PETITION FOR CLASS IV GROUNDWATER RECLASSIFICATION

Elizabeth Mine Superfund Site

Vermont Department of Environmental Conservation
Waste Management and Prevention Division
Sites Management Section

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ACRONYMS AND ABBREVIATIONS

ARARs	Applicable or Relevant and Appropriate Requirements
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Contaminant of Concern
CSM	Conceptual Site Model
EPA	Environmental Protection Agency
ESD	Explanation of Significant Differences
GWUR	Groundwater Use Restriction
IC	Institutional Controls
ICZ	Institutional Control Zone
MCL	Maximum Contaminant Level
MCLGs	Maximum Contaminant Level Goals
Nobis	Nobis Group®
NPL	National Priorities List
NTCRA	Non Time-Critical Remedial Action
RA	Remedial Action
RI	Remedial Investigation
ROD	Record of Decision
Site	Elizabeth Mine Superfund Site
TCRA	Time Critical Removal Action
TP	Tailings Pile
USGS	U.S. Geological Survey
VTDEC	Vermont Department of Environmental Conservation
VTGES	Vermont Groundwater Enforcement Standard
Weston	Weston Solutions, Inc.
WMA	Waste Management Area

1.0 Introduction

The purpose of this petition for groundwater reclassification is to present current and historical data in support of reclassifying the existing Class III groundwater designation within and adjacent to the Elizabeth Mine Superfund Site to a more restrictive Class IV groundwater classification.

This reclassification process establishes administrative or Institutional Controls (IC) to prevent and/or limit the use of known contaminated groundwater within a specific area when remedial efforts are not expected to achieve federal or state drinking water standards. The reclassification process is outlined in the VTDEC Procedure for Class IV Groundwater Reclassification, dated July 5, 2018.

The specific areas/zones discussed in this petition for reclassification include groundwater within the Underground Workings (Mine Pools) that have been in direct contact with the sulfide rocks and other waste associated with the abandoned mine and have become unsuitable for human consumption due to elevated metals. These naturally occurring, inorganic metals include cadmium, copper, manganese, mercury, and nickel.

The boundaries of the proposed reclassification area encompass the extent of the contaminated groundwater plume with various buffers to account for potential migration of dissolved metals within fractured bedrock. The reclassification boundaries have been adjusted to match existing parcel boundaries were appropriate for ease of field verification. In other areas where the reclassification boundary transects a parcel, the boundary line has been surveyed, and groundwater use on these transected parcels is additionally limited through a grant of environmental easement.

There are two distinct designations within the reclassification area: non-conditional and conditional. Areas identified as non-conditional indicate that the use of groundwater as a potable or public water supplies is prohibited, however, some agricultural, industrial or commercial uses of groundwater within this reclassification area may be considered by the Secretary. Areas identified as conditional indicate that the use of groundwater as a potable supply may be considered on a case-by-case basis by the Secretary, and a demonstration that a potable supply well within the conditional area would not cause contamination to spread, further degrade groundwater quality, or will not pose a risk to human health or the environment.

The bulk of the data presented in this report was taken from the Conceptual Site Model Update & Institutional Control Zone Report, prepared by Nobis, dated March 31, 2023 (Nobis 2023). A copy of this report and other supporting documentation is available online at:

https://anrweb.vt.gov/DEC/ERT/Hazsites.aspx?site=770186

2.0 Site Description and History

2.1 Site Description

The Elizabeth Mine (Site) is located in the towns of Strafford and Thetford in Orange County, and Sharon in Windsor County in east-central Vermont, approximately 2 miles southeast of the village of South Strafford on the eastern flank of Copperas Hill, Figure 1. It is approximately 15 miles north of White River Junction and 9 miles west of the Connecticut River. The Site includes three small watersheds containing Copperas Brook, Lord Brook, and Sargent Brook, which all discharge to the

West Branch of the Ompompanoosuc River, which joins the East Branch of the Ompompanoosuc River just before Union Village Dam.

The combined flow from the Ompompanoosuc River flows into the Connecticut River about ten miles downstream of the Site. The topography of the area is steep mountainous terrain with elevations ranging from 825 feet (ft) above mean sea level (msl) at the West Branch of the Ompompanoosuc River up to 1,600 ft above msl at the top of Copperas Hill.

In 2000, the primary physical features that were present when the Environmental Protection Agency (EPA) began work at the Site included the following:

- A 45-acre two-tiered flotation mill tailing impoundment with a tailing dam, designated Tailing Pile-1 (TP-1) and Tailing Pile-2 (TP-2).
- Two waste rock piles, designated Tailing Pile 3 (TP-3) and Tailing Pile 4 (TP-4), along with large areas of scattered waste rock.
- Three open rock cuts (the North Open Cut, the South Open Cut, and the South Mine), two of which contained pit lakes (located at the South Open Cut and South Mine).
- An area of stone foundations and lead remaining in the soil surrounding the Copperas Factories.
- A series of World War II (WWII)-era mine support buildings.
- Underground mine workings, including Adits (horizontal mine access/passage) and shafts (vertical or sloping mine access/passage) that connect to the surface, and the associated mine pool.

Site features of the Elizabeth Mine including the north and south cuts, southern drift, extent of the underground workings, tailing pile boundaries, site boundaries, and well locations are shown on Figure 2.

2.2 Operational History

The Elizabeth Mine operated from the early 1800s until its closure in 1958 (PAL, 2003a). The ore was initially valued for its iron content, and then its pyrrhotite content from which copperas (iron sulfate) was produced. The Copperas Factories were active from about 1810 until the 1880s. Copper mining began about 1830 with intermittent copper mining activity until 1942. The current site features associated with this period include the upper and lower Copperas Factories, South Mine, the North Open Cut, TP-3, and several shafts and adits. The mine was most productive from 1943 to 1958 when it was revived using modern mining technology to support the need for copper during WWII and the Korean War. This period included the addition of most of the recent site features such as the ore processing buildings, TP-1 and TP- 2, South Open Cut and the associated TP-4, and expansion of the North Open Cut. The mine was closed in 1958.

By the end of mining operations, the mine property encompassed approximately 1,400 acres and underground workings extended to approximately 1,000 ft below ground surface (bgs) and 8,000 linear ft with an estimated 5 miles of underground shafts and tunnels. When mining operations were abandoned, many of the underground areas flooded with groundwater, creating a mine pool containing about 116 million gallons of water. An air vent (also known as the Artesian Vent), created to provide ventilation for underground work areas, currently discharges mining influenced water (MIW) from the underground workings into the West Branch of the Ompompanoosuc River (WBOR). During the 1942-

1958 operational period, ore from waste piles at the Ely Copper Mine and Pike Hill Mine was brought to Elizabeth Mine for processing.

2.3 Regulatory and Investigative History

In 2006, the EPA signed a Record of Decision (ROD) to select the Remedial Action (RA) cleanup approach for the Site. The 2006 ROD was revised based on three Explanation of Significant Differences (ESDs) issued in 2008, 2015, and 2019.

The EPA then segregated the implementation of the 2006 ROD into three phases.

- Phase I RA addressed the Copperas Factories and was completed in 2010.
- Phase II RA addressed the Lord Brook Source Areas and was completed in 2020.
- Phase III RA includes site wide monitoring of the surface water, groundwater, sediments, final site restoration activities along with the implementation of Institutional Controls, which is the focus of this petition for reclassification.

Institutional Controls include land use restrictions to prevent future consumption of contaminated groundwater within specific areas of the Site. The contaminated groundwater is found within the Underground Workings of the Elizabeth Mine and within and adjacent to TP-1, TP-2, and TP-3. The TP-1 groundwater restriction also extends into some of the WWII Infrastructure Area. Some combination of local ordinances, deed notices, and/or restrictive covenants, coupled with periodic monitoring of compliance of the restrictions, would be used to provide awareness that the Underground Workings contain water that is unsuitable for ingestion and to prevent installation of a water supply well into the Underground Workings. No residential wells are currently installed in the Underground Workings.

EPA invoked a statutory Technical Impracticability Waiver, as permitted by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), for the groundwater within the Underground Workings. EPA determined that it is technically impracticable, from an engineering perspective, to achieve Federal Safe Drinking Water Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs), 40 C.F.R. Parts 141.11-.16 and 141.50- 53, and the State of Vermont Primary Groundwater Quality Standards, VT Env. Prot. R. Ch. 12-702 and 703 for the water within the Underground Workings (mine pool). Therefore, EPA waived these standards as applicable or relevant and appropriate requirements (ARARs) for the groundwater within the Underground Workings. This waiver applies to all of the inorganic constituents that are present in the naturally occurring material at the Site and specifically to cadmium, copper, manganese, mercury, and nickel, which were detected in the groundwater of the Underground Workings at concentrations above either MCLs, MCLGs, or the Vermont Primary Groundwater Quality Standards.

The groundwater contamination associated with TP-1, TP-2, and TP-3 is restricted to the area under the Waste Management Area (WMA), and the Institutional Controls will protect the integrity and long-term effectiveness of the response actions implemented as part of the Time Critical Remedial Action (TCRA) and Non-Time Critical Remedial Action (NTCRA). Periodic inspections would be performed to ensure compliance with the Institutional Controls. The long-term monitoring and maintenance activities for the TCRA and NTCRA will be implemented by the State of Vermont as part of this alternative.

The only groundwater contamination identified at the time of the 2006 ROD was beneath or immediately adjacent to the waste areas (TP-1, TP-2, TP-3, South Open Cut, South Mine, and TP-4) or within the Underground Workings, Figure 2. The 2006 ROD established a WMA that included TP-1, TP-2, TP-3, South Open Cut, and South Mine. The 2006 ROD also established a Technical Impracticability Zone for the contamination within the Underground Workings, including the three major Adits (1898 Adit, 1948 Adit, and Deep Adit). At the time of the 2006 ROD, one monitoring well location (MW-01C) defined the edge of the Waste Management Zone and the area just north of MW-01C extending to the 1898 Adit was not included in the Technical Impracticability Zone because samples collected from MW-01C in 2003 and 2006 did not show groundwater contamination above federal or state standards. After the signing of the 2006 ROD, a private well installed on a private property in close proximity to TP-3 and the 1898 Adit, just north of monitoring location MW-01C, was tested and found to be contaminated with cadmium, cobalt, iron, manganese, nickel and zinc. This location is designated HO1. The well was not put into use as a water supply and the property remains undeveloped.

In 2010, EPA performed an investigation to better define the extent of contamination north of MW-01C and to refine the extent of the area that may require groundwater use restrictions. The work is documented in a report entitled Final Institutional Control Zone Investigation Field Summary Report, Elizabeth Mine, South Strafford, Vermont (URS Corporation [URS], 2011). The report identified additional contamination at monitoring well IC10, which was located between wells MW-01C and HO1. Additional sampling of MW-01C, HO1, and IC10 along with other wells was performed from 2010-2017 to provide a better understanding of the contamination.

In 2018, EPA completed a report that updated the delineation of groundwater contamination and provided recommendations regarding the approach for groundwater use restrictions, entitled Institutional Control Zone Report Phase 3 Remedial Action Site-Wide Groundwater Remedial Design, Elizabeth Mine Superfund, Site South Strafford, Vermont, (AECOM, 2018). The report recommended that the area between the Deep Adit and 1898 Adit should be added to the Technical Impracticability Zone due to the presence of groundwater contamination at wells MW-01C, IC10, and HO1. The report determined that the 1948 Adit is not directly connected to the mine pool within the underground workings and is likely dry and that the Technical Impracticability Zone can be reduced in that area to a location closer to the underground workings.

Based on this updated information, the 2019 ESD provided the following revisions to the 2006 ROD:

- The Technical Impracticability Zone established by the ROD was revised to include the area between the Deep Adit and 1898 Adit due to the presence of groundwater contamination associated with the Underground Workings.

- The Technical Impracticability Zone was revised to exclude (remove from the Technical Impracticability Zone) the area associated with the 1948 Adit based on a more detailed evaluation of the Underground Workings.

- The Groundwater Compliance Levels were updated to include new Groundwater Compliance Levels for cobalt, copper and iron and a revised Groundwater Compliance Level for manganese. These changes were made either in response to recently identified exceedances of federal risk-based standards (for cobalt and iron) or due to a revision of standards within the

Vermont Groundwater Protection Rule and Strategy dated July 9, 2019 (for copper and manganese).

3.0 Geologic and Hydrogeologic Setting

3.1 Soils and Surficial Geology

Glacial till encountered at the Site consists of a poorly sorted to unsorted, non-stratified mix of sand, silt, clay, gravel, and rock fragments. During and after glacial retreat, sediment in upland areas was redeposited by meltwater along the valleys to create glaciofluvial and glaciolacustrine deposits; more recent alluvium (primarily sand and gravel) occurs along streams in the area.

Native material beneath the mine wastes generally consists of relatively thin (less than 6 ft) alluvial deposits, particularly adjacent to stream channels, underlain by a dense to very dense glacial till comprised of a poorly sorted mixture of gray, olive gray, and brown gravelly sand with varying amounts of silt and clay. Till thickness ranged from zero to nearly 90 ft in borings installed during the RI (URS, 2006a), with the greatest thicknesses generally found to the east and northeast of former TP-1. Closer to the Underground Workings, glacial till is generally less than 30 ft thick and is absent in some locations.

3.2 Bedrock Geology and Fractures

Bedrock underlying the Site is mapped as the Gile Mountain Formation and consists of metamorphosed pelitic schist, greywacke, and amphibolite (Howard, 1969; Seal et al., 2001; Slack et al., 2001). The ore deposits at Elizabeth Mine consist of iron sulfide in the form of pyrite or pyrrhotite, with lesser amounts of chalcopyrite, zinc (sphalerite) and lead, and trace amounts of other minerals. However, lead has not been encountered in significant concentrations outside of the Copperas Factories area; the lead in this is attributed to the remnants of lead vats used in the copperas manufacturing process. The ore body at the Elizabeth Mine is a north-trending layer of nearly continuous massive sulfide (with four ore shoots) that extends for approximately 2.1 miles.

To improve the Conceptual Site Model (CSM) and support an initial Institutional Control Zone (ICZ) delineation, Nobis conducted a study of bedrock fractures at the site (AECOM, 2018). The study included a photolineament analysis and outcrop measurements of bedrock fracture orientation, length, spacing, and apparent potential to conduct groundwater flow. Photolineaments are features that may indicate steeply dipping bedrock fractures that could be avenues for groundwater flow and contaminant transport.

These results were compared with existing borehole geophysical data and other information to characterize bedrock fractures and potential groundwater flow paths. The results of which are summarized in more detail in Section 2.2.1.2 and Appendix C of the ICZ Report (AECOM, 2018).

4.0 Groundwater Flow Characteristics

In addition to the water flowing into and through the Underground Workings, the current site groundwater system includes groundwater movement through the overburden, bedrock, and water piles (primarily the Tailing Impoundment). Prior to the remediation efforts, the South Open Cut and South

Mine pits lakes were also a source of groundwater recharge and were the headwaters for two tributaries to Lord Brook.

Previous studies (URS, 2006a; AECOM, 2018) have described shallow (saturated overburden) and deep (bedrock) groundwater flow regimes at the Site. Natural overburden deposits include alluvium in the stream valleys, stratified drift in the valley of the WBOR, and possibly sandy glacial till. Although the tailing and waste rock materials can be sufficiently permeable to conduct groundwater flow, much of this material now reside beneath the cover system installed over TP-1 and TP-2; water levels along with leachate flow at the toe of TP-1 document that the leachate flow from this material has been significantly reduced.

Where saturated overburden materials (whether naturally deposited or mine waste) exist in the subsurface, groundwater is unconfined and flows from areas with a higher head or water table to areas with lower water table. These conditions are not present throughout the Site and occur primarily in the TP-1 and TP-2 area and in stream valleys. In upland portions of the Site, permeable overburden is usually thin, unsaturated, and/or absent. Glacial till or bedrock (with or without a thin soil cover) may be present in these areas.

Low-permeability glacial till may be present beneath permeable overburden materials in the Site subsurface. This material may act as an aquitard between shallower (overburden) and deeper (bedrock) groundwater flow systems (URS, 2006a; AECOM, 2018). Also, weathered bedrock (saprolite) capable of stored or flowing groundwater may exist in or above the upper bedrock surface but beneath glacial till or other overburden deposits.

Beneath overburden deposits (where present), groundwater flows via bedrock fractures beneath the site. Porosity and permeability in the bedrock matrix beneath the Site is effectively zero (except possibly in local weathered bedrock deposits at the top of bedrock). Therefore, groundwater flow and contaminant transport can only occur in bedrock fractures that are sufficiently open and that are connected to sources of recharge and to other bedrock fractures.

Sources of recharge can include saturated overburden and waste material (where present), direct infiltration of precipitation and snow melt, infiltration of surface water (streams or former pit lakes before they were drained), or the mine pool in the Underground Workings. The elimination of the pit lakes in 2018 removed a source of recharge to bedrock in the southern part of the Site and reduced the pore volume available for water to contact potential source material.

While water-bearing fractures capable of contaminant transport are known to be present at depths of several hundred feet, for most wells in the area, fracture frequency is greatest in the upper 50 ft (AECOM, 2018, Appendix C). This indicates greater potential for groundwater flow and contaminant transport in the shallower bedrock than in the deeper bedrock.

Where water-bearing fractures are present and connected to other water-bearing fractures, bedrock groundwater flows from areas of higher head to lower head. The distance over which groundwater can flow in fractured bedrock beneath the Site is difficult to determine but is of key importance to designing the ICZ. A hydraulic connection has been proven between former well IC-10 and well HO-01, 275 ft apart (AMEC, 2014a and AECOM, 2018), indicating that in this area, groundwater can flow at least 275 ft via bedrock fractures.

Pumping a water well lowers its head and can locally reverse the direction of groundwater flow. Also, a water well that intersects multiple fractures with different heads can provide an avenue for vertical flow within the well bore, either upward or downward, cross connecting fractures and changing local groundwater hydraulics. Deep monitoring well IC-10, located east of the Underground Workings, showed significant mine-related impacts (AECOM, 2018). IC-10 also intercepted several water-bearing fractures and showed strong down-flow, with water exiting the borehole via a deep fracture. The average head in the well, though highly variable, was higher than 836 ft above msl, the elevation of the mine pool. Packer testing revealed that the head in the deep, outflowing fracture also had a higher head than the mine pool, prompting investigators to postulate that water from this impacted well flowed to the mine pool (AMEC, 2014a; AECOM, 2018). The IC-10 wellbore acted as a flow path, connecting shallower fractures to deeper fractures, thereby influencing contaminant transport in the rock mass in that vicinity. IC-10 was decommissioned in October 2018. The decommissioning of IC-10 blocked this flow path, thereby reducing or eliminating the cross-connection between the intercepted fractures and possibly reducing groundwater flow into the Underground Workings via the deep fracture.

Exchange of water between groundwater and surface water can also occur. In lower elevation portions of the Site, groundwater can either be discharged to a stream or be recharged by the stream (e.g. Copperas Brook or West Branch of the Ompompanoosuc River). Removal of the pit lakes has reduced or eliminated the opportunity for groundwater to surface water exchange in the upland and southern part of the Site.

A unique component of the flow regime at the Site is the presence of the mine pool in the Underground Workings. This mine pool formed in areas where past mining activities have excavated large caverns in the rock resulting in void spaces that eventually filled with water. This mine pool can interact with the surface water and groundwater by acting as a sink from water to collect, a large aperture conveyance, and a potential source.

The mine pool in the Underground Workings at the Elizabeth Mine developed over time due to groundwater seepage from the surrounding bedrock as well as from surface water infiltration through Adits, shafts, and open cuts. The mine pool discharges Acid Rock Drainage (ARD) to the ground surface at the Artesian Vent (URS, 2006b). This discharge point controls the head in the mine pool at 836 ft above msl. As described in previous reports (URS, 2006a and AECOM, 2018), the southern portion of the Underground Workings is not flooded but provides a conduit for water to flow northward and downward to the mine pool. To the north, the mine pool is fully confined within the Underground Workings. Adits, shafts, and voids at various depths and locations are expected to add complexity and delayed and variable responses to filling, emptying and other changes related to recharge events.

The potential remains for groundwater to flow from bedrock fractures into the Underground Workings and the mine pool or vice versa. Permeable bedrock fractures adjacent to the Underground Workings can be expected to discharge water to the mine pool if the head in the fracture is greater than 836 ft above msl. This would have the effect of lowering the head in surrounding bedrock fractures to just above 836 ft above msl. If a fracture in surrounding bedrock contains water with head lower than 836 ft above msl, either due to ambient or pumping conditions, water will flow out of the mine pool into the fractured rock mass if there is a hydraulic connection.

In 2016, the U.S. Army Corps of Engineers (USACE) and the U.S. Geological Survey (USGS) retrofitted and instrumented the Artesian Vent to automatically record discharge from the vent. Discharge measurements were collected every 15 minutes from October 20, 2016 to October 25, 2017, with results presented and interpreted in the ICZ Report (AECOM, 2018). Discharge varied from 20 gallons per minute (gpm) to more than 200 gpm and averaged 61.5 gpm. High discharges generally correlated with snow melt or significant rainfall events, but the correlation did not always occur. It is likely that at times infiltrating water filled natural porosity, bedrock fractures, or mine workings voids prior to manifesting as increased Artesian Vent discharge. Similar findings were identified as the result of flow monitoring and field measurements (geochemistry) performed at the Artesian Vent during 1898 Adit dewatering and closure activities from May 18, 2021, through October 5, 2021. Discharge from Adit dewatering activities was directed into the underground workings. Flow rate and geochemistry data collected from the Artesian Vent were plotted to analyze trends in flow, pH, temperature, specific conductance, total dissolved solids, oxidation reduction potential, and dissolved oxygen during 1898 Adit dewatering and the subsequent rebound to base flow conditions (Nobis, 2023). High discharges at the Artesian Vent generally correlated with dewatering, however, the correlation did not always occur.

5.0 Contaminant Fate and Transport

5.1 Contaminant Sources and Groundwater Transport

The primary sources of impacts to the mine pool at the Elizabeth Mine include residual mining waste remaining in the Underground Workings, as well as inflow from unflooded portions of the workings. Surface water inflow to the Underground Workings occurs primarily from the North Open Cut, and groundwater recharge to the mine pool also occurs via bedrock fractures (AECOM, 2018). The mine pool may also be impacted by entry of impacted groundwater via subsurface bedrock fractures. Following packer testing, AMEC concluded that impacted groundwater from well IC-10 flowed to the Underground Workings via a deep fracture, along which groundwater has been shown to exit the borehole (AMEC, 2014a). The contaminant history of MW-01C, located in the same area further supports that the mine pool may be the recipient of groundwater impacted by other sources such as waste rock, particularly TP-3. The contaminant trends in IC-10, HO-1, and MW-01C also suggest that removal of the source material from TP-3 may have substantially reduced the flux of contamination into the bedrock fracture system.

Ongoing potential sources of impacts to bedrock groundwater include waste rock that may remain outside the perimeter of the former TP-3 and the Underground Workings. Other areas of waste rock, including TP-1, TP-2, TP-4, the South Open Cut, and South Mine, have been moved and/or placed under low permeability cover, in the TP-1/TP-2 area or by filling in the South Open Cut and South Mine. (AECOM, 2018).

The likelihood that surface water could impact bedrock groundwater has been significantly reduced by the draining and backfilling of the South Mine and the South Open Cut. Surface water can still drain from the west of the South Open Cut, across the filled South Open Cut and eastward down the former haulage way toward Lord Brook, but the degree of impact has been reduced by the covering of the waste rock and placement of limestone rock in the channel.

Sampling in 2019 and 2020 documents a substantial decline in the concentration of contaminants released by the South Mine and South Open Cut. This data set is included in the 2022 Final Data Report (Nobis, 2020b). Surface water can still enter bedrock fractures and the Underground Workings via the North Open Cut and by sheet flow over remaining bedrock surfaces that are exposed. Surface water is unlikely to recharge bedrock groundwater in the eastern, lower elevation portions of the Site due the presence of low-permeability glacial till and/or low-permeability cover installed as part of a remedial action. The extent of overburden groundwater contamination is limited to the areas immediately below and adjacent to major waste areas and resides within the WMA. Sources of impact to overburden groundwater include TP-1 and TP-2, waste rock that may remain outside the perimeter of TP-3, residual mine waste in other areas such as Mine Road and the Tyson Shaft area, and upslope mine areas (AECOM, 2018). The RI Report (URS, 2006a) concluded that the most significant sources of ARD in terms of number and concentrations of leachable metals appeared to be exposed waste rock at TP-3 (which has been removed), oxidized tailings within TP-1 and TP-2 (which are beneath the cover system), and TP-4 (which was removed). Where metals leach into permeable, saturated overburden, the overburden groundwater will be impacted.

5.2 Groundwater Quality and Extent of Groundwater Impacts

The Elizabeth Mine ceased operation in 1958 and had been operating intermittently since the 1820s. Based on the 60 years since the closure and over a century since groundwater contamination begun, it is reasonable to assume that most of the substantial groundwater pathways that are connected to the waste areas would have become contaminated. In addition, the major source of groundwater contamination, (mine waste piles and tailings) outside of the Underground Workings have been removed and capped, resulting in isolation from water and oxygen. Only small residual amounts of waste remain in the forested areas.

The groundwater quality evaluation discussion is presented for the Mine Pool and the Underground workings as well as the overburden/bedrocks. The analytes measured in groundwater that may indicate water from the mine pools or water that has been in contact with mining waste material include sulfate, aluminum, copper, cobalt, iron, manganese, and zinc. The ore deposit is a sulfide deposit. As a result, sulfate (oxidized sulfide) is the most consistent indicator of mine related or natural ore deposit related impacts on groundwater. Sulfate is soluble, and levels of sulfate above background may be detected even when the other mine-related or ore body related constituents are not present.

The oxidation of sulfide ore creates acidity, lowering the pH to increase the solubility of aluminum, cobalt, copper, iron, manganese and zinc. Aluminum, iron and manganese can also be found in the non-sulfide soil and bedrock at the Site. Some characteristics of the contaminants to consider: zinc (associated with the ore deposits and relatively high solubility at more moderate pH); aluminum, iron, copper and cobalt (less soluble and may drop out of solution a short distance from the source); cadmium (similar to zinc, but at lower concentrations so that concentrations are more likely to be below detection limits); and manganese (may undergo redox reactions that reduce solubility; may be difficult to distinguish from background concentrations).

The analytical results for all available groundwater and mine pool locations are provided in the Final Data Summary Report (Nobis, 2023a), which includes analytical results and field parameters collected from mine pool samples, residential wells, overburden and waste material monitoring wells, and bedrock monitoring wells. Only analytes with significant numbers of exceedances or impacts to surface water (aluminum, cadmium, chromium, cobalt, iron, manganese, nickel, zinc, and sulfate) were included. Several of these analytes may be considered indicators for mine-impacted water, as described above. In order to compare similar sampling methods for deep bedrock boreholes, only open-borehole samples were included in the data set (packer samples were excluded). In addition, only locations with data from after 2006 were included in the evaluation.

The contaminants that most consistently exceed the Groundwater Monitoring Compliance Levels established in the 2006 ROD and 2019 ESD are cobalt and manganese. Manganese has a VTDEC standard of 300 µg/L whereas cobalt has an EPA derived risk-based standard of 6 µg/L.

Table 1 provides a summary of Groundwater Compliance Monitoring Levels from the 2019 ESD (EPA, 2019b), and Figure 3 depicts the interpreted extent of groundwater contamination.

5.2.1 Mine Pool

The samples collected from the Underground Workings at the Artesian Vent from 2002 through 2022 document that the mine pool has a low pH and contains levels of aluminum, cadmium, cobalt, copper, iron, manganese, nickel, zinc, and sulfate at levels above what is found in the adjacent bedrock groundwater and consistently exceeds the Groundwater Compliance Monitoring Levels for cobalt and manganese. The few samples that have been taken at depth at the Artesian Vent and South Vent suggest that there may be some geochemical stratification with higher levels of cobalt detected in the total metals analysis for a recent sample and higher levels of several metals for samples obtained in 2002 and 2003.

Water quality within the adits (from AB-1, AB-4 and AB-5) was generally similar to that of the Artesian Vent (deep) for 2020-2022 and the deeper (420 ft) sample from the South Vent, with higher cobalt and lower aluminum, iron, nickel, and sulfate. Water quality within the adits (from AB-1, AB-4 and AB-5) is likely representative of water that may exist in the open areas of the Underground Workings above the mine pool.

Taken together, these results suggest that the water within the workings varies in quality depending on sample location and depth, possibly indicating stratified and/or stagnant conditions in portions of the Underground Workings.

The apparent consistent decline in mine pool concentrations from within the Artesian Vent and its recharge, along with a less pronounced decline in concentrations from the South Vent indicate that the 2002-2003 sample results may not reflect current conditions. However, because of the hydraulics of the Underground Workings and potential for multiple sources of contamination (groundwater seepage, surface water infiltration, equipment remaining within the workings, and in-workings ARD from unmined ore), a reasonable analogue for the mine pool is to use the highest mine pool concentration from the Artesian Vent deep samples from 2020-2022. Note that the Artesian Vent discharge sample and shallower South Vent sample concentrations are lower than these concentrations.

Based on historical maps, the portion of the Underground Workings located between the North Open Cut and Mine Road, extending from the Deep Adit to the 1948 Adit, is expected to contain the largest number of voids and workings and therefore the largest amount of surface area for groundwater exposure and largest volume for water to accumulate. For this reason, it is expected that the most significant groundwater impacts within the workings are likely to occur in this area. However, impacted water that has the potential to affect adjacent bedrock groundwater has not been ruled out along the entire length of the Underground Workings.

Overall, the entire length or extent of the Underground Workings is assumed to contain water unsuitable for human consumption.

5.2.2 Overburden and Bedrock Wells

Monitoring wells at the Site generally fall into one of three categories: wells screened within overburden and waste material above bedrock, generally with short well screens; shallow bedrock wells generally installed within the top 20 ft of bedrock and with shallow well screens; and deep bedrock wells that are generally open boreholes and can be considered generally analogous to residential wells.

Overburden Groundwater:

Overburden impacts are limited to areas within the former waste areas or immediately adjacent. The wells location within the former TP-3 waste rock piles and wells within tailings at TP-1 and TP-2 document groundwater impacts within these waste materials.

Low pH groundwater, high sulfate levels, and elevated levels of aluminum, cadmium, cobalt, iron, and manganese were found in overburden wells within TP-3. Most of the groundwater at TP-3 is expected to discharge to the bedrock groundwater system, the Underground Workings, or surface water. The extent of overburden impacts associated with TP-3 is within the WMA.

Monitoring wells within TP-1 and TP-2 also contain elevated sulfate and metals. The CSM for this area indicates that the overburden groundwater is discharging at the toe of TP-1 due to a tight till layer beneath the tailing. This is consistent with the observation of leachate along the toe of TP-1 that is not being treated. The wells adjacent and downgradient of TP-1 and TP-2 also confirm that overburden impacts are limited to the WMA.

Bedrock Groundwater:

With the exception of the Underground Working, bedrock groundwater follows a similar pattern as the overburden groundwater with most of the contamination limited to the areas beneath the waste area or immediately adjacent to the waste areas. The few locations where bedrock groundwater contamination is located outside the WMA are:

- An area of bedrock groundwater contamination extends north from TP-3 covering an area between the Deep Adit and the 1898 Adit, as defined by wells MW-01C, IC-10, and H-O1. Both IC-10 and HO-1 were found to contain high levels of sulfate as well as elevated cadmium, cobalt, copper, iron, manganese, nickel, and zinc. These wells were unsuitable for use as a water supply. Bedrock well MW-01C, by contrast, contained elevated levels of sulfate and manganese with substantial variability. Metals concentrations in all three wells dropped significantly after the removal of the waste material from TP-3 and when pumping of the residential well pump in MW-01C was stopped. While these results are a positive indication of source removal at TP-3, the potential remains for a well located in the area between the Deep Adit and 1898 Adit to become contaminated if pumping influences were to cause migration of contaminated water into the well.
- A limited area just below the South Open Cut and TP-4, in the vicinity of former monitoring well IC-01, contains elevated concentrations of manganese and cobalt above the Groundwater Monitoring Compliance Levels. The extent of the contamination is estimated to be within 100 ft of the boundary of the WMA.
- A limited area just below the South Mine associated with wells IC-03, IC-13 and IC-14 contains groundwater impacted by cobalt and manganese. The extent of the contamination is estimated to be within 100 ft of the boundary of the WMA.

5.2.3 Residential Wells

Groundwater impacts have generally not been observed in any of the residential wells currently in use. Historically, there have been three residential wells which were located adjacent to TP-3 that were found to contain elevated levels of metal. One well was at the base of TP-3 along Mine Road and the other two were adjacent to TP-3 to the north between the Deep Adit and 1898 Adit. Sampling of these wells after the removal of the mine waste at TP-3 did show a significant decline in sulfate and metal concentrations but these samples were taken on wells that were not pumping or creating any stress on the groundwater system that could possibly induce flow from contaminated fractures into the well.

RES-04 was a shallow dug well that served a residence in the area near former TP-3 and was replaced by drilled bedrock well MW-01C in about 2001. In approximately 2003, the residents ceased using the dug well and a pump was placed in MW-01C, which was used for water supply until the home was no longer occupied. Several metals regularly exceeded groundwater compliance monitoring levels in both wells. The residence serviced by MW-01C has been abandoned since 2013 and the pump has since been removed.

Wells located away from TP-3 with previous elevated metals include RES-15, RES-16, and RES-23. Anomalous lead exceedances from February 2006 in these wells have not been repeated. Based on this pattern and absence of other COCs exceeding groundwater compliance monitoring levels, these are not considered indicative of mine-related impacts.

6.0 Buffer Zone Determination and Proposed Areas for Groundwater Reclassification

6.1 Buffer Zone Determination

The impacted groundwater zone selected for reclassification is the mine pool within the Underground Workings, and the surrounding aquifer which consists of a highly fractured bedrock. Therefore, given the uncertainties of flow within this environment, a site-specific Buffer Zone analysis was performed to identify the travel distance from the Underground Workings that would be necessary to reduce the contaminant levels to the Groundwater Monitoring Compliance levels (AECOM, 2018). The Buffer Zone refers to the extended area of delineation surrounding the mine pool and is included in the consideration of groundwater use restrictions.

Groundwater within the bedrock that migrates away from the mine pool is expected to be transported via discrete fractures and fracture zones. Concentrations of the known groundwater contaminants within the mine pool are expected to be diluted as it flows away from the Underground Workings area and encounters the surrounding background groundwater. Therefore, the distance at which the concentrations of contaminants drop below the target concentration depends on the source concentration, the diluting concentration, and the fracture spacing.

A complete description of the dilution calculations and the assumptions are presented in the AECOM Institutional Control Zone Report, Phase 3 Remedial Action, Site-Wide Groundwater, Remedial Design, Elizabeth Mine, South Strafford, Vermont, Prepared for United States Army Corps of Engineers New England District, dated May 25, 2018.

6.2 Proposed Areas for Groundwater Reclassification

Different areas of the Elizabeth Mine have different fracture networks, mine features, and monitoring and residential wells with chemical data that can be used to evaluate groundwater impacts. These subsections of recommended institutional controls are illustrated in Figure 4, and the recommended groundwater reclassification area as a whole is illustrated in Figure 5.

The boundaries of the proposed reclassification area encompass the extent of the contaminated groundwater plume with various buffers to account for potential migration of dissolved metals within fractured bedrock. The reclassification boundaries have been adjusted to match existing parcel boundaries were appropriate for ease of field verification. In other areas where the reclassification boundary transects a parcel, the boundary line has been surveyed, and groundwater use on these transected parcels is additionally limited through a grant of environmental easement.

Within the overall Class IV Groundwater Area shown on Figure 5, there are two distinct designations: non-conditional (purple area) and conditional (green area). Areas identified as non-conditional indicate that the use of groundwater as a potable or public water supplies is prohibited, however, some agricultural, industrial or commercial uses of groundwater within this reclassification area may be considered by the Secretary. Areas identified as conditional indicate that the use of groundwater as a potable supply may be considered on a case-by-case basis by the Secretary, and a demonstration that a potable supply well within the conditional area would not cause contamination to spread, further degrade groundwater quality, or will not pose a risk to human health or the environment.

Parcels included in the Class IV groundwater reclassification are listed in the table below:

Grand List SPAN Number	Physical Address	Reclassification Conditional or Non-Conditional
576-181-10802	119 Copperas Road	Non-Conditional
576-181-10771	96 Copperas Road	Non-Conditional
624-196-10307	35 Copperas Road	Non-Conditional
624-196-10847	240 Mine Road	Non-Conditional
624-196-10181	179 Mine Road	Non-Conditional
624-196-10671	149 Mine Road	Non-Conditional
642-202-11484	New Boston Road	Non-Conditional
624-196-10626	194 Mine Road	Non-Conditional
624-196-10039	200 Mine Road	Conditional
624-196-10055	190 Mine Road	Conditional
624-196-10269	192 Mine Road	Conditional
624-196-10275	172 Mine Road	Conditional
624-196-10579	146 Mine Road	Conditional
624-196-10660	136 Mine Road	Conditional
624-196-10657	129 Mine Road	Conditional
624-196-10077	115 Mine Road	Conditional
624-196-10133	101 VT Route 132	Conditional
624-196-10886	38 VT Route 132	Conditional
624-196-10075	20 Furnace Flats Road	Conditional
624-196-10643	16 Furnace Flats Road	Conditional
624-196-10823	66 Furnace Flats Road	Conditional

Parcels adjoining/abutted to the proposed Class IV groundwater reclassification area listed in the table below.

Grand List SPAN Number	Physical Address	Grand List SPAN Number	Physical Address
450-142-13126	829 Upper Turnpike Road	624-196-10007	78 VT Route 132
576-181-10771	245 Turnpike Road	624-196-10286	40 Furnace Flats Road
624-196-10305	100 Copperas Road	624-196-10528	52 Furnace Flats Road
624-196-10150	141 Turnpike Road	624-196-10148	28 Stocklas Road
624-196-10799	127 Turnpike Road	624-196-10718	35 Skunk Hollow Road
624-196-10306	79 Turnpike Road	624-196-10034	38 VT Route 132
624-196-10077	115 Mine Road	624-196-10257	4 Furnace Flats Road
624-196-10604	120 Mine Road	624-196-10189	165 Mine Road
624-196-10659	108 Mine Road	624-196-10425	166 Mine Road
624-196-10655	96 Mine Road	624-196-10421	170 Mine Road
624-196-10329	85 Mine Road	642-202-10283	2356 Gove Hill Road
624-196-10327	11 Tyson Road	642-202-10905	2526 Gove Hill Road
624-196-10360	100 VT Route 132	642-202-10702	35 Copperas Road

Each general area within the recommended Class IV reclassification area is described in the following subsections below.

6.2.1 Underground Workings

Analytical data from the Artesian Vent (location AV-01) indicate that the concentrations after October 2017 are similar to or slightly less than the previous concentrations. Additional sampling collected at different depths within the Artesian Vent and South Vent indicate that the contaminant concentrations within the mine pool are variable, but significantly lower than the RI (2002-2003) concentrations, with the highest concentrations deeper within the workings. The concentrations within the adits (AB-1, AB-4 and AB-5) are generally comparable to the concentrations from the mine pool. Therefore, the underground Workings are included in the groundwater reclassification area.

6.2.2 Area West of the Underground Workings

Groundwater samples were collected from IC wells 06, 08, and 09 and Residential wells 14, 15, 19, 20, 23, and 200 in 2018 through 2021, which are all located west of the underground workings and artesian vents. Analytical results of these groundwater samples were well below the groundwater compliance monitoring levels and the results are consistent with previous groundwater sampling activities and support the determination that groundwater impacts west of the underground workings are unlikely, and this area is not included in the groundwater reclassification area.

6.2.3 Area East of Underground Workings – South Mine

The South Mine contained a small pit lake and water filled workings. There are no known substantial underground workings associated with these features. The South Mine area (south of TP-4 and the

South Open Cut) was remediated in 2018 - 2019. The wells downgradient of the South Mine with sufficient data for analysis (IC-03 and IC-04) had increasing trends of indicator contaminants.

These areas extend beyond the WMA for IC-03, IC-04, and IC-14; therefore, a buffer zone is recommended 87 ft (one foliation fracture length) in the area east of the impacted wells. A buffer zone was added for the area beginning at the Strafford/Sharon line at the south end of the South Mine to TP-4. The buffer zone incorporates these distances and terminates to the south and north against the WMA.

6.2.4 Area East of Underground Workings – South Open Cut to Deep Adit

The South Open Cut contained a pit lake and some workings; however, there are no known substantial underground workings associated with these features. The South Open Cut pit lake and associated workings were drained and filled in 2018 – 2019.

Previous groundwater concentrations in IC-07 (decommissioned well located downgradient of the South Open Cut) exceeded groundwater compliance monitoring levels for metals and elevated sulfate. While iron exceeded groundwater compliance monitoring levels in two of the last three sampling rounds (2018-2019), it did so only in the total metals fraction. Dissolved metals concentrations were significantly and consistently lower throughout 2018-2019. IC-12, downgradient of IC-07, did not have any exceedances of groundwater compliance monitoring levels and define the eastern edge of the proposed groundwater classification area, east of the south cut.

Based on elevated concentration of various metals in former wells and current monitoring wells located south and east of the South Cut, and the location of TP-4, a buffer zone is recommended for the area between the southernmost IC wells and IC-15 bound on the eastern side by the town line for Thetford and Strafford (see figure 4).

6.2.5 Area East of Underground Workings – Deep Adit to 1998 Adit

The area east of the Underground Workings and between the Deep Adit and the 1898 Adit, particularly HO-01 and IC-10, have previously shown some of the highest bedrock groundwater concentrations of indicator contaminants above the groundwater compliance monitoring levels. The presence of a northeast-trending photolineament in the area may indicate a fracture zone that may have intercepted contaminated groundwater from TP-3 and transported that impacted groundwater to the area of IC-10 and HO-1. Other wells in the area which were sampled from 2018 to 2021 include MW-01C and MW-14B/C. Overall groundwater concentrations in this area have decreased significantly, likely because of the removal of waste material from TP-3 (work completed in 2010).

A buffer zone is recommended for this area, as shown on Figure 4.

6.2.6 Area East of Underground Workings – 1998 Adit to Southern Drift

Several residential wells between the 1898 Adit and the Northern Drift were sampled from 2018 through 2022: RES-01, RES-08, RES-16, RES-17, and RES-100. None of the samples collected exceeded groundwater compliance monitoring levels. In addition, no photolineaments have been identified in this area. Photolineaments are features that may indicate steeply-dipping bedrock fracture zones (Section 2.4) that could be avenues for groundwater flow and contaminant transport. Groundwater trend data are limited for these wells because of a low number of detections, but available data suggest that groundwater concentrations are decreasing over time or are stable. The absence of photolineaments and the concentration results suggest minimal potential impact due to the workings.

Based on this information, a buffer zone can be adjusted to be based on the distances in Table 3 calculated using the available deep mine pool analytical results as a source ("cobalt6") and a diluting concentration based on the detection limit for the most recent comprehensive sampling round (Fall 2021). If intersecting fractures are assumed to occur on average every 33 ft, it would require approximately 100 ft for concentrations to decrease below the groundwater compliance monitoring level for cobalt, measured from the outer edge of the upward projection of the area presumed to contain the mine pool.

Figure 4 shows the extent of the recommended 100-ft buffer between the 1898 Adit and Southern Drift.

Investigations and adit closure activities in 2020-2021 have provided additional detail regarding the condition of the 1898 Adit and the surrounding bedrock; these indicate that the bedrock is competent and that the water-filled portion of the adit poses relatively low risk to potential nearby wells. Therefore, a minimal Buffer Zone is recommended along the northern edge of the 1898 Adit (one average intersecting fracture spacing, or 33 ft) to address potential adit contamination west of the plugged/closed portion of the 1898 Adit (i.e. west side of Copperas Road). In addition, as indicated in the 2019 ESD (EPA, 2019b), the area around the 1948 Adit is no longer part of the Technical Impracticability Zone, as this feature is relatively shallow and recent investigations have indicated that it is not water-filled.

Figure 4 shows the extent of the 33-ft buffer zone north of the 1898 Adit and west of the concrete plug installed in the 1898 Adit in 2021.

6.2.7 Area East of the Underground Workings – Southern Drift to Northern Drift

The area between the Southern Drift and Northern Drift relies on the same data and uses the criteria as described in Section 6.2.6 above. The difference for this area is the extent of Groundwater Use Restriction is sufficiently conservative such that no additional buffer zone is recommended. Limited bedrock groundwater data are available north of the Northern Drift, from MW-17C and RES-18. Manganese concentrations in RES-18 exceeded the groundwater compliance monitoring level in multiple samples in 2019; however, samples collected in 2020 through 2022 were more than an order of magnitude below the compliance monitoring level, suggesting the 2019 elevated concentrations were related to disuse of the well and not native conditions. One sample from well MW-17C exceeded the criterion for iron, but in only one total metals sample (a duplicate); the other total iron sample was an order of magnitude lower than this and both dissolved iron results were more than two orders of magnitude lower than this. Therefore, the iron exceedance is considered to be an anomaly likely caused by elevated sample turbidity.

Although RES-18 and MW-17C do not appear to be impacted by the workings, a buffer zone is advisable given the lack of wells in this area. The buffer zone in this area was determined using distances in Table 3, with "cobalt6" as a source and a diluting concentration based on the detection limit for the most comprehensive recent residential sampling round (Fall 2021), in which cobalt was not detected. If intersecting fractures are assumed to occur on average every 33 ft, it would require approximately 100 ft for concentrations to decrease below the groundwater compliance monitoring level for cobalt. This buffer distance would be measured from the outer edge of the upward projection of the area presumed to contain Underground Workings, based on the best information available.

The extent of the recommended 100-ft buffer zone from the Northern Drift to the north side of the WBOR is shown on Figure 4.

6.2.8 Area East of Underground Workings – North of WBOR

A buffer zone is not recommended north of Route 132 and the WBOR because the Underground Workings plunge to the north, topography rises to the north, and existing homeowner wells in the area are not impacted. For these reasons, it is very unlikely that a new homeowner well in this area would receive impacted water from the mine pool.

7.0 Groundwater Reclassification Summary

Class IV designation provides warning to landowners, well drillers and to permitting agencies that groundwater beneath a Class IV Groundwater Area should not be used for potable water supplies. Permits for drinking water sources will not be issued within a Class IV Groundwater Area unless permitted by the Secretary on a site-specific basis. Applicable new ANR-permitted activities proposed within these areas are required to show that the activity will not further degrade groundwater quality or cause contamination to spread.

The aerial extent of the area where institutional controls are needed to prevent groundwater use is shown on Figure 4, and the recommended groundwater reclassification area as a whole is illustrated in Figure 5.

This area includes the Technical Impracticability Zone, the WMA, and a buffer zone along the Underground Workings that uses site specific factors to create a protective offset along eastern side of the Underground Workings as described in Section 3. A buffer zone was also presented for the WMA to address the limited areas of groundwater contamination that extends outside the WMA.

Within the area to be reclassified, well drillers and property owners should be advised that mine-impacted groundwater occurs in the area and that the possibility that a well on their property could pump impacted groundwater has not been ruled out. Testing for metals and sulfate should be done when the well is new and periodically thereafter.

8.0 References

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FIGURES

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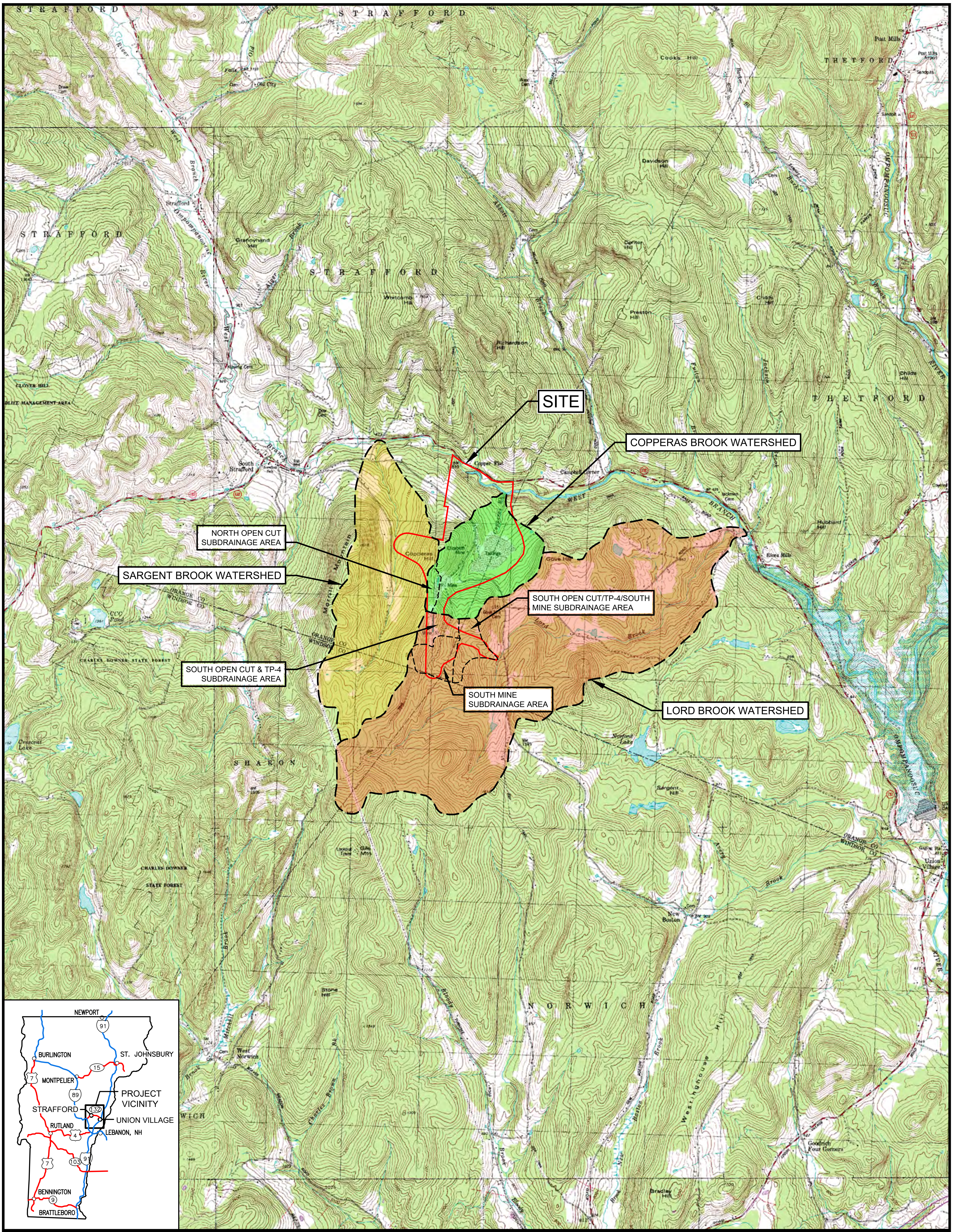

NORTH

APPROXIMATE SCALE
1 INCH = 4,000 FEET

USGS TOPOGRAPHIC MAP

SOUTH STRAFFORD, VERMONT (1981)
SHARON, VERMONT (1981)
CHELSEA, VERMONT (1981)
HANOVER, NEW HAMPSHIRE (1988)
LYME, NEW HAMPSHIRE (1988)

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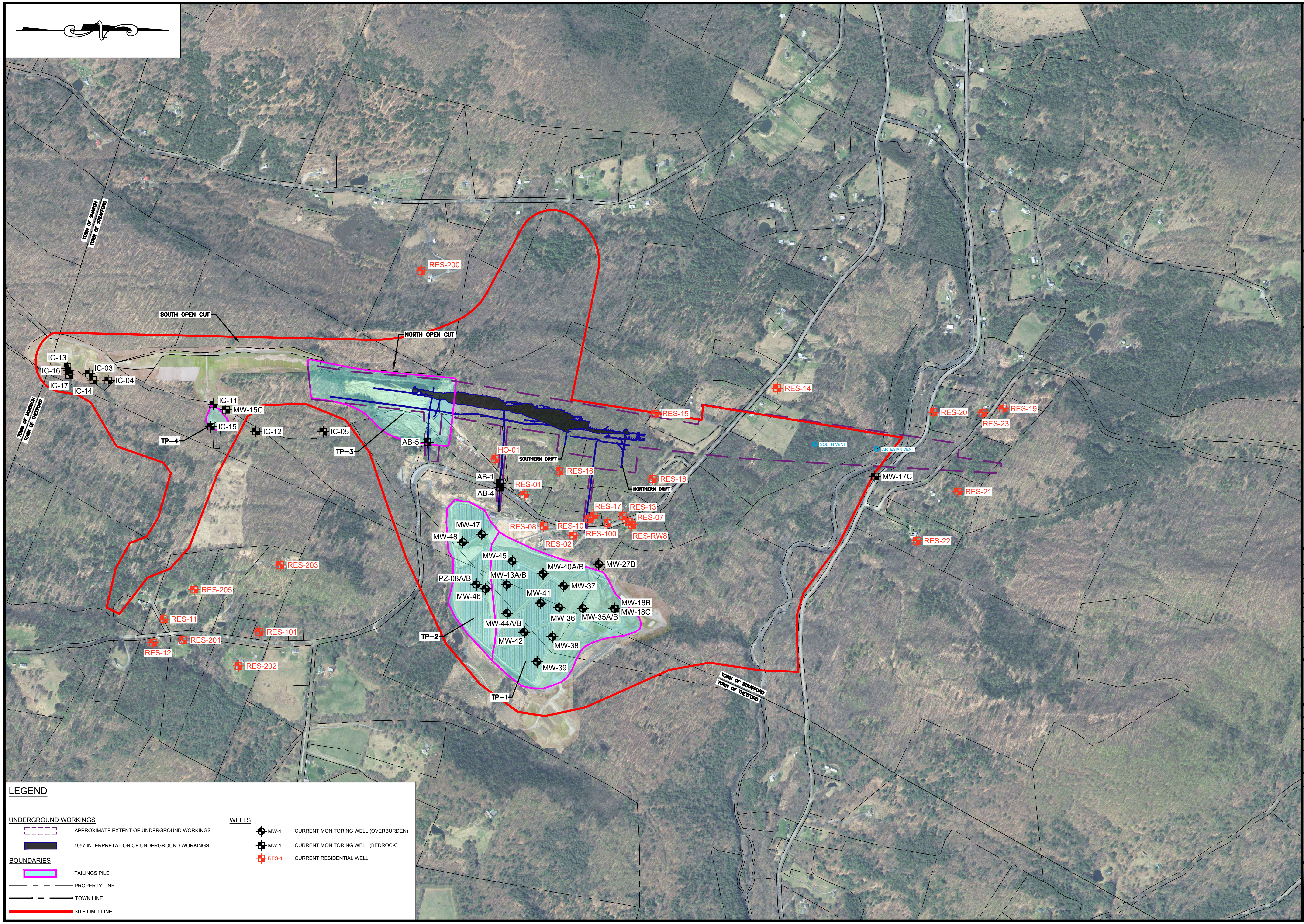
FIGURE 1

SITE LOCATION
ELIZABETH MINE SUPERFUND SITE
SOUTH STRAFFORD, VERMONT

DRAWN BY:	NZ	APPROVED BY:	JL
PROJECT NO.	94504.00	DATE:	MAY 2020



LEGEND

UNDERGROUND WORKINGS

- APPROXIMATE EXTENT OF UNDERGROUND WORKINGS
- 1957 INTERPRETATION OF UNDERGROUND WORKINGS

BOUNDARIES

- TAILINGS PILE
- PROPERTY LINE
- TOWN LINE
- SITE LIMIT LINE

WELLS

- MW-1 CURRENT MONITORING WELL (OVERBURDEN)
- MW-1 CURRENT MONITORING WELL (BEDROCK)
- RES-1 CURRENT RESIDENTIAL WELL

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ELIZABETH MINE SUPERFUND SITE

INSTITUTIONAL CONTROL ZONES

MINE ROAD
SOUTH STRAFFORD, VERMONT

NO.	DATE	DESCRIPTION

REVISIONS

0 500' 1000'
GRAPHIC SCALE

DATE:	JUNE 2026
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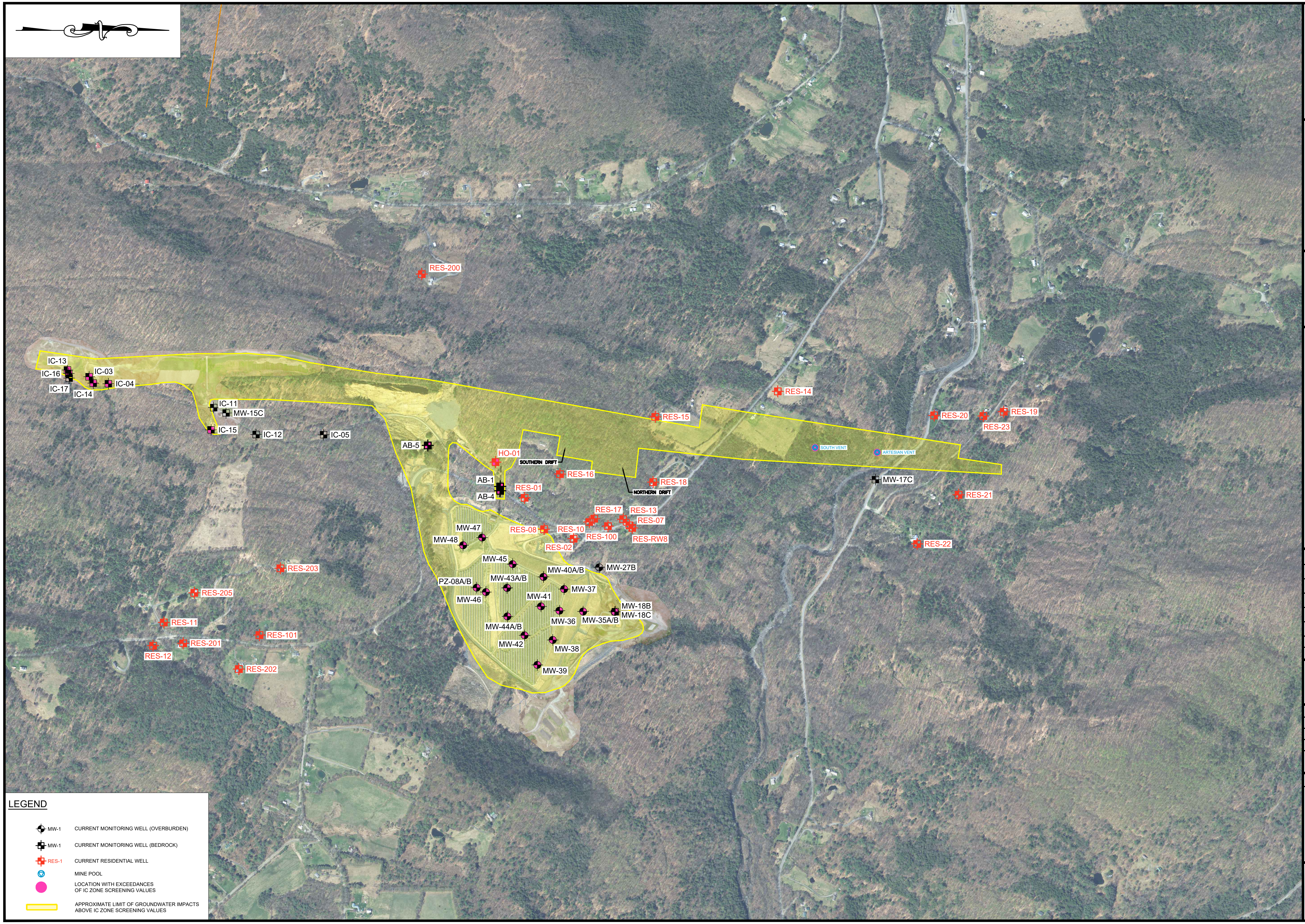
SHEET TITLE

SITE FEATURES

FIGURE
2



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MINE ROAD
SOUTH STRAFFORD, VERMONT

NO.	DATE	DESCRIPTION

REVISIONS

0 500' 1000'
GRAPHIC SCALE

DATE:	JUNE 2026
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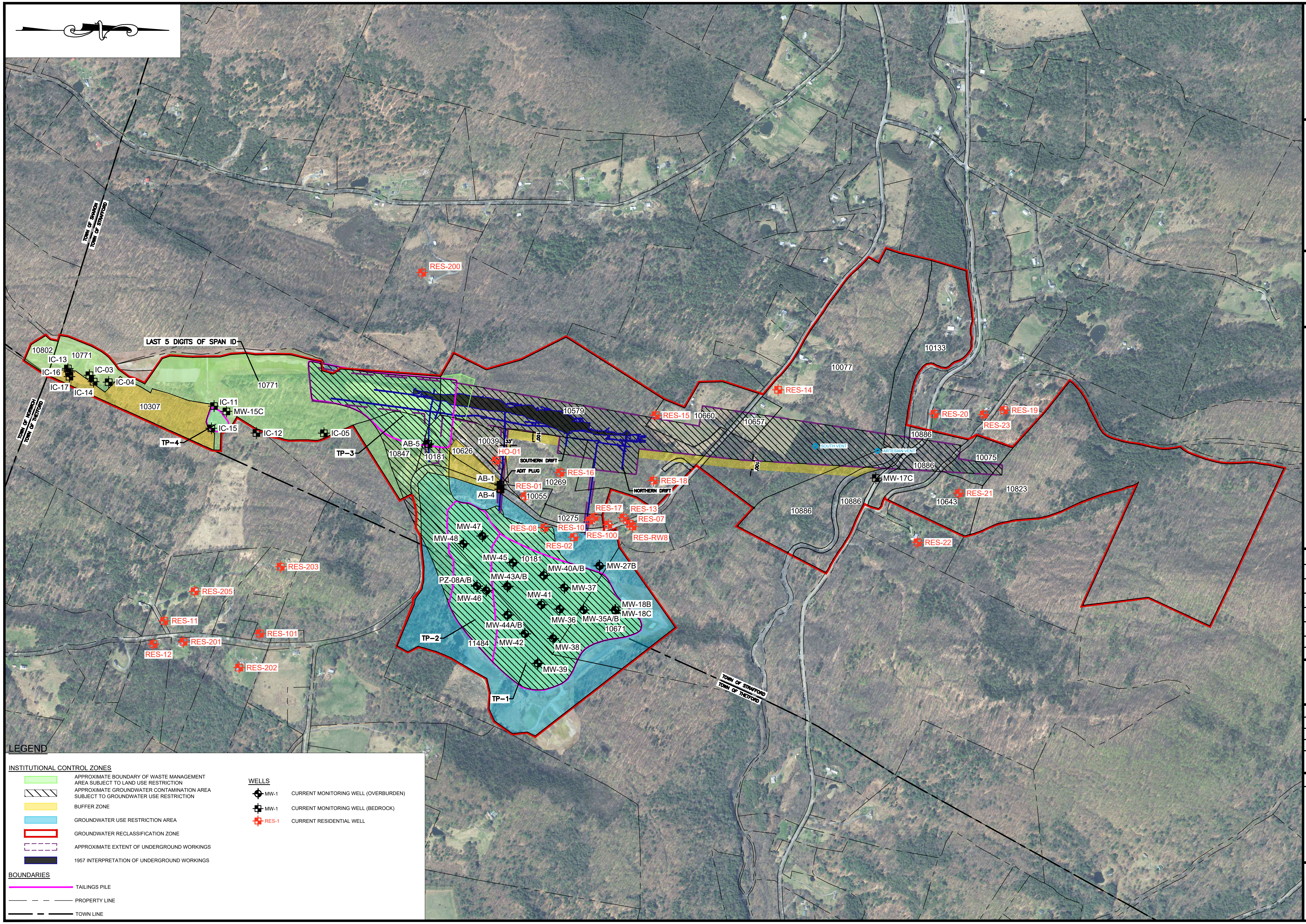
INTERPRETED EXTENT OF GROUNDWATER CONTAMINATION

FIGURE
3



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NO.	DATE	DESCRIPTION

REVISIONS

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GRAPHIC SCALE

DATE:	JUNE 2026
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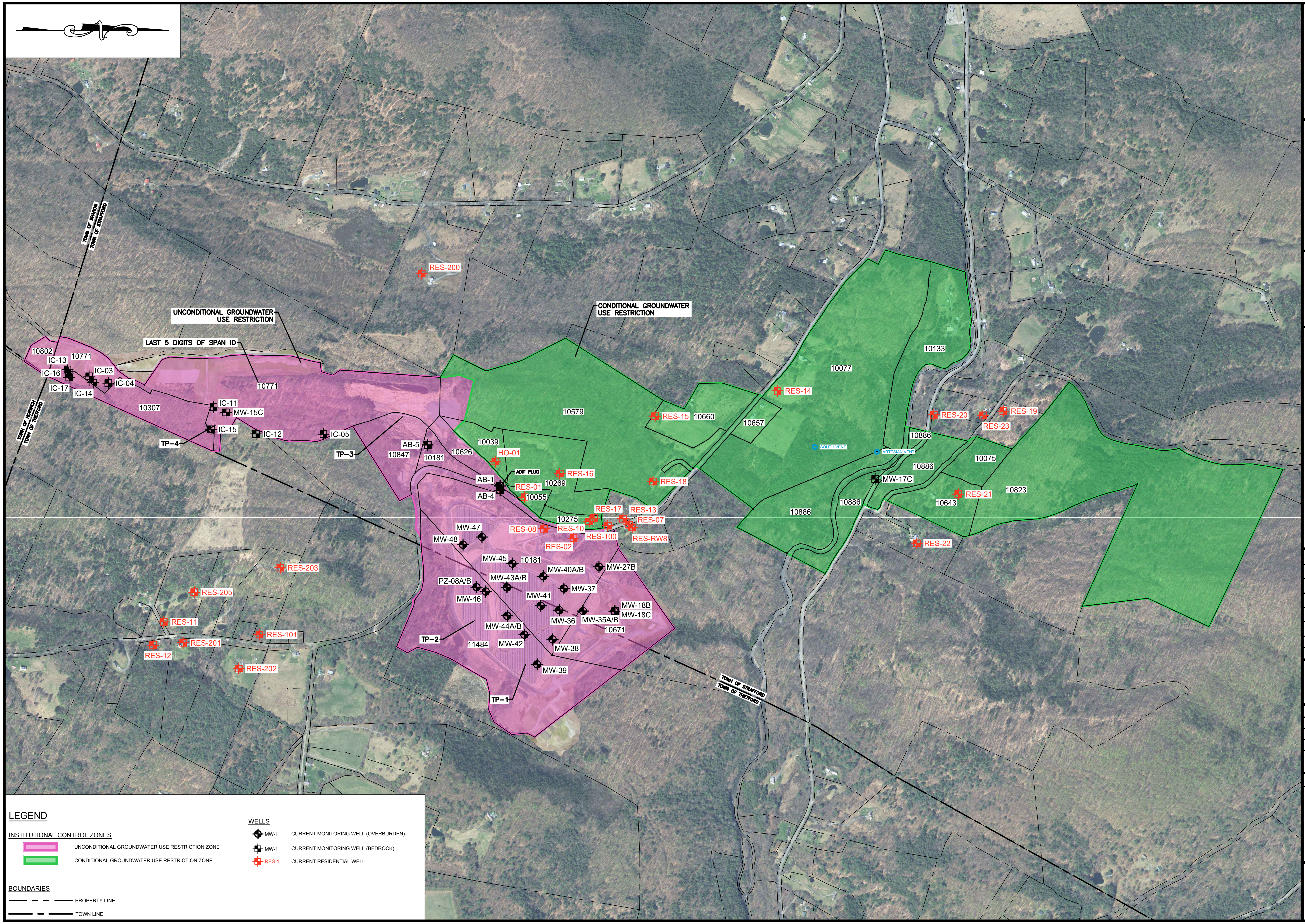
RECOMMENDED INSTITUTIONAL CONTROL ZONES

FIGURE
4



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INSTITUTIONAL CONTROL ZONES

MINE ROAD
SOUTH STRAFFORD, VERMONT

NO.	DATE	DESCRIPTION

REVISIONS

GRAPHIC SCALE: 0 – 500' – 1000'

DATE:	JUNE 2026
NOBIS PROJECT NO.	94507.00
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RECOMMENDED GROUNDWATER RECLASSIFICATION AREA

FIGURE
5

TABLES

Table 1
Groundwater Compliance Monitoring Levels
Elizabeth Mine Superfund Site
Strafford, Vermont

Constituent	2019 ESD Groundwater Compliance Monitoring Level	
	Value (μg/L)	Basis
Arsenic	10	MCL
Barium	2,000	MCL/MCLG
Cadmium	5	MCL/MCLG
Cobalt	6	Federal Risk-based: Hazard Quotient = 1
Copper	1,300	VTGES
Iron	14,000	Federal Risk-based: Hazard Quotient = 1
Lead	15	EPA Risk-Based Action Level
Manganese	300	VTGES
Mercury	2	MCL
Nickel	100	VTGES
Thallium	2	MCL/MCLG
Vanadium	89	Federal Risk-based: Hazard Quotient = 1
Zinc	3,130	Federal Risk-based: Hazard Quotient = 1

Source References:

MCL = Federal Safe Drinking Water Act, Maximum Contaminant Level (National Primary Drinking Water Regulations, May 2013)

MCLG = Federal Safe Drinking Water Act, Maximum Contaminant Level Goal (National Primary Drinking Water Regulations, May 2013)

2019 VTGES = Vermont Groundwater Enforcement Standards (Chapter 1 - Groundwater Protection Rule and Strategy, July 6, 2019)

Notes:

ESD = Explanation of Significant Differences for the Elizabeth Mine Superfund Site (EPA, September 2019)

5YR = Second Five-Year Review for the Elizabeth Mine Superfund Site (EPA, September 2019)

Screening values are based on hierarchy outlined in 5YR: risk-based level from ROD, then MCL and/or VTGES, then Tapwater RSL, then SMCL
μg/L = micrograms per liter

APPENDICES

Table A-1
Average Concentration Summary
Elizabeth Mine Superfund Site
Strafford, Vermont

AREA	**Site-Specific Screening Value (SSSV)**	Mine Pool				Workings, no mine pool	TP-1 Overburden and waste material - tailings impact			Downgradient/edge of TP-1 overburden				TP-2 Overburden and waste material		
DATE		pre-2006	2006-2012	2013-2017	2018-2023	2018-2023	pre-2006	2006-2012	2013-2017	pre-2006	2006-2012	2013-2017	2018-2023	pre-2006	2006-2012	2013-2017
Total Metals																
Aluminum	20000	10275	5237	3703	3217	4422	2030	6417	95937	76.5	126	433	511	1787	2080	21914
Cadmium	5	19.1	ND	ND	3.4	6.5	3.2	16.1	90.9	ND	3.2	0.4	ND	ND	7.6	21.8
Chromium	100	7.8	8.8	ND	6.0	13.2	6.7	61.9	642	ND	10.1	3.8	2.0	41.2	38.5	358
Cobalt	6	231.2	60.0	29.0	40.8	80.8	54.1	128	922	14.1	4.7	1.3	1.2	14.6	31.7	179
Copper	1300	2814	176	84.4	310	1161	327	2725	11875	7.2	7.3	13.9	3.3	6.2	181	2225
Iron	14000	81028	47856	42844	35386	26353	113585	693418	857585	1036	3197	410	725	31950	111371	221333
Manganese	300	1950	2119	1906	1460	929	5575	9144	5965	1146	1284	16.3	239	2106	2542	4105
Nickel	100	93.1	23.4	ND	20.2	37.7	39.6	84.4	406	5.7	15.0	37.2	5.1	27.3	31.3	225
Zinc	3130	5660	480	218	661	877	423	1475	11014	505.5	11.4	7.4	7.0	64.8	84.4	1573
Dissolved Metals																
Aluminum	20000	2455	4902	2800	2165	3787	1120	2578	295	ND	60.6	116	ND	ND	91.5	1971
Cadmium	5	0.5	7.0	8.1	2.7	6.9	3.9	12.1	7.6	ND	3.5	ND	ND	ND	8.1	18.2
Chromium	100	8.5	13.7	ND	6.1	13.1	3.8	33.5	35.6	ND	10.8	ND	ND	ND	ND	18.5
Cobalt	6	65.0	60.8	28.5	19.7	76.3	59.1	58.8	14.3	3.8	11.7	1.1	0.4	7.1	17.6	90.6
Copper	1300	133	167	60.6	52.2	1037	347	614	47.8	7.3	10.1	13.8	1.3	ND	16.8	621
Iron	14000	46517	46380	41133	33260	16765	116596	790898	186193	612	2984	ND	130	31764	94436	145417
Manganese	300	1971	2082	1887	1426	875	5363	9569	2637	1113	1259	ND	213	1997	2381	3882
Nickel	100	19.1	21.7	ND	10.3	35.2	42.3	51.7	34.9	5.6	15.6	35.3	2.9	ND	ND	53.0
Zinc	3130	484	477	214	151	846	503	1191	39.6	85.0	14.7	ND	5.9	46.4	18.3	808
Conventional Water Quality Parameters																
Sulfate	250000	408633	762182	595000	462900	581926	3210000	2210468	2446964	182500	203795	355000	465000	895000	847177	972500

Notes:
All units in micrograms per liter (µg/L)
-- = Not analyzed for this constituent
Shading = Exceeds SSSV
ND = not detected
See Table 1 for derivation of SSSV

Table A-1
Average Concentration Summary
Elizabeth Mine Superfund Site
Strafford, Vermont

AREA	Site-Specific Screening Value (SSSV)	TP-3 Overburden and waste material				Overburden Away from Workings				TP-3 Bedrock				South Mine Bedrock Wells		
DATE		pre-2006	2006-2012	2013-2017	2018-2023	pre-2006	2006-2012	2013-2017	2018-2023	pre-2006	2006-2012	2013-2017	2018-2023	2006-2012	2013-2017	2018-2023
Total Metals																
Aluminum	20000	44.1	178	106	214	744	355	ND	150	149	2235	1156	56	269	93	146
Cadmium	5	0.10	0.11	5.0	ND	ND	0.3	0.2	ND	0.2	1.7	3.5	ND	0	ND	2.8
Chromium	100	12.6	3.0	11.3	8.2	1.6	2.1	1.4	1.2	ND	4.3	8.5	7.9	4	ND	7.7
Cobalt	6	ND	ND	ND	8.1	ND	1.8	ND	0.1	ND	56.2	33.1	7.6	2	ND	9.3
Copper	1300	13.0	ND	ND	8.5	ND	3.1	ND	0.6	ND	443.8	21.8	7.7	9	ND	11.1
Iron	14000	945	2043	1378	3212	845	402	81	560	257	4983	4105	416	1607	7986	26799
Manganese	300	332	439	355	780	89	114	44	78	706	4983	955	178	163	433	580
Nickel	100	ND	ND	ND	8.2	ND	ND	ND	0.6	ND	4983	9.4	7.6	8.9	ND	15.6
Zinc	3130	ND	10.3	ND	9.3	ND	11.9	2.6	ND	17.1	4983	41.4	8.4	19.7	55.8	86
Dissolved Metals																
Aluminum	20000	ND	136	87	62	13.5	64.2	ND	ND	ND	109	107	ND	90.5	ND	51.6
Cadmium	5	ND	0.1	ND	ND	ND	0.3	ND	ND	0.2	1.2	4.2	ND	ND	ND	ND
Chromium	100	ND	2.8	ND	ND	ND	1.2	1.3	0.8	ND	3.2	8.7	ND	1.9	ND	6.2
Cobalt	6	ND	2.7	ND	ND	ND	6.0	ND	ND	ND	42.1	35.1	8.2	7.0	ND	8.3
Copper	1300	ND	7.0	ND	8.9	ND	ND	ND	1.7	ND	7.1	16.1	8.3	8.7	ND	10.1
Iron	14000	580	1000	492	228	ND	40.2	ND	470	31.7	1047	573	88.9	939	2548	3158
Manganese	300	336	261	242	222	70.5	3.5	ND	ND	667	1323	830	148	153	372	535
Nickel	100	ND	ND	ND	ND	ND	7.2	ND	ND	ND	11.1	10.9	8.2	8.9	ND	9.8
Zinc	3130	ND	ND	ND	9.3	ND	9.2	1.7	2.3	ND	67.7	35.4	ND	13.5	22.7	37.1
Conventional Water Quality																
Sulfate	250000	525000	465000	407500	362500	25000	14500	17000	25000	130250	336208	368250	181667	73056	129950	177190

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Table A-1
Average Concentration Summary
Elizabeth Mine Superfund Site
Strafford, Vermont

AREA	Site-Specific Screening Value (SSSV)	South Open Cut/TP-4 Area Bedrock Wells				Bedrock west of workings			Bedrock wells away from workings, close to tailings				Bedrock wells away (east) from tailings/workings, no impacts			
DATE		pre-2006	2006-2012	2013-2017	2018-2023	2006-2012	2013-2017	2018-2023	pre-2006	2006-2012	2013-2017	2018-2023	pre-2006	2006-2012	2013-2017	2018-2023
Total Metals																
Aluminum	20000	153	954	155	1495	167	847	155	849	713	34.4	74	61	54	58	254
Cadmium	5	ND	1.7	ND	3.8	0.3	0.4	ND	ND	0.3	ND	0.89	ND	1.9	ND	ND
Chromium	100	ND	7.6	ND	10.2	3.7	ND	5.6	21.4	3.0	ND	1.3	ND	5.1	ND	8.1
Cobalt	6	ND	6.7	7.3	15.0	5.7	ND	4.9	ND	8.7	ND	0.17	ND	ND	ND	ND
Copper	1300	ND	18.4	ND	27.5	40.4	20.2	10.6	ND	160	ND	3	ND	ND	14.5	ND
Iron	14000	606	1865	2604	46546	267	ND	2072	659	730	ND	370	ND	74	90	294
Manganese	300	101.9	274	332	957	23.2	13.6	38.4	16.2	68.4	ND	4.5	8.0	ND	ND	8
Nickel	100	ND	ND	ND	15.7	8.1	4.1	5.4	ND	6.2	0.88	2.1	ND	ND	4.4	8.1
Zinc	3130	ND	17.9	ND	35.7	10.9	9.7	20.9	ND	34.3	ND	4.4	ND	10.7	13.3	ND
Dissolved Metals																
Aluminum	20000	ND	81.2	238.4	66.4	102	120	55.5	22.0	159	ND	70	ND	38.1	ND	62
Cadmium	5	ND	1.8	ND	ND	0.4	ND	ND	ND	ND	ND	ND	ND	2.0	ND	ND
Chromium	100	ND	5.2	9.5	7.4	3.2	ND	ND	19.4	3.2	ND	ND	ND	5.6	ND	ND
Cobalt	6	ND	8.5	7.3	7.1	6.1	4.0	5.4	ND	0.5	1	ND	ND	5.4	ND	ND
Copper	1300	ND	15.6	ND	7.3	6.9	11.8	10.0	ND	ND	ND	ND	ND	ND	15.4	ND
Iron	14000	465	387	1171	1362	47.5	ND	138.8	ND	162	55.2	ND	ND	44	ND	58
Manganese	300	98	226	324	153	15.2	ND	6.0	1.4	7.2	ND	0.43	7	ND	ND	ND
Nickel	100	ND	9.3	7.8	7.7	8.7	3.9	5.8	ND	ND	0.79	1.2	ND	ND	4.6	8.9
Zinc	3130	ND	14.7	13.5	11.6	9.5	9.0	18.6	ND	11.3	ND	ND	ND	11.8	15.4	ND
Conventional Water Quality																
Sulfate	250000	52050	103400	107531	59677	16208	16250	13631	66450	88500	110000	100000	7260	8267	14142	10680

Notes:
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ND = not detected
See Table 1 for derivation of SSSV

Table A-1
Average Concentration Summary
Elizabeth Mine Superfund Site
Strafford, Vermont

AREA	Site-Specific Screening Value (SSSV)	Bedrock wells close to workings, no tailings, no apparent impacts				Bedrock wells close to workings, no tailings - impacted		
DATE		pre-2006	2006-2012	2013-2017	2018-2023	2006-2012	2013-2017	2018-2023
Total Metals								
Aluminum	20000	40.2	51.7	151	224.7	2485	758	780
Cadmium	5	ND	0.6	1.2	0.25	104.6	6.8	ND
Chromium	100	6.5	2.5	5.3	1.3	8.7	20.1	ND
Cobalt	6	ND	3.7	ND	0.83	1006	190	ND
Copper	1300	7.3	16.6	42.3	13.7	3330	299.1	ND
Iron	14000	233	122	1677	1887	131021	28034	5700
Manganese	300	99.7	17.4	29.2	49.7	5704	1668	65.0
Nickel	100	8.4	4.7	5.1	2.1	380	87	ND
Zinc	3130	50.9	13.6	59.0	15.1	5761	838	31.0
Dissolved Metals								
Aluminum	20000	--	ND	90.9	39.0	1397	147.1	ND
Cadmium	5	--	0.5	ND	ND	103	6.1	ND
Chromium	100	--	4.7	5.5	0.9	9.3	10.5	ND
Cobalt	6	--	7.7	5.0	0.29	962	172	ND
Copper	1300	--	9.4	15.7	7.6	3331	64.7	ND
Iron	14000	--	34.1	186	106.0	116075	20492	ND
Manganese	300	--	5.5	10.2	21.8	5335	1461	ND
Nickel	100	--	10.1	4.8	1.0	374	72	ND
Zinc	3130	--	14.7	32.6	12.5	5109	757	ND
Conventional Water Quality								
Sulfate	250000	61136	21500	21961	20774	1040750	305250	--

Notes:
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Shading = Exceeds SSSV
ND = not detected
See Table 1 for derivation of SSSV

Table A-2
Statistics for Dilution Calculations - Bedrock and Mine Pool 2016-2022
Elizabeth Mine Superfund Site
Strafford, Vermont

	Groundwater Compliance Monitoring Level	Minimum Value Detected			Maximum Value Detected			Maximum ÷ Minimum Value	Maximum ÷ Screening Value
		Value	Source	Date	Value	Source	Date		
Total Metals									
Cadmium	5	0.05	RES-18	08/21/19	13	AV-01 deep	05/14/21	260	2.60
Cobalt	6	0.058	RES-16	06/25/18	280	AV-01 deep	05/14/21	4,828	46.67
Copper	1300	1.0	RES-01	09/15/22	2100	AV-01 deep	05/14/21	2,100	1.62
Iron	14000	27	RES-01	10/19/18	56,000	South Vent	05/14/21	2,074	4.00
Manganese	300	0.21	RES-18	09/15/22	2,200	South Vent	05/14/21	10,476	7.33
Nickel	100	0.42	RES-01	10/19/18	140	AV-01 deep	05/14/21	333	1.40
Zinc	3130	2.2	RES-200	06/25/18	5,700	AV-01 deep	05/14/21	2,591	1.82
Dissolved Metals									
Aluminum	20000	6.2	MW-49C	06/27/19	3,400	AV-01 deep	01/7/21, 5/14/21	548	0.17
Cadmium	5	0.33	RES-16	09/15/22	3.8	AB-5	08/05/20	11.5	0.76
Cobalt	6	0.097	IC-09	05/12/21	70	HO-01	10/19/16	722	11.67
Copper	1300	0.67	RES-01	09/15/22	790	AB-5	08/05/20	1,179	0.61
Iron	14000	17	RES-18	08/28/19	55,000	South Vent	05/14/21	3,235	3.93
Manganese	300	0.31	RES-16	09/15/22	2,200	South Vent	05/14/21	7,097	7.33
Nickel	100	0.34	RES-01	06/25/18	44	AB-5	08/05/20	129	0.44
Zinc	3130	2.7	RES-200	06/25/18	565	IC-10	10/19-20/16	209	0.18
Conventional Water Quality Parameters									
Sulfate	250000	6000	RES-18	08/04/20	1,100,000	AV-01 deep	01/07/21	183	3.60

Notes:

All units in micrograms per liter (µg/L)
ND = not detected
NA = not applicable
Shading = exceeds site specific screening value
Comparison includes only bedrock groundwater close to or associated with the mine pool (north of South Open Cut) with data available between 2016 and 2022. Post-adit pumping samples from AB-1/AB-4 not included.