Bright Fields Groundwater, Inc.

3800 NE 399th Street
La Center, Washington 98629
Phone: (360) 263-6307
Internet: ddykes@tds.net

April 15, 2024

Michele Horn
Compliance Supervisor
Cowlitz County Department of Public Works
1600 13th Avenue South
Kelso, Washington 98626

SUBJECT: **2024 Background Groundwater Quality Data Reevaluation Report for the Headquarters Landfill Detection Monitoring Program**

Michele:

Please find enclosed a report documenting the reevaluation of background groundwater quality at the Headquarters Landfill. The reevaluation was completed following the approved procedures as referenced in the report. These procedures have been incorporated in the recently revised Sampling and Analysis Plan to guide future reevaluations.

The reevaluation confirmed the use of non-parametric prediction limits to test each quarters data relative to background. It also, however, resulted in several significant changes to what constitutes background. These changes include a narrowing of the parameters that are used to represent background, a determination that the downgradient data samples are not spatially stationary with the upgradient data samples, and that a large portion of the data samples are non-normal. Thirteen parameters were determined to be suitable for use in evaluating background groundwater quality at the landfill. This is within the ten to fifteen range described as adequate in the *Unified Guidance*. The lack of spatial stationarity means that the downgradient concentrations of these parameters are from a statistically different population than the upgradient data samples so should not be directly compared to the upgradient data. Substantial or complete portions of the downgradient data samples tested as temporally stationary and these portions were used as background data samples for intrawell testing. Prediction limits were determined for each parameter at each downgradient well from these data samples. About half of the data samples tested as non-normal and a consistent transformation to normalize the distribution was not apparent. A nonparametric prediction limit was selected for use so that all data samples would be consistently tested and used.

Spatial non-stationarity can result from differences in the aquifer geology, overlying land cover and use, impacts from the landfill, and other conditions. The spatial non-stationarity of the Headquarters Landfill monitoring wells appears to result primarily from different geologic rock types surrounding the wells. The predominant rock type at the landfill is described as a lithic tuff in the hydrogeologic characterization report (Tuppan, 2013) with a few basalt and andesitic basalt interbeds. The monitoring wells are installed in each of these three formations and the groundwater sampled from each was shown to differ by the reevaluation. Two wells (C-1 and P-9) were installed in andesitic basalt, however these flows appear to be at separate levels in the lithic tuff and the different groundwater chemistry may result from slight differences in the composition of the andesitic basalt flows. The hydraulic conductivity of the formation at each well also varies and is likely to result in different groundwater residence times and flow pathways to the wells. This may also contribute to the differences. For example, the pumping rate during sampling at P-9 is ten times the rate at C-1 with much less drawdown. Additionally, the groundwater level at P-9 fluctuates seasonally as much as fifteen feet while it hardly changes at C-1. This indicates that groundwater at P-9 is younger and fresher and is likely to react with the formation differently than the older water at C-1.

I reviewed the evaluation of background that was completed using the background data samples collected in 2013. This evaluation followed similar procedures to the current reevaluation with a few notable exceptions. In the original evaluation the background data samples were not tested for spatial stationarity, the parameters were not thoroughly evaluated for suitability in the comparison with background, and temporal stationarity was limited to one year. The original background evaluation was based on limited data samples generated by only eight samples collected within one year. The larger data samples generated by the quarterly monitoring program over the additional ten years of monitoring enhances the definition of background which substantially improves the testing of future data relative to background.

It has been my pleasure to provide these services to you. If you have any questions please give me a call at (360) 263-6307.

Sincerely,
Bright Fields Groundwater, Inc.

Dennis R. Dykes, R.G.
Hydrogeologist
Bright Fields Groundwater, Inc.

Enclosures: 2024 Background Data Reevaluation Report

2024 Background Data Reevaluation Report

Cowlitz County Headquarters Landfill Detection Monitoring Program

Prepared for
Cowlitz County Department of Public Works
April 15, 2024

Prepared by

Bright Fields Groundwater, Inc.

3800 NE 399th Street
La Center, Washington 98629
Phone: (360) 263-6307
Internet: ddykes@tds.net

Cowlitz County Headquarters Landfill
Detection Monitoring Program
2024 Background Data Reevaluation

Cowlitz County Solid Waste is implementing a detection monitoring program at the Headquarters Landfill. The Headquarters Landfill is an operational landfill regulated under WAC 173-351. The monitoring program is described in a Sampling and Analysis Plan that was updated in March 2024. Monitoring is guided by *Guidance for Monitoring at Landfills and Other Facilities Regulated Under Chapter 173-304, 173-306, 173-350 and 173-351 WAC* as updated in 2018. Chapter 6 of this guidance document describes statistical analysis requirements and procedures with reference to the USEPA *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance* (*Unified Guidance*) document.

Data collection by the detection monitoring program is designed to provide data that can be statistically evaluated quarterly to show whether the landfill has affected groundwater quality. The evaluations are designed to compare the most recent data to the background conditions in a statistically valid manner that minimizes the potential for false positive or false negative results. Background is defined as the natural condition of the groundwater unaffected by a release from the landfill. It is understood that background is not likely to be static so must be reevaluated periodically for both concentrations, variability and trends within the data.

This report describes the procedures that were used to reevaluate background conditions at the landfill. Background was last evaluated about ten years ago during permitting as a Municipal Solid Waste Landfill and was based on up to nine sampling events. Nearly forty additional sampling events have generated data that may be used to reevaluate background. The procedures include three phases.

In the first phase, the data quality was reviewed to assure usefulness in the analysis. This review included identifying outlier data, managing non-detections, determining sample independence and stationarity, and evaluating whether the populations are normally distributed. The data quality review focused on the data generated since January/February 2013 and on 19 parameters which had few non-detections and are likely to be present in the landfills leachate. Data generated in and after January 2013 were evaluated because this data was generated in compliance with the applicable regulations, the installation of bladder pumps and implementation of low flow sampling. Prior data was collected under a different regulations and using different sampling methods. This period includes data generated by 48 sampling events which is considered a statistically large sample size.

In the second phase, the data and site conditions were evaluated using statistical tests. This included selection of a subset of the monitoring parameters for statistical evaluation, evaluation of site specific hydrogeologic conditions, and further evaluation of the temporal and spatial variability of the data sets for effects on statistical tests.

In the third phase, the statistical evaluation method was selected and implemented. Statistical Interval methods are appropriate for background to compliance point comparisons. A Prediction Limit Test method was selected and prediction limits determined from the background data for the selected parameters. Data subsequently collected will compared to these prediction limits to determine of a potentially statistically significant increase in concentrations occurs.

Data Quality Evaluation for Use in Statistical Tests

Outliers

The *Unified Guidance* defines a statistical outlier as "a value originating from a different statistical population than the rest of the sample" and provides several methods for evaluating data identified as potential outliers. It also suggests that effort should be made to determine potential causes of data identified as potential outliers before deciding a course of action. Actions can include removing from or retaining the outlier in the dataset.

Potential outliers were identified using lower and upper interquartile values determined using spreadsheet functions. The first lower and upper boundaries were calculated using:

First Lower Boundary = first quartile ($x_{.25}$) - 1.5 x Interquartile Range (IQR)
First Upper Boundary = third quartile ($x_{.75}$) + 1.5 x IQR

The second lower and upper boundaries were calculated using:

Second Lower Boundary = $x_{.25}$ – 3.0 x IQR
Second Upper Boundary = $x_{.75}$ + 3.0 x IQR

Data between the first and second boundaries were considered mild outliers. Data below the second lower or above the second upper boundaries were considered extreme outliers.

The data samples for each inorganic parameter and metal from each well were evaluated. This included 29 of the 30 parameters. Bicarbonate outliers were assumed to the same as the alkalinity outliers because bicarbonate concentrations are calculated from the analyzed alkalinity concentrations. Therefore they were not directly evaluated. VOCs were not evaluated because only a few were detected and most detections were inconsistent.

Generally, the extreme outliers, outliers below or above the second lower or upper boundary, respectively, were removed from the data samples. Most of the outliers were above the upper boundary and a few were below the lower boundary. Several mild outliers were also removed because they were not reproduced in subsequent samples from the location, were at concentration near the upper boundary and were more than twice preceding and succeeding values.

Most parameters had none or one or two identified outliers requiring removal from statistical analysis. A few parameters had as many as six to eight outliers that required removal. Many of these outliers were preceded and succeeded by concentrations that were less than half the outlier concentration. Clusters of up to seven outliers were identified but only for two parameters at differing time periods and only one of these parameters was at more than one well. Two to six potassium outliers were identified in 2017/2018 at all four wells. These overlap a change in analytical laboratory which also affected reporting limits.

The outlier values are identified on the data tables with an asterisk and are excluded from statistical analyses.

Non Detections

Many parameters measured during monitoring were not detected at or above the analytical method detection limits (MDLs). Generally parameters at specific wells had few or a preponderance of non-detections. The parameters with very few non-detections were identified for inclusion in the statistical evaluation of background. The non-detected data for any of these parameters were converted to half the reporting limit for use in the statistical evaluation.

Non-detections for parameters with a preponderance of non-detections and not selected for background evaluation are shown on the data tables but not used in the statistical calculations. Because of the typically large proportion of non-detections for these parameters conversion of the reporting limit to a value would result in statistical calculations that were less accurate and not meaningful.

Statistical Independence

The regulations and guidance require that spatially and/or temporally independent data be used in the statistical evaluations. The data samples from different wells are spatially independent because of the spacing between wells. Data within samples collected at the same location are not spatially independent, therefore independence of each datum was achieved by allowing enough time between sampling events for the samples to be temporally independent. Temporal independence is assured when enough groundwater flows past the well so that different water is sampled during separate events. The *Unified Guidance* suggests that one to two months is typically sufficient but the amount of time needed depends on the local hydrogeologic conditions.

The linear groundwater velocity estimates included in the quarterly reports for the shallow aquifer zone range from a minimum of about 0.02 feet/day to about 0.19 feet/day. The quarterly sampling typically has occurred at 75 to 105 day intervals (averaging about three months between sampling events) so groundwater can be expected to flow more than 1.5 feet and as much as 20 feet depending on the location and how the hydraulic gradient varies between sampling events.

The distance groundwater is likely to be drawn from when sampling a well can be estimated using the length of the well screen, the low end of the range of effective porosity of the aquifer and the typical volume pumped during purging and sampling. The worst case can be calculated for well C-2 which is the slowest pumping well during sampling. At this well groundwater is estimated to be drawn from three or four inches around the well. This is much less than the distance groundwater can be expected to flow between sampling events. Therefore the time between the quarterly sampling events is sufficient for the analytical data to be independent.

A field duplicate is collected and analyzed each quarter from one well. These data are not statistically independent because the samples are collected at the same place and time as the sample. The duplicate data was removed to reduce the degrees of freedom that would be introduced by using replicates.

Normal Distribution

Prior to testing for normality and stationarity the parameters at each well were evaluated for use in the statistical tests. The *Unified Guidance* suggests that evaluation of between 10 and 15 parameters should be an adequate number for most conditions. Of the 29 inorganic parameters and metals 14 were identified to have numerous non-detections at several wells. The other 15 appeared to have a large sample size with few non-detections. Normality and stationarity were tested for these 15 parameters:

Alkalinity	Chloride	Sulfate	Total Dissolved Solids
Barium	Cadmium	Chromium	Copper
Nickel	Zinc	Calcium	Manganese
Magnesium	Potassium	Sodium	

The data for these 15 parameters were tested for normality. The Shapiro-Wilk Method was applied to data samples for each parameter from each well. This was completed after the outlier review. An Excel spreadsheet with the Real Statistics add-in was used. The null hypothesis was rejected (not normal) for 28 and not rejected (no evidence not normal) for 32 of the 60 data samples relative to the p-value 0.05. The non-normal data samples were typically right biased (skewed toward higher concentrations) which is common for water quality samples. A summary of the test results are in Attachment A.

The normal and non-normal data samples were distributed among the wells and parameters. C-1 had the most normal data samples (10 of the 15 parameters). P-9 had the most non-normal data samples (9 of the 15 parameters). C-2 had nearly the similar number of normal and non-normal distributions (7 normal and 8 non-normal) and U-1 had slightly more normal than non-normal samples (9 of 15 parameters). Calcium and sodium had normal data samples at all four wells and TDS, barium, cadmium and magnesium were normally distributed at three wells albeit in different groupings of wells. Copper and nickel data samples were non-normal at all four wells and alkalinity and manganese were non-normal at three wells.

Stationarity

Statistical tests typically require data that is spatially and/or temporally stationary. Spatial stationarity was evaluated using the procedure described in Chapter 13 of the *Unified Guidance*. This included generating side by side box plots of the data for each parameter for the wells. The box plots were visually evaluated to determine whether the boxes had largely overlapping interquartile ranges and whether the medians were similar. Temporal stationarity was evaluated by generating time series plots of the data samples for each parameter at each well. These plots were evaluated to identify apparent seasonal variations, randomness and generally rising or falling trends. The Rank von Neumann ratio test was also applied to the data. This non-parametric test was applied to the data samples because it is applicable to non-normally distributed data and can be applied to normal data. Visual evaluations were compared to the Rank von Neumann ratios.

The box plots and time series plots are included in Attachment A. A summary table of the Rank von Neumann ratio test results is also in Attachment A. A table summarizing the result of the Rank von Neumann test and visual trend evaluation is also in Attachment A.

Spatial Stationarity Evaluation: The box plots did not appear to align at the all four wells for any of the 15 parameters. The boxes appeared to align at three wells for one parameter, copper at C-1, C-2 and P-9. This represents one of the 60 possible three well groupings. Two well alignments appeared 8 times. When overlapped with the three well alignments there were 11 two well alignments of the 90 possible. Wells C-1 and C-2 aligned for the most parameters with 6 of the 15 possible. Additionally, three of these identified alignments were the same distribution, two non-normal and one normal.

The generally poor alignment of the box plots and sample distributions of these alignments indicates that the data samples are not spatially stationary. The spatial distribution appears to show that concentrations are mostly higher at the upgradient well U-1 and a mix of higher lower and similar at upgradient well P-9 when compared to downgradient data. The U-1 boxes are higher than 23 of the 30 boxes for the downgradient wells. They were lower than six boxes and similar to one. The P-9 boxes were higher than 14 of the 30 downgradient boxes, lower than 13 boxes and similar to three.

Temporal Stationarity Evaluation: The Rank von Neumann ratios were above the Critical Point (taken from Table 14-1 in the *Unified Guidance*) for 30 of the 58 data samples indicating a little more than half the data samples were independent. Few potential seasonal fluctuations were visually identified in the data and all of these were identified as not dependent data samples by the Rank von Neumann tests. These seasonal fluctuations appeared to be wet/dry season differences so the quarter of the highs and lows were not typically consistent which reduces potential autocorrelation. Data samples that appeared to be visually random tested as independent in 26 of the 48 of data samples. Data samples that visually showed trends on at least part of their trend line tested dependent in 6 of 10 data samples.

The number of independent and dependent data samples were distributed differently at each well. For C-1 data samples, 9 of the 15 parameters were identified as independent but at C-2 only three were identified as independent by the Rank von Neumann test. For the upgradient wells more parameters were independent than dependent (9 of the 14 data samples at P-9 and 9 of 14 at U-1).

Statistical Test Considerations

Identify Parameters for Evaluation

A preliminary review of the data samples identified parameters at the landfill with adequate data for use in the statistical tests. The monitoring program has analyzed the parameters listed in WAC 173-351 Appendices I and II quarterly for eleven years. These parameters are assumed to potentially meet the requirement that they should be expected to have the potential to be released from the landfill, are mobile and stable in groundwater, and may be at concentrations detectable in groundwater. Most of these parameters are not routinely detected in groundwater samples and therefore do not have data samples that can be statistically analyzed.

The monitored VOCs are rarely detected in groundwater and therefore cannot be statistically evaluated. This leaves 30 inorganic parameters, mostly metals. Two of these, bicarbonate and alkalinity, are related. Alkalinity is analyzed in the groundwater samples with bicarbonate calculated from this data therefore evaluation of bicarbonate is redundant. Of the 29 available parameters, 14 were identified to have numerous non-detections at several wells. The other 15 appeared to have a large sample size with few non-detections. Therefore normality and stationarity were tested for these 15 parameters.

The *Unified Guidance* suggests that evaluation of between 10 and 15 parameters should be an adequate number for most conditions. Several of the 15 identified parameters were reconsidered for use as indicators of background resulting in discontinuing the evaluation of two parameters (manganese and cadmium). The highest manganese concentration at U-1 was less than three times the leachate concentration suggesting that naturally occurring manganese may obscure detection of landfill sourced manganese. Most cadmium concentrations were below the method reporting limit and qualified as estimated. This reduces confidence in the statistical analysis and usefulness of cadmium as an indicator parameter. Cadmium may be useful in an investigation of a statistically significant increase in indicator parameters because the concentration in leachate is substantially higher.

A minimum of eight observations is required to evaluate background using statistical tests. The wells at the Headquarters Landfill have been monitored quarterly for 10 years under the current permit. An additional eight samples were collected the previous year to describe background conditions. Therefore the data samples for each parameter at each well included up to 48 sampling events which is considered a statistically large sample size. The sampling procedures and analytical program was consistent during this period. The laboratory analyses were also consistent except for one year when a different laboratory won the analytical contract. Some results and reporting limits were different during this year which is coincident with a portion of the identified outliers and fluctuations in some parameters.

The guidance suggests that the selected parameters should be expected to have the potential to be released from the landfill, mobile and stable in groundwater, and be at concentrations detectable in groundwater. A table showing the mean concentrations in groundwater and concentration in a leachate sample is included in Attachment B. This table also shows the ratio of the leachate concentration and the groundwater means. Note that quarterly analysis of leachate was recently added to the analytical program and the leachate concentrations shown on the table are for one sample collected in the first quarter 2024.

Copper and magnesium show trends in the more recent data from C-2, copper a falling trend and magnesium a slight rising trend. Concentrations in leachate are substantially higher than in downgradient groundwater and these parameters were retained as background indicators.

The following thirteen parameters were selected for evaluation of background at the landfill:

Alkalinity	Chloride	Sulfate	TDS
Barium	Chromium	Copper	Nickel
Zinc	Calcium	Magnesium	Potassium
Sodium			

Evaluation of Hydrogeologic Conditions of Each Well

The hydrogeologic conditions at each well were reviewed to evaluate similarities and differences between wells. The geology penetrated, measured hydraulic conductivity, surrounding apparent hydraulic gradient, and groundwater flow direction to and away from each well were considered. This information was used to evaluate the likelihood that the groundwater obtained from a well is similar to other wells. However the parameter data shows that groundwater chemistry is not spatially stationary.

The geology and hydrogeology of the site are described in *Hydrogeologic Characterization Report for the Proposed Cowlitz County Headquarters Landfill Project* (Tuppan, 2013). The site geology is described as being dominated by lithic tuffs with some tuffs and lava flows composed of basalt and basaltic andesite. These materials are described as deeply weathered in most explorations at the site. These materials tend to weather to silt, clay and silty sand which typically have low hydraulic conductivity. Structurally some tilting of the bedding has occurred and jointing was observed, but faulting has not been identified.

Three of the four wells were installed in weather lava flows. C-1 and P-9 were installed in andesitic basalt and C-2 was installed in basalt. The basalt at C-2 is described as somewhat less weathered than the andesitic basalt. It's unlikely that C1 and P-9 are installed in the same flow because the dip of bedding at C-1 is mapped as toward the northeast indicating P-9 is stratigraphically higher. U-1 was installed in lithic tuff.

Pumping rates at the wells vary substantially. P-9 is the highest yielding well at over 500 ml/minute and C-2 the lowest yielding at 50 ml/min. C-1 and U-1 can be pumped 100 to 200 ml/min. These differences highlight the effect of the less weathered basalt at C-2 and significant variability in the hydraulic conductivity around the site.

The differences in the lithology and hydraulic conductivity help explain the apparent non spatial stationarity of water quality at the landfill. Infiltrating water will interact differently with lithologies to develop different groundwater geochemistry. Additionally, lower hydraulic conductivity allows more time for water to interact with the minerology.

Evaluation of the Spatial Variation of the Selected Parameters

The box plots for the selected parameters at each well were reviewed for spatial variations. Few of the means were similar and few boxes overlapped within each area indicating spatial non-stationarity of the data samples. Several data samples from background wells appeared to overlap with data samples from various wells. The number is however small relative to the number of available comparisons and could be considered random, not an indication of spatial stationarity.

The prevailing spatial non-stationarity of the data samples indicates that interwell comparison of data samples would be limited to a relatively small portion of the data samples and likely to be coincidental. Intrawell testing of all data samples for use in the background evaluation was therefore indicated and completed. This is described in the next section.

Evaluation of the Temporal Variation of the Selected Parameters

The apparent spatial non-stationarity of the data samples necessitates use of intrawell evaluation of background. Each data sample was reviewed by visually evaluating trend plots to identify potential trends that would affect selection of a value to represent background for a parameter at a well. The Rank von Neumann testing of the data samples indicated that the possible seasonal trends visible for in a few data samples did not affect the independence of most of these data samples. An effect from these trends can therefore be discounted.

Data sample trends that appeared to be random are acceptable for intrawell testing. The Mann-Kendall test was applied to the downgradient data samples for the thirteen selected parameters. Seventeen of the 26 data samples tested did not have a trend, therefore, the look back period for most of the data samples was from February 2013 to October 2023. Shorter look back periods for seven of the remaining nine data samples were identified. Six of these precluded use of about the first half of the data sample and one the later half. These shortened look back periods included 18 to 29 values. Two data samples, copper and magnesium at C-2, showed small falling and rising trends, respectively, in the later several years of the data samples. The Sen's slope of these trends were tested and found to be quite small when compared to difference between the concentrations of these parameters in groundwater and leachate and may reflect natural variations. The trends in these data samples therefore do not appear to significantly change the risk of false positive or negative determinations when used to define background. These data samples were retained for the background evaluation.

Summaries of the look back periods and the Mann-Kendall trend tests is included in Attachment B.

Statistical Test Method

The guidance documents identify the Prediction Limit test as appropriate for comparison of compliance point and background groundwater data at landfills. This method uses a prediction limit determined from background data to test future compliance data. The null hypothesis assumes that the background and compliance point data are identical so if a future datum exceeds a prediction limit it is statistically shown to not be from the background distribution and may indicate a release from the landfill.

Prediction limits were determined using procedures described in the *Unified Guidance* (Chapter 18). The guidance describes procedures for normal and non-normal (parametric and non-parametric) data. The non-spatial stationarity and non-normal distribution of data samples guided the selection of the appropriate method for determining background values for the selected parameters

Interwell or Intrawell: The previous evaluations of the hydrogeologic conditions and temporal and spatial variation of the data for the selected parameters at each well have shown that intrawell comparisons can and must be used. The statistically useful portions of the background data for each parameter at each well were identified.

Parametric or Non-parametric: About half of the data samples tested non-normal. Visual review of the box plots and trend plots shows there is significant variability within the data samples making it unlikely that a simple transformation of the non-normal data to normal can be consistently applied to all the non-parametric data samples. Further, the normal and non-normal data samples appear to be mixed within most wells and between wells. This suggests that the distribution of the groundwater chemistry represented by the data samples of the parameters can and does vary spatially and temporally. The distribution of data within the data samples may also vary with the size of the sample. Use of non-parametric Prediction Limits avoids potential pitfalls of the potentially unknown data distributions.

Non-parametric Prediction Limit Test Method

Section 18.3 of the Unified Guidance describes a non-parametric prediction limit for comparison of future parameter values with background. The non-parametric prediction limit for a parameter is defined as the highest or second highest value within the background data sample. Outliers are to be removed from the background data sample and the sample tested for stationarity before a data sample is used for prediction limit testing. Future values for a parameter are compared to its prediction limit. If the value exceeds the prediction limit the null hypothesis is not accepted indicating the value may not be of the same population.

Significant restraints to the use of a non-parametric prediction limit are that the confidence interval (CI) requires a large background data sample and that the CI is not adjustable. The CI is calculated as $j/n+m$ where j is the rank of the value selected as the prediction limit, n is the number of data and m is the number of future values to be compared to the prediction limit. An acceptably high CI of above 95% can be achieved for the intrawell data samples at the Headquarters Landfill because the background data samples are large and one future value will be tested each quarter. Most of the data samples exceed n=40 with a few as small as 18 to 20. The CI is therefore between 95 and 98% for the background data samples if the highest value in the data sample is used as the prediction limit. If the second highest value is used the CI would be reduced to 89.5% for a few samples while most samples exceed 95%.

Background Levels

Selecting the highest ranked value in the background data sample as the prediction limit provides the highest confidence that a future value exceeding the prediction limit is not of the same population and is not a false positive. These values are summarized on Table 2.

Statistically Significant Increase (SSI) Criteria

Future compliance well parameter results will be compared to the Prediction Limits determined by these procedures. If a datum is above its prediction limit, retesting will be performed. Retest data must be independent and the guidance suggests that this typically requires two months between samples depending on the hydrogeologic conditions at the well. As a practical matter, it is often two or more months before the samples can be analyzed, the data validated, an exceedance of a prediction limit confirmed and resampling scheduled. In the context of a quarterly monitoring it is therefore practical to use the datum from the next scheduled sampling event for the retest.

Retesting differs from verification sampling in that the resample data is incorporated in the statistical properties of the sampling program. The data generated by retesting can therefore be tested by the prediction limit determination and included in the database. Verification samples may not be temporally independent.

If the retest datum is below the prediction limit the test passes and there is no SSI. If the retest fails, an SSI occurs for that parameter at that well. The initial response will be to evaluate the potential for this SSI being a false positive and evaluate the site wide false positive rate (SWFPR) as described in Chapter 19.2 of the *Unified Guidance*. The parameter will be evaluated with consideration of whether SSIs have occurred in the past and/or SSIs have occurred for other parameters at that well. Actions may be required if SSIs have occurred for a significant number of parameters downgradient of the landfill area. Cowlitz County proposes detailed review of the downgradient and background data for the landfill area as part of an initial action. This review will investigate if the SSIs are valid and evaluate the potential threat to environmental receptors.

WAC 173-351-440 requires assessment monitoring in response to an SSI. Assessment monitoring includes additional sampling events and parameters that require large volumes of water. The low yield of the wells at the Headquarters Landfill makes such sampling problematic. If future SSIs are determined to be significant at the Headquarters Landfill, Cowlitz County proposes to review the location of the SSIs relative to the waste stream in that part of the landfill to develop a more focused investigation than the assessment monitoring specified in the WAC.

References:

Bright Fields Groundwater, 2024. Sampling and Analysis Plan for the Cowlitz County Headquarters Landfill (Revised March 2024). March 5.

Carter, C. et al, Revised 2018. *Guidance for Monitoring at Landfills and Other Facilities Regulated Under Chapters 173-304, 173-306, 173-350, and 173-351 WAC*, Washington State Department of Ecology Publication 12-07-072, December.

Tuppan, E., 2013. *Hydrogeologic Characterization Report for the Proposed Cowlitz County Headquarters Landfill Project.*

Washington, State of, 2015. *Chapter 173-351 WAC Criteria for Municipal Solid Waste Landfills*. October 6.

USEPA, 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance,* Office of RCRA, Program Implementation and Information Division, March.

Table 1
Headquarters Landfill
Prediction Limits

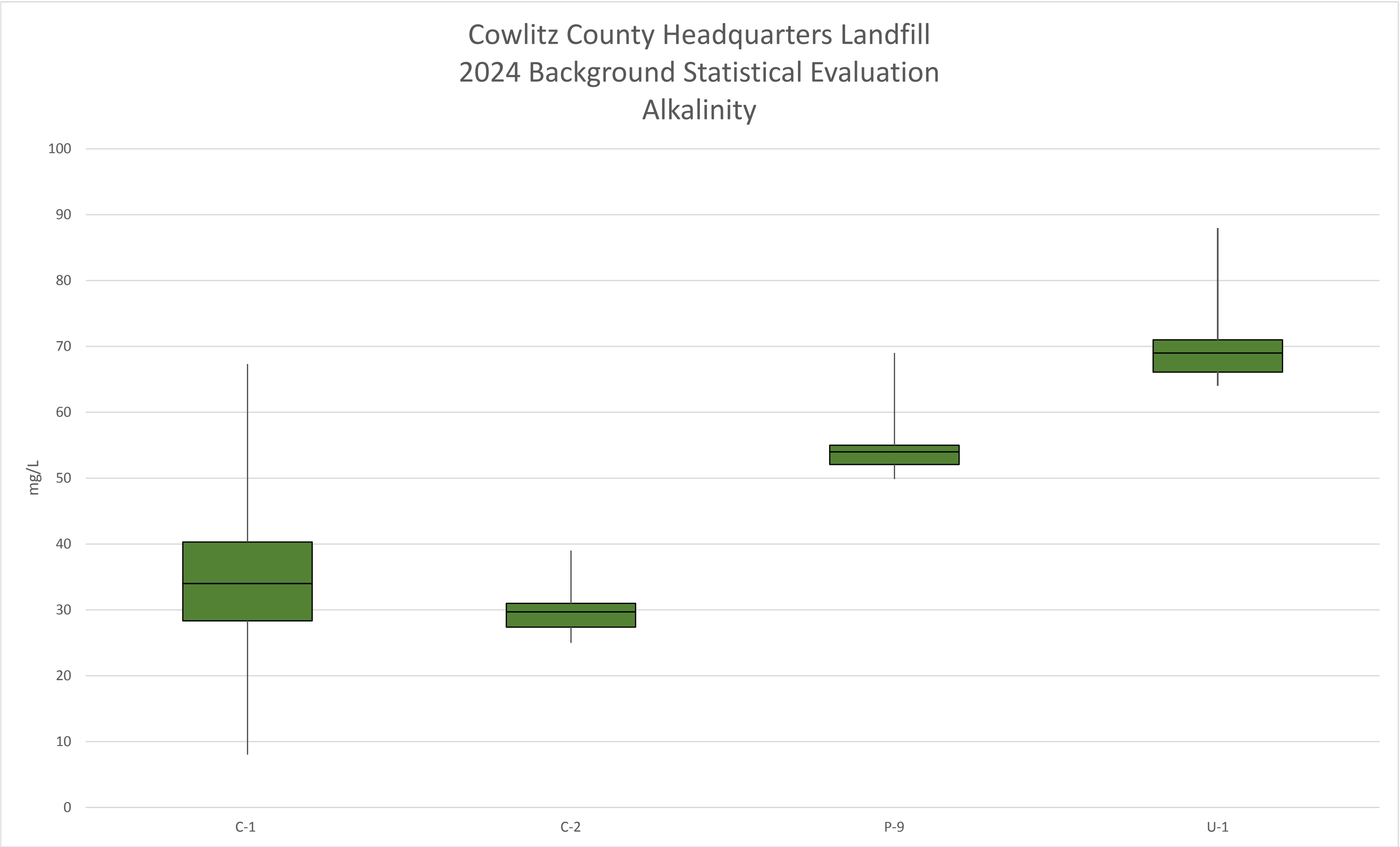
Note: Non-parametric prediction limit is highest concentration in intrawell background data samples.
Confidence interval >95% when one future value tested.
Concentrations are mg/L inorganic parameter and ug/L for metals.

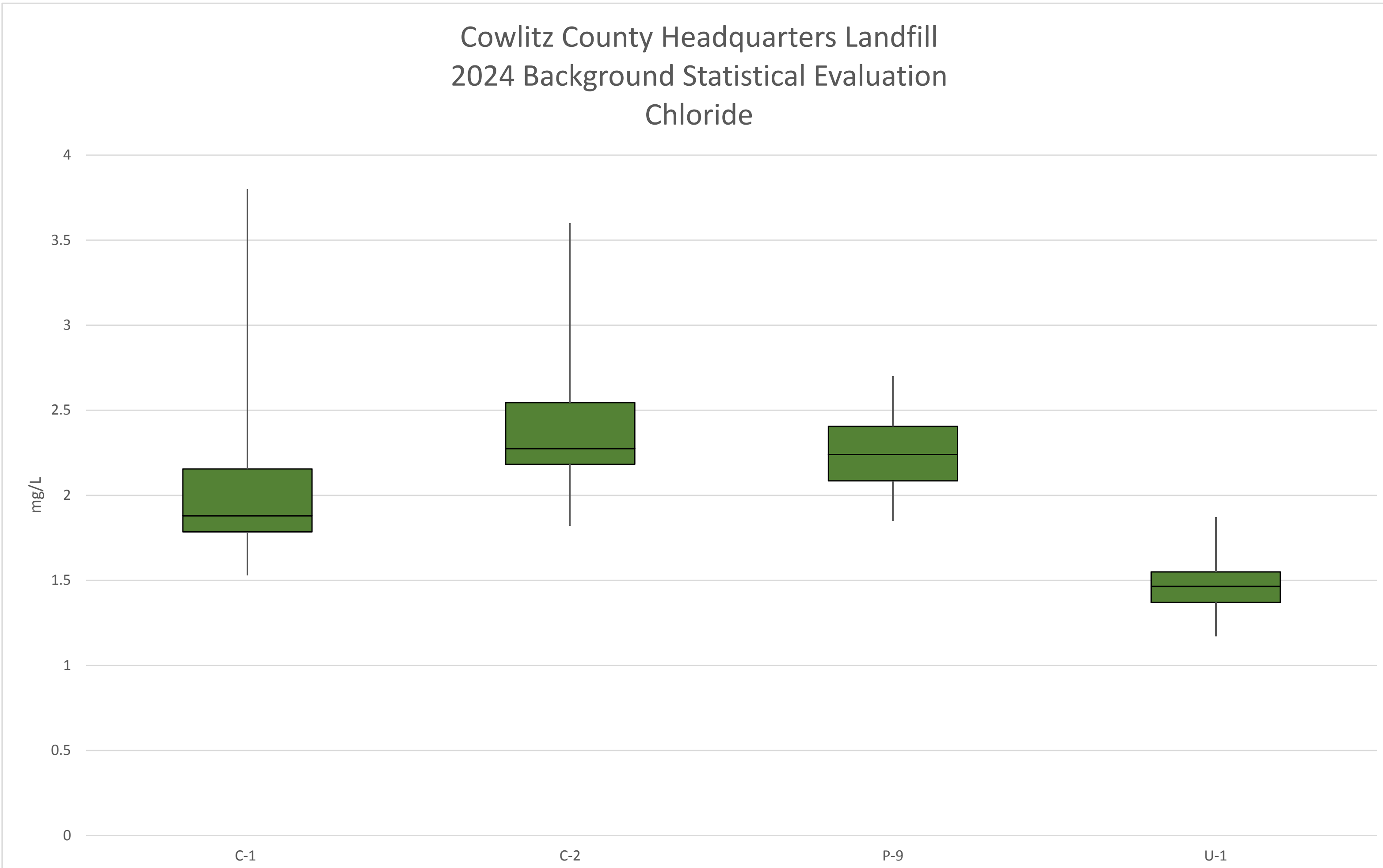
Well: Parameter	C-1	C-2
Alkalinity	67.3	39
Chloride	2.94	3.6
Sulfate	0.64	1.69
TDS	118	75
Barium	7.9	9.4
Cadmium	0.02	0.024
Chromium	0.28	0.28
Copper	0.33	0.7
Nickel	0.24	0.54
Zinc	1.7	2.07
Calcium	11400	3630
Magnesium	5270	1830
Manganese	9.6	133
Potassium	1390	990
Sodium	7940	9960

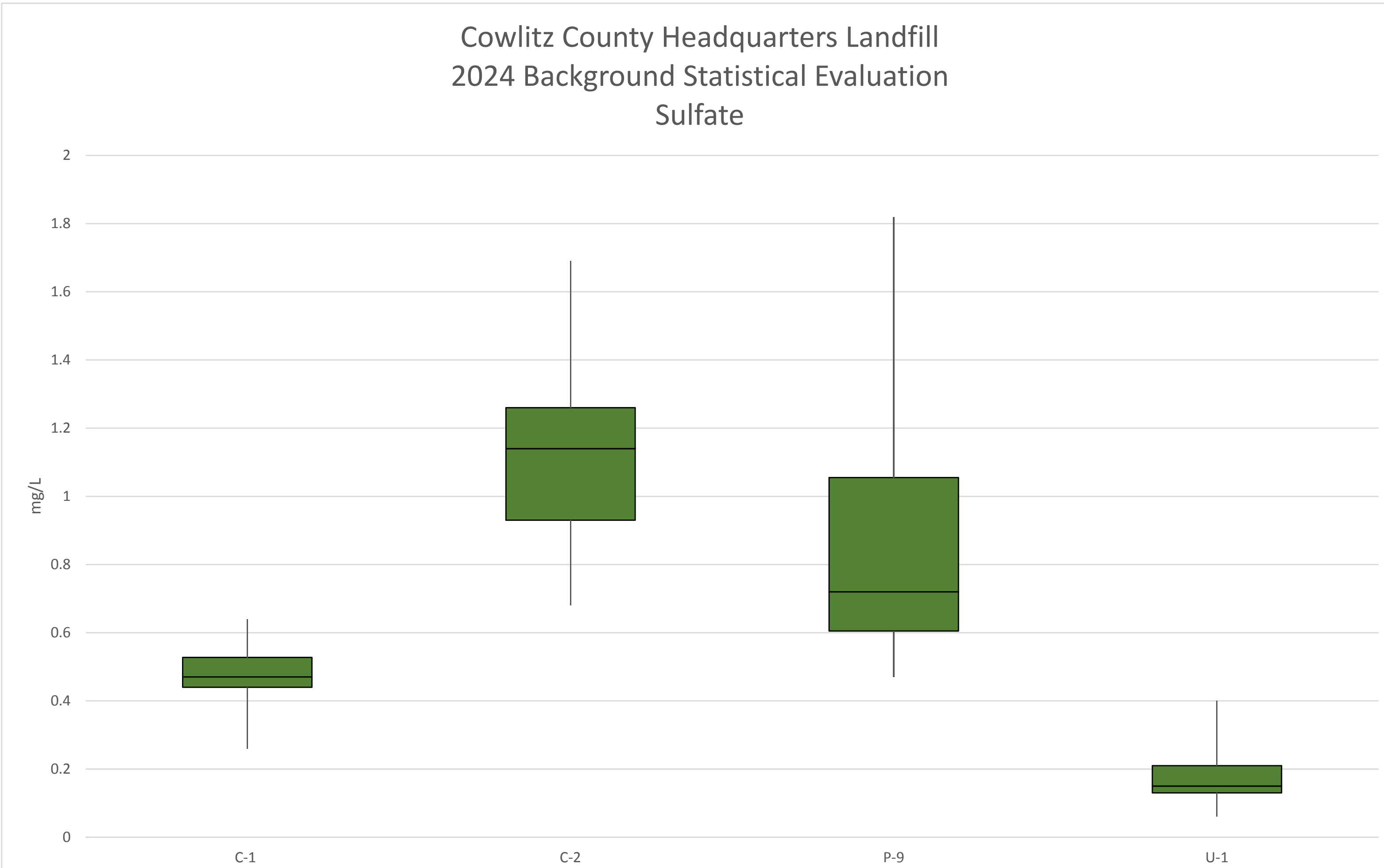
Headquarters Landfill
Shapiro-Wilk Method Normality Test Results

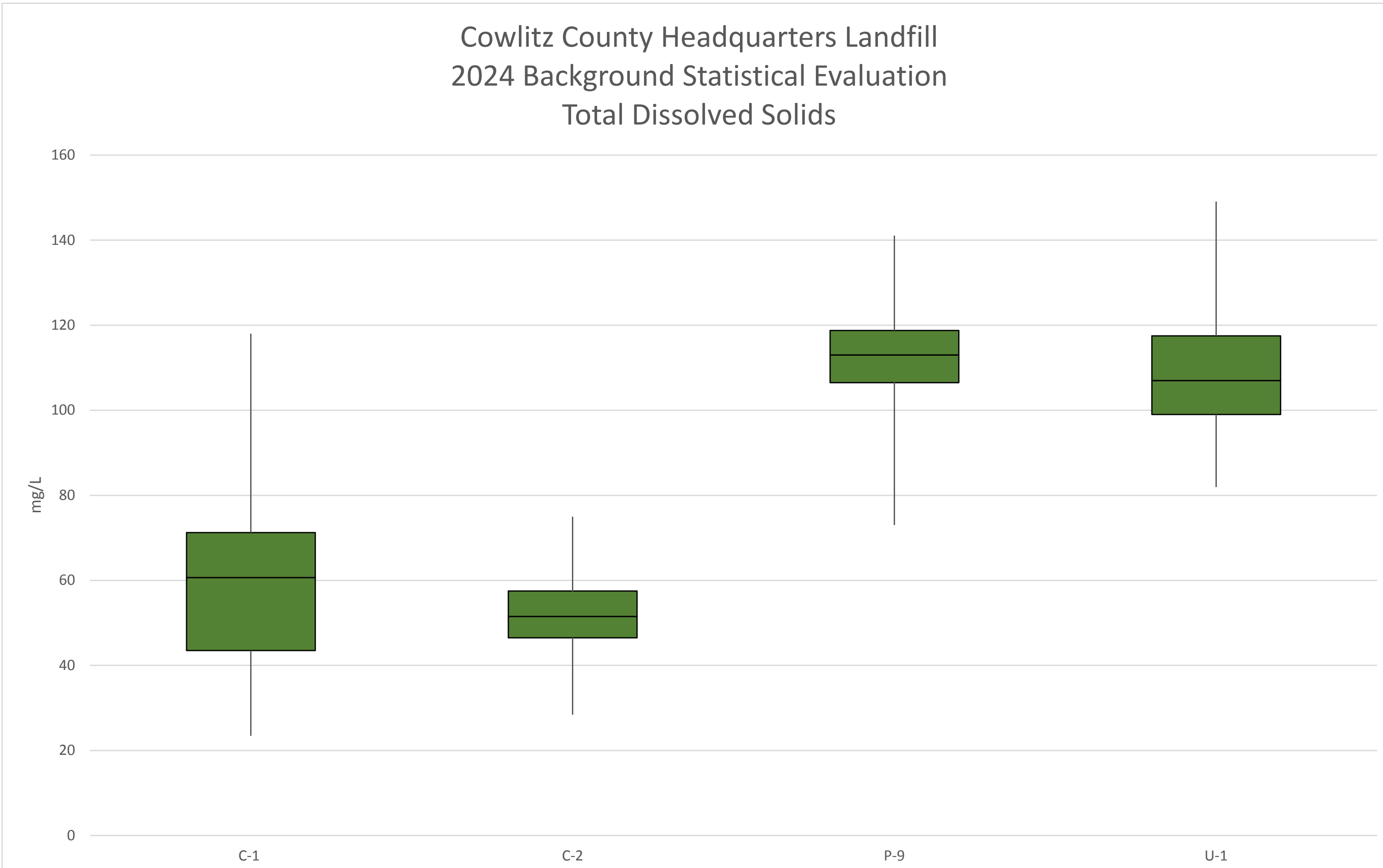
not rejected p-value>0.05
rejected p-value<0.05

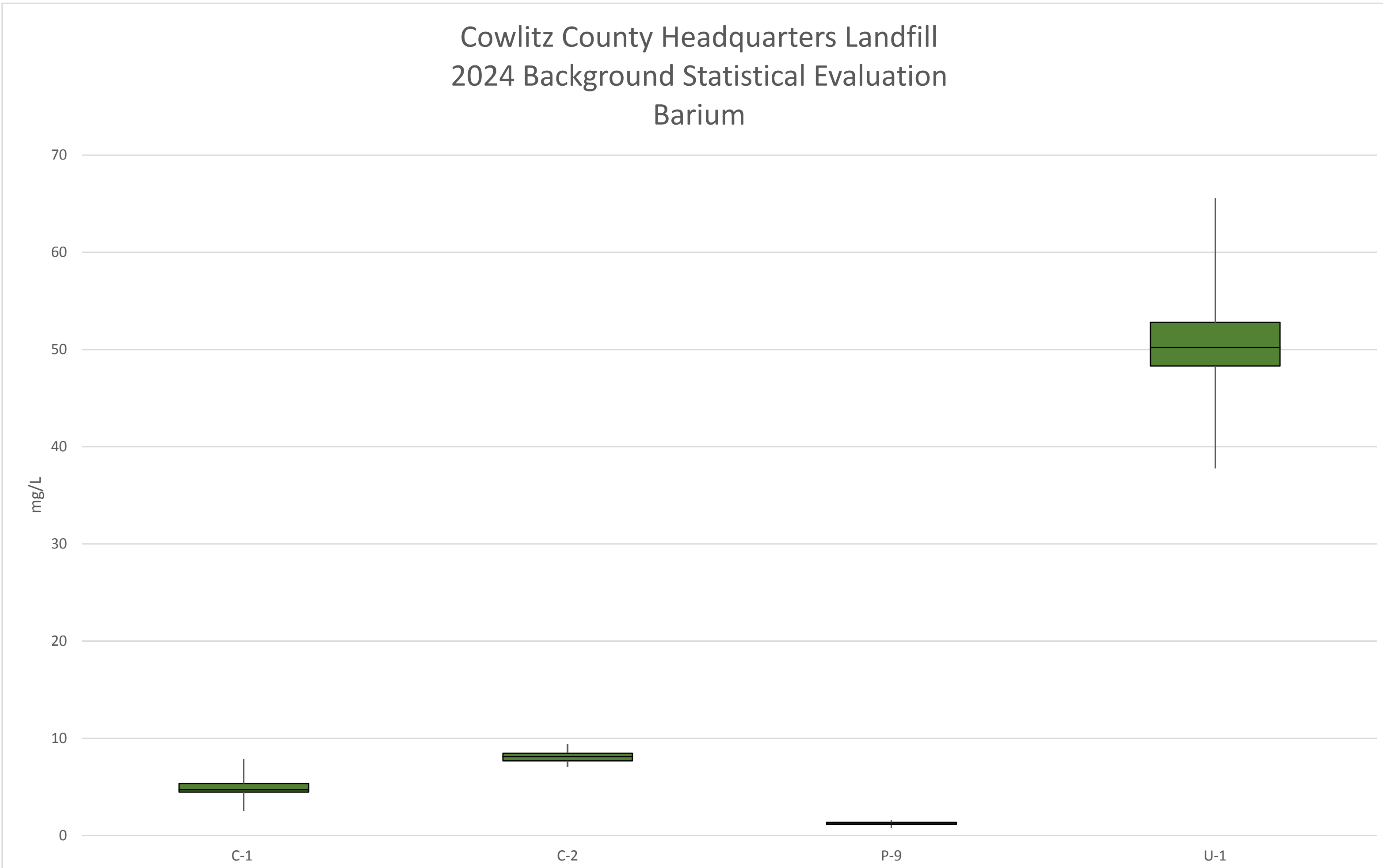
Well	C-1	C-2	P-9	U-1	Count	Count
Parameter					not rejected	rejected
Alkalinity	not rejected	rejected	rejected	rejected	1	3
Chloride	rejected	rejected	not rejected	not rejected	2	2
Sulfate	not rejected	not rejected	rejected	rejected	2	2
TDS	not rejected	not rejected	rejected	not rejected	3	1
Barium	not rejected	not rejected	not rejected	rejected	3	1
Cadmium	not rejected	not rejected	rejected	not rejected	3	1
Chromium	not rejected	not rejected	rejected	rejected	2	2
Copper	rejected	rejected	rejected	rejected	0	4
Nickel	rejected	rejected	rejected	rejected	0	4
Zinc	not rejected	rejected	rejected	not rejected	2	2
Calcium	not rejected	not rejected	not rejected	not rejected	4	0
Magnesium	not rejected	rejected	not rejected	not rejected	3	1
Manganese	rejected	rejected	rejected	not rejected	1	3
Potassium	rejected	rejected	not rejected	not rejected	2	2
Sodium	not rejected	not rejected	not rejected	not rejected	4	0
					32	28
					2.13	1.87
not reject Count	10	7	6	9	32	8
rejected Count	5	8	9	6	28	7


Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Alkalinity
mg/L
100
90
80
70
60
50
40
30
20
10
0
C-1
C-2
P-9
U-1

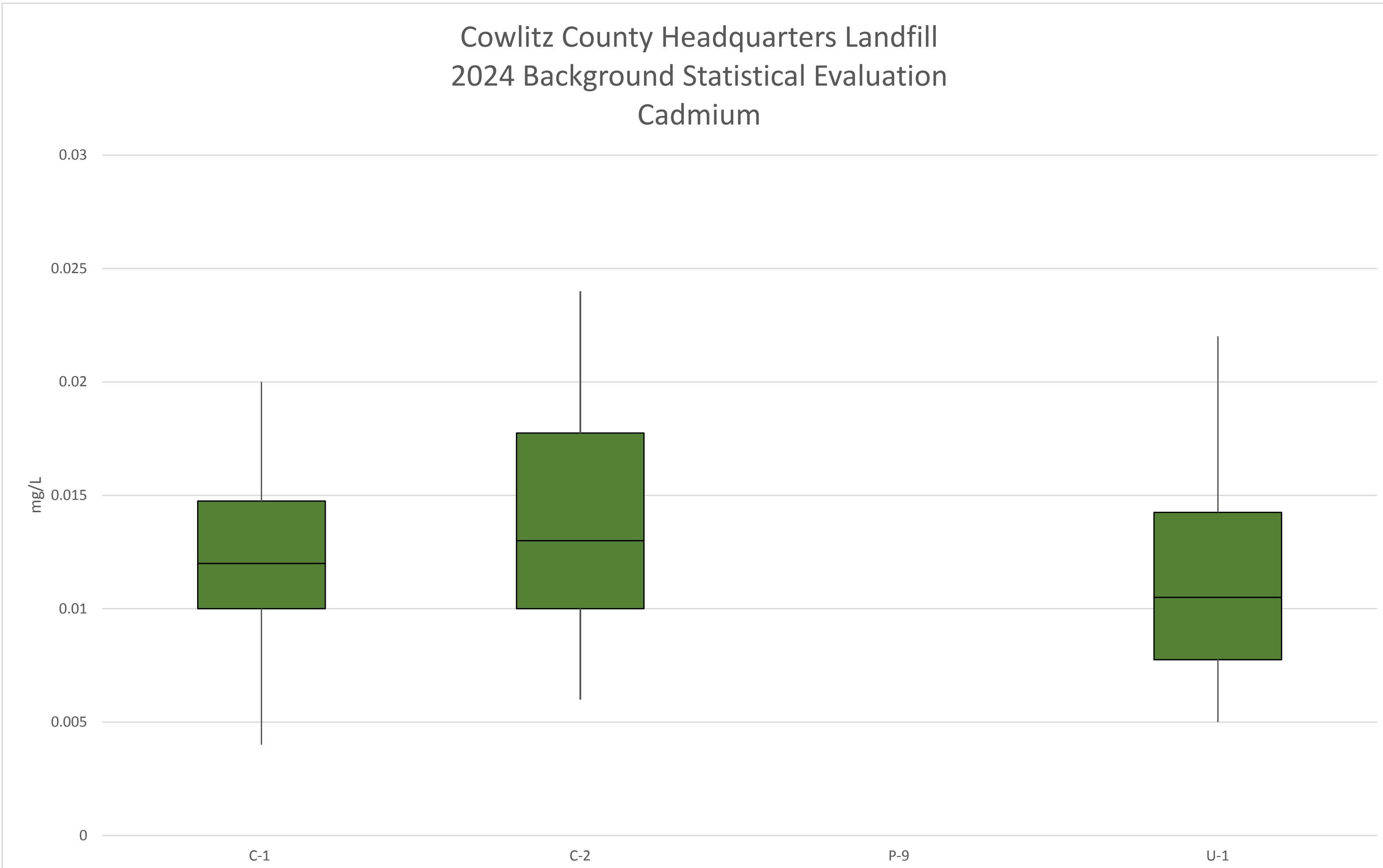

Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Chloride
mg/L
4
3.5
3
2.5
2
1.5
1
0.5
0
C-1
C-2
P-9
U-1

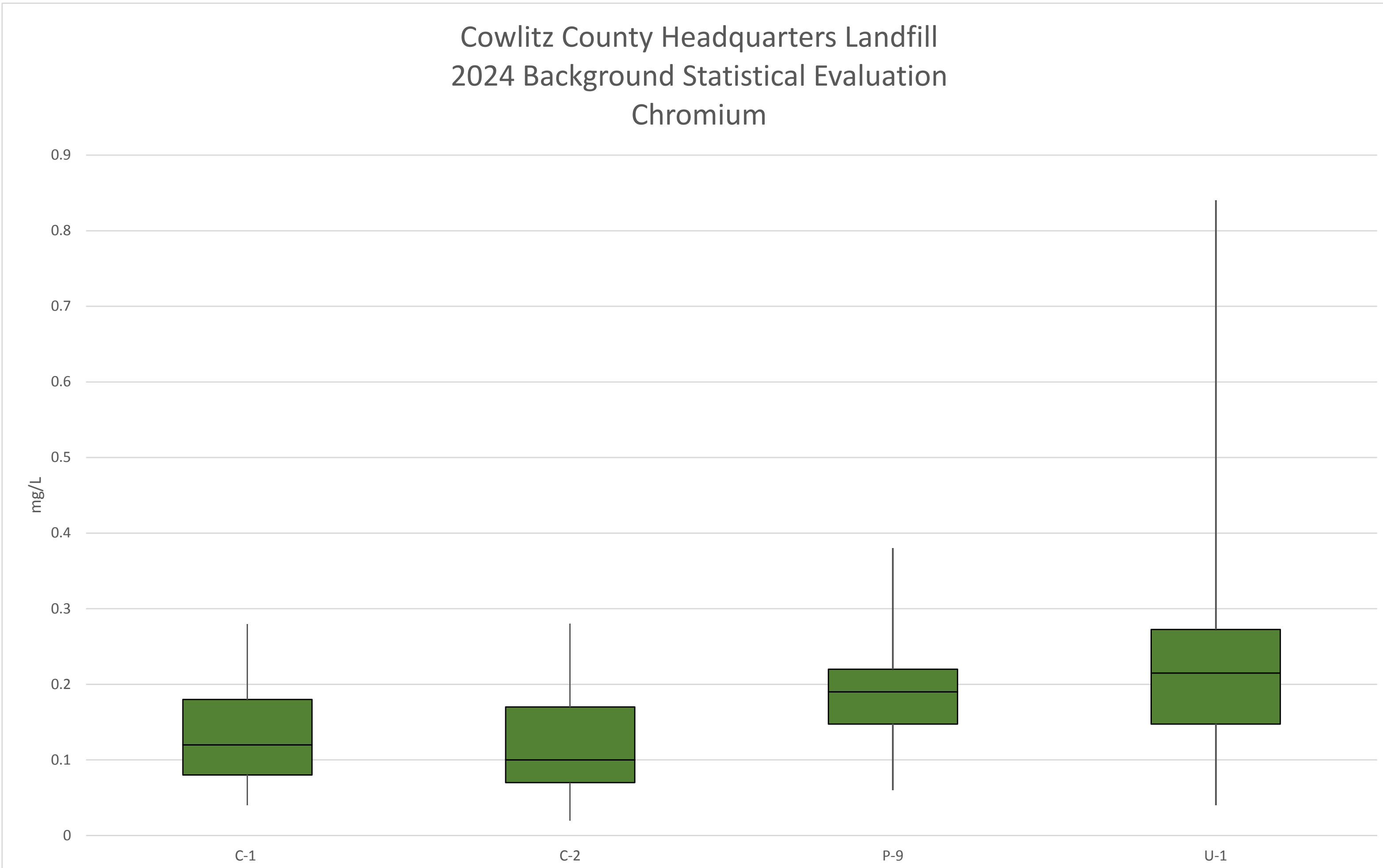

Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Sulfate
mg/L
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
C-1
C-2
P-9
U-1

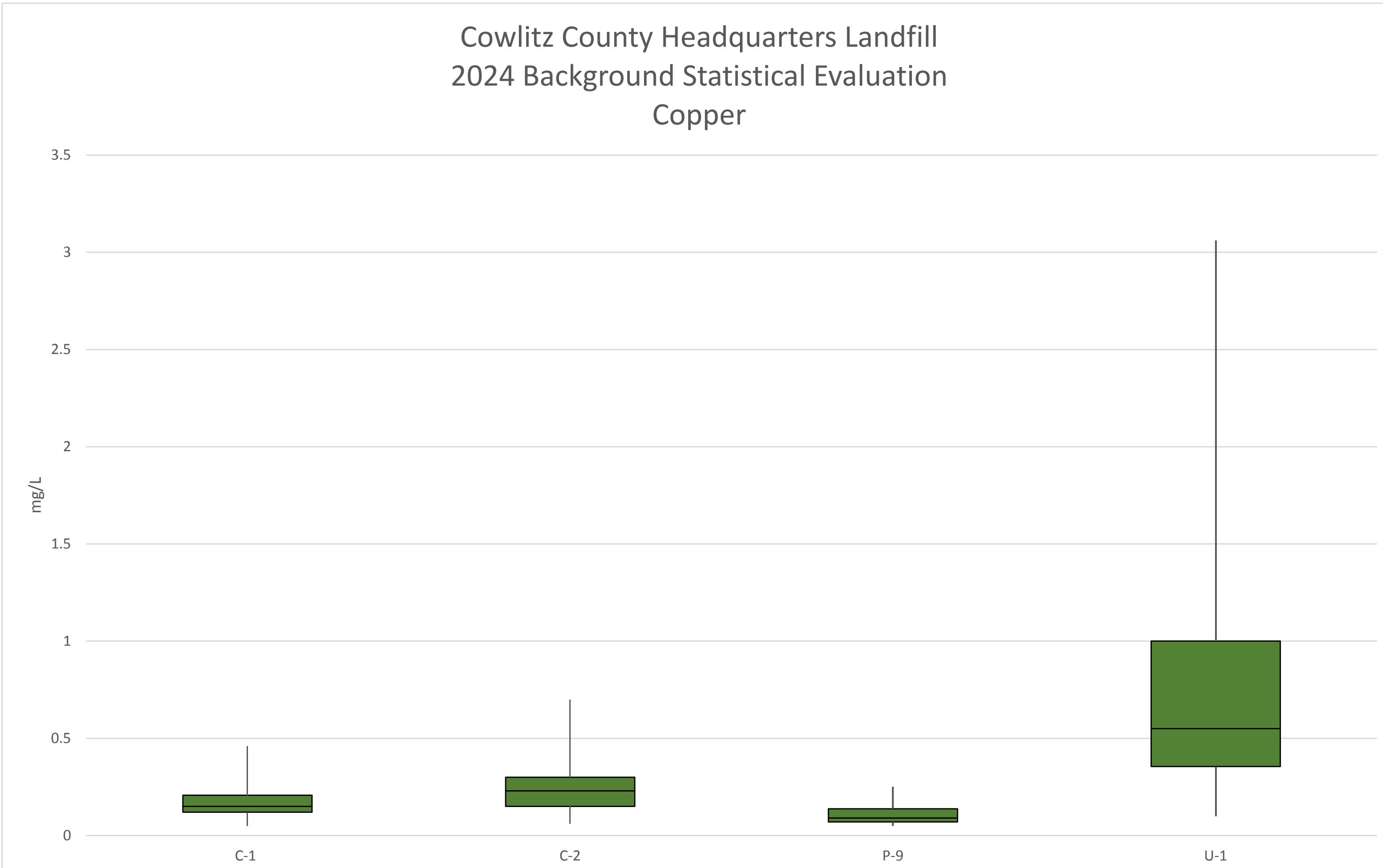

Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Total Dissolved Solids
mg/L
0
20
40
60
80
100
120
140
160
C-1
C-2
P-9
U-1

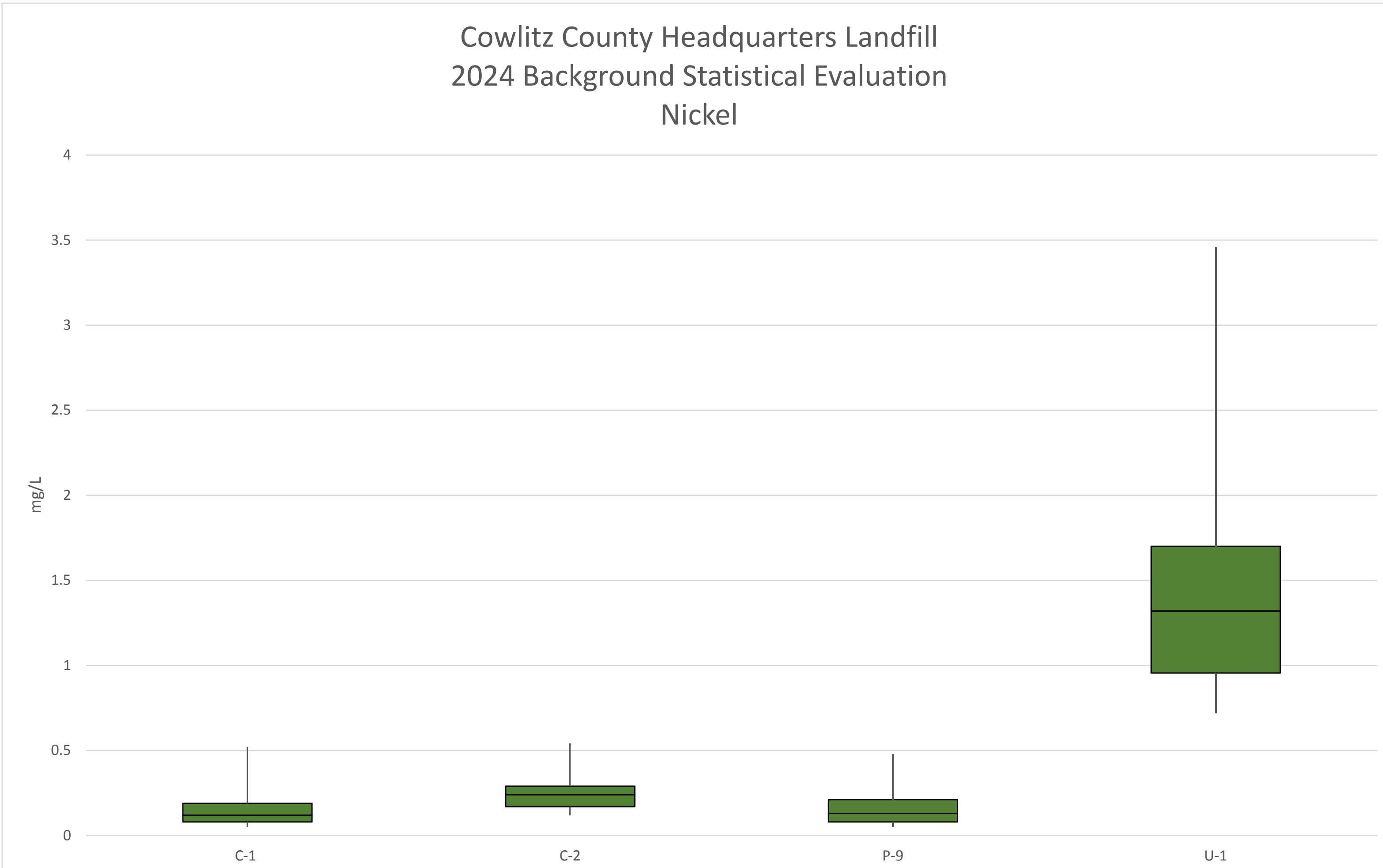


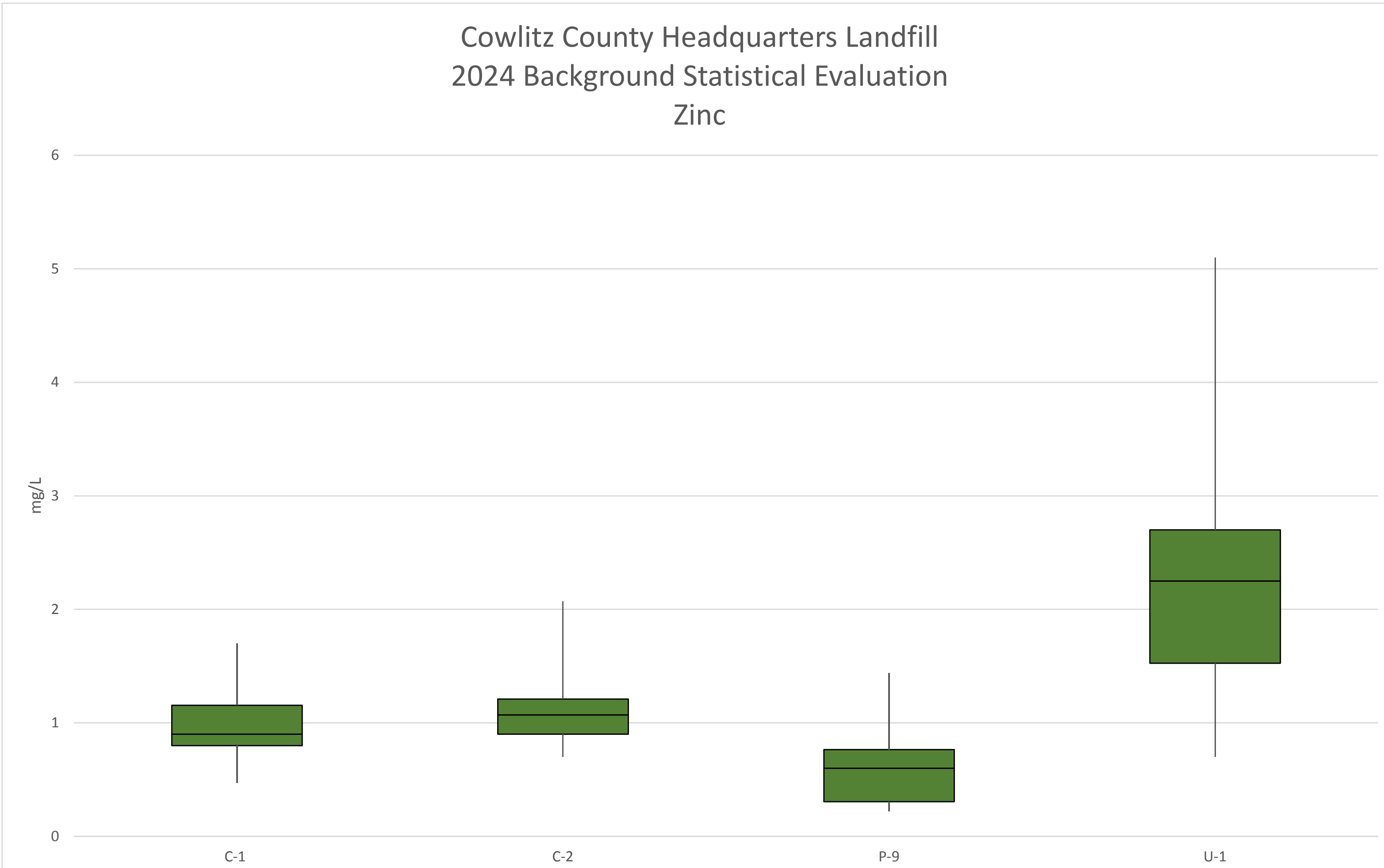
Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Barium
mg/L
70
60
50
40
30
20
10
0
C-1
C-2
P-9
U-1


Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Cadmium
mg/L
0.03
0.025
0.02
0.015
0.01
0.005
0
C-1
C-2
P-9
U-1

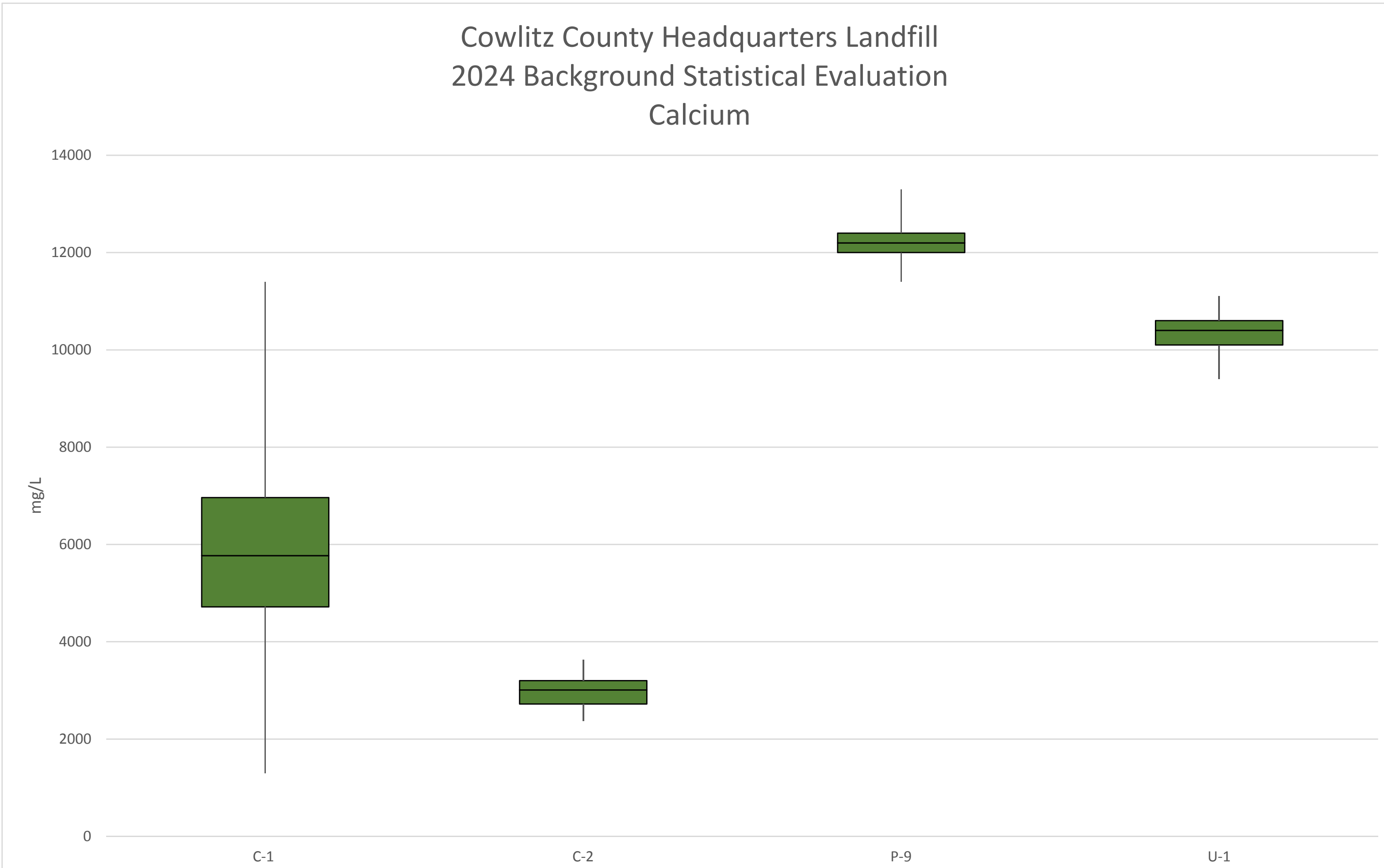

Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Chromium
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
mg/L
C-1
C-2
P-9
U-1


Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Copper
mg/L
3.5
3
2.5
2
1.5
1
0.5
0
C-1
C-2
P-9
U-1

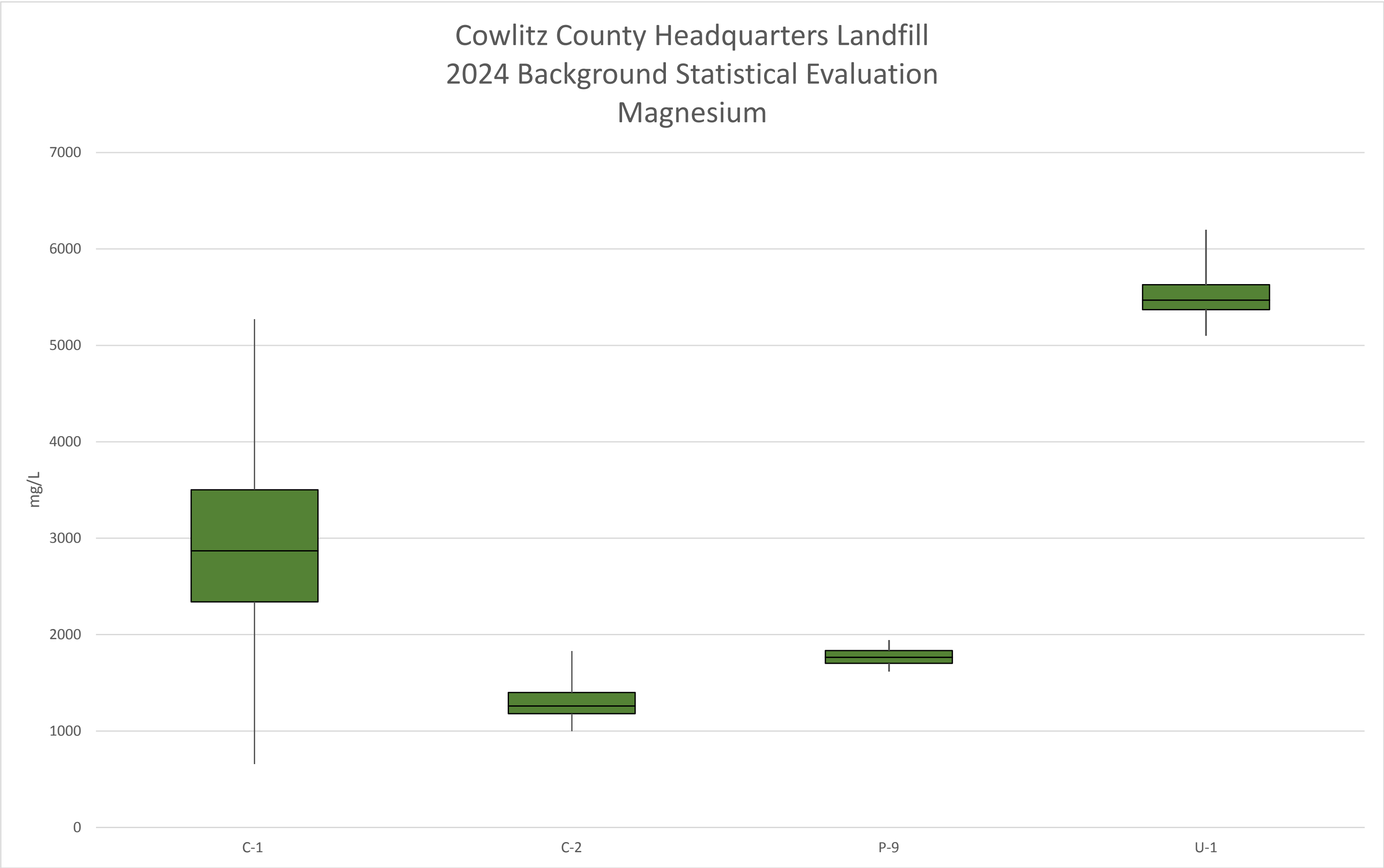

Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Nickel
mg/L
4
3.5
3
2.5
2
1.5
1
0.5
0
C-1
C-2
P-9
U-1

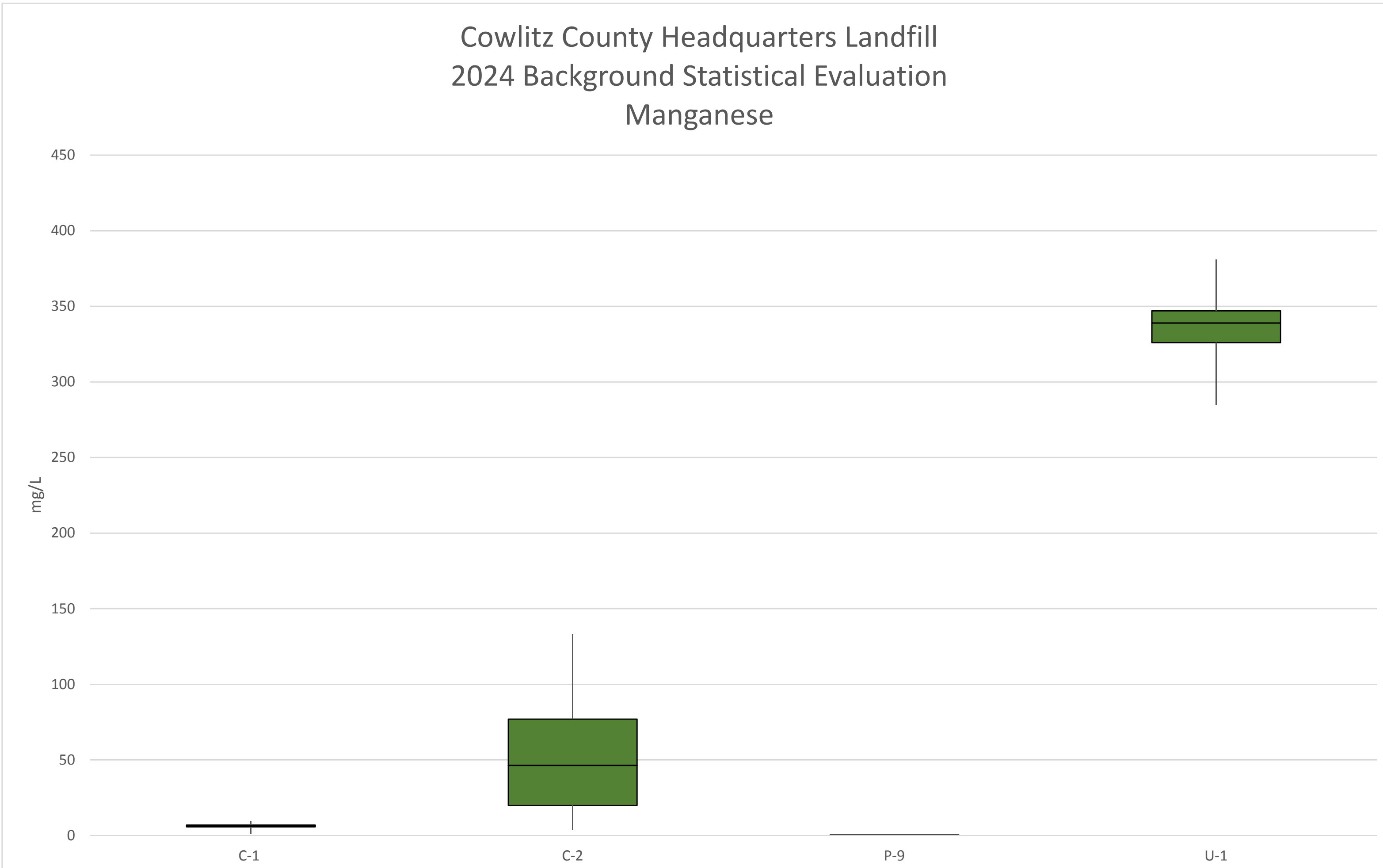


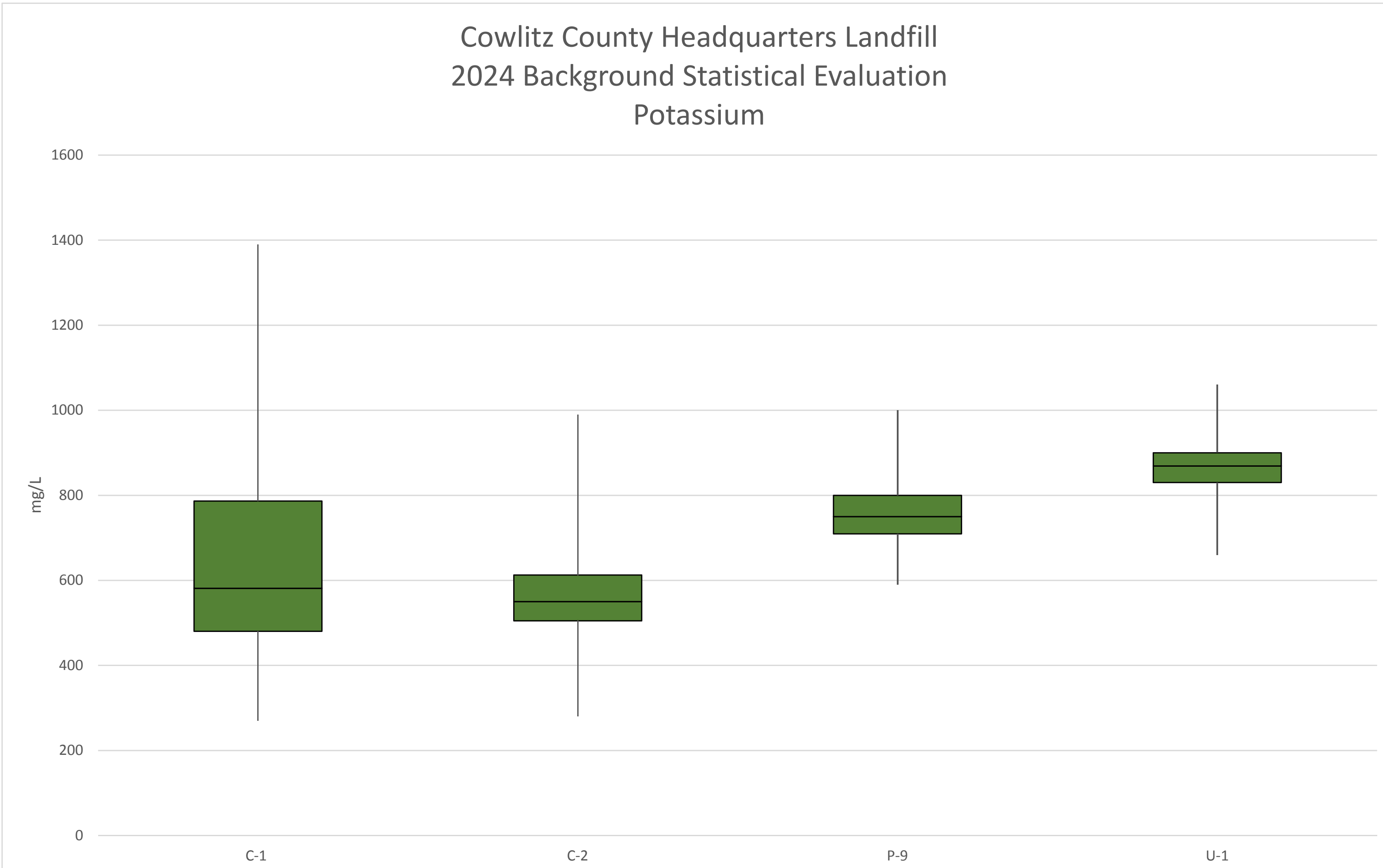
Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Zinc
mg/L
6
5
4
3
2
1
0
C-1
C-2
P-9
U-1

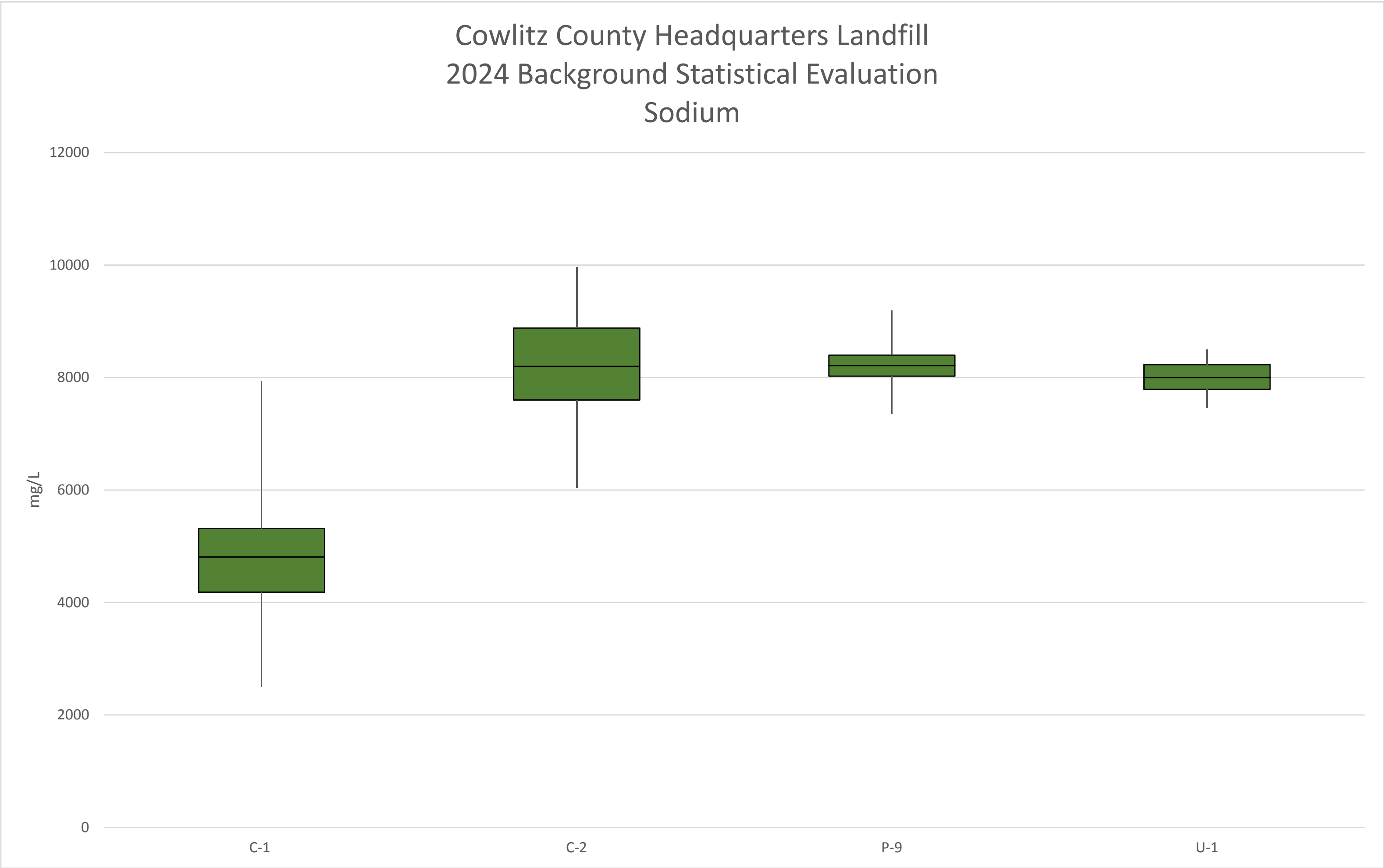


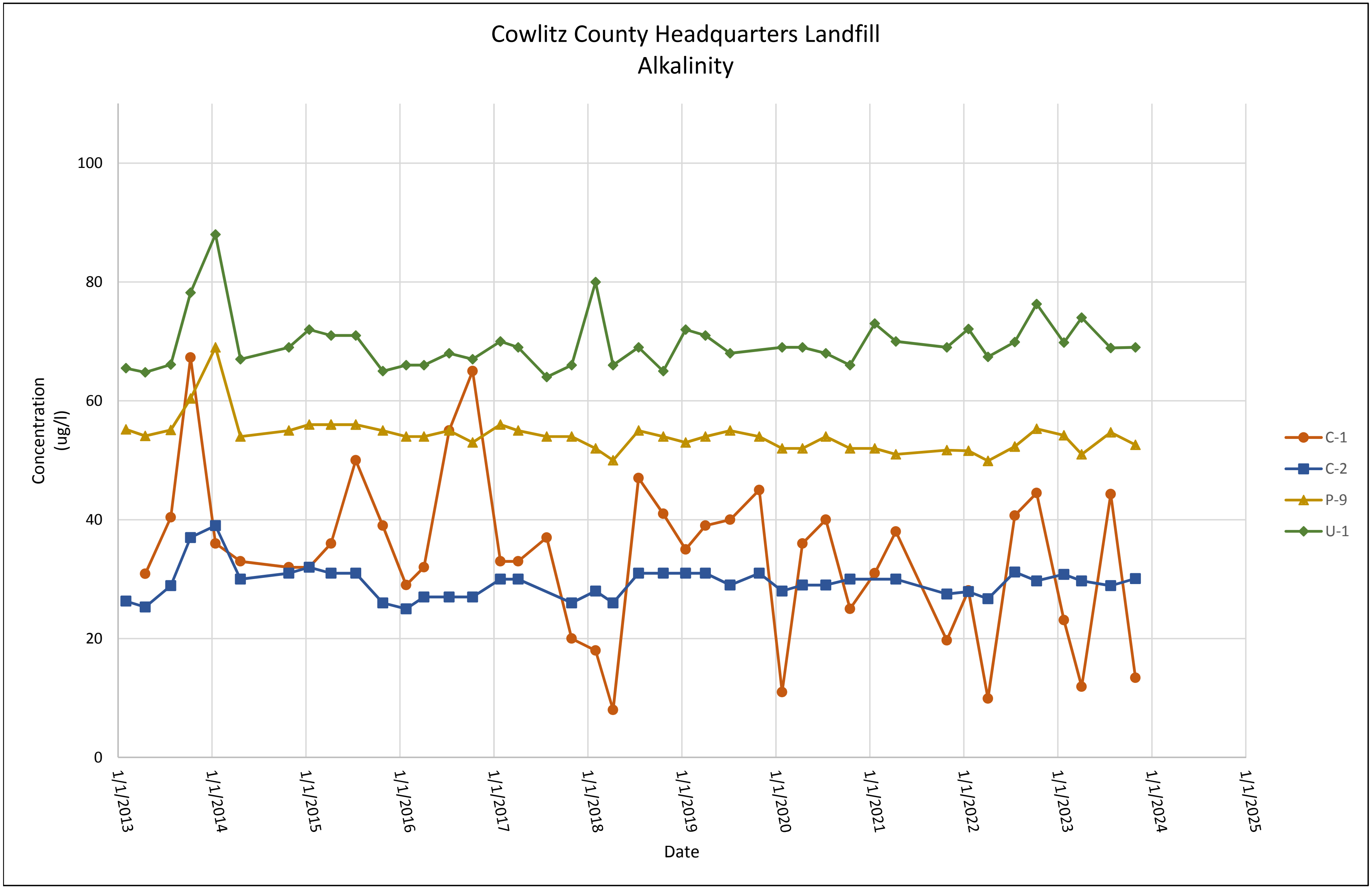
Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Calcium
14000
12000
10000
8000
6000
4000
2000
0
mg/L
C-1
C-2
P-9
U-1

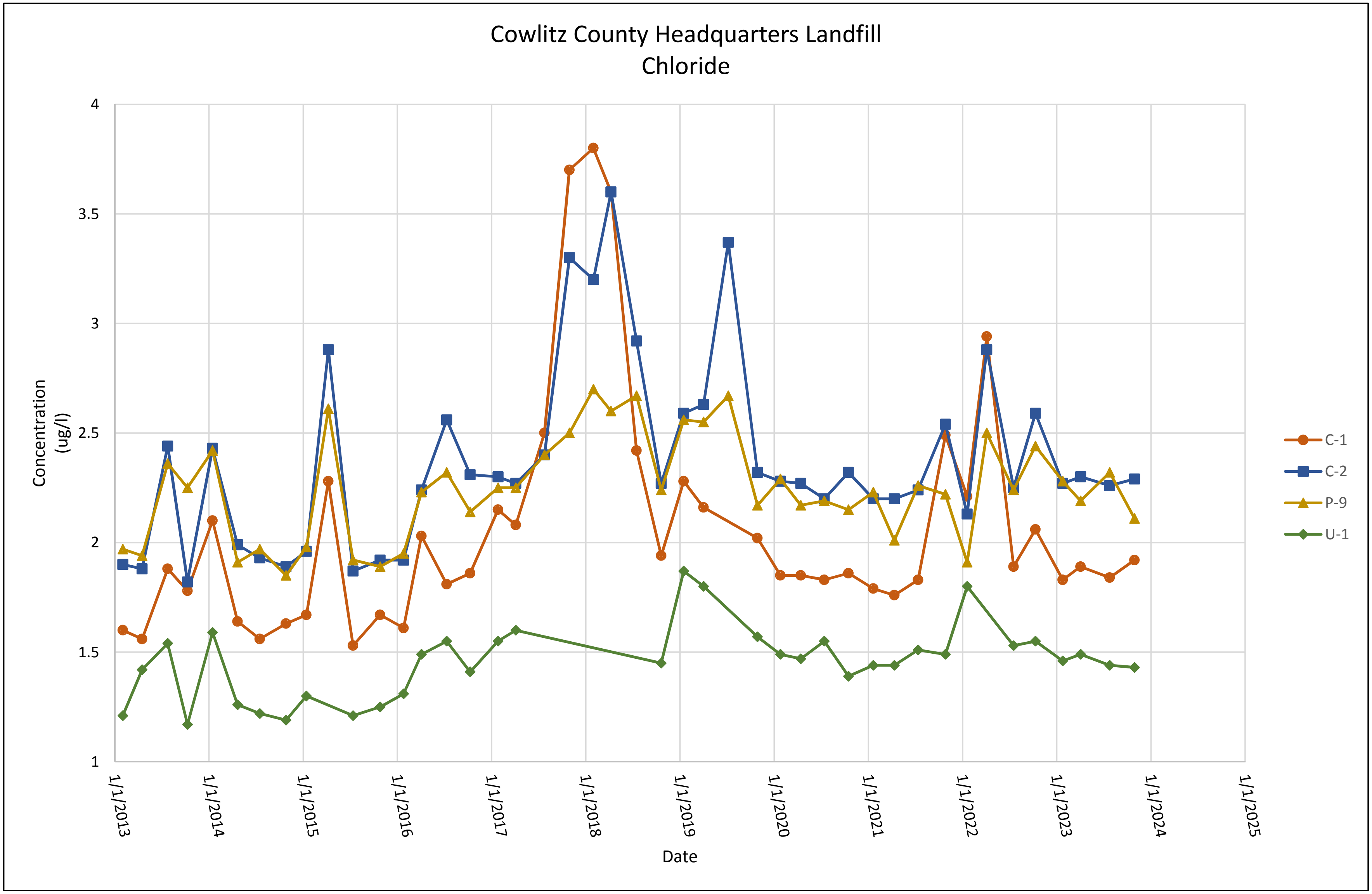

Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Magnesium
mg/L
7000
6000
5000
4000
3000
2000
1000
0
C-1
C-2
P-9
U-1

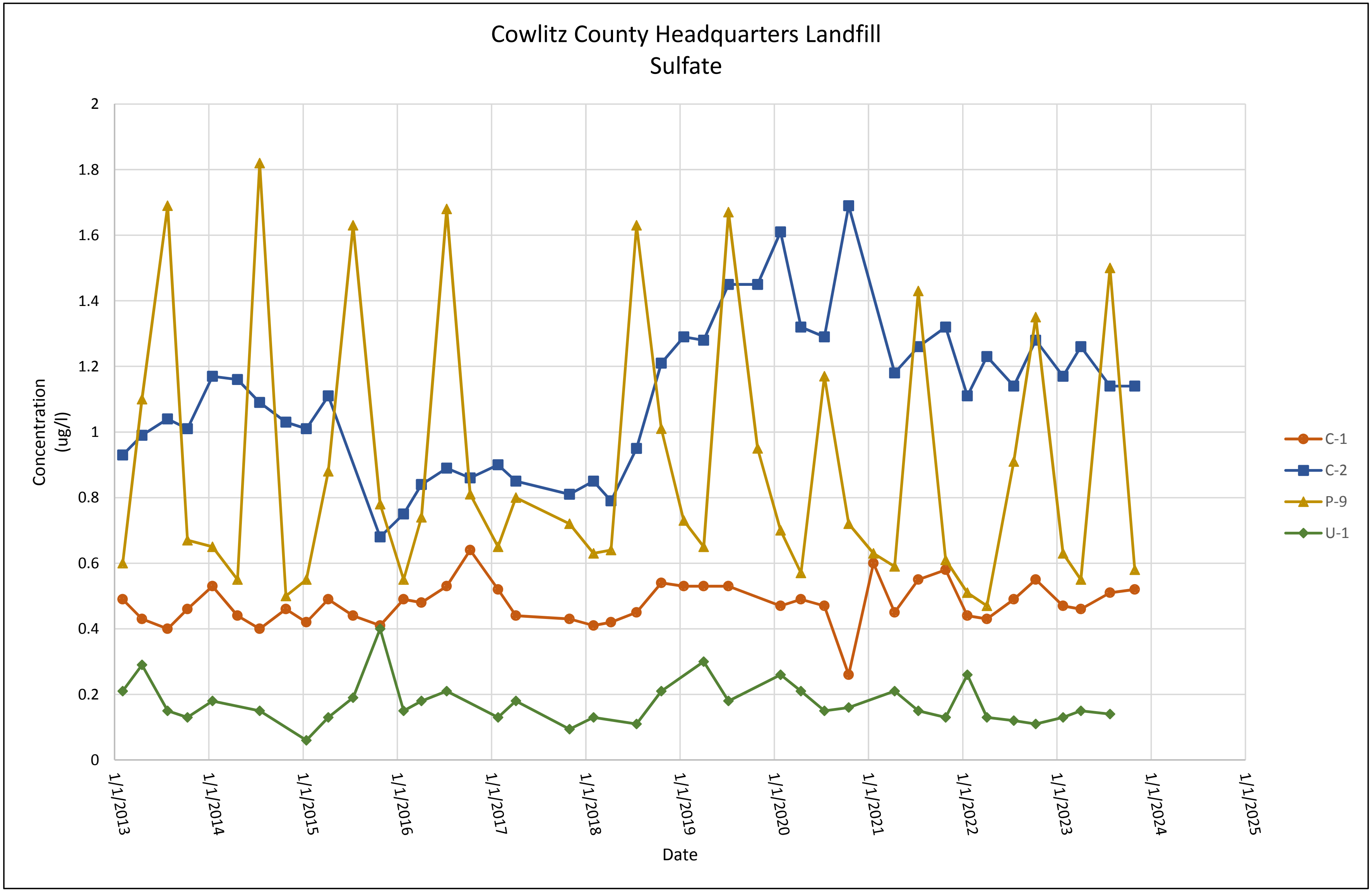

Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Manganese
mg/L
450
400
350
300
250
200
150
100
50
0
C-1
C-2
P-9
U-1


Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Potassium
mg/L
1600
1400
1200
1000
800
600
400
200
0
C-1
C-2
P-9
U-1

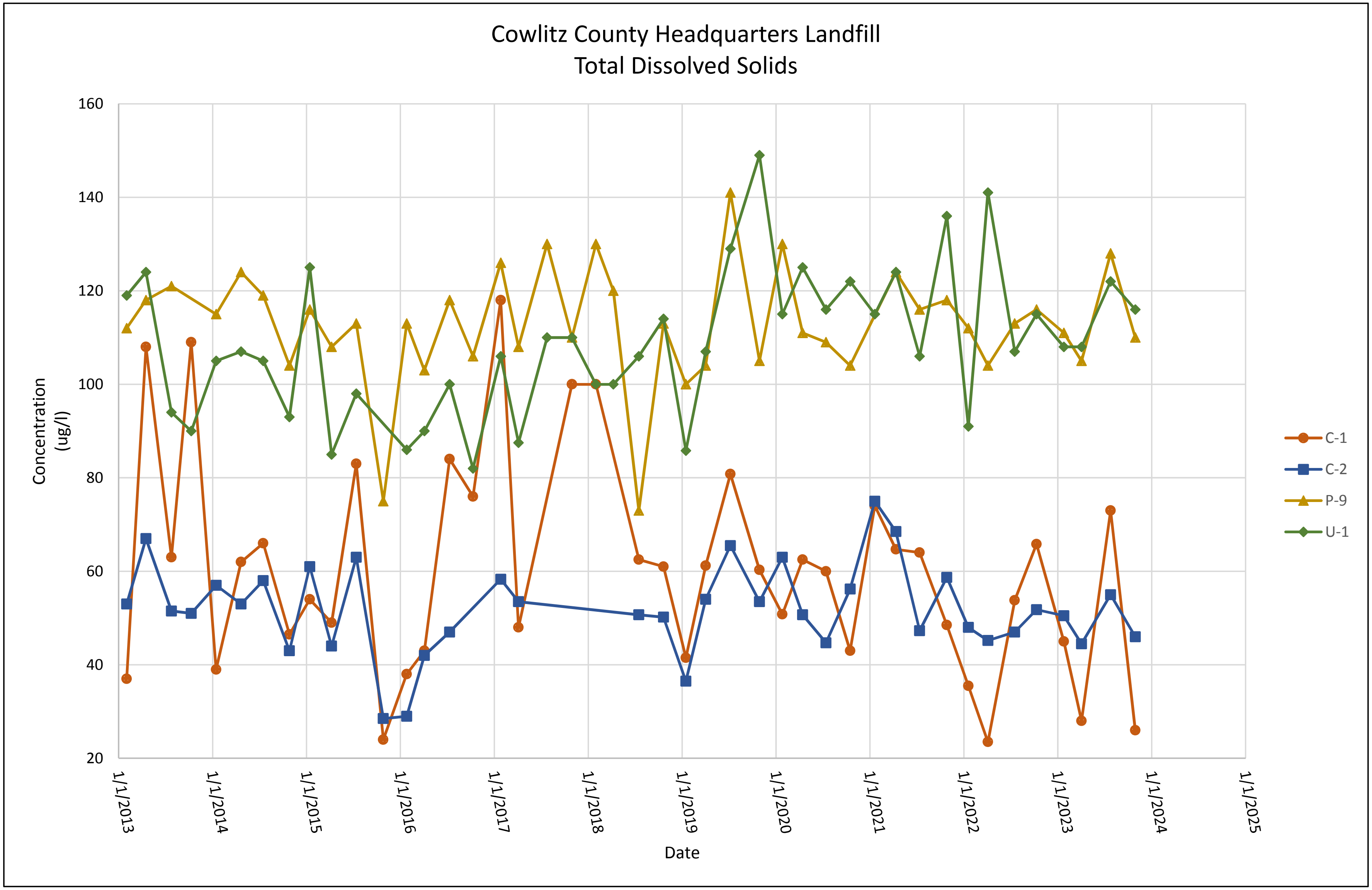

Cowlitz County Headquarters Landfill
2024 Background Statistical Evaluation
Sodium
12000
10000
8000
6000
4000
2000
0
mg/L
C-1
C-2
P-9
U-1

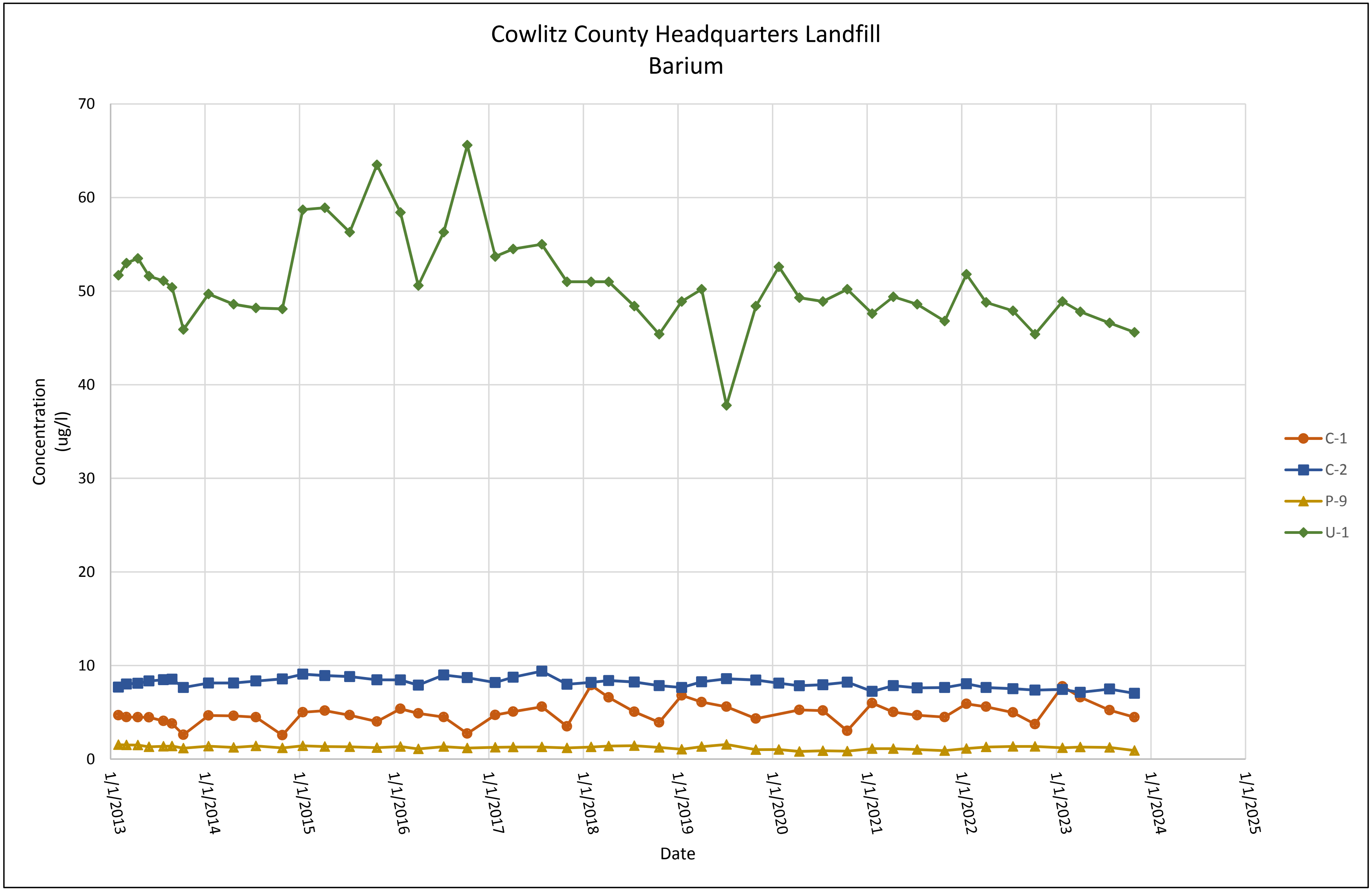

Cowlitz County Headquarters Landfill
Alkalinity
Concentration (ug/l)
0
20
40
60
80
100
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1


Cowlitz County Headquarters Landfill
Chloride
Concentration
(ug/l)
4
3.5
3
2.5
2
1.5
1
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1

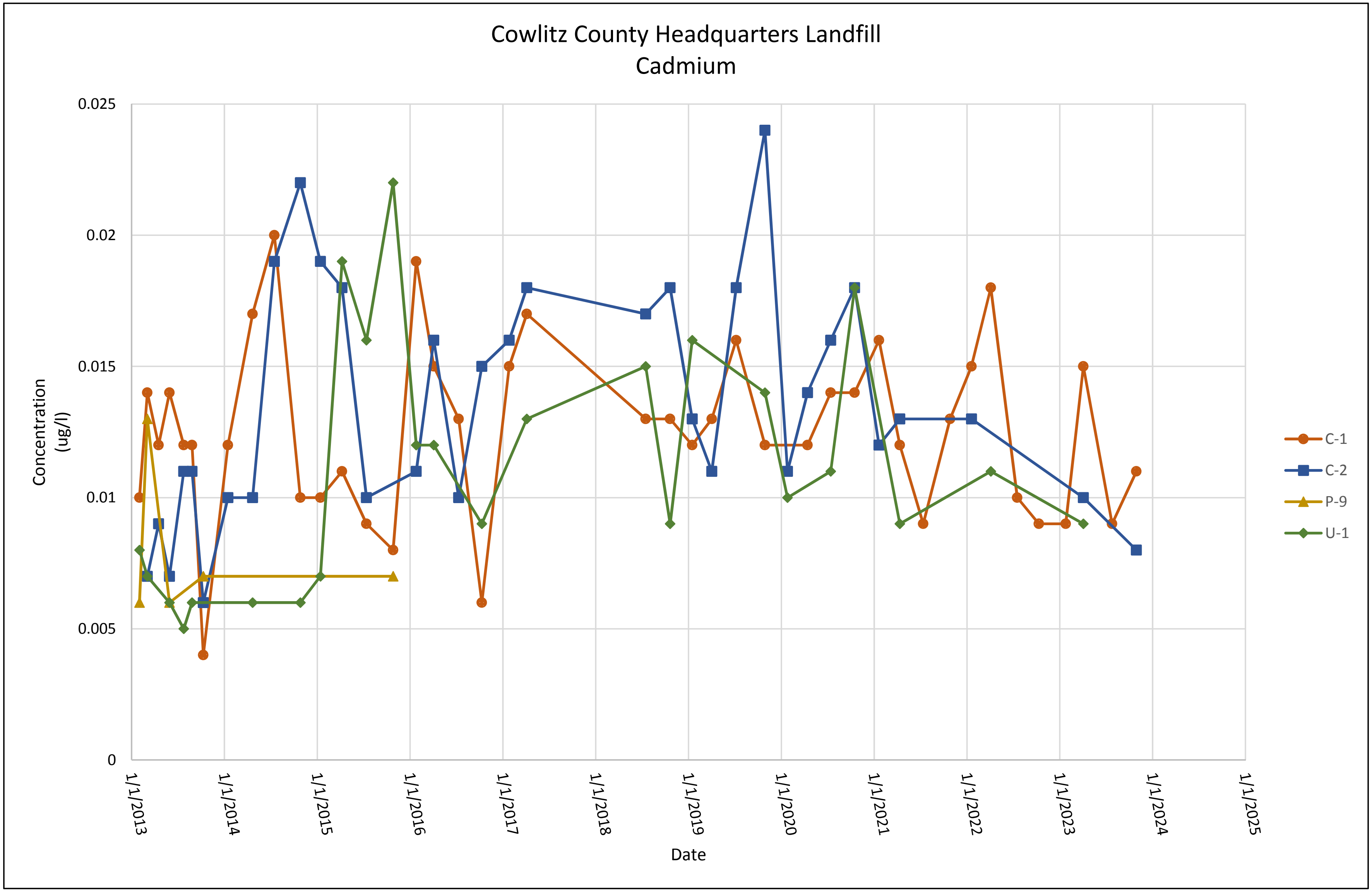


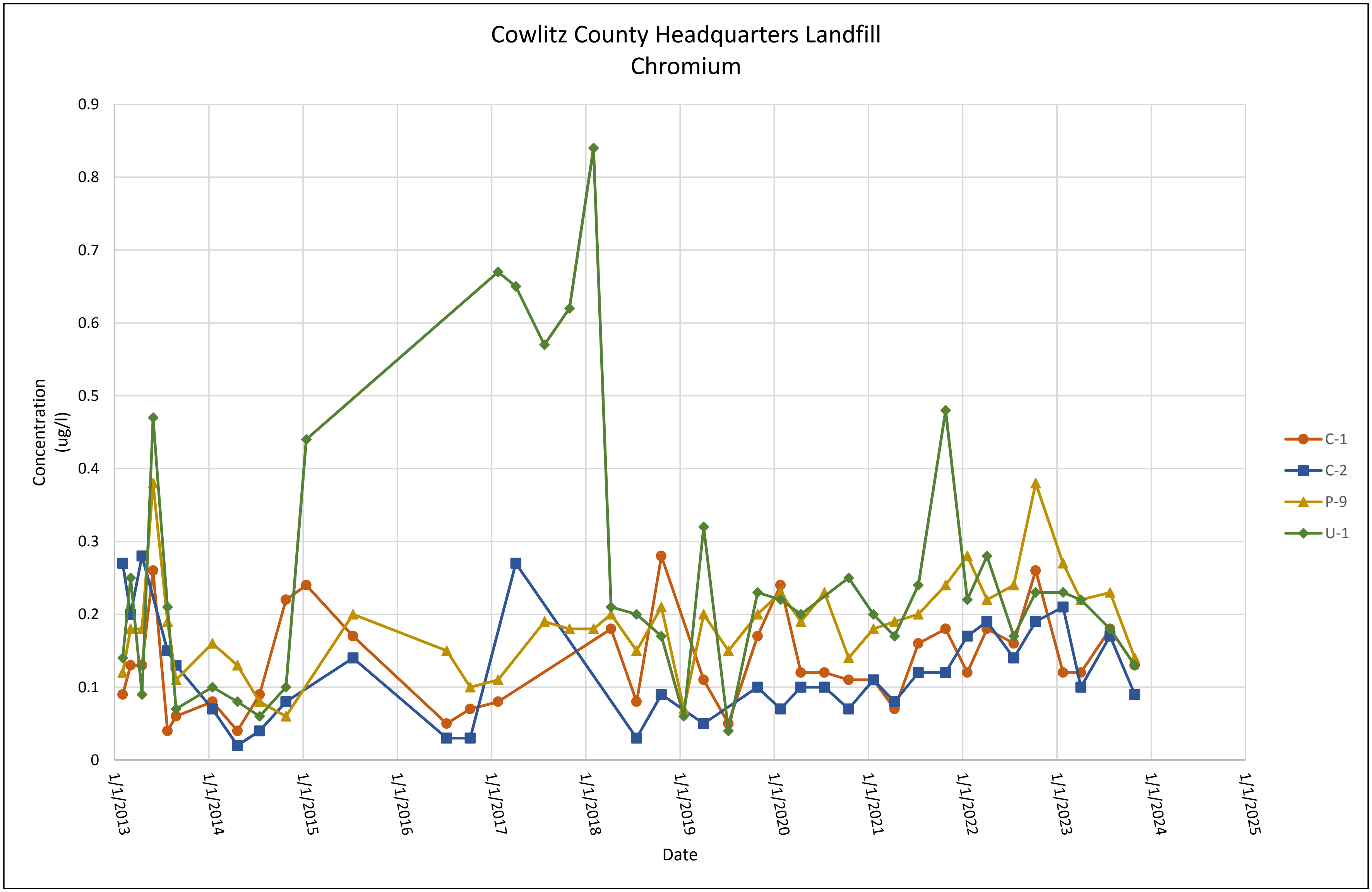
Cowlitz County Headquarters Landfill
Sulfate
Concentration (ug/l)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1

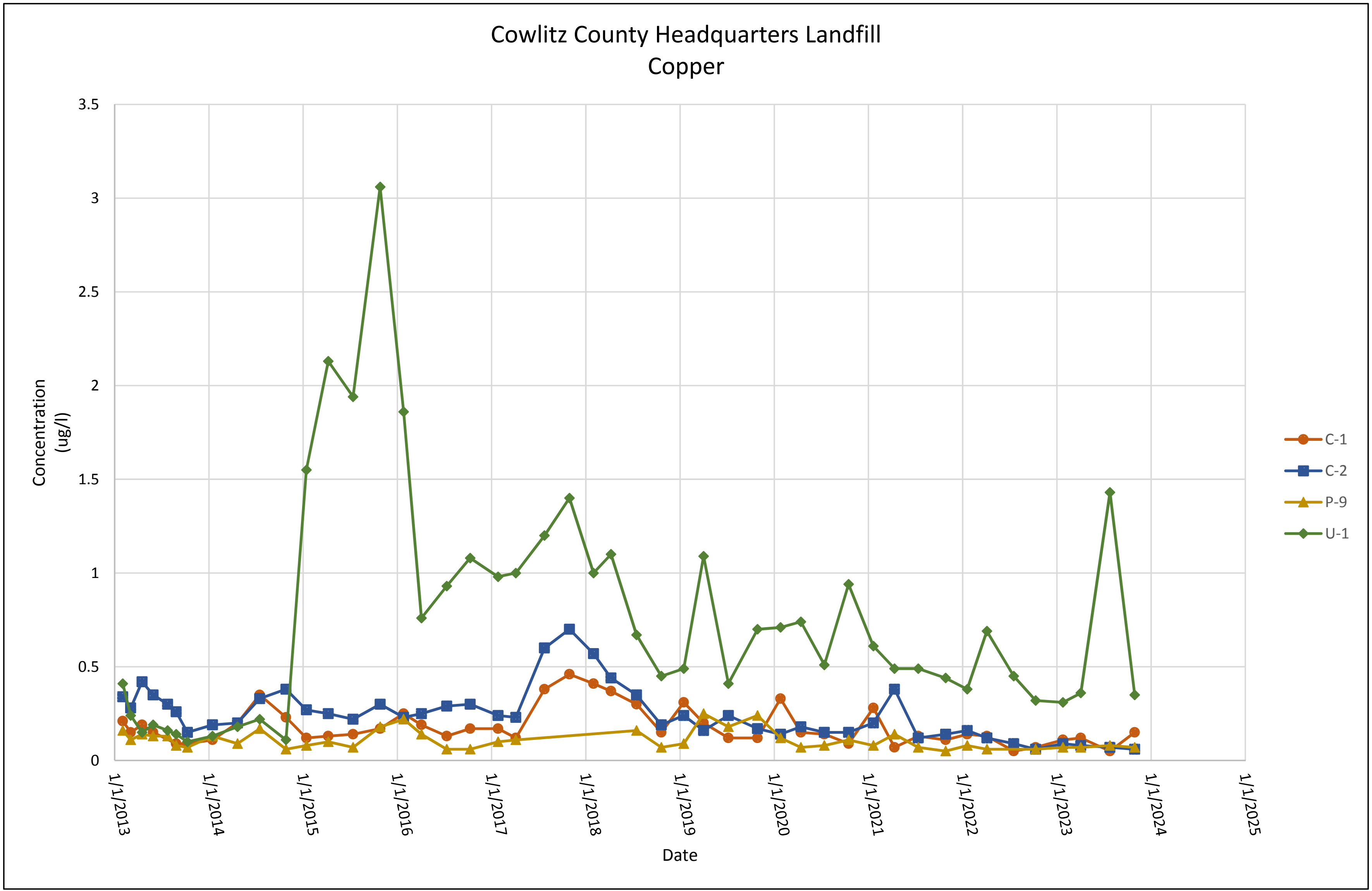

Cowlitz County Headquarters Landfill
Total Dissolved Solids
Concentration (ug/l)
160
140
120
100
80
60
40
20
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1



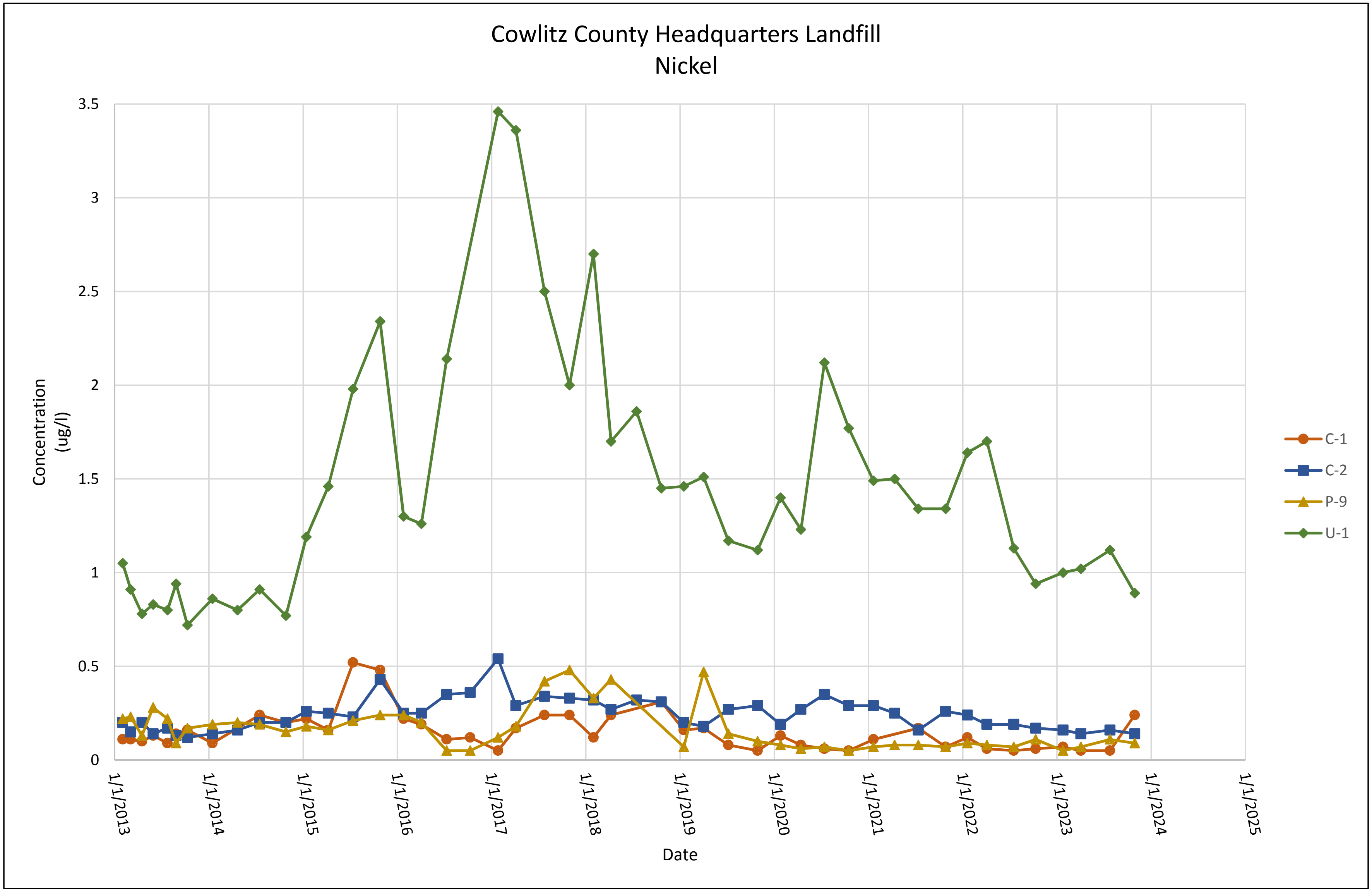
Cowlitz County Headquarters Landfill
Barium
Concentration (ug/l)
70
60
50
40
30
20
10
0
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1

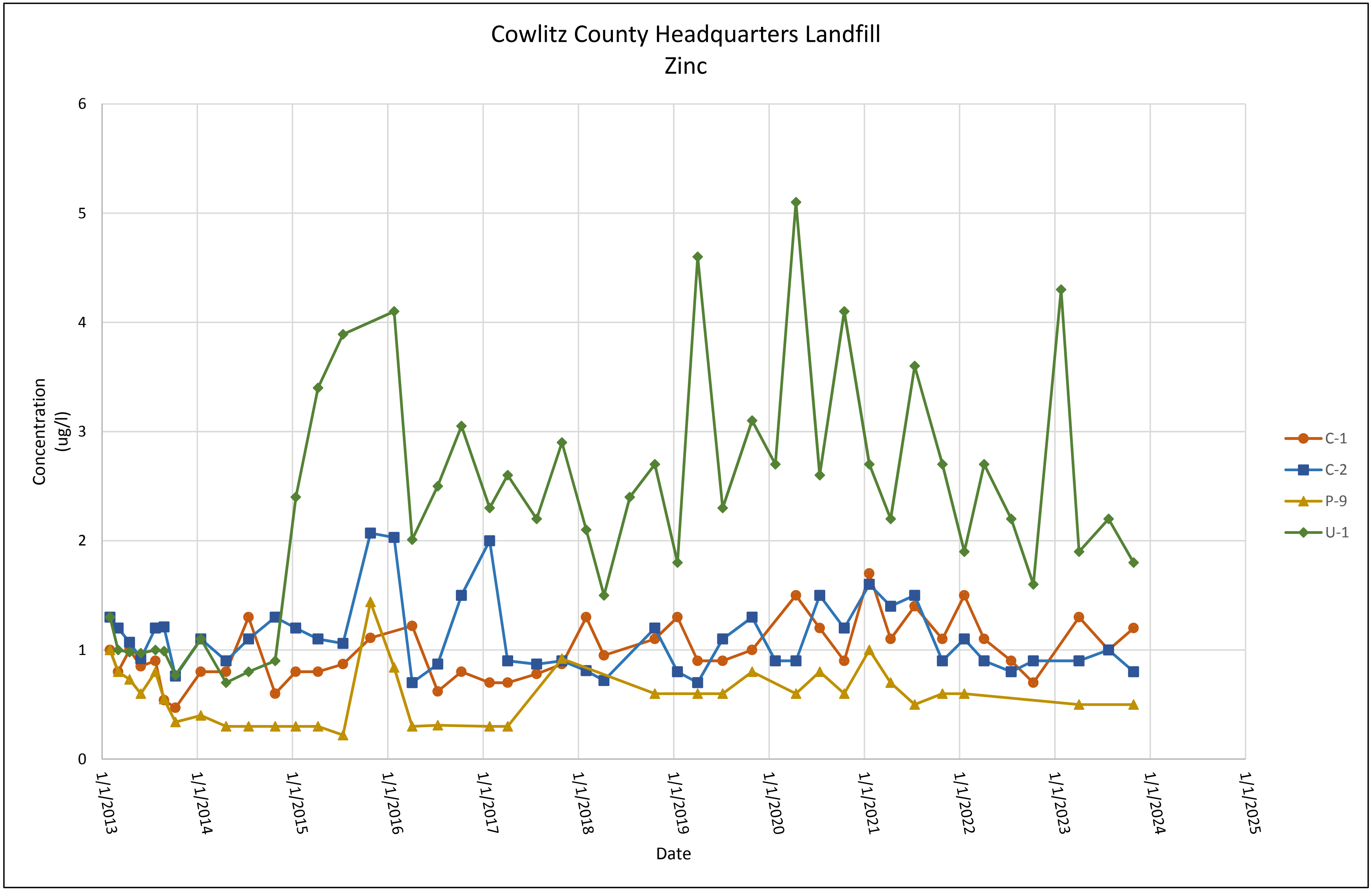

Cowlitz County Headquarters Landfill
Cadmium
Concentration (ug/l)
0.025
0.02
0.015
0.01
0.005
0
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1

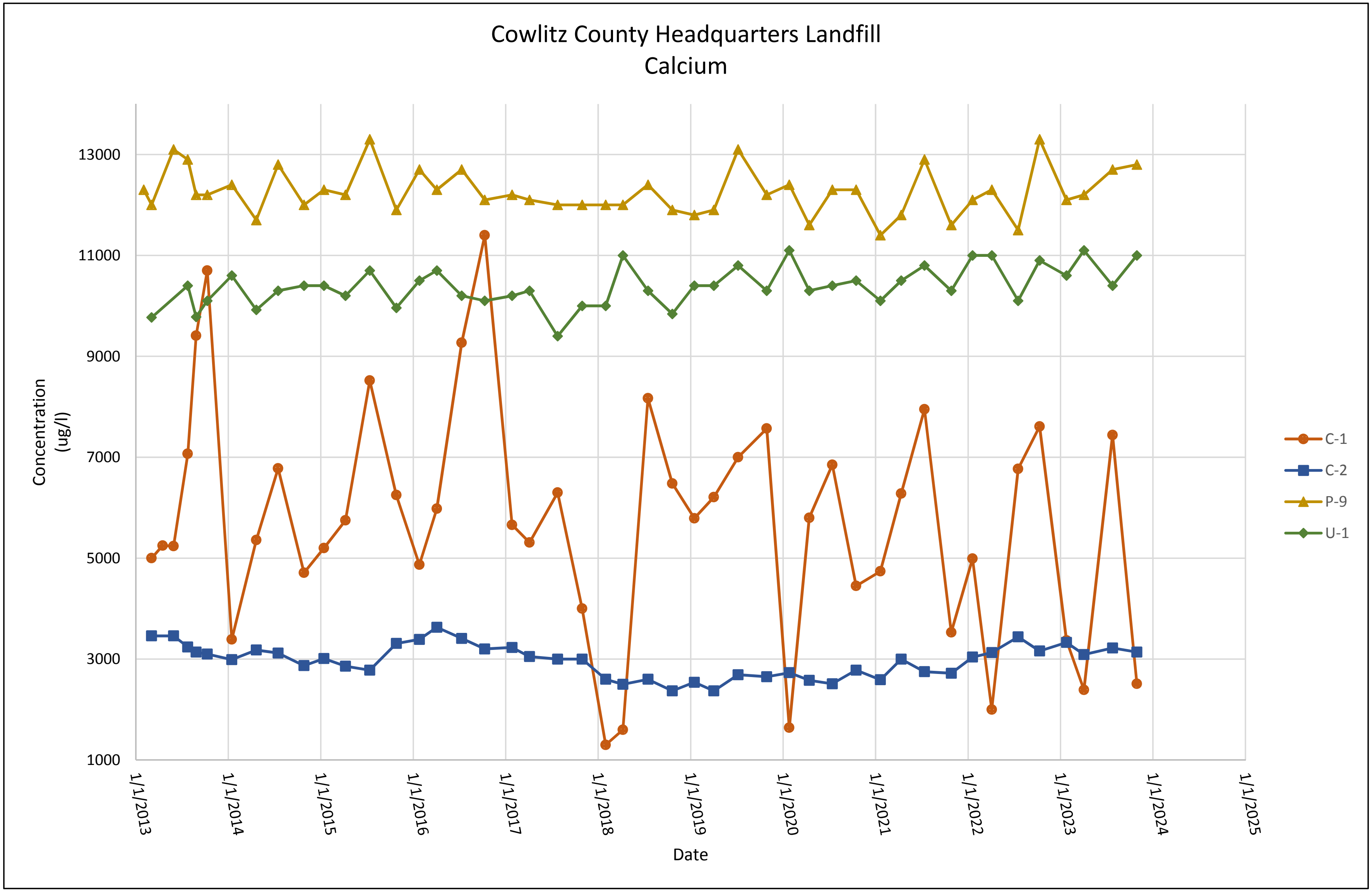

Cowlitz County Headquarters Landfill
Chromium
Concentration (ug/l)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1



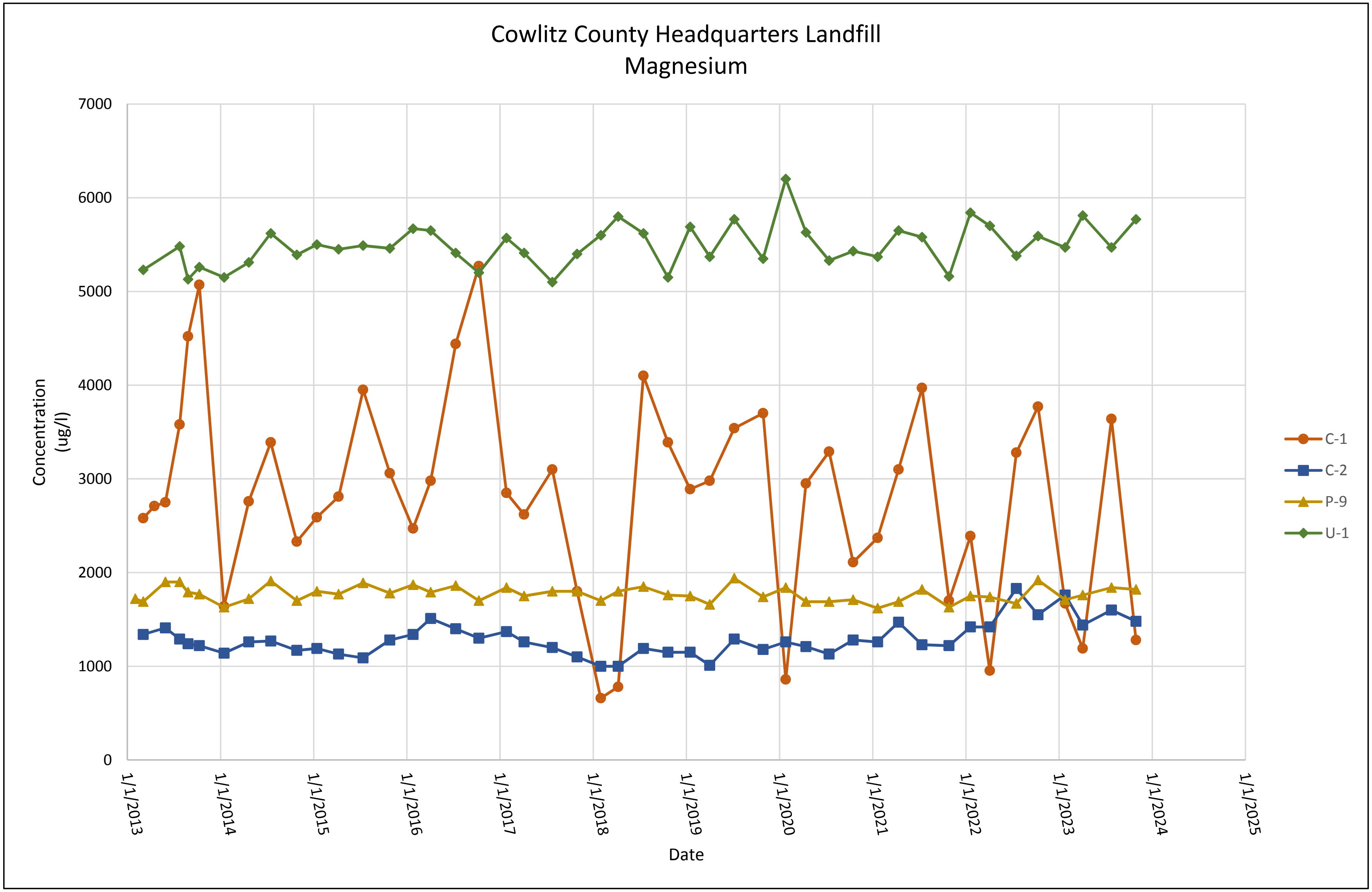
Cowlitz County Headquarters Landfill
Copper
Concentration (ug/l)
3.5
3
2.5
2
1.5
1
0.5
0
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1


Cowlitz County Headquarters Landfill
Nickel
Concentration (ug/l)
3.5
3
2.5
2
1.5
1
0.5
0
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1

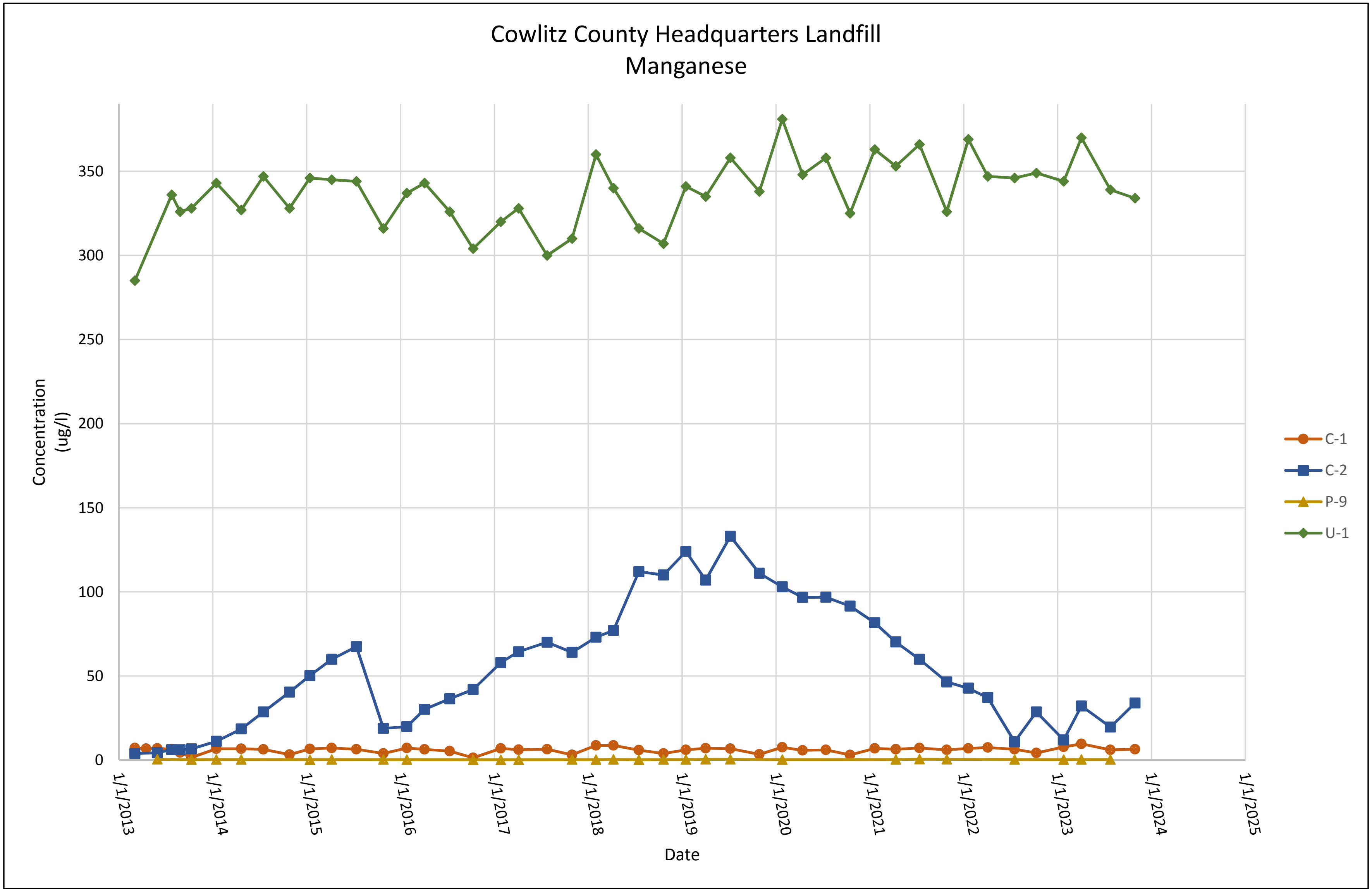

Cowlitz County Headquarters Landfill
Zinc
Concentration
(ug/l)
0
1
2
3
4
5
6
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1



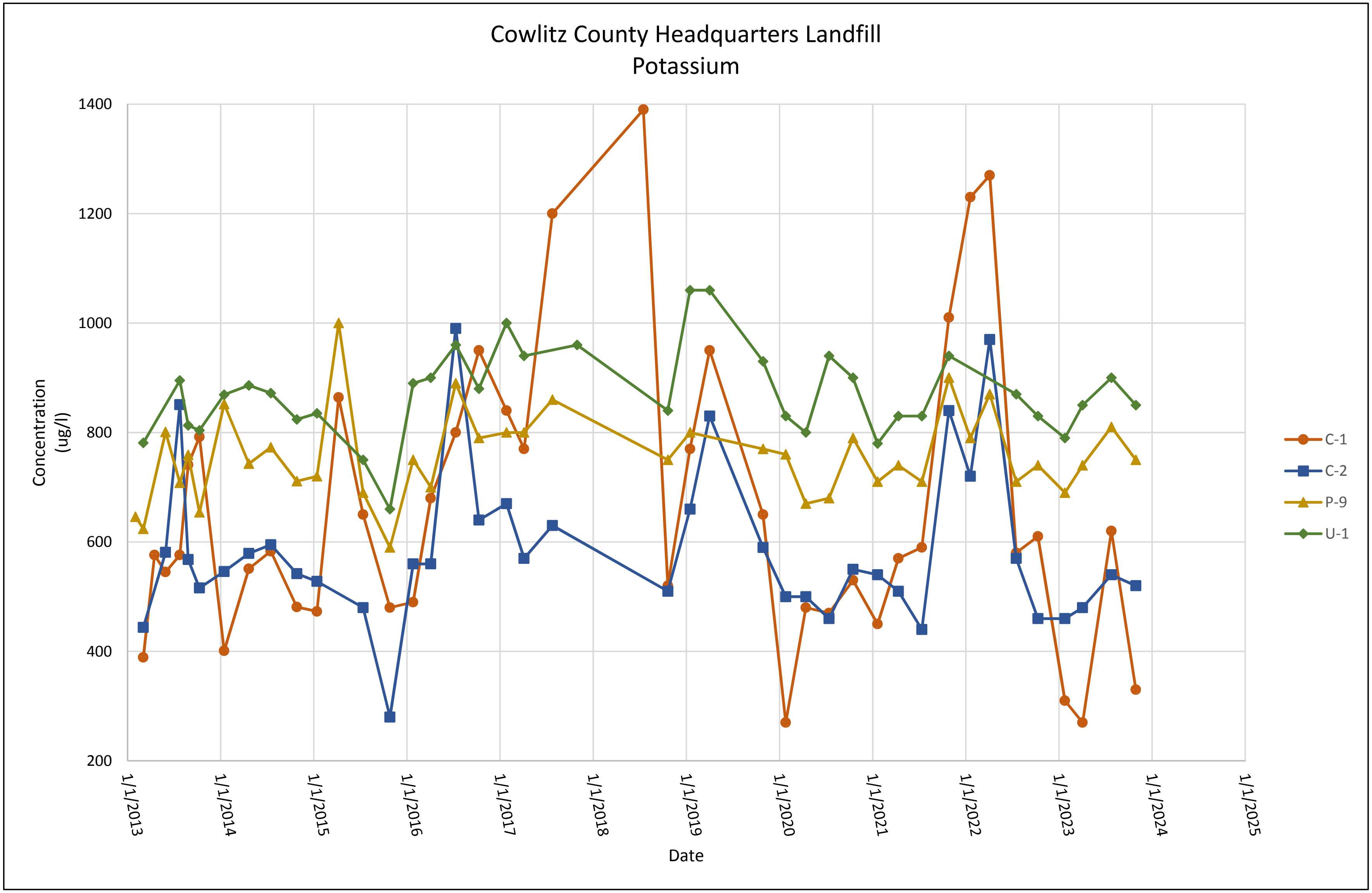
Cowlitz County Headquarters Landfill
Calcium
Concentration (ug/l)
13000
11000
9000
7000
5000
3000
1000
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1

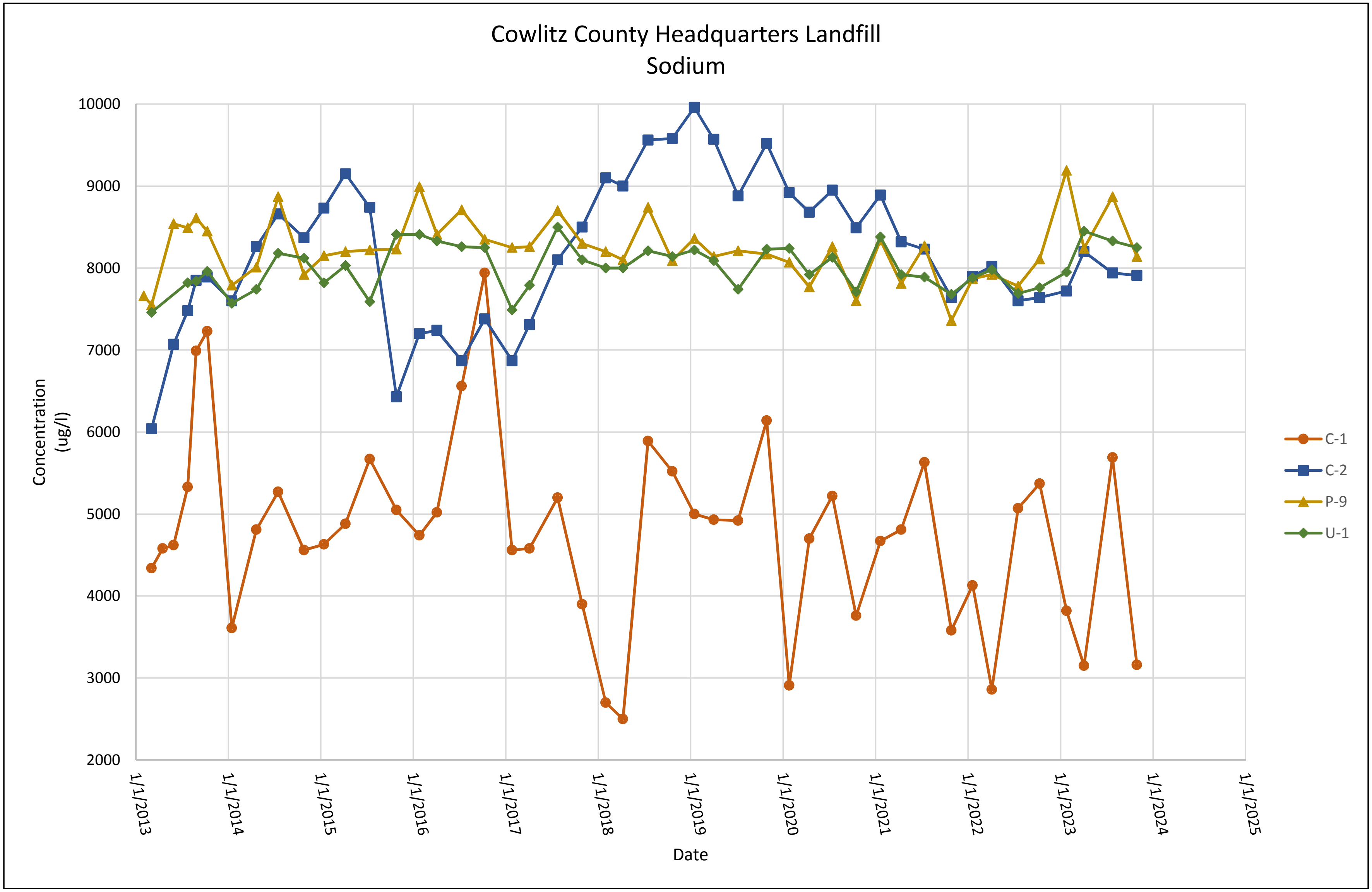


Cowlitz County Headquarters Landfill
Magnesium
Concentration (ug/l)
7000
6000
5000
4000
3000
2000
1000
0
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1



Cowlitz County Headquarters Landfill
Manganese
Concentration (ug/l)
0
50
100
150
200
250
300
350
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1


Cowlitz County Headquarters Landfill
Potassium
Concentration
(ug/l)
1400
1200
1000
800
600
400
200
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1



Cowlitz County Headquarters Landfill
Sodium
Concentration (ug/l)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1

Headquarters Landfill
Rank von Neuman ratio Summary

Parameter:			Alkalinity			Chloride			Sulfate		
					Temporally			Temporally			Temporally
	Indep-	Depen-		Critical	Independent		Critical	Independent		Critical	Independent
Well	endent	dent	v	Point	?	v	Point	?	v	Point	?
C-1	9	6	1.758	1.300	Yes	0.962	1.310	No	1.456	1.300	Yes
C-2	3	12	1.065	1.290	No	1.468	1.320	Yes	0.360	1.295	No
P-9	9	5	0.981	1.300	No	1.375	1.320	Yes	2.119	1.310	Yes
U-1	9	5	1.765	1.295	Yes	1.271	1.250	Yes	1.514	1.240	Yes
	30	28		Independent	2		Independent	3		Independent	3
				Dependent	2		Dependent	1		Dependent	1

Note: Crititcal Point for alpha=0.01 from Table 14.1 Unified Guidance

Headquarters Landfill
Rank von Neuman ratio Summary

Parameter:	TDS			Barium			Cadmium			Chromium		
Well	v	Critical Point	Temporally Independent ?	v	Critical Point	Temporally Independent ?	v	Critical Point	Temporally Independent ?	v	Critical Point	Temporally Independent ?
C-1	1.848	1.320	Yes	1.751	1.330	Yes	1.300	1.310	No	1.588	1.260	Yes
C-2	1.911	1.310	Yes	0.693	1.340	No	1.230	1.290	No	1.160	1.220	No
P-9	2.545	1.300	Yes	1.128	1.340	No	Insufficient data			1.177	1.290	No
U-1	1.515	1.320	Yes	0.801	1.340	No	Insufficient data			1.429	1.270	Yes
		Independent	4		Independent	1		Independent	0		Independent	2
		Dependent	0		Dependent	3		Dependent	2		Dependent	2

Note: Crititcal Point for alpha=0.01 from Table 14.1 Unified Guidance

Headquarters Landfill
Rank von Neuman ratio Summary

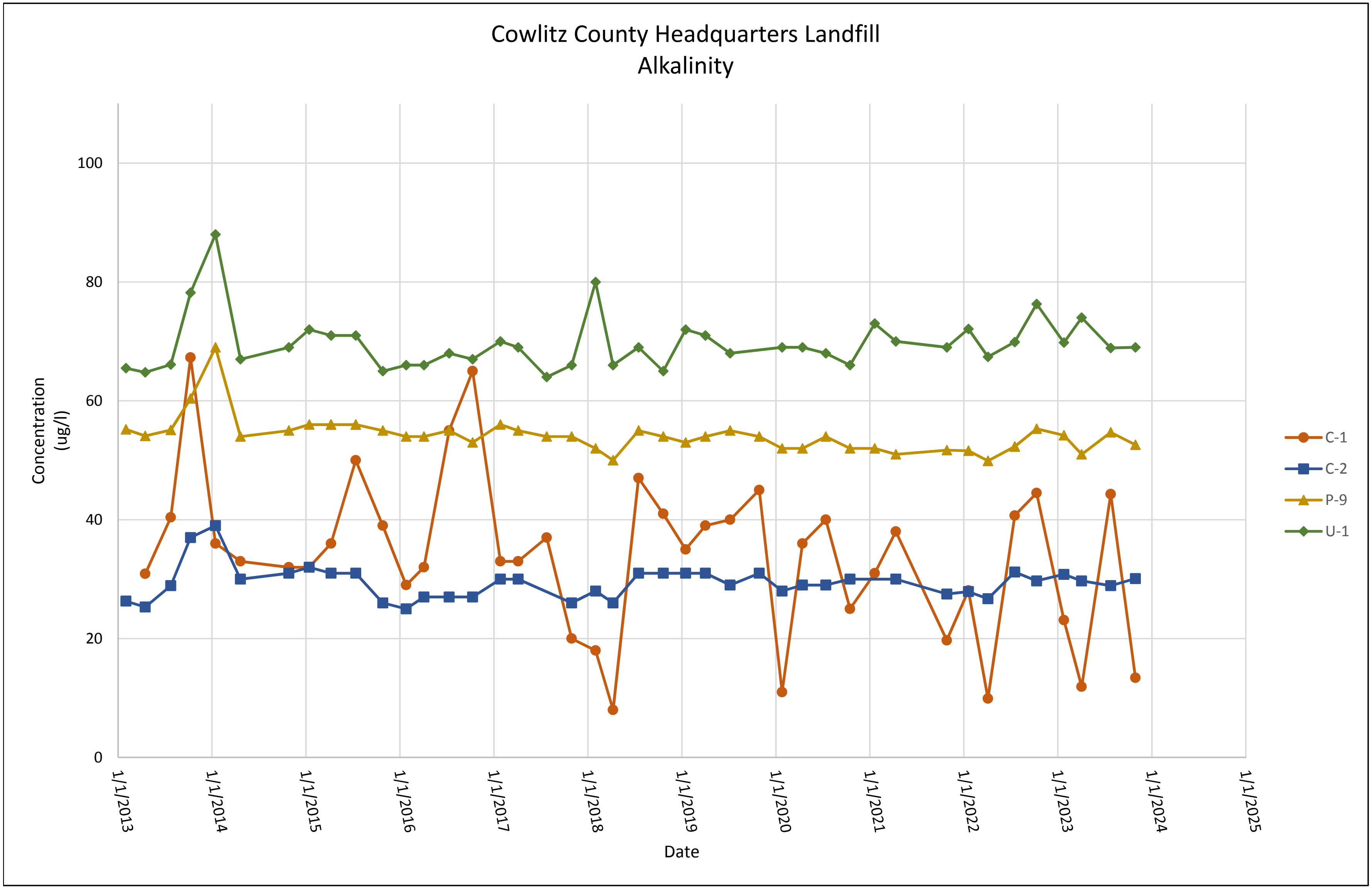
Parameter:	Copper			Nickel			Zinc			Calcium		
Well	v	Critical Point	Temporally Independent ?	v	Critical Point	Temporally Independent ?	v	Critical Point	Temporally Independent ?	v	Critical Point	Temporally Independent ?
C-1	1.240	1.330	No	1.003	1.325	No	1.303	1.310	No	1.771	1.330	Yes
C-2	0.555	1.340	No	0.597	1.340	No	1.522	1.325	Yes	0.384	1.325	No
P-9	1.491	13.000	No	0.953	1.325	No	1.296	1.240	Yes	2.440	1.330	Yes
U-1	0.736	1.340	No	0.383	1.330	No	1.043	1.330	No	1.925	1.325	Yes
	Independent		0	Independent		0	Independent		2	Independent		3
	Dependent		4	Dependent		4	Dependent		2	Dependent		1

Note: Crititcal Point for alpha=0.01 from Table 14.1 Unified Guidance

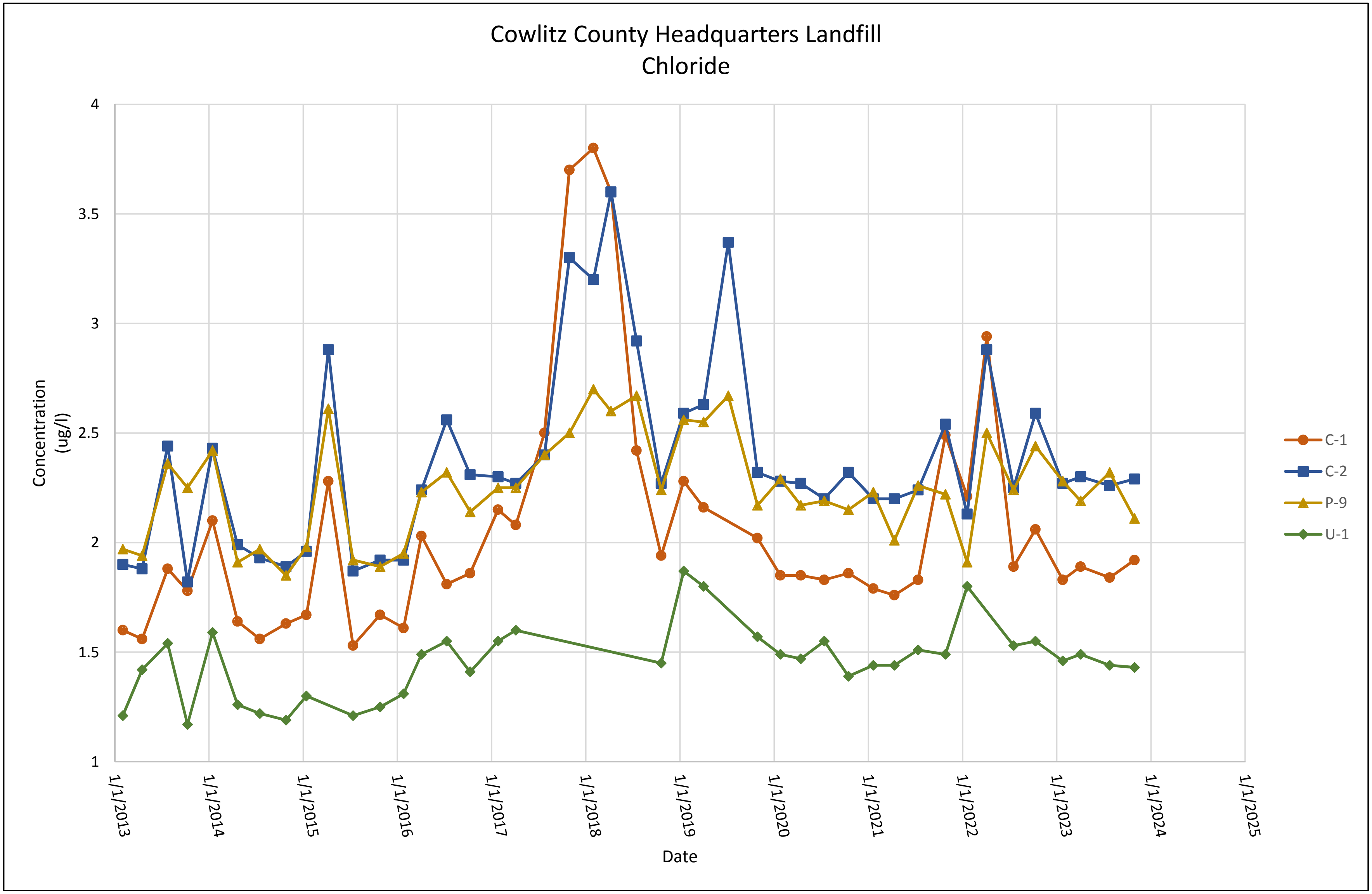
Headquarters Landfill
Rank von Neuman ratio Summary

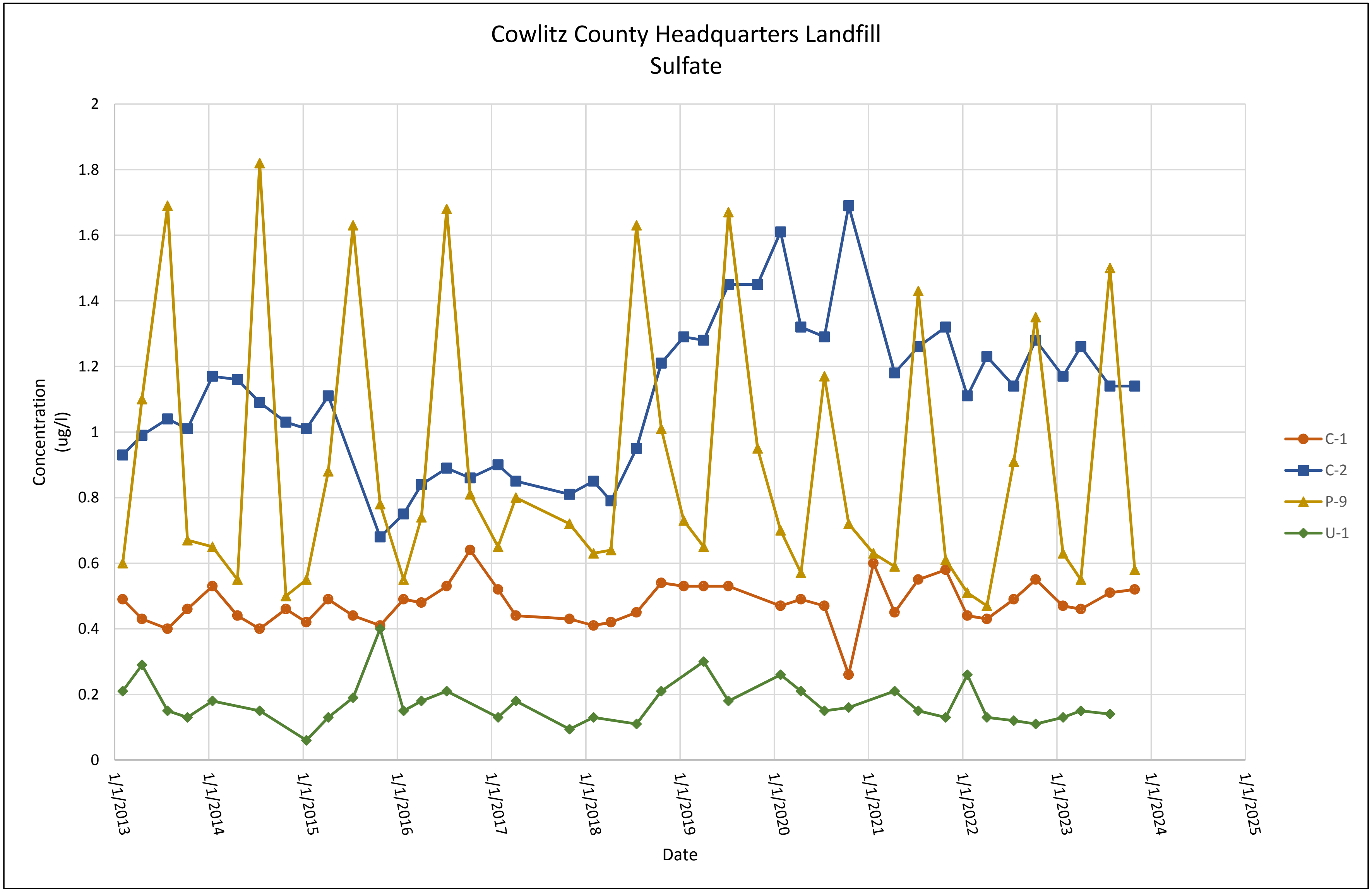
Parameter:	Magnesium			Manganese			Potassium			Sodium		
Well	v	Critical Point	Temporally Independent ?	v	Critical Point	Temporally Independent ?	v	Critical Point	Temporally Independent ?	v	Critical Point	Temporally Independent ?
C-1	1.744	1.330	Yes	2.137	1.330	Yes	1.117	1.240	No	1.811	1.330	Yes
C-2	0.606	1.325	No	0.160	1.325	No	1.153	1.310	No	0.357	1.325	No
P-9	2.221	1.330	Yes	1.272	1.150	Yes	1.984	1.310	Yes	1.730	1.330	Yes
U-1	2.025	1.325	Yes	1.512	1.325	Yes	1.239	1.295	No	1.435	1.325	Yes
		Independent	3		Independent	3		Independent	1		Independent	3
		Dependent	1		Dependent	1		Dependent	3		Dependent	1

Note: Crititcal Point for alpha=0.01 from Table 14.1 Unified Guidance

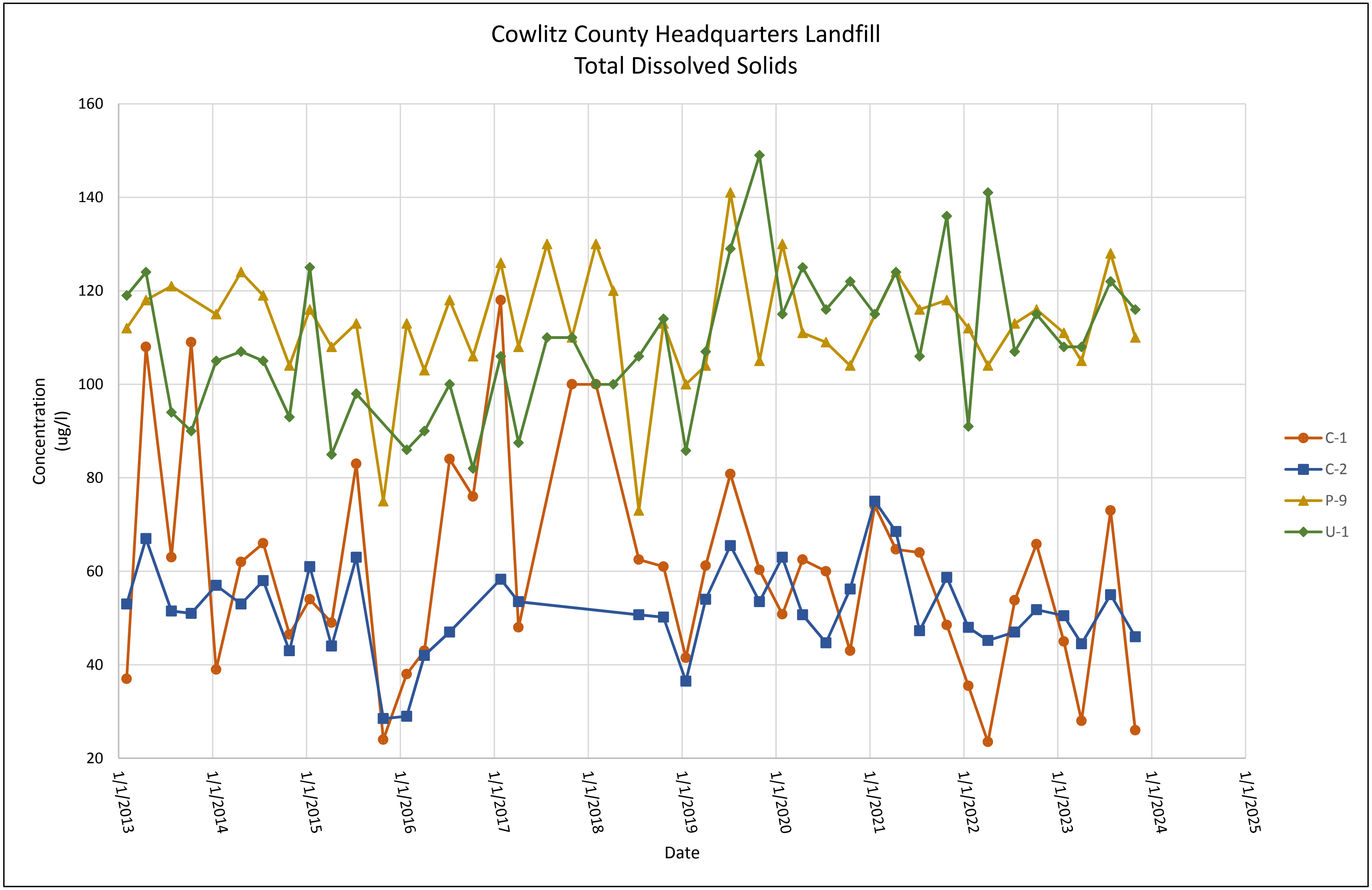


Cowlitz County Headquarters Landfill
Alkalinity
Concentration (ug/l)
Date
0
20
40
60
80
100
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
C-1
C-2
P-9
U-1

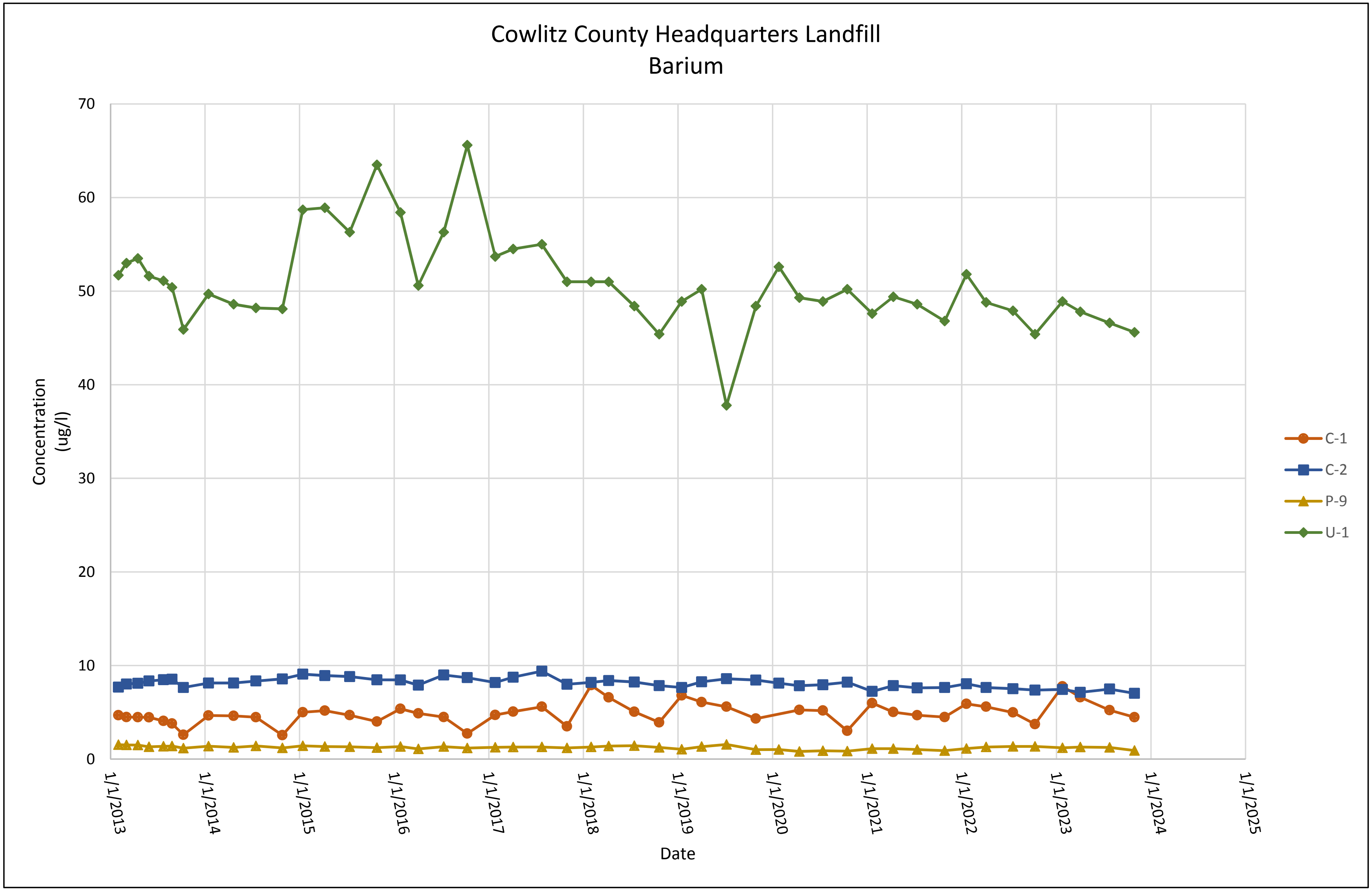

Cowlitz County Headquarters Landfill
Chloride
Concentration
(ug/l)
4
3.5
3
2.5
2
1.5
1
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1



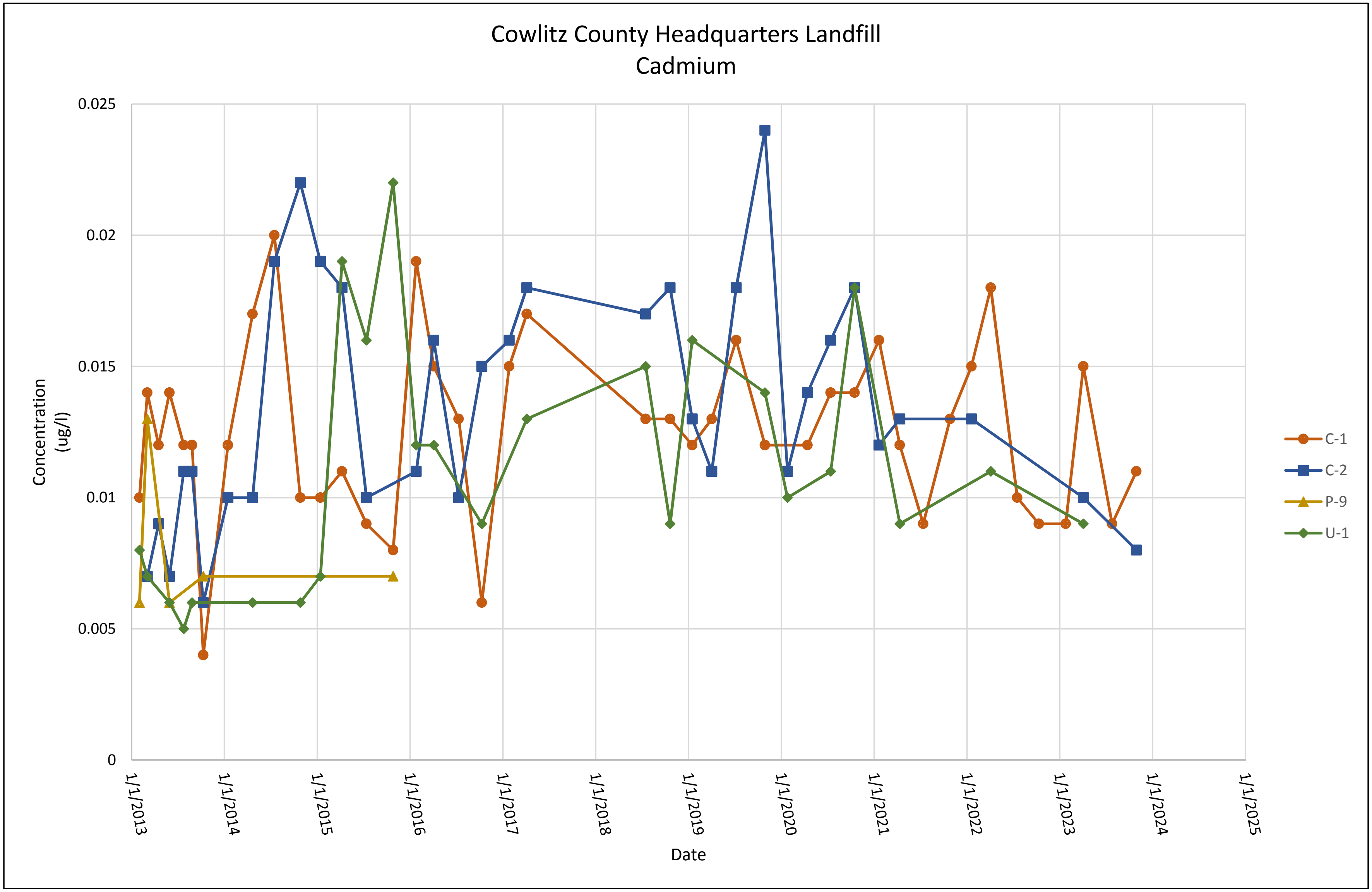
Cowlitz County Headquarters Landfill
Sulfate
Concentration (ug/l)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1

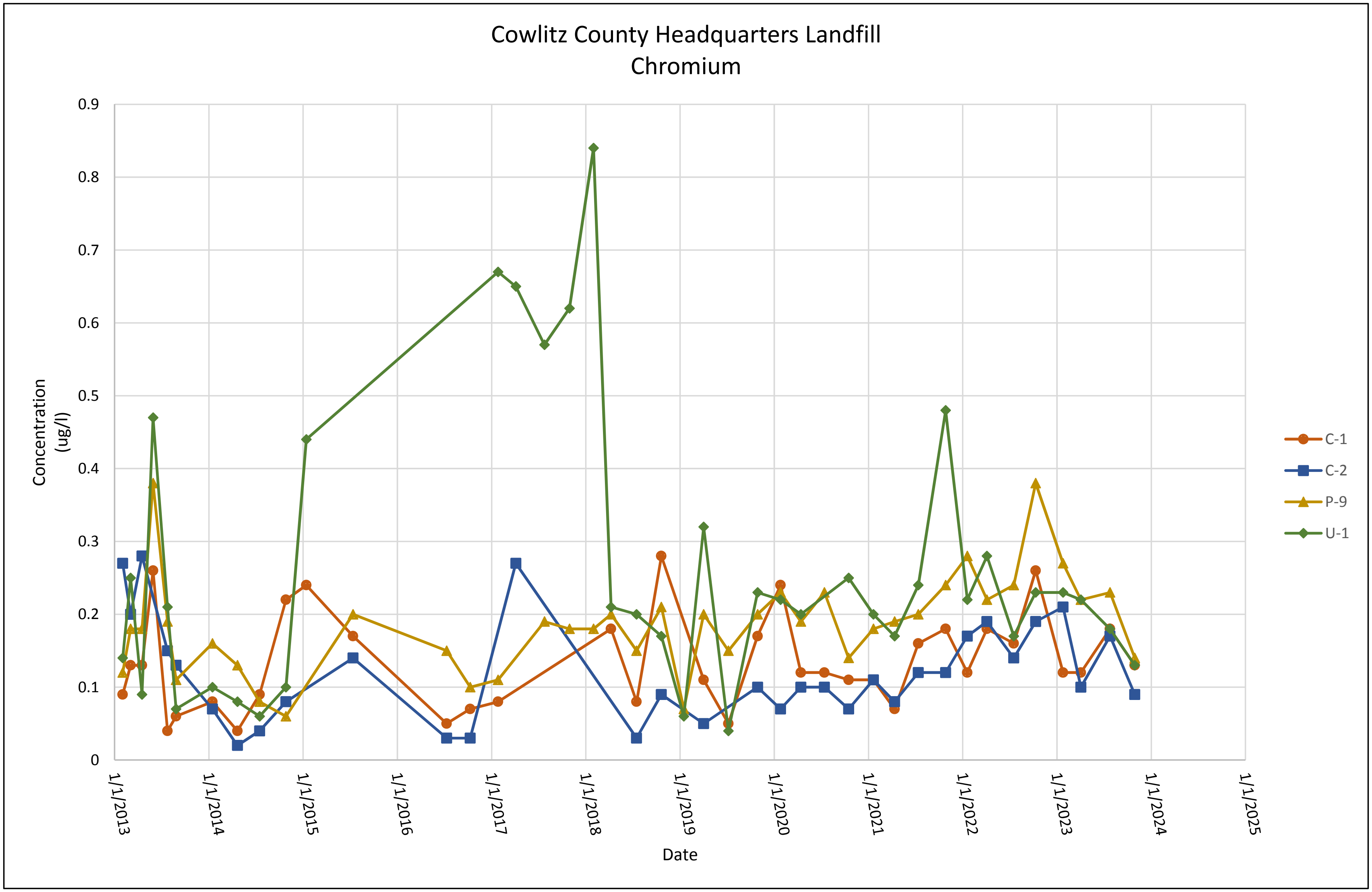


Cowlitz County Headquarters Landfill
Total Dissolved Solids
Concentration (ug/l)
160
140
120
100
80
60
40
20
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1

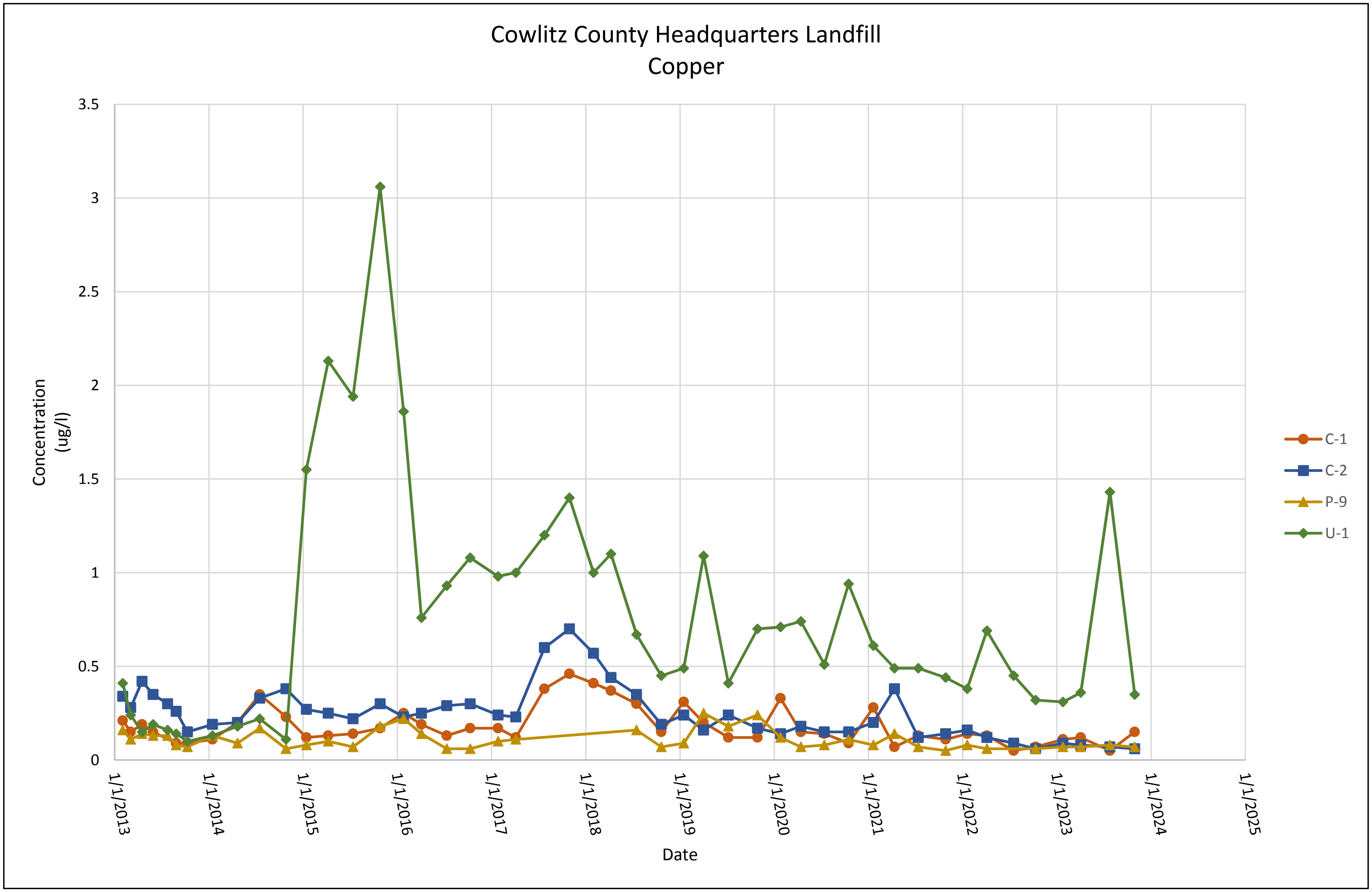


Cowlitz County Headquarters Landfill
Barium
Concentration (ug/l)
70
60
50
40
30
20
10
0
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1

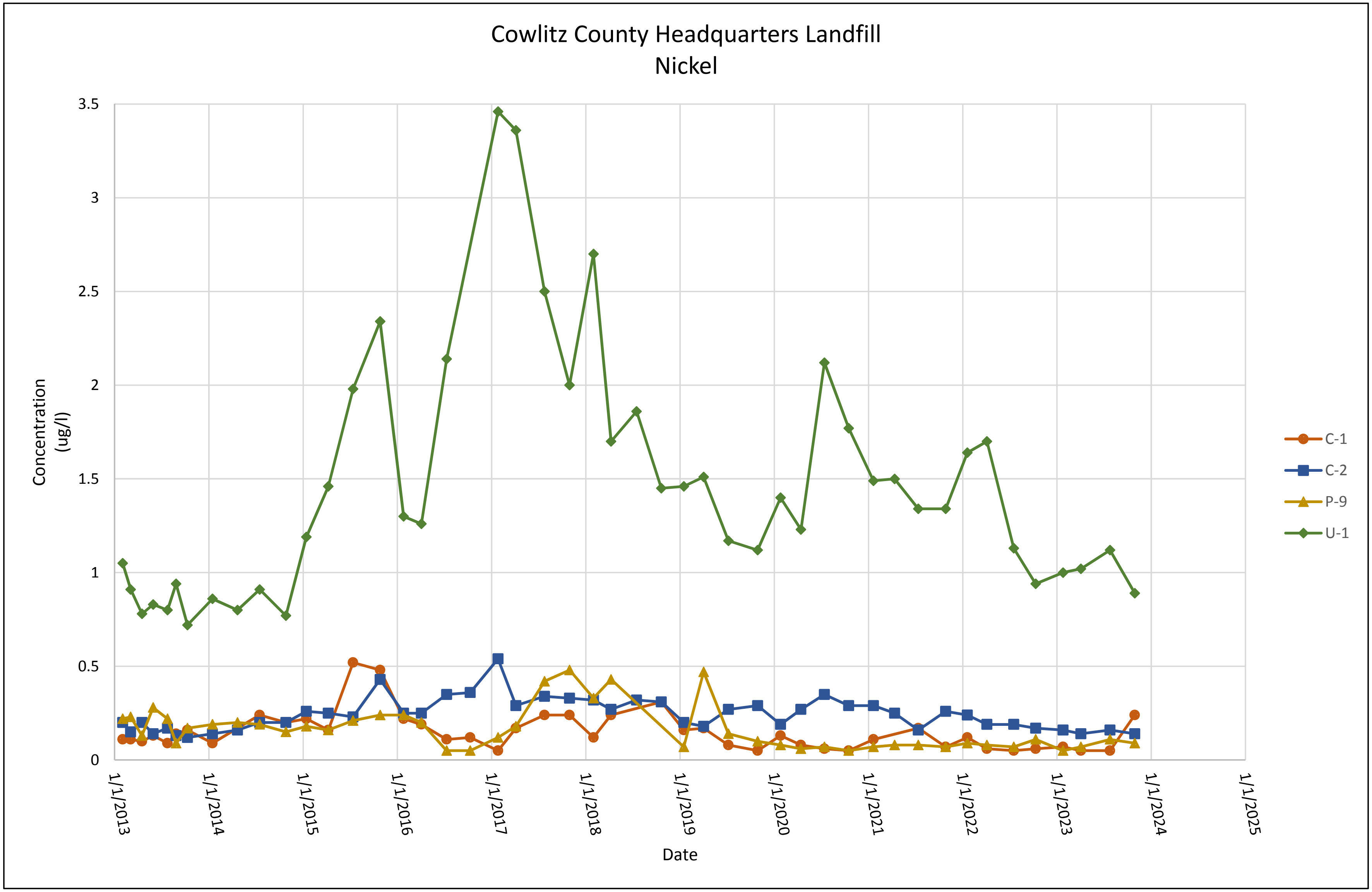

Cowlitz County Headquarters Landfill
Cadmium
Concentration (ug/l)
0.025
0.02
0.015
0.01
0.005
0
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1



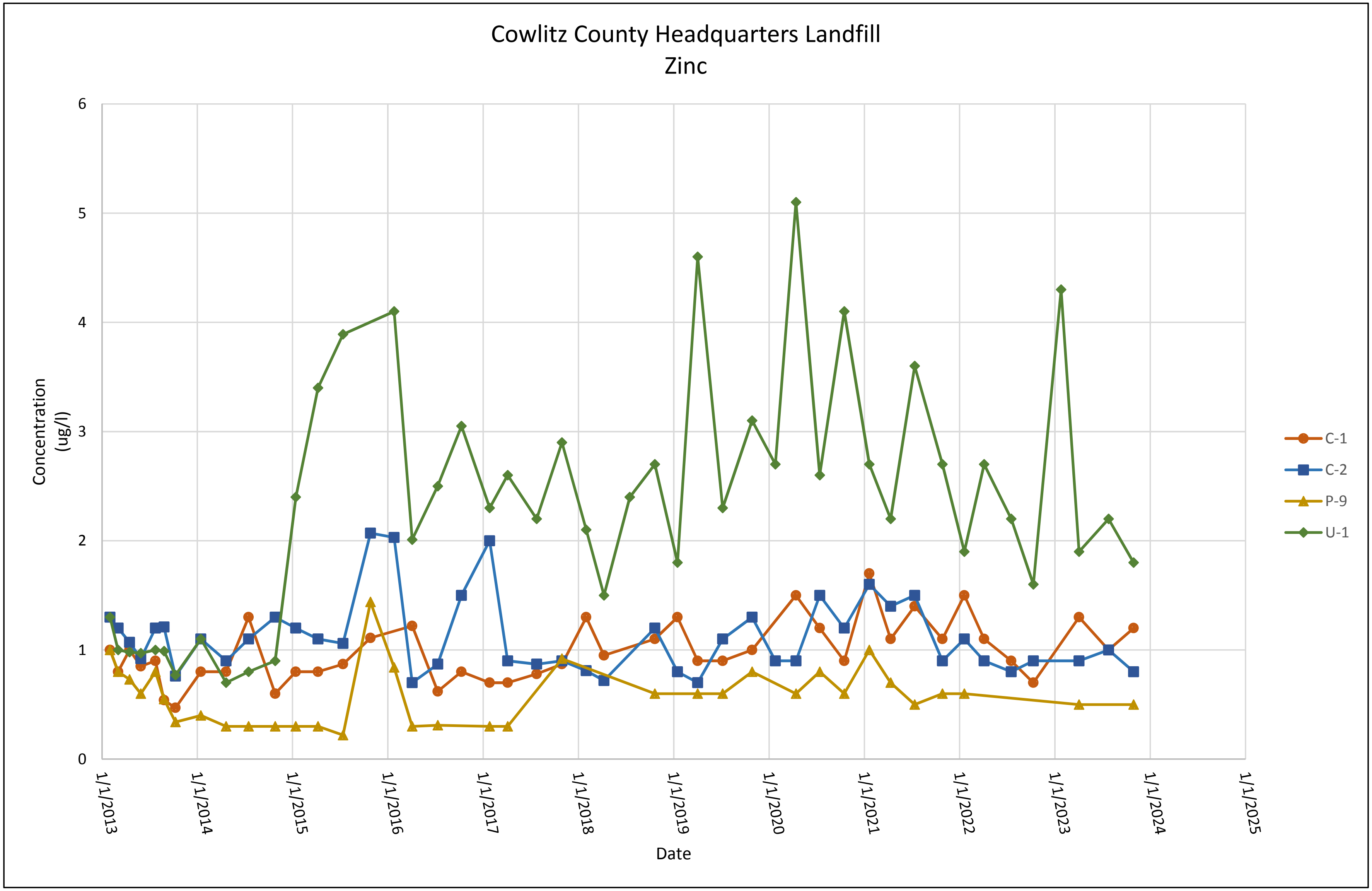
Cowlitz County Headquarters Landfill
Chromium
Concentration (ug/l)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1

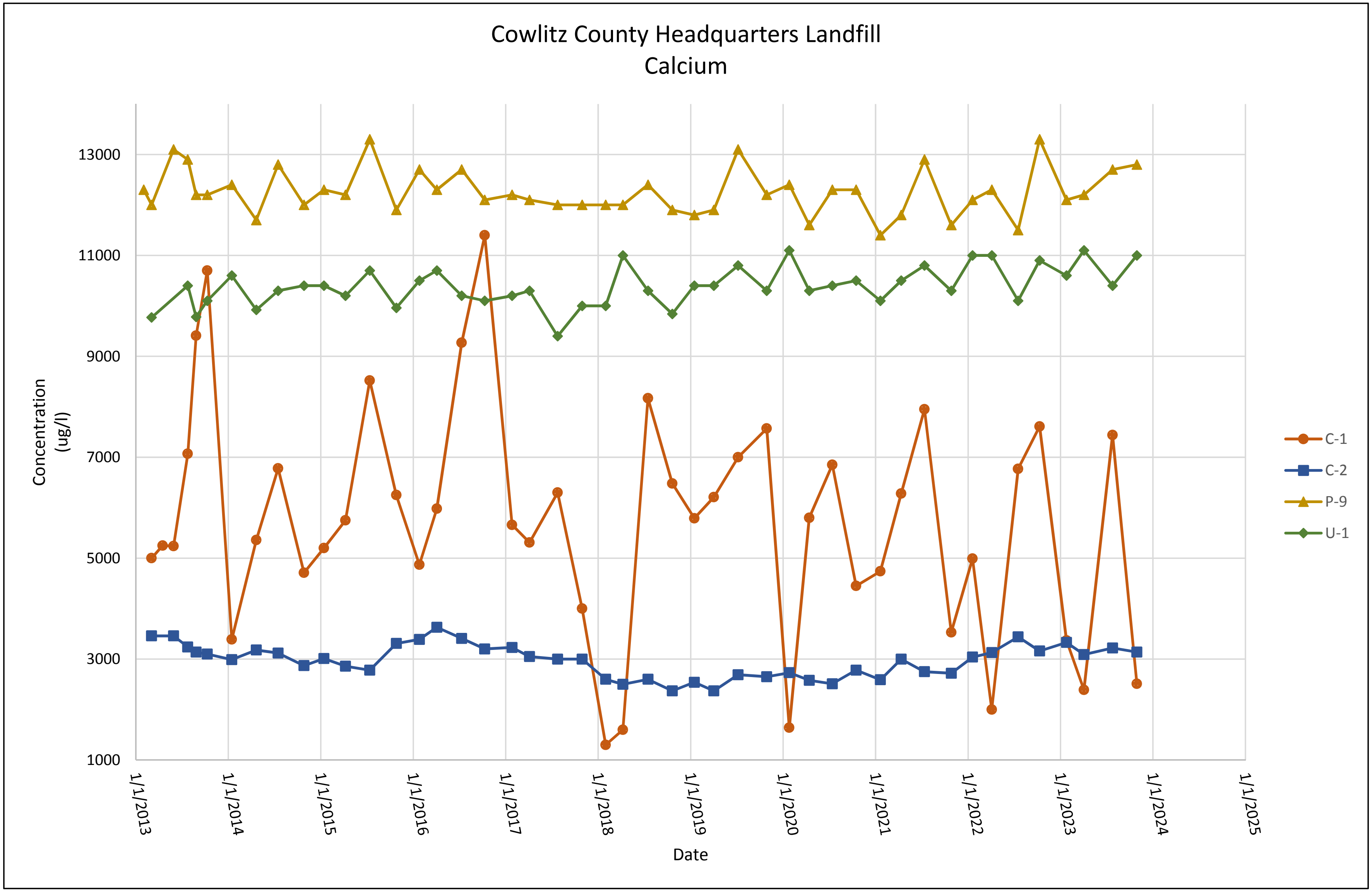


Cowlitz County Headquarters Landfill
Copper
3.5
3
2.5
2
1.5
1
0.5
0
Concentration (ug/l)
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1

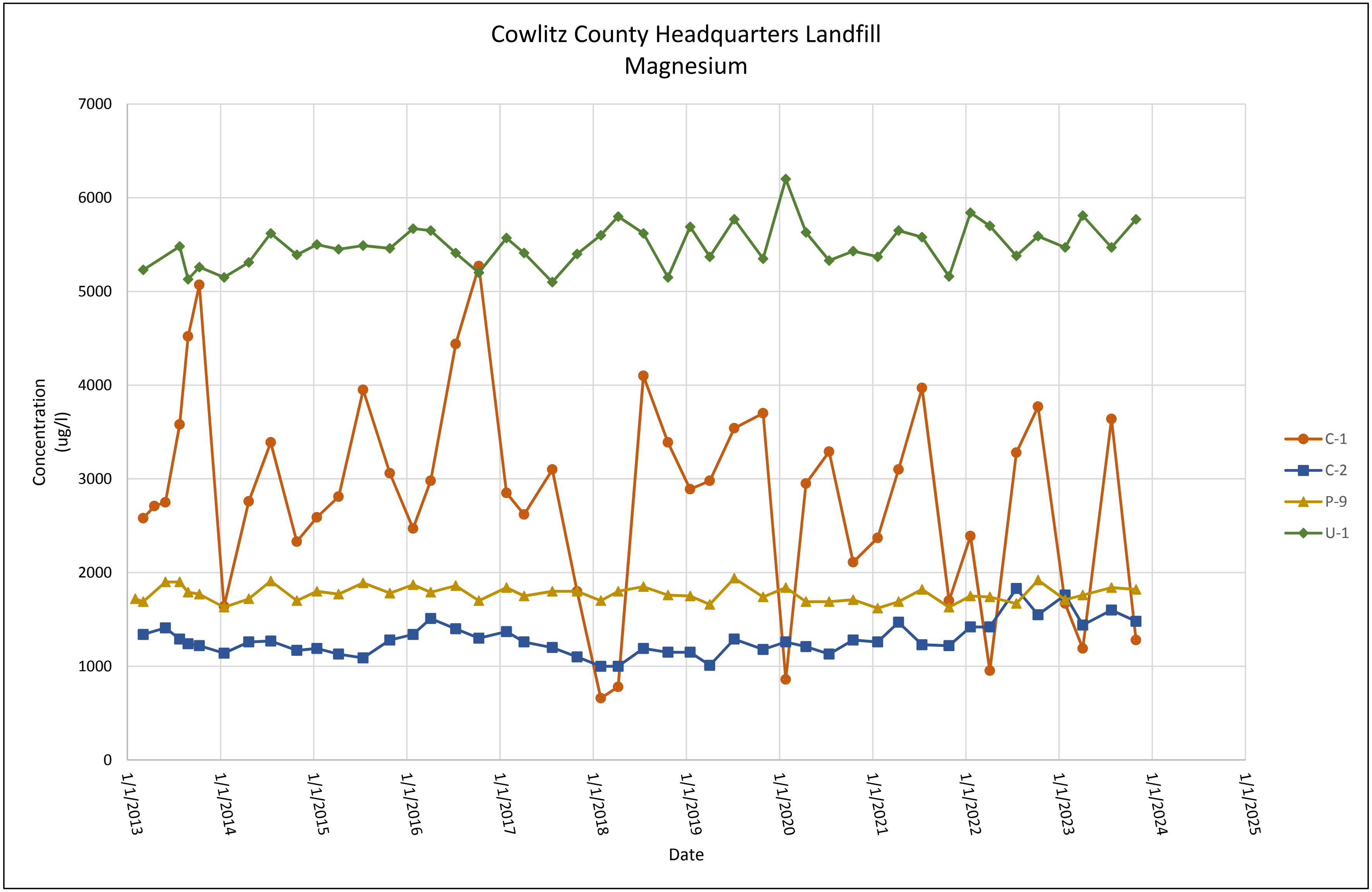


Cowlitz County Headquarters Landfill
Nickel
Concentration (ug/l)
3.5
3
2.5
2
1.5
1
0.5
0
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1

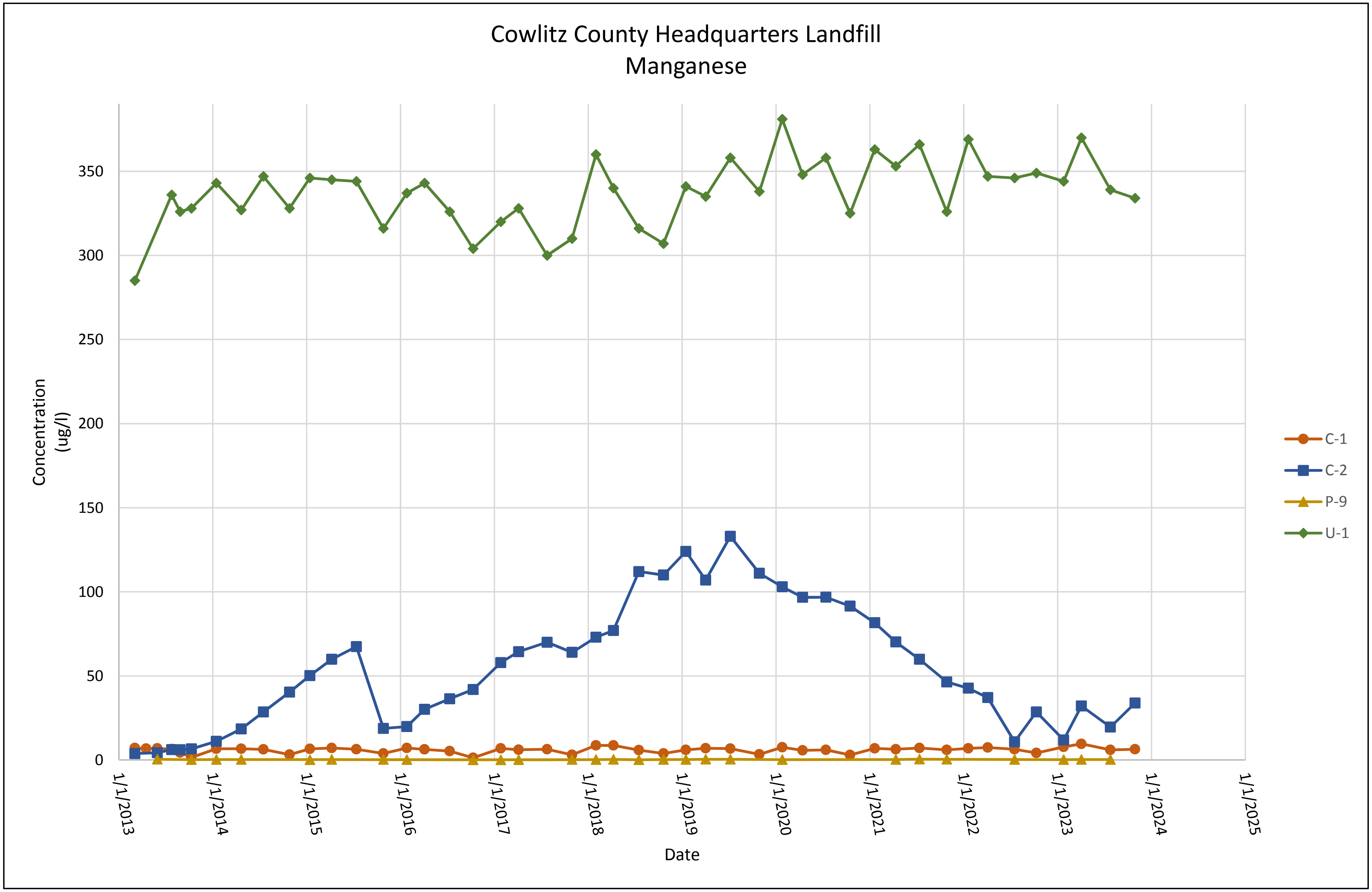

Cowlitz County Headquarters Landfill
Zinc
Concentration (ug/l)
0
1
2
3
4
5
6
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1



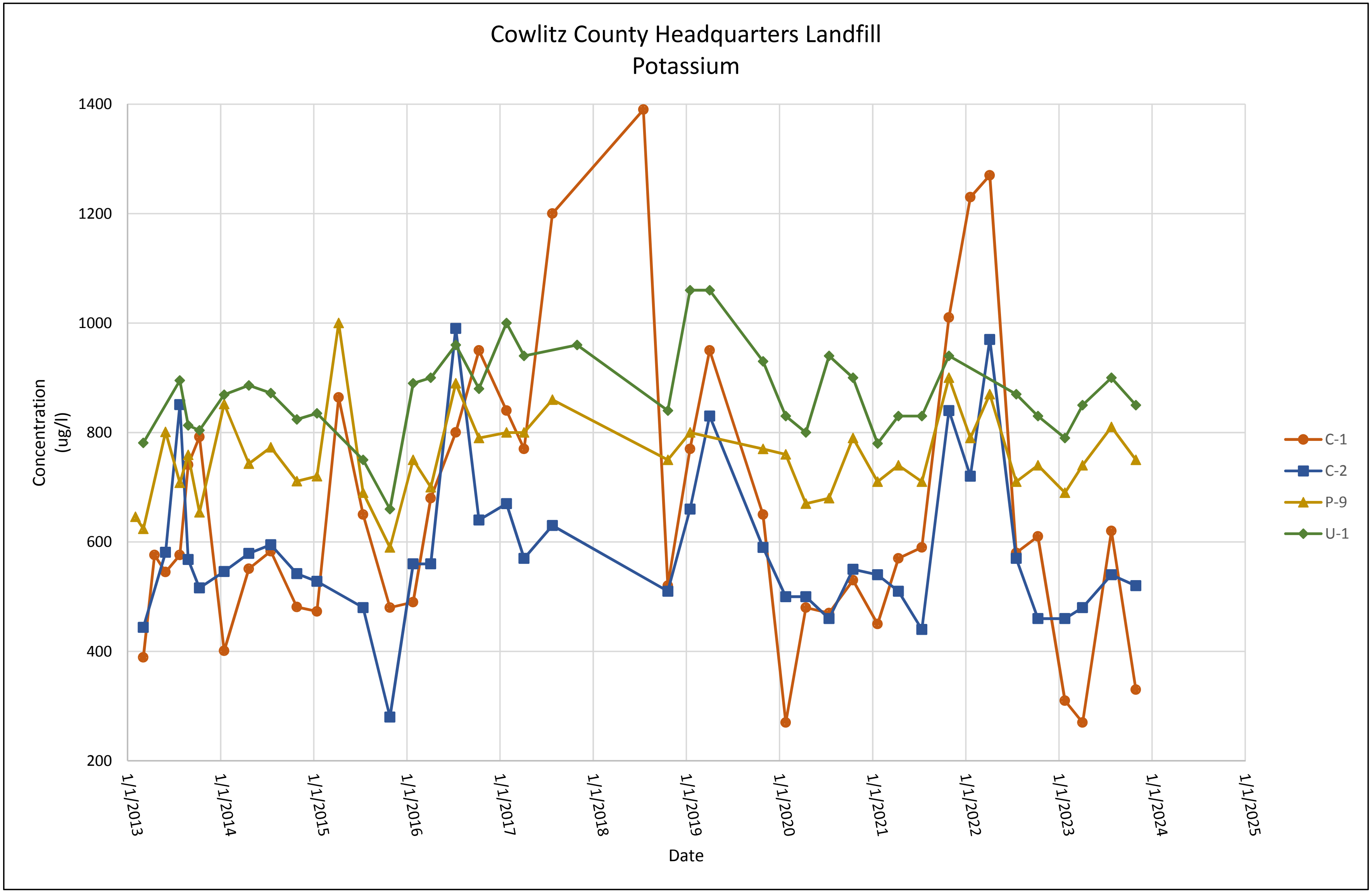
Cowlitz County Headquarters Landfill
Calcium
Concentration
(ug/l)
13000
11000
9000
7000
5000
3000
1000
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1



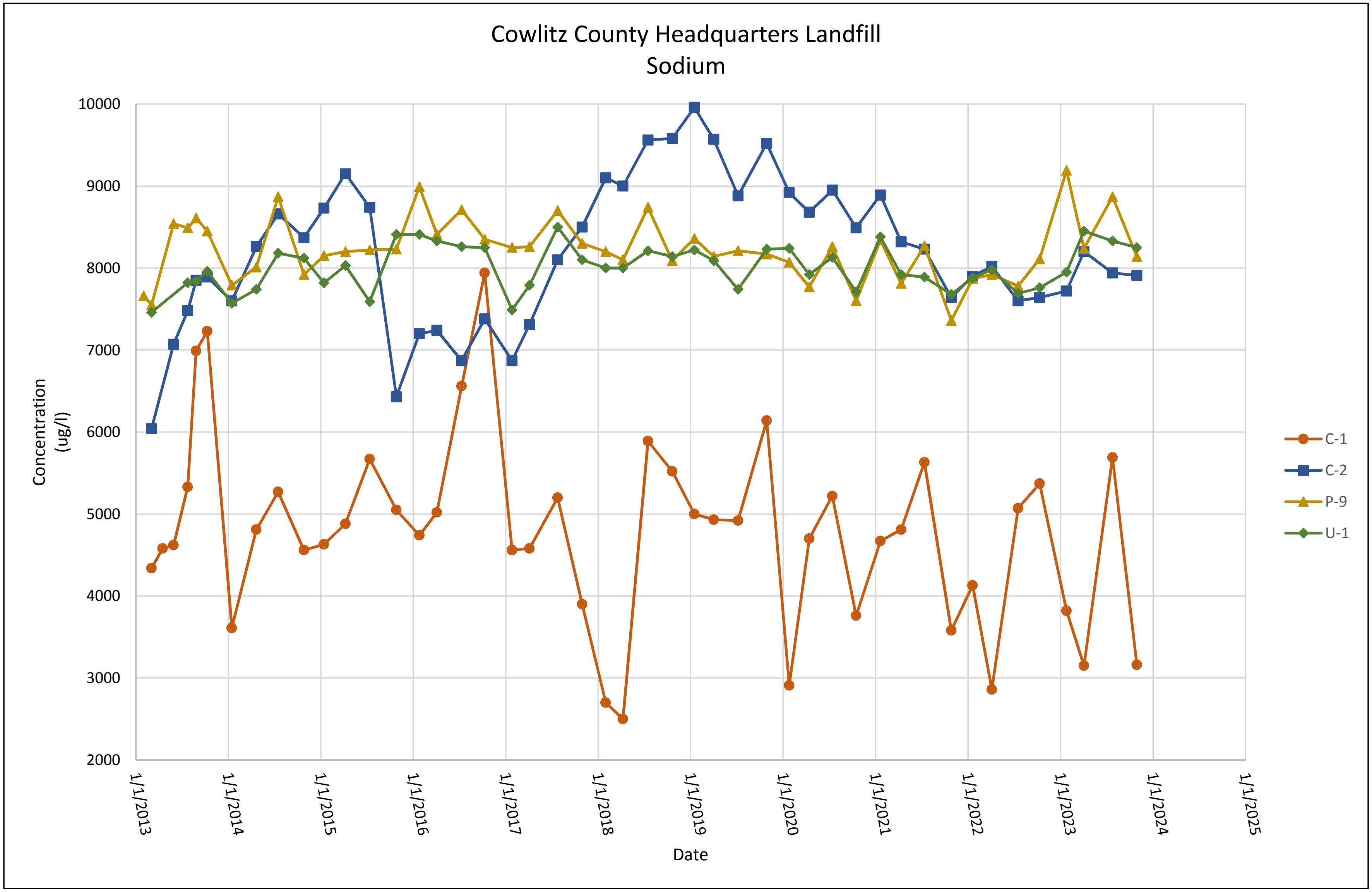
Cowlitz County Headquarters Landfill
Magnesium
Concentration (ug/l)
7000
6000
5000
4000
3000
2000
1000
0
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1



Cowlitz County Headquarters Landfill
Manganese
Concentration (ug/l)
350
300
250
200
150
100
50
0
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1



Cowlitz County Headquarters Landfill
Potassium
1400
1200
1000
800
600
400
200
Concentration
(ug/l)
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1



Cowlitz County Headquarters Landfill
Sodium
Concentration (ug/l)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
1/1/2022
1/1/2023
1/1/2024
1/1/2025
Date
C-1
C-2
P-9
U-1

Headquarters Landfill
Leachate Comparison

Location:	Leachate	C-1		C-2		P-9		U-1	
Parameter		Mean	Leach/C-1	Mean	Leach/C-2	Mean	Leach/P-9	Mean	Leach/U-1
Alkalinity	3000	33.83	88.68	29.40	102.04	54.15	55.41	69.7	43.07
Chloride	442	2.06	214.27	2.37	186.41	2.25	196.88	1.46	303.43
Sulfate	35	0.48	73.32	1.11	31.52	0.89	39.40	0.17	201.68
TDS	4210	60.31	69.81	51.85	81.19	112.76	37.34	108.70	38.73
Barium	539	4.88	110.37	8.12	66.38	1.24	433.38	50.87	10.60
Cadmium	0.643	0.01	51.44	0.01	47.42	0.01	82.44	0.01	57.16
Chromium	83.8	0.14	620.12	0.12	689.63	0.19	449.33	0.27	315.60
Copper	244	0.18	1352.29	0.25	986.07	0.11	2232.68	0.75	323.86
Nickel	86	0.15	572.49	0.24	357.70	0.16	525.10	1.46	59.06
Zinc	247	0.99	250.61	1.12	221.46	0.58	424.82	2.32	106.51
Calcium	121000	5736	21.09	2977	40.65	12261	9.87	10390	11.65
Magnesium	79700	2822	28.24	1290	61.79	1771	45.00	5491	14.51
Manganese	883	6.01	146.95	53.70	16.44	0.27	3306.66	337.4	2.62
Potassium	223000	660	338.10	584	381.78	756	294.96	870	256.24
Sodium	1290000	4787	269.48	8177	157.76	8223	156.87	8005	161.15

Note: Leachate sample collected in January 2024

Headquarters Landfill Background Re-evaluation 2024
Look Back Summary

Well / Parameter	C-1	C-2
Alkalinity	Feb 2013 to Oct 2023	Feb 2013 to Oct 2023
Chloride	Oct 2018 to Oct 2023	Feb 2013 to Oct 2023
Sulfate	Feb 2013 to Oct 2023	July 2018 to Oct 2023
TDS	Feb 2013 to Oct 2023	Feb 2013 to Oct 2023
Barium	Jan 2017 to Oct 2023	Oct 2013 to Oct 2019
Chromium	Feb 2013 to Oct 2023	Feb 2013 to Oct 2023
Copper	Jul 2019 to Oct 2023	Feb 2013 to Oct 2023
Nickel	Jan 2019 to Oct 2023	Feb 2013 to Oct 2023
Zinc	Oct 2015 to Oct 2023	Feb 2013 to Oct 2023
Calcium	Feb 2013 to Oct 2023	Feb 2013 to Oct 2023
Magnesium	Feb 2013 to Oct 2023	Feb 2013 to Oct 2023
Potassium	Feb 2013 to Oct 2023	Feb 2013 to Oct 2023
Sodium	Feb 2013 to Oct 2023	Feb 2013 to Oct 2023

Note: 2013 data are for pre-permit background samples and do not include data collected under the previous permit.

Headquarters Landfill Background Re-evaluation 2024
Mann-Kendall and Sen's Slope Summary

Parameter:			Alkalinity				Chloride				Sulfate			
Well	Trend	No Trend	Test	M-K Stat/ Sen's Slope	p value	Trend?	Test	M-K Stat/ Sen's Slope	p value	Trend?	Test	M-K Stat/ Sen's Slope	p value	Trend?
C-1	0	14	M-Kendall	-129	0.150	no	M-Kendall	-31	0.364	no	M-Kendall	174	0.060	no
			Sen's Slope	-0.289			Sen's Slope	-0.006			Sen's Slope	0.001		
			Look Back:	Feb 2013 to Oct 2023			Look Back:	Oct 2018 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
C-2	2	12	M-Kendall	12	0.897	no	M-Kendall	175	0.078	no	M-Kendall	-54	0.108	no
			Sen's Slope	0.000			Sen's Slope	0.009			Sen's Slope	-0.008		
			Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023			Look Back:	July 2018 to Oct 2023		
P-9	4	9	M-Kendall	-392	0.000	no	M-Kendall	122	0.221	no	M-Kendall	-97	0.315	no
			Sen's Slope	-0.103			Sen's Slope	0.004			Sen's Slope	-0.003		
			Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
U-1	6	8	M-Kendall	135	0.131	no	M-Kendall	161	0.029	yes	M-Kendall	-77	0.276	no
			Sen's Slope	0.075			Sen's Slope	0.007			Sen's Slope	-0.001		
			Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
	12	43		Trend		0		Trend		1		Trend		0
				No Trend		4		No Trend		3		No Trend		4

Note: Alpha=0.05 for both tests.

Headquart

Mann-Ken Mann-Kendall and Sen's Slope Summary

Well	TDS				Barium				Cadmium			
	Test	M-K Stat/ Sen's Slope	p value	Trend?	Test	M-K Stat/ Sen's Slope	p value	Trend?	Test	M-K Stat/ Sen's Slope	p value	Trend?
C-1	M-Kendall	-130	0.162	no	M-Kendall	-16	0.754	no	M-Kendall	-10	0.922	no
	Sen's Slope	-0.423			Sen's Slope	-0.004			Sen's Slope	0.000		
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Jan 2017 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
C-2	M-Kendall	-36	0.672	no	M-Kendall	-12	0.797	no	M-Kendall	87	0.199	no
	Sen's Slope	-0.071			Sen's Slope	-0.006			Sen's Slope	0.000		
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Oct 2013 to Oct 2019			Look Back:	Feb 2013 to Oct 2023		
P-9	M-Kendall	-36	0.704	no	M-Kendall	-378	0.001	yes				
	Sen's Slope	-0.040			Sen's Slope	-0.007						
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023						
U-1	M-Kendall	273	0.004	yes	M-Kendall	-404	0.000	yes	M-Kendall	69	0.071	no
	Sen's Slope	0.500			Sen's Slope	-0.133			Sen's Slope	0.000		
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
		Trend		1		Trend		2		Trend		0
		No Trend		3		No Trend		2		No Trend		3

Note: Alpha=0.05 for both tests.

Headquart
Mann-Ken Mann-Kendall and Sen's Slope Summary

Well	Chromium				Copper				Nickel			
	Test	M-K Stat/ Sen's Slope	p value	Trend?	Test	M-K Stat/ Sen's Slope	p value	Trend?	Test	M-K Stat/ Sen's Slope	p value	Trend?
C-1	M-Kendall	131	0.088	no	M-Kendall	-38	0.158	no	M-Kendall	-41	0.156	no
	Sen's Slope	0.002			Sen's Slope	-0.003			Sen's Slope	-0.002		
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Jul 2019 to Oct 2023			Look Back:	Jan 2019 to Oct 2023		
C-2	M-Kendall	69	0.291	no	M-Kendall	-547	0.000	yes	M-Kendall	-9	0.941	no
	Sen's Slope	0.002			Sen's Slope	-0.005			Sen's Slope	0.000		
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
P-9	M-Kendall	299	0.000	yes	M-Kendall	-207	0.025	yes	M-Kendall	-332	0.001	yes
	Sen's Slope	0.003			Sen's Slope	-0.001			Sen's Slope	-0.003		
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
U-1	M-Kendall	13	0.880	no	M-Kendall	-33	0.769	no	M-Kendall	116	0.276	no
	Sen's Slope	0.000			Sen's Slope	-0.003			Sen's Slope	0.006		
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
		Trend		1		Trend		2		Trend		1
		No Trend		3		No Trend		2		No Trend		3

Note: Alpha=0.05 for both tests.

Headquart
Mann-Ken Mann-Kendall and Sen's Slope Summary

Well	Zinc				Calcium				Magnesium			
	Test	M-K Stat/ Sen's Slope	p value	Trend?	Test	M-K Stat/ Sen's Slope	p value	Trend?	Test	M-K Stat/ Sen's Slope	p value	Trend?
C-1	M-Kendall	103	0.055	no	M-Kendall	-103	0.334	no	M-Kendall	-104	0.329	no
	Sen's Slope	0.013			Sen's Slope	-30.0			Sen's Slope	-16.7		
	Look Back:	Oct 2015 to Oct 2023			Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
C-2	M-Kendall	-127	0.215	no	M-Kendall	-162	0.115	no	M-Kendall	209	0.042	yes
	Sen's Slope	-0.003			Sen's Slope	-6.548			Sen's Slope	4.286		
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
P-9	M-Kendall	9	0.908	no	M-Kendall	-109	0.304	no	M-Kendall	-125	0.240	no
	Sen's Slope	0.000			Sen's Slope	-4.762			Sen's Slope	-1.176		
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
U-1	M-Kendall	281	0.008	yes	M-Kendall	308	0.003	yes	M-Kendall	246	0.017	yes
	Sen's Slope	0.033			Sen's Slope	13.6			Sen's Slope	6.250		
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
		Trend		1		Trend		1		Trend		2
		No Trend		3		No Trend		3		No Trend		2

Note: Alpha=0.05 for both tests.

Headquart
Mann-Ken Mann-Kendall and Sen's Slope Summary

Well	Potassium Test	Potassium M-K Stat/ Sen's Slope	Potassium p value	Potassium Trend?	Sodium Test	Sodium M-K Stat/ Sen's Slope	Sodium p value	Sodium Trend?
C-1	M-Kendall	21	0.828	no	M-Kendall	-130	0.222	no
	Sen's Slope	0.792			Sen's Slope	-18.421		
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
C-2	M-Kendall	-68	0.417	no	M-Kendall	129	0.210	no
	Sen's Slope	-0.909			Sen's Slope	14.508		
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
P-9	M-Kendall	76	0.382	no	M-Kendall	-112	0.293	no
	Sen's Slope	1.000			Sen's Slope	-4.516		
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
U-1	M-Kendall	51	0.512	no	M-Kendall	107	0.300	no
	Sen's Slope	0.660			Sen's Slope	4.000		
	Look Back:	Feb 2013 to Oct 2023			Look Back:	Feb 2013 to Oct 2023		
		Trend		0		Trend		0
		No Trend		4		No Trend		4

Note: Alpha=0.05 for both tests.