MARYLAND DEPARTMENT OF THE ENVIRONMENT

REPORT OF RESULTS FOR LEAD AND HEXAVALENT CHROMIUM GROUNDWATER INVESTIGATION

Green Valley / Monrovia
Frederick County, Maryland

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TABLE OF CONTENTS

EXHIBITS

FIGURES

TABLES

APPENDICES

List of Acronyms and Abbreviations

AOI – Area of Interest

ATSDR – Agency for Toxic Substances and Disease Registry

bgs – Below ground surface

CAP – Corrective action plan

Carroll – Carroll Independent Fuel Company

CDC – Centers for Disease Control and Prevention

COMAR – Code of Maryland Regulations

COP – Certificate of Potability

COPCs – Chemicals of potential concern

Cr – The elemental metal chromium

Cr VI – Hexavalent chromium, a valence state of the elemental metal chromium

CSF – Cancer slope-factor

CSM – Conceptual site model

DO – Dissolved oxygen

EPA – United States Environmental Protection Agency

EPCs – Exposure point concentrations

FCHD – Frederick County Health Department

ft – feet

GAC – Granular activated carbon

GES – Groundwater Environmental Services, Inc.

GVC Station – Former Green Valley Citgo station

HI – Hazard index

ISCO – *in-situ* chemical oxidation

Jenkins – Jenkins Environmental, Inc.

MCL – Maximum contaminant level

MCLG – Maximum contaminant level goal

MDE – Maryland Department of the Environment

MTBE – methyl tertiary-butyl ether

Md. Code Ann., Envir. – Environment Article of the Annotated Code of Maryland

µg/L – Micrograms per liter

µg/dL – Micrograms per deciliter

mg/kg – Milligrams per kilogram

NJDEP – New Jersey Department of Environmental Protection

ORP – Oxidation-reduction potential

Pb – The elemental metal lead

POET – Point of entry treatment

RfD – Reference dose

RSLs – Regional Screening Levels

SDWA – Safe Drinking Water Act

SSL – Soil screening level

USGS – United States Geological Survey

UST – Underground storage tank system

VOCs – Volatile organic compounds

Executive Summary

Since 2005, the Maryland Department of the Environment (MDE) has been investigating and overseeing the cleanup of petroleum contamination in the groundwater in the vicinity of the former Green Valley Citgo station (GVC Station) and the Green Valley Plaza at 11791 Fingerboard Road in Monrovia, Maryland. Petroleum contamination in groundwater, including methyl tertiary-butyl ether (MTBE), was found to be impacting six residential supply wells located down-gradient of the GVC Station as well as several commercial supply wells in the immediate vicinity of the GVC Station. Several interim measures were taken by Carroll Independent Fuel Company (Carroll), including installation and continued maintenance of point-of-entry water filtration treatment (POET) systems for impacted supply wells in 2007 and 2008, and removal of underground storage tanks in 2008. In September 2011, after MDE's approval, Carroll began operation of an *in-situ* chemical oxidation (ISCO) remediation system in the parking lot of the Green Valley Plaza, to address remaining petroleum contamination in the subsurface.

In July and August 2012, some residents of the Monrovia area raised concerns to MDE and the Frederick County Health Department (FCHD) through counsel that they thought the ISCO remediation system had contaminated drinking water supply wells throughout the Monrovia area with elevated levels of hexavalent chromium, a metal that is hazardous to human health. In response to the concerns raised and as a precautionary measure, on July 31, 2012, MDE directed that the ISCO remediation system be shut off, pending further investigation and water sampling. In August and September 2012, residents expressed concern through counsel that they thought the ISCO remediation system had also caused lead contamination in drinking water supply wells in the Monrovia area.

This *Report of Results for Lead and Hexavalent Chromium Groundwater Investigation* presents and discusses the results of the investigation conducted by MDE that addressed the following concerns: (a) whether concentrations of hexavalent chromium and/or lead are above health or regulatory standards used by MDE, such that there may be a public health risk warranting regulatory action; (b) whether detections of these metals in residential supply wells were connected to the operation of the ISCO remediation system at the GVC Station; (c) whether these metals are naturally-occurring in groundwater or originate from plumbing materials; and (d) whether subsurface water quality conditions, such as pH, are contributing factors in the presence of these metals in water. To address these concerns, between October 2012 and July 2013, MDE and FCHD collected samples from 25 residences surrounding and down-gradient of the GVC Station for analysis of hexavalent chromium and lead. Samples were collected from point-of-use locations (*e.g.* a kitchen faucet), as well as at various locations throughout the plumbing of several homes to try to identify the source of elevated lead concentrations, which had been reported by counsel for the residents.

Summary of Key Conclusions

Conclusions from the analysis of sampling results include:

1. Hexavalent chromium and lead concentrations at all residential properties were below conservative public health based concentrations at point-of-use locations;

2. There is no pattern in the residential well detections of hexavalent chromium that would correspond to a definable hexavalent chromium plume from a place of origin;

3. There is no pattern in the residential well detections of lead that would correspond to a definable lead plume from a single place of origin;

4. There is no correlation between the presence of hexavalent chromium and lead in samples from residential drinking water systems;

5. There is no correlation between the presence of MTBE and hexavalent chromium and/or lead in samples from residential drinking water systems; and

6. Statistical analysis of the monitoring well and residential supply well data sets reveal an inverse correlation between the mean metals concentrations, indicating that a single factor (*e.g.* ISCO) is unlikely to be the cause of both.

The detections of lead and hexavalent chromium in residential drinking water samples in the Monrovia area were determined to not be related to the operation of the ISCO remediation system. The ISCO remediation system had a highly-localized impact, based on data collected from monitoring wells in close proximity to the injection locations. The past operation of the ISCO remediation system is not expected to have any future impact on residential drinking water supplies.

Summary of Recommendations for Users of Drinking Water Wells

As a precaution and to limit potential exposures to lead in drinking water, users of groundwater in the area of interest and throughout the State are encouraged to: maintain their plumbing systems, periodically test water for the presence of contaminants, and follow other recommendations provided in the EPA publication "Drinking Water from Household Wells." Day-to-day steps that consumers can take to reduce exposure to lead in drinking water include:

1. **Let the water run from the faucet before using it for drinking or cooking for 15 to 30 seconds.**

2. **Never cook with or drink water from the hot water faucet.**

The groundwater in the area of interest typically has a low pH, and may be corrosive, so users may want to periodically test their drinking water for lead, flush sediments from water lines and pressure tanks, and consider the addition of a water treatment system that removes metals from the water and adjusts pH to recommended levels to make the water less corrosive to metallic plumbing materials. The easiest way to minimize exposure to metals in drinking water is to use bottled water for drinking and cooking. Some or all of these recommendations can help to reduce the likelihood of lead and other metals within the residential water supply systems.

1.0 Introduction

Since 2005, the Maryland Department of the Environment (MDE) has been investigating and overseeing the cleanup of petroleum contamination in the groundwater in the vicinity of the former Green Valley Citgo station (GVC Station) and the Green Valley Plaza at 11791 Fingerboard Road in Monrovia, Maryland (Figure 1). In April and May 2007, six residences located down-gradient of the GVC Station were known to have been impacted by petroleum contamination from the GVC Station, including the gasoline additive methyl tertiary-butyl ether (MTBE). Carroll Independent Fuel Company (Carroll) has maintained granulated activated carbon (GAC) treatment system to remove petroleum contamination from their potable water since 2007. A public informational meeting was held in May 2007 at Green Valley Elementary School.

In September 2011, after MDE's approval, Carroll began operation of an *in-situ* chemical oxidation (ISCO) remediation system, which was located in the parking lot of the Green Valley Plaza. The ISCO system was designed to remediate petroleum contamination from the GVC Station, particularly MTBE, which remained in the subsurface.

In July and August 2012, some residents of the Monrovia area raised concerns to MDE and the Frederick County Health Department (FCHD) through counsel that they thought the ISCO remediation system had contaminated drinking water supply wells throughout the Monrovia area with elevated levels of hexavalent chromium, a metal that is potentially hazardous to human health. In response to the concerns raised and as a precautionary measure, on July 31, 2012, MDE directed that the ISCO remediation system be shut off, pending further investigation and water sampling. In August and September 2012, residents expressed concern through counsel that they thought the ISCO remediation system had also caused lead contamination in drinking water supply wells in the Monrovia area.

This *Report of Results for Lead and Hexavalent Chromium Groundwater Investigation* presents and discusses the results of the investigation conducted by MDE that addressed the following concerns: (a) whether concentrations of hexavalent chromium and/or lead are above health or regulatory standards used by MDE, such that there may be a public health risk warranting regulatory action; (b) whether detections of these metals in residential supply wells were connected to the operation of the ISCO remediation system at the GVC Station; (c) whether these metals are naturally-occurring in groundwater or originate from plumbing materials; and (d) whether subsurface water quality conditions, such as pH, are contributing factors in the presence of these metals in water. This report includes background information, site information, sampling information, data collected, and the analyses of those data, including certain risk assessments, and provides MDE's observations, conclusions, and recommendations for both the residents in the area studied and users of residential supply wells throughout Maryland.[1]

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[1] In addition to the information referenced in and the documents appended to this Report, in planning, executing, and analyzing the investigation, MDE has relied upon other information, including the MDE Oil Control Program petroleum remediation file related to the GVC Station site, file number 05-0834FR.

2.0 Regulatory Background

2.1 Maryland Department of the Environment's Oil Control Program

Where there has been a discharge of oil[2] that may impact groundwater resources, MDE, usually through its Oil Control Program,[3] may order or take any actions authorized by §§ 4-401 through 4-708 of the Environment Article of the Annotated Code of Maryland and the Code of Maryland Regulations (COMAR) 26.10.01 through 26.10.16 that include, but are not limited to: investigation of the source, nature, and extent of the release; source repair or removal; and soil and/or water removal, remediation, sampling, and evaluation. MDE may require a party responsible for a discharge of oil from underground storage tanks to submit a corrective action plan (CAP) for the cleanup of the discharge. MDE reviews, may make modifications, and will either approve or reject proposed CAPs. After MDE has approved a CAP, with any modifications, it continues to oversee the responsible party's execution of the plan.

2.2 Regulation of Drinking Water Supplies and Private Supply Wells

2.2.1 Public Water Systems

The United States Environmental Protection Agency (EPA) regulates public drinking water systems through laws and regulations, including the federal Safe Drinking Water Act (SDWA) and Primary Drinking Water regulations (40 CFR 141).

The MDE Water Supply Program[4] implements the SDWA requirements and the corresponding and supplemental Maryland statutes and regulations. The Water Supply Program seeks to ensure that public drinking water systems provide safe and adequate water to all present and future users in Maryland, and that appropriate usage, planning and conservation policies are implemented for Maryland's water resources. This mission is accomplished through proper planning for water withdrawal, protection of water sources that are used for public water supplies, oversight and enforcement of routine water quality monitoring at public water systems, regular onsite inspections of water systems, and prompt response to water supply emergencies. The Water Supply Program's activities help to ensure safe drinking water for more than 5 million Marylanders that receive water from public water systems.

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[2] The terms "oil" and "petroleum," as used in this report and in Maryland law and regulations, include the chemical constituents of oil and petroleum products, not just fuel products themselves. (Md. Code Ann., Envir. § 4-401(h); COMAR 26.10.01.01B(14)). A "discharge" of oil or petroleum (including the chemical constituents), as used in this report and in Maryland law and regulations, includes the addition, introduction, leaking, spilling, dumping, pouring, pumping, emptying, or emitting any oil to State waters or the placing of any oil in a location where it is likely to reach State waters. (Md. Code Ann., Envir. § 4-401(d); COMAR 26.10.01.01B(7)).

[3] For more information on MDE's Oil Control Program please see the following link: http://www.mde.state.md.us/programs/Land/OilControl/OilControlProgram/Pages/Programs/LandPrograms/Oil_Control/pollutionmanagement/index.aspx

[4] For more information on MDE's Water Supply Program please see the following link: http://www.mde.state.md.us/programs/Water/Water_Supply/Pages/Programs/WaterPrograms/Water_Supply/index.aspx

2.2.2 Private Supply Wells

EPA does not regulate private supply wells (a.k.a. residential supply wells) (32).[5]

MDE's well construction program regulates the permitting and installation of water wells in the State of Maryland.[6] Well construction techniques and practices, whether employed to provide potable water supplies, monitoring of groundwater, or for irrigation, impact the public health and welfare in significant ways. An estimated 900,000 Marylanders obtain their drinking water from private wells. Strong well construction regulation is essential to protect these and other consumers of groundwater as well as the groundwater resource itself.

The process of well construction starts with obtaining the services of a State of Maryland licensed well driller. Local health departments, such as the FCHD, and other local permitting agencies (Approving Authorities) are delegated authority by MDE to enforce the State's water well construction regulations. Technical support is provided by MDE. A licensed well driller must obtain a well construction permit from the local county Approving Authority. Once a permit to drill is obtained and the well is completed, the well driller must turn in a completion report to the Approving Authority. Potable water supply wells are required to have a Certificate of Potability (COP) before they are put into service. A COP is issued after a series of laboratory tests indicate the water is safe for human consumption.

FCHD may issue COPs for new wells drilled in Frederick County after testing for bacteria, *E. coli*, nitrate, and turbidity, and other contaminants that may be of concern for a particular location. The FCHD makes some water testing for bacteria, *E. coli*, nitrate, and turbidity available for existing wells.[7]

EPA, the State of Maryland, and Frederick County do not have laws or regulations that require owners of individual drinking water supply wells to comply with ongoing monitoring or testing of the quality of their drinking water. It is the well owner's responsibility to check that the well and pumps are working properly and that the water is safe for consumption (32). The EPA "Drinking Water from Household Wells" January 2002 publication, EPA 816-K-02-003, contains information on groundwater, individual drinking water wells, natural and anthropogenic groundwater pollution, and recommends six steps to protect groundwater and drinking water safety. Among the six steps, EPA recommends that well owners conduct periodic water testing and regular maintenance of their drinking water wells.

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[5] See Appendix O for Reference 32, EPA "Drinking Water from Household Wells" January 2002.

[6] For more information on MDE's well construction program, see the link at: http://www.mde.state.md.us/programs/Water/BayRestorationFund/OnsiteDisposalSystems/Pages/WellConstruction.aspx

[7] For more information on Frederick County COPs and water testing, see the link at: http://frederickcountymd.gov/index.aspx?NID=2427

2.3 Hexavalent Chromium

Chromium (Cr) is an elemental metal that is found naturally in rocks, plants, soil, and animals. The most commonly occurring valence states of chromium in natural waters are trivalent chromium (Cr III) and hexavalent chromium (Cr VI) (33).[8] Trivalent chromium "is an essential human dietary element and is found in vegetables, fruits, meats, grains and yeast." (33)

Hexavalent chromium occurs naturally in soil, water, and air from the erosion of natural chromium deposits. Hexavalent chromium also may be produced by manmade processes. Hexavalent chromium can be mobilized in water, including groundwater, depending on water conditions, which may be natural or manmade, such as ISCO processes. Trivalent chromium compounds are generally insoluble in water, while many hexavalent chromium compounds are readily soluble in water (38).

Hexavalent chromium, like numerous other substances, is potentially hazardous to human health, and is characterized as a human carcinogen through inhalation. A meaningful assessment of health risks from exposure to hexavalent chromium will include the type of exposure (*e.g.* ingestion, inhalation, dermal contact), the concentration, the duration of the exposure, and other factors specific to individuals.

EPA has established an enforceable regulatory limit, a maximum contaminant level (MCL) of 100 micrograms per liter (µg/L) for total chromium (all valence states) in public drinking water systems. MDE uses the same MCL as guidance for groundwater investigations. EPA's current MCL for total chromium assumes that a water sample can contain up to 100 µg/L of hexavalent chromium. There is no MCL for hexavalent chromium alone, but EPA is evaluating the need for a separate MCL.[9]

In this groundwater investigation, due to the nature of hexavalent chromium as potentially hazardous to human health, MDE evaluated the potable well sampling results for hexavalent chromium using a far more conservative concentration than what is allowed with the current total chromium MCL of 100 µg/L. MDE used a risk calculation formula that resulted in a conservative lifetime exposure health based concentration of 0.3 µg/L of hexavalent chromium (see Appendix T for a discussion of the derivation of this number). The health based concentration of 0.3 µg/L of hexavalent chromium is not an MCL.

2.4 Lead

Lead is a naturally occurring elemental metal (Pb) that has been used in manmade products, including paint and plumbing systems. Lead can be found in air, soil, dust, food, and water (34).[10] As a naturally occurring metal, lead in the environment also may contribute to

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[8] See Appendix P for Reference 33, EPA website excerpt "Chromium in Drinking Water" June 2013.

[9] No state has a separate MCL for hexavalent chromium. However, California recently proposed a state MCL of 10 µg/L, for which the public review and comment period closed in October 2013.

[10] See Appendix Q for Reference 34, EPA handout "Is There Lead in My Drinking Water?" February 2005.

groundwater and drinking water conditions. The greatest risk of lead exposure is to infants, young children, and pregnant women. Scientists have linked the effects of lead with lowered IQ in children. Adults with kidney problems and high blood pressure can be affected by low levels of lead more than healthy adults. Lead is stored in the bones, and it can be released later in life (35).

The greatest potential for lead exposure is from swallowing or inhaling lead paint chips and dust. Drinking water can also be a source of exposure when corrosion causes lead-containing plumbing infrastructure components to leach lead into the water. Sources of total lead in water include undissolved, or particulate lead, and dissolved lead. Undissolved lead originates from the corrosion of particles from loose solder or other lead-containing plumbing infrastructure and from lead adsorbed onto iron deposits and other sediments. There are other potential sources of lead that may be in the water from the plumbing system including, but not limited to the submersible pump, well pump housings, the pitless adapter, the pressure tank, the piping, auxiliary treatment systems, and other brass alloy plumbing fixtures in the house that may contain lead such as faucets, valves, and fittings. Although no longer approved for use in potable plumbing systems, lead solder that was used to join copper pipes is also a source of lead in plumbing systems.

Particulate lead can collect in faucet strainers and aerators as well as in pressure tanks and hot water heaters. Although sediment filters can be effective in removing particulate lead, they also provide a place where the particulate lead can collect and potentially be released back into the water system as dissolved lead. Likewise, lead can be incorporated into pipe scaling compounds, depending on the chemistry of the water. In some instances, water supply systems may change the water chemistry through treatment, causing dissolved lead to be released into the water, or plumbing repairs can physically detach the pipe scales.

For public and private drinking water systems, the total lead concentration in water is influenced not only by the components and age of the plumbing system, but also the chemistry of the source water. In particular, the amount of lead leached depends upon the corrosivity of the source water and other factors, including water temperature and flow rate in the piping. The practice of grounding electrical systems on household plumbing can increase the amount of lead dissolved into the water. In addition, the longer that water stands idle in the plumbing and associated components, the more lead can dissolve into it.

2.4.1 Non-Enforceable Health Based Goal

Lead, like numerous other substances, is potentially hazardous to human health, and is characterized as a probable human carcinogen (36). A meaningful assessment of health risks from exposure to lead will include the type of exposure (*e.g.* ingestion, inhalation, dermal contact), the concentration, the duration of the exposure, and other factors specific to individuals.

Based on possible health risks, EPA has set a non-enforceable maximum contaminant level goal (MCLG)[11] for lead of zero.

2.4.2 Lead Action Level

Because lead contamination of drinking water often results from corrosion of plumbing materials located inside homes, EPA has not established an enforceable MCL for lead. Instead, through a regulation known as the Lead and Copper Rule, EPA seeks to protect public health by minimizing lead and copper levels in public drinking water systems by requiring public systems to follow a treatment technique to control the corrosivity of the water. The Lead and Copper Rule recognizes that lead and copper enter drinking water mainly from the corrosion of plumbing materials that contain these metals. It establishes a 15 μg/L action level for lead in public drinking water systems as the concentration at which additional investigation is warranted under specified circumstances.[12]

MDE similarly uses the 15 μg/L concentration as guidance for residential drinking water samples. However, if a groundwater sample (e.g. from a monitoring well) has a concentration of lead at or above 15 μg/L, then MDE will take that into consideration along with other site-specific factors to determine the need for further investigation.

2.4.3 Lead Solubility and pH

EPA has a non-enforceable guideline range of 6.5 to 8.5 for the pH of public drinking water. To monitor corrosivity, the Lead and Copper Rule regulations include testing for various water quality parameters, including pH, alkalinity, temperature, calcium, and conductivity when the lead action level of 15 μg/L is exceeded. The water pH is the strongest control on lead solubility, with lead being much more soluble at lower pH (17). Public water systems may be required to employ various methods of corrosion control treatment if water sampling concentrations of lead or copper exceed the action levels established in the regulations.

2.4.4 Relative Solubility of Lead and Hexavalent Chromium

The water solubility and mobility of metals is influenced by, but not limited to, a host of water chemistry characteristics including pH, oxidation-reduction potential (ORP), specific conductance, temperature, pressure, and hardness. In general terms, hexavalent chromium has a high water solubility (16), and under certain conditions, can migrate with groundwater once present. Lead has a low water solubility and is generally considered to be insoluble (17), making it far less likely to migrate in groundwater, although lead does become more soluble at lower pH.

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[11] MCLGs are non-enforceable, and represent the level of a contaminant in drinking water below which there is no known or expected risk to health as determined by EPA. MCLs are enforceable drinking water standards for public water systems. EPA sets MCLs as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration.

[12] See Appendix S for Reference 37, EPA "Lead and Copper Rule: A Quick Reference Guide" June 2008.

These general characteristics are exhibited in the EPA-derived protection of groundwater soil screening levels (SSL) for hexavalent chromium and lead. The protection of groundwater SSL is a risk-based soil concentration, above which there is risk that the contaminant in question has migrated to the groundwater. The SSL for lead in soil (15 milligrams per kilogram (mg/kg)) is much higher than the risk-based SSL for hexavalent chromium (0.00059 mg/kg) (5). This indicates that lead is much less soluble than hexavalent chromium in water, and can be present in soil at much higher concentrations before the groundwater is at risk of being contaminated.

Chromium can be released into the groundwater under oxidizing conditions, because trivalent chromium, which is highly insoluble, can be oxidized to more mobile hexavalent chromium. The solubility of lead, however, is not influenced significantly by changes in ORP, and instead the primary control on lead solubility is solution pH (38). Overall, however, the data and literature are clear regarding hexavalent chromium and lead; hexavalent chromium, when present, is significantly more soluble and mobile than lead, which is relatively insoluble and not mobile.

2.4.5 Plumbing Infrastructure

The federal and state governments have enacted laws designed to limit the amount of lead available to leach into individual water supply systems from plumbing, but homes built prior to their implementation are not required to be refitted with compliant components. In 1986, the federal government banned the use of lead solder containing greater than 0.2 percent lead and restricted the lead content of faucets, pipes, and other plumbing materials to 8 percent.

Since January 1995, all submersible pump manufacturers in America have agreed not to use leaded-brass components in submersible pumps. Until then, residential submersible pump housings could contain as much as 8 percent lead, which was used in the alloy to improve machinability. Manufacturing processes also influence the amount of lead leached from the fixtures. Lead leaching from identical brass alloys was shown to be greater for pumps and plumbing fixtures that were sand-cast rather than machined, fabricated, or permanent-mold units. Before 1994, a significant component of most commercially available submersible water pumps was a housing made from sand-cast leaded brass (26).

On January 1, 2012, §12-101 (H-1) of the Business Occupations and Professions Article of the Annotated Code of Maryland became effective, requiring that plumbing be “lead free” as defined below:

> (1) containing not more than 0.2% lead for solder and flux;
>
> (2) except as provided in item (3) of this subsection, containing not more than:
>
> (i) 4% lead by dry weight for individual plumbing fittings and fixtures; or
>
> (ii) 8% lead by dry weight for individual pipes and pipe fittings;
>
> (3) containing a percentage of lead for plumbing fittings and fixtures that is in

> compliance with standards established under 42 U.S.C.A. § 300g-6(e) of the federal Safe Drinking Water Act; and
>
> (4) containing not more than a weighted average lead content of 0.25% for the wetted surfaces of a pipe, pipe fitting, plumbing fitting, or fixture intended to dispense water for human consumption through drinking or cooking.

This Maryland law impacts both the plumbing in homes and components in wells, including submersible pumps, pitless adaptors, and pitless units. All devices installed prior to this date were not required to meet this standard, nor are these devices required to be upgraded at the time of sale or for building permit approval. Enforcement and implementation of plumbing code is through local jurisdictions.

2.5 Human Health Assessments in the Regulatory Process

A starting point for all toxicological analysis is the axiom that every substance can exhibit toxic effects if the dose is great enough. The federal and state environmental regulatory schemes are based on numerous considerations, including the assessment of acceptable levels of risk for numerous substances.

The objective of a human health assessment is to determine if concentrations of chemicals of potential concern detected in the water, soil, or air at a site or area pose a significant threat to people potentially exposed under a given land use scenario. Human health assessments are utilized throughout the regulatory process in assisting remedial managers in determining potential impacts to public health and assisting in making risk management decisions. A human health assessment is a qualitative and quantitative process designed to focus on the type and magnitude of human exposure to chemicals that may be originating at or migrating from a site. It is designed to depict the site's physical setting, identify potentially exposed populations, and applicable exposure pathways; to calculate concentrations of chemicals to which people may be exposed; and to estimate chemical intakes under the relevant exposure scenarios.

Human health assessments attempt to define and quantify the relationships between a source of contamination, a route of exposure, the release mechanisms and transport/migration pathways, and potential impact to people. The degree of risk incurred by people potentially exposed varies according to the means and duration of exposure and the specific chemical to which the person is exposed. An exposure, however long in duration, does not necessarily result in an "unacceptable" health or environmental risk, although risks generally increase with increased frequency and/or duration of exposure.

3.0 Groundwater Investigation Background

3.1 Area / Site Geology and Hydrogeology

This section presents MDE's understanding of the underlying bedrock and groundwater conditions. The following sections include information available from sources that include the United States Geological Survey (USGS), Maryland Geological Survey, MDE, Carroll's various site assessment and characterization reports, and individual supply well installation records.

3.1.1 Area Geology

The area of interest (AOI)[13] is located within the Westminster Terrane of the Piedmont Province (Figure 2). Stratigraphic units of the Westminster Terrane include the Prettyboy Schist, the Marburg Formation, the Ijamsville Formation, the Sams Creek Formation, and the Wakefield Marble. The formations are late Neoproterozoic and Lower Cambrian age and all characterized by low-grade metamorphism. The GVC Station is underlain by the Marburg Formation, which is predominantly comprised of a highly folded phylliticmetasiltstone.

Thin layers and lenses of muscovite-chlorite-paragonite-hematite phyllite that are lithologically similar to rocks of the Ijamsville Phyllite are locally seen within the fine-grained rocks but are too small to map. Quartz laminae are seen within the metasiltstone and may be the result of both sedimentary (turbidite) and metamorphic processes. The Marburg Formation contains a minor amount of hematiticphyllite that resembles rocks of the Ijamsville Phyllite.

The contact between the rocks of the Marburg Formation and the Sams Creek Formation is the Hyattstown thrust fault. The Hyattstown thrust fault places rocks of the Marburg Formation on rocks of the Sams Creek Formation. This geologic feature occurs to the west of the GVC Station, but there is no surface expression of this fault in the immediate vicinity. The Sams Creek Formation is primarily composed of muscoviticphyllite, metabasalt, and felsic schist within the vicinity of the Green Valley Garage. The metabasalt is mostly massive, aphanitic to porphyritic, and contains calcite-filled amygdules and epidosite nodules.

Sheath folds of metabasalt plunge moderately south to southeast in a zone of high strain near Monrovia, Maryland. The dominant foliation in rocks of the Marburg Formation above the Hyattstown fault is transposition foliation. Transposed beds are folded by west-verging, inclined to recumbent folds.

Several quarries and mines existed historically within a several mile radius of the site. The quarries and mines were characterized by economically significant concentrations of various minerals, ores, and/or rock types. They included marble quarries; slate quarries; limestone quarries; copper, silver, and lead mines; chromite mines, gold mines; and hematite, limonite, manganese, and iron ore mines. The closest mining or quarry operations to the GVC Station

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[13] The AOI for the MDE and FCHD lead and hexavalent chromium groundwater investigation includes the former GVC station, the Green Valley Plaza, the Green Valley Shopping Center, and nearby surrounding residential neighborhoods. The properties in the AOI with sampling results assessed in this report are depicted on Figure 1.

were marble quarries approximately 2.5 miles north and slate quarries approximately 2.75 miles west.

The Marburg Formation, formerly called Marburg Schist, extends north through portions of Frederick County and into Carroll County and Pennsylvania (30). In the mid-1980s, the Maryland State Department of Health and Mental Hygiene Office of Environmental Programs, the precursor agency to MDE, studied a site in a portion of the Marburg Formation located near Silver Run, Maryland in Carroll County, near the Pennsylvania border. As part of that site study, the State of Maryland drilled nine monitoring wells in the Marburg Formation. Some of the bedrock drill cuttings from those wells were submitted for laboratory analysis. The laboratory analysis revealed the presence of various metals in the bedrock, including concentrations of approximately 50 mg/kg lead and 80 to 100 mg/kg chromium (28).

3.1.2 GVC Station Site Geology

Boring log descriptions of bedrock penetrated at the GVC Station site indicate red-brown micaceous silt and clay overburden down to approximately 20 feet (ft) over a tan to brown weathered saprolite. Below approximately 30 ft to 32 ft, the bedrock consists of gray mica schist.

Photographs taken during the July 2008 removal of the underground storage tank system (UST) provide visual evidence of folding within the subsurface formation and show the relict bedding planes (Appendix R).

Geophysical testing completed on monitoring wells MW6, MW7, and MW8 in June 2008 revealed the mean fracture set direction is N25E dipping at 61SE and the mean bedding plane direction is N29E dipping at 63SE. Testing on commercial supply wells FR-94-1233 and FR-88-1366 showed a mean strike of fractures of N27E with a mean dip of 49SE. Testing of monitoring wells MW14D, MW16, and MW17 showed a mean strike of fractures at N31E with a mean dip of 58SE.

Due to the topographic relief of the site and surrounding property, the depth to groundwater in site monitoring wells occurs between 30 and 70 ft below ground surface (bgs) depending on the location. Groundwater movement is always from an area of higher hydraulic head to an area of lower hydraulic head and can be influenced by the strike and dip of subsurface structures including open fractures, bedding planes, foliation, faults, etc. Groundwater movement has been shown to be in a southwesterly direction and with a component trending to the south-southeast as influenced by the commercial supply wells.

Based on available well drilling logs for the residential wells within the study area, the predominant description of rock encountered was logged as slate. These descriptions were based upon the well driller's observations (Exhibit 1) and not necessarily based upon a true geologic identification. Phylliticmetasiltstones, which are characteristic of the Marburg Formation, can generally include transitions between slate and schist and therefore can have the appearance of slate, particularly during drilling.

Exhibit 1: Well Driller Observations		
Address	**Description**	**Depth**
3984 Farm	Slate	2’ to 400’
4016 Middleton	Shale and Slate	0’ to 500’
11711 Serene	Slate	10’ to 400’
11712 Serene	Slate	15’ to 400’
11713 Serene	Slate	12’ to 400’
11789 Thomas Spring	Slate	7’ to 100’
11894 Barley	Slate	10’ to 105’

3.2 Area Groundwater Resources

Monrovia is an unincorporated area of Frederick County, which is generally defined by the boundaries of its 21770 zip code. There is no aquifer in Maryland that the Maryland Geological Survey has designated as or called the “Monrovia aquifer.”

Public and private water supply wells in the Monrovia area and other areas of Frederick County typically pump from an unconfined, fractured-rock formation or a combination of formations. Within the Monrovia area, depending on how the boundaries of that area are described, wells may draw from bedrock formations that may include, but not be limited to, the Ijamsville Formation, the Marburg Formation, the Sams Creek Formation, or some combination of these formations. Water withdrawn from different wells in the Monrovia area may have different characteristics, due to the variability in the underlying bedrock formations that are known to exist across the area.

Various bedrock formations throughout the State, including the Ijamsville Formation, the Marburg Formation, and the Sams Creek Formation, contain chromium, and thus likely hexavalent chromium. If so, groundwater drawn from such bedrock formations may contain detectable concentrations of total chromium and hexavalent chromium. Similarly, lead in the natural environment may contribute to groundwater conditions. As previously discussed, analysis of bedrock drill cuttings from the Marburg Formation in the 1980s confirmed the presence of concentrations of lead and chromium in the samples.

3.2.1 Water Quality of Public Water Systems Near the AOI

The MDE Water Supply Program regulates two public drinking water supply systems in the immediate AOI and two more public drinking water supply systems in close proximity to the AOI in the Monrovia area of Frederick County. These public drinking water supply systems are subject to applicable provisions of the SDWA, including the Lead and Copper Rule. Water sampling of these systems has documented low, acidic (below 7.0) pH values common in this area of Central Maryland. Source water sampling from the point-of-entry into the water distribution systems, sampling that is considered to be reasonably representative of groundwater quality, has documented low concentrations of lead (up to 5.7 μg/L) in the groundwater supplying these systems.

Green Valley Plaza, where the GVC Station is located, is served by four production wells (FR-94-1281, FR-94-1233, FR-88-1366, FR-88-1394) and one standby well (FR-81-5955) (Figure 3), which are located in the Marburg Formation. Sampling results from Green Valley Plaza system from 2006 through 2011 have documented the low, acidic pH values common in this area of Central Maryland, including pH values as low as 5.5. The Green Valley Plaza water system exceeded the 15 μg/L lead action level during the monitoring period of June – September 2008, so it was required to optimize corrosion control treatment to make the water less corrosive to the plumbing. The existing corrosion control treatment (pH adjustment with sodium hydroxide) was ineffective at the time of lead/copper testing in 2008, because the pH was below recommended levels at 5.9. As a result, the sodium hydroxide chemical feed was adjusted to achieve a pH of 7.4 a result within the range of the EPA secondary standard for pH of 6.5 to 8.5.

As a result of exceeding the lead action level in 2008, the Green Valley Plaza system also was required to test a source water sample from the point-of-entry into the water distribution system for lead. The March 2009 source water sample showed a lead concentration of 5.7 μg/L.

The Green Valley Shopping Center adjoins the Green Valley Plaza to the east and is served by two production wells (FR-73-6634, FR-73-4918) (Figure 3) located in the Marburg Formation. A third well on the property (FR-73-7687) serves the All State Insurance Building. Sampling from the Green Valley Shopping Center public drinking water supply system similarly has documented the low, acidic pH values common in Central Maryland. The pH tested in March and April 2000 showed levels between 5.8 and 6.2, and in September and October 2004, pH levels were between 5.1 and 5.5 in the raw water and finished water, respectively.

Water from the Green Valley Shopping Center supply system exceeded the lead action level during the monitoring periods of January – June 1999, July – December 2003, and January – June 2005. As a result, this system was required to optimize corrosion control treatment to make the water less corrosive to the plumbing. In 2006, Green Valley Shopping Center installed pH adjustment water treatment (soda ash). Source water sampling for the Green Valley Shopping Center since 2000 has shown the following lead concentrations: March 2000, 7 μg/L; July 2004, 9 μg/L in FR-73-6634 and 5 μg/L in FR-73-4918; June 2006, non-detect (<5μg/L) in FR-73-6634 and 7 μg/L in FR-73-4918; and December 2006, non-detect (<5 μg/L) in both wells.

The Children's Center for Discovery (located approximately 1,400 ft west of the Green Valley Plaza) public drinking water supply system has one production well located in the Marburg formation. Water from this system exceeded the lead action level during the monitoring periods of July – December 1993 and January – June 1994. The July 1994 source water sample for the Children's Center for Discovery showed a lead concentration of 2.94 μg/L. The pH readings for this system have included the following results: 5.5 in March 2008; 6.0 in September 2009; 5.5 – 5.8 in October 2009; 5.6 in March 2010; 5.3 in June 2010; 6.4 in August 2010; 6.0 in March 2011; and 5.3 in October 2011. This system has no corrosion control water treatment, because it is considered optimized as a result of testing results under the lead and copper action levels in 2005 and 2006.

The Green Valley Elementary School (located approximately 3,100 ft west of the Green Valley Plaza) public drinking water supply system has two production wells located in the Sams Creek

Formation. The school's water supply system exceeded the lead action level during the monitoring periods of July – December 1992, July – December 1996, June – September 1999, June – September 2006, and June – September 2009. The pH tested in May and June 2000 was between 5.2 and 5.3 in the raw water. As a result of exceeding the lead action level, the school system was required to optimize corrosion control treatment to make the water less corrosive to the plumbing. In 1997, Green Valley Elementary installed pH adjustment (soda ash) and a corrosion inhibitor (phosphate-based) as corrosion control treatment. The March 2007 source water sample for the Green Valley Elementary School showed a lead concentration of 3 μg/L.

3.2.2 Groundwater Quality Network Data Near the AOI

In addition to the historical groundwater quality information available from the four regulated public drinking water supply systems discussed above, sampling from the Maryland Statewide Groundwater Quality Network also has documented acidic pH values and low concentrations of lead in the Marburg Formation (23). Two monitoring sites in the groundwater quality network were located in the Marburg Formation, the same geologic formation under much of the AOI. Sampling of groundwater monitoring site MO Be 62 in 1993 showed a pH value of 5.3 and a dissolved lead concentration of 5 μg/L (23).[14] The second Marburg Formation groundwater quality network monitoring site (CL Ae 1) was located in northern Carroll County, in the general area of the formation near where the Keystone Landfill study was conducted (23, 29). Sampling of groundwater monitoring site CL Ae 1 in 1992 documented a pH value of 5.3 and a dissolved lead concentration of 2 μg/L (23).

3.3 Petroleum Contamination from the Former Green Valley Citgo Station

3.3.1 The GVC Station Discharge

Since 2005, MDE has been investigating and overseeing the cleanup of dissolved phase petroleum contamination in the groundwater in the vicinity of the GVC Station (now the Monrovia BP) at 11791 Fingerboard Road, on the Green Valley Plaza property, in Monrovia, Maryland. As the owner of the petroleum USTs, Carroll was identified as a party responsible for a discharge of petroleum. The gasoline additive MTBE has been one of the predominant petroleum constituents found in the soil and groundwater originating from the GVC Station.

MTBE, a hydrophilic compound, is more soluble in water than other typical gasoline constituents (*e.g.* benzene). Once dissolved in water, MTBE does not tend to adsorb to soil particles, although it may be dissolved in the water adhered to soils above the water table (*i.e.* the soil moisture content). Additionally, once MTBE is dissolved in water, it does not readily volatilize out of water. These chemical characteristics, affinity for water, limited adsorbance to soil, and reluctance to volatilize once dissolved in water, allow for MTBE contamination to migrate relatively unimpeded with the flow of water in the ground.

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[14] The Maryland Department of Natural Resources' *Network Description and Initial Water-Quality Data from a Statewide Ground-Water-Quality Network in Maryland* Report of Investigations No. 60 (1996) placed the groundwater monitoring site MO Be 62 in the Ijamsville Formation (23), but more updated geologic mapping places the site in the Marburg Formation. *See* USGS. *Geologic Map of the Frederick 30' x 60' Quadrangle, Maryland, Virginia, and West Virginia, Pamphlet to Accompany Scientific Investigations Map 2889* (2007) (25).

Investigations conducted at the GVC Station identified vapor leaks from the station's pre-2008 retail fuel dispensing system (which has since been upgraded) as the most probable source of the petroleum contamination problem. Petroleum vapors escaped from the dispensing system's underground storage tanks and piping network and migrated into the surrounding soil. Over time, a portion of the contamination dissolved into infiltrating rainwater and was carried downward into the groundwater supply in the underlying saturated weathered-rock overburden/fractured rock (31).

3.3.2 The GVC Station Petroleum Study Area

The GVC Station Petroleum Study Area is focused on the commercial properties referred to as the Green Valley Plaza and the Green Valley Shopping Center and currently encompasses a number of residential properties to the south of the commercial properties, located along Greenridge Drive, Farm Lane and Rye Lane. To date, Carroll has installed and is required to sample 19 monitoring wells on the Green Valley Plaza property. During the course of the Oil Control Program petroleum investigation, MDE and Carroll established that the GVC Station Petroleum Study Area was to include the testing of the 19 monitoring wells, 29 residential potable wells, 3 water supply wells for the Green Valley Shopping Center, and 5 water supply wells for the Green Valley Plaza (Figure 1). Some of the wells in the GVC Station Petroleum Study Area are sampled quarterly, and some are sampled semi-annually. Carroll submits the results of the sampling analyses with a comprehensive data review to MDE on a quarterly basis.

3.3.3 Remediation of the Petroleum Contamination from the GVC Station

Carroll has taken measures to remediate MTBE and other impacts from the petroleum discharge. Over the course of the GVC petroleum groundwater investigation, MDE and Carroll have sampled more than 120 residential drinking water wells in the Monrovia area for volatile organic compounds (VOCs) in relation to the GVC Station and other potential sources of petroleum in the community of Monrovia. MTBE was identified as the primary contaminant of concern at the GVC Station Petroleum Study Area, given its persistence in the subsurface at the GVC Station and its detection in the six downgradient impacted residential drinking water supply wells (3923 Rosewood Drive, 3990 Farm Lane, 3992 Farm Lane, 3994 Farm Lane, 3996 Farm Lane, and 3997 Farm Lane).

A. 2007-2008 Granular Activated Carbon Treatment Systems Installed

Since early 2007, Carroll has maintained GAC treatment systems on the six residential drinking water wells impacted by MTBE (Figure 1). These residential wells are located in a groundwater flow path to the south/southwest of the GVC Station. The concentration of MTBE in the six wells exceeded the State Action Level of 20 µg/L.

On September 2, 2008, a GAC treatment system was installed on the blended influent of the Green Valley Plaza's five potable wells.

B. 2008 Source Removal

In July 2008, initial remedial activities involved the source removal of four UST systems at the GVC Station site. While there were no perforations observed in the removed tanks, petroleum vapors were noted in the surrounding soils. Carroll subsequently excavated more than 1,100 tons of soils, of which approximately 500 tons was determined to be petroleum impacted, for proper off-site disposal.

C. 2010-2012 ISCO Remediation Technology

In June 2010, MDE required Carroll to submit a CAP with the intention of remediating the dissolved phase petroleum contamination documented by more than five years of groundwater sampling and site characterization activities. Carroll, through its environmental consultant, Groundwater Environmental Services, Inc. (GES), proposed using ISCO to remediate the MTBE in the subsurface at the GVC Station. The proposed ISCO system was designed to work by injecting the oxidants ozone (in gas form) and hydrogen peroxide into a localized area in the groundwater. These oxidants were chosen because they have been shown to effectively break down MTBE and other gasoline contaminants. Additionally, both compounds have short half-lives in the environment due to their aggressive and unstable chemical forms and therefore would not persist long enough to promote the migration of metals over extended distances from the injection points. Ozone has a half-life measured in minutes to hours and peroxide has a half-life measured in days. One of the goals of the extended ISCO pilot testing was to increase dissolved oxygen (DO) concentrations in groundwater to facilitate microbial breakdown of the MTBE under aerobic conditions.

MDE determined that any implementation of ISCO at the Site would have to be completed in a phased approach, beginning with a small scale pilot test. Results of the small scale pilot test would be evaluated, and if they were favorable, GES would proceed with progressive injections of the ISCO compounds over increased intervals of time to achieve the destruction of the MTBE. Throughout ISCO implementation, GES was to closely monitor the groundwater and report the results to MDE.

In November 2010, MDE approved GES's pilot testing of the ISCO technology at the GVC Station site with additional sampling requirements and the installation of additional wells for injection and monitoring purposes. Prior to the start of the initial ISCO pilot test, baseline sampling was completed at selected monitoring wells for specified parameters to document pre-ISCO concentrations and establish site specific conditions. The area targeted for the ISCO injections is shown on Figure 3 down gradient (*i.e.* south) of the tank field. Due to the limited permeability of the subsurface formation, the initial two-day pilot test was limited to the injection of approximately 20 gallons of hydrogen peroxide into one of the injection wells (IW-1), screened between 63 and 73 ft bgs. The other two injection wells installed at the beginning of the project were screened between 93 and 103 ft bgs (IW-2) and 123 and 133 ft bgs (IW-3).

In March 2011, Carroll and GES submitted a CAP that proposed the continued use of ISCO technology to achieve the remedial goal after ruling out several other remedial technologies. In June 2011, MDE approved GES to conduct an extended eight-week pilot test and required Carroll to submit a revised CAP with a plan for additional sampling to ensure protection of public health and the environment.

In July 2011, MDE received the *CAP Implementation Plan – July 1, 2011*. The *CAP Implementation Plan* proposed additional injections of ozone and hydrogen peroxide over an eight-week period. After reviewing the initial ISCO pilot test data, MDE approved the *CAP Implementation Plan* and the extended pilot testing of the ISCO technology through correspondence dated August 24, 2011.

The ISCO system was enclosed in a trailer located in the parking lot of the Green Valley Plaza, and was surrounded by a 6-foot wooden fence. Piping from the ISCO system to the injection wells was buried underneath the asphalt pavement. The amount of ozone and hydrogen peroxide injected, the delivery rates/pressures, and the injection well locations were designed to focus the remedial actions on the contaminant source area. The ISCO unit operated again from September 14, 2011 to November 2011. During this period, a total of 15.8 gallons of hydrogen peroxide and 167 pounds of ozone gas were injected into the injections wells. In February 2012, MDE approved a third phase of ISCO system operation. A fourth injection well (IW-4, screened between 85 and 89 ft bgs) was installed in May 2012, which was utilized by the ISCO injection system June 2012 through August 1, 2012. The ISCO system operated from February 20, 2012 to August 1, 2012.

The ISCO system was shut down on August 1, 2012. The results of the third phase of ISCO injection activities is detailed in the *ISCO System Comprehensive Summary and Update to the Site Conceptual Model – September 28, 2012*. The report concluded the ISCO technology produced some significant reductions in dissolved phase petroleum constituents within the targeted area (immediate vicinity of the active tank field and north of the site building). The report noted that DO concentrations were increased down gradient of the injection sites, and although the ozone and hydrogen peroxide did not persist at that distance, the increased DO would provide a secondary benefit by enhancing the biodegradation of the petroleum contaminants.

Over the course of operation, GES's ISCO system injected approximately 515 pounds of ozone and 164 gallons of hydrogen peroxide into the subsurface. A total of four injection wells were installed in the study area and constructed such that the oxidants were delivered to discrete subsurface zones. Prior to, during, and after the ISCO injection activities, MDE required sampling of the on-site monitoring wells, the on-site drinking water wells, and selected off-site residential drinking water wells to ensure the protection of public health and the groundwater resource. Since the shutdown of the ISCO system in August 2012, MDE has asked Carroll to submit an alternative remediation plan to address the remaining dissolved phase petroleum impacts in the area of investigation.

For additional details on the MDE Oil Control Program's remediation case (Case No. 05-0834FR), please visit the following web page under the heading **FREDERICKCOUNTY, Monrovia, Green Valley Citgo**:
http://mde.maryland.gov/programs/Land/OilControl/RemediationSites/Pages/Programs/LandPrograms/Oil_Control/RemediationSites/index.aspx

3.4 Concerns Raised About Detections of Hexavalent Chromium and Lead

On July 30, 2012, MDE was directed to data indicating that hexavalent chromium was detected at 40 µg/L in a monitoring well approximately 20 ft from the ISCO system beginning in November 2011, and counsel for some residential property owners claimed to MDE that the ISCO system was threatening downgradient drinking water wells. As a precautionary measure, because there were positive detections of hexavalent chromium in close proximity to the treatment system, on July 31, 2012, the MDE ordered Carroll to shut down the remediation system, pending further investigation and sampling.

The information available on the geology and hydrogeology of the GVC Station Petroleum Study Area, including groundwater flow and scope of the MTBE contamination, and the ISCO system's limited zone of influence indicated that the ISCO system should not have affected residential drinking water sources. Nevertheless, on August 1, 2012, MDE directed Carroll to conduct a broad sampling round of potable and monitoring wells. MDE required Carroll to sample all residential potable wells (29 wells) and monitoring wells (19 wells) that are included in the GVC Station Petroleum Study Area sampling, the supply wells for the Green Valley Shopping Center (3 wells), and the supply wells for the Green Valley Plaza (5 wells). The August 1, 2012 directive included requirements that Carroll analyze the water samples for VOCs, total chromium, hexavalent chromium, and other water quality parameters.

On August 22, 2012, MDE was notified that some residential supply well samples collected in the area had detections of hexavalent chromium and lead. Counsel for some residential property owners alleged that the hexavalent chromium and lead detections in residential water samples were caused by the operation of the ISCO system. Based on the added concern raised regarding lead, Carroll had the samples previously collected in August 2012 re-analyzed for lead.

4.0 MDE and FCHD Residential Sampling, Investigation, and Results

4.1 Overview

At the time that concerns initially were raised about hexavalent chromium and lead in water samples, MDE was aware that baseline sampling conducted in the GVC study area prior to full implementation of the ISCO system showed the presence of total chromium (all valence states) in some residential water samples. However, MDE had not directed speciation of total chromium to distinguish between hexavalent and trivalent chromium until August 1, 2012. MDE also was aware that plumbing system infrastructure is a common source of lead in drinking water. The sampling data supplied to MDE by counsel for some residents and by Carroll seemed to have been obtained at varying locations within plumbing systems using undocumented controls and protocols. MDE determined that the sampling data provided to MDE through October 2012 was insufficient to properly distinguish lead concentrations that may be contributed by groundwater from those concentrations that may be attributable to plumbing or other unknown factors. MDE and the FCHD determined that additional information, including additional sampling, was necessary to assess the possible sources of the hexavalent chromium and lead and whether potential public health risks existed from the possible sources and/or concentrations.

4.2 MDE and FCHD Initial Residential Sampling: October – December 2012

4.2.1 Purpose

The data for hexavalent chromium and lead made available by Carroll and Jenkins Environmental, Inc. (Jenkins) through October 2012 indicated that regardless of source: (1) no hexavalent chromium detections in residential supply wells exceeded MDE's calculated conservative lifetime exposure health based concentration of 0.3 µg/L; and (2) no lead concentrations in point-of-use samples exceeded the 15 µg/L action level. Some water samples taken from other locations within home plumbing systems were above the recommended lead action level of 15 µg/L, warranting further investigation.

MDE and the FCHD developed a sampling plan and protocol for certain residential wells (Appendix A) based on information including: (1) MDE's knowledge of the GVC Station Petroleum Study Area, including environmental and sampling reports submitted by Carroll since 2006, the extent of the petroleum impact, and groundwater gradients and flow; and (2) the review of water sampling data that had been provided by Carroll and by Jenkins, through counsel for certain residents.

Twenty-four (24) residences were selected for the MDE and FCHD sampling program: the six (6) residences impacted by the MTBE plume with GAC systems maintained by Carroll (Figure 1), and eighteen (18) residences at which prior sampling by Jenkins or Carroll revealed a total or dissolved lead concentration greater than 15 µg/L. On October 10, 2012, MDE and FCHD finalized the sampling plan for their initial residential sampling with a goal of distinguishing lead contributions as a result of the groundwater (*i.e.* flushed sample) from lead contributions due to corrosion of components of the residential water supply system infrastructure (*i.e.* first draw sample).

4.2.2 Procedures

The October 10, 2012 sampling plan (Appendix A) is summarized below:

- The first draw sample was expected to represent the potential contribution of lead in the water as a result of the household plumbing system to which a user might be exposed.
- The flushed sample would be based on a purge of the plumbing system and should be a representative groundwater sample. Even with this purge, it was recognized that there was potential for the sample to not be fully representative of the groundwater, which could be due to specific features of the plumbing system (*e.g.* larger pressure tank, pump limitations).
- Samples were analyzed for chromium (total, dissolved, hexavalent), lead (total and dissolved), VOCs, pH, temperature, and ORP.
- Samples were collected by MDE's contractor in the presence of the homeowner and the FCHD official.
- Photographs were taken if allowed by the homeowner.
- Samples were collected as a First Draw and a Flushed sample.
- After sample collection, additional water was collected for the purpose of taking pH, ORP, and temperature readings. An Oakton ® 35618-Series pH 300 and 310 Portable Waterproof pH/mV/oC Meter was used to take the readings. The calibration log for the meter is included in Appendix B.
- Once samples were collected, they were filtered, preserved, labeled, and placed on ice according to the procedures dictated within the sampling plan.

All samples were collected according to the October 10, 2012 sampling plan and taken to the appropriate laboratories. Samples were delivered to the laboratories either the same day or the day following collection.

Samples were collected from 23 of the 24 selected residences between October 16, 2012 and December 1, 2012. One property owner did not call to schedule a sample collection appointment.

4.2.3 Documentation

Appendix B – Resident Questionnaires and Sample Collection Forms: Resident questionnaires were completed to the extent possible prior to the sampling appointment and were generally completed and signed by the resident and FCHD official at the time of the sampling appointment. Sample collection forms were completed in the field at the time of sample collection to document the sampling locations and conditions and signed by all present.

<u>Appendices C and D – Laboratory Reports</u>: The laboratory analytical reports are included in Appendices C and D, inclusive of the chain of custodies.

<u>Appendix E – Letters to Homeowners</u>: Homeowners were provided copies of their respective analytical results along with a cover letter explaining what their results indicate.

<u>Appendix F – Data Validation Reports</u>: All analytical data reports were submitted for third party data validation according to MDE and EPA Guidance (1, 18 through 21).

4.3 MDE and FCHD Additional Residential Sampling: March, June – July 2013

4.3.1 Purpose

During review of the sampling results from the MDE and FCHD Initial Residential Sampling round, MDE and FCHD found some results in which purportedly flushed samples had elevated levels of lead. MDE further considered its initial residential risk characterization analysis (presented in Section 5.5), and reviewed the October 10, 2012 sampling plan procedures and results as well as the sampling locations used by Jenkins and Carroll. MDE hypothesized that (1) although plumbing systems were being flushed at faucets, samples drawn from pressure tanks were essentially un-flushed; (2) pressure tanks contributed to the presence of high lead concentrations; and (3) the variability of lead results was due in part to variation in sample locations. MDE determined that a more robust sampling procedure was required to better identify and isolate the potential origins of lead detections and validate the previous results. Revised sampling plans were developed to better distinguish lead concentrations contributed from the plumbing systems versus the groundwater.

4.3.2 March 2013 Sampling Procedures

MDE's analysis and human health assessment determined that further sampling with a more controlled protocol was warranted for the residence at 11712 Serene Court, which had detections of the highest lead concentrations. In December 2012, a request for additional sampling was sent to 11712 Serene Court, which had the highest measured lead concentration during October 2012 sampling. This residential well was re-sampled in March 2013 using the modified sampling procedures described below:

- A trip blank (*i.e.* a quality assurance sample) was collected prior to mobilizing to the property.
- The amount of time since the last water usage at the residence was recorded and the electric supply to the submersible pump was turned off.
- The in-line valve located immediately upstream of the sediment filter was closed.
- The drain valve located at the bottom of the pressure tank was opened and a water sample was collected.
- The remaining water was drained from the pressure tank to the extent possible using a hose to a drain identified by the home owner.
- The volume and observable quality of drained water was recorded.

- The submersible pump electric supply was turned back on and the pressure tank was filled until normal operating pressure was attained.
- The pressure tank sample collection, draining, and refilling procedure was repeated until a total of three (3) water samples were collected.
- A field blank was collected.
- The submersible pump was returned to normal service, the in-line valve located upstream of the sediment filter was opened, and water was purged from the piping.

Field filtering for dissolved metals analyses and field measurement of pH, temperature, and ORP was completed, and the water samples were delivered to the laboratories for VOCs and metals analysis.

There was a sufficient volume of sediments available for analysis, so a sample of the sedimentary material was collected and sent to the laboratory for metals analysis. A portion of the sample was also transmitted to the MDE for analysis by a Professional Geologist for a general description of the material, which is included in Appendix H.

4.3.3 June and July 2013 Sampling Procedures

Results of the March 2013 sampling indicated that the source of high lead concentrations was sediments of plumbing system degradation and natural material collected in the plumbing system. Based on the results of the March 2013 sampling, MDE further refined the sampling protocol and sought additional sampling at seven residences to validate the findings regarding the source of the high lead concentrations.

Four of the residences (11713 Serene Court; 3991 Farm Lane; 3998 Farm Lane; and 3740 Blueberry Court) permitted MDE and FCHD to conduct additional sampling. Three other property owners did not respond to sampling requests from MDE and FCHD. The sampling protocol for residences sampled in June and July 2013 was as follows:

<u>Step 1</u>

- A sample was collected from the kitchen sink.
- A sample was collected from the pressure tank spigot.

<u>Step 2</u>

- The power to the submersible pump in the well was shut off.
- An isolation valve after the pressure tank was located and closed.
- The pressure tank was completely drained from the spigot at the base of the tank.
- Once drained, the valves were returned to normal and the power restored to the pump so that the pressure tank recharged.
- This process was repeated a total of three times with samples collected in between purges.
- If sufficient quantities of sediments were available a sample of that material was collected.
- Purge water was diverted to a suitable drain in the basement.

- At the conclusion of this series of purges, the power was restored to the pump and all valves placed into the normal operating position.
- The contractor ensured that all lines were purged of any air that may have been introduced during the procedure.

Step 3

- A hose was connected to the spigot at the base of the pressure tank.
- The isolation valve after the pressure tank was closed.
- The end of the hose was directed out of the home and to a suitable drainage area on the property.
- The well pump was allowed to discharge water for approximately 3 hours. This time allowed for several hundred gallons to be purged from the well to better ensure representative groundwater samples.
- Samples were collected intermittently during this time.
- Once the samples were collected, the plumbing service was returned to its normal operating condition.

Field filtering for dissolved metals analyses and field measurement of pH, temperature, and ORP was completed. The water samples were delivered to the laboratory for metals analysis.

In addition to the water samples described above, a sediment sample from 3998 Farm Lane was collected and delivered to the laboratory for metals analysis.

4.3.4 Exceptions

During sampling at 3998 Farm Lane, MDE’s contractor encountered notable complications that prevented the samples intended to be representative of the groundwater from being properly collected. During the well purging (Step 3), the well pump purged the water from the well faster than the groundwater could recharge. This resulted in the well essentially going dry. Unbeknownst to the resident and MDE’s contractor, grass, present in the well, was pulled into the pump when there was insufficient water, further complicating matters.

Upon the MDE contractor’s removing the well pump and piping to investigate the problem, it was also discovered that there was a rupture in the well pipe (black high density polyethylene piping). The MDE contractor made corrections to the well pump, replaced the damaged well pipe with new properly-rated piping, reinstalled the pump and pipe, made certain the well was operational, and chlorinated the well.

Due to these unusual events, including the well running dry and the necessary repair of the ruptured pipe, the purged well sample that was collected was not considered to be a controlled or representative sample. In August 2013, MDE sent an additional sampling request to the property owner. At the time this report was issued, the additional sampling request was not yet approved by the property owner.

4.3.5 Documentation

Appendix I – Resident Questionnaires and Sample Collection Forms: Resident questionnaires were completed to the extent possible prior to the sampling appointment and were generally completed and signed by the resident and the MDE contractor at the time of the sampling appointment. Sample collection forms were completed in the field at the time of sample collection to document the sampling locations and conditions and signed by all present.

Appendix J – Laboratory Reports: The laboratory analytical reports are included in Appendix J, inclusive of the chain of custodies.

Appendix K – Letters to Homeowners: Homeowners were provided copies of their respective analytical results along with a cover letter explaining what their results indicate.

Appendix H – Memorandum Re: Sediments: MDE's Professional Geologist memorandum and chain of custody regarding the sediments collected at 11712 Serene Court are included as Appendix H.

Appendix L – Data Validation Reports: All analytical data reports were submitted for third party data validation according to MDE and EPA Guidance (1, 18 through 21).

4.4 Results of MDE and FCHD Investigation

Results of the investigation conducted by MDE and FCHD for residential wells are presented in Table 1. Data from monitoring wells in the AOI are presented in Table 2, and data from the commercial supply wells serving the Green Valley Plaza, the Green Valley Shopping Center, and the All-State Building are presented in Table 3. Results of sampling reported by Carroll and Jenkins are also presented in these tables.

MDE's review of the sampling data sets showed no patterns that would correspond to lead and hexavalent chromium originating from the GVC Station and flowing with the known groundwater path to impact residential wells. The review of potential spatial correlation of these data determined that:

- There is no pattern in the residential well detections of hexavalent chromium that would correspond to a definable hexavalent chromium plume from a place of origin. There is no correlation between the known MTBE plume and the detections of hexavalent chromium in residential sampling.

- There is no pattern in the residential well detections of lead that would correspond to a definable lead plume from a place of origin. There is no correlation between the known MTBE plume and the detections of lead in residential sampling.

- There is no correlation between the detections of lead and the detections of hexavalent chromium in residential sampling.

5.0 Groundwater Quality in Monrovia

5.1 Lead and Chromium in the Marburg Schist and Monrovia Groundwater

As part of its investigation MDE considered whether there were potential public health concerns from metals in water that could be naturally contributed from the bedrock formations in the AOI. As discussed previously, lead and chromium are among the numerous naturally occurring elemental metals present in soils, sediment, and rock throughout Maryland. Metals, including chromium in its various valence states and lead, may exist in the groundwater in solid and/or dissolved form, as reflections of the characteristics of underlying bedrock formations and groundwater conditions. The solution and transport of naturally occurring metals in groundwater, derived from the geologic materials through which the groundwater moves, is a widely accepted scientific phenomenon (29).

The groundwater common to most of the siliceous metamorphic rocks in Central Maryland, such as those found in the Marburg Formation, are known to be acidic. Acidity is a groundwater characteristic that may contribute to leaching of metals from bedrock and to corrosion and leaching of metals including iron, copper and lead from plumbing.

MDE's investigation found data supporting lead and chromium as constituent metals in the Marburg bedrock formation underlying the AOI. The 1986 Keystone Landfill study report included analysis of rock cuttings from nine monitoring wells placed by the State of Maryland in the Marburg Formation near the Maryland-Pennsylvania border in Carroll County (28). The laboratory analysis of the rock samples revealed, among the metals present, concentrations of lead at approximately 50 mg/kg and chromium at approximately 80 to 100 mg/kg (28).

As previously discussed, water sampling conducted in the AOI in Marburg and Sam's Creek Formation wells has documented low, acidic pH levels and low concentrations of lead well before the sampling conducted during the MDE and FCHD Lead and Hexavalent Chromium Groundwater Investigation. In the 1990s, sampling from Marburg Formation wells within the statewide groundwater quality network revealed pH readings of 5.3 and dissolved lead concentrations of 2 and 5 µg/L (23). Sampling of regulated public drinking water supply systems in the immediate AOI and two more in close proximity in the Monrovia area also have documented acidic groundwater pH and concentrations of lead in source water samples ranging from 2.94 to 7.0 µg/L.

Similarly, some of the groundwater samples from the AOI for the MDE and FCHD investigation reflect low concentrations of lead, total chromium, and hexavalent chromium.[15] The sampling MDE conducted at 3991 Farm, 3740 Blueberry, and 11713 Serene in June and July 2013 obtained water samples that MDE considers reasonably representative of the groundwater in

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[15] The groundwater sampling is to be distinguished from the sampling taken within the plumbing systems of residences, such as first draw samples or flushed samples at a pressure tank locations, which were not considered fairly representative of groundwater conditions. Those samples with the "WP" (well purge) designation generally were considered representative of groundwater with noted exceptions.

each well. The groundwater samples had total lead concentrations ranging from non-detect to 3.6 μg/L and dissolved lead concentrations ranging from non-detect to 1.7 μg/L. MDE's June and July 2013 groundwater samples reflected total chromium concentrations ranging from non-detect to 14.7 μg/L; dissolved chromium concentrations were non-detect; and hexavalent chromium concentrations ranging from non-detect to 0.032 μg/L.

5.2 Groundwater pH in Area of Interest

The pH levels recorded during the MDE and FCHD investigation were predominantly acidic, in the range of +/- 5.0 (Tables 1 through 3). These pH levels are consistent with the pH readings that have been recorded in two Marburg Formation statewide groundwater quality network monitoring sites and in influent groundwater sampling of the water supply systems for the Green Valley Plaza, Green Valley Shopping Center, Green Valley Elementary School, and Children's Center for Discovery. Three of these regulated public water supply systems have been required by MDE since the 1990s to treat the influent groundwater to make it less corrosive by increasing the pH.

5.3 Impact of ISCO on Groundwater

Chemical oxidation can occur naturally and by manmade conditions. Under the appropriate subsurface conditions and chemical interactions, chemical oxidation may produce a desired oxidizing environment in the subsurface to facilitate the breakdown of contaminants. Certain water quality environments, including but not limited to oxidizing environments, whether naturally-occurring or created by chemical oxidation processes such as ISCO, may allow metals, if present, to be mobilized in the subsurface. The length of time metals may exist in a state capable of mobilization depends upon the persistence of the oxidants and the chemistry of the groundwater.

The ISCO remediation process that MDE approved for use by Carroll at the GVC Station was designed and intended to create an oxidizing environment in a discrete area in the subsurface near to the active underground storage tank system and proximal to the points of injection/treatment. The ISCO system at the GVC Station was approved with several safety measures/precautions in place. As previously described, these included a limited treatment area, baseline sampling, and frequent monitoring of the on-site and off-site monitoring wells throughout the phased ISCO implementation. The mass of oxidant, the delivery rates, and the injection locations were designed to be focused within the contaminant source area south of the UST field or the ISCO treatment area (Figure 3). In addition, as mentioned above, the oxidants used in this process were selected because of their short half-lives (minutes to hours), meaning that the impacted groundwater was expected to return to ambient state soon after ISCO injections were stopped.

In determining if the ISCO system mobilized lead and hexavalent chromium outside of the immediate area of treatment, it is important to recognize some of the general characteristics associated with naturally occurring metals in an aqueous media. The chemical properties of chromium and lead and their presence and stability in groundwater, as well as the chemical and physical properties of the groundwater, significantly influence whether or not these potential contaminants were or could be mobilized in the study area and to what degree these impacts may have occurred.

5.4 Influences on Groundwater Flow

The groundwater flow directions and rates at the GVC Station site are influenced by the geology and the commercial supply wells in the southeast corner of the property. Based on the historic MTBE migration pathways, the groundwater has been identified to migrate in a generally south to southwest direction as shown on Figures 6 through 8 from the GES *Supplemental Chromium and Lead Investigation Summary – September 28, 2012* report (included in Appendix M). However, it is apparent from the consistent piezometric surface elevations that there is a directional component to the southeast towards the commercial supply wells (Figure 3 of the *Second Quarter 2013 Monitoring Report – August 15, 2013* is included in Appendix M).

Hydraulic gradients were calculated between MW13 and MW17 and between MW8 and MW9 for the duration of the ISCO system operation (*i.e.* from September 2011 through July 2012). The monitoring well sets were selected based upon the identified contaminant flow characteristics and the identified hydraulic gradients.

The well set MW13 and MW17 represents the predominant and historic pathway of MTBE migration from the UST tank field as shown in Figures 6 through 8 from the GES *Supplemental Chromium and Lead Investigation Summary – September 28, 2012* report (Appendix M). The calculated average gradient during the September 2011 through July 2012 time frame was 0.0065 feet/foot.

The well set MW8 and MW9 represents the flow path from the parking lot area of the shopping center to the cluster of five commercial supply wells that clearly influence the hydraulic gradient locally as demonstrated in Figure 3 of the *Second Quarter 2013 Monitoring Report – August 15, 2013* (Appendix M). The calculated average gradient during the September 2011 through July 2012 time frame was 0.0186 feet/foot.

Contaminants can only flow with groundwater when they are in a mobile form and for as long as they exist in a mobile form. Moreover, contaminants can only flow with the groundwater direction and at the same groundwater rate of travel. They do not have independent mobility that would allow them to travel against groundwater flow or in directions different from each other. Similarly, if groundwater chemistry is altered by such a process as ISCO, the chemically altered groundwater generally can only flow with the groundwater direction and at the same groundwater rate of travel. Thus, altered groundwater and/or contaminants rendered mobile by certain water chemistry characteristics would travel together, in the same direction, at the same speed for as long as the chemistry maintains them in a mobile state.

The years of sampling data and knowledge of the extent of the MTBE plume in the GVC Station Petroleum Study Area is important in MDE’s evaluation of the sampling data on hexavalent chromium and lead. As discussed above, the commercial supply wells in the southeast corner of the Green Valley Plaza appear to influence the local groundwater hydraulics. This influence would play a part in the movement of contaminants in the subsurface. It should be noted that the wells in this area of the Green Valley Plaza and the adjacent wells on the Green Valley Shopping Center property have been collectively pumping since approximately 1994. So despite this local influence, the prevalent flow direction as apparent from the historical MTBE plumes discussed above is to the south to southwest.

Moreover, any groundwater altered due to the operation of the ISCO system would migrate in the direction of and at the rate of known groundwater flow. The effects from the ISCO system on groundwater movement (as opposed to chemistry changes) would be spatially and temporally limited by the length of time the system was in operation, the half-lives of the oxidants used, and the pressures used to inject the materials. The pressure changes noted in adjacent wells help to define the spatial limits of the injections therefore the radius of influence of the treatment system, which do not appear to extend beyond the treatment area (31). There is no evidence to suggest that the ISCO system's injection events exerted forces that were sufficient to alter groundwater flow such that they would have pushed contaminants in directions against the known groundwater flow.

6.0 Human Health Assessment and Risk Characterizations

6.1 Purpose

MDE may perform human health assessments to determine whether the presence of constituents of potential concern represent a risk to human health that warrants a regulatory action. The objective of this human health assessment is to determine if the chemical concentrations of hexavalent chromium and lead detected in water at residences in the study area present an unacceptable risk to people potentially exposed under a residential land use scenario.

The human health assessment will serve to identify if potential health hazards exist and whether the data patterns and assessment can identify sources of contamination. In conjunction with the assessment and any trends identified in the data analysis, as discussed further in Section 6.6, conclusions regarding potential health hazards and sources of contamination may be drawn.

This assessment is focused in nature and is limited to evaluating and assessing the potential risks of hexavalent chromium and lead in water at residences and supply wells in the study area. Primary guidance sources used to conduct the assessment include guidance and reports published by EPA, EPA Region 3, MDE, the Centers for Disease Control and Prevention (CDC), and the Agency for Toxic Substances and Disease Registry (ATSDR) (1-17).

6.2 Analytical Data and Assessment Methodology

6.2.1 Well Sampling Data Sets

In the course of its investigation of lead and hexavalent chromium in water samples in the AOI, MDE has reviewed and analyzed well sampling data from Carroll, Jenkins, and its own investigations performed in conjunction with the FCHD, as described below.

A. Carroll Sampling Data

As a party responsible for a discharge of oil, since approximately 2006, Carroll has been directed by MDE to collect, analyze, and submit to MDE various water sampling results for VOCs. The GVC Station Study Area includes 19 monitoring wells, 29 residential drinking water wells, and 8 commercial drinking water wells.

On August 1, 2012, after the issue of hexavalent chromium in groundwater sampling had been raised, MDE directed Carroll to conduct a broad round of sampling on all residential drinking water wells, commercial wells, and monitoring wells in the GVC Station Petroleum Study Area and to include analysis for VOCs, total chromium, and hexavalent chromium. Later, after lead was raised as an issue, Carroll had the comprehensive round of sampling analyzed for lead. Pursuant to the approved CAP, Carroll has continued to conduct water sampling on monitoring wells, potable wells, and commercial supply wells, with analytes including VOCs, total chromium, hexavalent chromium, and lead.

B. Jenkins Sampling Data

Certain residential water sampling results collected by Jenkins were submitted to MDE between approximately August 2012 and April 2013. The Jenkins samples include some data for VOCs, hexavalent chromium, and lead. Sampling protocols, standard operating procedures and any sampling and analysis plan utilized by Jenkins have not been provided to or reviewed by MDE.

C. MDE and FCHD Residential Sampling Data

1. MDE and FCHD Initial Residential Sampling,
October – December 2012

Using sampling procedures described in Section 4.2 above, MDE and FCHD sampled 23 residences between approximately October and December 2012.

2. MDE and FCHD Additional Residential Sampling,
March and June – July 2013

Using sampling procedures described in Section 4.3 above, MDE resampled the water at 11712 Serene Court in March 2013, and at an additional four residences between June and July 2013.

D. Data Validation

Data collected under MDE guidance in the AOI was validated by an independent third party following MDE and EPA guidance (1, 18 through 21). Data validation allows data to withstand independent review and allows a user to evaluate data reproducibility and quality. Consistent with federal Superfund guidance, data validation is often conducted to support investigations involving issues of public health to ensure that “[a] consistent, Agency-wide Quality System will provide, when implemented, the needed management and technical practices to assure that environmental data used to support Agency decisions are of adequate quality and usability for their intended purpose” (22). Portions of the data collected by Carroll do not appear to be validated. The data collected by Jenkins, with highest detections of lead consistently collected throughout the AOI, does not appear to be validated. Regardless of the apparent lack of data validation, as a conservative measure, all data provided to MDE was used throughout the evaluation process.

6.2.2 Selection of Chemicals of Potential Concern

Selecting chemicals of potential concern (COPCs) is a qualitative process to limit and focus the number of chemicals that are quantitatively evaluated in a baseline human health assessment. This assessment focuses on lead and hexavalent chromium in groundwater as COPCs in the AOI. The COPC screening criteria for the AOI were derived from MDE’s *Cleanup Levels for Soil and Groundwater* (2008) and the EPA Regional Screening Levels (RSLs) (2012). The more conservative of these values were used to select COPCs. These risk-based concentrations are based upon exposure pathways for which generally accepted methods, models, and assumptions have been developed for a specific land use, residential in this assessment.

For each residential and commercial supply well, the maximum lead and hexavalent chromium detections, regardless of data source or quality, were compared to MDE groundwater cleanup levels and EPA RSLs to identify each residential property warranting further assessment.

6.2.3 Exposure Assessment Methodology

The exposure assessment component of a health assessment defines and evaluates either quantitatively and/or qualitatively the type and magnitude of human exposure to chemicals originating at or migrating from a site. It is designed to depict the site's physical setting and identify potentially exposed populations and applicable exposure pathways in order to calculate concentrations of COPCs to which people may be exposed, and to estimate chemical intakes under the relevant exposure scenarios. Actual and/or potential exposures at a site depend on the likely pathways of contaminant release and transport and the patterns of human activity.

Given the variability of the data collected throughout the AOI, the data supporting the degree and magnitude of the ISCO treatments, the exposure and human health assessment can assist in ascertaining (a) whether a contaminant release occurred, (b) if so, whether any potential health impacts might be associated with such a release, or (c) whether the presence of a contaminant may result from other confounding factors.

6.2.4 Conceptual Site Model

The conceptual site model (CSM) for the AOI is limited to water exposure involving hexavalent chromium and lead. The CSM depicts the relationships among the following elements of a complete exposure pathway (*i.e.* a pathway that results in human exposure): source of contamination; exposure routes; contaminant release mechanisms and transport/migration pathways; and people potentially exposed.

These CSM elements establish the manner and degree to which a person may be exposed to chemicals at a site. The degree of risk incurred by a person varies according to the means and duration of exposure and the specific chemical to which the person is exposed. An exposure, however long in duration, does not necessarily result in a health or environmental risk that necessitates regulatory action, although risks generally increase with increased frequency and/or duration of exposure.

A degree of uncertainty exists concerning the sources of hexavalent chromium and lead at the GVC Station and at specific properties within the AOI, because the COPCs are metals that may occur naturally in the local rock formations. As previously discussed, lead constitutes one of the primary contaminants in all public water works and can often be found in drinking water samples. Additionally, the presence of lead in specific locations within an individual plumbing system is dependent on a multitude of factors including but not limited to the age and construction of the individual plumbing system; the presence of filters, water softeners, and pressure tanks; water chemistry of the groundwater; and the presence of metals within the geologic formations from which the water is extracted.

6.2.5 Potential Human Exposures and Exposure Pathways

The current land use in the AOI consists of residential lots with two adjacent shopping centers within the neighborhood. All homes in the immediate area are designed to use groundwater as their primary source of water. Current land use is residential and the child, adolescent, and adult residential populations were evaluated. In addition, a potential construction worker population was evaluated.

A resident may be exposed to contaminants of concern primarily via ingestion and dermal contact with chemicals present in the groundwater.

Lead exposures were only assessed for the incidental ingestion exposure route, and the dermal route of exposure was not evaluated quantitatively. Regulatory agencies like the EPA and the ATSDR have not yet identified a method suitable for evaluating the dermal exposure route to lead and the dermal route of exposure is not considered to be a sensitive chemical-induced end point considered to be of relevance to humans.

6.2.6 Exposure Point Concentrations

Water exposure point concentrations (EPCs) for lead and hexavalent chromium were evaluated at each residence. Given the limited number of positive hexavalent chromium detections in the data set for the AOI, the maximum hexavalent chromium data was utilized as the EPC for each residence.

Due to the inherent variability associated with lead analysis in drinking water from an individual plumbing system and residential well, lead was evaluated in the following manner. As a first step, the maximum detected lead concentration within each residence, regardless of sample location within the plumbing system, was used as the EPC. Lead concentrations were evaluated quantitatively using EPA's IEUBK (8) blood lead level model. If a home had a lead water concentration in excess of 15 µg/L, or the IEUBK model indicated potential blood lead levels in excess of the CDC blood lead level of concern concentration of 5 micrograms per deciliter (µg/dL) (15), then the water data was further evaluated. The additional evaluation was to determine data reproducibility, location of samples within the plumbing system of the home, and whether the sample(s) in question were from point-of-use locations within the home. Based upon this additional evaluation, determinations were made at each investigated residence regarding whether lead in water represented a potential health hazard.

6.2.7 Chemical Intake Estimation and Toxicity Criteria

Methodologies for estimating exposure intakes for the potential resident groups were calculated using current MDE and EPA risk assessment guidance (1 through 14). Lead was evaluated using the IEUBK blood lead level model (8). The assessment utilized the CDC blood lead level of concern concentration of 5 µg/dL (15). Modeled results used recommended default dietary, soil and dust, airborne, and maternal lead concentrations and resident specific water concentrations to estimate blood lead levels. The reference dose (RfD), toxicity value used to evaluate noncarcinogenic health effects, and the cancer slope-factor (CSF), toxicity value for carcinogenic effects, utilized in the assessment to quantify exposures were obtained from the EPA RSL table (2012).

Non-carcinogens exhibit a threshold effect that is defined as the RfD, which is the estimated daily intake that is not believed to be associated with adverse health effects. The hazard index (HI) is the standard unit for quantifying non-carcinogenic risk of a particular chemical. The HI is the ratio of the daily intake to the recommended RfD. An index greater than one (1) would indicate the possibility for an adverse health effect from the exposure (2,3,4).

Carcinogenic risk is defined as the chronic daily intake dose times the CSF. The risk is the probability of excess lifetime cancer from exposure to the chemical (2,3,4).

6.3 Early Screening Risk Calculation Results

Based on the data provided by Carroll and Jenkins through approximately October 2012, MDE conducted a screening risk calculation to determine what, if any, regulatory action may be warranted with regards to hexavalent chromium and lead in water sampling in the AOI. MDE's screening risk calculations showed that no hexavalent chromium detections in residential drinking water supply wells exceeded MDE's calculated conservative lifetime exposure health based concentration of 0.3 µg/L[16], indicating that there is no public health risk warranting regulatory action from drinking water exposures to hexavalent chromium. The screening showed that there were no lead concentrations in a point-of-use sample (*e.g.* a kitchen faucet) exceeding the 15 µg/L action level. However, some water samples taken from other locations within home plumbing systems (*e.g.*, near pressure tank valves) were detecting concentrations of lead above the recommended lead action level of 15 µg/L. Thus, further investigation into the source of, and potential health risks of, the higher lead concentrations was warranted.

6.4 Initial Risk Characterization Results

6.4.1 Overview

Based on a complete review of data collected during MDE and FCHD's sampling efforts in October – December 2012, March 2013, and all data submitted to MDE by Carroll, Jenkins, and residents, MDE completed a risk characterization as described above. The risk characterization results for each residential well were grouped into two categories: those warranting no further State action, and those warranting additional State assessment. Additionally, data from public supply wells present in the study area were analyzed assuming a residential use scenario. The data utilized in the assessment are presented in Tables 1 through 3 and sample calculations are provided in Appendix G. Every residential well within the study area for which data was received or data was collected by MDE and FCHD was assessed, and results of those assessments are presented below.

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[16] See Appendix T for a detailed explanation of the calculation of the conservative lifetime exposure health-based concentration for hexavalent chromium.

6.4.2 Residential Wells Warranting No Further State Action or Assessment

Of the 40 residential wells analyzed, 21 were found to warrant no additional State assessment for either hexavalent chromium or lead. Results of the quantitative risk estimates for the properties listed below (Exhibit 2) are detailed in Appendix G.

Exhibit 2: Residential Wells Warranting No Further State Action or Assessment After Initial Analysis

1	11711 Serene	12	3984 Rye
2	11879 Thomas Spring	13	3984A Farm
3	11812 Pine Tree[1]	14	3985 Farm
4	3737 Blueberry[2]	15	3990 Farm[1]
5	3739 Blueberry[2]	16	3992 Farm[1]
6	3829 Greenridge[2]	17	3992 Rye[1]
7	3835 Greenridge[1]	18	3994 Rye[2]
8	3933 Rosewood[1]	19	3995 Farm
9	3979 Farm	20	3996 Rye[1]
10	3981 Farm	21	4107 Cove Court[1]
11	3984 Farm		

1. Well had no detectable level of hexavalent chromium in the water samples at the reported detection limits; therefore, exposure to hexavalent chromium in water was not evaluated quantitatively.
2. Well had no detectable level of lead in the water samples at the reported detection limits; therefore, exposure to lead in water was not evaluated quantitatively.

Noncarcinogenic and carcinogenic risk estimates from the incidental ingestion of and dermal contact with hexavalent chromium in water were below an HI of one (1) for noncarcinogens and a 1 in 100,000 (1×10^{-5}) cancer risk for residential use populations. All risk estimates were significantly below MDE recommended lifetime exposure risk thresholds for residential use populations. Based upon these results, MDE concludes potential hexavalent chromium impacts to residential water for these homes in the AOI warrant no additional State assessment.

Modeled blood lead levels from incidental ingestion of lead in water for all properties listed above were below the CDC's 5 μg/dL blood lead level of concern. As stated previously, dietary, soil and dust, airborne, and maternal lead concentrations as well as the use of the maximum detected resident specific water concentration, regardless of location within the residence, were utilized to estimate resident specific blood lead level concentrations. Use of these assumptions may result in an overestimation of the modeled blood levels for specific residences versus actual blood lead levels for the above listed properties. Based upon these results no further State evaluation of lead in drinking water exposure hazards at the above listed properties is warranted.

6.4.3 Residential Wells for Which Further Data Analysis and Evaluation Were Performed

Of the 40 residential wells analyzed, 19 indicated that further data analysis was warranted. Results of the quantitative risk estimates for the properties listed below (Exhibit 3) are detailed in Appendix G.

Exhibit 3: Residential Wells at which Further Data Analysis and Evaluation were Performed

1	11712 Serene[1]	11	3989 Farm[1]
2	11713 Serene	12	3991 Farm
3	11894 Barclay Court	13	3993 Farm[1]
4	3740 Blueberry[1]	14	3994 Farm
5	3806 Greenridge	15	3996 Farm[1]
6	3833 Greenridge[1]	16	3997 Farm
7	3837 Greenridge	17	3998 Farm
8	3923 Rosewood	18	3998 Rye
9	3983 Farm[1]	19	4016 Middleton Drive
10	3987 Farm		

1. Property had no detectable level of hexavalent chromium in the water samples at the reported detection limits; therefore, exposure to hexavalent chromium in water was not evaluated quantitatively.

Noncarcinogenic and carcinogenic risk estimates from the incidental ingestion of and dermal contact with hexavalent chromium in water were below a HI of one (1) for noncarcinogens and a 1 in 100,000 (1 x 10^{-5}) cancer risk for residential use populations. All risk estimates were significantly below MDE recommended lifetime exposure risk thresholds for residential use populations. Based upon these results, MDE concludes potential hexavalent chromium impacts to residential drinking water for these homes in the study area warrant no additional State assessment.

Modeled blood lead levels from consumption of lead in water for the following properties listed below exceeded the CDC 5 μg/dL blood lead level of concern (Exhibit 4). However, these results were based upon the highest detected lead concentrations for each property (*i.e.* potential "outliers"). Subsequent data collected from the properties under controlled and documented methodologies were not consistent with the potential "outlier" concentrations used in the modeled blood lead levels. Running the blood lead level model utilizing the validated and controlled data set indicated modeled blood lead levels would be below the recommended CDC 5 μg/dL blood lead level of concern. The results for 3996 Farm Lane are of note because the First Draw sample collected by MDE and FCHD did present a concentration above 15 μg/L, however the modeled blood lead levels would be below the recommended CDC 5 μg/dL blood lead level of concern.

Of the 19 residences listed above (Exhibit 3), further data analysis and evaluation indicated that no further State action was warranted at the following 12 properties listed in Exhibit 4.

Exhibit 4: Residential Wells for which Further Data Analysis and Evaluation Indicate No Further State Action or Assessment are Warranted

1	11894 Barclay	7	3993 Farm
2	3806 Greenridge	8	3994 Farm
3	3923 Rosewood	9	3996 Farm
4	3983 Farm	10	3997 Farm
5	3987 Farm	11	3998 Rye
6	3989 Farm	12	4016 Middleton

As stated previously, dietary, soil and dust, airborne and maternal lead concentrations as well as the use of the maximum detected resident specific water concentration, regardless of location within the residence, were initially utilized to estimate resident-specific blood lead level concentrations. However, further analysis of the data indicated lead does not pose a potential health threat at these properties and no further evaluation of lead in water is warranted.

6.4.4 Residential – Additional Assessment Warranted

Data from the remaining seven residences listed in Exhibit 5 were analyzed further. Modeled blood lead levels from consumption of lead in water at these properties exceeded the CDC's 5 µg/dL blood lead level of concern.

Exhibit 5: Residential Wells that Warranted Seeking Further State Assessment

1	11712 Serene	5	3837 Greenridge
2	11713 Serene	6	3991 Farm
3	3740 Blueberry	7	3998 Farm
4	3833 Greenridge		

Subsequent data analysis and additional sampling (as described in Section 4.2.2) confirmed the presence of lead in the plumbing systems at these properties. Blood lead level modeling indicated potential blood lead levels in excess of the CDC's 5 µg/dL concentration, thus warranting further assessment. As stated previously, dietary, soil and dust, airborne, and maternal lead concentrations as well as the use of the maximum detected resident specific water concentration and confirmation sampling, regardless of location within the residence, were initially utilized to estimate resident specific blood lead level concentrations.

Given potential modeled blood lead levels greater than 5 µg/dL, additional sampling was proposed at each of these properties to try to isolate and identify lead sources within the plumbing systems. The additional sampling, described in Section 4.3.3, was conducted in June and July 2013. It should be noted that all point-of-use samples collected at these properties resulted in modeled blood lead levels below the CDC's 5 µg/dL blood lead level of concern.

6.4.5 Additional Residential Risk Characterization Results

Based on the additional sampling performed at the following residences in June and July 2013, quantitative risk estimates for three of the seven properties (listed in Exhibit 6) were performed and are presented in Appendix G.

Exhibit 6: Residential Wells Warranting No Further State Action or Assessment After Further State Assessment			
1	11713 Serene	3	3991 Farm
2	3740 Blueberry[1]		
1. Property had no detectable level of hexavalent chromium in the water samples at the reported detection limits; therefore, exposure to hexavalent chromium in water was not evaluated quantitatively.			

Noncarcinogenic and carcinogenic risk estimates from the incidental ingestion of and dermal contact with hexavalent chromium in water were below a HI of one (1) for noncarcinogens and a 1 in 100,000 (1 x 10^{-5}) cancer risk for residential use populations. All risk estimates were significantly below MDE recommended lifetime exposure risk thresholds for residential use. Based upon these results, MDE concludes potential hexavalent chromium impacts to residential drinking water for these homes in the study area warrant no additional assessment.

Modeled blood lead levels from consumption of lead in water for some locations other than point-of-use at the properties listed in Exhibit 6 exceeded the CDC 5 µg/dL blood lead level of concern. However, these results were based upon the highest detected lead concentrations for the property (*i.e.* potential outliers) from the June and July 2013 sampling event. Data collected from the properties under controlled and documented methodologies identified the sources of the outlier concentrations used in the initial modeled blood lead levels. Blood lead level modeling based upon the validated and controlled data set resulted in modeled blood lead levels below the recommended CDC 5 µg/dL blood lead level of concern at point-of-use locations.

As described in Section 4.3.4, MDE noted that during the additional sampling event at 3998 Farm, a portion of the sampling procedure was not completed, which resulted in no representative groundwater sample collected from this location. However, blood lead level modeling for 3998 Farm performed for the point-of-use location was below the recommended CDC 5 µg/dL blood lead level of concern.

The property owners of the three remaining properties (i.e. 3833 Greenridge Drive, 3837 Greenridge Drive, and 11712 Serene Ct.) were contacted via mail (and additional requests made via telephone and in-person visits) to allow for further sampling of the respective private drinking water supply wells, and permission to sample was not granted.

6.5 Commercial Supply Well Assessment

In addition to residential wells, eight commercial supply wells, serving the Green Valley Plaza the Green Valley Shopping Center, and the All State Insurance Building, are located in the AOI. The risks due to hexavalent chromium and lead were evaluated for each individual supply well in the AOI and the Green Valley Plaza point-of-use samples (Appendix G). Commercial supply wells were conservatively evaluated individually using a residential exposure scenario.

Commercial exposure scenarios have lower associated risks, but as a conservative measure, residential exposure was assumed for the commercial supply wells. This conservative assumption will lead to an overestimation of potential risks and should be considered in further recommendations regarding supply well requirements. The maximum detected hexavalent chromium and lead concentrations were used as the EPCs for each individual well and the point-of-use data set.

Noncarcinogenic risk estimates from the incidental ingestion of and dermal contact with hexavalent chromium in water were below a HI of one (1) for all supply wells and the point-of-use data. Carcinogenic risk estimates from incidental ingestion of and dermal contact with hexavalent chromium in water were below the MDE target 1 in 100,000 (1 x 10^{-5}) lifetime cancer risk for residential use of the following wells: Green Valley Plaza – FR-88-1366, FR-88-1394, FR-94-1281; All State Insurance – FR-73-7687; and Green Valley Shopping Center – FR-73-4918, and FR-73-6634. Additionally, carcinogenic risk estimates from incidental ingestion of and dermal contact with hexavalent chromium in water were below the MDE target 1 in 100,000 (1 x 10^{-5}) lifetime cancer risk for residential use populations at the point-of-use sampling location for the Green Valley Plaza.

Carcinogenic risk estimates from incidental ingestion of and dermal contact with hexavalent chromium exceeded MDE recommended lifetime cancer risk ranges for residential use of water from the following Green Valley Plaza supply wells: FR-81-5955 (the backup well for the supply system) and FR-94-1233. Based upon this result, potential lifetime carcinogenic risks associated with hexavalent chromium in water from supply wells FR-81-5955 and FR-94-1233 should be considered further in the ongoing groundwater investigation, recognizing that a residential use scenario is far more conservative than the wells' current use.

Modeled blood lead levels from consumption of lead in water were below the CDC 5 µg/dL blood lead level of concern for the point-of-use samples and for the following supply wells: Green Valley Plaza – FR-88-1366, FR-88-1394, FR-94-1281; All State Insurance – FR-73-7687; and Green Valley Shopping Center – FR-73-4918, and FR-73-6634.

Modeled blood lead levels were in excess of the CDC 5 µg/dL concentration at Green Valley Plaza supply well locations FR-81-5955 and FR-94-1233. Lead water concentrations from the point-of-use sampling location for the Green Valley Plaza were non-detect, which indicates that the individual well results do not represent a significant lead contamination issue. Further, it is important to note that FR-81-5955 is a backup well (i.e. not used on a regular or ongoing basis), water from FR-94-1233 is blended with three additional wells prior to finishing and distribution, and the entire water supply system is subject to continued monitoring by MDE's Water Supply Program.

7.0 Statistical Analyses of Water Sampling Results

As another approach to determine whether groundwater quality was impacted by the ISCO system, groundwater quality data from monitoring wells and nearby residential water systems were evaluated to identify any discernible data trends. Additionally when appropriate, the data were analyzed using a series of statistical evaluations. The statistical analyses were conducted using accepted statistical methodologies (27), and the results are discussed below. The data evaluation was performed on data collected from August 2012 to March 2013 by MDE and FCHD, Carroll, and Jenkins and is presented in Appendix N.

Mean hexavalent chromium and lead concentrations from monitoring wells, residential water system sampling locations, and commercial supply wells were calculated using all detections from all data sources (Jenkins, Carroll, and MDE/FCHD). The means for each of these datasets, as well as the percent of the dataset that were below detection limits (i.e. non-detect) are presented in Exhibit 7.

Exhibit 7: Summary Statistics for Hexavalent Chromium and Lead

	Hexavalent Chromium		Lead	
Data Set	Mean (µg/L)[1,2]	% non-detect	Mean (µg/L)[1,2]	% non-detect
Residential water system	0.030	72	30	38
Monitoring wells	3.2	44	5.8	40
Commercial supply wells	0.83	13	6.2	42

1. The means were calculated using the non-parametric Kaplan-Meier method.
2. The mean values reported are for all samples from all data sources, including non-detects.

7.1 Hexavalent Chromium Water Data

7.1.1 Monitoring Well and Residential Water System Sampling Comparison

Hypothesis testing of hexavalent chromium data from monitoring wells compared to residential water systems data was performed using the Wilcoxon-Mann-Whitney test. Statistical testing indicated that the residential water system samples (with a mean of 0.030 µg/L) do not exhibit any statistically significant relationship to the hexavalent chromium detections in the monitoring well network (with a mean of 3.2 µg/L). In addition, the Wilcoxon-Mann-Whitney test indicates that the hexavalent chromium detections in MW18S appear to be the result of the ISCO system. These observations are illustrated in the histograms in Appendix N.

In addition, hexavalent chromium detections throughout the residential water data set have been consistently low. Over the same monitoring period, the isolated detections of hexavalent chromium in the monitoring wells have shown an overall decreasing trend[17] (*e.g.* MW18S). This also indicates that hexavalent chromium was generated in an isolated discrete area and did not

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[17] In October 2013, sampling from MW18S indicated an increase in hexavalent chromium detections from the previous sampling results post August 2012. Additional sampling in December 2013 demonstrated a continued overall decrease in this well's hexavalent chromium concentration relative to the August 2012 data. MDE will conduct further investigation with Carroll and GES on the representativeness of MW18S.

migrate from the treatment area site at statistically significant concentrations, and therefore did not impact residential wells in the AOI.

Given the presence of chromium in the parent geologic formations in the area (as evidenced by the detections of total chromium levels in several wells and by the rock analysis of the Marburg formation (28)), the data indicate that the detections of hexavalent chromium in residential water systems are a function of background conditions. No residential samples or the commercial point-of-use samples exceeded the recommended health based criteria for hexavalent chromium (0.3 µg/L) and thus all are far below the presently enacted public water system drinking water MCL for total chromium (100 µg/L).

7.1.2 Monitoring Well and Commercial Supply Wells Sampling Comparison

Hypothesis testing of monitoring well data compared to commercial supply well data on hexavalent chromium was performed using the Wilcoxon-Mann-Whitney test. Statistical testing indicated that the mean/median of monitoring wells exhibited a statistically significant higher concentration of hexavalent chromium than that of the commercial supply well data set. This difference exists even though there is a much higher frequency of non-detects within the monitoring well network for hexavalent chromium (44 percent) than in the supply well data set (13 percent).

Two factors contribute to this result and the following conclusions and recommendations are drawn. First, hexavalent chromium in the monitoring well network has a high degree of variability and a relatively high number of non-detects, which is exhibited in the monitoring well histogram for hexavalent chromium (Appendix N). Many of the monitoring wells do not appear impacted by the ISCO system, the impacts of which were isolated to a limited area around MW18S. Secondly, the commercial supply well data set has a lower frequency of non-detects (13 percent) for hexavalent chromium than the residential wells (72 percent) and monitoring wells (44 percent). Based on a further analysis of the commercial supply well data in the AOI, hexavalent chromium appears to be present in most commercial supply wells at concentrations below MDE recommended non-carcinogenic and carcinogenic risk levels. These hexavalent chromium concentrations may be a function of naturally occurring background conditions. During one recent sampling event (October 18, 2013), concentrations of hexavalent chromium in supply wells FR-81-5955 and FR-94-1233 exceeded risk based concentrations. The measured hexavalent chromium concentration of FR-81-5955 was well below MDE recommended non-carcinogenic and carcinogenic risk levels during subsequent sampling (December 18, 2013). FR-94-1233 was not sampled in December, 2013.

Based on the location of FR-81-5955, which is located 400 ft to the west and side gradient to slightly upgradient of the ISCO treatment area; the lack of any significant historic MTBE contamination (*i.e.* maximum concentration of 0.3 µg/L); and based on the characterized hydraulics of the site and the treatment area, the detections of hexavalent chromium in this well are not likely to be related to the ISCO system and so are likely due to localized conditions of that well and plumbing system and the natural formation. However, the same conclusions cannot be drawn for FR-94-1233, which lies downgradient of the source area and has been previously impacted by MTBE. Thus, it is not easily discernible whether the detections in this well are a result of naturally occurring background conditions or the oxidizing environment generated by the ISCO system.

The data presented in this report indicate that continued monitoring of these two specific commercial supply wells (FR-81-5955 and FR-94-1233) for hexavalent chromium is warranted, in addition to the point-of-use sampling of the Green Valley Plaza. In addition, the origin of the hexavalent chromium in commercial supply well FR-94-1233 remains unclear. It should be noted, as discussed in Section 6.6, that the point-of-use hexavalent chromium concentrations for this supply well network are below MDE recommended lifetime exposure risk levels for residential use populations, which is a conservative analysis for a supply well network that is designated for commercial use.

7.2 Lead Water Data

7.2.1 Monitoring Well and Residential Water System Sampling Comparison

Mean lead concentrations from monitoring wells were compared to mean lead concentrations from the residential water system samples in the AOI. The Wilcoxon-Mann-Whitney test was used to compare the two data sets. This test indicates that the two data sets represent statistically different populations. Contrary to the hexavalent chromium data, the mean of lead concentrations for residential water samples (30 µg/L) was higher than the mean of lead for the monitoring well network (5.8 µg/L). In addition, the monitoring well lead concentrations had a lower standard deviation than the residential water system samples. More discussion on the variability in the residential water system lead data and the potential source of this variability is discussed in Section 7.2.2 below.

Data from the monitoring well network did not indicate that the ISCO system generated high concentrations of lead in groundwater. The monitoring well lead concentrations exhibit no decreasing or increasing trend with time and instead fluctuate around the mean. This observation is in agreement with the observed characteristics of lead, including low water solubility and a high risk-based SSL for the protection of groundwater (5, 17).

The monitoring well with the highest measured lead concentration (MW6: 99 µg/L) is often dry and does not yield much groundwater. The high lead result in this well is likely the result of suspended solids (*i.e.* dirt and sediments), which are common in wells that yield little water and are periodically dry. However, this does not explain the greater concentrations of lead in residential wells or the statistically significant difference between the two data sets, primarily because residential wells are to be constructed with solid casing into competent bedrock to avoid surface influences.

Monitoring well samples are collected, and the wells are designed, to reduce variability in results and identify contaminants and trends that may exist in the groundwater data set. Monitoring well data for naturally occurring metals, like lead and chromium, may be subject to a high degree of uncertainty due to the presence of suspended solids in the groundwater as well as sampling techniques. Environmental investigations focusing on metals attempt to reduce variability by filtering a portion of the samples where metals are constituents of concern. As part of the investigation at the GVC Station, Carroll measured both total and dissolved lead concentrations (Table 2). Every monitoring well sample for which the total lead concentration exceeds the MDE action level was non-detect for dissolved lead. Therefore, suspended lead is present in these wells rather than dissolved. If the ISCO system was the source of the elevated lead in the monitoring wells, it would be expected to be mobilized in solution (*i.e.* dissolved) rather than as suspended particles, which are more likely attributable to sampling protocol and well construction factors. Of note, dissolved phase lead was low throughout the monitoring well network, and was greatest at MW18S, immediately adjacent to the ISCO treatment area.

7.2.2 Data from Investigations of the Source of Lead in Residential Water Systems

In order to identify potential sources of elevated lead concentrations at several properties, detailed sampling at different locations within the plumbing inside these residences was conducted in March, June, and July 2013, following procedures described in Sections 4.3.2 and 4.3.3. MDE determined that point-of-use lead concentrations were below health-based concentrations of concern and that modeled blood lead levels were well below the CDC-recommended 5 µg/dL. In an effort to identify the source(s) of the high lead detections, MDE contractors took samples at specific locations in and surrounding the pressure tanks. The results, presented in Table 1 (11713 Serene Court, 3740 Blueberry Court, and 3991 Farm Lane), indicate that the sediments accumulated in and near the pressure tank likely are a source of total and dissolved lead detected in water samples collected from the pressure tank. Samples collected in the plumbing system farther from the pressure tank contain only trace amounts of lead.

Lead detections in residential supply well samples that were considered representative of groundwater (i.e. not influenced by sediments in pressure tanks) ranged from non-detect to 3.4 µg/L, which was consistent with the concentrations (2 and 5 µg/L) detected in the 1992 and 1993 sampling of wells in the MGS study discussed previously (23). These concentrations also are consistent with the lead concentrations measured in source water samples for the Green Valley Plaza, Green Valley Shopping Center, Green Valley Elementary School, and Children's Center for Discovery, which range from 2.94 to 7.0 µg/L. This indicates that the groundwater entering the plumbing systems does not have elevated levels of lead, either total or dissolved.

Both residences served by public water systems and residences supplied by private drinking water wells are expected to intake and accumulate sediments in plumbing. Similarly, both public water supplies and residential drinking water wells are subject to a degree of corrosion of the plumbing system infrastructure, depending on the water quality characteristics and the materials, quality, and age of the plumbing infrastructure itself. The sediments that accumulate in these systems may have multiple contributing sources. In the case of residential drinking water wells, sources may include the native formation material and degradation products of corrosive processes.

The sediments collected from the pressure tanks of two homes were analyzed in the laboratory. The sample collected from 11712 Serene Court also had sufficient volume to allow for inspection by an MDE staff Professional Geologist (see Appendix H). The geologist's inspection observed the presence of deposited sediments containing metals, the composition of which was confirmed by laboratory analysis. Based on additional information, the geologist's evaluation concluded that the sediments originated from or accumulated within the plumbing system and likely contributed to the elevated lead concentrations in samples collected within the plumbing system.

Laboratory analysis determined that the sediments collected from the pressure tanks were primarily iron and aluminum with lesser concentrations of other trace metals including lead. The material examined by MDE likely was primarily composed of an anaerobic corrosion product of various plumbing components, including the water pump and portions of the pipe and water tanks, which can occur in the presence of lower pH water. A fraction of the depositional sediment sample appeared to be quartz sand, which likely originated from the bedrock in which the well was drilled. This indicates that a small portion of the sediments, including perhaps metal-bearing sediments, were attributable to the bedrock formation.

This conclusion is supported by data from an adjacent property, 11713 Serene Court. A sample collected from the pressure tank at this property in September 2012 contained lead at 450 μg/L, an elevated concentration consistent with the high lead concentrations taken at the pressure tank at11712 Serene Court prior to pressure tank flushing. In the spring of 2013, the property owner at 11713 Serene Court replaced the pressure tank and the well pump. The June 2013 sampling conducted by MDE and FCHD did not show any significant levels of sediments or elevated levels of lead (total or dissolved) in the pressure tank samples at 11713 Serene Court. Over the three months since the installation of the new pressure tank and well pump, there had been no appreciable sediment accumulation in the pressure tank and no appreciable accumulation of lead deposits within or originating from metal corrosion and/or deposition throughout the plumbing infrastructure. This suggests that the corrosion products and natural sandy sediments observed at 11712 Serene Court take months to years to accumulate. In addition, this property is not in the groundwater flow path of the MTBE plume originating at the GVC station. Given these lines of evidence, it is improbable that the ISCO system was the cause of the sediment accumulation in the pressure tank or the lead concentrations in samples collected from the pressure tank.

During review of the third party data validation findings from samples collected at 11712 Serene Court in March 2013, it was noted that duplicate samples collected from the pressure tank had lead concentrations with a relative percent difference of 104. Sample PT1 had a lead concentration of 567 μg/L and sample PT1DB had a concentration of 180 μg/L, which represents a major disagreement between the duplicates. All supporting documentation accompanying these duplicates was acceptable (e.g. data validation and chain of custody), which indicates that the discrepancy is an accurate reflection of differences in the chemistry of the samples. The major disagreement between the duplicates is reasonably attributable to differences in suspended solids. The point-of-use ("first draw") sample for this residence had a lead concentration below the MDE action level, indicating, as with most plumbing systems, the suspended sediments are removed by the plumbing system (primarily a result of the filtration systems present). Unfortunately, the resident of 11712 Serene Court would not allow additional study of the groundwater entering the plumbing system. However, it is MDE's opinion that had additional sampling been allowed, the results would have been consistent with sampling at the 11713 Serene Court property, which showed no significant lead concentrations within the groundwater and lead concentrations that are consistent with historically documented samples in the area.

The New Jersey Department of Environmental Protection (NJDEP) has documented the same finding regarding the influence of pressure tanks on lead concentrations (24). In their report, NJDEP and Rutgers University noted that abnormally high lead concentrations resulted from samples collected from the pressure tank spigot without any significant flushing of the pressure tank. Additionally, this is further validated and documented in the SDWA water sampler certification program conducted throughout Maryland. The training and certification is explicit in its requirement that lead drinking water samples be collected from point-of-use locations.

In conclusion, the detailed sampling procedures implemented by MDE and FCHD in March, June, and July 2013 validated the hypothesis that the pressure tanks and other areas of deposition in the plumbing systems accumulate sediments, which can serve as a continued source of total and dissolved metals. It is MDE's opinion that the higher lead concentrations measured in water from pressure tanks were due primarily to the recovery of those sediments. There is no evidence to support the claim that the lead measured in water from pressure tanks or accumulation of the sediments themselves were caused by the ISCO system.

7.2.3 Monitoring Well and Commercial Supply Wells Sampling Comparison

In addition to the residential wells, mean lead concentrations from monitoring wells in the AOI were compared to mean lead concentrations from the commercial supply wells at the Green Valley Plaza and the Green Valley Shopping Center. Statistical analysis of these data indicates that the monitoring well lead data and commercial supply water lead data were essentially equal. The mean monitoring well and commercial supply well lead concentrations were 9 µg/L and 9.9 µg/L, respectively, using only detections, and 5.8 µg/L and 6.2 µg/L using detections and samples that were non-detect for lead. Based upon these results, the ISCO system does not appear to have generated lead in groundwater in the commercial supply wells at concentrations that are statistically distinguishable from the monitoring wells.

Based on lead concentrations, the only monitoring well that appears to be impacted by ISCO is MW18S, with total lead concentrations between 3.4 and 21.8 µg/L and dissolved lead concentrations between 2.1 and 18 µg/L. Total lead has also been measured at elevated levels in monitoring well MW2, between 21 and 36 µg/L. However, this well has a high sediment load, contains a minimal amount of water, and did not have any detected dissolved lead. Other data from MW2, such as high concentrations of iron (31), suggest that the samples were impacted by high sediment load. Lead does not appear to be migrating, but is present at low levels in groundwater. The low-level lead detections are reasonably attributable to background conditions and suspended solids in several monitoring wells and commercial supply wells. The supply well point-of-use sample concentrations were all below MDE recommended modeled blood lead levels.

The following commercial supply wells all had a total or dissolved lead greater than the MDE action level of 15 µg/L at least once between August 2012 and December 2013: FR-81-5955, FR-88-1394, FR-88-1366, FR-94-1233 and FR-73-7687. The elevated levels of total lead in these wells appear temporally sporadic and do not correspond with detections of dissolved lead. The two exceptions to this are well FR-73-7687, which was only sampled once during this time period, with both total and dissolved lead detections exceeding the MDE action level, and the

May 2013 sample for FR-88-1394. The Green Valley Plaza point-of-use samples were all non-detect for lead. However, additional sampling of the commercial supply wells is recommended to further document and confirm the sporadic nature of lead in these wells.

7.3 Temporal Data Trends

A final analysis of both hexavalent chromium and lead water concentrations was performed to ascertain whether any temporal trends exist that might help define the extent and significance of potential ISCO impacts, if any. Residential water data was compared with monitoring well data for hexavalent chromium and lead, and evaluated to identify any temporal trends within the data sets.

Mean hexavalent chromium and lead concentrations for the monitoring well network and residential wells were grouped by month(s) and are presented in Exhibit 8: Mean Hexavalent Chromium and Lead Concentrations Over Time (µg/L).

Exhibit 8: Mean Hexavalent Chromium and Lead Concentrations Over Time (µg/L)

	Residential Water		Monitoring Wells	
Month	Hexavalent Chromium[1]	Lead[2]	Hexavalent Chromium[1]	Lead[2]
August 2012	0.0293	44.0	7.43 (0.086[3])	9.38 (4.4[4])
September/October 2012	0.0322	34.8	0.72 (0.050)	3.51
November 2012	0.0297	2.8	-	-
December 2012/January 2013	0.020	4.4	0.78 (0.071)	4.36
February/March 2013[5]	0.0271	289	1.34 (0.064)	2.18

1. A hexavalent chromium detection limit of 0.02 µg /L was utilized for non-detect samples.
2. A lead detection limit of 1.0 µg /L was utilized for non-detect samples.
3. Hexavalent chromium monitoring well data in parentheses excludes MW18S
4. The mean lead monitoring well concentration was 4.4 µg /L when the intermittently dry MW6 well was removed from the data set.
5. Monitoring well data was collected in April 2013.

The mean of hexavalent chromium monitoring well data through March 2013, including non-detects, was 3.2 µg/L and the mean of hexavalent chromium residential water data was 0.030 µg/L. Residential water data was well below the recommended 0.3 µg/L conservative lifetime exposure health based concentration. As shown in Exhibit 8, the hexavalent chromium concentrations in residential water systems have fluctuated around the mean of 0.030 µg/L, well below levels warranting further evaluation, and appear to be neither increasing nor decreasing.

Excluding data from monitoring well MW18S, which appears to be impacted by the ISCO system, mean monitoring well hexavalent chromium concentrations over the study time period are all below conservative lifetime exposure health based concentration of 0.3 µg/L (Exhibit 8). While concentrations of hexavalent chromium appear to decrease over time, this trend is isolated to shallow monitoring well MW18S (Table 2). This further illustrates that the potential ISCO impacts are limited to areas immediately surrounding MW18S.

Carroll, through its contractor GES, proposed that well MW18S has geochemical conditions within the well that could cause the natural formation of hexavalent chromium independent of the oxidants injected as part of the ISCO remediation. However, other lines of evidence indicate that the groundwater in the vicinity of MW18S was influenced by the ISCO system, including pressure readings and analytical results. Pressure measured in MW18S increased during operation of the ISCO system (31). The hexavalent chromium concentration in this monitoring well has also declined steadily in the months since the ISCO system was shutdown (Table 2). However, as of December 2013, the hexavalent chromium concentration in this well had still not returned to less than 1 µg/L, as observed in other monitoring wells. The declining hexavalent chromium concentrations in this well since the ISCO system was shut-down in August 2012 indicate that the oxidizing potential of the injected oxidants was depleted, and that groundwater is returning to its ambient condition. While data collected in October 2013 showed a modest increase in the hexavalent chromium concentration at MW18S (Table 2) compared with the previous monitoring event in April 2013, subsequent sampling in December 2013 demonstrated that hexavalent chromium concentrations continue to decline relative to August 2012. MW18S is the only monitoring well with a clearly demonstrated pressure influence from the ISCO system in conjunction with a corresponding chemical concentration influence. MDE has directed Carroll to conduct additional investigation into this well, including whether the well is influenced by grout intrusion, which may be possible based on the high pH measurements from this well.

Rather than reduction from hexavalent to trivalent chromium (and therefore conversion to an insoluble form), another possible explanation for the reduction in the hexavalent chromium concentrations measured in the treatment area is transport away from the treatment area by groundwater. However, the groundwater flow rates in the area are so low that it is not possible to account for the reduction in hexavalent chromium over time solely due to transport away from monitoring well MW18S. In addition, none of the downgradient wells have shown a corresponding increase in hexavalent chromium or total chromium. No monitoring wells within the treatment area other than MW18S or throughout the rest of the site had hexavalent chromium detections over 1 µg/L, and all have remained consistently low through the post shutdown monitoring period. Therefore, after the ISCO system operation was suspended, the affected groundwater appears to have returned to its ambient reducing conditions, and hexavalent chromium that was mobilized due to the ISCO injections continues to be reverted back to the insoluble, trivalent form.

Changes in lead concentrations over time in the residential wells and monitoring wells were also analyzed. Residential water samples had a high degree of variability, and exhibited no discernible trend (either increasing or decreasing) with respect to time. The only correlation that could be drawn from the existing data is that water samples taken near known areas of deposition within the plumbing (*i.e.* pressure tanks) had higher concentrations of lead. Monitoring wells had, on average, lower lead detections than residential wells. When the one elevated lead concentration from monitoring well MW6 was excluded from the data set (MW6 is periodically dry and yields little water), monitoring well lead concentrations varied between 2.2 and 4.4µg/L during quarterly sampling events (Exhibit 8).

The mean lead concentrations detected in monitoring wells were below health-based concentrations and did not exhibit any discernible temporal trends, with the exception of

MW18S, which appears to be impacted by the ISCO system, and MW2, which appears to have a higher suspended sediment load and a minimal amount of water present (although enough water present to collect a sample, which is not typically the case for MW6). Despite total lead between 15 and 36 μg/L in MW2, dissolved lead has not been detected in this well, indicating that lead is present in fine particulate material rather than in solution. However, dissolved lead was measured in MW18S up to 18 μg/L (total lead up to 21.8 μg/L), further indicating ISCO may have impacted the groundwater in the immediate vicinity of MW18S. The total lead results in the monitoring wells exhibited low concentrations of lead with a moderate degree of variability and low mean total lead concentrations, with little to no temporal correlation (Exhibit 8). As with the hexavalent chromium, MW18S appears to be the only monitoring well impacted by operation of the ISCO system as indicated by dissolved lead.

8.0 Conclusions

8.1 Health Concerns

The concentrations of hexavalent chromium in water for all residential properties in the AOI were below the MDE-recommended 0.3 µg/L conservative lifetime exposure health based concentration. These concentrations are also far below the enforceable MCL of 100 µg/L for total chromium for public water systems. Therefore, there is no public health risk warranting regulatory action in the AOI from exposure to hexavalent chromium in water.

The concentrations of lead in point-of-use (*i.e.* faucet) samples at residences in the AOI were below the recommended lead action level of 15 µg/L with one exception: 3996 Farm Lane. All modeled blood lead levels, including those for 3996 Farm Lane, were below the recommended CDC 5 µg/dL modeled blood lead level of concern based upon the controlled and validated data sets used for the risk evaluations. In multiple residential systems, water samples taken at locations other than a point-of-use (*e.g.* a pressure tank) demonstrated lead concentrations that exceeded the 15 µg/L action level, but further investigation revealed the source of those elevated concentrations to be the sediments deposited within individual plumbing systems themselves. Therefore, MDE identified no health risk warranting regulatory action for those homes directly sampled by MDE and FCHD, despite the detections of lead concentrations above action levels at certain locations within some of the plumbing systems.

While certain individual commercial supply wells at the Green Valley Plaza and the Green Valley Shopping Center had hexavalent chromium and lead concentrations in excess of recommended residential exposure risk based screening concentrations, all point-of-use samples collected indicated that the finished commercial water supply (a blend of water from several wells) was below the conservative residential risk concentrations. Users of commercial supply wells do not consume, and thus are not exposed to, water in the higher quantities and durations that are incorporated into a residential risk exposure scenario. Therefore, MDE determined risk to be below levels warranting regulatory action for users of the commercial water supply for the Green Valley Plaza or Green Valley Shopping Center for point-of-use samples.

8.2 Hexavalent Chromium Detections

Chromium is found naturally in geologic formations throughout the State of Maryland. The presence of chromium in water samples in the AOI was documented in baseline sampling Carroll conducted in 2011. Some wells in the AOI had detections of total chromium, indicating the presence of chromium in the parent geologic formations in the area, and also as documented in the Keystone Landfill study report (28). Hexavalent chromium is a common valence state of chromium that occurs naturally in the environment from the erosion of natural chromium deposits.

Site-specific data demonstrate that hexavalent chromium is likely present due to natural geologic background conditions, and at concentrations typically below recommended health based criteria. The conclusion that the hexavalent chromium detections in residential wells are naturally occurring and not generated by operation of the ISCO system is further supported by the statistical analysis of the data, which showed that the residential water samples do not exhibit any statistically significant relationship to the apparent localized hexavalent chromium impacts in MW18S, part of the monitoring well network at the GVC Station. The differences in the data sets are further illustrated by the consistently low hexavalent chromium detections and the high number of non-detects of hexavalent chromium in the residential water data set as compared to the overall decreasing trend of hexavalent chromium in the impacted well within the monitoring well network.

Further, as the more water soluble and more mobile groundwater contaminant of concern (as compared to lead), hexavalent chromium would be expected to have demonstrated a plume and a corresponding gradient if it had originated from the ISCO system treatment location and migrated from the treatment area. There is no pattern in the residential well detections of hexavalent chromium that would indicate the presence of a definable hexavalent chromium plume from a single source, and no spatial correlation between the known MTBE plume and the detections of hexavalent chromium in residential sampling. None of the residential samples or the commercial supply well point-of-use samples exceeded the MDE recommended lifetime health based risk criteria for hexavalent chromium (0.3 µg/L). These findings demonstrate that the ISCO system did not cause the residential well hexavalent chromium detections, and that the low-level detections instead reflect the natural background conditions of the underlying bedrock and groundwater.

8.3 Lead Detections

Based on the evidence gathered through literary sources and empirical evidence, including MDE and FCHD's sampling efforts, MDE has determined that there are detectable levels of lead in the groundwater (+/- 5 µg/L) in the AOI, with pH levels generally at 5.5 and lower. MDE found that the elevated lead concentrations measured in samples collected from residential pressure tank spigots are not representative of groundwater, but instead are likely due to recovery of lead-bearing sediments deposited over time inside individual plumbing components. In addition, the groundwater of the Marburg Formation, the bedrock underlying the site, is well documented as acidic in the region, a condition that can lead to corrosion of plumbing components. Elevated lead levels may exist in plumbing systems, both public and private, where there is lead in the plumbing infrastructure components and water with a low pH. The low pH of the groundwater, existing background lead levels in the groundwater, and lead in sediments deposited in the plumbing infrastructure all contribute to the lead concentrations measured at various sampling points within individual residential plumbing systems.

The elevated levels of total and dissolved lead detected in samples collected from the pressure tanks are due to sediment accumulation in the plumbing components over time. The NJDEP and the Rutgers University study previously reached the same finding as MDE and FCHD. Specifically, even when the plumbing had been flushed at a kitchen faucet or other similar location, when a sample was collected from the pressure tank spigot, the sample was, in effect, an unflushed sample of relatively stagnant water from the pressure tank. When sampling was completed at 3991 Farm Lane, 11713 Serene Court, and 3740 Blueberry Court using a protocol designed to distinguish the groundwater conditions from the pressure tank conditions, it was clearly demonstrated that sediments deposited in the home plumbing systems were the primary source of the elevated lead detections, and not the groundwater. The pH of water in each of these homes was low and any pH adjustment equipment present in the plumbing system was installed after (*i.e.* downstream of) the pressure tank.

Further, analysis of sediments collected from the pressure tanks of two homes showed that the sediments were primarily iron and aluminum with lesser concentrations of other trace metals, including lead. While native formation material also was observed, the sediments did not appear to be composed significantly of native formation material. The sediments were determined to be predominantly an anaerobic corrosion product of man-made materials, *i.e.* a corrosion product of various plumbing components that would be expected to occur in the presence of lower pH water, such as that documented in the Marburg Formation. Corrosion is a constant process, influenced by the water chemistry, and the significant amount of corrosion product recovered from the flushed pressure tank systems indicated that the process took extended time to be created and collected. This conclusion is further supported by the flushing of the newly-installed pressure tank installed at the 11713 Serene Court property, which demonstrated no such accumulations of corrosion product.

Spatial analysis of data indicated that there is no pattern in the residential well detections of lead that would correspond to a definable lead plume from a single place of origin. There is no correlation between the known MTBE plume and the detections of lead in residential sampling. In addition, there is no correlation between the detections of lead and the detections of hexavalent chromium in residential sampling. These findings demonstrate that the ISCO system did not cause the residential well lead detections.

8.4 ISCO System Influence

The analytical data (VOCs, metals, water quality measurements, and pressure data) demonstrate that influence from the ISCO system was spatially limited to the treatment area, as the system was designed to be. The data does not reveal any connection between the known MTBE plume and the detections of either hexavalent chromium or lead in the residential water samples, meaning there are no corresponding hexavalent chromium and lead plumes that also originate from the GVC Station site and travel with the groundwater.

Within the treatment area of the ISCO operation, hexavalent chromium levels in MW18S increased while the system was operational. MW18S is located approximately 20 ft from the injection wells, where one expects to see groundwater chemistry directly impacted by the ISCO system.

The data from the commercial supply wells indicate low levels of naturally occurring hexavalent chromium from the parent bedrock, along with the possibility that the ISCO system caused increased hexavalent chromium detections in one commercial supply well (FR-94-1233). Continued monitoring of the groundwater will confirm whether these detections are of natural origin or are due in part to the ISCO system’s operation.

There is some evidence that suggests lead may have been locally mobilized in the treatment area, based on data from MW18S. However, these data also show that, in the immediate vicinity of the ISCO system, hexavalent chromium was mobilized more readily than lead. MDE concludes that most of the lead detections in the monitoring wells are not due to the ISCO system operation because: (a) The highest monitoring well detections of lead were total lead (*i.e.* not dissolved lead) in wells with minimal standing water at the time of sampling (*e.g.* MW2 and MW6); (b) The samples were determined to be highly impacted by sediments from the surrounding overburden[18]; (c) It is not uncommon to find lead in overburden soils within Maryland (1); and (d) In the presence of excess oxygen, such as at the water table, the mobilization of metals to a soluble form is a common occurrence (1). The correspondingly high levels of iron in samples with high lead detections for MW2 and MW6 demonstrate this point. Moreover the monitoring well data set for lead exhibited no clear decreasing or increasing trend, and the data fluctuates around the mean over time.

Statistical testing of hexavalent chromium data indicated that the monitoring wells and the residential wells represent two distinct populations, and in fact there is an inverse correlation between hexavalent chromium and lead concentrations in these two populations (*i.e.* where hexavalent chromium concentrations are higher, lead concentrations are lower and vice versa). This indicates that a single factor (*e.g.* ISCO) is unlikely to be the cause of both. This inverse correlation is even more significant when the relative solubility of hexavalent chromium and lead are considered.

The larger GVC Station Petroleum Study Area dataset indicates the ISCO system has significantly reduced MTBE concentrations in the source area and that the MTBE plume is diminishing over time. The reduction in MTBE concentrations with no corresponding hexavalent chromium or lead detections within the vast majority of wells demonstrates that any influence the ISCO system had on metal mobilization or chromium species conversion was limited spatially and was not long lasting due to: the short half-lives of the injected oxidants; the rate of groundwater flow; the limited geologic source material available to be converted and mobilized; and the unstable characteristics of species like hexavalent chromium, which is itself an oxidant and therefore would not be stable in the presence of organic material such as MTBE or other petroleum constituents.

Based on the data collected and evaluated, the ISCO system appears to have mobilized measurable levels of hexavalent chromium and lead in the immediate vicinity of monitoring well MW18S. In addition, the ISCO system may have impacted commercial supply well FR-94-1233; however, additional data is warranted to substantiate this concern. No ISCO related impacts to residential water systems were identified.

It is MDE’s opinion that the elevated lead levels and trace hexavalent chromium levels detected throughout the private residences are not the result of the ISCO system operation. They are the result of natural causes (*e.g.* low pH, sediment, and trace lead and chromium levels in groundwater and the underlying bedrock) and individual plumbing components.

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[18] This is not to be confused with the bedrock formation in which the majority of the drinking water supply wells are completed.

9.0 Recommendations

9.1 General

Hexavalent chromium and lead, like numerous other substances, are potentially hazardous to human health. A meaningful assessment of health risks from exposure to hexavalent chromium and/or lead will include the type of exposure (*e.g.* ingestion, inhalation, dermal contact), the concentration in water, the duration of the exposure, and other factors specific to individuals.

While MDE did not find any public health risks warranting regulatory action based on this investigation, MDE's finding does not affect and is not intended to influence people's rights to investigate, evaluate and respond independently to any issues or concerns they may have about their drinking water. People can seek the consultation of persons outside MDE and FCHD regarding concerns they may have about health, property, sampling, testing, data obtained, suggested courses of action, or other issues. If people have such concerns, they should consult with persons knowledgeable in their areas of concern.

9.2 Residential Well Owner Recommendations

This investigation by MDE and FCHD demonstrates that the accumulated sediments in certain areas of plumbing systems such as pressure tanks can have lead and other metals present. As this material accumulates over time in pressure tanks, filters, and/or hot water heaters, it can act as a continued source of lead in the water supply. Recovery of accumulated sediments or the acidic water that has been noted in the area coming into contact with these sediments can cause lead levels to exceed levels of concern at some locations within plumbing systems.

As a precaution, to help reduce the likelihood of lead and other metals in plumbing systems and particularly at points-of-use, users of water in the area are encouraged to do the following:

- maintain their plumbing systems,
- periodically test water for the presence of lead and other contaminants of concern,
- flush sediments from water lines, pressure tanks, and hot water heaters, and
- consider the addition of a more robust in-line sediment filtration mechanism(s) or a water filtration system that removes metals from the water and adjusts pH to recommended levels.

Residential well owners are encouraged to familiarize themselves with the EPA document "Drinking Water from Household Wells" (Appendix O) and to follow its recommendations. Day-to-day steps to reduce exposure to lead in drinking water[19] include the following:

1. **Let the water run from the faucet before using it for drinking or cooking.** The longer water stands in the plumbing, the more lead it may contain. Flushing the faucet means running the cold water faucet for 15 to 30 seconds. Although toilet flushing or showering flushes water through a portion of the plumbing system, you still need to flush

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[19] See Appendix Q for Reference 34, EPA handout "Is There Lead in My Drinking Water?" February 2005.

the water in each faucet before using it for drinking or cooking. Flushing the faucet is a simple and inexpensive measure you can take to protect your health. It usually uses less than one gallon of water. To conserve water, fill a couple of bottles for drinking water after flushing the faucet, and whenever possible use the first flush water to wash dishes or water plants.

2. **Never cook with or drink water from the hot water faucet.** Hot water can dissolve lead more quickly than cold water. If you need hot water, draw water from the cold water faucet and then heat it.

The steps described above will reduce the concentration of lead in drinking water. However, if residents are still concerned, bottled water may be used for drinking and cooking. They also are encouraged to be familiar with their plumbing system infrastructure and to follow the maintenance recommendations, if any, provided by manufacturers, installers, or plumbers.

9.3 Commercial and Monitoring Well Recommendations

MDE will maintain its directives to Carroll to continue the sampling and analysis of the commercial supply wells, as long as MDE deems it warranted, as described below.

Exhibit 9: Commercial Supply Wells that May Warrant Further Assessment			
1	FR-81-5955	2	FR-94-1233

- Continue sampling for hexavalent chromium, at a minimum, in these two commercial supply wells (Exhibit 9) and the point-of-use sampling location to determine if hexavalent chromium detections are the result of natural background conditions or are a byproduct of the ISCO system.

- Continue sampling for hexavalent chromium and lead in the monitoring well network over a time period to sufficiently demonstrate and document return to ambient conditions.

- Investigate the integrity of well MW18S to ensure representative samples are collected from the groundwater.

10.0 References

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FIGURES

Figure 1 Lead and Hexavalent Chromium Groundwater Investigation Area of Interest

Figure 2 Portion of the Geologic Map for the Frederick Quadrangle

Figure 3 Green Valley Citgo Station Petroleum Study Area

TABLES

Table 1 MDE-FCHD GV/Monrovia GW Investigation, Analytical Summary Table, Private Supply Wells

Table 2 MDE-FCHD GV/Monrovia GW Investigation, Analytical Summary Table, Monitoring Wells

Table 3 MDE-FCHD GV/Monrovia GW Investigation, Analytical Summary Table, Commercial Supply Wells

APPENDICIES

Appendix A Sampling and Analysis Plan for Site Specific Sampling Green Valley / Monrovia Frederick County, Maryland

Appendix B Property Owner Questionnaires, Field Sampling Forms, and Calibration Logs – October through December 2012

Appendix C Organic Analytical Laboratory Reports – October through December 2012

Appendix D Inorganic Analytical Laboratory Reports – October through December 2012

Appendix E Results Letters – October through December 2012

Appendix F Data Validation Reports – October through December 2012

Appendix G Risk Characterization Calculations

Appendix H MDE Sediment Analysis Memorandum

Appendix I Property Owner Questionnaires, Field Sampling Forms, and Calibration Logs – March and June through July 2013

Appendix J Analytical Laboratory Reports – March and June through July 2013

Appendix K Results Letters – March and June through July 2013

Appendix L Data Validation Reports – March and June through July 2013

Appendix M Groundwater Flow Assessment Materials

Appendix N Data Trend Analysis

Appendix O EPA, Drinking Water from Household Wells

Appendix P EPA, Chromium in Drinking Water Web Page Excerpt

Appendix Q EPA, Is There Lead in My Drinking Water?

Appendix R Photographs from tank removal at GVC Station

Appendix S EPA, Lead and Copper Rule: A Quick Reference Guide

Appendix T Discussion of Conservative Lifetime Exposure Health Based Concentration of Hexavalent Chromium