

## DRAFT MEMORANDUM

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**Project No.** 12393309-04

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**CC**

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### EVALUATION OF MANGANESE IN GROUNDWATER WITHIN THE VALLEY FILL AQUIFER

## 1.0 OVERVIEW

In response to Ohio Environmental Protection Agency (OEPA) comment #5 (OEPA 2021), an evaluation of manganese in groundwater within the Valley Fill Aquifer (VFA) was conducted. Water chemistry samples collected from the VFA were compared to samples collected from both surface water (Cross Creek and pools) and other groundwater bearing units (Interflow Zone, Colluvial Soil Water-Bearing Zone, Under Coal Zone, Upper Casselman, seeps, and bedrock) at the Site. Additionally, manganese concentrations of solid materials, both soil and industrial byproducts, were evaluated to determine likely sources of manganese to VFA groundwater.

Groundwater in eastern Ohio with manganese concentrations above the US EPA secondary Maximum Contaminant Level (MCL) of 50 µg/L has been well established (Jagucki et al. 2015, McMahon et al. 2019, OEPA 2017, OEPA 2022). Of all regional aquifer types (sandstone, carbonate, or sand and gravel) in Ohio, sand and gravel aquifers (e.g., Valley Fill) were most likely to contain groundwater with elevated concentrations of manganese (>600 µg/L; OEPA 2014). However, due to the industrial history of the Site (coal mining and ferrochrome production), additional sources of manganese in Valley Fill groundwater may be present. Possible sources of manganese to the VFA include:

- Coal Mine Drainage (CMD) from historic coal mining
- Natural soils elevated in manganese
- Ferrochrome byproducts (e.g., slag)

Groundwater flow within the VFA follows Cross Creek, migrating south then east across the Site. The VFA is confined and underlies a clay aquitard which separates overlying perched aquifers (the Interflow Zone and Colluvial Soil Water-Bearing Zone) from the VFA. Groundwater within the perched interflow aquifer could have migrated through ferrochrome byproducts, creating potential migration pathways for constituents originating from these byproducts to the VFA in locations where the aquitard is leaky.

North of the VFA is the former mine area, where wells of variable depths are screened in the Lower Pittsburgh formation and Under Coal Zone (siltstone and claystone) and the Upper Casselman formation (limestone and sandstone). Groundwater from the former mine area could migrate to the VFA through one of three pathways:

(1) horizontal flow of groundwater from the former mine area to the VFA, (2) flow from the former mine area into colluvial soil water which migrates downslope into the VFA, or (3) recharge from pooled surface water located at the toe slope of the former mine area (originally sourced from groundwater) to the VFA. Previously published research conducted by the United States Geological Survey (USGS), at the J11 watershed located approximately 10 miles southwest of the Site, examined groundwater quality before and after coal mining (Hren 1986). Post-mining, groundwater at J11 contained substantially higher concentrations of sulfate (360 mg/L), manganese (595 µg/L), and total dissolved solids (814 mg/L) compared to pre-mining baseline samples (84 mg/L, 30 µg/L, and 335 mg/L, respectively). These results indicate that if a migration pathway between the former mine area and the VFA exists, the former mine area would be a likely source of manganese to the VFA.

While deeper groundwater is typically associated with reducing conditions that are favorable for manganese mobility in groundwater, recent studies have shown that groundwater sampled from shallow wells (<50 m) generally contains the highest concentrations of manganese (Fisher and Davidson 2007; Gillispie et al. 2016). High manganese concentrations in these shallow groundwater systems are attributed to 1) shallow soils rich in total organic carbon (anoxic conditions), 2) underlying weathering bedrock, and 3) water-rock chemical disequilibrium. The VFA overlies weathered bedrock, is screened in the shallow subsurface in moderately reducing to slightly oxic conditions, and is likely comprised of young groundwater. A natural release of manganese to the VFA may thus be the cause for the elevated manganese concentrations.

## 2.0 MANGANESE GEOCHEMISTRY

Iron oxide coatings naturally form on sands and gravels of Valley Fill. In oxic conditions, manganese adsorbs to these iron oxide coatings, but in reducing conditions, manganese dissolves into groundwater (Hem 1985; OEPA 2014). The pH also plays an important role in the speciation and adsorption of manganese. Manganese in groundwater is generally present as Mn(II), but when conditions are alkaline (pH >10.5) or when groundwater is oxidized, Mn(IV) (hydr)oxides become the predominant manganese species and generally precipitate out of solution. The pH also impacts the adsorption of manganese onto iron oxides; at circumneutral to slightly basic pH (6.5 to 9), manganese is strongly adsorbed. However, when groundwater is acidic (<5) or basic (>10) manganese sorption onto iron oxides is ineffective and manganese which was previously adsorbed may be released. Thus, pH, redox conditions, and the presence or absence of iron oxides are important controls for manganese mobility in groundwater.

## 3.0 MANGANESE IN SOLIDS

Manganese concentrations were measured in solids associated with ferrochrome production, surficial soils collected from the former mine area, and soils from water bearing units at the Site (Interflow Zone, clay aquitard, VFA, and bedrock; Table 1). The dataset for manganese collected from solids at the Site is relatively large, but irregularly distributed, with most samples concentrated in the Site's lowlands. As a result, the solids data for the former mine area is limited.

Several background soil samples were collected from upland and lowland locations that are considered representative of natural soil in the area. Coal was not sampled as part of the Remedial Investigation (RI). Instead, the USGS database COALQUAL was used to determine manganese concentrations in coal in Jefferson County, Ohio (Palmer et al. 2015).

**Table 1: Summary of Manganese Content of Various Site Materials**

Site Location	Material	Minimum Concentration (mg/kg)	Median Concentration (mg/kg)	Maximum Concentration (mg/kg)	Samples Collected
Former Mine Area	Coal	4	15	105	23
Former Mine Area	Surficial Soil	13	510	5,400	30
Former Mine Area/Ridgetop	Slag	83	299	7,530	22
Lowlands <sup>2</sup>	Slag	94	616	3,640	11
Lowlands <sup>2</sup>	Building Dust	550	3,500	65,000	13
Lowlands <sup>2</sup>	Interflow Materials (sands and gravel with some fill)	690	18,000	56,000	5
Aquitard	Clay	360	780	6,000	28
Lowlands <sup>3</sup>	Valley Fill	300	1,100	3,400	13
Lowlands <sup>2</sup> /Ridgetop	Bedrock	310	850	1,200	3
Off-Site	Upland Background Soil	44	685	2,000	24
Off-Site	Lowland Background Soil	280	785	1,100	24

Notes:

<sup>1</sup>Coal concentrations for Jefferson County, OH from the USGS COALQUAL database.

<sup>2</sup>Indicates materials collected from above the clay aquitard.

<sup>3</sup>Indicates materials collected from below the clay aquitard.

Manganese concentrations at the Site were highest in building dust and Interflow Zone soils. Slag samples contained low concentrations of manganese (Figure 1). The clay aquitard underlying the Interflow Zone generally had a lower median concentration of manganese (780 mg/kg) compared to the overlying Interflow Zone (18,000 mg/kg) or underlying Valley Fill (1,100 mg/kg). The substantial difference in manganese concentrations between these layers likely indicates a limited connection (if any) between VFA solids and overlying Interflow Zone solids.

While median manganese concentrations for VFA sands and gravels (1,100 mg/kg) were lower than the median manganese concentrations for building dust (3,500 mg/kg) or Interflow Zone materials (18,000 mg/kg), the concentration of manganese in VFA materials is still high relative to most soil. For comparison, the average

manganese concentration in eastern United States soils is 260 mg/kg (Smith and Huyck 1999). Manganese depth profiles discussed in Gillispie et al. (2016) showed that shallow soils with elevated manganese concentrations (>500 mg/kg) generally correlate with elevated manganese concentrations in shallow groundwater (>50 µg/L). These results indicate that VFA sands and gravels likely contain sufficient manganese alone to elevate manganese concentrations in groundwater.

Manganese concentrations of materials associated with the former mine area (coal and surficial soil) were generally lower than manganese concentrations of materials collected from other Site locations. Additionally, coal typically contains lower concentrations of manganese, while manganese in CMD is typically high (Larsen and Mann 2005). The potential impact of CMD to the VFA is discussed further in Section 4.0.

The median manganese concentrations of background soil samples collected from upland and lowland locations ranged from 685 to 785 mg/kg, respectively. A maximum manganese concentration of 2,000 mg/kg observed in upland background soils indicates that manganese concentrations are locally elevated in some background soils.

## 4.0 MANGANESE IN VFA GROUNDWATER

A Piper plot was generated for groundwater and surface water samples to facilitate the identification of water types and source contributions to the VFA (Figure 2a, 2b). Figure 2a shows samples collected from the VFA compared to groundwater samples collected from primary groundwater bearing units at the Site (former mine area groundwater, seeps sourced from the former mine area, and the bedrock aquifer) and perched water units (Interflow Zone and Colluvial Soil Water-Bearing Zone). VFA groundwater samples were generally water type Ca-HCO<sub>3</sub>, although several VFA samples were water type Na-Cl or Ca-Cl, similar to bedrock aquifer groundwater samples (Na-Cl or Na-HCO<sub>3</sub>). Groundwater samples collected from perched aquifers (Interflow Zone and Colluvial Soil Water-Bearing Zone) were also typically water type Ca-HCO<sub>3</sub>, potentially indicating flow from perched water to the underlying VFA. Groundwater samples collected from the former mine area were mostly water type Ca-SO<sub>4</sub>; the high relative abundance of sulfate in former mine area groundwater likely indicates impacts from historic coal mining (Hren 1986; Larsen and Mann 2005). Several seeps were water type Ca-HCO<sub>3</sub> similar to VFA groundwater, however, these samples were clearly impacted by slag (pH>10). Seep sample SSW-071 (water type Ca-HCO<sub>3</sub>) may not be impacted by slag (average pH of 7.8) but may be sourced from a thin limestone unit in the Ridgetop area which is parallel to the seep.

Figure 2b, shows groundwater samples collected from the VFA compared to surface water samples (Cross Creek and ponds). Generally, surface water samples were water type Ca-SO<sub>4</sub>, similar to groundwater samples collected from the former mine area (Figure 2a). Several pond water samples were water type Ca-HCO<sub>3</sub> like most VFA groundwater. Similar to seeps with Ca-HCO<sub>3</sub> water type, these ponds also were high in pH (>10), indicating impacts from slag, and likely do not reflect mixing between ponds and VFA groundwater.

### 4.1 Saturation Index Modeling

To evaluate the potential for manganese reactions in Interflow Zone wells and VFA wells (which could affect the interpretation of manganese concentration data), precipitation of manganese-bearing minerals was evaluated with the help of the geochemical modeling code PHREEQC (Parkhurst and Appelo 2013), using a saturation index (SI) calculation:

$$SI = \log (IAP/K_{sp})$$

The saturation index is the ratio of the ion activity product (IAP) of a mineral to the solubility product (Ksp). An SI value greater than zero indicates that the solution is supersaturated with respect to a particular mineral phase and, therefore, precipitation of this mineral may occur. An evaluation of precipitation kinetics is then required to determine whether the supersaturated mineral will indeed form. An SI value less than zero indicates the solution is undersaturated with respect to a particular mineral phase. An SI value close to zero indicates equilibrium conditions exist between the mineral and the solution. SI values between -0.5 and 0.5 are generally considered to represent “equilibrium” herein to account for the uncertainties inherent in the analytical methods and geochemical modeling (Nordstrom and Alpers 1999). The widely accepted thermodynamic database Minteq.v4, 2017 edition (USEPA 1998, as amended) was used as a basis for the thermodynamic constants required for modeling, with additions and modifications from recent literature as required. Relevant manganese-bearing minerals that were evaluated included rhodochrosite, manganite, and others that would be kinetically feasible to form under low-temperature conditions, as listed in Table 6.14 in Nordstrom and Alpers (1999). Calculated mineral saturation indices are presented in Table 2.

Mineral saturation can play an important role in the attenuation of manganese directly by their removal through precipitation (e.g., manganese minerals) or by providing sorptive surfaces or opportunities for co-precipitation (e.g., manganese co-precipitation on calcite). The results of the saturation index modeling can be summarized as follows:

- Iron-bearing minerals: Ferrihydrite [Fe(OH)<sub>3</sub>(am)] was indicated to be oversaturated in VFA wells MW-03 and MW-10 and Interflow Zone wells MW-11 and MW-12, indicating potential for ongoing precipitation of solid-phase iron oxides in some groundwater. However, sequestration of manganese through sorption onto ferrihydrite is known to be minimal in high pH groundwater (e.g., impacted by slag) (see Section 2). Siderite (FeCO<sub>3</sub>) was found to be in equilibrium with groundwater in VFA wells MW-02 and KMW-01.
- Other minerals: All Interflow Zone and VFA groundwater samples were simulated to be in equilibrium or oversaturated with respect to calcite (CaCO<sub>3</sub>). Rhodochrosite (MnCO<sub>3</sub>) was oversaturated or in equilibrium in most groundwater samples. Manganese (hydr)oxides were undersaturated in Interflow Zone and VFA groundwater.

In summary, several mineral phases likely help govern groundwater composition at some or all Interflow Zone and VFA wells: calcite, ferrihydrite, siderite, and rhodochrosite. In the case of rhodochrosite, the dissolved concentrations of manganese may be reduced through its formation, and some manganese may also be attenuated through sorption onto ferrihydrite at circumneutral to slightly basic pH. Manganese co-precipitation with calcite is also likely based on the literature (e.g., Roadcap et al. 2005) and was confirmed through analysis of seep precipitates on-Site (manganese concentrations ranging from 230 to 290 mg/kg).

## 4.2 MW-01 and MW-02

VFA wells MW-01 and MW-02 had the highest manganese concentrations of all VFA wells (dissolved and total manganese concentrations ranging from 3,200 to 3,600 µg/L and 3,000 to 3,600 µg/L, respectively; see Figures 3 to 6). These wells are located at the toe-slope of the former mine area and its primary surface water drainage (see Remedial Investigation (RI) Figure 1.4-6), and downgradient of the Plant Area. The close proximity of MW-01 and MW-02 to both the former mine area and Plant Area requires an evaluation of both areas as possible sources.

While some manganese may be released naturally from local soil/rocks in the VFA at MW-01 and MW-02, the manganese concentrations observed at these wells were approximately 13 standard deviations higher than the mean total manganese concentration for sand and gravel aquifers in Ohio (mean 195 µg/L, standard deviation of 230 µg/L; OEPA 2016). These results indicate that sands and gravels of the VFA are unlikely to be a significant source of manganese in MW-01 and MW-02.

The major relative ion abundance of MW-01 and MW-02 was compared to former mine area waters (groundwater, seeps, ponds, colluvial soil water) and Plant Area groundwater (Interflow Zone well MW-15) using a Piper diagram (Figure 7a). Samples collected from MW-01 and MW-02 were similar in water type (Ca-HCO<sub>3</sub>) to colluvial soil water (MW-09) but plotted away from former mine area seeps (SSW-11), former mine area groundwater (MW105-S, MW106, MW114-S), former mine area ponds (SSW-10) and Plant Area groundwater (MW-15). These results indicate that colluvial soil water may be migrating to the underlying VFA in locations where the clay aquitard is leaky or not present.

Schoeller diagrams presenting major ions and manganese showed elevated concentrations of sulfate in former mine area waters (MW114-S, MW-105-S, MW106, SSW11, and SSW10) and MW-01 relative to other samples, suggesting an influence from CMD (Figure 7b). Manganese concentrations were also elevated (max concentrations >3,000 µg/L) in these samples, except for seep and pond samples SSW10 and SSW11, providing additional support for a release of manganese from the former mine area. Oxic conditions (average dissolved oxygen concentration of 3 mg/L) at SSW10 and SSW11 likely cause the removal of manganese through precipitation of manganese hydroxides (Section 2.0), resulting in lower concentrations of manganese in seeps and ponds than in groundwater. Carbonate alkalinity (HCO<sub>3</sub> plus CO<sub>3</sub>) was low in some former mine area groundwater samples, likely due to the consumption of alkalinity by acidity generated through oxidation of sulfide minerals present in coal and coal waste products. The lower pH of former mine area groundwater samples MW105-S and MW106 (5.59 and 6.65, respectively) supports this hypothesis.

Contour maps of manganese (total and dissolved) and sulfate in groundwater also indicate that manganese is likely migrating from the former mine area to MW-01 and MW-02 (Figures 3 to 6, and 8). Sulfate is a common byproduct of CMD but was observed at low concentrations (<10 mg/L) in waters impacted by slag (SSW-05, SSW-043, and SSW-081). Sulfate concentrations in MW-01 and MW-02 were approximately two (MW-01) to four (MW-02) standard deviations higher than the average sulfate concentration in groundwater from Ohio sand and gravel aquifers (mean concentration of 74 mg/L, standard deviation of 44 mg/L; OEPA 2016). Additionally, MW-01 contained the highest concentration of sulfate in all the VFA wells (280 mg/L) and is located closest to the former mine area. Therefore, manganese in MW-01 and MW-02 likely originates from the former mine area.

### 4.3 MW-03

MW-03 is located in the Plant Area, between the North Mill Building and Cross Creek, within the surface water drainage of the former mine area (RI Figure 1.4-6). Total and dissolved manganese concentrations in MW-03 were variable, ranging from 120 to 770 µg/L and 110 to 700 µg/L, respectively. Sulfate concentrations in MW-03 (average concentration of 125 mg/L) were similar to VFA well MW-02 (average concentrations of 125 mg/L), potentially indicating a component of flow from the former mine area to MW-03 (Figure 8). However, the manganese concentrations observed in MW-03 were substantially lower than in MW-02 (maximum of 770 µg/L compared to 3,600 µg/L for total manganese, respectively). MW-03 is screened beneath a thick zone of the clay aquitard (12 feet) and within a surface water drainage where a smaller fraction of the total flow originates within the former mine area.

Piper diagrams comparing MW-03 to upgradient waters and downgradient waters are shown in Figures 9a and 9b. MW-03 contained a lower relative abundance of magnesium and bicarbonate compared to waters in the Plant Area (Figure 9a) but plotted closely with VFA wells MW-01, MW-02, MW-016, and colluvial soil water sample MW-09 (Figure 9b). Ternary diagrams of conservative ions chloride, sulfate, and sodium for upgradient and downgradient waters also showed MW-03 plotting closely with downgradient VFA/colluvial soil water samples and away from most upgradient water samples (Figures 10a and 10b). Additionally, the hydraulic gradient of groundwater within perched water zones of the former mine area (Under Coal/Upper Casselman) is south towards the VFA, implying that some former mine area groundwater is migrating to the VFA. While the water chemistry results are not definitive (e.g., VFA hydraulic gradient trends north/east away from the former mine area), CMD from the former mine area entering through the surface water drainage area is likely the predominant source of manganese to MW-03.

#### 4.4 MW-05 and MW-06

MW-05 is located southeast of the South Mill Building just north of Cross Creek while MW-06 is located approximately 1,000 feet south of MW-05. Total manganese concentrations in groundwater samples collected from MW-05 and MW-06 ranged from 370 to 920 µg/L and 100 to 180 µg/L, respectively. Dissolved manganese concentrations of groundwater samples collected from MW-05 and MW-06 ranged from 290 to 910 µg/L and 88 to 160 µg/L, respectively. A Piper diagram (Figure 11) displaying samples collected from MW-05 and MW-06 compared to MW-11, MW-12, and other nearby wells, shows that MW-05 and MW-06 were similar in water type to MW-11 (water type Ca-HCO<sub>3</sub>), but differed from MW-12 (water type K-HCO<sub>3</sub>). This result may indicate that seepage from the Interflow Zone to the VFA near the South Mill Building is limited, despite positive detections for hexavalent chromium in both Interflow Zone well MW-12 (0.68 to 1.4 mg/L) and VFA well MW-05 (0.038 mg/L).

Perched groundwater sample RBH-03S, which is screened below slag on the Ridgetop, also displayed a similar water type as MW-05 and MW-06 and may indicate flow from the Ridgetop to the VFA. However, the relative abundance of major ions for MW-05 and MW-06 was most similar to VFA well RBA-04S (a downgradient well with no history of exceedances) and also comparable to Ohio sand and gravel aquifer averages (OEPA 2016), indicating that manganese in MW-05 and MW-06 may also be naturally occurring. East of the RBA-4 well cluster, an area which includes MW-05 and MW-06, groundwater in the VFA is generally reduced (Eh < -140 mV) and pH is circumneutral (Figure 12 and 13), creating conditions that promote the natural release of manganese to groundwater.

Sulfate concentrations observed in MW-05 and MW-06 (77 to 84 mg/L and 55 to 69 mg/L, respectively) were similar to the average sulfate concentration for sand and gravel aquifers in Ohio (74 mg/L; OEPA 2016), but substantially lower than sulfate concentrations of perched groundwater and seeps of the former mine area (>300 mg/L). Additionally, MW-05 and MW-06 are located far enough away from the surface drainage and groundwater pathways (0.35 and 0.5 miles, respectively) that flow from the former mine area to MW-05 and MW-06 is unlikely.

Average concentrations of manganese (total and dissolved) in MW-11 (99 µg/L total and 1.6 µg/L dissolved) and MW-12 (46 µg/L total and non-detect for dissolved) were substantially lower compared to VFA wells (average of 880 µg/L total and 820 µg/L dissolved). Higher total manganese concentrations relative to dissolved manganese in Interflow Zone Wells MW-11 and MW-12 indicate that some manganese is present in solution, but likely as colloidal-sized particulate matter or as precipitating minerals (e.g., calcite; Roadcap et al. 2005; Table 2).

Manganese present as particulate matter in the Interflow Zone is unlikely to migrate through the clay aquitard to the underlying VFA.

MW-05 and MW-06 were similar in water type and major ion concentration to averages for Ohio sand and gravel aquifers, supporting the conclusion that manganese may be naturally occurring.

## 4.5 MW-10

MW-10 is located at the toe slope of the Ridgetop at the intersection between Cross Creek and McIntyre Creek upgradient of both the former mine area and the Plant Area. Manganese concentrations for MW-10 ranged from 830 to 1,300 µg/L for total manganese and 190 to 390 µg/L for dissolved manganese. A Piper diagram (Figure 14) displaying bedrock wells screened below the VFA (RBA-04D and RBA-05D), MW-10, and upgradient VFA well RBA-05I shows similarity in water type between MW-10 and bedrock wells (RBA-05D and RBA-04D; water type Na-Cl). Groundwater in MW-10 and bedrock well RBA-04D contained elevated concentrations of sodium and chloride relative to all other wells on site, with sodium concentrations greater than 1,200 mg/L and chloride concentrations greater than 1,900 mg/L. Molar ratios of nearly 1:1 between sodium and chloride and high total dissolved solids concentrations (>2,800 mg/L) at both MW-10 and RBA-04D indicate dissolution of evaporative minerals may be occurring (e.g., halite (NaCl)). While water type and concentrations of major ions were similar between MW-10 and RBA-04D, manganese concentrations at MW-10 (maximum total manganese concentration of 1,300 µg/L) were elevated relative to RBA-04D (maximum total manganese concentration of 64 µg/L), indicating that while major ions at MW-10 appear to be sourced from bedrock, manganese may not be. Nonetheless, chemical indicators for other sources (e.g., sulfate for former mine area or chromium for slag) were found at low concentrations in MW-10 (<1 mg/L sulfate and <0.05 mg/L for total chromium), indicating that manganese at MW-10 may be naturally released from weathered bedrock near MW-10.

## 5.0 CONCLUSIONS

This review of manganese sources and potential pathways to VFA wells was conducted to evaluate manganese concentrations in groundwater greater than the MCL (50 µg/L) found in Site wells MW-01, MW-02, MW-03, MW-05, MW-06, and MW-10. Based on the results of this assessment, the following is concluded for manganese in VFA groundwater:

- CMD from the former mine area is likely the predominant source of manganese in wells MW-01, MW-02, and MW-03
- Manganese in wells MW-05, MW-06, and MW-10 is likely due to natural release of manganese from soils in the VFA
- Manganese release from slag is likely very limited

Attachments:

## TABLES

Table 1 Summary of Manganese Content of Various Site Materials

Table 2 Relevant Mineral Phases – Saturation Indices

## FIGURES

Figure 1 Manganese of Solids - Maximum

Figure 2 Trilinear (Piper) Diagrams of Groundwater (a) and Surface Water (b) at the Site

Figure 3 Dissolved Manganese in Groundwater - Minimum

Figure 4 Dissolved Manganese in Groundwater - Maximum

Figure 5 Total Manganese in Groundwater - Minimum

Figure 6 Total Manganese in Groundwater - Maximum

Figure 7 Trilinear (Piper) (a) and Schoeller (b) Diagrams of Groundwater Near VFA Wells MW-01 and MW-02

Figure 8 Sulfate in Groundwater - Maximum

Figure 9 Trilinear (Piper) Diagrams of Groundwater Upgradient (a) and Downgradient (b) of MW-03

Figure 10 Ternary Diagrams of Groundwater Upgradient (a) and Downgradient (b) of MW-03

Figure 11 Trilinear (Piper) Diagram of Groundwater Near MW-05 and MW-06

Figure 12 ORP of Valley Fill Aquifer Groundwater - Minimum

Figure 13 pH of Valley Fill Aquifer Groundwater - Minimum

Figure 14 Trilinear (Piper) Diagram of Groundwater Near MW-10

[https://golderassociates.sharepoint.com/sites/100059g/deliverables/ri\\_report/mn\\_comment\\_response/memorandum/draft\\_to\\_agency/12393309-04-m-rev\\_c-manganese comment\\_reponse\\_071822\\_r1.docx](https://golderassociates.sharepoint.com/sites/100059g/deliverables/ri_report/mn_comment_response/memorandum/draft_to_agency/12393309-04-m-rev_c-manganese_comment_reponse_071822_r1.docx)

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Table

**TABLE 2  
GEOCHEMICAL MODELING  
RELEVANT MINERAL PHASES - Saturation Indices  
VALLEY FILL AQUIFER AND INTERFLOW ZONE, FORMER SATRALLOY SITE**

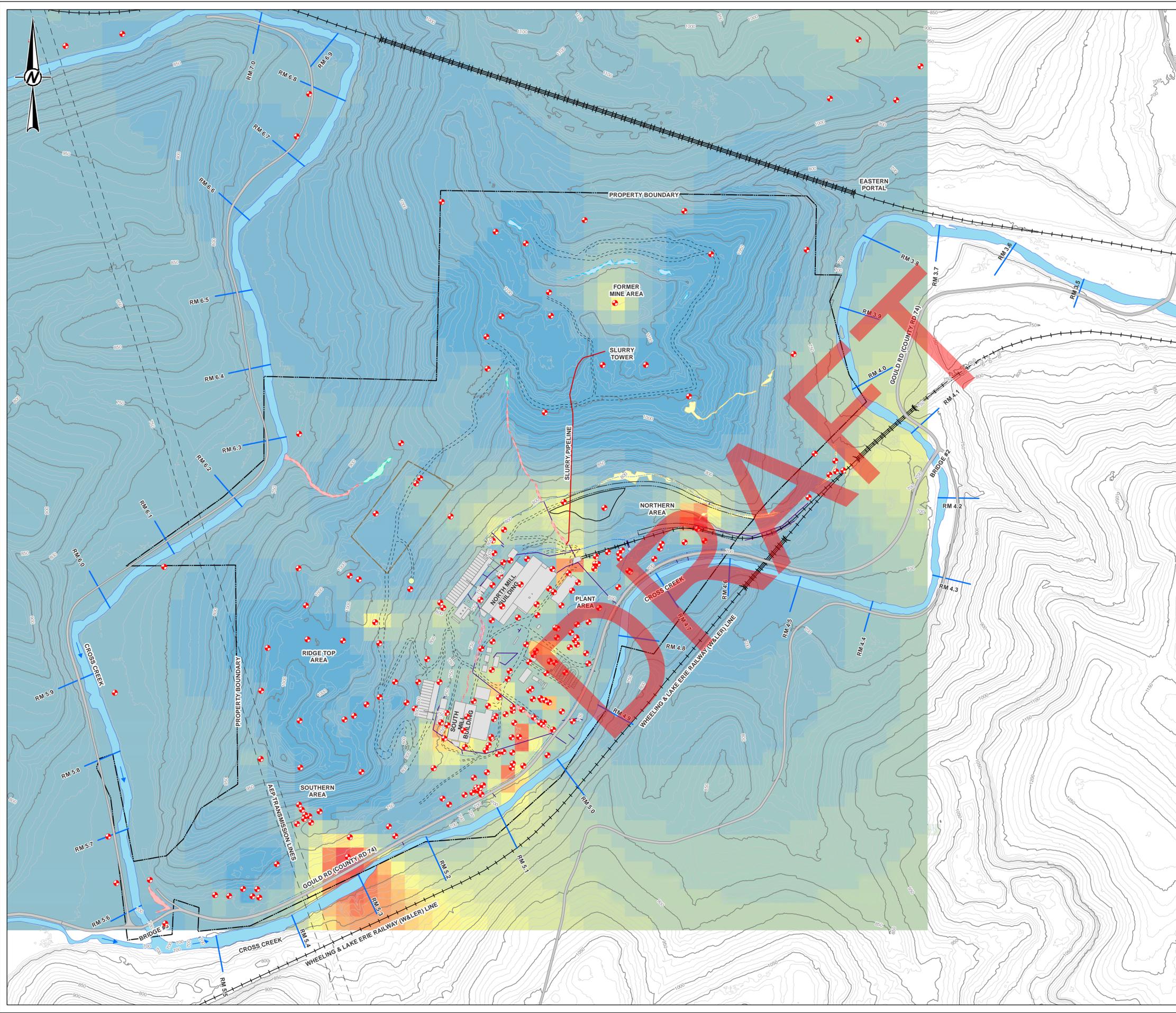


MINERAL PHASES - Saturation Indices		MW01	MW02	MW03	MW05	MW06	MW10	MW16	RBA04S	RBA04I	KMW01	RBA05I	MW11	MW12	MW14	MW15
Ferrihydrite	Fe(OH) <sub>3</sub>	-2.34	-0.80	<b>1.41</b>	-1.69	-2.48	<b>2.20</b>	-5.22	-0.63	-1.01	-0.95	-2.41	<b>0.23</b>	<b>1.62</b>	<b>-0.41</b>	-2.73
Siderite	FeCO <sub>3</sub>	-1.03	<b>-0.30</b>	-1.02	-1.52	-0.93	-1.30	-2.08	-1.35	-0.64	<b>0.05</b>	-0.98	-8.42	-4.68	-0.75	-1.24
Manganite	MnO(OH)	-9.93	-7.91	-6.25	-9.23	-10.70	-6.04	-15.17	-9.55	-8.43	-10.71	-10.00	-2.36	-3.61	-8.51	-9.29
Pyrochroite	Mn(OH) <sub>2</sub>	-6.12	-3.30	-5.37	-6.64	-6.22	-6.86	-10.15	-7.59	-4.90	-6.20	-5.30	-0.63	-2.14	-6.55	-5.90
Pyrolusite	MnO <sub>2</sub>	-21.23	-19.92	-14.89	-19.66	-23.26	-13.44	-27.94	-19.02	-20.63	-22.85	-22.70	-11.38	-12.34	-19.09	-21.52
Rhodochrosite	MnCO <sub>3</sub>	<b>0.39</b>	<b>1.63</b>	<b>0.26</b>	<b>-0.14</b>	<b>-0.30</b>	-0.72	-3.09	-1.25	<b>0.63</b>	-0.74	<b>0.30</b>	-1.94	-0.83	<b>-0.15</b>	<b>0.85</b>
Calcite	CaCO <sub>3</sub>	<b>0.19</b>	<b>1.19</b>	<b>0.65</b>	<b>0.01</b>	<b>0.50</b>	<b>-0.10</b>	<b>-0.48</b>	<b>0.17</b>	<b>0.74</b>	<b>0.33</b>	<b>0.33</b>	<b>2.56</b>	<b>1.41</b>	<b>-0.32</b>	<b>0.44</b>

**Notes:**  
Saturation indices >-0.5 identified by red bold type and grey shading

DRAFT

## Figures



**LEGEND**

- + Sampling Location - Manganese
- EXISTING FACILITY
- EXISTING ON-SITE ACCESS ROAD
- COUNTY ROAD
- FENCE LINE
- CREEK FLOW
- RIVER MILE MARKER AND LABEL
- CROSS CREEK
- AEP TRANSMISSION LINE
- EXISTING PROPERTY BOUNDARY
- INHOLDING PROPERTY BOUNDARY
- EXISTING RAILROAD
- FORMER RAIL SPUR/LOW RAIL SPUR
- EXISTING SLURRY PIPELINE
- MAJOR DRAINAGE DITCH
- STORM PIPELINE
- INTERMITTENT JURISDICTIONAL WATERS OF THE U.S. (CORPS)
- PERENNIAL JURISDICTIONAL WATERS OF THE U.S. (CORPS)
- ISOLATED WETLANDS (OEPA JURISDICTION)
- OPEN WATER (NON-JURISDICTIONAL)
- CONTOUR (50 FT INTERVAL)
- CONTOUR (10 FT INTERVAL)

**Manganese**

- 20 - 400
- 500 - 800
- 900 - 1,000
- 2,000 - 2,000
- 3,000 - 2,000
- 3,000 - 3,000
- 4,000 - 3,000
- 4,000 - 4,000
- 5,000 - 4,000
- 6,000 - 5,000
- 6,000 - 6,000
- 7,000 - 7,000
- 8,000 - 7,000
- 8,000 - 8,000
- 9,000 - 9,000
- 10,000 - 10,000
- 20,000 - 10,000
- 20,000 - 20,000
- 30,000 - 20,000

**NOTE(S)**

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3. WESTLAND RESOURCES, INC. (WETLANDS, 2013)
4. COORDINATE SYSTEM: NAD 1983, STATE PLANE OHIO NORTH (FT) FIPS 3401

CLIENT  
**CYPRUS AMAX MINERALS COMPANY**

---

PROJECT  
**SATRALLOY REMEDIAL INVESTIGATION**

---

TITLE  
**MANGANESE OF SOLIDS - MAXIMUM**

---

CONSULTANT	YYYY-MM-DD	2022-04-08
	DESIGNED	BVJ
	PREPARED	TH
	REVIEWED	BI
	APPROVED	LH

---

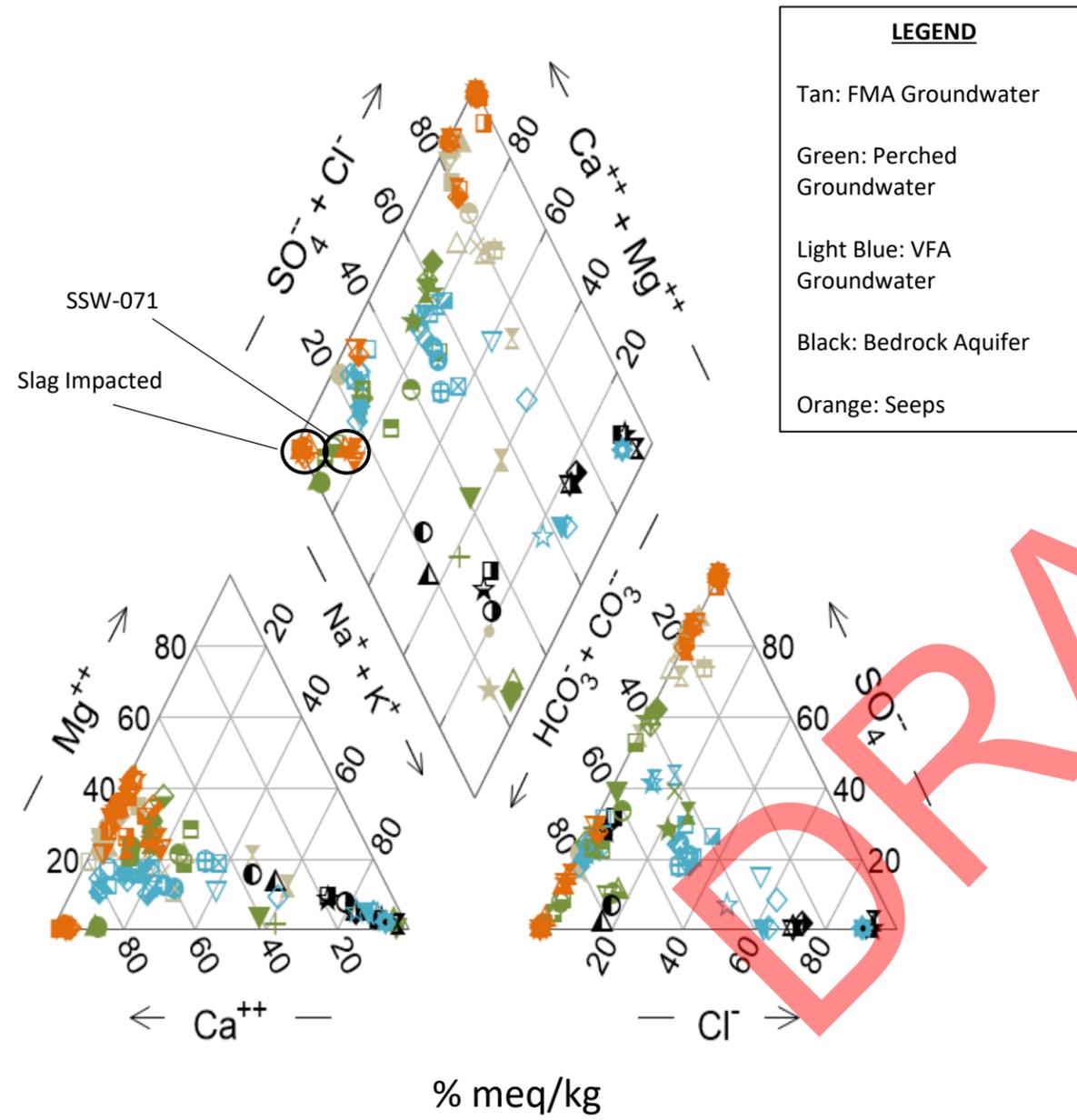
PROJECT NO. 1239330902	PHASE 600	REV. 1	FIGURE <b>1</b>
---------------------------	--------------	-----------	--------------------

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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANS/D

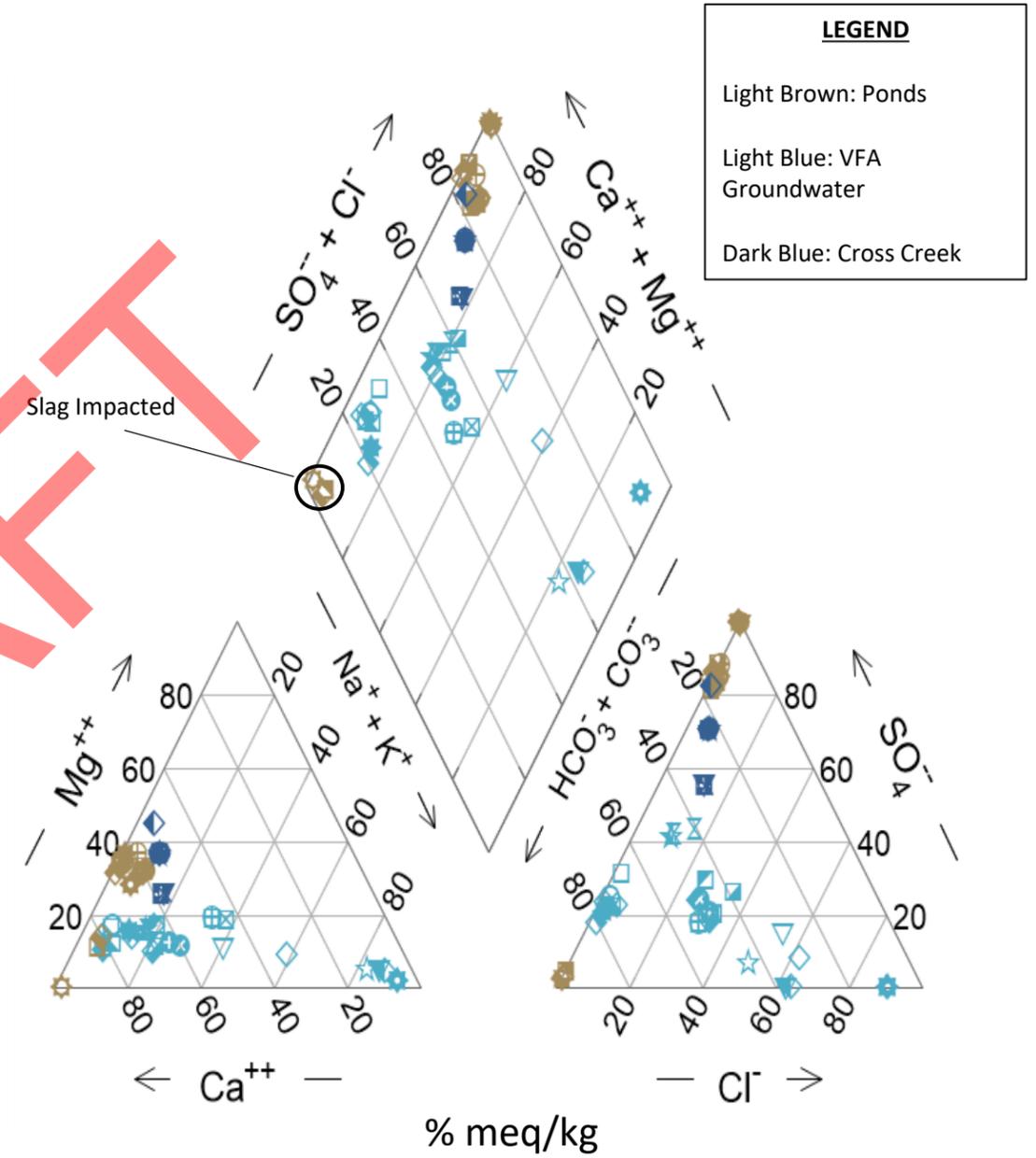
(a)

Groundwater



(b)

Surface Water



Notes: Slag Impacted water (pH>10) is poorly represented by a Piper Diagram due to poor analytical accuracy for measuring total alkalinity of high pH water.

CLIENT  
CYPRUS AMAX MINERALS COMPANY

CONSULTANT



PROJECT  
FORMER SATRALLOY SITE  
FORMER MINE AREA INVESTIGATION

TITLE  
Trilinear (Piper) Diagrams of Groundwater (a) and  
Surface Water (b) at the Site

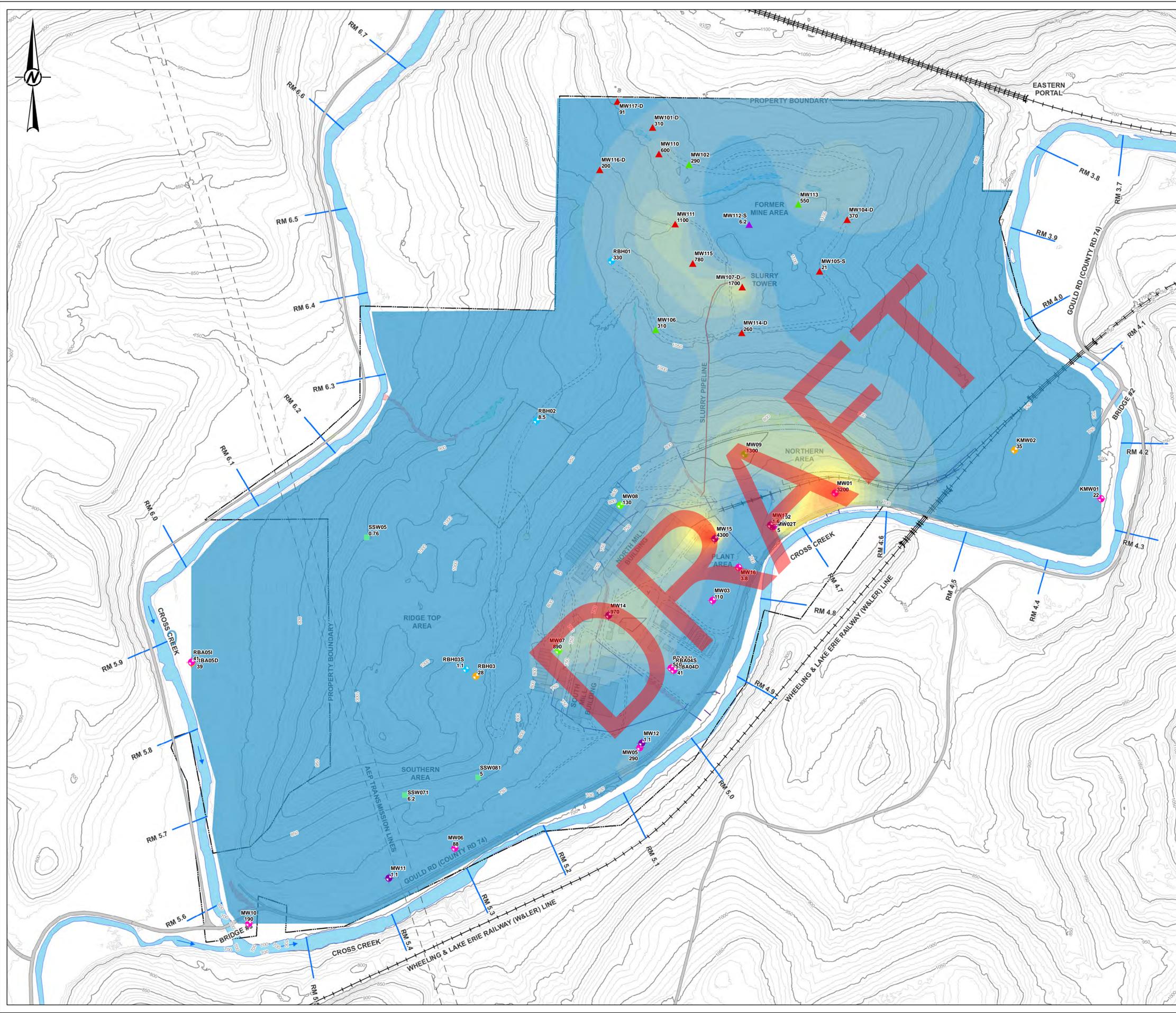
DRAFT

PROJECT NO.  
12393309X10

PHASE

REV.  
A

FIGURE  
2



**LEGEND**

- COLLUVIAL SOIL
- INTERFLOW
- ▲ LOWER PITTSBURGH
- PERCHED BEDROCK
- REGIONAL BEDROCK
- SITE SURFACE WATER
- ▲ UNDER COAL ZONE
- ▲ UPPER CASSELMAN
- VALLEY FILL
- EXISTING FACILITY
- EXISTING ON-SITE ACCESS ROAD
- COUNTY ROAD
- FENCE LINE
- CREEK FLOW
- RIVER MILE MARKER AND LABEL
- CROSS CREEK
- AEP TRANSMISSION LINE
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- INHOLDING PROPERTY BOUNDARY
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- EXISTING SLURRY PIPELINE
- MAJOR DRAINAGE DITCH
- STORM PIPELINE
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- PERENNIAL JURISDICTIONAL WATERS OF THE U.S. (CORPS)
- ISOLATED WETLANDS (OEPA JURISDICTION)
- OPEN WATER (NON-JURISDICTIONAL)
- CONTOUR (50 FT INTERVAL)
- CONTOUR (10 FT INTERVAL)

**Mn Concentration (µg/L)**

- 0
- 200
- 400
- 600
- 800
- 1000
- 1200
- 1400
- 1600
- 1800
- 2000
- 2200
- 2400
- 2600
- 2800
- 3000
- 3200
- 3400
- 3600
- 3800



**NOTE(S)**

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4. COORDINATE SYSTEM: NAD 1983, STATE PLANE OHIO NORTH (FT) FIPS 3401

CLIENT  
CYPRUS AMAX MINERALS COMPANY

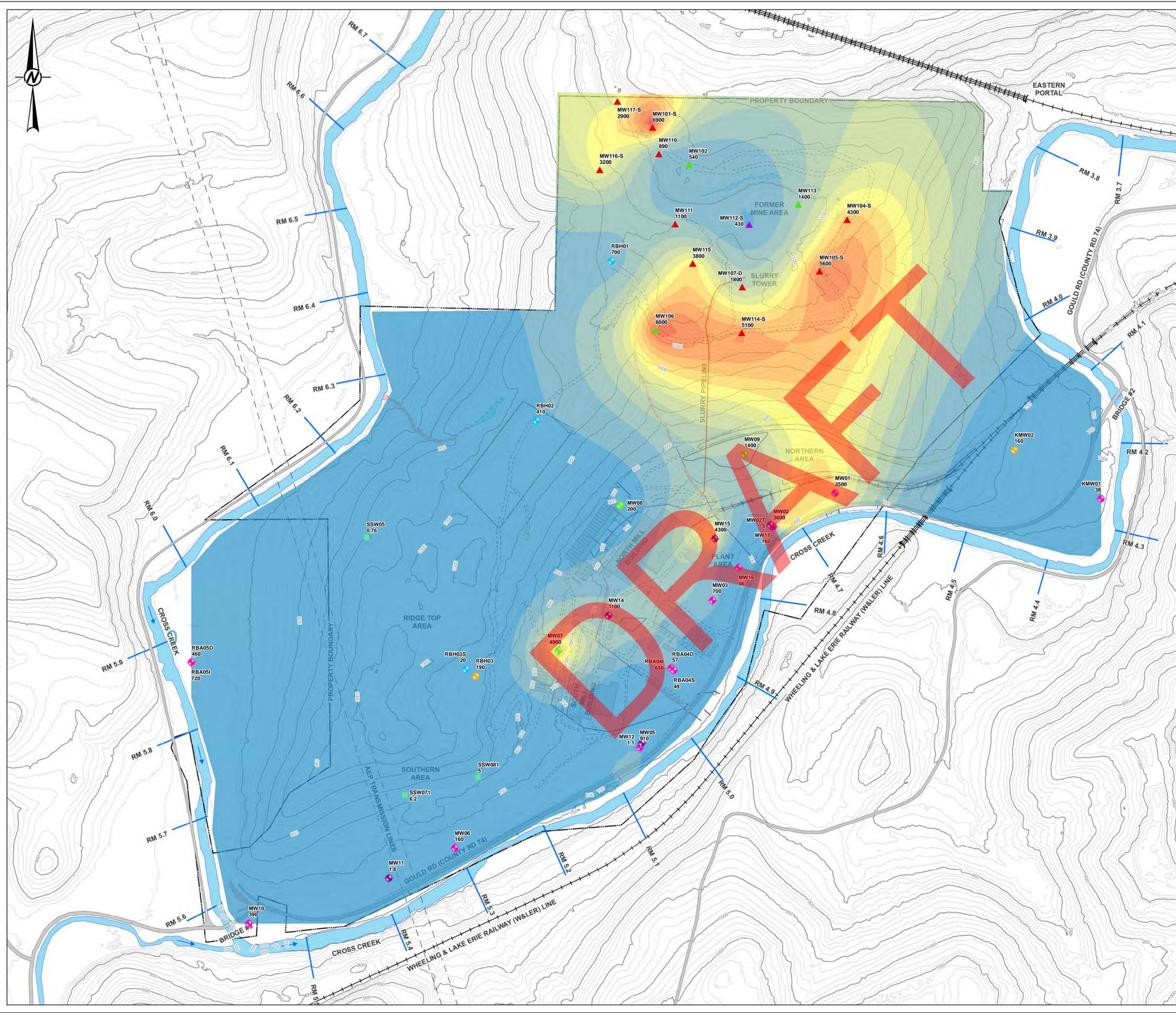
PROJECT  
SATRALLOY REMEDIAL INVESTIGATION

TITLE  
DISSOLVED MANGANESE IN GROUNDWATER - MINIMUM

CONSULTANT	YYYY-MM-DD	2022-05-17
	DESIGNED	BVJ
	PREPARED	TH
	REVIEWED	BI
	APPROVED	LH

PATH: G:\GIS\Sheet\Sheet\4-27-2022\1239330902\_600\_00E\_Manganese\_Min\_Discover.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANS/D

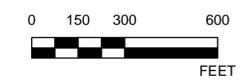


**LEGEND**

- COLLUVIAL SOIL
- INTERFLOW
- LOWER PITTSBURGH
- PERCHED BEDROCK
- REGIONAL BEDROCK
- SITE SURFACE WATER
- UNDER COAL ZONE
- UPPER CASSELMAN
- VALLEY FILL
- EXISTING FACILITY
- EXISTING ON-SITE ACCESS ROAD
- COUNTY ROAD
- FENCE LINE
- CREEK FLOW
- RIVER MILE MARKER AND LABEL
- CROSS CREEK
- AEP TRANSMISSION LINE
- EXISTING PROPERTY BOUNDARY
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- PERENNIAL JURISDICTIONAL WATERS OF THE U.S. (CORPS)
- ISOLATED WETLANDS (OEPA JURISDICTION)
- OPEN WATER (NON-JURISDICTIONAL)
- CONTOUR (50 FT INTERVAL)
- CONTOUR (10 FT INTERVAL)

**Mn Concentration (µg/L)**

- 0
- 500
- 1000
- 1500
- 2000
- 2500
- 3000
- 3500
- 4000
- 4500
- 5000
- 5500
- 6000



**NOTE(S)**

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- COORDINATE SYSTEM: NAD 1983, STATE PLANE OHIO NORTH (FT) FIPS 3401

CLIENT  
**CYPRUS AMAX MINERALS COMPANY**

PROJECT  
**SATRALLOY REMEDIAL INVESTIGATION**

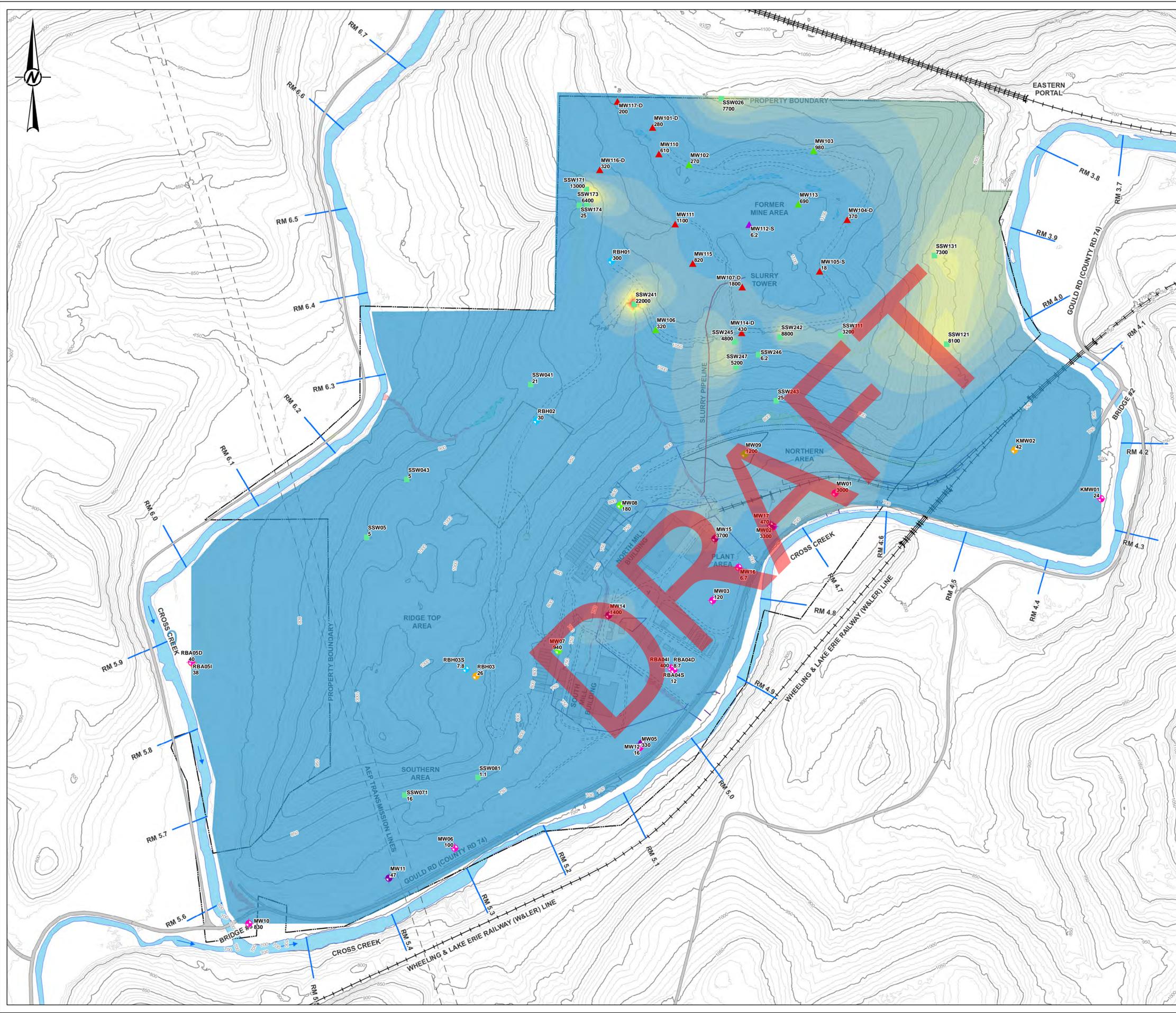
TITLE  
**DISSOLVED MANGANESE IN GROUNDWATER - MAXIMUM**

CONSULTANT	YYYY-MM-DD	2022-05-17
DESIGNED	BVJ	
PREPARED	TH	
REVIEWED	BI	
APPROVED	LH	

PROJECT NO. 1239330902      PHASE 600      REV. 1      FIGURE 4

PATH: G:\GIS\Shelby\4-27-2021\239330902\_600\_002\_Manganese\_max\_Disolved.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANS/D

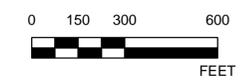


**LEGEND**

- COLLUVIAL SOIL
- INTERFLOW
- ▲ LOWER PITTSBURGH
- PERCHED BEDROCK
- REGIONAL BEDROCK
- SITE SURFACE WATER
- ▲ UNDER COAL ZONE
- ▲ UPPER CASSELMAN
- VALLEY FILL
- EXISTING FACILITY
- EXISTING ON-SITE ACCESS ROAD
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- PERENNIAL JURISDICTIONAL WATERS OF THE U.S. (CORPS)
- ISOLATED WETLANDS (OEPA JURISDICTION)
- OPEN WATER (NON-JURISDICTIONAL)
- CONTOUR (50 FT INTERVAL)
- CONTOUR (10 FT INTERVAL)

**Mn Concentration (µg/L)**

- 0
- 1000
- 2000
- 3000
- 4000
- 5000
- 6000
- 7000
- 8000
- 9000
- 10000
- 11000
- 12000
- 13000
- 14000
- 15000
- 16000
- 17000



**NOTE(S)**

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CLIENT  
**CYPRUS AMAX MINERALS COMPANY**

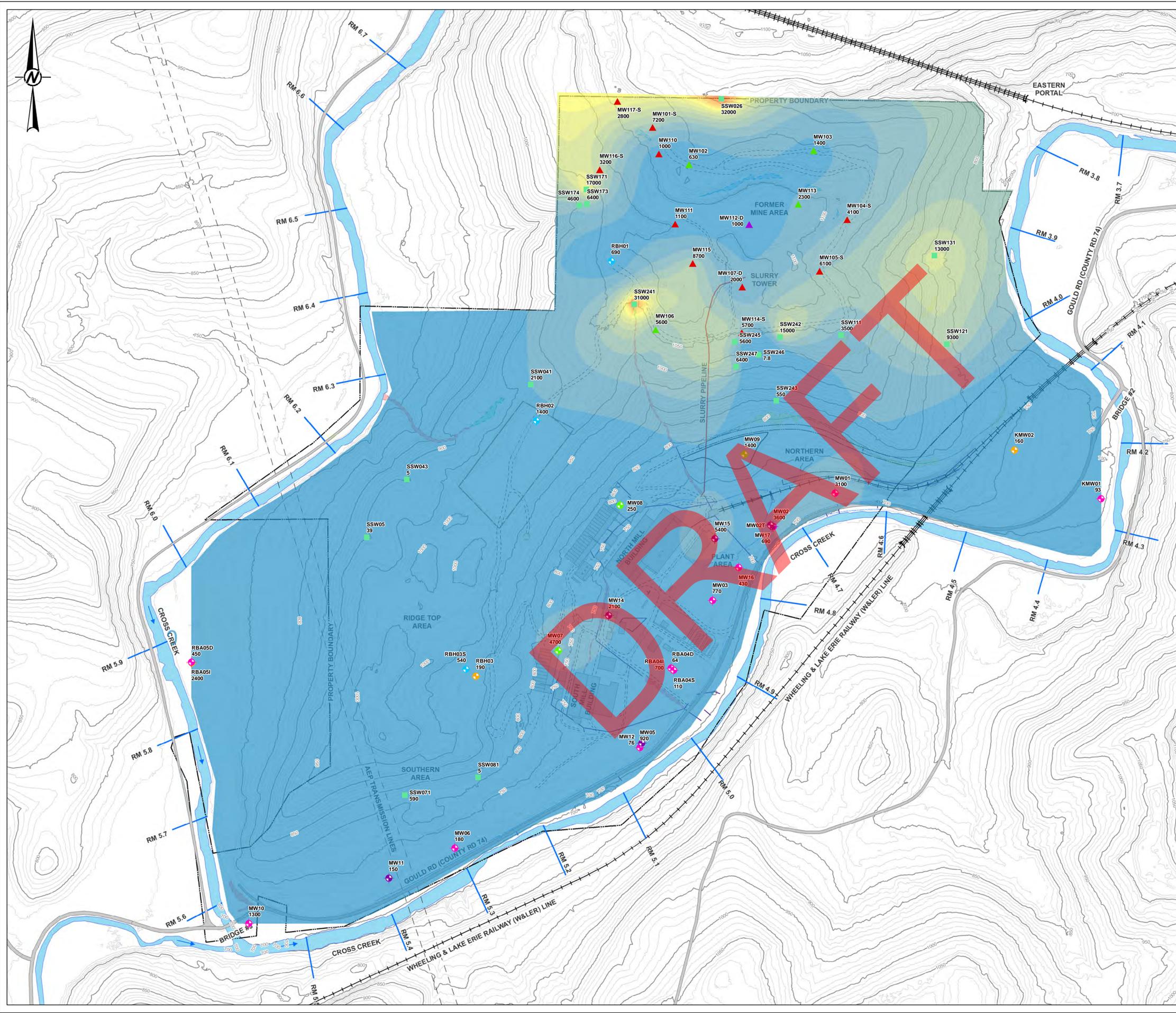
PROJECT  
**SATRALLOY REMEDIAL INVESTIGATION**

TITLE  
**TOTAL MANGANESE IN GROUNDWATER - MINIMUM**

CONSULTANT	YYYY-MM-DD	2022-05-17
DESIGNED		BVJ
PREPARED		TH
REVIEWED		BI
APPROVED		LH

PATH: G:\GIS\Sheets\Satralloy\4-27-2022\1239330902\_600\_00E\_Manganese\_Min\_Total.mxd

1 in IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANS/D



**LEGEND**

- COLLUVIAL SOIL
- INTERFLOW
- ▲ LOWER PITTSBURGH
- PERCHED BEDROCK
- REGIONAL BEDROCK
- SITE SURFACE WATER
- ▲ UNDER COAL ZONE
- ▲ UPPER CASSELMAN
- VALLEY FILL
- EXISTING FACILITY
- EXISTING ON-SITE ACCESS ROAD
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- PERENNIAL JURISDICTIONAL WATERS OF THE U.S. (CORPS)
- ISOLATED WETLANDS (OEPA JURISDICTION)
- OPEN WATER (NON-JURISDICTIONAL)
- CONTOUR (50 FT INTERVAL)
- CONTOUR (10 FT INTERVAL)

**Mn Concentration (µg/L)**

0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000
28000
30000
32000

0 150 300 600  
FEET

**NOTE(S)**

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CLIENT  
CYPRUS AMAX MINERALS COMPANY

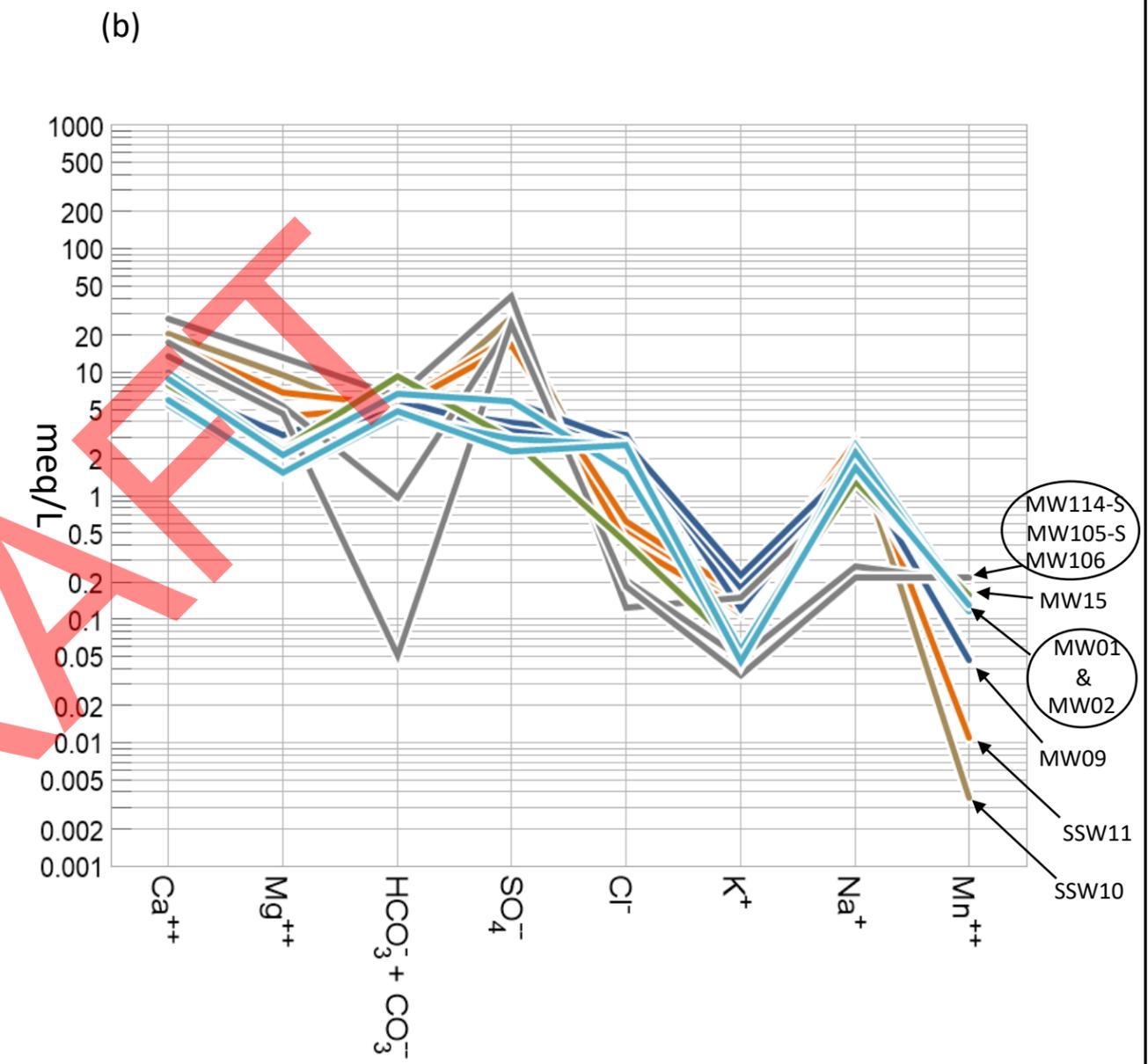
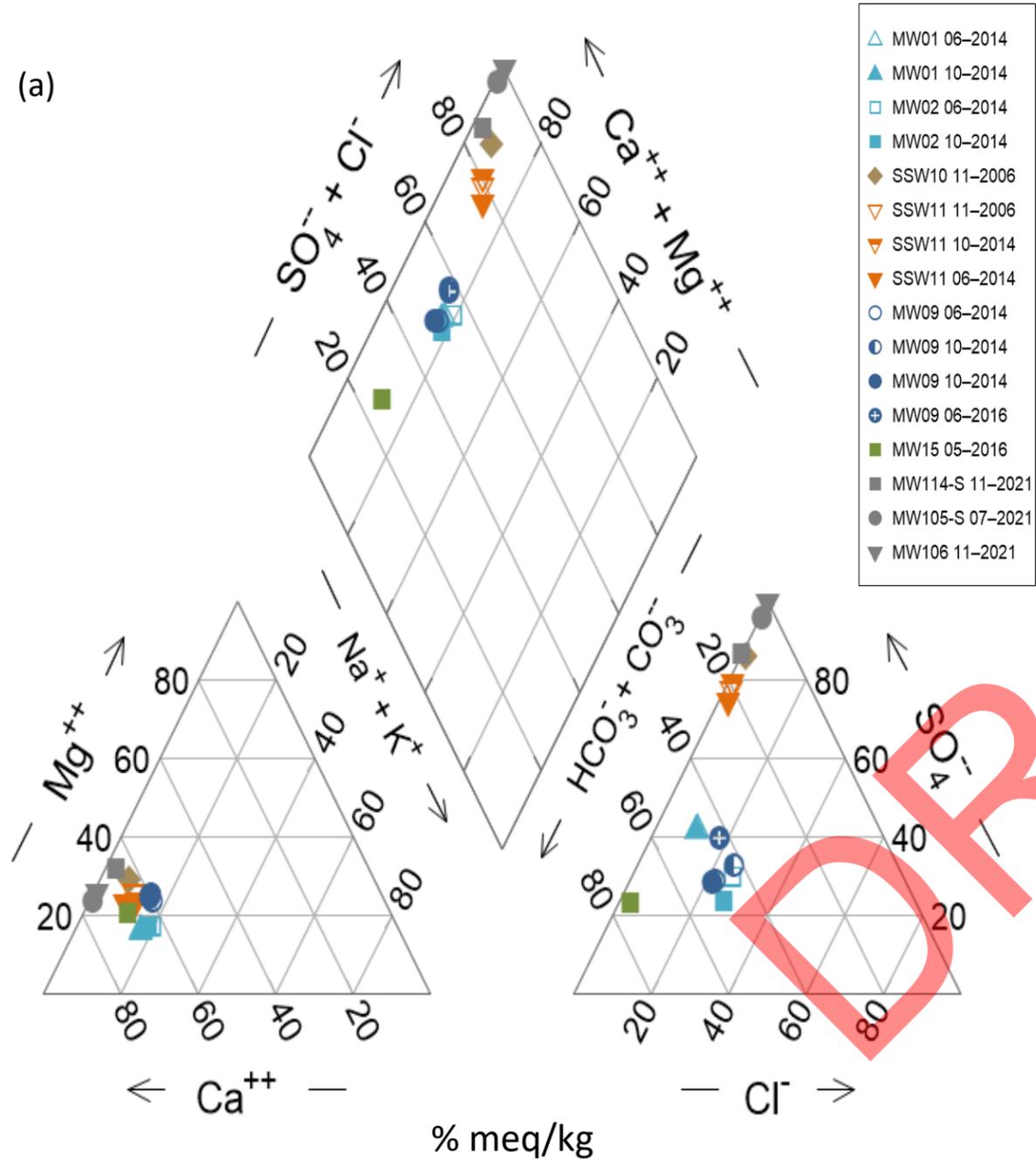
PROJECT  
SATRALLOY REMEDIAL INVESTIGATION

TITLE  
**TOTAL MANGANESE IN GROUNDWATER - MAXIMUM**

CONSULTANT	YYYY-MM-DD	2022-05-17
	DESIGNED	BVJ
	PREPARED	TH
	REVIEWED	BI
	APPROVED	LH

PATH: G:\GIS\Sheet\Sheet\4-27-2022\1239330902\_600\_002\_Manganese\_max\_total.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSD



CLIENT  
CYPRUS AMAX MINERALS COMPANY

PROJECT  
FORMER SATRALLOY SITE  
FORMER MINE AREA INVESTIGATION

CONSULTANT



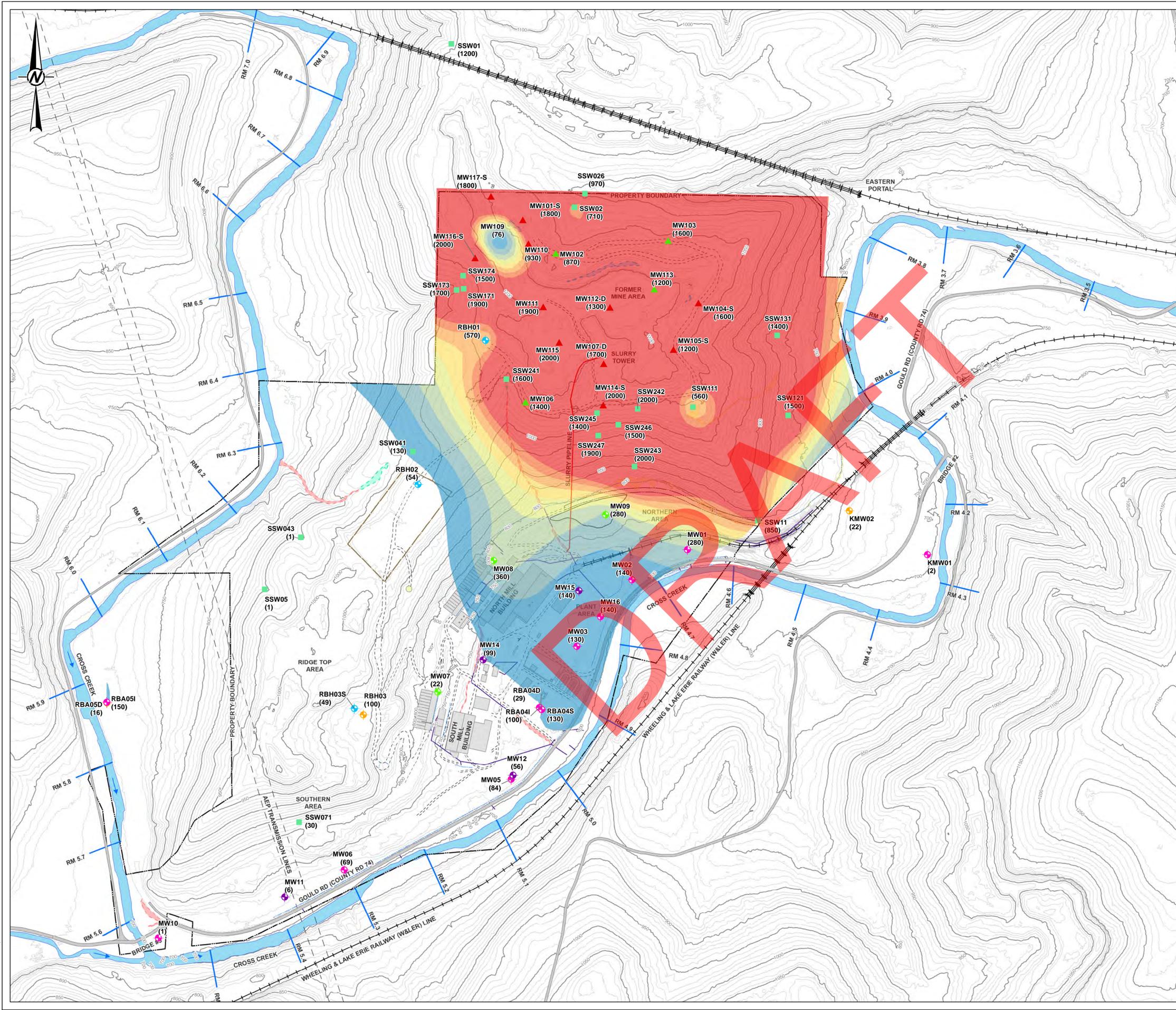
TITLE  
**Trilinear (Piper) (a) and Schoeller (b) Diagrams  
of Groundwater Near VFA Wells MW-01 and MW-02**  
**DRAFT**

PROJECT NO.  
12393309X10

PHASE

REV.  
A

FIGURE  
7



**LEGEND**

- COLLUVIAL SOIL
- INTERFLOW
- PERCHED BEDROCK
- REGIONAL BEDROCK
- SITE SURFACE WATER
- UNDER COAL ZONE
- UPPER CASSELMAN
- VALLEY FILL
- EXISTING FACILITY
- EXISTING ON-SITE ACCESS ROAD
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- ISOLATED WETLANDS (OEPA JURISDICTION)
- OPEN WATER (NON-JURISDICTIONAL)
- CONTOUR (50 FT INTERVAL)
- CONTOUR (10 FT INTERVAL)

**Sulfate Concentration (mg/L)**

- 100
- 200
- 300
- 400
- 500
- 600
- 700
- 800 - 1900

**NOTE(S)**

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- WESTLAND RESOURCES, INC. (WETLANDS, 2013)
- COORDINATE SYSTEM: NAD 1983, STATE PLANE OHIO NORTH (FT) FIPS 3401

0 150 300 600  
FEET

CLIENT  
**CYPRUS AMAX MINERALS COMPANY**

PROJECT  
**SATRALLOY REMEDIAL INVESTIGATION**

TITLE  
**SULFATE IN GROUNDWATER - MAXIMUM**

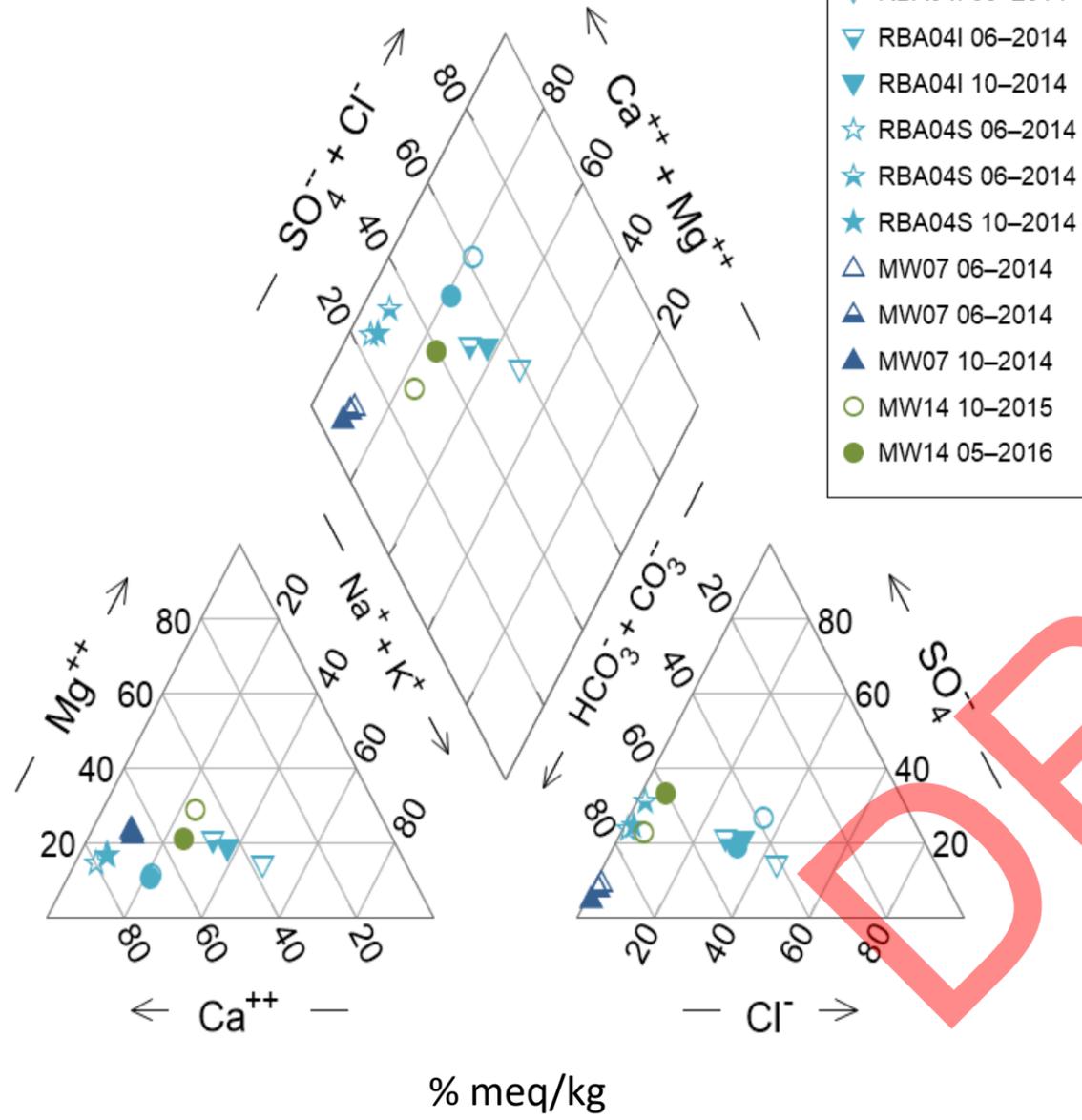
CONSULTANT	YYYY-MM-DD	2022-05-17
	DESIGNED	BVJ
	PREPARED	TH
	REVIEWED	BI
	APPROVED	LH

PROJECT NO. 1239330902      PHASE 600      REV. 1      FIGURE 8

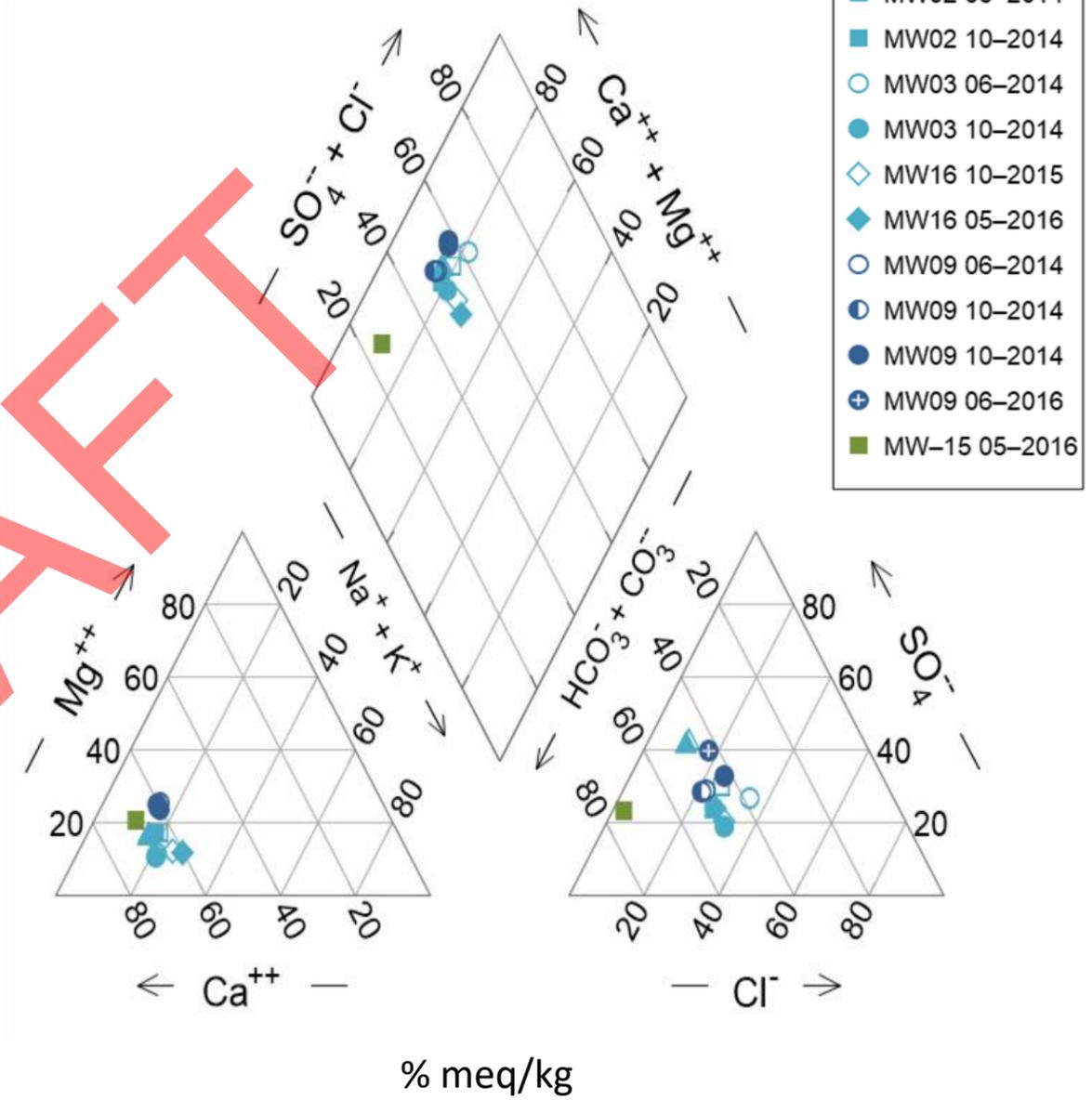
PATH: G:\GIS\Site\Satralloy\1239330902\_600\_005\_Sulfate\_concentration.mxd

1 in IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANS/D

(a) Upgradient



(b) Downgradient



CLIENT  
CYPRUS AMAX MINERALS COMPANY

PROJECT  
FORMER SATRALLOY SITE  
FORMER MINE AREA INVESTIGATION

CONSULTANT



TITLE  
**Trilinear (Piper) Diagrams of Groundwater Upgradient (a) and Downgradient (b) of MW-03**  
**DRAFT**

PROJECT NO.  
12393309X10

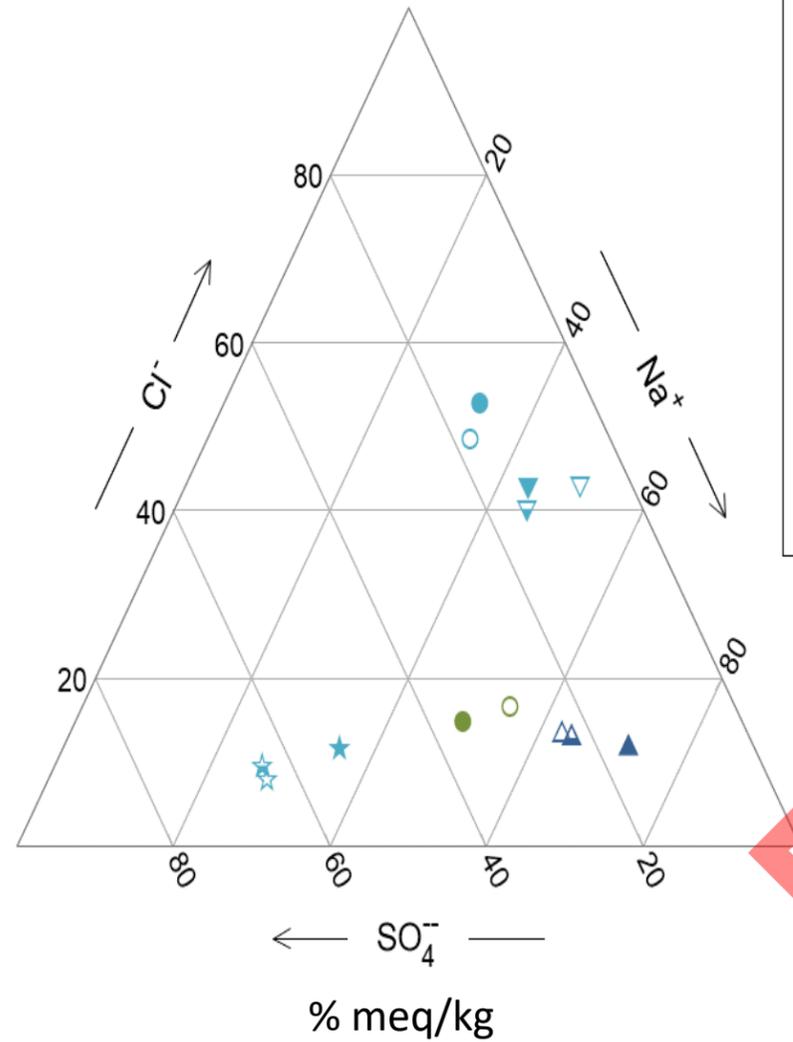
PHASE

REV.  
A

FIGURE  
9

(a)

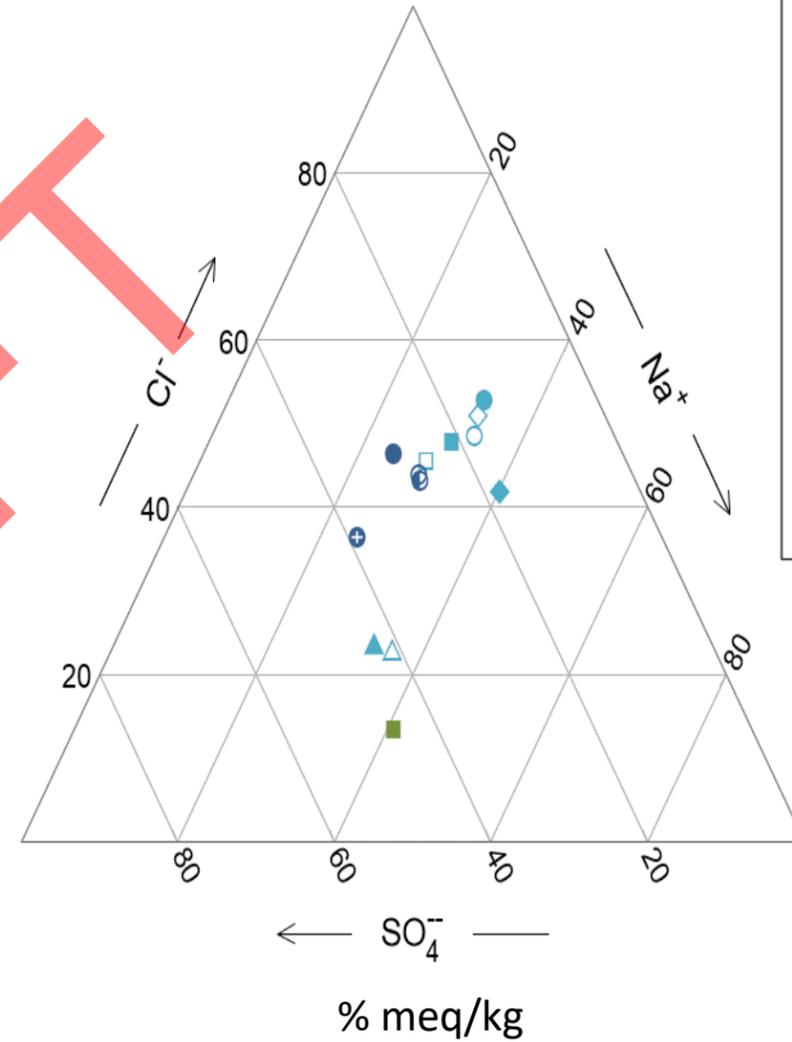
Upgradient



- MW03 06-2014
- MW03 10-2014
- ▽ RBA04I 06-2014
- ▼ RBA04I 06-2014
- ▼ RBA04I 10-2014
- ☆ RBA04S 06-2014
- ☆ RBA04S 06-2014
- ☆ RBA04S 10-2014
- △ MW07 06-2014
- ▲ MW07 06-2014
- ▲ MW07 10-2014
- MW14 10-2015
- MW14 05-2016

(b)

Downgradient



- △ MW01 06-2014
- ▲ MW01 10-2014
- MW02 06-2014
- MW02 10-2014
- MW03 06-2014
- MW03 10-2014
- ◇ MW16 10-2015
- ◆ MW16 05-2016
- MW09 06-2014
- MW09 10-2014
- MW09 10-2014
- MW09 10-2014
- ⊕ MW09 06-2016
- MW-15 05-2016

DRAFT

CLIENT  
CYPRUS AMAX MINERALS COMPANY

PROJECT  
FORMER SATRALLOY SITE  
FORMER MINE AREA INVESTIGATION

CONSULTANT



TITLE  
**Ternary Diagrams of Groundwater Upgradient (a) and  
Downgradient (b) of MW-03**

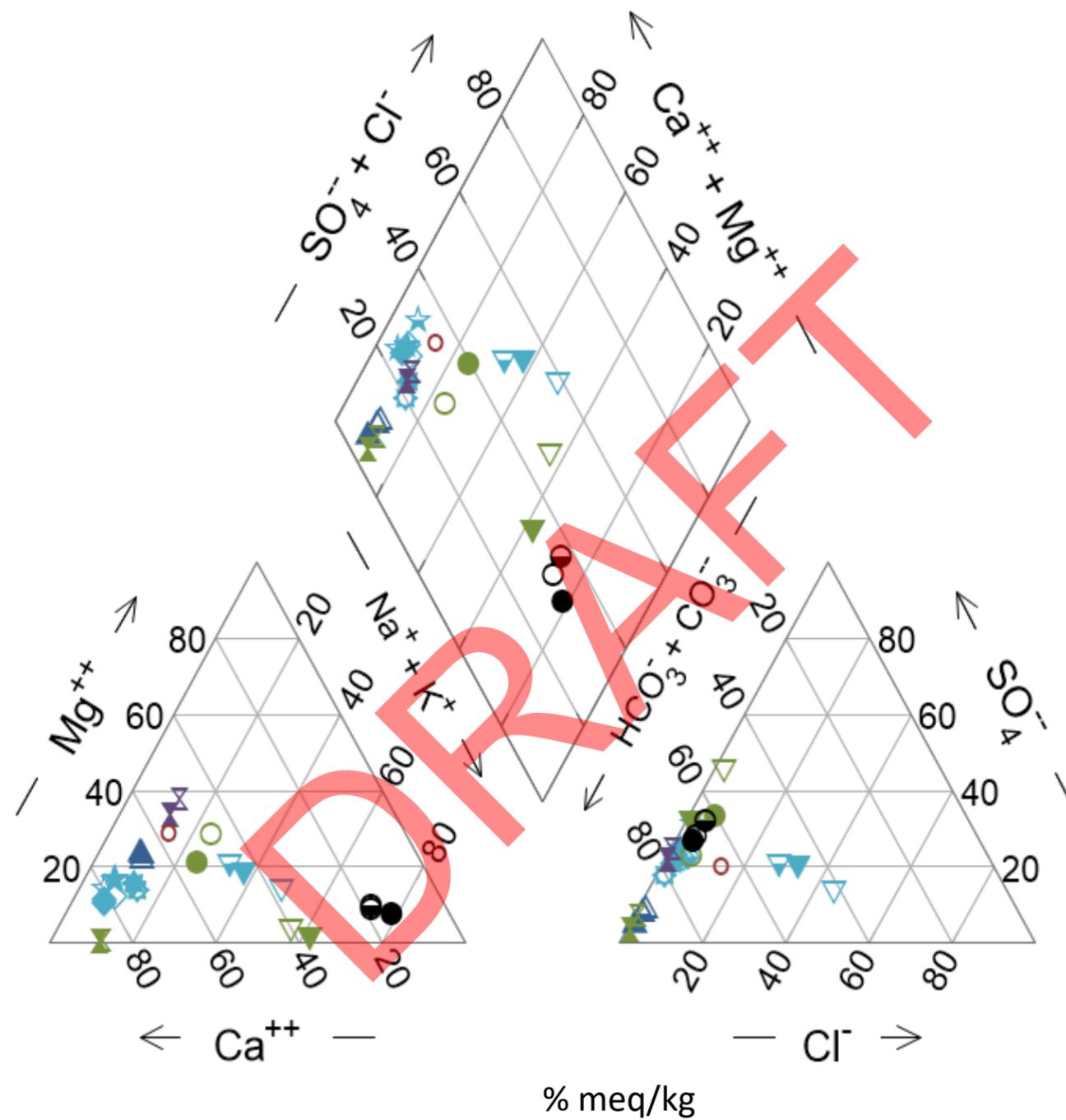
**DRAFT**

PROJECT NO.  
12393309X10

PHASE

REV.  
A

FIGURE  
10



- ◇ MW05 06-2014
- ◆ MW05 10-2014
- ◆ MW05 05-2016
- ⊗ MW06 06-2014
- ⊗ MW06 10-2014
- ▽ RBA04I 06-2014
- ▽ RBA04I 06-2014
- ▽ RBA04I 10-2014
- ☆ RBA04S 06-2014
- ☆ RBA04S 06-2014
- ☆ RBA04S 10-2014
- △ MW07 06-2014
- △ MW07 06-2014
- △ MW07 10-2014
- ⋈ MW11 10-2015
- ⋈ MW11 05-2016
- ▽ MW12 10-2015
- ▽ MW12 05-2016
- MW14 10-2015
- MW14 05-2016
- ⋈ RBH03S 10-2015
- ⋈ RBH03S 05-2016
- RBH03 06-2014
- RBH03 06-2014
- RBH03 10-2014
- Sand And Gravel

CLIENT  
CYPRUS AMAX MINERALS COMPANY

PROJECT  
FORMER SATRALLOY SITE  
FORMER MINE AREA INVESTIGATION

CONSULTANT

TITLE  
**Trilinear (Piper) Diagram of Groundwater Near MW-05 and MW-06**



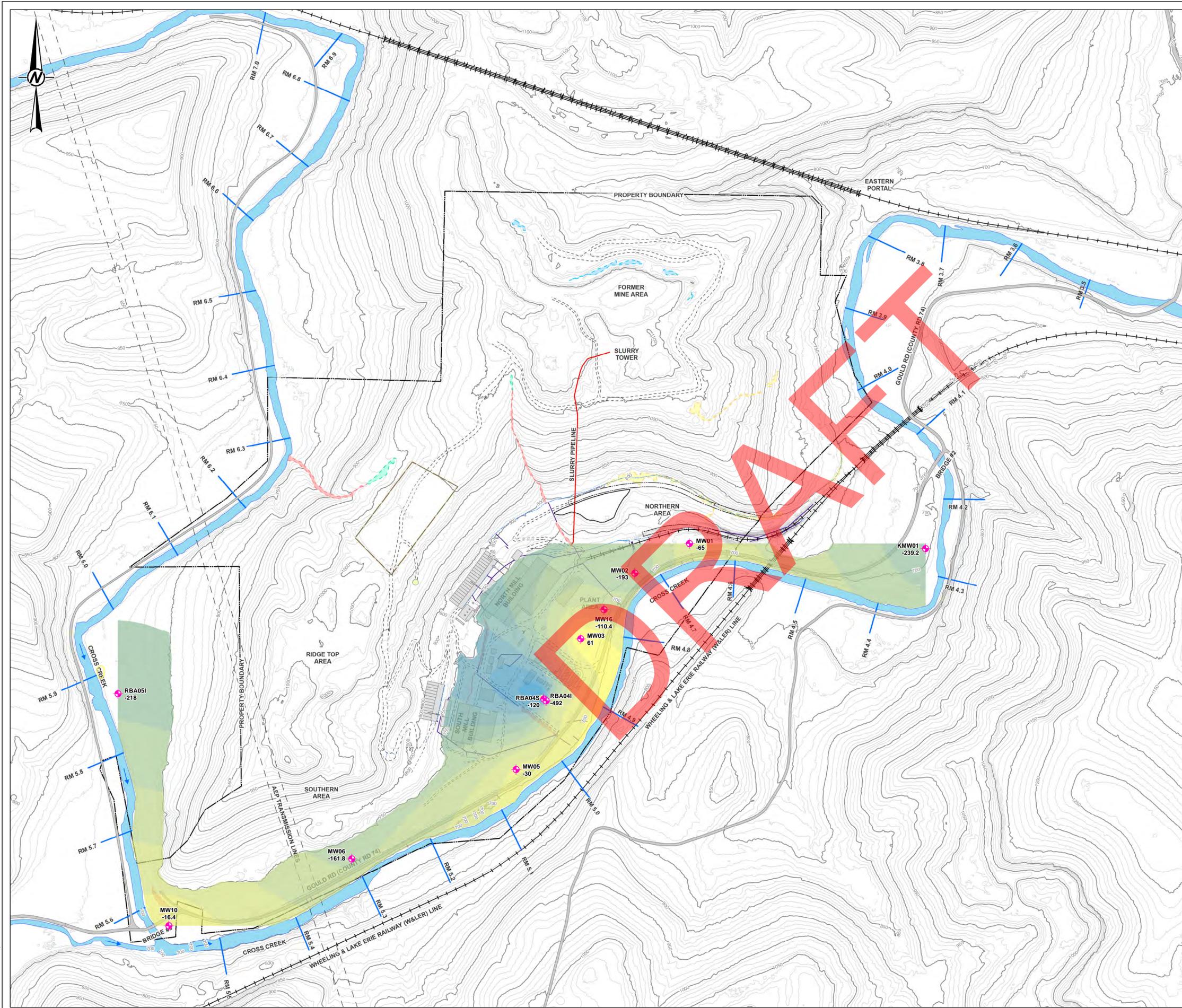
**DRAFT**

PROJECT NO.  
12393309X10

PHASE

REV.  
A

FIGURE  
11

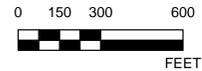


**LEGEND**

- Valley Fill
- EXISTING FACILITY
- EXISTING ON-SITE ACCESS ROAD
- COUNTY ROAD
- FENCE LINE
- CREEK FLOW
- RIVER MILE MARKER AND LABEL
- CROSS CREEK
- AEP TRANSMISSION LINE
- EXISTING PROPERTY BOUNDARY
- INHOLDING PROPERTY BOUNDARY
- EXISTING RAILROAD
- FORMER RAIL SPUR/LOW RAIL SPUR
- EXISTING SLURRY PIPELINE
- MAJOR DRAINAGE DITCH
- STORM PIPELINE
- INTERMITTENT JURISDICTIONAL WATERS OF THE U.S. (CORPS)
- PERENNIAL JURISDICTIONAL WATERS OF THE U.S. (CORPS)
- ISOLATED WETLANDS (OEPA JURISDICTION)
- OPEN WATER (NON-JURISDICTIONAL)
- CONTOUR (50 FT INTERVAL)
- CONTOUR (10 FT INTERVAL)

**Min ORP (mV)**

- 450
- 400
- 350
- 300
- 250
- 200
- 150
- 100
- 50
- 0
- 50
- 100
- 150
- 200
- 250
- 300
- 350
- 400
- 450



**NOTE(S)**

- BASE TOPOGRAPHY DATED 2003 PROVIDED BY JEFFERSON COUNTY, OHIO, ENGINEER'S OFFICE. HORIZONTAL DATUM: NAD 1983, STATE PLANE OHIO NORTH (FT) FIPS 3401. VERTICAL DATUM: NAVD88 (EST. 1991). ADDITIONAL TOPOGRAPHY BASED ON FIELD OBSERVATIONS AND MEASUREMENTS.
- PROPERTY BOUNDARY BY BONAR SURVEYING, BERGHOLZ, OHIO, DATED OCTOBER 17, 2006.
- WETLANDS DELINEATION PERFORMED IN 2015 AND 2016, PROVIDED BY WESTLAND RESOURCES, INC.
- THE RIVER MILE MARKERS SHOWN FOR CROSS CREEK ARE FROM OHIO STATE DNR WEBSITE, JUNE 2012.
- SITE ADDRESS: 4243 COUNTY ROAD 74, MINGO JUNCTION, OH 43938
- SITE INFRASTRUCTURE IS DEPICTED AS EXISTING AT THE TIME OF THE RI/F/S. SEE THE INTERIM ACTION REPORT FOR MORE RECENT MODIFICATIONS TO SITE INFRASTRUCTURE.

**REFERENCE(S)**

- JEFFERSON COUNTY (TOPOGRAPHY, 2003)
- BONAR SURVEYING (PROPERTY BOUNDARY, 2006)
- WESTLAND RESOURCES, INC. (WETLANDS, 2013)
- COORDINATE SYSTEM: NAD 1983, STATE PLANE OHIO NORTH (FT) FIPS 3401

CLIENT  
**CYPRUS AMAX MINERALS COMPANY**

PROJECT  
**SATRALLOY REMEDIAL INVESTIGATION**

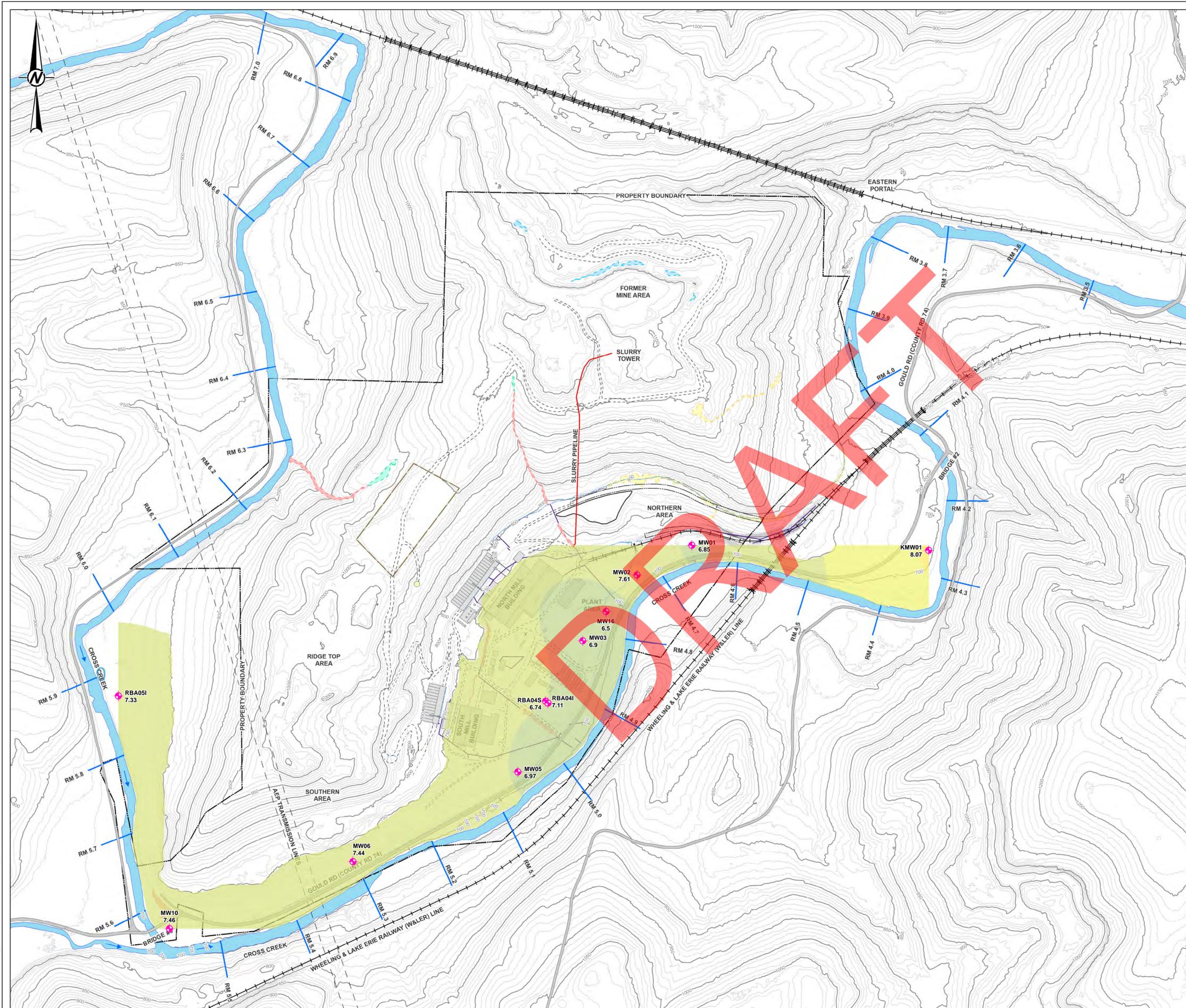
TITLE  
**ORP OF VALLEY FILL AQUIFER GROUNDWATER - MINIMUM**

CONSULTANT	YYYY-MM-DD	2022-05-03
	DESIGNED	BVJ
	PREPARED	TH
	REVIEWED	BI
	APPROVED	LH

PROJECT NO. 1239330902      PHASE 600      REV. 1      **FIGURE 12**

PATH: G:\GIS\Sheet\Satralloy\4-27-2022\1239330902\_600\_00E\_CRP.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANS/D



**LEGEND**

- Valley Fill
- EXISTING FACILITY
- EXISTING ON-SITE ACCESS ROAD
- COUNTY ROAD
- FENCE LINE
- CREEK FLOW
- RIVER MILE MARKER AND LABEL
- CROSS CREEK
- AEP TRANSMISSION LINE
- EXISTING PROPERTY BOUNDARY
- INHOLDING PROPERTY BOUNDARY
- EXISTING RAILROAD
- FORMER RAIL SPUR/LOW RAIL SPUR
- EXISTING SLURRY PIPELINE
- MAJOR DRAINAGE DITCH
- STORM PIPELINE
- INTERMITTENT JURISDICTIONAL WATERS OF THE U.S. (CORPS)
- PERENNIAL JURISDICTIONAL WATERS OF THE U.S. (CORPS)
- ISOLATED WETLANDS (OEPA JURISDICTION)
- OPEN WATER (NON-JURISDICTIONAL)
- CONTOUR (50 FT INTERVAL)
- CONTOUR (10 FT INTERVAL)

**Min pH**

- 0
- 4.5
- 5
- 5.5
- 6
- 6.5
- 7
- 7.5
- 8
- 8.5
- 9
- 9.5
- 10
- 10.5
- 11
- 11.5



**NOTE(S)**

1. BASE TOPOGRAPHY DATED 2003 PROVIDED BY JEFFERSON COUNTY, OHIO, ENGINEER'S OFFICE. HORIZONTAL DATUM: NAD 1983, STATE PLANE OHIO NORTH (FT) FIPS 3401. VERTICAL DATUM: NAVD88 (EST. 1991). ADDITIONAL TOPOGRAPHY BASED ON FIELD OBSERVATIONS AND MEASUREMENTS.
2. PROPERTY BOUNDARY BY BONAR SURVEYING, BERGHOLZ, OHIO, DATED OCTOBER 17, 2006.
3. WETLANDS DELINEATION PERFORMED IN 2015 AND 2016, PROVIDED BY WESTLAND RESOURCES, INC.
4. THE RIVER MILE MARKERS SHOWN FOR CROSS CREEK ARE FROM OHIO STATE DNR WEBSITE, JUNE 2012.
5. SITE ADDRESS: 4243 COUNTY ROAD 74, MINGO JUNCTION, OH 43938
6. SITE INFRASTRUCTURE IS DEPICTED AS EXISTING AT THE TIME OF THE RI/F/S. SEE THE INTERIM ACTION REPORT FOR MORE RECENT MODIFICATIONS TO SITE INFRASTRUCTURE.

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1. JEFFERSON COUNTY (TOPOGRAPHY, 2003)
2. BONAR SURVEYING (PROPERTY BOUNDARY, 2006)
3. WESTLAND RESOURCES, INC. (WETLANDS, 2013)
4. COORDINATE SYSTEM: NAD 1983, STATE PLANE OHIO NORTH (FT) FIPS 3401

CLIENT  
CYPRUS AMAX MINERALS COMPANY

PROJECT  
SATRALLOY REMEDIAL INVESTIGATION

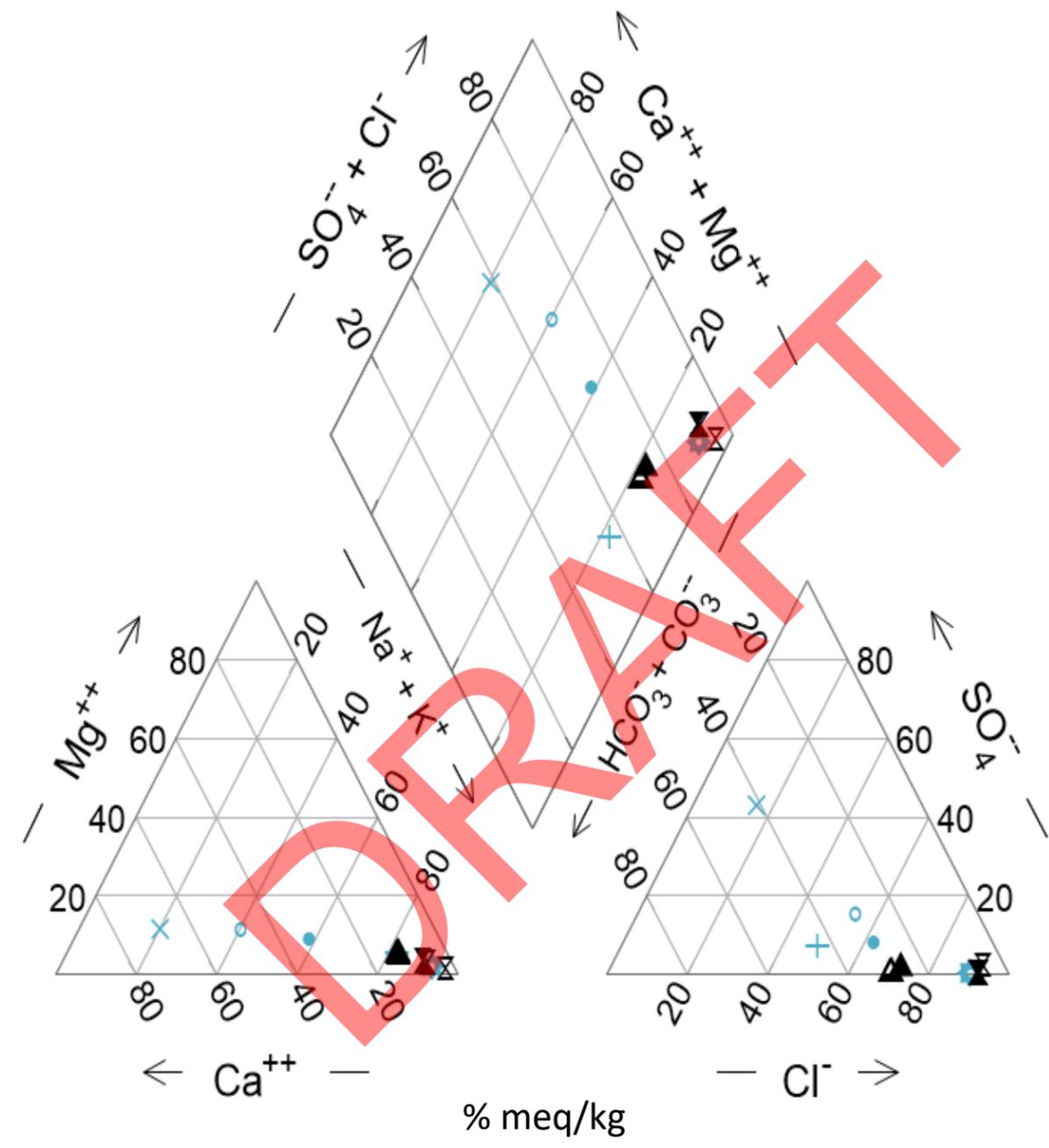
TITLE  
**pH OF VALLEY FILL AQUIFER GROUNDWATER - MINIMUM**

CONSULTANT	YYYY-MM-DD	2022-05-03
DESIGNED	BVJ	
PREPARED	TH	
REVIEWED	BI	
APPROVED	LH	

PROJECT NO. 1239330902      PHASE 600      REV. 1      **FIGURE 13**

PATH: G:\GIS\Sheet\Satralloy\4-27-2022\1239330902\_600\_00E\_pH.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANS/D



- ⊗ MW10 10-2015
- ⊗ MW10 05-2016
- RBA05I 06-2014
- RBA05I 10-2014
- × RBA05I 06-2015
- + RBA05I 10-2015
- ⊗ RBA04D 06-2014
- ⊗ RBA04D 06-2014
- ⊗ RBA04D 10-2014
- △ RBA05D 06-2014
- ▲ RBA05D 10-2014
- ▲ RBA05D 06-2015

CLIENT  
CYPRUS AMAX MINERALS COMPANY

PROJECT  
FORMER SATRALLOY SITE  
FORMER MINE AREA INVESTIGATION

CONSULTANT

TITLE  
**Trilinear (Piper) Diagram of Groundwater Near MW-10**



**DRAFT**

PROJECT NO.  
12393309X10

PHASE

REV.  
A

FIGURE  
14