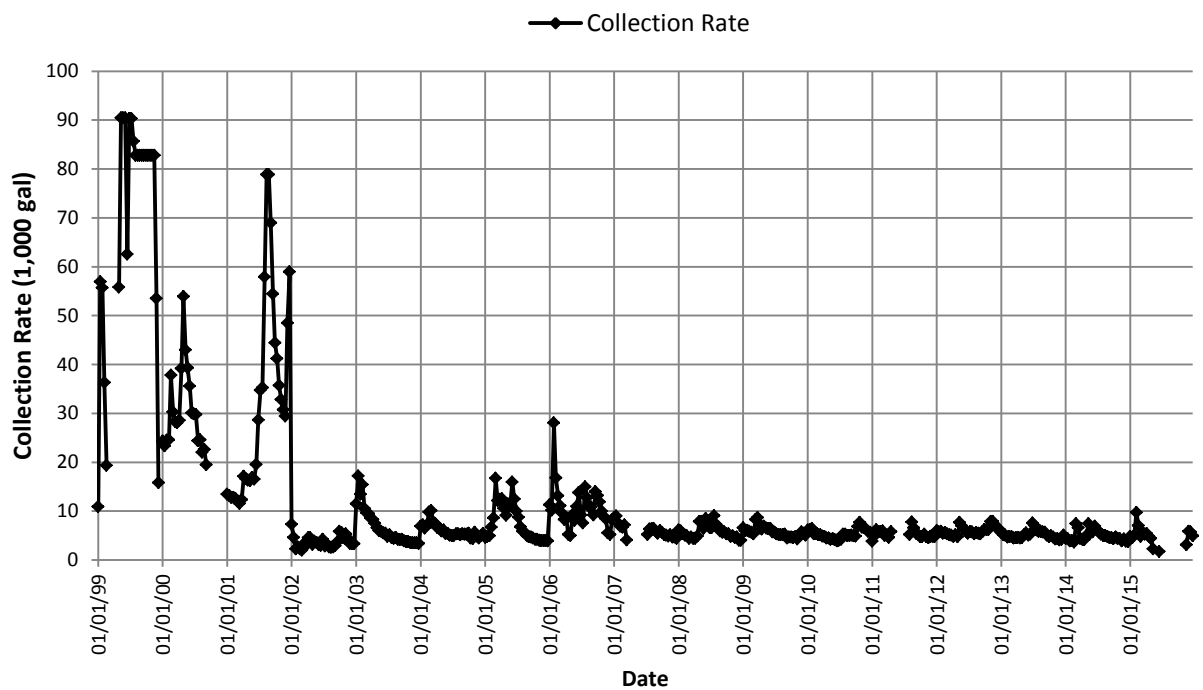
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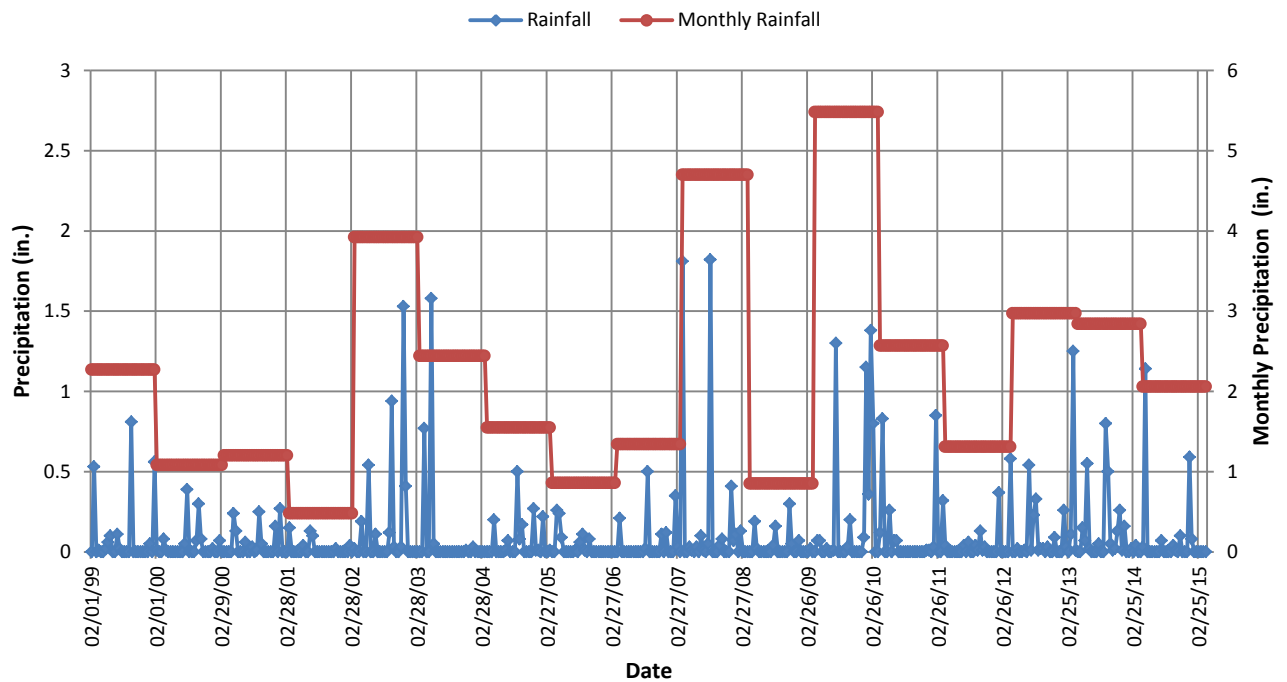
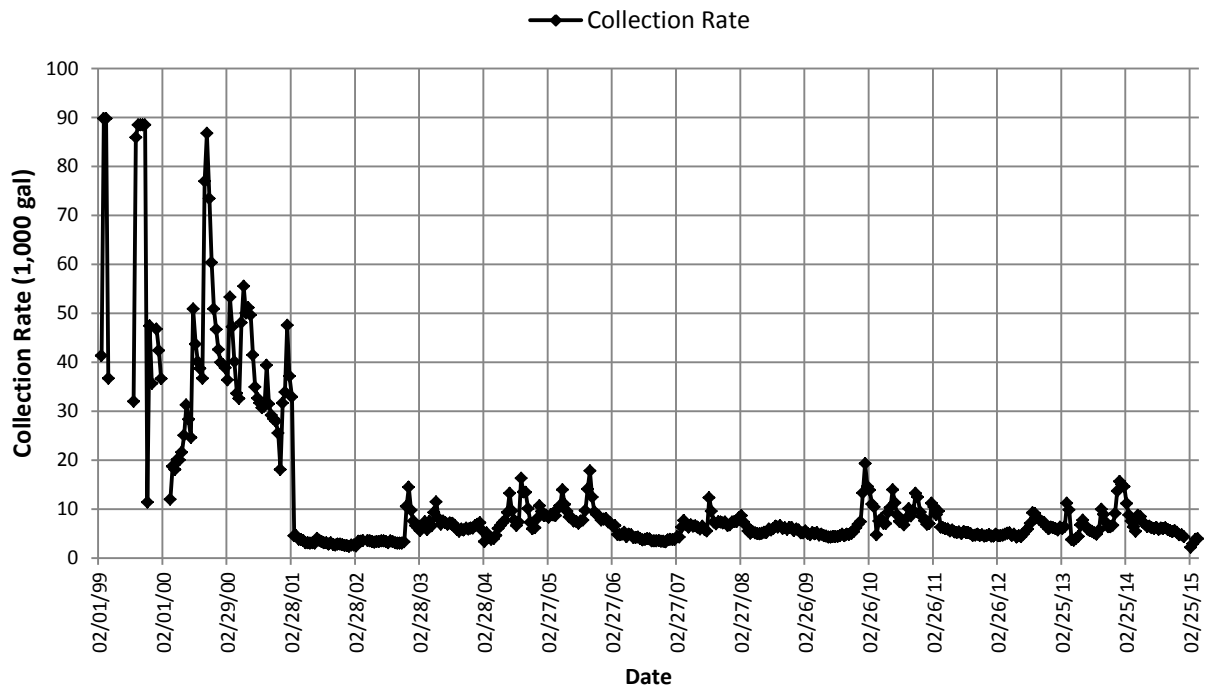
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Figure 3.2-1
January Collection Rate
and Precipitation
Original Drain
Landfill Section 2/8



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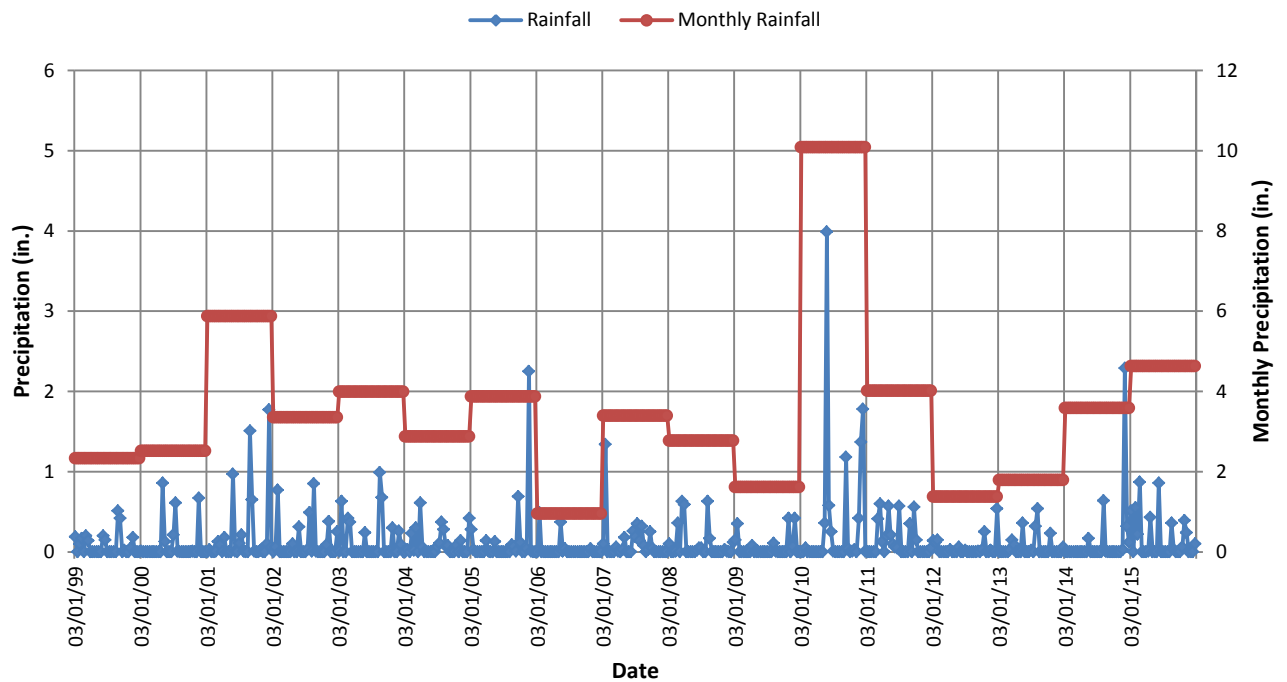
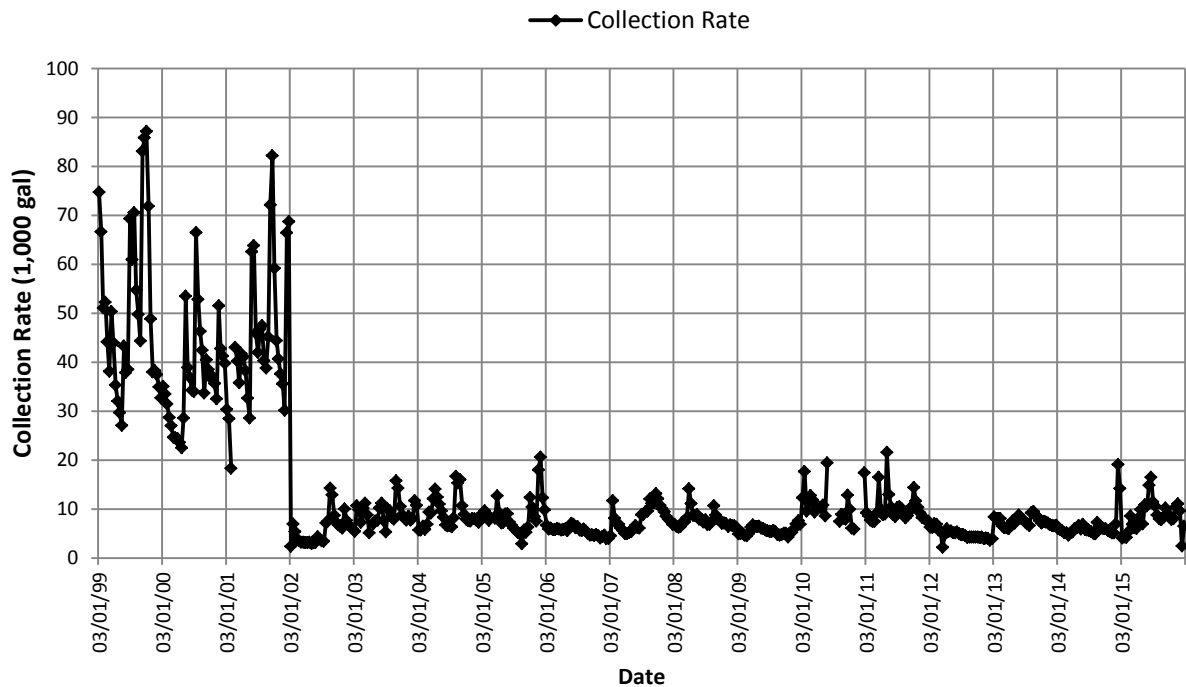
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and Landfill Section 3/4
Report

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Figure 3.2-2
February Collection Rate
and Precipitation
Original Drain
Landfill Section 2/8



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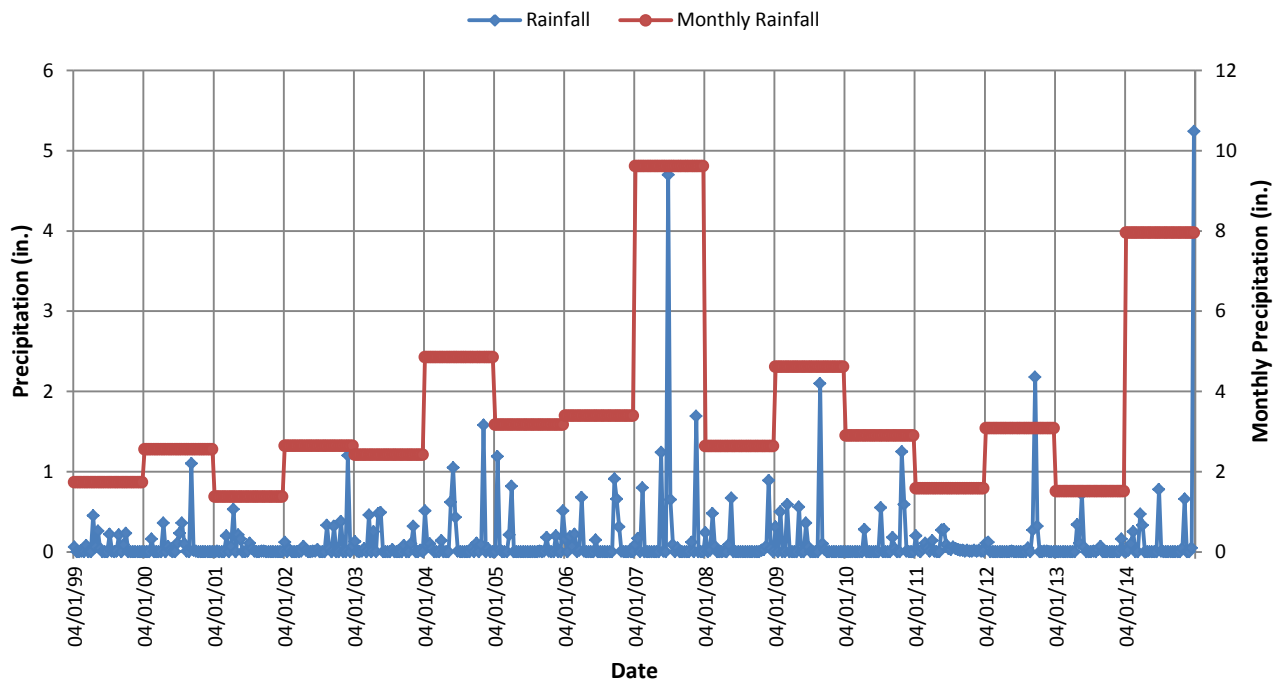
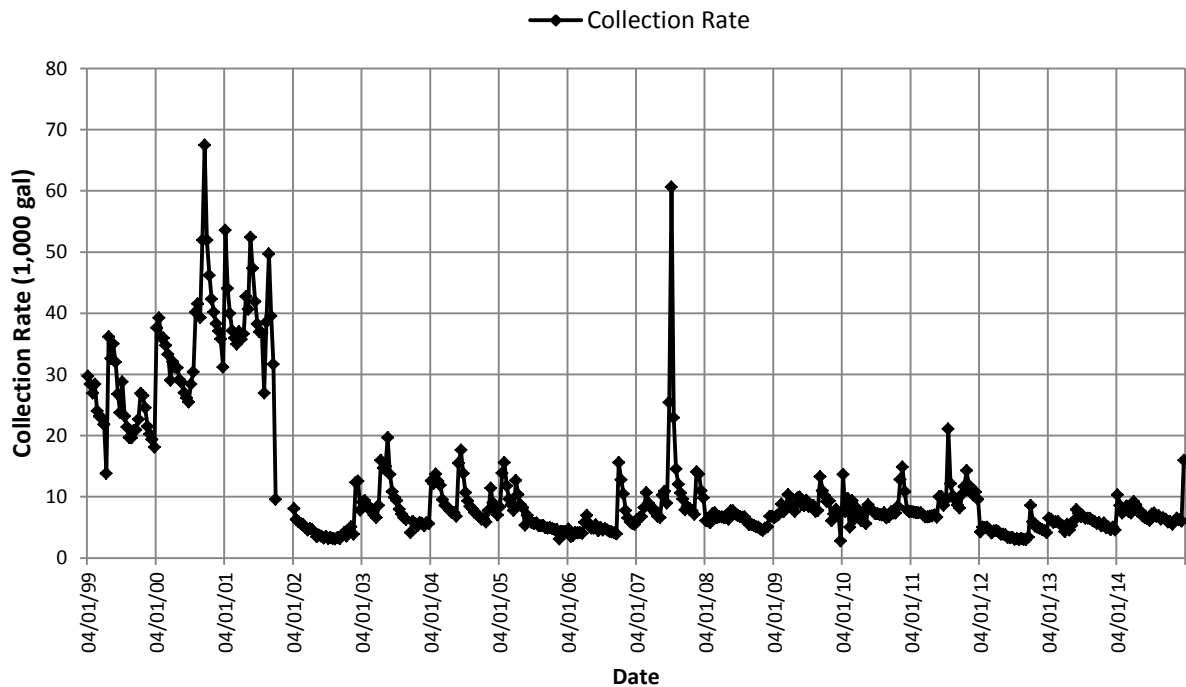
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Figure 3.2-3
March Collection Rate
and Precipitation
Original Drain
Landfill Section 2/8



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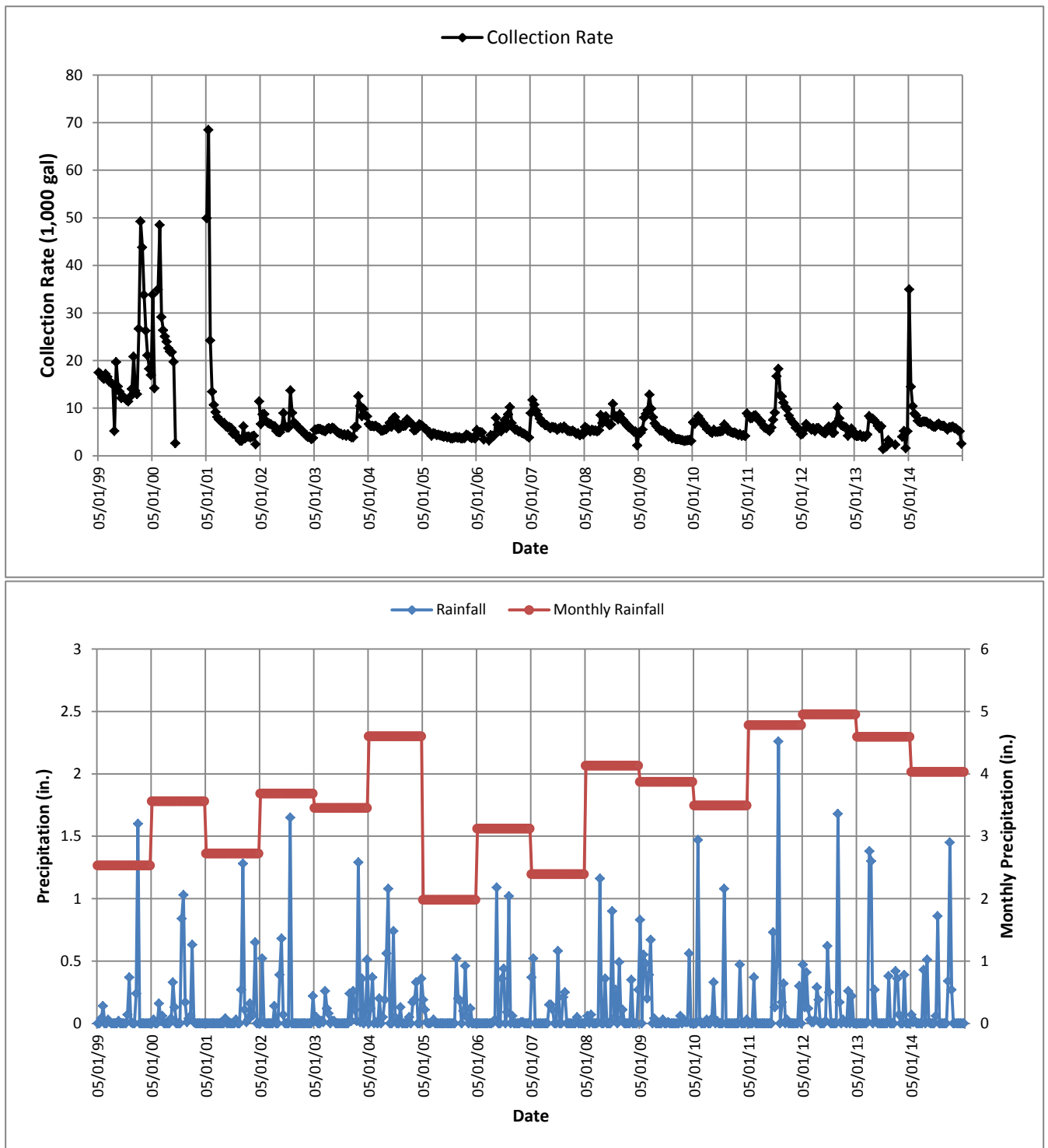
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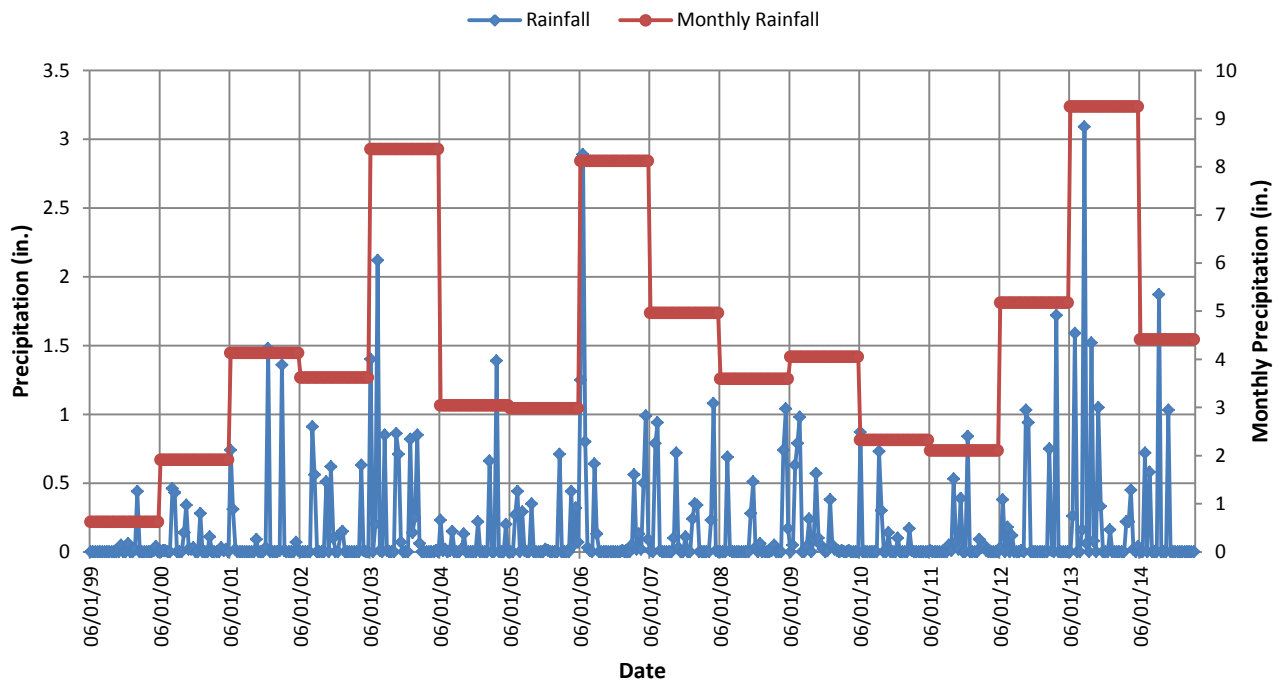
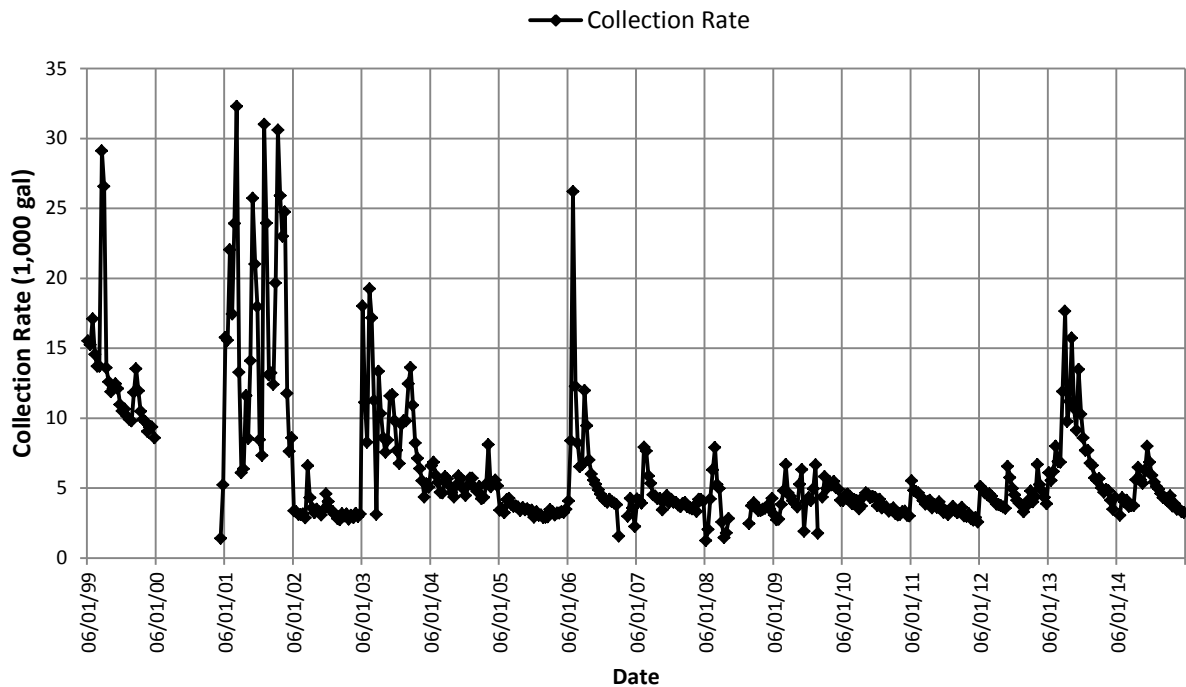
Leachate Controls
at Landfill Section 2/8
and Landfill Section 3/4
Report

Fresh Kills Landfill

Figure 3.2-4
April Collection Rate
and Precipitation
Original Drain
Landfill Section 2/8



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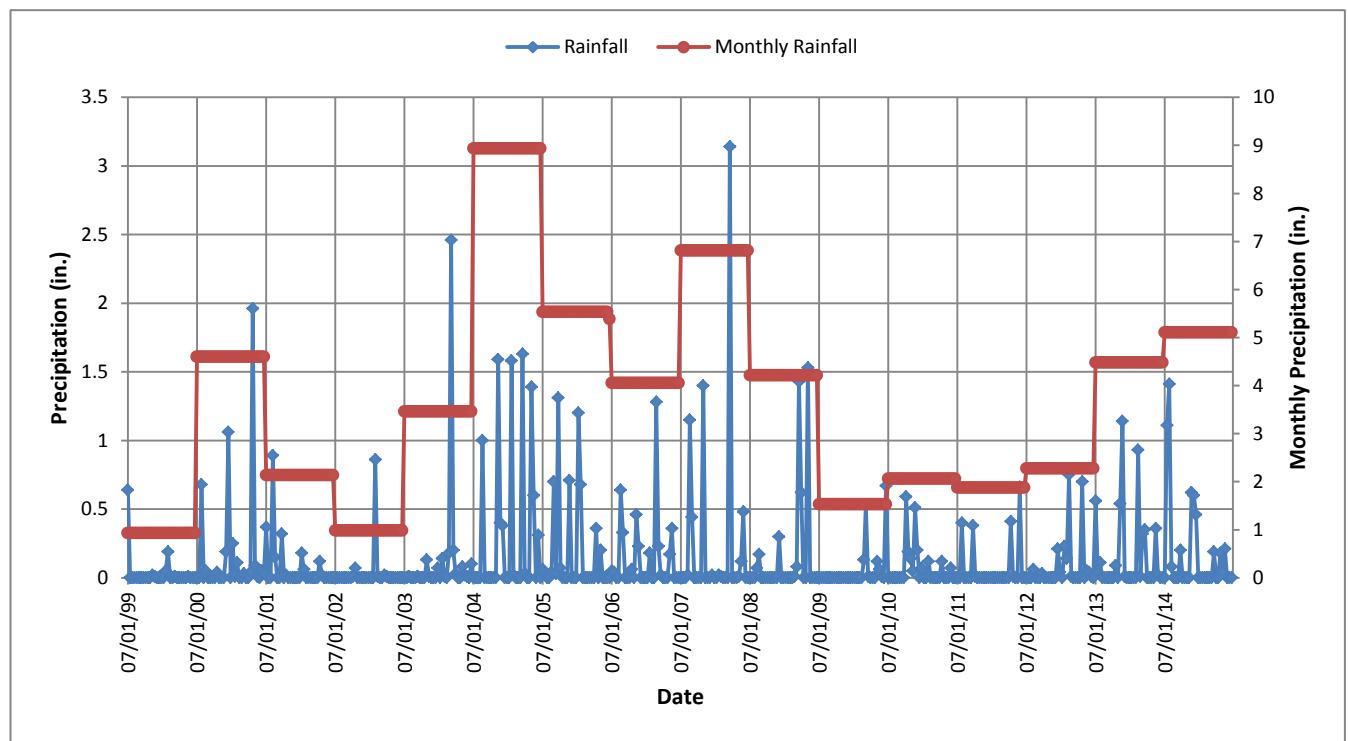
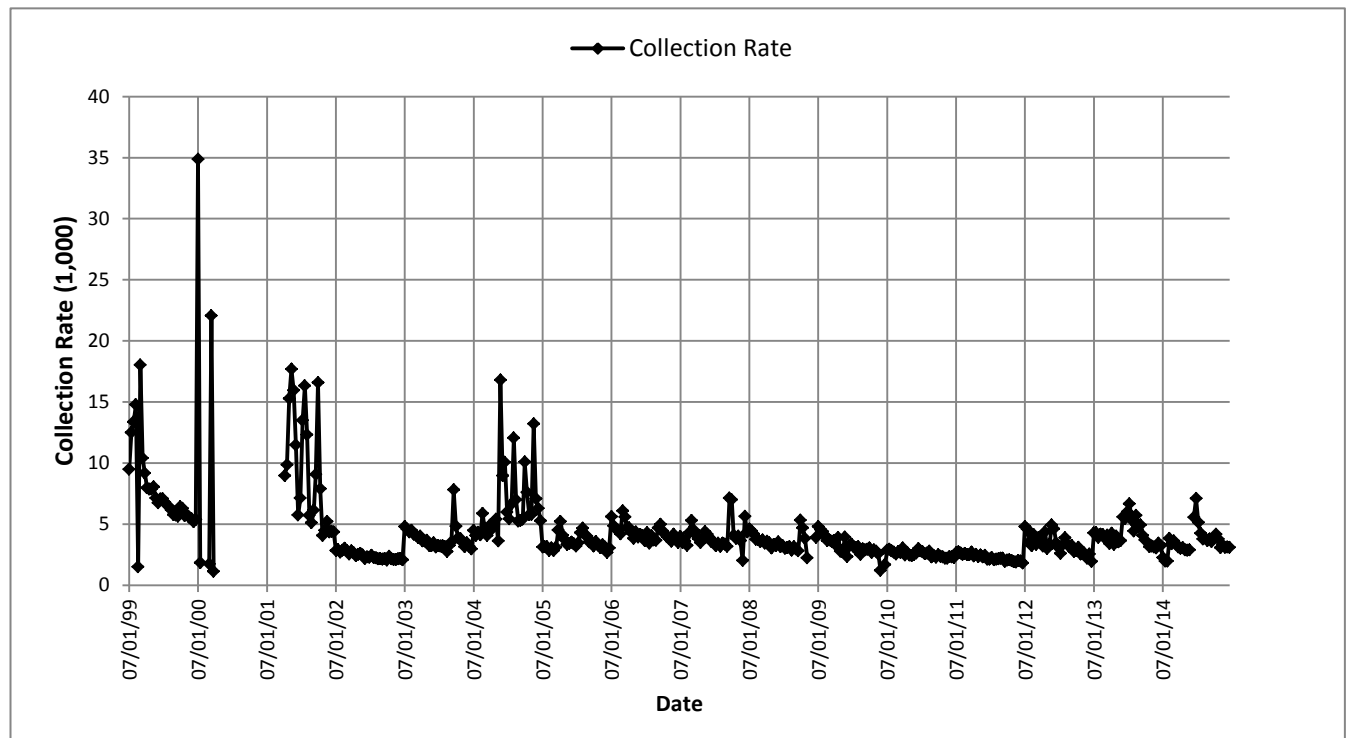
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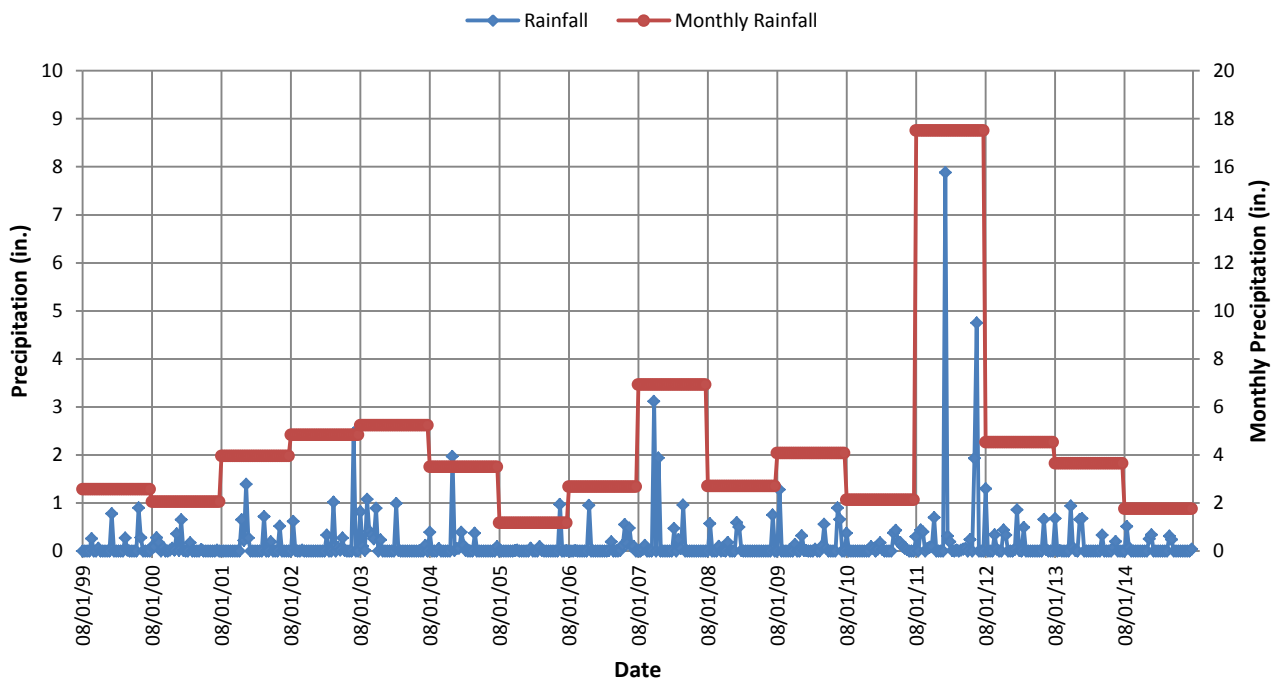
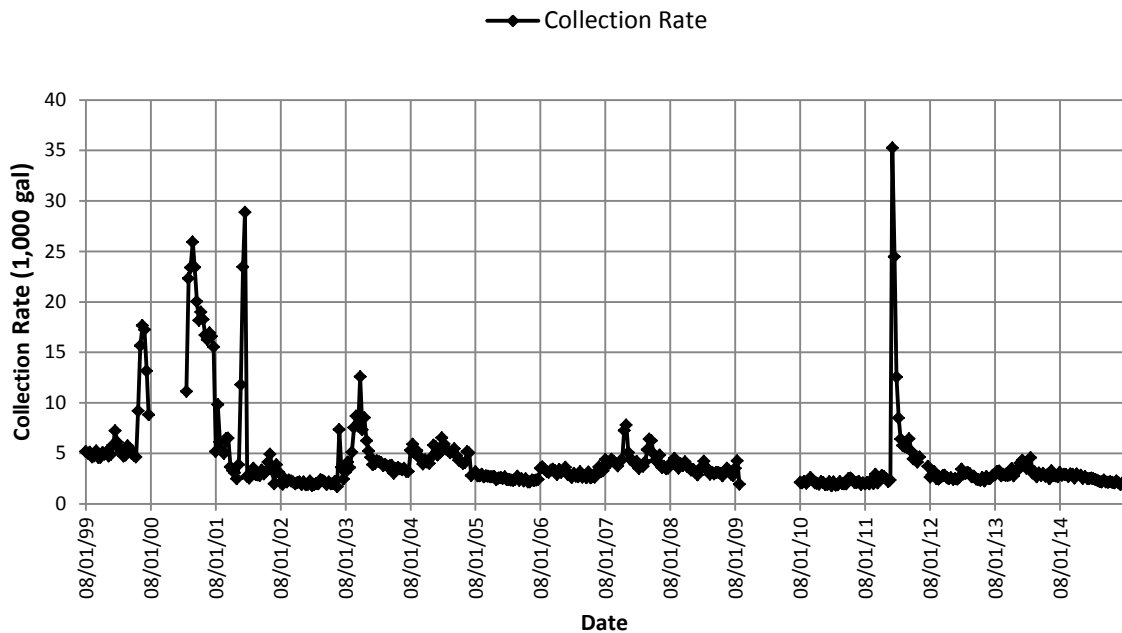
Leachate Controls
at Landfill Section 2/8
and Landfill Section 3/4
Report

Fresh Kills Landfill

Figure 3.2-6
June Collection Rate
and Precipitation
Original Drain
Landfill Section 2/8



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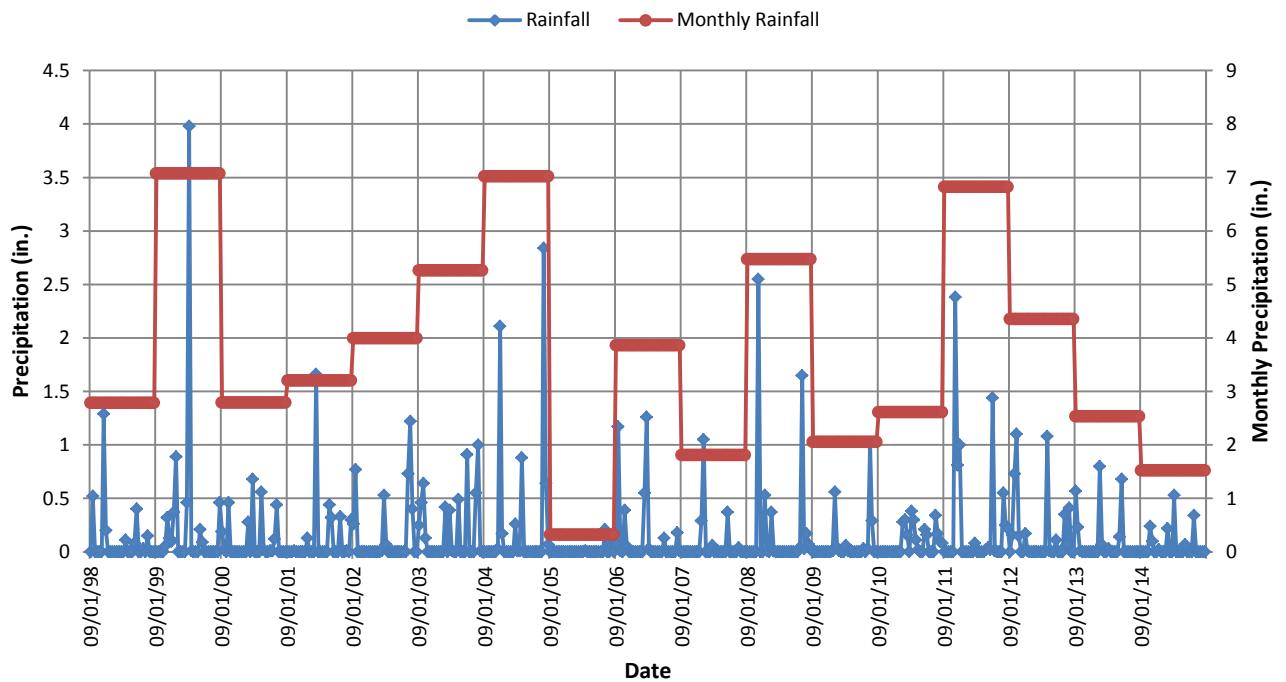
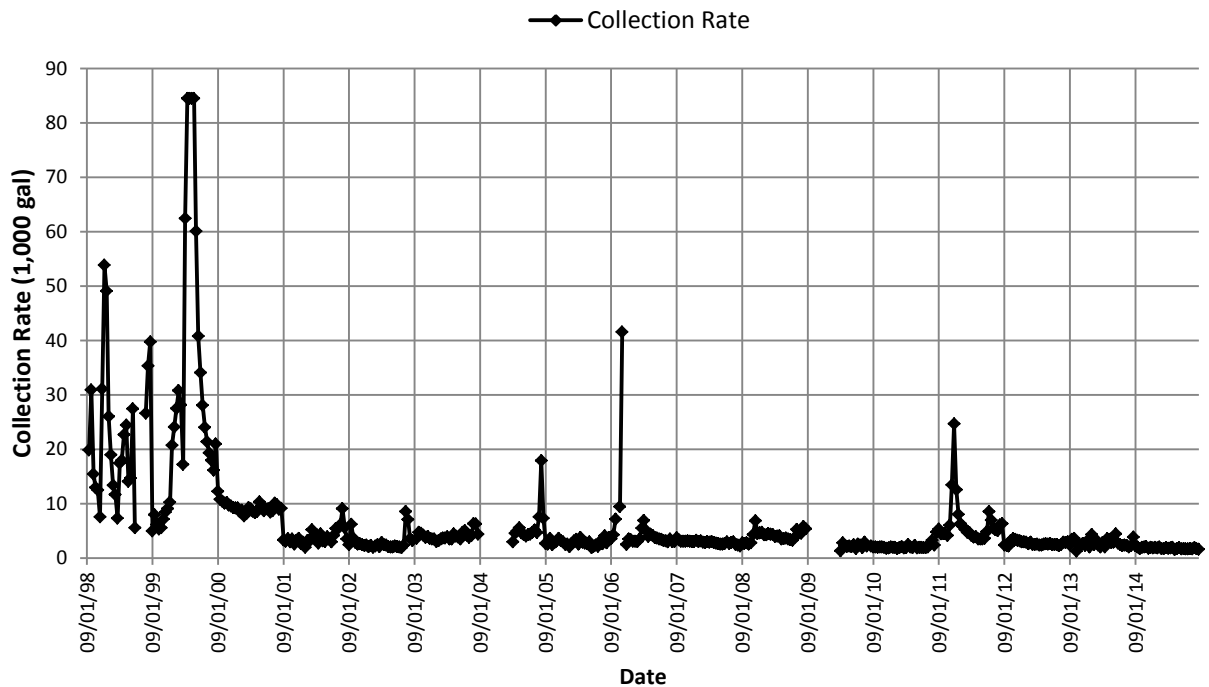
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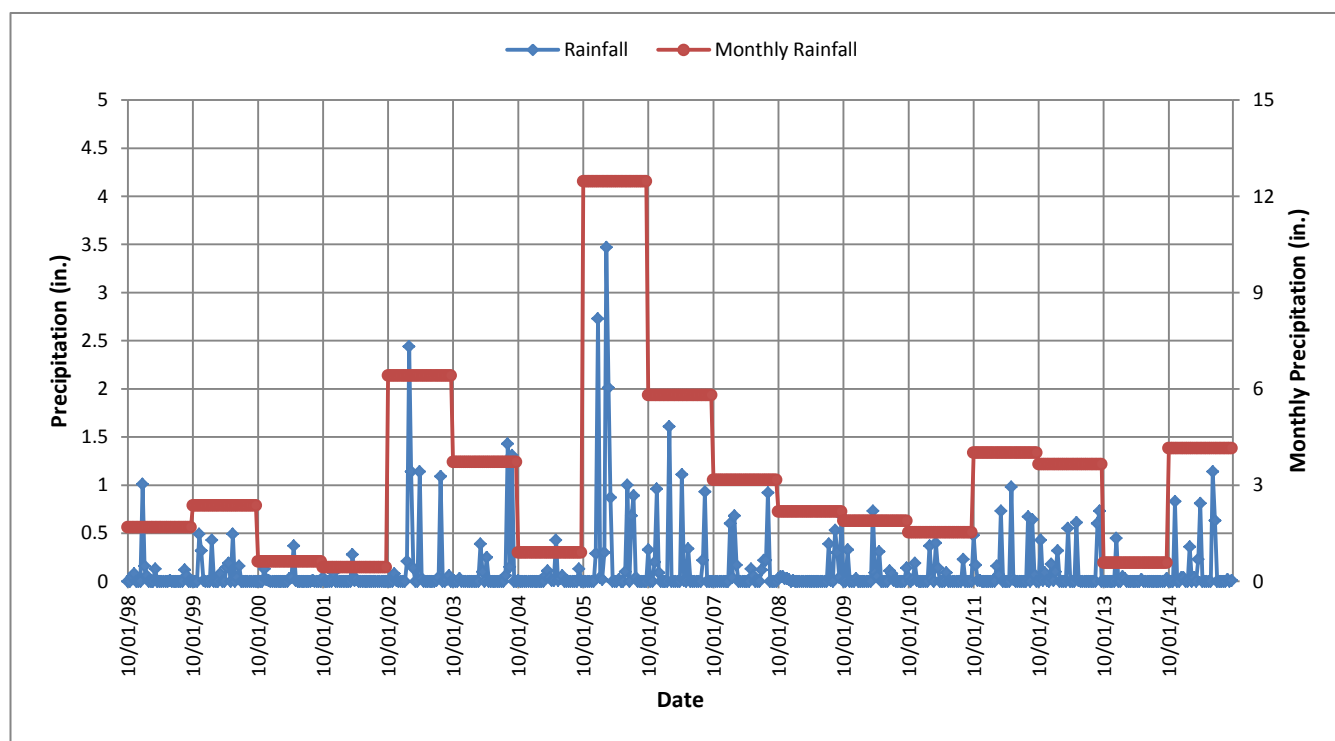
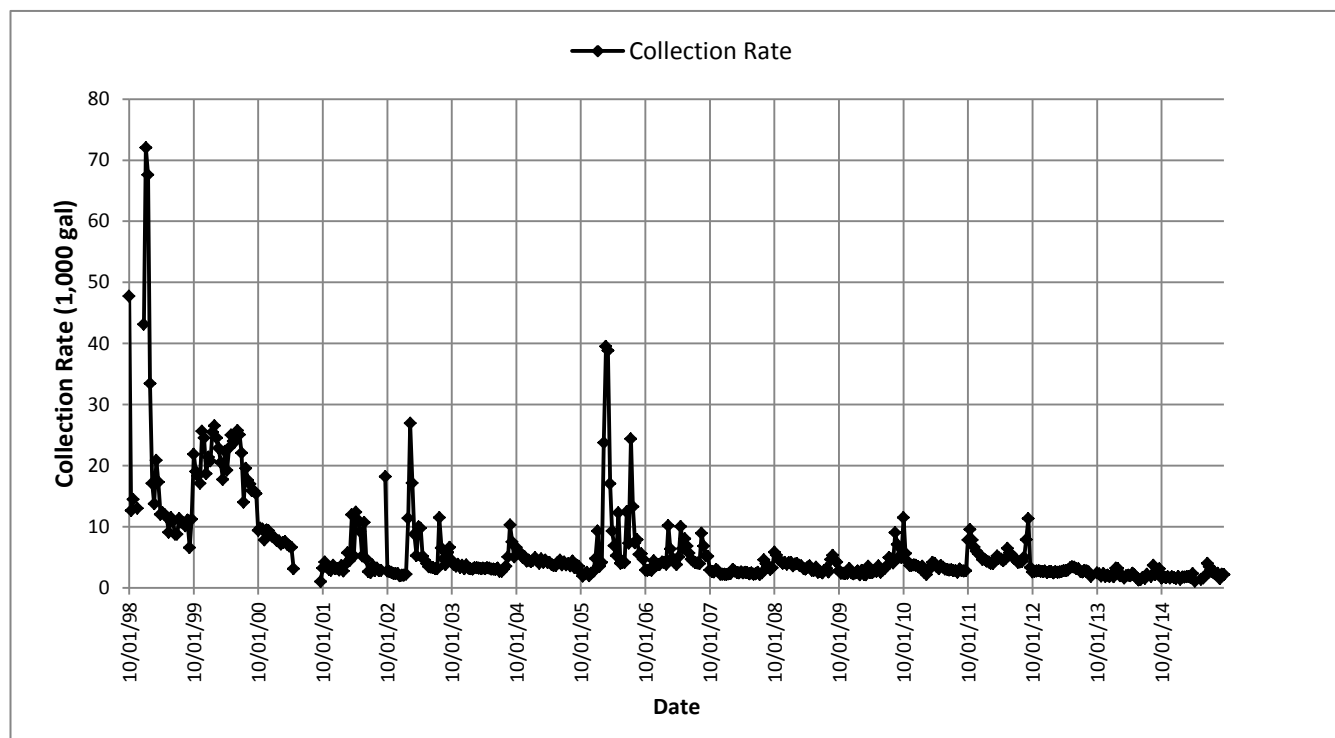
Leachate Controls
at Landfill Section 2/8
and Landfill Section 3/4
Report

Fresh Kills Landfill

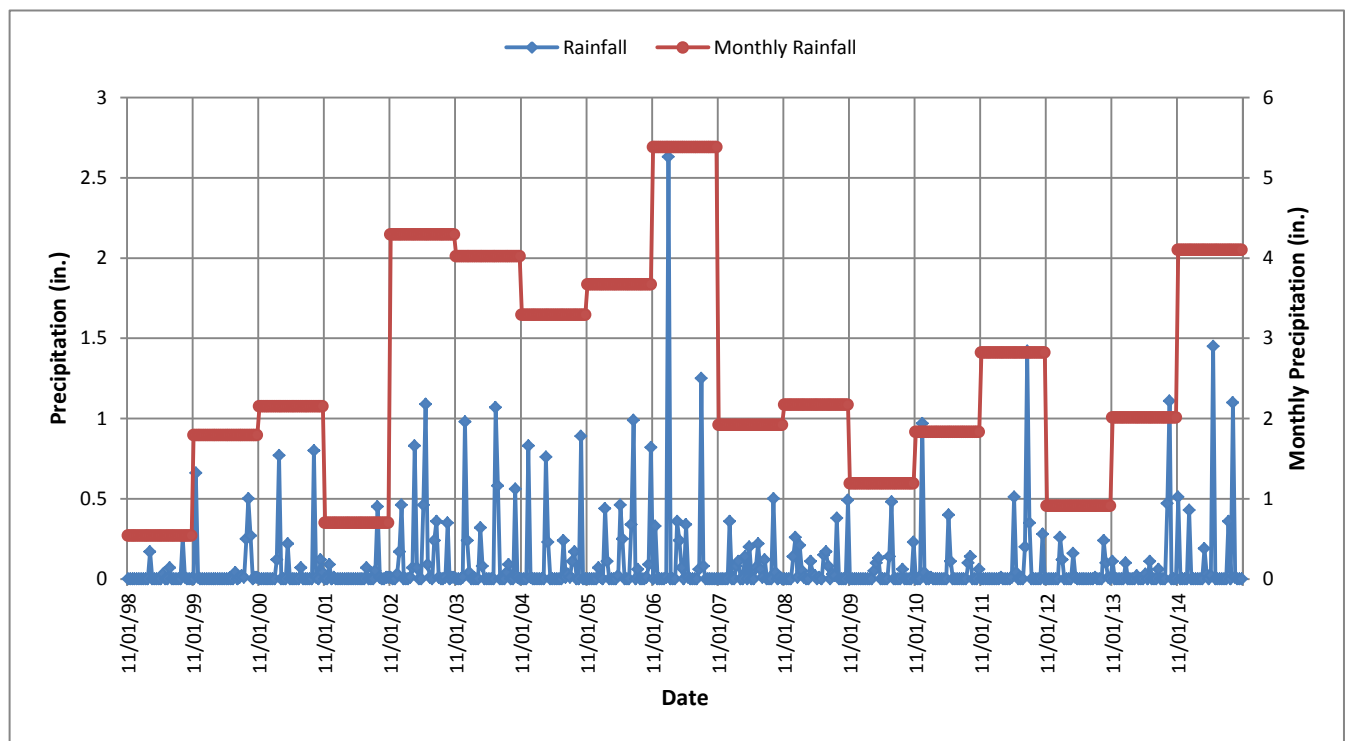
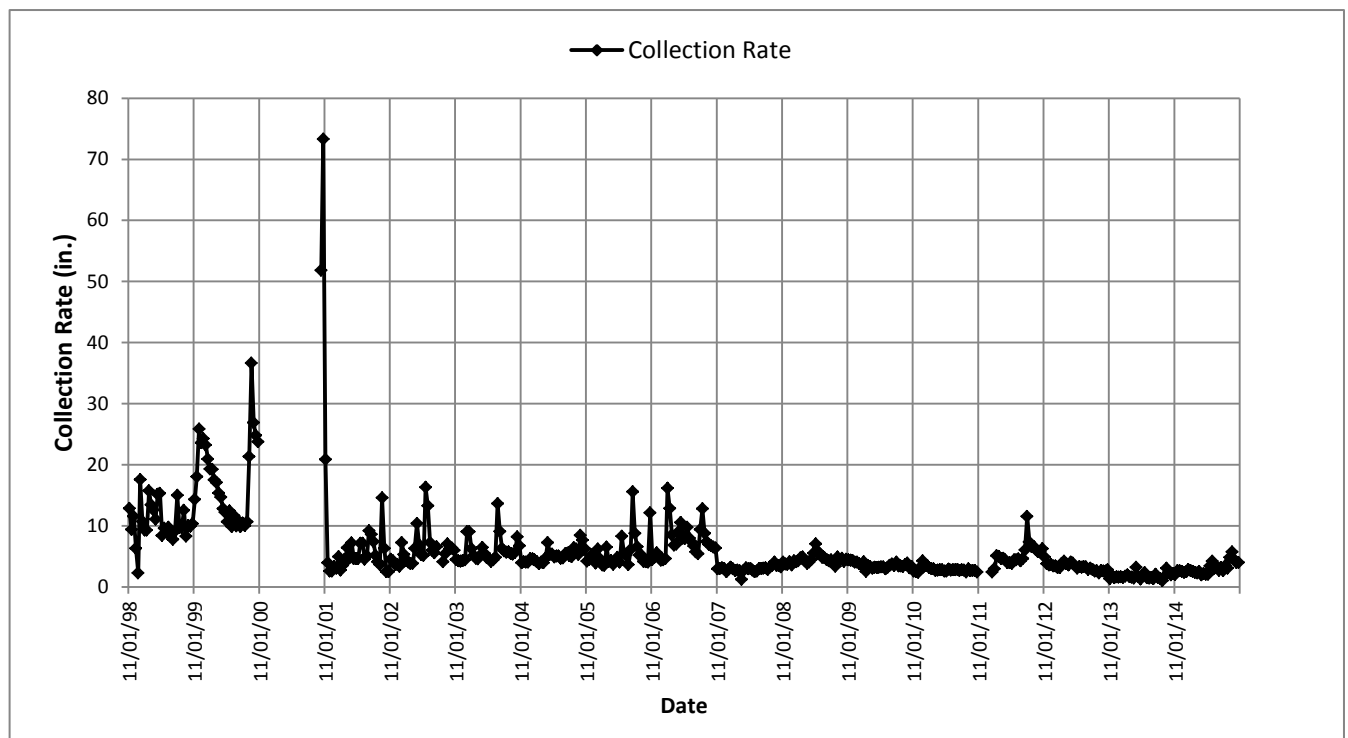
Figure 3.2-8
August Collection Rate
and Precipitation
Original Drain
Landfill Section 2/8



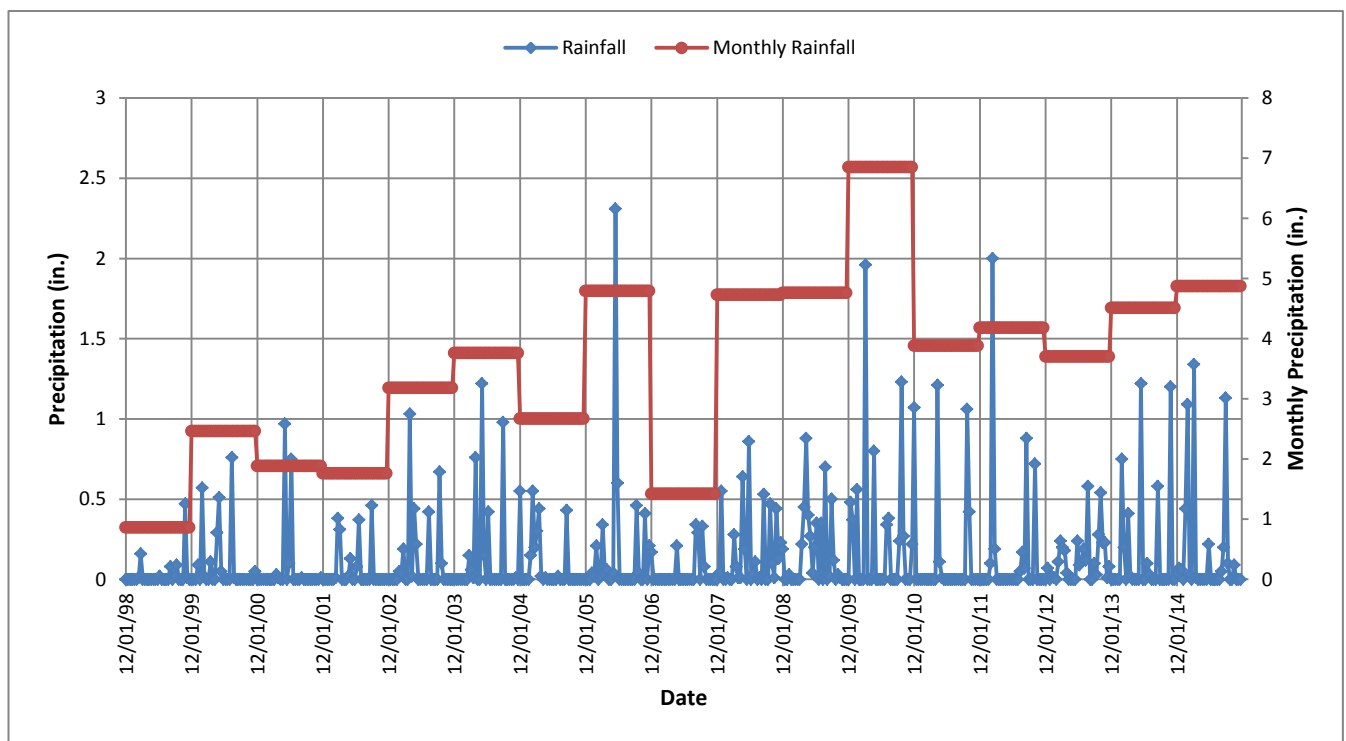
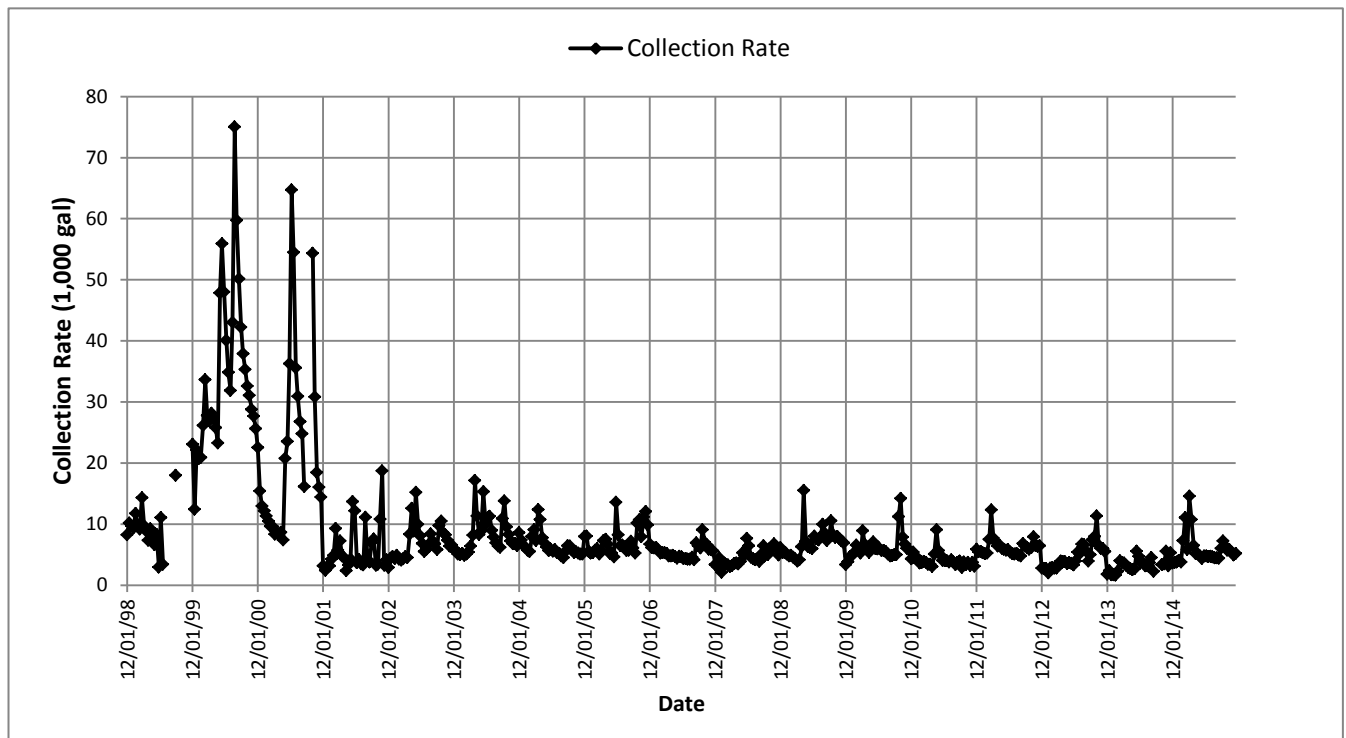
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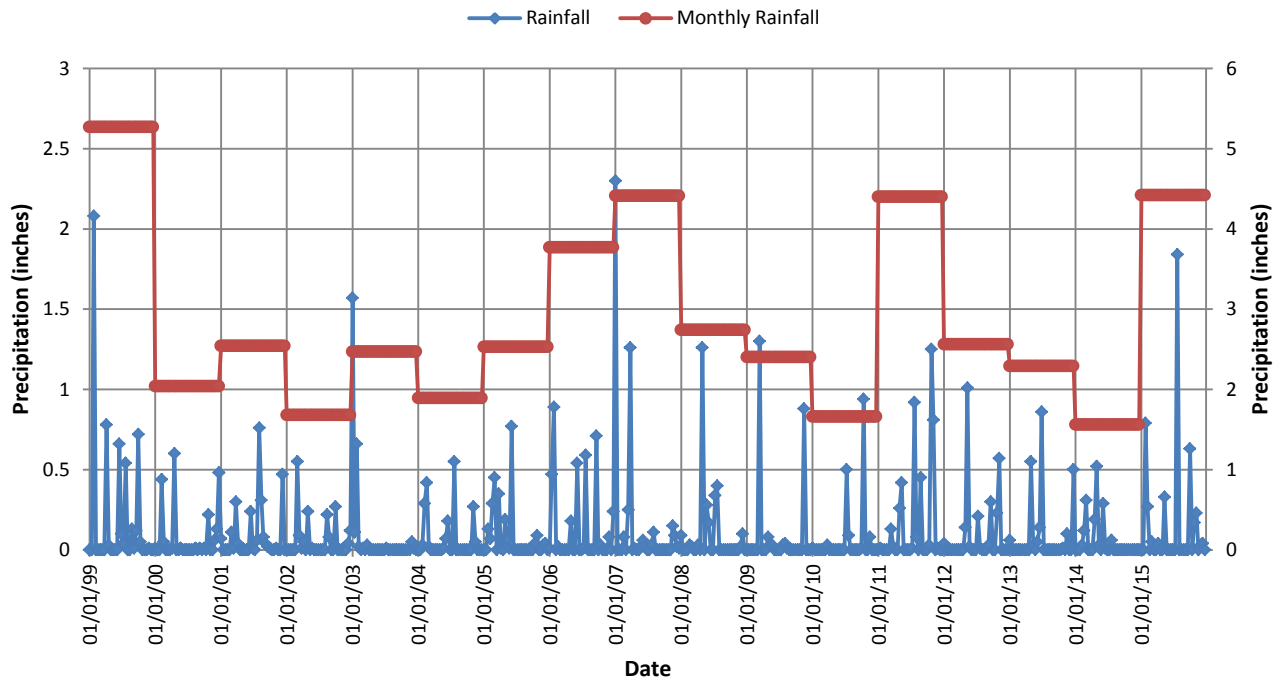
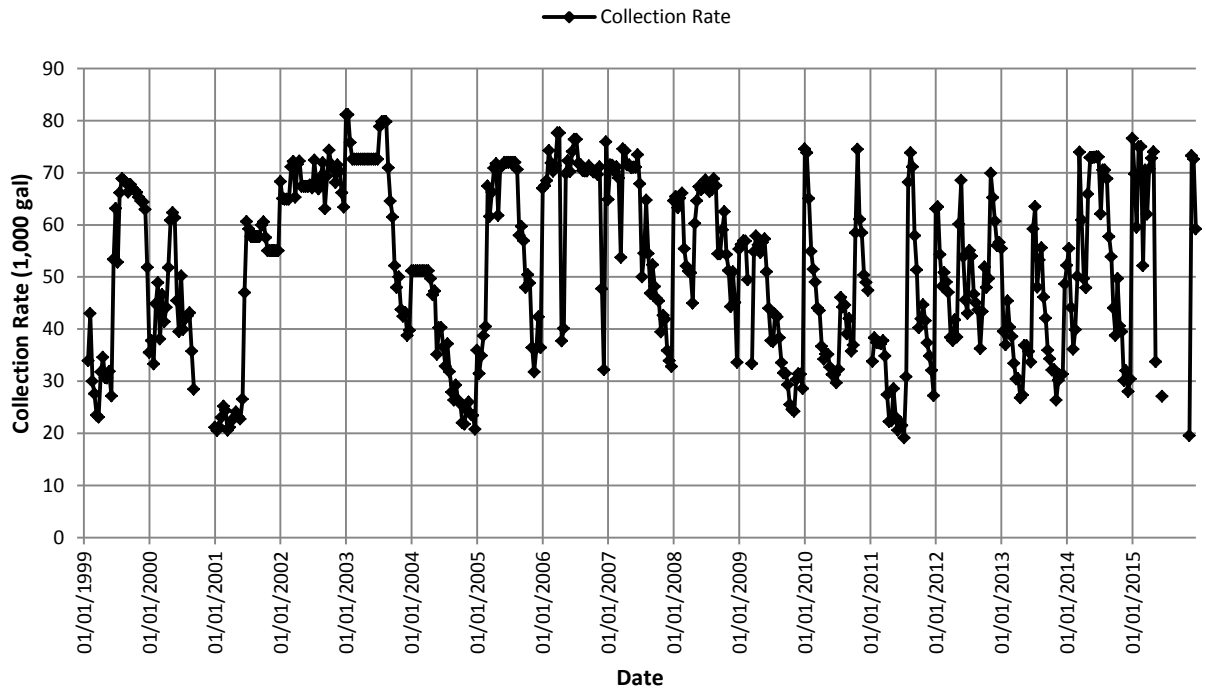
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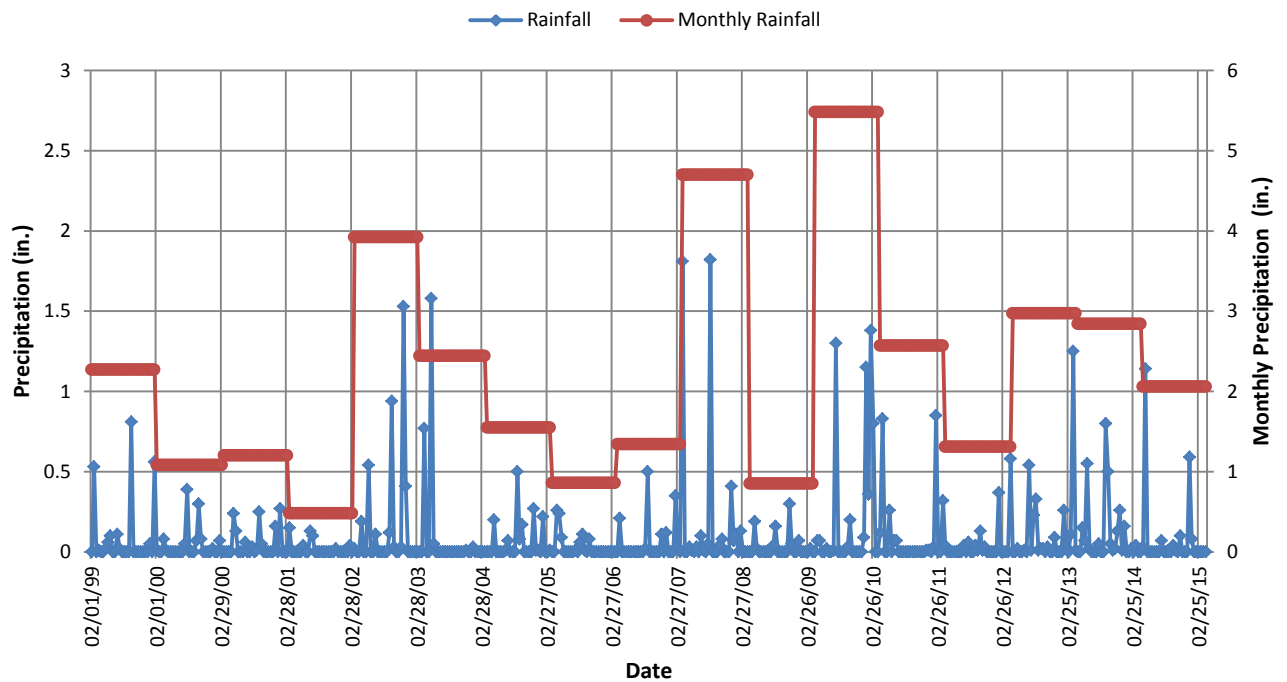
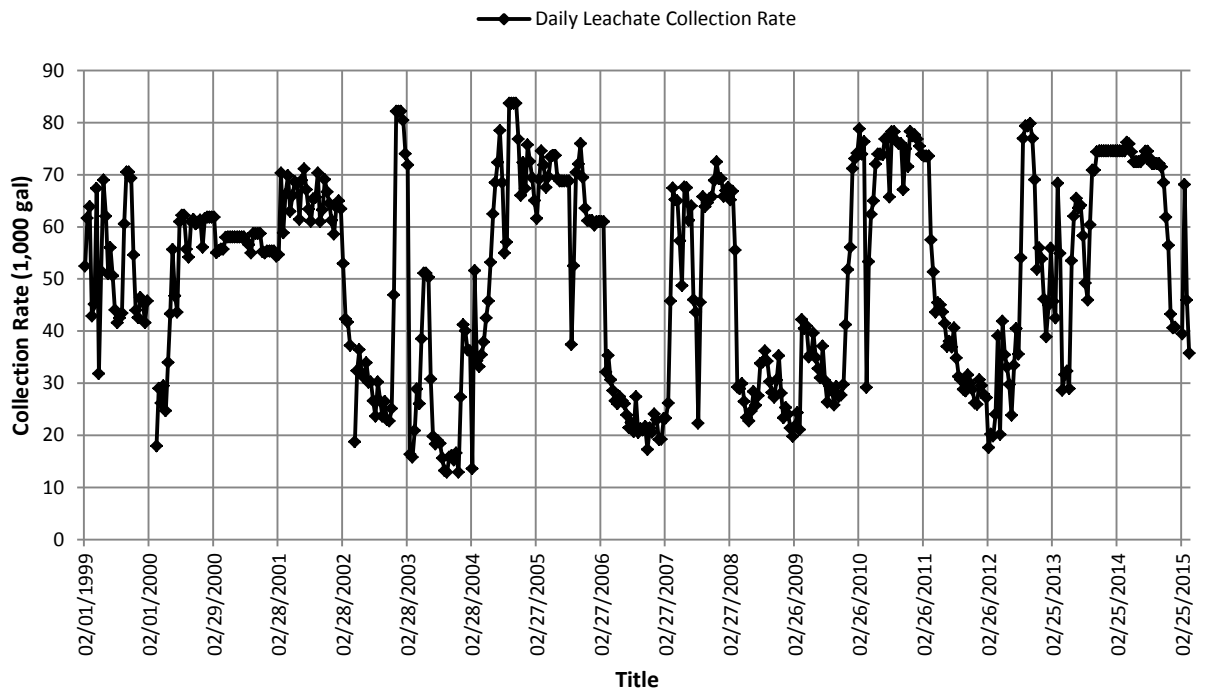
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and Landfill Section 3/4
Report

Fresh Kills Landfill

Figure 3.2-13
January Collection Rate
and Precipitation
Original Drain
Landfill Section 3/4



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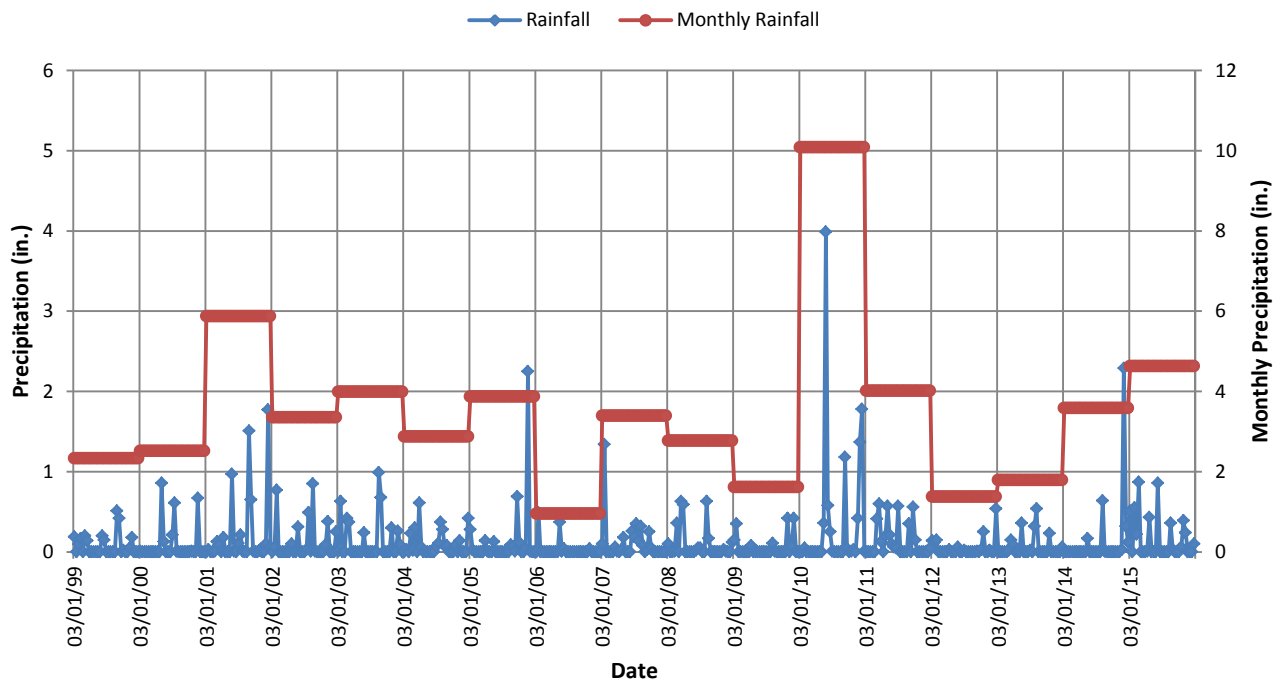
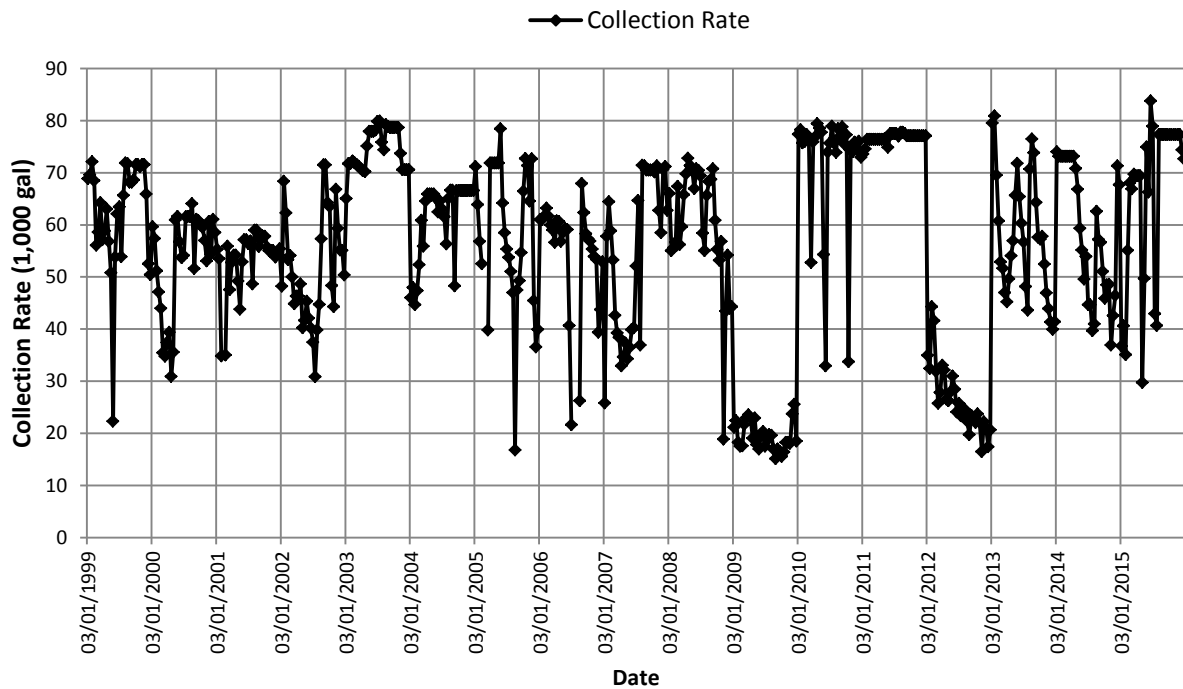
Under the Direction of:



Leachate Controls at
Landfill Section 2/8
and Landfill Section 3/4
Report

Fresh Kills Landfill

Figure 3.2-14
February Collection Rate
and Precipitation
Original Drain
Landfill Section 3/4



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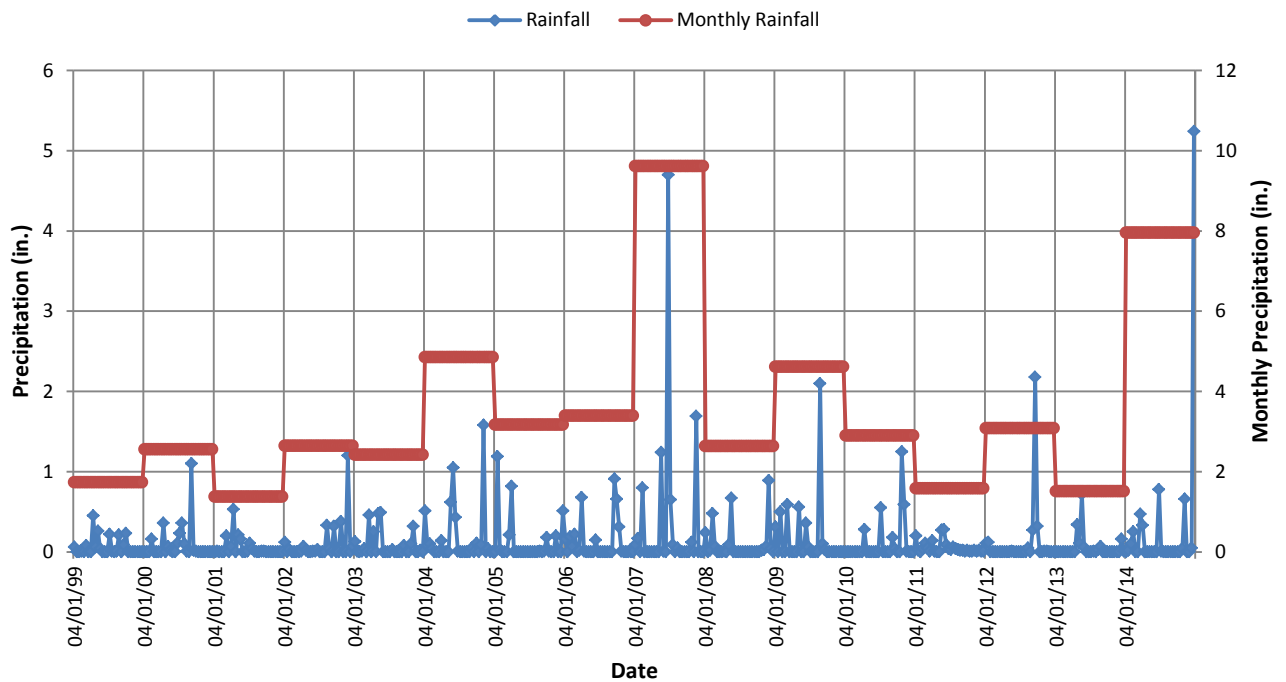
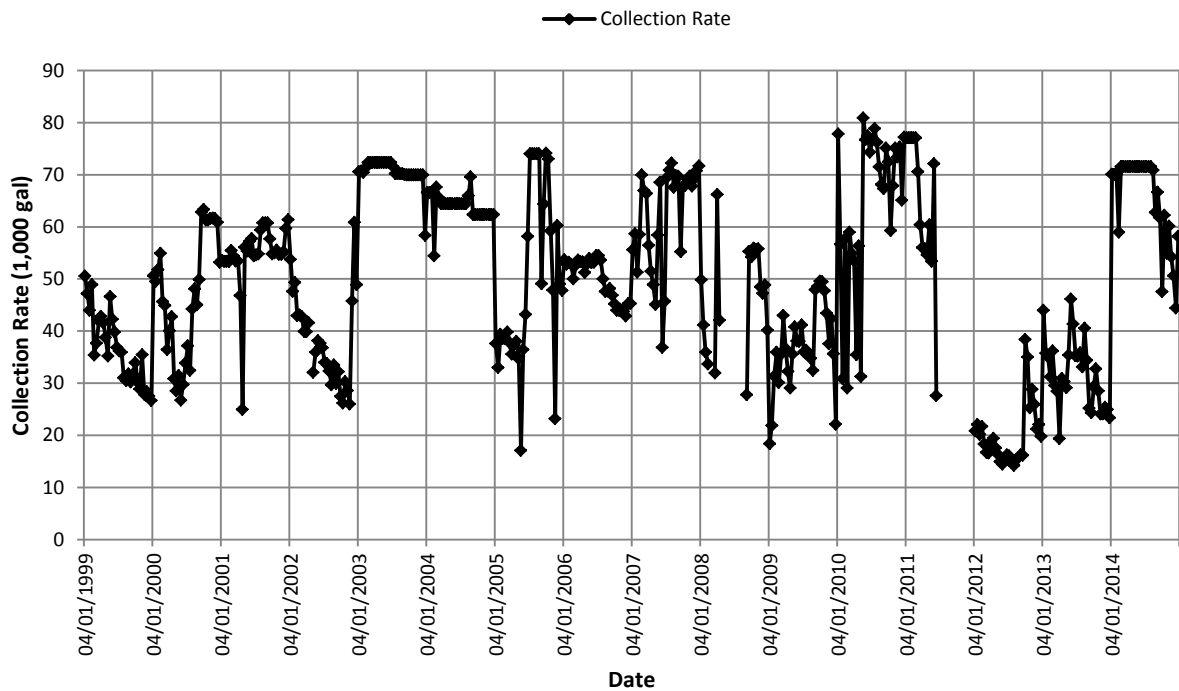
Under the Direction of:



Leachate Controls at
Landfill Section 2/8
and Landfill Section 3/4
Report

Fresh Kills Landfill

Figure 3.2-15
March Collection Rate
and Precipitation
Original Drain
Landfill Section 3/4



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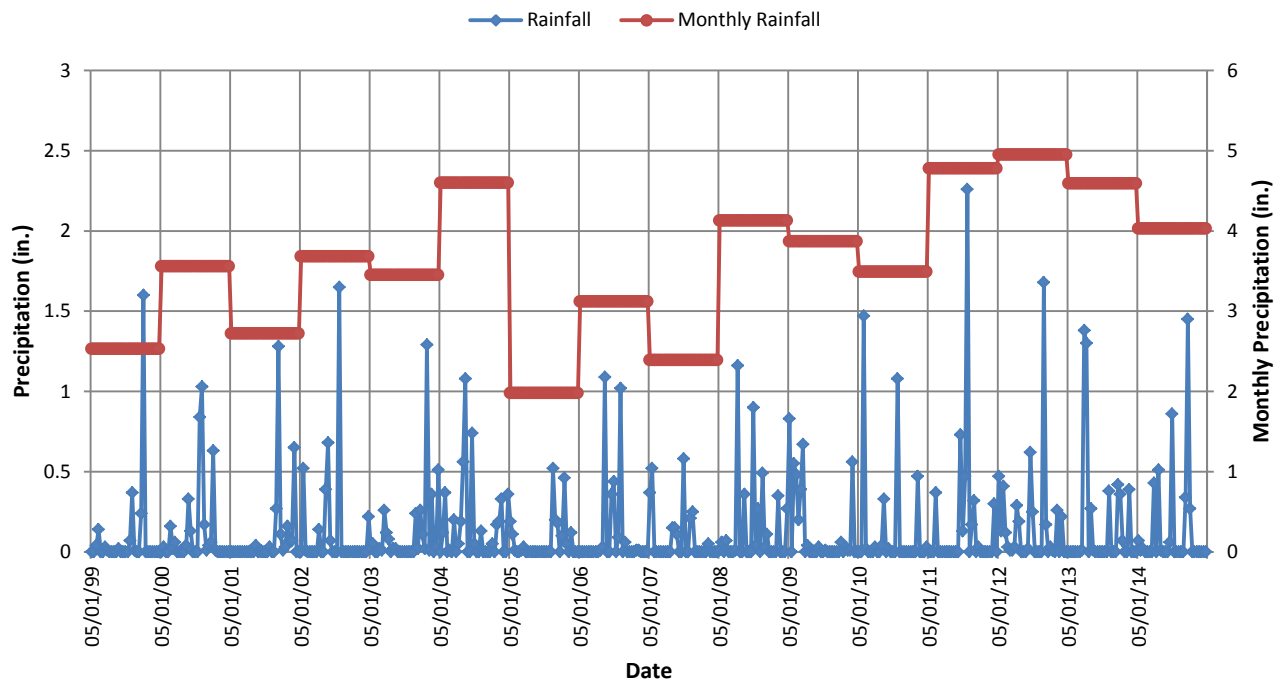
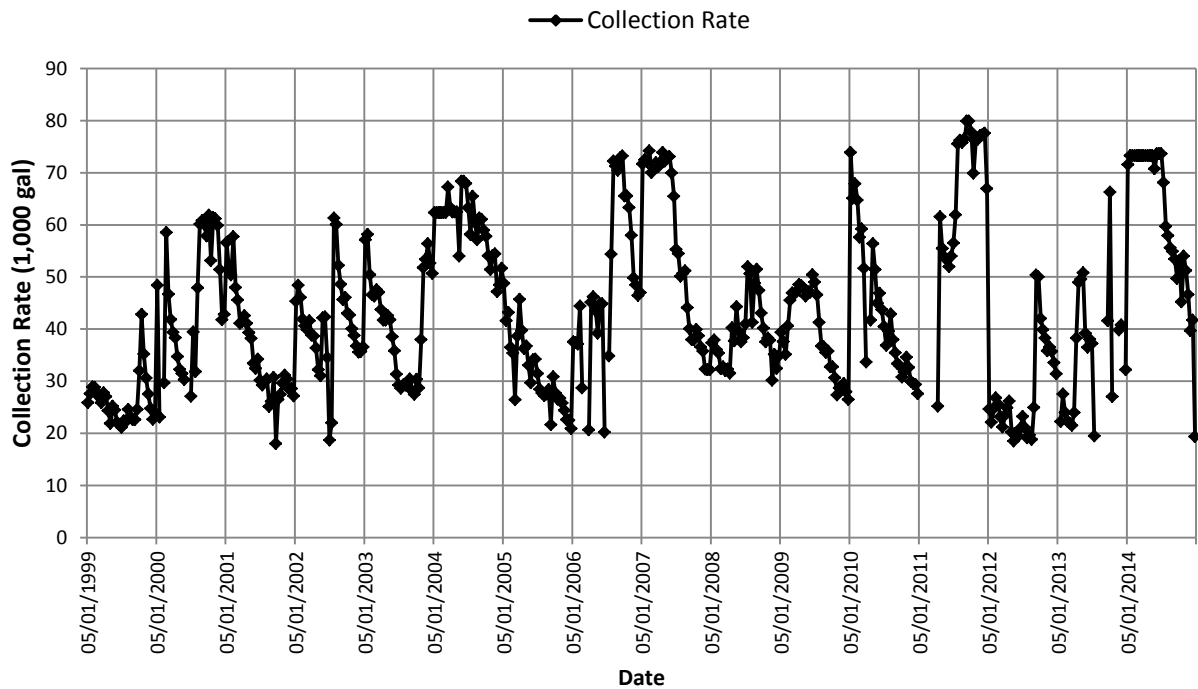
Under the Direction of:



Leachate Controls at
Landfill Section 2/8
and Landfill Section 3/4
Report

Fresh Kills Landfill

Figure 3.2-16
April Collection Rate
and Precipitation
Original Drain
Landfill Section 3/4



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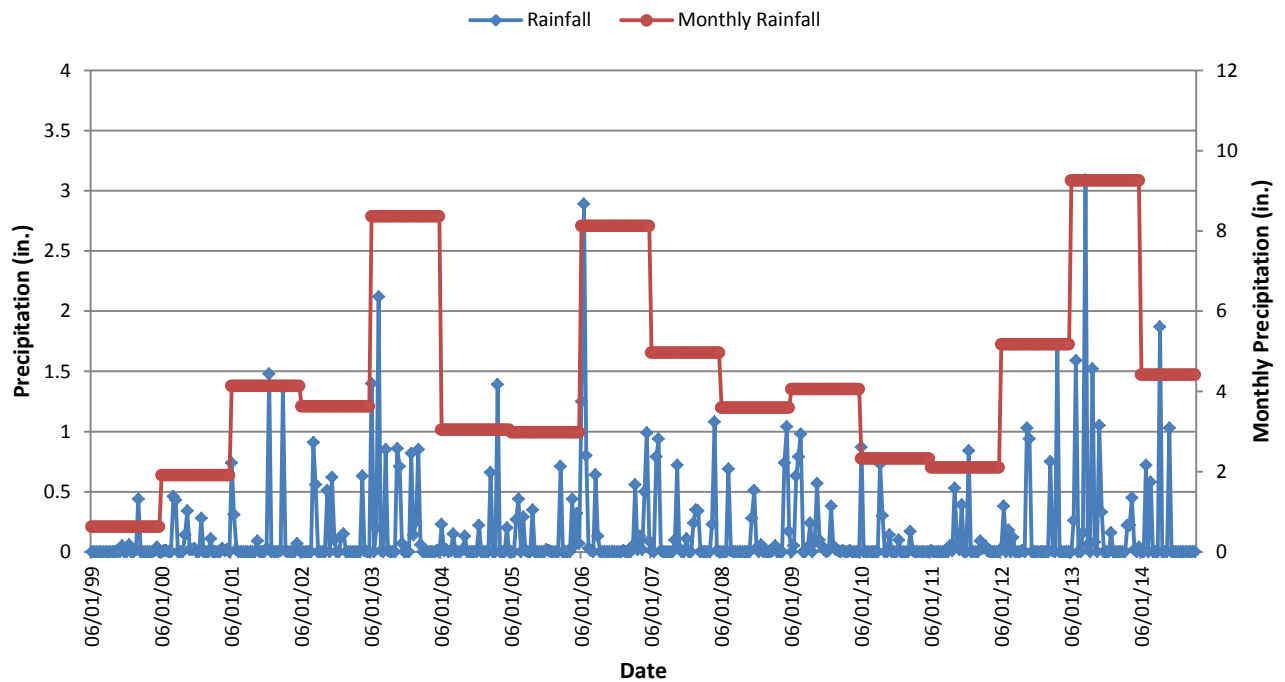
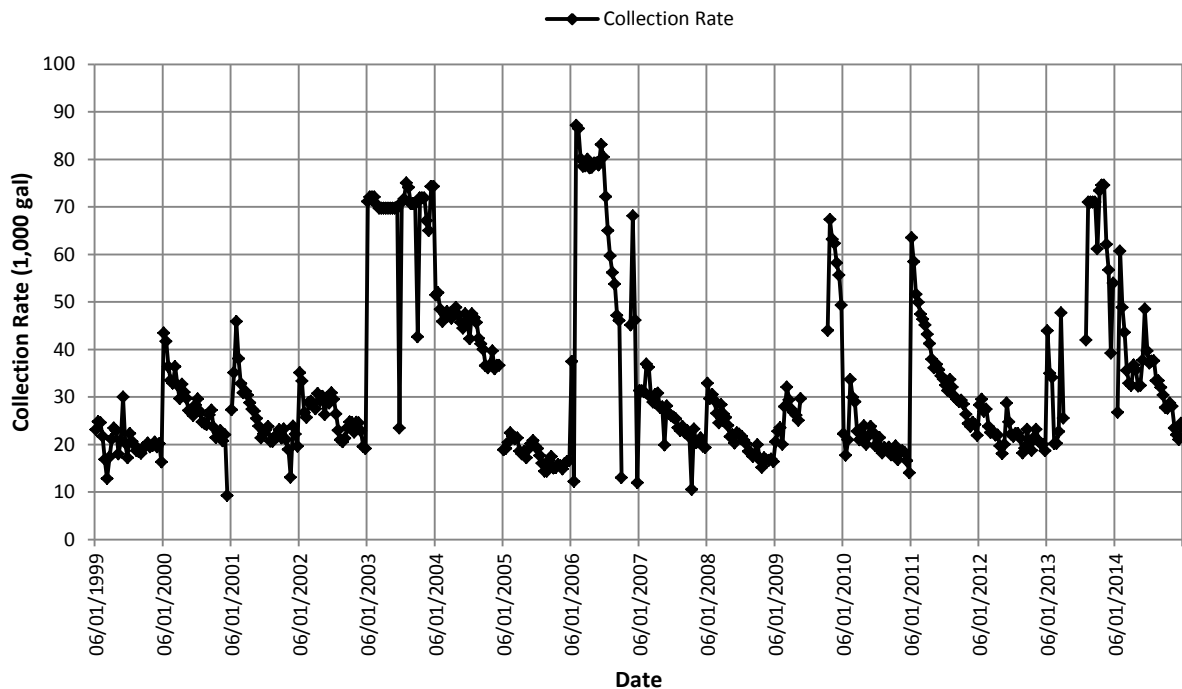
Under the Direction of:



Leachate Controls at
Landfill Section 2/8
and Landfill Section 3/4
Report

Fresh Kills Landfill

Figure 3.2-17
May Collection Rate
and Precipitation
Original Drain
Landfill Section 3/4



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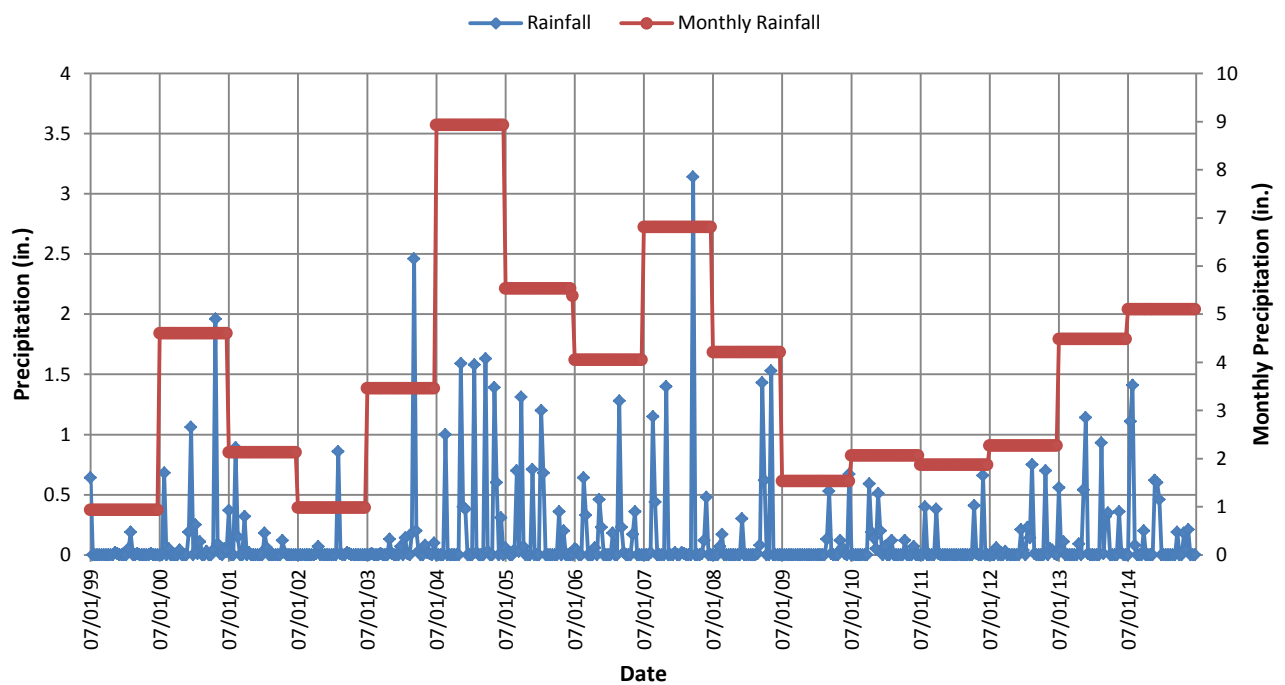
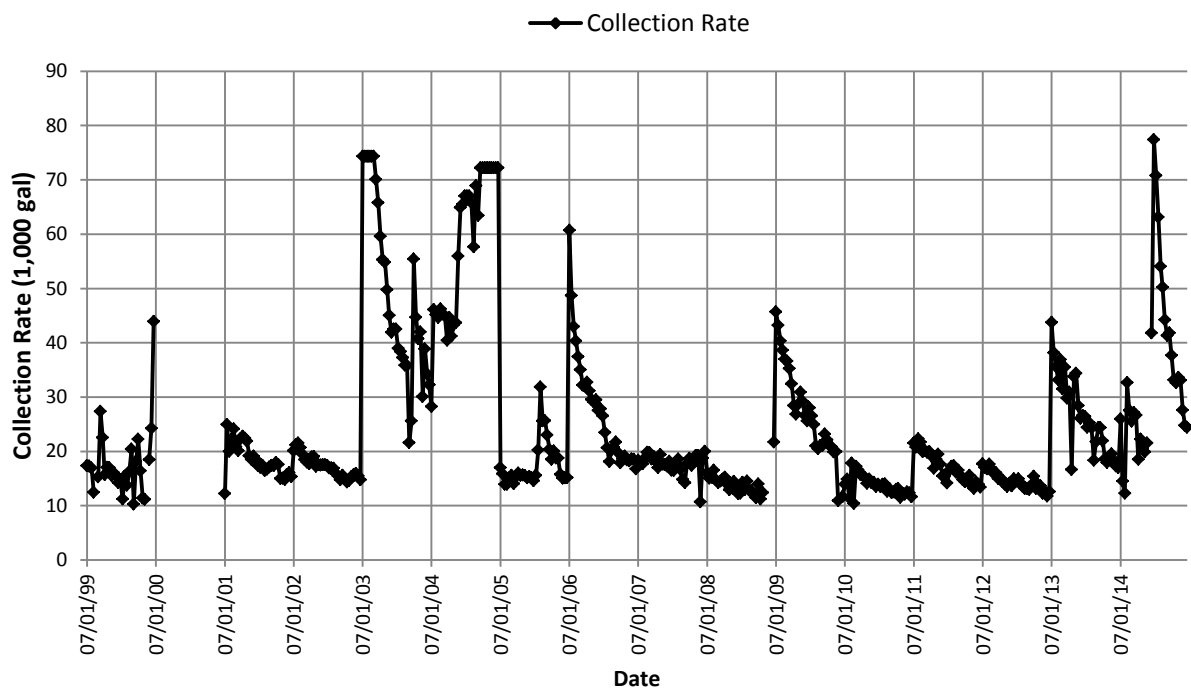
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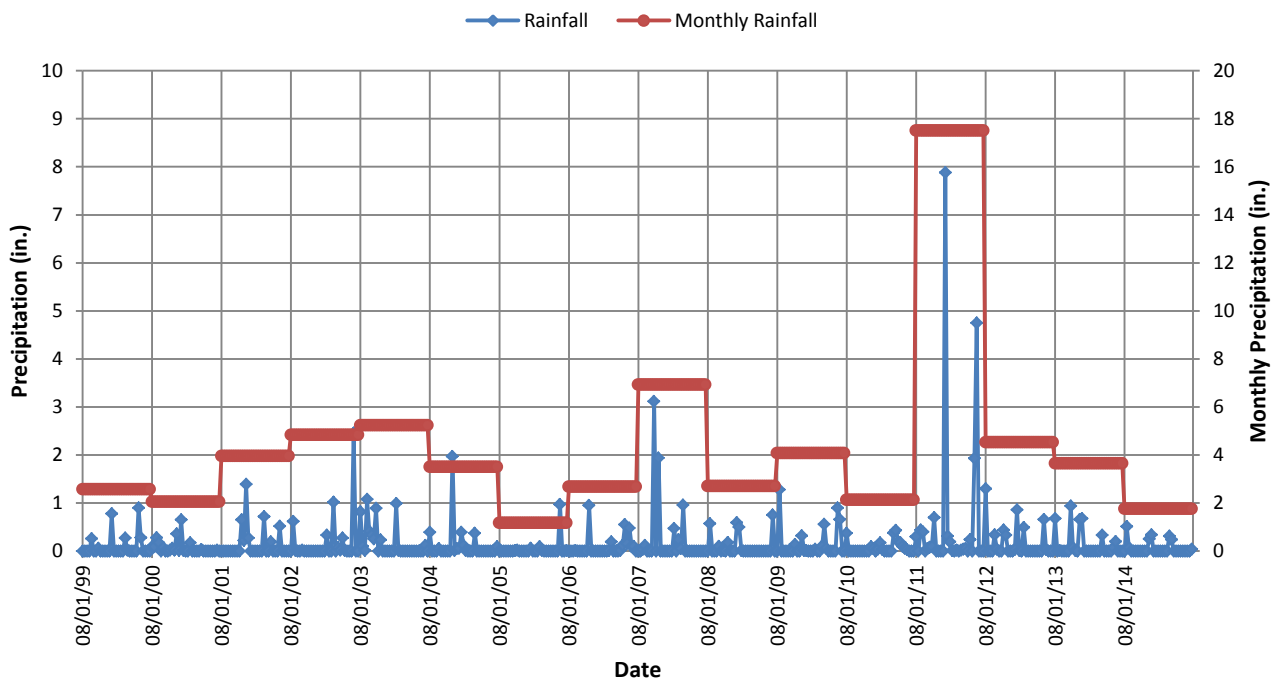
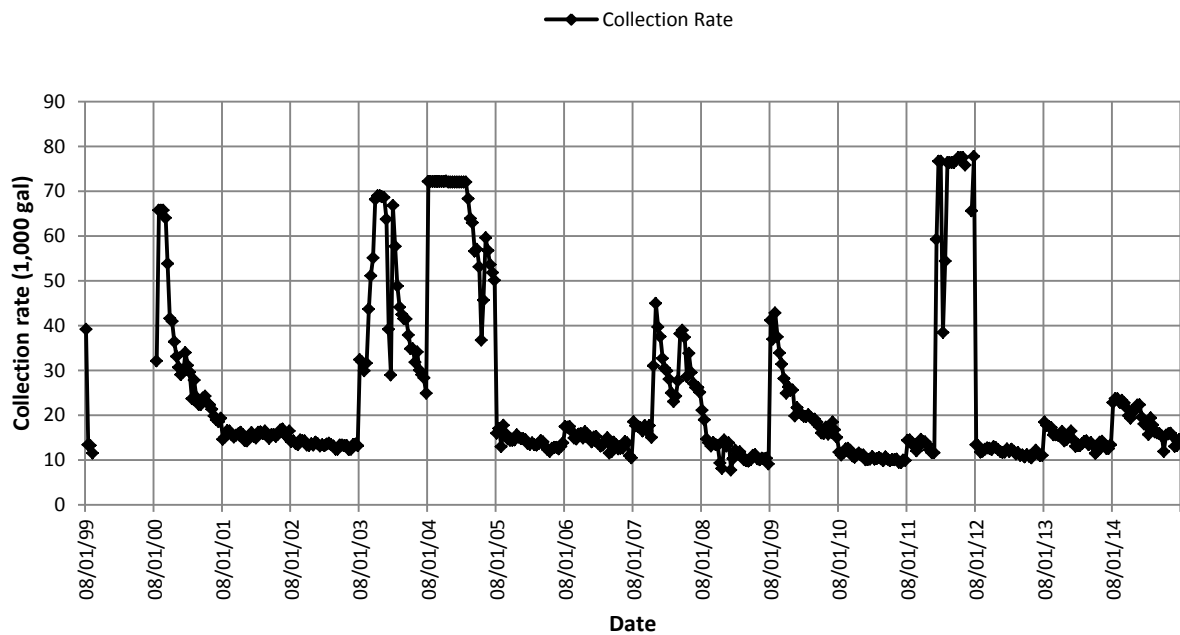
Leachate Controls at
Landfill Section 2/8
and Landfill Section 3/4
Report

Fresh Kills Landfill

Figure 3.2-18
June Collection Rate
and Precipitation
Original Drain
Landfill Section 3/4



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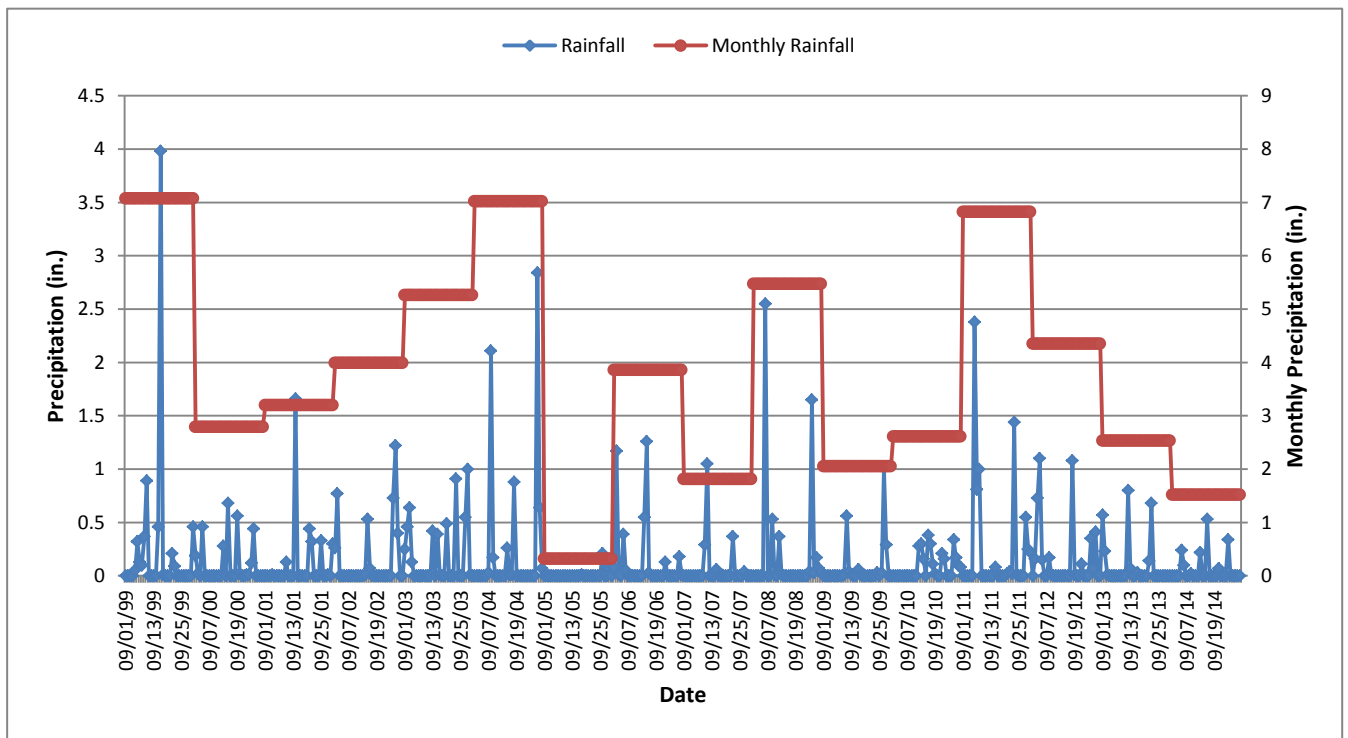
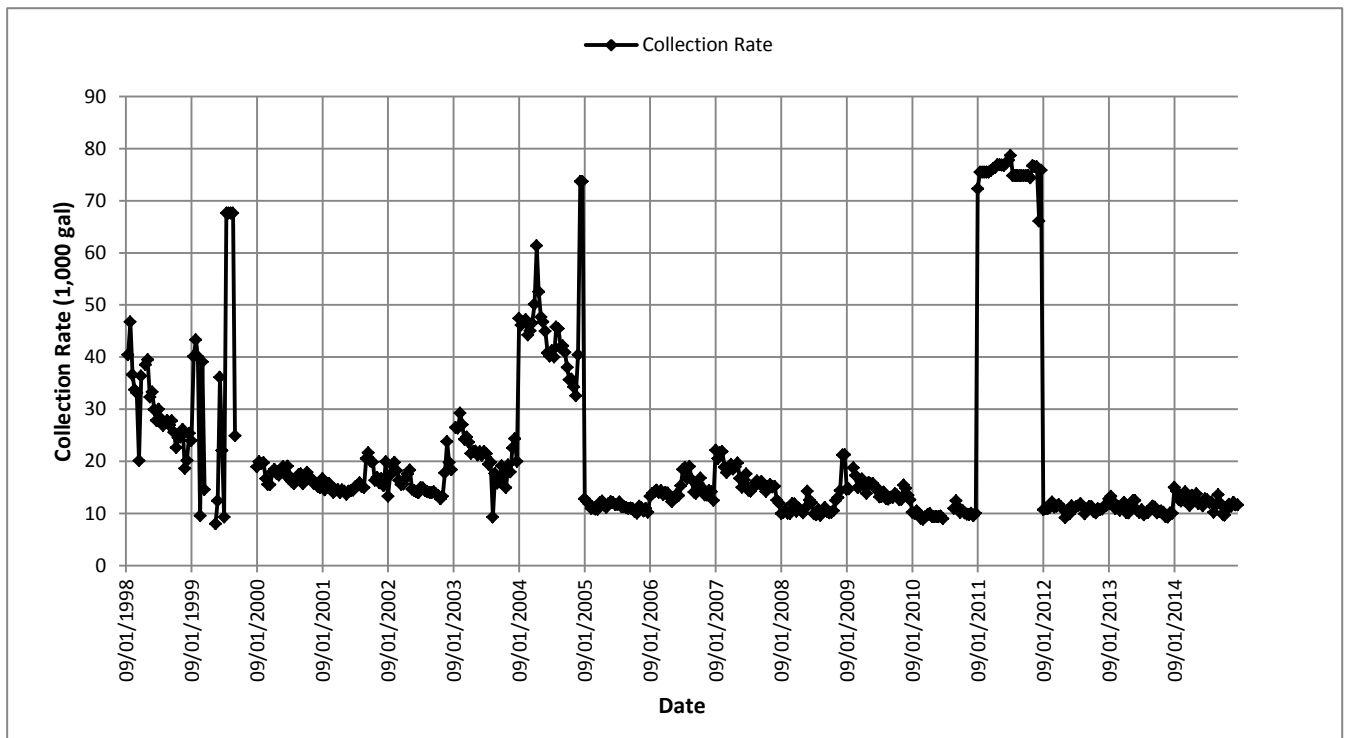
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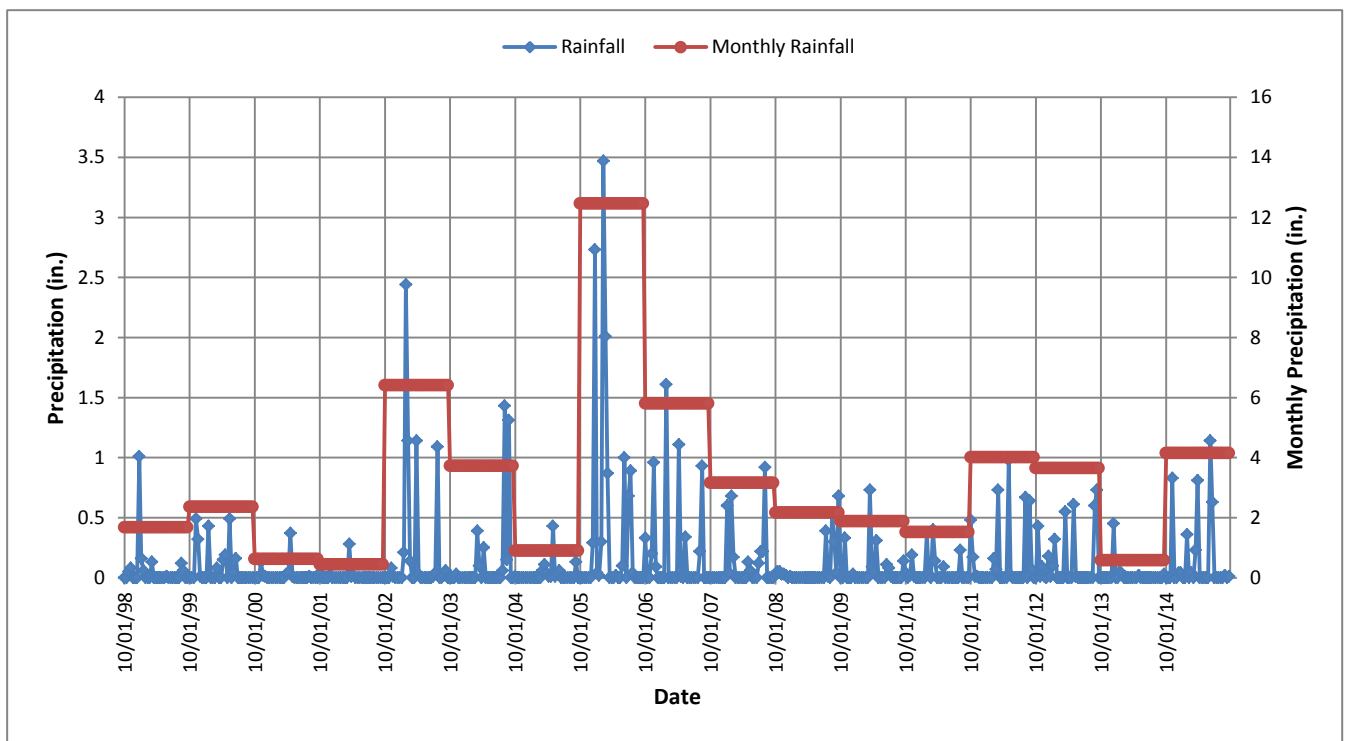
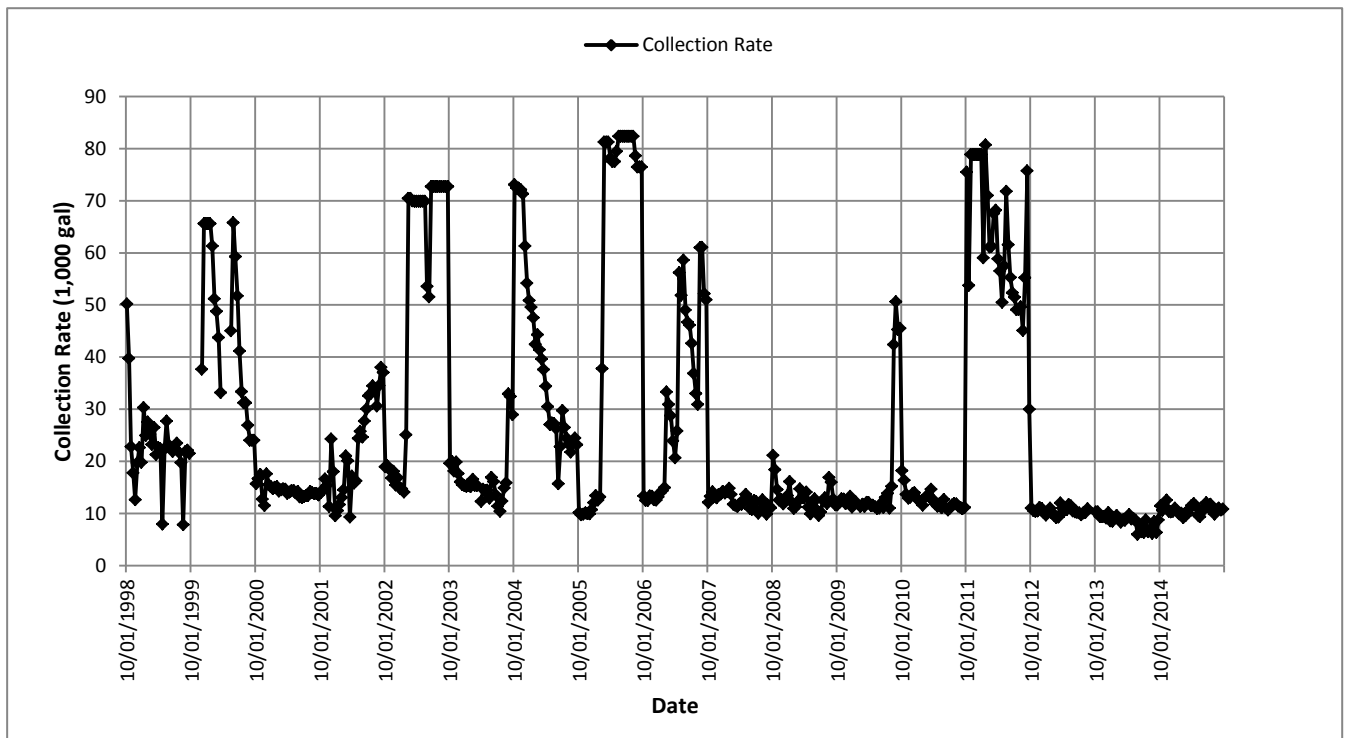
Leachate Controls at
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Report

Fresh Kills Landfill

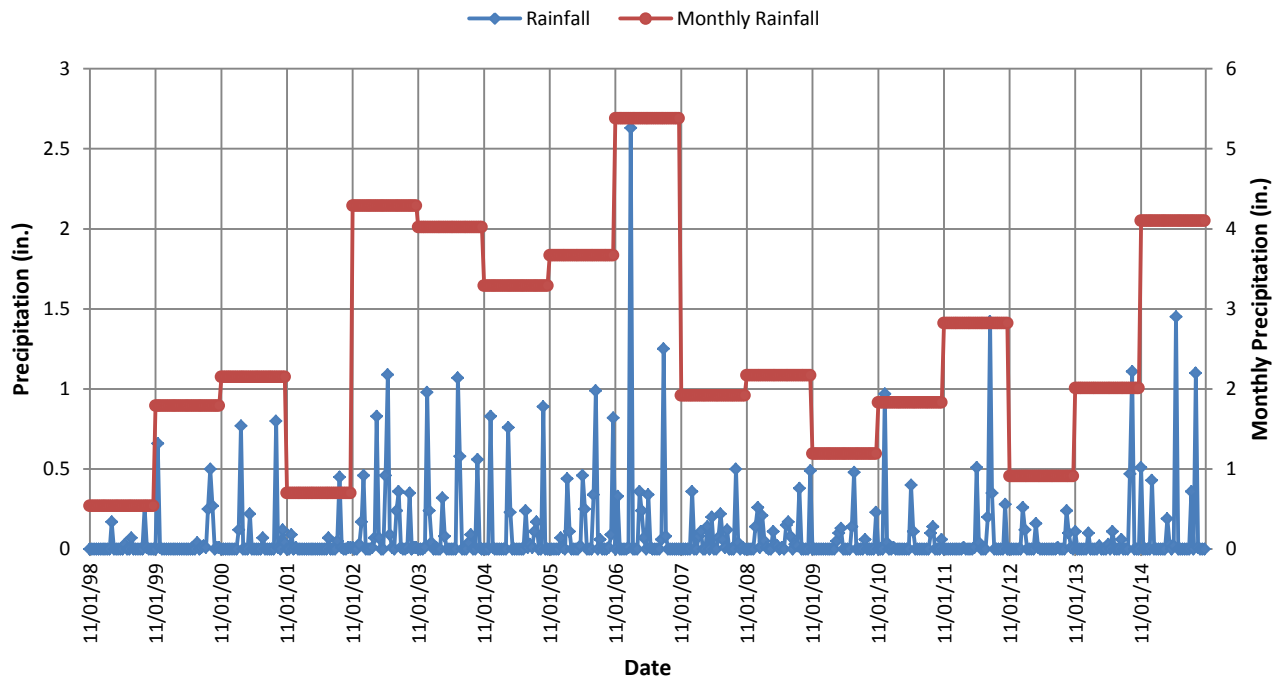
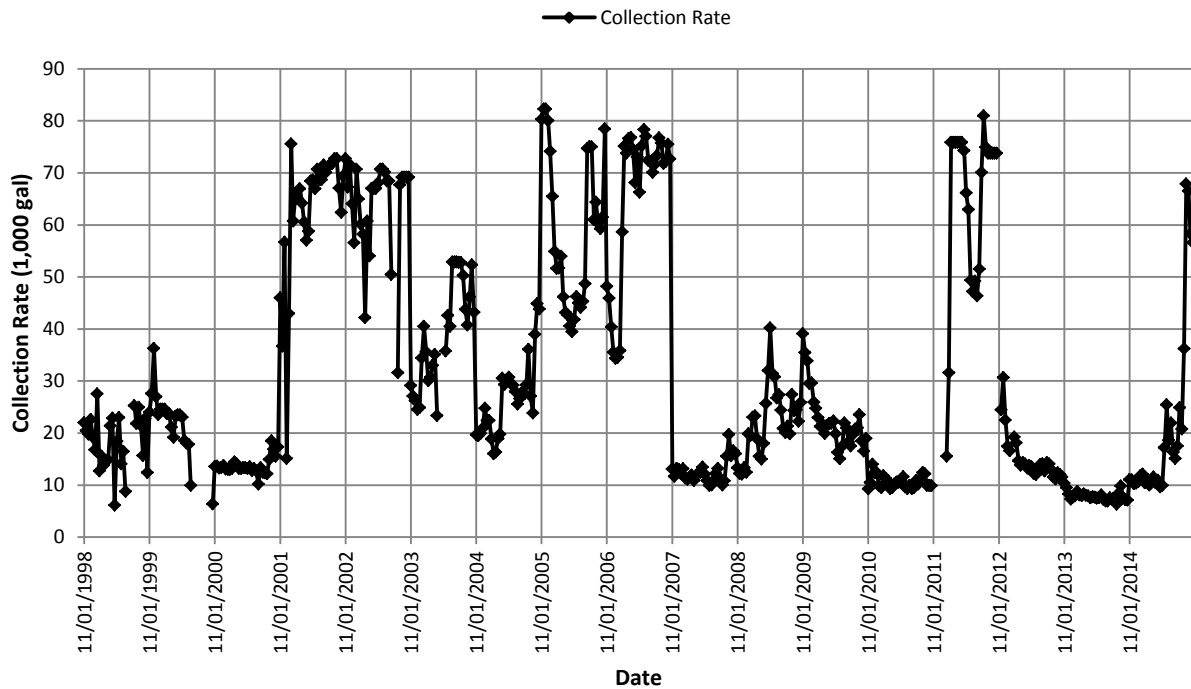
Figure 3.2-20
August Collection Rate
and Precipitation
Original Drain
Landfill Section 3/4



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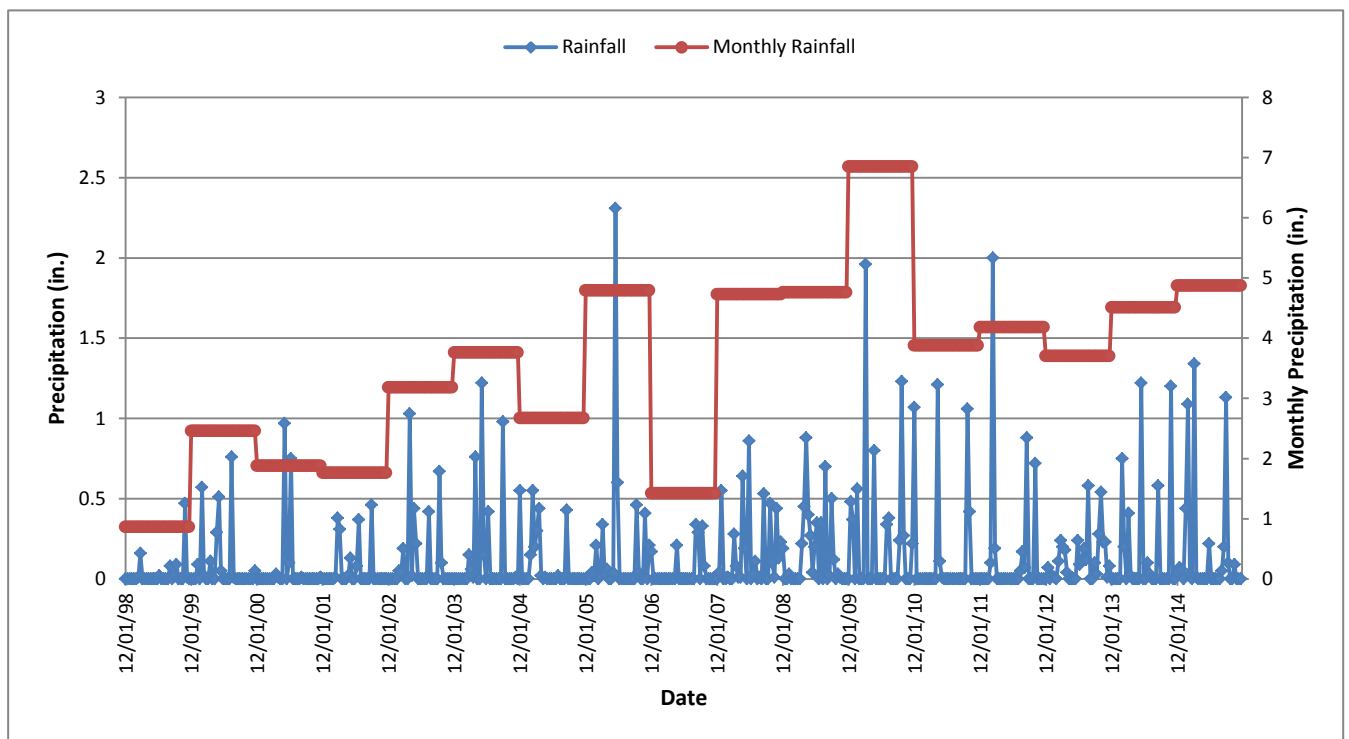
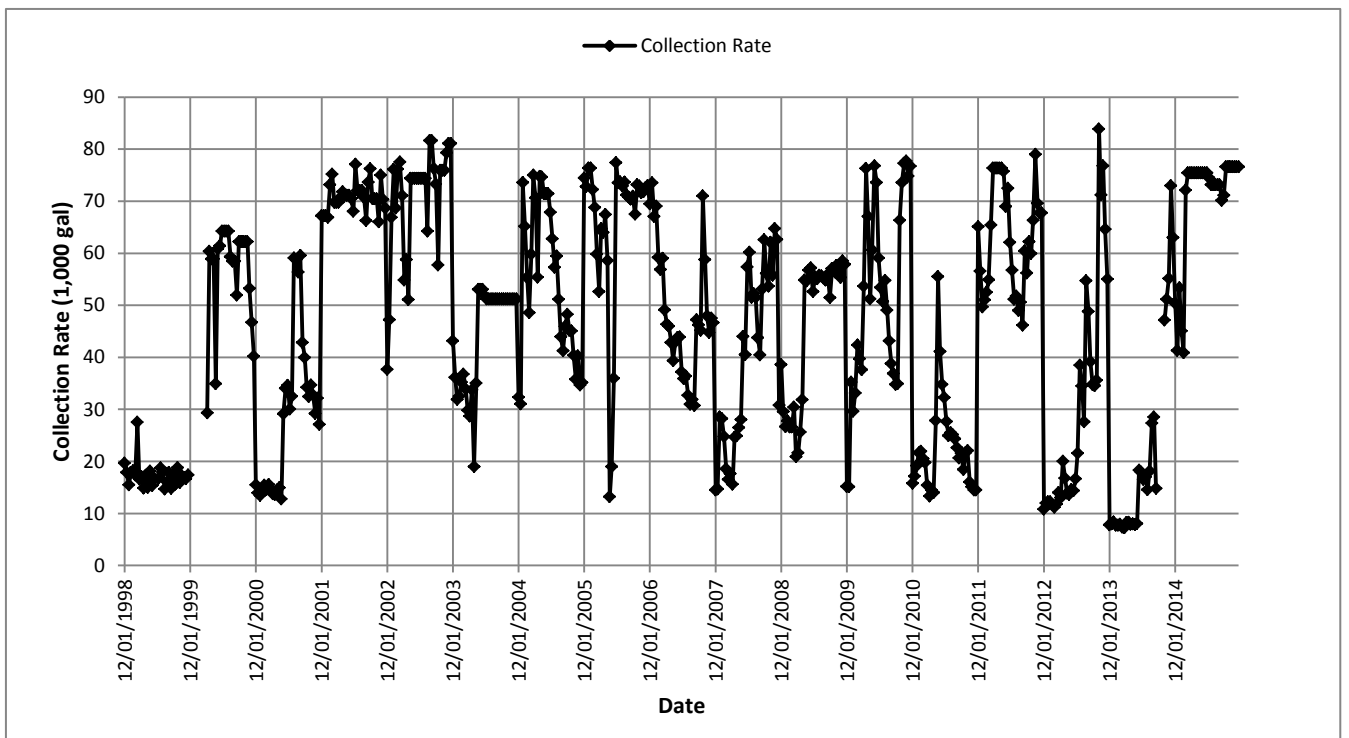
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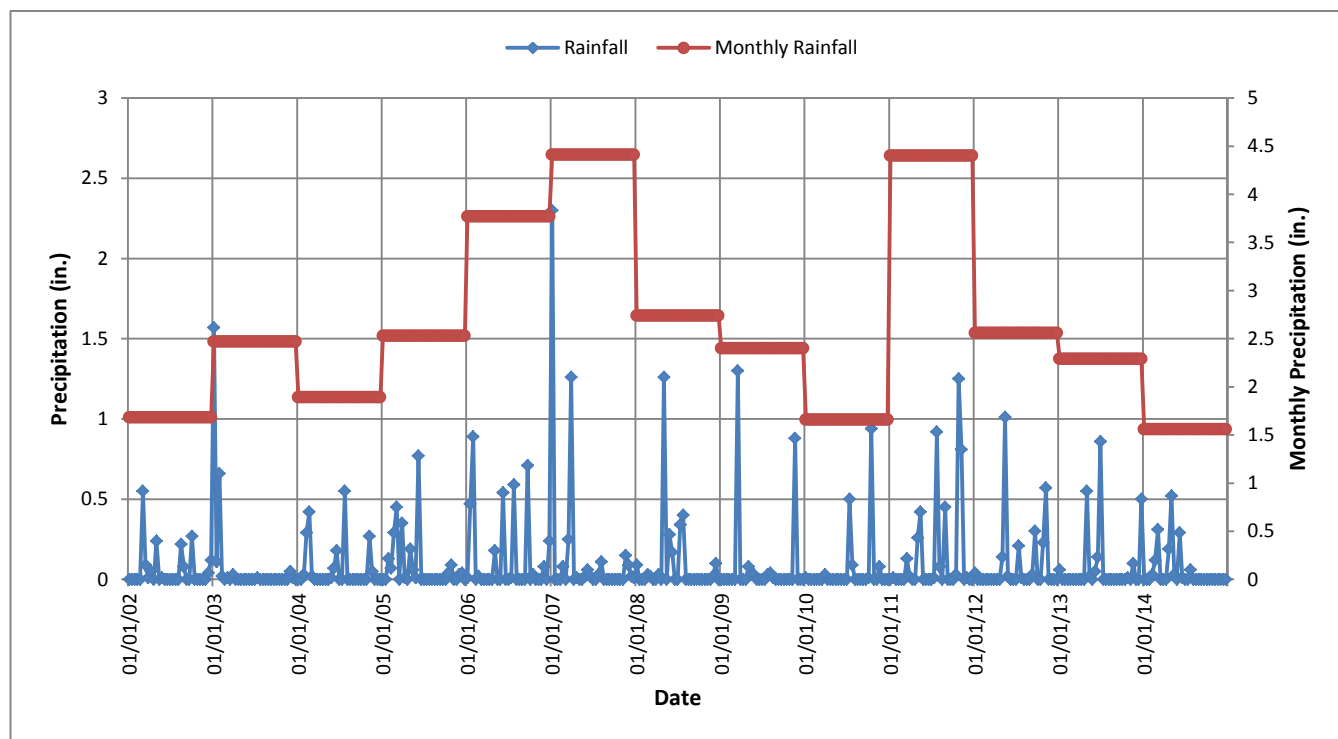
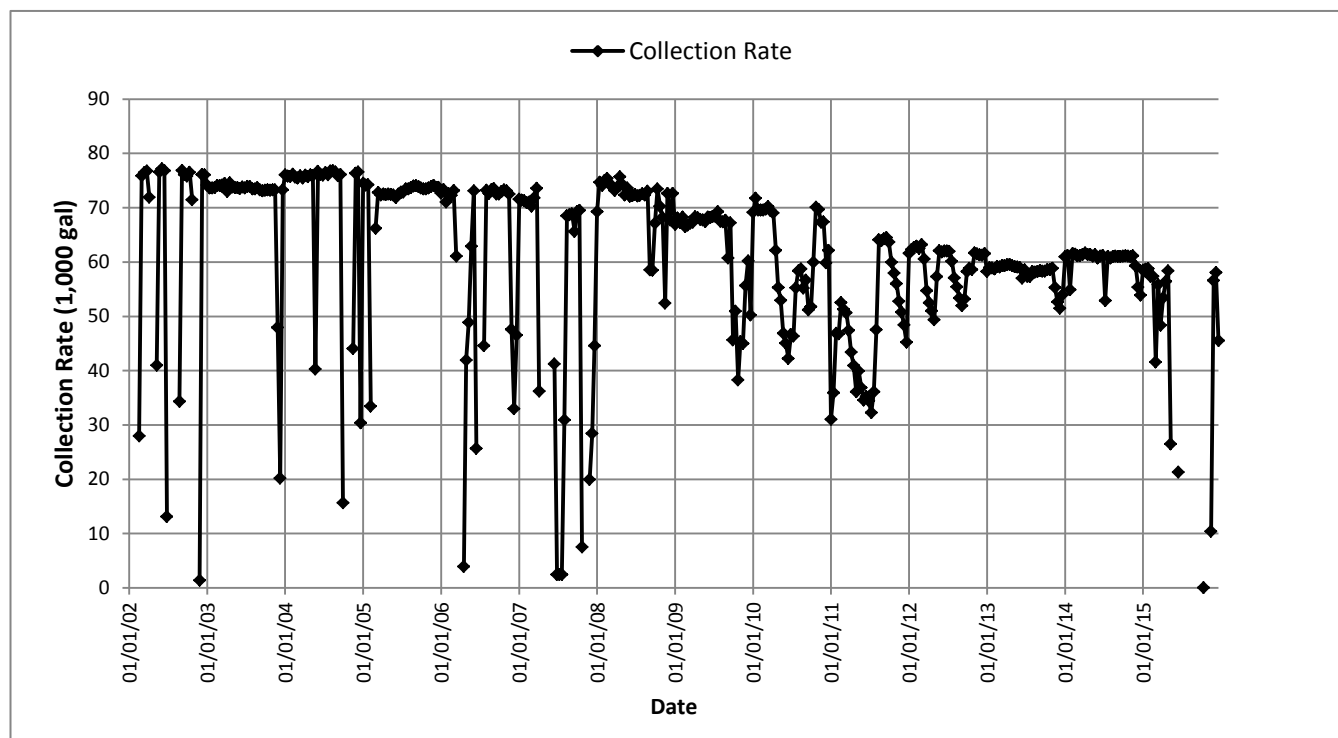
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and Landfill Section 3/4
Report

Fresh Kills Landfill

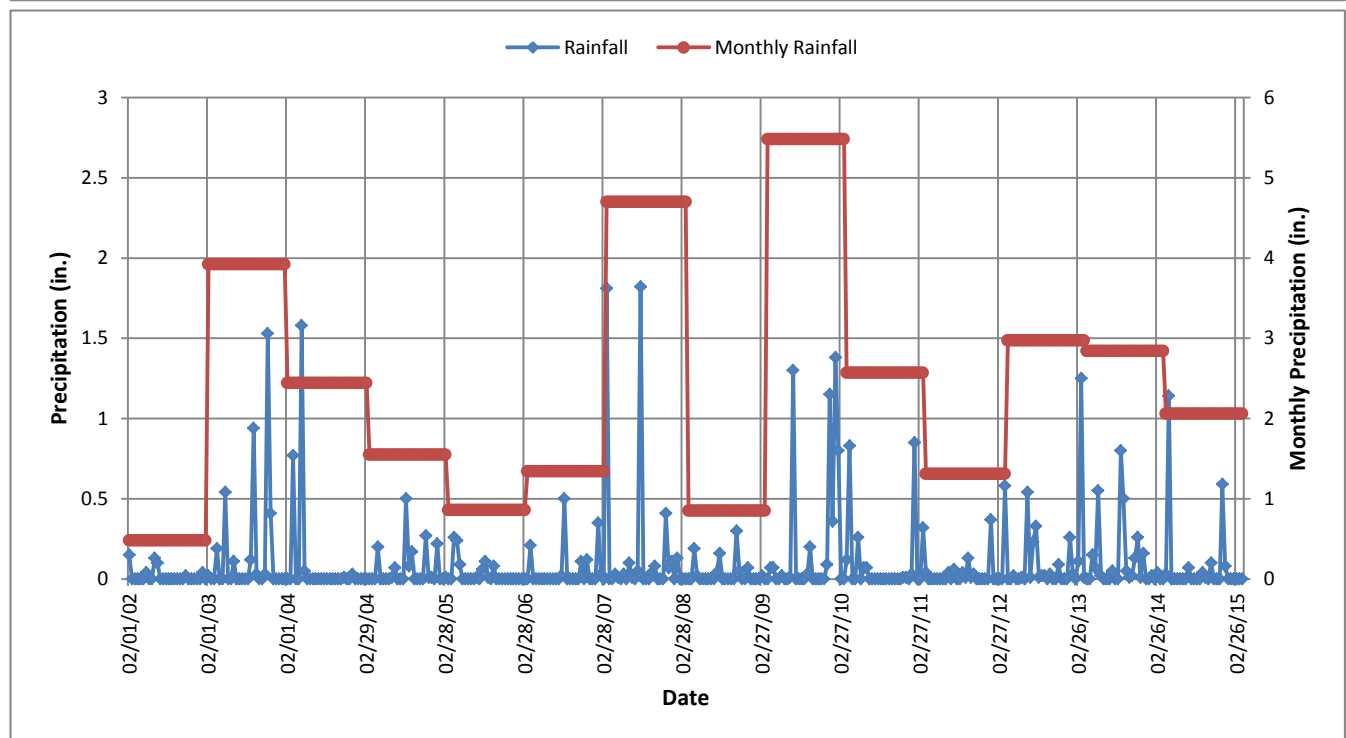
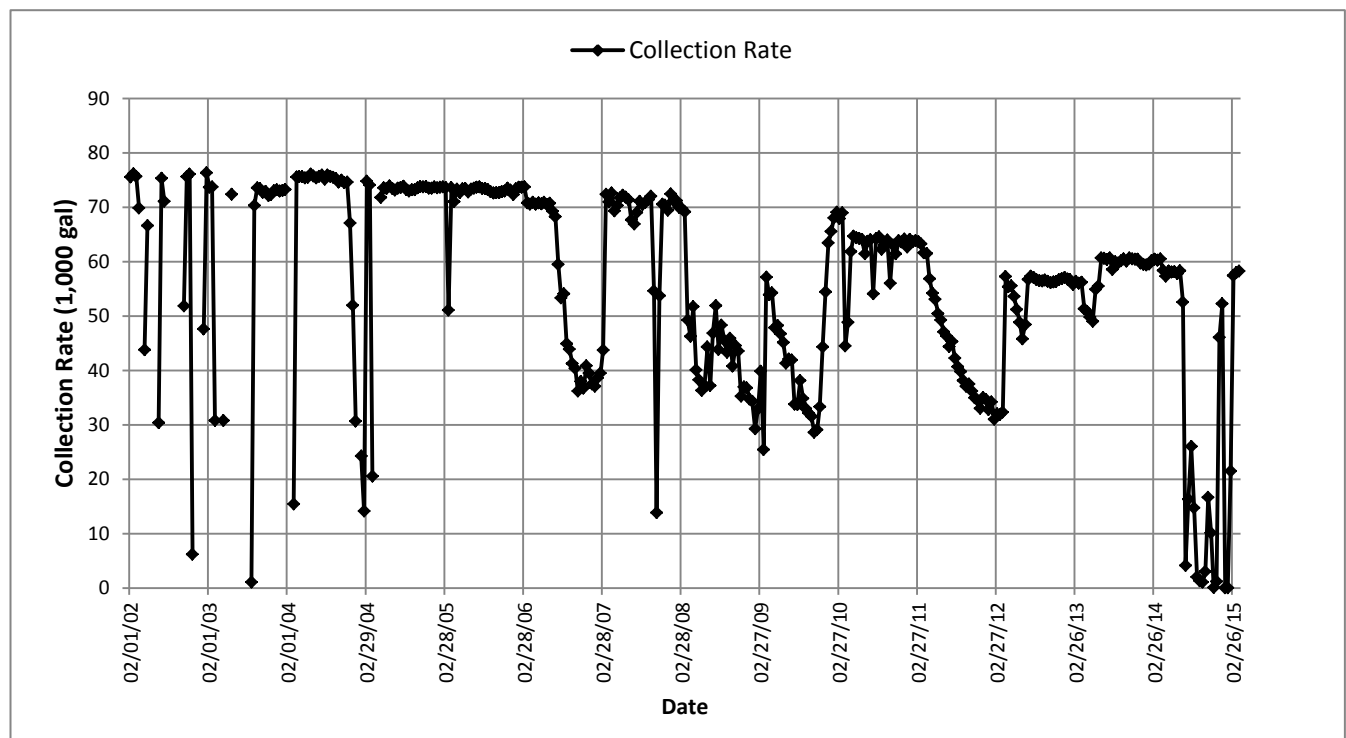
Figure 3.2-23
November Collection Rate
and Precipitation
Original Drain
Landfill Section 3/4



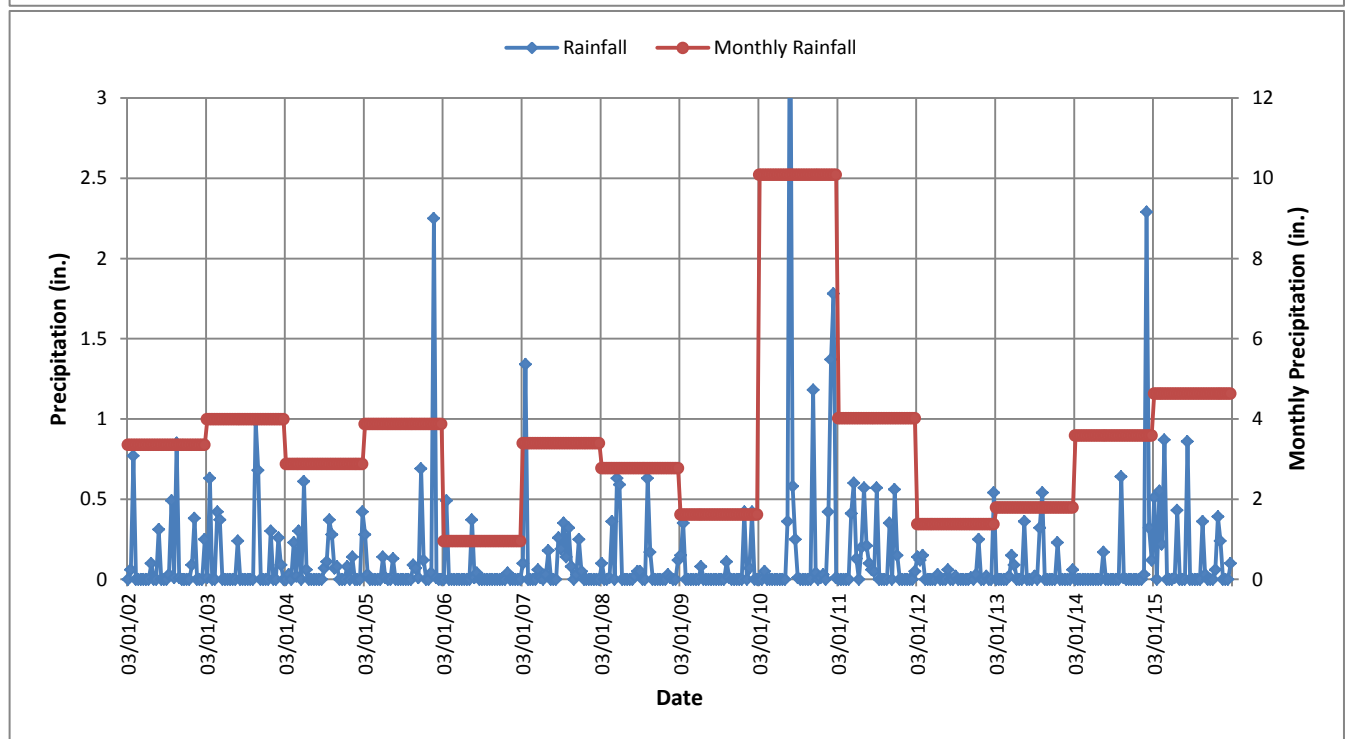
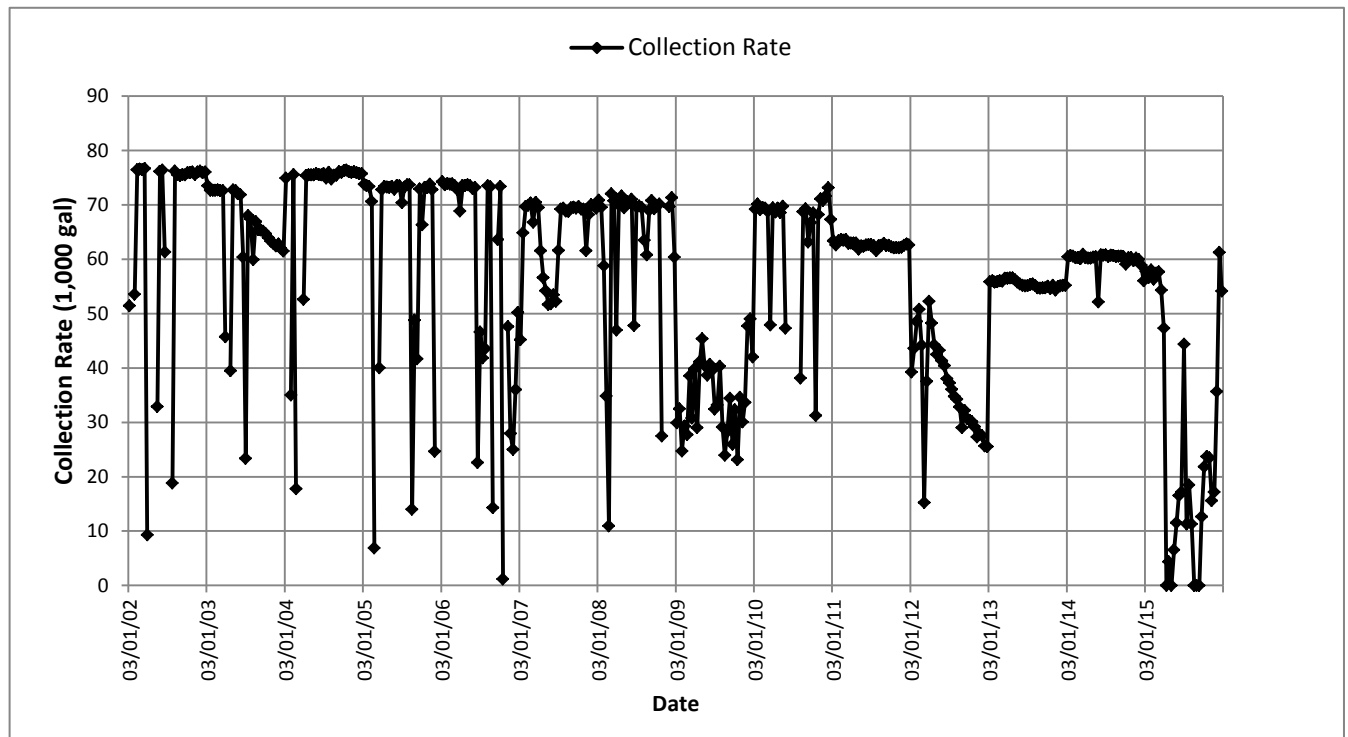
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Date: May 2015	Job Number: 151771				



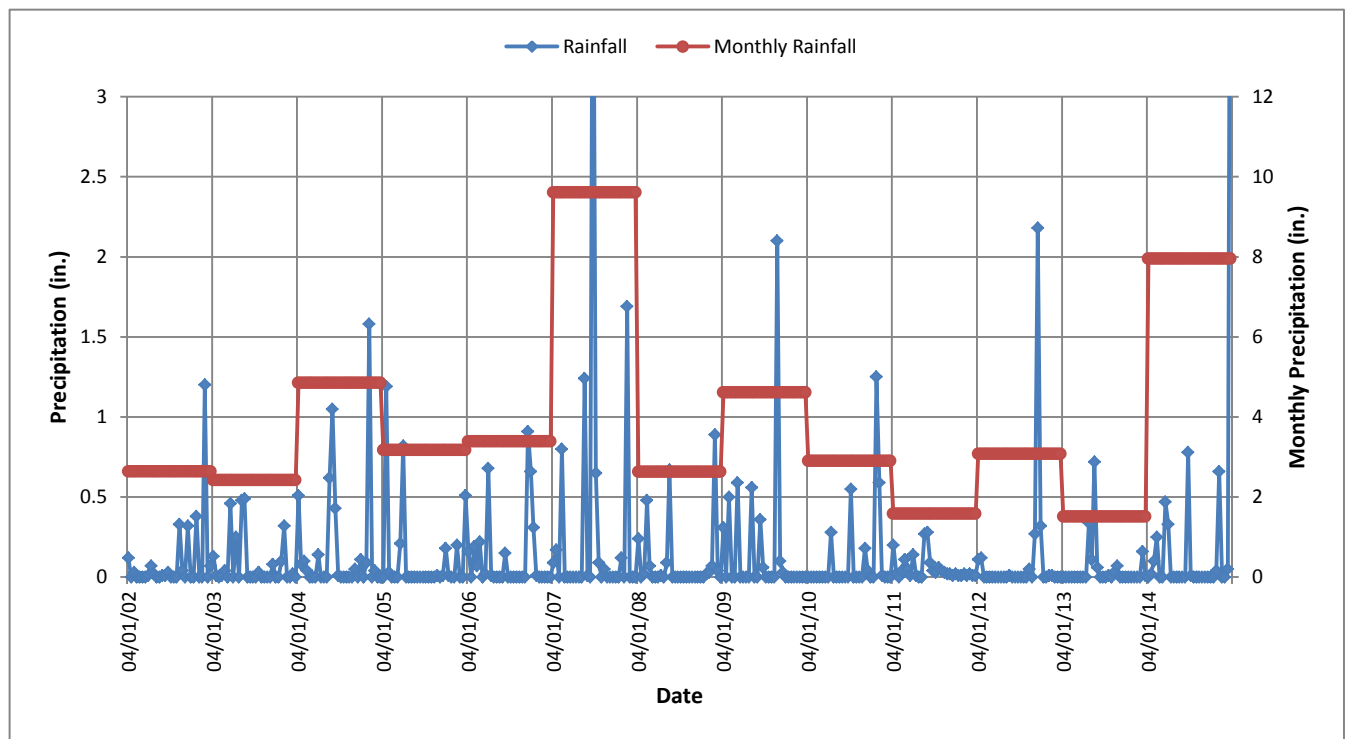
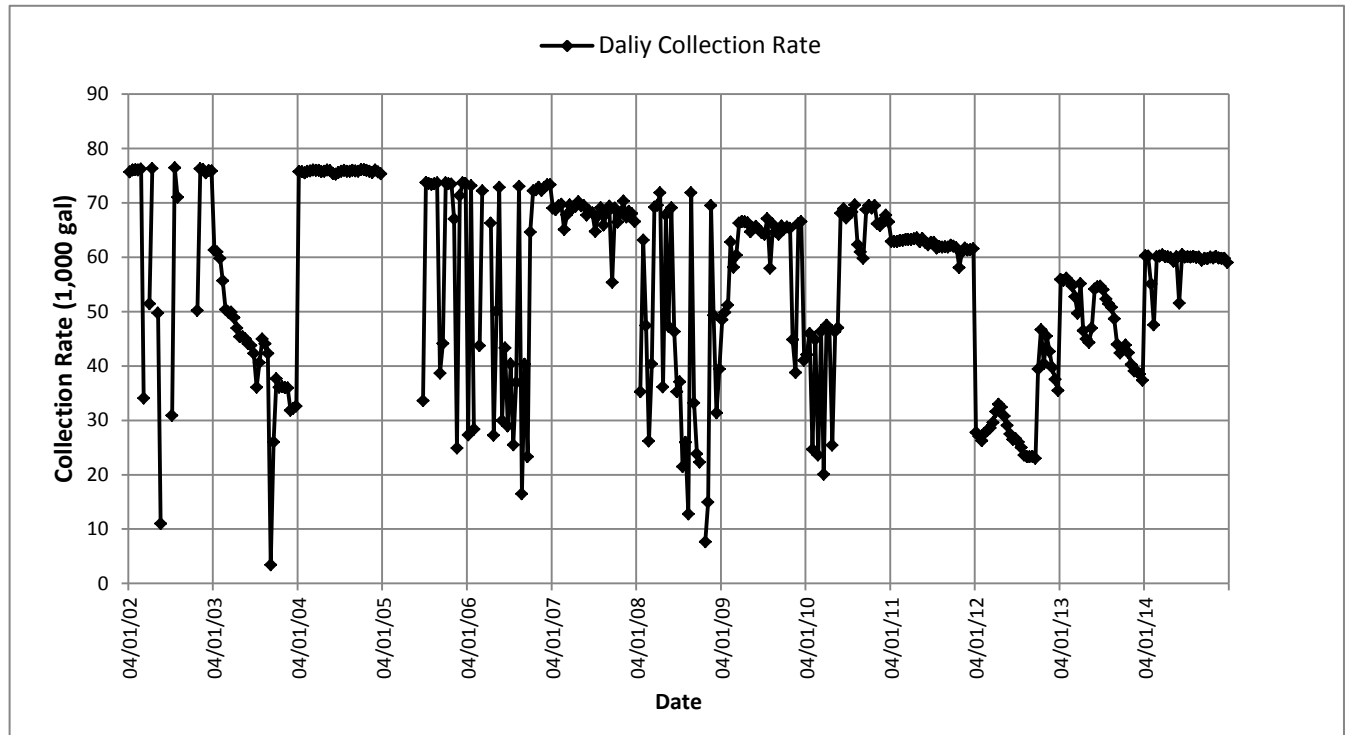
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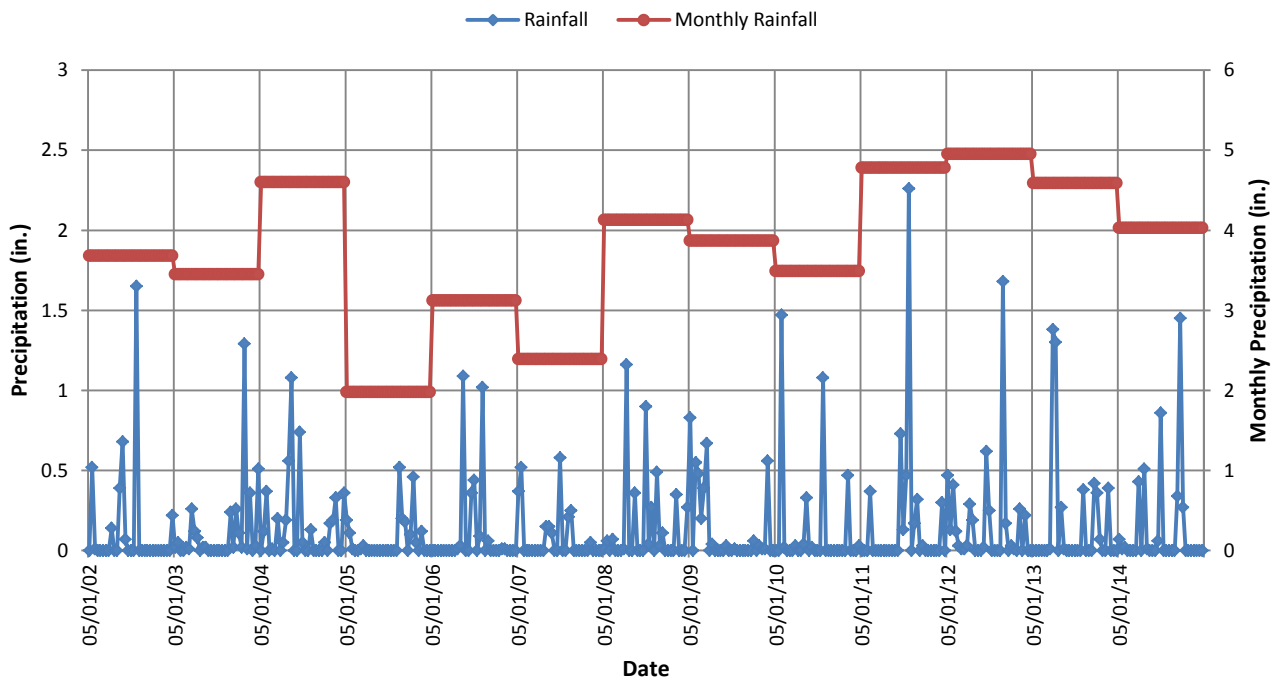
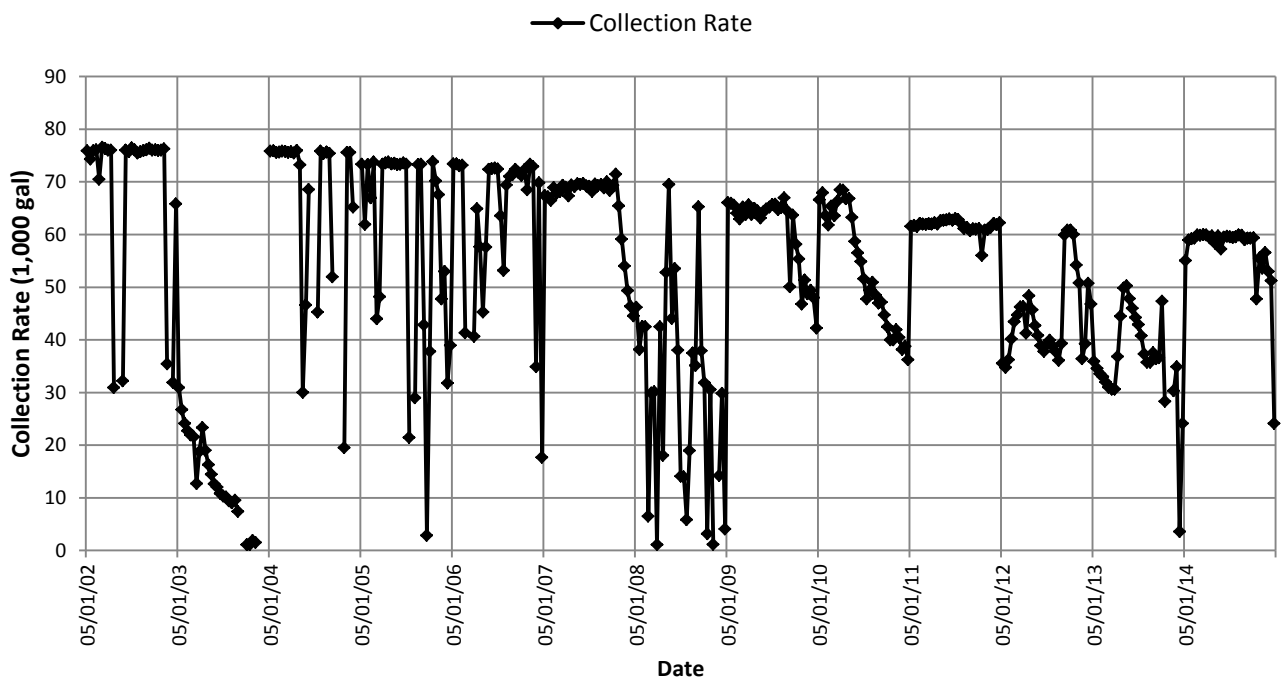
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May 2015	151771				



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EJW

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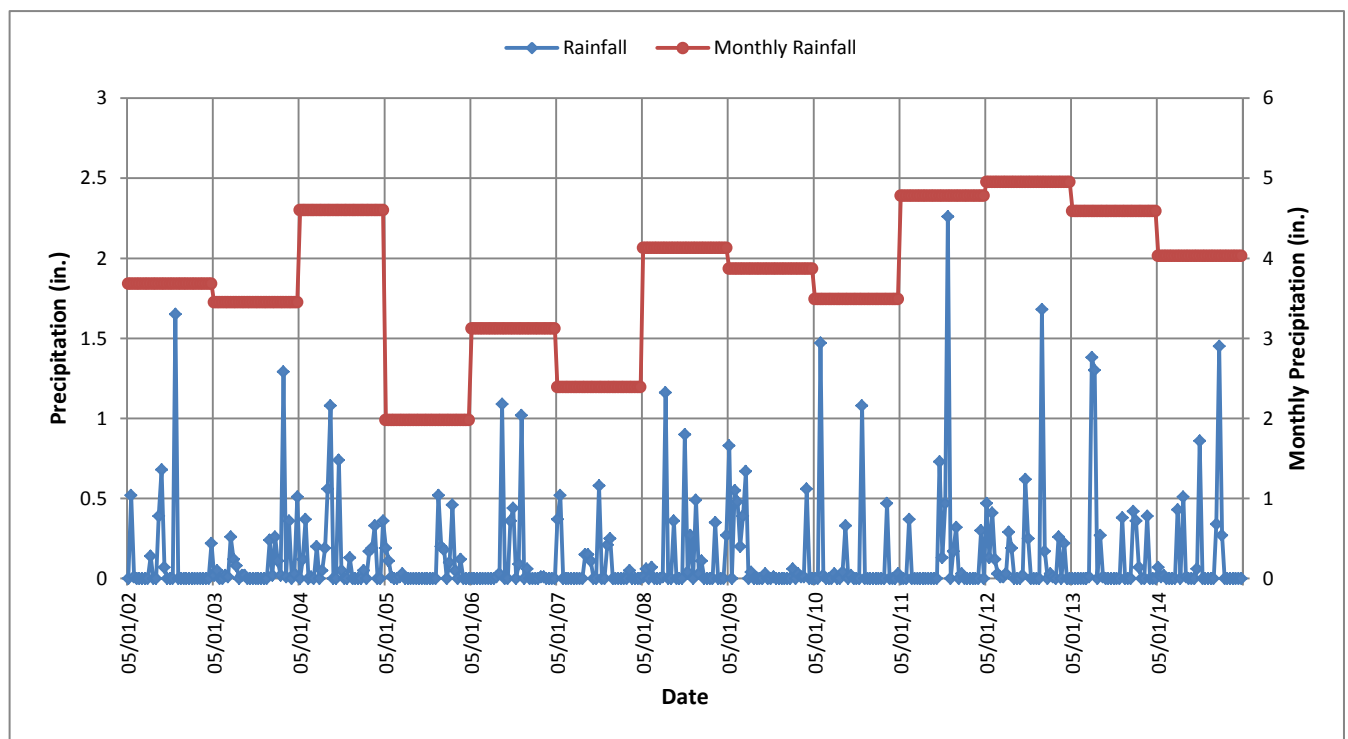
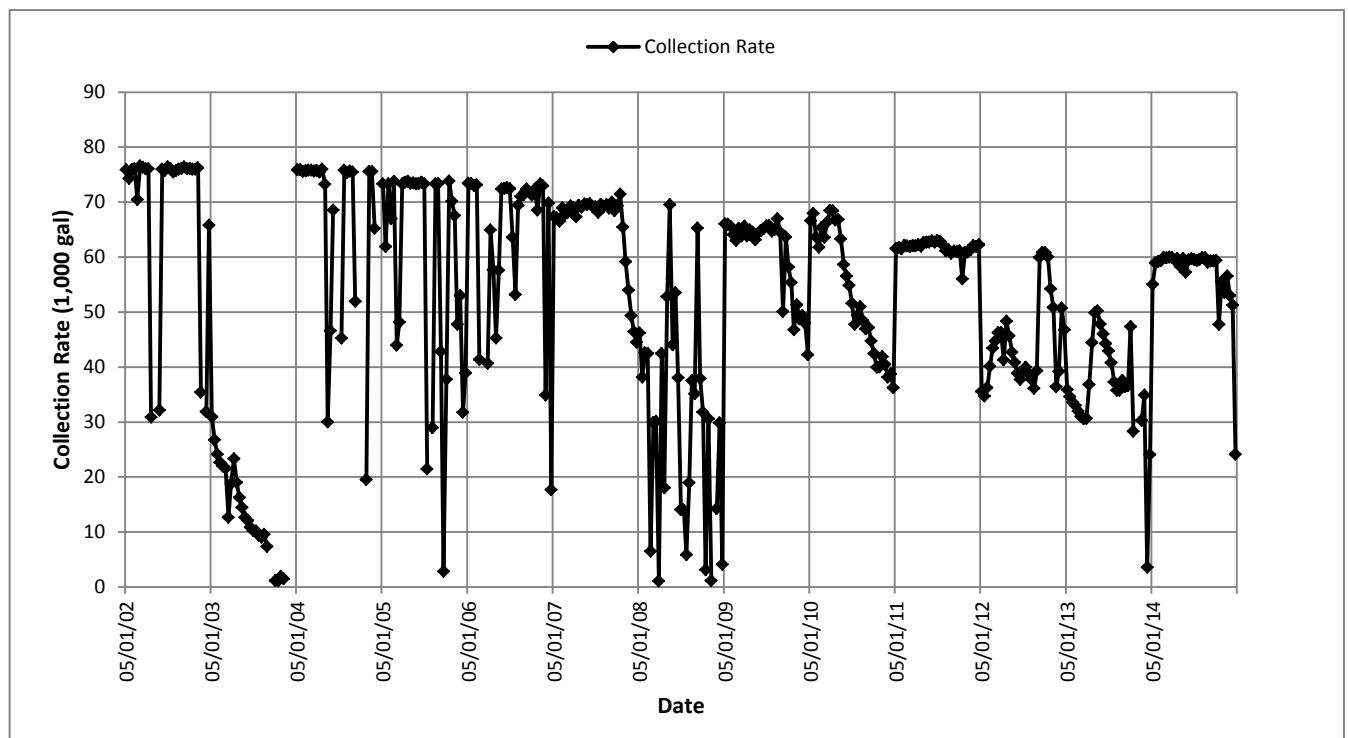
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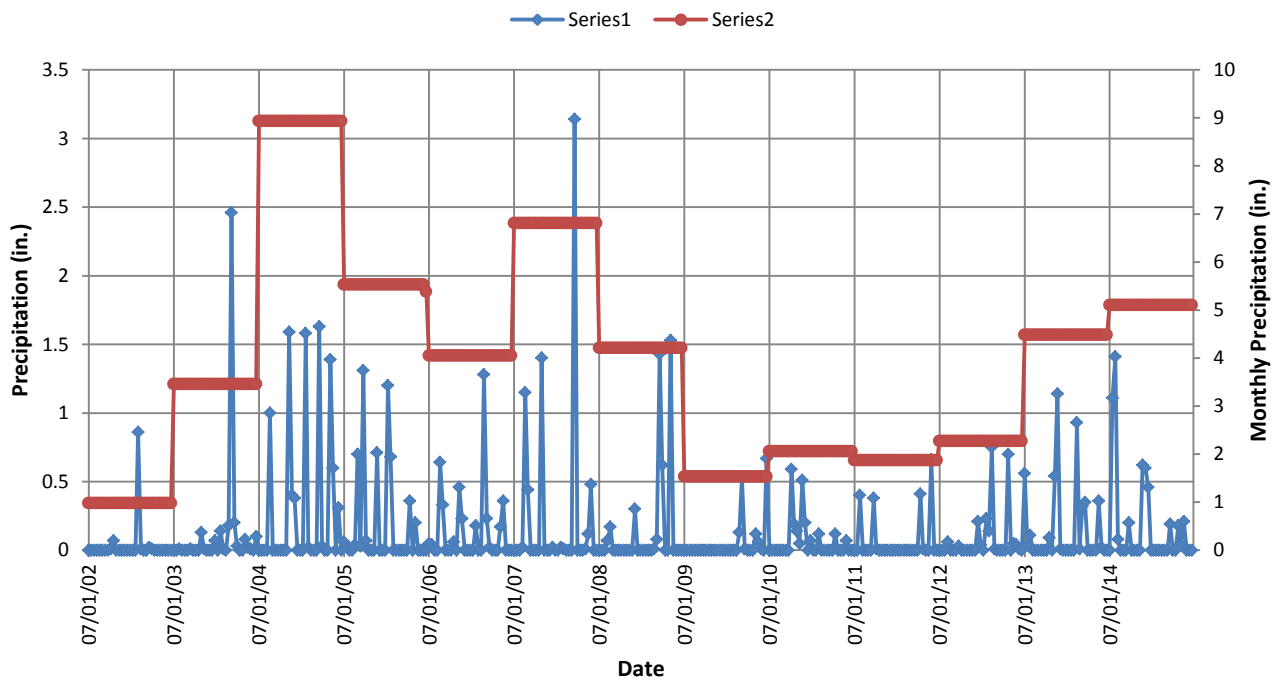
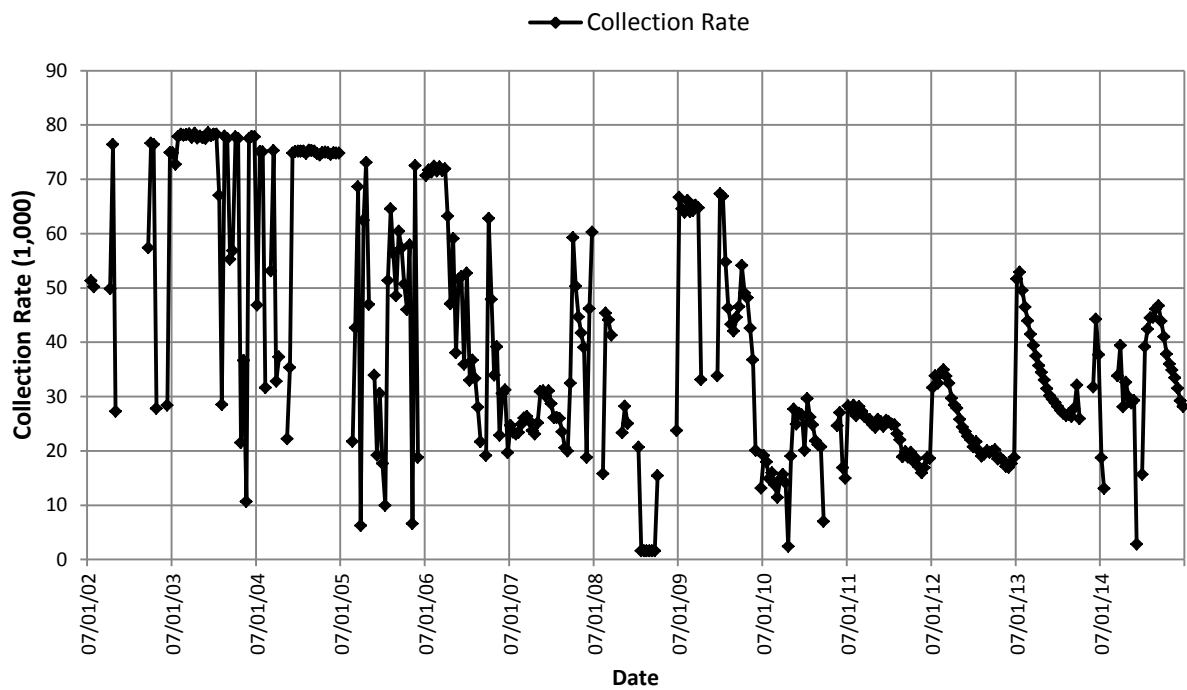
Leachate Controls
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Report

Fresh Kills Landfill

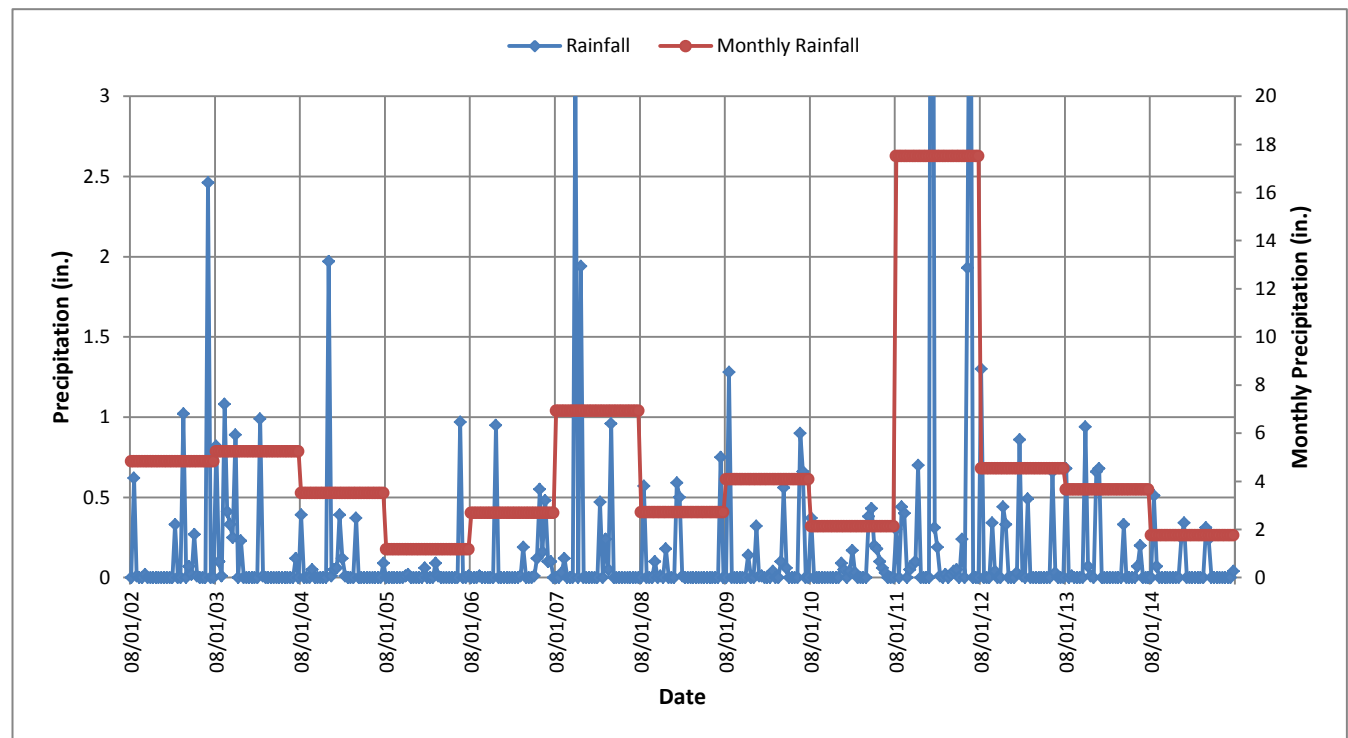
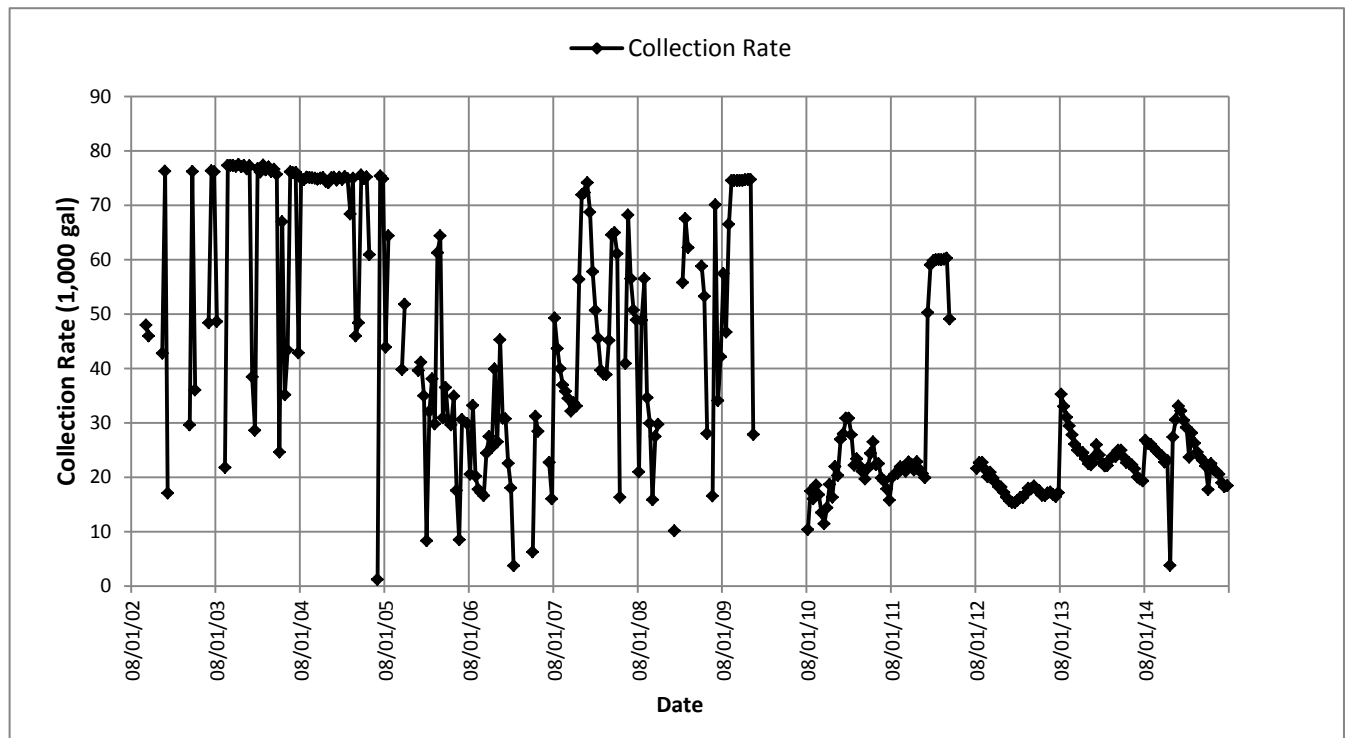
Figure 3.2-29
May Collection Rate
and Precipitation
Supplemental Drain
Landfill Section 2/8



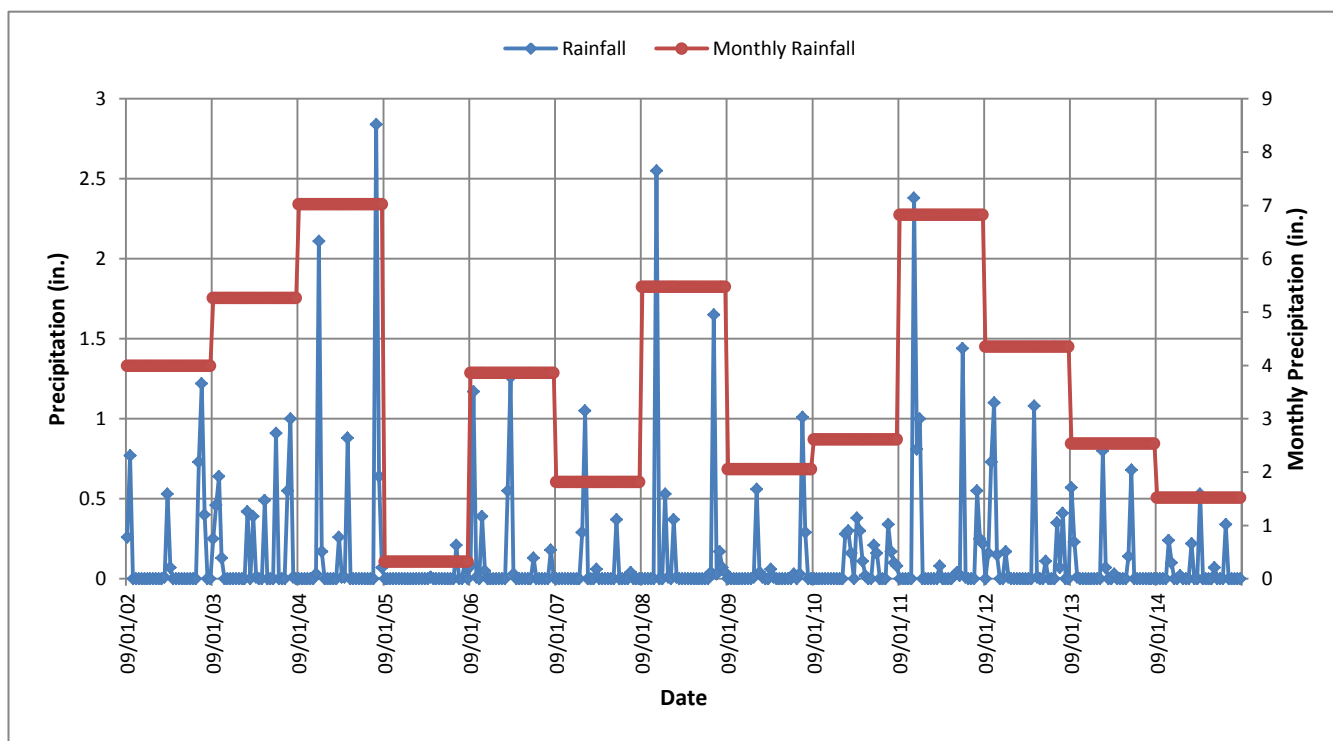
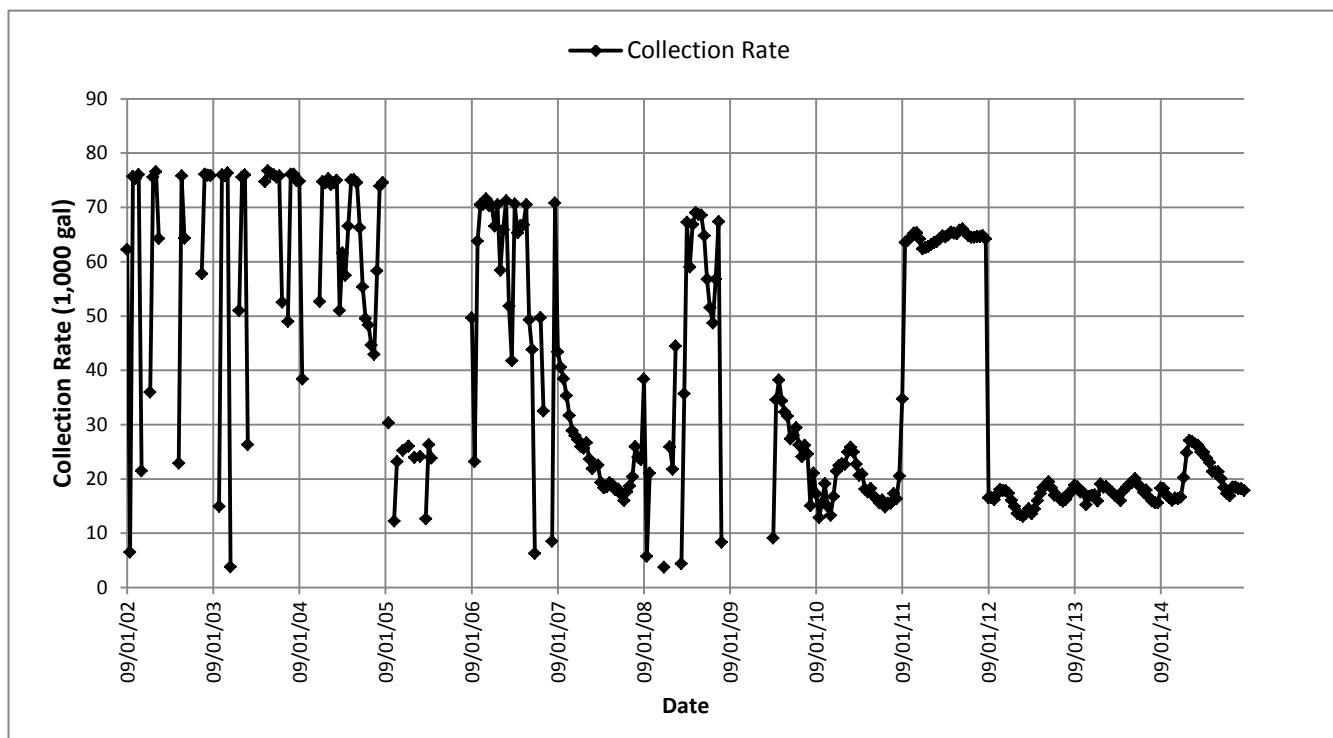
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Date:	Job Number:				
May 2015	151771				



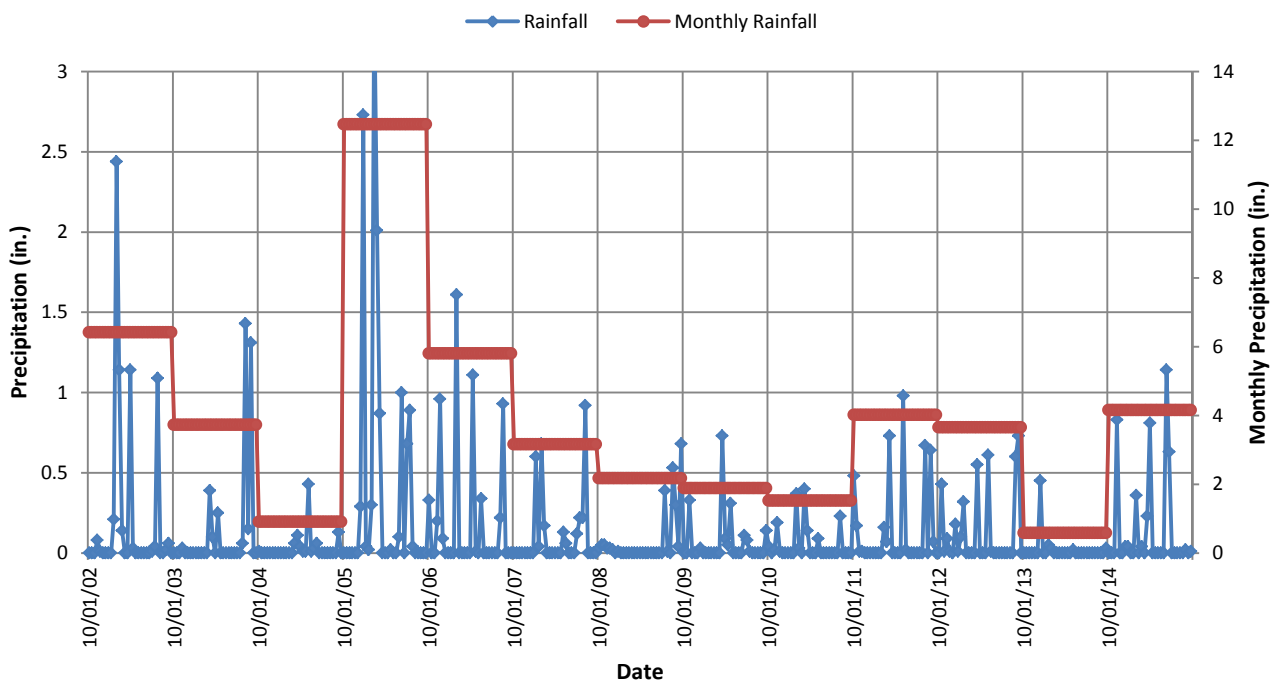
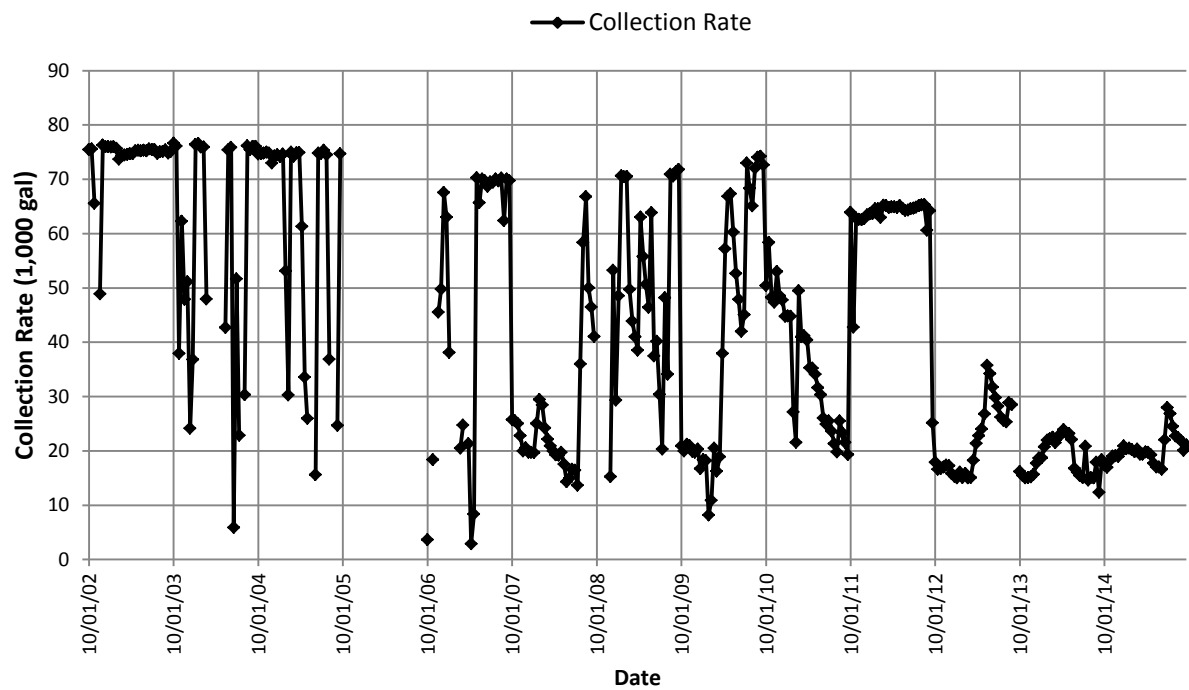
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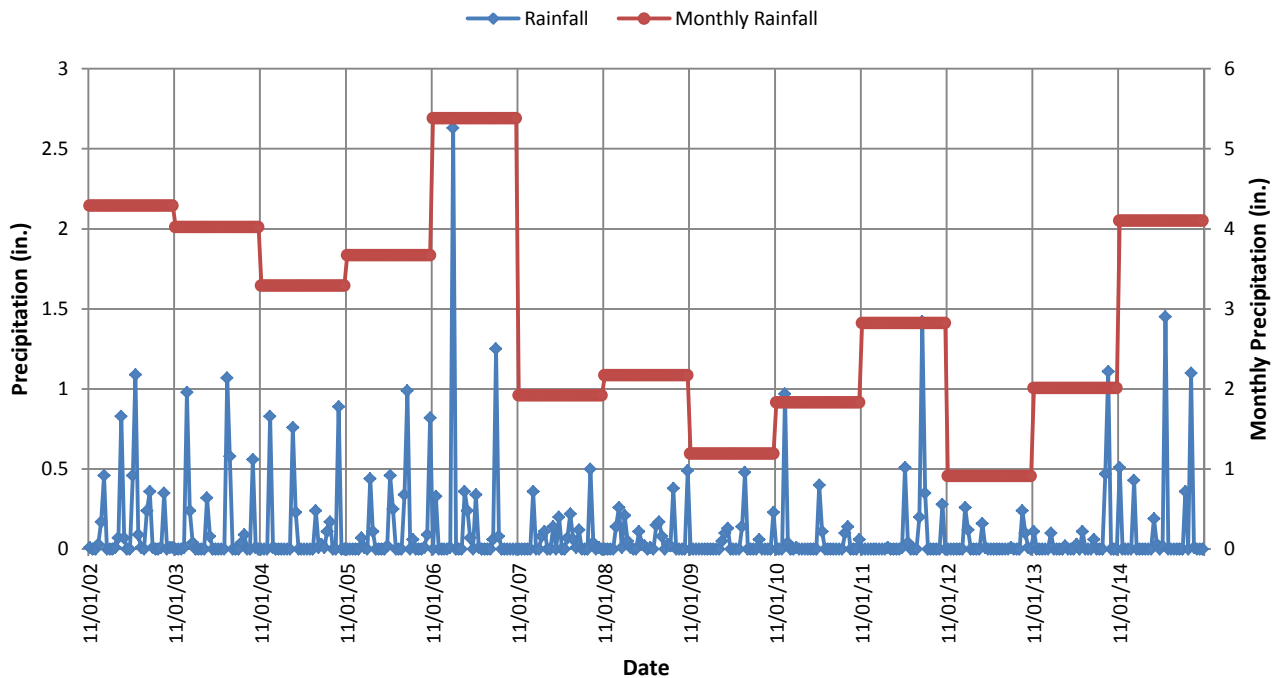
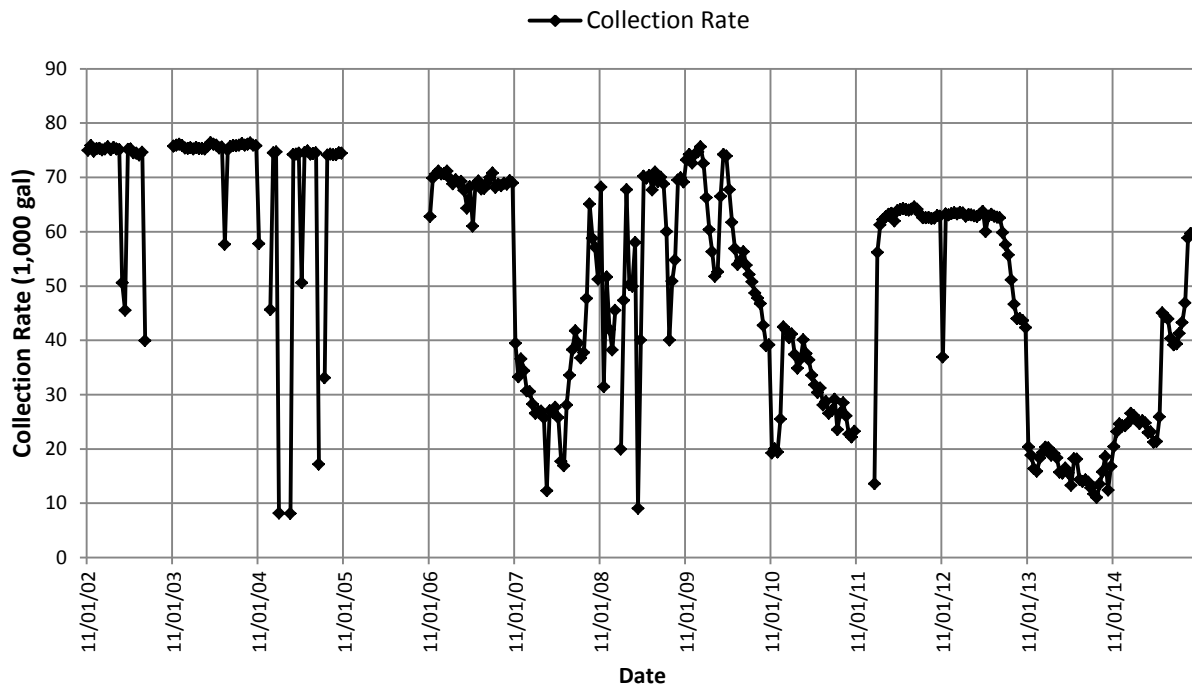
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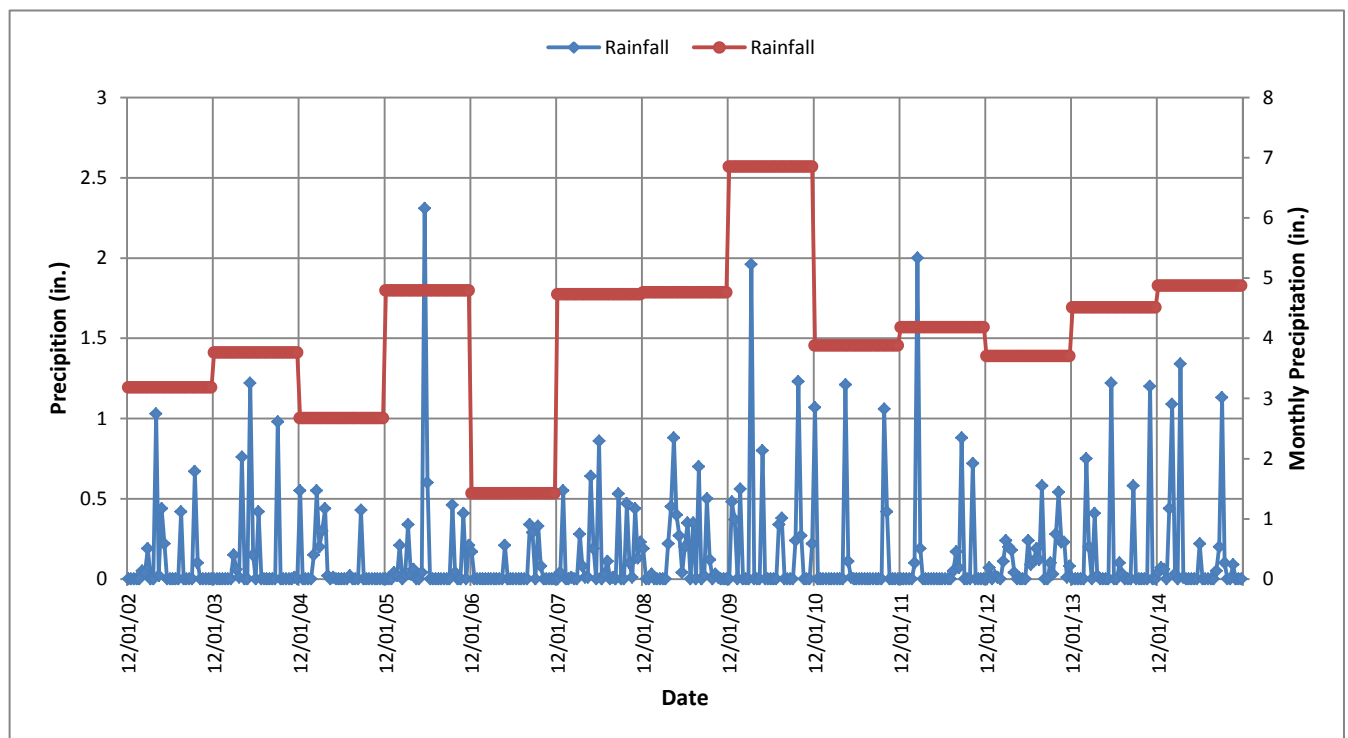
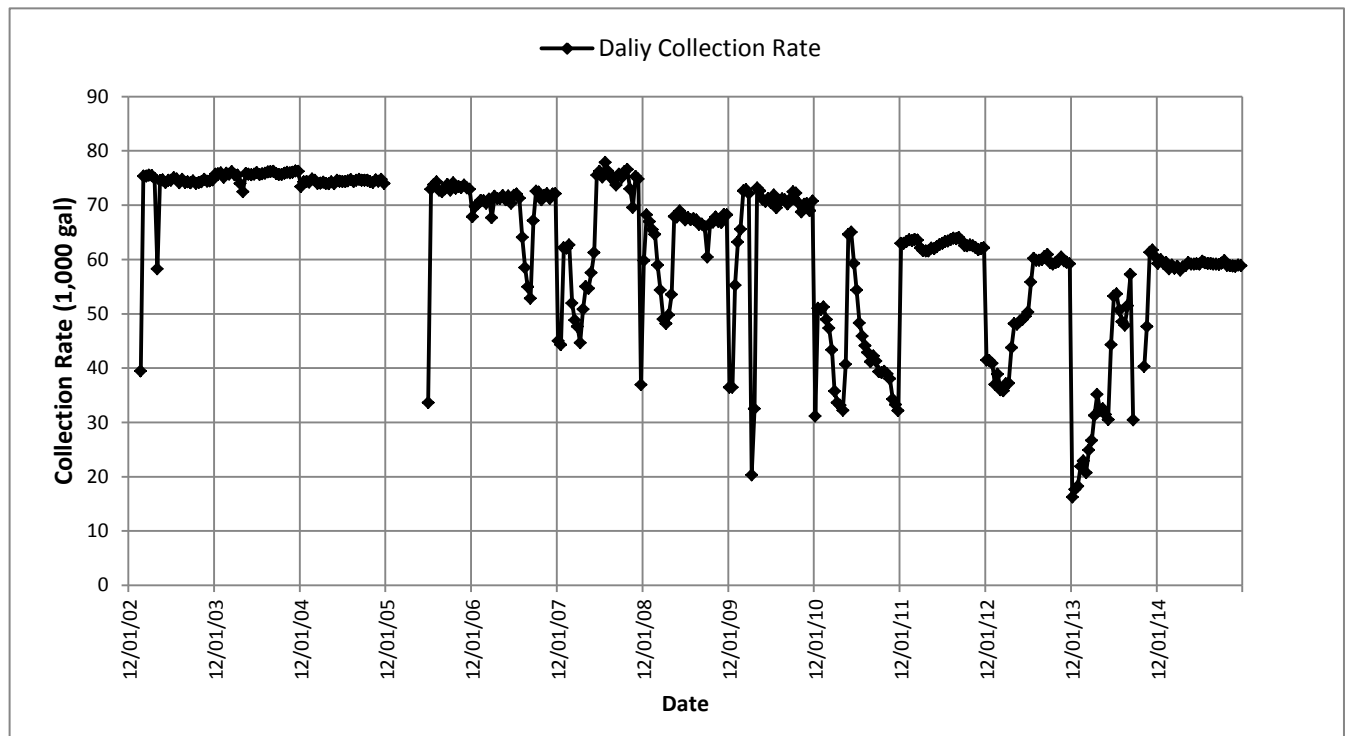
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Date:	Job Number:				
May 2015	151771				



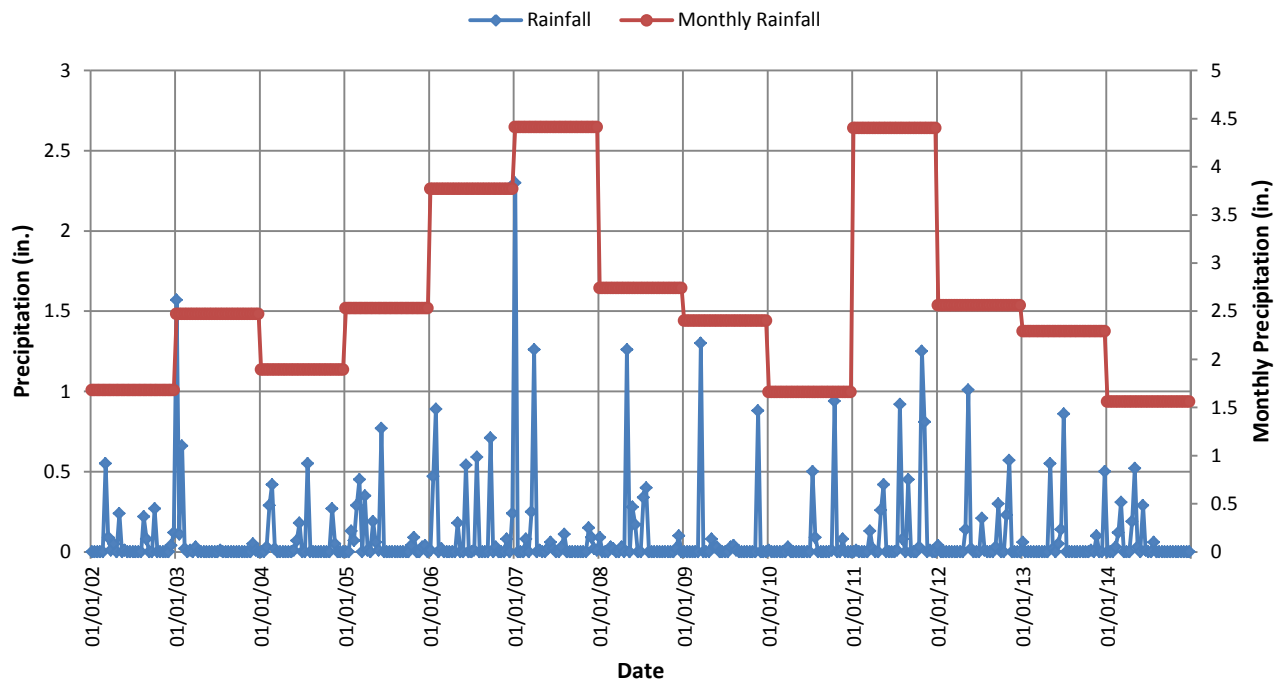
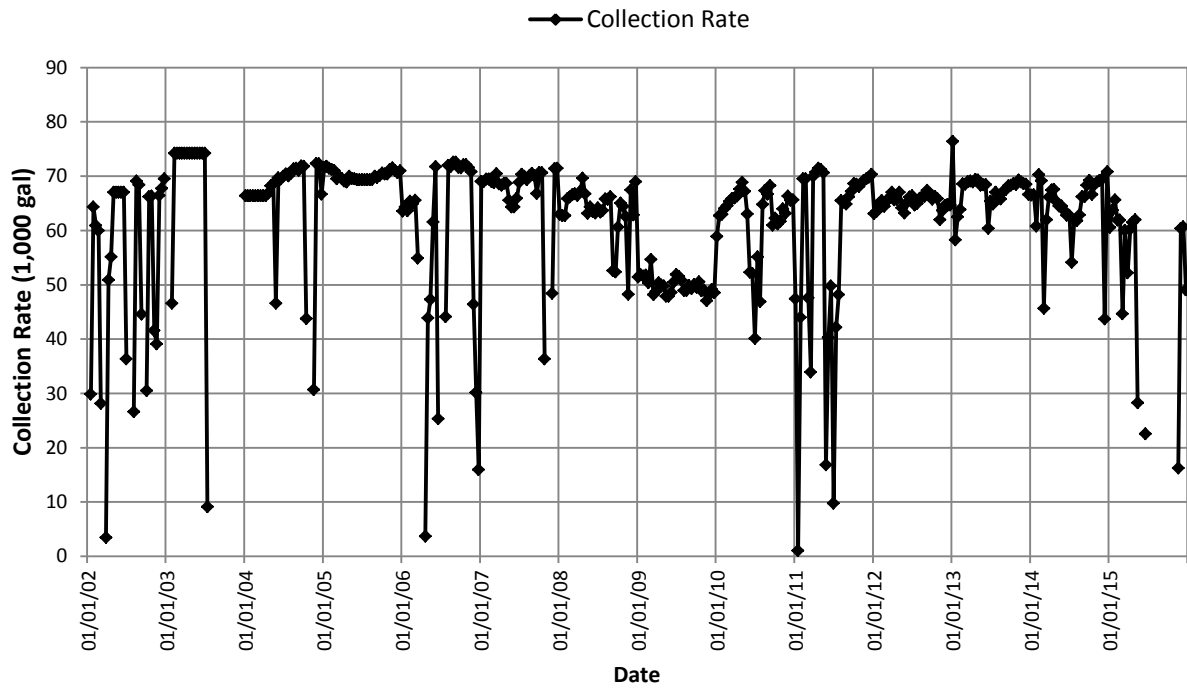
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Date:	Job Number:				
May 2015	151771				



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EJW

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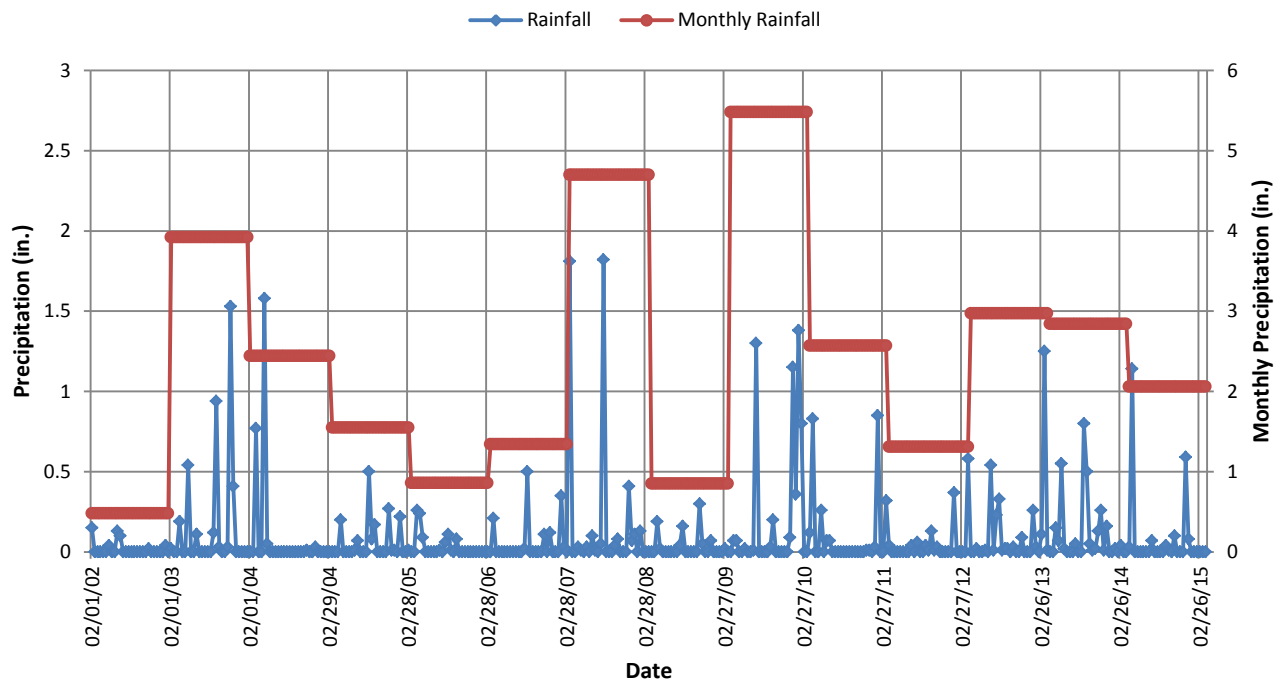
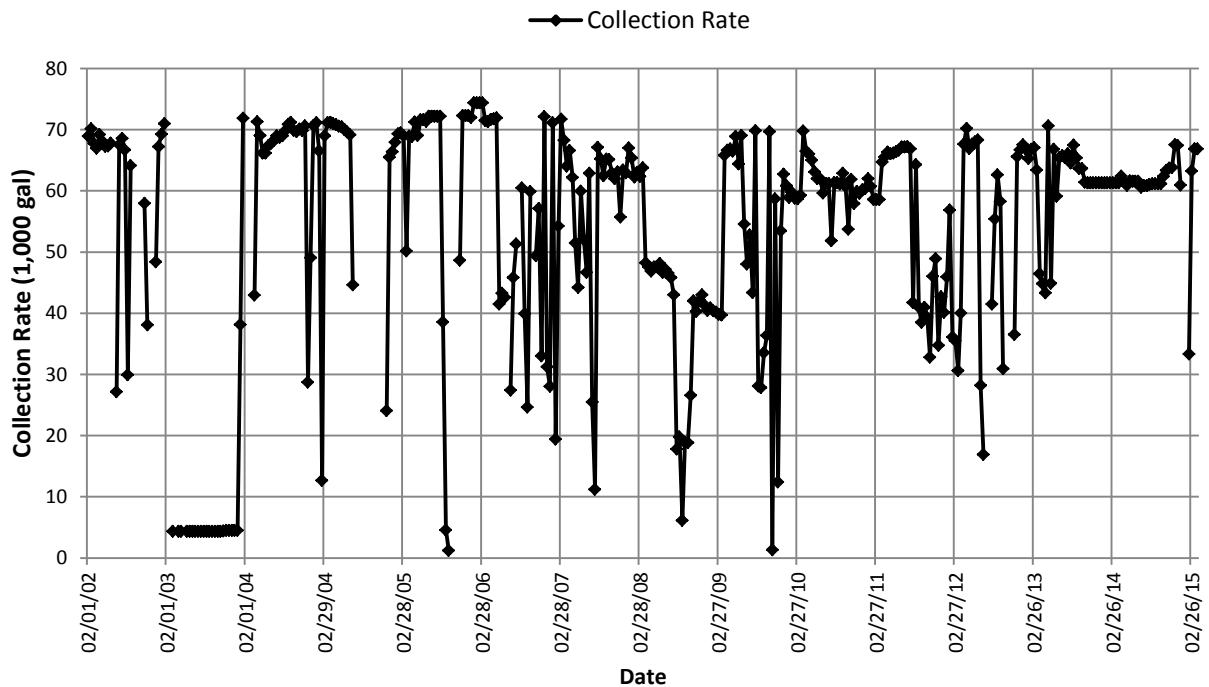
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Under the Direction of:



Leachate Controls
at Landfill Section 2/8
and Landfill Section 3/4
Report
Fresh Kills Landfill

Figure 3.2-37
January Collection Rate
and Precipitation
Supplemental Drain
Landfill Section 3/4



Prepared By:



Generated By:

DJD

Date:

May 2015

Approved By:

EJW

Job Number:

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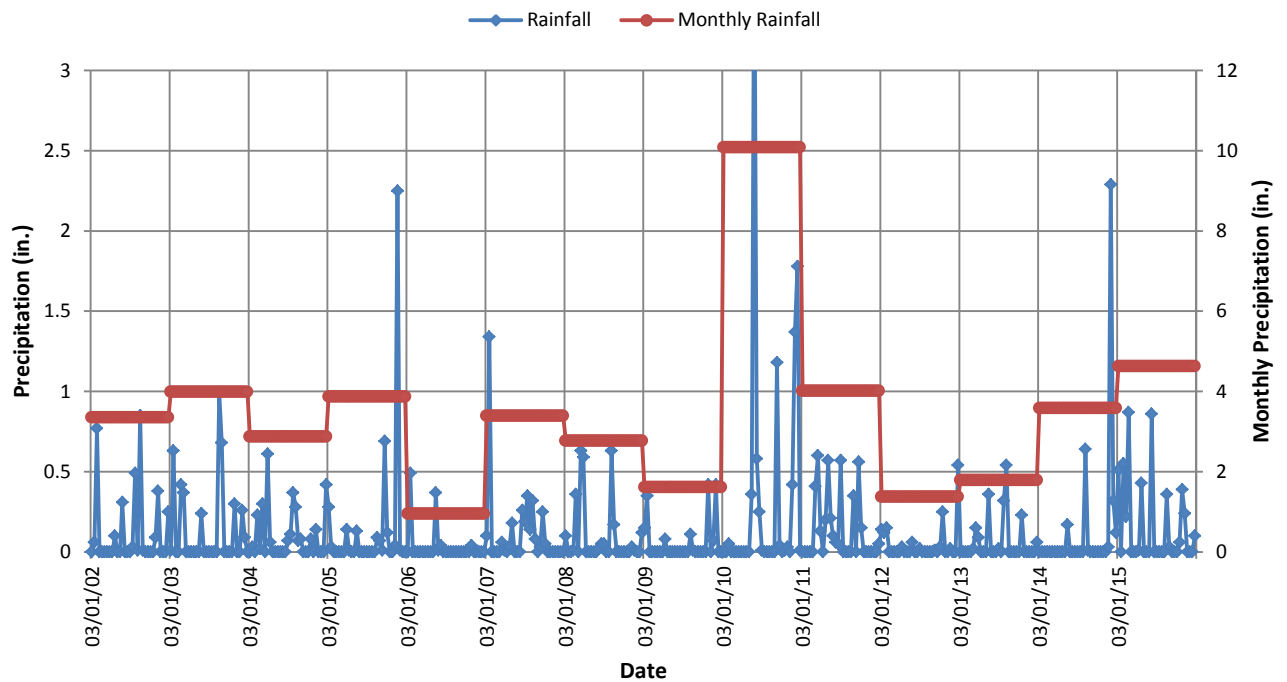
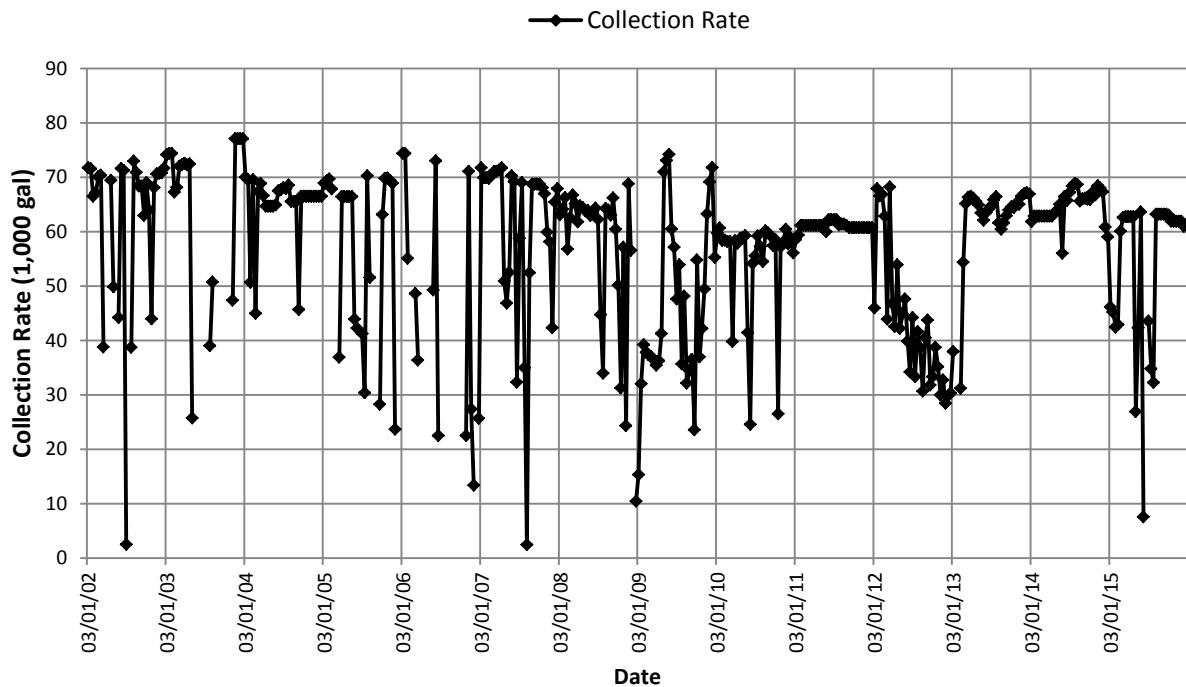
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Leachate Controls
at Landfill Section 2/8
and Landfill Section 3/4
Report

Fresh Kills Landfill

Figure 3.2-38
February Collection Rate
and Precipitation
Supplemental Drain
Landfill Section 3/4



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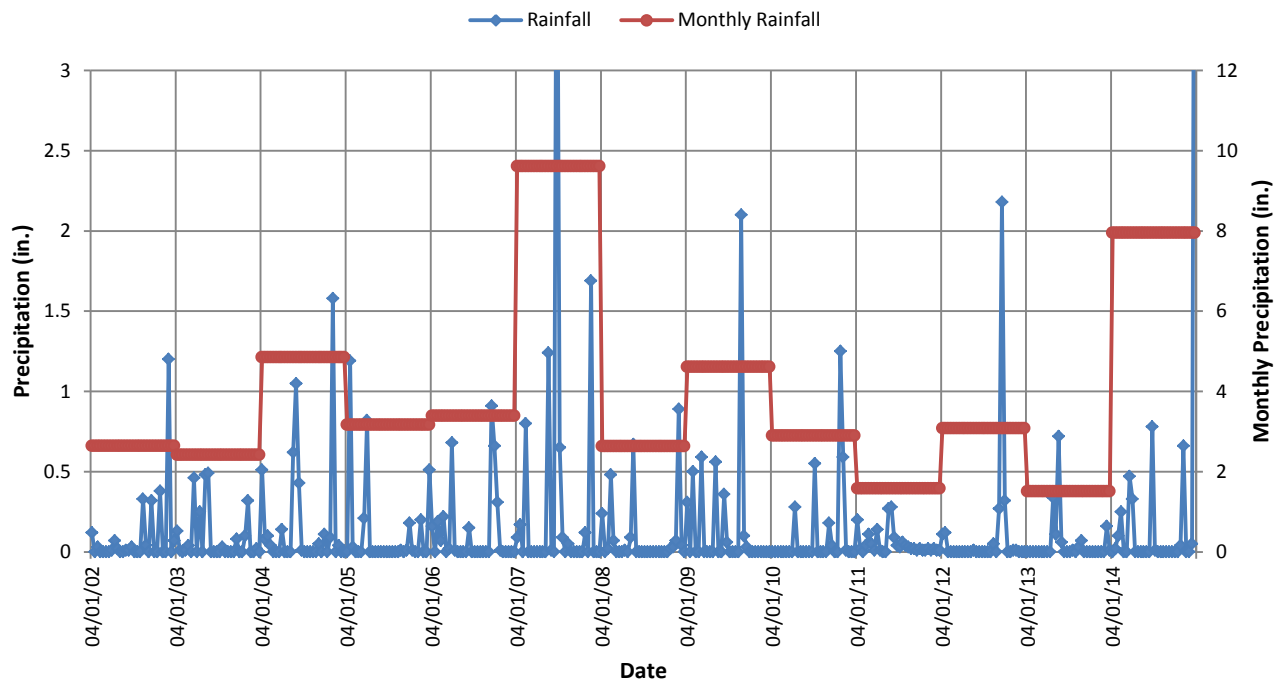
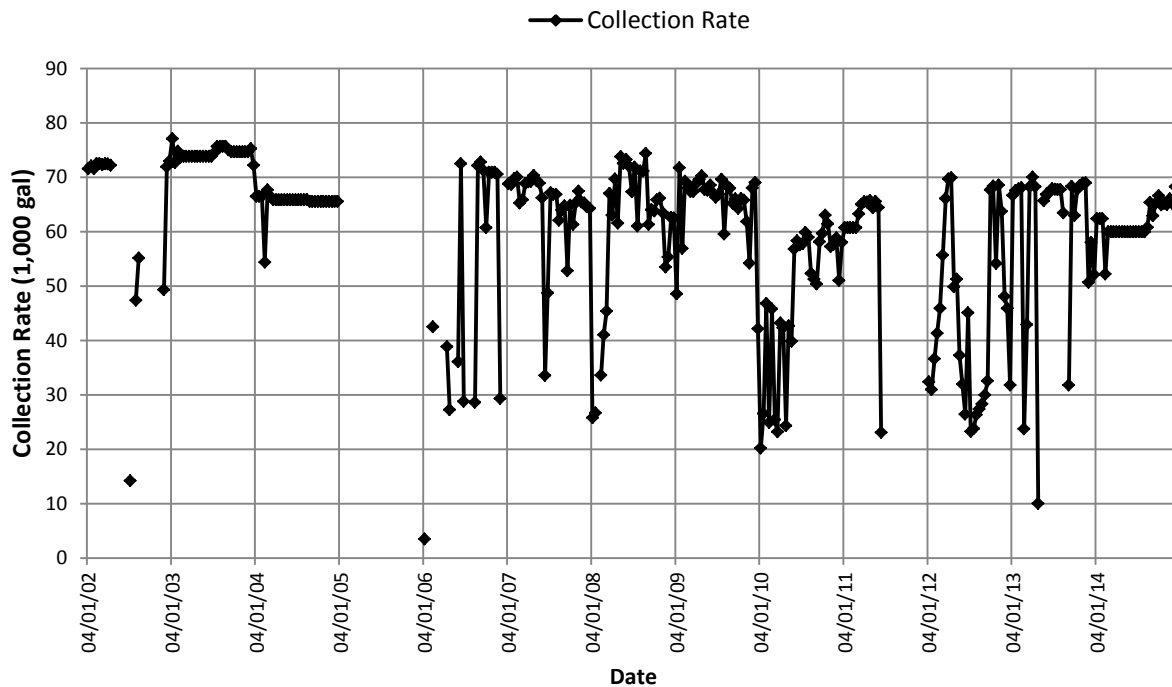
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Fresh Kills Landfill

Figure 3.2-39
March Collection Rate
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Supplemental Drain
Landfill Section 3/4



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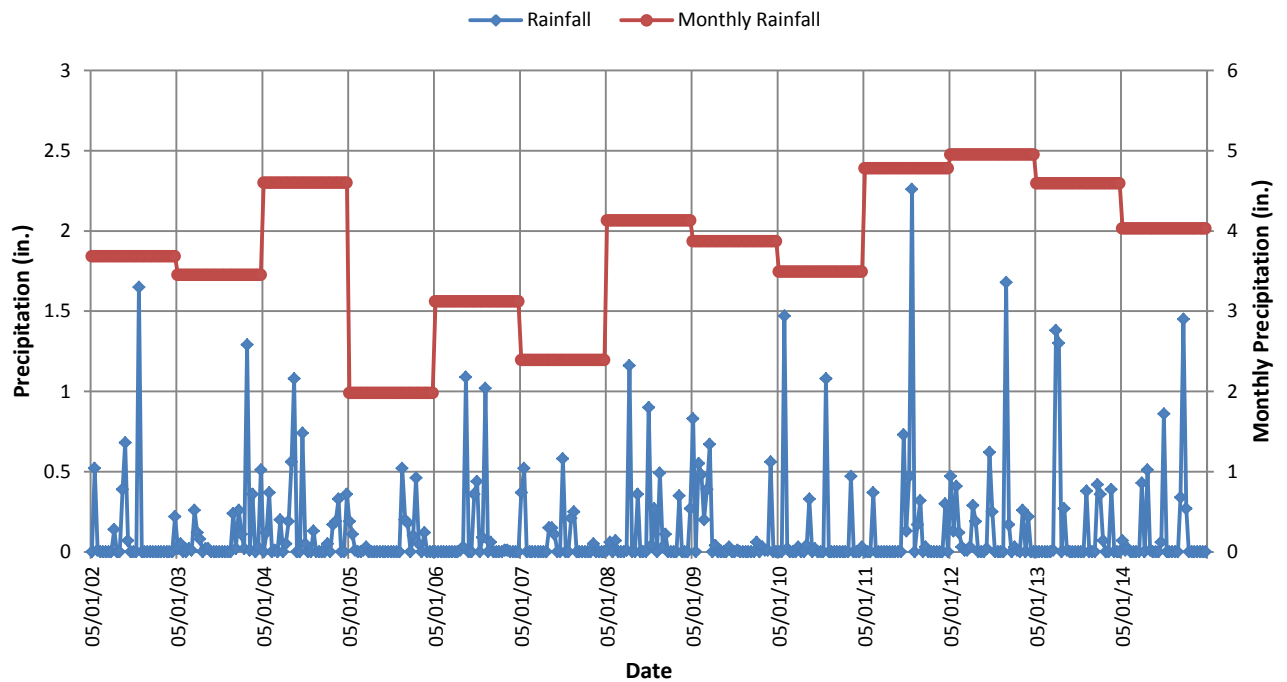
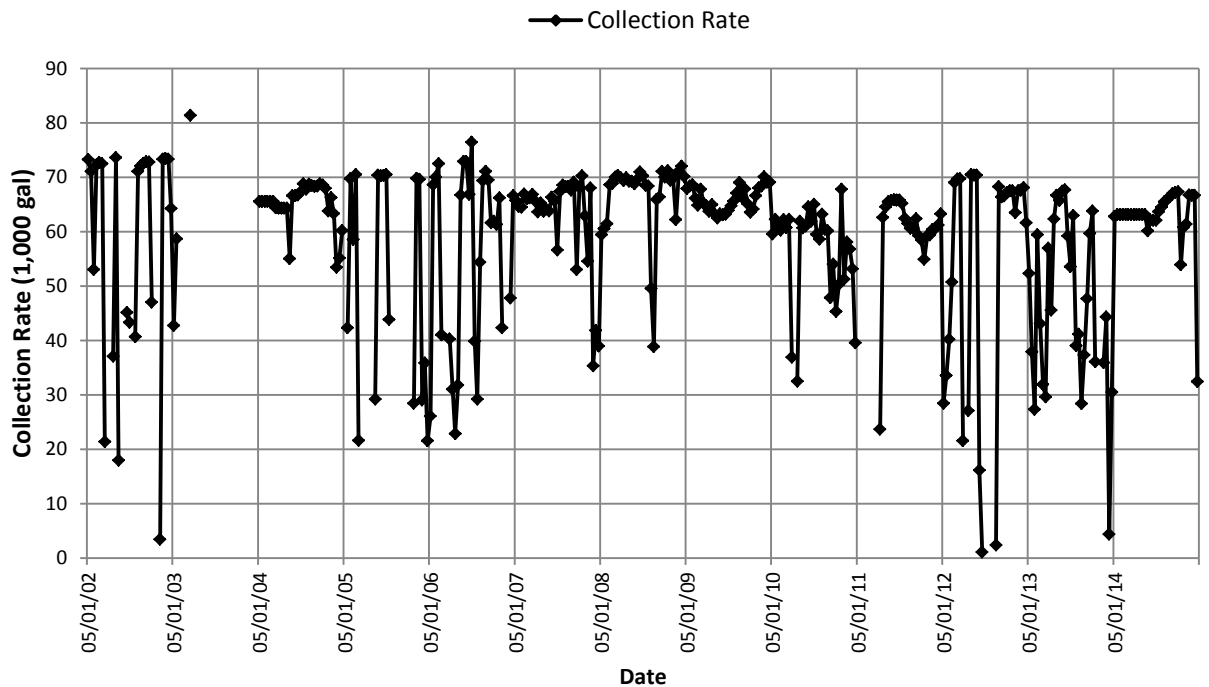
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Fresh Kills Landfill

Figure 3.2-40
April Collection Rate
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Supplemental Drain
Landfill Section 3/4



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Job Number:

May 2015

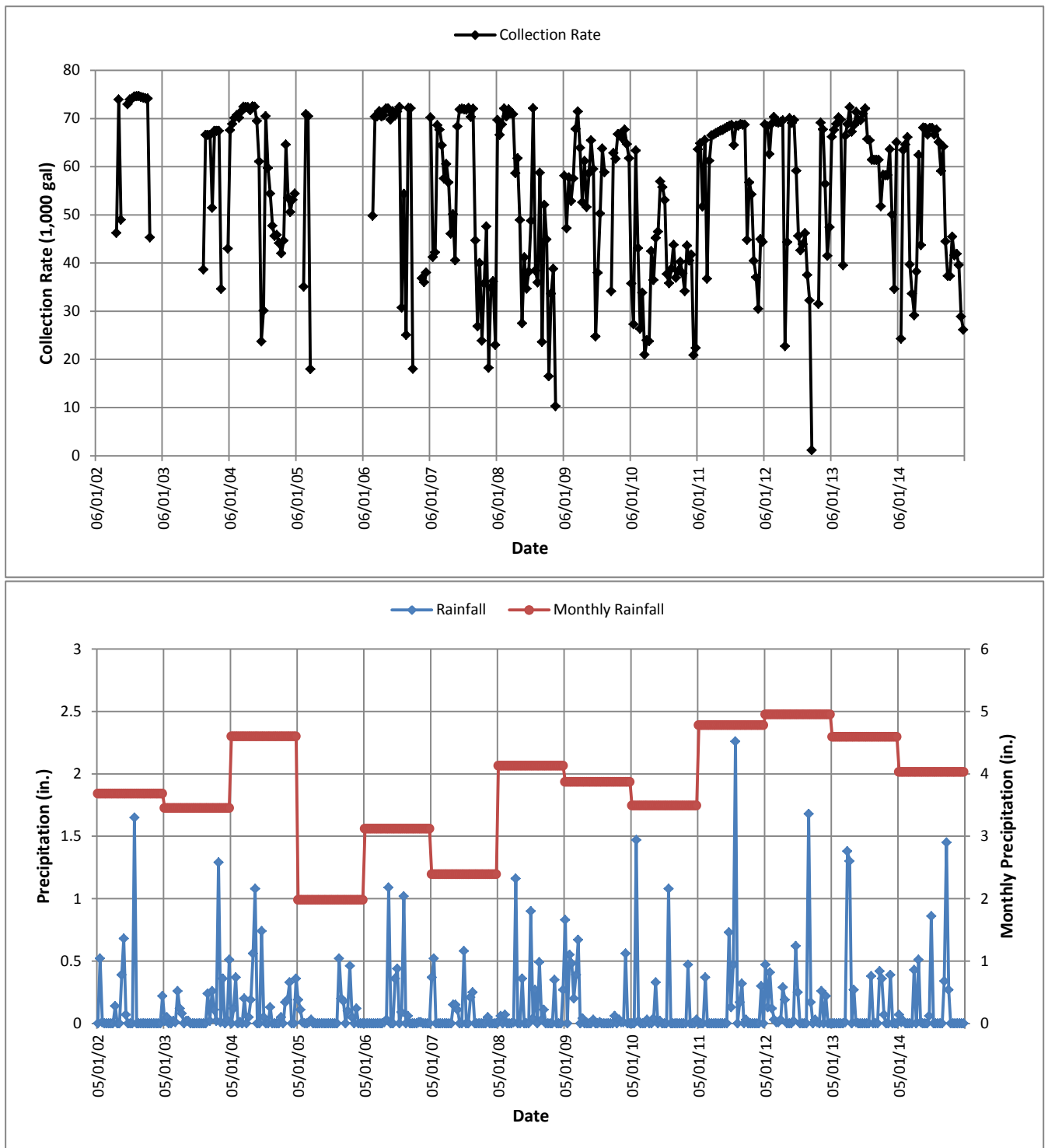
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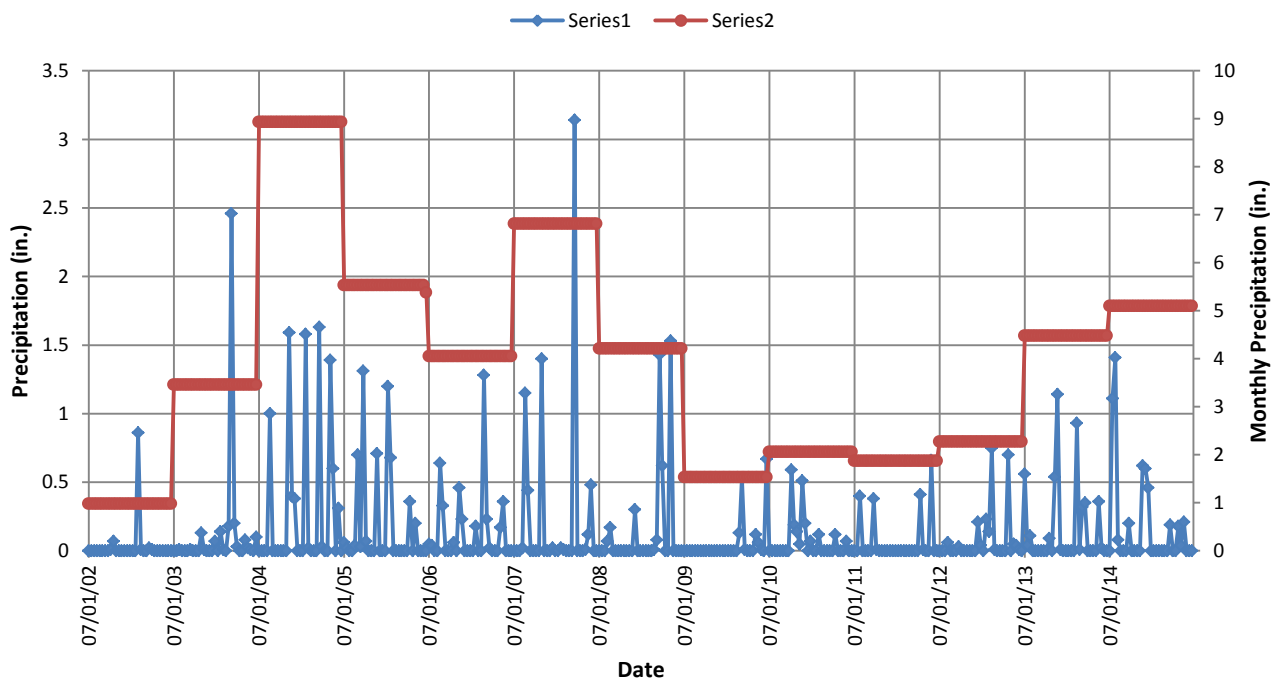
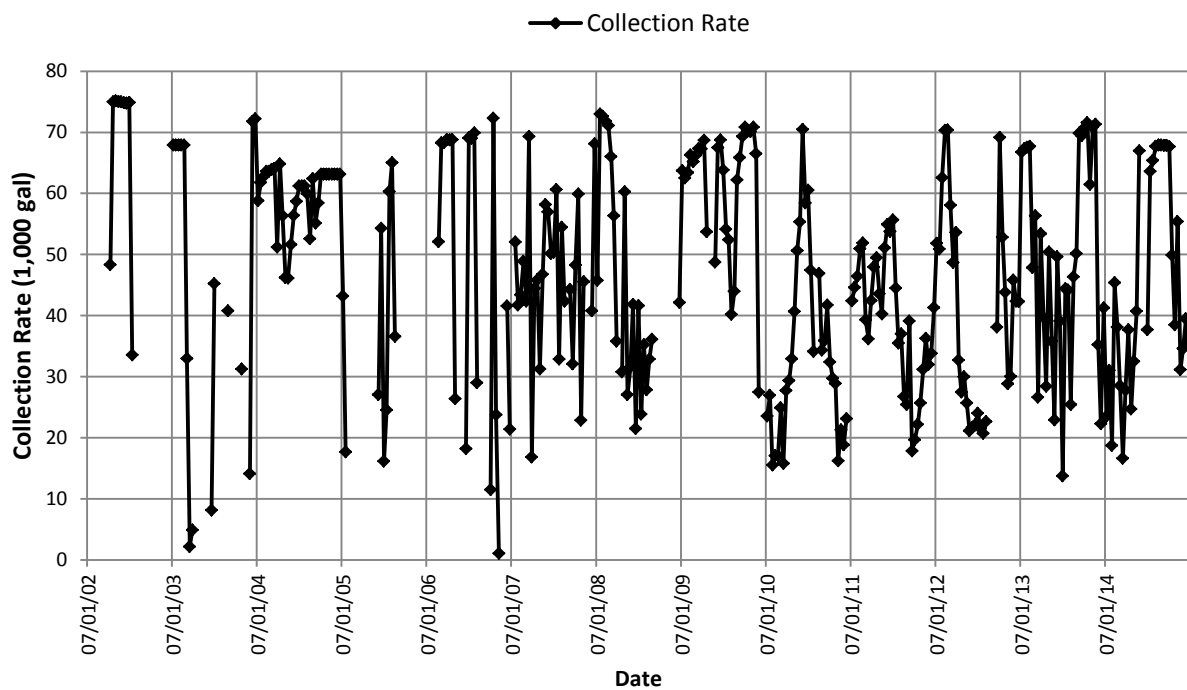
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and Landfill Section 3/4
Report

Fresh Kills Landfill

Figure 3.2-41
May Collection Rate
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Supplemental Drain
Landfill Section 3/4



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May 2015	151771	Figure 3.2-42 June Collection Rate and Precipitation Supplemental Drain Landfill Section 3/4	



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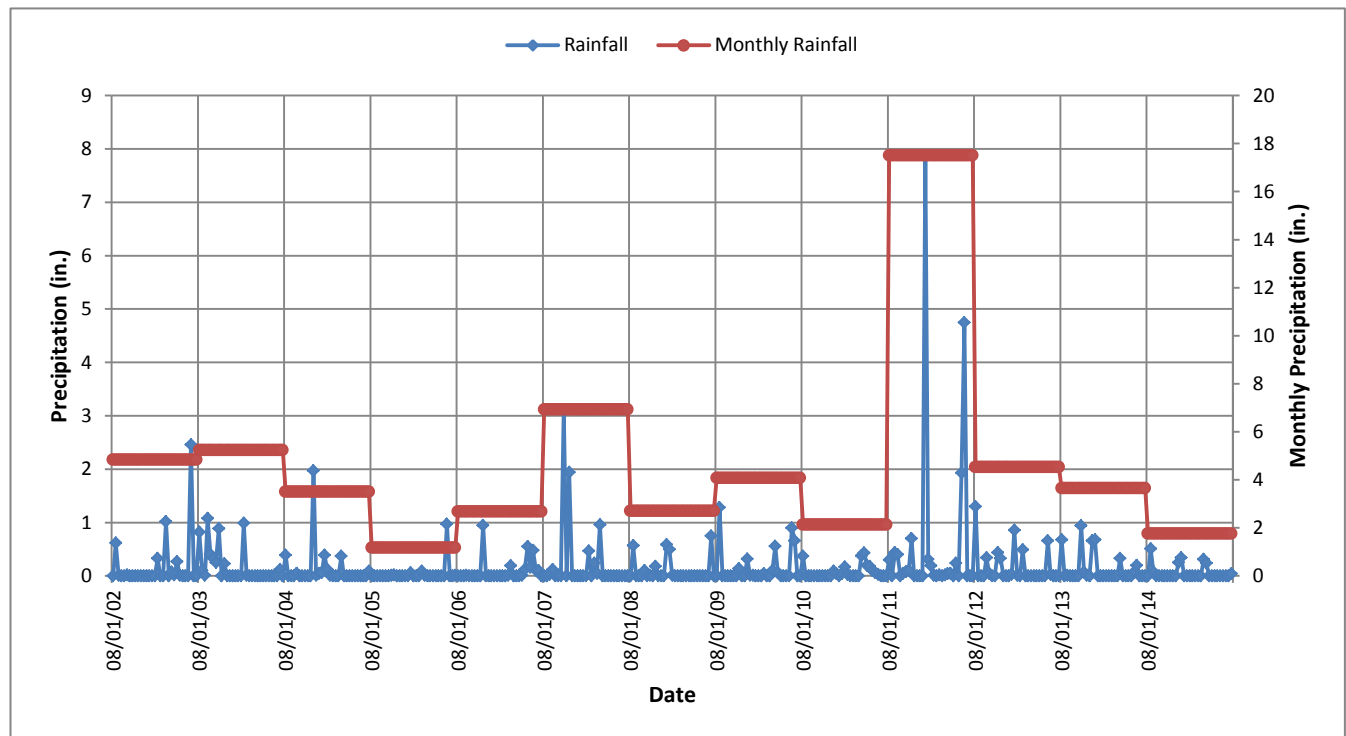
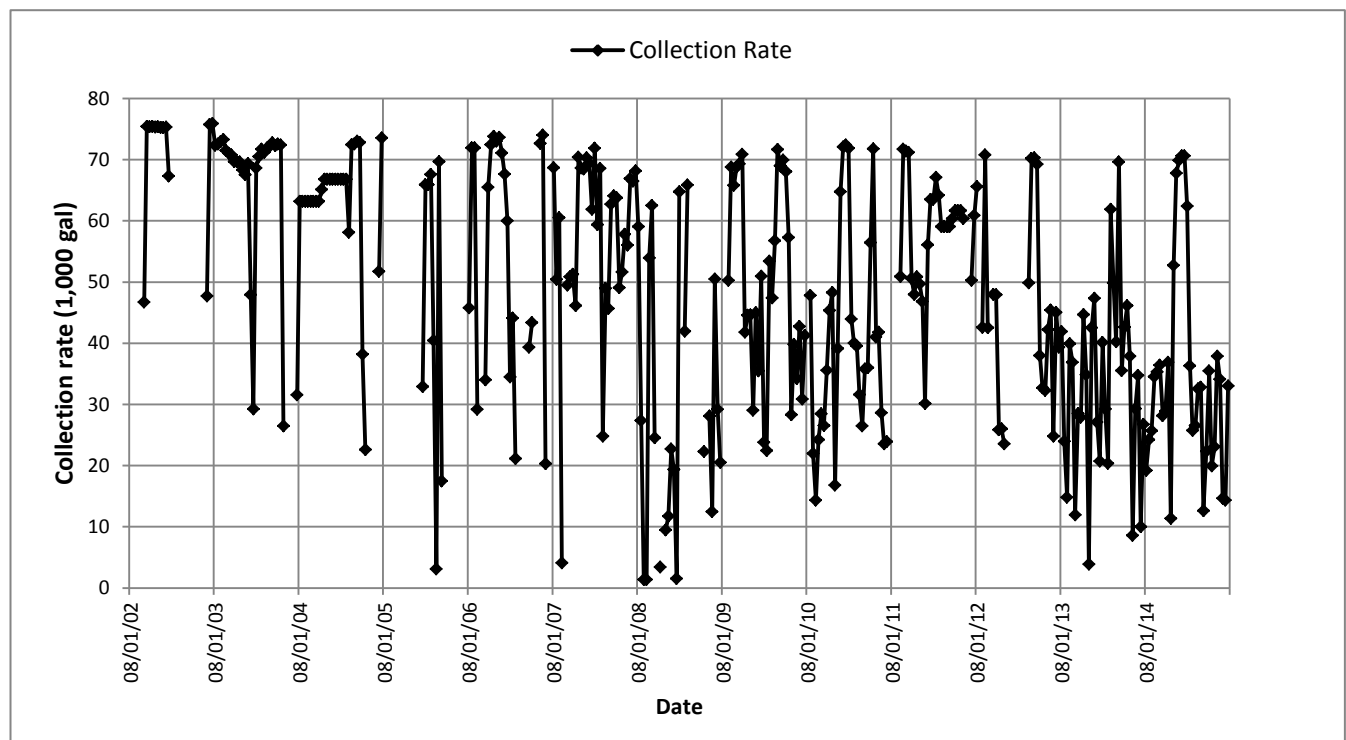
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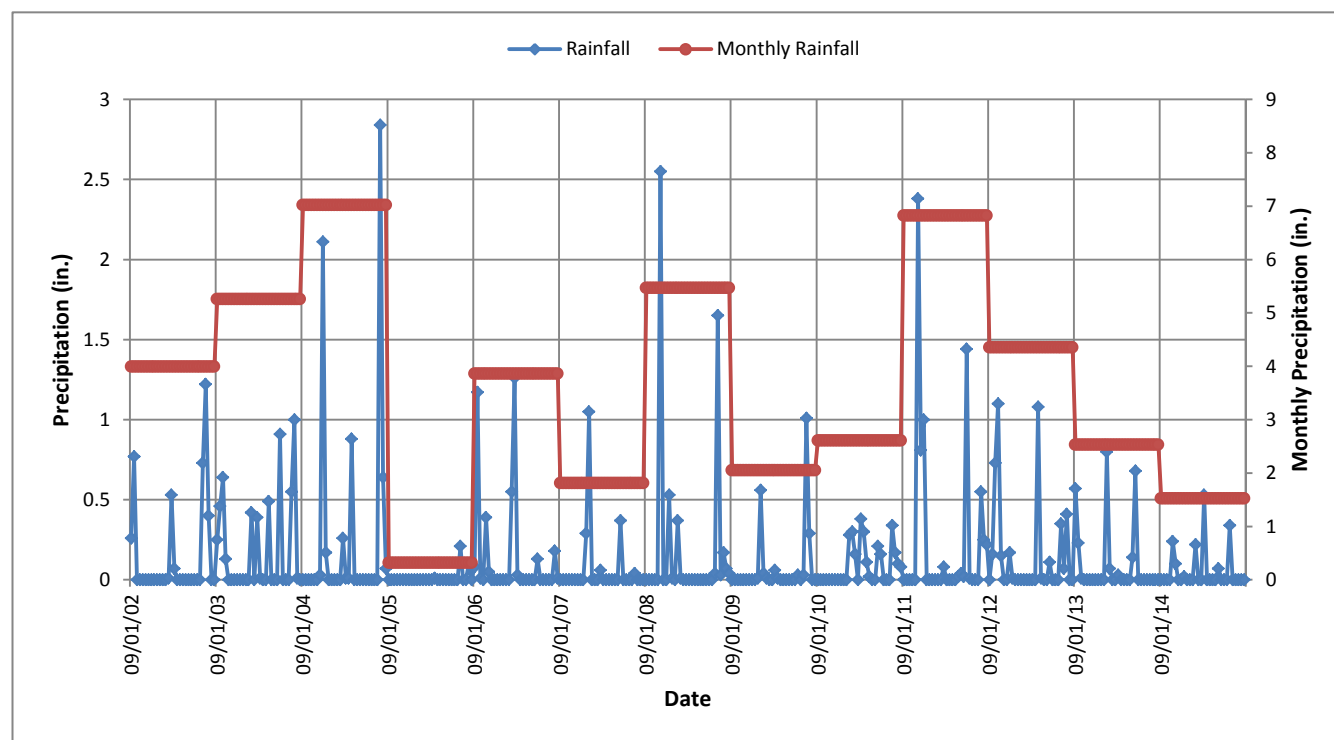
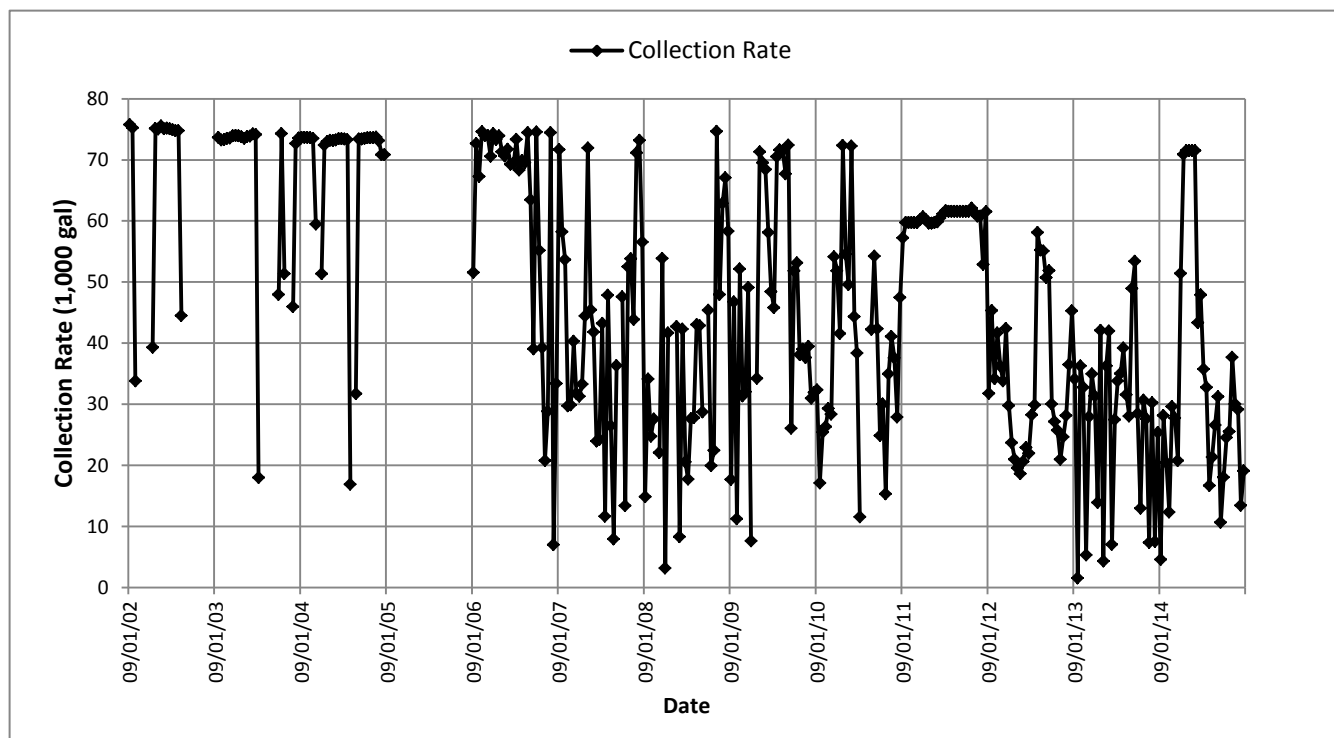


Leachate Controls
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and Landfill Section 3/4
Report
Fresh Kills Landfill

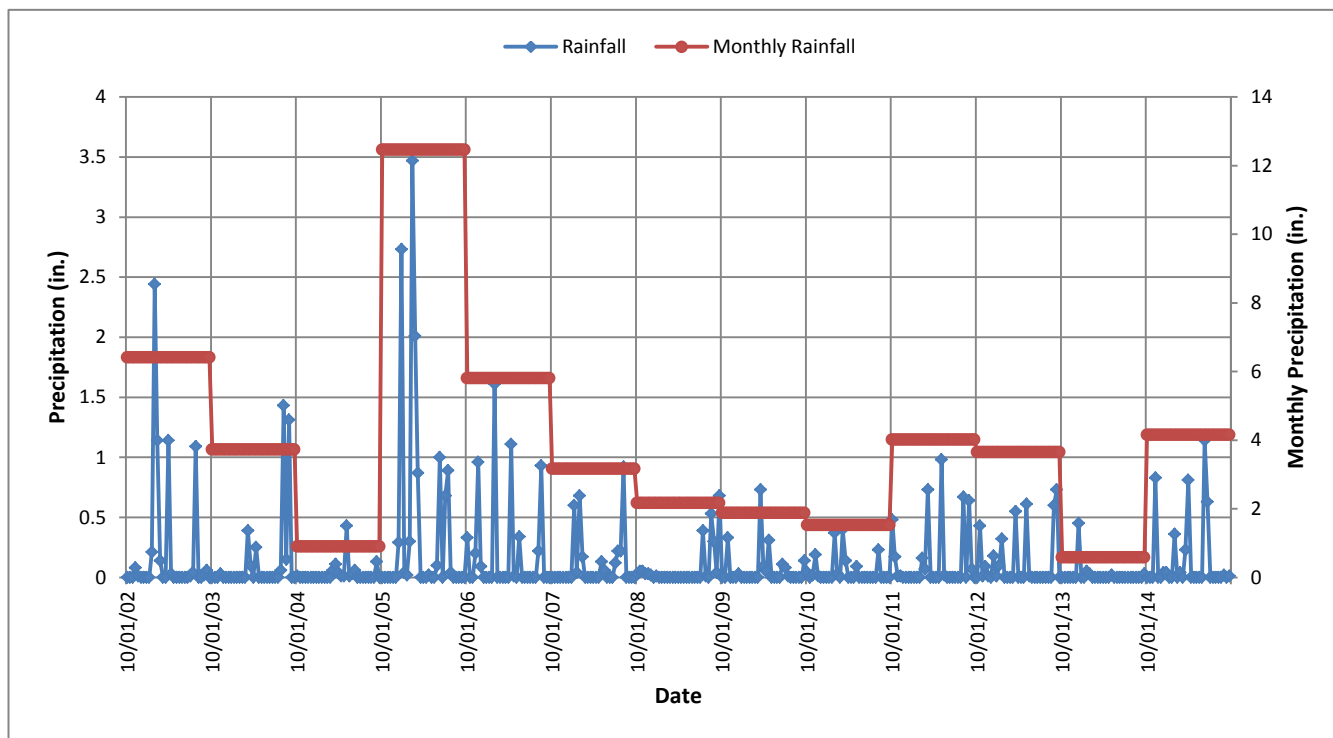
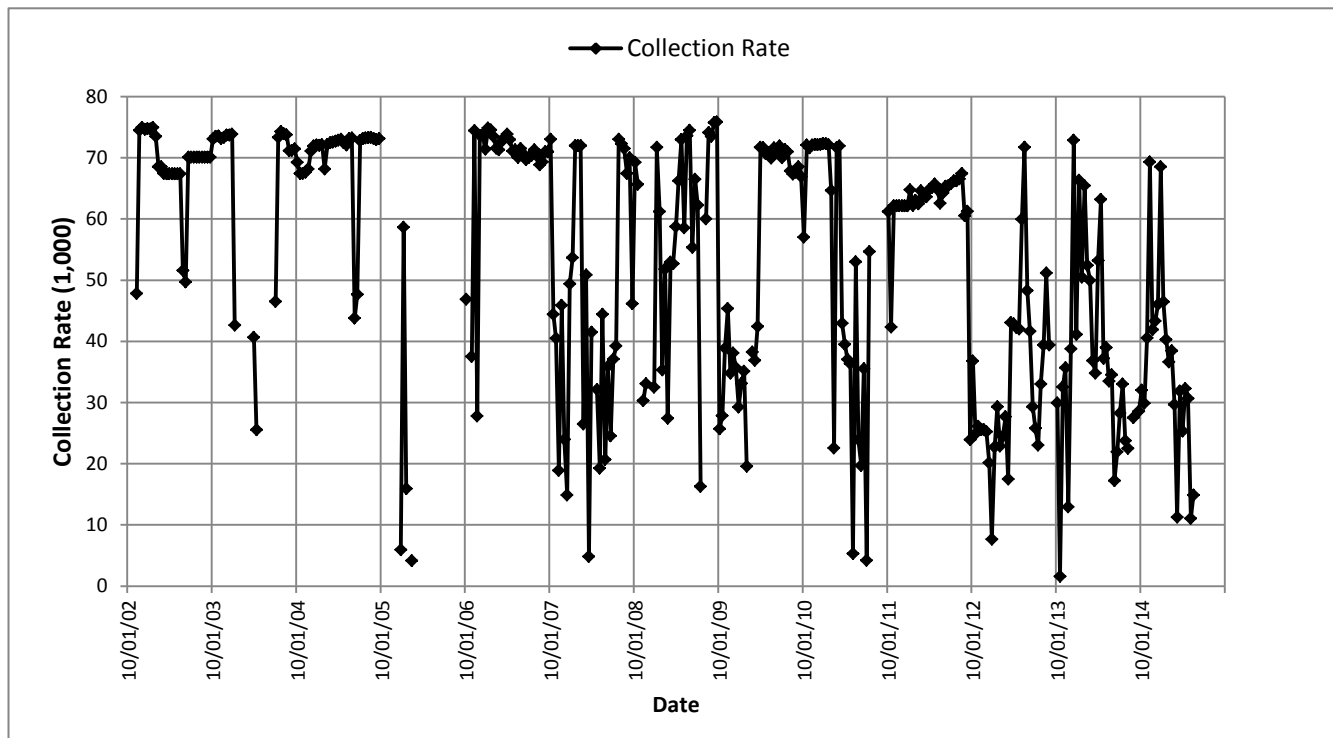
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July Collection Rate
and Precipitation
Supplemental Drain
Landfill Section 3/4



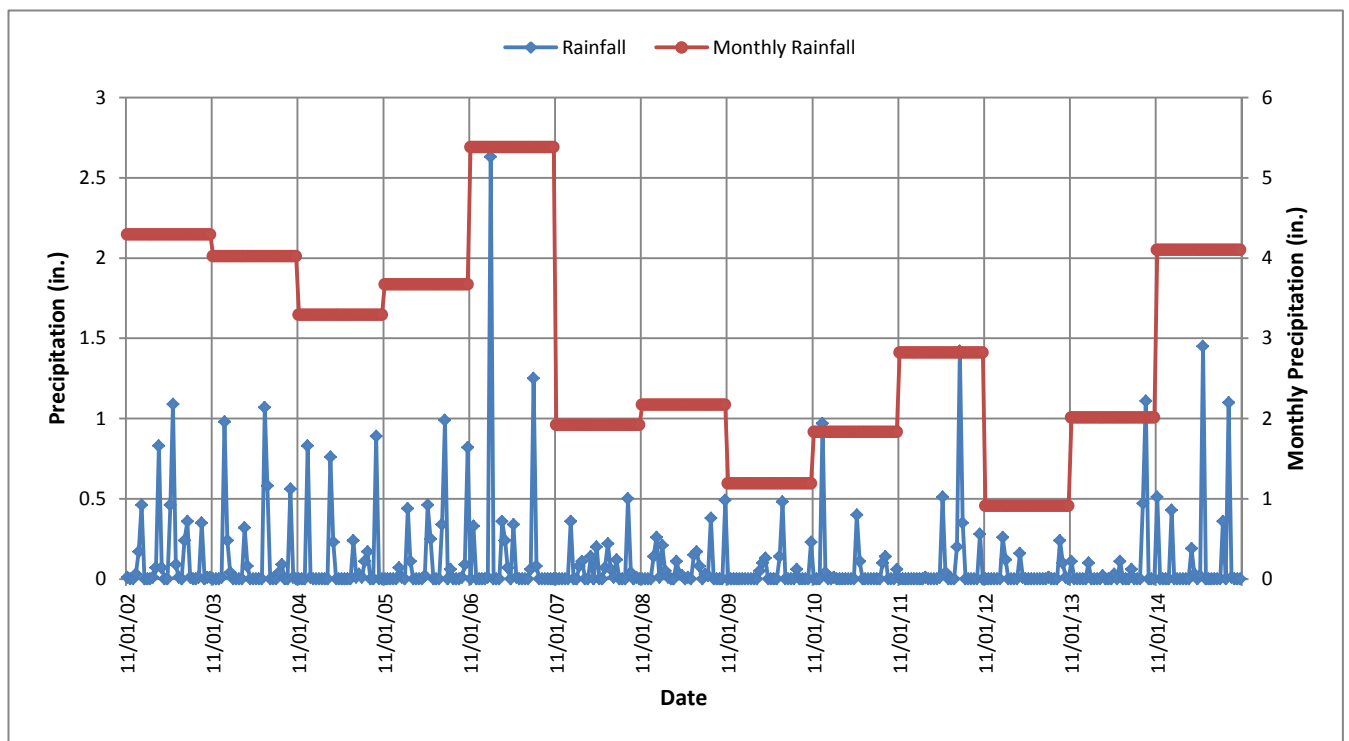
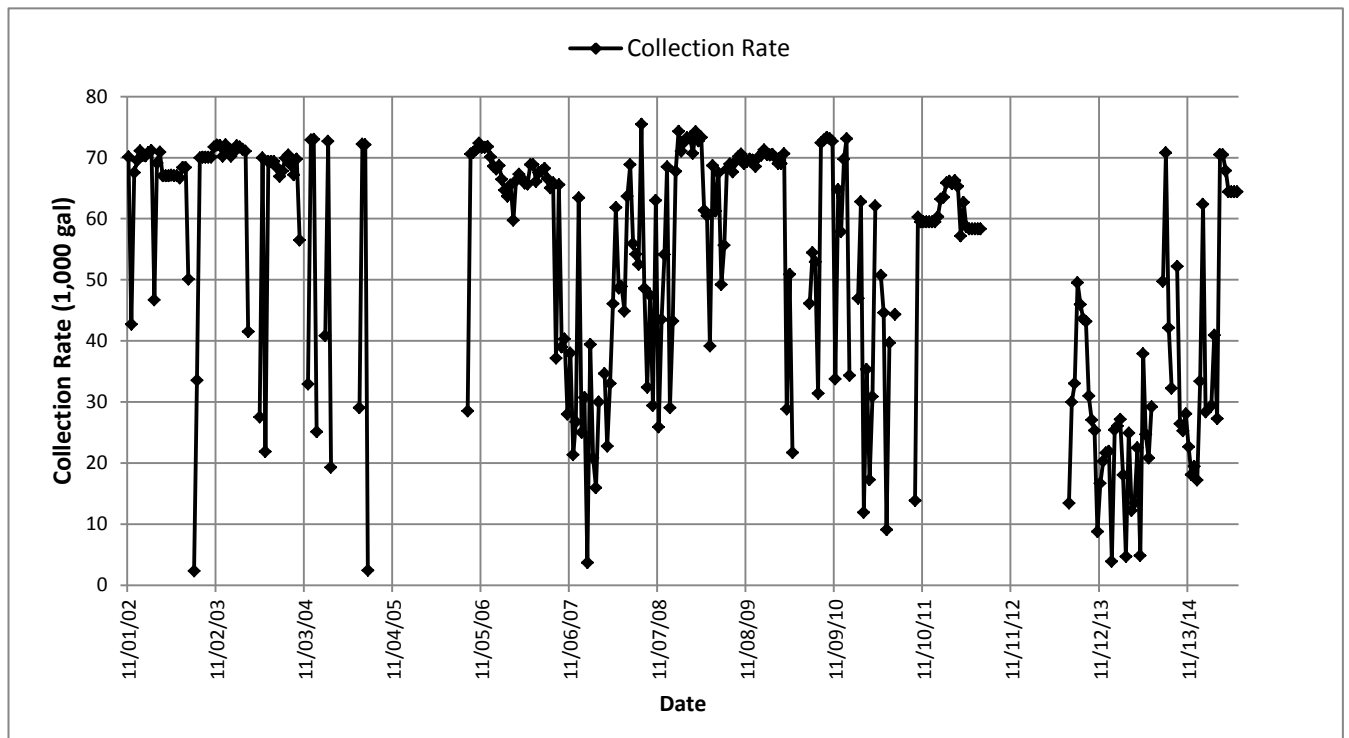
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Date: May 2015	Job Number: 151771				



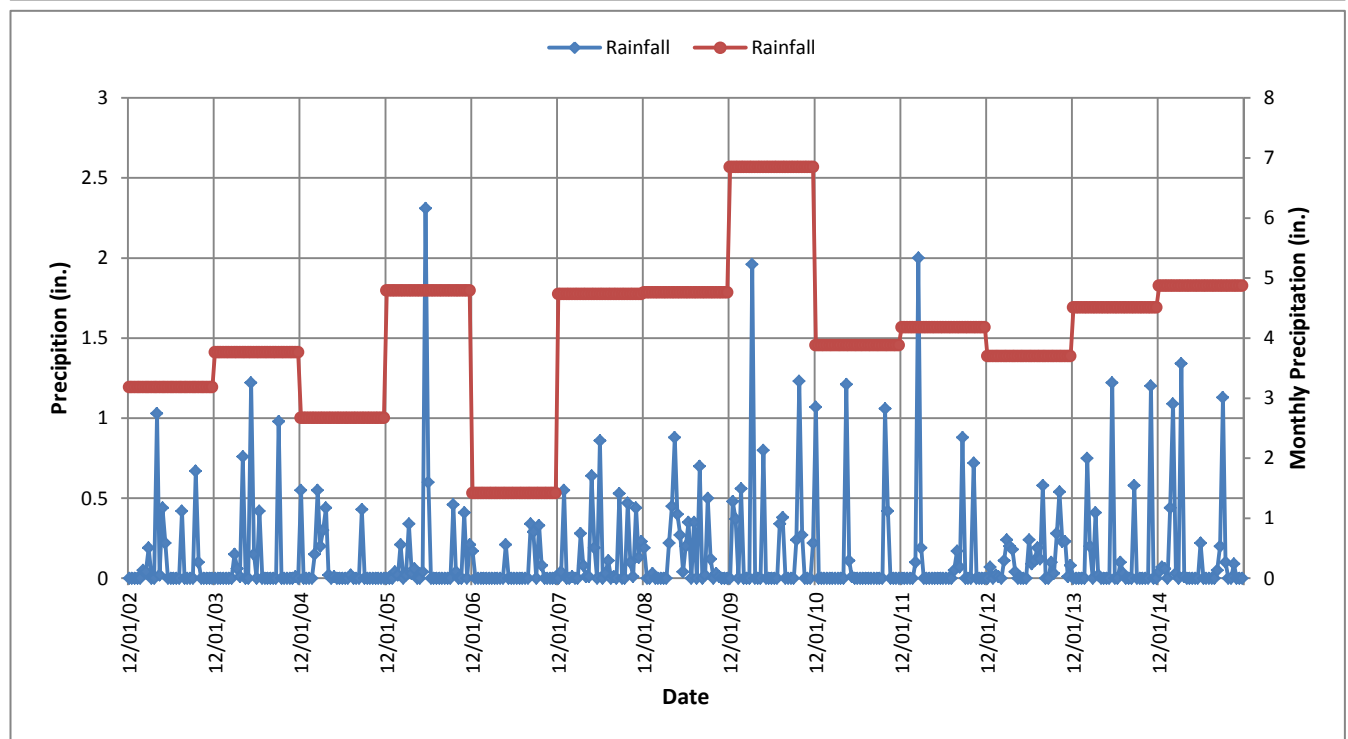
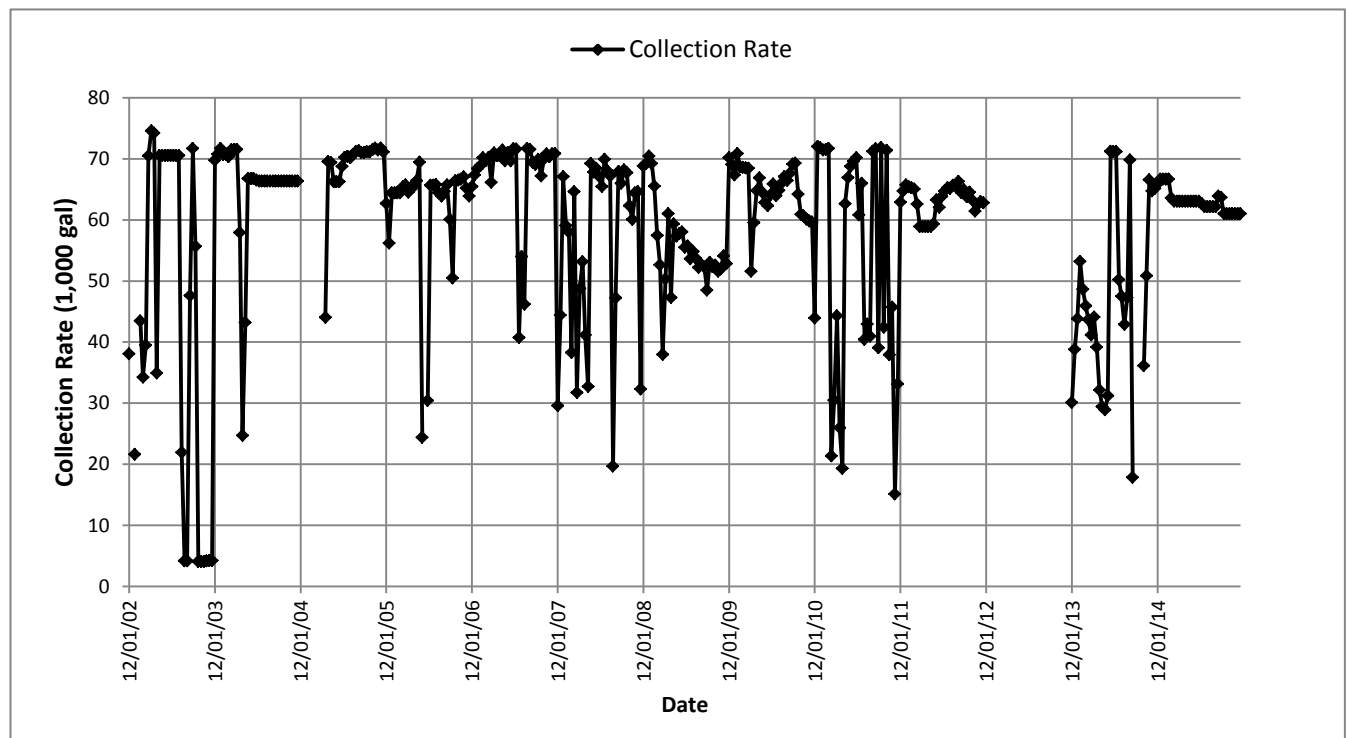
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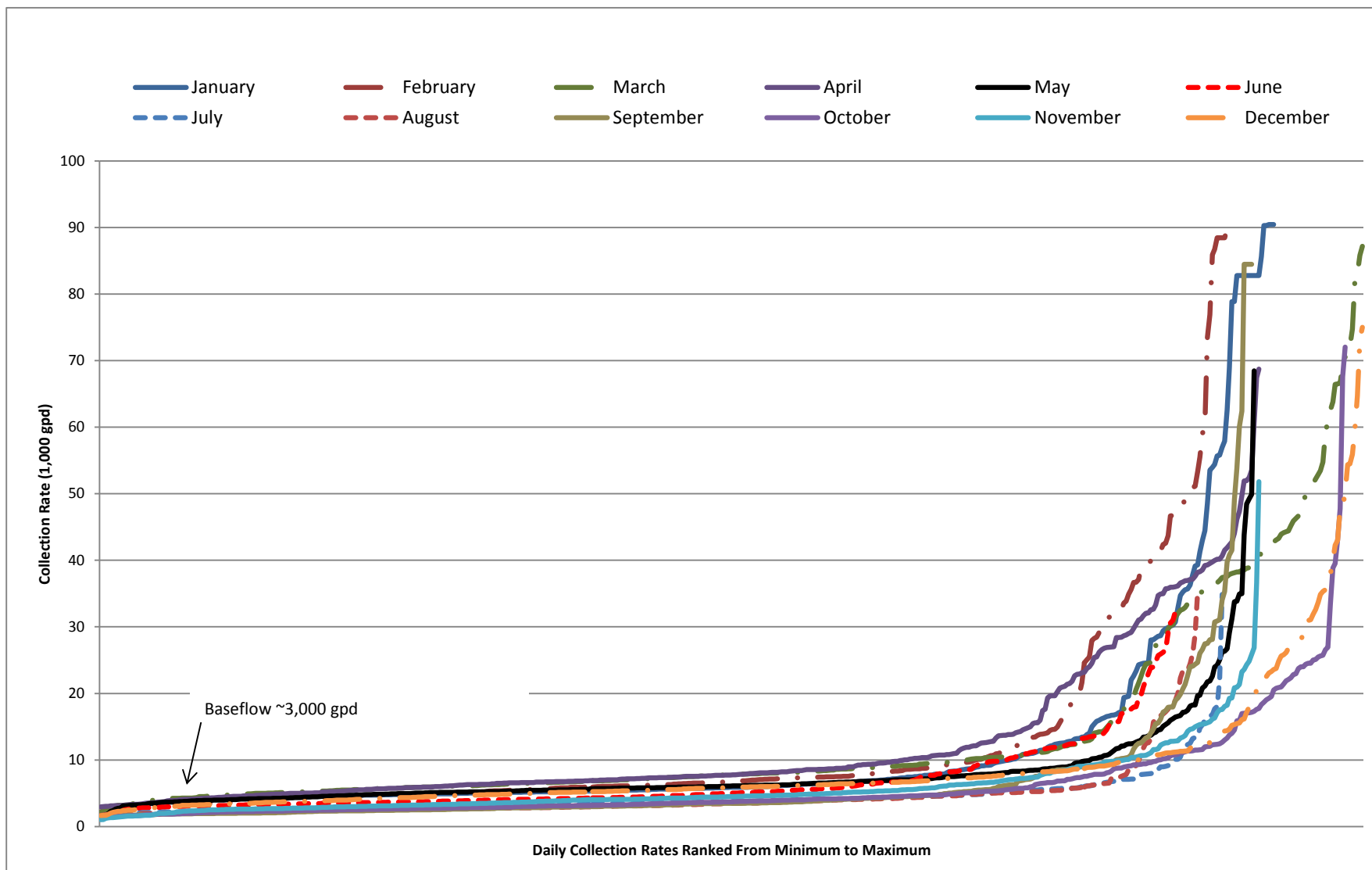
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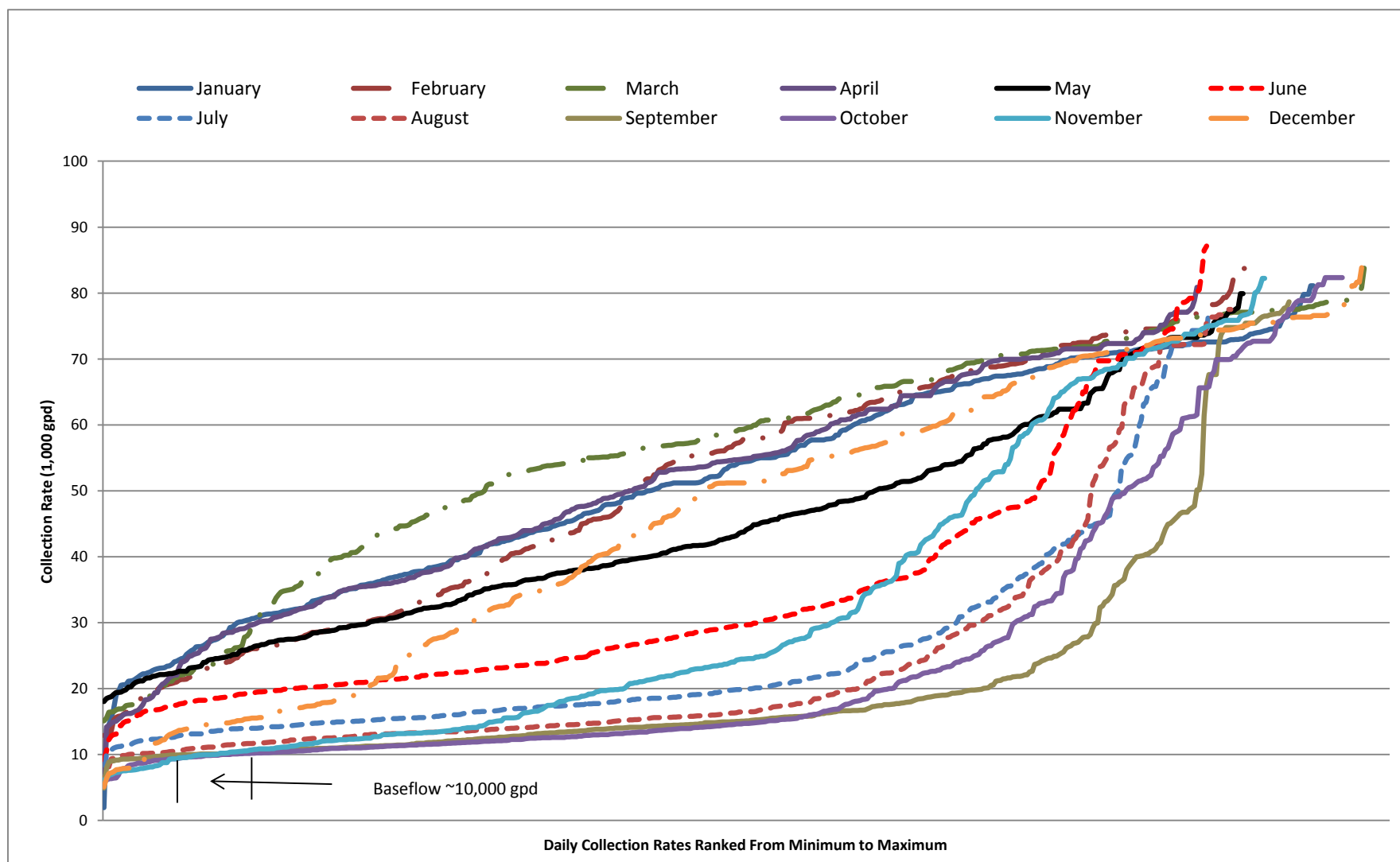
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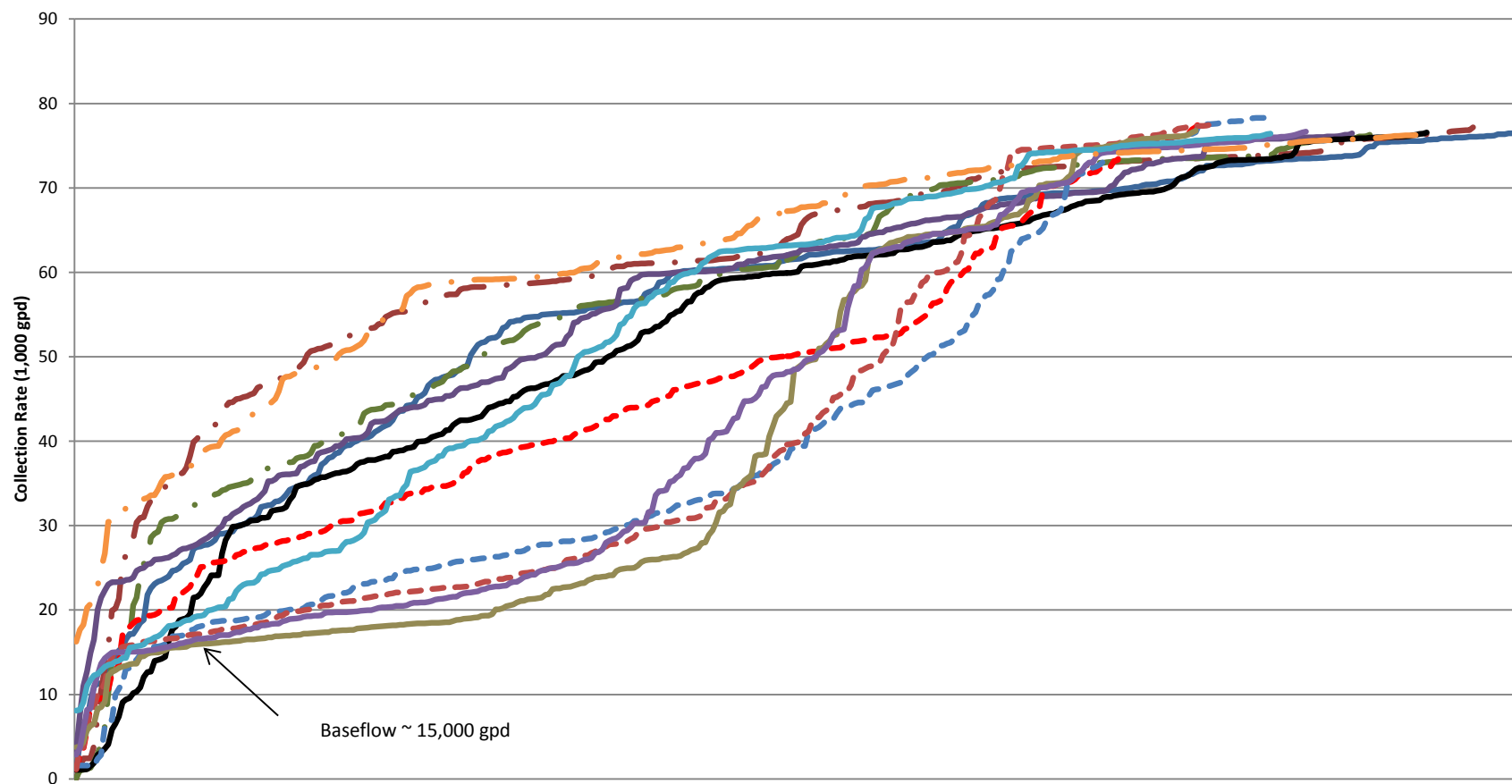


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July 2015	151771				

March January February April May June
 July August September October November December



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Under the Direction of:



Leachate Controls at
Landfill Section 2/8
and Landfill Section 3/4
Report

Fresh Kills Landfill

Figure 3.2-51
Daily Collection Rates
Seasonality Evaluation
Supplemental Leachate Collection Drain
Landfill Section 2/8

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DJD

Date:

July 2015

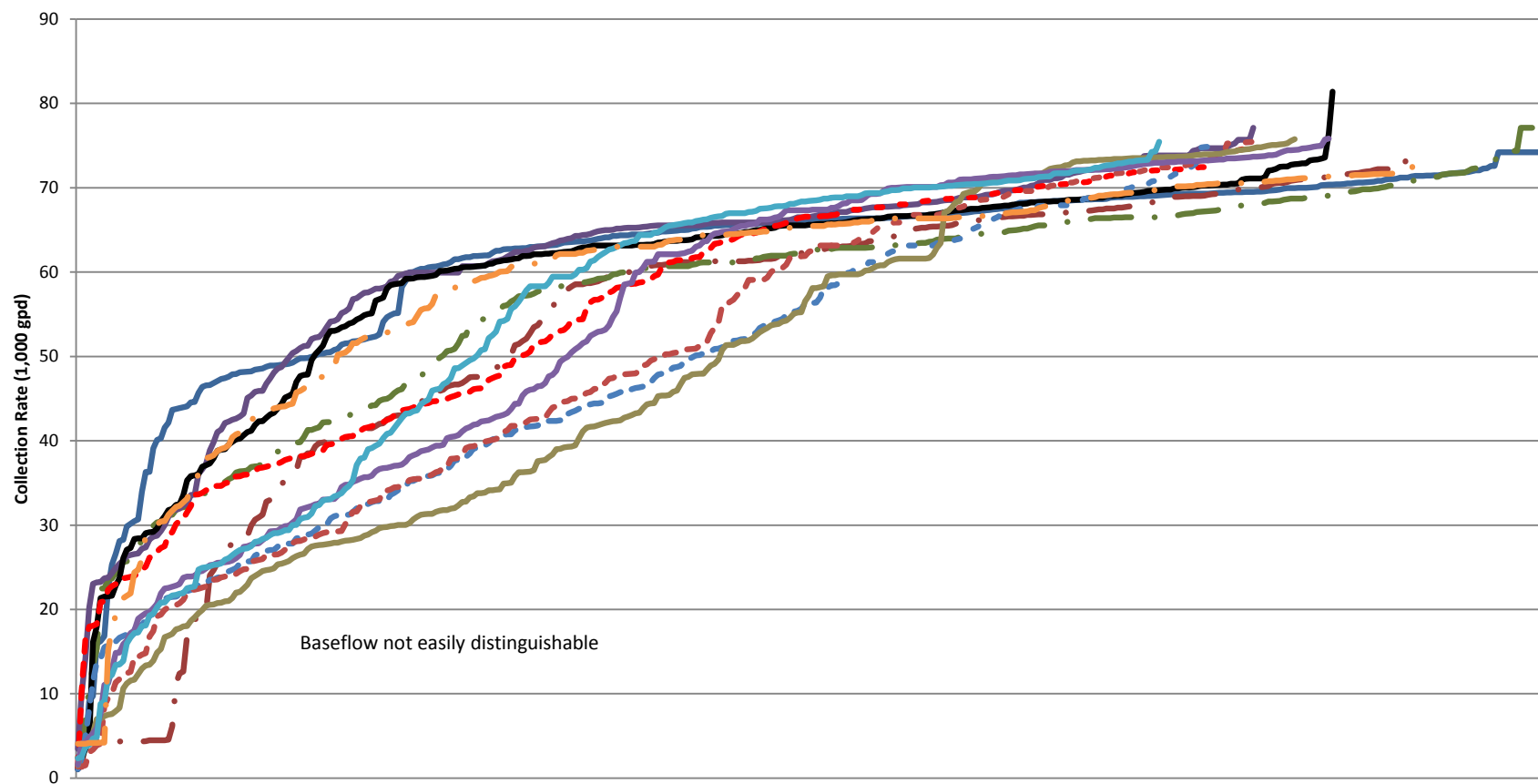
Approved By:

EJW

Job Number:

151771

January February March April May June
 July August September October November December



Daily Collection Rates Ranked From Minimum to Maximum

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Leachate Controls at
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and Landfill Section 3/4
Report

Fresh Kills Landfill

Figure 3.2-52
Daily Collection Rates
Seasonality Evaluation
Supplemental Leachate Collection Drain
Landfill Section 3/4

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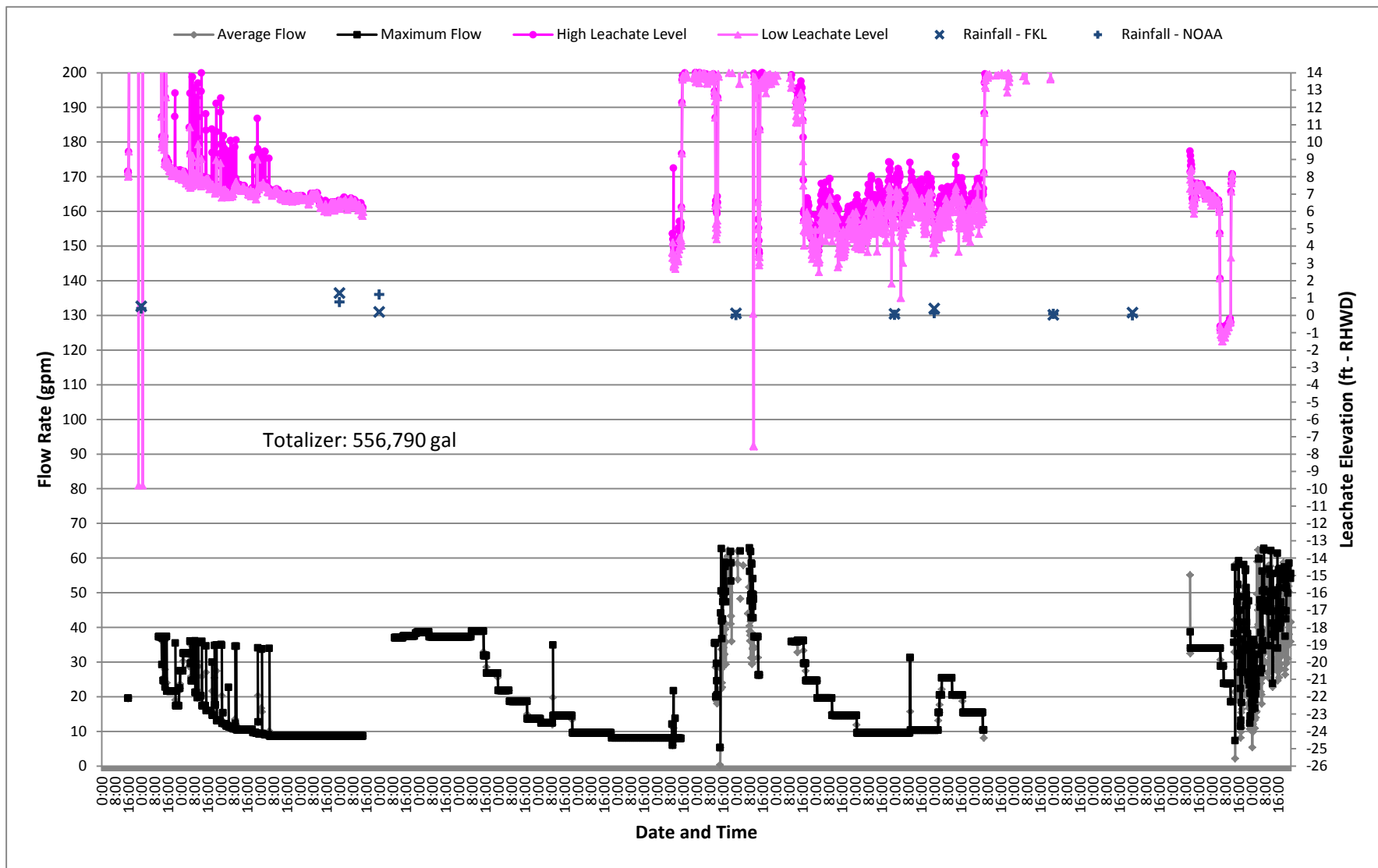
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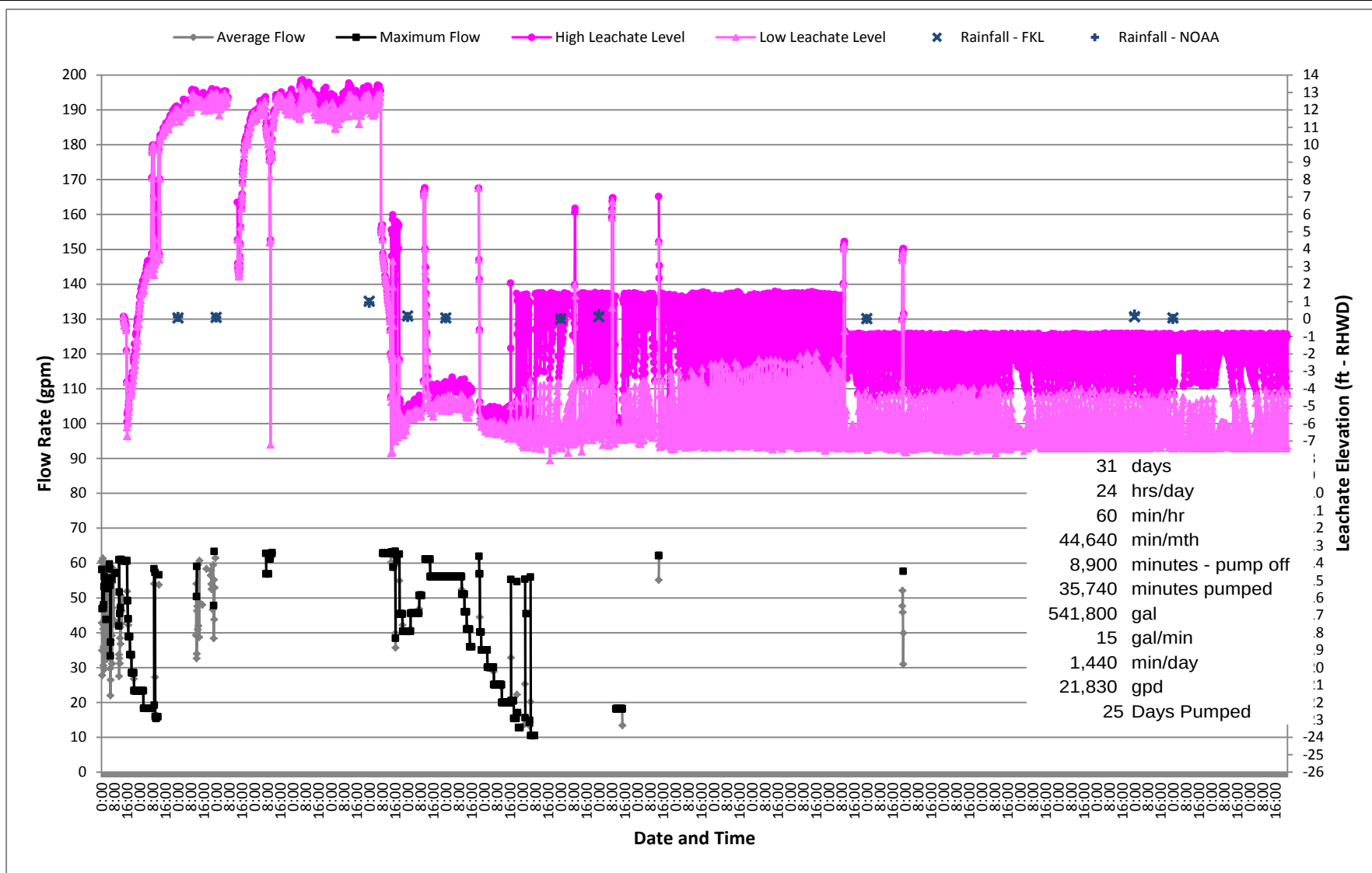
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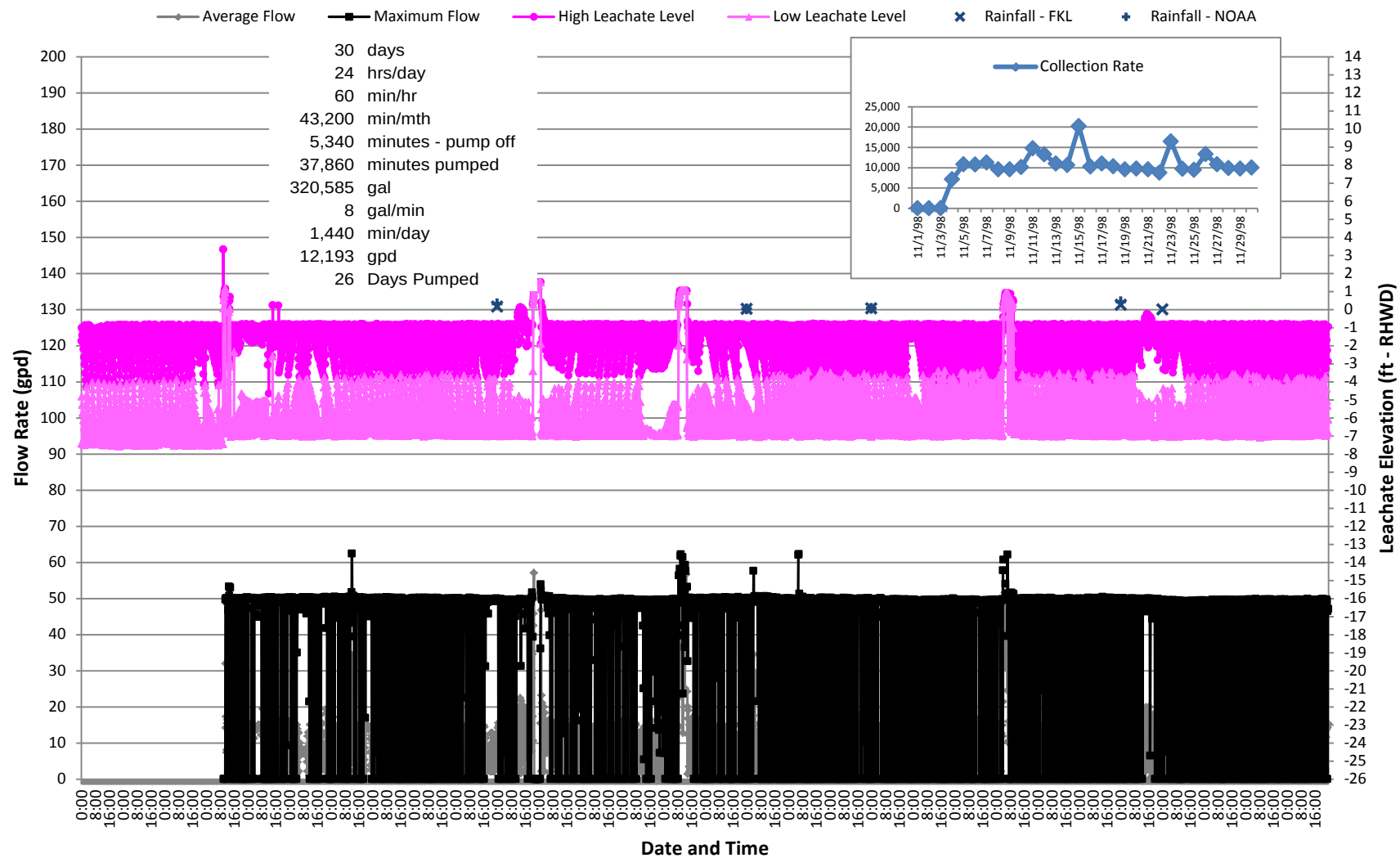
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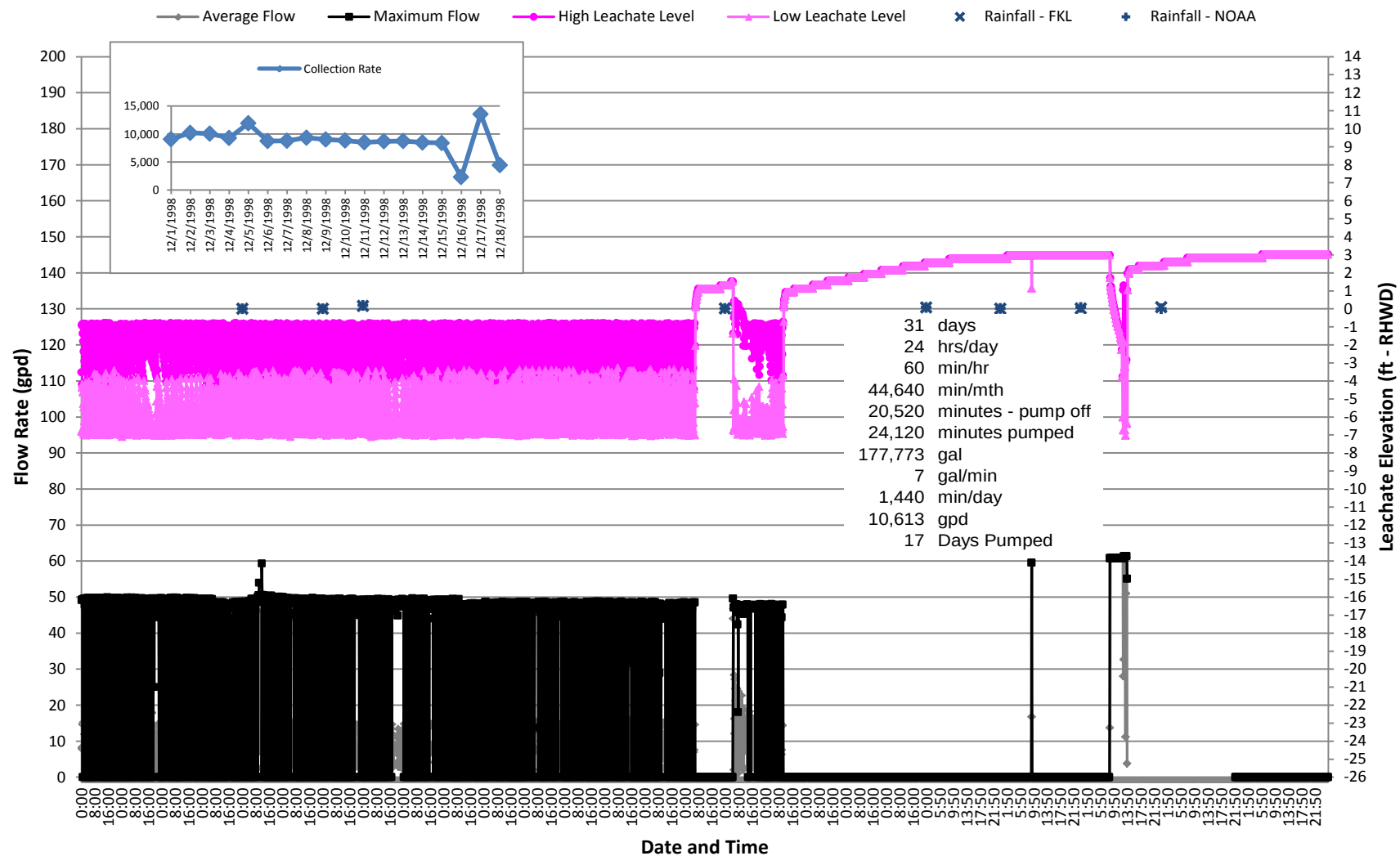
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Date:	Job Number:				
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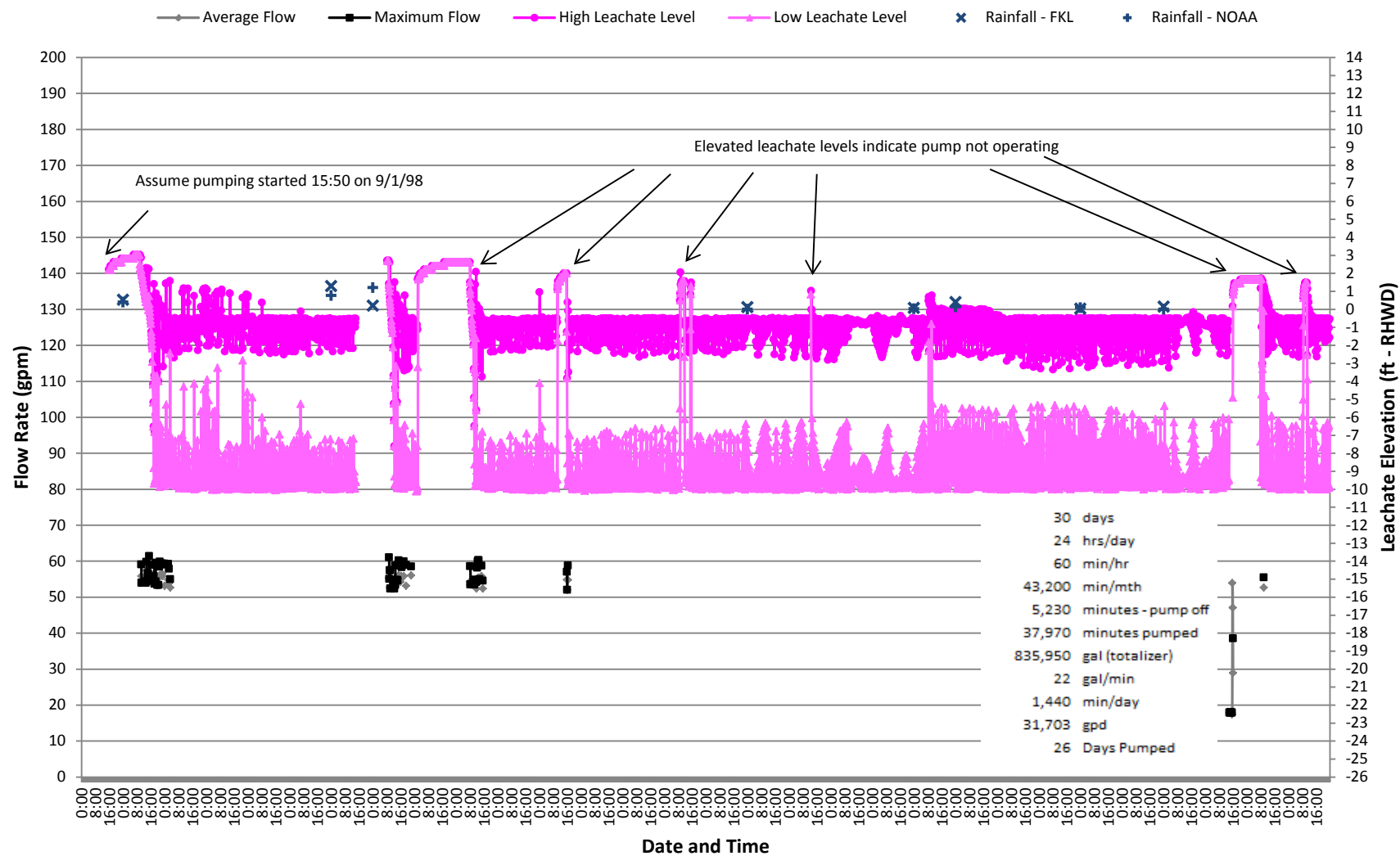
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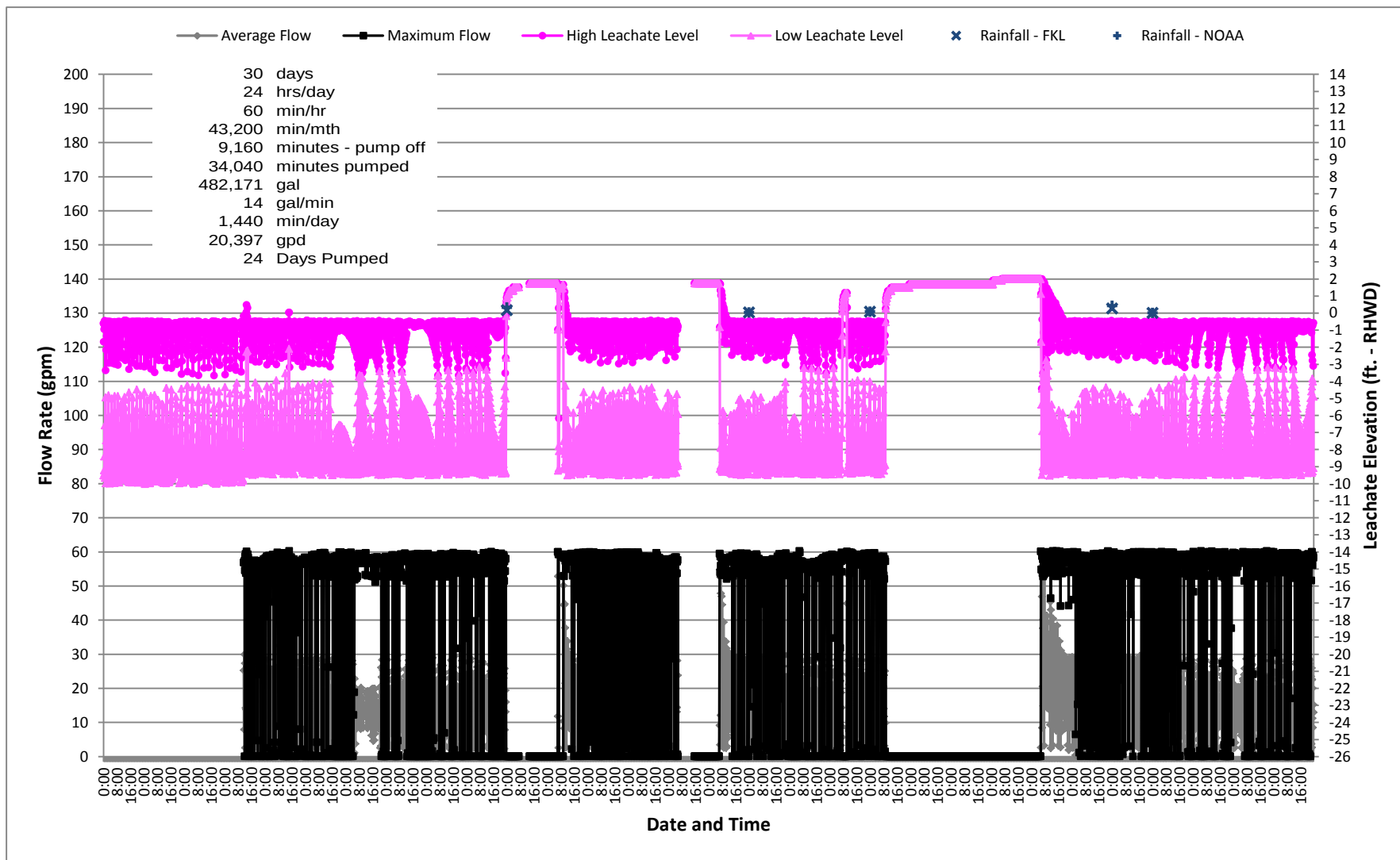
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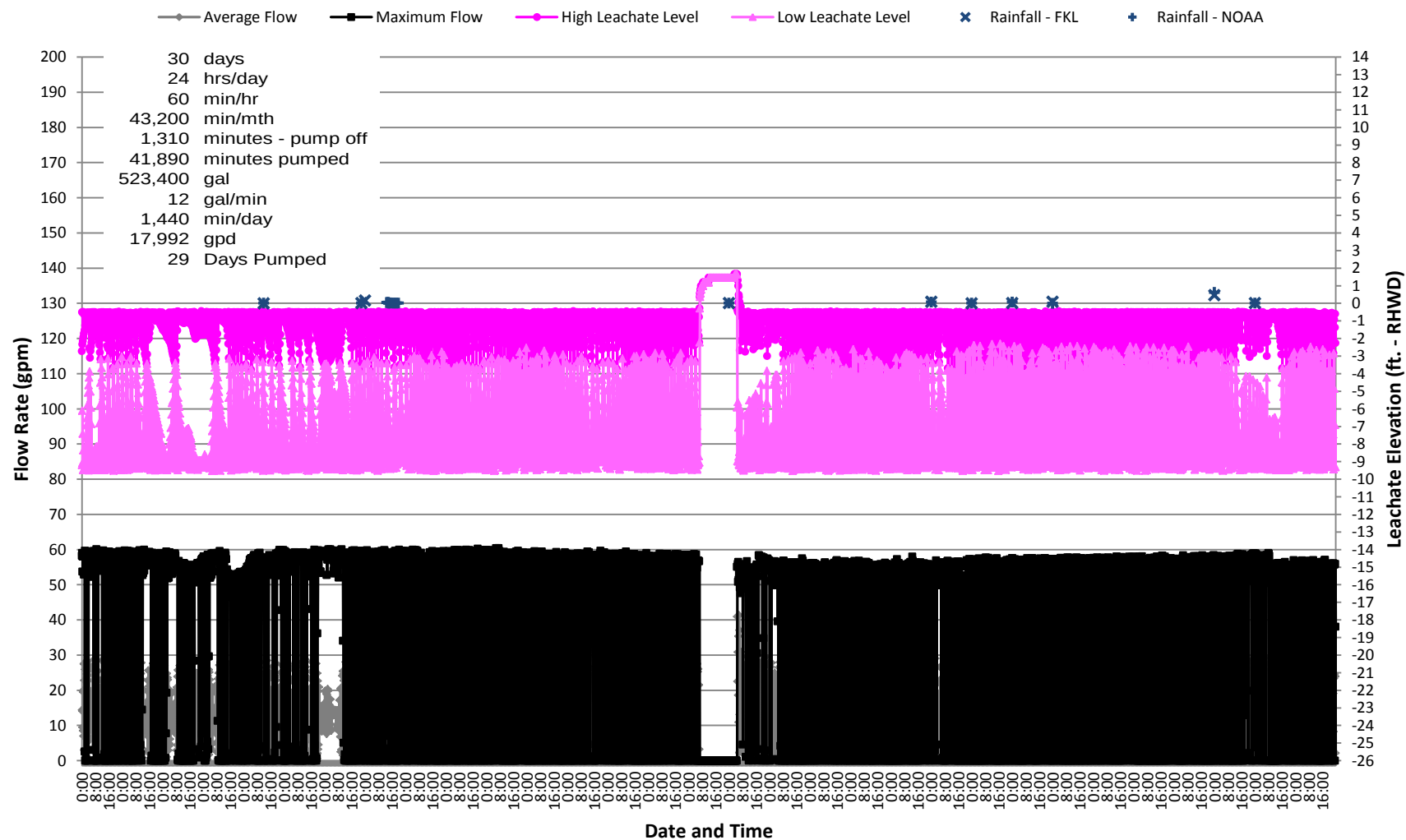
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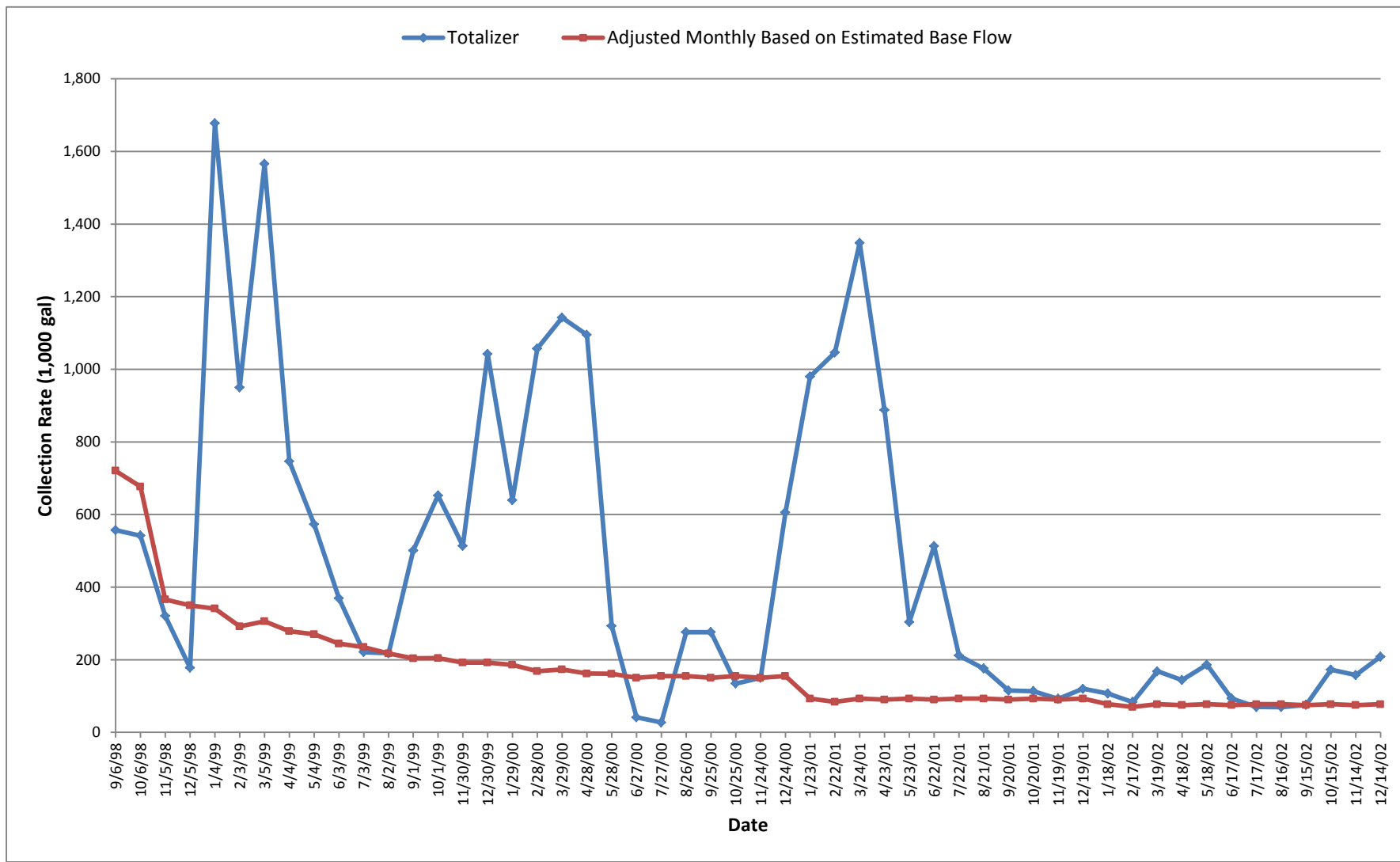
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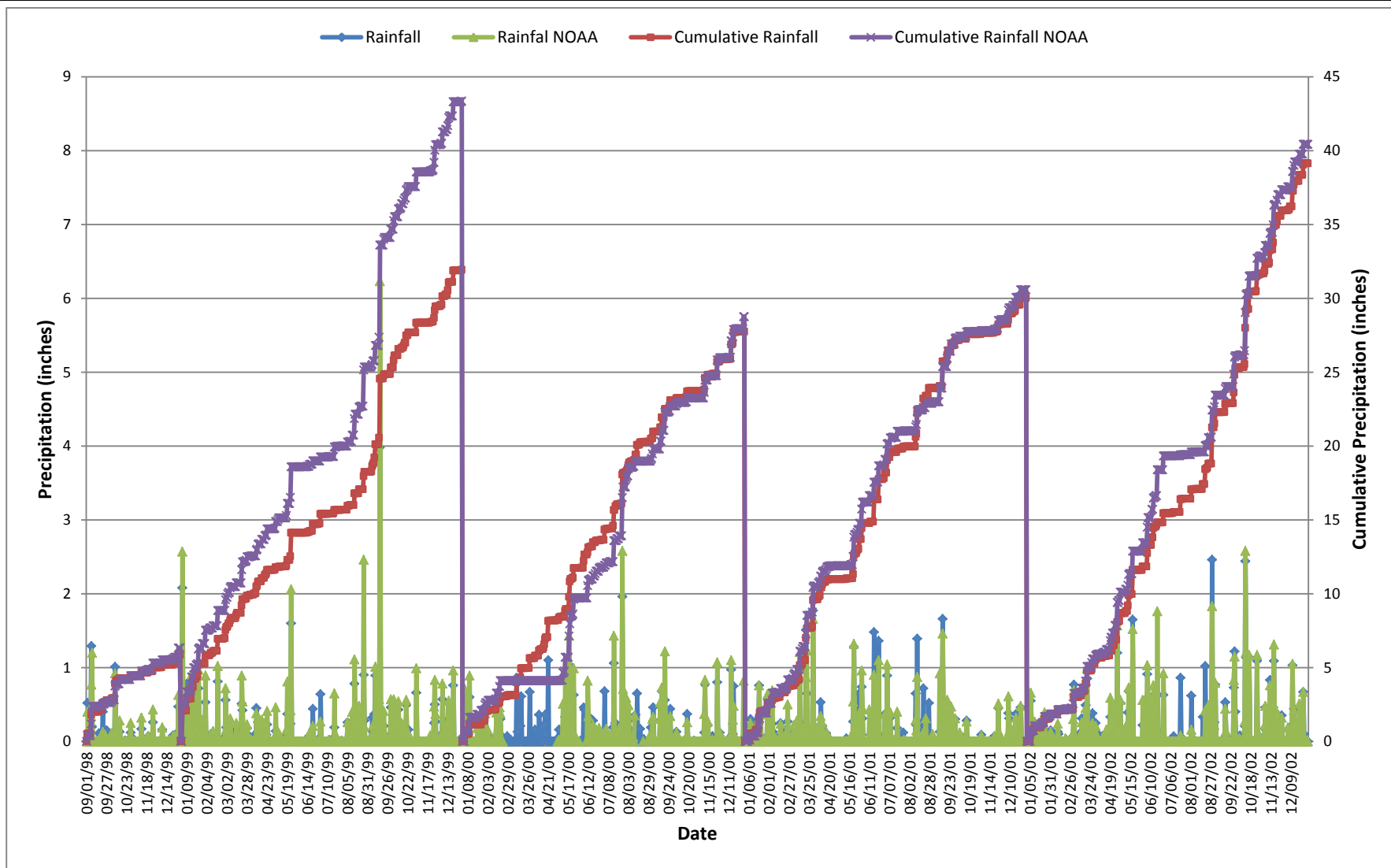
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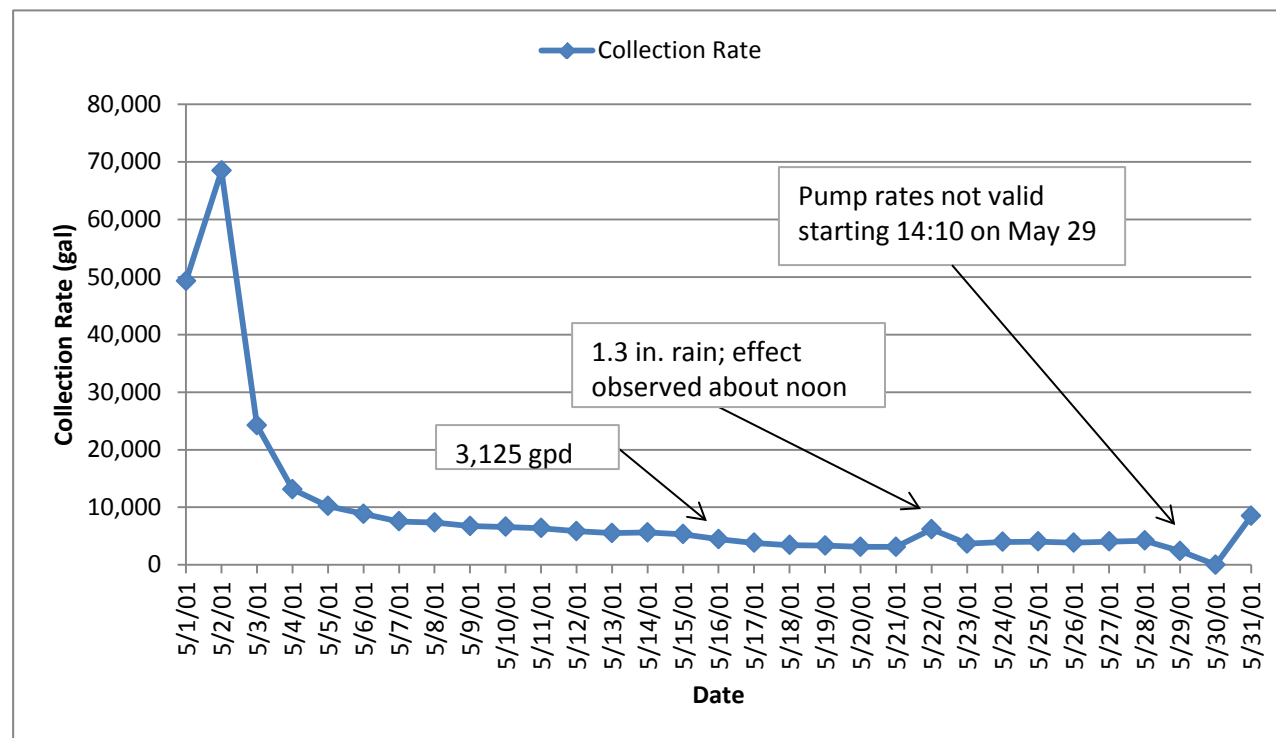
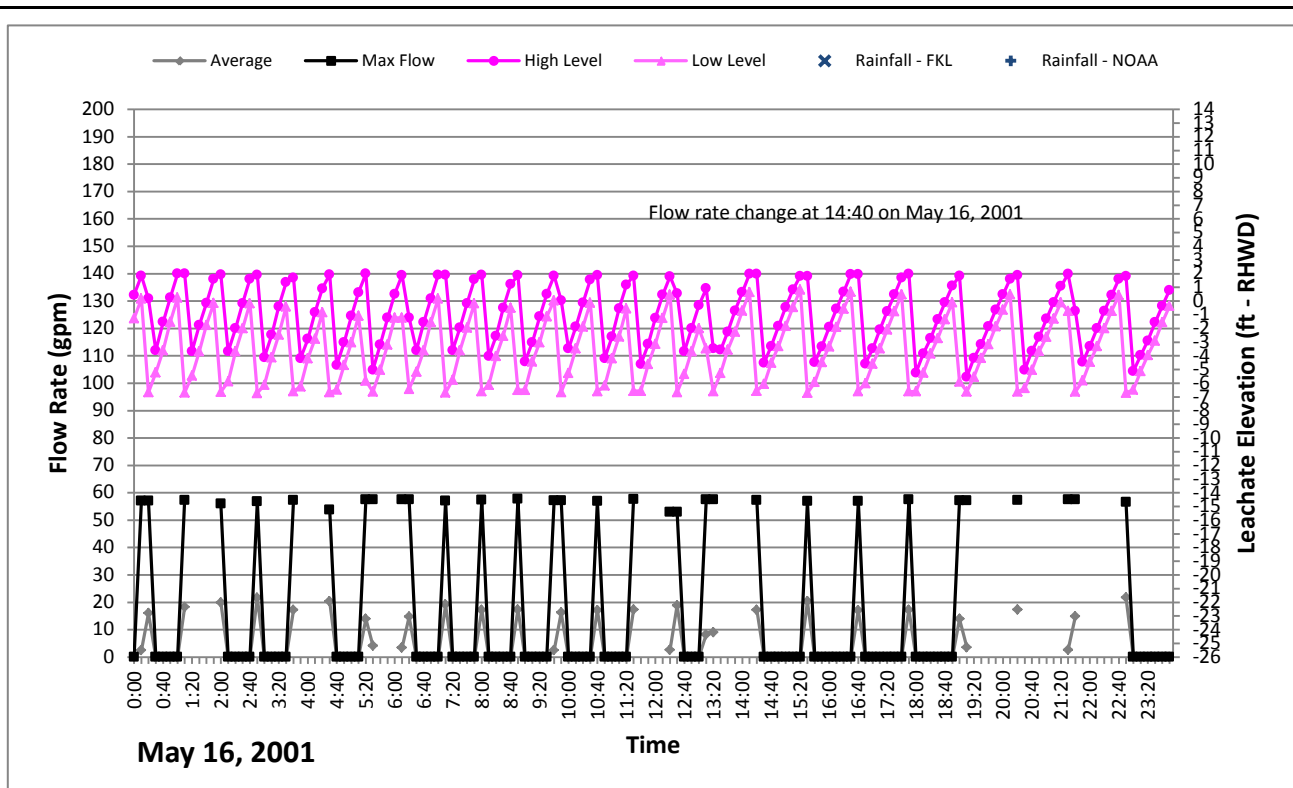
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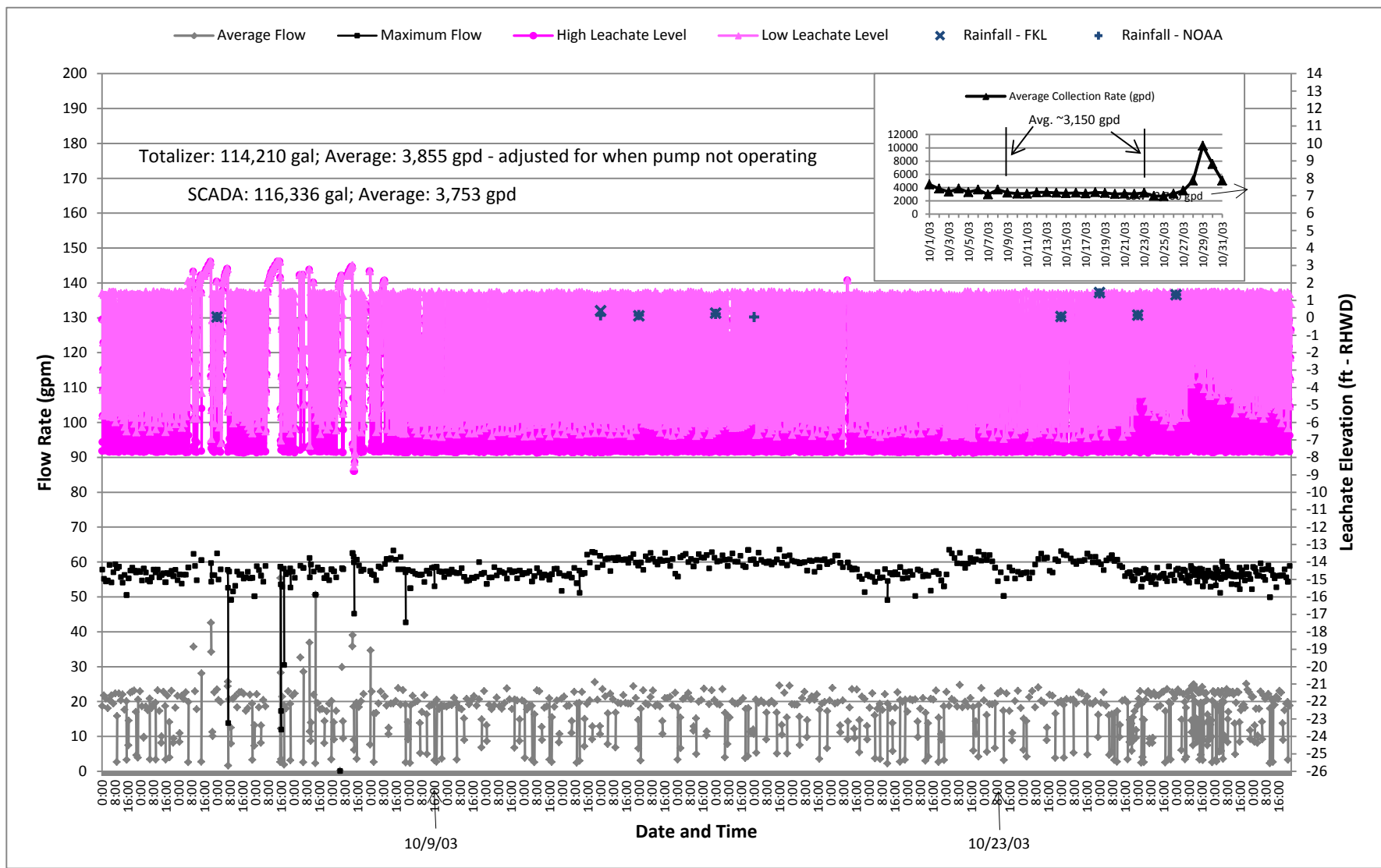
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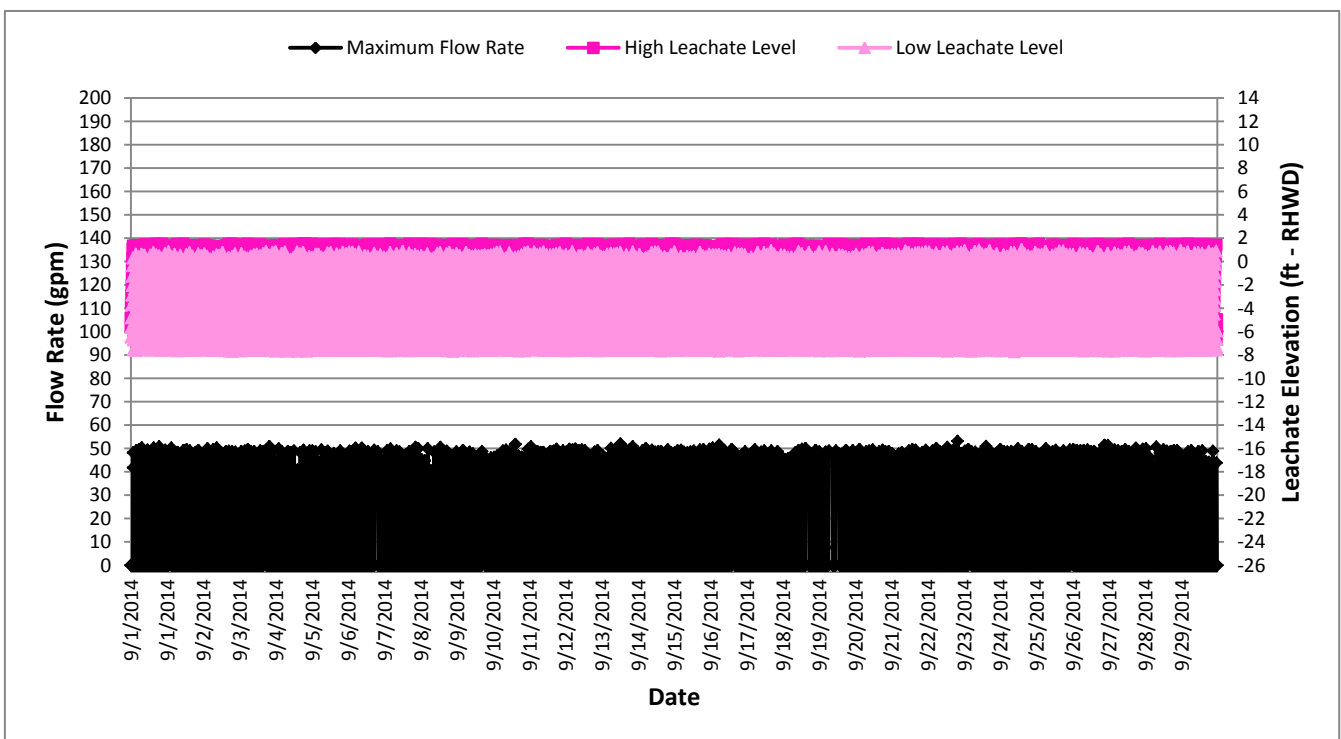
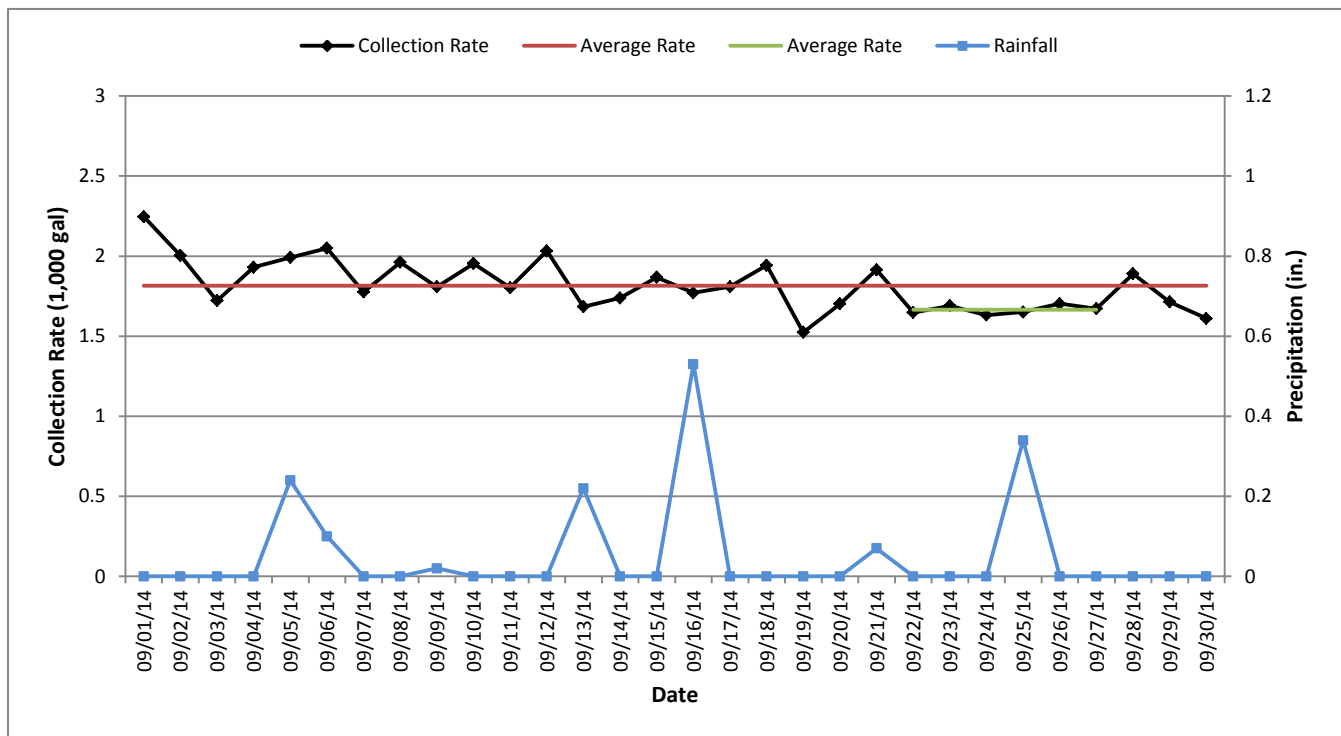
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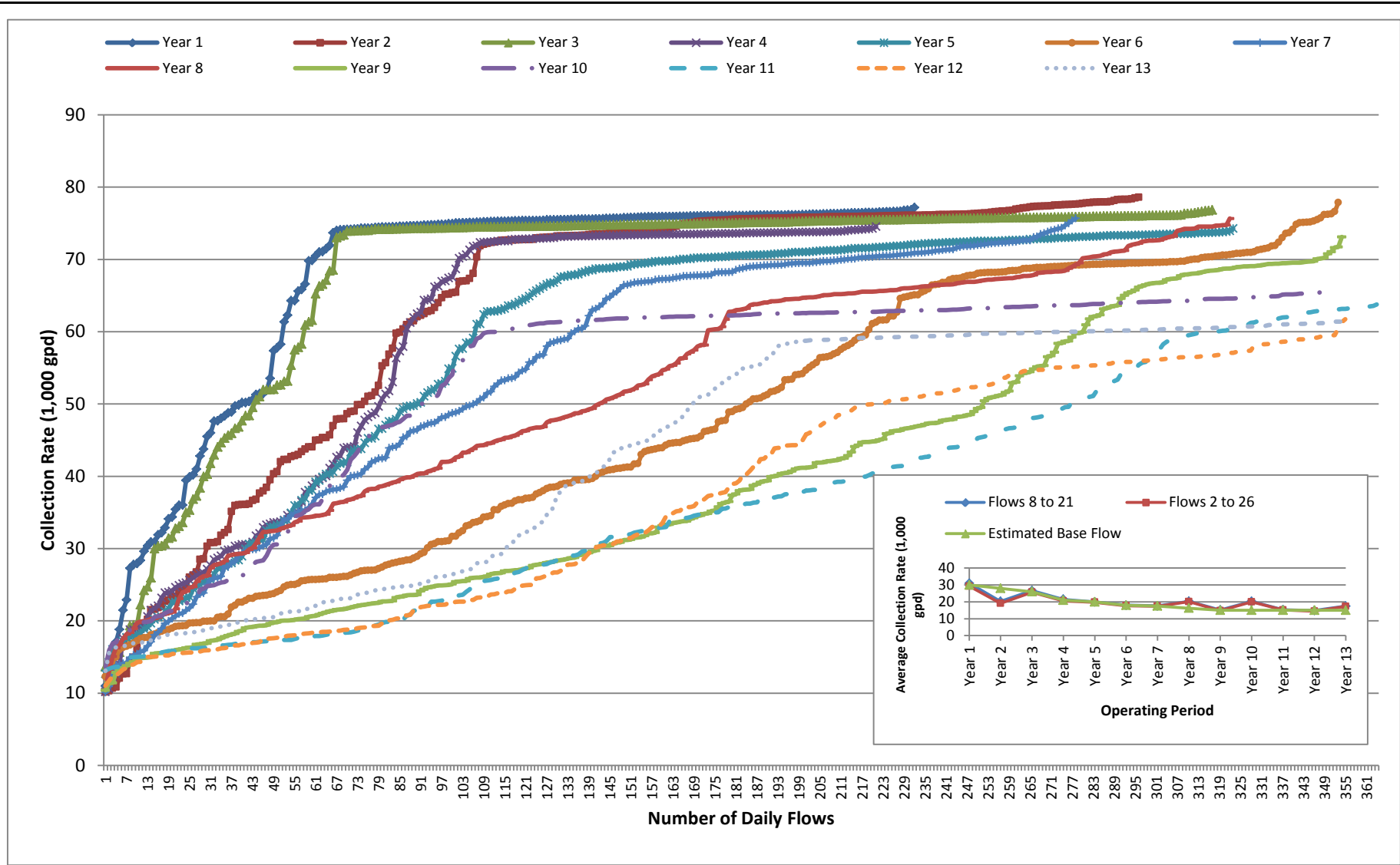
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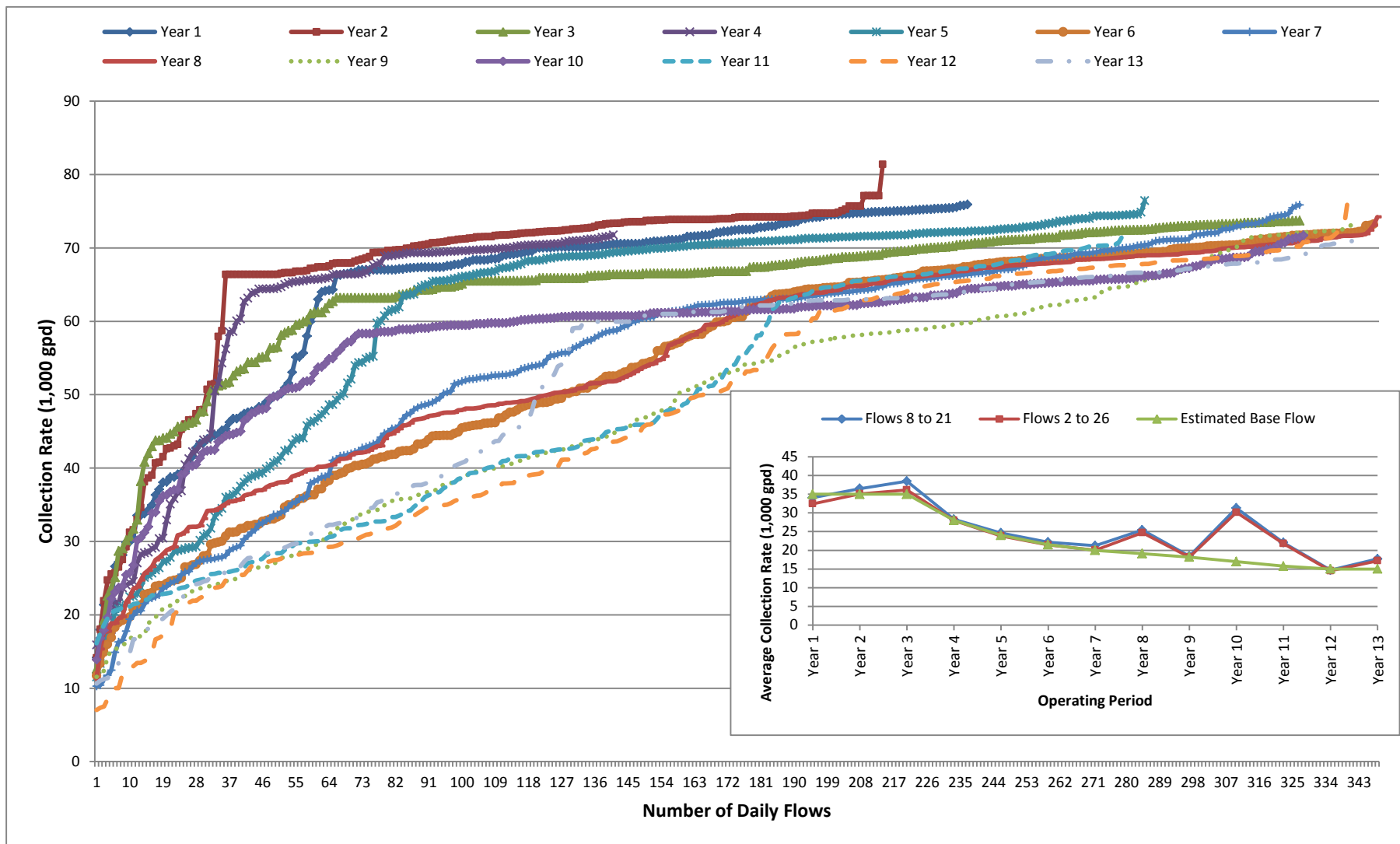
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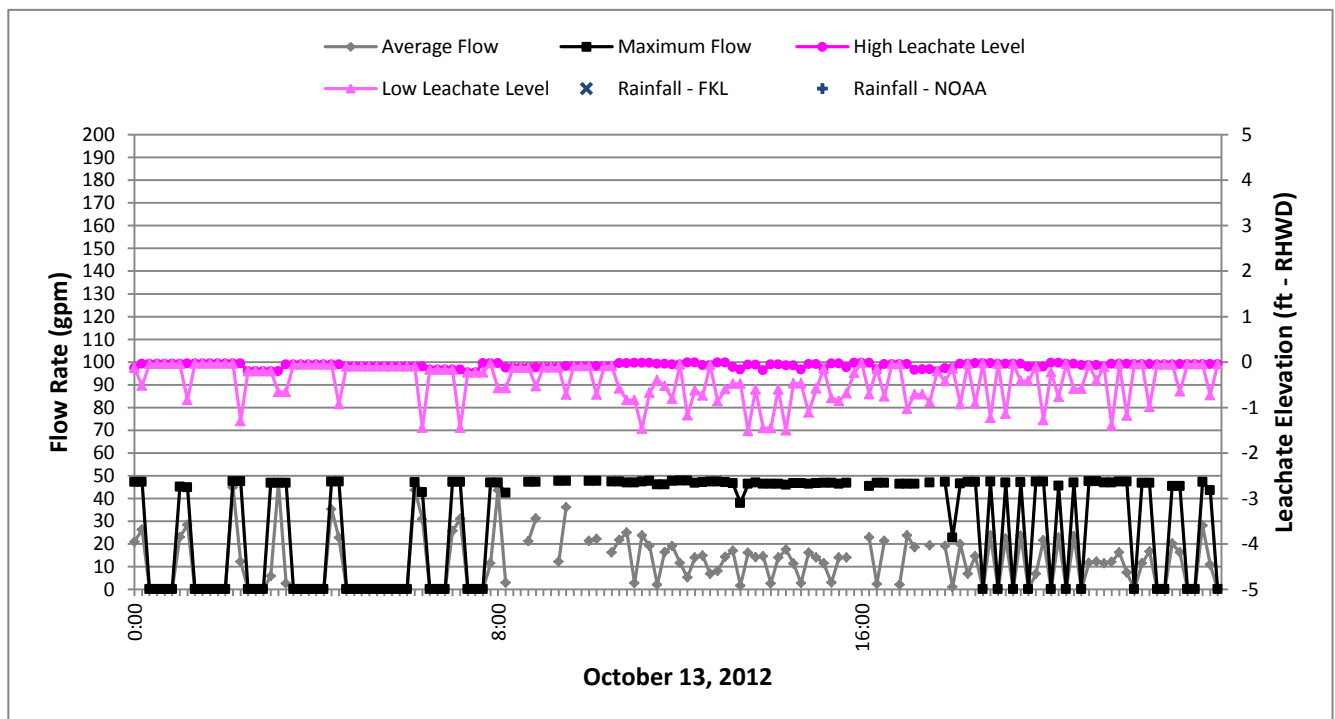
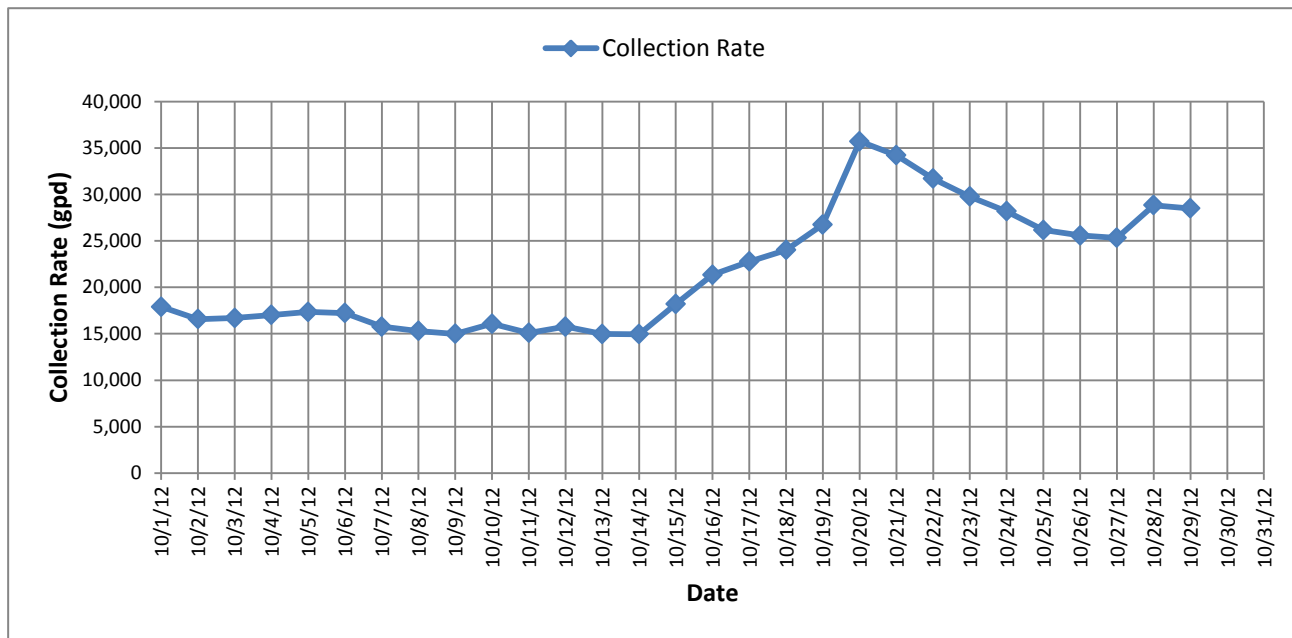
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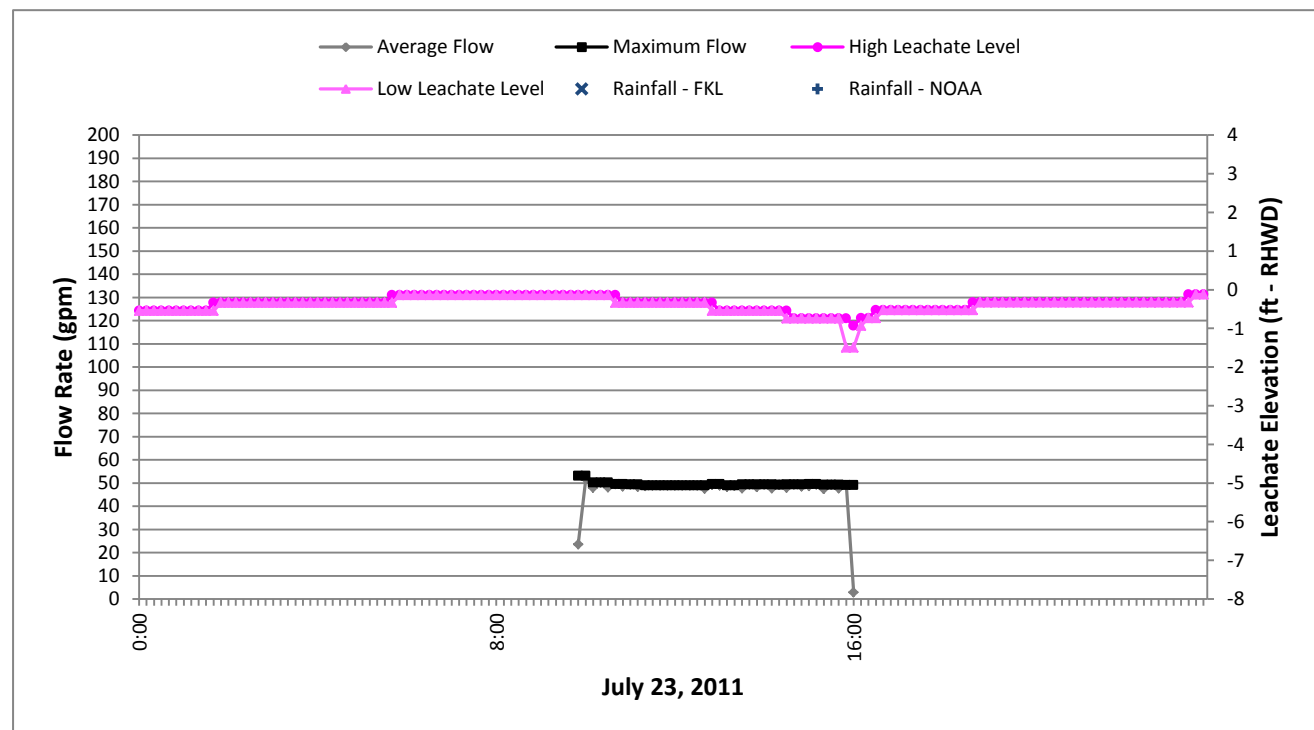
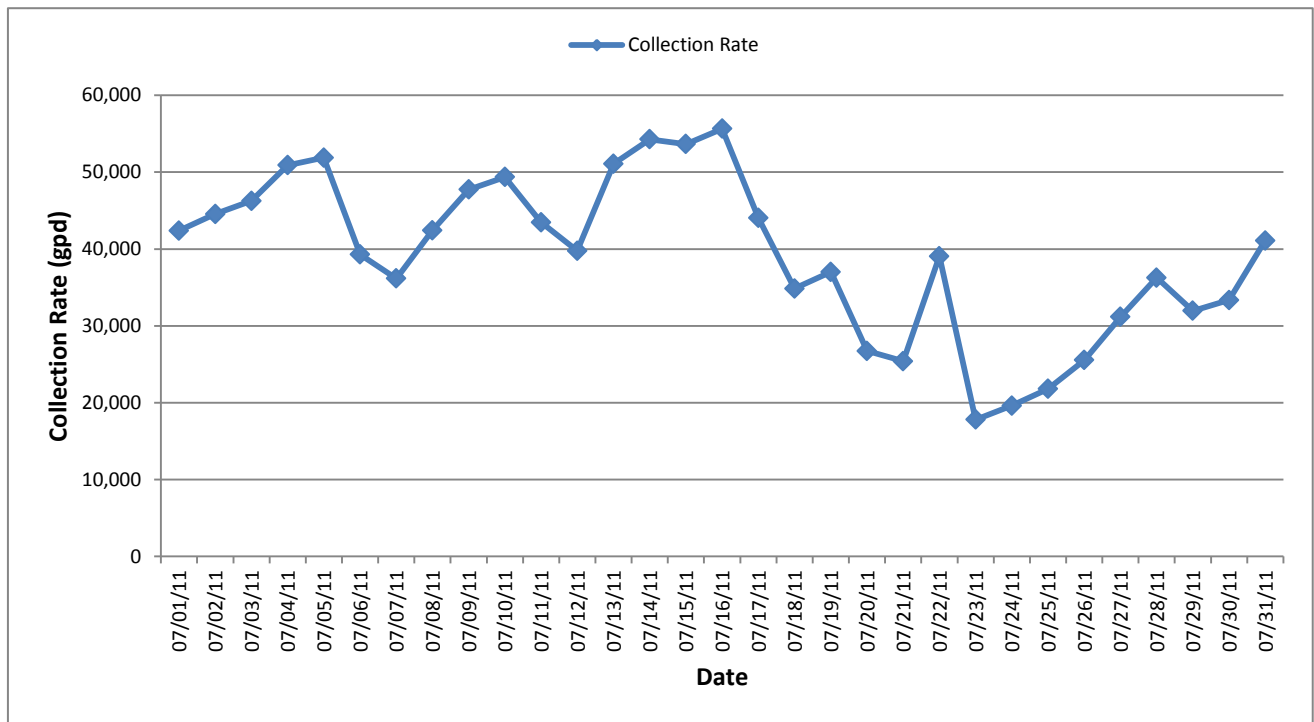
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4.0 Evaluation of Environmental Data

This chapter summarizes the environmental data collected at Fresh Kills Landfill applicable to the evaluation of the leachate controls at Landfill Section 2/8 and Landfill Section 3/4. Groundwater chemistry data is evaluated from shallow/refuse monitoring wells at Landfill Section 2/8 and Landfill Section 3/4 as they relate to the original collection drains, the supplemental collection drains, or the areas of each section for which there are no drains. Water level elevation data is presented and evaluated for select shallow/refuse monitoring wells contiguous to the original drains at Landfill Section 2/8 and Landfill Section 3/4. Surface water chemistry data is also presented for the creeks that border the landfill sections at Fresh Kills Landfill as well as for the smaller tributaries of those creeks.

4.1 Groundwater Chemistry

The shallow/refuse groundwater monitoring well array in Landfill Section 2/8 and Landfill Section 3/4 consists of wells installed at approximate 500-foot intervals around each landfill section. Figure 4.1-1 shows the location of the shallow/refuse groundwater monitoring wells in Landfill Section 2/8 and Landfill Section 3/4 which are addressed in this report. The majority of the groundwater monitoring wells that comprise the shallow/refuse groundwater monitoring array for the groundwater quality monitoring program were installed in 1991 and 1992 by IT Corporation as part of the hydrogeological investigation. One additional shallow/refuse groundwater monitoring well, 2W93:IT322S in Landfill Section 2/8, was installed by IT Corporation in 1993. Monitoring well AW90:AK13Z installed by Wehran as part of the Fresh Kills Ash/Residue Landfill project was incorporated as part of the shallow/refuse groundwater monitoring well array at Landfill Section 3/4.

The number of wells in the shallow/refuse groundwater monitoring well array in Landfill Section 2/8 and Landfill Section 3/4 has been reduced since monitoring has been performed under the EMP in 2003. The following wells have been removed from the groundwater monitoring well array and are not addressed in this report:

- Wells IT414S and IT418S were removed from the array in 2006 because these wells were historically dry.
- Wells IT415S and IT417S were removed from the array in 2007 because of the lack of accessibility to the wells as a result of the closure of Landfill Section 3/4 and the ability of other wells at the toe of slope sufficiently monitor this portion of the landfill.

Twenty-one additional wells were removed from the array in 2013 as approved by the NYSDEC based on the *Proposed Modification to the Shallow/Refuse Groundwater Monitoring Well Array*

Report (Shaw, 2011). The groundwater chemistry in these wells is addressed in this report based on data collected prior to their removal from the array:

- Nine shallow/refuse monitoring wells in Landfill Section 2/8 (IT303S, IT306S, IT316S, IT317S, IT319S, IT320S, IT321S, IT322S, and IT323S).
- Twelve shallow/refuse monitoring wells in Landfill Section 3/4 (AK13Z, IT401S, IT404S, IT408S, IT411S, IT412S, IT419S, IT420S, IT421S, IT427S, IT428S, and IT433S).

Currently, 20 monitoring wells in the shallow/refuse zone (10 in Landfill Section 2/8 and 10 in Landfill Section 3/4) are monitored during each 2-year period for a total of 69 leachate indicator, inorganic, and organic parameters. This group of wells is comprised of monitoring wells that are not contiguous to the leachate collection drains in Sections in 2/8 and 3/4 and monitor potential leachate impact in the shallow/refuse monitoring zone where no leachate control system has been constructed.

This section describes and evaluates the groundwater chemistry in the shallow/refuse zone as measured in the shallow/refuse groundwater monitoring wells based on the cumulative data for each of the wells that were part of the historical well array. In particular this section addresses the changes in groundwater composition at each of the shallow/refuse zone monitoring wells with respect to the leachate control at each Landfill Section. As such, the monitoring wells are grouped and evaluated as follows:

- Landfill Section 2/8 Original Drain
- Landfill Section 2/8 Supplemental Drain
- Landfill Section 2/8 Small Mound (North Mound) – No Drain
- Landfill Section 3/4 Original Drain
- Landfill Section 3/4 Supplemental Drain
- Landfill Section 3/4 Southern Perimeter – No Drain

In the following sections, the groundwater chemistry evaluation process is described followed by the evaluation of groundwater chemistry for Landfill Section 2/8 and Landfill Section 3/4.

4.1.1 Groundwater Chemistry Evaluation Approach

Groundwater quality monitoring analytical data are evaluated in several manners:

- Piper and Stiff diagrams
- Time series plots for select leachate indicator parameters
- Statistical trend analysis

Piper and Stiff diagrams directly address the groundwater composition at each well; the locations of the data on the Piper diagrams and the shapes of the Stiff diagrams distinguish between the water types seen at Fresh Kills Landfill, which are primarily leachate, seawater, and natural groundwater. Time-series plots address changes in other key leachate indicator parameters individually that are not directly represented in the Piper and Stiff diagrams. Statistical trend analyses evaluate each of the parameters monitored in the groundwater monitoring program and provide a broader description of changes in groundwater chemistry. Each of these approaches is described in more detail below:

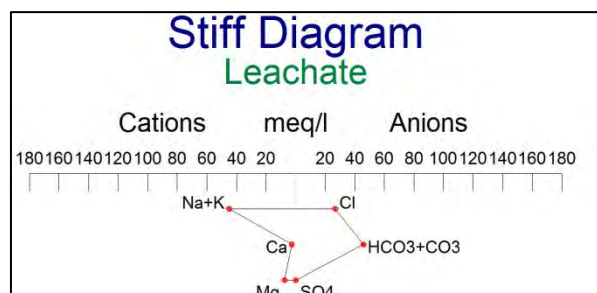
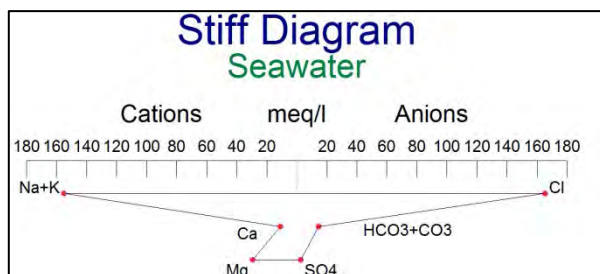
4.1.1.1 Piper and Stiff Diagrams

The proportions of many dissolved solutes in leachate and natural groundwater should be different because the composition of landfill waste and its associated geochemical relations are different than the mineral-water reactions in the underlying geologic materials. In general, groundwater that has mixed with seawater has a very typical sodium-chloride composition that is clearly discernible on the Piper and Stiff diagrams. Groundwater that shows evidence of leachate mixing has a distinctive sodium-bicarbonate composition, which is also evident on the Piper and Stiff diagrams.

A Stiff diagram is a type of plot that depicts water composition by shape recognition. The anions chloride, bicarbonate, and sulfate (Cl^- , HCO_3^- , and SO_4^{2-}) are plotted on the right side of the diagram, and the cations sodium, potassium, calcium, and magnesium (Na^+ , K^+ , Ca^{2+} , and Mg^{2+}) are plotted on the left side of the diagram. Stiff diagrams use absolute concentrations in meq/L; the concentrations are connected to form a closed polygon. The shape of the Stiff diagram reflects chemical composition and the size of the diagram reflects total dissolved solids when the scale remains constant.

The scale of the Stiff diagram is not normally adjusted or expanded for comparative analysis. This is because the distinctive shape of the diagram, including the lack of a distinct pattern due to very low total dissolved solids (TDS) (i.e., generally less than 1,000 mg/L), represents the fundamental basis for distinguishing between water types.

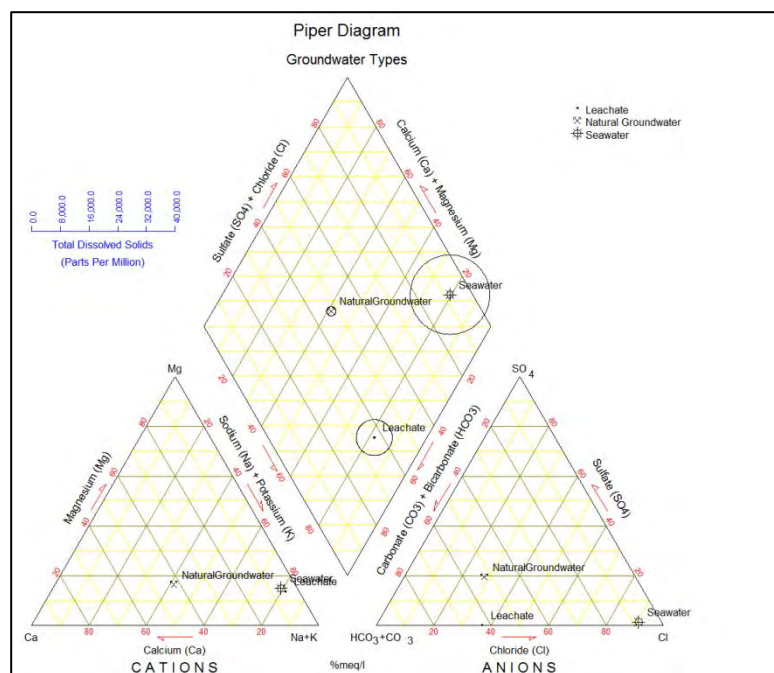
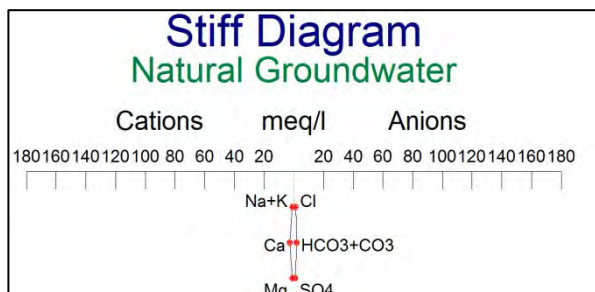
Leachate has a typical sodium-bicarbonate water composition that has a distinctive asymmetrical shape. Seawater has a sodium-chloride water



composition that has a distinctive T-shaped or “bird-like” outline. Both leachate and seawater

have high TDS compared to native groundwater; therefore, native groundwater is identified by its lack of definition (i.e., thin line shape).

A Piper diagram consists of three separate diagrams that form a large triangle (see example figure below). The relative abundance of cations (Na^+ , K^+ , Ca^{2+} , and Mg^{2+}) in percentage milliequivalents per liter (meq/L) is plotted on the lower left triangle. The relative abundance of



The relative abundance of anions (Cl^- , HCO_3^- , and SO_4^{2-}) in percentage meq/L is plotted on the lower right triangle. Straight lines projected from the triangles into the central diamond define the position of a point that reflects overall water composition. The size of the circle surrounding each data point in the central diamond is proportional to TDS of the individual groundwater samples.

Piper diagrams are useful for interpreting individual water compositions and mixtures of compositions. Typically, leachate

will plot near the bottom of the central diamond (sodium-bicarbonate water composition), and seawater will plot near the right corner of the central diamond (sodium-chloride water composition). Groundwater not showing leachate or seawater influence is variable depending on the mineral composition of the monitoring zone and generally plots in the left central area of the central diamond.

Piper and Stiff diagrams are presented in figures for each shallow/refuse zone monitoring well evaluated in this section. Data from each year of monitoring for which sufficient and usable data was obtained is plotted on the Piper and Stiff diagrams for each well. Where the Piper diagrams are difficult to assess due to the numerous sample points presented, a second figure is also presented for the monitoring well with fewer (usually five) data points presented to better illustrate the trends in groundwater chemistry.

4.1.1.2 *Time-Series Plots*

Ammonia, boron, and total dissolved solids are three parameters that are used to indicate leachate influence at Fresh Kills Landfill. Time series plots for these parameters are evaluated for each of the shallow/refuse zone monitoring wells in Landfill Sections 2/8 and 3/4. Time-series plots are presented for separately for each parameter as well as for each well grouping as described in Section 4.1.

4.1.1.3 *Statistical Trend Analysis*

Trends in groundwater chemistry data at Fresh Kills Landfill are evaluated by the Mann-Kendall test for trend. The Mann-Kendall test for trend was used to determine if an analyte shows a statistically significant trend in concentration or value at a specific well location. Mann-Kendall tests for trend were performed at the 99 percent confidence level on the data and were used to evaluate data from two periods:

- The cumulative period - 1991 through the most recent monitoring period.
- The post-closure period - 1998 through the most recent monitoring period.

The cumulative period shows trends beginning before the installation of final cover and/or drains. The post-closure period shows trends since the completion of final cover and/or drain installation.

The tables provided in this section present the results of the Mann-Kendall for the parameters currently assessed in the groundwater monitoring program. Results are presented by the monitoring well groupings described in Section 4.1. The most recent monitoring period for which data is assessed for individual monitoring wells is provided in the applicable tables.

4.1.2 *Landfill Section 2/8*

The evaluation of groundwater chemistry at Landfill Section 2/8 is presented in three well groupings:

- Wells associated with the Original Leachate Collection Drain (as well as the extensions) constructed along the southern side of Landfill Section 2/8.
- Wells associated with the Supplemental Leachate Collection Drain constructed along the eastern boundary of Landfill Section 2/8 along Richmond Creek.
- Wells within the Small Mound (North Mound) which are not associated with perimeter drains.

4.1.2.1 *Landfill Section 2/8 – Original Leachate Collection Drain*

Eight shallow/refuse monitoring wells are present in the monitoring well array in Landfill Section 2/8 within the area of the original drain and its extensions (Figure 4.1-1). These include monitoring wells IT308S and IT324S which are located just northwest of the extent of the collection drain, monitoring wells IT323S, IT322S, and IT320S which are located along the collection drain on the interior side of the collection drain, and monitoring wells IT306S, IT321S, and IT319S which are located along the collection drain on the exterior side of the collection drain.

Piper and Stiff diagrams are shown in Figure 4.1-2 through Figure 4.1-9 for the shallow/refuse zone monitoring wells associated with the original drain.

Monitoring well IT324S, which is located south of the western extent of the original drain plots in the upper-left portion of the Piper diagram (Figure 4.1-2) which is usually associated with natural groundwater. The shape of the Stiff diagrams for this well shows a lack of a distinct pattern due to very low TDS (i.e., generally less than 1,000 mg/L), which is also indicative of natural groundwater. The Piper and Stiff diagrams for monitoring well IT324S are most-representative of groundwater that does not show leachate or seawater influence and can be used for comparison to the Piper and Stiff diagrams for the other monitoring wells to determine groundwater characteristics.

Monitoring well IT320S, sampled from 1992 through 1998, plots in the lower portion of the Piper diagram (Figure 4.1-3) indicating a leachate composition. The plots show decreasing sizes (lower TDS) indicating decreasing leachate concentration. This is also reflected in the Stiff diagrams which exhibit a distinctive leachate shape with decreasing size.

Monitoring wells IT322S plots mostly in the central portion of the Piper diagram (Figure 4.1-4) which is non-conclusive or indicative of mixed types. IT322S is located on the interior side of the collection drain well within the extent of the final cover and is, therefore, not affected by precipitation. The Stiff diagrams for IT322S show a leachate mixing shape throughout the cumulative period with a relatively constant size consistent with its location interior to the drain and within the extent of the final cover. The lack of temporal variation in the Piper and Stiff diagrams is expected based on the location of the monitoring well; even though the volume of leachate is reduced, the concentration of leachate is expected to remain consistent since the well is isolated from other groundwater inputs (e.g., precipitation) that would affect the concentrations.

Monitoring wells IT323S and IT321S plot mostly in the central portion of the Piper diagram (Figure 4.1-5 and Figure 4.1-6) which is non-conclusive or indicative of mixed-water types; IT323S is located on the interior side of the collection drain and IT321S is located on the exterior

side of the collection drain. The Stiff diagrams for IT323S and IT321S show a leachate mixing shape (sodium-bicarbonate composition) during the pre-closure period changing to a calcium-bicarbonate composition shape (indicative of more natural groundwater influence) during the construction of final cover and through the most recent monitoring periods. The size of the Stiff diagrams decreases during these periods indicating a reduction in concentration. Few samples were collected from IT323S during the post-closure period due to insufficient groundwater because of the wells close proximity to the collection drain.

Monitoring well IT308S, which is located just northwest of the extent of the original drain, and monitoring wells IT306S and IT319S, which are located on the exterior side of the original drain plot to the left-central or upper portion of the Piper diagram (Figure 4.17 through Figure 4.1-9, respectively) representative of more natural groundwater. The shapes of the Stiff diagrams for these wells are also not indicative of leachate. In particular, the Stiff diagrams for IT306S lack a distinctive shape indicative of natural groundwater throughout the entire monitoring period. The shapes of the Stiff diagrams for IT308S and IT319S, though of different composition, show a decrease in size (i.e., decrease in TDS) indicating a reduction in concentration.

Time series plots for ammonia, boron, and total dissolved solids are shown in Figure 4.1-10 through Figure 4.1-12, respectively, for the shallow/refuse zone monitoring wells associated with the original collection drain. In general, concentrations of these leachate indicator parameters decreased or remained relatively constant at most wells. The individual parameters and wells are discussed below:

Pre-closure concentrations of ammonia were greater than 100 mg/L at IT323S, IT321S, and IT320S while pre-closure concentrations were between 10 mg/L and 100 mg/L at IT308S and IT322S. The remaining three wells (IT306S, IT319S, and IT324S) showed low levels of ammonia (<10 mg/L). Ammonia concentrations decreased at IT308S and IT321S to below 10 mg/L whereas the concentrations at IT323S decreased to slightly above 10 mg/L. Concentrations at IT322S remained relatively consistent. It should be noted that both IT323S and IT322S are both located on the interior side of the collection drain; in particular, IT322S is located well within the extent of the final cover and is, therefore, not affected by precipitation. The ammonia concentrations at IT320S decreased to less than half its initial concentrations through 1998 when sampling was no longer possible due to insufficient water in the well. Concentrations at IT306S, IT319S, and IT324S remained relatively consistent with low concentrations about 1 mg/L or less.

Pre-closure concentrations of boron were elevated (4 mg/L) at IT320S; concentrations of boron decreased to less than 3 mg/L through 1998 when sampling was no longer possible due to insufficient water in the well. Boron concentrations in the other wells were less than 2 mg/L and have generally decreased.

Total dissolved solids concentrations exhibited decreasing concentrations in most wells associated with the original drain, indicating a reduction in any leachate concentrations. A statistically significant increase was noted, however, at IT322S which is located on the interior side of the collection drain. Due to its location well within the extent of the final cover, this increase is not unexpected since inputs to groundwater (e.g., precipitation) have been reduced or eliminated in the area of IT322S.

As described above, the time-series plots for ammonia, boron, and TDS at the wells associated with the original drain at Landfill Section 2/8 show decreases in these typical leachate indicator parameters and are consistent with the assessment of changes in groundwater composition as described by the Piper and Stiff diagrams.

Sixty-nine parameters were evaluated at the seven shallow/refuse monitoring zone associated with the original drain at Landfill Section 2/8 to determine the presence of statistically significant trends in concentration or values. The statistically significant trends identified are presented in Table 4.1-1 and are summarized below:

- Of the 60 statistically significant trends identified the majority (43 or 72%) show decreasing concentrations.
- No statistically significant increasing trends were indicated for organic parameters.
- Most of the statistically significant increasing trends (65%) were for non-leachate indicator inorganic parameters and represent changes in composition related to decreasing concentrations of leachate and greater proportions of natural groundwater.
- Statistically significant increasing trends for Part 360 leachate indicator parameters were indicated in two of the seven wells (IT306S and IT322S).
- Since the concentrations of ammonia at IT306S are consistently about 1 mg/L and below the groundwater standard of 2 mg/L, the statistically significant increase in ammonia concentrations indicated by the Mann-Kendall test is not significant since it is not indicative of leachate influence.
- The statistically significant increasing trends at IT322S for the Part 360 leachate indicator parameters chemical oxygen demand, chloride, TDS, and hardness are likely due the location of IT322S on the interior side of the collection drain and well within the extent of the final cover where there is little dilution affect expected from precipitation.

The Piper and Stiff diagrams, time-series plots, and statistical trend analyses, as described above, indicate decreasing leachate concentrations in most wells. The few exceptions (e.g., IT322S) are expected based on the location of the monitoring wells in relation to the collection drain and the final cover.

4.1.2.2 *Landfill Section 2/8 – Supplemental Leachate Collection Drain*

Five shallow/refuse monitoring wells are present in the monitoring well array in Landfill Section 2/8 within the area of the supplemental collection drain located to the east parallel to Richmond Creek (Figure 4.1-1). These include monitoring wells IT315S and IT318S which are located just northwest and south, respectively, of the extent of the supplemental drain, monitoring well IT303S which is located along the supplemental drain on the interior side of the drain, and monitoring wells IT316S and IT317S which are located along the supplemental drain on the exterior side of the drain.

Piper and Stiff diagrams are shown in Figure 4.1-13 through Figure 4.1-17 for the shallow/refuse zone monitoring wells associated with the Supplemental Leachate Drain.

Monitoring wells IT315S, IT317S, and IT318S plot in the lower portion of the Piper diagram (indicative of leachate) during the pre-closure period. They show both decreased size and a trend to the left and central portion of the Piper diagram in the post-closure period. This indicates increased natural groundwater (Figure 4.1-13 through Figure 4.1-15, respectively). The Stiff diagrams also show a distinctive leachate shape changing to a smaller non-descript shape which is more indicative of dilute natural groundwater. These changes are apparent with the completion of final cover and appear to accelerate with the installation of the supplemental collection drains.

Monitoring well IT303S, which is located on the interior side of the collection drain, plots mostly in the lower portion of the Piper diagram (Figure 4.1-16), indicative of leachate, throughout the cumulative monitoring period. The shape of the Stiff diagrams for this well is also indicative of leachate composition. The Stiff diagrams exhibit a slight decrease in size through the monitoring period, indicating slight decreases in concentration.

Monitoring well IT316S plots in the lower portion of the Piper diagram (Figure 4.1-17), indicative of leachate composition, during the period 1992 through 1995. It plots in the left and central portion with smaller size during the period 1996 through 2001 during the completion of final cover, indicative of dilute groundwater and decreased leachate concentrations. It plots to the right of the Piper diagram with greater size during the period of 2002 to 2012 following the completion of supplemental drains indicating seawater mixing.

Time series plots for ammonia, boron, and total dissolved solids are shown in Figure 4.1-18 through Figure 4.1-20, respectively, for the shallow/refuse zone monitoring wells associated with the supplemental drain. In general, concentrations of these leachate indicator parameters decrease or remained relatively constant at most wells. The individual parameters and wells are discussed below:

Pre-corrective measures concentrations of ammonia were greater than 100 mg/L at all five wells. Ammonia concentrations decreased at two of these wells (IT315S and IT317S) to below 10 mg/L and at one well (IT316S) to slightly above 10 mg/L. Ammonia concentrations at IT318S also decreased to about 30 mg/L. Concentrations at IT303S, located on the interior side of the collection drain, decreased somewhat but remained above 100 mg/L.

Pre-corrective measures concentrations of boron were elevated (4-6 mg/L) at all five wells. Concentrations of boron decreased to approximately 1 mg/L or less in four of the five wells. Concentrations of boron at IT303S, located on the interior side of the collection drain, decreased but remained elevated (3-4 mg/L).

Pre-corrective measures concentrations of total dissolved solids (TDS) were between 1000 mg/L and 6000 mg/L. TDS concentrations in three of the five wells decreased to below 1000 mg/L. The TDS concentration in monitoring well IT303S, located on the interior side of the collection drain, remained relatively constant. The TDS concentration at monitoring well IT316S, located on the exterior side of the collection drain, showed an increase beginning around 2002 at the time of the completion of the supplemental control drains to approximately 10,000 mg/L, likely due to increased seawater influence.

As described above, the time-series plots for ammonia, boron, and TDS at the wells associated with the supplemental drain at Landfill Section 2/8 show decreases in these typical leachate indicator parameters and are consistent with the groundwater composition seen in the Piper and Stiff diagrams.

Sixty-nine parameters at five shallow/refuse monitoring zone associated with the supplemental drain at Landfill Section 2/8 were evaluated to determine the presence of statistically significant trends in concentration or values. The statistically significant trends identified are presented in Table 4.1-2 and are summarized below:

- Of the 109 statistically significant trends identified the majority (92 or 84%) show decreasing concentrations.
- No statistically significant increasing trends were indicated for organic parameters.
- Most of the statistically significant increasing trends (65%) were for inorganic parameters not identified as Part 360 leachate indicator parameters and represent changes in composition related to decreasing concentrations of leachate and greater proportions of natural groundwater or seawater.
- Statistically significant increasing trends for Part 360 leachate indicator parameters were indicated in three of the five wells (IT315S, IT316S, and IT318S). These increases are likely due to increases in suspended solids during sample collection (turbidity at IT315S

and IT316S) or increases in seawater concentrations (hardness at IT316S and sulfate at IT318S).

The Piper and Stiff diagrams, time-series plots, and statistical trend analyses, as described above, indicate decreasing leachate concentrations in most wells. The few exceptions (e.g., IT303S and IT316S) are expected based on the location of these monitoring wells in relation to the supplemental drain.

4.1.2.3 *Landfill Section 2/8 – Small Mound (North Mound) – No Drains*

A total of five shallow/refuse monitoring wells are present in the monitoring well array in Landfill Section 2/8 within the Small Mound (North Mound) located in the northwest portion of Landfill Section 2/8 (Figure 4.1-1); there are no collection drains located in the Small Mound. The monitoring wells located on the Small Mound include monitoring wells IT301S, IT302S, IT312S, IT313S, and IT325S.

Piper and Stiff diagrams are shown in Figure 4.1-21 through Figure 4.1-25 for the shallow/refuse zone monitoring wells associated with the Small Mound.

Monitoring wells IT301S and IT312S plot in the lower portion of the Piper diagram (Figure 4.1-21 and Figure 4.1-22, respectively), indicative of leachate composition, throughout the cumulative monitoring period. The Stiff diagrams exhibit a distinctive leachate shape with a similar size throughout the monitoring period indicating consistent concentrations.

Monitoring wells IT313S and IT325S plot slightly more towards center than IT301S and IT312S on the Piper diagram (Figure 4.1-23 and Figure 4.1-24, respectively), indicative of lower leachate concentrations, throughout the cumulative monitoring period and show a slight decrease. The shape of the Stiff diagrams, though not of a distinctive leachate shape, are also suggestive of lower concentrations.

Monitoring well IT302S plots in the left-central portion of the Piper diagram (Figure 4.1-25), not indicative of leachate, throughout the cumulative monitoring period. The Stiff diagrams exhibit a non-distinct non-leachate shape with a slight decrease in size through the monitoring period.

Time series plots for ammonia, boron, and total dissolved solids are shown in Figure 4.1-26 through Figure 4.1-28, respectively, for the shallow/refuse zone monitoring wells associated with the Small Mound. In general, concentrations of these leachate indicator parameters decreased or remained relatively constant at most wells; the individual parameters and wells are discussed below:

Pre-closure concentrations of ammonia were greater than 100 mg/L at all four of the five wells, and concentrations of ammonia at IT302S were somewhat lower (50-80 mg/L). Ammonia

concentrations decreased at monitoring well IT302S to below 10 mg/L whereas the concentrations at IT312S, IT313S, and IT325S decreased to less than 100 mg/L. Concentrations at IT301S decreased somewhat but remained above 100 mg/L.

Pre-closure concentrations of boron were elevated (2-9 mg/L) at all five wells. Concentrations of boron decreased somewhat but still remained elevated (1-6 mg/L).

Pre-corrective measures concentrations of total dissolved solids (TDS) were between 1000 mg/L and 4000 mg/L. TDS concentrations remained relatively constant in all five wells.

As described above, the time-series plots for ammonia, boron, and TDS at the wells associated with the Small Mound at Landfill Section 2/8 show either decreases in these typical leachate indicator parameters or relatively constant concentrations. They are consistent with changes in groundwater composition as seen in the Piper and Stiff diagrams.

Sixty-nine parameters at five shallow/refuse monitoring zone associated with the Small Mound at Landfill Section 2/8 were evaluated to determine the presence of statistically significant trends in concentration or values. The statistically significant trends identified are presented in Table 4.1-3 and are summarized below:

- Of the 37 statistically significant trends identified the majority (31 or 84%) show decreasing concentrations.
- No statistically significant increasing trends were indicated for organic parameters.
- Most of the statistically significant increasing trends (83%) were for inorganic parameters not identified as Part 360 leachate indicator parameters. These represent changes in groundwater composition related to decreasing concentrations of leachate and greater proportions of natural groundwater.
- A statistically significant increasing trend for a Part 360 leachate indicator parameter was indicated in one well (turbidity at IT325S). This increase is likely due to increases in suspended solids during sample collection.

The Piper and Stiff diagrams, time-series plots, and statistical trend analyses, as described above, indicate decreasing leachate concentrations in most wells.

4.1.3 Landfill Section 3/4

The evaluation of groundwater chemistry at Landfill Section 3/4 is presented in three well groupings:

- Wells associated with the Original Leachate Collection Drain constructed along the western side of Landfill Section 3/4.

- Wells associated with the Supplemental Leachate Collection Drain constructed along the eastern boundary of Landfill Section 3/4 along Main Creek.
- Wells along the southern perimeter of Landfill Section 3/4 not associated with any leachate collection drains.

4.1.3.1 *Landfill Section 3/4 – Original Leachate Collection Drain*

Seven shallow/refuse monitoring wells are present in the monitoring well array in Landfill Section 3/4 within the area of the original drain (Figure 4.1-1). These include monitoring wells IT413S which is located just northeast of the extent of the collection drain, monitoring wells IT427S, IT428S, IT408S, and IT401S which are located along the interior side of the collection drain, and monitoring wells IT411S and IT412S which are located along the exterior side of the collection drain.

Piper and Stiff diagrams are shown in Figure 4.1-29 through Figure 4.1-35 for the shallow/refuse zone monitoring wells associated with the original drain at Landfill Section 3/4.

Monitoring well IT427S plots in the lower portion of the Piper diagram (Figure 4.1-29) indicative of leachate for the period 1992 through 2002; no sample has been collected since 2002 because of insufficient groundwater in the well due to its close proximity to the collection drain. The plots show decreasing sizes (lower TDS) indicating decreasing leachate concentrations. This is also reflected in the Stiff diagrams which exhibit a distinctive leachate shape with decreasing size.

Monitoring well IT413S plots in the lower portion of the Piper diagram (Figure 4.1-30) indicative of leachate for the period 1992 through 1997 and in the left portion of the Piper diagram indicative of less leachate and more natural groundwater in 2004 which was the last period for which sampling was possible; since 2004, groundwater was insufficient in the well for sampling. The plots show decreasing sizes (lower TDS) indicating decreasing leachate contributions. This is also reflected in the Stiff diagrams which exhibit a distinctive leachate shape with decreasing size during the pre-closure period and an indistinct non-leachate shape in 2004.

Monitoring well IT428S plots in the lower portion of the Piper diagram (Figure 4.1-31), indicative of leachate, throughout the cumulative monitoring period. The Stiff diagrams exhibit a distinctive leachate shape throughout the monitoring period. Both the Piper diagram and Stiff diagrams show decreasing sizes (lower TDS) indicating decreasing leachate concentrations.

Monitoring wells IT408S, IT401S, IT411S, and IT412S plot mostly in the lower portion of the Piper diagram (Figure 4.1-32 through Figure 4.1-35, respectively), indicative of leachate, through most of the cumulative monitoring period. The recent data for each of these wells plot

in central portion of the Piper diagram which indicating decreased leachate concentrations. The Stiff diagrams exhibit a distinctive leachate shape with decreasing size during most of the cumulative monitoring period with the recent data showing an indistinct non-leachate shape.

Time series plots for ammonia, boron, and total dissolved solids are shown in Figure 4.1-36 through Figure 4.1-38, respectively, for the shallow/refuse zone monitoring wells associated with the original drain at Landfill Section 3/4. In general, concentrations of these leachate indicator parameters decreased at most wells; the individual parameters and wells are discussed below:

Pre-closure concentrations of ammonia were greater than 100 mg/L at the seven wells associated with the original drain. Ammonia concentrations decreased in all wells but remained elevated at IT427S, IT428S, and IT408S; these wells are located on the interior side of the collection drain.

Pre-closure concentrations of boron (2-7 mg/L) were elevated at all seven wells. Concentrations of boron decreased in all wells. The highest boron concentrations in the post-closure period are present at the wells located on the interior side of the collection drain (IT427S, IT428S, and IT408S).

Total dissolved solids concentrations exhibited decreasing concentrations in the seven wells associated with the original drain indicating a reduction in leachate concentrations. Pre-closure concentrations (2,000-8,000 mg/L) decreased to less than 2000 mg/L in all wells with the exception of IT427S where the TDS concentration decreased to about half its initial level through 2002 when sampling was no longer possible due to insufficient water in the well related to its close proximity to the collection drain.

As described above, the time-series plots for ammonia, boron, and TDS at the wells associated with the original drain at Landfill Section 3/4 show decreases in these typical leachate indicator parameters and are consistent with the changes in groundwater composition seen in the Piper and Stiff diagrams.

Sixty-nine parameters were evaluated at five shallow/refuse monitoring zone wells associated with the original drain at Landfill Section 3/4 to determine the presence of statistically significant trends in concentration or values. The statistically significant trends identified are presented in Table 4.1-4. The assessment of the results presented in the table provides the following observations:

- Of the 126 statistically significant trends identified, the majority (113 or 90%) show decreasing concentrations.
- No statistically significant increasing trends were indicated for organic parameters.

- Most of the statistically significant increasing trends (69%) were for inorganic parameters not identified as Part 360 leachate indicator parameters and represent changes in composition related to decreasing concentrations of leachate and greater proportions of natural groundwater or seawater.
- Statistically significant increasing trends for Part 360 leachate indicator parameters were indicated in three of the five wells (IT428S, IT411S, and IT412S). These increases (i.e., turbidity and sulfate) are likely due to increases in suspended solids or increases in seawater concentrations.

The Piper and Stiff diagrams, time-series plots, and statistical trend analyses, as described above, indicate decreasing leachate concentrations in all wells associated with the original collection drain at Landfill Section 3/4.

4.1.3.2 Landfill Section 3/4 – Supplemental Leachate Collection Drain

A total of seven shallow/refuse monitoring wells are present in the monitoring well array in Landfill Section 3/4 within the area of the supplemental drain located to the east parallel to Main Creek (Figure 4.1-1). These include monitoring wells IT403S and IT422S which are located just north and south, respectively, of the extent of the supplemental drain, monitoring wells IT420S and IT404S which are located the interior side of the collection drain, and monitoring wells IT419S, IT421S, and IT433S which are located along the exterior side of the collection drain.

Piper and Stiff diagrams are shown in Figure 4.1-39 through Figure 4.1-45 for the shallow/refuse zone monitoring wells associated with the supplemental drain.

Monitoring wells IT404S and IT422S plot in the lower and lower portion of the Piper diagram (Figure 4.1-39 and Figure 4.1-40), indicative of leachate, throughout the cumulative monitoring period. The Stiff diagrams exhibit a distinctive leachate shape with a generally similar size throughout the monitoring period.

Monitoring wells IT403S, IT419S, and IT420S plot in the lower portion of the Piper diagrams (Figure 4.1-41 through Figure 4.1-43) during the earlier years of monitoring, indicative of leachate influence, and migrate up and to the left during later years indicating decreases in leachate influence. The shape of the Stiff diagrams display a distinctive leachate shape during the pre-closure period and a smaller size and shape during the post-closure period representing a more dilute and non-leachate influenced groundwater.

Monitoring wells IT421S and IT433S plot in the lower portion of the Piper diagram, indicative of leachate, during the period 1992 through 1999, they plot in the left and central portion with smaller size during the period 2000 through 2001 indicative of a more dilute and non-leachate groundwater, and they plot to the right of the Piper diagram with greater size during the period of

2002 to 2012 indicative of seawater mixing. The Stiff diagrams show a distinctive leachate shape, indistinct non-leachate groundwater shape, and seawater shape during these same periods.

Time-series plots for ammonia, boron, and total dissolved solids are shown in Figure 4.1-46 through Figure 4.1-48, respectively, for the shallow/refuse zone monitoring wells associated with the supplemental drain at Landfill Section 3/4. In general, concentrations of these leachate indicator parameters remained decreased or remained relatively constant at most wells; the individual parameters and wells are discussed below:

Pre-closure concentrations of ammonia were greater than 100 mg/L at all seven wells. Ammonia concentrations decreased in all monitoring wells, though concentrations at IT404S and IT422S decreased remained above 100 mg/L.

Pre-closure concentrations of boron (3-7 mg/L) were elevated at all seven wells. Concentrations of boron decreased in six of the seven wells; the concentration of boron in IT422S, which is located south of the extent of the supplemental drain, remained relatively constant.

Pre-closure concentrations of total dissolved solids (TDS) were between 2000 mg/L and 6000 mg/L. TDS concentrations remained relatively constant in two wells (IT422S and IT404S which are located south of the extent of and on the interior side of the supplemental drain, respectively), decreased in three wells (IT403S, IT419S, and IT420S), and increased in two wells (IT433S and IT421S which are both located exterior to the supplemental drain).

As described above, the time-series plots for ammonia, boron, and TDS at the wells associated with the supplemental drain at Landfill Section 3/4 show decreases in these typical leachate indicator parameters for most wells or increases due to greater seawater concentrations; these are consistent with the assessment of changes in groundwater composition as described by the Piper and Stiff diagrams.

Sixty-nine parameters at seven shallow/refuse monitoring zone wells associated with the supplemental drain at Landfill Section 3/4 were evaluated to determine the presence of statistically significant trends in concentrations or values. The statistically significant trends identified are presented in Table 4.1-5 and are summarized below:

- Of the 121 statistically significant trends identified, the majority (105 or 87%) show decreasing concentrations.
- No statistically significant increasing trends were indicated for organic parameters.
- Most of the statistically significant increasing trends (69%) were for inorganic parameters not identified as Part 360 leachate indicator parameters and represent changes in

composition related to decreasing concentrations of leachate and greater proportions of natural groundwater or seawater.

- Statistically significant increasing trends for Part 360 leachate indicator parameters were indicated in three of the seven wells (IT403S, IT421S, and IT433S). These increases are likely due to increases in suspended solids during sample collection (turbidity at IT403S) or increases in seawater concentrations (hardness and sulfate at IT421S and/or IT433S).

The Piper and Stiff diagrams, time-series plots, and statistical trend analyses, as described above, indicate decreasing leachate concentrations in all wells associated with the supplemental drains at Landfill Section 3/4.

4.1.3.3 *Landfill Section 3/4 – Southern Perimeter (No Drains)*

Eight shallow/refuse monitoring wells are present in the monitoring well array in Landfill Section 3/4 along the southern perimeter of Landfill Section 3/4 and are not contiguous to either the original drain or the supplemental leachate control drain. These include monitoring wells IT422S, IT405S, IT423S, IT424S, IT406S, IT425S, IT426S, and IT407S (IT422S is located at the southern extent of the original drain and is also addressed in Section 4.1.3.1).

Piper and Stiff diagrams are shown in Figure 4.1-40 and Figure 4.1-49 through Figure 4.1-55 for the shallow/refuse zone monitoring wells associated with the southern perimeter of Landfill Section 3/4.

Monitoring wells IT426S and IT407S plot in the lower portion of the Piper diagram (indicative of leachate) during the pre-closure period and show decreased size and a trend to the left-central portion of the Piper diagram indicative of reduced leachate concentrations (Figure 4.1-49 and Figure 4.1-50). The Stiff diagrams also show a distinctive leachate shape changing to a smaller non-descript shape indicative of non-leachate groundwater.

Monitoring wells IT406S and IT425S plot in the lower portion of the Piper diagram (indicative of leachate) during the pre-closure period and show a somewhat decreased size and a trend to the left portion (IT406S) or central portion (IT425S) of the Piper diagram indicative of more dilute groundwater with less leachate influence (Figure 4.1-51 and Figure 4.1-52). The Stiff diagrams also show a distinctive leachate shape changing to a smaller non-descript shape indicative of dilute non-leachate groundwater.

Monitoring wells IT422S, IT423S, IT424S, and IT405S plot mostly in the right-lower portion of the Piper diagram (Figure 4.1-40 and Figure 4.1-53 through Figure 4.1-55, respectively), indicative of a leachate-seawater mixed groundwater composition, throughout the cumulative monitoring period; the plot for IT405S shows a slight trend upward indicating increased seawater

influence. The shapes of the Stiff diagrams for these wells are suggestive of both leachate and seawater and remain relatively constant in size.

Time series plots for ammonia, boron, and total dissolved solids are shown in Figure 4.1-56 through Figure 4.1-58, respectively, for the shallow/refuse zone monitoring wells associated with the southern perimeter of Landfill Section 3/4. In general, concentrations of these leachate indicator parameters decrease or remained relatively constant at most wells; the individual parameters and wells are discussed below:

Pre-closure concentrations of ammonia were greater than 100 mg/L at seven of the eight wells; concentrations at IT424S were elevated but below 100 mg/L. Ammonia concentrations decreased at all wells though ammonia concentrations at IT422S, IT423S, and IT425S remained above 100 mg/L.

Pre-closure concentrations of boron (2-7 mg/L) were elevated at all eight wells. Concentrations of boron decreased to less than 3 mg/L in six of the wells, but concentrations at IT422S and IT423 remained relatively constant and elevated (4-7 mg/L).

Pre-closure period concentrations of total dissolved solids (TDS) were between 2000 mg/L and 8000 mg/L. TDS concentrations in four of the eight wells decreased though concentrations in two of those wells (IT406S and IT425S) remained elevated (1000 mg/L – 2000 mg/L). The TDS concentrations in monitoring wells IT422S, IT405S, and IT424S remained relatively constant. The TDS concentration at monitoring well IT423S showed an increase from approximately 6,000 mg/L to approximately 8,000 mg/L.

As described above, the time-series plots for ammonia, boron, and TDS at the wells associated with the original drain at Landfill Section 2/8 show decreases at most wells in these typical leachate indicator parameters and are consistent with the assessment of changes in groundwater composition as described by the Piper and Stiff diagrams.

Sixty-nine parameters at eight shallow/refuse monitoring zone wells on the southern perimeter of Landfill Section 3/4 were evaluated to determine the presence of statistically significant trends in concentration or values. The statistically significant trends identified are presented in Table 4.1-6 and are summarized below:

- Of the 106 statistically significant trends identified, the majority (95 or 90%) show decreasing concentrations.
- No statistically significant increasing trends were indicated for organic parameters.

- Most of the statistically significant increasing trends (81%) were for inorganic parameters not identified as Part 360 leachate indicator parameters and represent changes in composition related to decreasing concentrations of leachate and greater proportions of natural groundwater or seawater.
- Statistically significant increasing trends for Part 360 leachate indicator parameters were indicated in two of the eight wells (IT423S and IT426S). These increases are likely due to increases in suspended solids during sample collection (turbidity at IT426S) or increases in seawater concentrations (chemical oxygen demand and TDS at IT423S).

The Piper and Stiff diagrams, time-series plots, and statistical trend analyses, as described above, indicate decreasing leachate concentrations in most wells.

4.2 *Water Levels*

Water level measurements are collected from select shallow/refuse monitoring wells as well as piezometer sets along the drains are evaluated in this section on a monthly basis. This water level measurement data is addressed in this section.

4.2.1 *Monitoring Wells*

Monthly water levels are measured at select shallow/refuse monitoring wells associated with the original drains at Landfill Section 2/8 and Landfill Section 3/4 by the Fresh Kills Landfill Leachate Treatment Plant operator. At Landfill Section 2/8, shallow/refuse zone monitoring wells IT306S, IT319S, IT320S, and IT321S are monitored. These wells are located outside the drain. At Landfill Section 3/4, shallow/refuse zone monitoring wells IT401S, IT408S, IT412S, IT427S, and IT428S are monitored. Wells IT401S, IT427S, and IT428S are located inside the drain whereas IT408S and IT412S are located outside the drain.

The monthly water levels are presented graphically on Figure 4.2-1 through Figure 4.2-4 for monitoring wells IT306S, IT319S, IT320S, and IT321S, respectively, and on Figure 4.2-5 through Figure 4.2-9 for monitoring wells IT401S, IT408S, IT412S, IT427S, and IT428S, respectively. Based on these figures, the following observations can be made:

- Water levels dropped after the construction of the collection drain in most wells.
- Water levels appear to be demonstrating a gradual increase after operation of the collection drain.
- Water levels are variable at the wells monitored.

The lower water levels after the completion of the drain is expected for wells within close proximity to the drain due to changes in hydrology due to the pumping from the drain as well as from the presence of the drain itself.

As presented previously in Chapter 3.0, pumping rates as well as cycle times between pumping have changed significantly at the collection drains; pumping rates have decreased and the time between cycles has lengthened due to reduced leachate flow at the perimeter. These changes are reflected in lesser effects on the contiguous monitoring well water elevations and a gradual increase in water levels.

Much of the variability of the water level elevations can be attributed to seasonality effects. Table 4.2-1 and Table 4.2-2 present the average monthly water levels for each of the wells monitored in Landfill Section 2/8 and Landfill Section 3/4, respectively. In order to provide a valid estimate of the monthly average a trimmed-mean approach is used in that the highest and lowest water level measurement for each month is not used; additionally, any obvious outliers remaining are also discarded so as not to be affected by extreme weather events. The monthly average water levels are presented in Table 4.2-1 and Table 4.2-2 sorted from lowest to highest for each month. The monthly average data is also presented graphically in Figure 4.2-10 and Figure 4.2-11 for Landfill Section 2/8 and Landfill Section 3/4, respectively. These tables and figures show the following:

- The lowest groundwater elevations occur in the July-October period, with the lowest monthly groundwater elevations generally occurring in August.
- The highest groundwater elevations occur in the January-April period, with the highest monthly groundwater elevations generally occurring in March.

The water levels can be affected by seasonality in two ways: seasonal precipitation and seasonal effects on precipitation (e.g., evaporation, soil porosity and hydraulic conductivity, plant uptake, and transpiration). On a short time frame, precipitation events may have more episodic effects on shallow groundwater levels. On a long time frame, however, precipitation effects on shallow groundwater levels tend to a seasonal pattern.

4.2.2 *Piezometer Sets*

Four piezometer sets each are located along the supplemental leachate collection drains in Landfill Section 2/8 (MP281, MP282, MP283, and MP284) and Landfill Section 3/4 (MP341, MP342, MP343, and MP344). Each set consists of one piezometer inside the drain (e.g., MP281I), one piezometer outside the drain (e.g., MP281O), and one piezometer within the drain itself (e.g., MP281D).

Water levels are measured at least monthly at each of the piezometers. The water levels are presented graphically on Figure 4.2-12 through Figure 4.2-15 for the piezometer sets MP281, MP282, MP283, and MP284, respectively, and on Figure 4.2-16 through Figure 4.2-19 for the piezometer sets MP341, MP342, MP343, and MP344, respectively.

Based on these figures, the following observations can be made:

- Water levels are generally higher in the inner piezometers of the following piezometer sets: MP281, MP283, MP284, MP341, and MP343.
- Water levels are generally higher in the outer piezometers of the following piezometer sets: MP282, MP342, and MP344.
- As expected, water levels in the drain piezometers are usually lesser than the higher of the inner and outer piezometer water levels.
- Water levels appear to be demonstrating a gradual increase in the inner and outer piezometers.
- Water levels are variable at the wells monitored.

The differences in piezometer water elevations between the inner piezometers and outer piezometers indicate the direction of the predominant flow into the collection drains. The generally higher water elevations in the inner piezometers of MP281, MP283, MP284, MP341, and MP343 indicate that the flow into the collection drain is dominated by outward flow from the landfill whereas the generally higher water elevation in the outer piezometers of MP282, MP342, and MP344 indicate that the flow into the collection drain may be dominated by inward flow towards the landfill. The higher water elevations in the outer piezometers could be due to the presence of the final cover, the patterns of groundwater recharge related to surface runoff swales and drainage patterns, or tidal infiltration from surrounding surface water bodies (i.e., Main Creek and Richmond Creek). Regardless of the cause, the inward flow to the drains in certain portions of the supplemental collection drain may contribute significant amounts of groundwater to the base flow from the supplemental drains.

Since the water levels in the drain piezometers are usually less than both the inner and outer piezometer water levels, some inward flow to the drains is expected even in areas where the water elevations are higher in the inner piezometers than the outer piezometers. This would add an additional level of conservatism when estimating the base flow due to leachate from the supplemental drains.

As presented previously in Chapter 3.0, pumping rates as well as cycle times between pumping have changed significantly at the collection drains; pumping rates have decreased and the time between cycles has lengthened due to reduced leachate flow at the perimeter. These changes are reflected in lesser effects on the contiguous monitoring well water elevations and a gradual increase in water levels.

Much of the variability of the water level elevations can be attributed to seasonality effects. As an example, Figure 4.2-20 presents the average monthly water levels for the MP342 piezometer set. The monthly average data is presented graphically with Period 1 representing January to

Period 12 representing December. As can be seen, the July through September period represents the lowest elevations for each piezometer and the highest elevations occur in February or March.

4.3 Surface Water Chemistry

To determine the potential for leachate in shallow groundwater to affect surface water quality, monitoring of surface water quality in the Fresh Kills Landfill tidal creeks and reference areas has been conducted beginning with the surface water and sediment investigation performed in 1991-1992. Long-term monitoring of surface water began in 1994 and continues under the EMP. Implementation of corrective measures at the Landfill, including installation of the leachate collection and containment system at Section 1/9 and 6/7 and final cover at Sections 2/8 and 3/4, was essentially completed in 1998. Additionally, final cover installation was completed at Section 6/7 in November 2011. Monitoring results from 1991 to 1997 define baseline conditions for comparison to the post-corrective measures implementation period (1998 to present). Surface water monitoring is performed annually, and sediment and benthic ecology sampling is conducted biennially. Surface water samples are collected from 10 locations within the Arthur Kill, Fresh Kills Creek, Main Creek, and Richmond Creek (Figure 4.3-1).

Leachate Indicator Parameters in Surface Water – In order to assess potential leachate effects in surface water, an evaluation was performed to identify specific leachate constituents and other parameters that indicate such effects. Currently, eleven parameters are considered to be indicators of potential leachate influence in surface water at Fresh Kills Landfill:

- Alkalinity
- Ammonia
- Barium
- Color
- Copper
- Dissolved oxygen (DO)
- Lead
- Manganese
- Nickel
- Total Kjeldahl nitrogen (TKN)
- Zinc

Statistical analysis for trends and significant differences is performed annually on the surface water indicator parameter data. This analysis has consistently found that, where a statistically significant trend or difference has been identified, in nearly all cases an improvement in water quality is indicated. For example, as shown in the following tables, in the data evaluation reported in the *2014 Annual Surface Water and Sediment Monitoring Report*, the Mann-Kendall

test for trend found statistically significant improving water quality in both the cumulative period (1991-2014) and the post corrective measures period (1998-2014).

Statistically significant decreasing trends in ammonia concentrations over the cumulative 1991-2014 period were found at Fresh Kills Creek Station 8, Richmond Creek Station 10 and Station 12, Main Creek Station 13 and Station 16, freshwater Richmond Creek Station 30, and freshwater Main Creek Station 31. Significant decreasing trends at Fresh Kills Creek Station 8, Richmond Creek Station 10, Main Creek Station 13 and Station 16, Main Creek Station 28, freshwater Richmond Creek Station 30, and freshwater Main Creek Station 31 were indicated for the post-corrective measures period (1998-2014) alone. The decreasing trends at Station 10, 12, 13, 16 and Station 30 were also indicated by significant differences between the pre- and post-corrective measures periods' concentrations as seen through the Wilcoxon rank sum test, while the t-test, indicated significant differences between the pre- and post-corrective measures periods at Stations 8, 10, 12, 16 and 30.

Statistical trend analysis data from shallow/refuse groundwater monitoring wells indicated that several parameters, particularly alkalinity, ammonia, color and TKN, were shown to have statistically significant decreasing trends in most of the shallow/refuse groundwater monitoring wells that are located outside the leachate collection and containment systems and collection drains near the surface water monitoring stations. These data support a relationship between improving surface water quality and shallow groundwater quality.

Results of Mann-Kendall Test for Trends for Surface Water Indicator Parameters											
Station	Parameters										
	Alkalinity	Ammonia	Barium	Color	Copper	DO	Lead	Manganese	Nickel	TKN	Zinc
Arthur Kill											
02	↓↓			↓		↑		↓	↓↓		
Fresh Kills Creek											
05	↓↓			↓	↓	↑↑		↓↓	↓↓	↓	
08	↓↓	↓↓		↓				↓↓	↓↓	↓	
Richmond Creek											
10	↓↓	↓↓						↓	↓	↓	
12	↓↓	↓							↓		

Results of Mann-Kendall Test for Trends for Surface Water Indicator Parameters

Station	Parameters										
	Alkalinity	Ammonia	Barium	Color	Copper	DO	Lead	Manganese	Nickel	TKN	Zinc
Main Creek											
13	↓↓	↓↓									
16	↓	↓↓	↑						↓		
Upstream Main Creek											
28		↓	↑↑	↓							
Upstream Freshwater Richmond Creek											
30		↓↓			↓				↓↓		
Upstream Freshwater Main Creek											
31		↓↓	↑↑	↓	↓↓				↓	↓	

Notes: ↓ Statistically significant decreasing concentration over the combined pre- and post-corrective measures period
 ↑ Statistically significant increasing concentration over the combined pre- and post-corrective measures period
 ↓↓ Statistically significant decreasing concentration over the post-corrective measures period
 ↑↑ Statistically significant increasing concentration over the post-corrective measures period

Predicted and Actual Ammonia Concentrations – As a component of the surface water and sediment investigation, a calibrated surface water hydrodynamic model was used to evaluate the effects of landfill leachate on surface water quality by determining the portion of the ambient concentration of a parameter that is attributable to leachate loading and was presented in the *Final Surface Water and Sediment Report* (FSWSR) (IT, 1993b). The model application confirmed that ammonia, iron, barium and zinc contributed to surface water by leachate are measureable, while lesser components of leachate such as vanadium, arsenic and lead have an insignificant impact on water quality. As reported in the FSWSR, the ammonia concentrations attributable to leachate predicted to occur in two Fresh Kills Creek locations was 0.27 mg/L near the confluence with Main and Richmond Creeks, and 0.23 mg/L further downstream, 0.18 mg/L in Main Creek, and 0.27 mg/L in Richmond Creek.

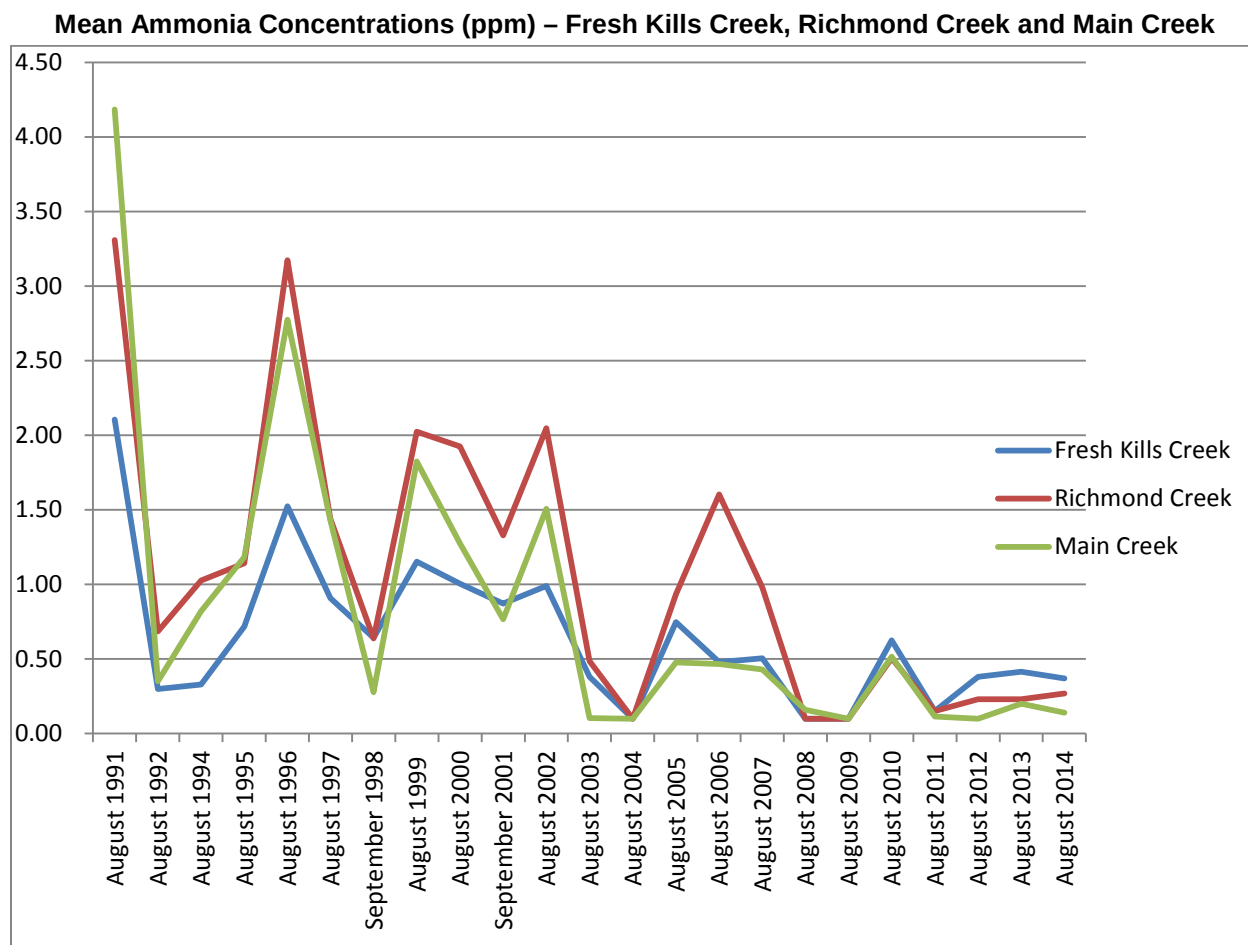
The hydrodynamic model was refined and the predicted instream ammonia concentrations attributable to leachate were reported in the *Final Leachate Report and Corrective Action Report* (FLMR) (IT, 1994). The model was used to predict in-stream ammonia concentrations over time assuming the implementation of Site-wide Corrective Measures Alternative 1. These results are shown in the following Table.

<i>Model Predicted In-Stream Ammonia Concentration Attributable to Leachate (mg/L)</i>			
	1993	1997	2015
Fresh Kills Creek	0.62	0.28	0.12
Main Creek	0.35	0.17	0.07
Richmond Creek	0.46	0.23	0.10

As shown in the table, the model predicted that the surface water ammonia concentrations would decrease substantially after implementation of Corrective Measure Alternative 1, which included capping and closure of Landfill Sections 2/8 and 3/4.

The model prediction of decreasing surface water ammonia concentrations has been verified by the annual monitoring results. The trend of decreasing mean ammonia concentrations in the Landfill creeks is visually depicted in the figure below which shows the mean ammonia concentrations in each of the three Landfill creeks for all monitoring years.

It is important to note that the concentrations of ammonia measured in the Landfill creeks include loadings attributable to the Landfill as well as loading from upstream sources, from adjacent wetlands and from the Arthur Kill, and therefore the in-situ concentrations are likely to be higher than that which would result from the Landfill alone. Even though there are multiple sources of ammonia to the Fresh Kills Landfill tidal creeks, ammonia concentrations have not exceed applicable NYSDEC acute criteria in recent years of the monitoring program.



Small Tributary Studies - As a supplement to the monitoring of the principal waterways within and adjacent to the Fresh Kills Landfill, a study of seven small on-site surface drainages was conducted in 1994 and reported in the report entitled *Final Technical Report – Small Tributary Study* (IT, 1995). The small tributaries and the sampling stations addressed in the study are presented on Plate 1 of the *Final Technical Report – Small Tributary Study* (IT, 1995) which is presented in Appendix A of this report. This small tributary investigation evaluated water quality in each tributary for leachate influence based on the analytes that were determined to be indicators of leachate influence in surface water. A limited investigation of stream flow volume was also conducted. From these data, it was determined that, during worst-case low flow conditions, the percentage of flow attributable to leachate ranged from 2 percent to a maximum of 50 percent of stream flow. The small tributary study predicted that planned corrective measures including capping, construction of stormwater detention basins and collection and treatment of leachate would result in improved water quality in all tributaries and their receiving waters. This predicted improvement in surface water quality in the receiving waters has and continues to occur, as demonstrated by statistical analysis of leachate indicator concentrations in surface water and sediment and benthic ecology quality metrics.

An additional study of Richmond Creek Tributary 1 was performed in 2000 in order to meet the requirements specified in the Consent Judgment and Order (CJO) Civil No. 95-1259 (JBW) paragraph 2 dated January 13, 2000. The CJO stipulates that the New York City Department of Sanitation (NYCDOSS) shall quantify the average annual fresh water flow and leachate flow into Richmond Creek Tributary-1 (RCT-1) pursuant to the methodology set forth in the *Final Technical Report Small Tributary Study* (IT, 1995). This study, entitled *Leachate Impact Study of Richmond Creek Tributary-1* (IT, 2000) was performed with year 2000 groundwater flux values so as to determine the flow conditions into RCT-1 subsequent to the closure of Section 2/8 and construction and operation of the supplemental leachate controls.

The base-flow conditions for RCT-1 as presented in the FTS are as shown in the following table:

Small Tributary Study Location	Drainage Area (Sq. mi.)	Average Annual Fresh Water Flow (cfs) ^B	Groundwater Inflow (cfs)	% Leachate (FHR, 1993)	Leachate Inflow (cfs)
Richmond Creek Tributary-1 Station T-7	1.2	1.2	0.26	75%	0.20

The average daily model simulated leachate flux from the refuse mounds at Landfill Section 2/8 into the RCT-1 drainage area for the year 2000 is 11,214 gallons per day (gpd). Based on the average annual fresh water flow in the RCT-1 drainage area of 1.2 cfs (775,000 gpd), the potential leachate flow into RCT-1 is estimated to be reduced to approximately 1.4 percent of the total average annual fresh water flow into RCT-1 subsequent to implementation of corrective measures.

Table 4-1-1
Results of Mann-Kendall Tests for Trend
Shallow/Refuse Monitoring Zone - Landfill Section 2/8 - Original Drain

Parameter	Monitoring Well ^a													
	IT308S	IT323S	IT322S	IT306S	IT321S	IT319S	IT324S	Monitoring Period ^b						
	1998-2014	1991-2014	1998-2008	1991-2008	1998-2013	1991-2013	1998-2012	1991-2012	1998-2012	1991-2012	1998-2010	1991-2010	1998-2012	1991-2012
Leachate Indicators														
Alkalinity (As CaCO ₃)	○													
Ammonia							●			○				
Boron	○	○		○		○				○				
Bromide												○		
Chemical Oxygen Demand (COD)		○			●				○	○				
Chloride		○			●				○	○		○		
Color		○												
Sulfate					○									
Total Dissolved Solids	○	○			●	●								
Total Hardness					●									
Total Kjeldahl Nitrogen				○						○				
Total Organic Carbon		○								○				
Turbidity		○			○	○								
Inorganics														
Aluminum		○												
Arsenic							○							
Barium		○			●								●	●
Calcium										●				●
Iron		○				○				○				
Magnesium		○			●									
Manganese	●			●	○					●				
Nickel						○				○				
Potassium	○	○								○				
Sodium	○				●				○	○				
Vanadium							●							
Organics														
Chlorobenzene										○				

Legend: ● Statistically significant increasing trend in concentration or value.
○ Statistically significant decreasing trend in concentration or value.

Notes: ^a Refer to Figure 4.1-1 for the location of the monitoring wells.

^b 1998-2014 Post-Corrective Measures Monitoring Period (January 1998 through October 2014 sampling quarters).
1991-2014 Cumulative Monitoring Period (January 1991 through October 2014 sampling quarters).

Mann-Kendall Analysis shown inclusive of most recent sample collected through 2014.

Mann-Kendall Analysis not shown if no sample collected since 2010 (e.g., IT320S due to insufficient water or insufficient recharge).

Table 4.1-2
Results of Mann-Kendall Tests for Trend
Shallow/Refuse Monitoring Zone - Landfill Section 2/8 - Supplemental Drains

Parameter	Monitoring Well ^a									
	IT315S		IT303S		IT316S		IT317S		IT318S	
	Monitoring Period ^b									
	1998-2012	1991-2012	1998-2013	1991-2013	1998-2012	1991-2012	1998-2008	1991-2008	1998-2014	1991-2014
Leachate Indicators										
Alkalinity (As CaCO3)	○	○	○			○		○	○	○
Ammonia	○	○	○			○		○	○	○
Biochemical Oxygen Demand (BOD)									○	
Boron	○	○	○			○		○	○	○
Chemical Oxygen Demand (COD)	○	○						○	○	○
Chloride	○	○							○	○
Color			○			○		○		○
Sulfate									●	●
Total Dissolved Solids	○							○	○	○
Total Hardness						●				
Total Kjeldahl Nitrogen	○	○						○	○	○
Total Organic Carbon	○	○	○			○		○	○	○
Turbidity		●				●				
Inorganics										
Arsenic						○				
Barium	○	○						○		
Calcium		●	●							●
Chromium	○	○						○		○
Cobalt									○	
Iron	●	●	●							●
Magnesium	○	○						○	○	○
Manganese		●	●							●
Potassium	○	○			●			○	○	○
Sodium	○	○						○	○	○
Vanadium	○	○	○			○		○	○	○
Organics										
Benzene		○						○	○	
Chlorobenzene								○	○	○
Naphthalene										○

● Statistically significant increasing trend in concentration

Legend: or value.

○ Statistically significant decreasing trend in concentration or value.

Notes: ^a Refer to Figure 4.1-1 for the location of the monitoring wells.

^b 1998-2014 Post-Corrective Measures Monitoring Period (January 1998 through October 2014 sampling quarters).

1991-2014 Cumulative Monitoring Period (January 1991 through October 2014 sampling quarters).

Mann-Kendall Analysis shown inclusive of most recent sample collected through 2014.

Mann-Kendall Analysis not shown if no sample collected since 2010 (e.g., IT320S due to insufficient water or insufficient recharge).

Table 4.1-3
Results of Mann-Kendall Tests for Trend
Shallow/Refuse Monitoring Zone - Landfill Section 2/8 - Small Mound (No Drains)

Parameter	Monitoring Well ^a									
	IT301S		IT302S		IT312S		IT313S		IT325S	
	Monitoring Period ^b									
	1998-2014	1991-2014	1998-2012	1991-2012	1998-2012	1991-2012	1998-2009	1991-2009	1998-2012	1991-2012
Leachate Indicators										
Alkalinity (As CaCO3)				○		○		○	○	○
Ammonia				○		○				
Boron				○						
Chemical Oxygen Demand (COD)									○	
Color		○				○				
Total Dissolved Solids						○				
Total Kjeldahl Nitrogen				○		○		○		
Total Organic Carbon		○		○						○
Turbidity									●	
Inorganics										
Arsenic								○		
Barium				○						
Calcium									○	
Cobalt						○				○
Copper			●							●
Iron						●		●		
Magnesium								●		
Manganese										○
Potassium				○						
Tin		○								
Vanadium		○								
Organics										
Benzene	○									○
Naphthalene	○	○								

Legend: ● Statistically significant increasing trend in concentration or value.

○ Statistically significant decreasing trend in concentration or value.

Notes: ^a Refer to Figure 4.1-1 for the location of the monitoring wells.

^b 1998-2014 Post-Corrective Measures Monitoring Period (January 1998 through October 2014 sampling quarters).

1991-2014 Cumulative Monitoring Period (January 1991 through October 2014 sampling quarters).

Table 4.1-4
Results of Mann-Kendall Tests for Trend
Shallow/Refuse Monitoring Zone - Landfill Section 3/4 - Original Drain

Parameter	Monitoring Well ^a									
	IT428S		IT408S		IT411S		IT412S		IT401S	
	Monitoring Period ^b									
	1998-2012	1991-2012	1998-2011	1991-2011	1998-2013	1991-2013	1998-2012	1991-2012	1998-2013	1991-2013
Leachate Indicators										
Alkalinity (As CaCO3)	○	○	○	○	○	○			○	
Ammonia		○	○	○	○	○	○		○	
Boron			○		○	○			○	
Chemical Oxygen Demand (COD)		○	○	○	○	○	○		○	
Chloride	○	○	○	○	○	○	○	○	○	
Color		○						○		
Sulfate					●					
Total Dissolved Solids		○	○	○	○	○			○	
Total Kjeldahl Nitrogen	○	○	○	○	○	○	○	○	○	
Total Organic Carbon	○	○		○	○	○		○	○	
Turbidity	●	●					●			
Inorganics										
Aluminum		○								
Arsenic		○								
Barium					○					
Calcium			●		●			●		
Chromium	○	○	○		○		○			
Cobalt		○	○	○	○		○		○	
Copper					●					
Iron			●					●		
Magnesium					○	○			○	
Manganese			●	●	●					
Nickel		○	○	○			○			
Potassium		○	○	○	○	○			○	
Sodium	○	○	○		○	○			○	
Tin	○	○	○	○						
Vanadium	○	○	○	○	○	○	○		○	
Organics										
2-Methylnaphthalene					○					
Acenaphthene					○				○	
Benzene									○	
Naphthalene		○						○		
Xylene, (Total)		○								

Legend: ● Statistically significant increasing trend in concentration or value.
○ Statistically significant decreasing trend in concentration or value.

Notes: ^a Refer to Figure 4.1-1 for the location of the monitoring wells.

^b 1998-2014 Post-Corrective Measures Monitoring Period (January 1998 through October 2014 sampling quarters).
1991-2014 Cumulative Monitoring Period (January 1991 through October 2014 sampling quarters).

Table 4.1-5
Results of Mann-Kendall Tests for Trend
Shallow/Refuse Monitoring Zone - Landfill Section 3/4 - Supplemental Drain

Parameter	Monitoring Well ^a													
	IT403S	IT419S	IT420S	IT404S	IT421S	IT433S	IT422S	Monitoring Period ^b						
	1998-2014	1991-2014	1998-2013	1991-2013	1998-2010	1991-2010	1998-2013	1991-2013	1998-2012	1991-2012	1998-2012	1991-2012	1998-2013	1991-2013
Leachate Indicators														
Alkalinity (As CaCO ₃)		○	○	○		○				○		○		
Ammonia		○	○			○	○			○		○	○	
Biochemical Oxygen Demand (BOD ₅)										○				
Boron	○	○	○	○	○	○				○		○		○
Bromide									●		●	●		
Chemical Oxygen Demand (COD)	○	○	○	○		○								
Chloride		○	○	○	○	○								
Color			○			○	○			○		○	○	
Total Dissolved Solids		○		○		○								
Total Hardness										●				
Total Kjeldahl Nitrogen		○	○			○				○		○		
Total Organic Carbon		○	○	○		○			○	○		○	○	
Turbidity		●	○						○					
Inorganics														
Aluminum		○												
Barium	●	●	○			○								
Cadmium	●													
Calcium	●	●								●				
Chromium		○				○	○			○		○		
Cobalt		○		○		○			○	○				
Iron		●	○						○		○		●	
Magnesium			○	○		○	●							
Manganese		●								●				
Nickel										○				○
Potassium	○	○	○	○		○								
Sodium	○	○	○	○		○								
Tin		○					○			○				
Vanadium	○	○		○		○	○			○		○	○	○
Organics														
Benzene		○					○							
Chlorobenzene		○					○							

Legend: ● Statistically significant increasing trend in concentration or value.

○ Statistically significant decreasing trend in concentration or value.

Notes: ^a Refer to Figure 4.1-1 for the location of the monitoring wells.

^b 1998-2014 Post-Corrective Measures Monitoring Period (January 1998 through October 2014 sampling quarters).
1991-2014 Cumulative Monitoring Period (January 1991 through October 2014 sampling quarters).

Mann-Kendall Analysis shown inclusive of most recent sample collected through 2014.

Mann-Kendall Analysis not shown if no sample collected since 2010 (e.g., IT413S and IT427S due to insufficient water or insufficient recharge).

Table 4.1-6
Results of Mann-Kendall Tests for Trend
Shallow/Refuse Monitoring Zone - Landfill Section 3/4 - Southern Perimeter (No Drains)

Parameter	Monitoring Well ^a															
	IT422S		IT405S		IT423S		IT424S		IT406S		IT425S		IT426S		IT407S	
	Monitoring Period ^b															
	1998-2013	1991-2013	1998-2014	1991-2014	1998-2011	1991-2011	1998-2014	1991-2014	1998-2010	1991-2010	1998-2014	1991-2014	1998-2012	1991-2012	1998-2014	1991-2014
Leachate Indicators																
Alkalinity (As CaCO3)				○									○	○	○	○
Ammonia	○			○					○	○				○	○	○
Boron		○		○										○	○	○
Chemical Oxygen Demand (COD)			○	○		●								○	○	○
Chloride										○				○		○
Color	○			○				○		○				○		○
Total Dissolved Solids						●				○				○	○	○
Total Kjeldahl Nitrogen				○					○	○				○		○
Total Organic Carbon	○			○						○				○	○	○
Turbidity						○		○				○	●	●		
Inorganics																
Aluminum				○										○		
Arsenic				○				○		○						
Barium				●	●			○								○
Cadmium															●	●
Calcium										●					○	●
Chromium				○		●								○		○
Cobalt			○	○		●				○				○		○
Copper																
Iron	●					○		○					●	●		●
Lead														○		
Magnesium				○	●										○	○
Manganese																●
Nickel		○		○		●	○	○	○					○		○
Potassium				○					○	○				○		○
Sodium						●			○					○		○
Tin						●								○		
Vanadium	○	○		○						○				○		
Organics																
Benzene				○								○				
Chlorobenzene												○				

Legend: ● Statistically significant increasing trend in concentration or value.
○ Statistically significant decreasing trend in concentration or value.

Notes: ^a Refer to Figure 4.1-1 for the location of the monitoring wells.

^b 1998-2014 Post-Corrective Measures Monitoring Period (January 1998 through October 2014 sampling quarters).
1991-2014 Cumulative Monitoring Period (January 1991 through October 2014 sampling quarters).

Mann-Kendall Analysis shown inclusive of most recent sample collected through 2014.
Mann-Kendall Analysis not shown if no sample collected since 2010 (e.g., IT413S and IT427S due to insufficient water or insufficient recharge).

Table 4.2-1
Evaluation of Seasonality of Groundwater Elevations
Groundwater Monitoring Wells Contiguous to Original Drain
Landfill Section 2/8

Monitoring Wells							
IT319S		IT320S		IT321S		IT306S	
Period	Period Average	Period	Period Average	Period	Period Average	Period	Period Average
8	0.680	8	2.382	8	9.467	8	4.812
7	1.046	7	2.658	7	9.654	9	4.885
9	1.378	9	2.671	9	10.036	7	4.922
10	1.446	10	2.754	10	10.089	10	4.932
6	1.689	6	2.869	6	10.434	11	4.967
11	1.815	5	2.896	11	10.455	6	5.053
5	1.939	11	2.994	5	10.741	5	5.072
1	2.109	1	3.215	2	11.184	12	5.123
12	2.181	2	3.281	4	11.259	2	5.145
4	2.207	12	3.332	1	11.308	4	5.187
3	2.217	3	3.347	12	11.333	1	5.191
2	2.231	4	3.402	3	11.433	3	5.211

Period Average - Includes all measurements except high and low values from each period and obvious outliers

Table 4.2-2
Evaluation of Seasonality of Groundwater Elevations
Groundwater Monitoring Wells Contiguous to Original Drain
Landfill Section 3/4

IT401S		IT408S		Monitoring Wells IT412S		IT427S		IT428S	
Period	Period Average	Period	Period Average	Period	Period Average	Period	Period Average	Period	Period Average
8	4.491	8	3.568	8	9.467	9	4.543	8	5.481
7	4.721	9	3.624	7	9.654	8	4.611	9	5.502
10	4.820	10	3.683	9	10.036	7	4.757	7	5.576
11	4.838	11	3.692	10	10.089	10	4.829	11	5.699
9	4.859	7	3.782	6	10.434	11	4.833	10	5.705
6	5.095	5	3.934	11	10.455	12	5.018	6	5.875
5	5.278	1	3.973	5	10.741	6	5.063	12	5.971
4	6.221	6	4.088	2	11.184	2	5.163	2	6.064
1	6.281	12	4.090	4	11.259	5	5.243	5	6.078
12	6.619	2	4.097	1	11.308	1	5.272	1	6.179
3	6.699	3	4.192	12	11.333	4	5.459	4	6.300
2	6.810	4	4.478	3	11.433	3	5.513	3	6.319

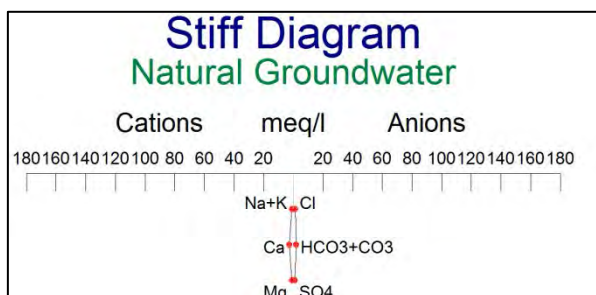
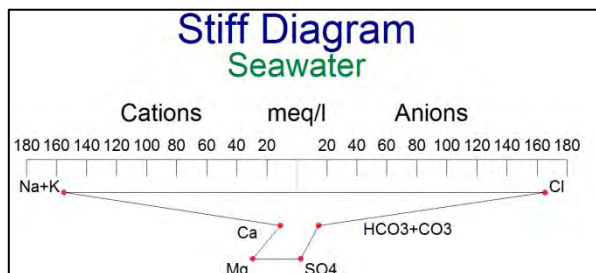
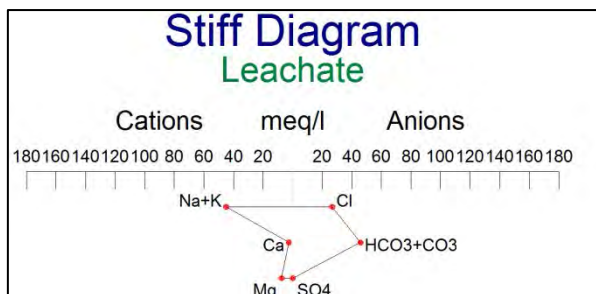
Period Average - Includes all measurements except high and low values from each period and obvious outliers

Chapter 4.0 Figures

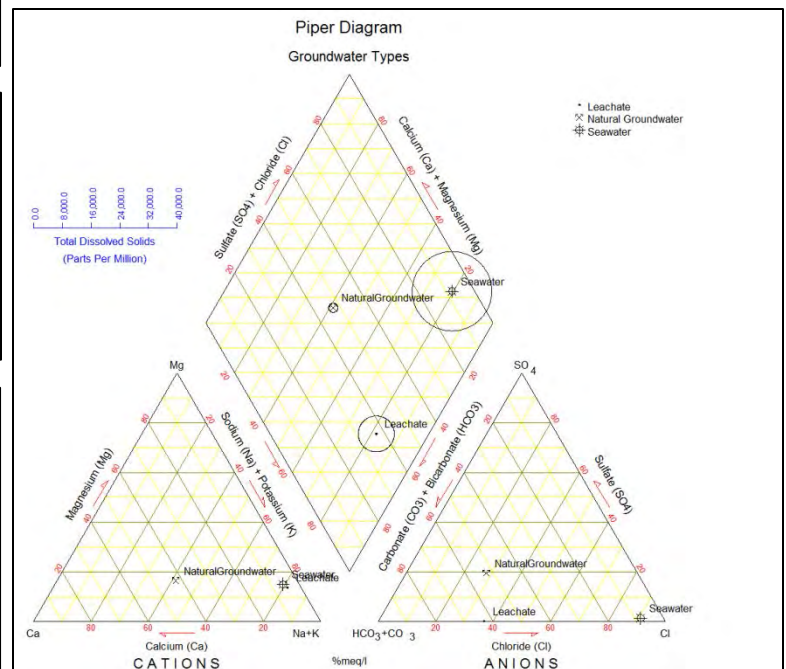
Description of Figures in Chapter 4.0

Figure 4.1-1 Shallow/Refuse Groundwater Monitoring Well Array presents the locations of the shallow/refuse groundwater monitoring wells in each of the four Fresh Kills Landfill sections as well as the locations of the Original Drains, Supplemental Extensions to the Original Drains, and the Supplemental Drains in Landfill Sections 2/8 and 3/4.

Figures 4.1-2 through 4.1-9, 4.1-13 through 4.1-17, 4.1-21 through 4.1-25, 4.1-29 through 4.1-35, 4.1-39 through 4.1-45, 4.1-49 through 4.1-55 present the Piper and Stiff diagrams for the groundwater samples collected from each of the shallow/refuse groundwater monitoring wells in Landfill Sections 2/8 and 3/4. The size and shape of the Stiff diagrams for each sample and the size and location of the samples on the Piper diagrams are based on the proportions of many dissolved solutes which are different in leachate, seawater, and natural groundwater. In the Stiff diagrams, leachate has a typical sodium-bicarbonate water composition that has a distinctive asymmetrical shape; seawater has a sodium-chloride water composition that has a distinctive T-shaped or “bird-like” outline; and natural groundwater is identified by its lack of definition (i.e., thin line shape). In the Piper diagrams, leachate will typically plot near the bottom of the central diamond (sodium-bicarbonate water composition), seawater will plot near the right corner of the central diamond (sodium-chloride water composition); and groundwater not showing leachate or seawater influence is variable depending on the mineral composition of the monitoring zone and generally plots in the left central area of the central diamond.



water composition); and groundwater not showing leachate or seawater influence is variable depending on the mineral composition of the monitoring zone and generally plots in the left central area of the central diamond.



Figures 4.1-10,18,26,36,46,56 (Ammonia Concentrations), Figures 4.1-11,19,27,37,47,57 (Boron Concentrations), and Figures 4.1-12,20,28,38,48,58 (Total Dissolved Solids Concentrations) present time-series plots for ammonia, boron, and total dissolved solids (three parameters that are used to indicate leachate influence at Fresh Kills Landfill) for each of the shallow/refuse groundwater monitoring wells in Landfill Sections 2/8 and 3/4.

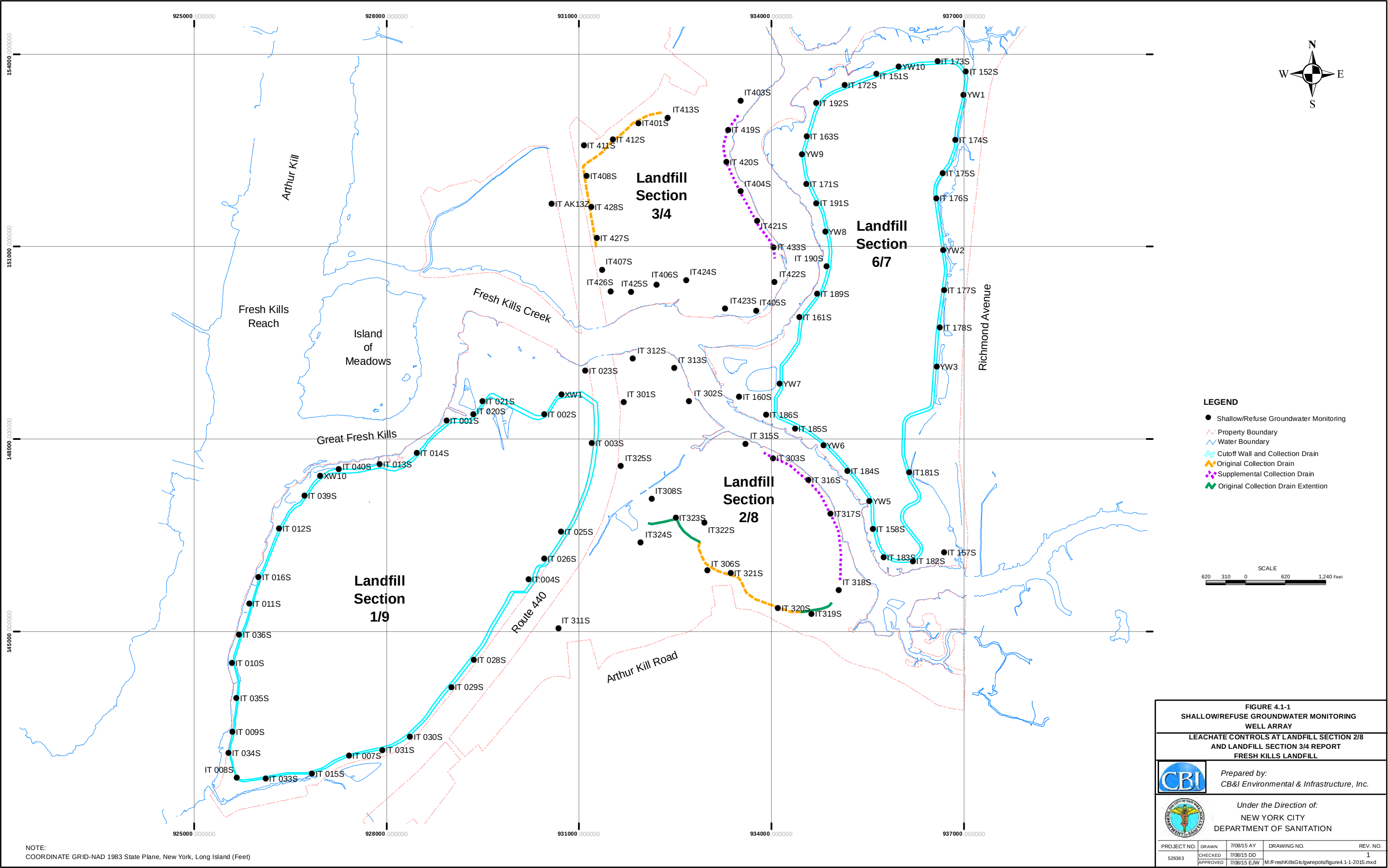
Figure 4.2-1 through 4.2-9 present monthly water level elevation data for select shallow/refuse groundwater monitoring wells in Landfill Sections 2/8 and 3/4 located along the Original Drains.

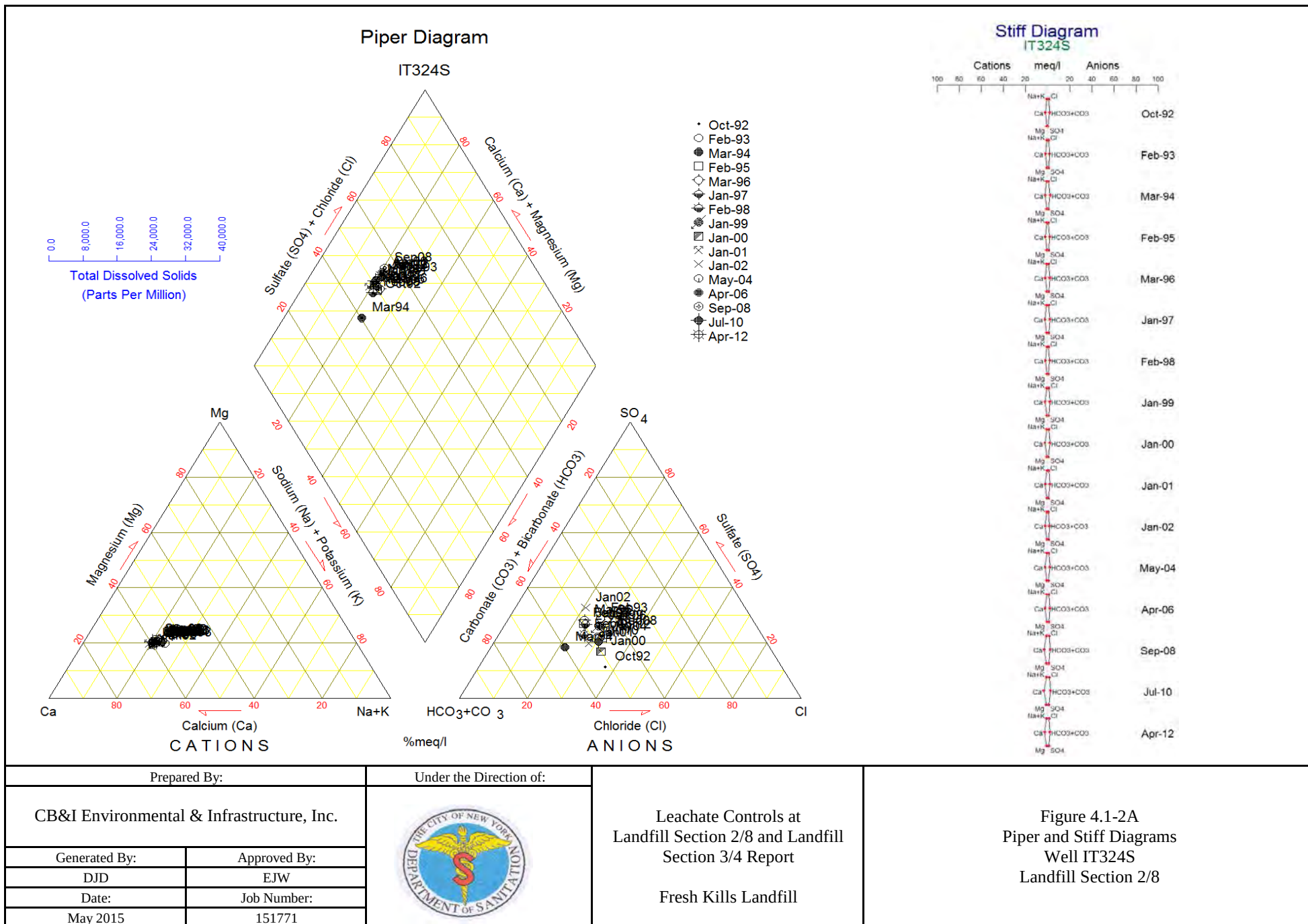
Figure 4.2-10 and 4.2-11 present average water level elevation data for each month for select shallow/refuse groundwater monitoring wells in Landfill Sections 2/8 and 3/4 located along the Original Drains; this data illustrates the seasonality of water level elevations along the Original Drains.

Figure 4.2-12 through 4.2-19 present monthly water level elevation data for groundwater piezometer sets in Landfill Sections 2/8 and 3/4 located along the Supplemental Drains and illustrate the relationship between water level elevations within the drains, interior to the drains, and exterior to the drains.

Figure 4.2-20 presents average water level elevation data for each month for an example piezometer set (MP342 in Landfill Section 3/4) located along the Supplemental Drain; this data illustrates the seasonality of water level elevations along the Supplemental Drains.

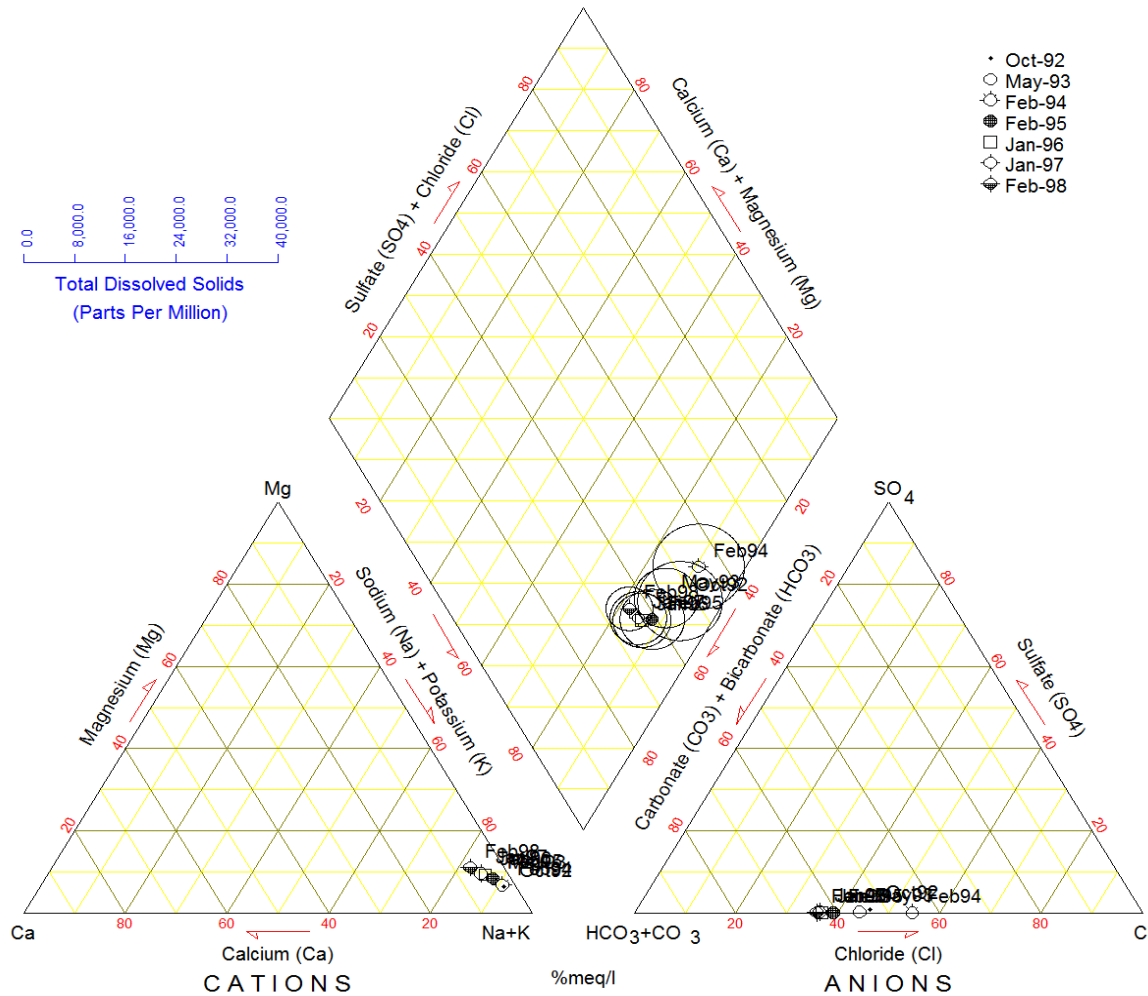
Figure 4.3-1 presents the surface water sample collection stations and their relationship to the shallow/refuse groundwater monitoring wells.





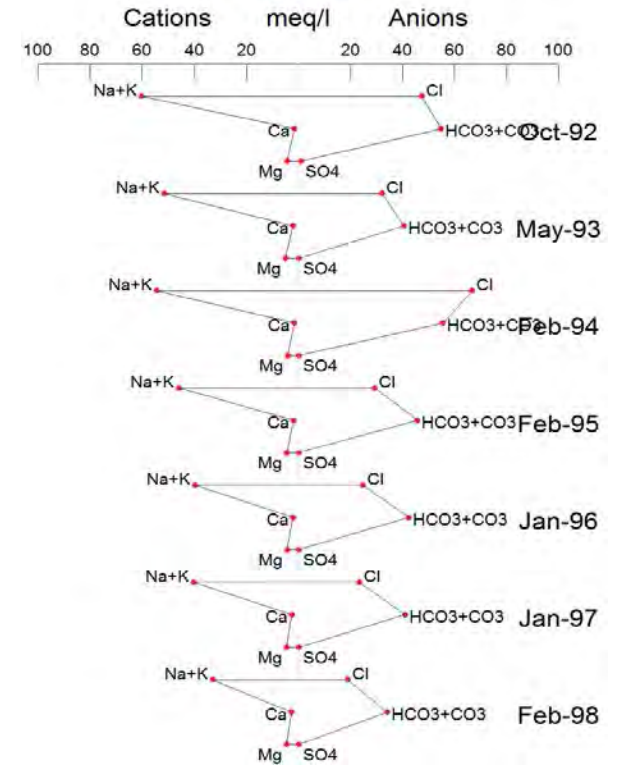
Piper Diagram

IT320S



Stiff Diagram

IT320S



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Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-3A
Piper and Stiff Diagrams
Well IT320S
Landfill Section 2/8

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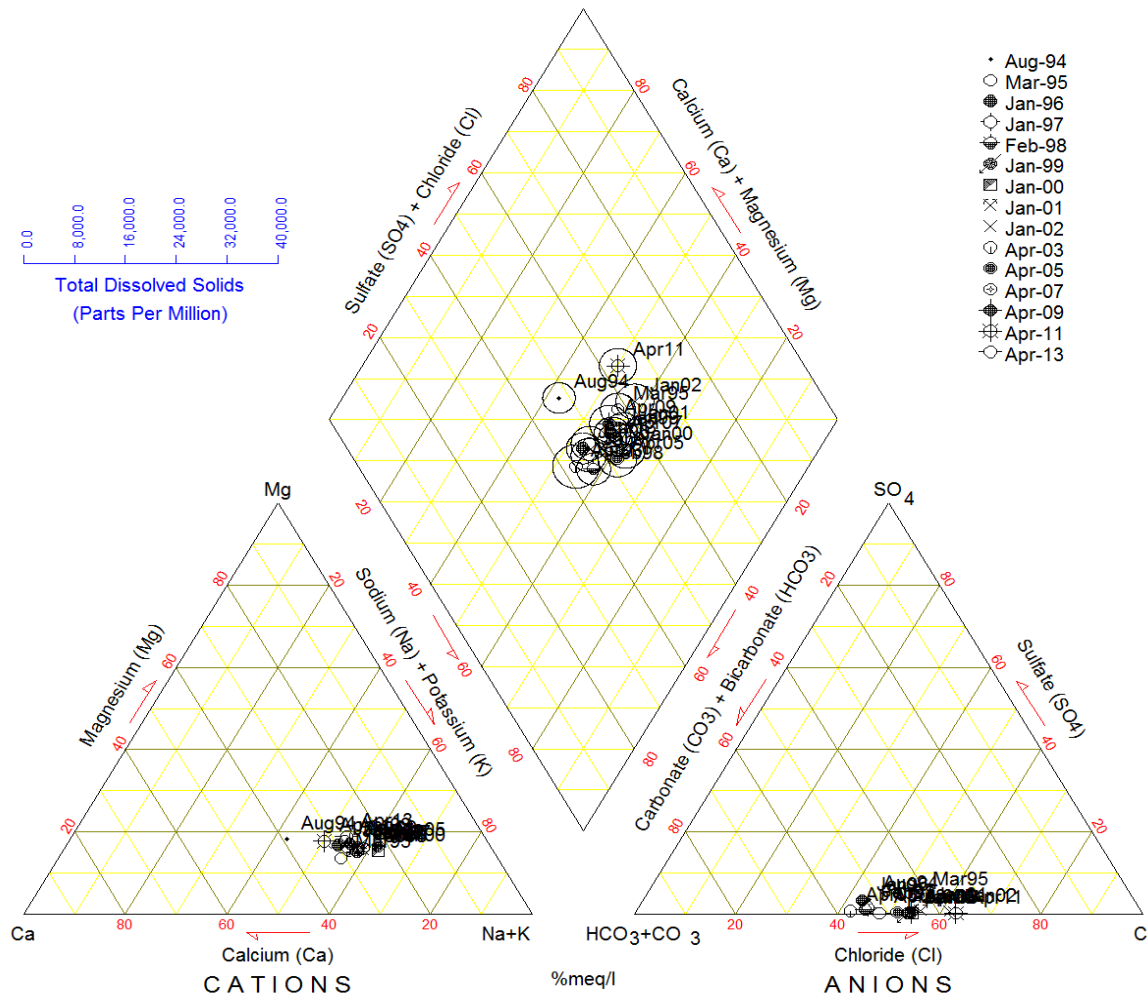
Job Number:

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Piper Diagram

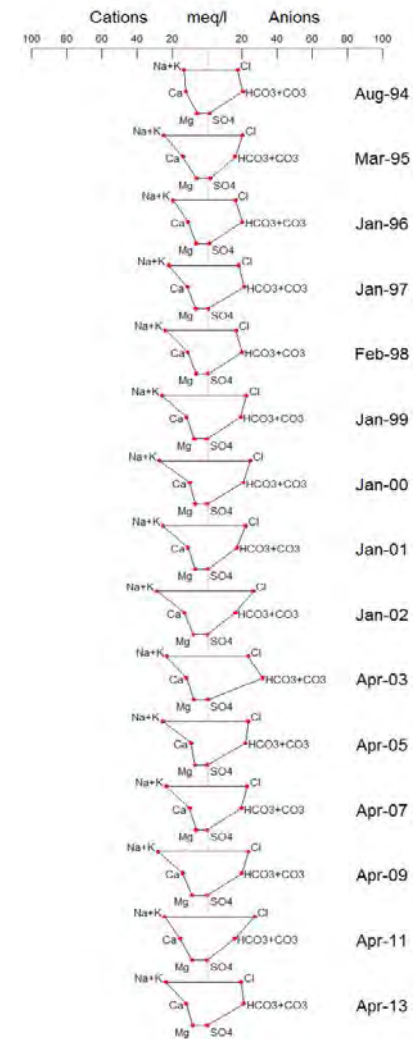
IT322S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT322S



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Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-4A
Piper and Stiff Diagrams
Well IT322S
Landfill Section 2/8

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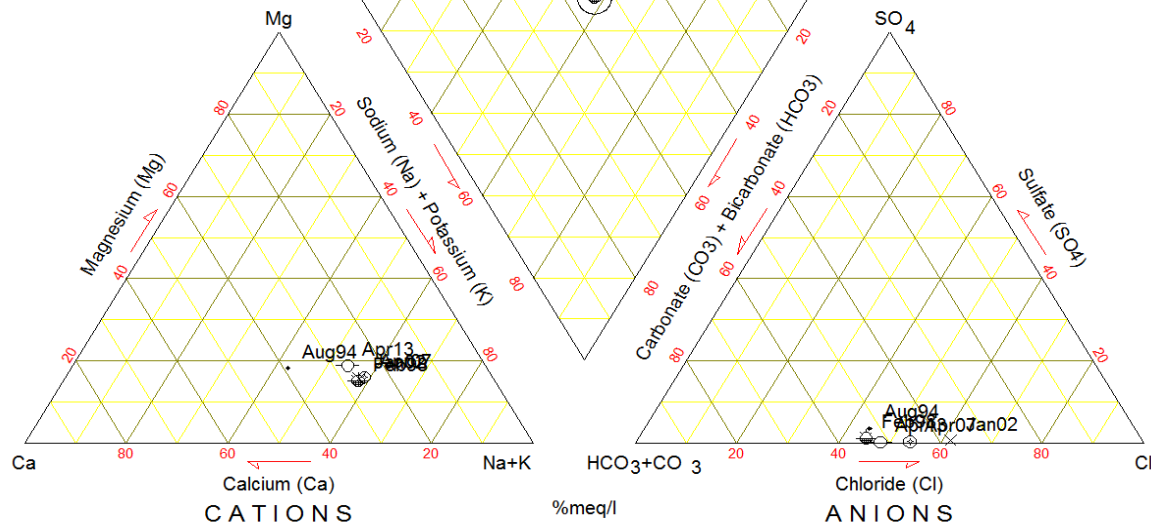
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Piper Diagram

IT322S

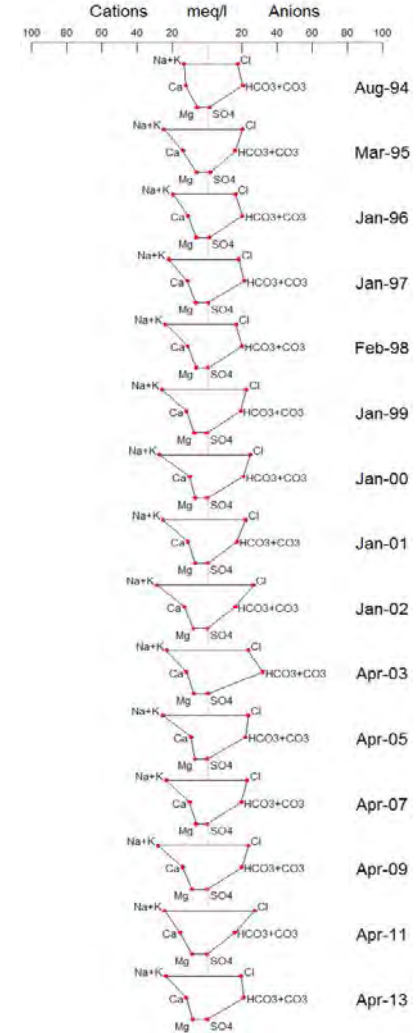
- Aug-94
- Feb-98
- × Jan-02
- ⊗ Apr-07
- Apr-13

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT322S



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Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-4B
Piper and Stiff Diagrams
Well IT322S
Landfill Section 2/8

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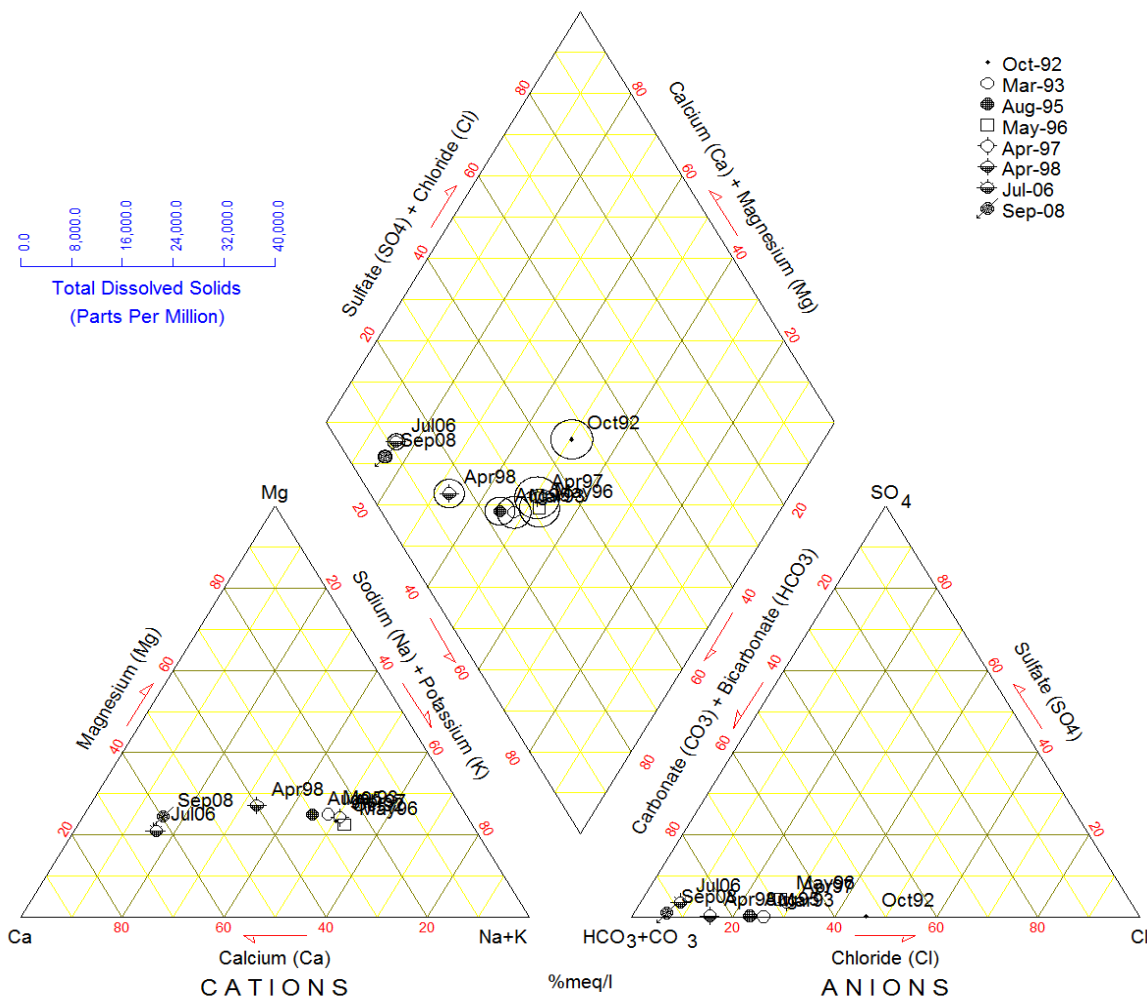
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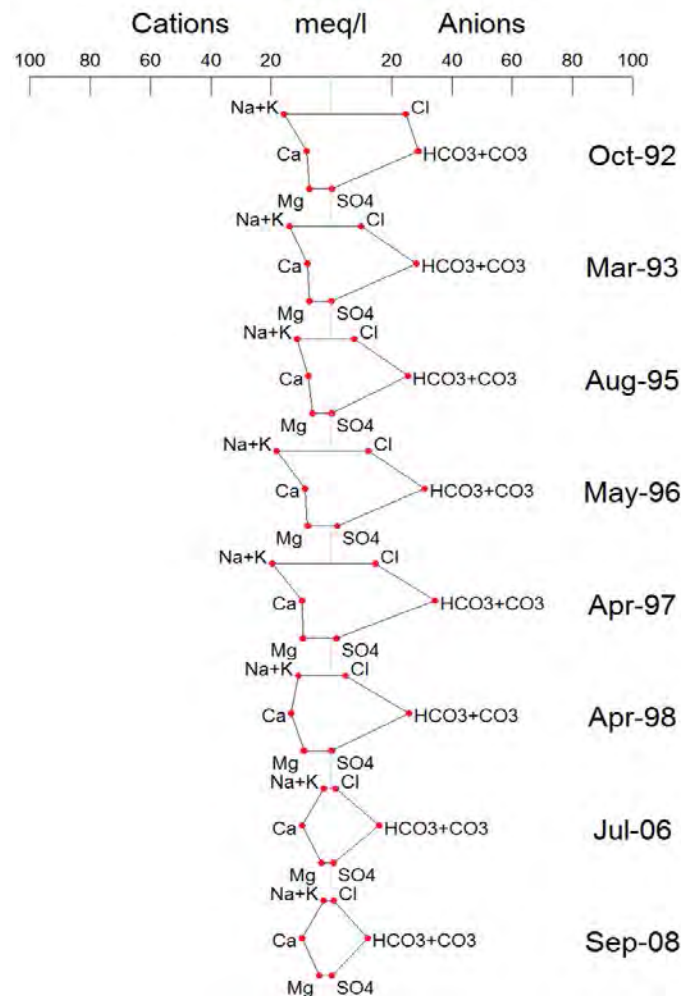
Piper Diagram

IT323S



Stiff Diagram

IT323S



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Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-5A
Piper and Stiff Diagrams
Well IT323S
Landfill Section 2/8

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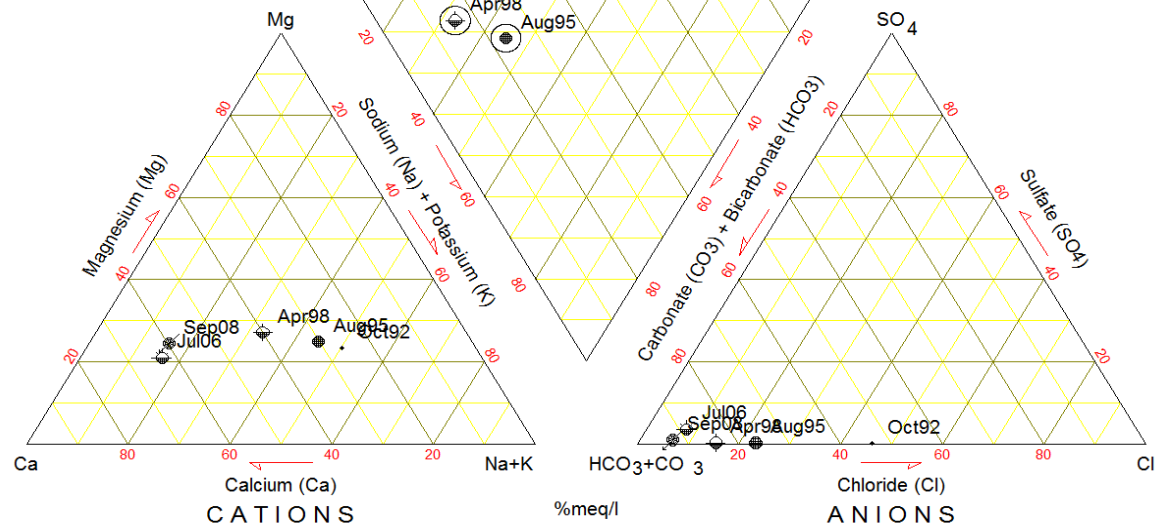
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Piper Diagram

IT323S

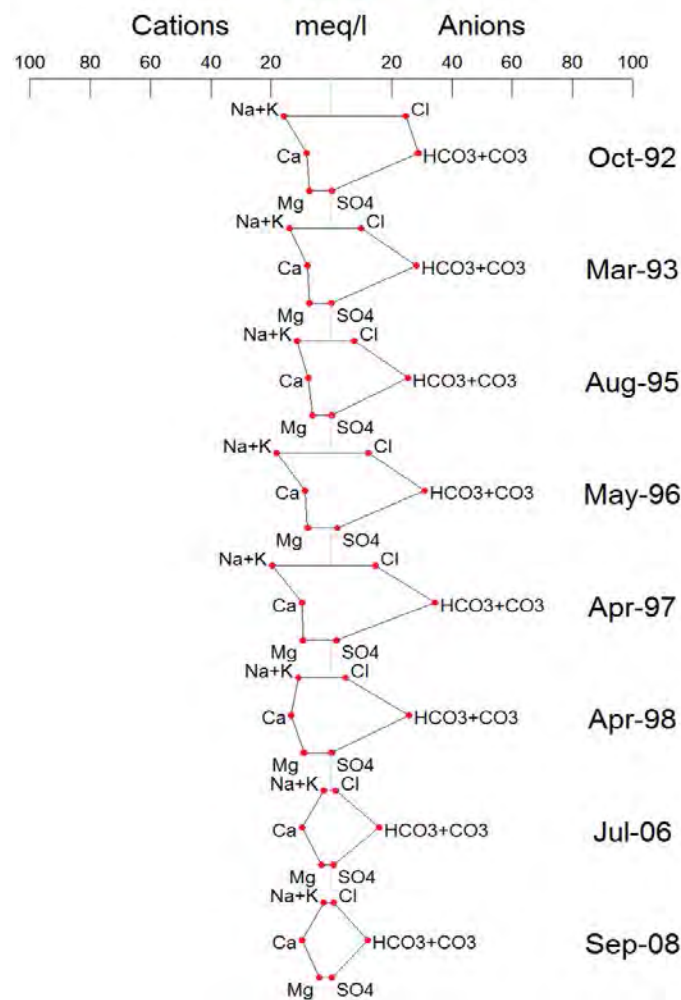
0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)

- Oct-92
- Aug-95
- Apr-98
- Jul-06
- Sep-08



Stiff Diagram

IT323S



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Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-5B
Piper and Stiff Diagrams
Well IT323S
Landfill Section 2/8

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Approved By:

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EJW

Date:

Job Number:

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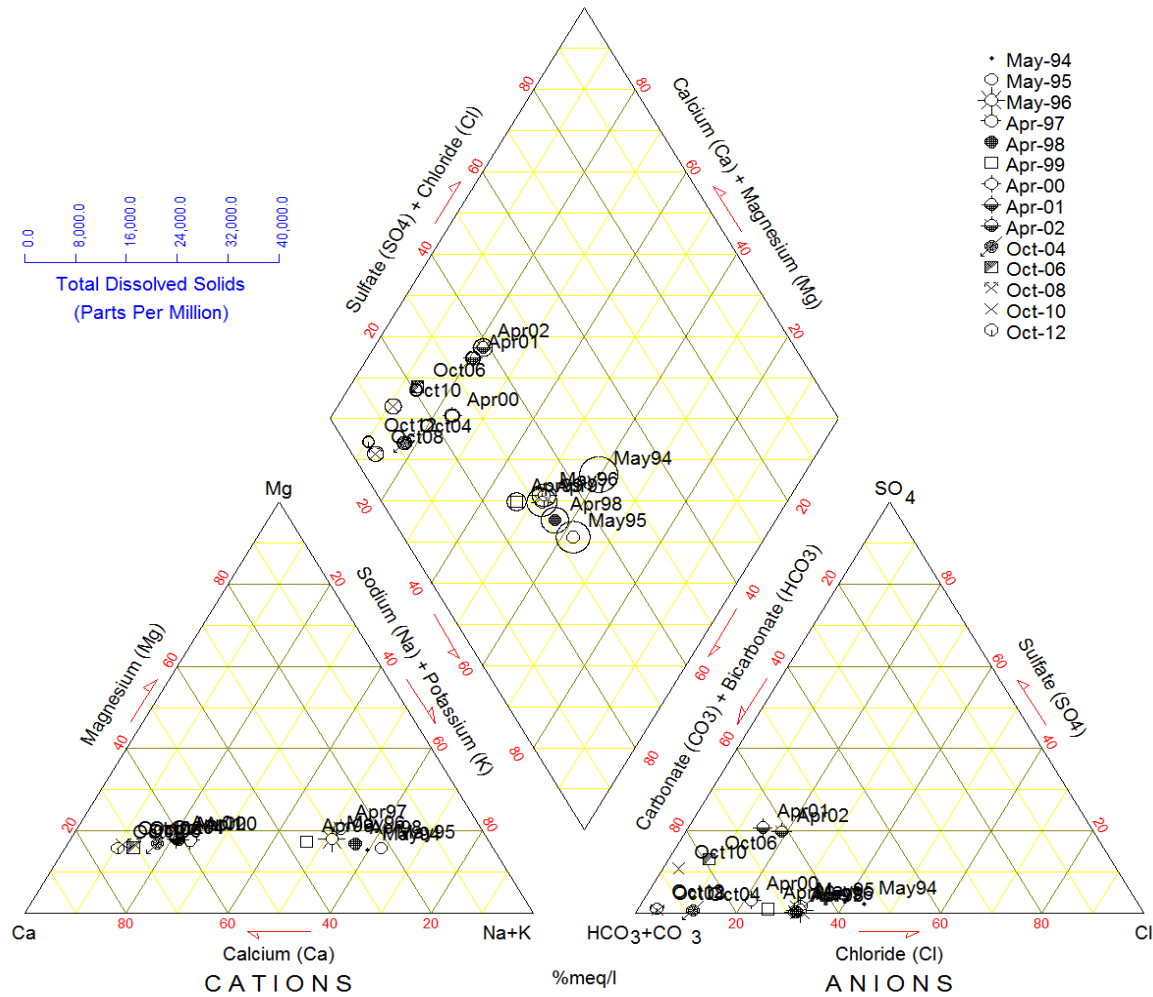
151771

Piper Diagram

IT321S

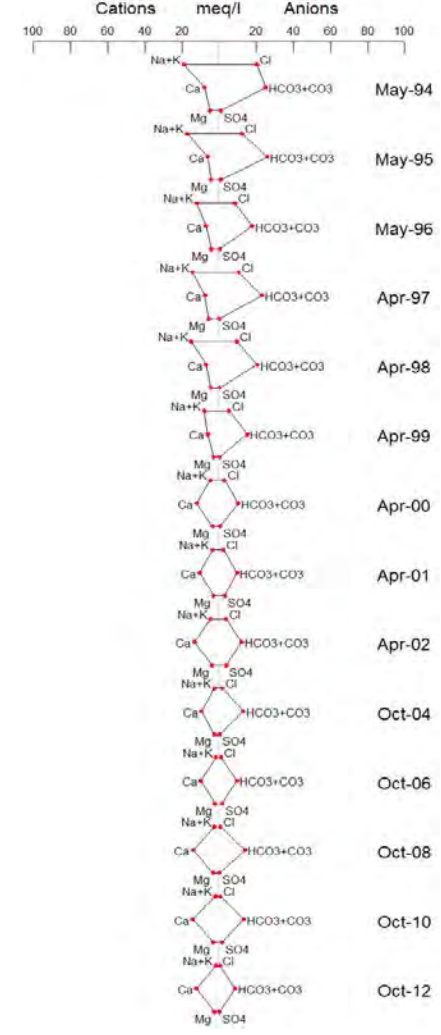
0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)

- May-94
- May-95
- ⊗ May-96
- ⊙ Apr-97
- ⊕ Apr-98
- Apr-99
- ◇ Apr-00
- ⊖ Apr-01
- ⊗ Apr-02
- ⊕ Oct-04
- ⊖ Oct-06
- ⊗ Oct-08
- ⊕ Oct-10
- Oct-12



Stiff Diagram

IT321S



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Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-6A
Piper and Stiff Diagrams
Well IT321S
Landfill Section 2/8

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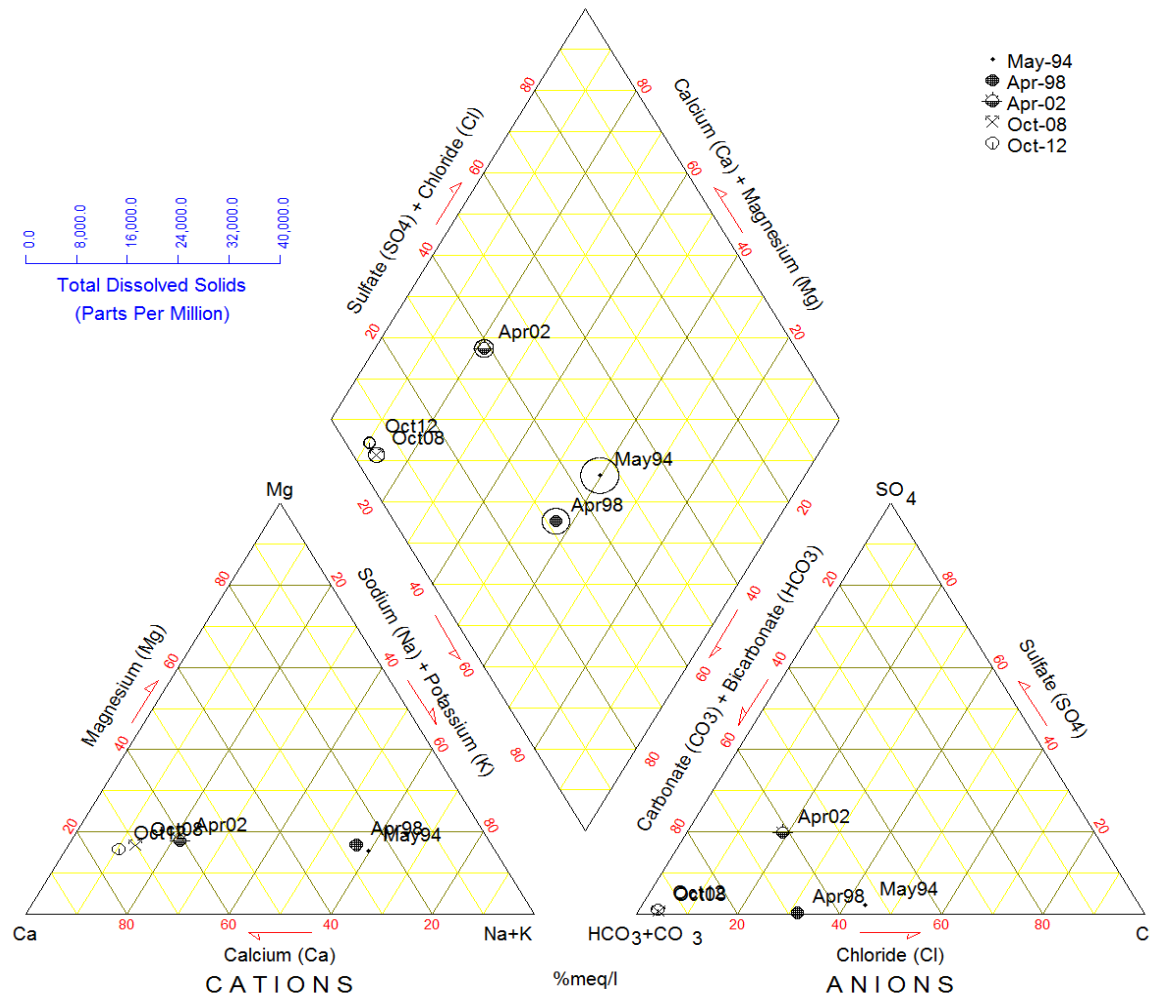
May 2015

151771

Piper Diagram

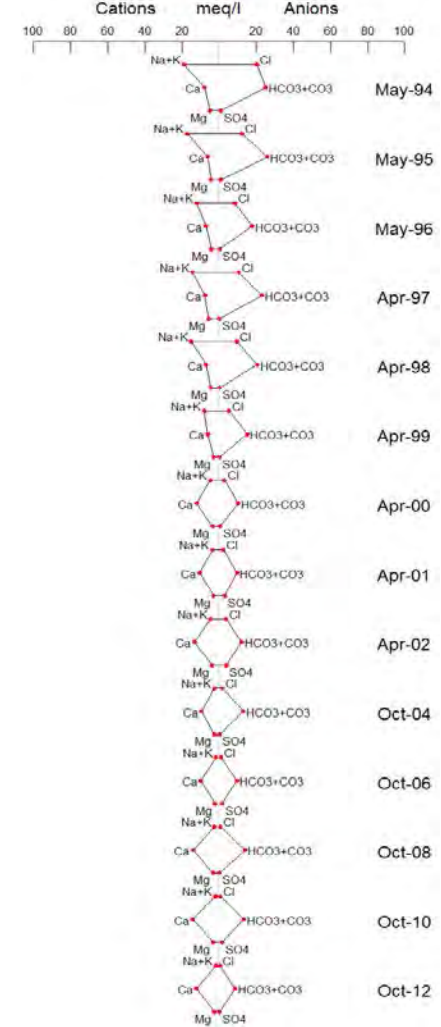
IT321S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT321S



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Leachate Controls at
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Fresh Kills Landfill

Figure 4.1-6B
Piper and Stiff Diagrams
Well IT321S
Landfill Section 2/8

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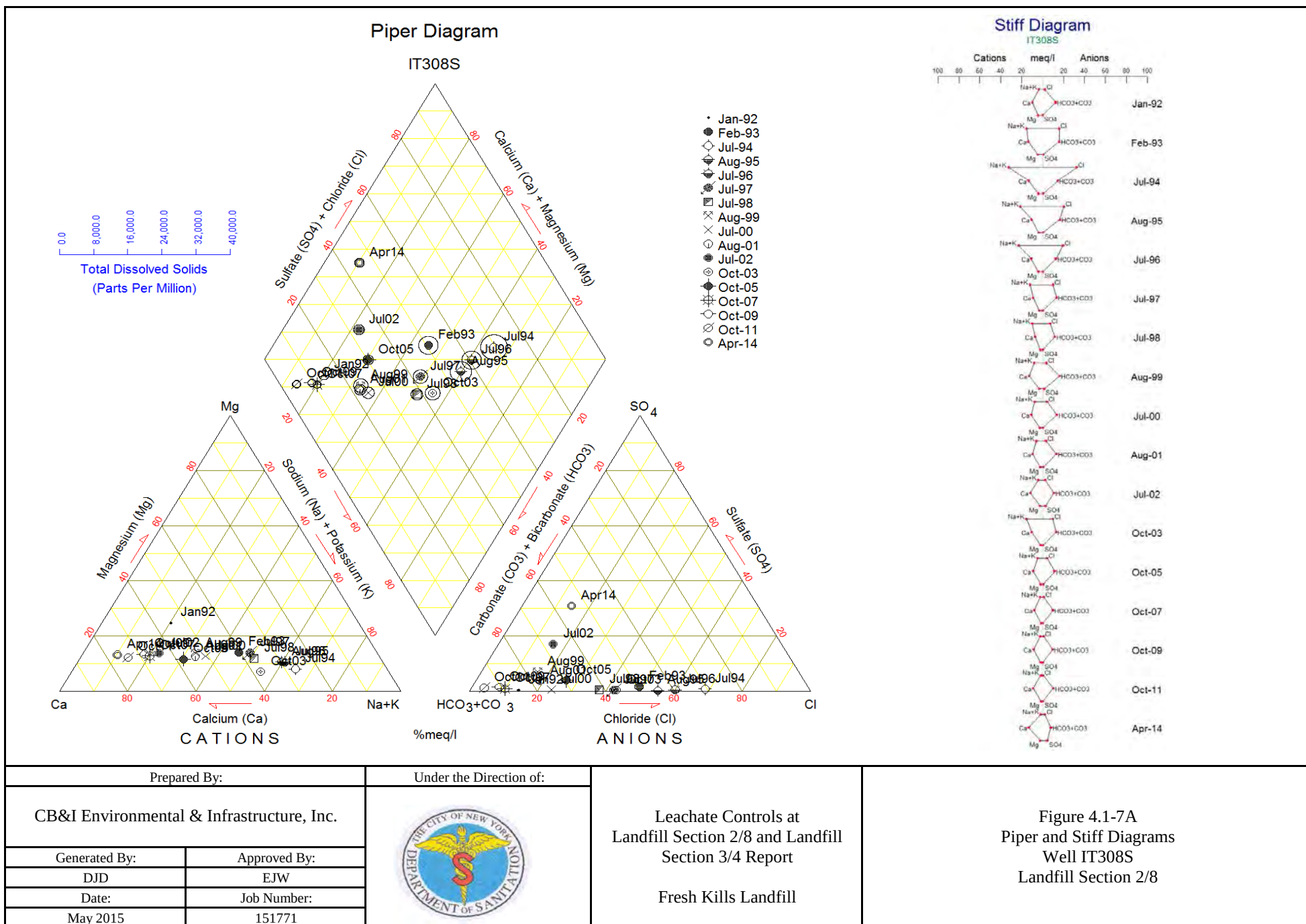
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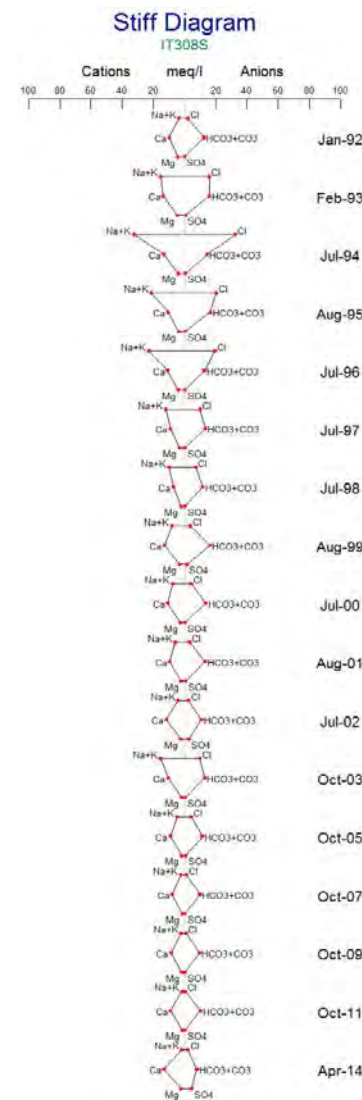
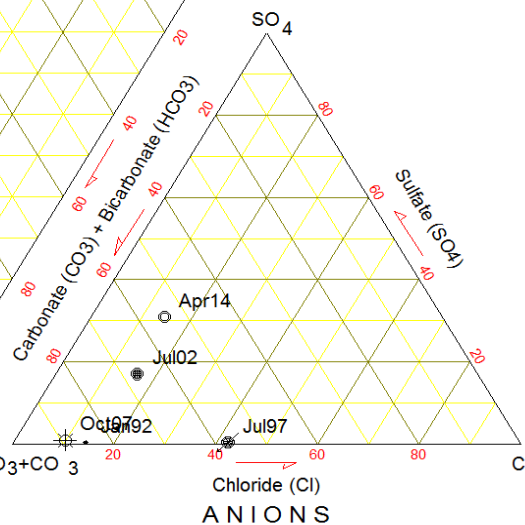
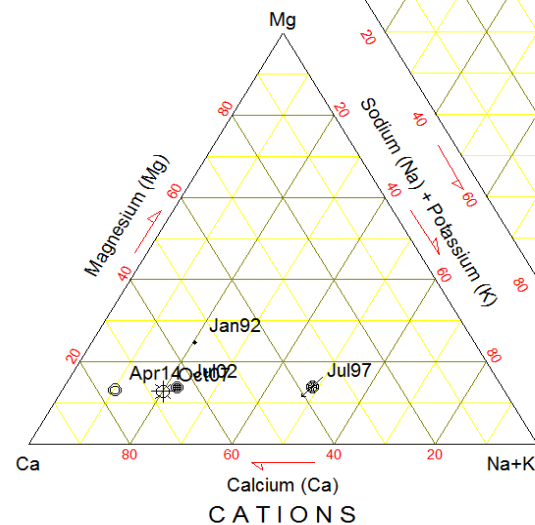
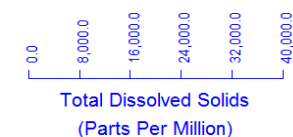
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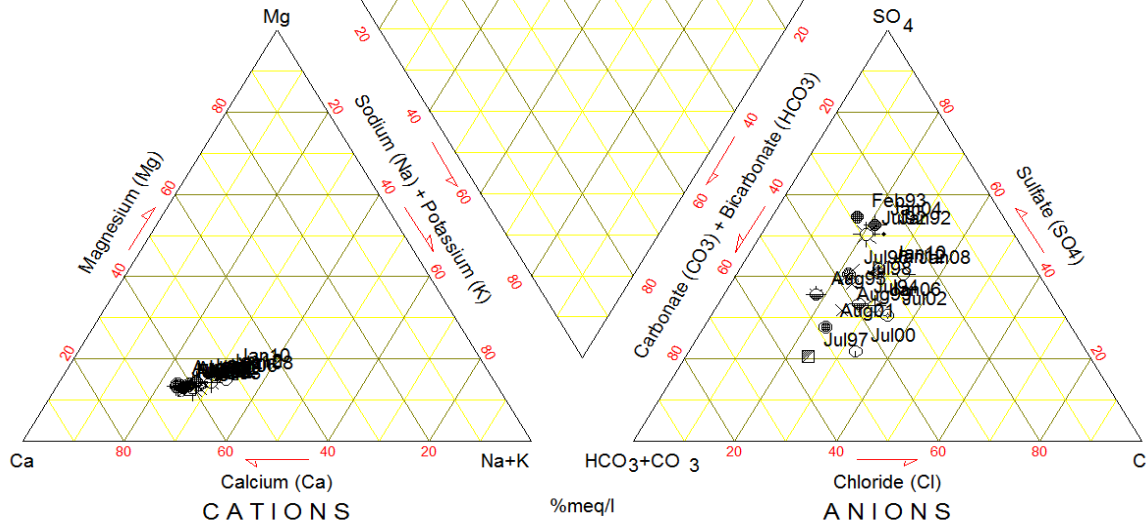
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DJD	EJW			
Date:	Job Number:			
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Figure 4.1-7B
Piper and Stiff Diagrams
Well IT308S
Landfill Section 2/8

Piper Diagram

IT306S

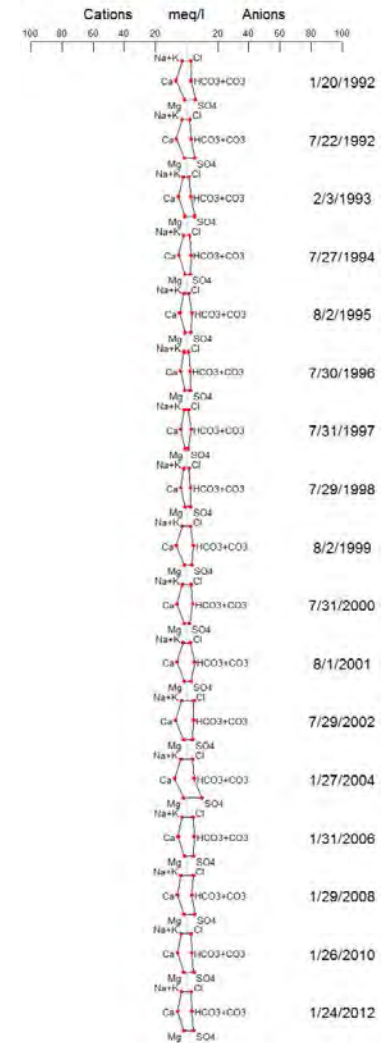
0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



- Jan-92
- Jul-92
- Feb-93
- Jul-94
- Aug-95
- Jul-96
- Jul-97
- Jul-98
- Aug-99
- Jul-00
- Aug-01
- Jul-02
- Jan-04
- Jan-06
- Jan-08
- Jan-10
- Jan-12

Stiff Diagram

IT306S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-8A
Piper and Stiff Diagrams
Well IT306S
Landfill Section 2/8

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

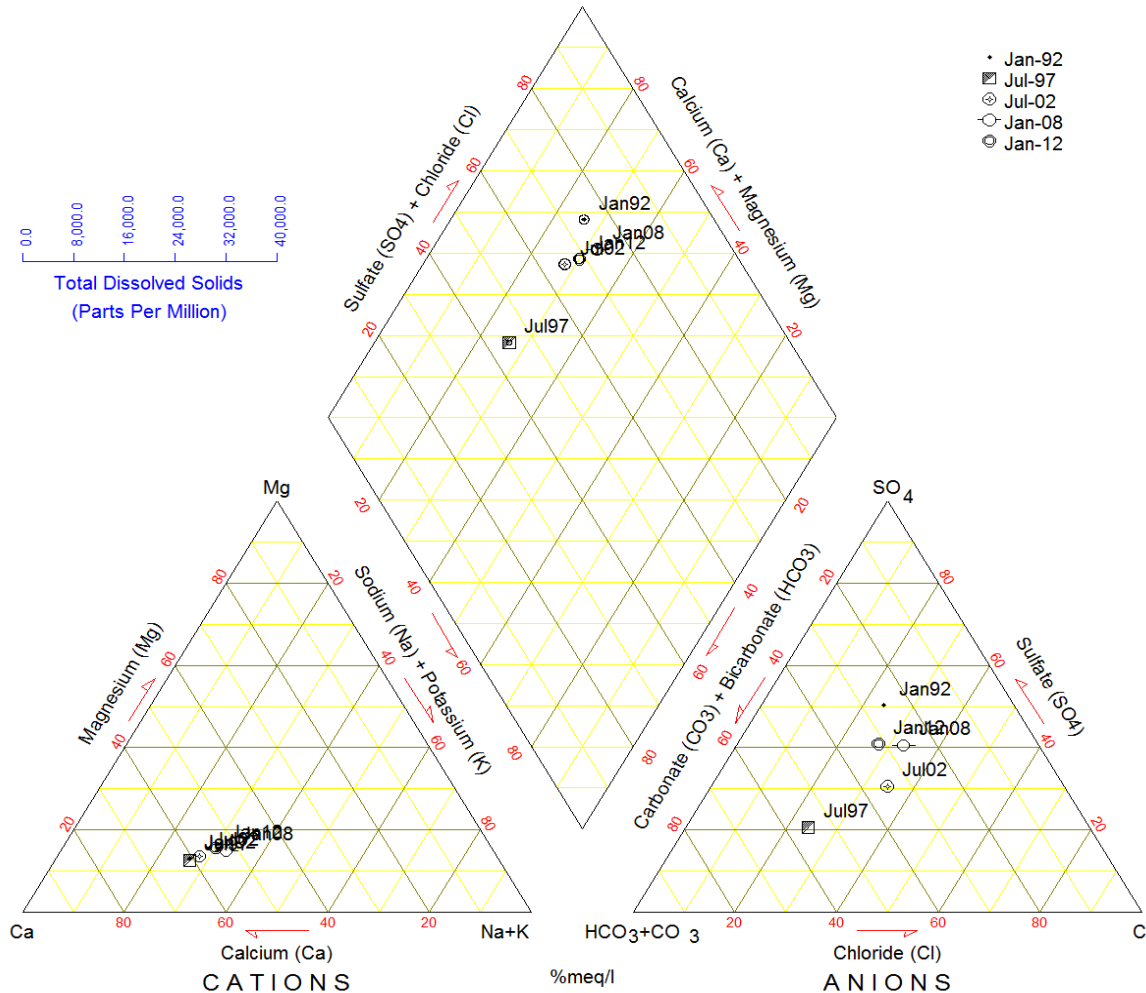
May 2015

151771

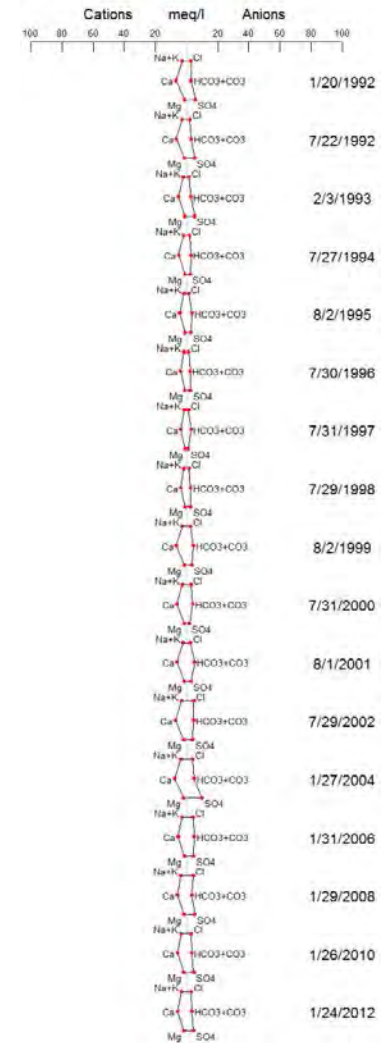
Piper Diagram

IT306S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram IT306S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-8B
Piper and Stiff Diagrams
Well IT306S
Landfill Section 2/8

Generated By:

Approved By:

DJD

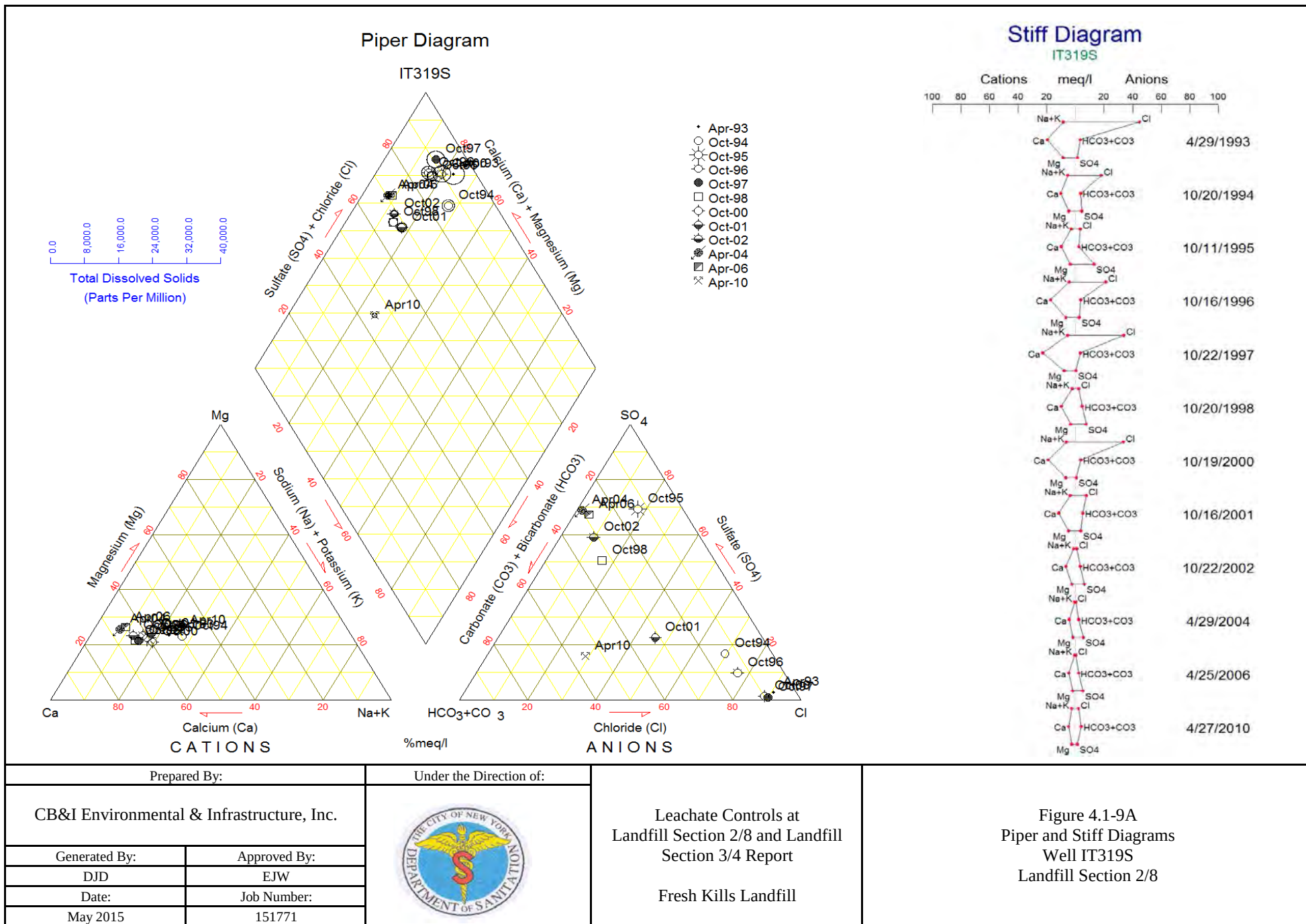
EJW

Date:

Job Number:

May 2015

151771



Prepared By:

CB&I Environmental & Infrastructure, Inc.

Under the Direction of:

Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-9A
Piper and Stiff Diagrams
Well IT319S
Landfill Section 2/8

Generated By:

DJD

Date:

May 2015

Approved By:

EJW

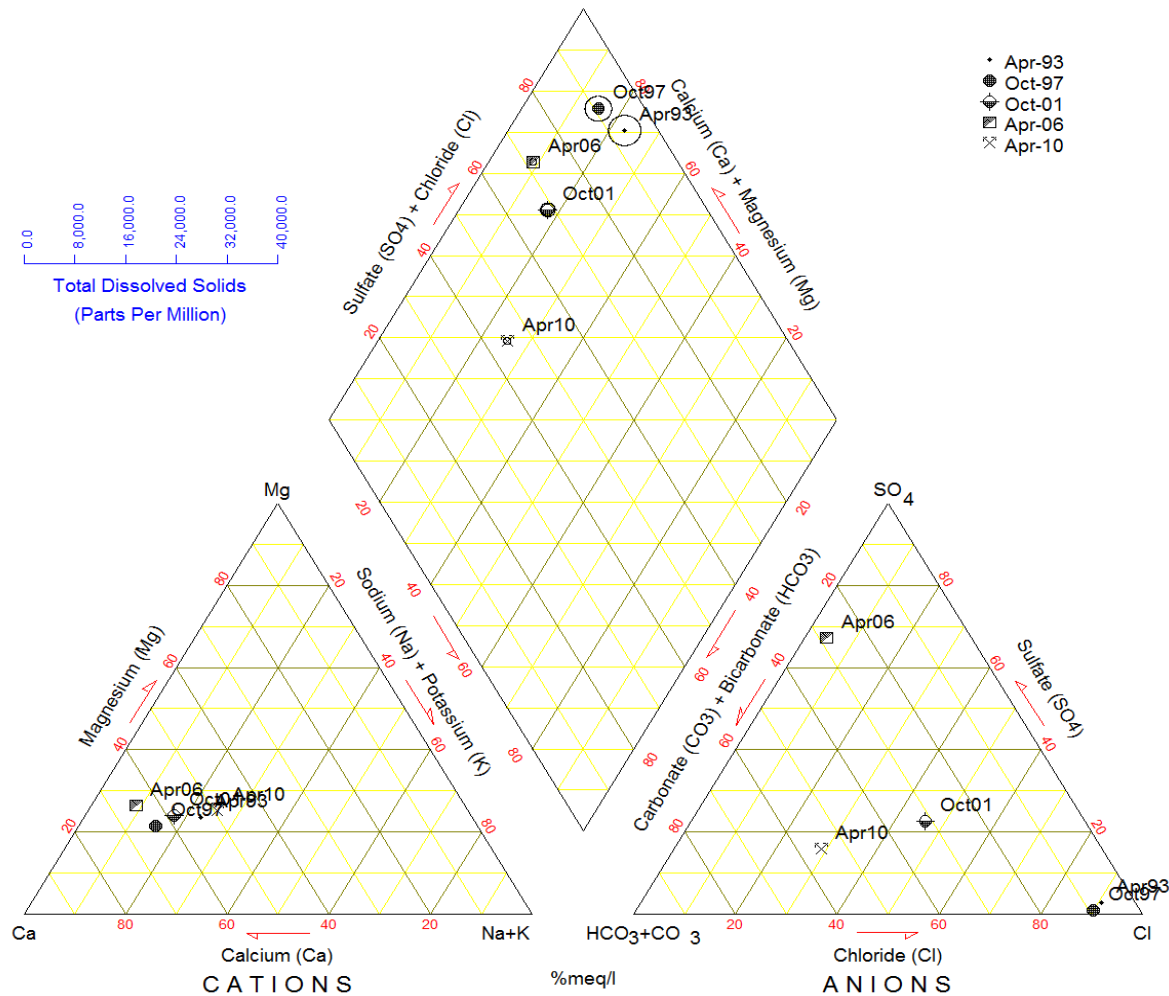
Job Number:

151771

Piper Diagram

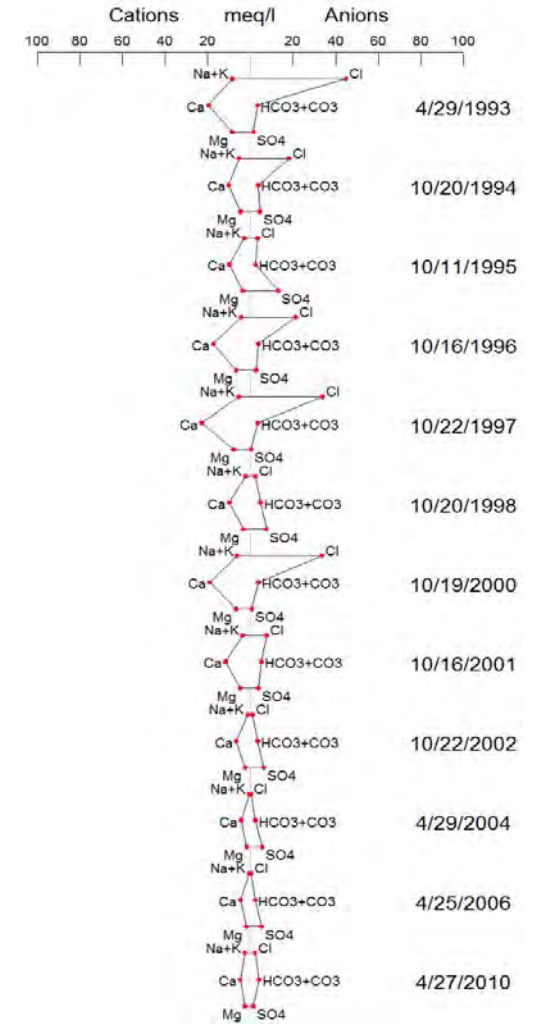
IT319S

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Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT319S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-9B
Piper and Stiff Diagrams
Well IT319S
Landfill Section 2/8

Generated By:

Approved By:

DJD

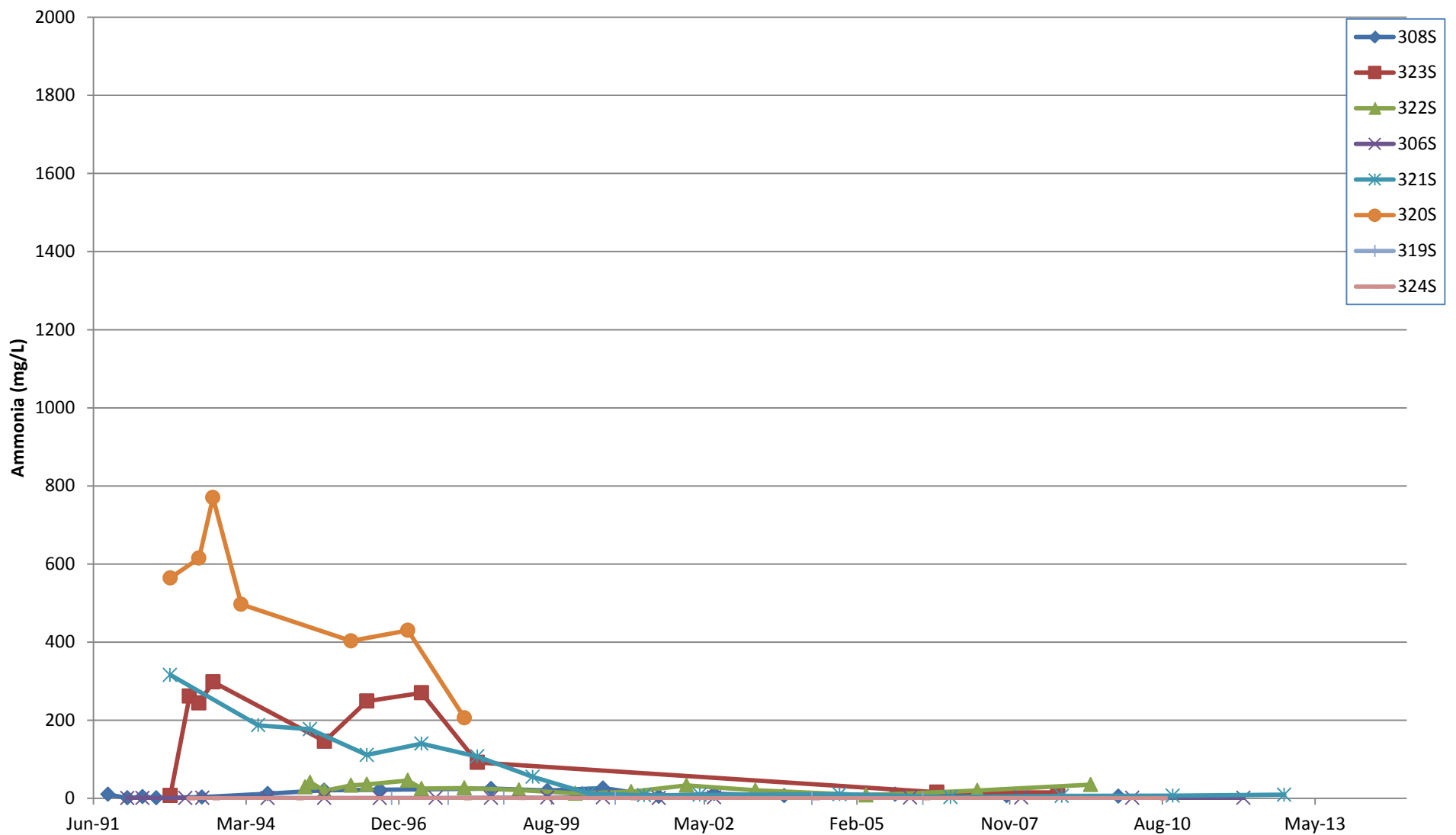
EJW

Date:

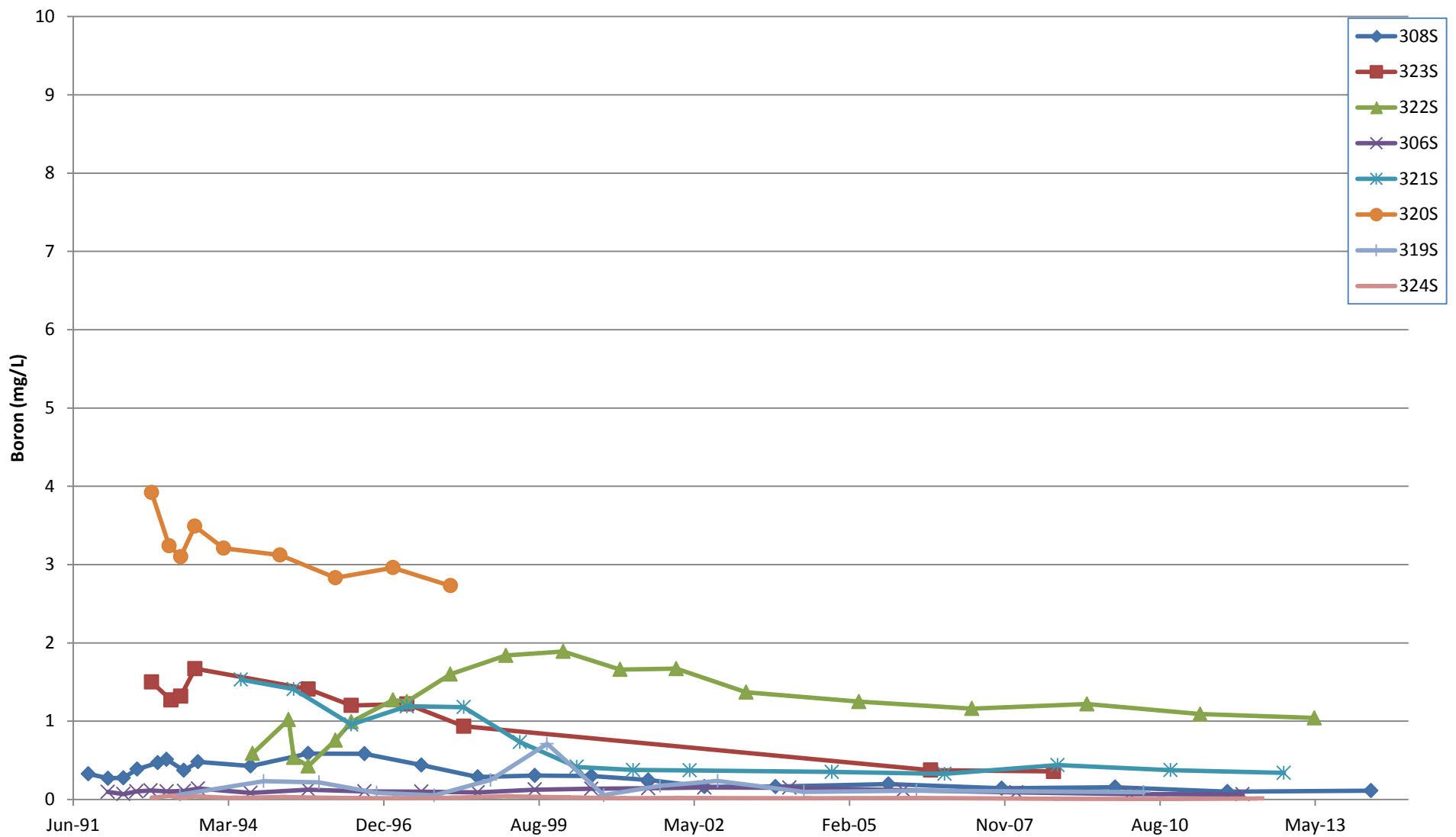
Job Number:

May 2015

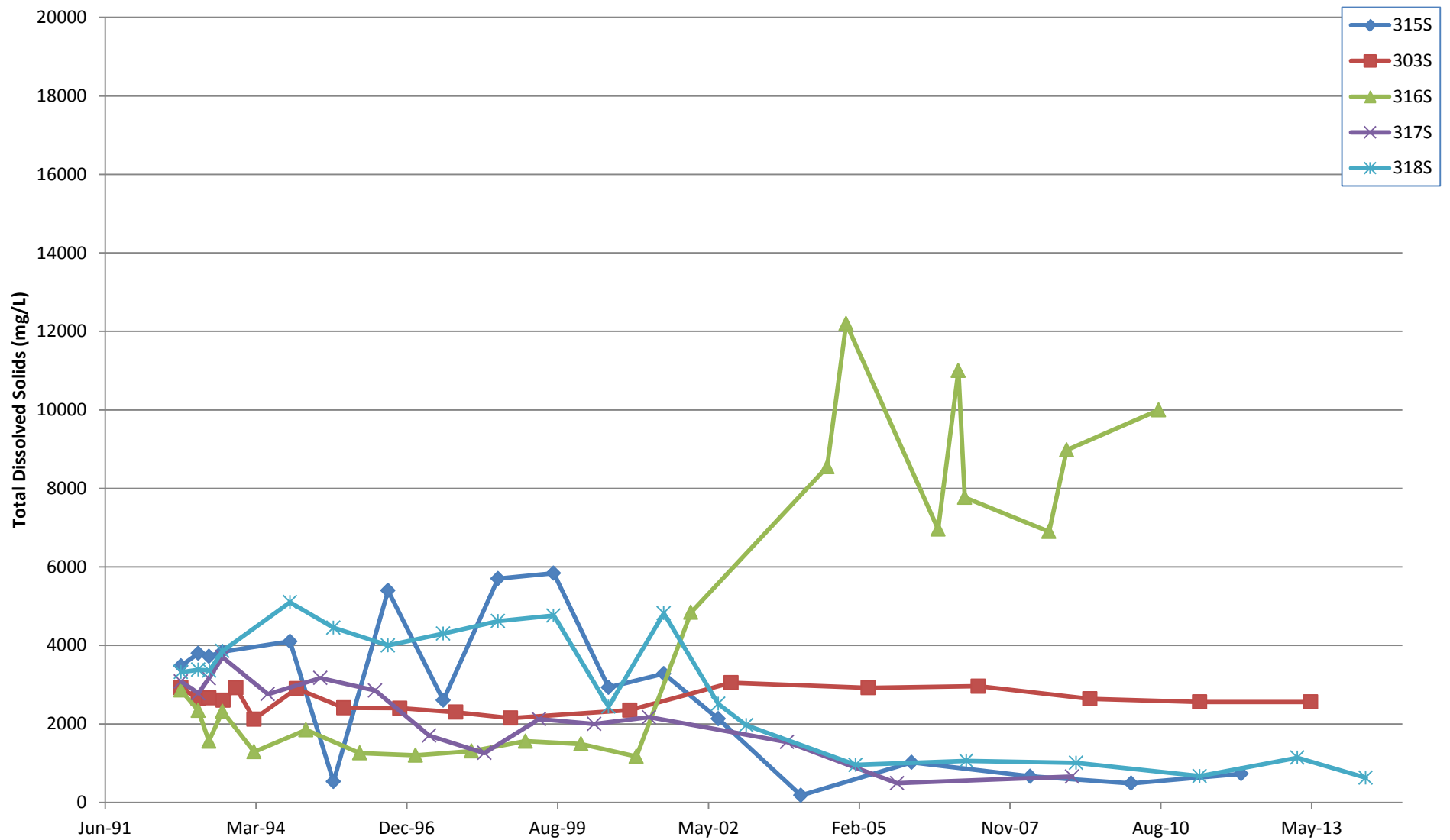
151771



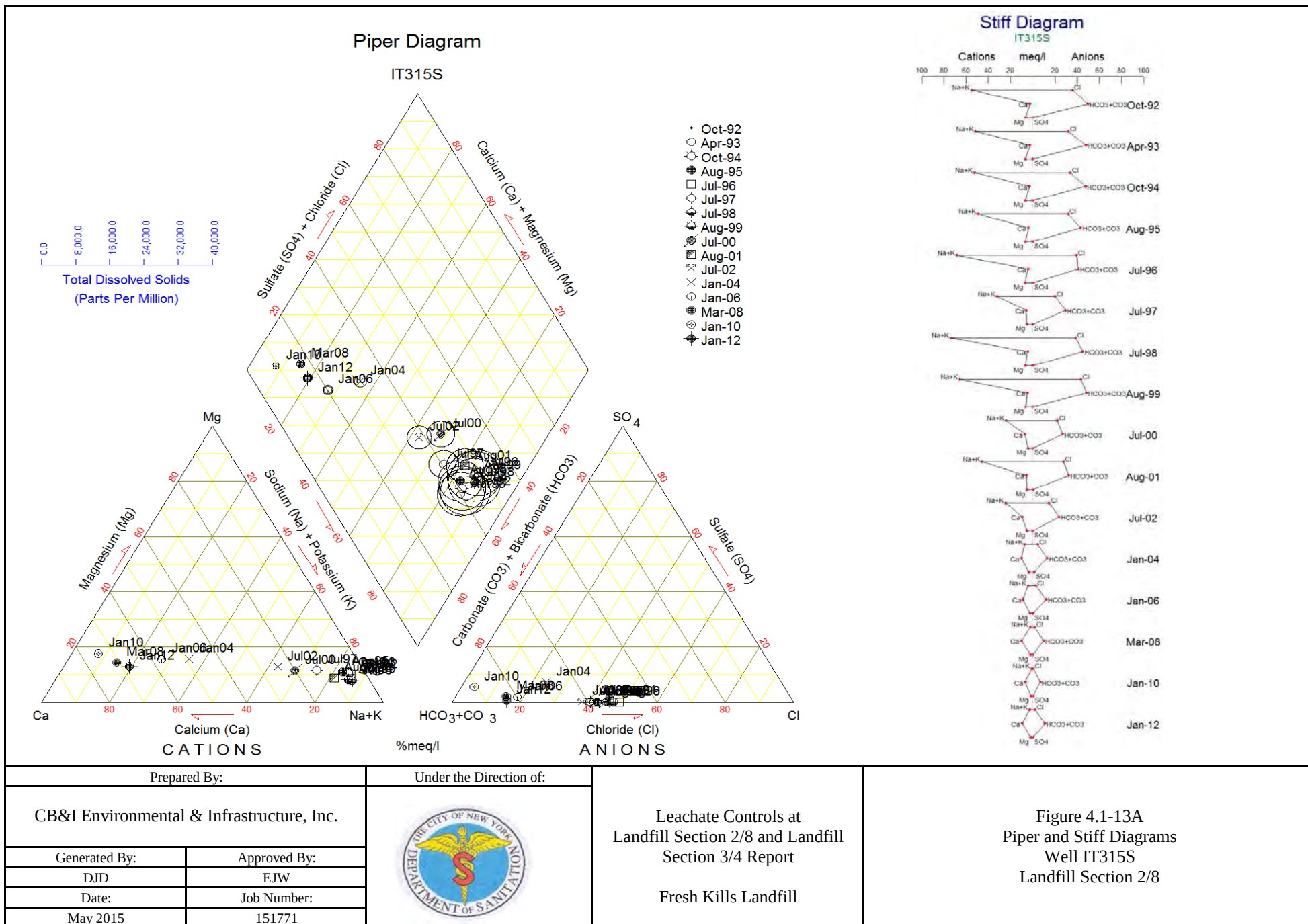
Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-10 Ammonia Concentrations (mg/L) Landfill Section 2/8 - Original Leachate Drain
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				

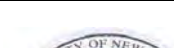


Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-11 Boron Concentrations (mg/L) Landfill Section 2/8 - Original Drain
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				



Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-12 Total Dissolved Solids Concentrations (mg/L) Landfill Section 2/8 - Original Drain
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				

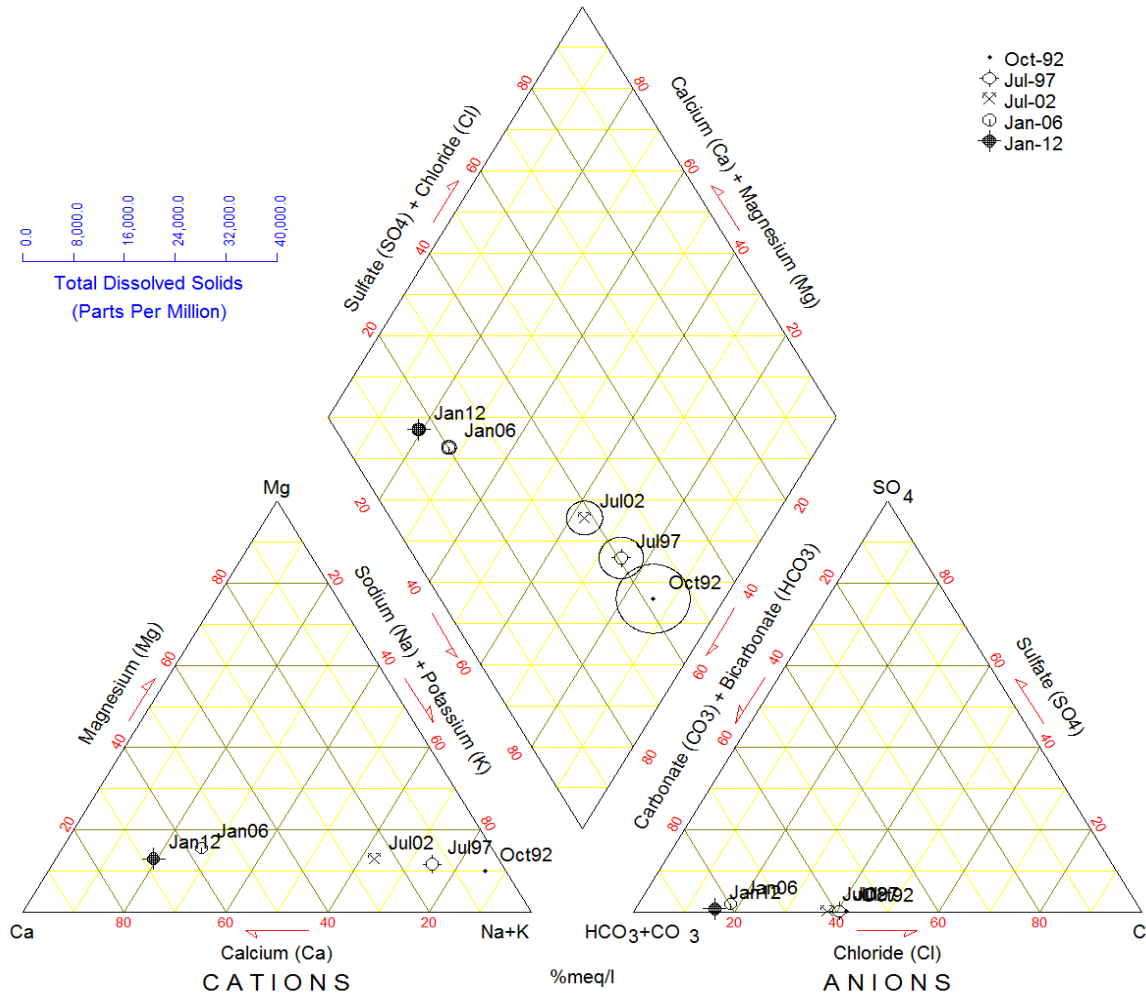


Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-13A Piper and Stiff Diagrams Well IT315S Landfill Section 2/8
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				

Piper Diagram

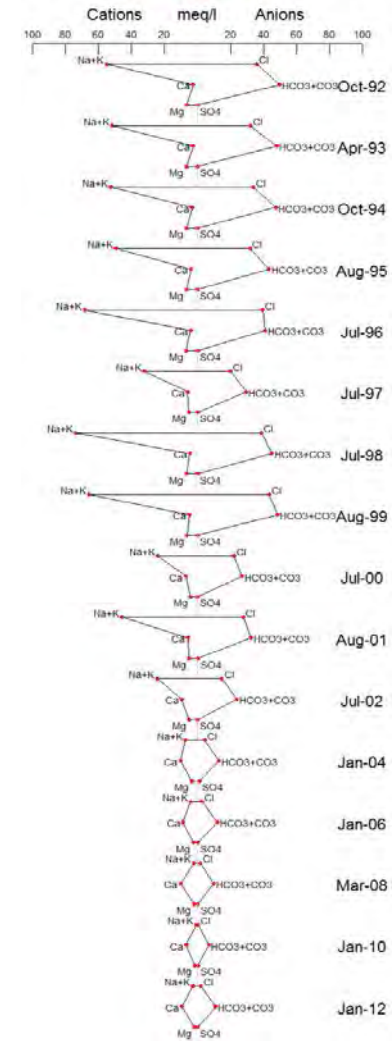
IT315S

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Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT315S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-13B
Piper and Stiff Diagrams
Well IT315S
Landfill Section 2/8

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

May 2015

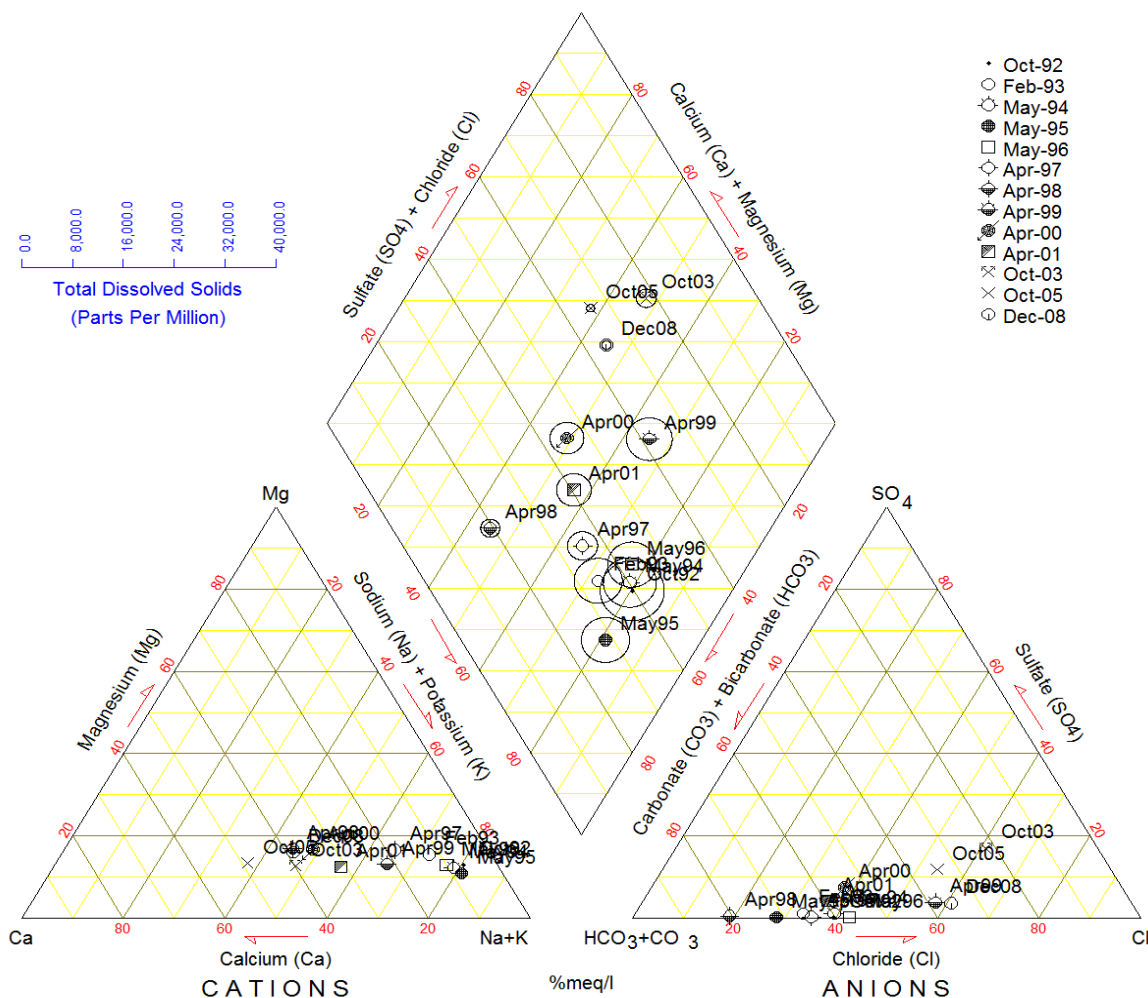
151771

Piper Diagram

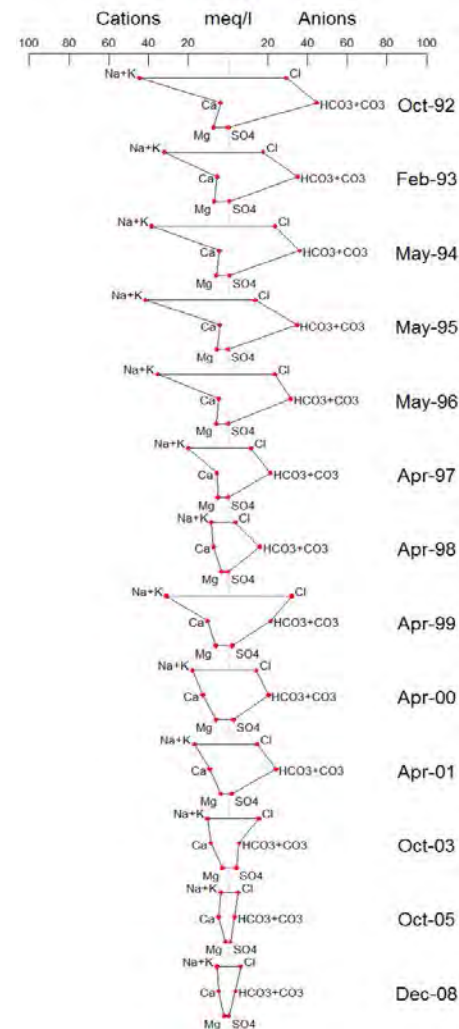
IT317S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)

- Oct-92
- Feb-93
- ⊙ May-94
- May-95
- May-96
- ◇ Apr-97
- ⊕ Apr-98
- ⊗ Apr-99
- ⊘ Apr-00
- ⊙ Apr-01
- ⊗ Oct-03
- ⊘ Oct-05
- ⊙ Dec-08



Stiff Diagram IT317S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-14A
Piper and Stiff Diagrams
Well IT317S
Landfill Section 2/8

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

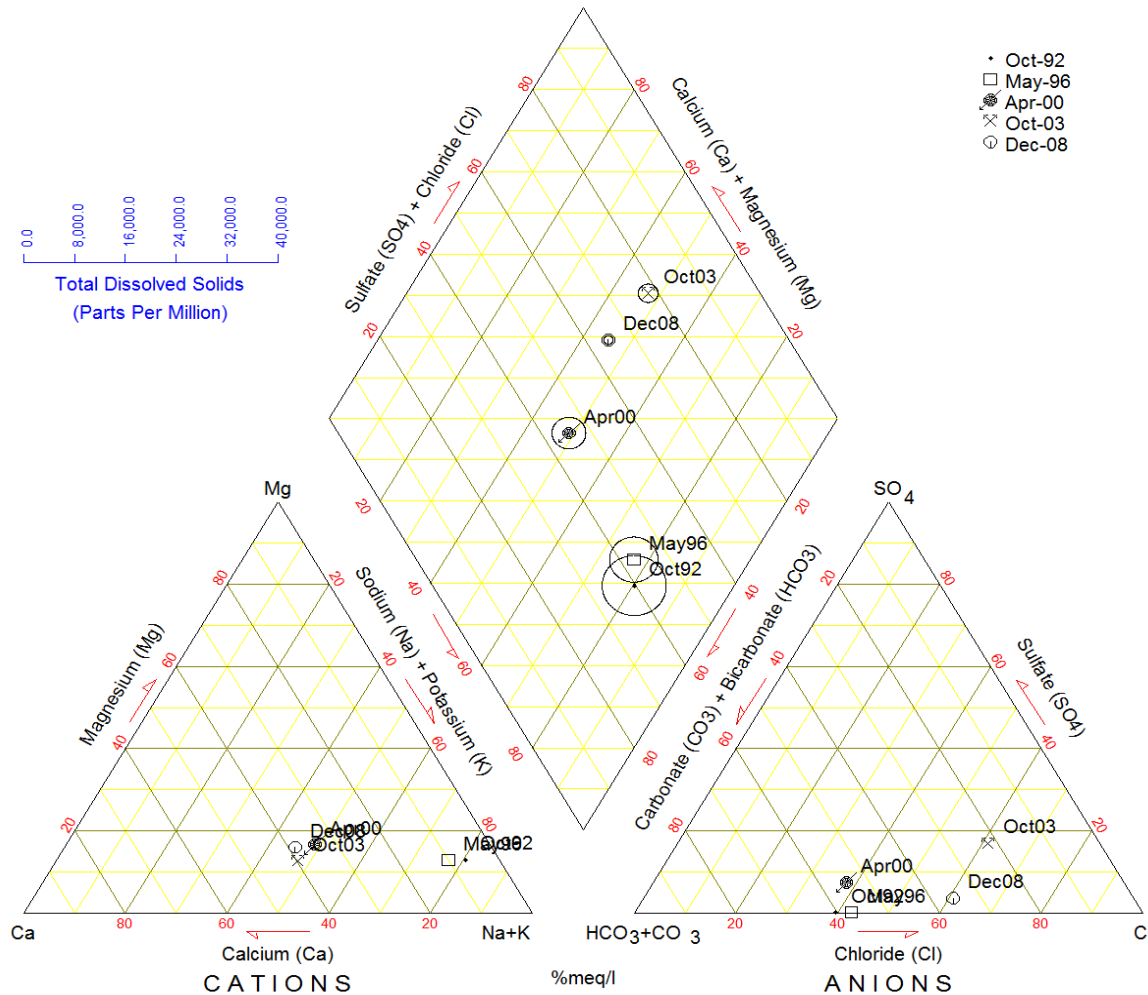
May 2015

151771

Piper Diagram

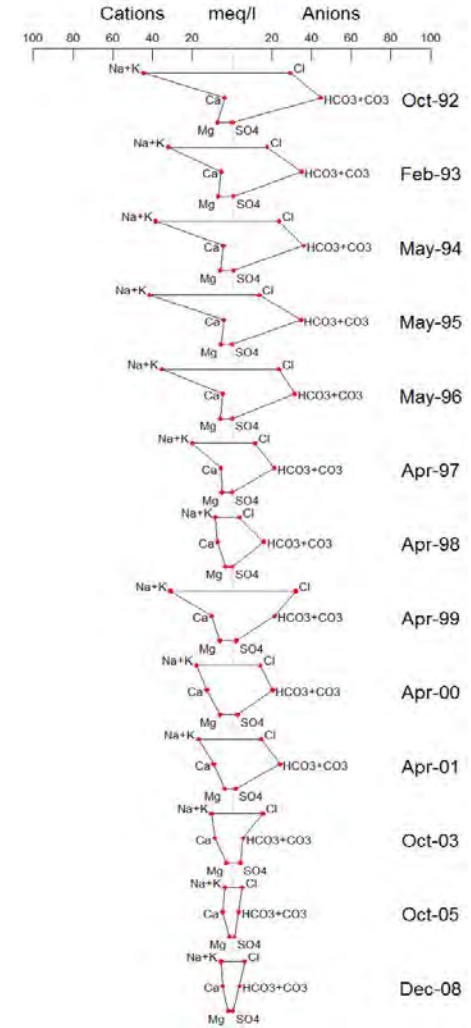
IT317S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT317S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-14B
Piper and Stiff Diagrams
Well IT317S
Landfill Section 2/8

Generated By:

Approved By:

DJD

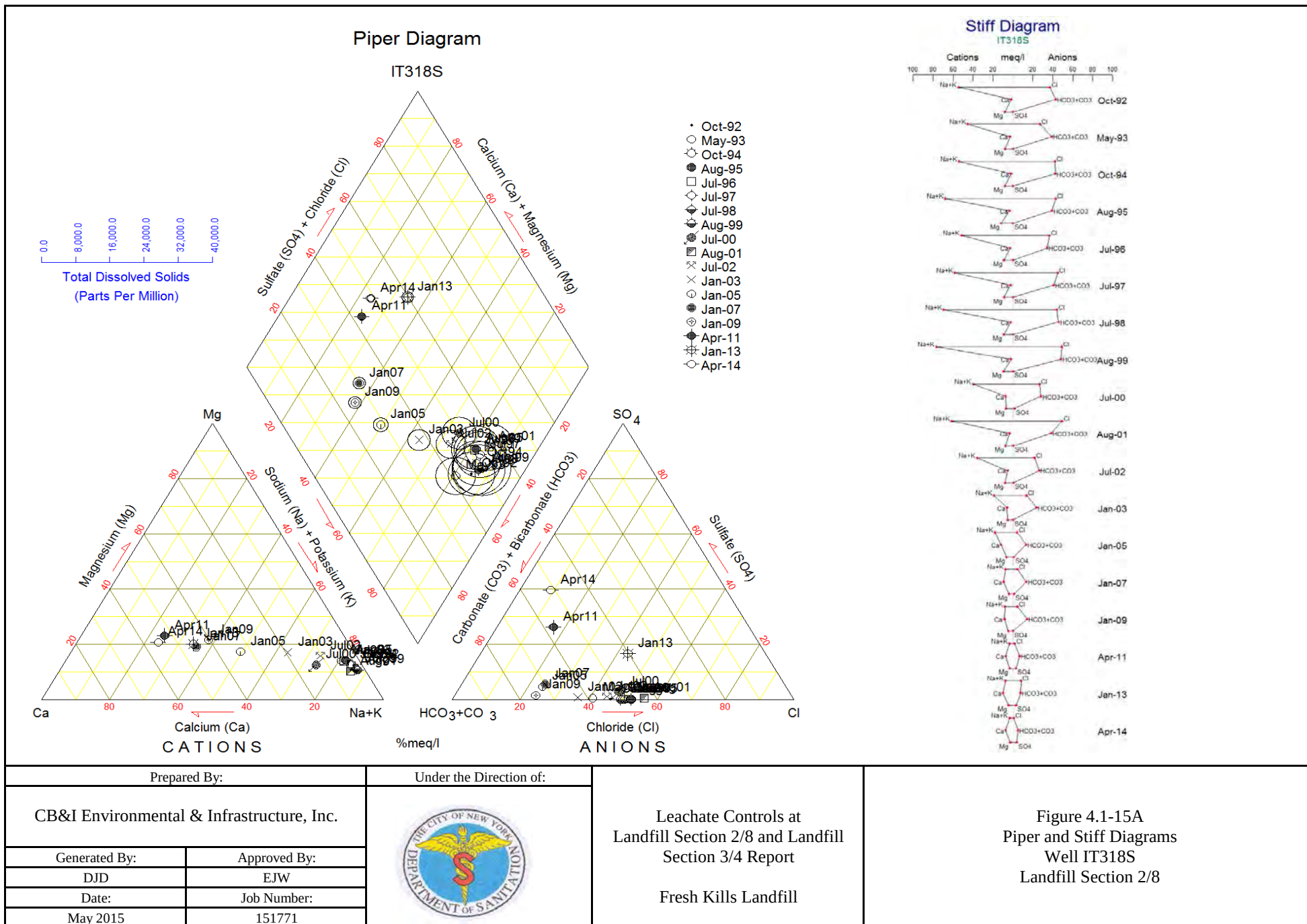
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Date:

Job Number:

May 2015

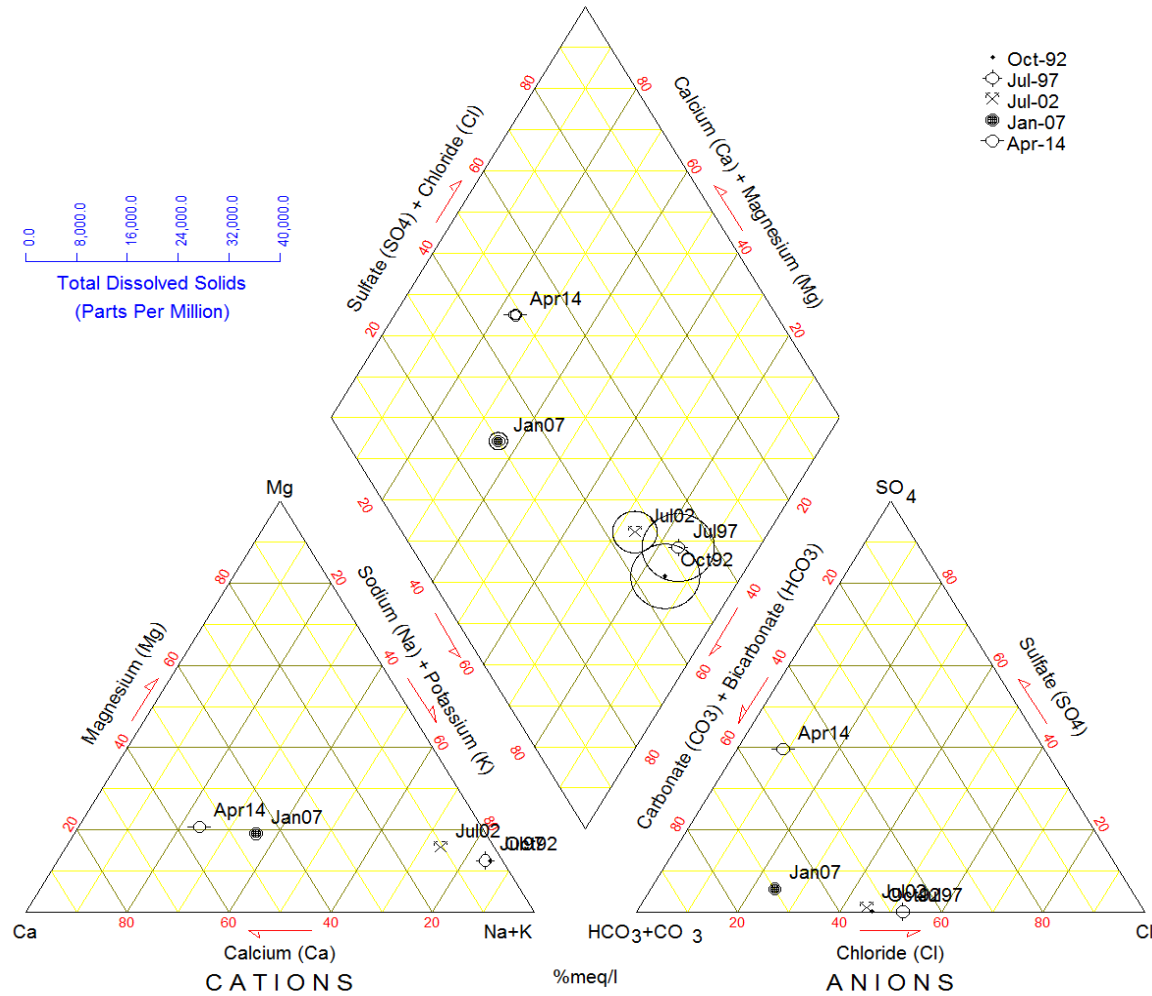
151771



Piper Diagram

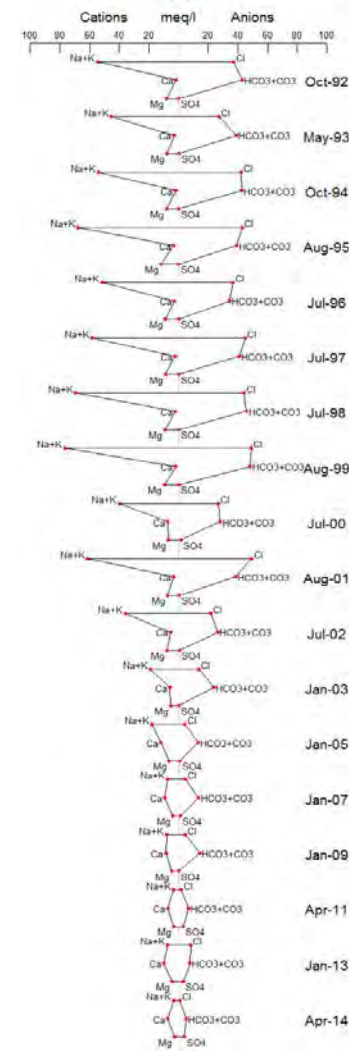
IT318S

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Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT318S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-15B
Piper and Stiff Diagrams
Well IT318S
Landfill Section 2/8

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

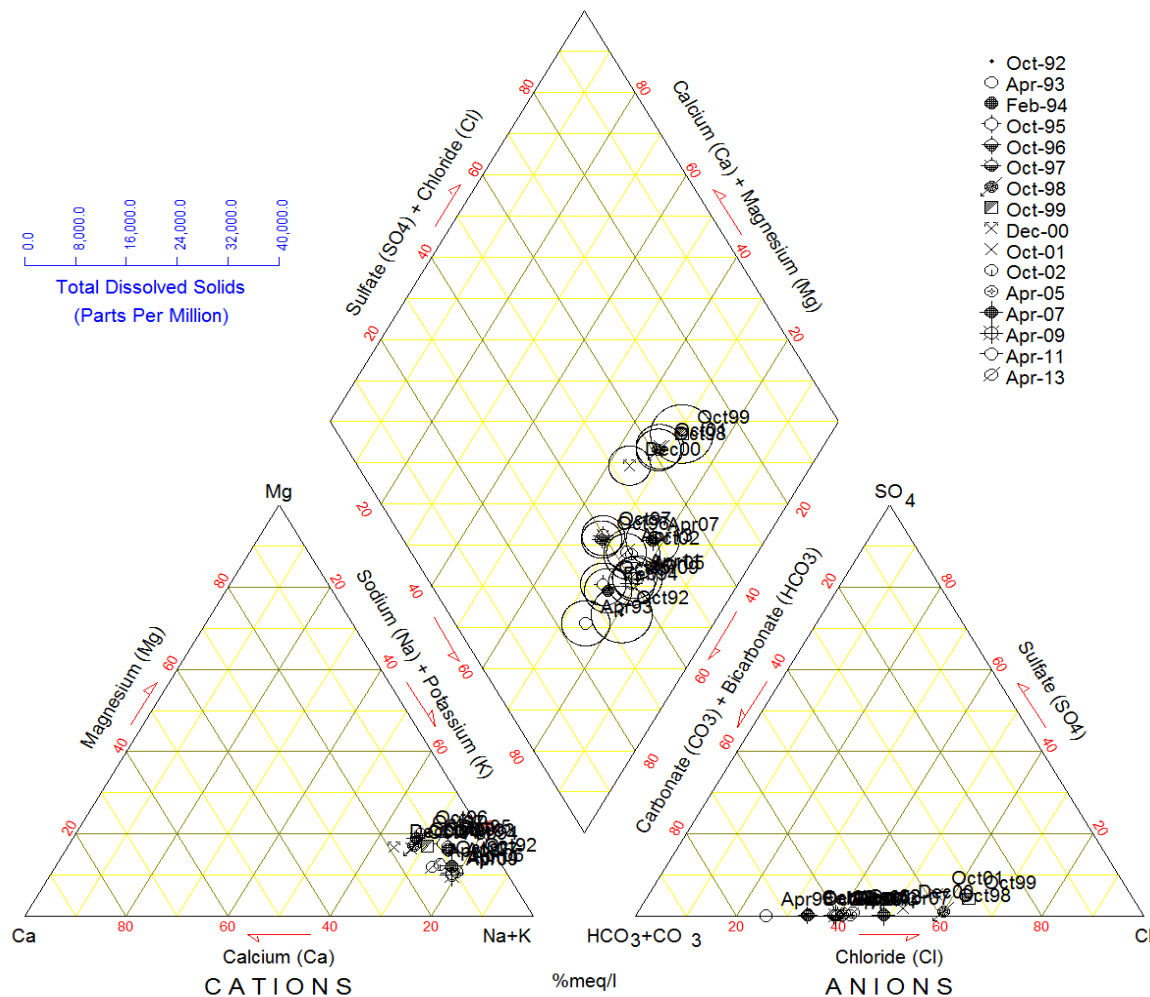
May 2015

151771

Piper Diagram

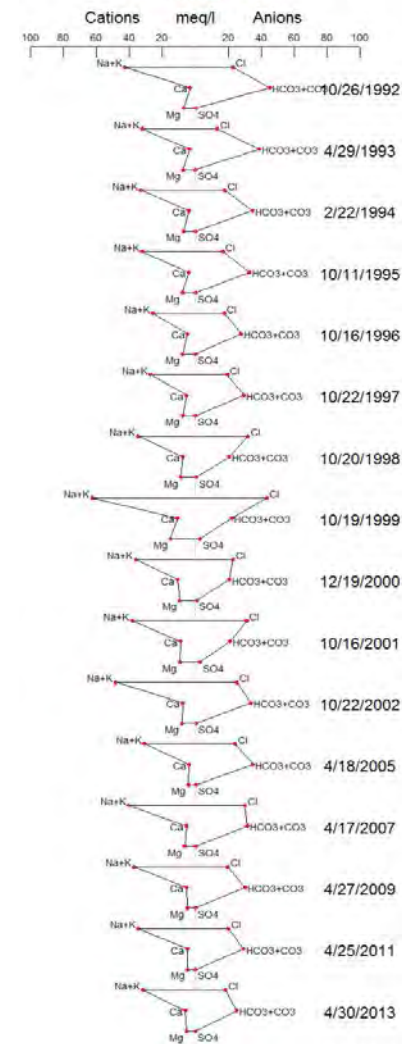
IT303S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT303S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-16A
Piper and Stiff Diagrams
Well IT303S
Landfill Section 2/8

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

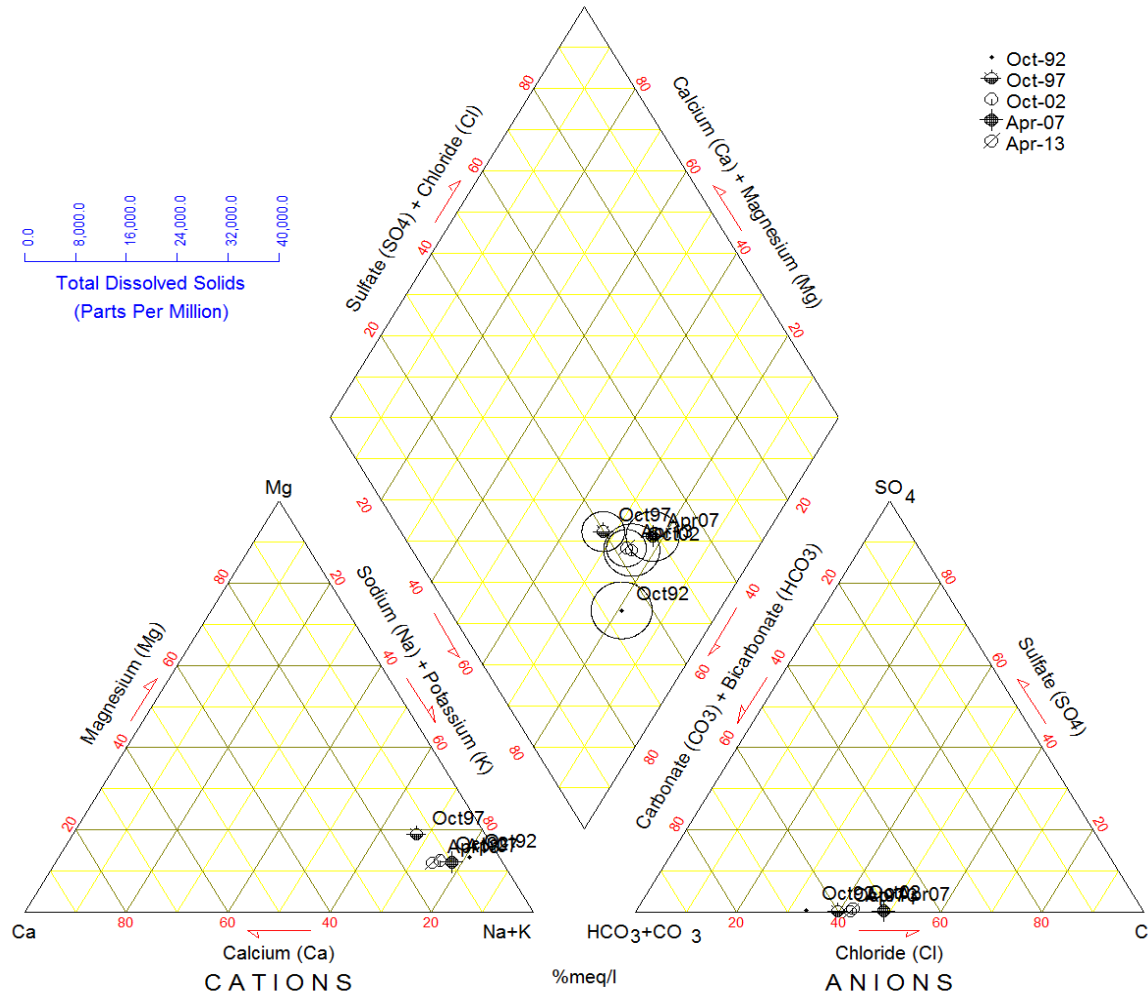
May 2015

151771

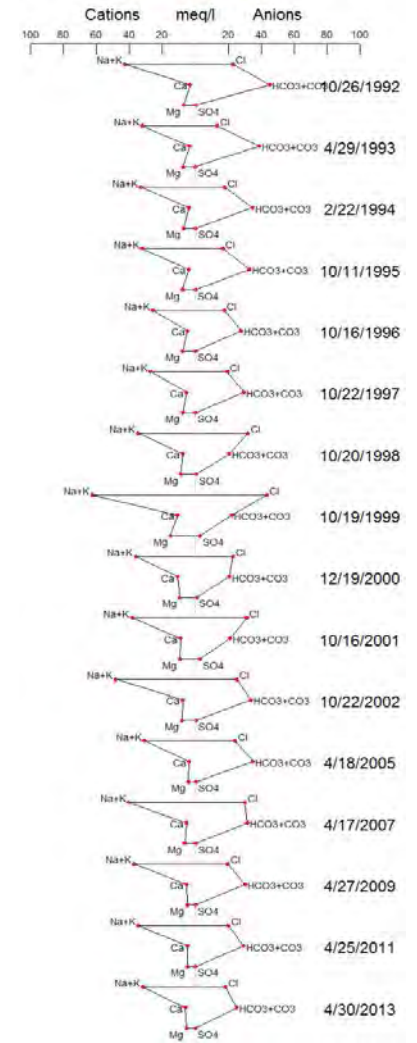
Piper Diagram

IT303S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram IT303S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-16B
Piper and Stiff Diagrams
Well IT303S
Landfill Section 2/8

Generated By:

Approved By:

DJD

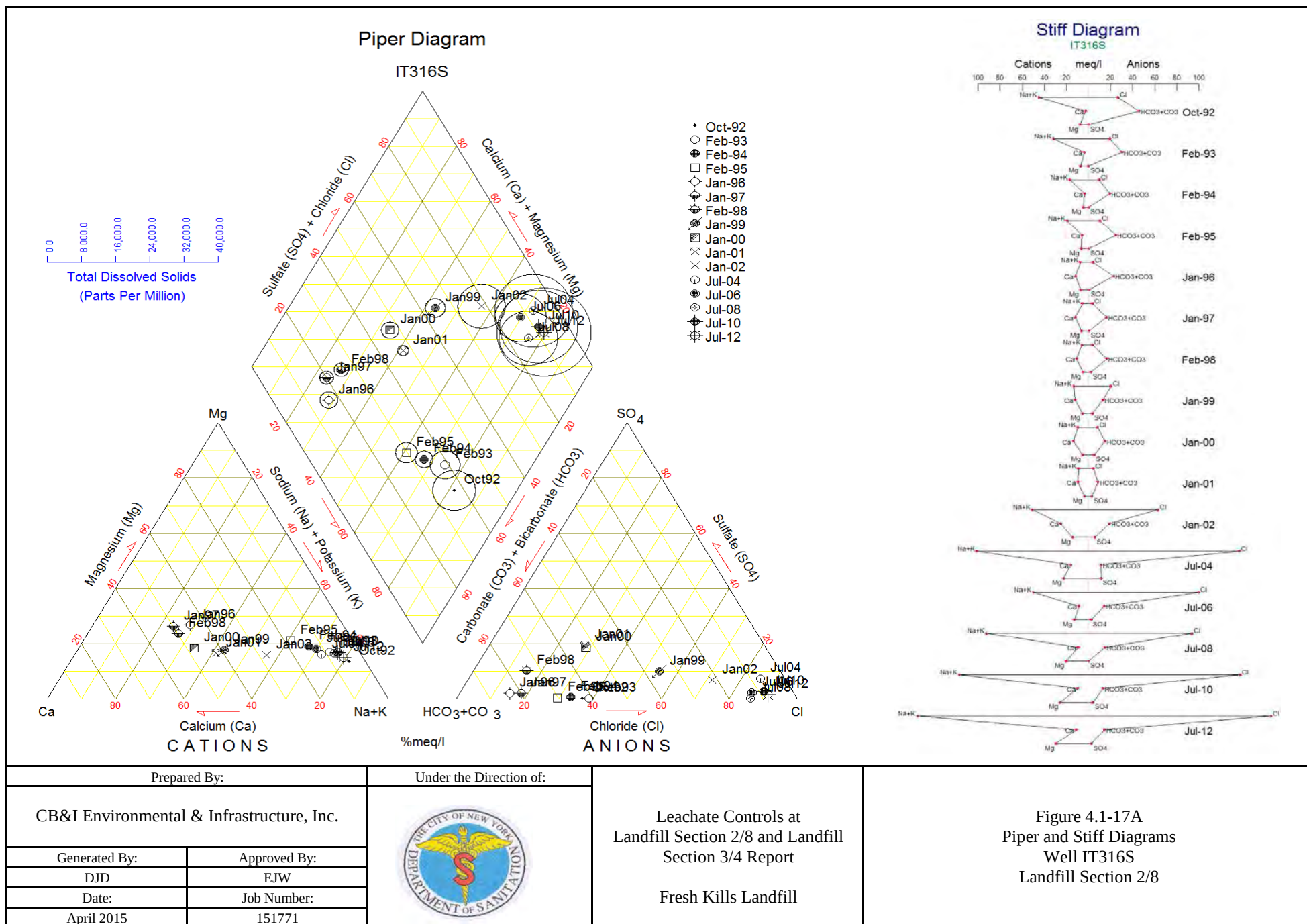
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Date:

Job Number:

May 2015

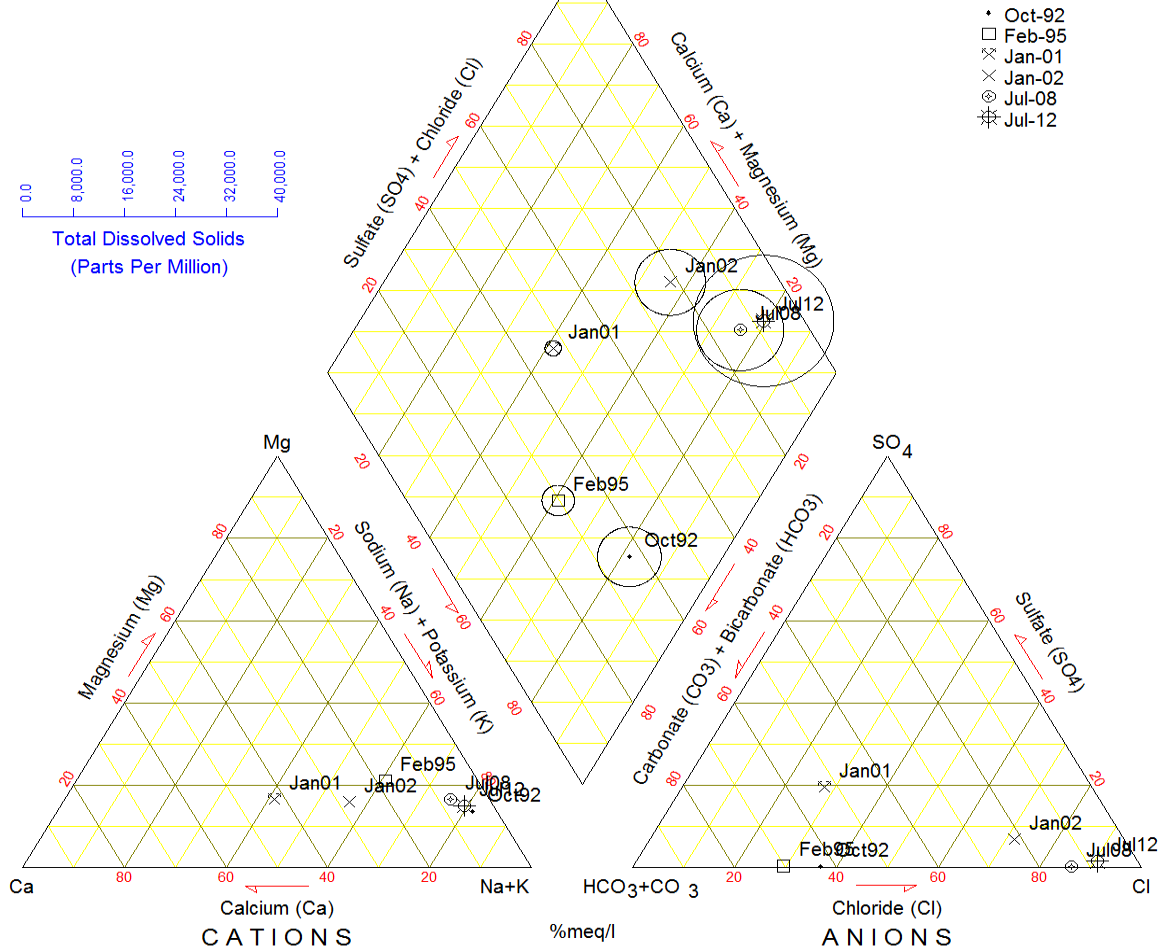
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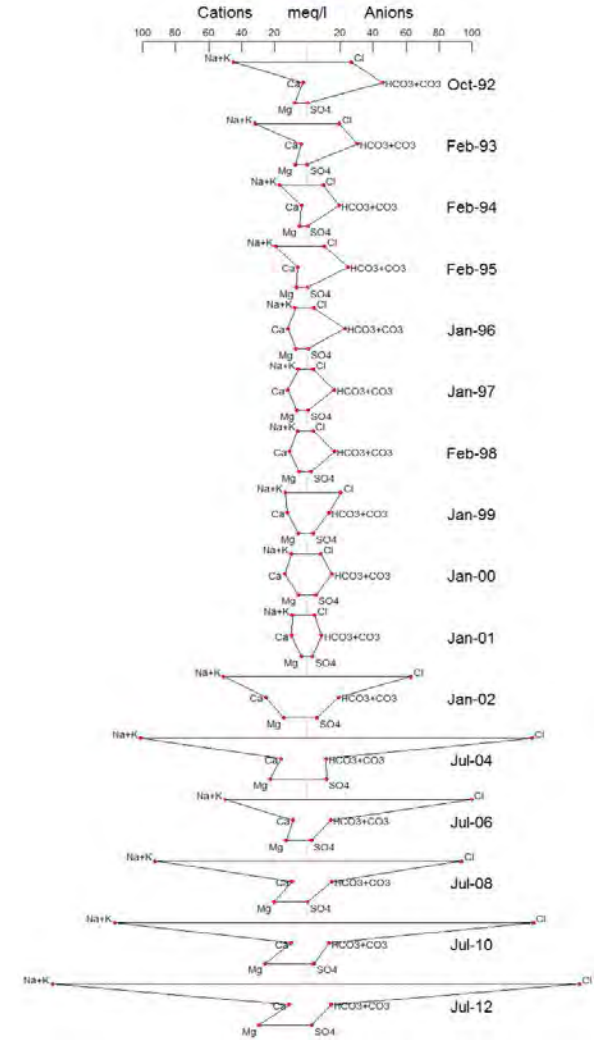
Piper Diagram

IT316S

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Total Dissolved Solids
(Parts Per Million)



Stiff Diagram IT316S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-17B
Piper and Stiff Diagrams
Well IT316S
Landfill Section 2/8

Generated By:

Approved By:

DJD

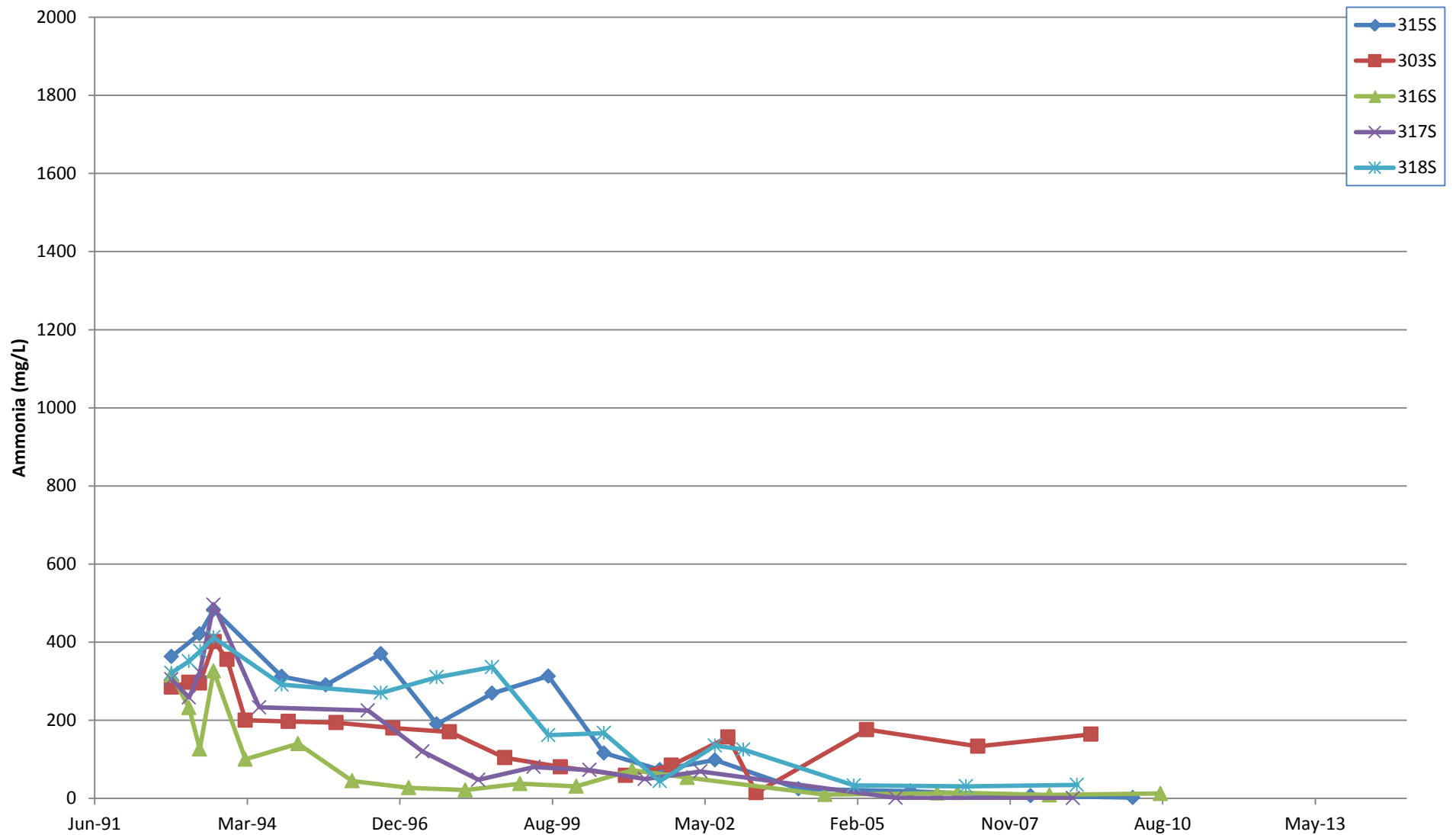
EJW

Date:

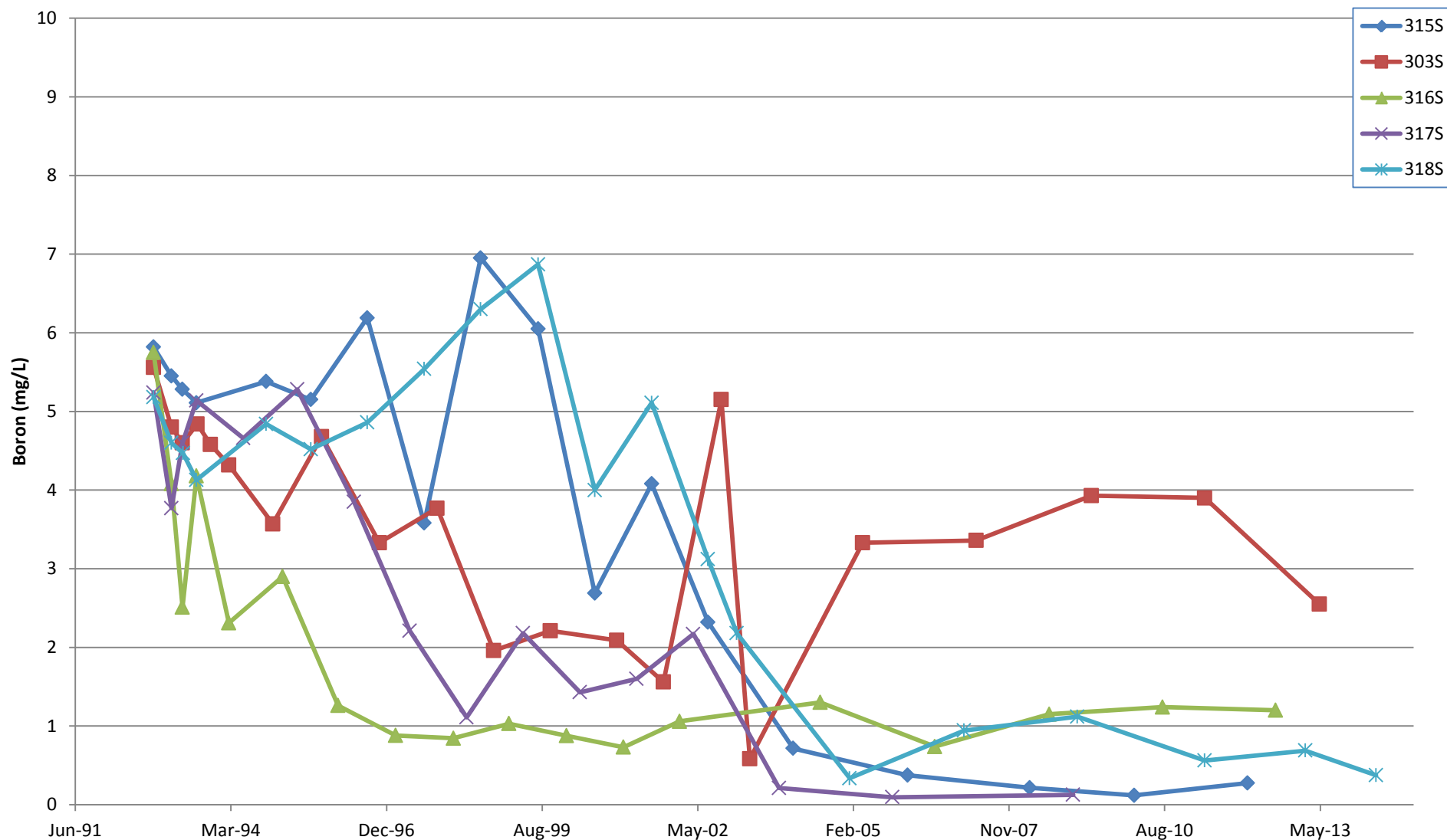
Job Number:

April 2015

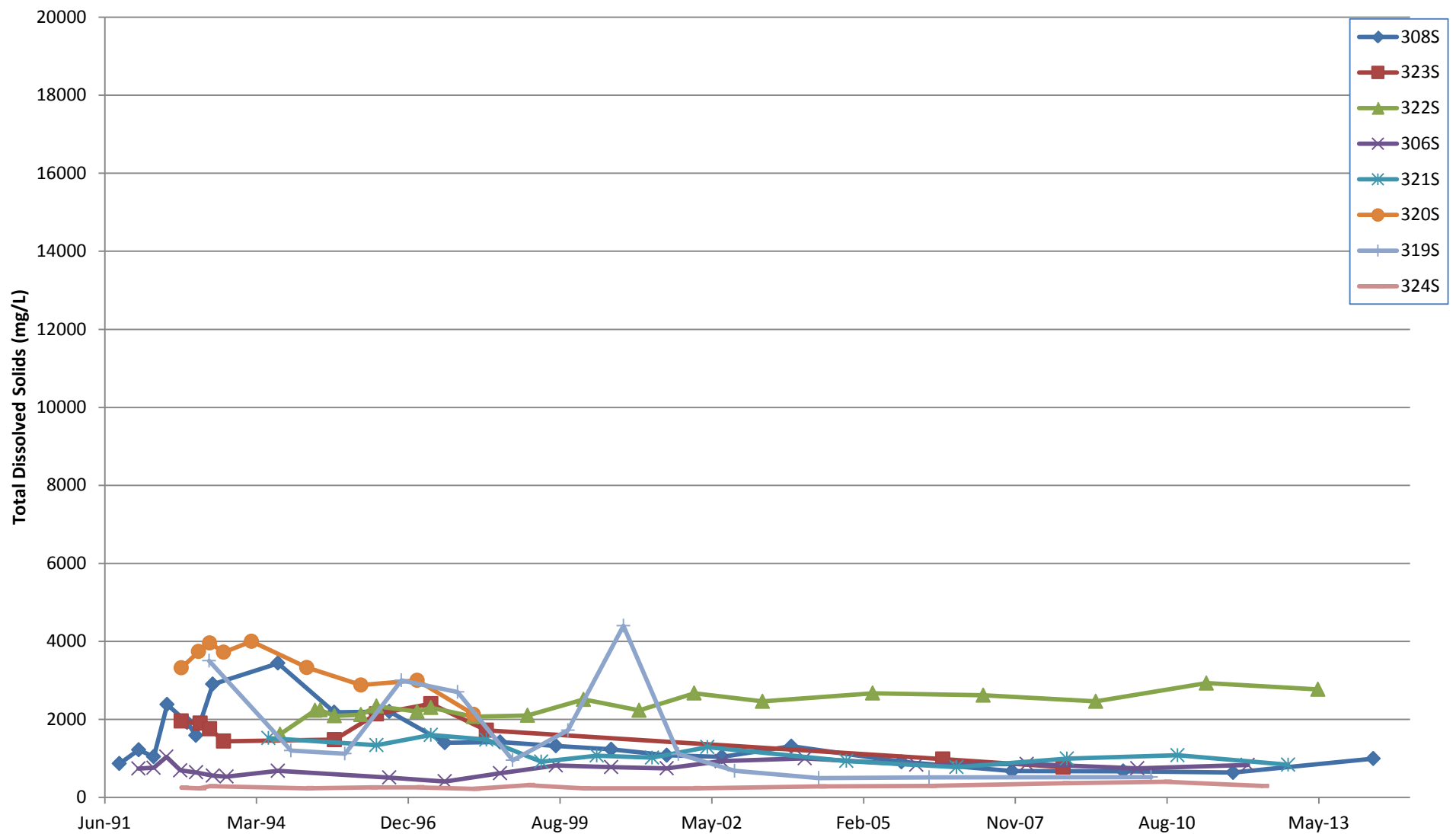
151771



Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-18 Ammonia Concentrations (mg/L) Landfill Section 2/8 - Supplemental Drain
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				



Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-19 Boron Concentrations (mg/L) Landfill Section 2/8 - Supplemental Drains
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				



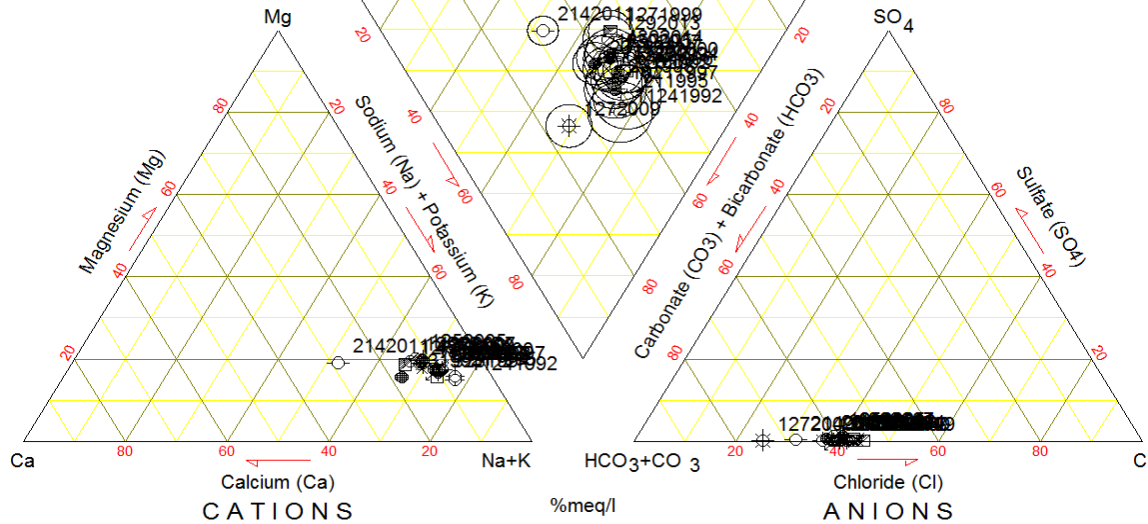
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CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				

Piper Diagram

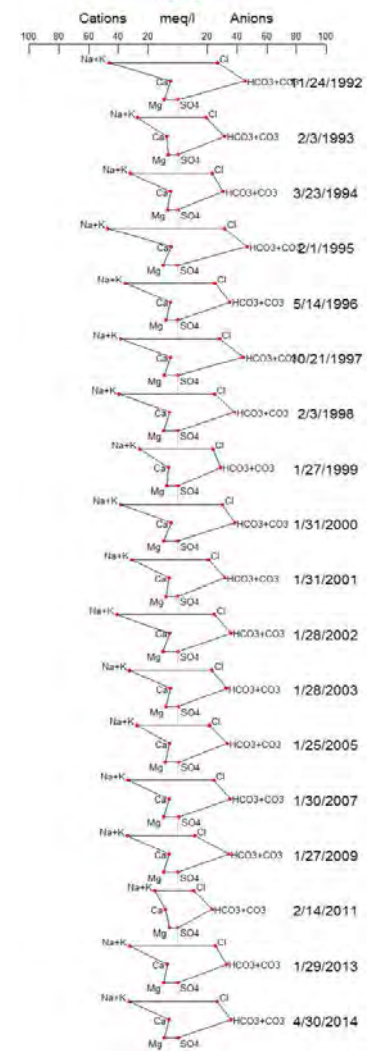
IT301S

- 11/24/1992
- 2/3/1993
- 3/23/1994
- 2/1/1995
- 5/14/1996
- 10/21/1997
- 2/3/1998
- 1/27/1999
- 1/31/2000
- 1/31/2001
- 1/28/2002
- 1/28/2003
- 1/25/2005
- 1/30/2007
- 1/27/2009
- 2/14/2011
- 1/29/2013
- 4/30/2014

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-21A
Piper and Stiff Diagram
Well IT301S
Landfill Section 2/8

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

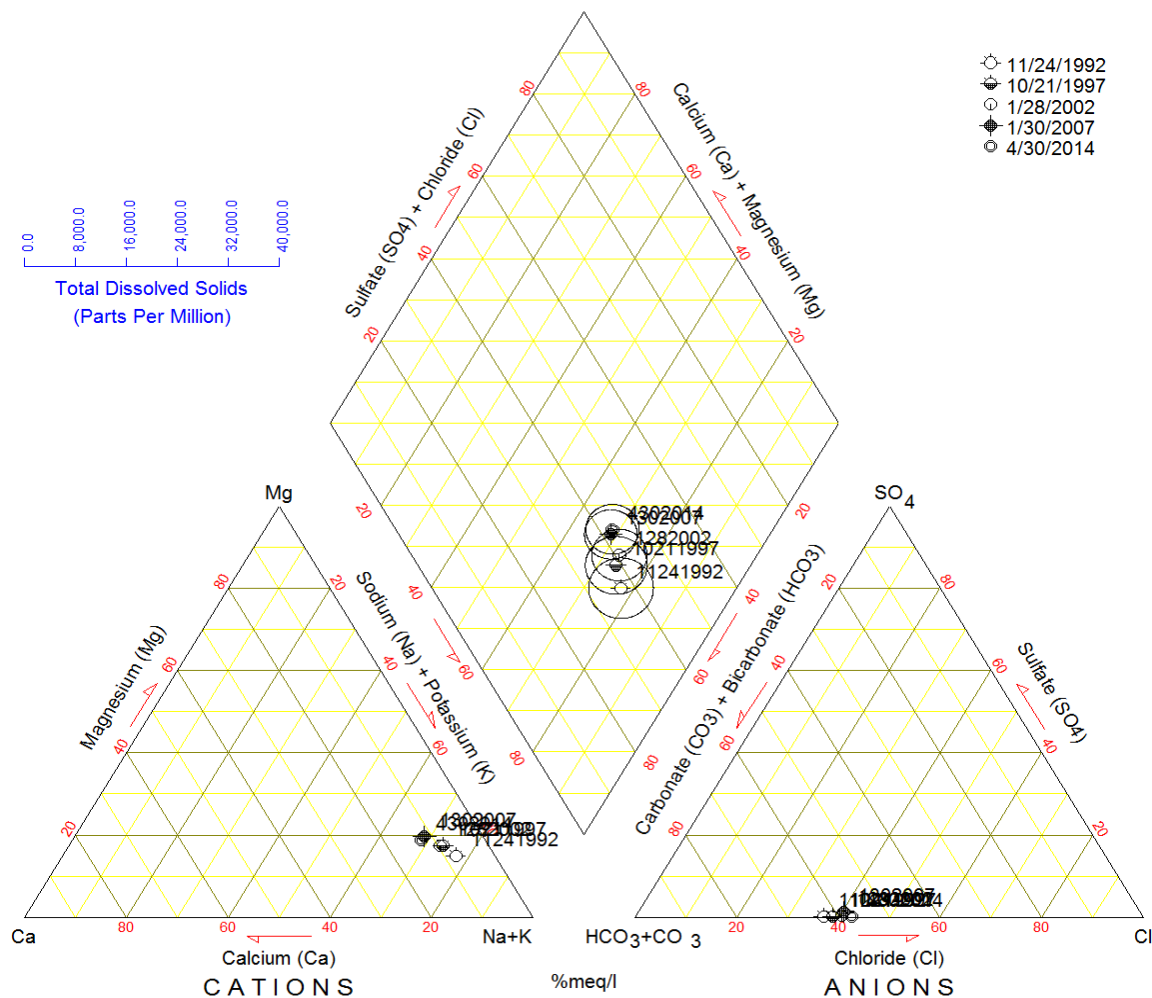
May 2015

151771

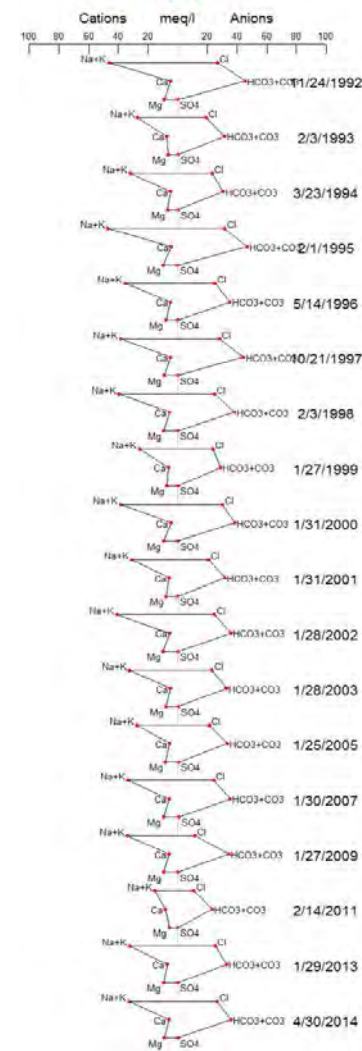
Piper Diagram

IT301S

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Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

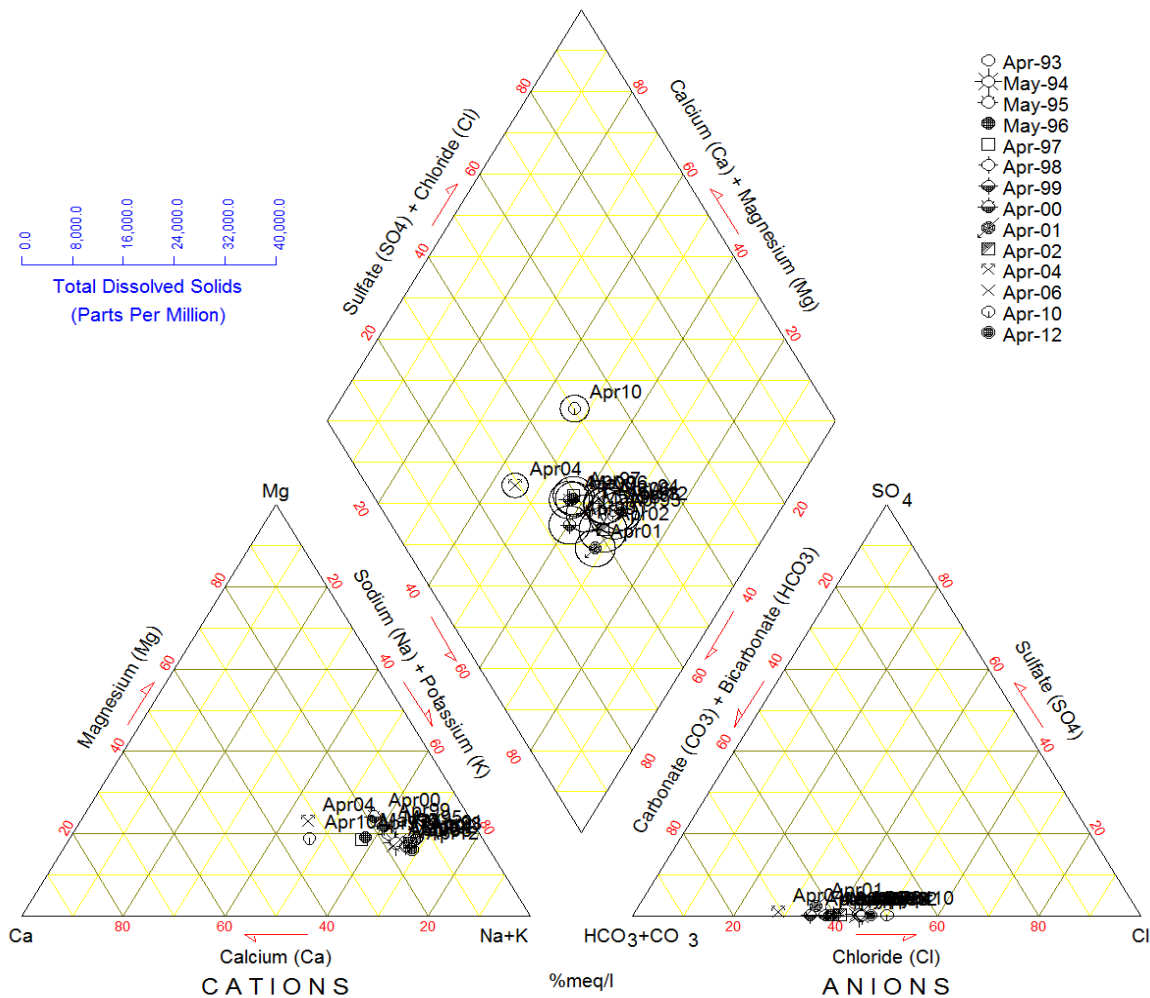


Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-21B Piper and Stiff Diagrams Well IT301S Landfill Section 2/8
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				

Piper Diagram

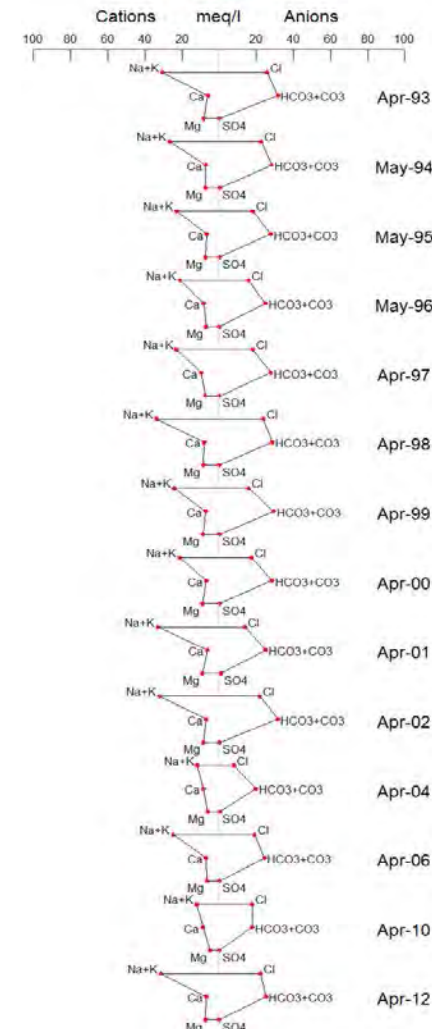
IT312S

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Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT312S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-22A
Piper and Stiff Diagrams
Well IT312S
Landfill Section 2/8

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

April 2015

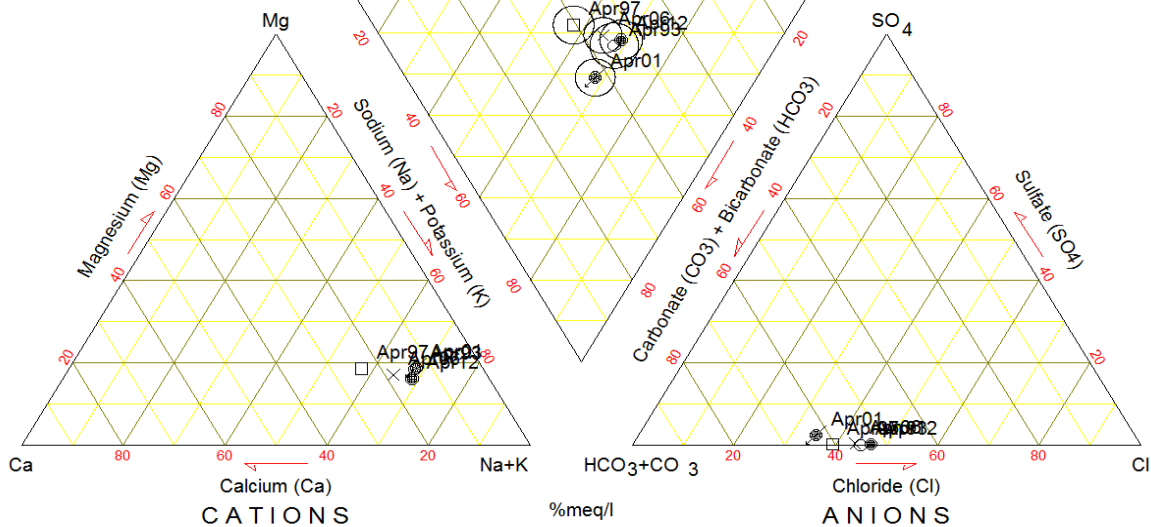
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Piper Diagram

IT312S

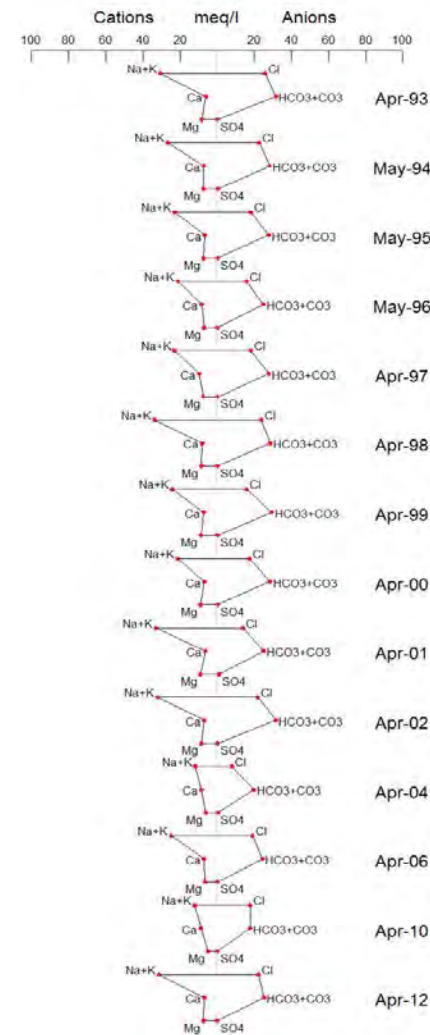
- Apr-93
- Apr-97
- Apr-01
- × Apr-06
- Apr-12

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT312S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-22B
Piper and Stiff Diagrams
Well IT312S
Landfill Section 2/8

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

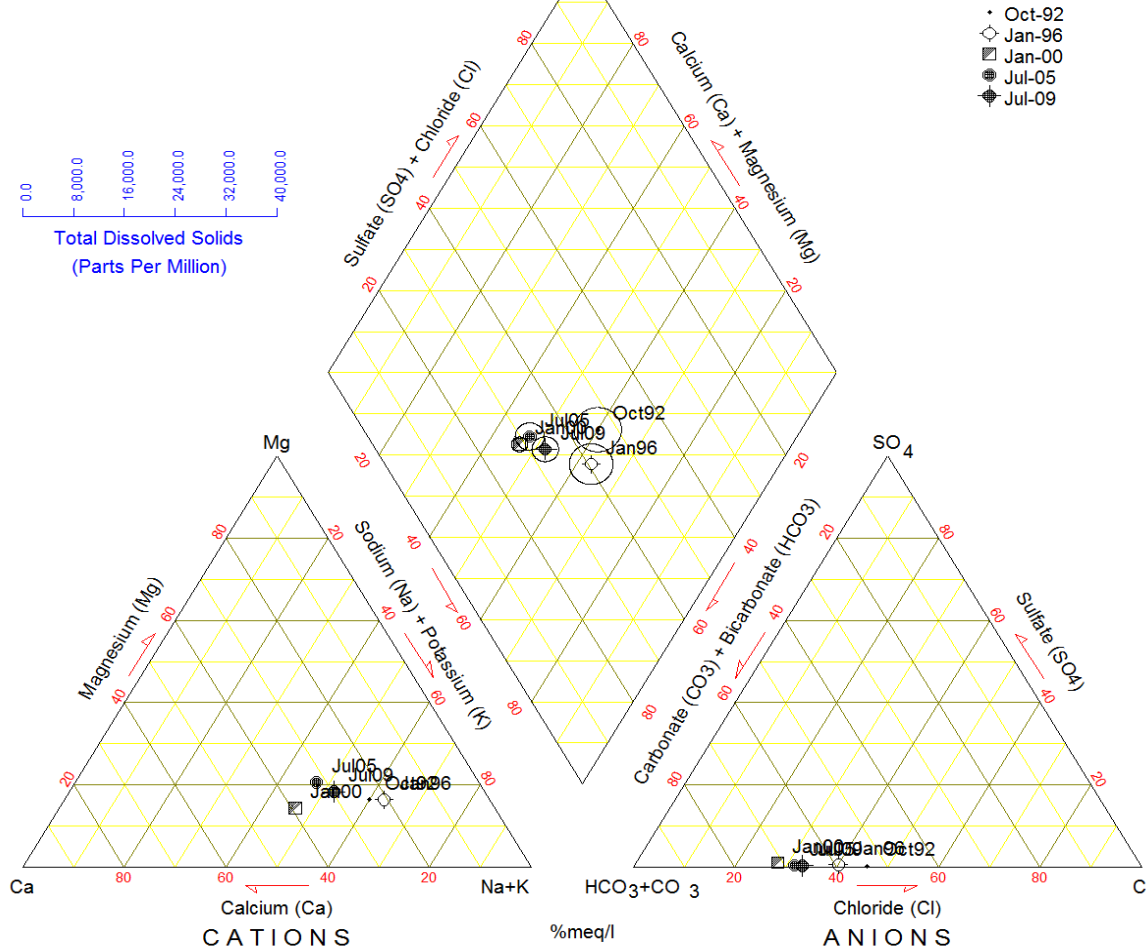
April 2015

151771

Piper Diagram

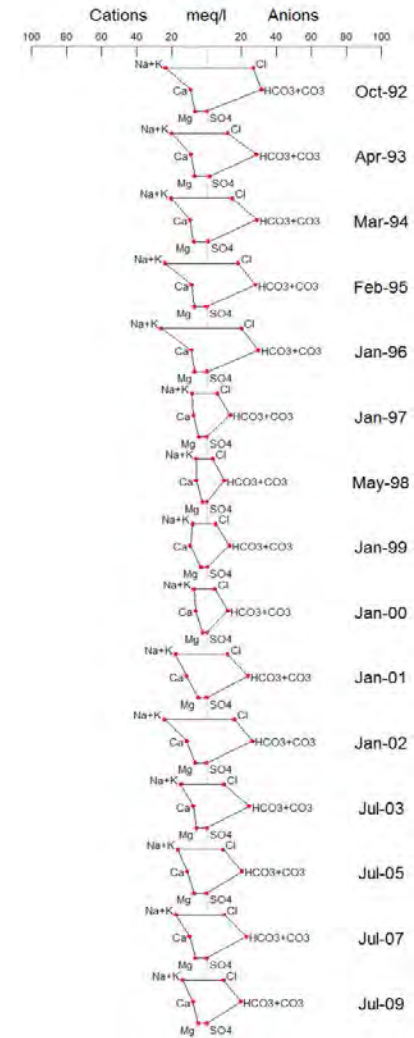
IT313S

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Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT313S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-23B
Piper and Stiff Diagrams
Well IT313S
Landfill Section 2/8

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

April 2015

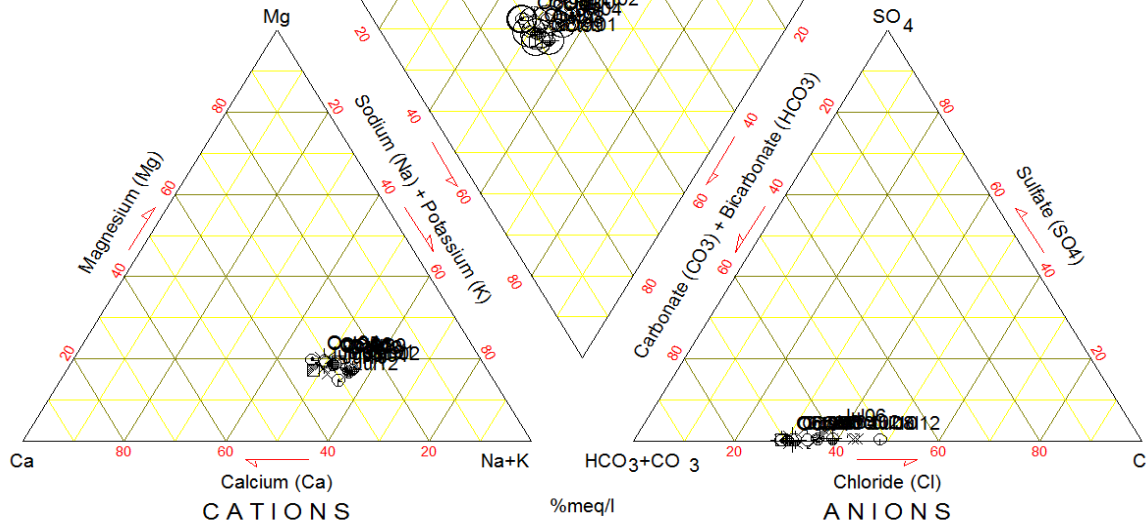
151771

Piper Diagram

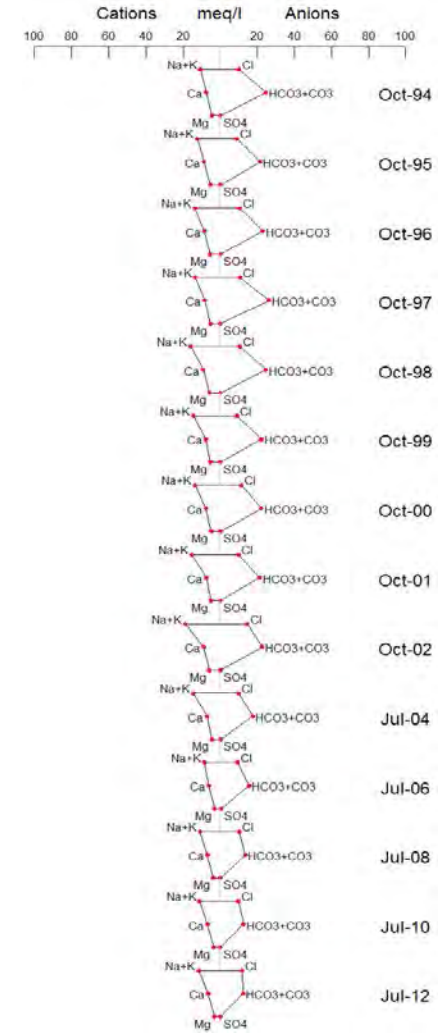
IT325S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)

- Oct-94
- Oct-95
- ⊙ Oct-96
- ⊙ Oct-97
- Oct-98
- Oct-99
- ◇ Oct-00
- ⊙ Oct-01
- ⊙ Oct-02
- ⊙ Jul-04
- ⊙ Jul-06
- ⊙ Jul-08
- ⊙ Jul-10
- Jul-12



Stiff Diagram IT325S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-24A
Piper and Stiff Diagrams
Well IT325S
Landfill Section 2/8

Generated By:

Approved By:

DJD

EJW

Date:

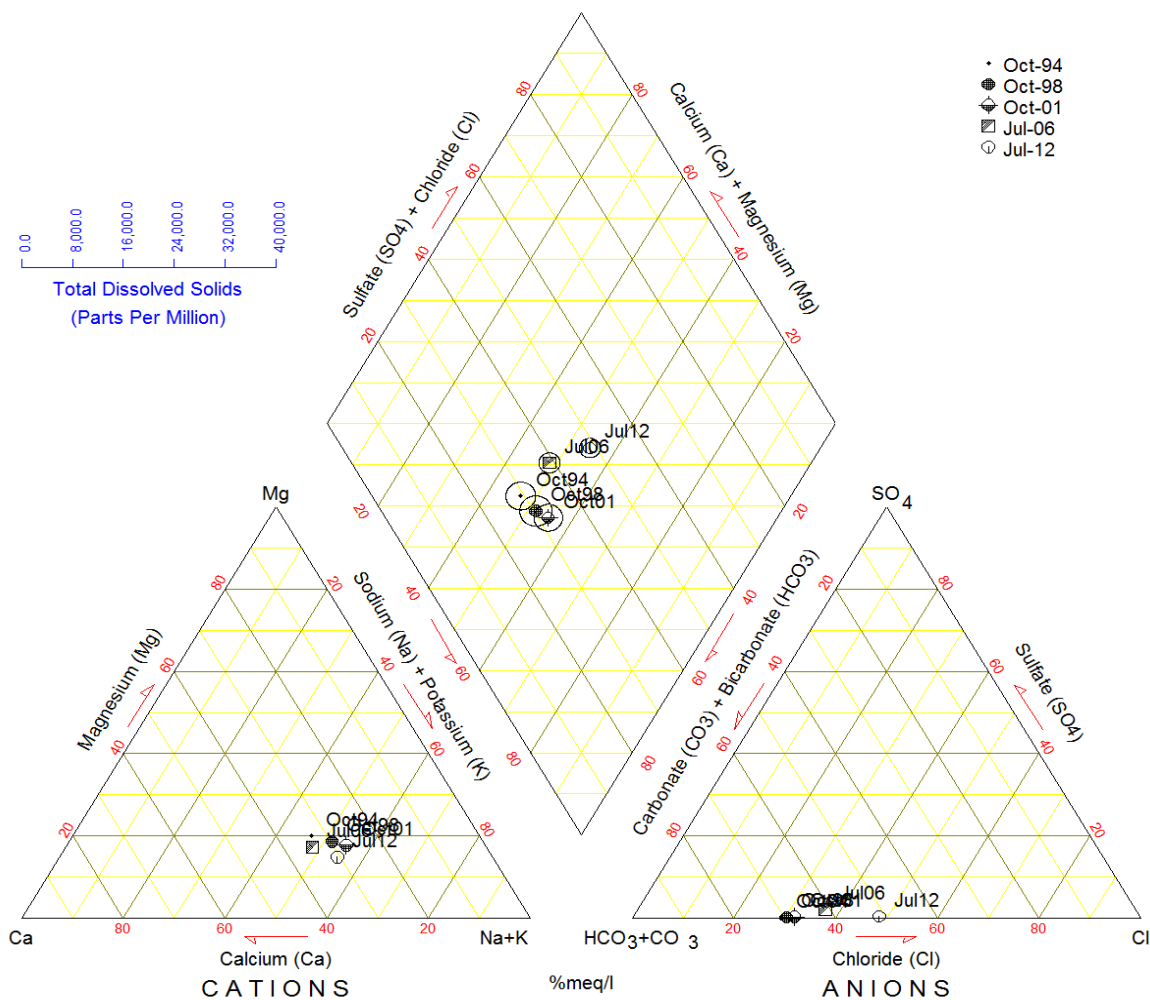
Job Number:

May 2015

151771

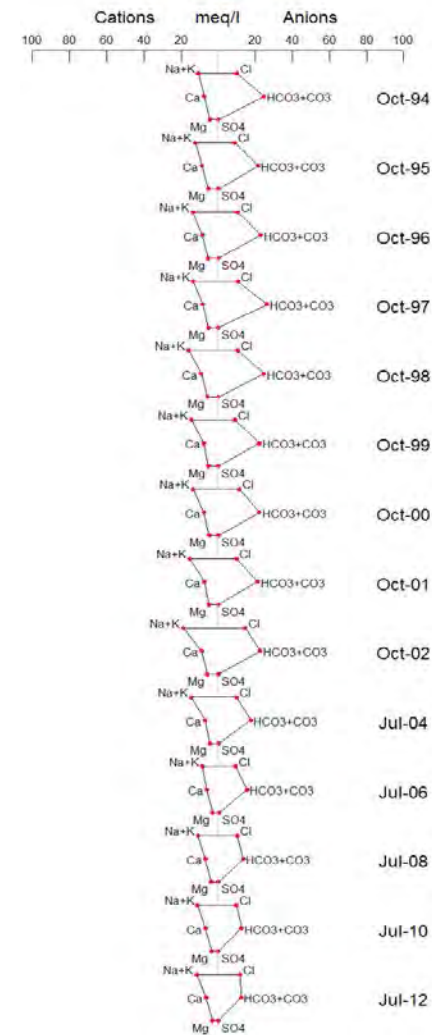
Piper Diagram

IT325S



Stiff Diagram

IT325S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-24B
Piper and Stiff Diagrams
Well IT325S
Landfill Section 2/8

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

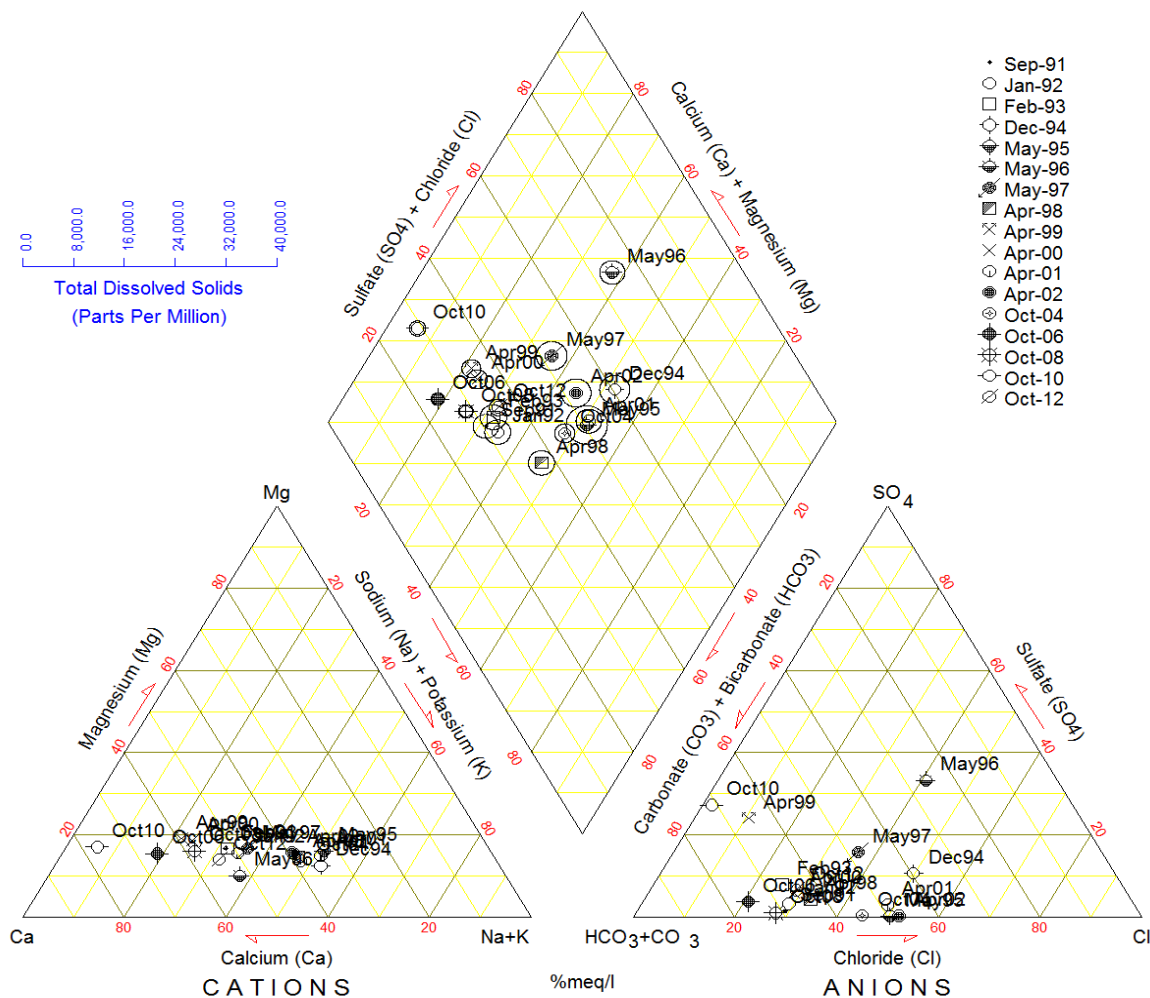
May 2015

151771

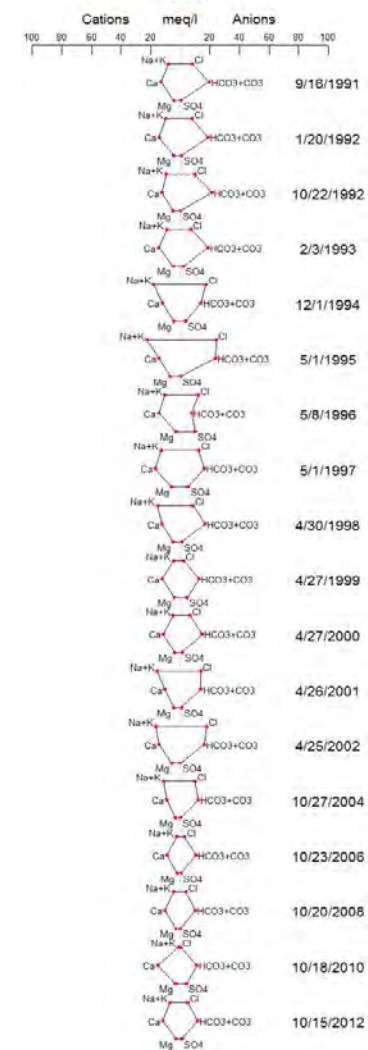
Piper Diagram

IT302S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram IT302S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-25A
Piper and Stiff Diagrams
Well IT302S
Landfill Section 2/8

Generated By:

Approved By:

DJD

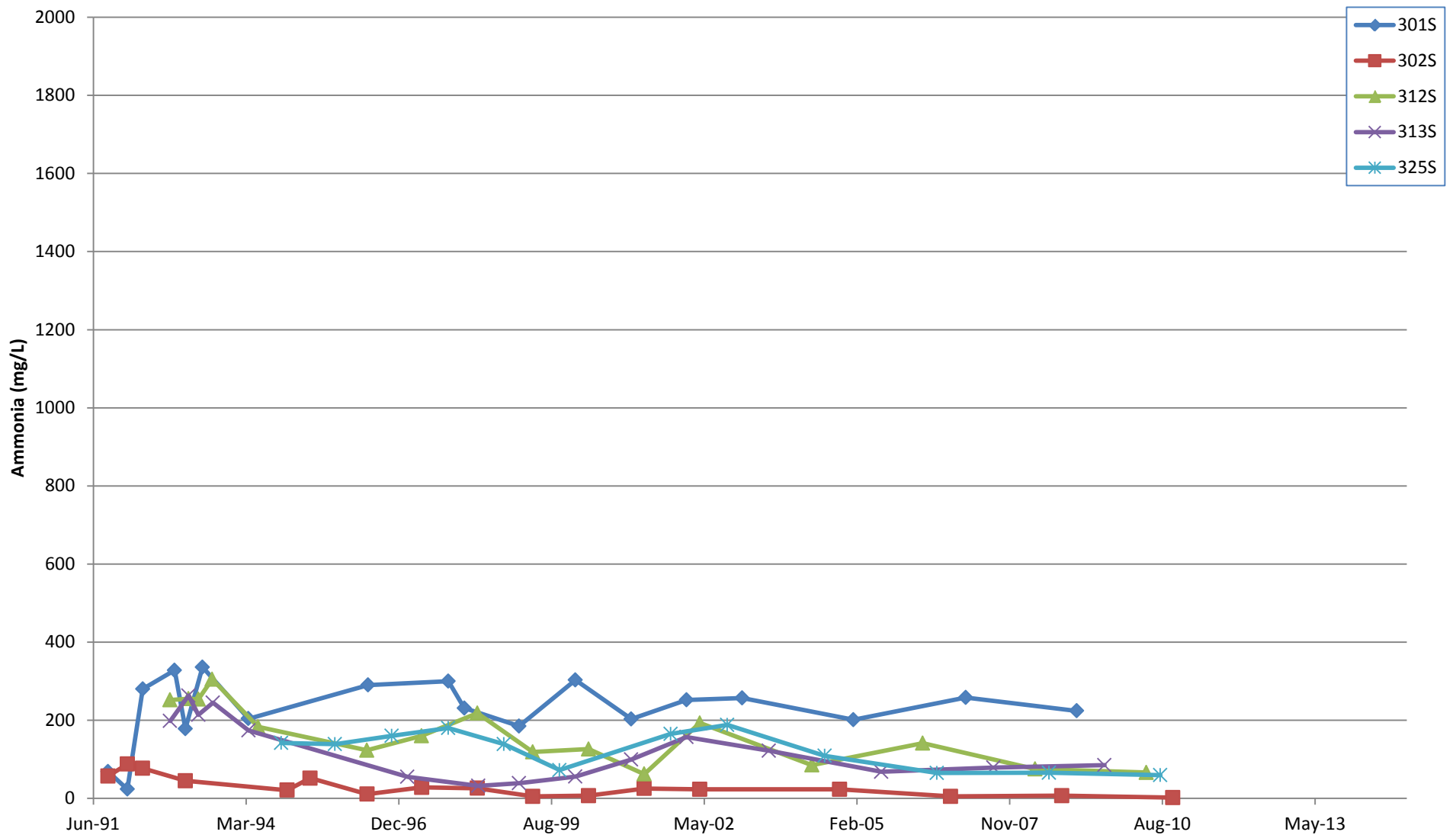
EJW

Date:

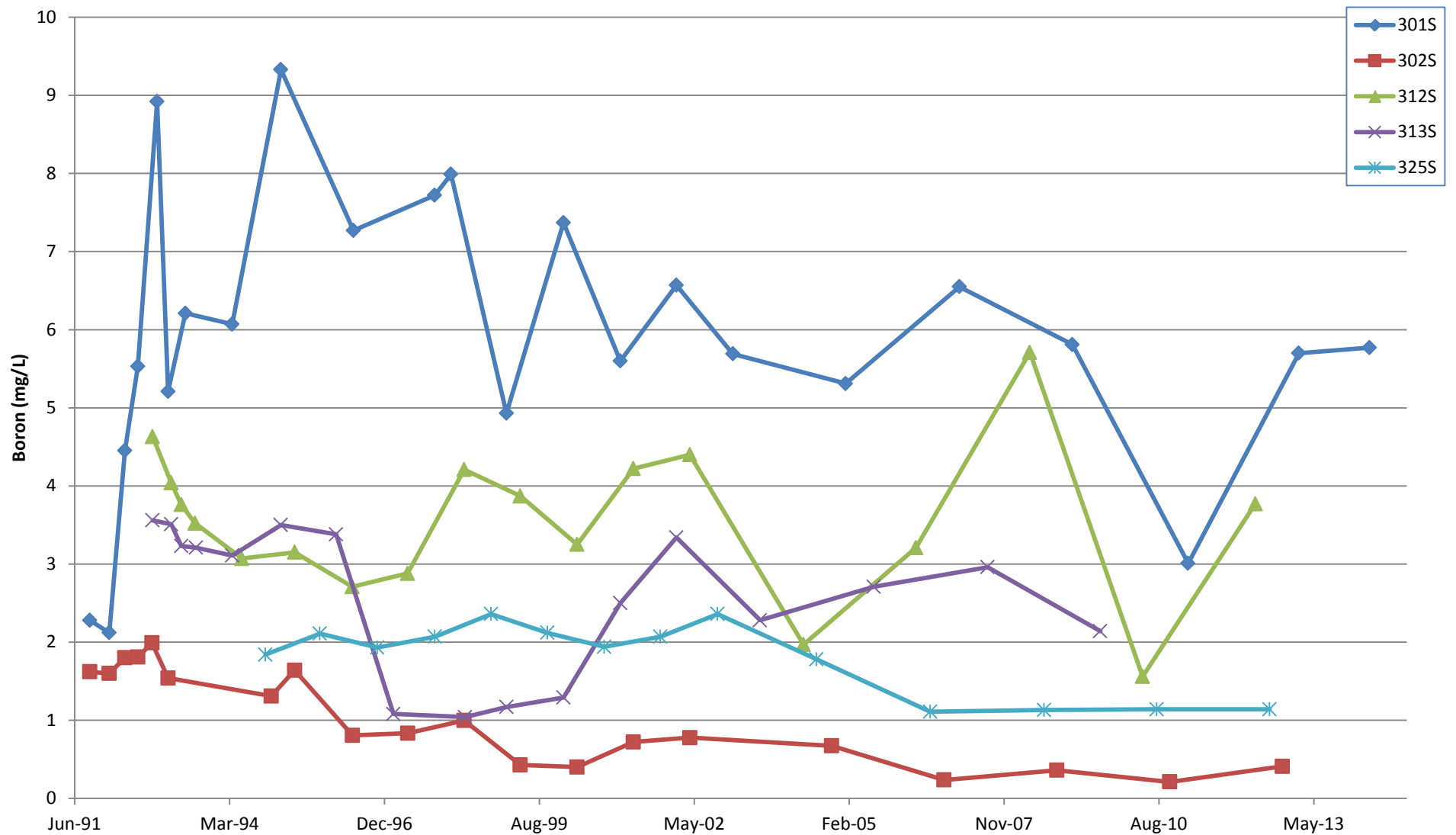
Job Number:

May 2015

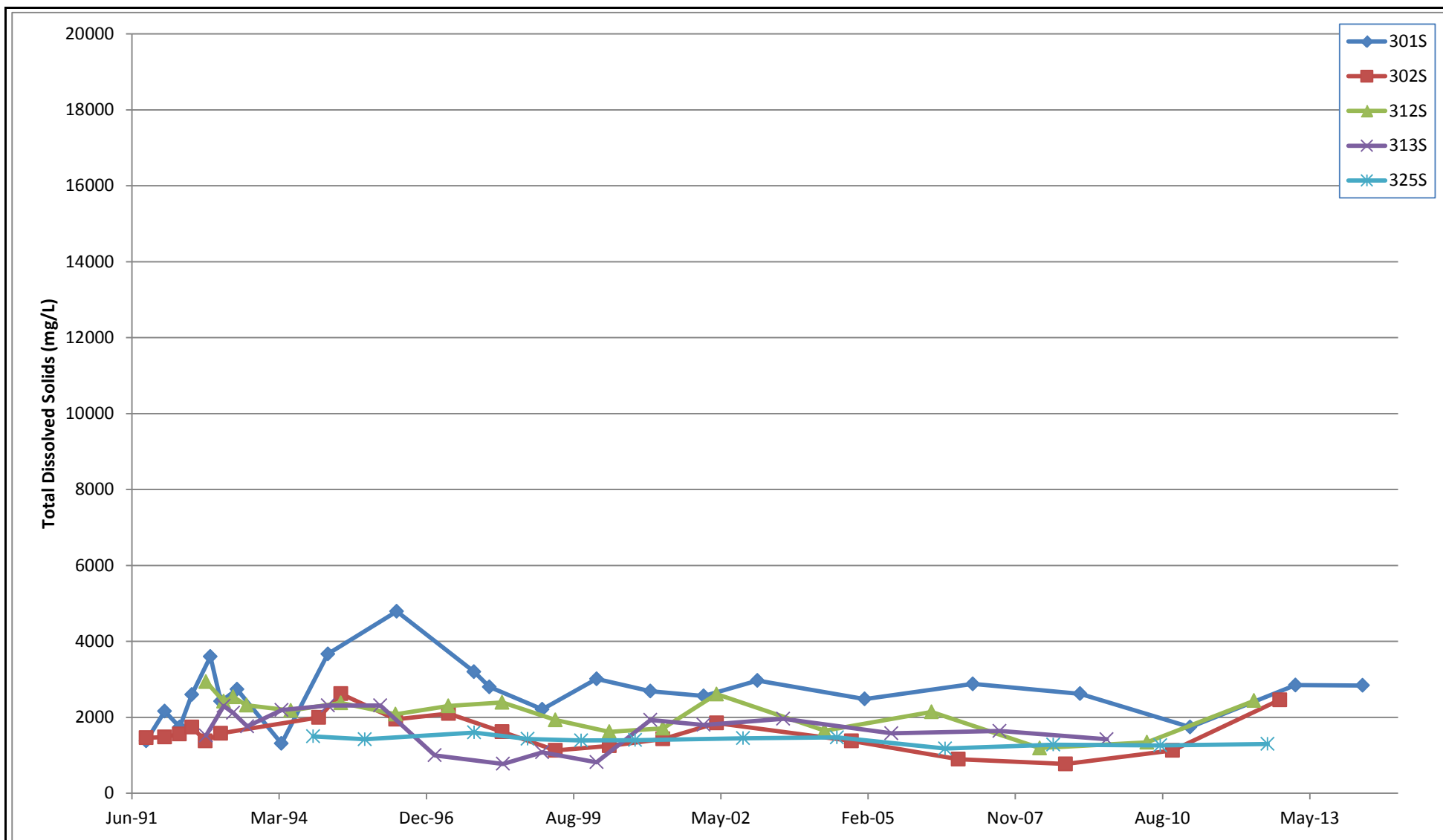
151771



Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-26 Ammonia Concentrations (mg/L) Landfill Section 2/8 - Small Mound (No Drains)
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				



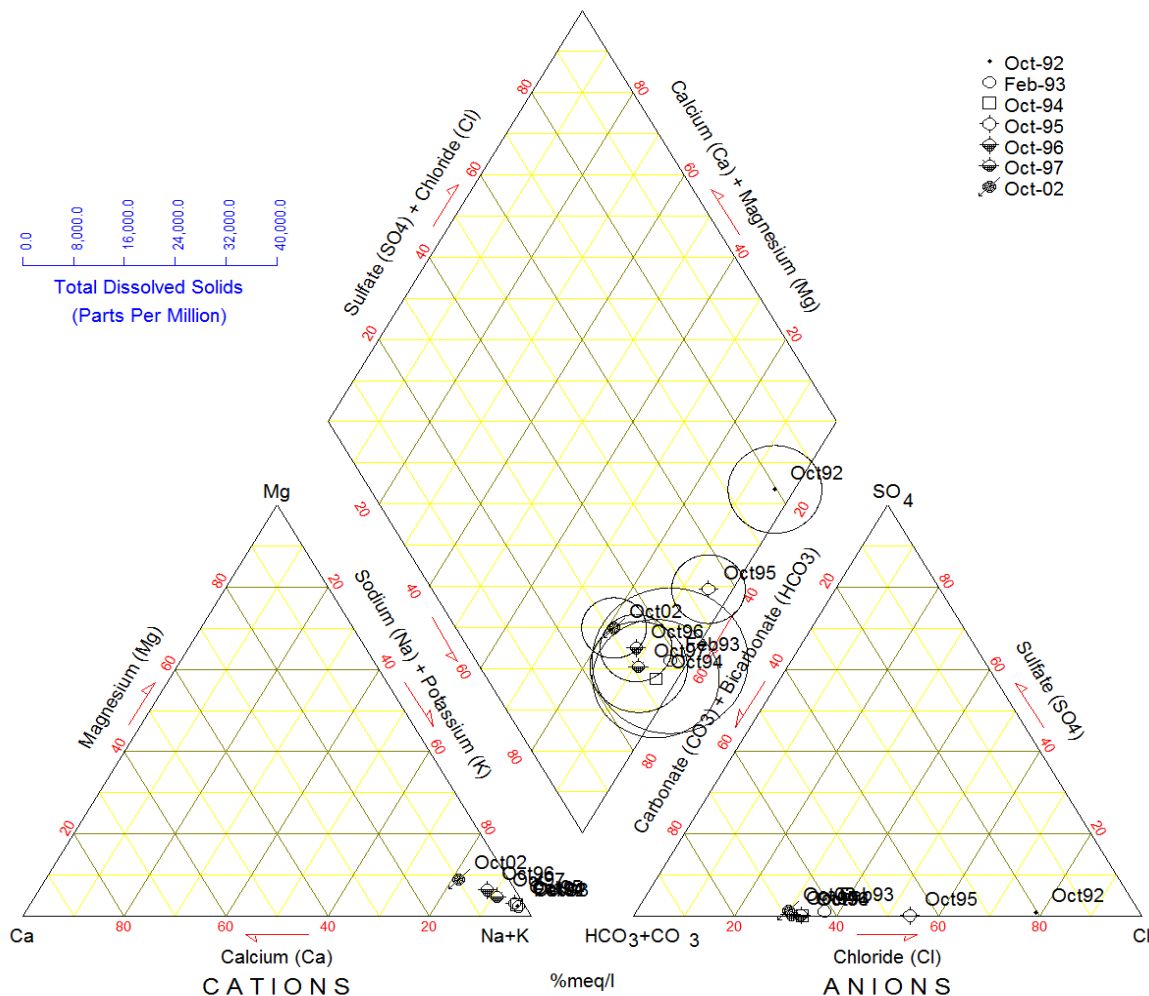
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CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				



Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-28 Total Dissolved Solids Concentrations (mg/L) Landfill Section 2/8 - Small Mound (No Drains)
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				

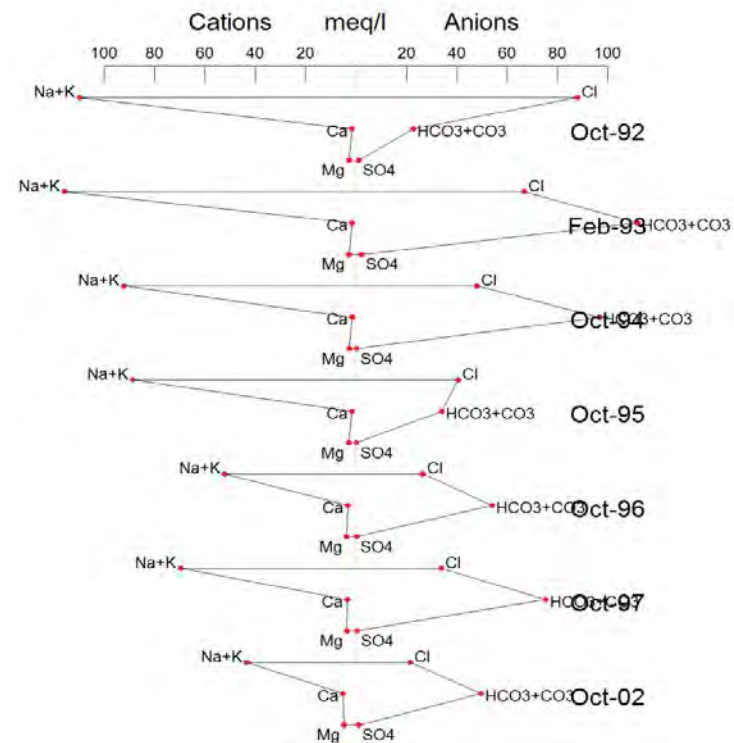
Piper Diagram

IT427S



Stiff Diagram

IT427S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Landfill Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-29A
Piper and Stiff Diagrams
Well IT427S
Landfill Section 3/4

Generated By:

Approved By:

DJD

EJW

Date:

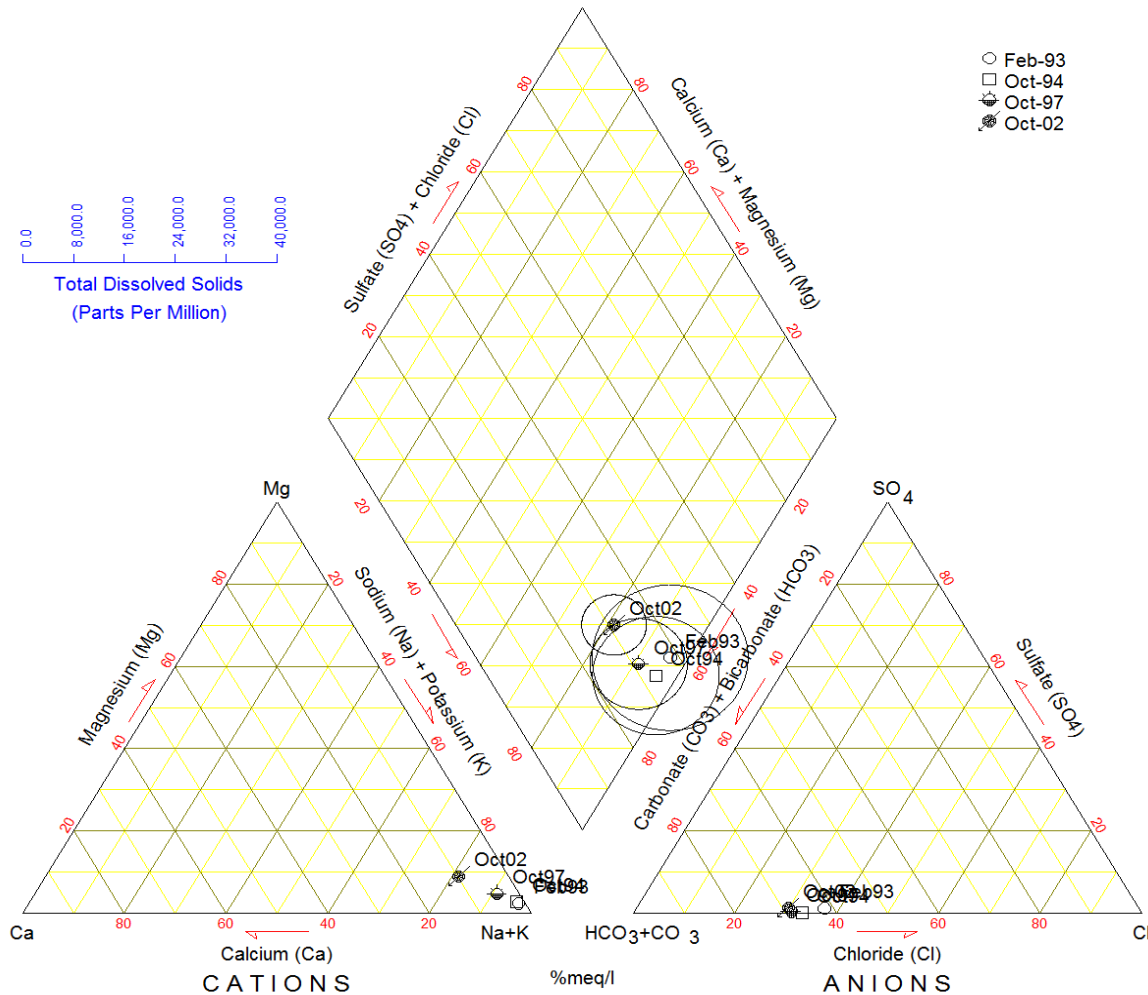
Job Number:

May 2015

151771

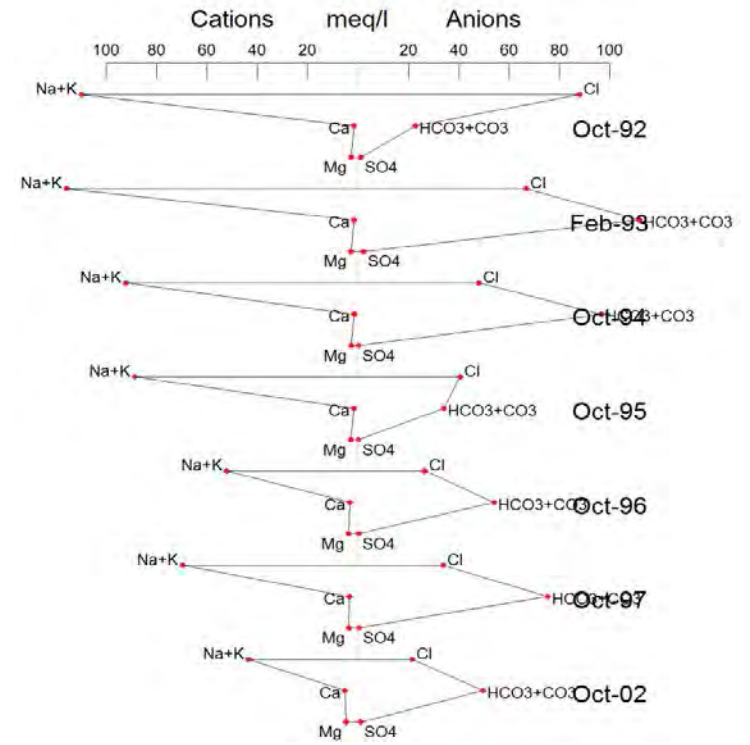
Piper Diagram

IT427S



Stiff Diagram

IT427S



Prepared By:

CB&I Environmental & Infrastructure, Inc.

Under the Direction of:



Landfill Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-29B
Piper and Stiff Diagrams
Well IT427S
Landfill Section 3/4

Generated By:

DJD

Approved By:

EJW

Date:

May 2015

Job Number:

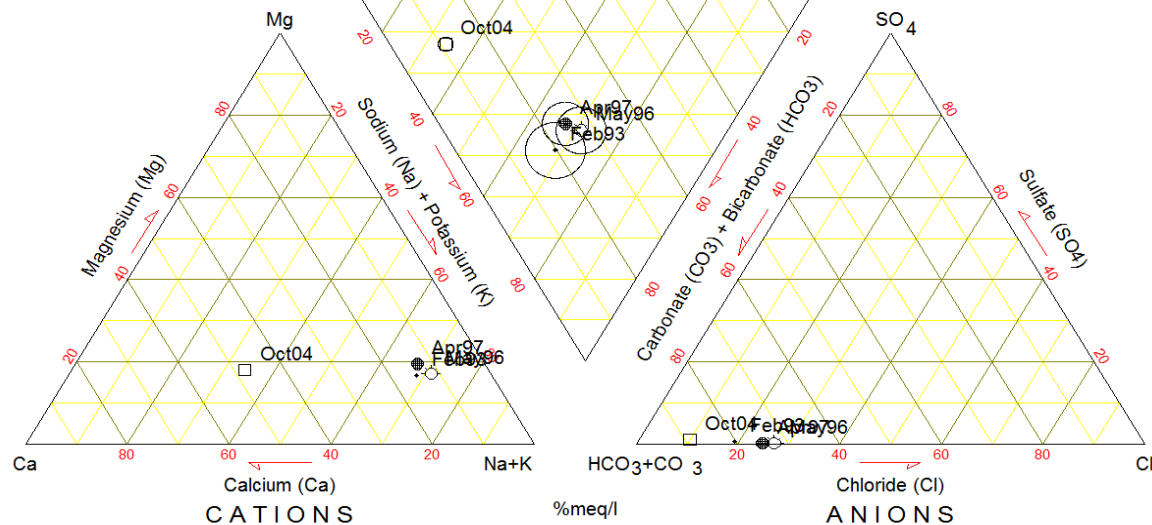
151771

Piper Diagram

IT413S

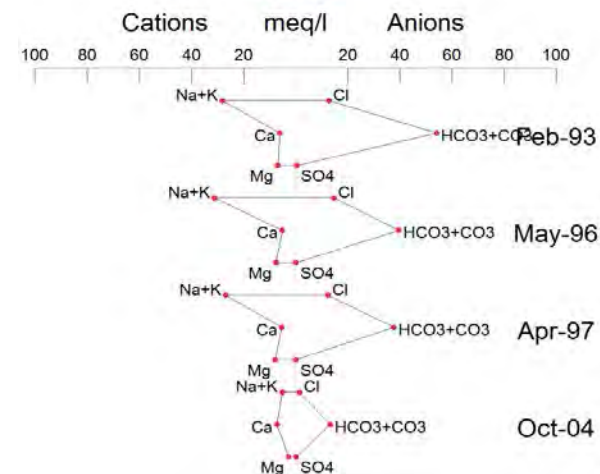
- Feb-93
- May-96
- Apr-97
- Oct-04

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT413S



Prepared By:

CB&I Environmental & Infrastructure, Inc.

Under the Direction of:



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-30
Piper and Stiff Diagrams
Well IT413S
Landfill Section 3/4

Generated By:

DJD

Approved By:

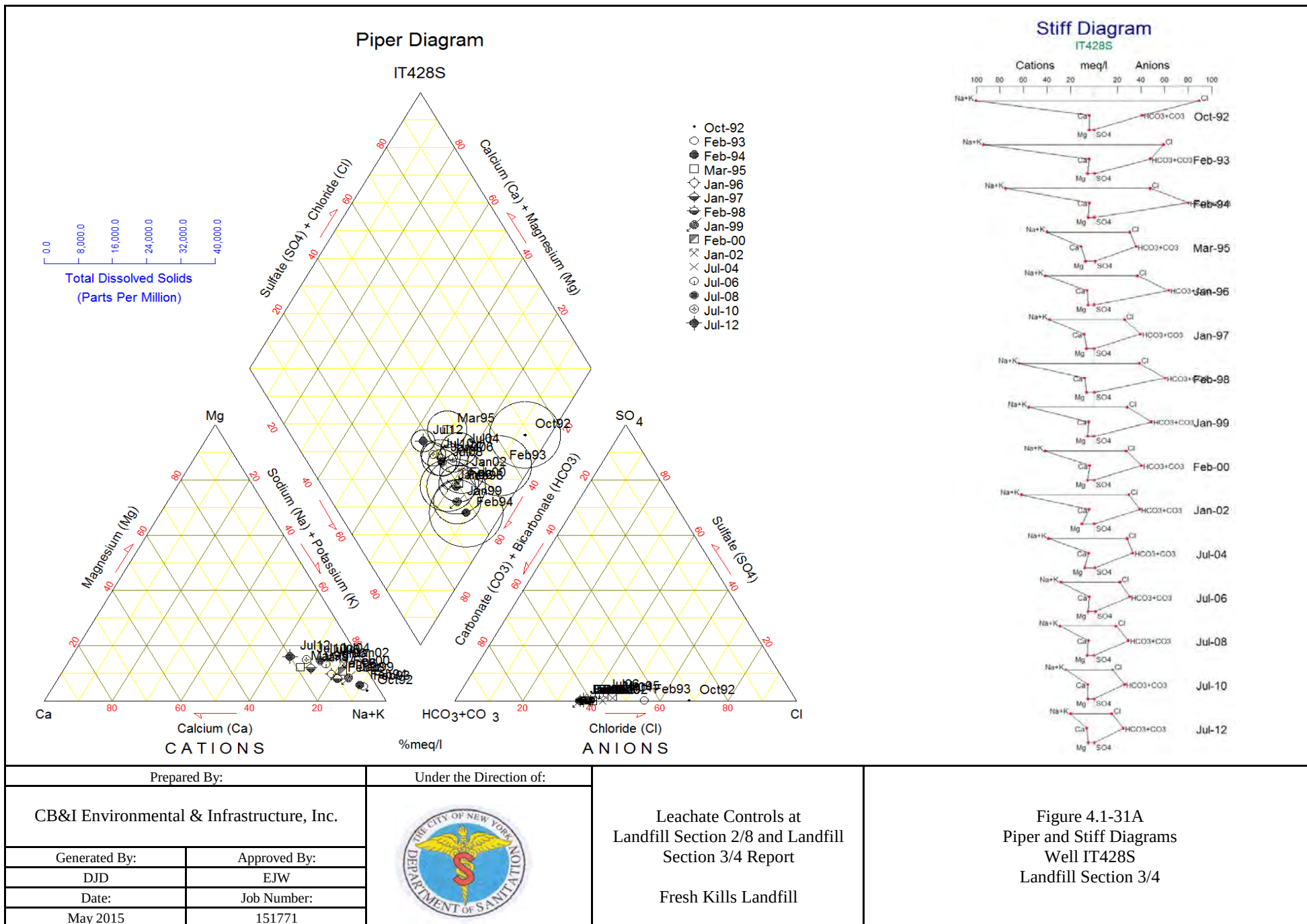
EJW

Date:

May 2015

Job Number:

151771



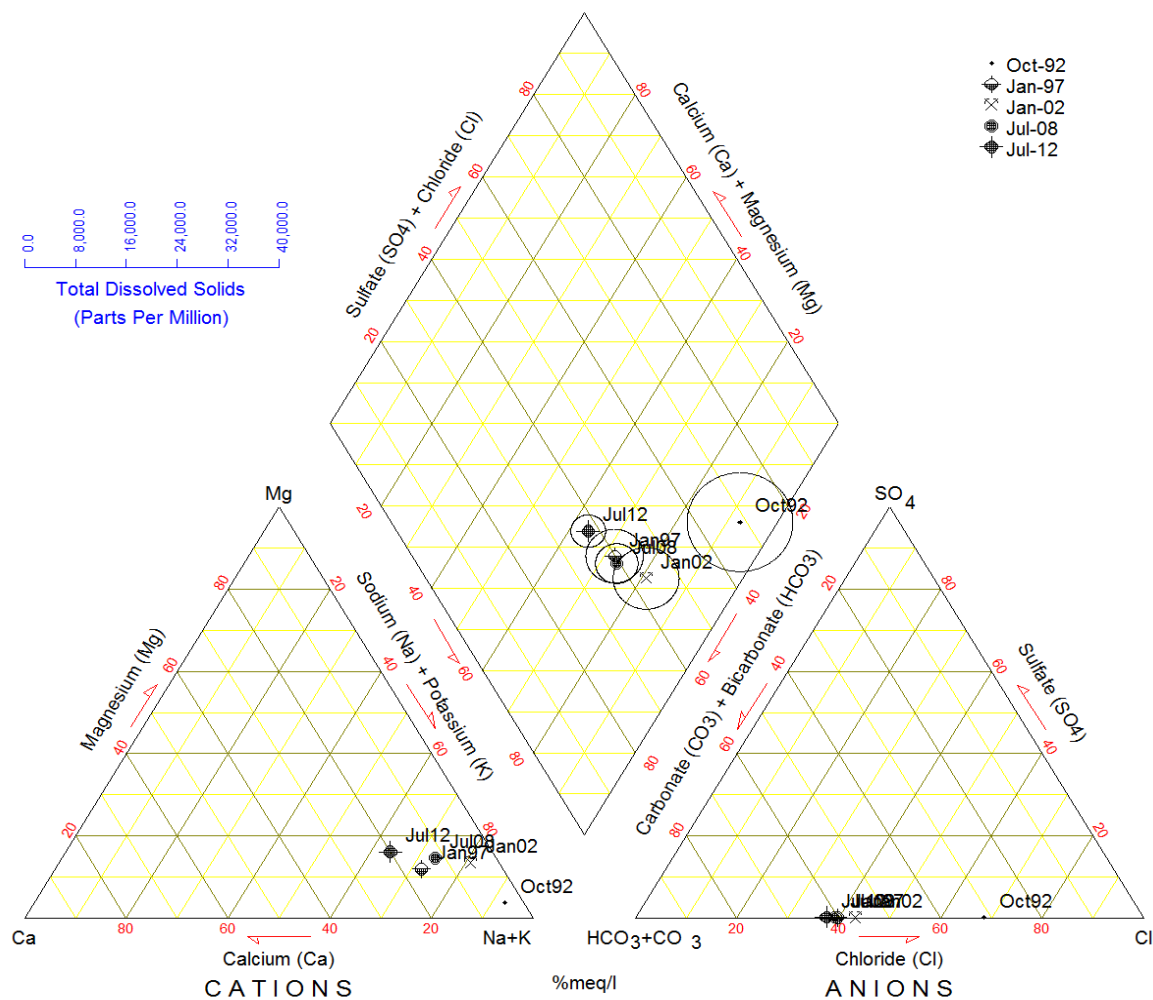
Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-31A Piper and Stiff Diagrams Well IT428S Landfill Section 3/4
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				

Piper Diagram

IT428S

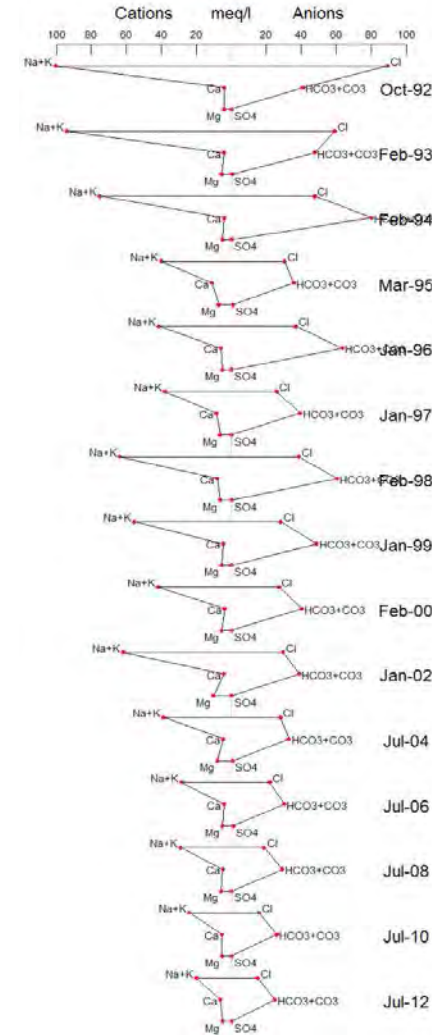
0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)

- Oct-92
- ◊ Jan-97
- ✕ Jan-02
- Jul-08
- ◆ Jul-12



Stiff Diagram

IT428S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-31B
Piper and Stiff Diagram
Well IT428S
Landfill Section 3/4

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

May 2015

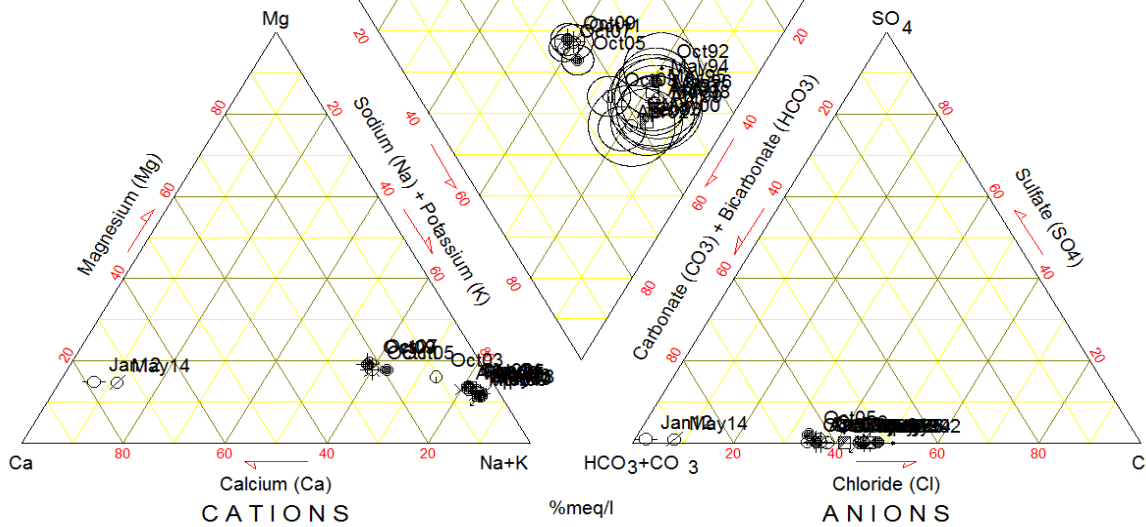
151771

Piper Diagram

IT408S

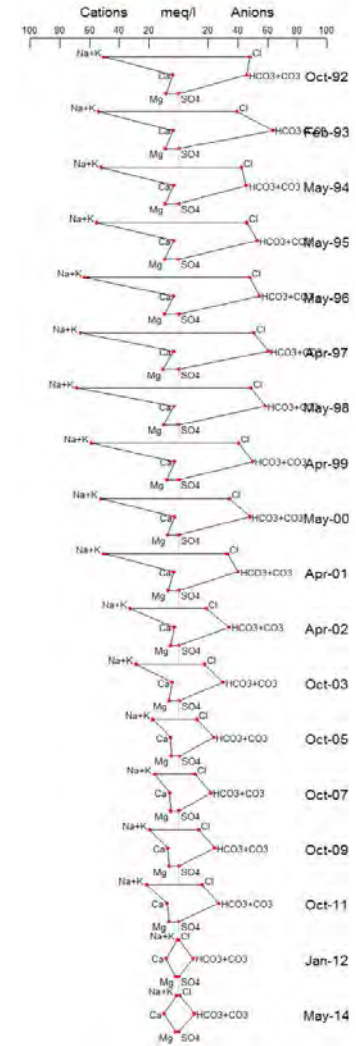
0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)

- Oct-92
- Feb-93
- May-94
- May-95
- ◇ May-96
- ◆ Apr-97
- ⊙ May-98
- ⊗ Apr-99
- ⊠ May-00
- × Apr-01
- ⊙ Apr-02
- Oct-03
- Oct-05
- ⊙ Oct-07
- ⊗ Oct-09
- ⊠ Oct-11
- Jan-12
- ⊙ May-14



Stiff Diagram

IT408S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-32A
Piper and Stiff Diagram
Well IT408S
Landfill Section 3/4

Generated By:

Approved By:

DJD

EJW

Date:

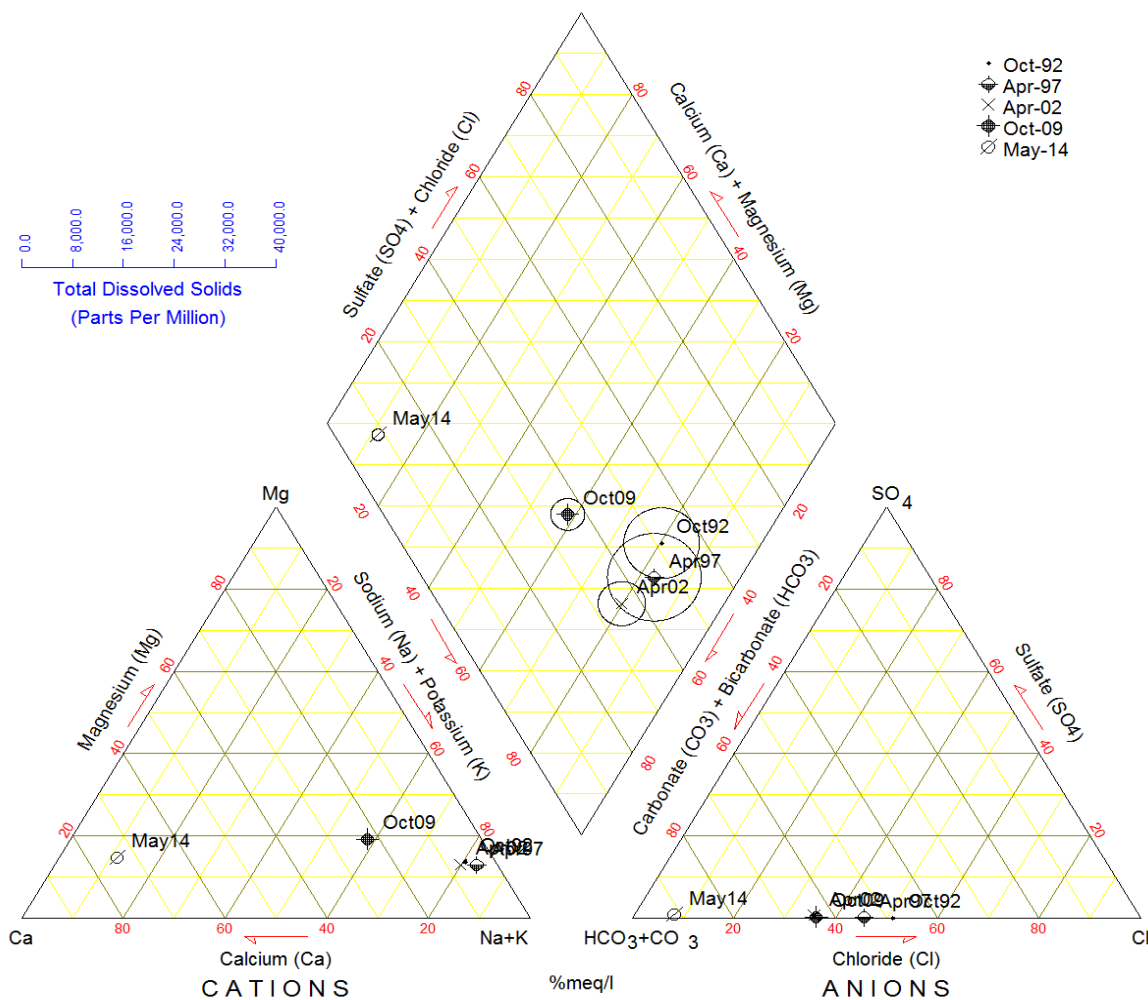
Job Number:

May 2015

151771

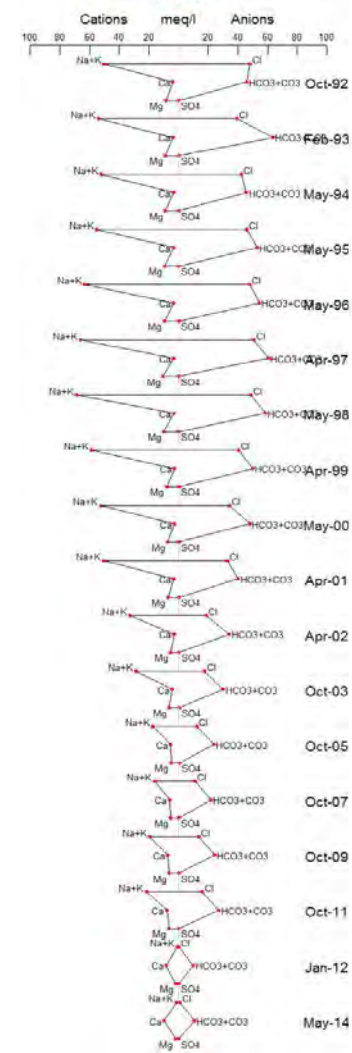
Piper Diagram

IT408S



Stiff Diagram

IT408S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
 Landfill Section 2/8 and Landfill
 Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-32B
 Piper and Stiff Diagram
 Well IT408S
 Landfill Section 3/4

Generated By:

Approved By:

DJD

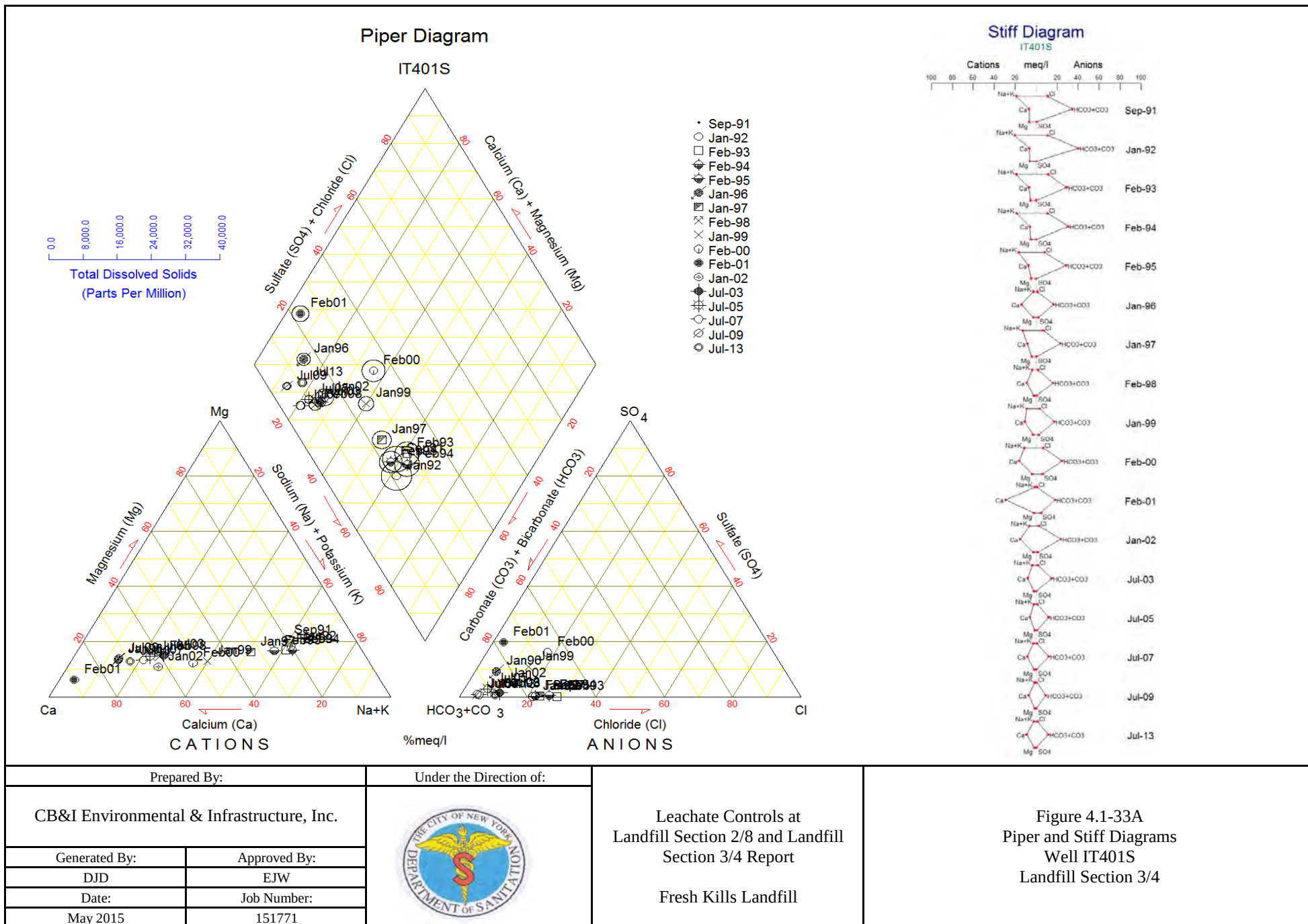
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Date:

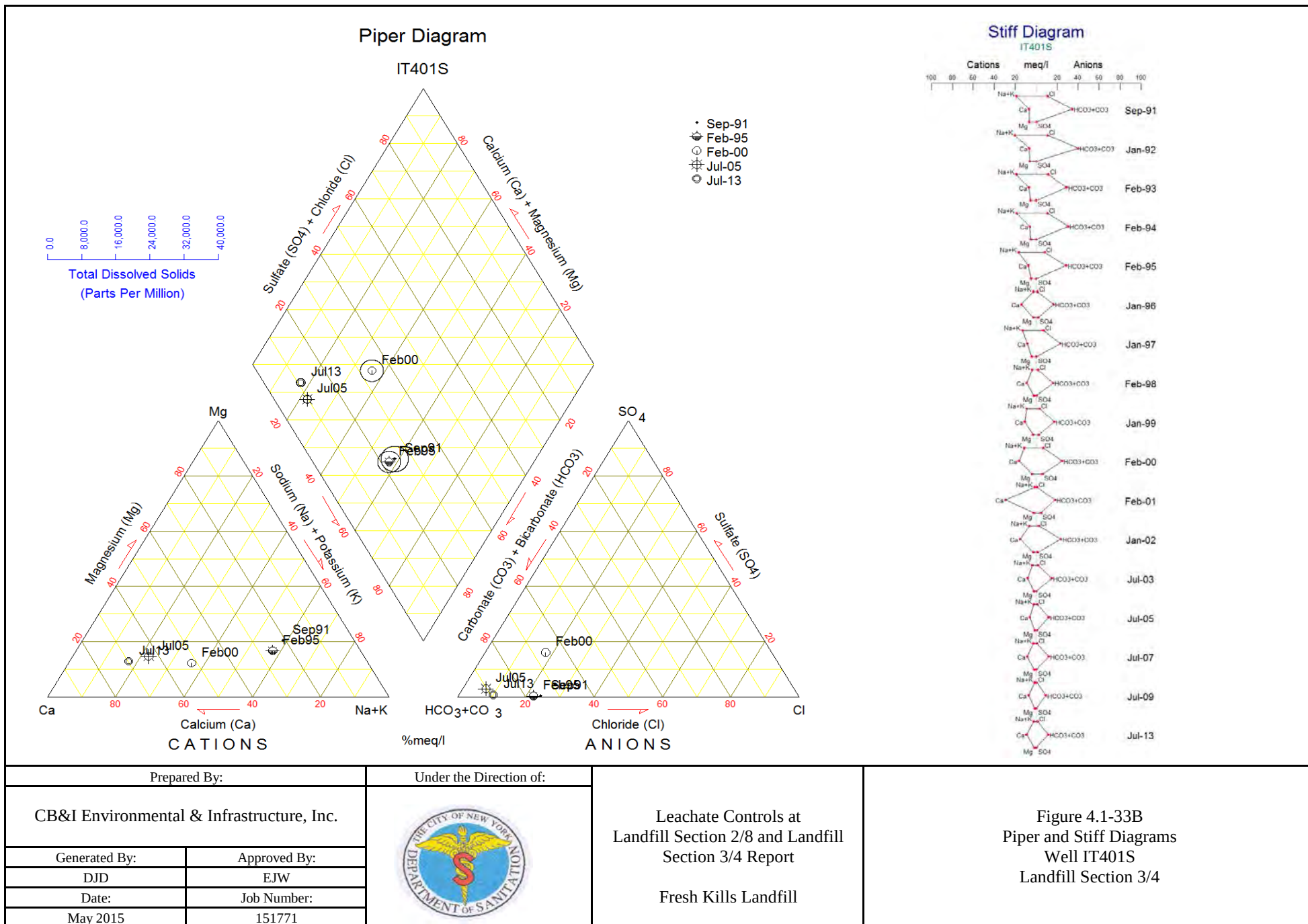
Job Number:

May 2015

151771

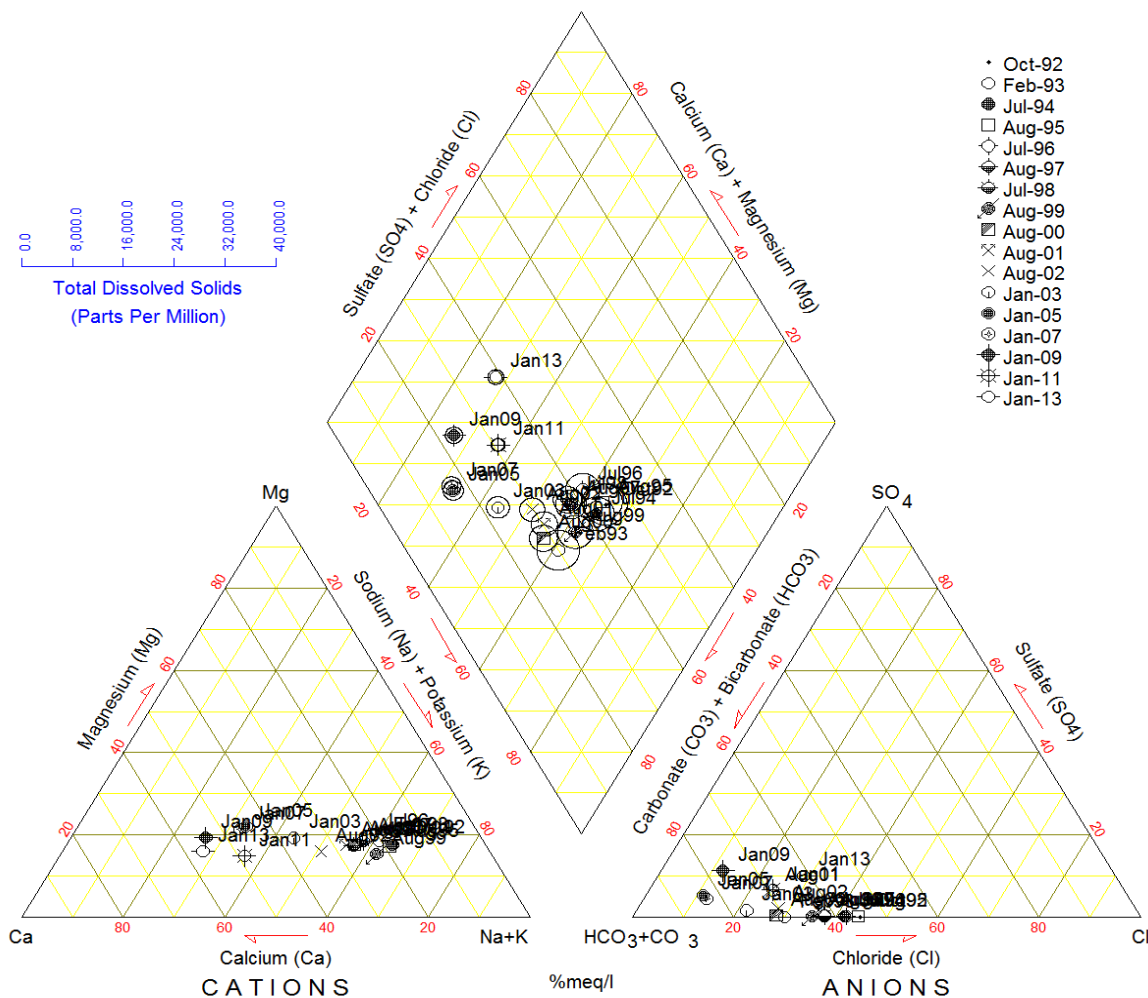


Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-33A Piper and Stiff Diagrams Well IT401S Landfill Section 3/4
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				



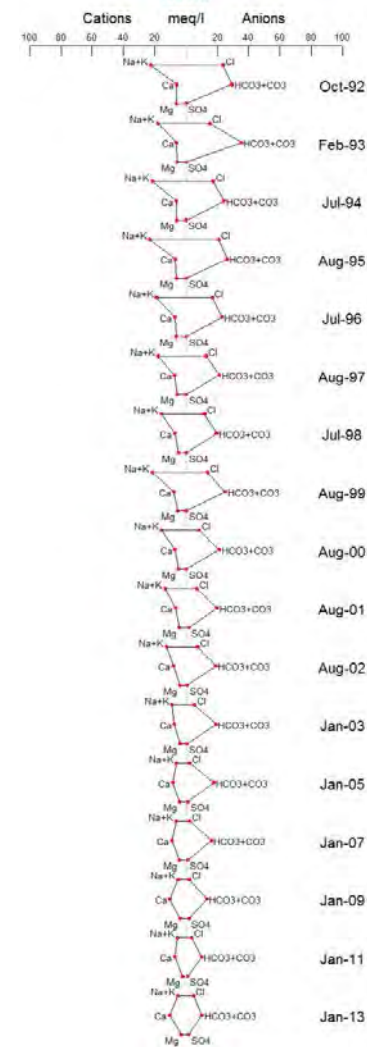
Piper Diagram

IT411S



Stiff Diagram

IT411S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-34A
Piper and Stiff Diagrams
Well IT411S
Landfill Section 3/4

Generated By:

Approved By:

DJD

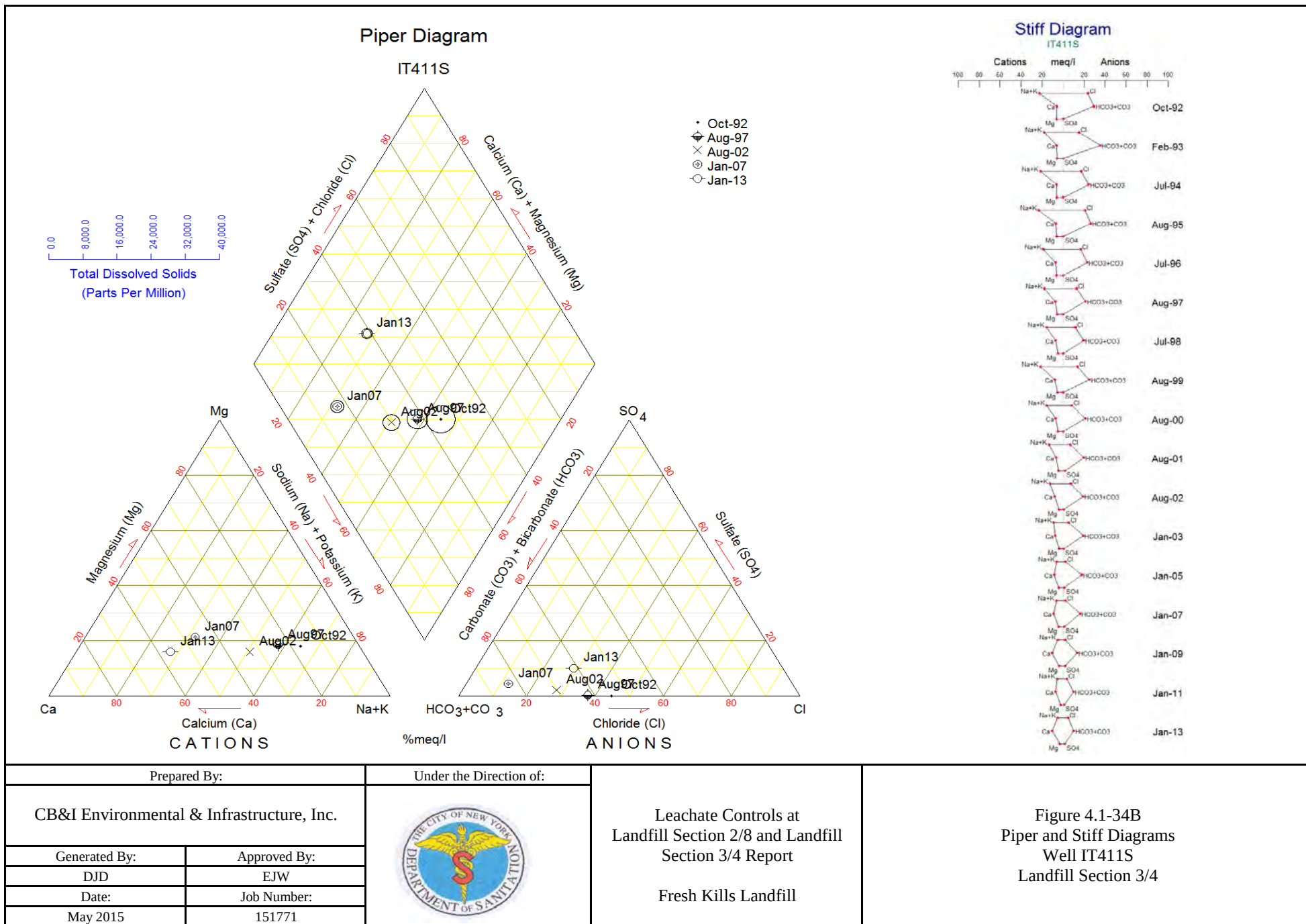
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Date:

Job Number:

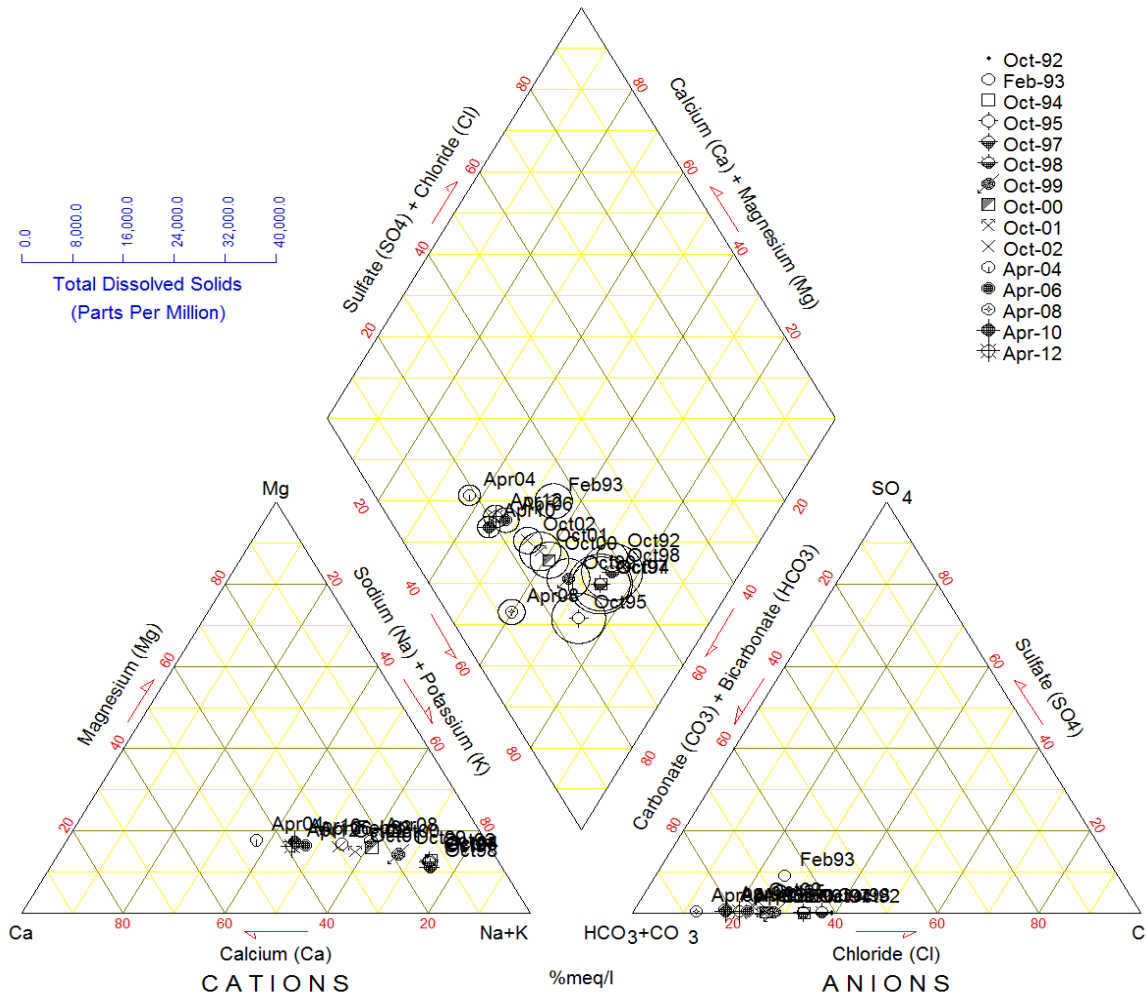
May 2015

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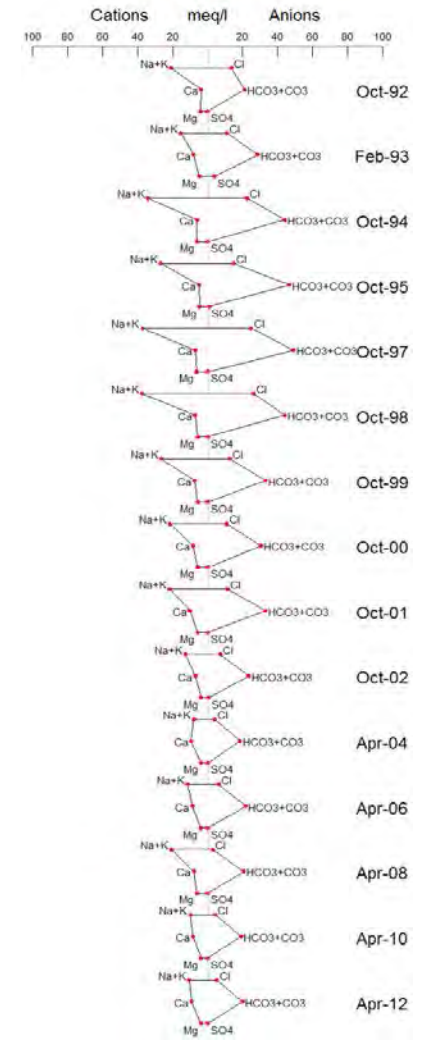


Piper Diagram

IT412S



Stiff Diagram IT412S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-35A
Piper and Stiff Diagrams
Well IT412S
Landfill Section 3/4

Generated By:

Approved By:

DJD

EJW

Date:

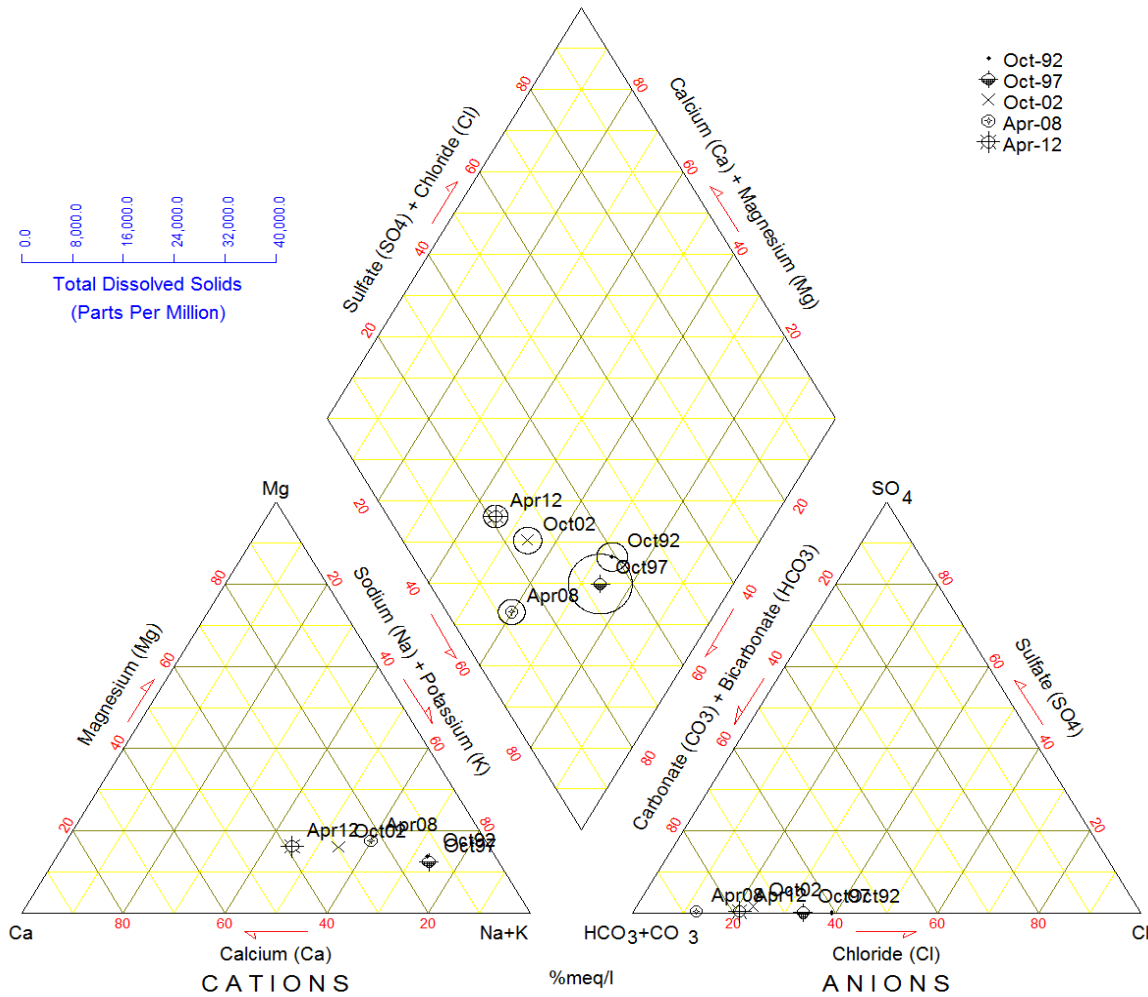
Job Number:

May 2015

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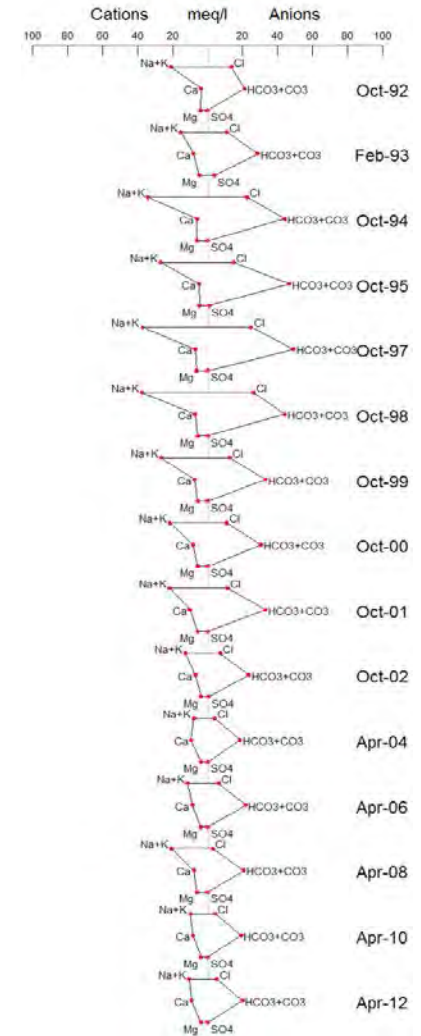
Piper Diagram

IT412S



Stiff Diagram

IT412S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
 Landfill Section 2/8 and Landfill
 Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-35B
 Piper and Stiff Diagrams
 Well IT412S
 Landfill Section 3/4

Generated By:

Approved By:

DJD

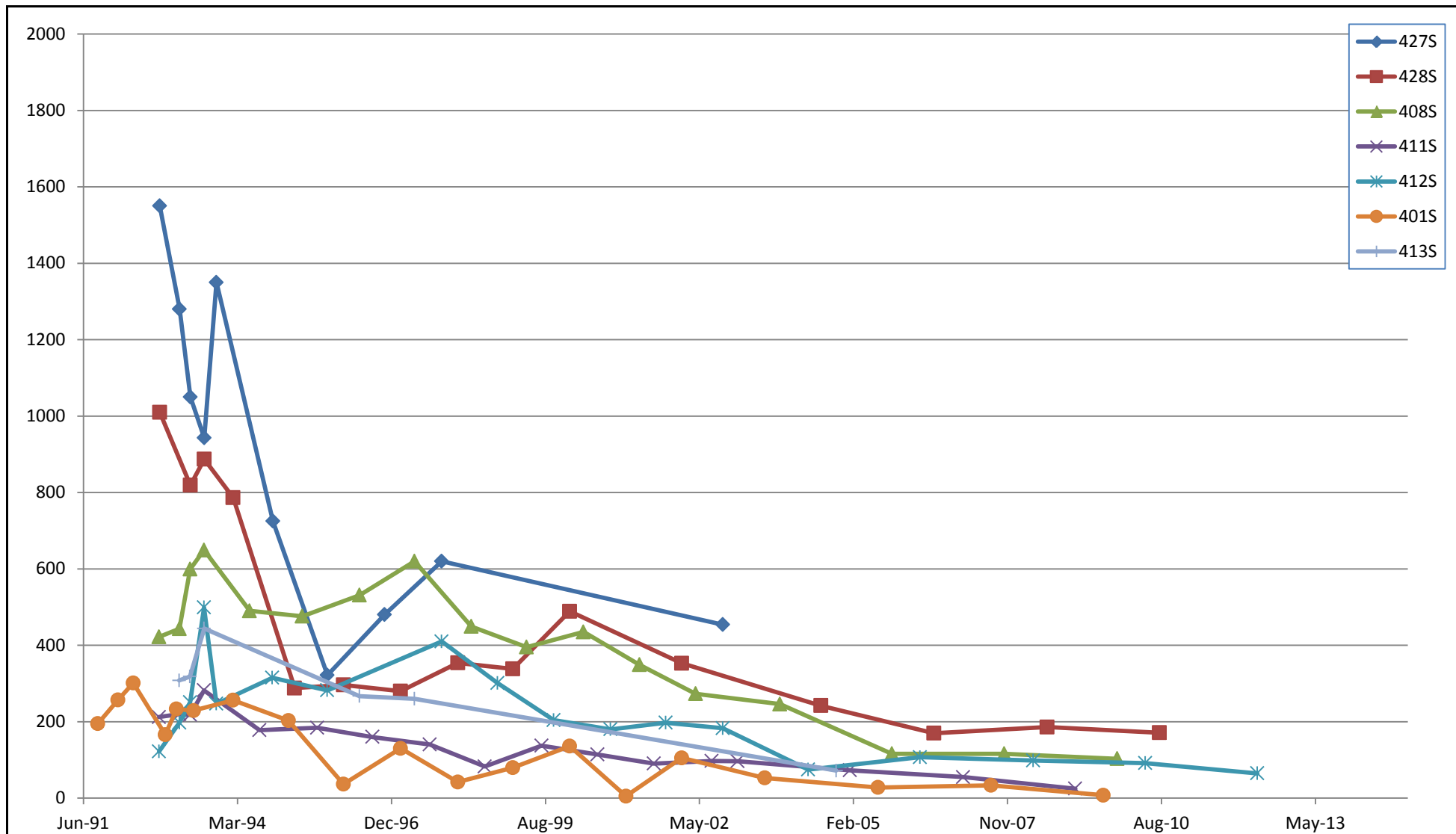
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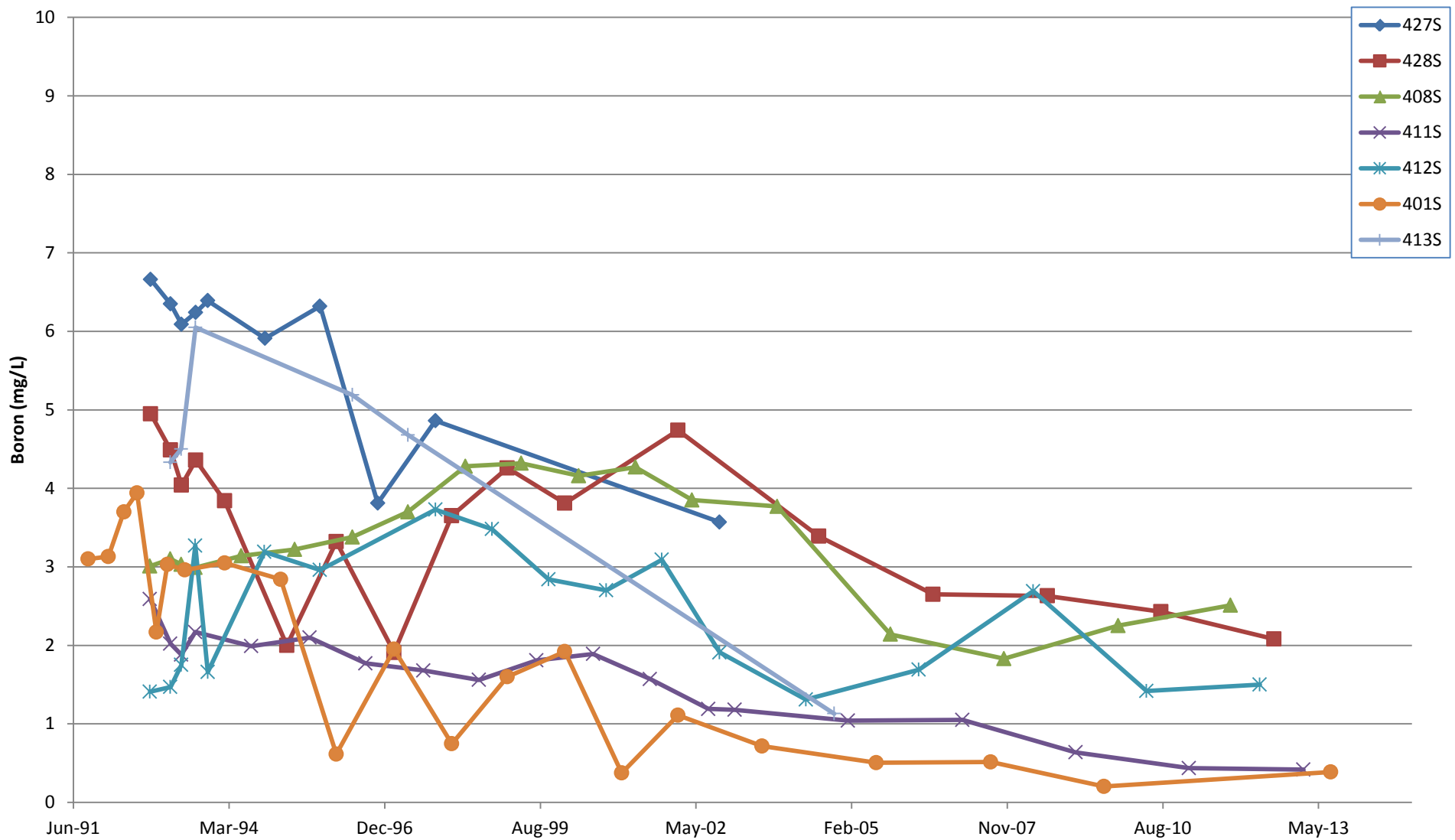
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May 2015

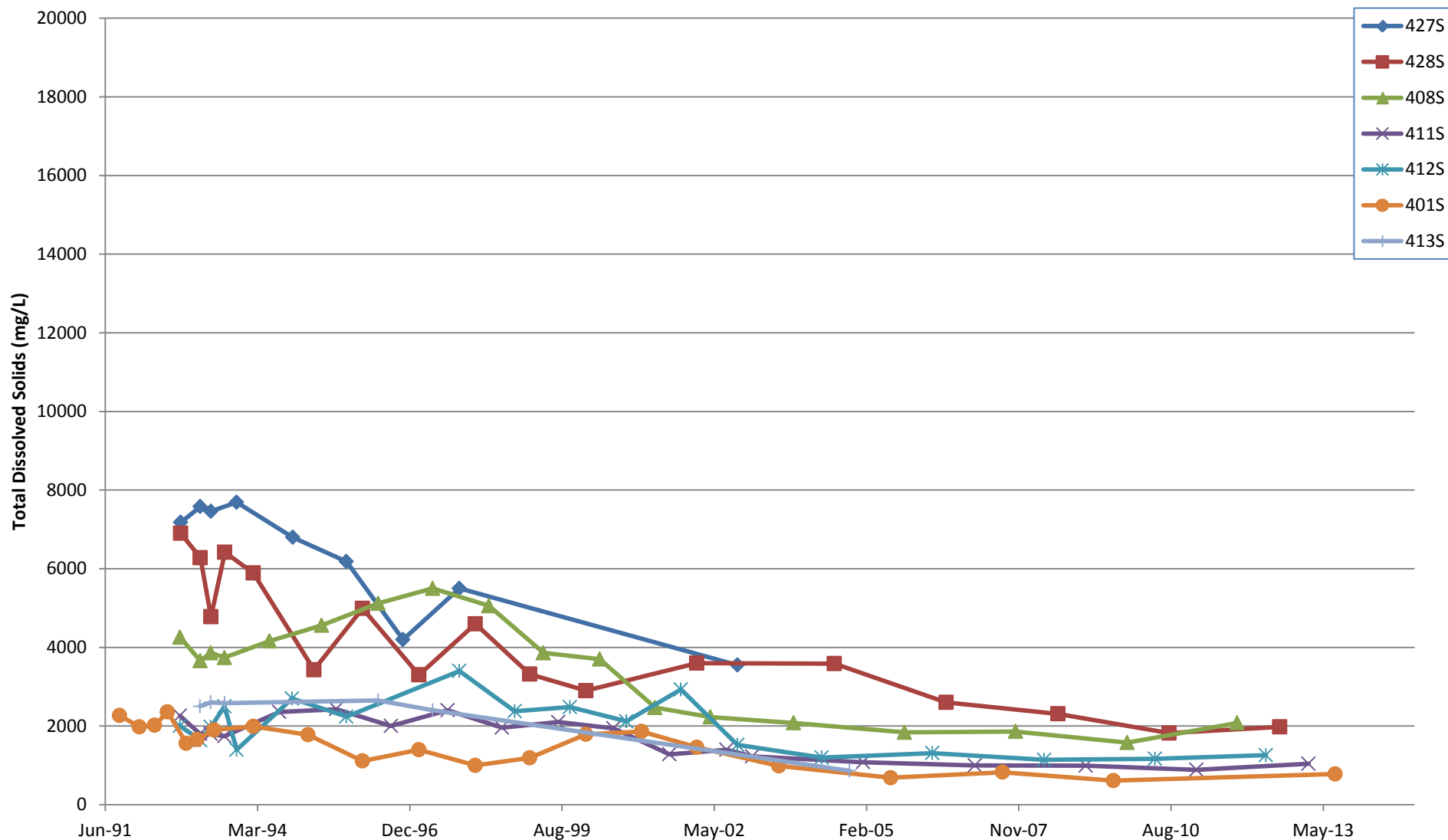
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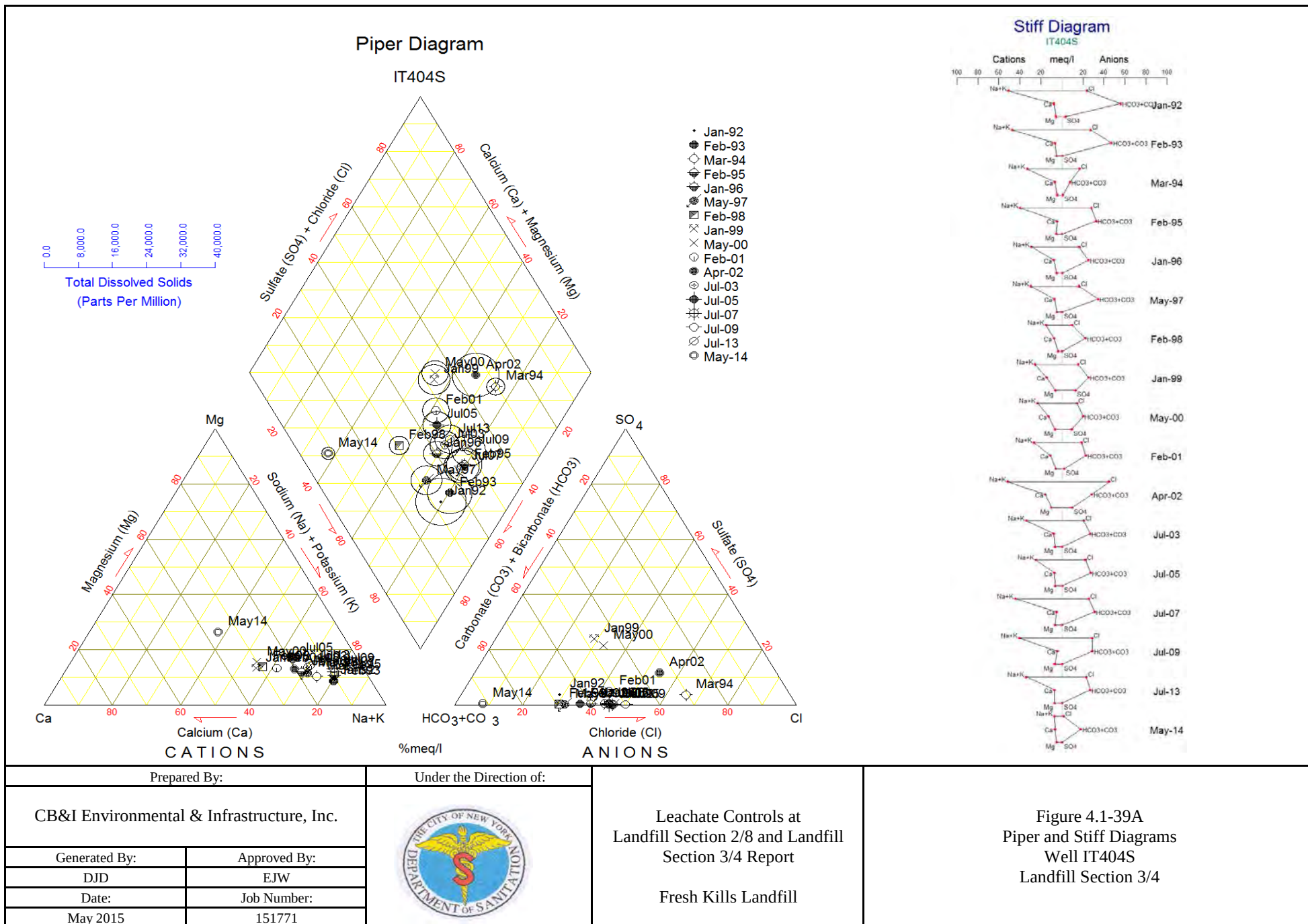
Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-36 Ammonia Concentrations (mg/L) Landfill Section 3/4 - Original Drain
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				



Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-37 Boron Concentrations (mg/L) Landfill Section 3/4 - Original Drain
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				



Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-38 Total Dissolved Solids Concentrations (mg/L) Landfill Section 3/4 - Original Drain
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				



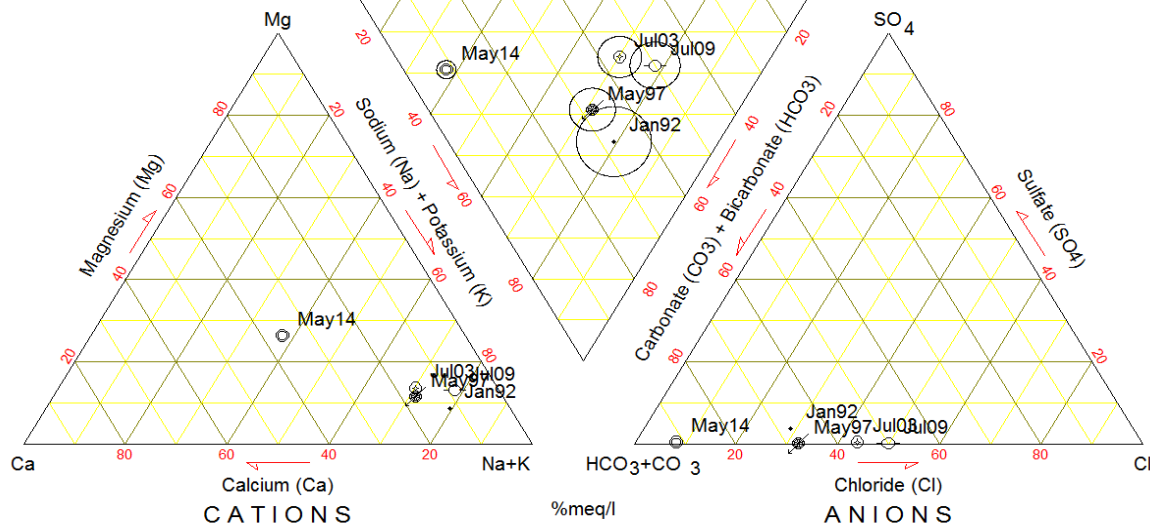
Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-39A Piper and Stiff Diagrams Well IT404S Landfill Section 3/4
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				

Piper Diagram

IT404S

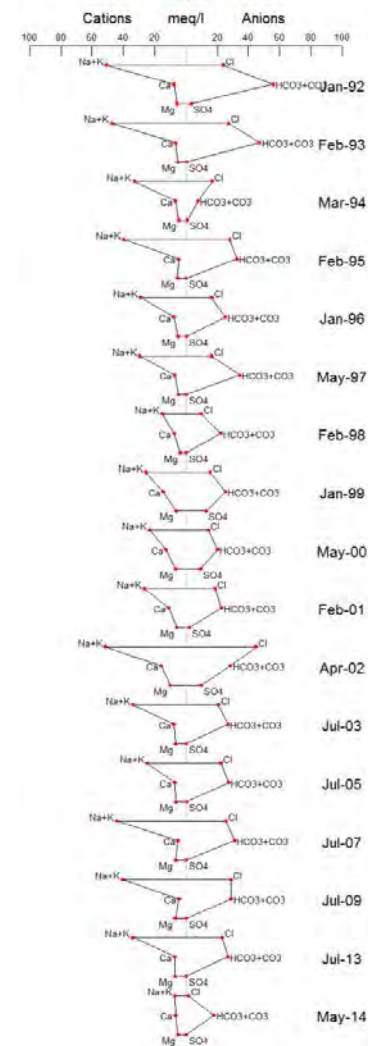
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Total Dissolved Solids
(Parts Per Million)

- Jan-92
- May-97
- Jul-03
- Jul-09
- May-14



Stiff Diagram

IT404S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-39B
Piper and Stiff Diagrams
Well IT404S
Landfill Section 3/4

Generated By:

Approved By:

DJD

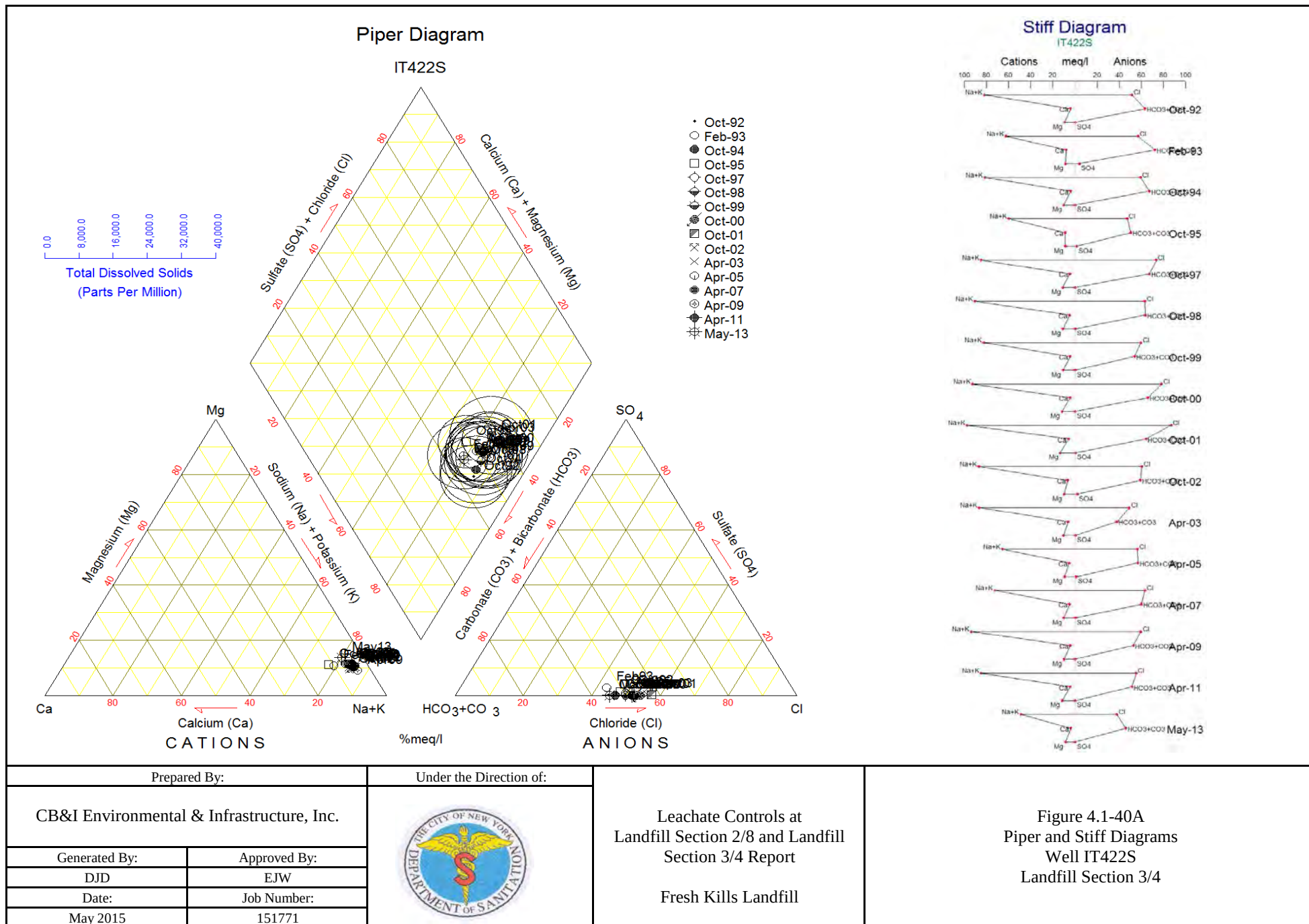
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Date:

Job Number:

May 2015

151771

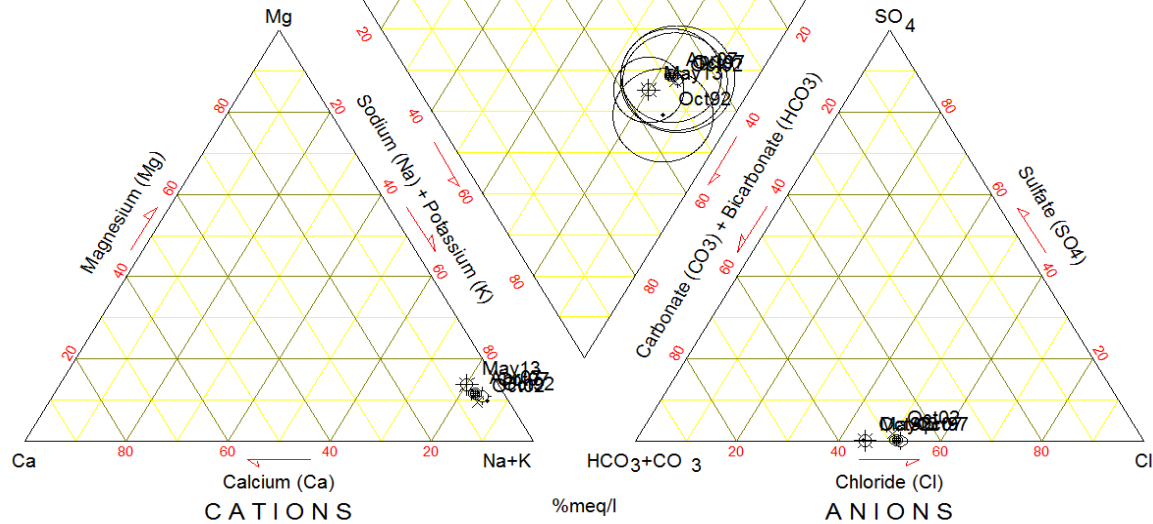


Piper Diagram

IT422S

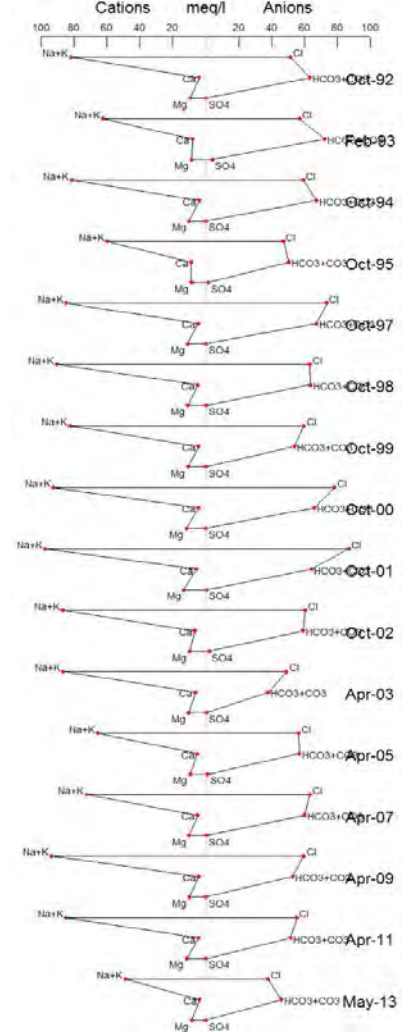
0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)

- Oct-92
- ◊ Oct-97
- ✕ Oct-02
- Apr-07
- ✱ May-13



Stiff Diagram

IT422S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-40B
Piper and Stiff Diagrams
Well IT422S
Landfill Section 3/4

Generated By:

Approved By:

DJD

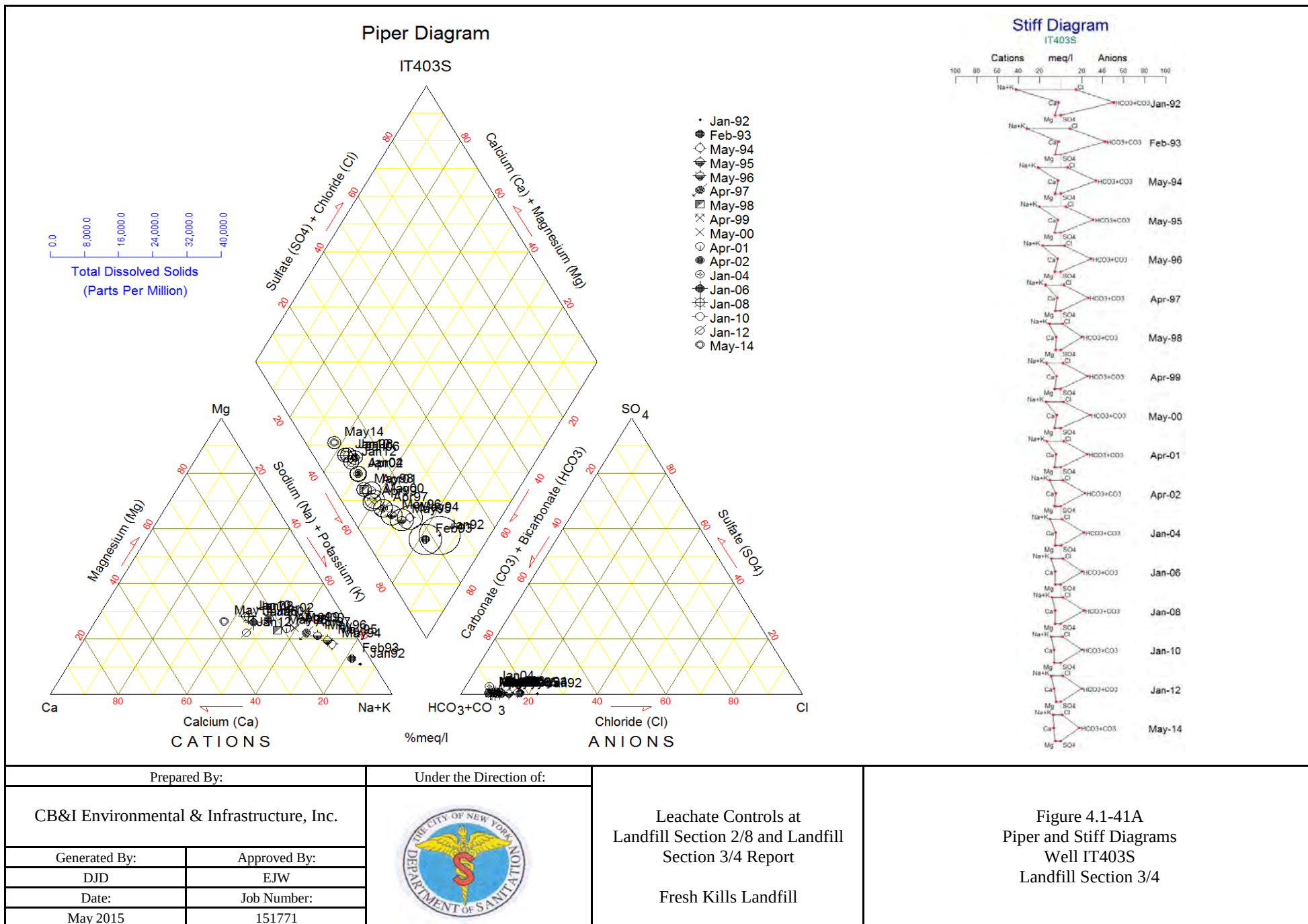
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Date:

Job Number:

May 2015

151771

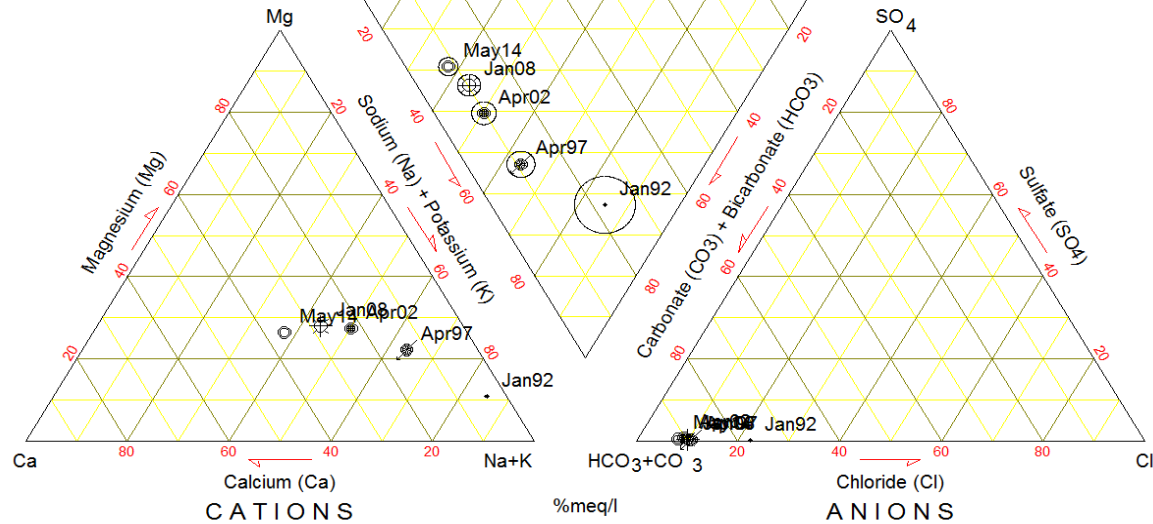


Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-41A Piper and Stiff Diagrams Well IT403S Landfill Section 3/4
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				

Piper Diagram

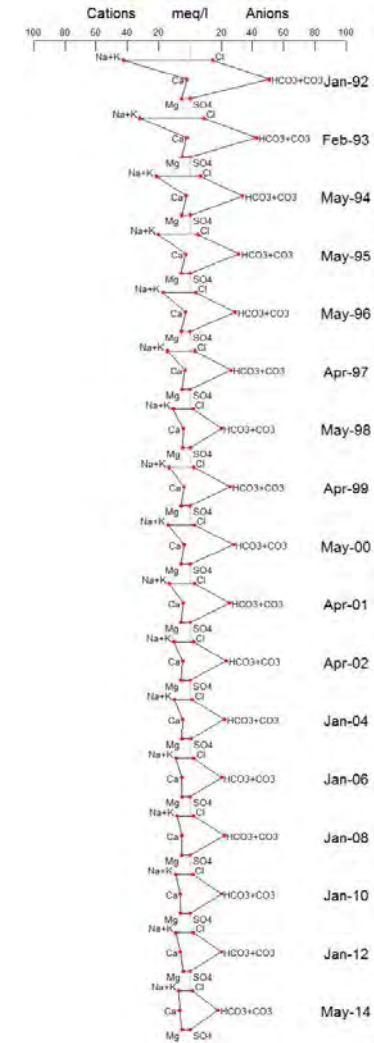
IT403S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT403S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-41B
Piper and Stiff Diagrams
Well IT403S
Landfill Section 3/4

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

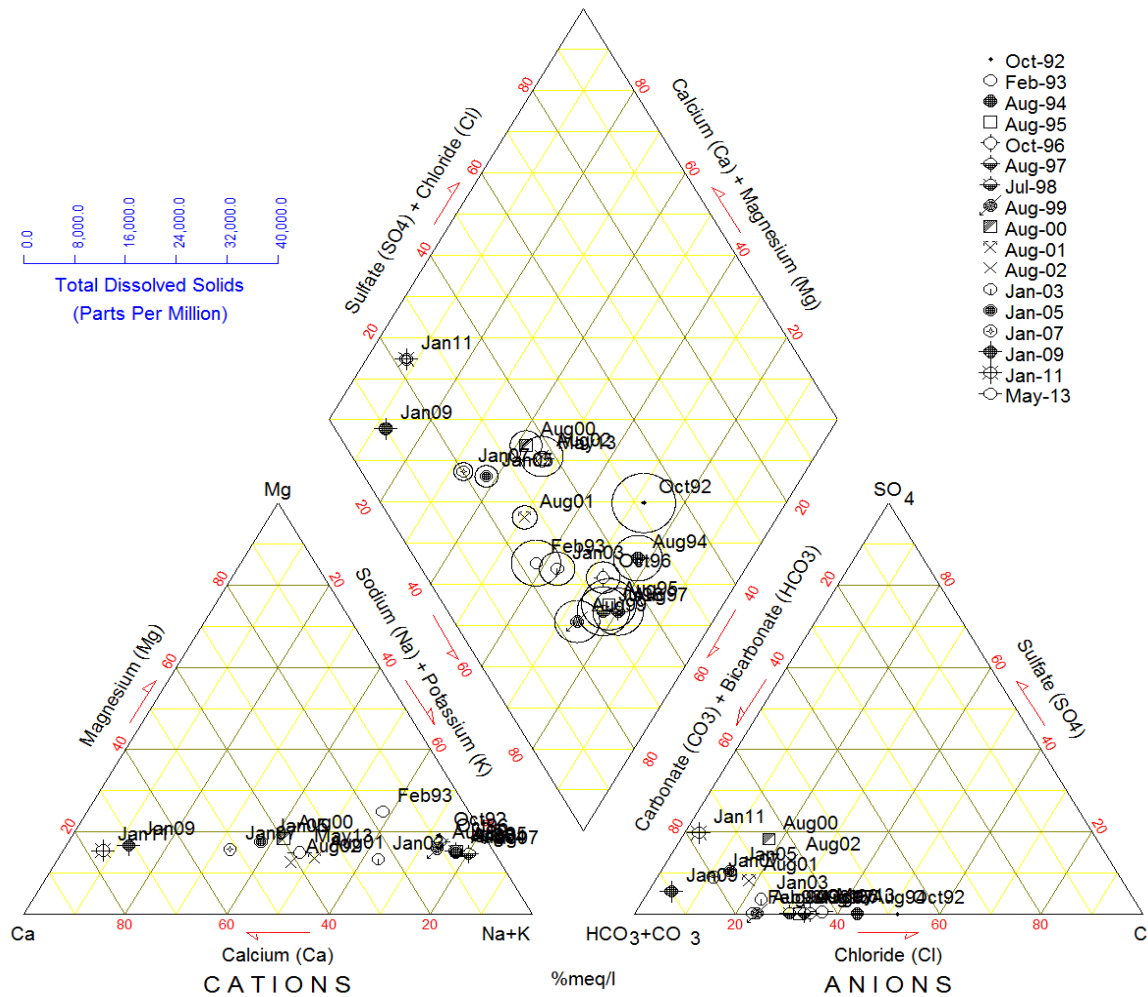
May 2015

151771

Piper Diagram

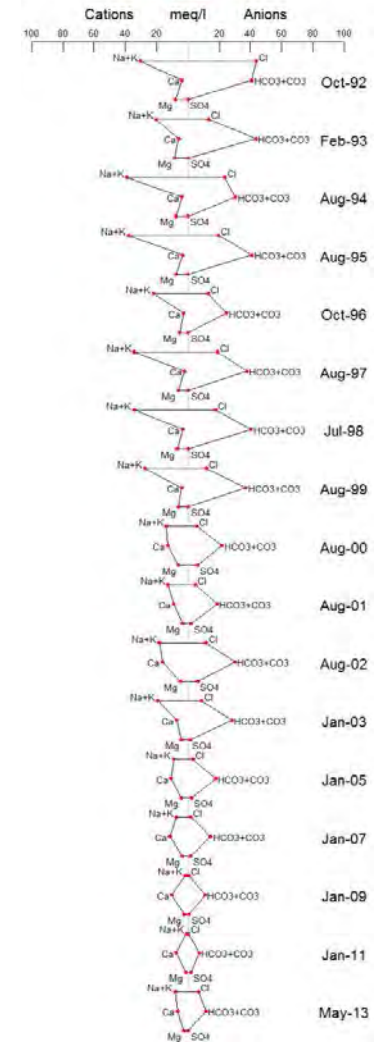
IT419S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT419S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-42A
Piper and Stiff Diagrams
Well IT419S
Landfill Section 3/4

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

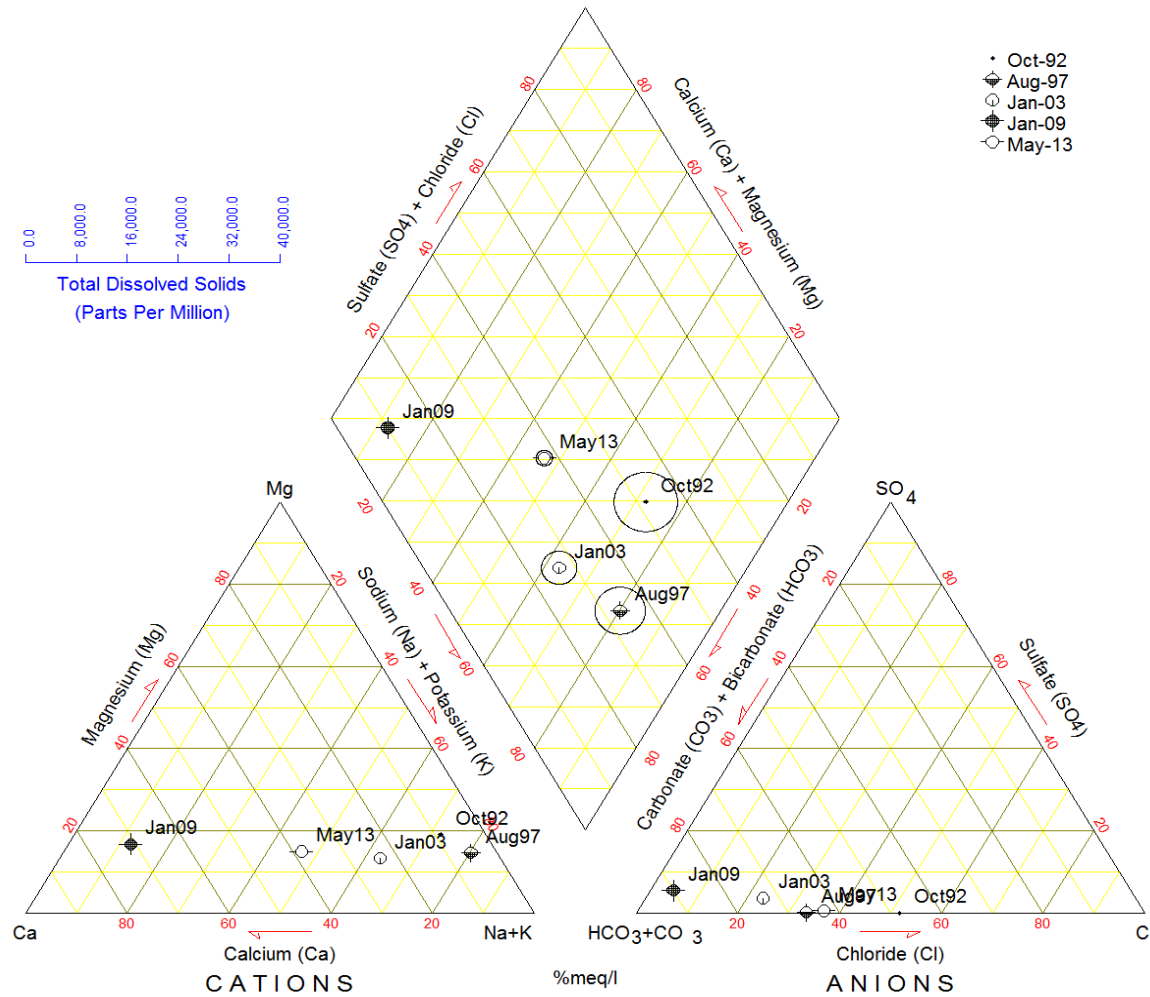
May 2015

151771

Piper Diagram

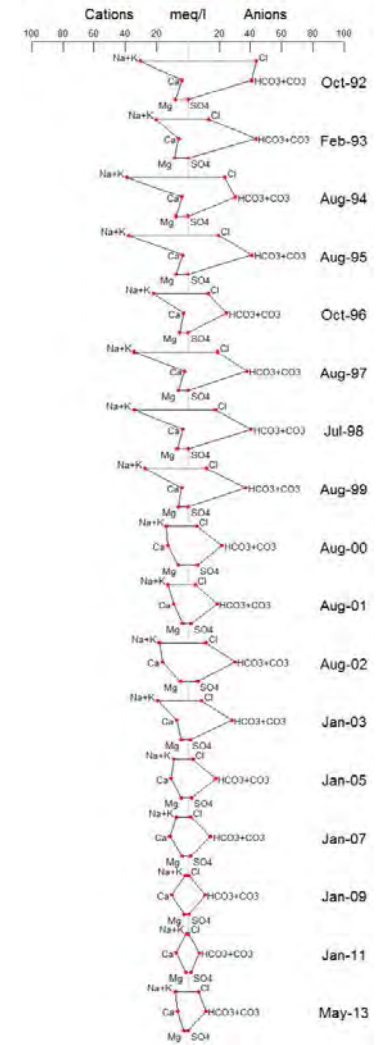
IT419S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT419S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-42B
Piper and Stiff Diagrams
Well IT419S
Landfill Section 3/4

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

May 2015

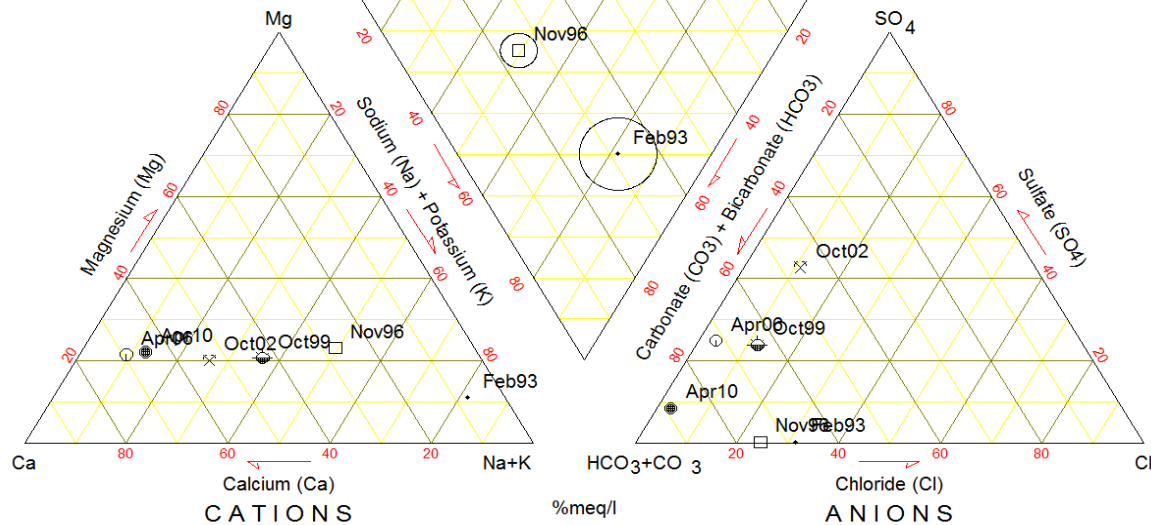
151771

Piper Diagram

IT420S

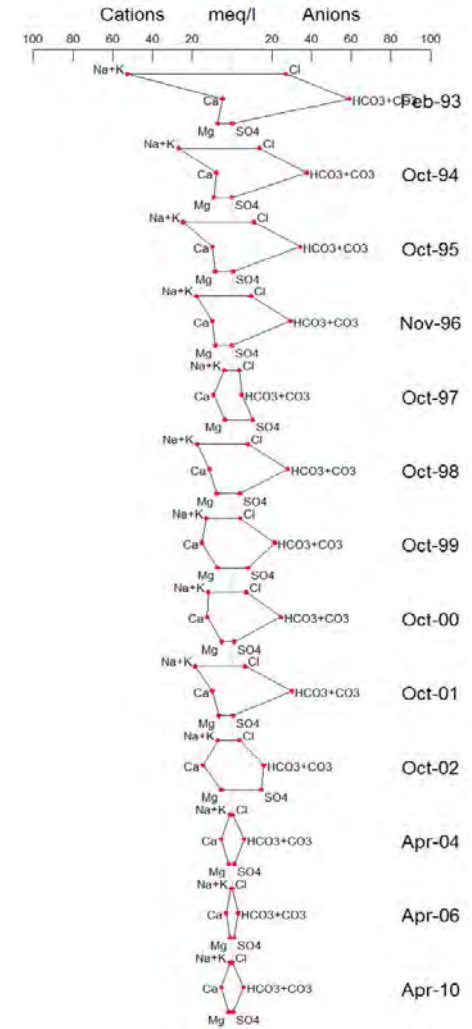
0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)

- Feb-93
- Nov-96
- ⊗ Oct-99
- ⊗ Oct-02
- Apr-06
- Apr-10



Stiff Diagram

IT420S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-43B
Piper and Stiff Diagrams
Well IT420S
Landfill Section 3/4

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

May 2015

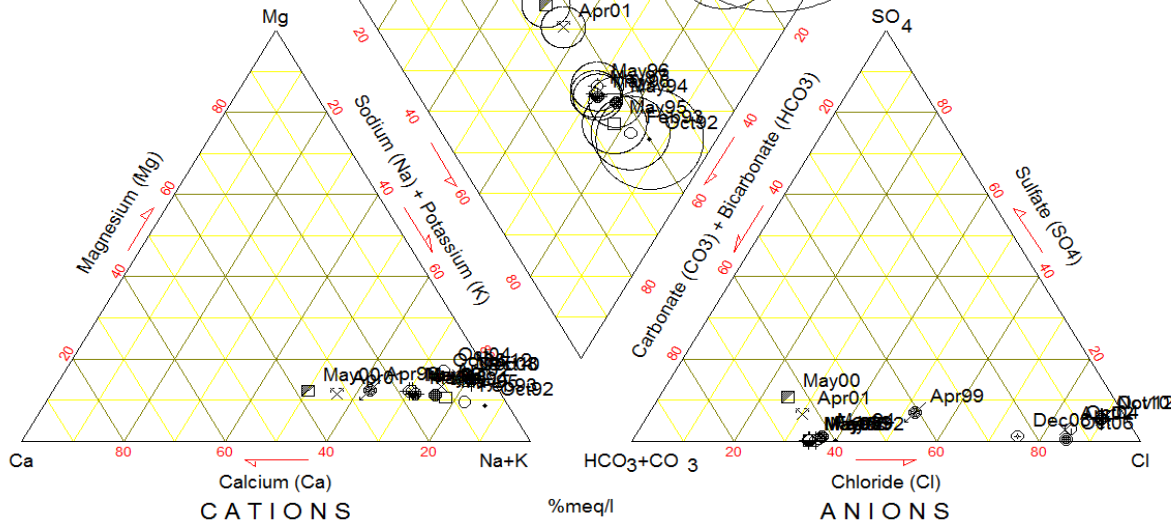
151771

Piper Diagram

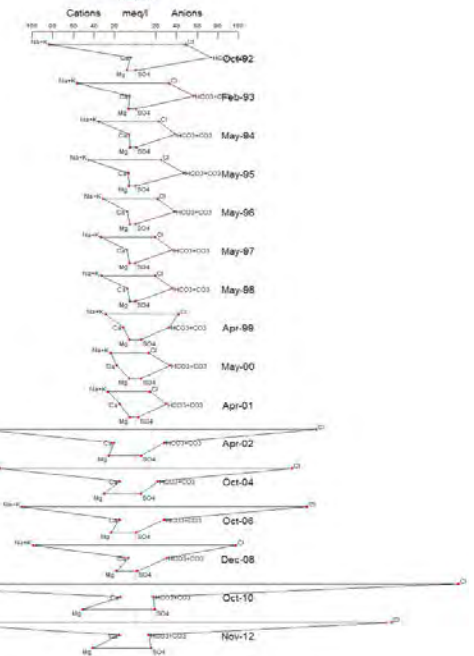
IT421S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)

- Oct-92
- Feb-93
- May-94
- May-95
- ◇ May-96
- ◆ May-97
- ⊠ May-98
- ⊞ Apr-99
- ⊞ May-00
- × Apr-01
- × Apr-02
- Oct-04
- Oct-06
- Dec-08
- Oct-10
- ⊞ Nov-12



Stiff Diagram



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-44A
Piper and Stiff Diagrams
Well IT421S
Landfill Section 3/4

Generated By:

Approved By:

DJD

EJW

Date:

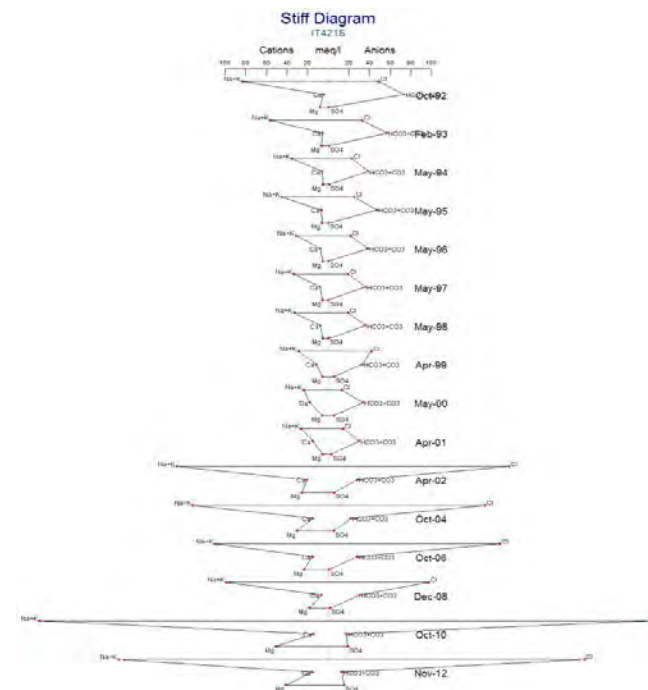
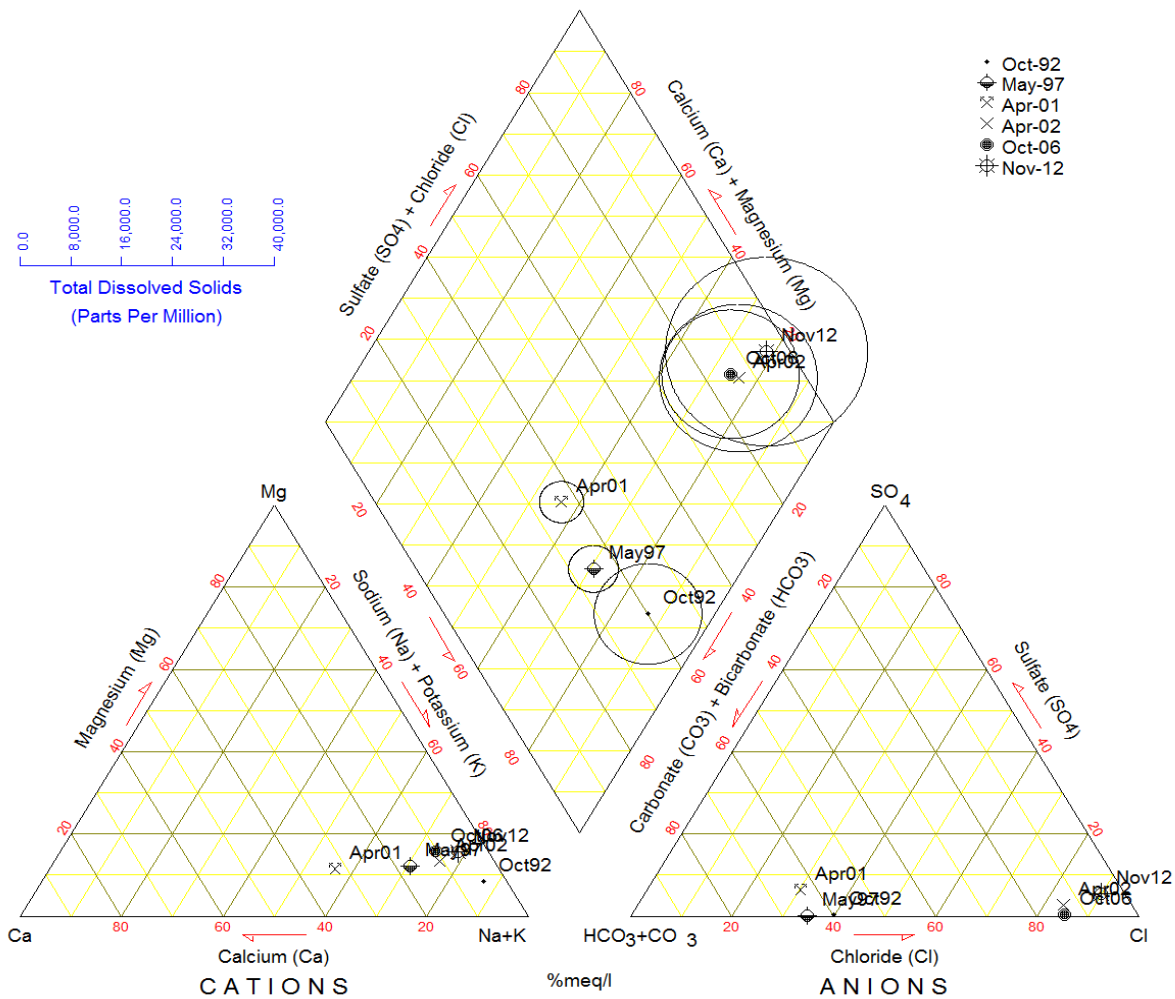
Job Number:

May 2015

151771

Piper Diagram

IT421S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-44B
Piper and Stiff Diagrams
Well IT421S
Landfill Section 3/4

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

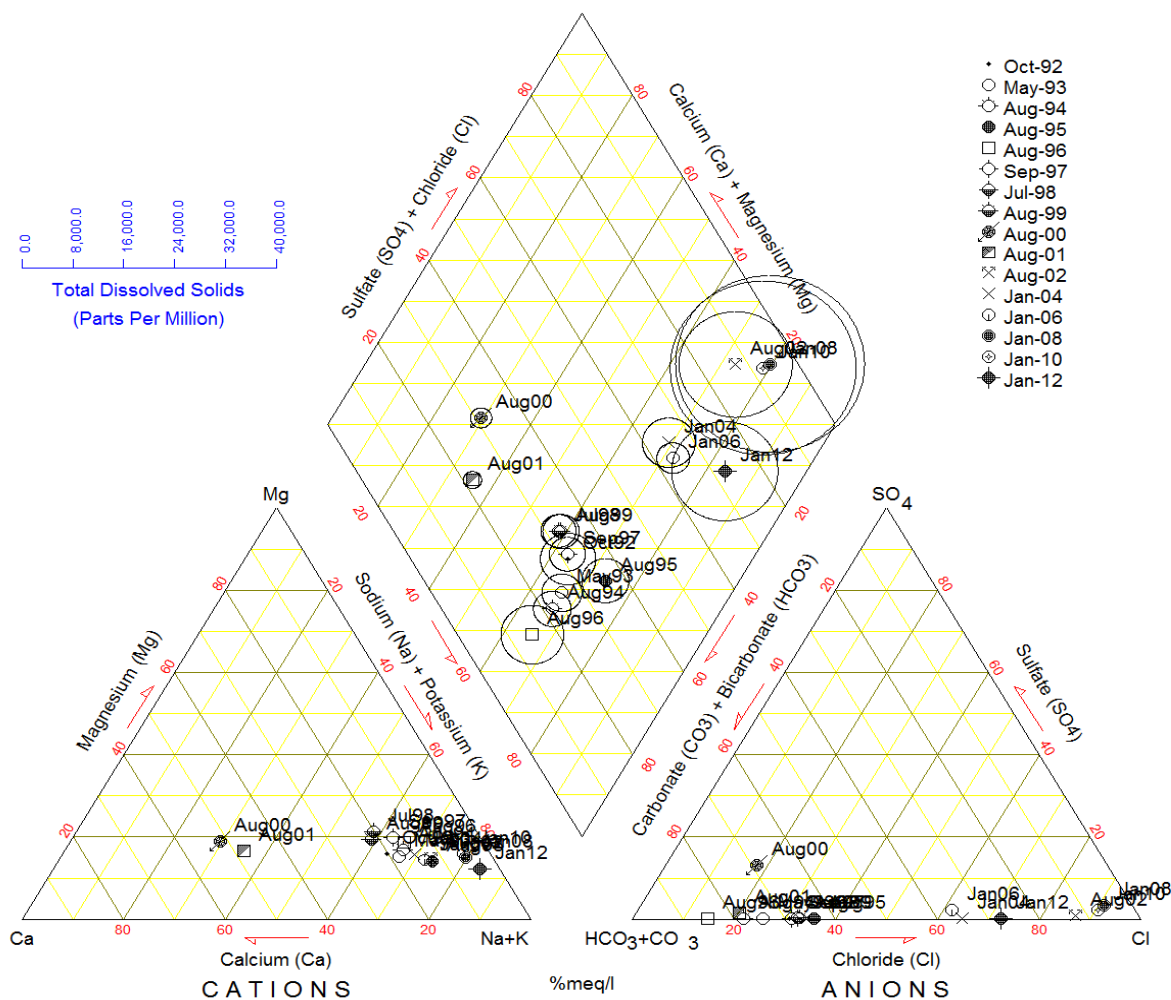
May 2015

151771

Piper Diagram

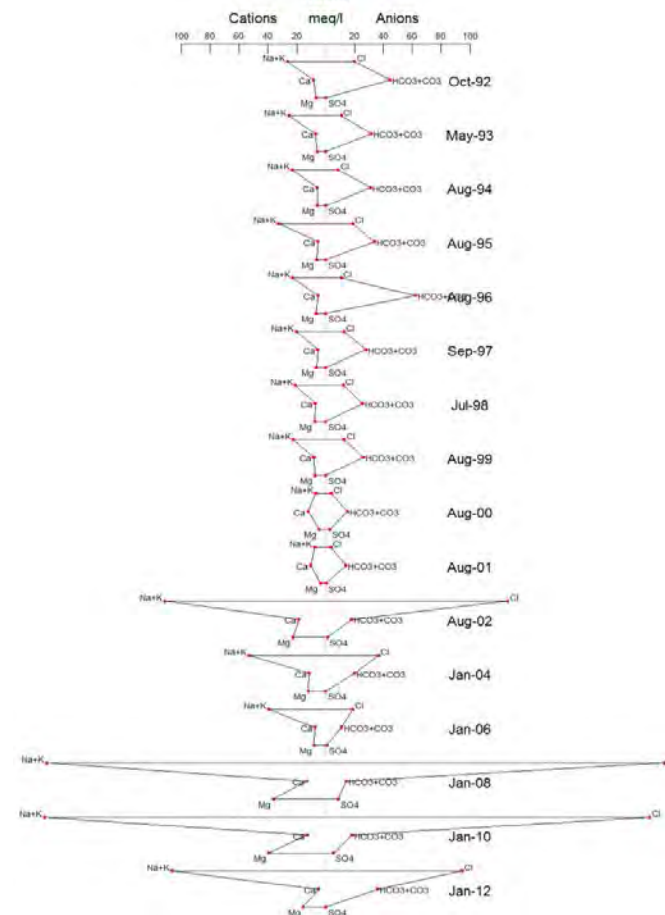
IT433S

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Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT433S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-45A
Piper and Stiff Diagrams
Well IT433S
Landfill Section 3/4

Generated By:

Approved By:

DJD

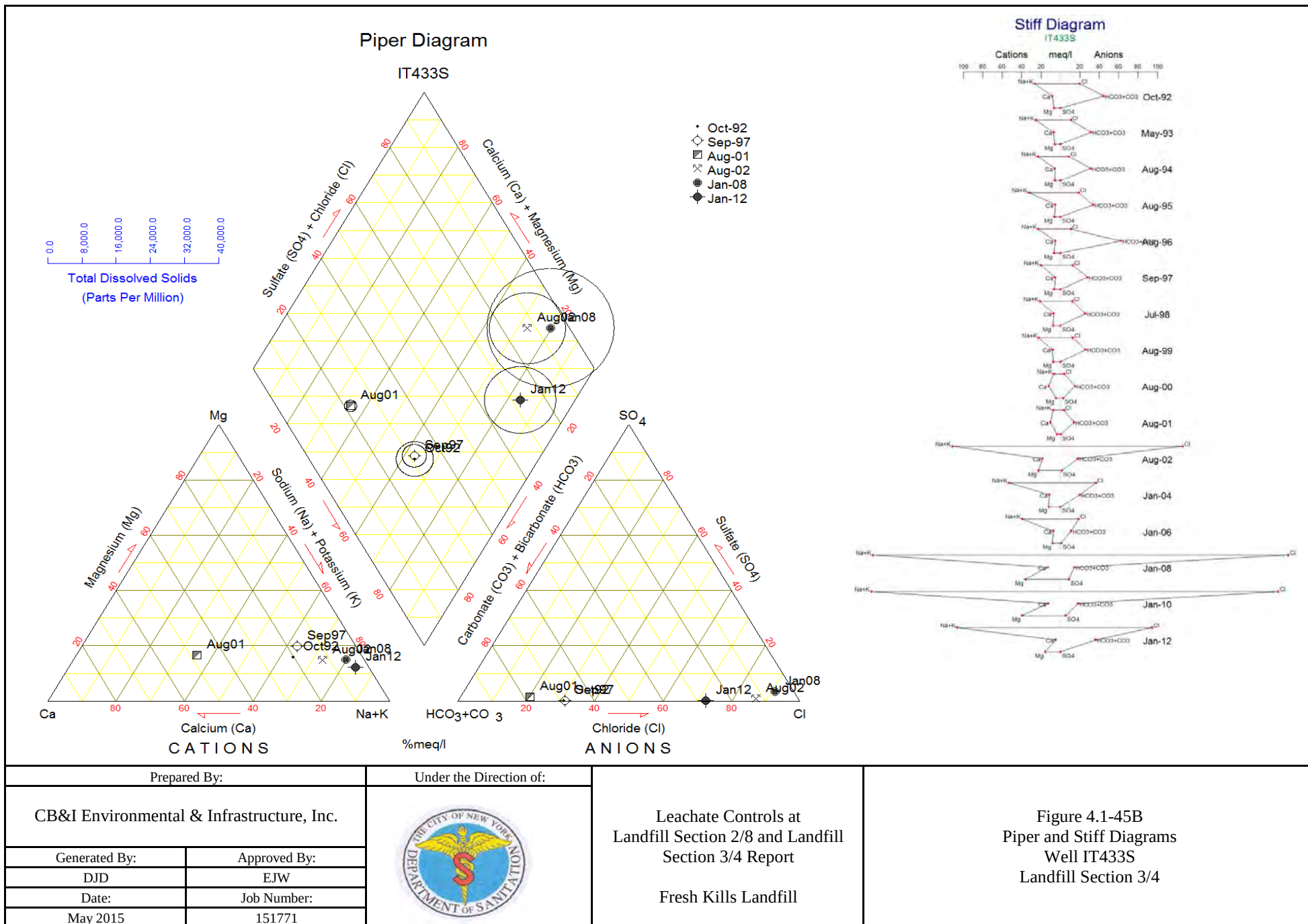
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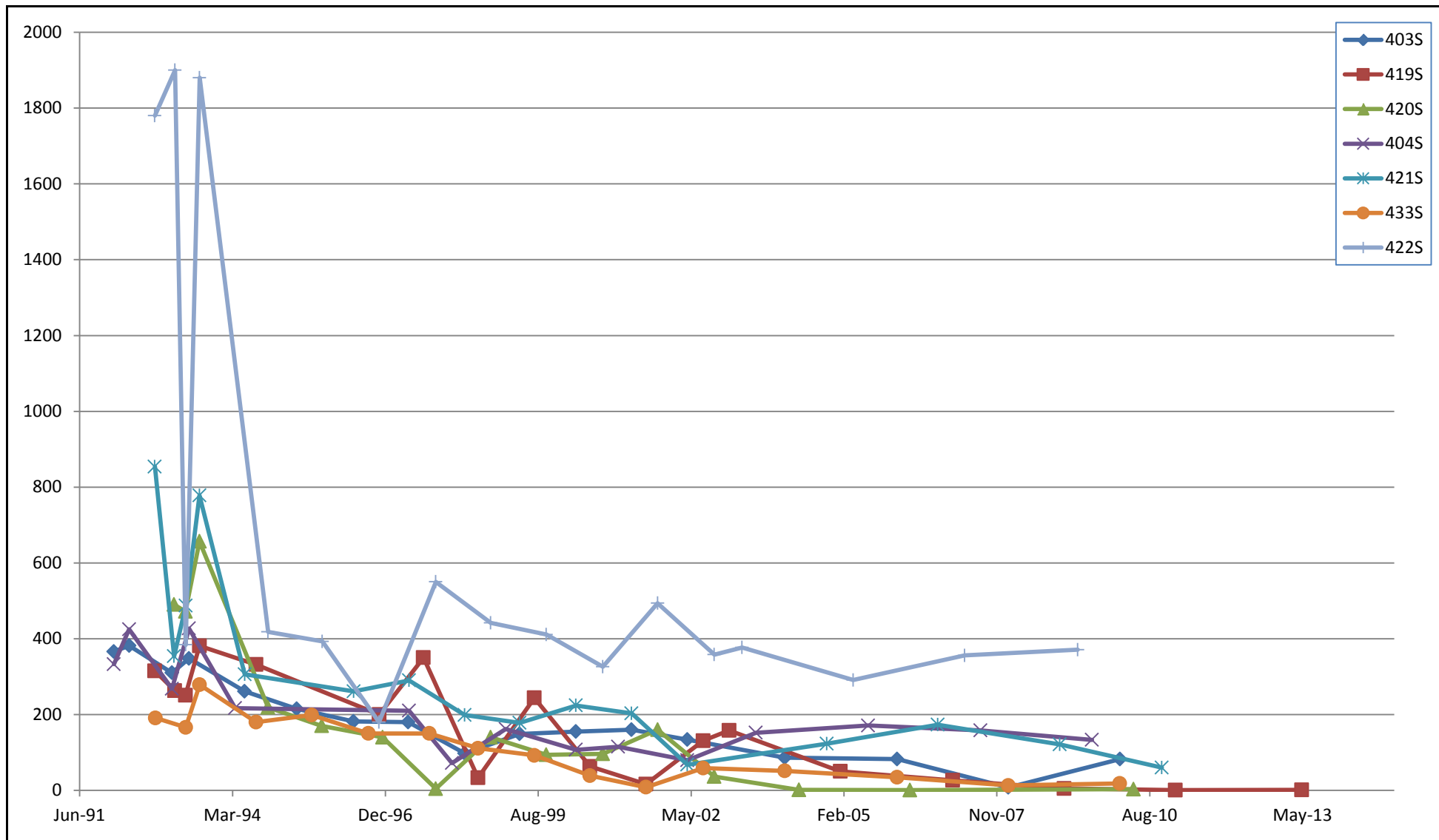
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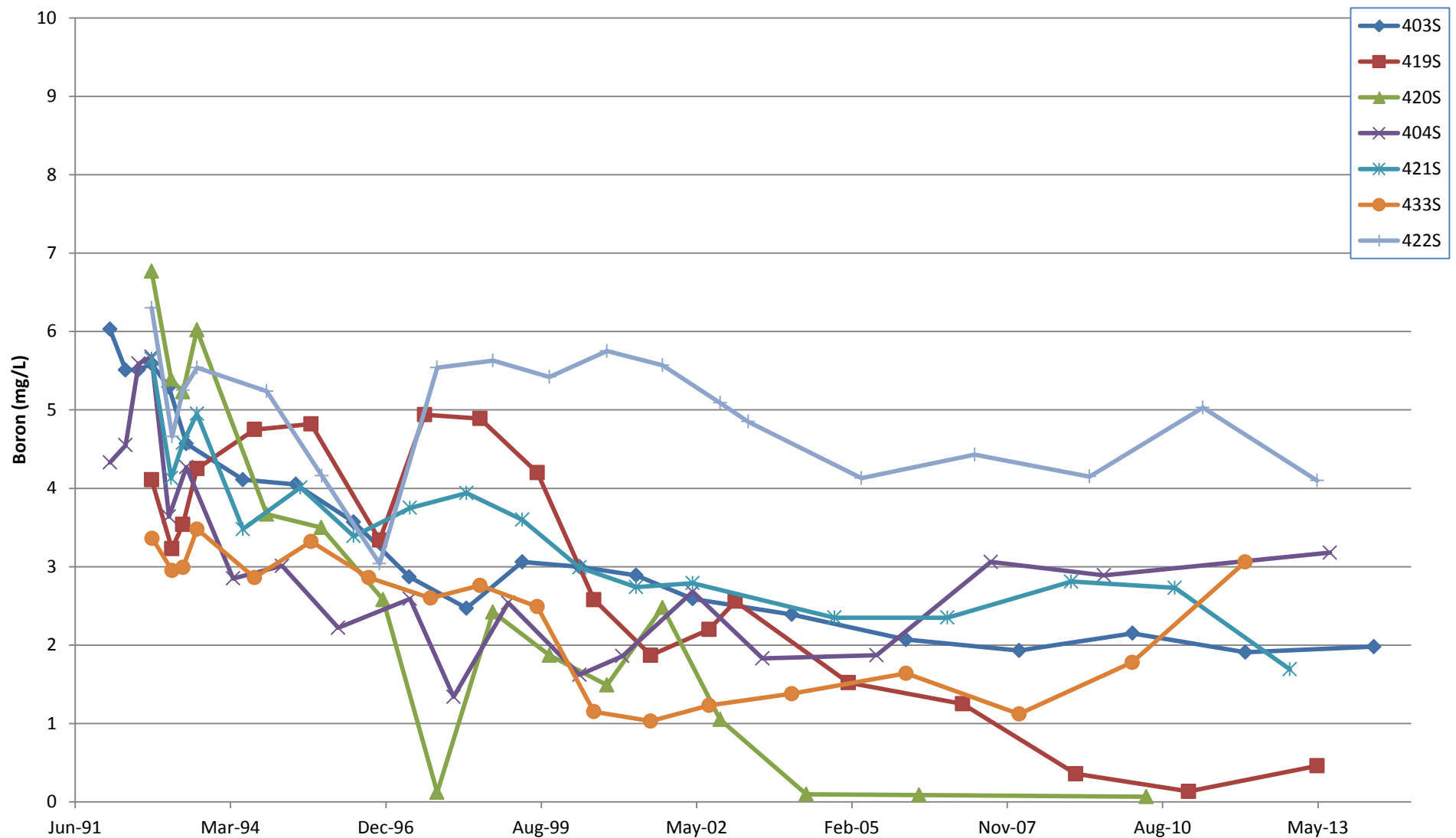
May 2015

151771

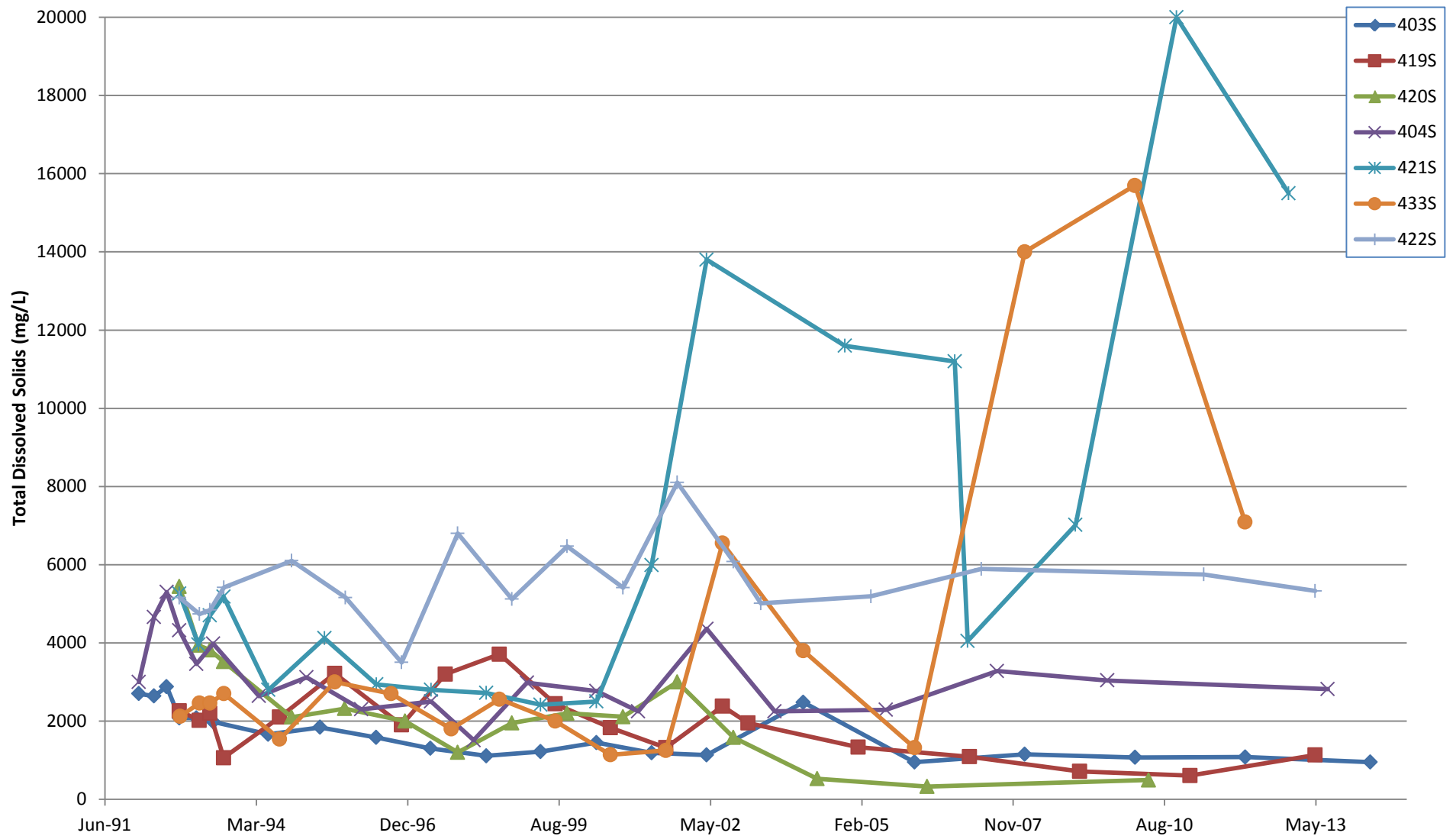




Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-46 Ammonia Concentrations (mg/L) Landfill Section 3/4 - Supplemental Drain
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				



Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.1-47 Boron Concentrations (mg/L) Landfill Section 3/4 - Supplemental Drain
CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				



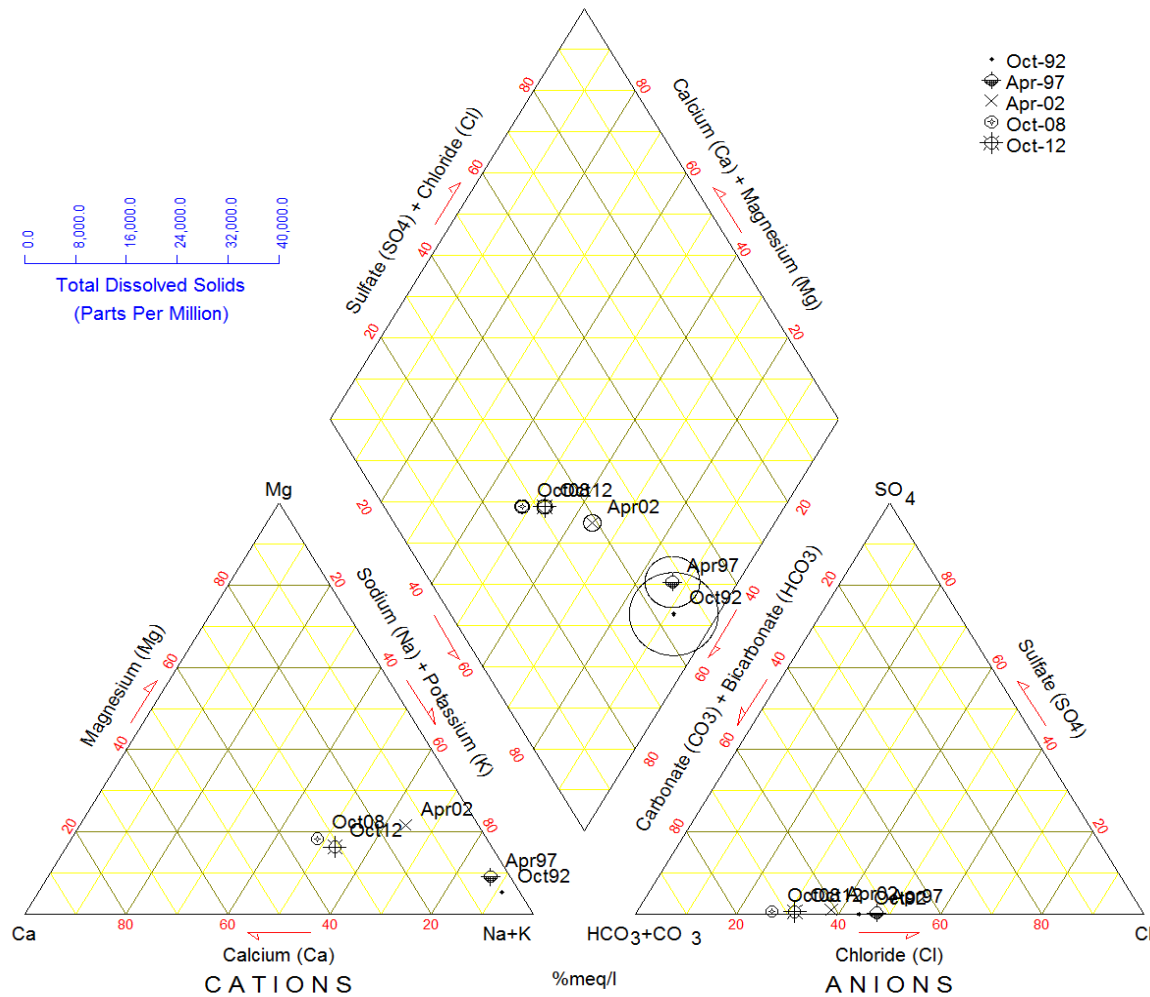
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CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
May 2015	151771				

Piper Diagram

IT426S

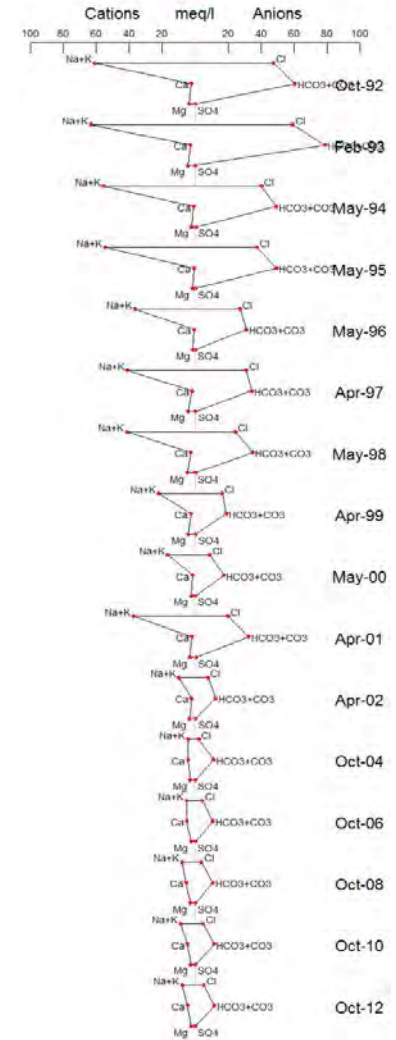
- Oct-92
- ◊ Apr-97
- × Apr-02
- ⊕ Oct-08
- ⊛ Oct-12

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT426S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-49B
Piper and Stiff Diagrams
Well IT426S
Landfill Section 3/4

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

May 2015

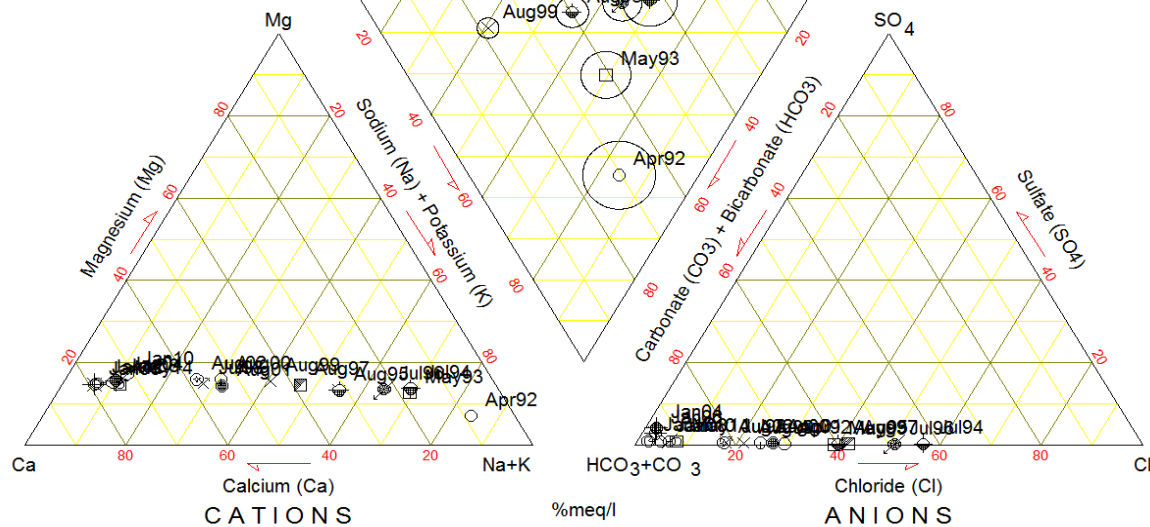
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Piper Diagram

IT407S

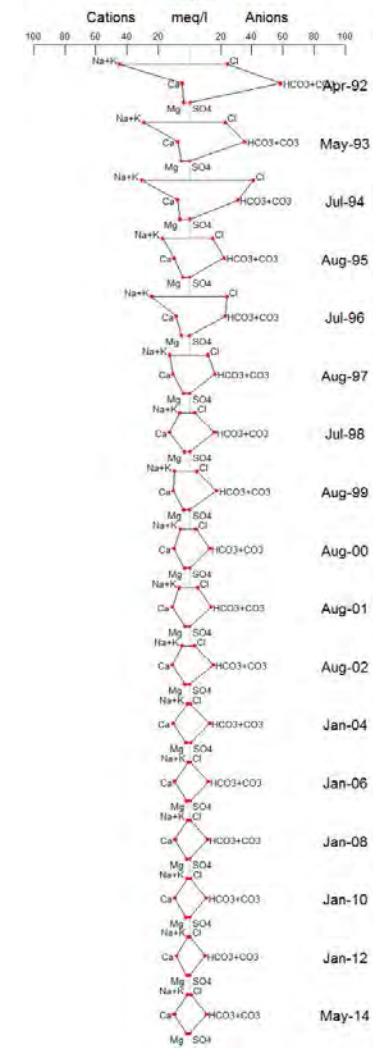
0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)

- Apr-92
- May-93
- ◇ Jul-94
- ⊕ Aug-95
- ⊗ Jul-96
- ⊠ Aug-97
- ⊡ Jul-98
- ⊞ Aug-99
- ⊟ Aug-00
- ⊠ Aug-01
- ⊡ Aug-02
- ⊞ Jan-04
- ⊟ Jan-06
- ⊠ Jan-08
- ⊡ Jan-10
- ⊞ Jan-12
- ⊟ May-14



Stiff Diagram

IT407S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-50A
Piper and Stiff Diagrams
Well IT407S
Landfill Section 3/4

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

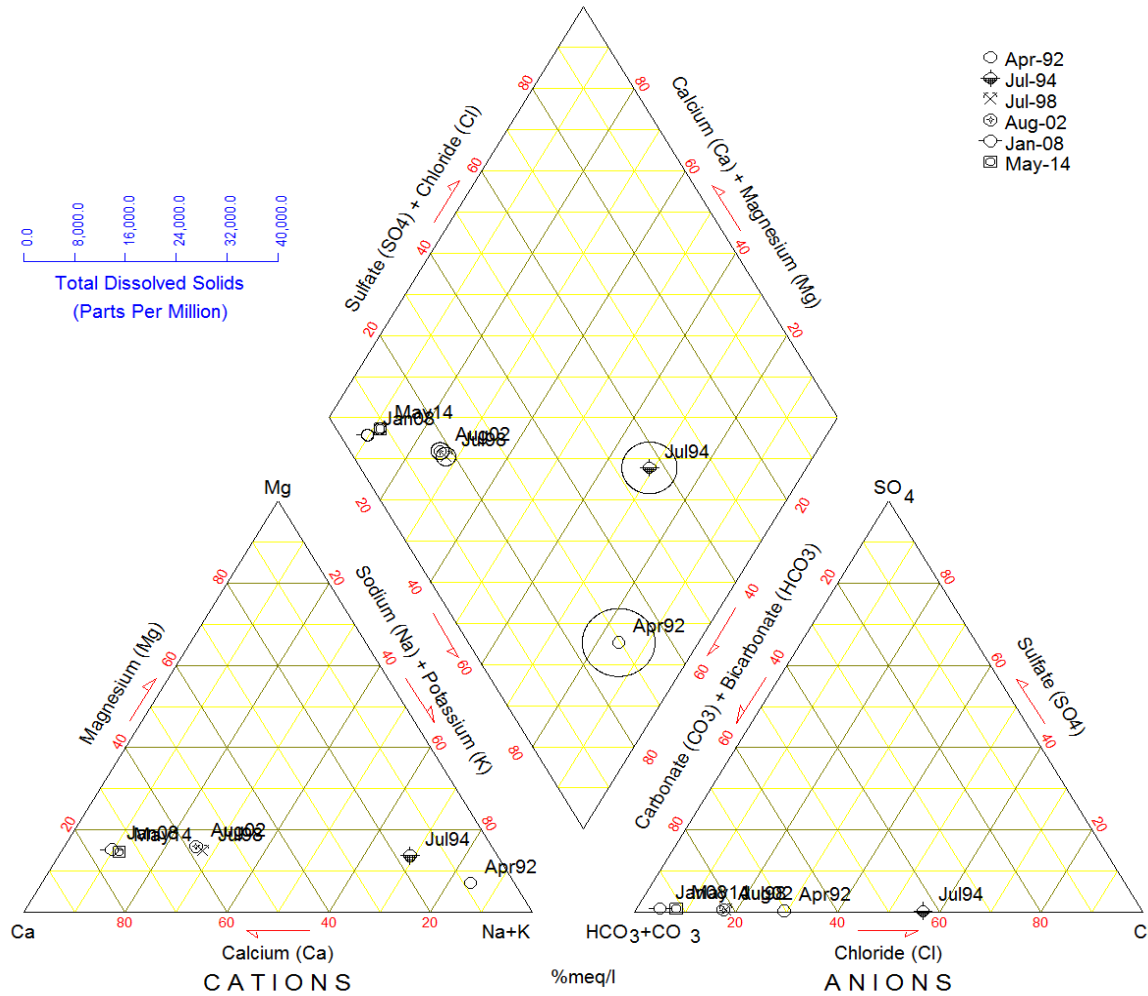
April 2015

151771

Piper Diagram

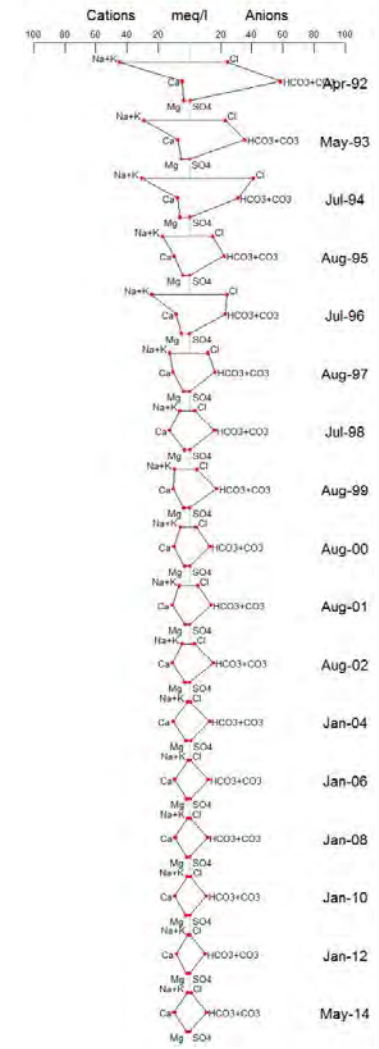
IT407S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT407S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-50B
Piper and Stiff Diagrams
Well IT407S
Landfill Section 3/4

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

April 2015

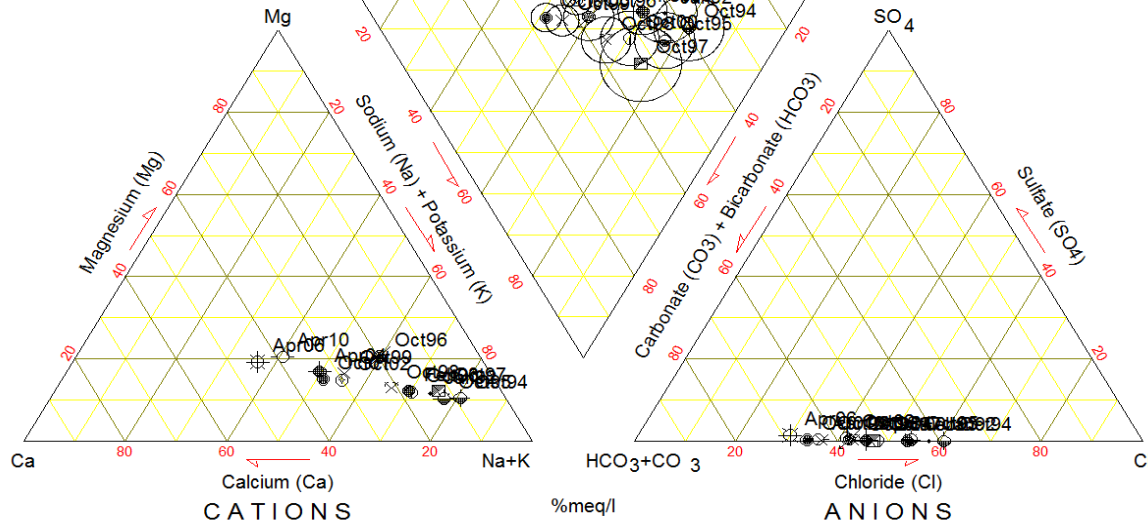
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Piper Diagram

IT406S

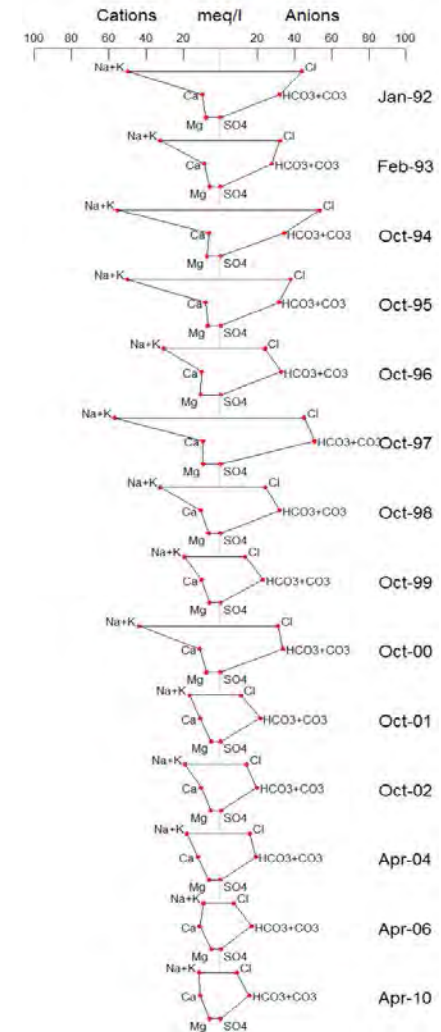
0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)

- Jan-92
- Feb-93
- ◆ Oct-94
- ◆ Oct-95
- ◆ Oct-96
- ◆ Oct-97
- ◆ Oct-98
- × Oct-99
- Oct-00
- Oct-01
- Oct-02
- ◆ Apr-04
- ◆ Apr-06
- Apr-10



Stiff Diagram

IT406S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-51A
Piper and Stiff Diagrams
Well IT406S
Landfill Section 2/8

Generated By:

Approved By:

DJD

EJW

Date:

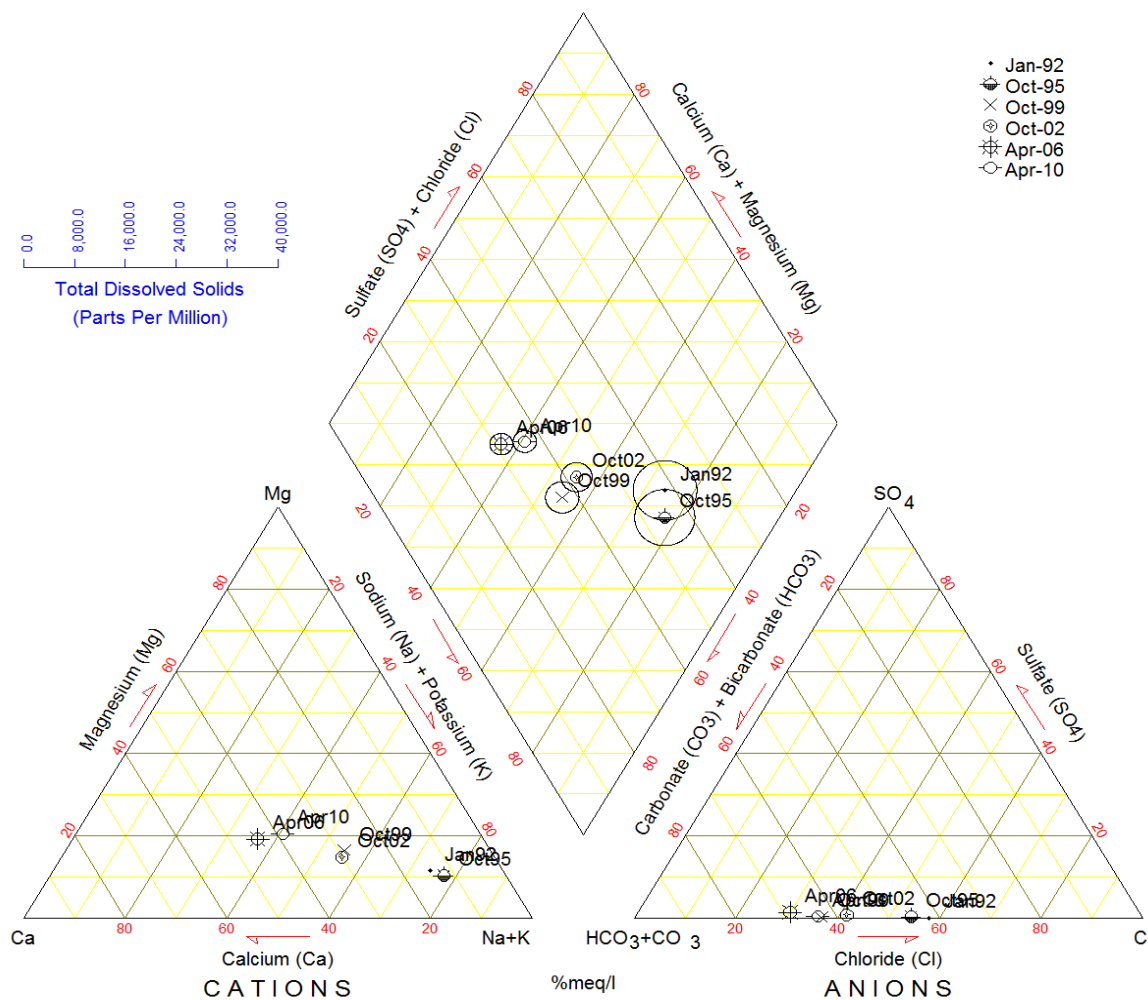
Job Number:

May 2015

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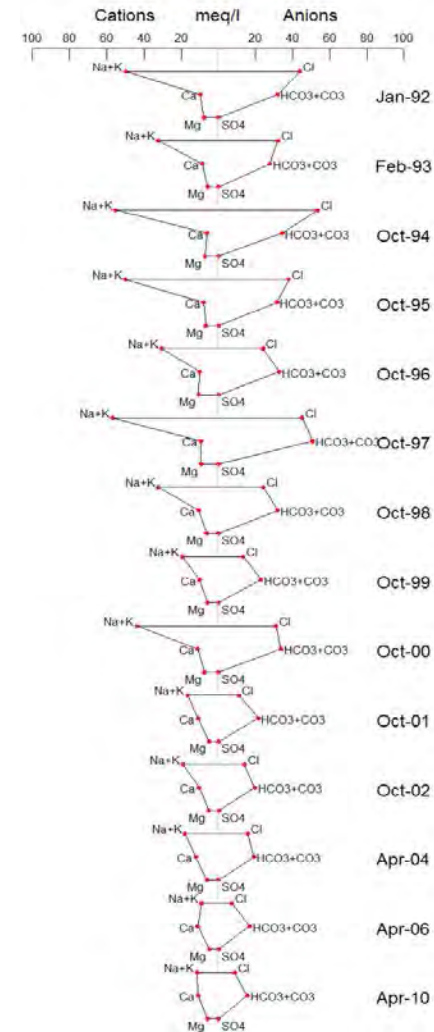
Piper Diagram

IT406S



Stiff Diagram

IT406S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
 Landfill Section 2/8 and Landfill
 Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-51B
 Piper and Stiff Diagrams
 Well IT406S
 Landfill Section 2/8

Generated By:

Approved By:

DJD

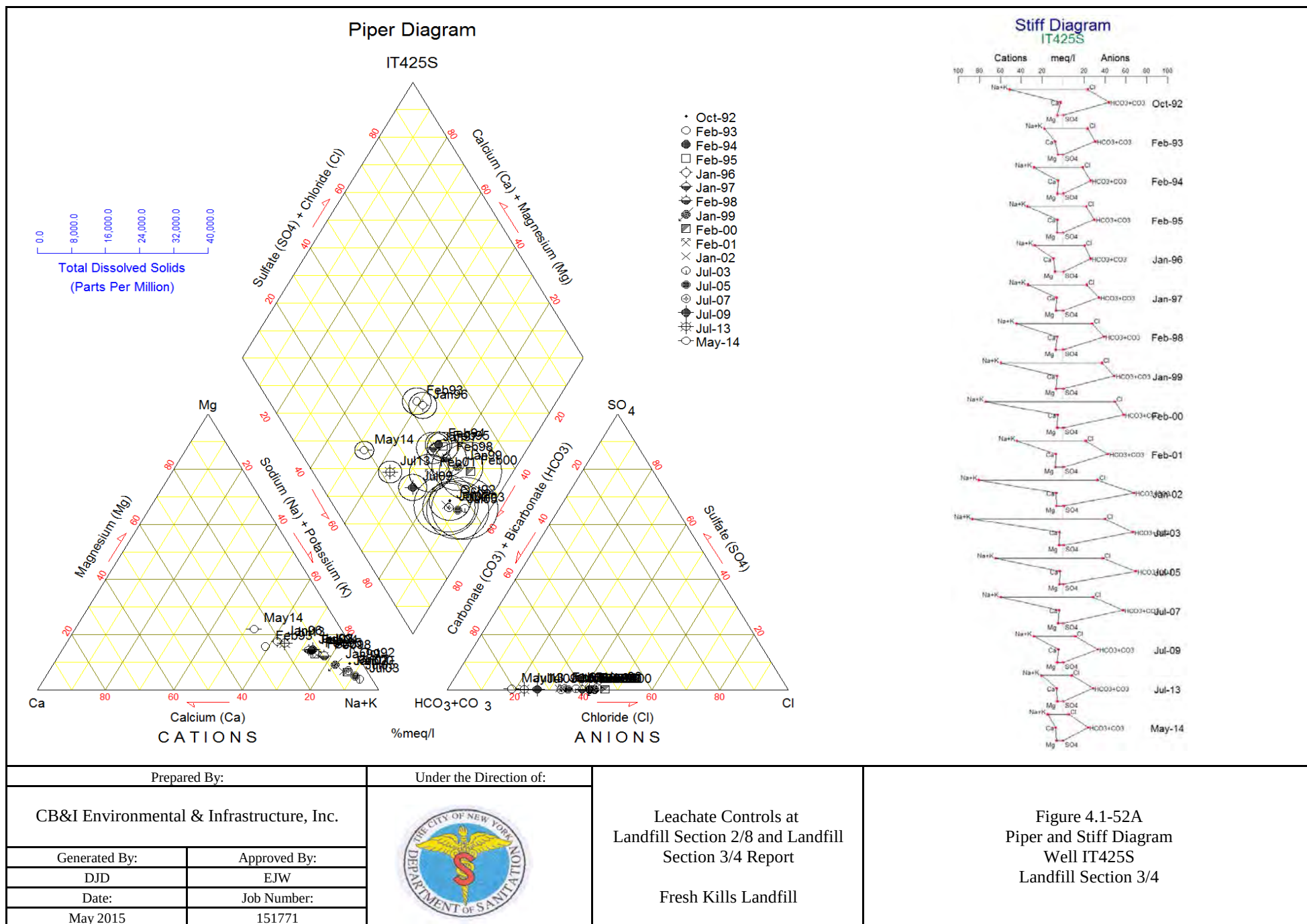
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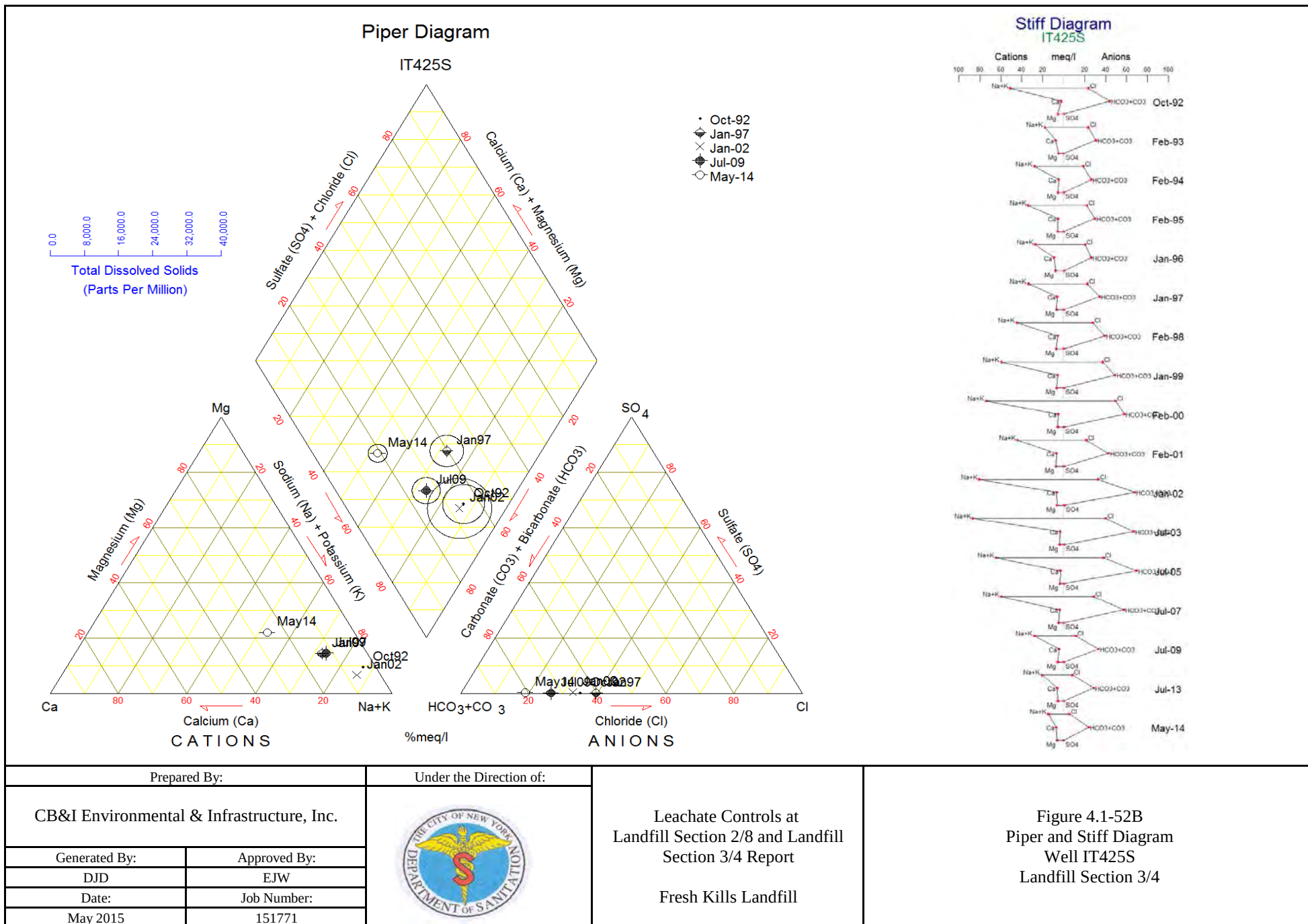
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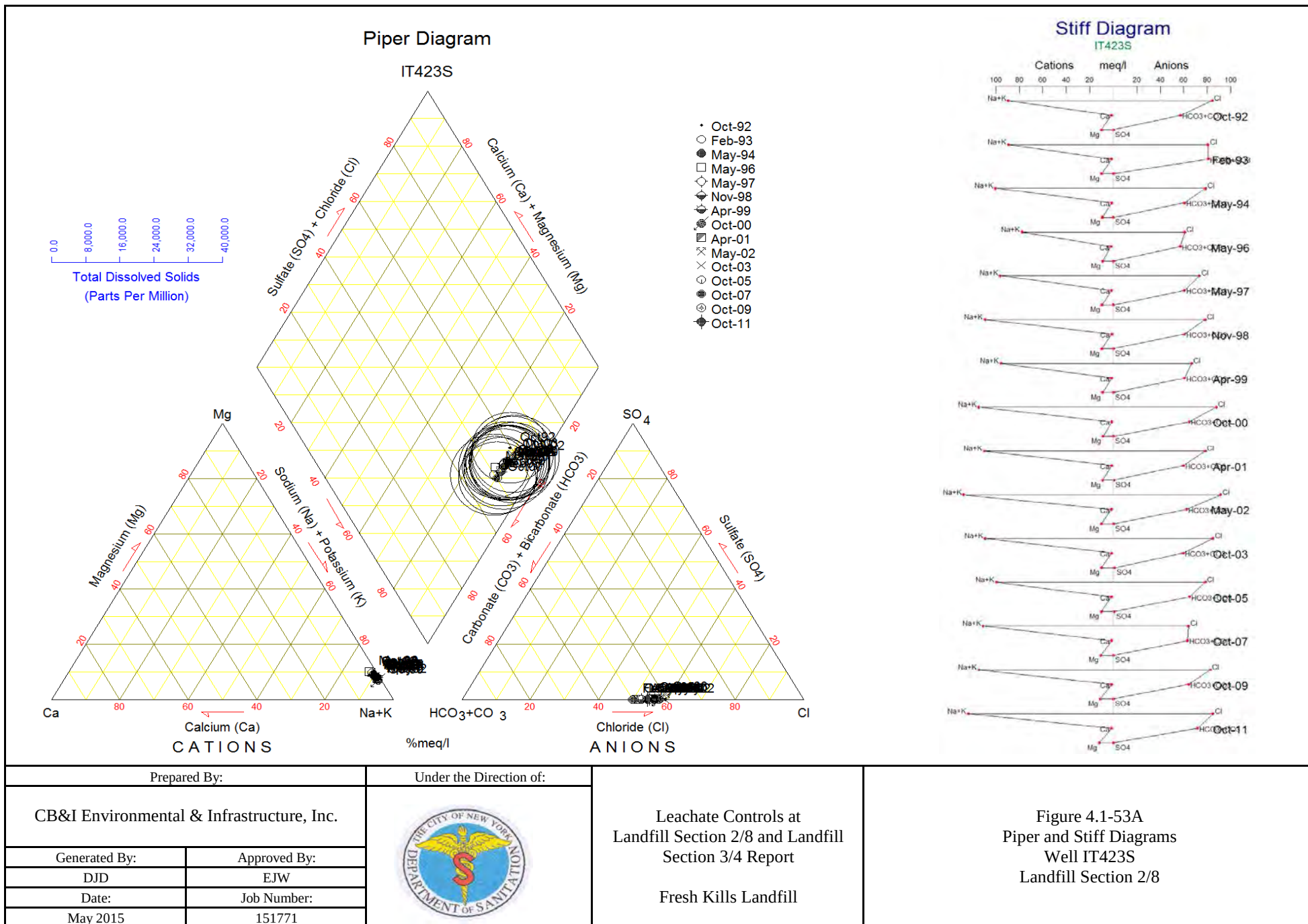
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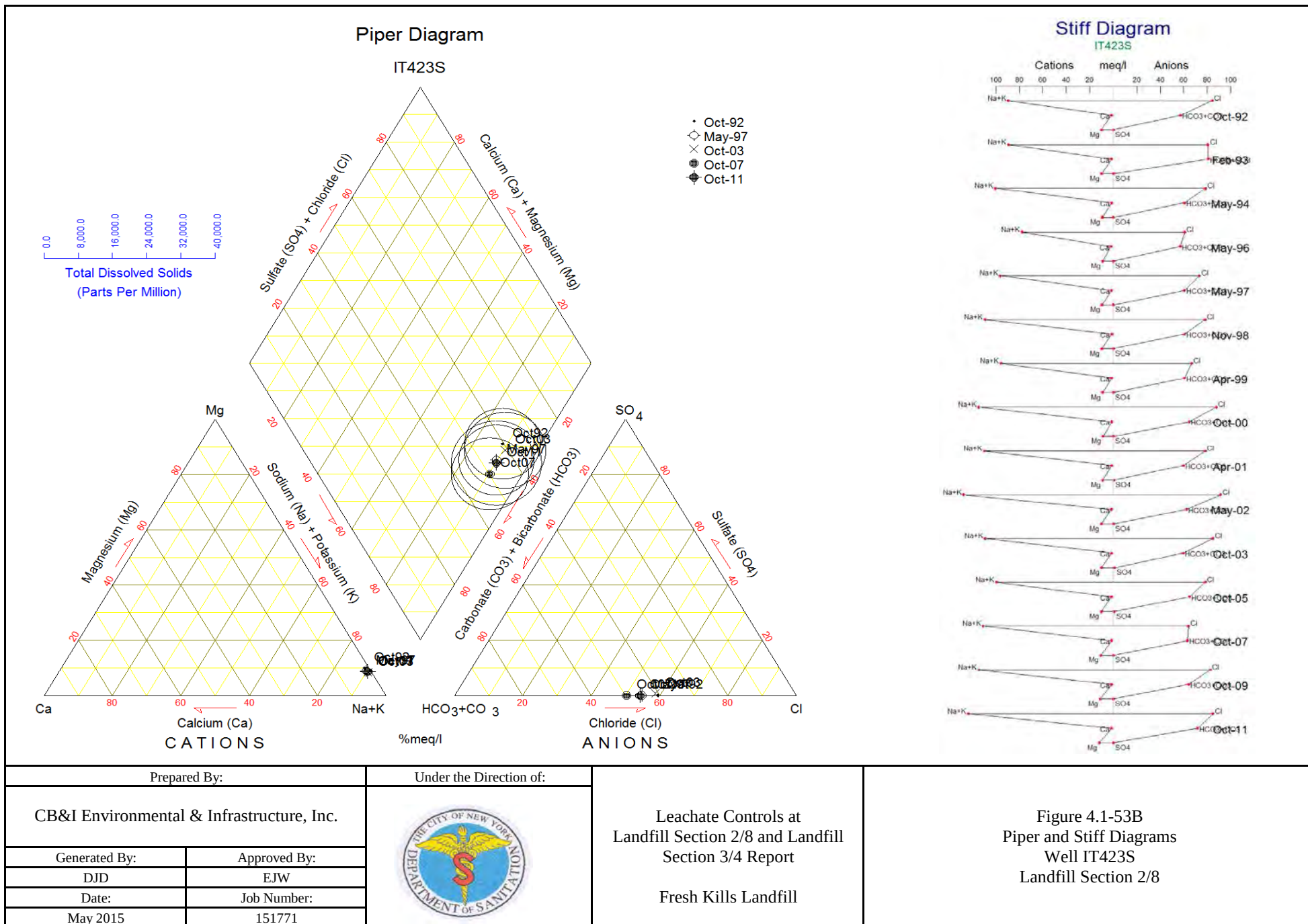
May 2015

151771







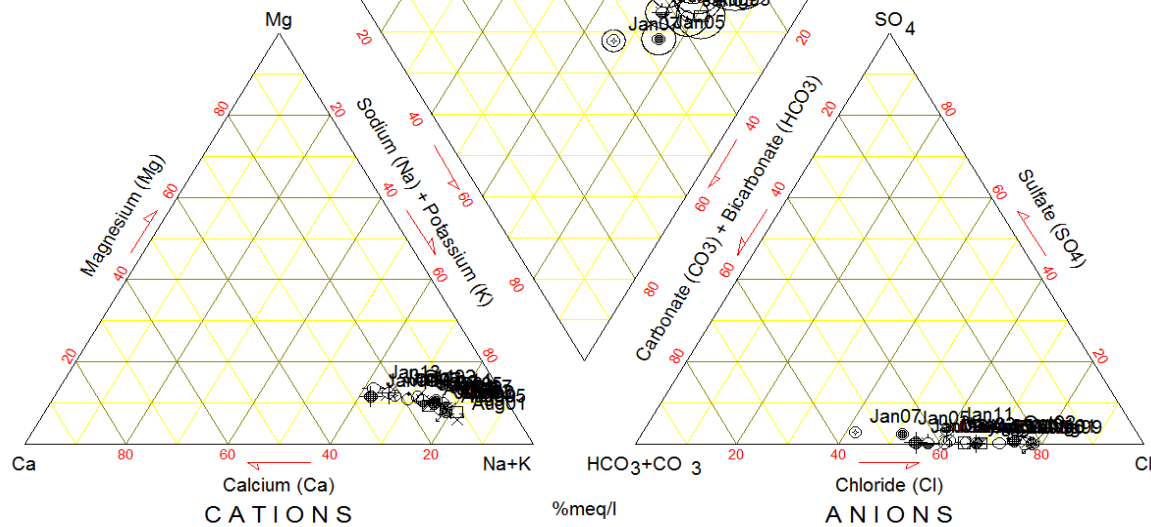


Piper Diagram

IT424S

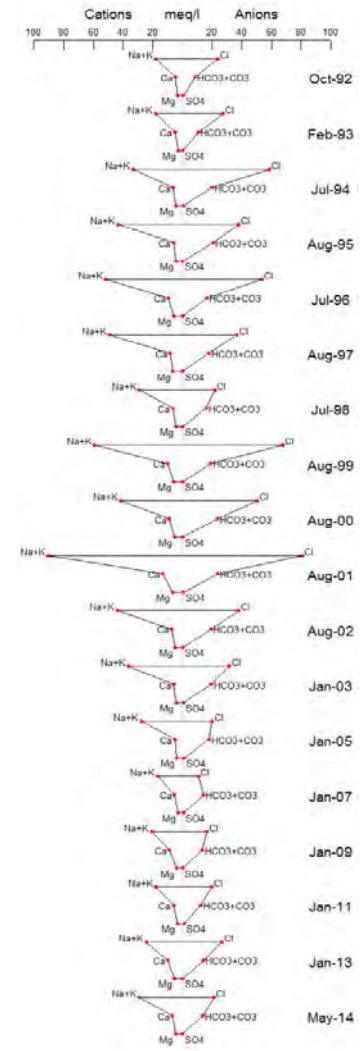
0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)

- Oct-92
- Feb-93
- Jul-94
- Aug-95
- ◇ Jul-96
- ◆ Aug-97
- ⊕ Jul-98
- ⊗ Aug-99
- ⊠ Aug-00
- ⊡ Aug-01
- ⊢ Aug-02
- ⊣ Jan-03
- ⊤ Jan-05
- ⊥ Jan-07
- ⊦ Jan-09
- ⊧ Jan-11
- ⊨ Jan-13
- ⊩ May-14



Stiff Diagram

IT424S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-54A
Piper and Stiff Diagrams
Well IT424S
Landfill Section 2/8

Generated By:

Approved By:

DJD

EJW

Date:

Job Number:

May 2015

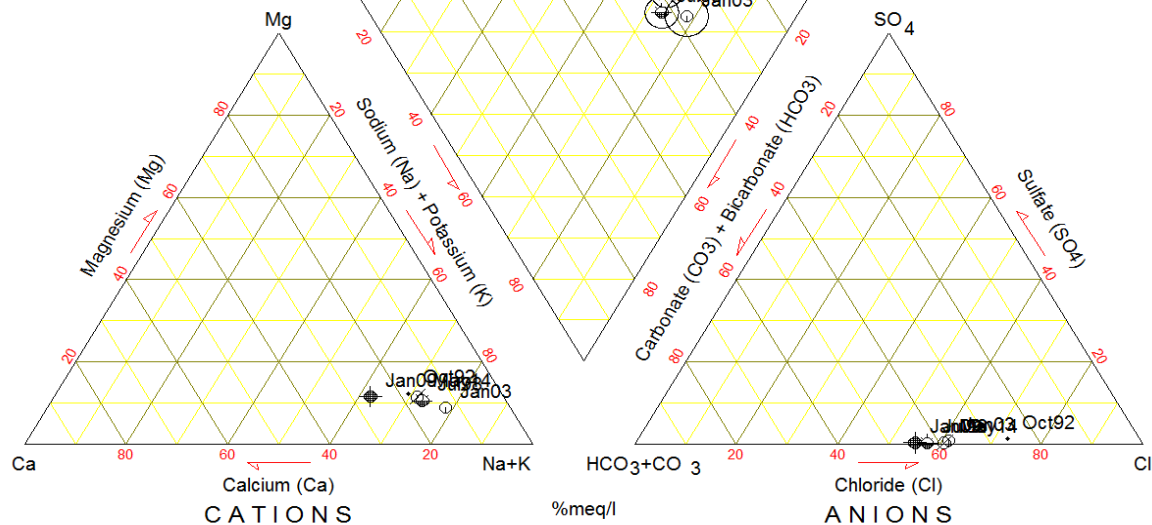
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Piper Diagram

IT424S

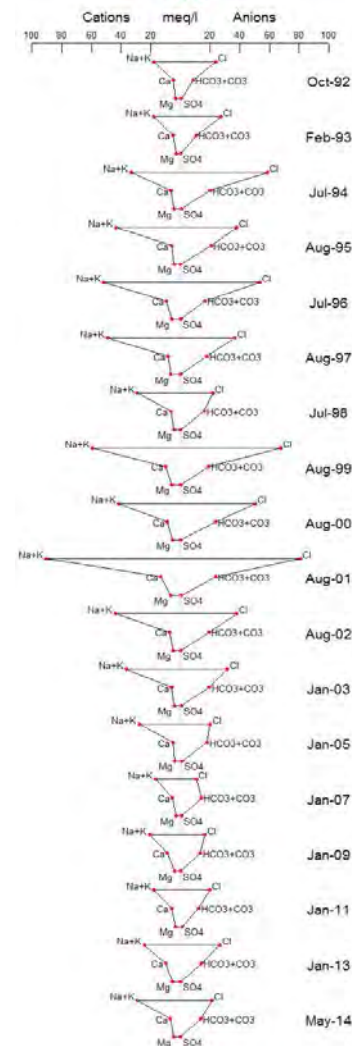
- Oct-92
- ◐ Jul-98
- ◑ Jan-03
- ◒ Jan-09
- ◓ May-14

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT424S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 4.1-54B
Piper and Stiff Diagrams
Well IT424S
Landfill Section 2/8

Generated By:

Approved By:

DJD

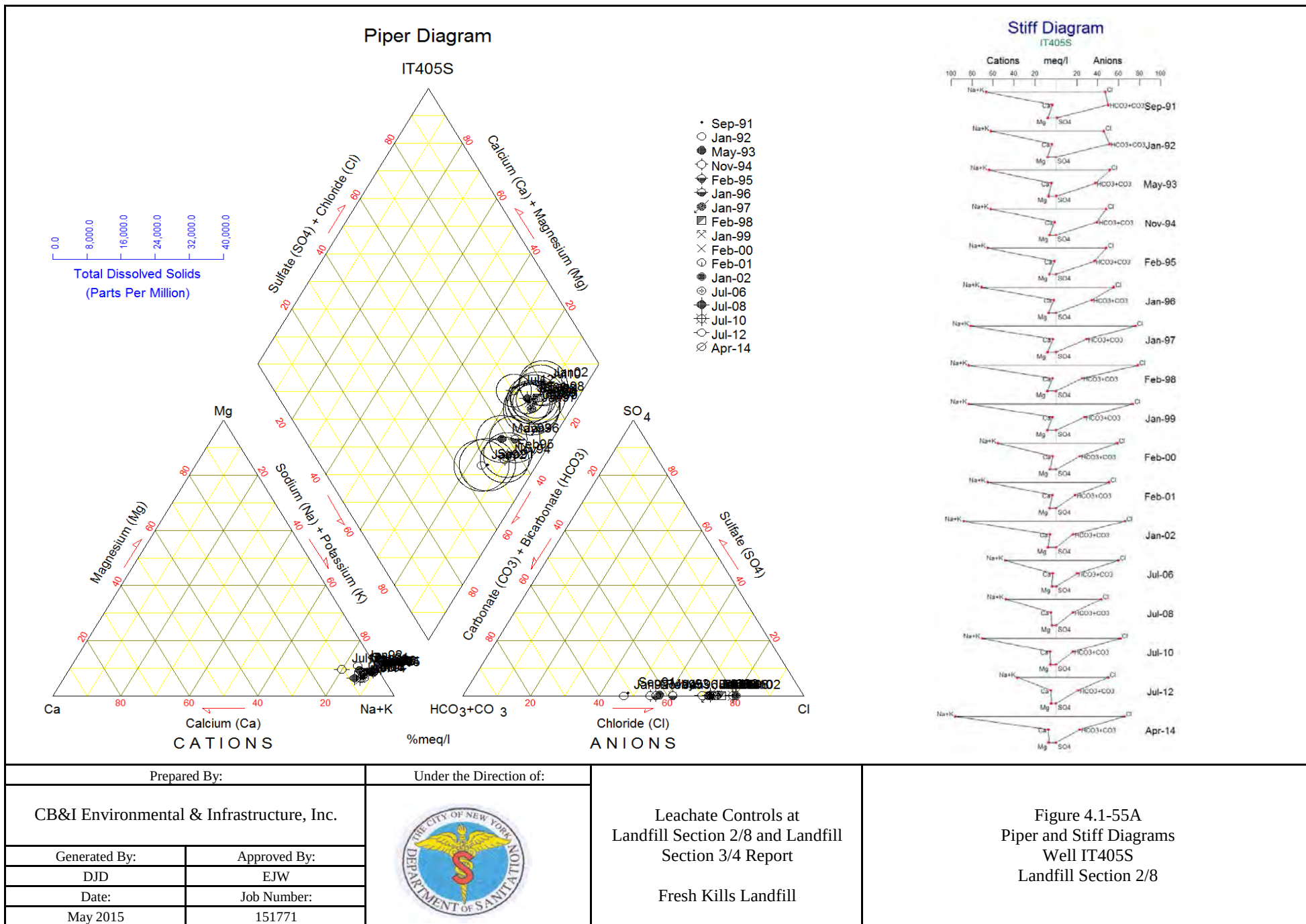
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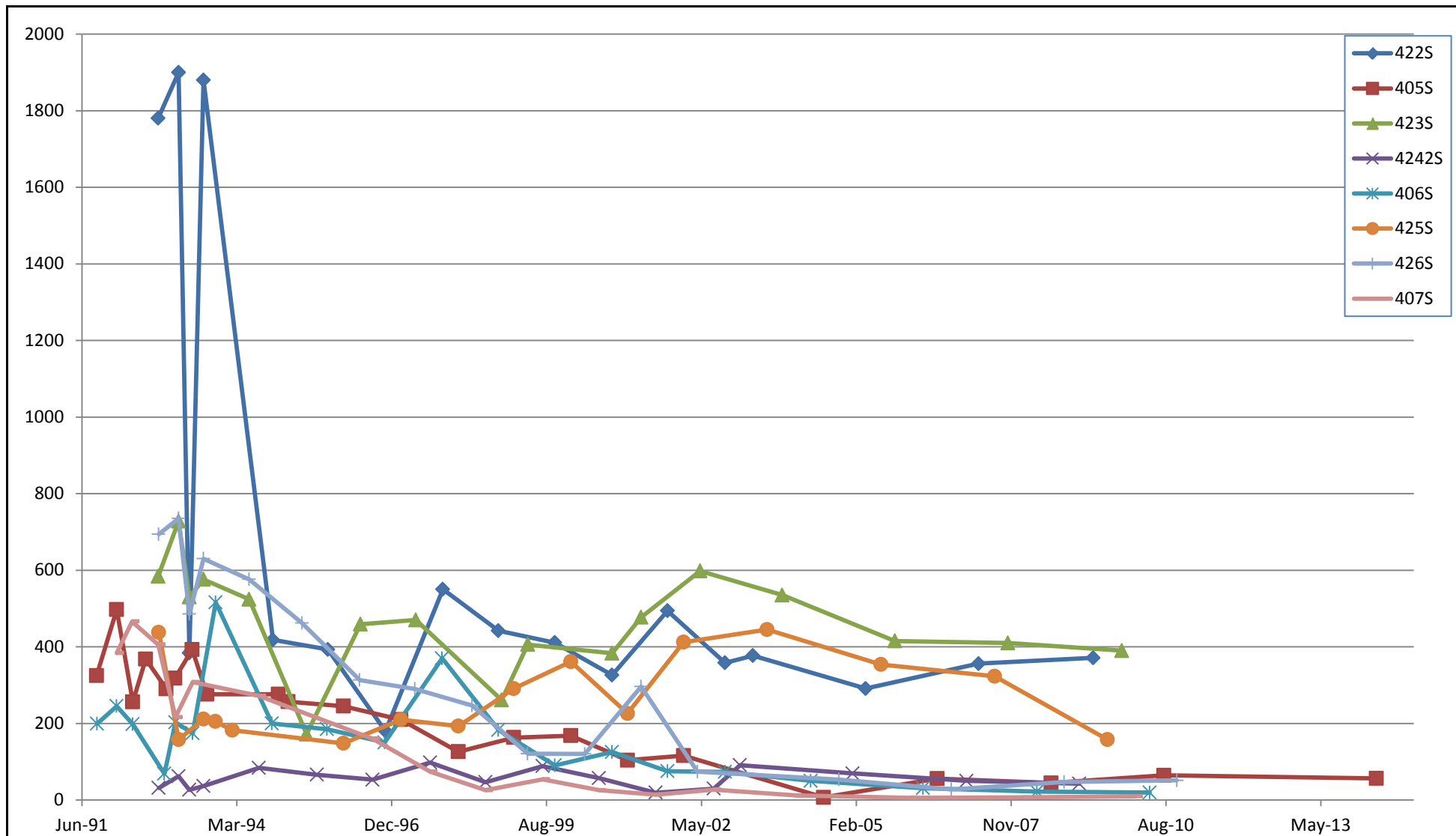
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May 2015

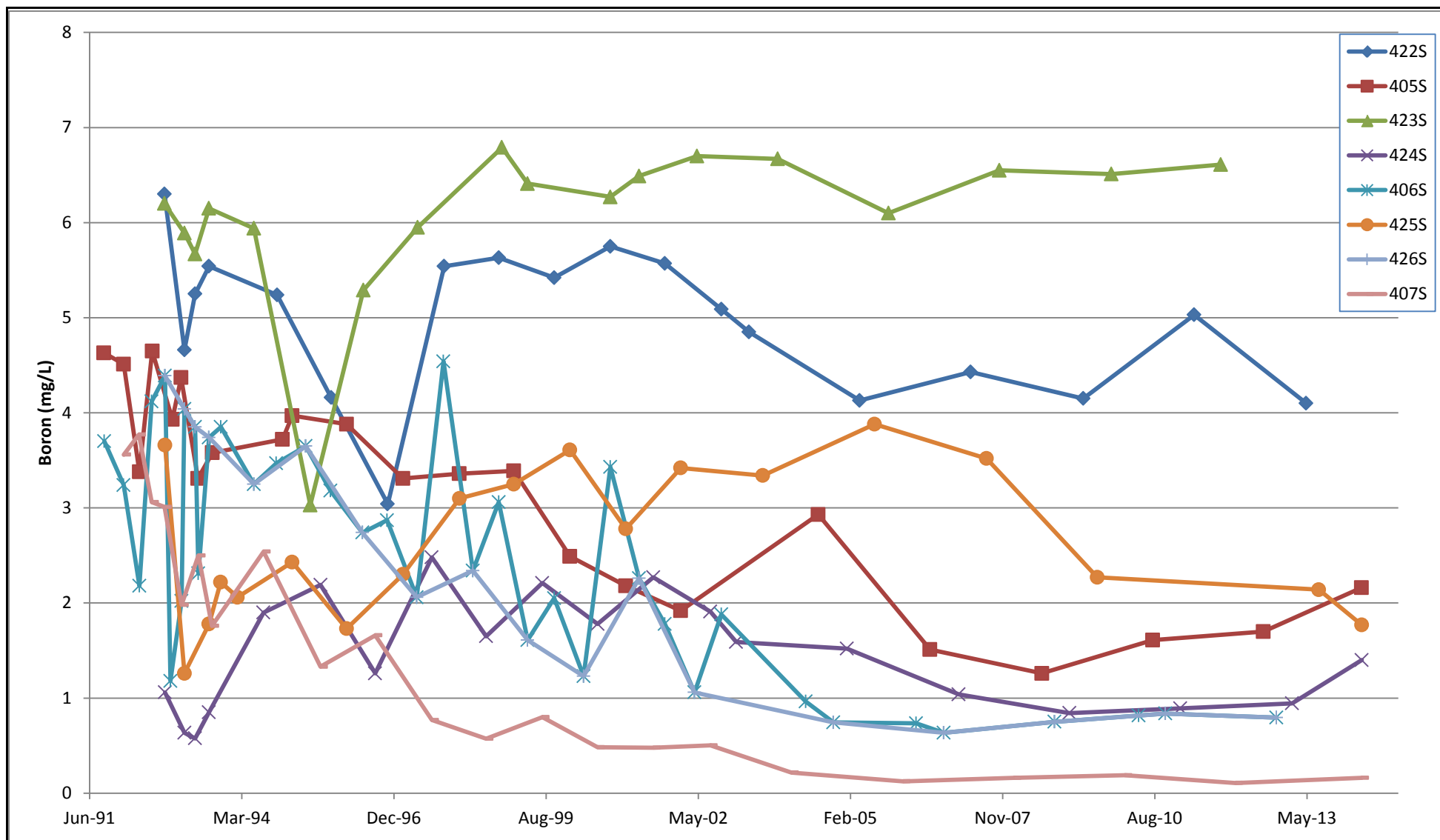
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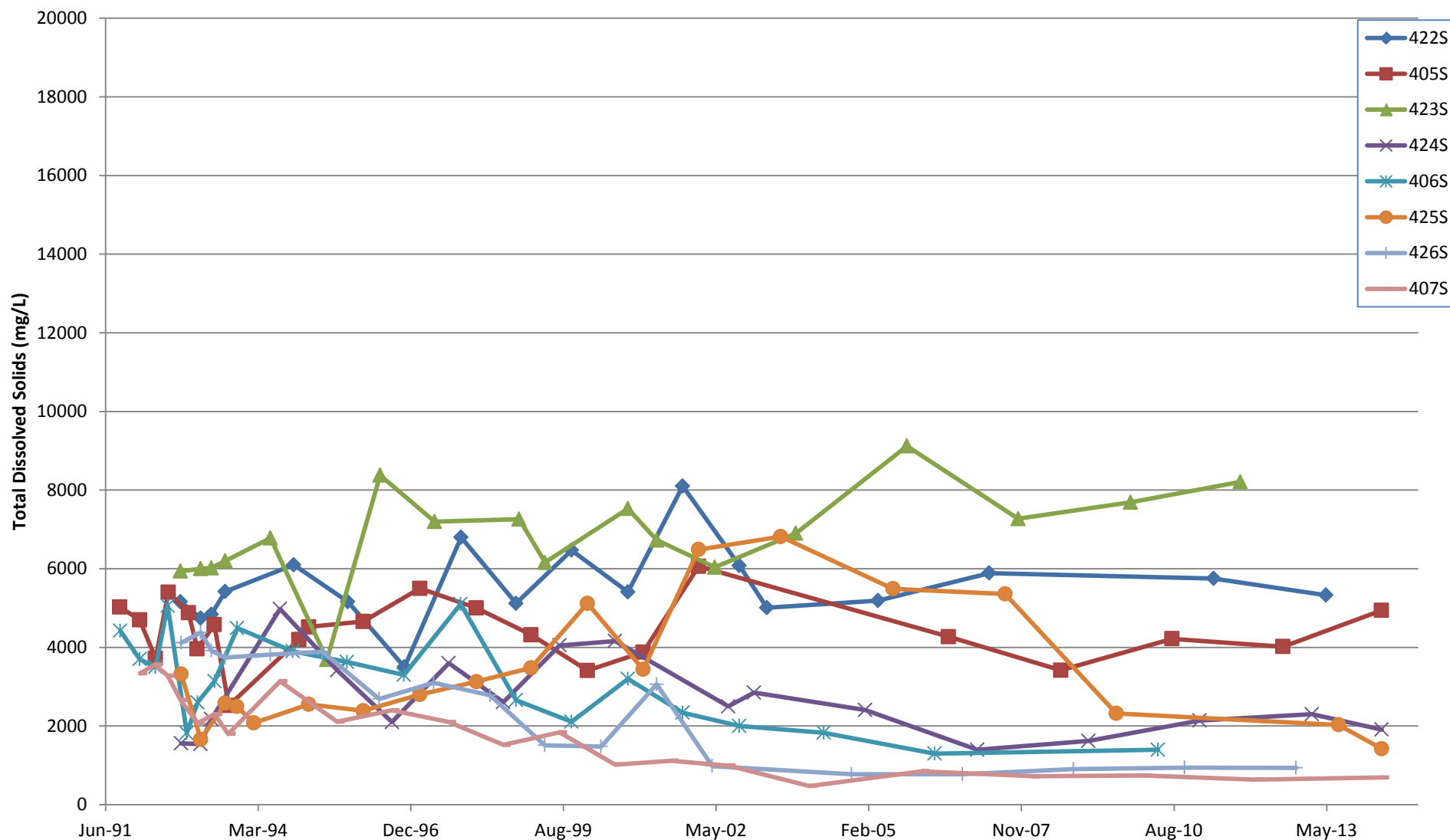
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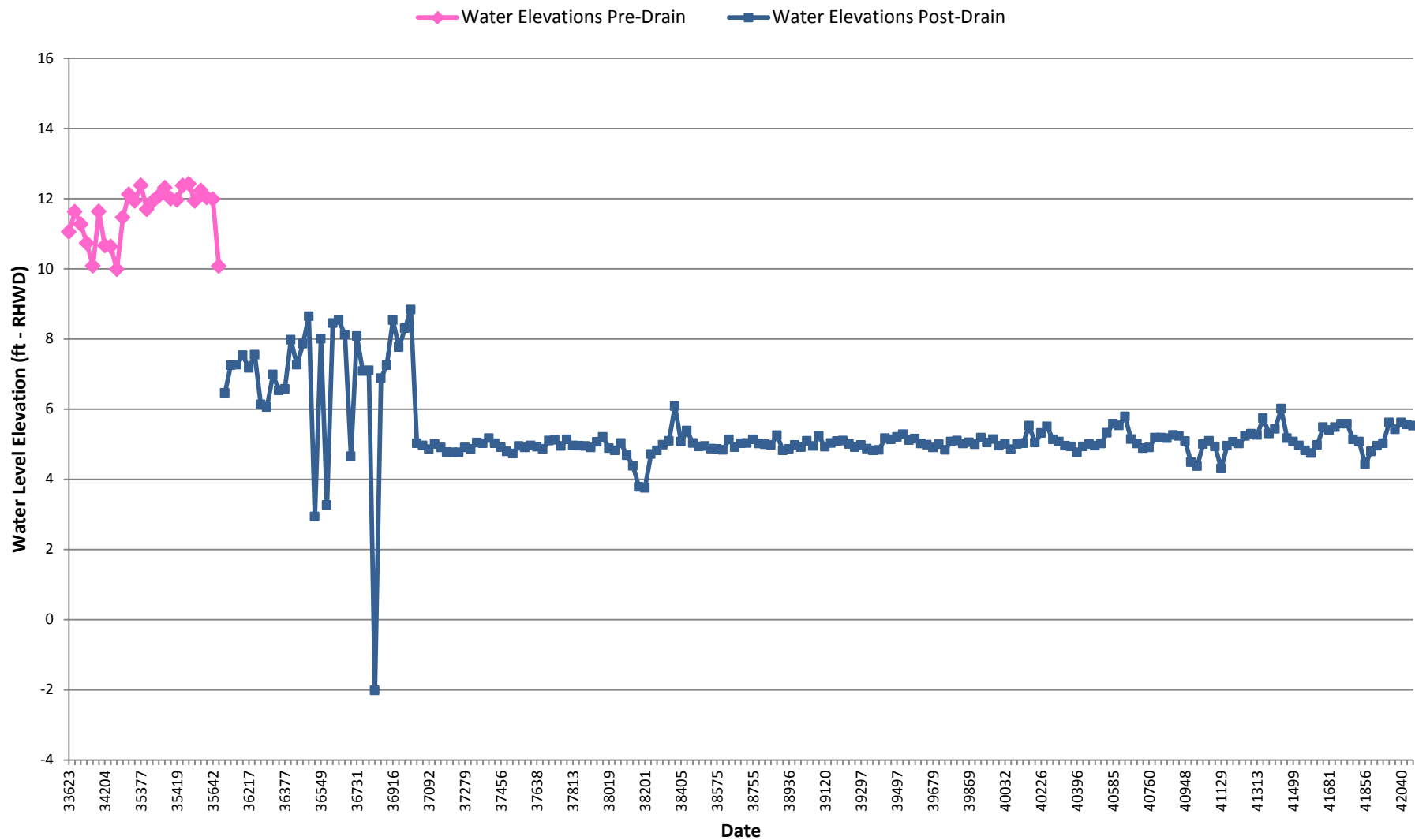
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CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
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Date:	Job Number:				
May 2015	151771				



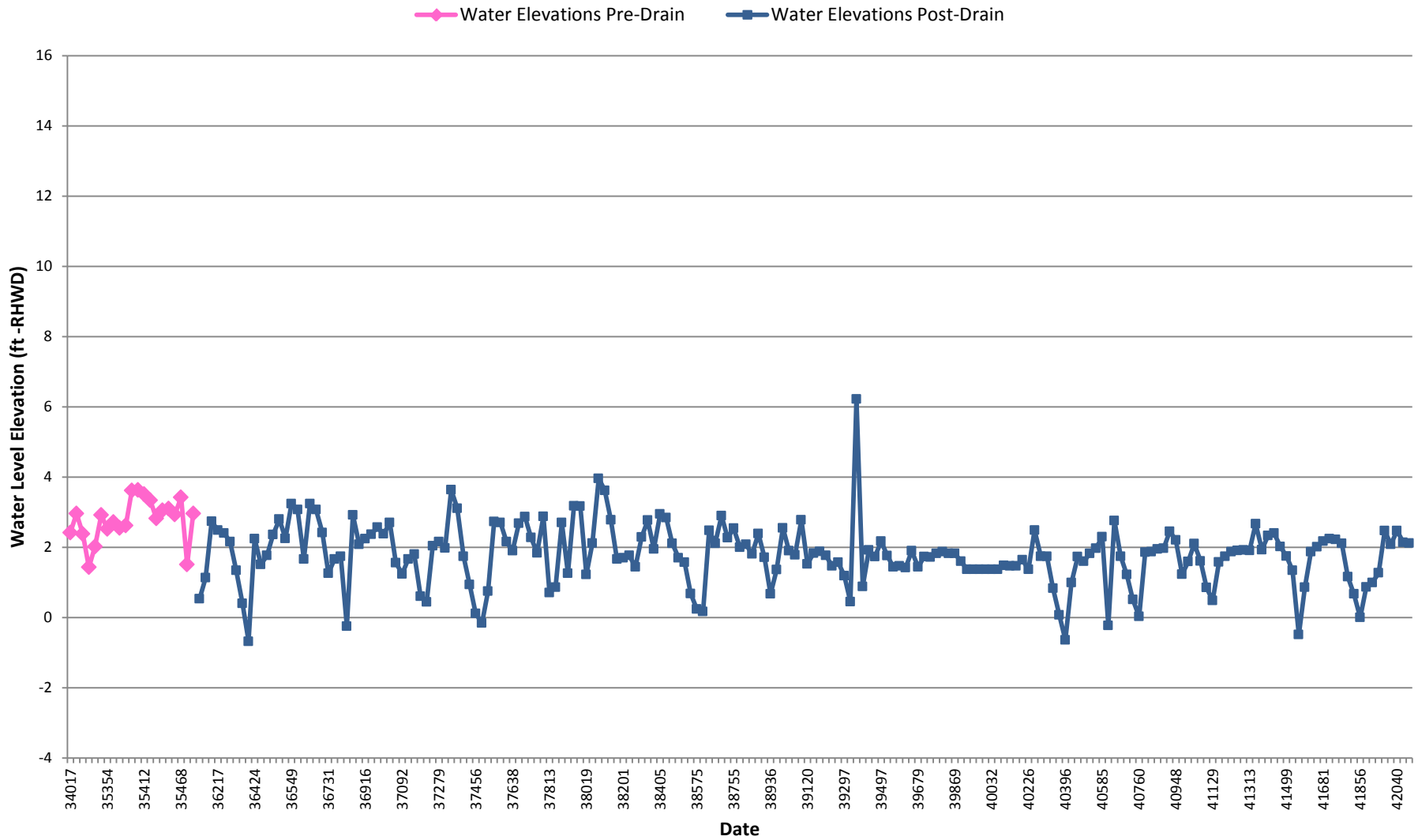
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May 2015	151771				



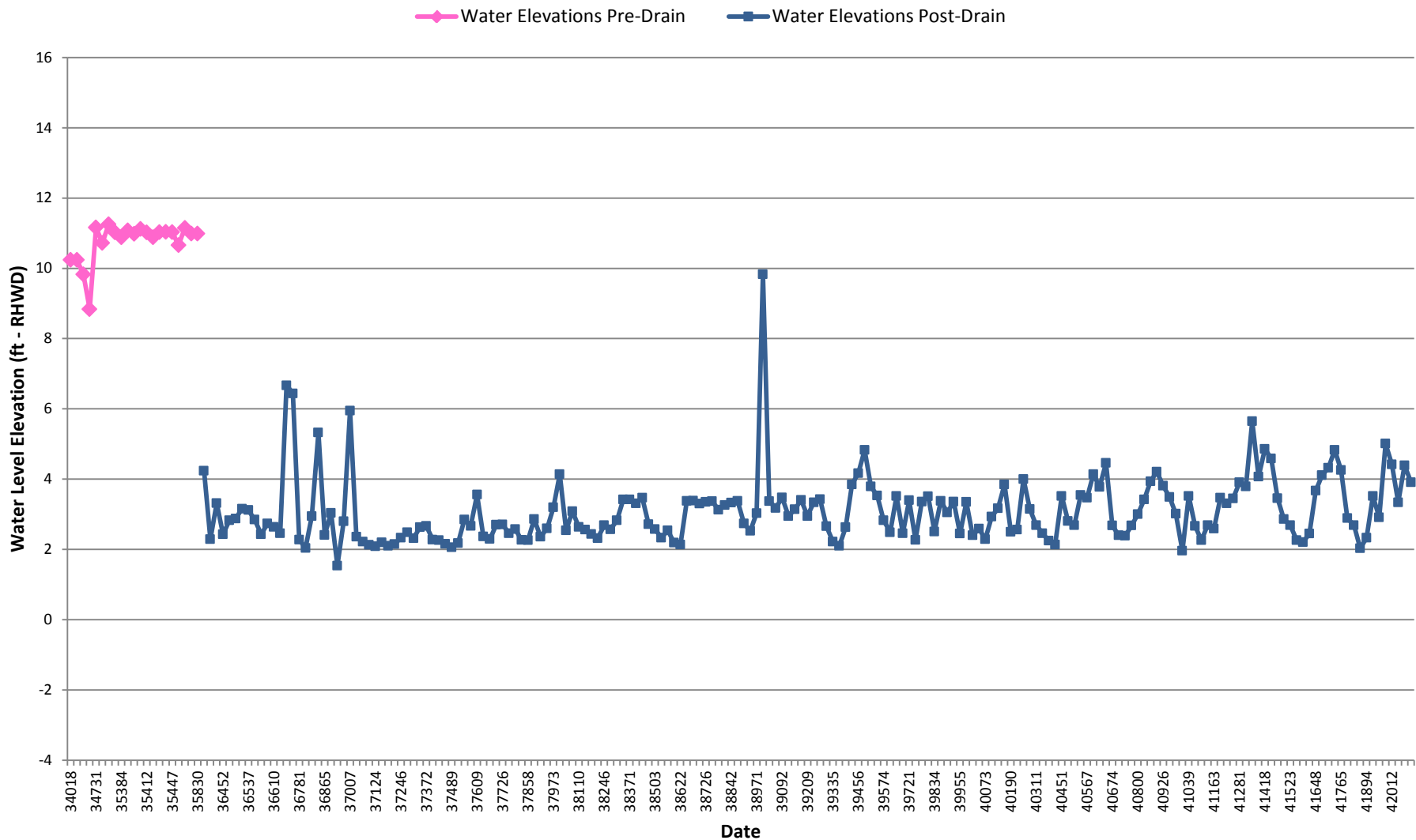
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DJD	EJW				
Date:	Job Number:				
May 2015	151771				



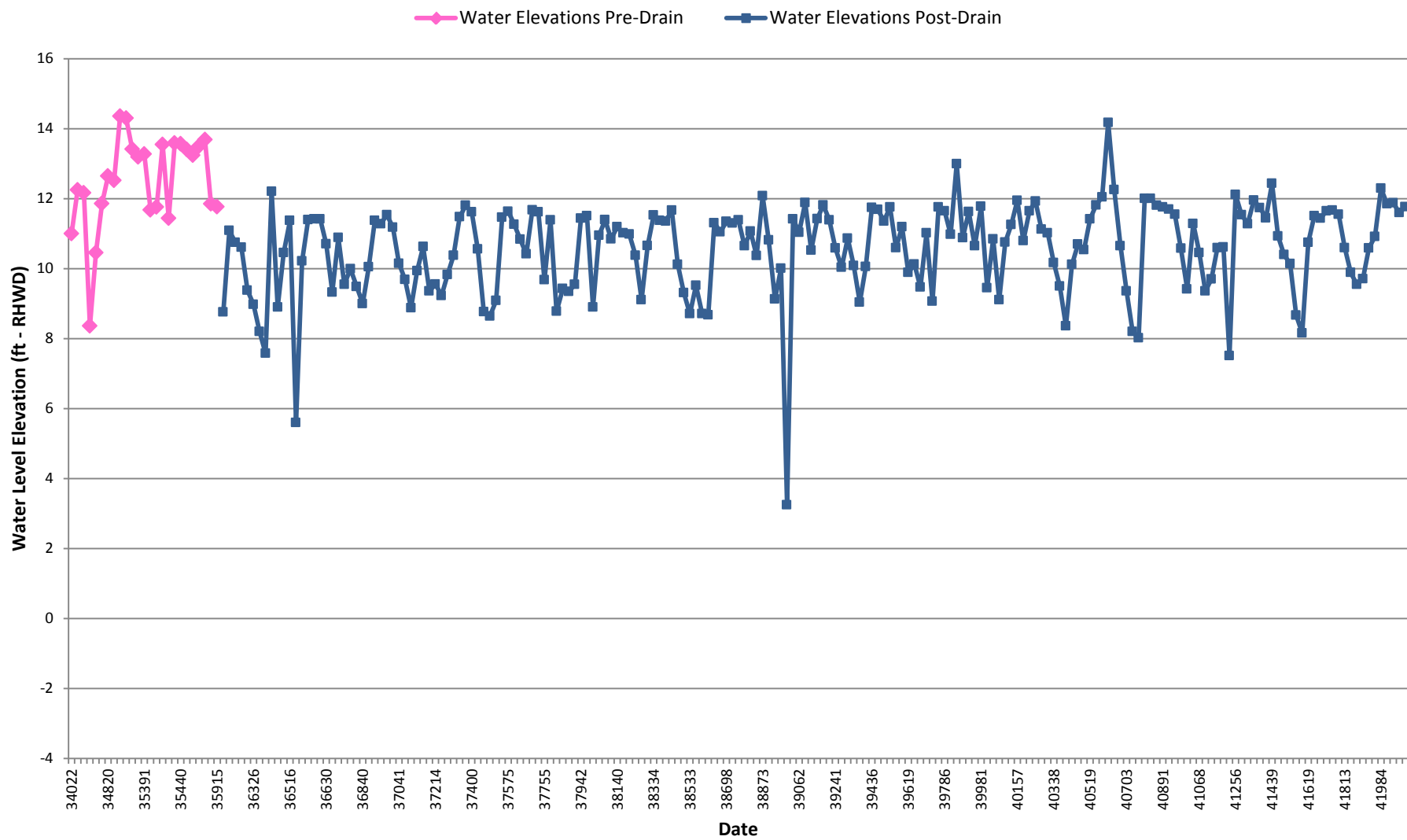
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Generated By:	Approved By:				
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Date:	Job Number:				
July 2015	151771				



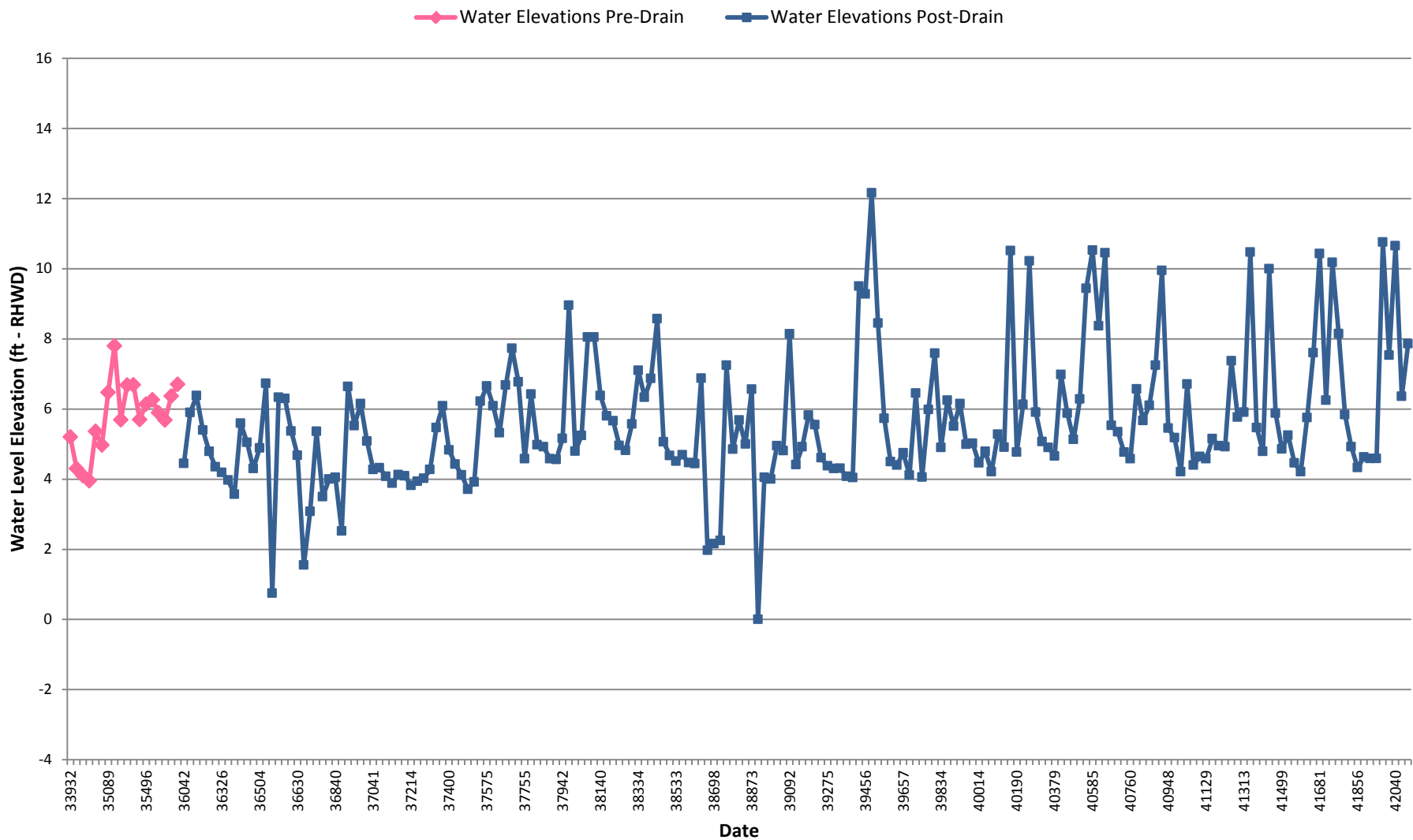
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CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
July 2015	151771				



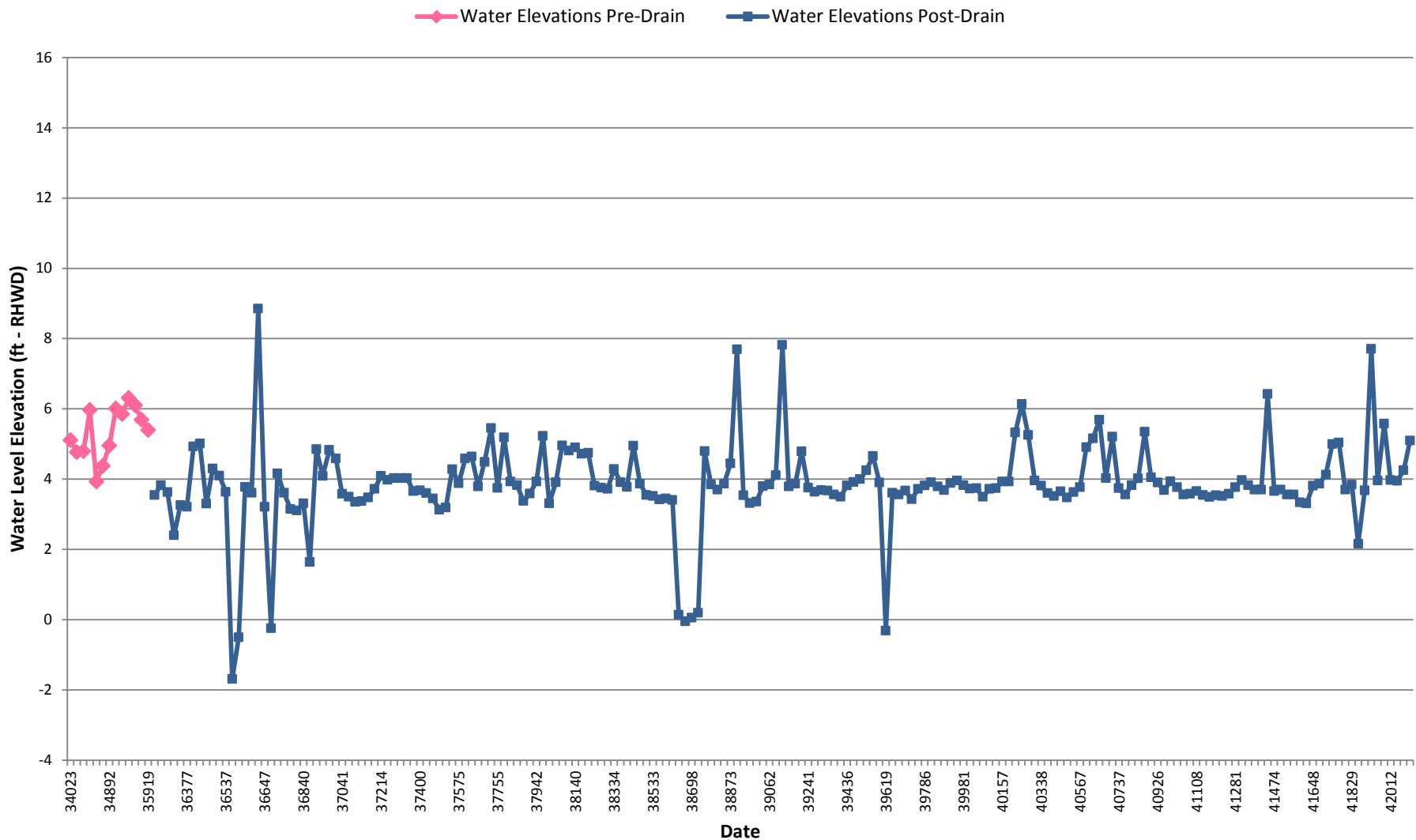
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CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
July 2015	151771				



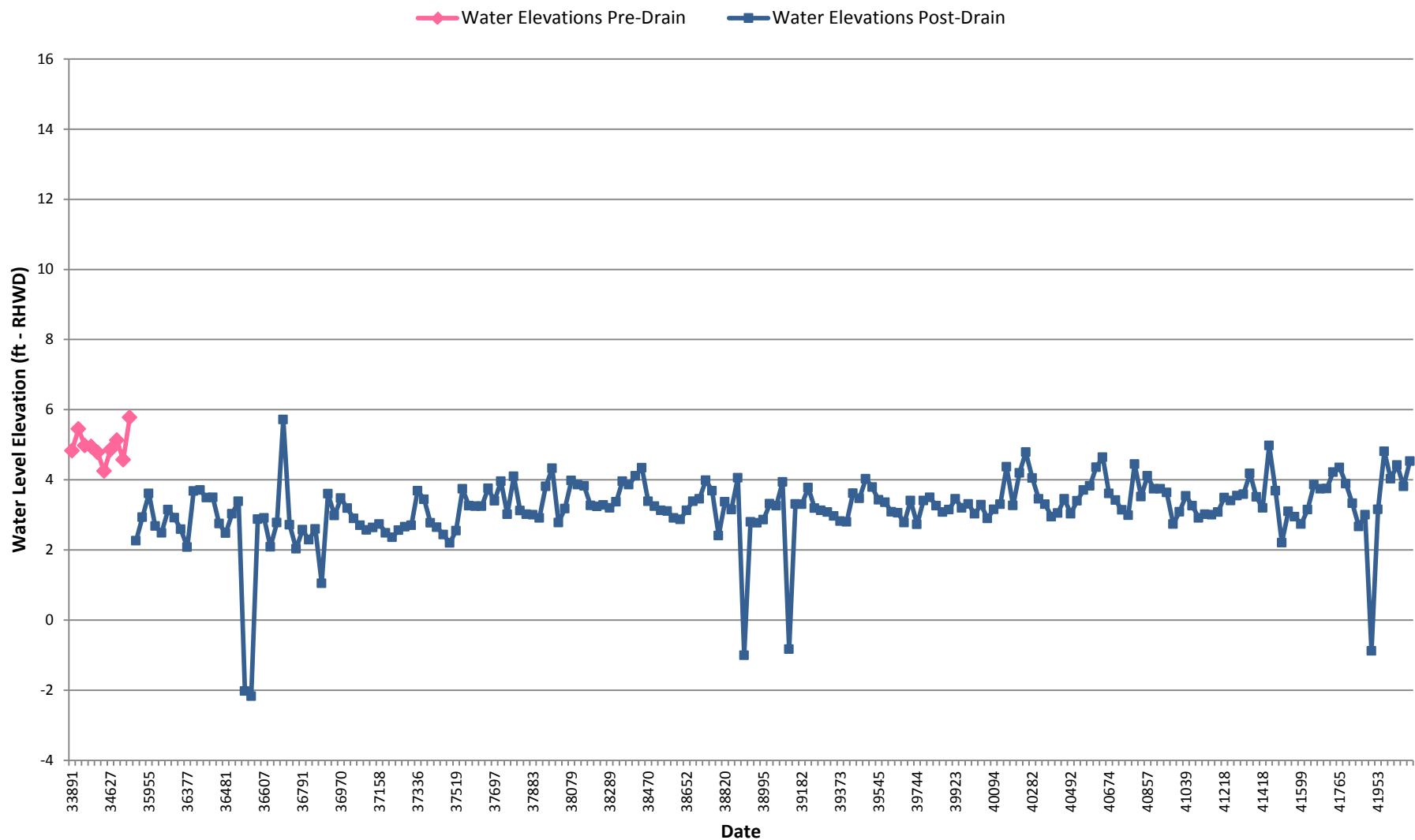
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Date:	Job Number:				
July 2015	151771				



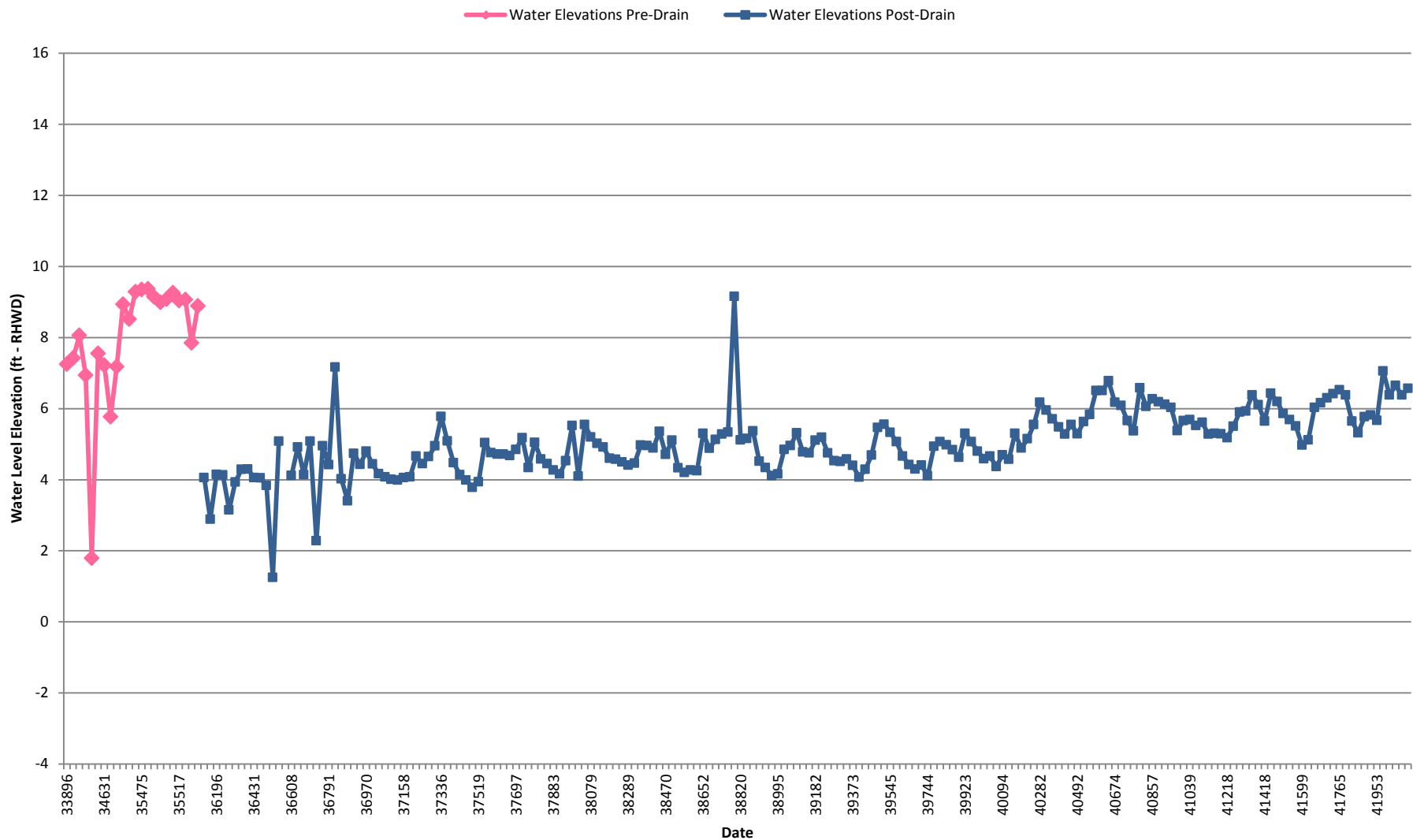
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Date:	Job Number:				
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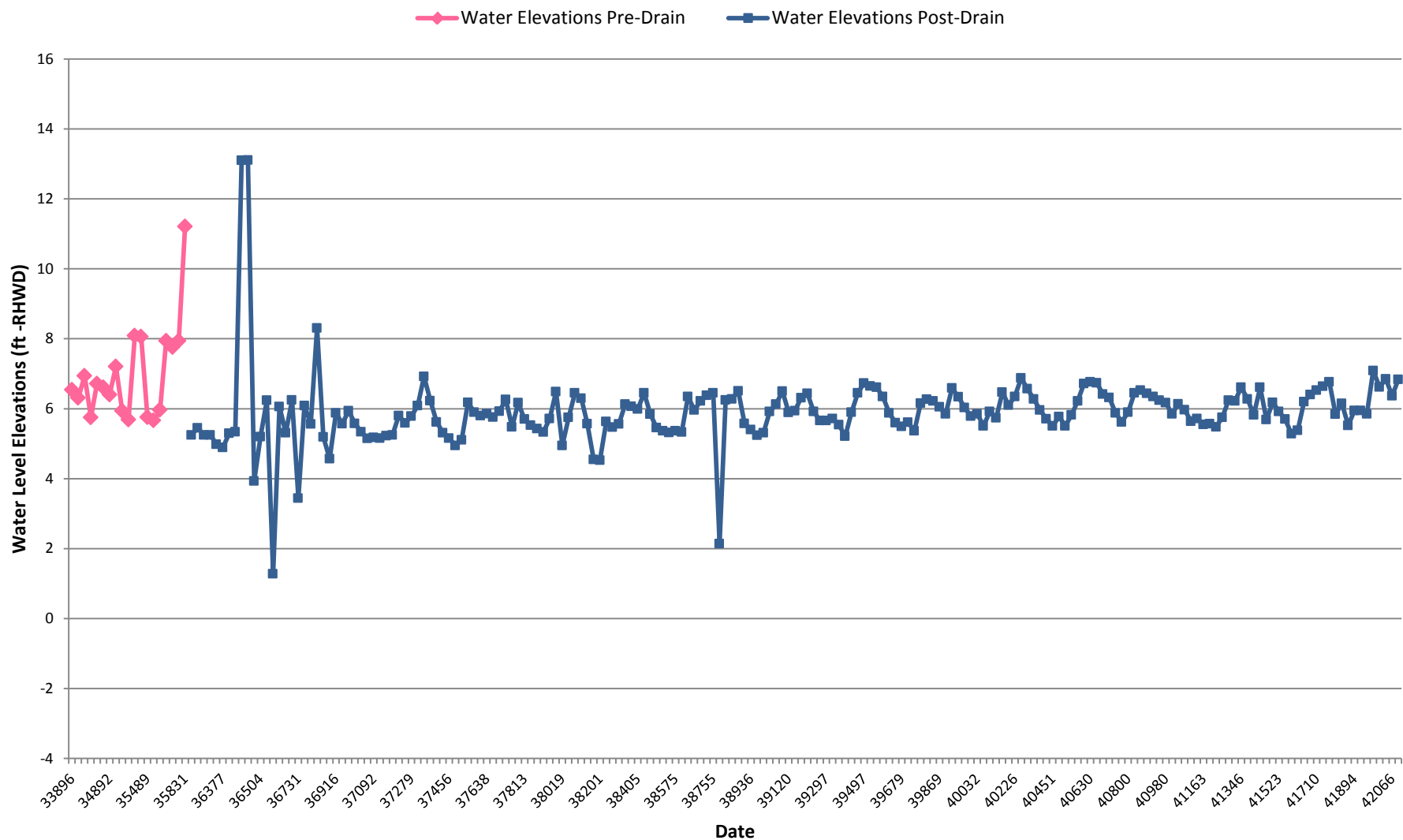
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Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
July 2015	151771				



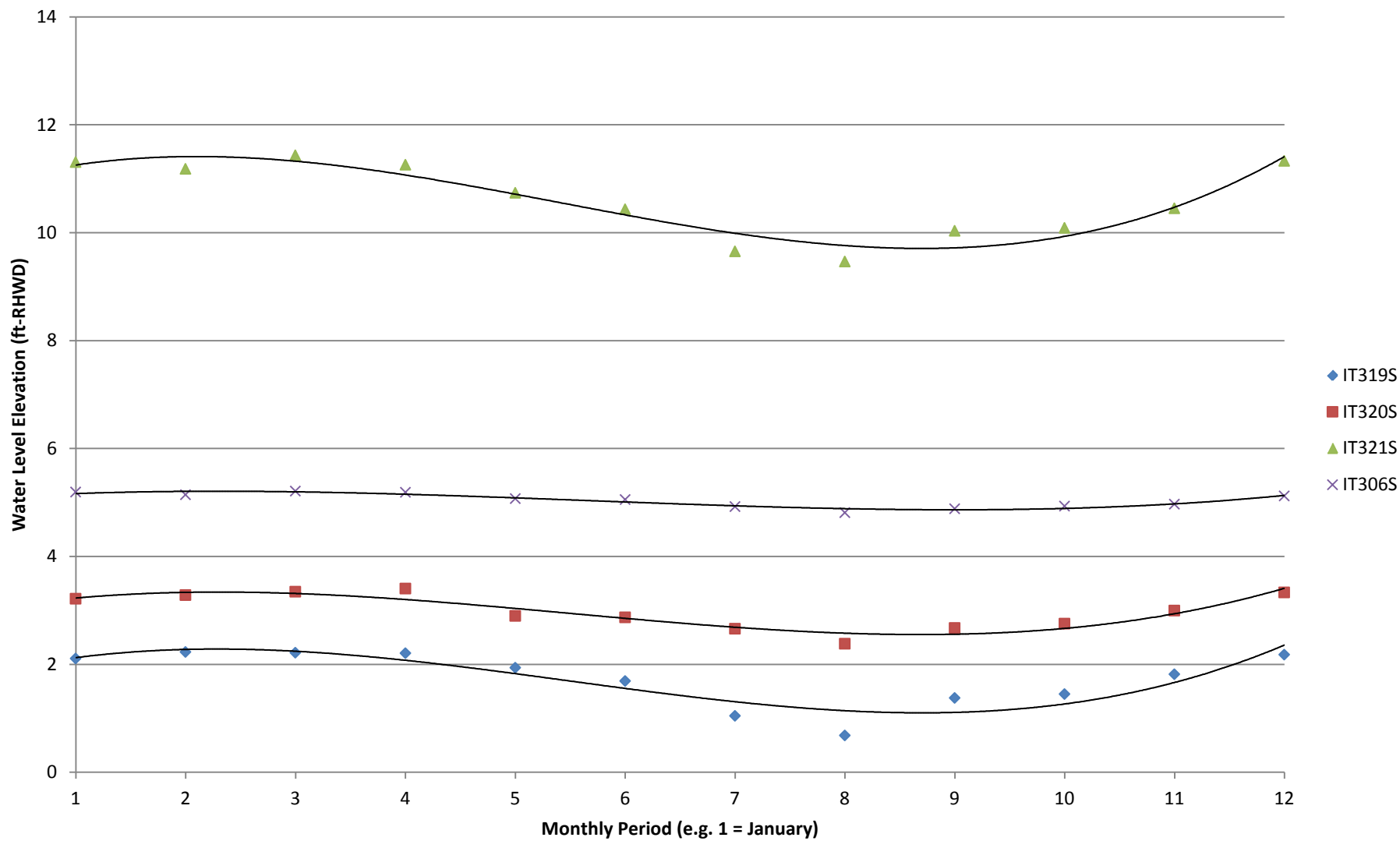
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Date:	Job Number:				
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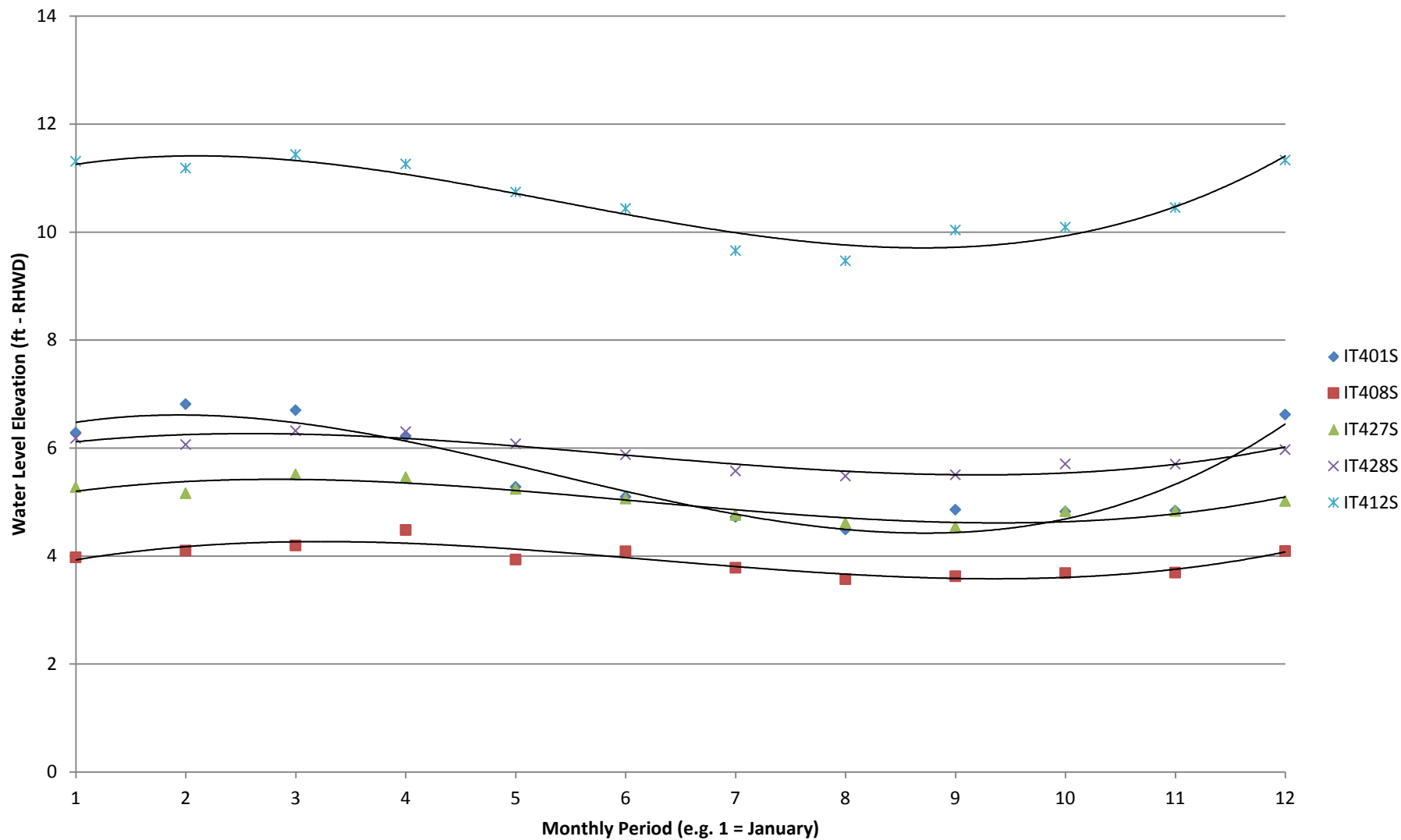
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Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
July 2015	151771				



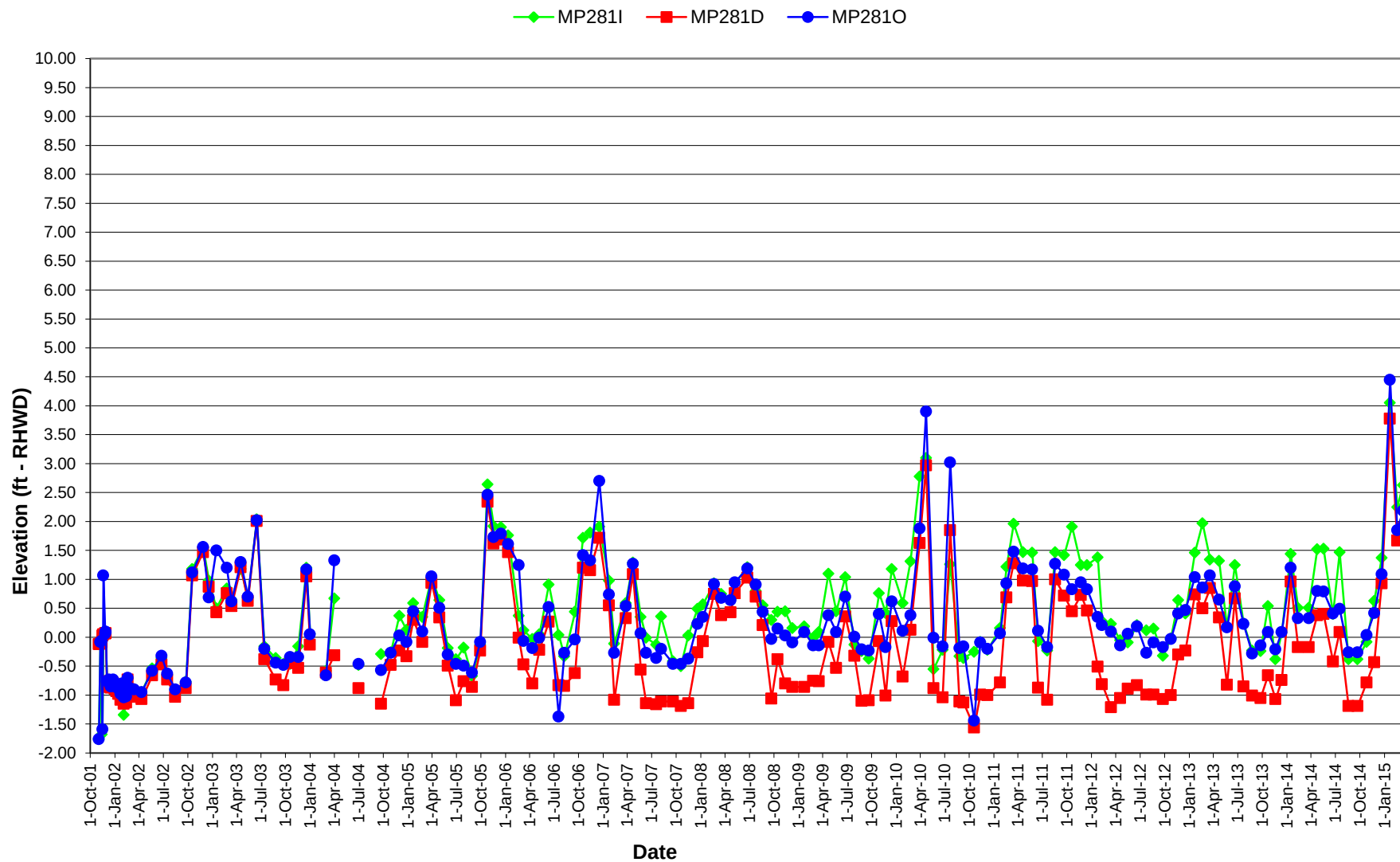
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Generated By:	Approved By:				
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Date:	Job Number:				
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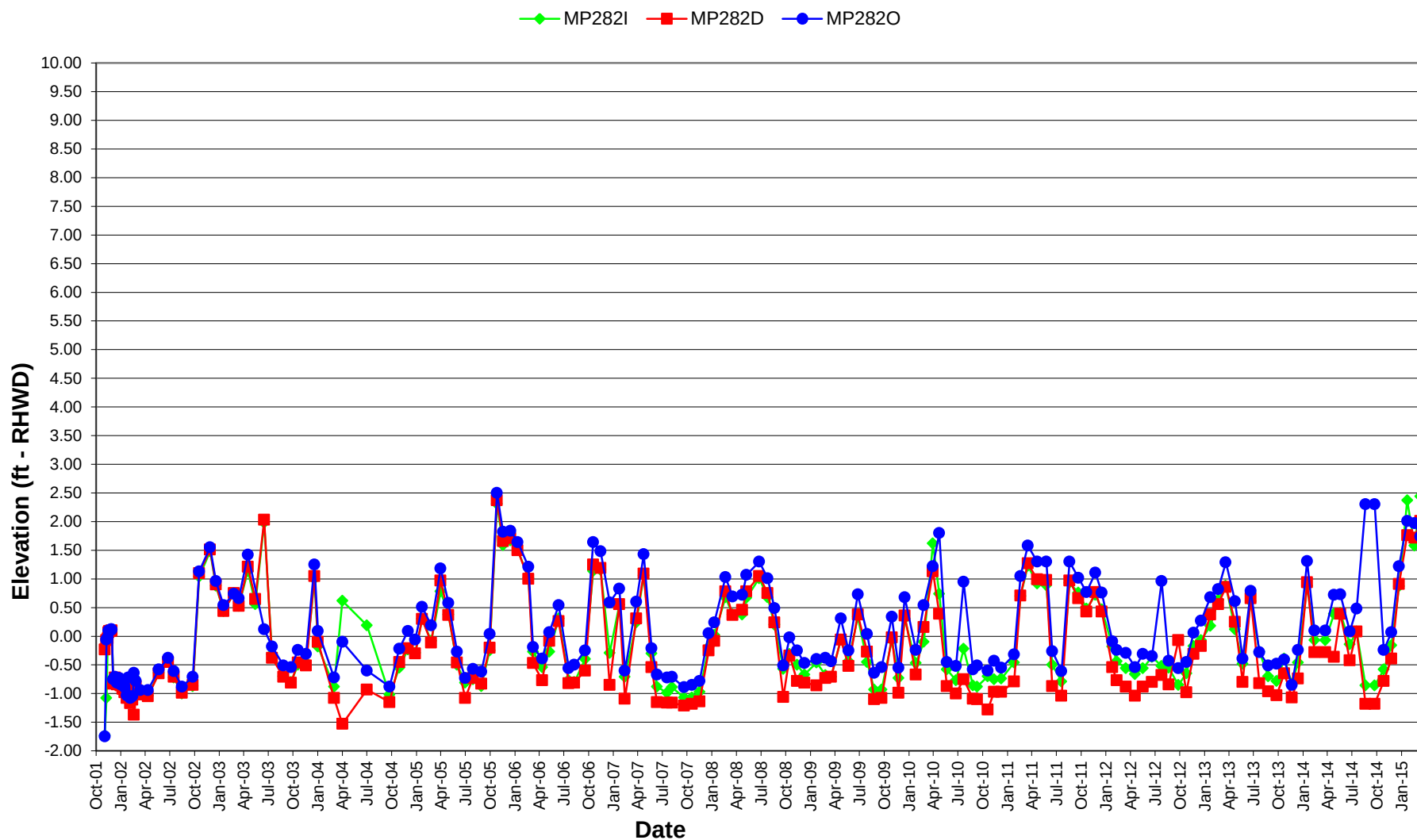
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CB&I Environmental & Infrastructure, Inc.					
Generated By:	Approved By:				
DJD	EJW				
Date:	Job Number:				
July 2015	151771				



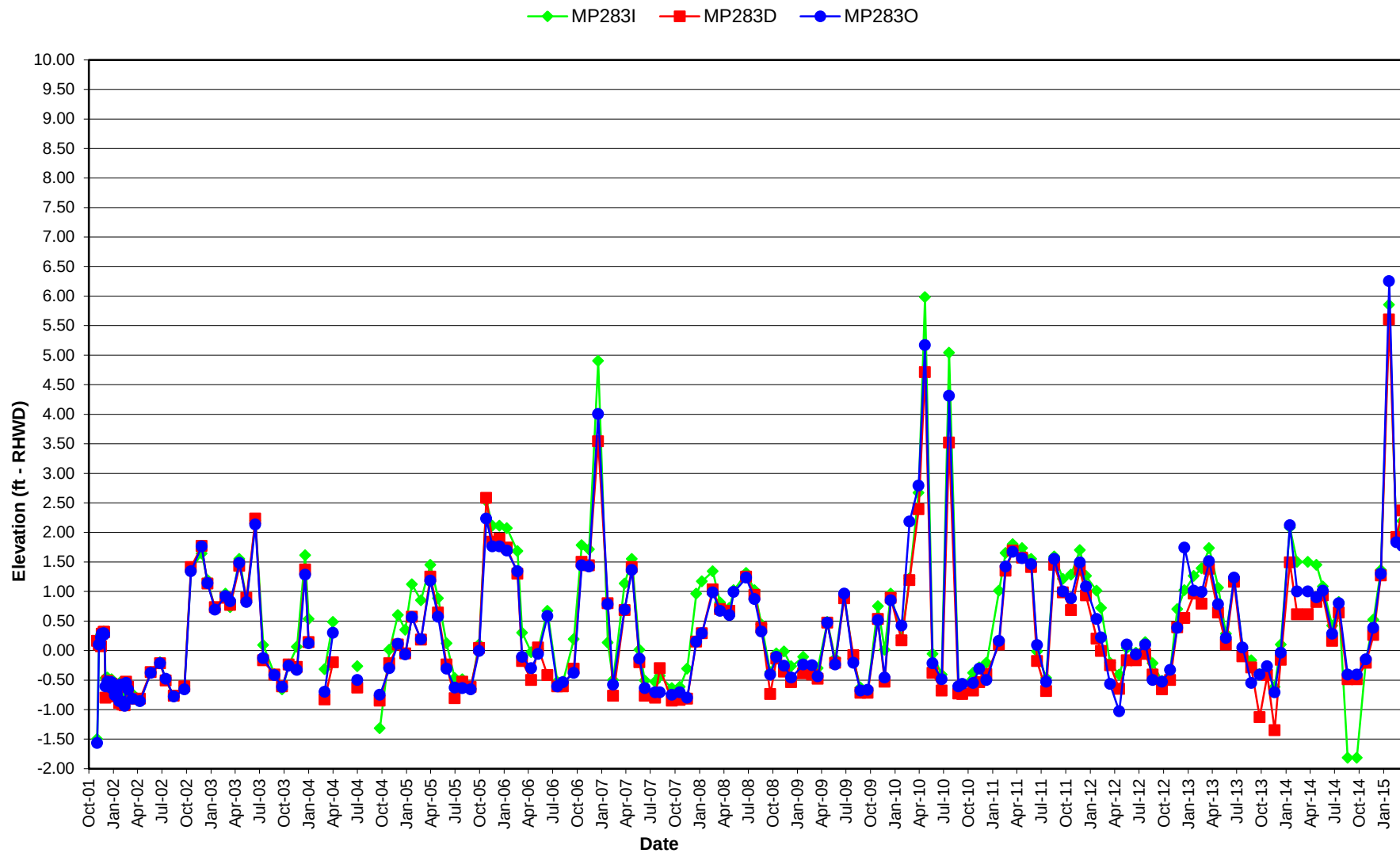
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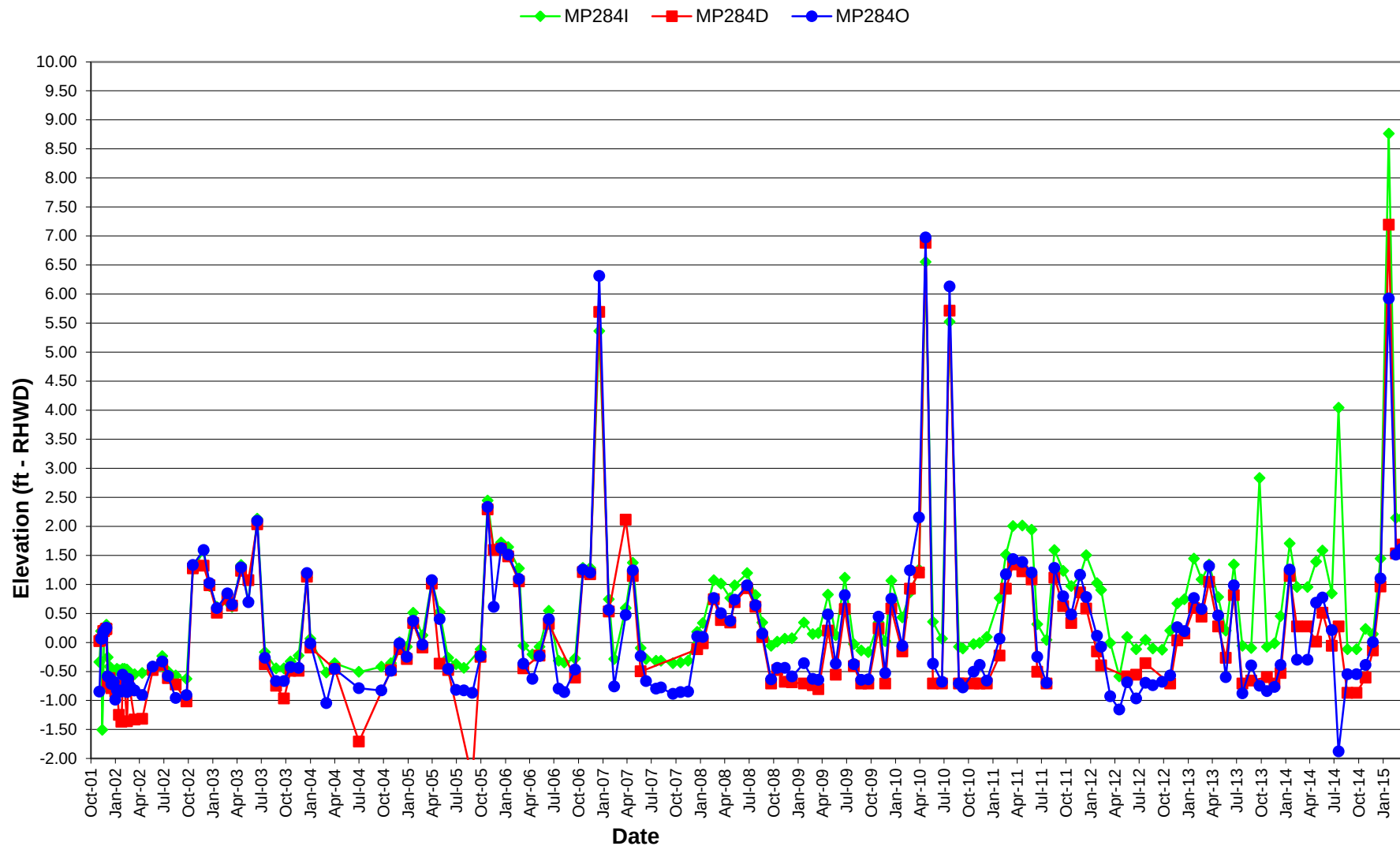
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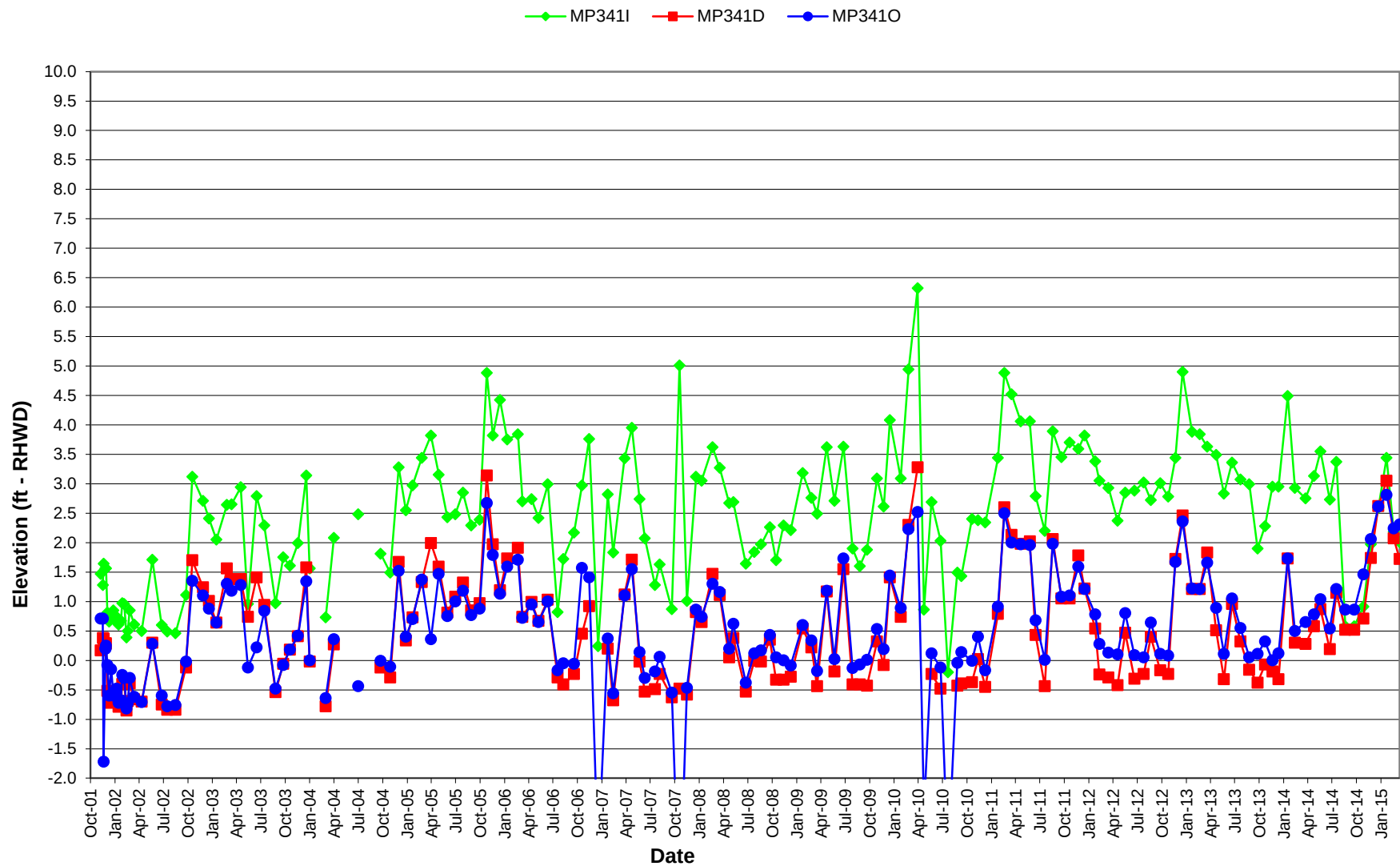
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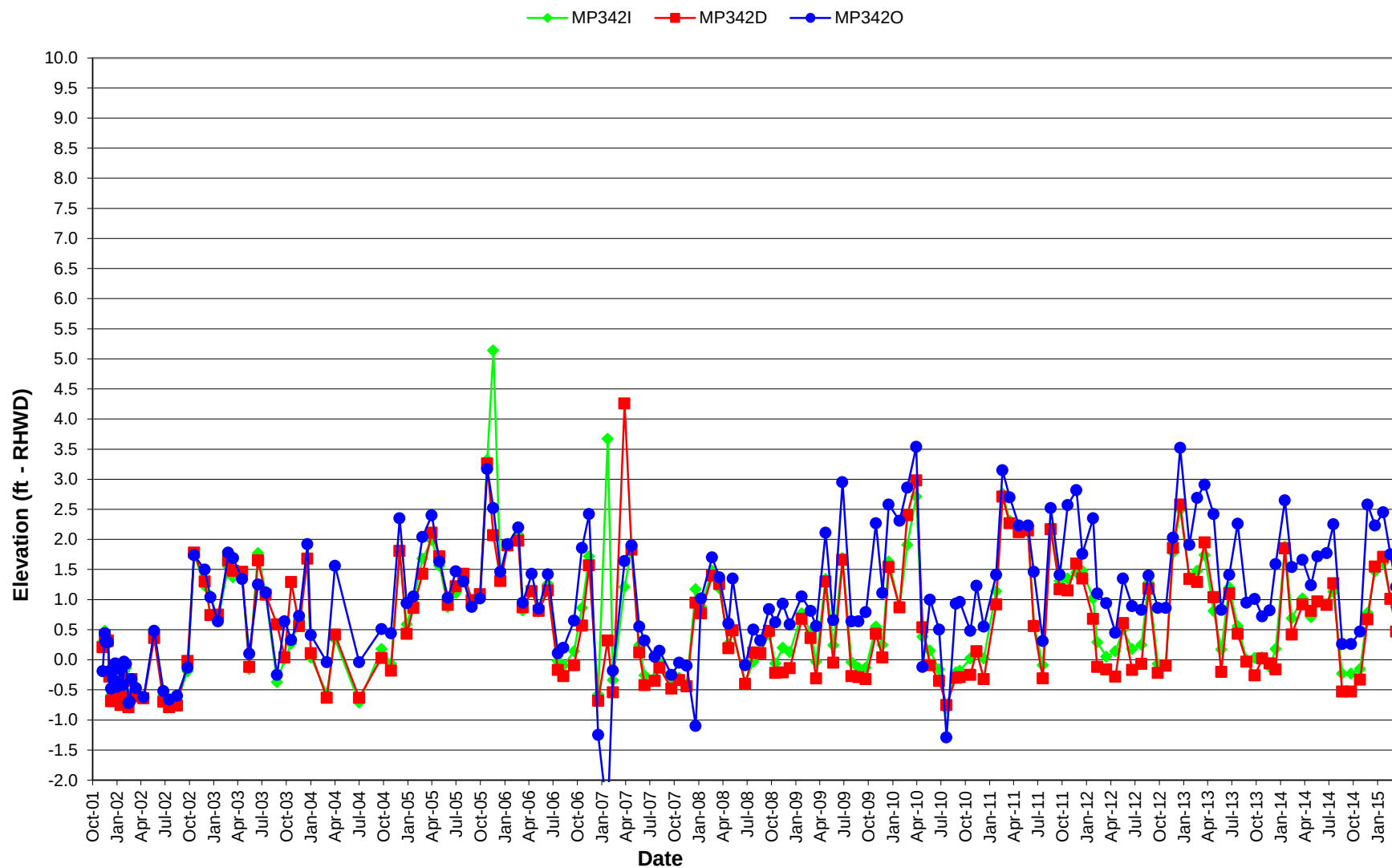
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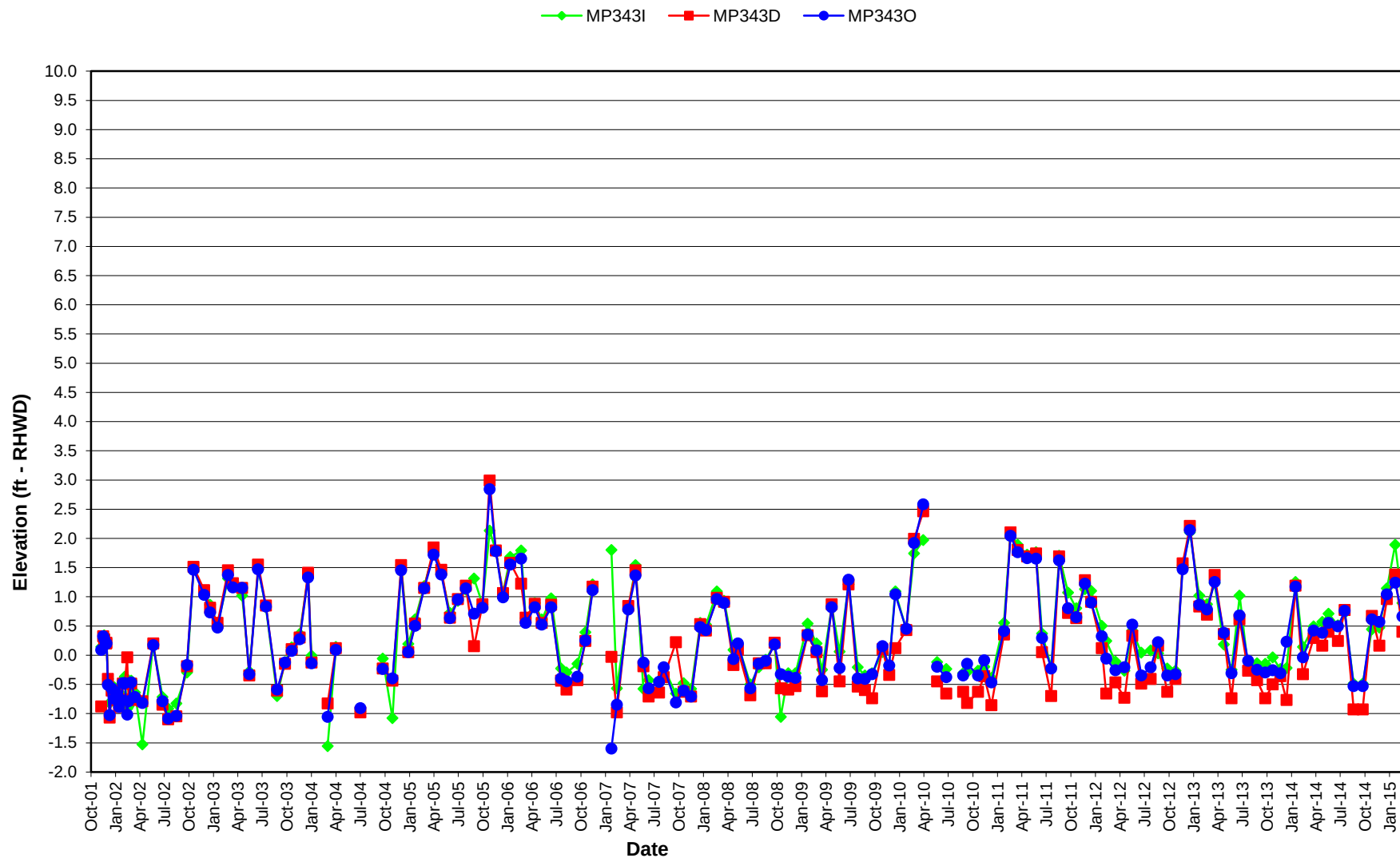
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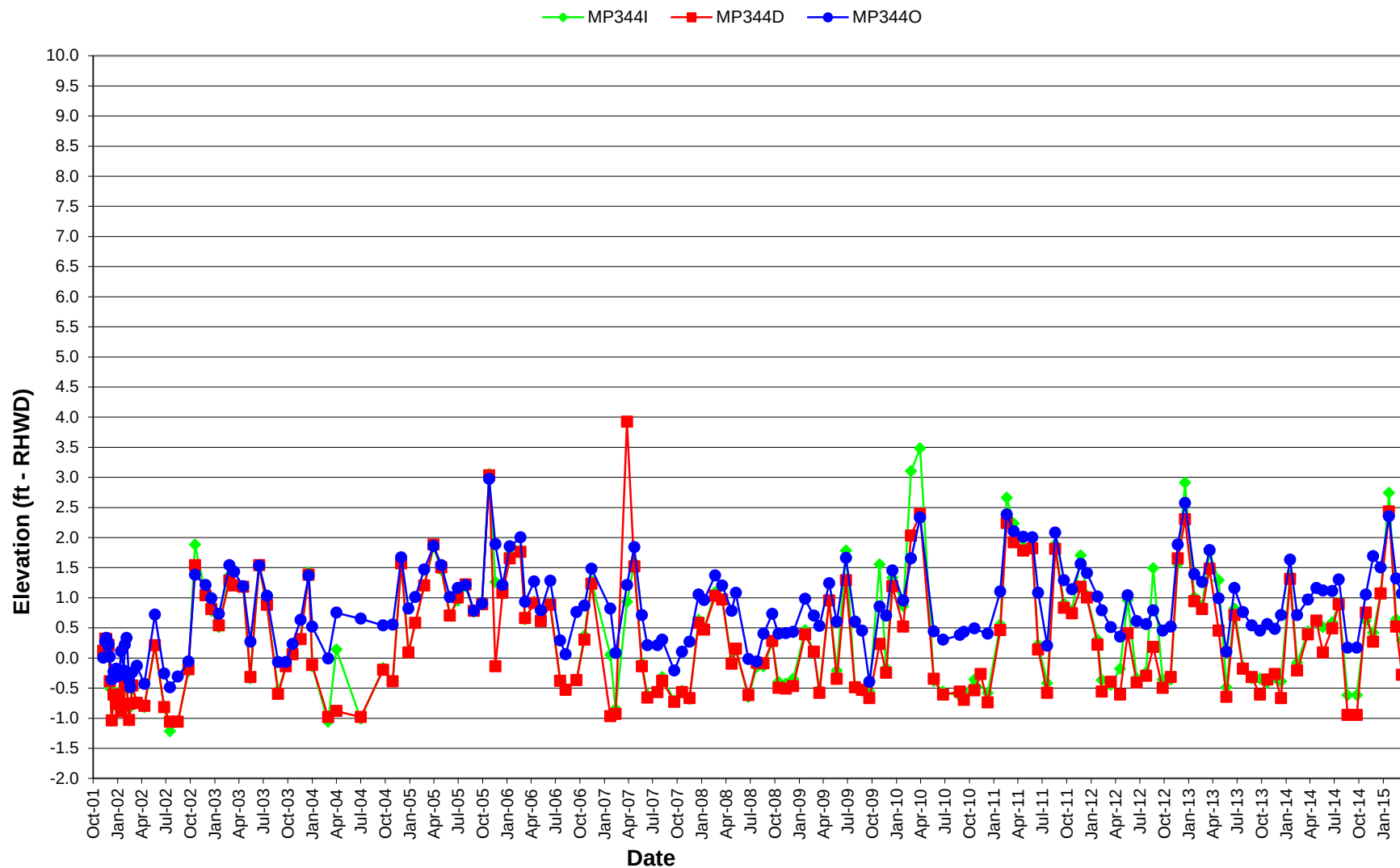
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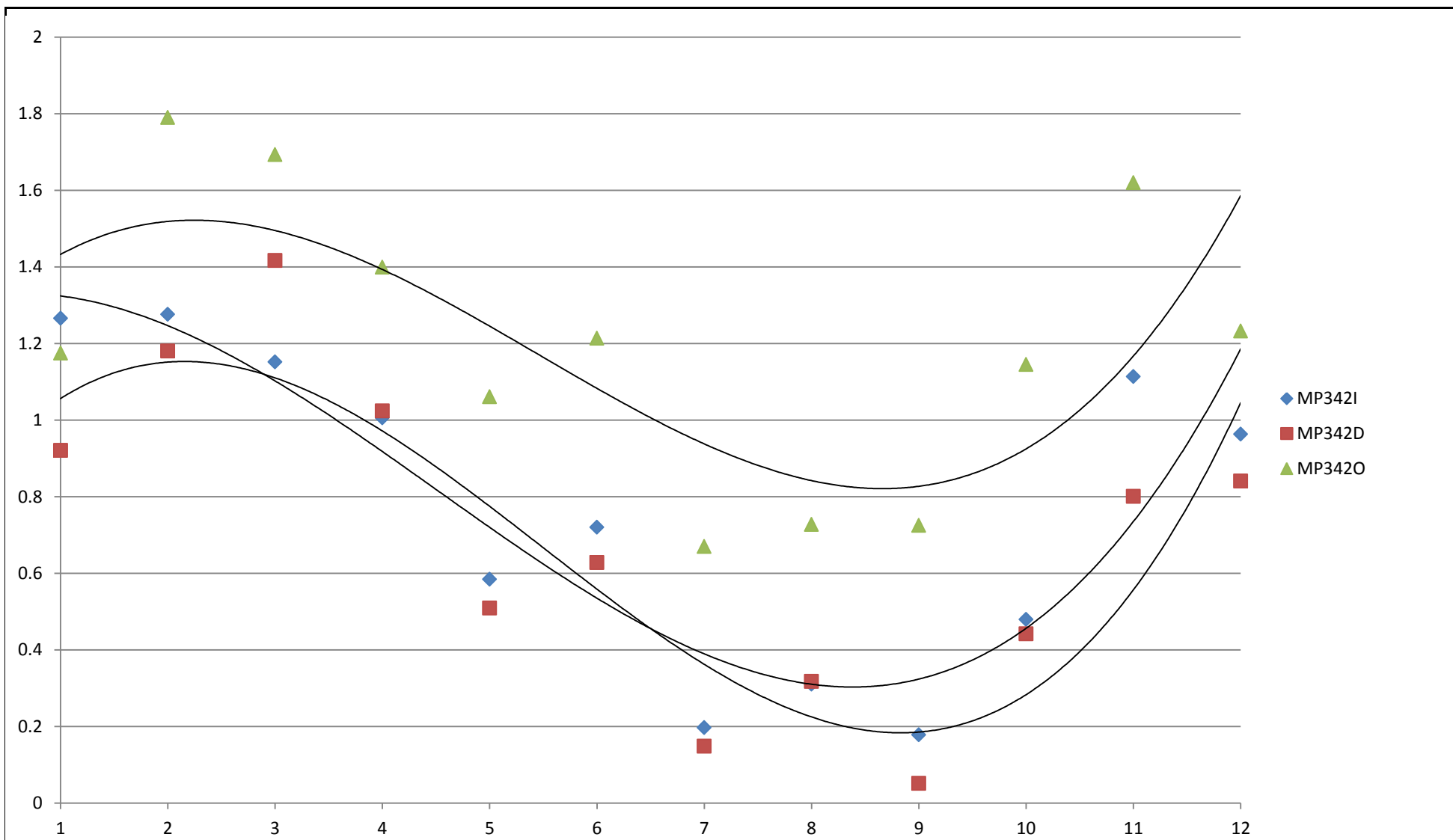
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Prepared By:		Under the Direction of:		Leachate Controls at Landfill Section 2/8 and Landfill Section 3/4 Report Fresh Kills Landfill	Figure 4.2-18 Water Level Elevations Monitoring Piezometer Set MP343 Supplemental Leachate Collection Drain Landfill Section 3/4
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5.0 *Summary and Conclusions*

This chapter provides a summary overview of the leachate control objectives at Sections 2/8 and 3/4. The data utilized to perform an evaluation as to whether the systems achieved the objectives is described and the conclusions of the evaluation are presented.

5.1 *Leachate Control Objectives*

The overall leachate control prescribed in the Consent Order was related to Sections 1/9 and 6/7 and required a minimum of 80% or the maximum extent practicable. Leachate discharge during the 1993 baseline period was established as the basis for determining the 80% goal which was determined by the three-dimensional numerical groundwater flow model that was developed as part of an extensive hydrogeological investigation performed in 1990 through 1992. In order to achieve this goal, it was recommended in the Final Leachate Mitigation Report & Corrective Measures Assessment Report (IT Corporation, 1994) that Site-Wide Alternative 1 be implemented. Site-Wide Alternative 1 consists of the following components: capping, closure containment, collection and treatment at Landfill Sections 1/9 and 6/7, and capping and closure at Landfill Sections 2/8 and 3/4. The engineering design and construction of Alternative 1 was completed in 1998.

In March 1995, NYSDEC issued a Notice of Milestone Deficiency (NOMD) related to Sections 2/8 and 3/4 leachate control (NYSDEC, 1995). NYSDEC directed the New York City Department of Sanitation (DSNY) to develop additional leachate controls at the closed Sections 2/8 and 3/4 to mitigate potential leachate impacts on small streams and drainage channels adjacent to the landfill.

As part of an implementation agreement between DSNY and NYSDEC for leachate control at Sections 2/8 and 3/4 DSNY proposed to install either:

- Center leachate recovery wells, as a means of source reduction, or
- Partial perimeter drains to intercept potential leachate migration to the small tributaries.

Ultimately DSNY implemented both systems with considerations. These considerations being a replacement schedule for center leachate recovery wells and restricted flows to the leachate treatment plant.

An additional legal requirement facing DSNY was the Consent and Judgment Order (CJO) – Civil No. 95-1259 (JBW), which was related to a Clean Water Act citizen's suit. Data evaluation and report preparation related to this Consent and Judgment Order was performed between 1999 and 2000. This Judgment order required installation of supplemental leachate

controls to collect additional leachate and to control potential migration of leachate to surface water bodies adjacent to the Sections 2/8 and 3/4.

The leachate control systems at Sections 2/8 and 3/4 evaluated in this report consist of the following components:

- final cover and drainage,
- perimeter leachate collection drains both original and supplemental, and
- center leachate recovery wells.

Because of the low leachate collection rates, problems with structural integrity and operations, and cost to install compared to the amount of leachate collected by the center leachate recovery wells, it is recommended in a 2003 report that the leachate recovery well program be abandoned. This recommendation was approved by NYSDEC; therefore, the center leachate recovery wells program was not evaluated in this report.

5.2 *Data Evaluation*

To determine the effect of the final cover and drainage and leachate collection drains leachate control systems components, collection rate data for the leachate collection drains and environmental monitoring data were evaluated.

Leachate collection rates are obtained through the use of two methods:

- Continuous electronic data recorded by the Supervisory Control and Data Acquisition (SCADA) system.
- Manual readings of totalizers installed leachate collection well at each drain.

The SCADA system also records leachate elevations in the drains that were used to evaluate the drain operation.

The monthly totalizer readings were summed to provide annual leachate collection rates. Flow rates were downloaded from the SCADA system to determine daily collections rates. The collection rates were evaluated on an annual, monthly and daily basis to determine trends in the collection rates.

Groundwater chemistry data was evaluated from shallow/refuse monitoring wells at Landfill Section 2/8 and Landfill Section 3/4 as they relate to the original collection drains, the supplemental collection drains, portions of each landfill section where there are no drains. The evaluations concentrated on the primary components of groundwater: sodium, potassium, calcium, magnesium, bicarbonate (alkalinity) and sulfate. Parameters known to be good

indicators of leachate influence, namely ammonia, boron and total dissolved solids were also evaluated.

Water level elevation data were evaluated for select shallow/refuse monitoring wells contiguous to the original drains at Landfill Section 2/8 and Landfill Section 3/4 as well as piezometer sets installed as part of the supplemental drains. This allowed for determining changes in the hydraulic gradients due to the leachate control systems.

Surface water chemistry data was evaluated for the creeks that border the landfill sections at Fresh Kills Landfill as well as for the smaller tributaries of those creeks. Ammonia was the primary parameter used to demonstrate changes in surface water because ammonia was used by the model to predict changes based on the implementation of the site-wide leachate controls.

5.3 *Summary of Evaluation*

An evaluation of the leachate controls at Landfill Sections 2/8 and 3/4 show that the components of leachate collection rates include:

- Horizontal leachate flow from refuse mounds
- Groundwater flow from outside of collection drains
- Surface water (Richmond and Main Creeks) flow towards drains (Supplemental Drains)
- Precipitation – directly into drains, surface runoff and seepage through final cover
- Operation of collection well pumps (operational down time)
- Collection well pump off elevation

As demonstrated in Chapter 3.0 precipitation has the largest effect on the leachate collection rates. The effects of precipitation on leachate collection rates may be seen on Figure 5.1-1, which illustrates annual leachate collection rates for the original drain at Landfill Section 3/4. Overall, leachate collection rates are declining. However, in 2011 total precipitation was unusually high - 60 inches of precipitation fell compared to the normal annual total of about 40 inches. This additional 20 inches of precipitation resulted in approximately 10 million gallons of additional leachate collected compared to the prior year.

The contribution of groundwater flow into the drains is more difficult to determine but likely is not significant in the original drains based on groundwater elevations in the groundwater monitoring wells proximate to the original drains. Based on the evaluation of the water levels from the piezometer sets located adjacent to the Supplemental Drains, surface water flow from Main and Richmond Creeks likely has an effect on leachate collection rates. However, the volume of surface water contribution to the total leachate collected is difficult to determine. The change in groundwater composition in the monitoring wells located between the drains and the

creeks to a seawater-influence and the inward gradient observed in the piezometer sets indicate the likelihood of some surface water contribution to the leachate collection volume.

Pump downtime occurs when the pump is not operating (as compared to when the pump is cycling because the pumping rate exceeds the recharge rate) and may be observed in the annual collection rate graphs. As shown in Figures 5.1-2 and 5.1-3 for the Supplemental Drains at Sections 2/8 and 3/4, respectively, the annual collection rate for Year 2005 is lower than the subsequent annual periods, which is unexpected given the overall trend. In 2005, the system did not operate for approximately 190 days at Section 2/8 and for approximately 240 days in Section 3/4. This downtime resulted in approximately 5 million fewer gallons being collected in the Section 2/8 drain and 10 million fewer gallons being collected in the Section 3/4 drain, changing the overall trend in leachate collection rates. The overall trend did resume after the period of prolonged downtime.

The pump off elevation settings have a lesser effect on the overall leachate collections rates. This effect is primarily only important when evaluating daily collection rates to determine base flow conditions; if the pump off was set higher than the bottom of the drain, the collection rate may be biased low and infer a lower base flow.

Taking into account the above influences on the collection rates, base flows were determined for each of the four drains for each annual period. These base flows were used to determine the total amount of leachate collected per year. This was then plotted against the sum of the totalizer for the year. These plots are provided in Figures 5.1-4 through 5.1-7 and show a decreasing trend in the base flow over time, as well as general overall decreasing trends in the totalizers. The tables provided along with the graphs on these figures show that the leachate represents about 34 % to 50% of the volume collected.

5.4 *Conclusions*

The calculated base flow rates as presented in Chapter 3.0 show a reduction in flow rate in the original drains from 1998 to 2015 of approximately 90% for Landfill Section 2/8 and approximately 70% for Landfill Section 3/4. In comparison, the model predicted that the total leachate flux, as provided in Section 1.2, to decrease by approximately 80% at Landfill Section 2/8 and approximately 65% for Landfill Section 3/4 in the 2000 to 2015 model output years. The model also predicted that flow in both Landfill Section 2/8 and Landfill Section 3/4 would be reduced to less than 80% of the 1993 baseline flow by or before 2012; specifically, 80% leachate control efficiency was projected to occur in 2006 at Section 2/8 and 2012 at Section 3/4. The decreases in estimated base flows in the collection drains agrees with the model predicted decreases. Therefore, more than an 80% abatement of leachate flow has been achieved.

Additionally, the horizontal flux controlled by the original drains at Sections 2/8 and 3/4 was estimated based on Year 2000 model boundary fluxes. The estimates are shown in the tables below for Landfill Section 2/8 and Landfill Section 3/4 and indicate that 80% leachate control efficiency was achieved four years sooner in Section 2/8 and two years sooner in Section 3/4. This estimate also shows only a one to two percent difference in the 2015 model year between final cover only and final cover with the partial perimeter drains. This would indicate that there is no marginal benefit to additional collection, and that within the accuracy of the model, leachate flows have been controlled to the maximum extent practicable.

Landfill Section 2/8

Site-Wide Alternative 1 - Final Cover					Site-Wide Alternative 1 - Final Cover with Partial Perimeter Drain				
Year	Uncontrolled Leachate Flux (gpd) ^b			Leachate Control Efficiency ^d	Horizontal Flux Controlled by Original Drain (gpd) ^c	Uncontrolled Leachate Flux (gpd) ^b			Leachate Control Efficiency ^d
	Horizontal	Vertical	Total			Horizontal	Vertical	Total	
2000 ^a	48,627	3,687	52,314	70%	13,129	35,498	3,687	39,185	78%
2001	46,000	3,565	49,565	72%	12,420	33,580	3,565	37,145	79%
2002	43,373	3,443	46,816	74%	11,711	31,662	3,443	35,105	80%
2003	40,746	3,321	44,067	75%	11,001	29,745	3,321	33,065	81%
2004	38,119	3,198	41,318	77%	10,292	27,827	3,198	31,026	82%
2005	35,492	3,076	38,569	78%	9,583	25,909	3,076	28,986	84%
2006	32,865	2,954	35,820	80%	8,874	23,992	2,954	26,946	85%
2007	30,238	2,832	33,071	81%	8,164	22,074	2,832	24,906	86%
2008	27,612	2,710	30,321	83%	7,455	20,156	2,710	22,866	87%
2009	24,985	2,588	27,572	84%	6,746	18,239	2,588	20,827	88%
2010	22,358	2,466	24,823	86%	6,037	16,321	2,466	18,787	89%
2011	19,731	2,344	22,074	88%	5,327	14,403	2,344	16,747	91%
2012	17,104	2,221	19,325	89%	4,618	12,486	2,221	14,707	92%
2013	14,477	2,099	16,576	91%	3,909	10,568	2,099	12,667	93%
2014	11,850	1,977	13,827	92%	3,199	8,650	1,977	10,628	94%
2015 ^a	9,223	1,855	11,078	94%	2,490	6,733	1,855	8,588	95%

Notes: ^a Model output year

^b Linear interpolation between model output years

^c Based on Year 2000 model boundary fluxes; 27% controlled by drain

^d As a percentage of total uncontrolled leachate from in the 1993 baseline period

 Year 80% leachate control efficiency achieved

**Landfill Section
3/4**

Site-Wide Alternative 1 - Final Cover					Site-Wide Alternative 1 - Final Cover with Partial Perimeter Drain				
Year	Uncontrolled Leachate Flux (gpd) ^b			Leachate Control Efficiency ^d	Horizontal Flux Controlled by Original Drain (gpd) ^c	Uncontrolled Leachate Flux (gpd) ^b			Leachate Control Efficiency ^d
	Horizontal	Vertical	Total			Horizontal	Vertical	Total	
2000^a	65,278	14,070	79,348	60%	18,278	47,000	14,070	61,070	65%
2001	62,279	13,609	75,888	62%	17,438	44,841	13,609	58,450	67%
2002	59,280	13,147	72,427	64%	16,598	42,682	13,147	55,829	68%
2003	56,281	12,686	68,967	66%	15,759	40,522	12,686	53,209	70%
2004	53,282	12,225	65,507	67%	14,919	38,363	12,225	50,588	71%
2005	50,283	11,764	62,047	69%	14,079	36,204	11,764	47,967	73%
2006	47,284	11,302	58,586	71%	13,240	34,044	11,302	45,347	74%
2007	44,285	10,841	55,126	72%	12,400	31,885	10,841	42,726	76%
2008	41,286	10,380	51,666	74%	11,560	29,726	10,380	40,106	77%
2009	38,287	9,919	48,206	76%	10,720	27,567	9,919	37,485	79%
2010	35,288	9,457	44,745	78%	9,881	25,407	9,457	34,865	80%
2011	32,289	8,996	41,285	79%	9,041	23,248	8,996	32,244	82%
2012	29,290	8,535	37,825	81%	8,201	21,089	8,535	29,624	83%
2013	26,291	8,074	34,365	83%	7,361	18,930	8,074	27,003	85%
2014	23,292	7,612	30,904	85%	6,522	16,770	7,612	24,383	86%
2015^a	20,293	7,151	27,444	86%	5,682	14,611	7,151	21,762	88%

Notes: ^a Model output year^b Linear interpolation between model output years^c Based on Year 2000 model boundary fluxes; 28% controlled by drain^d As a percentage of total uncontrolled leachate from in the 1993 baseline period
 Year 80% leachate control efficiency achieved

The lower leachate flows and consistent precipitation runoff has changed the groundwater composition at the toe of slope. Factors contributing to the change in groundwater composition include the following:

- Final cover installation precluding additional leachate generation.
- With no leachate generation, horizontal leachate flow is reduced over time due to the lack of new leachate generation.
- Drainage swales control the amount of runoff at the toe of slope.
- While horizontal leachate flow reduces, precipitation runoff remains relatively consistent based on annual precipitation rates.

This is supported by the change in groundwater composition seen in the groundwater monitoring wells which began prior to the initiation of the operation of the drains, as seen in IT316S in Section 2/8 and IT407S in Section 3/4, which are not adjacent to drains (see Figures 5.1-8 and 5.1-9). Therefore, upon termination of the operation of the drains it is expected that the groundwater composition at the toe of slope will continue to show a non-leachate influence. Where a seawater influence was developed along Main and Richmond Creeks due to the operation of the drains, this influence will change to a non-leachate influence.

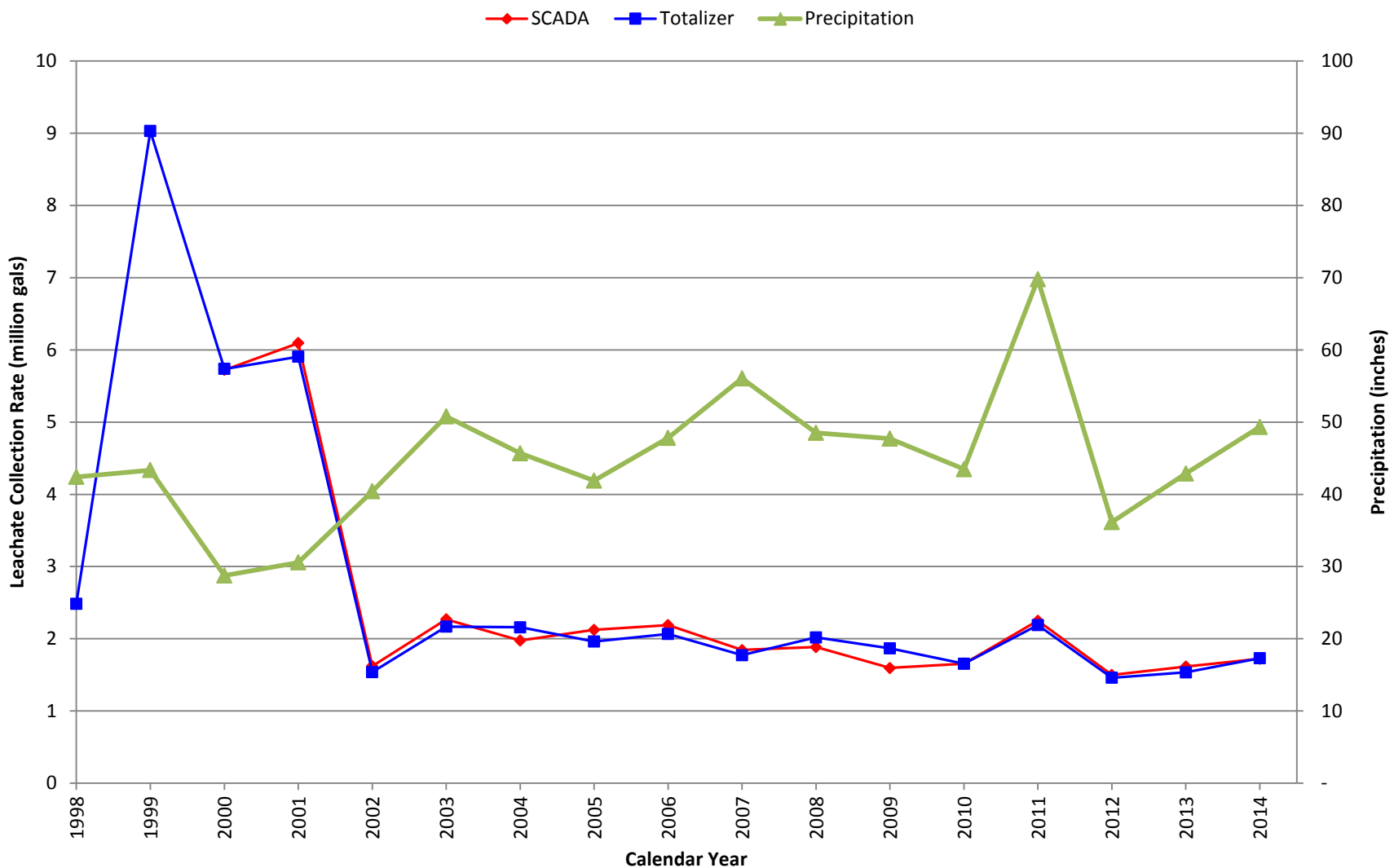
Chapter 5.0 Figures

Description of Figures in Chapter 5.0

Figures 5.1-1 through 5.1-3 Annual Leachate Collection Rates present the leachate collection rates related to each of the drains for data reported through the Supervisory Control and Data Acquisition (SCADA) (continuous electronic) and for data reported through the totalizers (manual); the SCADA system continuously records operational data for the leachate collection drains and the totalizer readings are obtained on a monthly basis by the operator of the Fresh Kills Landfill Leachate Treatment Plant. These totalizer readings are presented in the Monthly Operating Report prepared by the operator of the Fresh Kills Landfill Leachate Treatment Plant under the direction of DSNY. Precipitation rates are also included on the figures.

Figures 5.1-4 through 5.1-7 present the annual totalizer collection rates and the annual amount of leachate collected per year based on the based flow determined for each of the four drains.

Figures 5.1-8 and 5.1-9 Piper and Stiff Diagrams show a change in groundwater composition seen in the groundwater monitoring wells beginning prior to the initiation of the operation of the drains in IT316S in Section 2/8 and IT407S in Section 3/4, which are not adjacent to drains.



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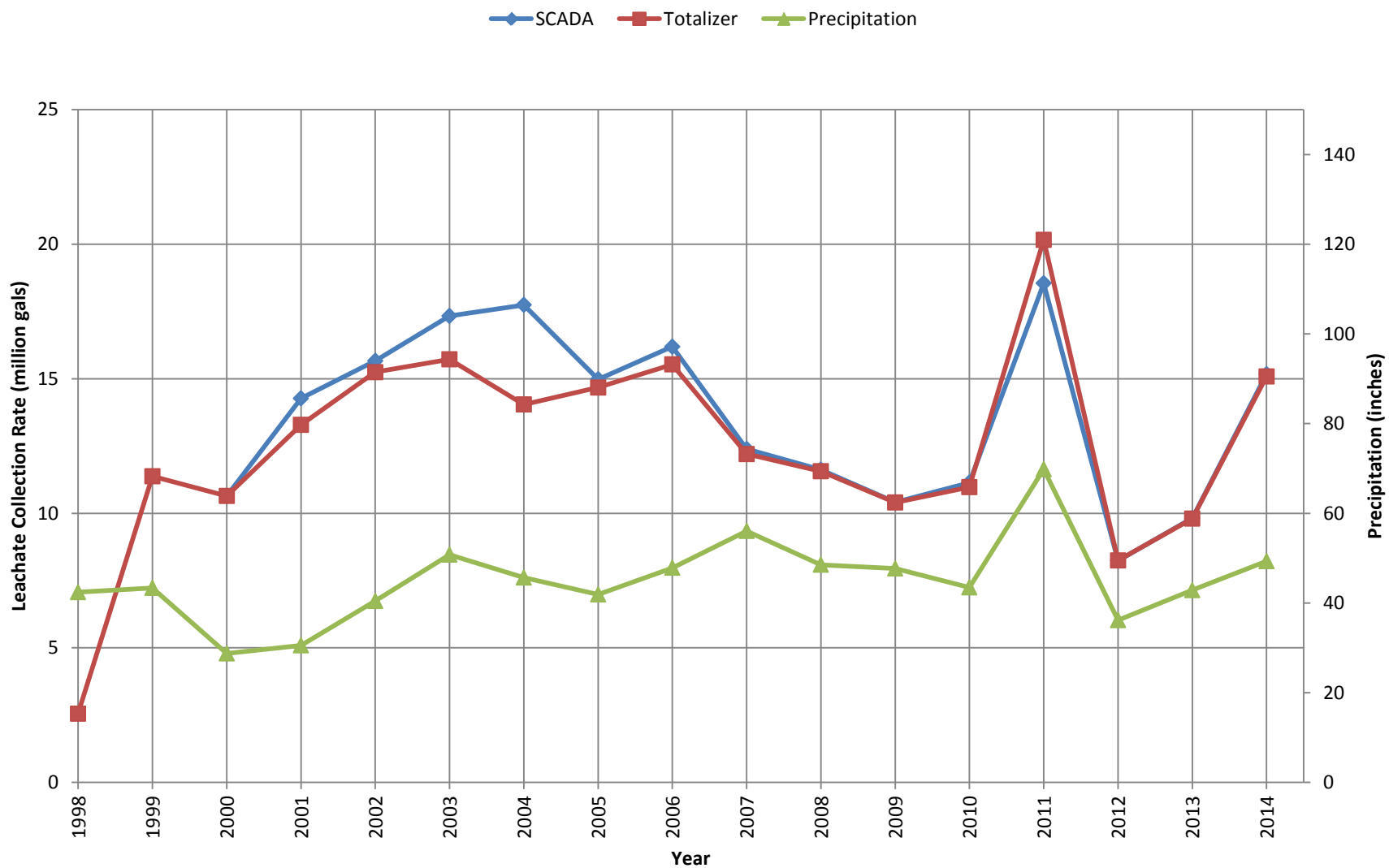
Under the Direction of:



Sections 2/8 and 3/4
Leachate Controls Report

Fresh Kills Landfill

Figure 5.1.1
Annual Leachate Collection Rates
Original Leachate Collection Drain
Landfill Section 2/8



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Under the Direction of:

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Sections 2/8 and 3/4
Leachate Controls Report

Fresh Kills Landfill

Figure 5.1-2
Annual Leachate Collection Rates
Original Leachate Collection Drain
Landfill Section 3/4

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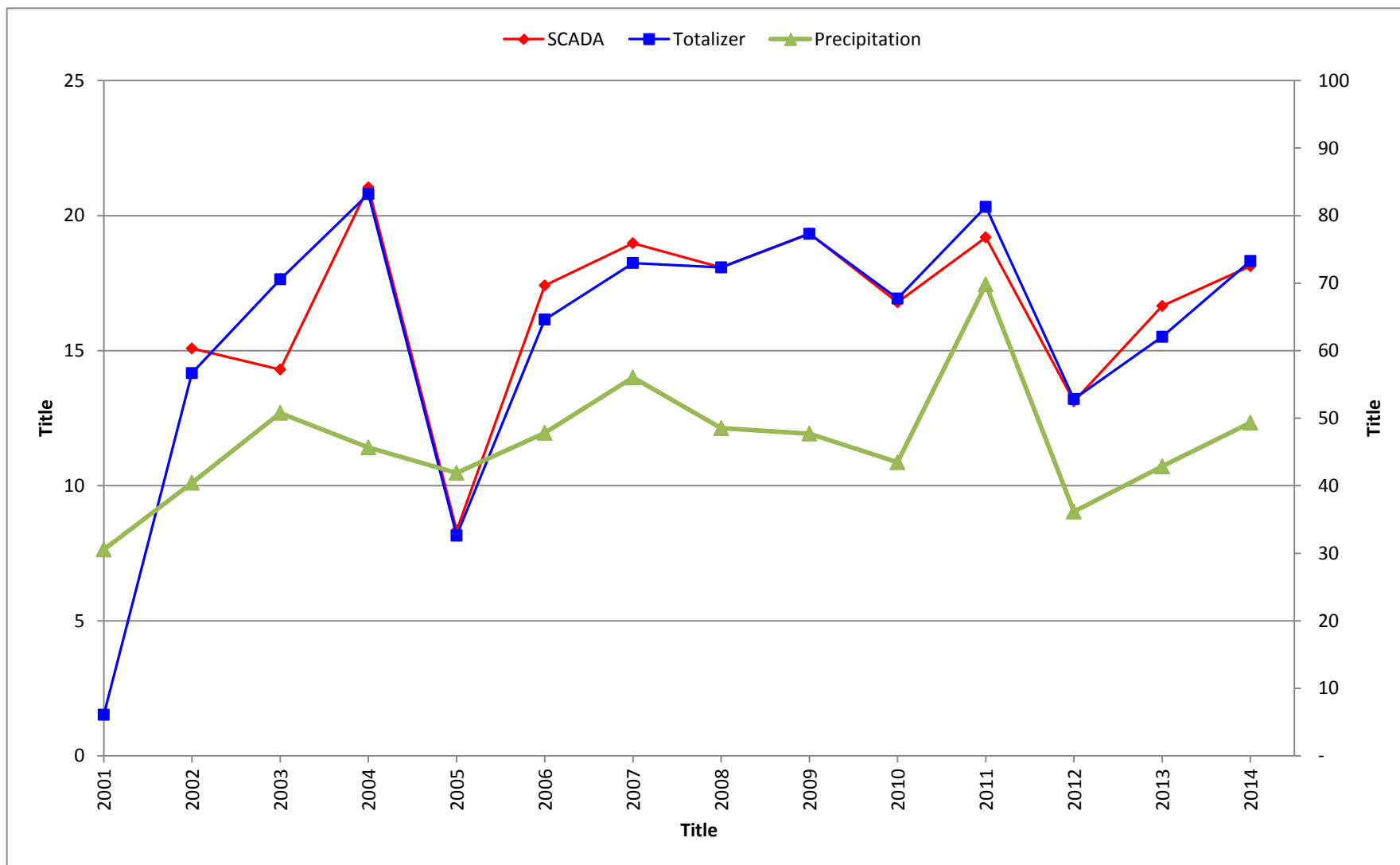
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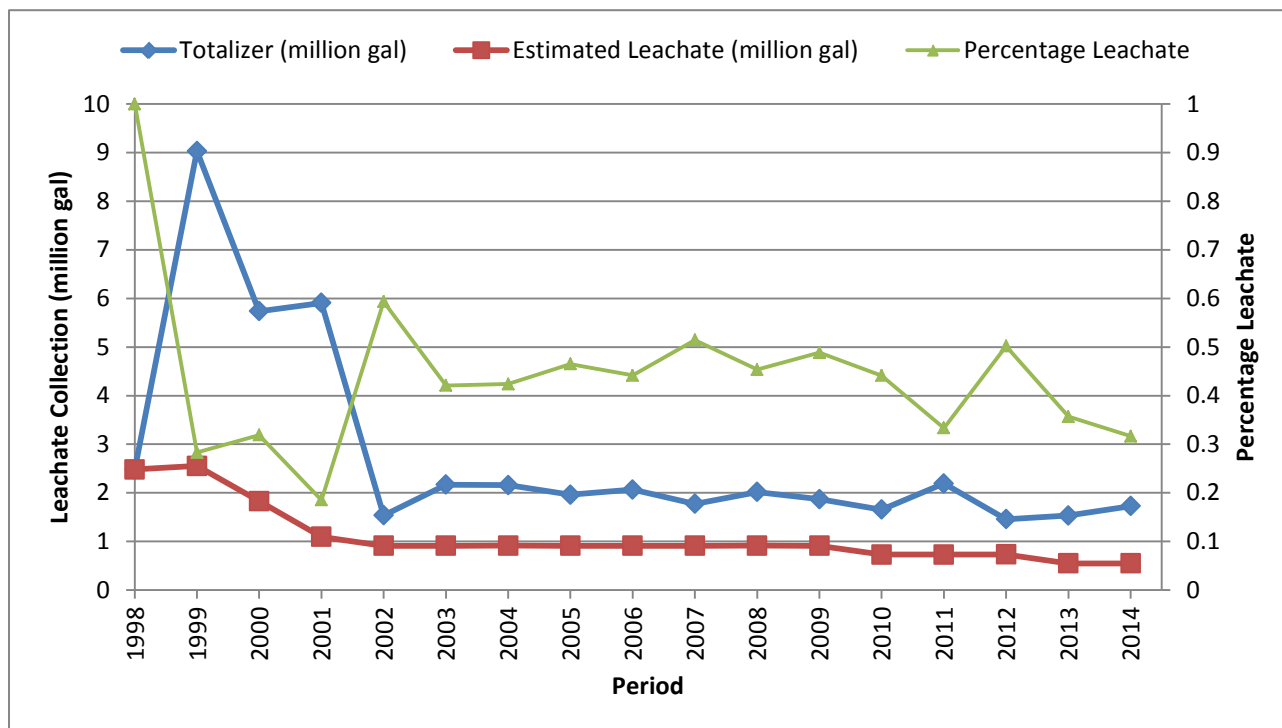
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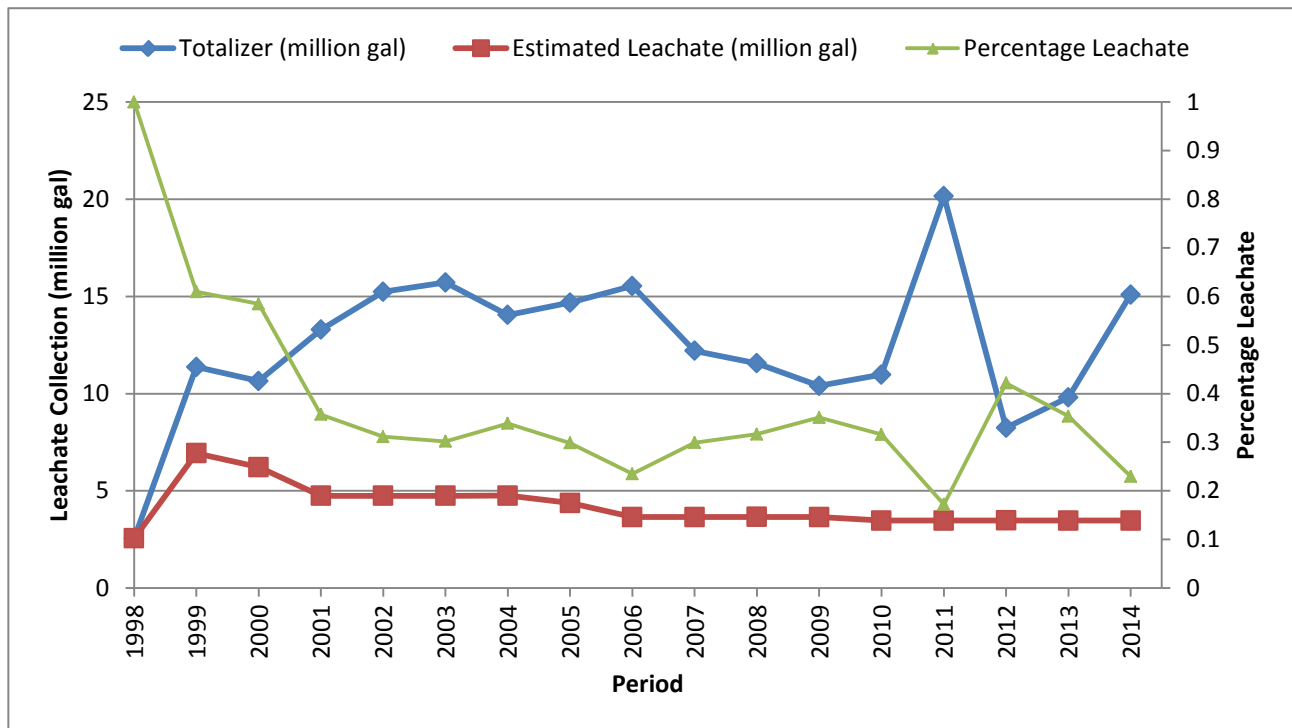


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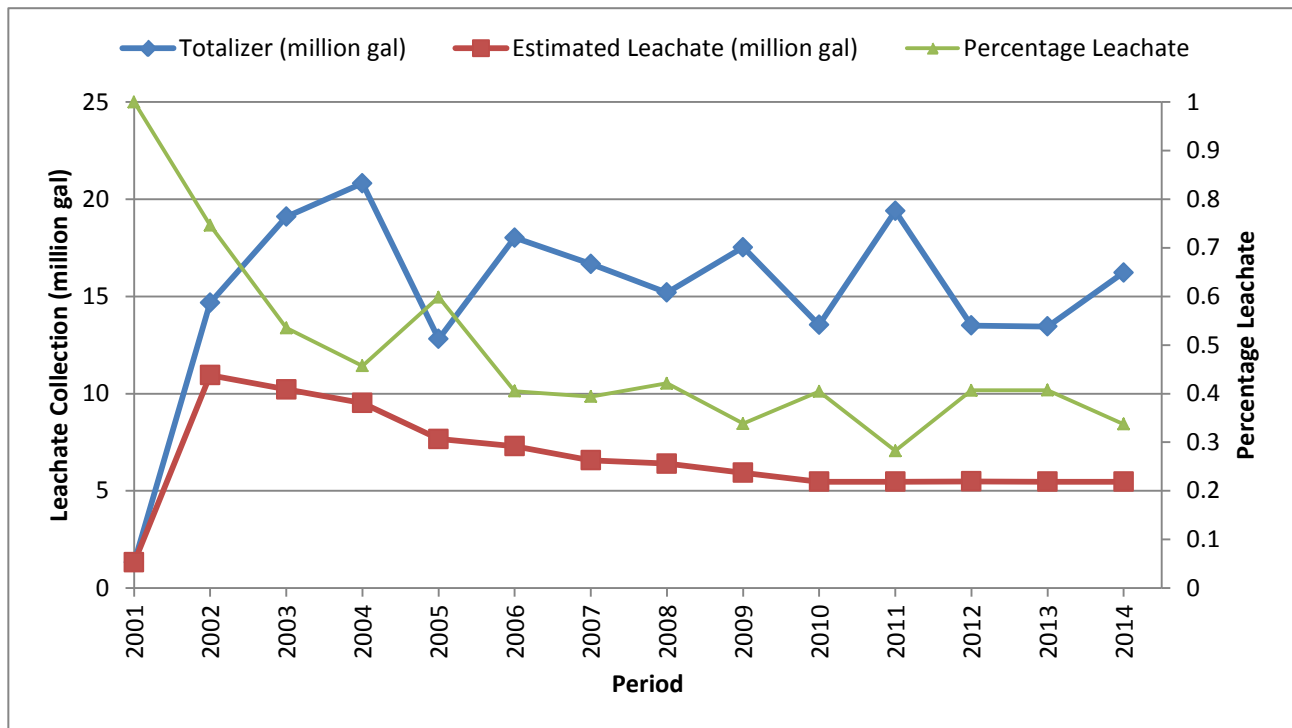
Year	Totalizer (million gal)	Estimated Leachate (million gal)	Percentage Leachate
1998	2.5	2.5	1
1999	9.0	2.6	0.28
2000	5.7	1.8	0.32
2001	5.9	1.1	0.19
2002	1.5	0.9	0.59
2003	2.2	0.9	0.42
2004	2.2	0.9	0.42
2005	2.0	0.9	0.46
2006	2.1	0.9	0.44
2007	1.8	0.9	0.51
2008	2.0	0.9	0.45
2009	1.9	0.9	0.49
2010	1.7	0.7	0.44
2011	2.2	0.7	0.33
2012	1.5	0.7	0.50
2013	1.5	0.5	0.36
2014	1.7	0.5	0.32
Total	47.3	18.6	0.39

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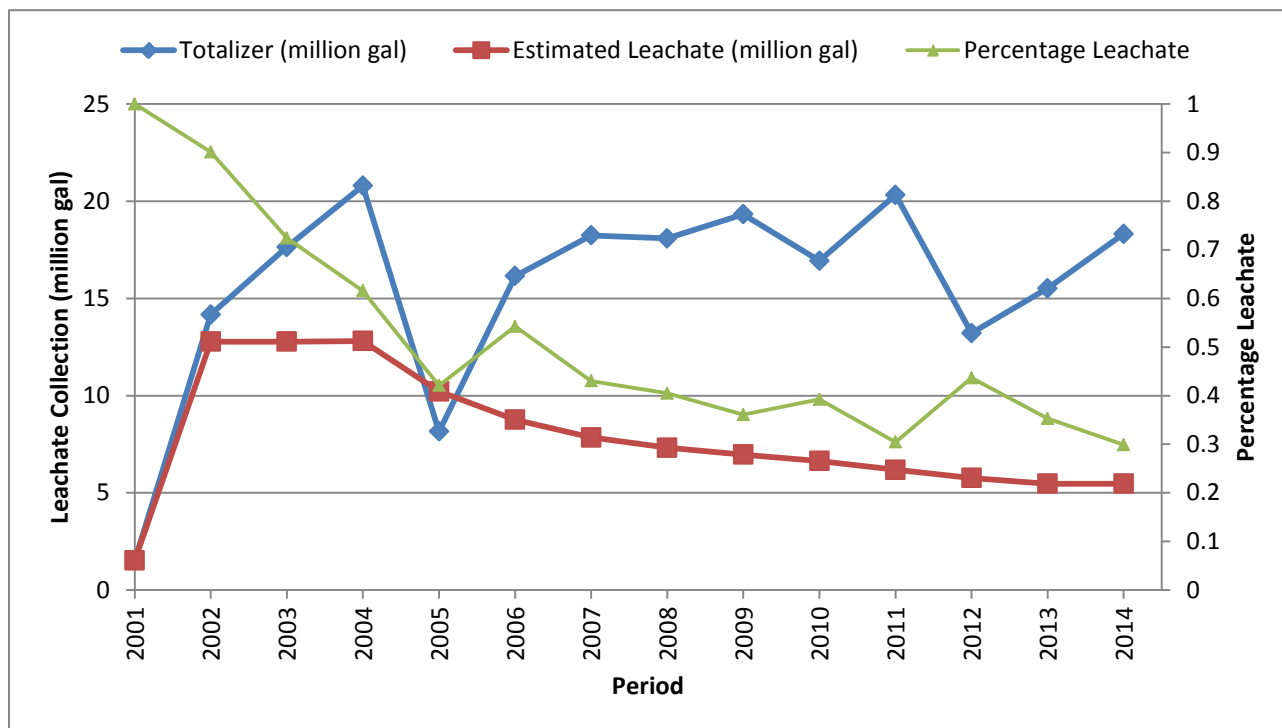
Year	Totalizer (million gal)	Estimated Leachate (million gal)	Percentage Leachate
1998	2.6	2.6	1
1999	11.4	6.9	0.61
2000	10.6	6.2	0.58
2001	13.3	4.7	0.36
2002	15.2	4.7	0.31
2003	15.7	4.7	0.30
2004	14.0	4.8	0.34
2005	14.7	4.4	0.30
2006	15.5	3.7	0.23
2007	12.2	3.7	0.30
2008	11.6	3.7	0.32
2009	10.4	3.7	0.35
2010	11.0	3.5	0.32
2011	20.2	3.5	0.17
2012	8.2	3.5	0.42
2013	9.8	3.5	0.35
2014	15.1	3.5	0.23
Total	211.5	71.0	0.34

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Year	Totalizer (million gal)	Estimated Leachate (million gal)	Percentage Leachate
2001	1.3	1.3	1
2002	14.7	11.0	0.75
2003	19.1	10.2	0.54
2004	20.8	9.5	0.46
2005	12.8	7.7	0.60
2006	18.0	7.3	0.41
2007	16.7	6.6	0.39
2008	15.2	6.4	0.42
2009	17.5	5.9	0.34
2010	13.5	5.5	0.40
2011	19.4	5.5	0.28
2012	13.5	5.5	0.41
2013	13.5	5.5	0.41
2014	16.2	5.5	0.34
Total	212.3	93.3	0.44

Prepared By:		Under the Direction of:		Sections 2/8 and 3/4 Leachate Controls Report Fresh Kills Landfill	Figure 5.1-6 Leachate Collection Rates Supplemental Collection Drain Landfill Section 2/8
					
Generated By:	Approved By:				
Date: July 2015	EJW Job Number:				



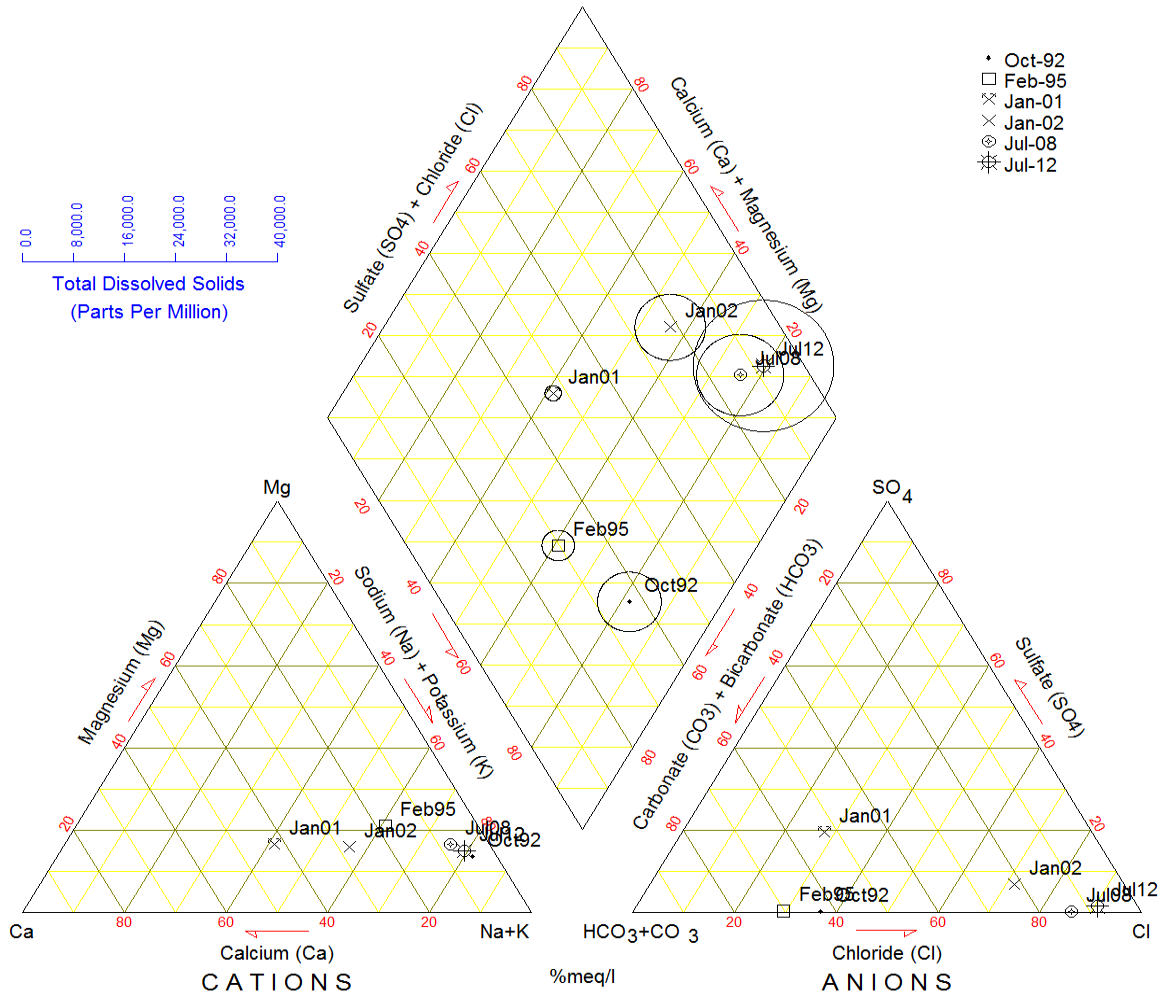
Year	Totalizer (million gal)	Estimated Leachate (million gal)	Percentage Leachate
2001	1.5	1.5	1
2002	14.2	12.8	0.90
2003	17.6	12.8	0.72
2004	20.8	12.8	0.62
2005	8.2	10.2	0.42
2006	16.2	8.8	0.54
2007	18.2	7.8	0.43
2008	18.1	7.3	0.40
2009	19.3	7.0	0.36
2010	16.9	6.6	0.39
2011	20.3	6.2	0.30
2012	13.2	5.8	0.44
2013	15.5	5.5	0.35
2014	18.3	5.5	0.30
Total	218.4	110.5	0.51

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Generated By:	Approved By:				
Date: July 2015	EJW Job Number:				

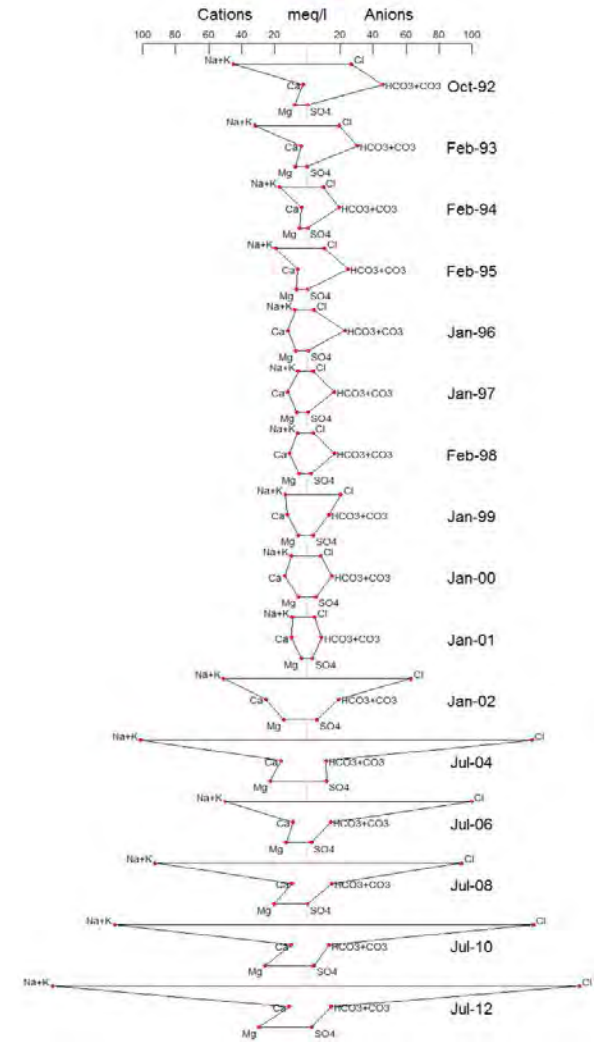
Piper Diagram

IT316S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram IT316S



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Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 5.1-8
Piper and Stiff Diagrams
Well IT316S
Landfill Section 2/8

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Approved By:

DJD

EJW

Date:

Job Number:

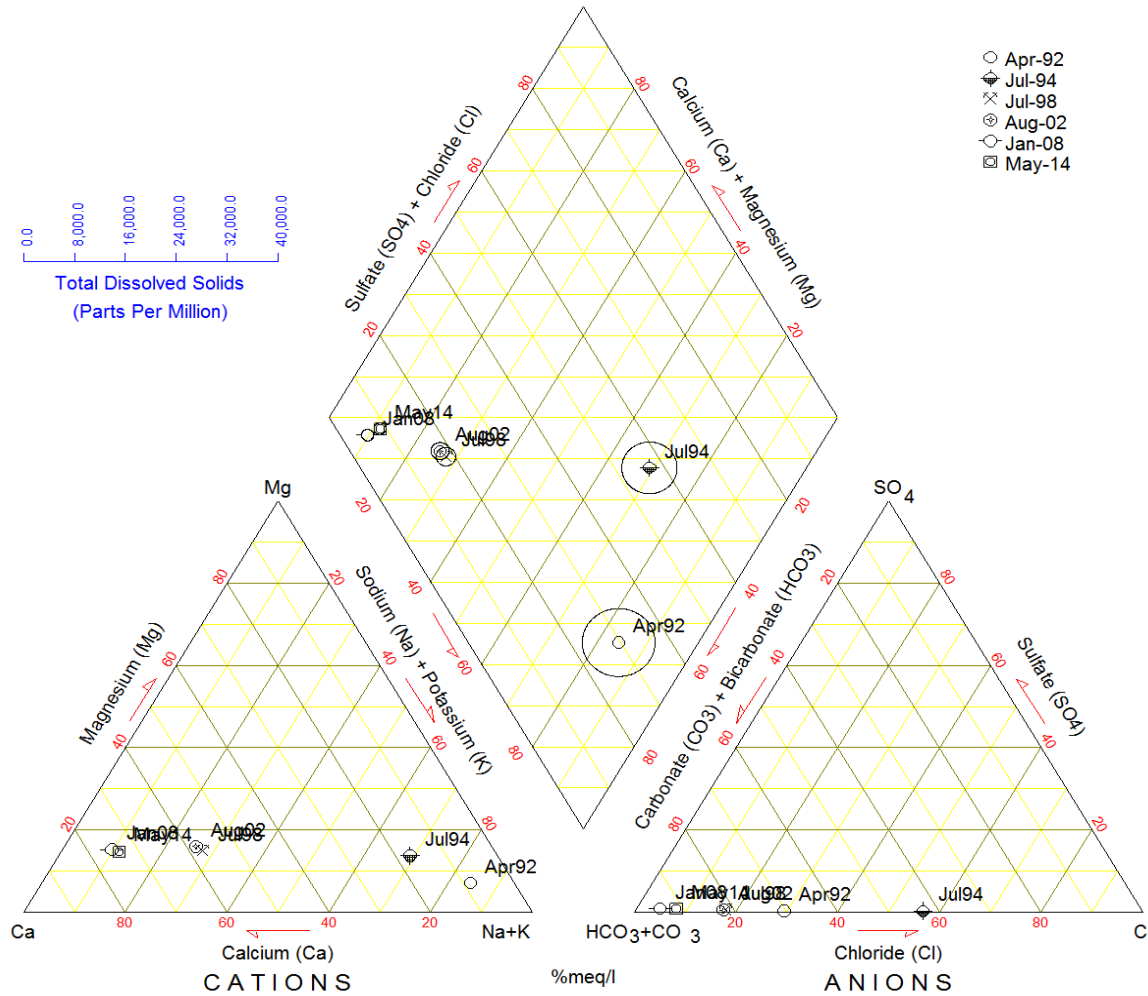
April 2015

151771

Piper Diagram

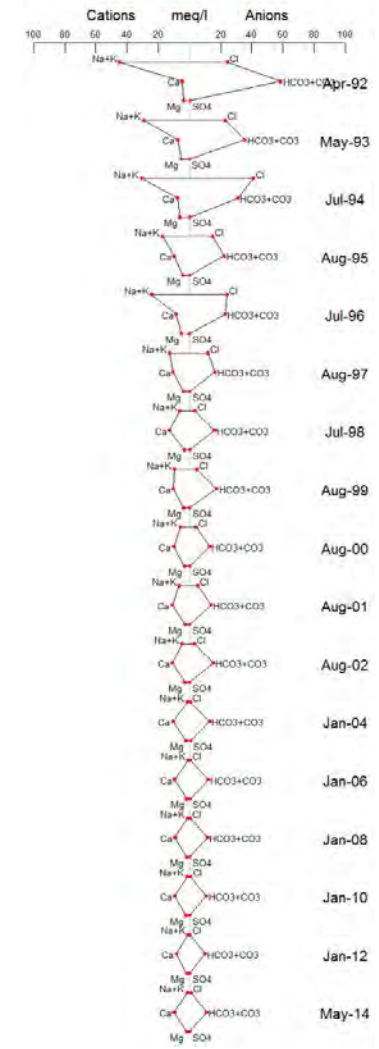
IT407S

0.0 8,000.0 16,000.0 24,000.0 32,000.0 40,000.0
Total Dissolved Solids
(Parts Per Million)



Stiff Diagram

IT407S



Prepared By:

Under the Direction of:

CB&I Environmental & Infrastructure, Inc.



Leachate Controls at
Landfill Section 2/8 and Landfill
Section 3/4 Report

Fresh Kills Landfill

Figure 5.1-9
Piper and Stiff Diagrams
Well IT407S
Landfill Section 3/4

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DJD

EJW

Date:

Job Number:

April 2015

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6.0 *Recommendations*

Based on the evaluation of the leachate collection rates and groundwater analytical data the objectives of the leachate control systems at Sections 2/8 and 3/4 have been met. This evaluation shows that final cover is effective in controlling leachate generation as supported by the base flow leachate collection rates having decreased over time. The final cover and drainage components of the leachate control system also affect the groundwater composition at the perimeter of the landfill sections with a reduced-leachate to non-leachate compositions being observed. The evaluation also shows that precipitation runoff accounts for a majority of the volume of water collected at the four drains along with surface water in the supplemental leachate collection drains at Landfill Sections 2/8 and 3/4.

Therefore, it is recommended that the operation of the drains be terminated. The drains may be left in-place, but the associated aboveground appurtenances can be removed.

7.0 References

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APPENDIX A

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