INTERIM ENGINEERING OBSERVATIONS
&
ASSESSMENT REPORT

Forensic Cast Iron Sewer Pipe Study
Former Kast Property
Carousel Tract Residences

City of Carson, CA

September 14, 2017

Project No. 01176-001

PREPARED BY:

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Former Kast Property, Carousel Tract Residences, City of Carson, CA
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1.0 INTRODUCTION

This document, titled *Interim Engineering Observations & Assessment Report, Forensic Cast Iron Sewer Pipe Study, Former Kast Property, Carousel Tract Residences, Carson, CA* has been prepared by HG Cornerstone, LLC ("HGC") on behalf of the City of Carson, California (the "City") under City Purchase Order Number CO2022 RC003559, dated February 27, 2017 and the Contract Services Agreement between Aleshire & Wynder, LLP ("City Attorney") acting as City Attorney, and HGC, dated February 1, 2017, to provide forensic engineering consulting services related to the Carousel Tract of residential lots and homes (the "Property").

HGC was contracted to provide a forensic engineering evaluation and expert witness consulting services as necessary and required in order to form an expert opinion as to whether a causal connection (or connections) exists between residential cast iron sewer pipe degradation and associated pipe failures observed and the environmental contamination present within the soil at the Carousel Tract of residential lots and homes. The present day single-family residential homes within the Carousel Tract were constructed on what was known as the former "Kast Property". The former Kast Property was formerly utilized for crude oil storage by Shell Oil Products US ("Shell") before the homes were built.

HGC undertook a forensic engineering assessment concerning cast iron sewer pipe failures on the Property in order to form an expert opinion. In doing so, HGC initiated a limited study involving background and engineering research, the field sampling and analytical laboratory testing of site soils, the collection of cast iron sewer pipe specimens, and other forensic engineering work.

The specific components outlining the planned forensic engineering assessment concerning cast iron sewer pipe failures were set forth in prior document prepared by HGC tiled "*Cast Iron Sewer Pipe Forensic Testing & Evaluation Protocols, Carousel Tract, Carson, CA*", dated March 28, 2017. A copy of that document is provided herein as Appendix A. HGC's field study was conducted in general conformance with the protocols and procedures outlined and described in that document.

As of the date of this report, the overall sewer pipe study remains incomplete. Therefore, this report presents only interim observations, findings, and conclusions. To date, HGC has completed the major components of our field study pertaining to the cast iron sewer pipe degradation and failures observed within the Carousel Tract of the City of Carson. Additionally, the selected analytical laboratories have tested soil samples collected during that study. Those test results have been received by HGC and are presented and discussed herein.

The remaining work to be performed includes: 1) the metallurgical examination of the cast iron pipe specimens collected and, 2) other work yet to be completed including recommended further study and analytical laboratory testing as discussed below in Section 5. The remaining work is currently on hold pending budget approval by the City to continue this study.

This report summarizes a number of HGC's main activities and a number of our preliminary findings, based upon key observations made in the field, coupled with the soil sample analytical results received and background and engineering research that has been performed to date.

2.0 FIELD STUDY SUMMARY

The field portion of our forensic study was conducted from about May 12, 2017 to June 14, 2017. HGC's field study was performed while Shell was implementing its soil remediation activities within the Carousel Tract. Those activities included excavation and removal of impacted soils in and around the houses of the Carousel Tract, among other things. The remediation work did not include the excavation of soils from beneath the foundations of the houses where much of the cast iron sewer piping was located. The cast iron sewer piping, mainly located beneath a typical house's concrete foundation, typically only extended about 10 or 15 feet or so beyond the house, where it transitioned into clay sewer piping, before connecting to the main City sewer collection pipe located in the street.

The remediation work being performed at the time is outlined and described in the document tilted *Revised Remedial Action Plan, Former Kast Property, Carson, California*, dated June 30, 2014, prepared by URS Corporation and Geosyntec Consultants. The soil excavation activities described in that document were being carried out in pre-selected, phased groups of residential lots termed "clusters". HGC's field study included residential lots located both within and outside of Shell's current and active "Cluster 4" impacted soil excavation area.

In all, a total of six homes were included in HGC's field study including three homes from within the current Shell "Cluster 4" impacted soil excavation area, and three homes located outside of the Cluster 4 excavation area that were not subject to excavation activities (i.e., excavation activities either had not yet commenced at those homes or were not planned). The homes included in HGC's field study are each listed in Table 2.0 presented below.

The homes that were included in HGC's field study were selected based largely upon the following criteria:

1. For homes outside of the current Shell "Cluster 4" impacted soil excavation area, HGC tried to identify homes with sewer pipe issues reported by the homeowner or resident.

2. For homes within the current Shell "Cluster 4" impacted soil excavation area, HGC tried to identify homes with observable cast iron sewer pipe degradation, exposed by excavation activities. However, HGC was only able to select from a few homes in Cluster 4 due to the inherent limitations to access posed by the ongoing excavation activities.

3. Overall, HGC tried to include a cross section of homes exhibiting moderate to extreme sewer pipe issues located in residential lots showing varying degrees of soil impact.

On April 6, 2017 HGC observed cast iron sewer pipe sections that were collected by Shell during their soil excavation activities. These pipe sections were extremely degraded and showed signes of moderate to severe corrosion.

A total of four separate phases of investigation were performed by HGC during our field study. These phases are listed and described below:

Phase I – Home Visits for Information Gathering

May 12, 2017

HGC conducted visits of homes within the Carousel Tract in order to discuss sewer pipe issues with the residents, understand the nature and degree of sewer and related issues directly from the residents, and evaluate the physical locations and site constraints as necessary and required in preparation for the upcoming sewer piping field study.

The residents discussed a variety of issues pertaining to their sewer pipes ranging from pipe blockages to having been told by a plumbing contractor that either a full or partial cast iron sewer pipe replacement would be necessary. Several residents had already either replaced all of their cast iron pipes or had rerouted some of their cast iron pipes along the outside of the home.

HGC also observed a sewer pipe replacement project being performed at 352 East 244th Street. This project was highly invasive and involved the opening up of walls and concrete floors to excavate, remove and replace the cast iron sewer pipe located below the foundation. The piping removed was observed to be highly degraded.

Phase II – Cast Iron Sewer Pipe Camera Inspections & Physical Locations, at Homes Outside of Current Shell Excavation Area (Cluster No. 4)

May 23, 2017

HGC observed sewer pipe camera inspections performed by a plumbing contractor and physically located the position and depth of cast iron sewer pipes at seven homes within the Carousel Tract to evaluate potential cast iron sewer pipe sections to remove as samples. HGC screened homes for accessible and removable sewer pipe sections to include in study. HGC also had cast iron sewer pipe sections precisely located underground for upcoming exploratory excavation.

Camera pipe inspections were recorded and revealed interior cast iron pipe sections that varied from normal to extremely degraded with holes through the pipe walls, allowing waste water to exit the sewer pipe and directly enter the soil beneath the home. Sewer pipe location work revealed that: 1) much of the cast iron piping that extends from the concrete house foundations was inaccessible for our study because it was located directly beneath concrete site paving, and 2) cast iron piping that was accessible for our study typically only extended about 12 to 18 inches or so from beyond the concrete house foundations (from where it transitioned into clay pipe). Degraded cast iron sections were mainly identified well beneath the concrete house foundations, typically beneath bathroom and kitchens.

Several of the residents of the homes inspected agreed to participate in our study and to allow us to collect cast iron sewer pipe segments and soil samples.

Phase III – Cast Iron Sewer Pipe Physical Locations & Observations, at Homes Inside of Current Shell Excavation Area (Cluster No. 4)

June 5, 2017

HGC met with Mr. Deny Gomez, Principal Program Manager, Soil & Groundwater FDG, Shell Oil Products US at the Carousel Tract to evaluate accessible, potential cast iron sewer pipe sample locations for field study within Shell's current, active impacted soil excavation area (Cluster No. 4). Viewed active soil excavation area.

HGC located cast iron sewer piping made partially accessible by soil excavation activities and assessed potential cast iron sewer pipe sampling locations. HGC discuss logistics of performing sampling work with Mr. Gomez and AECOM personnel in preparation for our onsite field study.

A number of active soil excavations had been conducted to approximately 5 feet below ground surface (bgs). These excavations revealed that the cast iron piping in this area typically only extends about one to several feet or so from beyond the concrete house foundations (from where it transitions into clay pipe).

Phase IV – Cast Iron Sewer Pipe Specimen Collection & Soil Sampling

This phase involved the collection of cast iron sewer pipe segments as sample specimens and the collection of soil samples from adjacent to the pipe sections before they were removed. Cast iron sewer piping was exposed either by Shell (i.e., were located inside of the Cluster 4 active excavation area), or by professional plumbing contractors. All pipe sections were removed by professional plumbing contractors.

Soil samples were collected from locations immediately adjacent to the cast iron sewer pipe sections that were removed and saved as specimens for later metallurgical examination. The soil samples were shipped to analytical laboratories for various analyses. The chemical compounds analyzed for generally followed the compounds previously detected in the soils of the Property that had been identified as Constituents of Concern. These generally included Total Petroleum Hydrocarbons (TPH) as gasoline, diesel, and motor oil, Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs) including Polynuclear Aromatic Hydrocarbons (PAHs), and metals.

Selected soil samples were analyzed by all or some of the following specific test methodologies:

- Soil pH
- Soil Moisture Percent Content by ASTMD2216
- Metals by EPA 6010B/7471A CAC Title 22 Metals
- TPH Gasoline and Diesel by EPA 8015B (M) C6-C44 (includes the Gasoline carbon-chain range C4 to C12 and the Diesel carbon-chain range C10 to C28)
- TPH as Petroleum Oil by EPA 8015B (M) TPH Motor Oil (includes the Motor Oil carbon-chain range C17 to C44)
- VOCs by EPA 8260B Volatile Organics
- PAHs by EPA 8720 PAHs
- SVOCs by EPA 8270C Semi-Volatile Organics

Selected soil samples were also selected for analyses by metagenomics testing, a genetic assay of microbes in the soil. Metagenomics testing constitutes an analysis of the microbial composition in a given soil sample and provides a detailed report that identifies the type and relative quantity of microbes (bacteria) present in the soil. The focus of the metagenomics testing was the isolation and characterization (whole genome sequencing) of microbes that degrade hydrocarbons, produce acid as a waste product, and/or degrade iron.

Table 2.0 below lists the specific residential addresses that were included in our onsite sample collection efforts along with other pertinent information.

Table 2.0
Summary of Cast Iron Sewer Pipe & Soil Sample Locations

Date	Address	Field Work Performed	Notes
6/7/17	24706 Ravenna Ave.	Collected cast iron sewer pipe specimen and adjacent soil samples, including a "Y" and short length of pipe extending from side of house.	This home was located INSIDE of the Cluster 4 active excavation area.
6/12/17	24403 Ravenna Ave.	Excavated cast iron pipe only. No sample collection performed.	This home was located OUTSIDE of the Cluster 4 active excavation area. No samples could be collected since pipe segment located was fully encased in concrete from house foundation concrete over-pour.
6/13/17	24602 Neptune Ave.	Collected cast iron sewer pipe specimen and adjacent soil samples, including short piece of pipe segment at clay pipe intersection in front of house. Received pipe segments and small soil sample that were previously collected by owner of home next door.	This home was located OUTSIDE of the Cluster 4 active excavation area. This home is not slated for excavation of impacted soils by Shell (home is located next door to 24608 Neptune Ave.-- a full cast iron sewer pipe replacement was performed there during August 2016, as reported by homeowner, Mr. Chuck Keith).
6/14/17	24426 Ravenna Ave.	Collected cast iron sewer pipe specimen and adjacent soil samples, including cast iron bathtub trap removed by others.	This home was located OUTSIDE of the Cluster 4 active excavation area. Homeowner was having some cast iron pipe beneath a ground floor bathroom replaced on the same day.
6/14/17	24709 Panama Ave.	Collected cast iron sewer pipe specimen and adjacent soil samples, including short piece of pipe segment at clay pipe intersection in front of house.	This home was located INSIDE of the Cluster 4 active excavation area.
6/14/17	24723 Panama Ave.	Collected cast iron sewer pipe specimen and adjacent soil samples, including short piece of pipe segment at clay pipe intersection in front of house and galvanized water pipe specimen also from front of house.	This home was located INSIDE of the Cluster 4 active excavation area.

3.0 OBSERVATIONS & FINDINGS

The following key observations were made during HGC's field study.

3.1 Soil Conditions Observed

The condition of the soil exposed during our pipe sample excavation and removal work varied from un-noticeably impacted by petroleum hydrocarbons (staining and odors not observed) to obviously impacted by petroleum hydrocarbons (staining and odors observed). The petroleum hydrocarbon impact to the soil observed included a vast amount of striation as the soil color went from brown to gray to black over a relatively short distance and depth with irregular patterns or banding. Also, pockets of a tar-like substance were observed periodically in the soil at various depths that changed from a solid state to a sticky, highly viscous flowing liquid when heated by the sun.

There was no real identifiable pattern as to where petroleum hydrocarbon impact was observed or located or to what degree, either in lateral spread or according to depth. Photograph No. 1 below shows a typical excavation within the Cluster No. 4 area. Obvious petroleum hydrocarbon impact bands and spot locations can be observed as gray and black areas of discoloration.

The soil type observed from the surface to approximately 5 feet bgs was mainly clayey silt, brown, slightly plastic with a very small percentage of fine sand. The soil varied in moisture content from very dry and brittle at the surface (when exposed to the sun) and very damp to wet beneath the surface. The soil was very tight, condensed and exhibited very poor drainage qualities.

Soil pH readings collected in the field indicate that the pH of the soil sampled was generally in the neutral range. However, it is important to note that the soil pH can vary widely based upon location, temperature, and chemical constituents present throughout the soil. Also, corrosion can and does occur in soil with a relatively neutral pH.

Soil resistively field testing was conducted and the results indicated that the soil within the Carousel Tract is moderately to highly corrosive.

3.2 Cast Iron Pipe Conditions Observed

The cast iron sewer pipe segments observed in the field study were generally covered with a naturally-occurring protective outer and inner scale that formed during the time that the pipe was in service. A high degree of corrosion was not observed on these pipes so long as the naturally-occurring protective outer scale was intact.

Photograph No. 2, attached below, shows a cast iron sewer pipe specimen removed that displays a naturally-occurring protective outer and inner scale. The part of this pipe segment that appears rusted and corroded did not have an outer scale that formed because it was located beneath a rubberized no-hub pipe connection.

The degraded pipe sections collected by Shell and by homeowners observed no longer possessed a naturally-occurring protective outer scale and exhibited severe corrosion. Many were no longer in a serviceable condition and would have been leaking directly into the soil prior to removal.

Photograph No. 3, attached below, shows a cast iron sewer pipe segment provided by a homeowner. This pipe segment does not possess a protective outer scale and shows severe signs of corrosion. This pipe is no longer in a serviceable condition and would have been leaking directly into the soil prior to its removal.

3.3 Soil Sample Analytical Results

The analytical test results of soil samples that were collected from the five homes within the Carousel tract field study have been received from the analytical laboratories. Some of the key results received are summarized herein.

3.3.1 Analytical Results – Constituents of Concern

Crude oil as Total Petroleum Hydrocarbons (TPH) was detected in soil samples from all five homes sampled ranging from approximately 20 parts per million (ppm) to 1,900 ppm. The heaviest TPH concentrations were detected in the hydrocarbon range for crude oil. These results are generally consistent with the ranges that would be expected for TPH in soils located within the Carousel Tract.

Since the soil samples were collected immediately adjacent to cast iron sewer pipes, it can be concluded that crude oil (i.e., TPH) was identified in soil in direct contact with the cast iron sewer pipes. Therefore, the potential effects of crude oil on pipe corrosion could occur based on TPH impact identified and its direct proximity to, and direct ccontact with, the cast iron sewer piping.

A copy of the executive summary from the analytical report concerning the chemical compounds analyzed for is attached as Appendix B and provides a detailed summary of the analytical test results.

3.3.2 Analytical Results – Metagenomics Testing

The metagenomics testing detected bacteria in soil samples from two homes sampled within the Carousel tract associated with Microbial Influenced Corrosion (commonly referred to as MIC). The types of bacteria detected associated with MIC were Sulfate- and Sulfur-Reducing Bacteria (SRB) at 0.3% of the microbe population, Acid-Producing Bacteria (APB) at 8.2% of the microbe population, and Sulfur-Oxidizing Bacteria (SOB) at 0.3 to 0.9% of the microbe population.

Each of these bacteria detected in the soil samples can influence the corrosion of cast iron piping, or act to worsen or accelerate existing pipe corrosion. The highest population of bacteria of concern was APB that creates acids that lead to corrosion or can exacerbate an existing corrosion condition.

A copy of the metagenomics testing reports received from the analytical laboratory are attached as Appendix C.

4.0 INTERIM STUDY ANALYSIS & PRELIMINARY CONCLUSIONS

Following is a brief, interim analysis of HGC's observations and findings stemming from our study thus far. More work needs to be performed to complete our study so the discussion that follows should be considered preliminary in nature and is subject to change based upon additional, updated or differing observations, data, information and findings.

4.1 Potential Corrosion Mechanisms from Petroleum Hydrocarbons in Soil

Based upon research and a review of available literature, much of it prepared by the oil and gas industry, several electrochemical mechanisms can present that influence the corrosion of cast iron and steel in damp or wet soil when exposed to petroleum hydrocarbons and chemical compounds found in crude oil. These mechanisms can accelerate the natural degradation of cast iron in soil that has been impacted by petroleum hydrocarbons.

The normal service life of buried cast iron can typically range from 100 to over 150 yeas or even longer depending upon site conditions and the specific alloy of the cast iron. This timeframe is supported by both research and the recent input and feedback from several local plumbing contractors. Typically, cast iron sewer pipe develops a natural internal and external layer, or protective scale, made up of rust and mineral deposits that prevents or significantly slows down the electrochemical corrosion process. This type of protective layer was observed on a number of exposed sewer pipes.

However, the external naturally occurring protective scale cannot and does not always develop along the entire length of pipe or, once formed, it can become degraded by chemical action. For example, when objects are in direct contact with the pipe (e.g., other building elements or rubberized pipe connectors), the outer protective scale may be prevented from developing. Also, certain chemicals can prevent the protective scale form developing or can completely degrade it once formed. When the outer protective scale cannot develop, is degraded, or is removed by external forces, the exposed cast iron becomes susceptible to rapidly occurring corrosion under the right conditions.

The presence of chemical constituents found in petroleum hydrocarbons, when mixed with water, can facilitate corrosion. Corrosion of steel pipe and service equipment is a major problem for the oil and gas industry when petroleum hydrocarbons are mixed or cut with water (typically above approx. 40 to 50% water content). Some chemicals and impurities in crude oil can facilitate corrosion. The most severely corroded pipe segments observed did not display the typical naturally occurring external protective scale.

Some key preliminary and theoretical pipe corrosion mechanisms that may have been influenced or caused by the presence of petroleum hydrocarbons in the soil, including chemical compounds found in crude oil, are summarized below. <u>As these are theoretical and preliminary, they need to be correlated with the additionally proposed metallurgical examination of the cast iron pipe specimens collected and additionally proposed analytical laboratory testing.</u>

1. **Some chemicals and impurities found in crude oil can facilitate corrosion.** Crude oil comprises a mixture of thousands of organic substances, mainly hydrocarbons, with some admixture of oxygen-, nitrogen-, and sulphur-containing organic compounds, along with some inorganic species (e.g., metals). Crude oil itself is generally not found to be corrosive. However, when water is mixed with petroleum hydrocarbons including crude oil (especially by mixing more than approx. 40 to 50% water content), the elemental composition of the specific hydrocarbon components, and chemical constituents (fractional compounds), corrosive gasses, and impurities naturally occurring in the crude oil can, however, locally lower the pH and create an electrolytic condition that promotes the corrosion of steel and cast iron. Soil consists of soil particles, water, and air (i.e., the soil-gas-water system). The water in soil can absorb chemical constituents that facilitate the corrosion process. The air in soil can contain corrosive gasses that become absorbed into the soil water and further facilitate the corrosion process. This occurs on a micro scale and can happen quickly or can take a more prolonged period of time. Thus, the presence of hydrocarbons in the soil can facilitate corrosion by influencing the water chemistry of the soil-gas-water system. The extent of corrosion is also influenced by the soil temperature (and temperature differentials which also influence pH), carbon dioxide, hydrogen sulfide, salts (e.g., sodium chloride, calcium chloride, and magnesium chloride), and light organic acids.

2. **Wet soil facilitates pipe corrosion.** The soil within the Carousel Tract is very tight and exhibits very poor drainage. Also, the concrete foundations or the former crude oil storage tanks left below grade, located at approximately 8 to 12 feet bgs, act as a soil water drainage barrier, trapping water and acting to keep soil moisture levels elevated. The owners of 24403 Ravenna Avenue reported that Shell (or its contractors) intentionally broke up the subsurface concrete slab located beneath their front yard for the purpose of promoting better soil drainage (at that time, water was found to fill an exploratory trench dug down to about 8 feet bgs). These conditions, that promote water accumulation and retention within the soil, and the associated soil moisture (even slight dampness) are sufficient to facilitate pipe corrosion (especially when moist soil is in contact with the cast iron pipes for prolonged periods of time, even intermittently).

3. **Corrosion can occur in varied pH conditions.** Acidic conditions (low pH) do not have to prevail in order for corrosion to occur. Water with dissolved oxygen levels of only 50-100 parts per billion (ppb) can facilitate the corrosion process even at or near neutral pH depending upon other variables. The soil pH levels can also vary along the length of buried piping setting up pH gradients that can facilitate the corrosion process. The soil

pH levels along the cast iron piping will vary as caused by the chemical constituents within the soil, their concentrations, soil moisture content, and dissolved oxygen levels. The pH level of soil is also temperature dependent. The pH levels in soil will vary based upon temperature (e.g., from hot water flowing through buried drainpipes) and tend to vary along the length of the pipe, also facilitating corrosion by setting up pH gradients.

4. **Wet soil containing chemical constituents from crude oil can facilitate corrosion.** Some chemicals and impurities naturally occurring in crude oil dissolved in soil water can create an elevated electrolytic condition that promotes the corrosion of steel and cast iron. Furthermore, our recent onsite soil resistivity measurements indicate that the soil tested is moderately to severely corrosive. Corrosive chemical constituents present in the soil can dissolve the cast iron pipe's naturally occurring external layer of protective scale, leaving the cast iron exposed and susceptible to corrosion.

5. **Gasses dissolved in water can facilitate corrosion.** Gasses that become dissolved in soil water (and thus the moisture that contacts the cast iron pipes), including dissolved oxygen, carbon dioxide, and hydrogen sulfide gas, can cause corrosion. These gasses are normally associated with petroleum hydrocarbon induced corrosion and both oxygen and carbon dioxide have been detected in the gasses extracted from soil beneath the Carousel houses by Shell's consultants during soil gas testing. Also, vapor extraction systems installed and operated beneath houses can act to replenish soil gasses (as these move through the soil just below the house's foundation via the vapor extraction system) that can then become absorbed by the underlying soil water. Dissolved oxygen is the most corrosive followed by carbon dioxide, then hydrogen sulfide.

6. **Hydrocarbon-degrading bacteria can facilitate corrosion.** The occurrence of some hydrocarbon-degrading bacteria in hydrocarbon-impacted soil can facilitate electrochemical corrosion reactions. These bacteria can produce waste products that are able to cause corrosion of cast iron.

4.2 Preliminary Interim Conclusions Regarding Cast Iron Pipe Corrosion Mechanisms

Both degraded and non-degraded cast iron sewer pipes have been observed within the Carousel Tract within our study. The non-degraded piping appeared in a condition normal to its age and use. The degraded cast iron piping observed appeared to be severe and premature. A fair amount of sporadic hydrocarbon impact to the soil was observed.

Several key theoretical pipe corrosion mechanisms that may have been influenced by, or directly caused by, the presence of petroleum hydrocarbons in the soil have been identified, as listed above in Section 4.1. These theoretical mechanisms seem to support the position that the hydrocarbon impacted soil has, in fact, caused, or has at least contributed to the cause of, premature degradation of cast iron sewer pipes that were in contact with the hydrocarbon impacted soil, in the form of corrosion.

However, these theoretical mechanisms need to be corroborated and supported by: 1) the metallurgical examination of the cast iron pipe specimens collected, and 2) other work yet to be completed including recommended further study and analytical laboratory testing. Once these action items have been completed, an expert opinion can be developed as to whether or not a causal connection exists between the hydrocarbon impact to the soil and the levels of cast iron pipe deterioration observed (or whether or not that determination can be made).

4.3 Preliminary Interim Conclusions Regarding Potentially Adverse Health Effects

It should also be noted that due to the severity of many of the degraded cast iron sewer pipes, a condition has developed allowing the direct infiltration of raw sewerage from leaking or degraded pipes directly into the soils beneath the affected houses within the Carousel Tract. This condition presents a potential threat to soil and groundwater since the constituents of raw sewerage can and do include bacteria, viruses, parasites, chemicals harmful to human health and the environment including, for example, carcinogens from household cleaning products, and hormones, pharmaceuticals, and radioactive substances from medications.

Additionally, another hazardous condition has development due to the severe degradation of cast iron sewer pipes. The leaking, degraded, broken sewer pipes can no longer protect the occupants of the home from direct exposure to sewer gasses. It is well established that sewer gases can include such potentially dangerous and harmful gasses such as hydrogen sulfide, esters, ammonia, carbon monoxide, methane, sulfur dioxide, and nitrogen oxides. Sewer gasses like hydrogen sulfide, for example, are extremely harmful to human health at certain levels.

Whether or not a causal connection is affirmed between the constituents of concern identified in the soil and the cast iron sewer pipe degradation observed the potentially dangerous and harmful conditions identified above need to be addressed presently.

5.0 RECOMMENDED FURTHER STUDY & TESTING

HGC is presently waiting on budget approval for the planned metallurgical work to be performed on cast iron sewer pipe specimens collected. Therefore, information and findings regarding this study will be updated and modified, as necessary, in the near future.

5.1 Critical Next Steps of the Study

Several key theoretical pipe corrosion mechanisms that may have been influenced or caused by the presence of petroleum hydrocarbons in the soil have been identified (as discussed in our prior memorandum dated June 21, 2017). These theoretical mechanisms need to be corroborated and supported by: 1) the metallurgical examination of the cast iron pipe specimens collected, and 2) other work yet to be completed, including recommended further study and more specific analytical laboratory testing on soil samples collected for chemical compounds specifically found in crude oil that contribute to, or cause, corrosion of cast iron.

It will be critical to perform the metallurgical examination of the cast iron pipe specimens collected in order to evaluate or determine:

1. The specific cast iron alloy(s) in question;

2. Specifically identify the chemical makeup of the corrosion products found on the pipe specimens collected, and elemental species present, in order to evaluate the possible corrosion mechanism(s) and assess to what degree the possible corrosion mechanism(s) may be linked to the constituents of concern found in the soil; and

3. Specifically identify types of corrosion mechanisms observed.

The metallurgical examination will allow for proper identification of the chemical reactions, electrochemical corrosion process(es), and/or MIC processes that may have taken place, in turn, leading to the identification of a potential casual connection between the cast iron degradation observed and the presence of crude oil. Once these action items have been completed, an expert opinion can be developed as to whether or not a causal connection exists between the hydrocarbon impact to the soil and the level of cast iron pipe deterioration observed (or whether or not that determination can be made).

Presently, HG Cornerstone is waiting for additional budget approval to complete the above-described work, which is still required in order to complete the project, as outlined in our previous status update memorandum dated June 21, 2017.

5.2 Additionally Recommended Further Study & Testing

Based upon the research and observations made thus far, the following action items are recommended to further augment our study, in additional to the metallurgical examination discussed above in Section 5.1. The costs for these additional items is not included in the budget summary discussions above or below, but can be estimated upon request.

1. Perform more targeted chemical analytical testing on some of the soil samples previously collected to identify chemical constituents in the soil, stemming from the presence of crude oil and other hydrocarbons that can facilitate corrosion and increase corrosion rates.

2. Collect and analyze soil additional samples from other non-crude-oil-impacted sites in the vicinity to be analyzed for certain chemical constituents to establish appropriate “background” levels for comparison purposes

3. Perform on onsite soil percolation test to evaluate the percolation rate of the soil.

4. Perform certain geotechnical testing on the soil to definitively establish and define its physical makeup and soil parameters.

5. Include more homes in the study in the future.

6.0 DISCLAIMER

This report has been prepared subject to and pursuant to the terms, conditions, exclusions, assumptions, and limitations of the Contract Services Agreement between Aleshire & Wynder, LLP (the "City Attoenry") and HG Cornerstone, LLC dated, February 1, 2017, issued under City of Carson (the "City") Purchase Order Number CO2022 RC003559, dated February 27, 2017, to provide forensic engineering consulting services related to the Carousel Tract of residential lots and homes (the "Property").

Acceptance of, use of, and/or reliance upon this report constitutes the City Attorney's and the City's full agreement and acceptance of those terms, conditions, assumptions, and limitations. This report has been prepared for the sole informational purposes and use by the City Attorney and the City, as of the time and date of its preparation, and as of the time and date when our observations of the Property were made. This report shall not be relied upon by any third party.

The observations, findings, conclusions, and recommendations presented in this report shall pertain only to those specific locations and physical parts, components, and/or aspects of the structure(s), building(s), or site(s) that were in fact observed at the time the observations were made and any assessment work performed by the HG Cornerstone, LLC. Observations and assessments of conditions elsewhere in the building(s), structure(s), or site(s) are not included in and were not intended or addressed in this report, and could differ significantly. The identification and documentation of each and every defect or deficiency present within the entire building(s), structure(s), or site(s) within the Property are not intended or offered, and no guarantee or warrantee associated with such is either offered or implied herein.

Only readily select, accessible areas of the Property and subject areas of interest were observed. HG Cornerstone, LLC's assessment activities did not include a complete, exhaustive or invasive assessment of all structures and buildings and/or their component parts, or surrounding environment (including the air, water and soil), whether readily accessible, visible or concealed during the assessment, nor did it include a comprehensive check of all work against applicable building codes, laws, regulations, ordinances, etc. Our assessment work was limited in scope, nature, location, and was performed under time constraints and physical constraints, therefore other potential unidentified or unseen issues with the Property, building(s), structure(s), or site(s) may exist that were not observed, but that may require or necessitate correction, repair, replacement, remediation, or completion.

This report does not contain an offer to perform any design, remediation, or repair work. This report does not constitute an engineering design or complete, comprehensive repair or remediation methodology or scope of work. Any oral statements made by HG Cornerstone, LLC or its personnel at any time are not considered to be part of this report.

We reserve the right to modify our observations, findings, conclusions, and recommendations at any time based upon any new, supplemental, conflicting, or differing information or data received or obtained. Additional assessment work and studies may be warranted, necessary, or required.

The services of HG Cornerstone, LLC have been offered and performed applying the normal degree of skill and care ordinarily used and exercised under similar conditions by similar professionals practicing in the local vicinity at the same timeframe.

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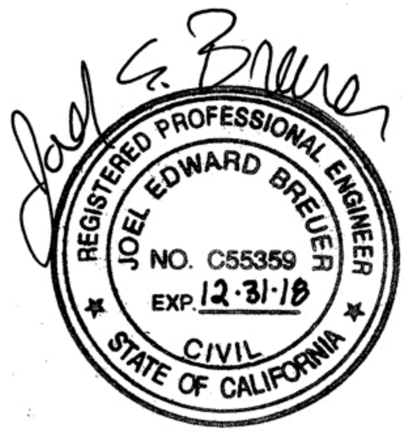
This report has been prepared to the best of my knowledge with information believed to be true, accurate, and reliable at the time and place of report preparation. Please do not hesitate to contact me with any questions, concerns, or comments pertaining to this report.

Sincerely,

HG Cornerstone, LLC



Joel E. Breuer, PE
Managing Partner

PHOTOS

PHOTOGRAPH NO. 1 - 6/7/17
Typical soils excavation within "Cluster No. 4" at 24706 (background) and 24712 Ravenna Avenue (foreground)
(petroleum hydrocarbon impact bands and spot locations can be observed)

PHOTOGRAPH NO. 2 - 6/13/17

Cast iron sewer pipe specimen removed from 24602 Neptune Avenue.
The left section of the pipe exhibits a naturally occurring protective scale. The right section of the pipe does not as it was covered by a rubberized pipe connecting band.

PHOTOGRAPH NO. 3 - 6/13/17

Cast iron sewer pipe specimen removed from 24608 Neptune Avenue by homeowner on or about 8/31/16. This pipe section does not exhibit a naturally occurring protective scale and has severely corroded.

APPENDIX A

Document: "*Cast Iron Sewer Pipe Forensic Testing & Evaluation Protocols, Carousel Tract, Carson, CA*", dated March 28, 2017

HG Cornerstone, LLC

946 Great Plain Avenue, No. 294, Needham, MA 02492 Phone/Fax: (617) 575-2300

EXPERT WITNESS · FORENSIC ENGINEERING · CONSTRUCTION DEFECTS · CASUALTY CLAIMS

*****Letter of Transmittal*****

Date: March 28, 2017

To: Mr. Brian Wright-Bushman, Associate
Aleshire & Wynder, LLP
18881 Von Karman Ave., Suite 1700
Irvine, CA 92612

From: Joel E. Breuer, PE

Project No: 01176-001

Subject: *Cast Iron Sewer Pipe Forensic Testing & Evaluation Protocols, Former Kast Property, Carousel Tract Residences, Carson, CA*

Dear Mr. Wright-Bushman:

Pursuant to our most recent discussions and our Contract Services Agreement dated February 1, 2017, I have prepared a detailed outline of the forensic testing and evaluation protocols that I am recommending concerning the cast iron sewer pipes located within the Carousel Tract properties. This document is attached for your review and comment.

Barring any presently unknown facts, conditions, or circumstances, the attached protocols should prove to be sufficient. Should you have any questions, concerns, require further information, or if you would like to discuss the contents of this document in more detail, please do not hesitate to contact me at (617) 575-2300 or by email at jb@hgcornerstone.com. Thank you.

Sincerely,

-JEB-

Joel E. Breuer, PE, Managing Partner
HG Cornerstone, LLC

ENGINEER'S ASSESSMENT
&
TESTING PROTOCOLS

Cast Iron Sewer Pipe Forensic Testing & Evaluation

Former Kast Property
Carousel Tract Residences
Carson, CA

MARCH 28, 2017

PREPARED BY:

HG CORNERSTONE, LLC
946 Great Plain Avenue, No. 294
Needham, MA 02492
Phone / FAX: (617) 575-2300
www.hgcornerstone.com

PREPARED FOR:

THE CITY OF CARSON, CA

Project No: 01176-001

Written By: JOEL E. BREUER, P.E.

ENGINEER'S ASSESSMENT
&
TESTING PROTOCOLS

Cast Iron Sewer Pipe Forensic Testing & Evaluation

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Cast Iron Sewer Pipe Forensic Testing & Evaluation Protocols
Carousel Tract, Carson, CA
March 28, 2017

1.0 INTRODUCTION

This document, titled *Cast Iron Sewer Pipe Forensic Testing & Evaluation Protocols* has been prepared by HG Cornerstone, LLC ("HGC") on behalf of the City of Carson, California (the "City") under City Purchase Order Number CO2022 RC003559, dated February 27, 2017 and the Contract Services Agreement between Aleshire & Wynder, LLP, acting as City Attorney, and HGC, dated February 1, 2017, to provide consulting services related to the Carousel Tract of residential lots and homes.

The main objective of HGC shall be to formulate an expert opinion as to whether a causal connection (or connections) exists between known residential sewer pipe failures and the environmental contamination present within the soil at the Carousel Tract of residential lots and homes constructed on the former "Kast Property" (collectively, the "Property") formerly utilized for crude oil storage by Shell Oil Products US ("SOPUS"). In order to form an expert opinion, HGC shall undertake a forensic engineering assessment concerning sewer pipe failures on the Property and shall perform a limited work scope of research, sampling, testing, and other forensic engineering work.

Two overarching phases of evaluation will be conducted by HGC during the assessment work in forming HGC's expert opinion: 1) evaluating a potential correlation between the hydrocarbon contamination (and other types of soil contamination, if present) and the corrosion of existing sewer pipes; and 2) evaluating a potential correlation between physical soil conditions and characteristics, including soil moisture content, potentially acting alone or in combination with the presence of environmental contamination, and the corrosion of existing cast iron sewer pipes.

The protocols presented herein have been prepared to define and implement the forensic assessment, testing, and failure analyses of corroded or degraded sewer pipes on the Property (the "Protocols"). The Protocols include a description of the onsite observations, sampling, and forensic testing of soil and sewer pipes at three or more individual lots located within the Property (the "Site(s)").

HGC and the City Attorney will collaborate to determine appropriate and available Sites for investigation and testing. The Protocols provide an overview and outline of the planned onsite evaluation work including documenting the onsite conditions observed, strategic soil and sewer pipe sample collection, analytical laboratory testing including soil properties/toxicity characterization and metallurgical testing and analyses, and other action items that may be incorporated based upon ongoing observations and findings.

This document presents the intended and planned protocols and evaluation methods to be utilized by HGC in performing the forensic portion of its work. The specific tests, evaluation methods, schedule, and overall approaches presented herein are anticipated to be sufficient and pertinent to the requirement of this assessment.

The evaluation and testing Protocols presented herein are provided moreover as guidelines that may be adapted or modified as needed based upon actual conditions encountered, and scheduling and budgetary limitations. Therefore, this document should be regarded as one that is flexible and can changed as necessary and required. These Protocols shall be subject to change should HGC deem that modification is necessary and required and as approved by the City.

2.0 SITE SELECTION, PLANNING & SCHEDULING

It is anticipated that HGC will conduct an onsite assessment of current conditions as they pertain to sewer pipe failures at three Sites (or as many Sites as practicable during this limited assessment) where corroded or degraded cast iron sewer pipes and contaminated soil conditions exist and are available and accessible for assessment work by HGC. The specific Sites to be evaluated shall be selected based upon:

1. Current information that is available on the number, location, and status of known sewer pipe failures from City employees, City officials, SOPUS, consultants, residents, and others.

2. HGC's review of background information including, but not limited to, the Revised Remedial Action Plan, dated June 30, 2014, prepared by URS Corporation and Geosyntec Consultants and associated documents, Property Specific Remedial Action Plans (PSRAPs) (if available), and any other site-specific information available regarding sewer pipe corrosion or degradation and associated sewer pipe failures as provided by the City of Carson, residents of the Carousel Tract, SOPUS personnel, consultants, plumbing contractors previously called upon to make repairs or perform sewer pipe replacement for homeowners, or others.

3. Visual observations made by HGC during an initial site visit just prior to the implementation of these Protocols.

4. Discussions and coordination between HGC, the City, SOPUS personnel, consultants, individual property owners, and others as necessary to obtain proper site access and to coordinate with ongoing soil excavation activities.

5. Other factors that may be deemed to have a bearing on site selection.

In order to select individual Sites for evaluation, HGC will conduct an initial onsite assessment of current conditions as they pertain to sewer pipe failures. Visual observations will be made of ongoing remedial soil excavation work by SOPUS and the condition of exposed utilities, as well as known sewer pipe failures that are accessible to HGC.

HGC will observe and evaluate the physical properties and characteristics of soil conditions and exposed cast iron sewer pipes, and gather other pertinent information. The selection of individual Sites for evaluation may be conducted by hand-excavating sewer pipes for visual observation and assessment prior to implementation of the planned cluster-based soil excavation activities to be performed by SOPUS. This will allow for a more strategic Site selection process and for the assessment work to be carried out in undisturbed locations. The selection of individual Sites for evaluation may be subject to change based upon actual field conditions, new information or data obtained, and other factors.

Once the individual Sites have been identified for field evaluation, individual site access agreements will be executed between the homeowners and the City (permitting HGC access to conduct its field work at each Site), a tentative schedule shall be established for execution of these Protocols, and SOPUS shall be so informed and formally coordinated with. Underground Service Alert ("USA") will be contacted for any scheduled excavation activities that are necessary and required to uncover buried sewer pipes, in the event that the sewer pipes will not already be exposed by SOPUS during their planned cluster-based soil excavation activities.

3.0 PROTOCOLS FOR ONSITE WORK ACTIVITIES

3.1 Protocols for Residential Sewer Pipe Evaluations

The following action items are intended to be performed at each Site:

1. Locate the cast iron portion of the main sewer soil pipe exiting the structure.

2. At Sites not previously excavated and exposed by SOPUS: A) mark out indented excavation area(s) and contact USA in advance to identify, locate, and mark out any underground utilities in the immediate vicinity; B) coordinate with SOPUS to properly handle the soil being excavated above and around the sewer piping and provide clean backfill material as necessary; and C) coordinate with a plumbing contractor to remove and replace selected sewer pipe sections (i.e., as necessary to collect pipe specimens and keep the sewer piping in service).

3. Excavate in and around the cast iron sewer pipe to uncover and expose approximately the upper one third of the pipe for visual observation. Use a standard tape measure and level to plot the location of the pipe, its approximate length and depth below grade, and calculate its approximate slope.

4. Photodocument the partially exposed sewer pipe, surrounding soil, and conditions observed.

5. At selected locations along the pipe, excavate the soil to a depth below the pipe to fully uncover and expose short lengths of the pipe (approximately 12 inches or so in length). This will expose limited or "keyed" portions of the cast iron all the way around the pipe to visually observe the top, sides and bottom portions of the pipe and look for signs of corrosion and/or disintegration.

6. By visual observation, assess and document the soil type(s) surrounding the cast iron pipe using the Unified Soil Classification System and document other notable and/or relevant physical conditions encountered.

7. Take soil moisture content readings at various locations using a standard soil moisture probe.

8. Collect undisturbed soil samples, using the methodologies described below in Section 3.2, immediately adjacent to the undisturbed, buried portions of the pipe in the immediate vicinity of where signs of pipe corrosion and/or disintegration have been observed in various stages, and or other locations as deemed necessary and appropriate. Photodocument soil sample collection locations and sewer pipe conditions directly adjacent to sample locations.

9. Measure the pH, temperature, and moisture content of the soil immediately adjacent to the buried sewer pipe using field techniques and methods suitable and appropriate for soil testing and evaluation.

10. Tag and mark the locations on the sewer pipe immediately adjacent to soil sample collection and/or where soil pH measurements were taken using plastic zip-type ties affixed to the pipe such that they are immovable.

11. After soil sample collection, fully and permanently remove selected cast iron pipe sections from the ground for visual observation, evaluation, and potential testing. Properly and systematically mark and photodocument each pipe section removed for further study.

12. Clean the surface area of certain cast iron sections using deionized water and a nylon brush. Evaluate cleaned pipe sections using a magnifying loop or a hand held microscope and document general condition including any corrosion or degradation observed. Select sections to be sampled for further metallurgical testing and analyses.

13. Cut away smaller pipe sections of interest as specimens for metallurgical evaluation and testing. Use standard industry pipe cutting techniques including, but not limited to, manual cast iron pipe cutters and power tools equipped with metal cutting wheels. Collect duplicate specimens if possible and if conditions allow. Properly label and photodocument each specimen.

14. Properly package selected cast iron pipe specimens for metallurgical testing and analyses and ship to the selected materials laboratory under properly executed evidence release form(s). Properly label, photodocument, and package selected remaining cast iron pipe sections for storage for potential future evaluation, assessment, and/or analysis.

The above protocols are subject to change or modification based upon onsite assessment activities, actual field conditions, and other factors.

3.2 Soil Sample Collection Protocols

1. Personnel wearing new, industrial-grade, Nitrile disposal gloves and using clean, stainless steel collection tools shall collect soil samples. Collection tools such as a trowel or spatula shall be decontaminated prior to each sample collected using a laboratory-grade decontamination solution such as Alconox (or equal) and rinsed with deionized water.

2. For soil samples to be analyzed for volatile organic compounds (if any) an appropriate field sample collection device such as and EnCore or TerraCore sampling device (or equal) shall be utilized.

3. Samples collected by the use of a trowel or spatula shall be placed into glass jars of appropriate volume for the intended analysis(es), with zero headspace and the lids shall be secured with a laboratory-grade film such as Parafilm (or equal).

4. The requisite number of duplicate samples shall be collected as necessary and required for data validation and quality assurance/quality control purposes as recommended by the analytical laboratory.

5. All samples shall be labeled upon sample collection showing the sample number, date and time of collection, initials of the collector, the sample media, and other pertinent information.

6. All samples shall be transported to the selected analytical laboratory(ies) on the same day of collection under a properly executed chain-of custody form provided by the analytical laboratory. The transport container for the samples shall be an ice chest filled with frozen ice packs or dry ice.

4.0 ANALYTICAL & FORENSIC TESTING

Samples of soil and cast iron pipe specimens will be evaluated and tested using the test methodologies described below.

4.1 Analytical Laboratory & Test Methodologies for Soil Samples

4.1.1 TPH and VOCs

It is anticipated that the selected analytical laboratory for soil sample analyses shall be Eurofins Calscience, Inc. located in Garden Grove, California. The chemical compounds to be analyzed for shall generally follow the compounds previously detected in the soils of the Property that have been identified as Constituents of Concern. These will generally include Total Petroleum Hydrocarbons (TPH) as gasoline, diesel, and motor oil, Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs) including Polynuclear Aromatic Hydrocarbons (PAHs), and metals.

Selected soil samples shall be analyzed by all or some of the following specific test methodologies:

- Soil pH
- Soil Moisture Percent Content by ASTMD2216
- Metals by EPA 6010B/7471A CAC Title 22 Metals
- TPH Gasoline and Diesel by EPA 8015B (M) C6-C44 (includes the Gasoline carbon-chain range C4 to C12 and the Diesel carbon-chain range C10 to C28)
- TPH as Petroleum Oil by EPA 8015B (M) TPH Motor Oil (includes the Motor Oil carbon-chain range C17 to C44)
- VOCs by EPA 8260B Volatile Organics + Oxygenates Prep 5035
- PAHs by EPA 8720 PAHs
- SVOCs by EPA 8270C Semi-Volatile Organics

The above-listed test methods and analytical laboratories are subject to change or modification based upon onsite assessment activities, actual field conditions, and other factors.

4.1.2 Metagenomics Testing

Selected soil samples shall be transported to the selected analytical laboratory for metagenomics testing, a genetic assay of microbes in the soil. It is anticipated that the selected metagenomics testing laboratory will be IEH Laboratories, located in Lake Forest Park, WA.

Metagenomics testing constitutes an analysis of the microbial composition in a given soil sample and provides a detailed report that identifies the type and relative quantity of microbes (bacteria) present in the soil. The focus of the metagenomics testing will be the isolation and characterization (whole genome sequencing) of microbes that degrade hydrocarbons, produce acid as a waste product, and/or degrade iron. A general description of metagenomics testing and the test methodology employed are provided in Appendix A.

The above-listed test methods and analytical laboratories are subject to change or modification based upon onsite assessment activities, actual field conditions, and other factors.

4.2 Testing & Evaluation of Cast Iron Specimens

4.2.1 Metallurgical Evaluation & Testing

The metallurgical evaluation and testing will involve the failure analysis, corrosion phenomena analysis, and materials characterization of selected cast iron specimens. This will include the identification and characterization of the cast iron alloy and an examination of corrosion or degradation of the cast iron specimens for failure analysis.

It is anticipated that the selected venue for metallurgical evaluation and testing will be the metallurgical laboratory section of the Massachusetts Institute of Technology (MIT), School of Engineering, Department of Materials Science and Engineering, located in Cambridge, MA. It is anticipated that Dr. Harold R. Larson, Sc.D., Research Affiliate, will oversee and conduct the metallurgical evaluation, testing, and failure analyses.

It is anticipated that the specific metallurgical evaluation and test methods to be employed shall include the following:

4.2.1.1 HiROX Microscope Examination

Initially, each specimen will be examined using a HiROX Microscope capable of rendering a three-dimensional compounded enlargement of the surface areas of a given specimen in its original (unprepared/unpolished) physical condition. The type and degree of corrosion or degradation will be evaluated and characterized. Digital microscopic images are also produced and are recorded.

4.2.1.2 Scanning Electron Microscope / Energy Dispersive X-Ray Spectroscopy (SEM/EDX)

This test utilizes a scanning electron microscope (a Model JOEL 6610LV is intended) fitted with an energy dispersive X-ray spectrometer to more closely examine both unprepared/unpolished and prepared/polished samples. This test will also result in an elemental analysis or chemical characterization of a sample called an EDX spectrum. The unique atomic structure of each element detected is displayed as its own unique peak on an X-ray spectrum. This allows for elemental composition analyses of a given metal surface or substance. Scanning electron microscope images are also produced and are recorded.

The above-listed test methods and analytical laboratories are subject to change or modification based upon onsite assessment activities, actual field conditions, and other factors.

5.0 ASSUMPTIONS

The following assumptions are made with regard to implementing the Protocols and may affect the selection and number of individual Sites, schedule, and other aspects of implementing the Protocols:

1. All field work at the three (3) Sites can be conducted and completed in three (3) consecutive days with one (1) consecutive day prior to that for preparations by HGC (i.e., no remobilization(s) will be necessary).

2. HGC will have direct and unrestricted access to three (3) Sites with previously known sewer pipe corrosion or degradation issues.

3. The sewer piping sections and soil requiring observation and sample collection by HGC will be fully excavated and uncovered by others at each Site sufficient to allow the efficient and timely collection of undisturbed samples. Also, HGC shall be allowed a reasonable, uninterrupted time allotment by others, at each Site, in order to perform HGC's work.

4. Permission for HGC to enter the Sites and perform destructive sample collection and destructive testing thereon will be obtained by the City or City Attorney in advance of the commencement of these Protocols.

5. Adequate samples of soil and sewer pipe sections (having the requisite characteristics, chemical/physical makeup, properties, condition and volume), and the requisite number and location of said adequate samples, can be collected during (i.e., at three (3) Sites), sufficient for HGC to obtain the necessary and required data and information during HGC's field observations, field assessment work, and analytical testing of samples, on which to base HGC's expert opinion and/or make further recommendations.

6. Physical repairs, restoration work, or cleanup/disposal at, or associated with, destructive sample collection sites and study areas on the Property and individual Sites, stemming from HGC's activities, is not necessary or required by HGC. This includes any materials, labor, supplies, costs, or fees for items such as plumbing repairs, soil backfill, soil compaction, foundation/concrete repair, landscaping, irrigation repair/relocation, incidental repairs, cleaning, collection, storage, transport, and/or disposal of any waste or debris generated at destructive study areas and destructive sample collection sites (including existing soil, sewer pipes (or sewer pipe sections), sewer pipe waste/inner contents, existing concrete, etc.), and any other similar or related work.

APPENDIX A

Description & Test Methodologies
for
Metagenomics Testing

Institute for Environmental Health
Molecular Epidemiology Inc.
15300 Bothell Way NE
Lake Forest Park, WA 98155

Phone: (206) 522-5432

Metagenomics Test Description

The Metagenomics Test aims to provide a comprehensive identification of microorganisms present in a given sample. The method takes advantage of state of the art DNA sequencing technology, that allows for an unbiased quantitative identification of microorganisms independent of their capability to grow under laboratory conditions. Therefore, this test alleviates many limitations of classical microbiological testing methods that depend on growth of microorganisms.

In brief, DNA is isolated from sample material using established DNA isolation techniques. Bacterial taxonomic marker genes are amplified by PCR, purified, and the DNA is subsequently sequenced. From each sample a minimum of 10,000 sequence reads should be obtained to assure a comprehensive and representative microbial profile. The microorganisms from which each DNA sequence originated, are identified based on the identified genetic markers and most current bacterial taxonomy available.

The final report gives a breakdown of the major groups of organisms by their lifestyle and frequency in the given sample, followed by a detailed list of bacteria identified in each of these groups. If basic information about metabolism, typical environment is available, this information is added in form of a note.

IEH Laboratories & Consulting Group
15300 Bothell Way NE
Lake Forest Park WA 98155
Telephone: +1 (206) 522 5432
Fax: +1 (206) 237 3957
Website: www.iehinc.com

Metagenomics Method Summary

DNA preparation and library construction

Water sample was filtered by 0.2µm pore size of polycarbonate filter membrane for environmental DNA (eDNA) extraction. eDNA was directly extracted from the filter membrane by using PowerSoil DNA isolation kit (MO BIO, Carlsbad, CA). DNA concentration was determined by UV spectrophotometer (Nanodrop, Wilmington, DE). For 16S metagenomics analysis, 16S ribosomal RNA gene (V3-V5 region) was amplified using bacterial universal primers fused to barcode and adapter sequence for MiSeq sequencer (Illumina, San Diego, CA) and purified by DNA purification kit (Pibio, Seattle, WA). Amplicon libraries were generated by KAPA DNA library preparation kit (Kapa Biosystems, Wilmington, MA). The following PCR condition was used: 2 min at 95 °C, 25 or 30 cycles of [15 s at 95 °C, 30 s at 57 °C, 40sec 72 °C], 72°C for 5mins. The number of PCR cycles were decided based on 16S Realtime PCR result. Minimal number of PCR cycles was used for reducing PCR bias. Amplicon libraries were normalized based on Realtime PCR and Qubit fluorometer data and pooled together in equimolar ratio. Normalized pooled library was sequenced using MiSeq reagent kit V3 (300�2) chemistry on the MiSeq sequencer (Illumina, San Diego, CA).

Determination of 16S rRNA gene copy number:

The copy number of 16S rRNA gene was quantified by intercalating dye based Realtime PCR with same primer for 16S library construction. Realtime PCR was conducted by ABI 7500 (Applied Biosystems, Carlsbad, CA). Gene copy number was calculated based on *E. coli* genomic DNA and could be varied by different microorganisms. Because of this variation, the relative abundance of 16S rRNA genes in environmental samples can be attributed both to variation in the relative abundance of different organism.

Sequence analysis:

The quality of the raw sequence data was evaluated with FastQC. Then, demultiplexing was performed to remove Phi X sequences, and to sort the sequences to the appropriate samples based on their barcodes, allowing for 1 to 2 mismatches. Quality filtering was done using split libraries fastq python script (QIIME Version 2) prior to merging the forward and reverse reads. Average lengths of all reads and the number of effective reads [with at least 90 % of the maximum theoretical length (465 bp for 2 × 300 bp kits)] were calculated for forward and reverse reads, respectively, after quality filtering. Paired end reads of sufficient length (minimum 50 base overlap between forward and reverse reads) were merged into full length sequences by join-paired ends python script (QIIME version 2). Taxonomical and phylogenetic assignment of representative OTUs was determined by MEI ACA002 pipeline (MEI curated proprietary database).

APPENDIX B

Analytical Laboratory Report for Soil Samples
Abbreviated Version - Executive Summary only

Date of Report: 07/12/2017

Joel Breuer

HG Cornerstone, LLC
Three Center Plaza, Suite 210
Boston, MA 02108

Client Project:	01176-001 City Of Carson
BCL Project:	Soil Samples
BCL Work Order:	1716457
Invoice ID:	B272116

Enclosed are the results of analyses for samples received by the laboratory on 6/14/2017. If you have any questions concerning this report, please feel free to contact me.

Revised Report: This report supercedes Report ID 1000621765

Sincerely,

Contact Person: Christina Herndon
Client Service Rep

Stuart Buttram
Technical Director

Table of Contents

Table of Contents

Executive Summary - Detections

Constituent	Result	PQL	MDL	Units	Method	Lab Quals
1716457-01 **24706RA, 6/7/2017 3:20:00PM, Joel Breuer**						
TPH - C15 - C16	0.53	1.0	0.50	mg/kg	EPA-8015CC	J
TPH - C17 - C18	1.3	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C19 - C20	1.7	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C21 - C22	2.3	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C23 - C28	11	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C29 - C32	10	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C33 - C36	9.3	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C37 - C40	17	1.0	0.50	mg/kg	EPA-8015CC	
TPH (Total)	54	10	2.3	mg/kg	EPA-8015CC	
Moisture	10.1	0.05	0.05	%	Calc	
pH	8.61	0.05	0.05	pH Units	EPA-9045D	pH1:1
pH Measurement Temperature	24.8	0.1	0.1	C	EPA-9045D	
Solids	89.9	0.05	0.05	%	SM-2540G	
Arsenic	2.1	1.0	0.40	mg/kg	EPA-6010B	
Barium	64	0.50	0.18	mg/kg	EPA-6010B	
Beryllium	0.27	0.50	0.047	mg/kg	EPA-6010B	J
Chromium	12	0.50	0.050	mg/kg	EPA-6010B	
Cobalt	4.3	2.5	0.098	mg/kg	EPA-6010B	
Copper	7.9	1.0	0.050	mg/kg	EPA-6010B	
Lead	4.6	2.5	0.28	mg/kg	EPA-6010B	
Mercury	0.039	0.16	0.019	mg/kg	EPA-7471A	J
Molybdenum	0.34	2.5	0.050	mg/kg	EPA-6010B	J
Nickel	8.4	0.50	0.15	mg/kg	EPA-6010B	
Silver	0.17	0.50	0.067	mg/kg	EPA-6010B	J
Vanadium	20	0.50	0.11	mg/kg	EPA-6010B	
Zinc	24	2.5	0.087	mg/kg	EPA-6010B	
1716457-02 **SCBM, 6/12/2017 1:00:00PM, Joel Breuer**						
pH	8.44	0.05	0.05	pH Units	EPA-9045D	pH1:1
pH Measurement Temperature	24.8	0.1	0.1	C	EPA-9045D	
1716457-03 **24602NA, 6/13/2017 12:20:00PM, Joel Breuer**						
TPH - C17 - C18	0.86	1.0	0.50	mg/kg	EPA-8015CC	J
TPH - C19 - C20	1.2	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C21 - C22	1.4	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C23 - C28	6.6	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C29 - C32	2.6	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C33 - C36	2.4	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C37 - C40	4.6	1.0	0.50	mg/kg	EPA-8015CC	

Executive Summary - Detections

Constituent	Result	PQL	MDL	Units	Method	Lab Quals
1716457-03 **24602NA, 6/13/2017 12:20:00PM, Joel Breuer**						
TPH (Total)	20	10	2.3	mg/kg	EPA-8015CC	
pH	8.32	0.05	0.05	pH Units	EPA-9045D	pH1:1
pH Measurement Temperature	25.2	0.1	0.1	C	EPA-9045D	
Solids	90.8	0.05	0.05	%	SM-2540G	
Arsenic	1.6	1.0	0.40	mg/kg	EPA-6010B	
Barium	68	0.50	0.18	mg/kg	EPA-6010B	
Beryllium	0.27	0.50	0.047	mg/kg	EPA-6010B	J
Cadmium	0.060	0.50	0.052	mg/kg	EPA-6010B	J
Chromium	11	0.50	0.050	mg/kg	EPA-6010B	
Cobalt	4.2	2.5	0.098	mg/kg	EPA-6010B	
Copper	7.7	1.0	0.050	mg/kg	EPA-6010B	
Lead	4.1	2.5	0.28	mg/kg	EPA-6010B	
Mercury	0.034	0.16	0.019	mg/kg	EPA-7471A	J
Molybdenum	0.15	2.5	0.050	mg/kg	EPA-6010B	J
Nickel	7.2	0.50	0.15	mg/kg	EPA-6010B	
Silver	0.15	0.50	0.067	mg/kg	EPA-6010B	J
Vanadium	20	0.50	0.11	mg/kg	EPA-6010B	
Zinc	21	2.5	0.087	mg/kg	EPA-6010B	
1716457-04 **24426RA, 6/14/2017 12:40:00PM, Joel Breuer**						
TPH - C12 - C14	0.91	1.0	0.50	mg/kg	EPA-8015CC	J
TPH - C15 - C16	0.99	1.0	0.50	mg/kg	EPA-8015CC	J
TPH - C17 - C18	2.1	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C19 - C20	3.3	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C21 - C22	4.2	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C23 - C28	20	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C29 - C32	21	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C33 - C36	21	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C37 - C40	35	1.0	0.50	mg/kg	EPA-8015CC	
TPH (Total)	110	10	2.3	mg/kg	EPA-8015CC	
Moisture	14.3	0.05	0.05	%	Calc	
pH	8.37	0.05	0.05	pH Units	EPA-9045D	pH1:1
pH Measurement Temperature	24.6	0.1	0.1	C	EPA-9045D	
Solids	85.7	0.05	0.05	%	SM-2540G	
Arsenic	3.4	1.0	0.40	mg/kg	EPA-6010B	
Barium	74	0.50	0.18	mg/kg	EPA-6010B	
Beryllium	0.40	0.50	0.047	mg/kg	EPA-6010B	J
Cadmium	0.075	0.50	0.052	mg/kg	EPA-6010B	J
Chromium	23	0.50	0.050	mg/kg	EPA-6010B	

Executive Summary - Detections

Constituent	Result	PQL	MDL	Units	Method	Lab Quals
1716457-04 **24426RA, 6/14/2017 12:40:00PM, Joel Breuer**						
Cobalt	5.8	2.5	0.098	mg/kg	EPA-6010B	
Copper	13	1.0	0.050	mg/kg	EPA-6010B	
Lead	7.7	2.5	0.28	mg/kg	EPA-6010B	
Mercury	0.038	0.16	0.019	mg/kg	EPA-7471A	J
Molybdenum	0.25	2.5	0.050	mg/kg	EPA-6010B	J
Nickel	17	0.50	0.15	mg/kg	EPA-6010B	
Silver	0.17	0.50	0.067	mg/kg	EPA-6010B	J
Vanadium	29	0.50	0.11	mg/kg	EPA-6010B	
Zinc	40	2.5	0.087	mg/kg	EPA-6010B	
1716457-06 **24709PA, 6/14/2017 3:20:00PM, Joel Breuer**						
TPH - C15 - C16	0.54	1.0	0.50	mg/kg	EPA-8015CC	J
TPH - C17 - C18	1.3	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C19 - C20	1.7	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C21 - C22	2.1	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C23 - C28	9.6	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C29 - C32	5.3	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C33 - C36	4.2	1.0	0.50	mg/kg	EPA-8015CC	
TPH - C37 - C40	5.8	1.0	0.50	mg/kg	EPA-8015CC	
TPH (Total)	32	10	2.3	mg/kg	EPA-8015CC	
Moisture	11.4	0.05	0.05	%	Calc	
pH	7.86	0.05	0.05	pH Units	EPA-9045D	pH1:1
pH Measurement Temperature	24.2	0.1	0.1	C	EPA-9045D	
Solids	88.6	0.05	0.05	%	SM-2540G	
1716457-07 **24732PA, 6/14/2017 2:33:00PM, Joel Breuer**						
Pyrene	0.61	1.0	0.27	mg/kg	EPA-8270C	J,A01
Acenaphthene	0.087	0.030	0.012	mg/kg	EPA-8270C-SIM	A01
Anthracene	0.14	0.030	0.012	mg/kg	EPA-8270C-SIM	A01
Benzo[a]anthracene	0.33	0.030	0.011	mg/kg	EPA-8270C-SIM	A01
Benzo[b]fluoranthene	0.20	0.030	0.0095	mg/kg	EPA-8270C-SIM	A01
Benzo[k]fluoranthene	0.16	0.030	0.011	mg/kg	EPA-8270C-SIM	A01
Benzo[a]pyrene	0.29	0.030	0.0095	mg/kg	EPA-8270C-SIM	A01
Benzo[g,h,i]perylene	0.13	0.030	0.011	mg/kg	EPA-8270C-SIM	A01
Chrysene	0.36	0.030	0.0097	mg/kg	EPA-8270C-SIM	A01
Fluoranthene	0.12	0.030	0.014	mg/kg	EPA-8270C-SIM	A01
Fluorene	0.081	0.030	0.011	mg/kg	EPA-8270C-SIM	A01
Phenanthrene	0.15	0.030	0.012	mg/kg	EPA-8270C-SIM	A01
Pyrene	0.67	0.030	0.015	mg/kg	EPA-8270C-SIM	A01

Executive Summary - Detections

Constituent	Result	PQL	MDL	Units	Method	Lab Quals
1716457-07 **24732PA, 6/14/2017 2:33:00PM, Joel Breuer**						
TPH - C12 - C14	59	20	10	mg/kg	EPA-8015CC	A01
TPH - C15 - C16	79	20	10	mg/kg	EPA-8015CC	A01
TPH - C17 - C18	130	20	10	mg/kg	EPA-8015CC	A01
TPH - C19 - C20	140	20	10	mg/kg	EPA-8015CC	A01
TPH - C21 - C22	150	20	10	mg/kg	EPA-8015CC	A01
TPH - C23 - C28	480	20	10	mg/kg	EPA-8015CC	A01
TPH - C29 - C32	380	20	10	mg/kg	EPA-8015CC	A01
TPH - C33 - C36	300	20	10	mg/kg	EPA-8015CC	A01
TPH - C37 - C40	210	20	10	mg/kg	EPA-8015CC	A01
TPH (Total)	1900	200	47	mg/kg	EPA-8015CC	A01
Moisture	9.04	0.05	0.05	%	Calc	
pH	7.85	0.05	0.05	pH Units	EPA-9045D	pH1:1
pH Measurement Temperature	24.2	0.1	0.1	C	EPA-9045D	
Solids	91.0	0.05	0.05	%	SM-2540G	

HG Cornerstone, LLC		**Reported:**	07/12/2017 13:49
Three Center Plaza, Suite 210		Project:	Soil Samples
Boston, MA 02108		Project Number:	01176-001 City Of Carson
		Project Manager:	Joel Breuer

Laboratory / Client Sample Cross Reference

Laboratory	Client Sample Information			
1716457-01	**COC Number:**	---	**Receive Date:**	06/14/2017 20:00
	Project Number:	---	**Sampling Date:**	06/07/2017 15:20
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	24706RA	**Lab Matrix:**	Solids
	Sampled By:	Joel Breuer	**Sample Type:**	Soil
1716457-02	**COC Number:**	---	**Receive Date:**	06/14/2017 20:00
	Project Number:	---	**Sampling Date:**	06/12/2017 13:00
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	SCBM	**Lab Matrix:**	Solids
	Sampled By:	Joel Breuer	**Sample Type:**	Soil
1716457-03	**COC Number:**	---	**Receive Date:**	06/14/2017 20:00
	Project Number:	---	**Sampling Date:**	06/13/2017 12:20
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	24602NA	**Lab Matrix:**	Solids
	Sampled By:	Joel Breuer	**Sample Type:**	Soil
1716457-04	**COC Number:**	---	**Receive Date:**	06/14/2017 20:00
	Project Number:	---	**Sampling Date:**	06/14/2017 12:40
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	24426RA	**Lab Matrix:**	Solids
	Sampled By:	Joel Breuer	**Sample Type:**	Soil
1716457-05	**COC Number:**	---	**Receive Date:**	06/14/2017 20:00
	Project Number:	---	**Sampling Date:**	06/12/2017 14:20
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	24723PA	**Lab Matrix:**	Solids
	Sampled By:	Joel Breuer	**Sample Type:**	Soil
1716457-06	**COC Number:**	---	**Receive Date:**	06/14/2017 20:00
	Project Number:	---	**Sampling Date:**	06/14/2017 15:20
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	24709PA	**Lab Matrix:**	Solids
	Sampled By:	Joel Breuer	**Sample Type:**	Soil
1716457-07	**COC Number:**	---	**Receive Date:**	06/14/2017 20:00
	Project Number:	---	**Sampling Date:**	06/14/2017 14:33
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	24732PA	**Lab Matrix:**	Solids
	Sampled By:	Joel Breuer	**Sample Type:**	Soil

APPENDIX C

Analytical Laboratory Metagenomics Testing Reports for Soil Samples

Laboratories & Consulting Group

Customer Information:	Report No. 1118483-01
Joel Breuer	Requested Services:
HG Cornerstone, LLC	I. Total Bacterial Count
946 Great Plain Ave	II. Metagenomics Testing X
Needham, MA 02492	III. PCR Quantification
P: (617) 575-2300 E: N/A	

IEHMG-Sample ID:	1118483-01	Collection Date/Time:	Not specified
Customer Sample ID:	24706RA-008	Date/Time Received:	
Sample Type:	Soil	Comments: **City of Carson, Carousel tract sewer pipe study 01176-001, Sampled by JEB 6/7/17 3:30PM**	
Sample Source:	Soil at cast iron sewer pipe		

I. Total Bacterial Count		Comments:
Dilution Level:	N/A	N/A
Total Cell Count: cells/ml	N/A	

II. Metagenomics Testing		**Comments:**
Sample Molecular Barcode:	N/A	N/A
Amount of DNA Extracted:	N/A	
Total Number of Reads:	458,570	

Identified Types of Organism (see next page for details)	**% of Total**
A. Sulfate- and sulfur-reducing bacteria	<0.1%
B. Acid-producing bacteria	<0.1%
C. Nitrate-reducing bacteria	<0.1%
D. Iron-reducing bacteria	<0.1%
E. Methanogens	<0.1%
F. Sulfur-oxidizing bacteria	0.3%
G. Iron-oxidizing bacteria	<0.1%
H. Ammonia- and nitrite-oxidizing bacteria	<0.1%
I. Common drinking water flora	<0.1%
J. Coliforms / indicator species	<0.1%
K. Bacterial groups that include potentially pathogenic organisms	<0.1%
L. Other & unknown bacteria	99.0%

III. PCR Quantification

Type of Organism	**16SrRNA genes (per ml)**	**Standard Deviation (per ml)**
A. Total Bacteria	N/A	N/A
B. Total Archaea	N/A	N/A

Prepared by: Sukkyun Han 7/14/2017

Reviewed by: Cesar Nadala, Ph.D. 7/14/2017

Metagenomics Test (Detailed Results)

A. Sulfate- and Sulfur-reducing Bacteria

This group comprises all organisms that are known for their ability to convert sulfur compounds such as sulfates, sulfites, thiosulfates, and forms of elemental sulfur to hydrogen sulfide. Activity of these organisms is often associated with increased sulfur content of crude product.

Species Identification	% of total
None identified	<0.1

B. Acid-producing Bacteria

This category inlcudes organisms that degrade complex organic matter through fermentation. Fermentation products often include short chain organic acids such as lactic acid, acetic acid or butyric acid.

Species Identification	% of total
None identified	<0.1

C. Nitrate-reducing Bacteria

These organisms are often competing with sulfate-reducing bacteria. Frequent occurrence of these organisms can help mitigating adverse effects of sulfate-reducing bacteria.

Species Identification	% of total
None identified	<0.1

D. Iron-reducing Bacteria

Bacteria that mobilize iron. These organisms also compete with sulfate-reducing bacteria. They are commonly found in soil, sediments and aquifers.

Species Identification	% of total
None identified	<0.1

E. Methanogens

Methanogens are all organisms that produce methane from organic acids or hydrogen. These organisms often compete with sulfate-and sulfur-reducing organisms, nitrate-reducing organisms, as well as iron-reducing organisms. Due to technical limitations the number of methanogen species and frequency may be underestimated.

Species Identification	% of total
None identified	<0.1

---

* = Genus identification not unambiguously possible.
sp. = Species identification not unambiguously possible.

Metagenomics Test (Detailed Results)

F. Sulfur-oxidizing Bacteria

Bacteria that oxidize sulfur compounds remove hydrogen sulfide. These organism can help mitigate adverse effects of sulfate-reducing bacteria.

Species Identification		**% of total**
1. Limnobacter sp.	(Strict oxygen requirement)	0.3
Fraction of all organisms		0.3

G. Iron-oxidizing Bacteria

Microorganisms that are capable of oxidizing reduced or metallic forms of iron leading to formation of rust. These bacteria often form flocs or biofilms encrusted with metal precipitates.

Species Identification	**% of total**
None identified	<0.1

H. Ammonia- and Nitrite-oxidizing Bacteria

Microorganisms that oxidize reduced nitrogen species and release nitrites and nitrates. These organisms are commonly found in freshwater, rivers, lakes and soils. Some strains are resistant to disinfectants and can grow on chloramines and methylamines. Due to technical limitations ammonia-oxidizing Archaea are not systematically detected.

Species Identification	**% of total**
None identified	<0.1

I. Common Drinking Water Flora

This group includes bacterial genera that are commonly found in drinking water, drinking water distribution systems, and drinking water biofilms. These microorganisms constitute harmless water flora.

Species Identification	**% of total**
None identified	<0.1

J. Coliforms / Indicator Species

This group comprises genera of typical coliform bacteria and other indicator species associated with fecal contamination.

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* = Genus identification not unambiguously possible.
sp. = Species identification not unambiguously possible.

Metagenomics Test (Detailed Results)

Species Identification	**% of total**
None identified	<0.1

K. Bacterial Groups That Include Potentially Pathogenic Organisms

This category includes bacterial genera or species that are known to harbor potential pathogenic organisms. This doesn not consitute that actual pathogens were present in the sample. Further testing would be required to detect and confirm presence of pathogenic microorganisms.

Species Identification	**% of total**
None identified	<0.1

L. Other & Unidentified Microorganisms

Other and unidentified organisms comprise all organisms that do not belong to either of the categories listed above or could not be identified based on current genetic methods.

	Species Identification		**% of total**
1.	Syntrophobacteraceae sp. *		2.2
2.	Betaproteobacteria group sp. *		1.9
3.	Syntrophobacteraceae sp. *		1.8
4.	Deeply branching Unclassified group sp. *		1.1
5.	Syntrophobacteraceae sp. *		0.8
6.	E29 group sp. *		0.7
7.	Syntrophobacteraceae sp. *		0.6
8.	Betaproteobacteria group sp. *		0.6
9.	Pseudomonas sp.		0.6
10.	Rhizobiales group sp. *		0.6
11.	Nitrospiraceae sp. *	(Likely nitrite oxidizer)	0.6
12.	Nitrospira sp.	(Likely nitrite oxidizer)	0.6
13.	GN15 group sp. *		0.6
14.	Betaproteobacteria group sp. *		0.5
15.	Gammaproteobacteria group sp. *		0.5
16.	Bacillus sp.		0.5
17.	Rhodospirillaceae sp. *		0.5
18.	Nitrospira sp.	(Likely nitrite oxidizer)	0.5
19.	Nitrospira sp.	(Likely nitrite oxidizer)	0.5
20.	Chromatiales group sp. *		0.5
21.	43093 group sp. *		0.5
22.	PK329 group sp. *		0.5
23.	E29 group sp. *		0.5

* = Genus identification not unambiguously possible.
sp. = Species identification not unambiguously possible.

Metagenomics Test (Detailed Results)

24. Koribacteraceae sp. *	(common in soil)	0.4
25. EC1113 group sp. *		0.4
26. S0208 group sp. *		0.4
27. 0319-6A21 sp. *		0.4
28. RB41 group sp. *		0.4
29. PBS-25 group sp. *		0.4
30. 43093 group sp. *		0.4
31. Ellin6513 group sp. *		0.4
32. Chlamydiales group sp. *		0.4
33. Syntrophobacteraceae sp. *		0.3
34. Cytophagaceae sp. *		0.3
35. Bacillaceae sp. *		0.3
36. Rhizobiales group sp. *		0.3
37. Betaproteobacteria group sp. *		0.3
38. Sinobacteraceae sp. *		0.3
39. Syntrophobacteraceae sp. *		0.3
40. Rhodospirillaceae sp. *		0.3
41. Comamonadaceae sp. *		0.3
42. Solibacterales group sp. *	(Common in soil)	0.3
43. Nitrospiraceae sp. *	(Likely nitrite oxidizer)	0.3
44. (iii)1-15 group sp. *		0.3
45. Ellin6513 group sp. *		0.3
46. 0319-6A21 sp. *		0.3
47. Fimbriimonadaceae sp. *		0.3
48. MND1 group sp. *		0.3
49. Ellin6513 group sp. *		0.3
50. PAUC26f sp. *		0.3
51. IS-44 group sp. *		0.3
52. CandidatusXiphinematobacter sp.		0.3
53. Syntrophobacteraceae sp. *		0.3
54. Sinobacteraceae sp. *		0.2
55. Sinobacteraceae sp. *		0.2
56. Syntrophobacteraceae sp. *		0.2
57. Deltaproteobacteria group sp. *		0.2
58. Rhodospirillaceae sp. *		0.2
59. Syntrophobacteraceae sp. *		0.2
60. Rhodospirillaceae sp. *		0.2
61. Deeply branching Unclassified group sp. *		0.2
62. Syntrophobacteraceae sp. *		0.2
63. Nitrospiraceae sp. *	(Likely nitrite oxidizer)	0.2
64. Coxiellaceae sp. *	(Strict oxygen requirement)	0.2

* = Genus identification not unambiguously possible.
sp. = Species identification not unambiguously possible.

Metagenomics Test (Detailed Results)

65. Cellvibrio sp. (Strict oxygen requirement, fixes nitrogen; found in soil) 0.2
66. Chromatiales group sp. * 0.2
67. TM1 group sp. * 0.2
68. CandidatusMethylomirabilis sp. 0.2
69. DA101 sp. 0.2
70. C20 group sp. * 0.2
71. GCA004 group sp. * 0.2
72. RB41 group sp. * 0.2
73. MND1 group sp. * 0.2
74. MSB-5A5 group sp. * 0.2
75. RB41 group sp. * 0.2
76. Chromatiales group sp. * 0.2
77. envOPS12 group sp. * 0.2
78. koll11 group sp. * 0.2
79. S0208 group sp. * 0.2
80. Rubrobacteraceae sp. * 0.2
81. NB1-i sp. * 0.2
82. TM1 group sp. * 0.2
83. (iii)1-15 group sp. * 0.2
84. (iii)1-15 group sp. * 0.2
85. PAUC37f group sp. * 0.2
86. (iii)1-15 group sp. * 0.2
87. GCA004 group sp. * 0.2
88. VHS-B5-50 group sp. * 0.2
89. Deeply branching Unclassified group sp. * 0.2
90. Rhizobiales group sp. * 0.1
91. Sphingobacteriales group sp. * 0.1
92. Bacillus sp. 0.1
93. Deeply branching Unclassified group sp. * 0.1
94. Betaproteobacteria group sp. * 0.1
95. Erythrobacteraceae sp. * 0.1
96. Cytophagaceae sp. * 0.1
97. Deeply branching Unclassified group sp. * 0.1
98. Deeply branching Unclassified group sp. * 0.1
99. Oxalobacteraceae sp. * 0.1
100. Rhodospirillaceae sp. * 0.1
101. Syntrophobacteraceae sp. * 0.1
102. Rhodospirillaceae sp. * 0.1
103. Deltaproteobacteria group sp. * 0.1
104. Betaproteobacteria group sp. * 0.1
105. Cytophagaceae sp. * 0.1

* = Genus identification not unambiguously possible.
sp. = Species identification not unambiguously possible.

Report No. 1118483-01

Metagenomics Test (Detailed Results)

106.	Betaproteobacteria group sp. *		0.1
107.	Cupriavidus sp.		0.1
108.	Syntrophobacteraceae sp. *		0.1
109.	Sphingobacteriales group sp. *		0.1
110.	Bradyrhizobiaceae sp. *		0.1
111.	Koribacteraceae sp. *	(common in soil)	0.1
112.	Acidobacteria-5 group sp. *	(Diverse group of common soil bacteria)	0.1
113.	Methylophilaceae sp. *	(Likely methylotroph)	0.1
114.	Nitrospira sp.	(Likely nitrite oxidizer)	0.1
115.	Nitrospira sp.	(Likely nitrite oxidizer)	0.1
116.	Nitrospira sp.	(Likely nitrite oxidizer)	0.1
117.	Hyphomicrobiaceae sp. *	(Strict oxygen requirement)	0.1
118.	Alphaproteobacteria group s	(Sulfur reducer)	0.1
119.	Pedosphaerales group sp. *		0.1
120.	Chromatiales group sp. *		0.1
121.	S085 group sp. *		0.1
122.	Gemm-1 group sp. *		0.1
123.	0319-6A21 sp. *		0.1
124.	PAUC26f sp. *		0.1
125.	Chromatiales group sp. *		0.1
126.	Gemm-1 group sp. *		0.1
127.	Chromatiales group sp. *		0.1
128.	Fimbriimonadaceae sp. *		0.1
129.	Chromatiales group sp. *		0.1
130.	S085 group sp. *		0.1
131.	Gemm-1 group sp. *		0.1
132.	MND1 group sp. *		0.1
133.	JH-WHS99 group sp. *		0.1
134.	Chromatiales group sp. *		0.1
135.	43063 group sp. *		0.1
136.	SJA-28 group sp. *		0.1
137.	Caldilineaceae sp. *		0.1
138.	koll11 group sp. *		0.1
139.	CCM11a group sp. *		0.1
140.	Chromatiales group sp. *		0.1
141.	PAUC26f sp. *		0.1
142.	Legionellales group sp. *		0.1
143.	Ellin6513 group sp. *		0.1
144.	CandidatusEntotheonella sp.		0.1
145.	Cytophagaceae sp. *		0.1
146.	Deltaproteobacteria group sp. *		0.1

* = Genus identification not unambiguously possible.
sp. = Species identification not unambiguously possible.

Metagenomics Test (Detailed Results)

147.	Deeply branching Unclassified group sp. *	0.1
148.	Other (including below 0.1% frequency)	58.4
	Fraction of all organisms	99.0

* = Genus identification not unambiguously possible.
sp. = Species identification not unambiguously possible.

Laboratories & Consulting Group

Customer Information:	Report No. 1118483-02
Joel Breuer	Requested Services:
HG Cornerstone, LLC	I. Total Bacterial Count
946 Great Plain Ave	II. Metagenomics Testing X
Needham, MA 02492	III. PCR Quantification
P: (617) 575-2300 E: N/A	

IEHMG-Sample ID:	1118483-02	Collection Date/Time:	Not specified
Customer Sample ID:	24709PA-006	Date/Time Received:	
Sample Type:	Soil	Comments: **City of Carson, Carousel tract sewer pipe study 01176-001**	
Sample Source:	Sewer pipe study		

I. Total Bacterial Count

Dilution Level:	N/A	Comments: N/A
Total Cell Count: cells/ml	N/A	

II. Metagenomics Testing

Sample Molecular Barcode:	N/A	**Comments:** N/A
Amount of DNA Extracted:	N/A	
Total Number of Reads:	405,423	

Identified Types of Organism (see next page for details)	% of Total
A. Sulfate- and sulfur-reducing bacteria	0.3%
B. Acid-producing bacteria	8.2%
C. Nitrate-reducing bacteria	0.1%
D. Iron-reducing bacteria	<0.1%
E. Methanogens	<0.1%
F. Sulfur-oxidizing bacteria	0.9%
G. Iron-oxidizing bacteria	<0.1%
H. Ammonia- and nitrite-oxidizing bacteria	<0.1%
I. Common drinking water flora	<0.1%
J. Coliforms / indicator species	<0.1%
K. Bacterial groups that include potentially pathogenic organisms	<0.1%
L. Other & unknown bacteria	90.2%

III. PCR Quantification

Type of Organism	16SrRNA genes (per ml)	Standard Deviation (per ml)
A. Total Bacteria	N/A	N/A
B. Total Archaea	N/A	N/A

Prepared by: Sukkyun Han 7/14/2017

Reviewed by: Cesar Nadala, Ph.D. 7/14/2017

Report No. 1118483-02

Metagenomics Test (Detailed Results)

A. Sulfate- and Sulfur-reducing Bacteria

This group comprises all organisms that are known for their ability to convert sulfur compounds such as sulfates, sulfites, thiosulfates, and forms of elemental sulfur to hydrogen sulfide. Activity of these organisms is often associated with increased sulfur content of crude product.

	Species Identification		% of total
1.	Desulfobacca sp.		0.2
2.	Desulfobacca sp.		0.1
	Fraction of all organisms		0.3

B. Acid-producing Bacteria

This category inlcudes organisms that degrade complex organic matter through fermentation. Fermentation products often include short chain organic acids such as lactic acid, acetic acid or butyric acid.

	Species Identification		% of total
1.	Paenibacillus sp.		2.6
2.	Paenibacillus sp.		2.2
3.	Paenibacillus macerans	(also known as nitrogen fixer)	1.7
4.	Paenibacillus sp.		0.4
5.	Streptomyces sp.		0.4
6.	Alicyclobacillus sp.		0.3
7.	Paenibacillus sp.		0.2
8.	Alicyclobacillus sp.		0.2
9.	Paenibacillus sp.		0.1
10.	Alicyclobacillus sp.		0.1
	Fraction of all organisms		8.2

C. Nitrate-reducing Bacteria

These organisms are often competing with sulfate-reducing bacteria. Frequent occurrence of these organisms can help mitigating adverse effects of sulfate-reducing bacteria.

	Species Identification		% of total
1.	Azoarcus sp.	(Degrades aromatic compounds; found in soil and sludge)	0.1
	Fraction of all organisms		0.1

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D. Iron-reducing Bacteria

Bacteria that mobilize iron. These organisms also compete with sulfate-reducing bacteria. They are commonly found in soil, sediments and aquifers.

Species Identification		**% of total**
None identified		<0.1

E. Methanogens

Methanogens are all organisms that produce methane from organic acids or hydrogen. These organisms often compete with sulfate-and sulfur-reducing organisms, nitrate-reducing organisms, as well as iron-reducing organisms. Due to technical limitations the number of methanogen species and frequency may be underestimated.

Species Identification		**% of total**
None identified		<0.1

F. Sulfur-oxidizing Bacteria

Bacteria that oxidize sulfur compounds remove hydrogen sulfide. These organism can help mitigate adverse effects of sulfate-reducing bacteria.

Species Identification		**% of total**
1. Sulfuritalea sp.		0.5
2. Sulfuricurvum kujiense	(also known as nitrate reducer)	0.4
Fraction of all organisms		0.9

G. Iron-oxidizing Bacteria

Microorganisms that are capable of oxidizing reduced or metallic forms of iron leading to formation of rust. These bacteria often form flocs or biofilms encrusted with metal precipitates.

Species Identification		**% of total**
None identified		<0.1

H. Ammonia- and Nitrite-oxidizing Bacteria

Microorganisms that oxidize reduced nitrogen species and release nitrites and nitrates. These organisms are commonly found in freshwater, rivers, lakes and soils. Some strains

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are resistant to disinfectants and can grow on chloramines and methylamines. Due to technical limitations ammonia-oxidizing Archaea are not systematically detected.

Species Identification	% of total
None identified	<0.1

I. Common Drinking Water Flora

This group includes bacterial genera that are commonly found in drinking water, drinking water distribution systems, and drinking water biofilms. These microorganisms constitute harmless water flora.

Species Identification	% of total
None identified	<0.1

J. Coliforms / Indicator Species

This group comprises genera of typical coliform bacteria and other indicator species associated with fecal contamination.

Species Identification	% of total
None identified	<0.1

K. Bacterial Groups That Include Potentially Pathogenic Organisms

This category includes bacterial genera or species that are known to harbor potential pathogenic organisms. This doesn not consitute that actual pathogens were present in the sample. Further testing would be required to detect and confirm presence of pathogenic microorganisms.

Species Identification	% of total
None identified	<0.1

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L. Other & Unidentified Microorganisms

Other and unidentified organisms comprise all organisms that do not belong to either of the categories listed above or could not be identified based on current genetic methods.

	Species Identification		% of total
1.	Methylophilales group sp. *		10.0
2.	B110 group sp. *		4.4
3.	Proteobacteria group sp. *		3.0
4.	Dechloromonas sp.	(Chlorate reduction)	2.7
5.	Betaproteobacteria group sp. *		2.4
6.	ABY1 group sp. *		1.9
7.	Koribacteraceae sp. *	(common in soil)	1.8
8.	LCP-6 sp.		1.6
9.	BPC076 group sp. *		1.6
10.	Deeply branching Unclassified group sp. *		1.4
11.	AKIW659 sp. *		1.2
12.	Anaerolinaceae sp. *		1.2
13.	GCA004 group sp. *		1.0
14.	GN15 group sp. *		0.8
15.	GCA004 group sp. *		0.8
16.	SBla14 group sp. *		0.7
17.	LCP-6 sp.		0.7
18.	Comamonadaceae sp. *		0.7
19.	Ellin6513 group sp. *		0.6
20.	Thermodesulfovibrionaceae sp. *		0.6
21.	Koribacteraceae sp. *	(common in soil)	0.6
22.	GCA004 group sp. *		0.5
23.	Syntrophobacteraceae sp. *		0.5
24.	Proteobacteria group sp. *		0.5
25.	Betaproteobacteria group sp. *		0.5
26.	Thermodesulfovibrionaceae sp. *		0.4
27.	BD2-6 sp.		0.4
28.	GOUTA19 sp.		0.4
29.	TM1 group sp. *		0.4
30.	Proteobacteria group sp. *		0.4
31.	Betaproteobacteria group sp. *		0.4
32.	Betaproteobacteria group sp. *		0.4
33.	envOPS12 group sp. *		0.3
34.	CandidatusSolibacter sp.		0.3
35.	Unclassified Unclassified		0.3
36.	JH-WHS47 group sp. *		0.3

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37. Ellin6513 group sp. *		0.3
38. Syntrophobacteraceae sp. *		0.3
39. Deeply branching Unclassified group sp. *		0.3
40. Dechloromonas sp.	(Chlorate reduction)	0.3
41. Solibacterales group sp. *	(Common in soil)	0.3
42. Ellin6513 group sp. *		0.2
43. A31 group sp. *		0.2
44. GOUTA19 sp.		0.2
45. BPC076 group sp. *		0.2
46. CandidatusMethylomirabilis sp.		0.2
47. Ignavibacteriaceae sp. *		0.2
48. MBNT15 group sp. *		0.2
49. GCA004 group sp. *		0.2
50. Ellin6513 group sp. *		0.2
51. MBNT15 group sp. *		0.2
52. Oxalobacteraceae sp. *		0.2
53. Deeply branching Unclassified group sp. *		0.2
54. Anaerolinaceae sp. *		0.2
55. Rhodocyclaceae sp. *		0.2
56. Koribacteraceae sp. *	(common in soil)	0.2
57. JH-WHS47 group sp. *		0.1
58. GAL15 group sp. *		0.1
59. JH-WHS47 group sp. *		0.1
60. AKIW659 sp. *		0.1
61. Thermodesulfovibrionaceae sp. *		0.1
62. Gemm-2 group sp. *		0.1
63. Thermoleophilia group sp. *		0.1
64. 0319-7L14 group sp. *		0.1
65. DS-18 group sp. *		0.1
66. Melioribacteraceae sp. *		0.1
67. S085 group sp. *		0.1
68. JH-WHS47 group sp. *		0.1
69. NKB15 group sp. *		0.1
70. (iii)1-15 group sp. *		0.1
71. MND1 group sp. *		0.1
72. BPC076 group sp. *		0.1
73. Thermodesulfovibrionaceae sp. *		0.1
74. Paenibacillaceae sp. *		0.1
75. Pseudomonas sp.		0.1
76. Actinobacteria group sp. *		0.1
77. Deeply branching Unclassified group sp. *		0.1

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78.	Rhodocyclaceae sp. *		0.1
79.	Betaproteobacteria group sp. *		0.1
80.	Gallionella sp.		0.1
81.	Comamonadaceae sp. *		0.1
82.	Koribacteraceae sp. *	(common in soil)	0.1
83.	Betaproteobacteria group sp. *		0.1
84.	Syntrophobacteraceae sp. *		0.1
85.	Syntrophobacteraceae sp. *		0.1
86.	Betaproteobacteria group sp. *		0.1
87.	Rhodocyclaceae sp. *		0.1
88.	Other (including below 0.1% frequency)		36.9
	Fraction of all organisms		90.2

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