

**Appendix H**  
**Mine Water Plume Location and**  
**Identification Phase I Results and Phase 2**  
**& 3 Work Plan**



**Mine Water Plume Location and Identification**  
**Phase 1 Results and Phase 2 & 3 Workplan**  
**Sterling Troy Mine**

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### **Mine Water Plume Location and Identification**

Phase 1 Results and Phase 2 & 3 Workplan  
Genesis Inc. Troy Mine

#### **1.0 INTRODUCTION**

This report summarizes results of investigations in 2000 and 2001 that were conducted to locate and identify the minewater flowpath from the decant pond at the Troy Mine tailings impoundment. Additionally, this report describes the workplan for continued investigation of the minewater flowpath in 2001 and 2002.

Phase 1 results continue to support the hypothesis that copper in minewater that is discharged to the decant ponds is strongly attenuated (immobilized) in the groundwater system, probably within a short distance of the decant ponds. Groundwater quality data suggests that the groundwater in deeper gravel/sand units near the decant ponds (e.g., units monitored by wells IW-1, MW-95-7, and MW-95-8) is derived primarily from minewater disposed in the decant ponds. This groundwater does not contain elevated copper concentrations (0.003 mg/L or less). However, tracer test results suggest that these gravel units are not the primary groundwater flowpath for decant pond water. Based on Phase 1 results and review of the local geology, it is hypothesized that a shallow gravel unit may provide the primary flowpath for transport of water from the decant ponds. While this shallow unit is believed to transport water primarily laterally away from the decant pond, some slow transport of water downward to the deeper gravels (i.e., leakage through the silts/fine sands that underlie the shallow gravel) is believed to also occur. The slow rate of the vertical transport of water to the deeper gravels is believed to account for the lack of detection of the tracer in the deeper gravels during the 2001 tracer test. Phases 2 and 3 of the evaluation include additional monitoring well drilling targeting the shallow gravel unit and an additional groundwater tracer test.

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### 1.1 BACKGROUND

The Troy Mine was developed by Asarco in 1979 and went into production in 1981. The mine was operated by Asarco until 1993 when the mine was placed on temporary shutdown. In 1999, the mine was purchased by Genesis Inc., a subsidiary of Sterling Mining Company. Since 1993, Asarco and Genesis Inc. have disposed of water from the underground workings by discharge to the impoundment in one of three ways:

- Sprinkler irrigation over the impoundment (primarily during the growing season).
- Discharge to the decant pond (also known as the barge pond).
- Discharge to the Section III pond.

The primary chemical of concern in mine water is copper, which is typically present at concentrations of approximately 0.1 mg/L. For comparison, surface water in Lake Creek adjacent to the impoundment typically contains approximately 0.003 mg/L and the chronic aquatic life standard for copper is approximately 0.004 mg/L (assuming hardness of 35 mg/L). In spite of the higher copper concentrations discharged to the impoundment, copper concentrations in Lake Creek and in monitoring wells installed in the impoundment vicinity have not increased measurably as a result of the discharge (*see* Summit, 1999; Parametrix, 1999).

The observation that mine water has been discharged with little or no apparent effect on ambient water quality has led to the preliminary consideration of continued discharge of mine water to the decant pond as a potential long-term method of mine water disposal (see Revised Reclamation Plan, Sterling 2000). In order for impoundment discharge to be considered further, both the physical flow paths and the transport and attenuation mechanisms for copper in the impoundment/groundwater system must be understood. In particular, the flow paths must be identified so that an effective groundwater monitoring system can be installed. Transport and attenuation mechanisms must be understood to determine the long-term fate of constituents in mine water and the effects of long-term discharge on ambient groundwater and stream quality.

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In September 2000, Hydrometrics prepared a “Minewater Fate and Transport Study Plan” (Hydrometrics, 2000a) to collect information needed to evaluate the fate and transport of mine water that is disposed at the decant pond. An initial obstacle to the study of fate and transport in the system is the absence of any evidence of a copper-bearing mine water discharge plume in the groundwater system. Therefore, the first phase of the fate and transport study is to locate and identify the groundwater flow paths for discharged mine water. Later phases of the study plan will identify probable fate and transport mechanisms, and evaluate potential implications under a long-term discharge scenario.

Plume location and identification is anticipated to consist of three phases as follows:

1. Sampling and evaluation of all available monitoring wells and further evaluation of water quality data.
2. Construction, sampling, and evaluation of additional excavations, borings, and wells to supplement the existing monitoring well network.
3. Tracer testing to verify plume location and flow paths

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### **1.2 PHASE 1 SUMMARY**

As initially proposed in the study plan, Phase 1 of plume location consisted of sampling and evaluation of all available monitoring wells and further evaluation of water quality data. Based on the water quality evaluation it was thought that one of the existing wells (IW-1, the “irrigation well”) was effectively monitoring the mine water plume. Therefore, a preliminary tracer test was conducted in spring 2001 to test the hypothesis that well IW-1 is located in, and monitors, the minewater plume. Results of this tracer test (summarized in Section 3 of this report) indicate that none of the existing wells is located in the primary flowpath from the pond. Based on these Phase 1 results, it is determined that additional investigations as outlined in Phases 2 and 3 of the Fate and Transport Study are needed. Workplans for Phases 2 and 3 are described in Section 4 of this report.

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### **2.0 METHODS**

Monitoring and testing plans for Phase 1 work are included in Appendices A through D. The following sections provide an overview of the plans and methods. Locations of wells near the tailings impoundment are shown on Figure 1.

#### **2.1 SAMPLING AND EVALUATION OF MONITORING WELLS**

A proposed plan for groundwater monitoring in and near the tailings impoundment was submitted to MDEQ by Genesis Inc. in August 2000. This plan (see Appendix A) proposed sampling of 9 wells near the impoundment (MW-1, MW-2, MW-3, MW-4, MW-95-5, MW-95-7, MW-95-8, IW-1 or the Irrigation well, and the Quonset hut well). All of the wells were sampled on September 7, 2000 except for MW-95-7 which was dry. Wells MW-95-5 and MW-95-8 were sampled by bailing with disposable plastic bailers. The remaining wells were sampled with submersible pumps.

#### **2.2 TRACER TEST**

Tracer testing at the decant pond consisted of adding salt (NaCl or sodium chloride) to the mine water flowing to the decant pond to raise the TDS, specific conductivity, sodium, and chloride concentrations of water in the decant pond to levels much higher than ambient groundwater. At the same time, monitoring of groundwater in adjacent wells was conducted in order to identify increases in these chemical parameters in groundwater and thus locate the minewater flowpath in the groundwater system. Methods of conducting the tracer test were originally described in a December 4, 2001 letter from Sterling Mining Co. (Frank Duval) to MDEQ (Abe Horpestad) proposing the test and requesting permission from DEQ to run the test (see Appendix B). As originally proposed, the tracer test was to consist of adding salt to the minewater inflow to the decant pond at the rate of approximately 500 pounds per day for a period of about 18 days. MDEQ granted approval to conduct the tracer test on January 22, 2001 (see Appendix B).

### **FIGURE 1 MONITORING WELL LOCATIONS**

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In February 2001, it was recognized that minewater flows were sufficiently low that all minewater flows to the decant pond could be suspended for a period of about 2 weeks. Without minewater inflows to the pond, it was believed that it would be easier to simply add the salt to the pond as a “slug” and eliminate the need for daily salt additions. Moreover, it was believed that slug addition of salt would result in more constant salt concentrations in the pond and overall a better tracer test. The testing protocol was revised in a February 2, 2001 letter to MDEQ (see Appendix C). The revised testing protocol also provided a monitoring schedule and analytical parameter list.

During preparation for the tracer test it was discovered that the system for remote monitoring of some wells in the tailings impoundment area were not functioning, perhaps as the result of snowplowing to access the wells. Therefore, the monitoring schedule for the tracer test was revised to eliminate remote monitoring (see Appendix D).

The tracer test was conducted during the period of March 8 to May 31, 2001. In general, monitoring during the test followed the schedule outlined in Table 1 of Appendix D. A timeline and summary of the tracer test is as follows:

- March 8 – All wells and decant ponds were sampled to collect baseline water quality data for major ions, nutrients, and metals prior to tracer (salt) addition. Decant pond cell #3 and well MW-97-14 were dry and could not be sampled.
- March 12 – Salt addition started at 8 am; 5 tons of salt were added by 9:50 am and 10 tons of salt were added by 11:45 am. Salt was added to the reclaim water pipeline at the mill pond. At 2:30 pm, monitoring of the decant pond specific conductivity was started.
- March 13 – Mine water flows to decant pond were shut off at 5 pm. Decant pond staff gage installed. Decant pond specific conductivity monitoring continued (3 times daily) and daily sampling of wells IW-1, MW-95-3, MW-95-7, and MW-95-8 was initiated.
- March 16 – Decant pond monitoring continued on a daily basis.

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- March 14 through April 2 – Daily sampling of wells (IW-1, MW-95-3, MW-95-7, and MW-95-8) and decant ponds continued. (March 18 – Decant pond #3 dry and no longer sampled. March 30 – Well MW-95-8 dry and could not be sampled.)
- April 2 – All wells, including MW-1 through MW-4, MW-95-5, and MW-97-12 sampled prior to reduction in monitoring frequency to weekly.
- April 9 – Mine water flow to decant pond resumed; water from section 3 pond allowed to flow to decant pond.
- April 9 through May 31 – Weekly sampling of wells and decant ponds continued. (April 25, decant pond #2 dry and could no longer be sampled. May 31, well MW-95-8 again contained water and was sampled.)
- May 31 – Tracer test terminated.

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### **3.0 PHASE 1 RESULTS**

Phase 1 results continue to support the hypothesis that copper in minewater that is discharged to the decant ponds is strongly attenuated (immobilized) in the groundwater system, probably within a short distance of the decant ponds. Groundwater quality data suggests that the groundwater in deeper gravel/sand units near the decant ponds (e.g., units monitored by wells IW-1, MW-95-7, and MW-95-8) is derived primarily from minewater disposed in the decant ponds. This groundwater does not contained elevated copper concentrations (0.003 mg/L or less). However, tracer test results suggests that these gravel units are not the primary groundwater flowpath for decant pond water. Based on Phase 1 results and review of the local stratigraphy (see Section 4), it is hypothesized that a shallow gravel unit may provide the primary flowpath for transport of water from the decant ponds. While this shallow unit is believed to transport water primarily laterally away from the decant pond, some slow transport of water downward to the deeper gravels (i.e., leakage through the silts/fine sands that underlie the shallow gravel) is believed to also occur. The slow rate of the vertical transport of water to the deeper gravels is believed to account for the lack of detection of the tracer in the deeper gravels during the relatively short duration of the tracer test.

#### **3.1 GROUNDWATER SAMPLING AND EVALUATION**

Groundwater quality data for wells around the decant ponds was collected three times in the past year (September 2000, March 2001, April 2001). Comparisons of groundwater quality data and minewater/decant pond water are provided in Tables 1 through 3 and Piper diagrams in Appendix E. As these comparisons indicate, groundwater in wells near the decant pond (IW-1, MW-95-8, MW-95-7) has an overall chemical signature that is very similar to the decant pond with the exception of the lack of copper in groundwater. This is true not only of major ion chemistry as shown by the Piper diagrams, but also nitrate + nitrite concentration (see Tables 1-3). Of particular note on the Piper diagrams is the seasonal shift in decant water composition and corresponding shifts in groundwater composition between September 2000 and March 2001.

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**TABLE 1 SEPTEMBER 2000 WATER QUALITY DATA**

	Service Adit Minewater	IW-1	QW-1	MW-4	MW-2	MW-3	MW-1	MW95-8	MW95-5
Alkalinity.	76	72	24	16	156	124	108	170	170
Arsenic	0.003	<0.003	<0.003	<0.003	0.027	0.01	0.007	<0.003	0.003
Calcium	23	26	7	4.3	29	36	33	62	47
Carbonate	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Copper	0.056	0.002	0.001	<0.001	<0.001	0.001	<0.001	0.003	0.003
Iron	<0.020	<0.020	0.16	<0.020	<0.020	7.8	7.7	<0.020	30
Hardness	81	86	24	15	109	106	103	184	171
Bicarb.	76	72	24	16	156	124	108	170	170
Potassium	<2	<2.0	<2.0	<2.0	2.7	1.1	1.5	2.1	10
Magnesium	5.5	5	1.7	1	8.7	4	5.3	6.9	13
Manganese	0.024	0.081	0.018	0.04	0.25	0.66	0.57	<0.005	4.8
Sodium	NA	3	<2.0	<2.0	21	5.1	4.9	2.5	7.7
Ammonia	0.1	0.061	<0.050	0.13	0.43	0.39	0.11	0.051	0.21
Nitrate+nitrite	0.69	0.69	<0.050	0.11	0.094	<0.050	0.12	1.2	0.075
Lead	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
pH	8.3	7.2	6.3	6.6	7.5	6.9	6.9	7.9	6.3
Antimony	0.009	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Silica	NA	9.3	8.4	7.5	11	28	22	11	65
Sulfate	15	19	3.9	2.6	<2.0	<2.0	9.1	15	7.3
TDS	112	115	52	36	197	166	159	235	361
Zinc	<0.010	<0.010	0.32	0.023	<0.010	<0.010	<0.010	0.19	0.35

Note: All units (mg/L) except pH (std. units), alkalinity, carbonate, bicarbonate and hardness (all mg/L as CaCO<sub>3</sub>), ammonia and nitrate + nitrite (mg/L as N). All metals are dissolved.

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**TABLE 2. MARCH 2001 WATER QUALITY DATA (BEFORE TRACER TEST)**

	MW 95-5	MW 95-4	MW 95-3	MW 97-12	MW-1	MW-2	MW-3	MW-4	MW 95-7	MW 95-8	IW-1	DECANT POND 1	DECANT POND 2
Alkalinity.	154.	22.	89.	61.	114.	21.	113.	168.	71.	81.	75.	74.	76.
Arsenic	0.008	0.004	<0.002	<0.002	0.006	<0.002	0.019	0.029	0.002	<0.002	<0.002	<0.002	<0.002
Calcium	46.	38.	130.	12.	35.	4.6	32.	30.	30.	41.	28.	31.	30.
Chloride-	3.9	4.2	2.7	3.0	2.1	<1.0	1.1	<1.0	<1.0	1.1	<1.0	<1.0	<1.0
Carbonate	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Copper	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.049	0.043
Iron	36.	17.	0.22	0.20	6.9	<0.030	12.	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Hardness	171.	139.	503.	54.	111.	16.	97.	112.	92.	125.	98.	116.	113.
Bicarb.	154.	22.	89.	61.	114.	21.	113.	168.	71.	81.	75.	74.	76.
Potassium	11.	24.	74.	5.3	1.1	<1.0	<1.0	2.4	<1.0	<1.0	<1.0	<1.0	<1.0
Magnesium	13.	11.	43.	5.6	5.7	1.1	3.9	9.0	4.1	5.6	6.7	9.5	9.1
Manganese	5.8	3.0	0.99	0.10	0.55	0.14	0.59	0.24	<0.005	<0.005	<0.005	0.040	0.037
Sodium	9.0	35.	53.	5.8	5.6	<1.0	5.4	23.	1.3	1.3	2.0	1.6	1.5
Ammonia	0.60	4.2	10.	<0.10	<0.10	0.20	0.30	0.42	<0.10	<0.10	<0.10	<0.10	<0.10
Nitrate+nitrite	0.19	0.31	<0.10	<0.10	0.32	0.13	<0.10	<0.10	1.1	1.6	0.79	1.6	1.4
Lead	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
pH	8.0	6.6	7.9	6.7	8.0	6.9	7.2	8.2	8.1	8.4	8.1	8.3	8.2
Antimony	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.011	0.011
Silica	58.	43.	10.	54.	25.	10.	30.	13.	12.	9.8	9.8	8.1	8.3
Sulfate	9.2	292.	693.	14.	9.6	5.3	1.4	1.2	27.	41.	25.	39.	42.
TDS	284.	406.	1060.	150.	160.	31.	178.	197.	136.	164.	133.	171.	164.
Zinc	<0.010	<0.010	<0.010	<0.010	<0.010	0.013	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010

Note: All units (mg/L) except pH (std. units), alkalinity, carbonate, bicarbonate and hardness (all mg/L as CaCO<sub>3</sub>), ammonia and nitrate + nitrite (mg/L as N). All metals are dissolved.

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**TABLE 3. APRIL 2001 WATER QUALITY DATA (AFTER TRACER ADDITION PERIOD)**

	DECANT POND-1	DECANT POND-2	MW-95-3	MW-95-7	IW-1
Alkalinity.	50.	76.	146.	220A	70.
Arsenic	<0.002	<0.002	0.002	<0.002	<0.002
Calcium	22.	30.	130.	32.	26.
Chloride-	96.	67.	2.6	1.3	<1.0
Carbonate	<1.0	<1.0	<1.0	<1.0	<1.0
Copper	0.040	0.036	<0.002	0.002	<0.002
Iron	<0.050	<0.050	<0.050	<0.050	<0.050
Hardness	82.	113.	502.	96.	90.
Bicarb.	50.	76.	146.	220A	70.
Potassium	1.6	1.9	79.	1.8	1.5
Magnesium	6.5	9.2	43.	4.2	6.2
Manganese	0.053	0.036	1.0	<0.005	<0.005
Sodium	51.	38.	56.	1.5	2.8
Ammonia	<0.10	<0.10	12.	0.12	<0.10
Nitrate+nitrite	0.80	1.5	<0.050	1.0	0.71
Lead	<0.002	<0.002	<0.002	<0.002	<0.002
pH	7.8	8.0	7.8	7.9	8.0
Antimony	0.007	0.010	<0.005	<0.005	<0.005
Silica	7.0	7.3	10.	11.	13.
Sulfate	33.	40.	730.	31.	24.
TDS	243.	246.	1051.	160.	135.
Zinc	<0.010	<0.010	<0.010	<0.010	<0.010

Note: All units (mg/L) except pH (std. units), alkalinity, carbonate, bicarbonate and hardness (all mg/L as CaCO<sub>3</sub>), ammonia and nitrate + nitrite (mg/L as N). All metals are dissolved. Alkalinity and bicarbonate values for MW-95-7 are suspected to be in error (cation/anion balance is significantly off); 70 mg/L assumed for Piper diagram in Appendix E.

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### 3.2 TRACER TEST

The addition of salt to the decant ponds caused the following changes in decant pond water chemistry:

- increased the specific conductivity (SC) of the decant ponds to approximately 400 to 700 micromhos/cm (2 to 3 times higher than ambient groundwater, i.e. IW-1, MW-95-7 and MW-95-8);
- increased the sodium concentration to 40 to 90 mg/L (20 to 50 times higher than ambient groundwater); and
- increased the chloride concentration to 60 to 160 mg/L ( 60 to 160 times higher than ambient groundwater).

The premise of the tracer test is that because SC, sodium, and chloride were elevated in the decant pond by the salt addition, the presence of increased concentrations of these parameters in ambient groundwater would demonstrate a connection (i.e., a groundwater flowpath) between the decant ponds and the monitoring wells. Because of residual process water within the tailings, the specific conductivity and sodium concentrations in water in well MW-95-3 (completed in the tailings west of the decant ponds) were similar to, or higher than decant pond water prior to, during, and after the tracer test. Therefore, the presence of increased SC and sodium in well MW-95-3 is unrelated to the addition of salt to decant pond water.

#### 3.2.1 Chemical Effects of the Tracer on Groundwater

Results of the groundwater tracer test are shown in the trend plots (SC, sodium, chloride versus time) in Appendix F. Overall, there was no meaningful increase in concentrations of the tracer (salt) in any monitoring wells during the test. Therefore, the tracer test indicates poor hydrologic connection (low or slow rate of flow) between the decant ponds and the units in which the monitoring wells are completed. As noted above, groundwater quality data suggests that the groundwater in deeper gravel/sand units near the decant ponds (e.g., units monitored by wells IW-1, MW-95-7, and MW-95-8) is derived primarily from

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minewater disposed in the decant ponds. However, tracer test results suggests that these gravel units are not the primary groundwater flowpath for decant pond water.

### 3.2.2 Decant Pond Infiltration Rate

Water levels in the decant ponds were monitored over the course of the tracer addition period (24 days, from March 13 to April 6) while no water was discharged to the ponds. Based on the volume of water lost from the ponds over this period it is possible to calculate an infiltration rate for the ponds. Decant pond #1 and decant pond #2 have surface areas of approximately 3.2 and 1 acres, respectively and during the tracer addition period, water levels in the ponds dropped 10.7 and 8.8 feet, respectively. Total volume of water infiltrated through the ponds is therefore approximately 14 million gallons. Since the tracer addition period was 34,380 minutes, the average infiltration rate for the period was about 400 gpm or about 0.2 in/hr (0.4 ft/day).

The calculated infiltration rate is not particularly high and is in the range of what might be expected for a fine sand. However, this infiltration rate implies that the hydraulic conductivity of the groundwater aquifer that transports the minewater away from the decant pond is much larger, perhaps on the order of 500 ft/day or more, typical of coarse sands or gravel. The decant ponds have a large surface area for infiltration (about 180,000 ft<sup>2</sup>) and the hydraulic gradient in the pond is 1 (vertical gradient). In the groundwater system near the pond it is likely that the gradient is much less than 1 (i.e. flow is not strictly vertical but likely has a large horizontal component) and the cross-sectional area of the aquifer is likely a fraction of the surface area of the ponds. Given the likely much lower gradient and smaller area of the aquifer in the flowpath, the aquifer would have to have a much higher hydraulic conductivity to transmit the flow from the decant ponds.

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### 4.0 PHASE 2 AND 3 WORKPLAN

#### 4.1 CONCEPTUAL MODEL OF HYDROGEOLOGIC SYSTEM

Groundwater in the Lake Creek Valley occurs in glaciolacustrine deposits and alluvium (Levings et al, 1984). Within the glaciolacustrine deposits groundwater occurs primarily in the sand, gravel, and cobble zones. Silt and clay zones within the glaciolacustrine deposits are confining beds that restrict vertical ground-water movement. Although the general directions of groundwater movement in the area are likely towards the north (in the general direction of flow in Lake Creek) and towards the west (toward Lake Creek), local groundwater flow directions are likely controlled primarily by the location and orientation of permeable water bearing zones within the glaciolacustrine and alluvial deposits.

Previous monitoring well drilling (see Summit and MF&G, 1996) and geotechnical boring investigations (see Woodward-Clyde, 1977) in the area have identified the presence of sand and gravel zones within the glaciolacustrine deposits in the general vicinity of the decant ponds. As summarized in the Draft EIS (p. 103),

”The surficial geology of the pond [tailing impoundment] site reflects the complex geology of the area and varies from fine-grained clayey silts to coarse rock and gravel. The coarser deposits tend to be nearer the edge of the valley and along the lower reaches of Camp Creek. Test wells and test holes also reflect the complex geology of the area with substantial vertical variations in materials encountered.”

The most notable sand and gravel occurrences in wells and test holes are summarized in Table 4. Data from wells and test holes suggest permeable gravels are located at or near the surface near the decant ponds and extending to the east and south of the ponds. Gravels are also present at depth near the decant ponds and to the west of the impoundment near Lake Creek. Groundwater sampling and

## REVIEW DRAFT

tracer testing in spring 2001 indicate that the groundwater in deeper gravel/sand units near the decant ponds (e.g., units monitored by wells IW-1, MW-95-7, and MW-95-8) is derived primarily from minewater disposed in the decant ponds. However, tracer test results suggests that these gravel units are not the primary groundwater flowpath for decant pond water. Based on Phase 1 results and review of the local stratigraphy (see Section 4), it is hypothesized that the shallow gravel unit may provide the primary flowpath for transport of water from the decant ponds. While this shallow unit is believed to transport water primarily laterally away from the decant pond, some slow transport of water downward to the deeper gravels (i.e., leakage through the silts/fine sands that underlie the shallow gravel) is believed to also occur. The slow rate of the vertical transport of water to the deeper gravels is believed to account for the lack of detection of the tracer in the deeper gravels during the relatively short tracer test.

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**TABLE 4. IDENTIFIED PERMEABLE ZONES IN THE VICINITY OF  
THE DECANT PONDS**

Well/Boring	Location	Zone Description	Other
MW-95-7	Approx. 250 feet east southeast of decant pond #3	Gravel 0 to 18 ft bgs;	Well screened 79 to 89 ft bgs.
MW-95-8	Approx. 50 feet north of decant pond #1, north side of Section 2/3 divider dike.	Gravel, cobbles, sand 0 to 20 ft bgs;	Well screened 48 to 53 ft bgs.
IW-1	Approx. 20 feet north of decant pond #1.	No drilling logs can be found, Asarco internal memos refer to well as screened in “lower sand and gravel aquifer”.	Well screened 190 to 210 ft bgs.
MW-1	Approx. 4,000’ northwest of decant ponds between dike and Lake Creek	Clean sand and gravel 160 to 280 bgs	Well perforated 55’ to 100’ bgs in silt/clay and 160’ to 280’t bgs
MW-3	Approx. 3,000’ west of decant ponds between dike and Lake Creek.	Sand and gravel 118 to 125’ bgs	Open-ended casing
TH-10	Section 2 approx. 1,000’ west of decant ponds	Very gravelly sand 8 to 40’ bgs	Field permeability 4,400 ft/yr
TH-11	In section 1 approx. 800’ south of decant ponds	Gravel 0 to 40’ bgs	Field permeability 8,100 ft/yr
TH-12	Southeast portion section 2; approx. 1200 feet southwest decant ponds	Gravelly sand to gravel 5 to 40’bgs	Field permeability 1,100 ft/yr

\*bgs = below ground surface.

**4.2 PHASE 2 MONITORING WELL INSTALLATION AND TESTING**

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The primary target for additional borings and well construction is shallow gravel and cobble units similar to the shallow materials encountered in well MW-95-8 (located 50 feet north of the decant pond), well MW-95-7 (located approximately 250 feet east of the decant pond), and exposed in the terraces immediately to the northeast of the decant pond. The quantity of water disposed in the decant pond (greater than 1,000 gpm or more at times) requires that the pond must be underlain by a relatively permeable unit in order to percolate and transmit the disposed water. The presence of approximately 20 feet of “gravel, cobbles and sand” material at MW-95-8 and MW-95-7 (Appendix II in MFG and Summit, 1996) suggests that surficial gravel materials are a likely conduit for mine water flows.

In summer 2001, excavations were made adjacent to the decant pond in an attempt to locate the surficial gravel materials and install monitoring wells as proposed in the first step in Phase II of the Fate and Transport Study (Hydrometrics, 2000). Although the surface of the tailings near the ponds is stable and workable by heavy equipment, it was not possible to maintain an open excavation sufficient to reach the base of the tailings. Therefore, future work will require drill rigs.

The proposed drilling program to install monitoring wells is anticipated to require one or two phases, Phases 2a and 2b. Phase 2a will include initial well installation to find and identify the groundwater flow path(s) from the decant ponds. Phase 2a will be comprised of wells relatively close to the ponds. Proposed Phase 2a monitoring well locations are shown on Figure 1. Wells are proposed to the west of decant pond #1, south of decant pond #1, south of decant pond #2, north of decant ponds #1 and #2 near the pond divider dike, and east of decant pond #3. Anticipated depth of completion of the wells is 20 to 40 feet, within the shallow gravel zone. Typical monitoring well construction details are shown on Figure 2. Actual well locations and construction details will be selected in the field and may be modified based on field conditions. Wells will be

## **REVIEW DRAFT**

developed after well construction by pumping with a submersible pump, purging with rig air, bailing, or surging with a block.

Phase 2b of well installation will include wells completed further downgradient in the groundwater flowpath(s) identified in Phase 2a. The exact number and locations of Phase 2b wells will be determined based on Phase 2a results.

Monitoring wells completed in Phase 2 will be sampled after well development for the water quality parameters listed in Table 2.

### **4.3 PHASE 3 GROUNDWATER TRACER TEST**

The need for another groundwater tracer test will be determined based on the results of monitoring well installation and sampling. If a chemical tracer from minewater (i.e., copper) can be found in the monitoring wells then tracer testing may not be needed. If it is believed that the minewater flowpath has been found but minewater can not be definitively identified in groundwater based on water quality analyses, then a tracer test will be conducted. Protocol for the tracer test would be developed at that time, similar to the protocol used in spring 2001 (e.g. see Appendix D).

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**TABLE 2 ANALYTICAL PARAMETERS FOR GROUNDWATER  
MONITORING AT THE TROY MINE**

Analytical Parameter	Required Reporting Value * (mg/L)	Analytical Method **
<i>Common Ions and Physical Parameters</i>		
pH	0.1 S.U.	EPA 150.1
TDS	(10)	EPA 160.1
Calcium	(1)	EPA 6010
Magnesium	(1)	EPA 6010
Hardness	(1)	ASTM 2340B
Potassium	(2)	EPA 6010
Sodium	(1)	EPA 6010
Total Alkalinity as CaCO <sub>3</sub>	(1)	EPA 310.1
Bicarbonate	(1)	EPA 310.1
Carbonate	(1)	EPA 310.1
Chloride	(1)	EPA 300.0
Sulfate	(1)	ASTM 9036
Silica	(0.1)	EPA 6010
Temperature (field)	0.1 °C	(field)
Specific Conductivity (field)		(field)
Static Water Level (field)		(field)
<i>Nutrients</i>		
Ammonia as N	0.05	EPA 350.1
Nitrate + Nitrite as N	0.01	EPA 353.2
<i>Dissolved Metals (filtered sample)</i>		
Antimony	0.003	EPA 6020M
Arsenic	0.003	EPA 6020M
Copper	0.001	EPA 6020M
Iron	0.01	EPA 6010/6020
Lead	0.003	EPA 6020M
Manganese	0.005	EPA 6020M
Zinc	0.01	EPA 6020M

\* Values in parentheses are detection limit goals, no RRVs exist for these parameters.

\*\* Dissolved metals will be analyzed by ICP-MS (methods 6010, 6020, or 6020M).

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**FIGURE 2 TYPICAL SHALLOW MONITORING WELL  
CONSTRUCTION**

## **REVIEW DRAFT**

### **5.0 REFERENCES**

- Hydrometrics, 2000. Minewater Fate and Transport Study Plan – Draft.  
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- Summit Envirosolutions, 1999 Site Instrumentation Status Report Troy Tailings  
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- Woodward-Clyde Consultants, 1977. Phase II Geotechnical Services, Troy  
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**APPENDIX A**

**GROUNDWATER MONITORING PROPOSAL**  
**(August 16, 2000 letter from Genesis Inc. to MDEQ)**

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**APPENDIX B**

**TRACER TEST PROPOSAL, REQUEST AND APPROVAL**

**(December 4, 2001 letter from Genesis Inc. to MDEQ)**

**(January 22, 2001 letter from MDEQ to Genesis Inc.)**

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**APPENDIX C**

**TRACER TEST PROTOCOL REVISION 1**  
**(February 2, 2001 letter from Hydrometrics to MDEQ)**

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February 2, 2001

Mr. Joe Gurrieri  
MT Dept. of Environmental Quality  
PO Box 200901  
Helena, MT 59620-0901

RE: Groundwater Tracer Test at the Troy Mine

Dear Joe:

Sterling Mining Company received permission from MDEQ (Abe Horpestad) to proceed with the tracer test at the Genesis Inc. Troy Mine and was requested by Abe to inform you of our progress. Because minewater flows and conditions at the decant ponds have changed somewhat since the tracer test proposal was submitted in early December, we are planning to modify the test procedure. This letter describes the modifications to the tracer test and our final proposed monitoring schedule.

Schedule

We are tentatively planning to start the test the week of February 12, 2001 and would like you to observe the test, if possible. This schedule is contingent on our testing and identifying an appropriate method to add the salt to the ponds. As we have discussed, it will be important to make sure that all of the salt is dissolved quickly in the ponds. We will do some testing of salt additions prior to the start of the actual tracer test. We will inform you of any changes to this schedule.

Test Modification

Based on current conditions in the ponds and mine water flow rates, we now plan to add all of the salt to the ponds (approximately 10 tons) and cease all minewater flows to the ponds for the duration of the salt addition period (approximately 1 to 2 weeks).

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As described in Sterling's tracer test proposal, in December the decant ponds contained approximately 12 million gallons of water and mine water inflows to the ponds were approximately 470 gpm. Based on these water volumes, we intended to add approximately 5 tons of salt to the ponds to achieve the desired initial TDS concentration in the ponds. Then approximately 500 pounds of salt would be added daily to maintain this TDS.

Currently, the volume of water in the ponds is much higher (21 million gallons) and minewater flows are much lower (around 200 gpm). At these flow rates, Sterling can divert all minewater flows to the thickener and mill water pond for storage and thereby eliminate minewater flows to the decant ponds for a period of approximately 1 to 2 weeks (actual duration of minewater storage will depend on precipitation runoff to mill water pond during this period). Given these conditions, we believe that it will be easier to simply add the salt to the pond as a "slug" and eliminate the need for daily salt additions. Moreover, this will result in more constant TDS concentrations in the pond. Therefore, we intend to add all of the salt to the pond over an approximately 8 hour period. We plan to add the salt into the tailings reclaim water line (the buried 10-inch line that goes from the mill water pond to the decant pond) at the mill water pond. At the end of the salt addition the reclaim water line will be turned off and minewater flow will be diverted to the thickener and/or mill water pond

### Proposed Monitoring Schedule

The overall schedule for monitoring is described in attached Table 1. In this table, "tracer addition period" means the period after the salt has been added to the pond and during the period that mine water is not discharged to the pond.

Prior to tracer addition, the decant pond and adjacent monitoring wells (Irrigation Well, MW-95-3, MW-95-7, and MW-95-8) will be sampled and analyzed for major ion, nutrient, metals and physical parameters according to the schedule in the attached Table 2. Wells around the perimeter of the impoundment will also be sampled for the complete analytical schedule.

During tracer addition, the specific conductivity (SC) of the various waters will be measured daily to track TDS concentrations and waters will be sampled weekly for sodium and chloride. Waters to be monitored include the decant pond and adjacent monitoring wells and wells that can be remotely monitored. Specific conductivity will be measured at four points (1 point along each side) in each pond. To document mixing in the ponds, specific conductivity in the ponds will be measured three times per day during the first 3 days of the test.

If the tracer is detected at adjacent monitoring wells during the tracer addition period, then the decant pond and adjacent monitoring wells will be sampled and analyzed for major ion, nutrient, and metal parameters according to the schedule in Table 2.

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At the end of the tracer addition period, the decant pond and adjacent monitoring wells will be sampled and analyzed for major ion, nutrient, and metal parameters (Table 2). Perimeter monitoring wells will be sampled and analyzed for specific conductivity, sodium, and chloride. If the specific conductivity of any perimeter well is more than 10 percent higher than pre-test baseline conductivity, then the well will be sampled for a full suite of analytical parameters (Table 2).

If the tracer has not been detected at adjacent monitoring wells by the end of the tracer addition period, monitoring of SC will be continued on a daily basis for an additional two weeks, then on a weekly basis thereafter. Sodium and chloride will also be monitored weekly in the adjacent wells until the test is terminated.

At the end of the tracer test, the decant pond and adjacent monitoring wells will be sampled and analyzed for major ion, nutrient, and metal parameters (Table 2). Perimeter monitoring wells will be sampled and analyzed for specific conductivity, sodium, and chloride. If the specific conductivity of any perimeter well is more than 10 percent higher than pre-test baseline conditions, then the well will be sampled for a full suite of analytical parameters (Table 2).

Water levels in the ponds will be monitored with staff gages throughout the test. Static water levels in the wells will be monitored at the time of sampling, or in instrumented wells, continuously throughout the test.

The decision of when to terminate the test will be based on monitoring results and will be coordinated with DEQ.

Please let me know if you would like any modifications to this test. I look forward to seeing you on Site for this tracer test.

Sincerely,

Scott Mason  
Geochemist

c: Bruce Clark  
Frank Duval

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**Table 1. Monitoring Schedule for Troy Tracer Test**

Monitoring Location	Pre-Test Baseline	Tracer Addition Period			End of Tracer Addition Period		Post Tracer Addition Period			End of Test	
	Major Ions, Nutrients, & Metals (see Table 2)	Continuous Specific Conductivity	Daily Specific Conductivity & Water Level	Weekly Sodium and Chloride	Major Ions, Nutrients, & Metals (see Table 2)	Sodium, Chloride, & Specific Conductivity Only	Continuous Specific Conductivity	Daily Specific Conductivity & Water Level	Weekly Sodium and Chloride	Major Ions, Nutrients, & Metals (see Table 2)	Sodium, Chloride, & Specific Conductivity Only
Decant Pond 1 *	Yes		Yes **	Yes	Yes			Yes	Yes	Yes	
Decant Pond 2 *	Yes		Yes **	Yes	Yes			Yes	Yes	Yes	
Decant Pond 3 *	Yes		Yes **	Yes	Yes			Yes	Yes	Yes	
Irrigation Well	Yes		Yes	Yes	Yes			Yes	Yes	Yes	
MW-95-8	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	
MW-95-7	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	
MW-95-3	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	
MW-95-4	Yes	Yes	Yes		?	Yes	Yes	Yes		?	Yes
MW-97-12	Yes	Yes	Yes		?	Yes	Yes	Yes		?	Yes
MW-97-14	Yes	Yes	Yes		?	Yes	Yes	Yes		?	Yes
MW-95-5	Yes	Yes	Yes		?	Yes	Yes	Yes		?	Yes
MW-1	Yes				?	Yes				?	Yes
MW-2	Yes				?	Yes				?	Yes
MW-3	Yes				?	Yes				?	Yes
MW-4	Yes				?	Yes				?	Yes

Notes:

? Well will be sampled for major ions, nutrients, and metals per Table 2 only if specific conductivity is 10% or more greater than pre-test result.

\* Specific conductivity will be measured at four points (1 point along each side) in each pond.

\*\* Specific conductivity will be measured three times per day during the first 3 days of the test to document mixing in the ponds.

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**TABLE 2 ANALYTICAL PARAMETERS FOR GROUNDWATER  
MONITORING AT THE TROY MINE**

Analytical Parameter	Required Reporting Value * (mg/L)	Analytical Method **
<i>Common Ions and Physical Parameters</i>		
pH	0.1 S.U.	EPA 150.1
TDS	(10)	EPA 160.1
Calcium	(1)	EPA 6010
Magnesium	(1)	EPA 6010
Hardness	(1)	ASTM 2340B
Potassium	(2)	EPA 6010
Sodium	(1)	EPA 6010
Total Alkalinity as CaCO <sub>3</sub>	(1)	EPA 310.1
Bicarbonate	(1)	EPA 310.1
Carbonate	(1)	EPA 310.1
Chloride	(1)	EPA 300.0
Sulfate	(1)	ASTM 9036
Silica	(0.1)	EPA 6010
Temperature (field)	0.1 °C	(field)
Specific Conductivity (field)		(field)
Static Water Level (field)		(field)
<i>Nutrients</i>		
Ammonia as N	0.05	EPA 350.1
Nitrate + Nitrite as N	0.01	EPA 353.2
<i>Dissolved Metals (filtered sample)</i>		
Antimony	0.003	EPA 6020M
Arsenic	0.003	EPA 6020M
Copper	0.001	EPA 6020M
Iron	0.01	EPA 6010/6020
Lead	0.003	EPA 6020M
Manganese	0.005	EPA 6020M
Zinc	0.01	EPA 6020M

\* Values in parentheses are detection limit goals, no RRVs exist for these parameters.

\*\* Dissolved metals will be analyzed by ICP-MS (methods 6010, 6020, or 6020M).

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**APPENDIX D**

**TRACER TEST PROTOCOL REVISION 2**  
**(March 6, 2001 letter from Hydrometrics to MDEQ)**

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March 6, 2001

Mr. Joe Gurrieri  
MT Dept. of Environmental Quality  
PO Box 200901  
Helena, MT 59620-0901

RE: Groundwater Tracer Test at the Troy Mine

Dear Joe:

Sterling Mining Company received permission from MDEQ (Abe Horpestad) to proceed with the tracer test at the Genesis Inc. Troy Mine and was requested by Abe to inform you of our progress. Because the remote groundwater monitoring system was damaged and is no longer functioning, the planned monitoring schedule has changed somewhat since the tracer test proposal revision in early February. This letter describes the modifications to the proposed monitoring schedule. We plan to conduct pre-test sampling of the wells on March 8 and 9 and to start the tracer (salt) addition on March 12, 2001.

The revised schedule for monitoring is described in attached Table 1. In this table, "tracer addition period" means the period after the salt has been added to the pond and during the period that mine water is not discharged to the pond. Revisions to the Table have been done in "redline" mode (additions are italicized, deletions are strikeout) to clarify the changes that have been made. The primary change is that continuous monitoring of wells is not possible and will not be done. To offset the loss of continuous specific conductivity data, the frequency of sampling of wells near the decant pond for SC, sodium, and chloride has been increased from weekly to daily.

Please let me know if you would like any modifications to the planned monitoring schedule.

Sincerely,

**REVIEW DRAFT**

Scott Mason  
Geochemist

c: Abe Horpestad  
Bruce Clark  
Frank Duval

**REVIEW DRAFT**

**Table 1. Revised Monitoring Schedule for Troy Tracer Test**

Monitoring Location	Pre-Test Baseline	Tracer Addition Period		End of Tracer Addition Period		Post Tracer Addition Period		End of Test	
	Major Ions, Nutrients, & Metals (see Table 2)	Daily Specific Conductivity, Sodium, Chloride & Water Level		Major Ions, Nutrients, & Metals (see Table 2)	Sodium, Chloride, Water Level & Specific Conductivity Only	Daily Specific Conductivity, Sodium, Chloride & Water Level		Major Ions, Nutrients, & Metals (see Table 2)	Sodium, Chloride, Water Level & Specific Conductivity Only
Decant Pond 1 *	Yes	Yes **		Yes		Yes		Yes	
Decant Pond 2 *	Yes	Yes **		Yes		Yes		Yes	
Decant Pond 3 *	Yes	Yes **		Yes		Yes		Yes	
Irrigation Well	Yes	Yes		Yes		Yes		Yes	
MW-95-8	Yes	Yes		Yes		Yes		Yes	
MW-95-7	Yes	Yes		Yes		Yes		Yes	
MW-95-3	Yes	Yes		Yes		Yes		Yes	
MW-95-4	Yes			?	Yes			?	Yes
MW-97-12	Yes			?	Yes			?	Yes
MW-97-14	Yes			?	Yes			?	Yes
MW-95-5	Yes			?	Yes			?	Yes
MW-1	Yes			?	Yes			?	Yes
MW-2	Yes			?	Yes			?	Yes
MW-3	Yes			?	Yes			?	Yes
MW-4	Yes			?	Yes			?	Yes

Notes:

? Well will be sampled for major ions, nutrients, and metals per Table 2 only if specific conductivity is 10% or more greater than pre-test result.

\* Specific conductivity will be measured at four points (1 point along each side) in each pond.

\*\* Specific conductivity will be measured three times per day during the first 3 days of the test to document mixing in the ponds.

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**TABLE 2 ANALYTICAL PARAMETERS FOR GROUNDWATER  
MONITORING AT THE TROY MINE**

Analytical Parameter	Required Reporting Value * (mg/L)	Analytical Method **
<i>Common Ions and Physical Parameters</i>		
pH	0.1 S.U.	EPA 150.1
TDS	(10)	EPA 160.1
Calcium	(1)	EPA 6010
Magnesium	(1)	EPA 6010
Hardness	(1)	ASTM 2340B
Potassium	(2)	EPA 6010
Sodium	(1)	EPA 6010
Total Alkalinity as CaCO <sub>3</sub>	(1)	EPA 310.1
Bicarbonate	(1)	EPA 310.1
Carbonate	(1)	EPA 310.1
Chloride	(1)	EPA 300.0
Sulfate	(1)	ASTM 9036
Silica	(0.1)	EPA 6010
Temperature (field)	0.1 °C	(field)
Specific Conductivity (field)		(field)
Static Water Level (field)		(field)
<i>Nutrients</i>		
Ammonia as N	0.05	EPA 350.1
Nitrate + Nitrite as N	0.01	EPA 353.2
<i>Dissolved Metals (filtered sample)</i>		
Antimony	0.003	EPA 6020M
Arsenic	0.003	EPA 6020M
Copper	0.001	EPA 6020M
Iron	0.01	EPA 6010/6020
Lead	0.003	EPA 6020M
Manganese	0.005	EPA 6020M
Zinc	0.01	EPA 6020M

\* Values in parentheses are detection limit goals, no RRVs exist for these parameters.

\*\* Dissolved metals will be analyzed by ICP-MS (methods 6010, 6020, or 6020M).

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**APPENDIX E**

**PIPER DIAGRAMS**

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**APPENDIX F**

**TRACER TEST RESULTS – SC, Na, CL Trendplots**

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