SW 670

Applied Geotechnology Inc.

A Report Prepared for

Snohomish County Public Works
2930 Wetmore
Everett, Washington 98201

SUMMARY REPORT
COMPREHENSIVE HYDROGEOLOGIC AND
ENGINEERING STUDY - PHASE I
CATHCART LANDFILL
SNOHOMISH COUNTY, WASHINGTON

Ent 2/21/03

AGI Project Number 15,512.103

by

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INTRODUCTION

This report summarizes Applied Geotechnology Inc.'s (AGI) Phase I Hydrogeologic and Engineering Study for the referenced project. Our services were provided to Snohomish County (the County) under Master Agreement 9270 and Work Authorization No. 4. The following sections discuss our scope of services for the investigation, related background information, our Phase I findings, and recommendations for further studies.

PROBLEM STATEMENT

Cathcart Landfill (the landfill) is located on the south side of the Snohomish River Valley in Snohomish County, Washington as shown on Figure 1. The landfill site occupies approximately 198 acres, with the refuse fill area comprising approximately 60 acres. Existing landfill features are depicted on the Site Map, Figure 2. Refuse placement began in June 1980 and continued through June 1992, when the landfill was permanently closed.

The Snohomish County Regional Landfill (regional landfill) and a leachate pretreatment facility are located immediately east of the landfill. The regional landfill was recently constructed but is not currently accepting refuse. The pretreatment facility was designed to handle effluent from both the Regional and Cathcart Landfills.

The County currently faces several issues associated with landfill impacts to groundwater and surface water. We understand the key issue is the unanticipated requirement for treatment of these waters. AGI has been requested by the County to study information developed by others during previous hydrogeologic studies and to conduct this additional investigation, which includes general recommendations for potential mitigation measures. The County has identified three specific problem areas:

- Leachate-impacted groundwater seeps into an existing stormwater detention pond located north of the landfill. This requires that surface water in the detention pond be pumped and handled through the leachate pretreatment system rather than directly discharged to Garden Creek as originally intended.

- Leachate-impacted groundwater is being captured in the landfill's underdrain system. This system was originally designed to drain directly to Garden Creek via the north stormwater detention pond. Impacted underdrain water must be pumped to the leachate pretreatment facility for handling.

- Surface water runoff from the northern (older) portion of the landfill cap contains elevated chemical concentrations, including specific conductance and sulfate. Runoff from this area joins with runoff from the southern portion of the landfill and discharges into the north stormwater detention pond. Because chemical concentrations in surface runoff remain high upon entering the pond, it cannot be discharged to Garden Creek, and must also be handled through the leachate pretreatment system.

The County has stated that these conditions require virtually all surface water runoff from the landfill and a substantial volume of groundwater be treated as leachate and pumped to the on-site pretreatment facility. With the influx of this additional water into the pretreatment facility, discharge volumes are higher than anticipated and occasionally exceed the capacity of the Silverlake Water District's pumping station downstream. Tank trucks must therefore be used to transport excess treated water off site to the City of Everett's treatment plant.

SCOPE OF SERVICES

The overall purpose of our study is to identify potential mitigation measures for reducing the total amount of groundwater and surface water requiring discharge through the on-site pretreatment facility.

AGI has completed Phase I of the study. The primary goal of this phase was to become familiar with current and historic site and landfill conditions, and define what further investigation may be needed to develop and evaluate remediation options. AGI's Phase I scope of services included:

- Task 1 - Data Review and Compilation:
  - Review available literature regarding site landfill and hydrogeologic conditions.
  - Review available plans and specifications regarding landfill liner and cap construction.
- Task 2 - Site Reconnaissance
  - Perform site reconnaissance to identify surficial geology around the landfill and conditions related to leachate generation and migration.
- Task 3 - Flow Rates
  - Establish Garden Creek flow rates upstream and downstream of the landfill.
- Task 4 - Interviews and Meetings
  - Interview County personnel familiar with past landfill construction and operating practices.
  - Discuss our preliminary findings with the County upon completion of Phase I.
- Task 5 - Summary Report
  - Prepare this report summarizing our findings and providing recommendations for Phase II.

Documents reviewed to date include:

- *Cathcart Landfill Snohomish County Special Report* (Stetson, Anderson, and Tanaka, 1981).
- *Letter report to Snohomish County Public Works Department* (Converse Consultants, NW, 1988).
- *Phase II Hydrogeologic Study* (Converse Consultants, NW, 1989).
- *Cathcart Landfill Water Balance Investigation* (Converse Consultants, NW, 1991).
- *Phase III Hydrogeologic Investigation* (Converse Consultants, NW, 1991).
- *Geologic Logging, Construction Observation, and Operational Recommendations for Monitoring Wells W-2 and G16-S and Gas Probe GP-5* (Golder Associates, 1992).
- *Construction and Contract Documents and Drawings for Stages 1 and 2, 3 and 4, and 5 and 6* (Snohomish County Department of Public Works, Solid Waste Division, various dates).

AGI personnel visited the site on October 30, November 3, and November 15, 1993 as part of the Phase I study. To date we have interviewed Messrs. Ken Moser, Jerry Bundy, and Dave Schonhard of the County. A considerable amount of information regarding groundwater hydrogeology, landfill construction, and surface water hydraulics was available for our review. However, tabulated historic water level and chemistry information was not available from the County at the time this report was prepared.

SITE HYDROGEOLOGY AND LANDFILL HISTORY

SITE PHYSICAL ENVIRONMENT

Our knowledge of site geologic and hydrogeologic conditions is based on review of the referenced studies. These studies indicate the landfill is underlain by Tertiary sandstone and weakly bedded siltstone bedrock. Unconsolidated deposits overlying the bedrock are Vashon lodgement till around the landfill perimeter, and recent Garden Creek fluvial deposits below the center of the landfill. Fluvial deposits are also located in the Garden Creek drainage up- and downstream of the landfill.

Groundwater occurs primarily in the fluvial deposits and to a lesser extent in the underlying bedrock, and has been characterized by the referenced studies as distinct aquifers termed the Upper and Lower Aquifers, respectively. Groundwater flow throughout the unconsolidated sediments varies depending on local subsurface conditions such as porosity, permeability, and upgradient sources and hydraulic pressures. Groundwater in the bedrock flows primarily through fractures and along bedding planes. Volumes and velocities of groundwater flow in the bedrock are low relative to the unconsolidated sediments.

The landfill is located in a drainage basin that encompasses runoff and surface water from the approximately 700-acre Garden Creek watershed (Converse, 1991). Water from the Garden Creek watershed drains through the Garden Creek channel northward to the Snohomish River Valley and thence to the Snohomish River, which is located approximately 1-1/2 miles east of the landfill. The refuse fill area of the landfill is located over the former Garden Creek channel as shown on Figure 1.

LANDFILL CONSTRUCTION AND SITE DEVELOPMENT

Landfill design and early site preparation took place in the late 1970s. The landfill site is depicted on Figure 2. Site preparation included excavating the sandstone and siltstone bedrock along the sides of Garden Creek Valley and filling the stream channel at the center. Garden Creek was redirected from its natural channel to a ditch along the landfill's west side (see Figure 2) and ultimately back to its original alignment north of the landfill. Redirecting Garden Creek included constructing a temporary holding pond at the landfill's south end to reduce Garden Creek flow rates. The pond was constructed by damming Garden Creek with an earth-filled dam.

Site preparation also included constructing a stormwater detention pond at the landfill's north end. The detention pond was created by physically blocking the former Garden Creek bedrock channel with an earth dam comprising a bentonite clay core. The pond's outlet discharges into Garden Creek.

The landfill was constructed in a series of six stages starting with Stages 1 and 2 in 1979. Stages 1 and 2 design included provisions to limit the impacts to the hydrologic environment from the refuse, including:

- Placing a 30-mil PVC liner directly on the bedrock or backfill and a 30-mil Hypalon liner along the landfill's side walls. Liner seams were field-welded by the installation contractor.

- Installing a leachate collection system on top of the liner and two pretreatment lagoons at the north end of the landfill (as shown on Figure 2) for treating collected leachate. The leachate collection system comprises a grid of perforated pipes that lead to a solid leachate main along the center of the landfill. The leachate collection piping exits the north end of the landfill and discharges into a lift station, where leachate is pumped to a pretreatment lagoon.

Prior to liner installation, an underdrain pipe was placed down the centerline of the landfill to drain incidental surface water ponded at the upstream edge of the excavated landfill area. Underdrain piping discharged into the stormwater detention pond.

Seepage pressures caused liner upwelling throughout much of the Stage 1 and 2 area. Most of the upwelling was reportedly along the east side of the landfill excavation. County personnel construction notes indicate the liner was subsequently cut in numerous locations to relieve upward hydraulic pressures. Stetson, et al., reported some of these cuts were fitted with one-way relief valves designed to permit only upward water flow through the

liner. The Stetson report further stated the underdrain system was retrofitted with lateral perforated underdrains along the landfill flanks in order to convey groundwater to the centerline underdrain. County personnel reported all liner cuts were subsequently field repaired prior to placing refuse.

Refuse placement commenced after the liner was repaired. County personnel stated that heavy equipment periodically contacted and ripped the liner as the refuse was placed. Once a refuse height of 10 feet was reached, the perforated lateral drains were permanently grout sealed. The solid centerline underdrain was not grouted.

As refuse placement in Stages 1 and 2 commenced, liner placement for Stages 3 through 6 progressed two stages at a time. The design drawings and specifications indicate Stage 3 through 6 construction was similar to that for Stages 1 and 2. During Stages 3 through 6, lateral perforated underdrains were installed along the landfill flanks to relieve upwelling pressures by conveying groundwater to the centerline underdrain. Construction notes indicate upwelling and liner flotation still occurred in various areas throughout these stages as well. Most upwelling was reportedly along the east side of the landfill excavation. Refuse was placed over these areas to mitigate the occasional upwelling. The lateral underdrains in Stages 3 through 6 were reportedly not sealed after refuse height reached 10 feet. Underdrain flow was directed to the north stormwater detention pond and ultimately discharged into Garden Creek.

County personnel stated that during construction of Stages 5 and 6, seepage along the landfill's south face was extensive and occurred almost continuously during construction. Seepage appeared to be caused by surface water infiltration through the south holding pond dam. Water seepage was collected by the underdrain and piped to the north stormwater detention pond.

County personnel stated refuse fill throughout the landfill was placed in approximately 10-foot layers (lifts). Refuse filling proceeded from Stage 3 to Stage 6 two stages at a time.

LANDFILL CLOSURE

In 1990 the County began final closure of the landfill in accordance with applicable state and federal regulations. Closure measures included:

- Constructing a multilayer synthetic cap. The cap was ultimately vegetated and heavily fertilized to promote growth. Fertilization was more prevalent in Stages 1 and 2 and was significantly reduced in Stages 3 through 6.

- Constructing a surface water drainage ditch on the landfill cap. The ditch drains cap runoff and discharges into the north stormwater detention pond.

- Constructing the current leachate pretreatment facility.

- Rerouting the underdrain into lift station SP-4 rather than the stormwater detention pond. Underdrain flow is now directed to the leachate pretreatment facility.

- Removing accumulated sediment in the stormwater detention pond to increase pond capacity and accommodate additional surface water runoff from the cap.

Closure of Stages 1 and 2 was completed by November 1991. By November 1992, Stages 3 through 6 were also closed and capped.

Landfill gas generation is high at Cathcart. The County operates a gas venting and combustion (flare) system (located as shown on Figure 2) in order to capture and destroy the gas. Gas extraction piping was installed in Stages 1 and 2 in 1990 and the flares ignited. Extraction piping was extended into later stages as landfill closure progressed through 1992. The County plans to complete expansion of the system's flare capacity in January 1994.

POST-CONSTRUCTION LANDFILL SITE HYDROLOGY

Post-construction hydrology includes surface water via Garden Creek and surface water runoff from the landfill cap. Garden Creek surface water flows into the south holding pond, where it is channeled into the diversion ditch along the landfill's west side. The diversion ditch discharges into the natural Garden Creek stream channel north of the landfill. Surface water runoff from the landfill cap is directed into drainage ditches located along the landfill's perimeter. Runoff then flows into the north detention pond, where it is collected and pumped to the pretreatment system.

The Garden Creek diversion along the landfill's west side is not lined and, during wet periods, has been shown to lose up to 30 percent of its flow through infiltration (Converse, 1991). County personnel have further stated they estimate the creek may lose as much as one-half its volume along this reach during high flows.

In addition, the south holding pond is not lined and therefore probably loses significant volumes of water through infiltration to the natural drainage directly beneath the landfill. During our site visit on November 15, 1993, the outflow from the south pond was visibly lower (roughly approximated at 5 gallons per minute) than the combined inflow (roughly approximated at 10 gallons per minute) from two influent streams shown on Figure 2. It is expected much of this flow percolates directly to the former creek bed below the landfill.

The referenced studies state groundwater beneath the landfill originates east, west, and south of the landfill. Groundwater flows to the north, likely along the former creek bed, through the underdrain system, and beneath but adjacent to the landfill liner. At the north end of the landfill, groundwater is hydraulically connected to the detention pond. The detention pond water level likely reflects the groundwater piezometric surface.

WATER QUALITY

Several studies have been conducted to evaluate leachate chemistry and the extent and magnitude of the landfill's impacts on groundwater and surface water quality. Pertinent studies include the Stetson, et al. Special Report (1981) and three hydrogeologic investigations (Converse, 1988; 1989; 1991).

As previously stated, AGI was unable to obtain tabulated historic water quality information from the County at the time this report was prepared. Available water quality data are discussed below.

GROUNDWATER

Previous hydrogeologic investigations included installation of 27 groundwater monitoring wells and two groundwater extraction wells. The County began a groundwater monitoring program in the early 1980s. The program currently includes quarterly sampling and analytical testing of water from 24 monitoring wells. The following constituents are analyzed:

pH
Total Organic Carbon (TOC)
Specific Conductance
Sulfate
Chemical Oxygen Demand (COD)
Nitrate
Nitrite
Chloride
Ammonia
Total Coliform
Volatile Organic Compounds (VOCs)
Dissolved Metals (As, Ba, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Ni, Se, Ag, Zn)

Recent groundwater monitoring program data (August 1993 sampling) indicate groundwater downgradient of the landfill is impacted to the extent that, if extracted, it also requires treatment due to high conductivity, sulfate, chloride, and manganese concentrations.

SURFACE WATER

Surface water is routinely sampled at the north stormwater detention pond, six locations along Garden Creek, and various locations where surface water runoff from the cap drains into a collection system. County personnel stated these samples are analyzed for the same constituents as groundwater except for VOCs and COD. Hardness, turbidity, and fecal coliform are also included in the analyses. County personnel further stated water quality test results indicate the presence of high concentrations of various constituents. Water quality data were not available for our review during this Phase I study.

According to the County, high concentrations of chloride and sulfate and high turbidity and specific conductance in cap surface water runoff have been attributed to various sources, including landfill leachate, landfill gas, and fertilizers applied to cap vegetation. County personnel stated that water quality routinely exceeds Garden Creek discharge requirements.

UNDERDRAIN

Chemical analyses of underdrain flow were last conducted in 1991. Landfill personnel stated the concentrations of several constituents exceeded allowable Garden Creek discharge requirements. Chemical data were not available for our review during our Phase I study.

The County assumed this impact was attributable to leachate and therefore began rerouting the underdrain from the detention pond to the leachate pretreatment facility in 1989. Diversion of the underdrain flows to the pretreatment facility continues under the assumption that this flow remains impacted.

PAST AND CURRENT LANDFILL MITIGATION MEASURES

The County began a limited groundwater extraction program in 1988 that was designed to intercept and remove leachate-impacted groundwater downgradient of the landfill before it reached the north stormwater detention pond. Groundwater extraction was accomplished by groundwater monitoring well G-5 (well locations are shown on Figure 2). Pumped groundwater was discharged into the pretreatment lagoons. The source of the impacts to groundwater was assumed to be leachate released directly from the landfill or from loss and infiltration out of the treatment lagoons themselves. Monitoring well G-5 was replaced in 1989 with a larger diameter extraction well, W-1 shown on Figure 2, to accommodate higher discharge rates.

Immediately prior to removing accumulated sediment from the north stormwater detention pond in 1990, the pond level was lowered by pumping surface water from the pond. Pond discharge water was routed to the pretreatment facility based on the water quality data. As a result of pumping from the north pond, groundwater levels in W-1 dropped to levels below the well pump. Another extraction well, W-2, was subsequently installed at the location shown on Figure 2 in order to provide continued groundwater extraction from this area. However, after the well was installed, groundwater levels were found to be lower than the W-2 well pump.

Direct surface water pumping from the north pond continued, as needed, to control pond water level. Pond pumping maintained a water level below the operating levels of W-1 and W-2 well pumps. The north stormwater detention pond is currently pumped, as needed, to maintain desired water levels. Discharge water is routed to the pretreatment facility. As a result, no water is discharged into Garden Creek. During our November 15 site visit, Garden Creek flow downstream of the pond was estimated at 2 gallons per minute.

According to the County, the north pretreatment lagoon was removed and backfilled in 1990. This measure was taken due to suspected leachate leakage that was evidenced by water quality data from nearby wells; additionally, the lagoon's service was no longer required due to construction of the pretreatment facility for the regional landfill. The south pretreatment lagoon was reconstructed in 1992 as an overflow pond for the leachate pipeline and connects to pump station SP-3.

PHASE I FINDINGS AND CONCLUSIONS

Our findings and conclusions presented below are based on review of available literature, interviews with County personnel, recent site visits, our understanding of landfill construction sequences and difficulties, geological information in our files, and our professional judgement.

SOURCES OF IMPACT

Groundwater and Underdrain

Groundwater flows beneath the landfill through the underdrain system along the former creek bed, and below but adjacent to the landfill liner. Because the liner integrity is likely compromised, we believe groundwater enters the landfill and commingles with landfill leachate. Impacted groundwater likely seeps back through the liner and is either captured in the underdrain system or north detention pond, or bypasses the entire collection system.

Surface Water

Surface water runoff may be impacted from fertilizers used to promote vegetative growth on the landfill cap. County personnel have stated that concentrations of various constituents exceed Garden Creek discharge requirements. Because water quality data were not available for our review, it is unknown at this time how much and what impact fertilizers may have on surface water quality data.

POSSIBLE MITIGATION MEASURES

Reducing groundwater flow below the landfill appears to be of primary importance to mitigate impacted groundwater and underdrain water. Our recommendations for mitigation will not be definitive until Phase II completion; however, based on our current knowledge of the landfill, we suggest the following may be considered:

a) Trenching and installing a french drain along the east margin of the landfill (likely located along the east side of the landfill perimeter road). This drain would be of sufficient depth to intercept groundwater entering the east side of the landfill. Collected groundwater would be directed by gravity into the north stormwater detention pond or directly into Garden Creek.

b) Lining the south holding pond and the Garden Creek diversion ditch to prevent infiltration into the landfill from the south and west.

c) Redirecting groundwater throughflow that enters the landfill area from the south. Options to accomplish this include installing a cutoff or slurry wall along the south edge of the landfill and completing groundwater extraction wells designed to withdraw redirected groundwater and discharge it to the north stormwater detention pond or directly into Garden Creek.

Additionally, surface water runoff collected in the north storm water pond may be impacted by groundwater. We suggest lining the north pond as a measure to mitigate this impact.

RECOMMENDATIONS FOR FURTHER INVESTIGATION

Phase II of our study will be more specific in nature. The purpose of Phase II is to complete our understanding of site hydrologic conditions and recommend possible solutions to reduce the amount of impacted water currently routed to the on-site pretreatment facility. Before such recommendations are appropriate, however, we feel it is essential to characterize the effects of the closure measures on the various flows and their chemistry. Current mitigation needs would best be based on current, post-closure conditions. Specific investigation tasks we propose are outlined below:

- Water Quality Data: Recent groundwater, surface water, and underdrain water quality data should be obtained. Water quality data are essential in evaluating present-day constituent concentrations, specifically for the underdrain system, which was last tested in 1991.

  Historical water quality data should be graphically analyzed for trends over time. This analysis is important to determine effects on the chemistry of the leachate collection system, underdrain, and cap runoff over time, specifically after the cap was placed.

- Water Balance Study: A water balance was performed for the landfill in 1990 prior to installation of the landfill cap. Installation of the landfill cap since the 1990 study has significantly reduced the amount of precipitation infiltration into the landfill and greatly increased the surface water runoff. We recommend a new water balance be performed in order to estimate groundwater flow into, around, and beneath the landfill.

  This task would include measuring and quantifying all flows into and out of the landfill drainage systems and watershed by the following:

  1) Comprehensive review of leachate and underdrain flows, and north detention pond discharges.

  2) Review of water level data from the Upper and Lower Aquifer monitoring wells, extraction wells W-1 and W-2, and the north stormwater detention pond.

3) Comprehensive review of leachate, underdrain, landfill cap runoff, and groundwater chemistry.

4) Review of all chemistry data for the Upper and Lower Aquifer monitoring wells, and the north stormwater detention pond.

- Water Inflow Evaluation: In order to adequately evaluate water inflow and assess design criteria for the french drain and cutoff/slurry wall, or lining the south pond and Garden Creek, we recommend an additional evaluation investigation. The evaluation will include:

  - Installing a series of piezometers around the landfill's east and south sides.

  - Evaluating soil type and in situ permeability.

  - Estimating in situ flow rates.

  - Performing detailed hydrogeologic and engineering analyses.

  - Preparing design criteria, plans, and specifications as necessary.

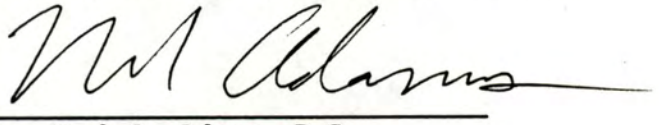
DISTRIBUTION

10 copies

Snohomish County Public Works
2930 Wetmore
Everett, Washington 98201

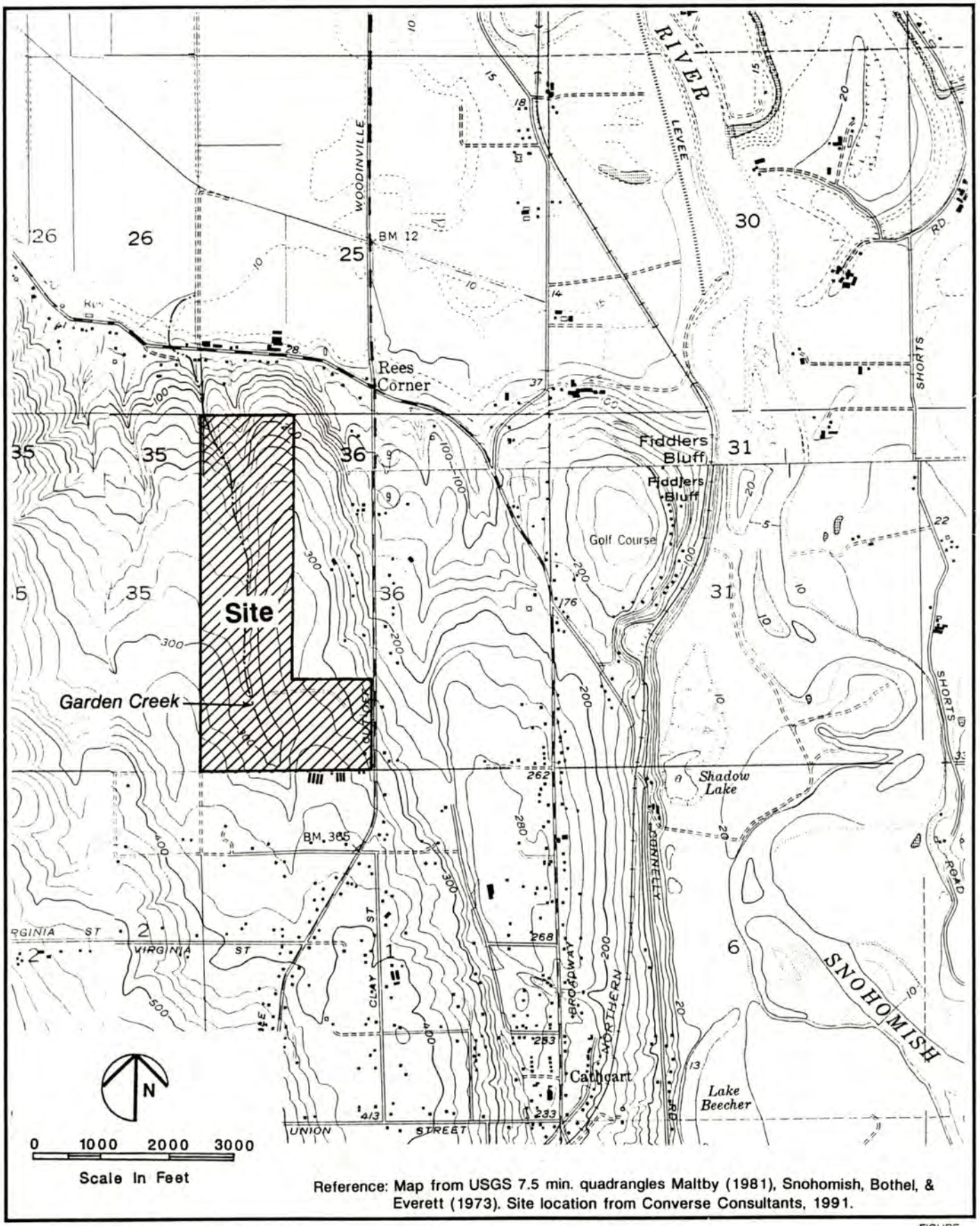
Attention: Mr. Ken Moser

Quality Assurance/Technical Review by:



Mr. Mark A. Adams, P.G.
Principal Geologist

TMM/JMS/tag



Reference: Map from USGS 7.5 min. quadrangles Maltby (1981), Snohomish, Bothel, & Everett (1973). Site location from Converse Consultants, 1991.

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Vicinity Map

Snohomish County Public Works/Cathcart Landfill
Snohomish County, Washington

FIGURE
1

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
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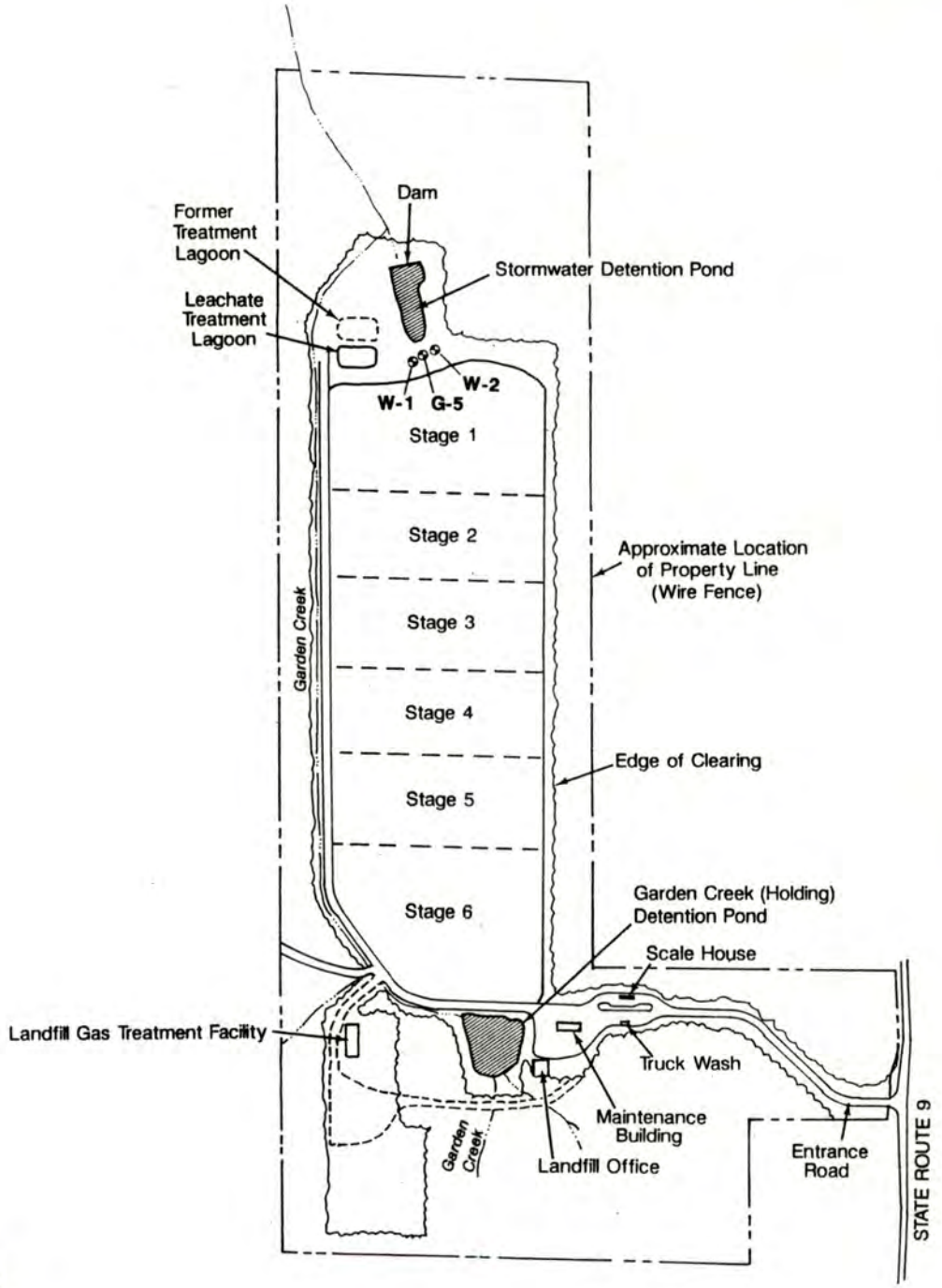

Reference: Converse Consultants, 1991.

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Site Plan

Snohomish County Public Works/Cathcart Landfill
Snohomish County, Washington

FIGURE
2

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15,512.103	DFF		2-2-94		

APPENDIX A

Historical Timeline For Cathcart Landfill

APPENDIX A

Historical Timeline For Cathcart Landfill

Time Period / Date	Activity
Late 1970s	Landfill designed and constructed
February 1980	Independent investigation of liner integrity performed for Snohomish County (County) due to Washington State Department of Ecology's (Ecology) opinion that liner construction was inadequate. (Raymond Vail, Assoc., *Technical Assistance; Cathcart Sanitary Landfill.*)
Early 1980s	County began groundwater monitoring program.
June 1980	Landfill opened; refuse placement began.
August 29, 1980	Generation of leachate first noted.
September 2, 1980	Sampling indicated presence of leachate in site surface water drainage system.
September 1980	Based on September 2, 1980 results, routine sampling initiated.
November 20, 1980	Sufficient sampling data gathered to indicate contamination of the underdrain with leachate. Ecology notified County that it had determined the underdrain flow was contaminated and this constituted a violation of the National Pollutant Discharge Elimination System (NPDES) permit.
December 9, 1980	County again notified by Ecology letter of the continuing problem.
March 5, 1981	Final warning letter issued by Ecology to County requiring: 1) immediate steps to remove impounded leachate; 2) implement operational procedures to allow continual drainage of the landfill leachate collection system into the aerated lagoon; and 3) a written response within 30 days providing a current status report and a time schedule for a permanent solution to the leachate/treatment disposal need.
April 30, 1981	County sent response letter to Ecology indicating operational procedures had been modified to remove impounded leachate from Phase I and to route contaminated surface runoff into the leachate collection system.

Time Period / Date	Activity
May 14, 1981	Routine inspection made to gather water quality samples at the landfill. Leachate still impounded on the liner and leachate collection line plugged; evidence of leachate being discharged into the underdrain through manhole No. 2. *Sphaerotilus*-type growth noted at the outlet from the north holding pond; black sulfide deposits characteristic of anaerobic conditions also noted on the riprap in the channel at this location.
May 15, 1981	Ecology sent letter to County discussing leachate problems.
June 4 and 29, 1981	Sampling and inspection indicate continued discharge of leachate into the lower holding pond, and leachate impounded on the Phase I liner.
August 17, 1981	Ecology issued compliance order DE 81-505.
1981	North leachate treatment lagoon installed.
1981	Leachate drain between Stages 1 and 2 collapsed; 400 feet eventually replaced with thicker (1-inch) HDPE ~~liner~~ pipe.
June 19, 1985	Landfill personnel began keeping daily records of leachate flow.
March 1987	Leachate drain videoed; no breaks indicated, but video indicates a weld on one of the joints in Stage 4 failed, causing distortion of the pipe sidewall.
1988	Sludge removed from north leachate lagoon; liner observed to be floating between quarry spalls.
January 1988	County begins limited groundwater extraction program, pumping leachate-impacted groundwater from G-5 to treatment lagoons. This was done to intercept groundwater and keep it from reaching the north pond. Possible sources of groundwater contamination assumed to be landfill leachate or treatment lagoons.
July 12, 1988	County contracted Converse Consultants Northwest to perform preliminary hydrogeologic evaluation; six new groundwater monitoring wells installed.
September 27, 1988	Converse issued *Preliminary Hydrogeologic Study* report.
1989	Underdrain re-routed to pretreatment facility.
February and June 1989	Supplemental contracts awarded to Converse.

Time Period / Date	Activity
February 1989	Landfill personnel began keeping daily records of underdrain flow.
February 1989	W-1 (6-inch) installed with submersible pump to replace G-5.
November 9, 1989	Converse issued *Phase II Hydrogeologic Study* report.
December 1989	Extraction of leachate-impacted groundwater began at W-1.
January 1990	Ecology representatives visited landfill to check locations of existing wells; suggested installation of a new background well.
Spring 1990	Conditional use permit for landfill modified to allow for vertical expansion of the landfill in Stages 3 through 6.
Spring 1990	North leachate lagoon abandoned.
March 1, 1990	Landfill personnel begin recording water levels in north detention pond.
Feb. - Oct. 1990	Field work for water balance conducted.
Aug. - Sept. 1990	New background well (G-15S) installed (contracted September 1990).
Prior to closure measures, 1990	Gas venting/combustion begun.
Aug. - Sept. 1990	North leachate lagoon removed and backfilled.
Aug. - Oct. 1990	North detention pond drained and sediments removed.
November 1, 1990	Pond pumped dry.
Fall 1990	North detention pond improved to handle increased runoff from final closure of Stages 1 and 2.
November 1, 1990	G-5A and W-1, located in fill material adjacent to north detention pond, dry on November 1.
January 1991	Stages 1 through 2 filled, covered, capped, and seeded. Stages 3 through 6 active until June 1992.
January 10, 1991	Converse issued *Cathcart Landfill Water Balance Investigation* report.
Summer 1991	Landfill accepting approximately 1,000 tons of waste per day.

Time Period / Date	Activity
Fall 1991	Golder Associates performed geophysical survey.
December 30, 1991	Converse issued *Phase III Hydrogeologic Study* report.
January 1992	Basketball removed from underdrain.
February 7, 1992	W-2 installation complete; water level at Elevation 200.94.
June 1992	Refuse placement continued as additions to Stages 3, 4, 5, and 6.
June 1992	Landfill closed to refuse placement.
November 1992	Stages 3 through 6 closed and capped (final closure).
August 20, 1992	Golder Associates issued *Geologic Logging, Construction Observation, and Operational Recommendations for Monitoring Wells W-2, G16-S, and Gas Probe GP-5* draft report.
March - June 1993	North Pond pumped into SP-1.
June 1994	W-1 pumped.

APPENDIX B

Garden Creek Weirs

AGI TECHNOLOGIES

APPENDIX B

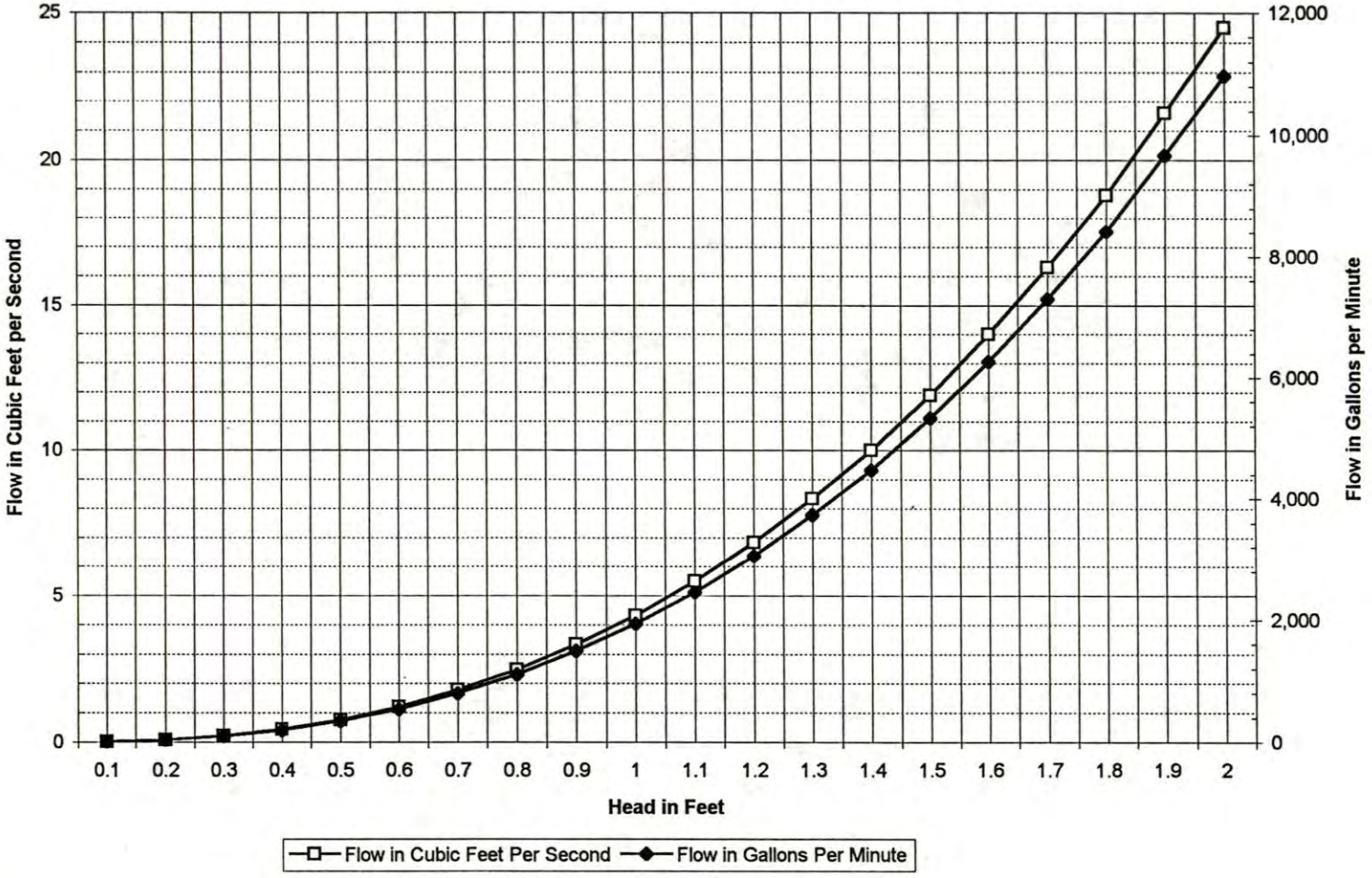
Garden Creek Weirs

Four weirs were installed in Garden Creek along the landfill's west side to quantify Garden Creek flows along the length of the landfill. The weirs were fabricated at AGI prior to installation and installed August 30 through September 5, 1994. Each weir was constructed with the following specifications:

- Material: Marine plywood
- Length: 12 feet
- Height: 4 feet
- Wall Thickness: 3/4 inch
- V-notch Angle: 120 degrees

Weir installation was accomplished by lowering each weir into cuts excavated into the dry channel of Garden Creek. Each weir was then set in place by backfilling around the weir's base and sides with concrete. An existing weir located downstream from the Cathcart Landfill was repaired by erecting it back to a vertical position and setting it in concrete along its sides. The completed weirs were reviewed and approved by Snohomish County Solid Waste Division and Community Development personnel.

Flow in the creek is measured by converting the creeks's upstream pool level read on the weir's staff gauge to flow values. A rating curve for the 120 degree V-notch weirs is shown on **Plate B-1.**



AGI TECHNOLOGIES

120° V-Notch Weir Flow Rating Curve

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **B-1**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMM		

APPENDIX C

Subsurface Investigation Activities and Boring Logs

APPENDIX C

Subsurface Investigation Activities and Boring Logs

DRILLING

Drilling was performed by Layne Environmental Services of Tacoma, Washington using an AP 1000 percussion drill rig equipped with dual-wall 6-inch inside-diameter steel conductor casing. Drilling activities were performed May 2 through May 5, 1994. AGI Technologies (AGI) characterized geologic conditions by:

- Examining drill cuttings during removal from the borehole.
- Observing the resistance to drilling as indicated by drill rate and behavior.
- Collecting soil samples at 5-foot intervals using a modified California Sampler (2.5-inch inside-diameter). The sampler was driven with a 140-pound hammer dropped from a height of approximately 30 inches.

All boreholes were logged by an AGI geologist, who examined and classified the materials encountered, obtained representative soil samples, and recorded pertinent information, including soil sample depths, stratigraphy, and groundwater occurrence. Soils were classified in the field in accordance with the Unified Soil Classification System (USCS) and Physical Properties Criteria for Rock Description, which are presented on **Plates C-1** and **C-2**. Following completion of drilling, the borings were converted to groundwater piezometers. Typical piezometer construction is shown on **Plate C-3**. Piezometer construction is further discussed below.

Soil samples were sealed to limit moisture loss, labeled, and transported to our laboratory for further geologic classification. Boring logs were modified where needed to reflect the laboratory sample examination. Boring logs are presented on **Plates C-4** through **C-11**. The stratification lines shown on the individual logs represent the approximate boundaries between soil types; actual transitions may be either more gradual or more abrupt. The conditions depicted are for the dates and locations indicated only, and may not be representative of conditions at other locations and times.

Ambient air quality at borehole locations was monitored to ensure volatile organic compound (VOC) vapors and combustible gases did not exceed action levels established in the site Health and Safety Plan. Prior to drilling, an explosimeter was used to monitor air quality and combustible gases at each drill site. During drilling, ambient air quality and combustible gas parameters were measured near the top of the borehole and in the worker's breathing area.

The drill rig, conductor casing, and downhole sampling tools were decontaminated with a high-pressure steam cleaner prior to drilling each boring. Steam cleaning was performed at Snohomish County's (County) wash rack and oil/water separator located at Cathcart Landfill. Soil sampling equipment was typically decontaminated between sampling intervals by washing it in a solution of phosphate-based soap and tap water followed by a tap water rinse when needed.

PIEZOMETER INSTALLATION

Borings PZ-1 through PZ-7 and G-24 were advanced to depths of 45 to 70 feet below ground surface (bgs). One piezometer each was installed in borings PZ-1 through PZ-7 as the conductor casing was extracted after reaching total boring depth. PZ-1 through PZ-4 screens were set in the Qtb Aquifer, and PZ-5 through PZ-7 screens were set in the Tertiary sandstone. The piezometers were constructed in accordance with Washington Administrative Code (WAC), Chapter 173-160 *Standards for Resource Protection Wells* (March 13, 1990). Typical piezometer construction details are presented on **Plate C-3**. Piezometer construction details are presented on the boring logs (**Plates C-4** through **C-11**).

General procedures for piezometer construction are summarized below.

- Piezometers were constructed of 1-inch-diameter, flush-threaded, coupled Schedule 80 blank PVC riser pipe and machine-slotted (0.010-inch slot) screen with a bottom cap. The length of the well assembly (PVC riser, screen, and end cap) was measured and recorded prior to installation. The blank riser pipe extends from the top of the screen to approximately 1/2 foot below ground surface.

- Colorado 10-20 silica sand was used to fill the boring annulus from the bottom of the screen to 2 to 3 feet above the top of the screen. During installation, depths to the piezometer construction materials were measured frequently with a precleaned, weighted measuring tape to prevent overfilling or bridging inside the drill conductor casing.

- Piezometers were sealed with bentonite chips and a bentonite-based grout to form an annular hydraulic seal above the screen sand pack.

- Protective well monuments with locking caps were installed over the PVC well casings and set in a 4-foot-square by 1/2-foot-thick concrete ground pad. No piezometers are in access and perimeter roads.

CUTTINGS AND DEVELOPMENT WATER DISPOSAL

Soil cuttings generated during drilling were placed on visqueen and left at each drill site. The cuttings were subsequently removed by the County and transported to the landfill stockpile area.

UNIFIED SOIL CLASSIFICATIONS SYSTEM

MAJOR DIVISIONS					TYPICAL NAMES
COARSE GRAINED SOILS More than half is larger than No. 200 Sieve	GRAVELS More than half coarse fraction is larger than No. 4 sieve size	Clean gravels with little or no fines	GW		Well graded gravels, gravel-sand mixtures
			GP		Poorly graded gravels, gravel-sand mixtures
		Gravels with over 12% fines	GM		Silty Gravels, poorly graded gravel-sand-silt mixtures
			GC		Clayey gravels, poorly graded gravel-sand-clay mixtures
	SANDS More than half coarse fraction is smaller than No. 4 sieve size	Clean sands with little or no fines	SW		Well graded sands, gravelly sands
			SP		Poorly graded sands, gravelly sands
		Sands with over 12% fines	SM		Silty sand, poorly graded sand-silt mixtures
			SC		Clayey sands, poorly graded sand-clay mixtures
FINE GRAINED SOILS More than half is smaller than No. 200 Sieve	SILTS AND CLAYS Liquid limit less than 50		ML		Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity
			CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL		Organic clays and organic silty clays of low plasticity
	SILTS AND CLAYS Liquid limit greater than 50		MH		Inorganic silts, micaceous or diatomacious fine sandy or silty soils, elastic silts
			CH		Inorganic clays of high plasticity, fat clays
			OH		Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS			PT		Peat and other highly organic soils

SAMPLE

- "Undisturbed"
- Bulk/Grab
- Not Recovered
- Recovered, Not Retained

CONTACT BETWEEN UNITS

- Well Defined Change
- Gradational Change
- Obscure Change
- End of Exploration

BLOWS PER FOOT

Hammer is 140 pounds with 30-inch drop, unless otherwise noted

- S - SPT Sampler (2.0-Inch O.D.)
- T - Thin Wall Sampler (2.8-Inch Sample)
- H - Split Barrel Sampler (2.4-Inch Sample)

MOISTURE DESCRIPTION

- Dry - Considerably less than optimum for compaction
- Moist - Near optimum moisture content
- Wet - Over optimum moisture content
- Saturated - Below water table, in capillary zone, or in perched groundwater

PHYSICAL PROPERTY TESTS

Consol	-	Consolidation
LL	-	Liquid Limit
PL	-	Plastic Limit
Gs	-	Specific Gravity
SA	-	Size Analysis
TxS	-	Triaxial Shear
TxP	-	Triaxial Permeability
Perm	-	Permeability
Po	-	Porosity
MD	-	Moisture/Density
DS	-	Direct Shear
VS	-	Vane Shear
Comp	-	Compaction

UU - Unconsolidated, Undrained
CU - Consolidated, Undrained
CD - Consolidated, Drained

AGI TECHNOLOGIES

Soil Classification/Legend

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE **C1**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	ALW	6 March 95	TMM		

soilcls.cdr

I CONSOLIDATION OF SEDIMENTARY ROCKS; usually determined from unweathered samples. Largely dependent on cementation.

U = unconsolidated
P = poorly consolidated
M = moderately consolidated
W = well consolidated

II BEDDING OF SEDIMENTARY ROCKS

Splitting Property	Thickness	Stratification
Massive	Greater than 4.0 ft.	very thick bedded
Blocky	2.0 to 4.0 ft.	thick-bedded
Slabby	0.2 to 2.0 ft.	thin-bedded
Flaggy	0.05 to 0.2 ft.	very thin-bedded
Shaly or platy	0.01 to 0.05 ft.	laminated
Papery	less than 0.01 ft.	thinly laminated

III FRACTURING

Intensity	Size of Pieces in Feet
Very little fractured	Greater than 4.0
Occasionally fractured	1.0 to 4.0
Moderately fractured	0.5 to 1.0
Closely fractured	0.1 to 0.5
Intensely fractured	0.05 to 0.1
Crushed	Less than 0.05

IV HARDNESS

1. **Soft** — Reserved for plastic material alone
2. **Low hardness** — can be gouged deeply or carved easily with a knife blade
3. **Moderately hard** — can be readily scratched by a knife blade; scratch leaves a heavy trace of dust and is readily visible after the powder has been blown away.
4. **Hard** — can be scratched with difficulty; scratch produces little powder and is often faintly visible.
5. **Very hard** — cannot be scratched with knife blade; leaves a metallic streak.

V STRENGTH

1. **Plastic** or very low strength
2. **Friable** — crumbles easily by rubbing with fingers.
3. **Weak** — An unfractured specimen of such material will crumble under light hammer blows.
4. **Moderately strong** — Specimen will withstand a few heavy hammer blows before breaking.
5. **Strong** — Specimen will withstand a few heavy ringing hammer blows and will yield with difficulty only dust and small flying fragments.
6. **Very strong** — Specimen will resist heavy ringing hammer blows and will yield with difficulty only dust and small flying fragments.

VI WEATHERING — The physical and chemical disintigration and decomposition of rocks and minerals by natural processes such as oxidation, reduction, hydration, solution, carbonation, and freezing and thawing.

- **D. Deep** — Moderate to complete mineral decomposition; extensive disintegration; deep and thorough discoloration; many fractures, all extensively coated or filled with oxides, carbonates and/or clay or silt
- **M. Moderate** -- Slight change or partial decomposition of minerals; little disintegration; cementation little to unaffected. Moderate to occasionally intense discoloration. Moderately coated fractures.
- **L. Little** — No megascopic decomposition of minerals; little or no effect on normal cementation. Slight and intermittent, or localized discoloration. Few stains on fracture surfaces.
- **F. Fresh** — Unaffected by weathering agents. No disintegration or discoloration. Fractures usually less numerous than joints.

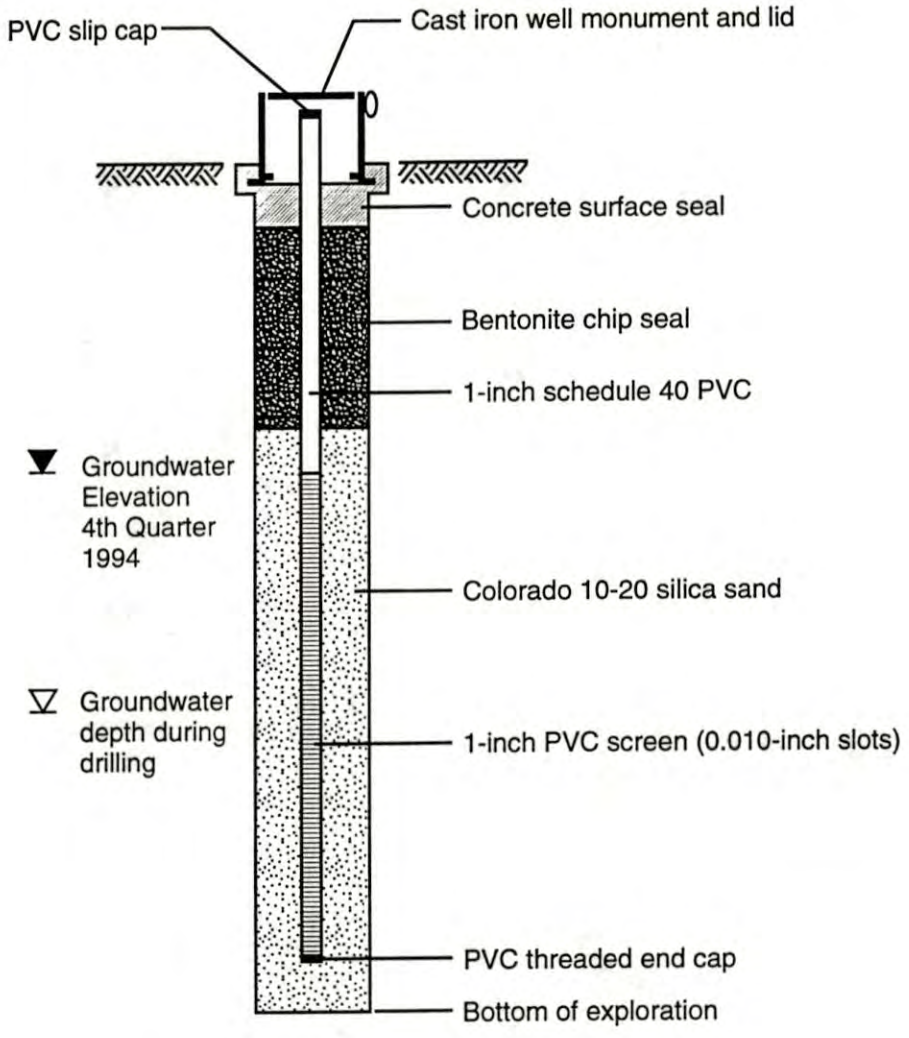
AGI TECHNOLOGIES

Physical Properties Criteria for Rock Description

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE **C2**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	JFL		TMM		



AGI TECHNOLOGIES

Monitoring Well Construction

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE C3

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	10 May 95	TMM		

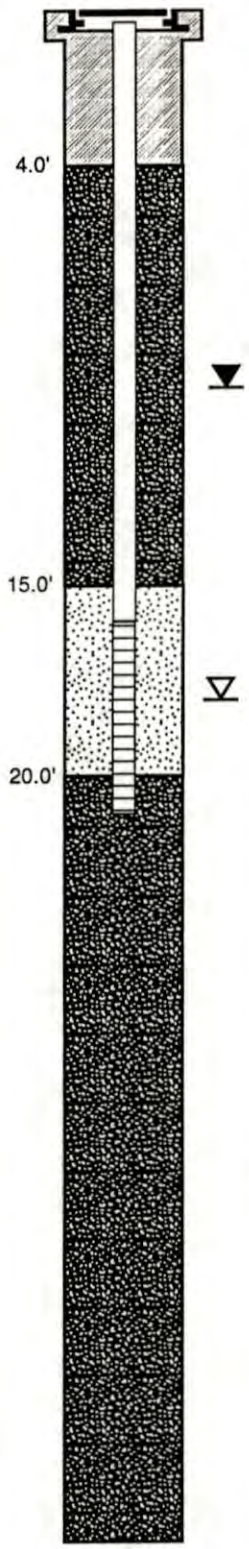
wellcons.cdr

Equipment: AP 1000 Dual Wall

Top of Casing Elevation: 318.84 feet

Start Date: 5/5/94

Well Construction Summary



Blows per Foot	Depth (feet)	Sample	
	0		BROWN SILTY SAND (SM) moist; with some gravel (Fill).
	5		BROWN GRAY SANDY SILT (ML) very stiff, moist; with some gravel and wood fragments (Fill).
31			BROWN GRAY SILTY SAND (SM) moist (Fill).
	10		BROWN SANDY SILT (ML) medium stiff, moist; with some sand and gravel and a trace of organics.
9			BROWN SILT (MH) elastic, wet; with some sand and gravel.
	15		Becomes reddish brown, very stiff, with a trace of gravel.
27			
	20		RED BROWN SILTSTONE, low hardness, moist; weak, deeply oxidized.
50/6"			DARK GRAY SANDY SILTSTONE, well consolidated, flaggy, moderately hard, weak, fresh to little weathered, sand is very fine grained.
	25		
			Becomes well consolidated, platey.
	30		With some sand and a trace of shells.
	35		
	40		

AGI TECHNOLOGIES

Log of Well PZ-1 (0-40')

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE **C4a**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
512108mw.cdr	15,512.108	JFL/ALW	4 April 95	TMM	

Equipment: AP 1000 Dual Wall

Top of Casing Elevation: 318.84 feet

Start Date: 5/5/94

Blows per Foot | Depth (feet) | Sample

40
45
50
55
60
65
70
75
80

Boring terminated on 5/5/94.
Groundwater encountered at 18 feet during drilling.

AGI TECHNOLOGIES

Log of Well PZ-1 (40-60')

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE C4b

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	JFL/ALW	4 April 95	TMM		

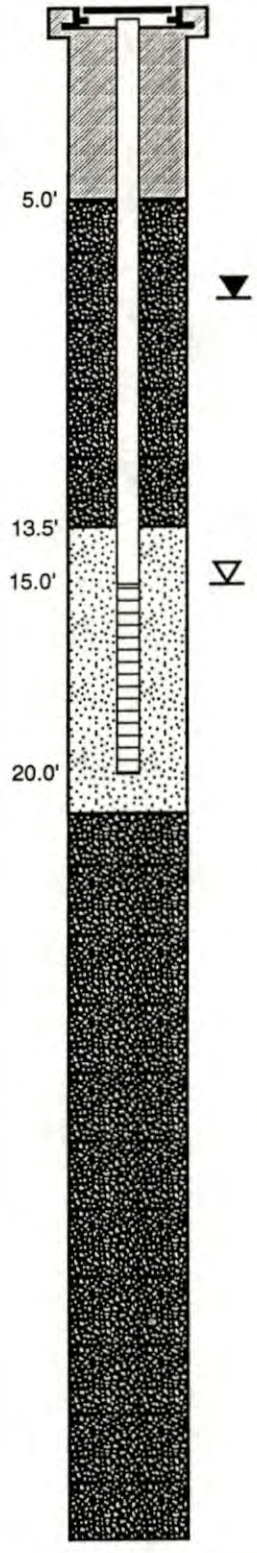
512108mw.cdr

Equipment: AP 1000 Dual Wall

Top of Casing Elevation: 319.63 feet

Start Date: 5/4/94

Well Construction Summary



Blows per Foot	Depth (feet)	Sample	
	0		BROWN SILTY SAND (SM) moist; with some gravel (Fill).
37	5		GRAY BROWN SANDY SILT (ML) very stiff, moist; with some gravel and a trace of organics (Fill).
27	10		GRAY BROWN SILTY SAND (SM) medium dense, moist; with some gravel and a trace of wood fragments (Till).
	15		BROWN SANDY SILT (MH) elastic, wet; with some gravel.
36	20		
	25		GRAY SANDY SILTSTONE, well consolidated, flaggy, moderately hard, weak, fresh, fine to medium grained sand.
	30		
	35		With a trace of wood fragments.
	40		

AGI TECHNOLOGIES

Log of Well PZ-2 (0-40')

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE **C5a**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	JFL/ALW	4 April 95	TMM		

512108mw.cdr

Equipment: AP 1000 Dual Wall

Top of Casing Elevation: 319.63 feet

Start Date: 5/4/94

65.0'

Blows per Foot | Depth (feet) | Sample

40

45

With shell fragments.

With a trace of organics and wood fragments.

50

DARK GRAY SANDY SILTSTONE, well consolidated, flaggy, moderately hard, fresh, fine to medium sand.

55

60

65

Boring terminated on 5/5/94.
Groundwater encountered at 15 feet during drilling.

70

75

80

AGI TECHNOLOGIES

Log of Well PZ-2 (40-65')

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE C5b

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	JFL/ALW	4 April 95	TMM		

512108mw.cdr

Equipment: AP 1000 Dual Wall

Top of Casing Elevation: 324.18 feet

Start Date: 5/4/94

Well Construction Summary

Blows per Foot	Depth (feet)	Sample	
	0		BROWN SANDY SILT (ML) stiff, moist; with some gravel and a trace of organics (Fill).
16	5		
			Becomes red brown, saturated, very stiff.
	10		
34			BROWN SILTY SAND (SM) dense, saturated; with some gravel (Till).
			Becomes moist.
50/4"	15		
			Becomes gray.
50/5"	20		
			With a trace of gravel.
	25		
	30		GRAY GRAVELLY SILT (ML) very stiff, moist; with some sand.
	35		DARK GRAY SILTSTONE, moderately consolidated, low hardness, weak, fresh.
	40		

AGI TECHNOLOGIES

Log of Well PZ-3 (0-40')

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE C6a

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
512108mw.cdr	15,512.108	JFL/ALW	4 April 95	TMM	

Equipment: AP 1000 Dual Wall

Top of Casing Elevation: 324.18 feet

Start Date: 5/4/94

Blows per Foot | Depth (feet) | Sample

45.0'

40

Platey with oriented mica flakes.

45

Boring terminated on 5/4/94
Groundwater encountered at 12 feet during drilling.

50

55

60

65

70

75

80

AGI TECHNOLOGIES

Log of Well PZ-3 (40-45')

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE **C6b**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	JFL/ALW	4 April 95	TMM		

512108mw.cdr

Equipment AP 1000 Dual Wall

Top of Casing Elevation 323.18 feet

Start Date 5/4/94

Well Construction Summary

Blows per Foot	Depth (feet)	Sample	
	0		BROWN SANDY SILT (ML) stiff, moist; with some gravel (Fill).
17	5		
			Becomes very stiff, wet (Till).
27	10		
			With a trace of wood fragments. Becomes gray, very hard.
	15		GRAY SANDY SILT (ML) very hard, moist; with a trace of gravel.
50			
50/4"	20		
	25		DARK GRAY SILT (ML) very hard, moist; with a trace of gravel (weathered siltstone).
50/3"			
			With some bedrock fragments. Bedrock encountered at approximately 32 feet.
	30		
			DARK GRAY SILTSTONE, moderately consolidated, platey, low hardness, weak, fresh to little weathered, with thin micaceous laminations.
	35		
	40		

AGI TECHNOLOGIES

Log of Well PZ-4 (0-40')

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE C7a

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	JFL/ALW	4 April 95	TMR		

512108mw.cdr

Equipment AP 1000 Dual Wall

Top of Casing Elevation 323.18 feet

Start Date 5/4/94

Blows per Foot | Depth (feet) | Sample

40
45
50
55
60
65
70
75
80

DARK BROWN CLAY (OL) stiff, wet; with a trace of organics.

DARK GRAY SILTSTONE, moderately consolidated, platey, low hardness, weak, fresh to little weathered, with thin micaceous laminations.

Boring terminated on 5/4/94.

Groundwater encountered at 10 feet during drilling.

AGI TECHNOLOGIES

Log of Well PZ-4 (40-45')

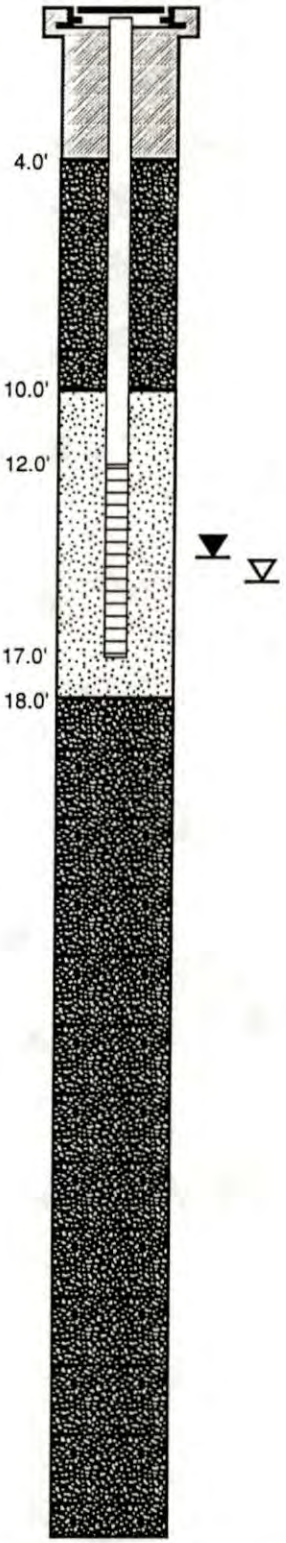
Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE C7b

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	JFL/ALW	4 April 95	TMM		

512108mw.cdr

Well Construction Summary



Equipment AP 1000 Dual Wall

Top of Casing Elevation 311.16 feet

Start Date 5/6/94

Blows per Foot	Depth (feet)	Sample	
	0		GRAY SAND (SW-SM) moist; with some silt and gravel (Fill).
20	5		BROWN ORGANIC SILT (OL) very stiff, wet; with some fine sand and gravel and a trace of wood fragments (Fill).
			GRAY SILTY SAND (SM) wet; with some gravel (Fill).
12	10		BROWN SANDY SILT (ML) stiff, saturated; with some gravel and a trace of wood fragments (Fill).
61	15		GRAY BROWN SILTY GRAVEL (GM) dense, saturated; with some sand (Alluvium).
			Bedrock encountered at 18 feet.
	20		DARK GRAY SILTSTONE, poorly consolidated, low hardness, friable to weakly strong, fresh.
			Becomes moderately hard and moderately strong.
	25		Becomes dry.
	30		With thin seams of coal and mica.
	35		
	40		

AGI TECHNOLOGIES

Log of Well PZ-5 (0-40')

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE **C8a**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
512108mw.cdr	15,512.108	JFL/ALW	4 April 95	TMM	

Equipment AP 1000 Dual Wall

Top of Casing Elevation 311.16 feet

Start Date 5/6/94

45.0'

Blows per Foot | Depth (feet) | Sample

40

Becomes shaley.

45

Boring terminated on 5/6/94.
Groundwater encountered at 15 feet during drilling.

50

55

60

65

70

75

80

AGI TECHNOLOGIES

Log of Well PZ-5 (40-45')

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE C8b

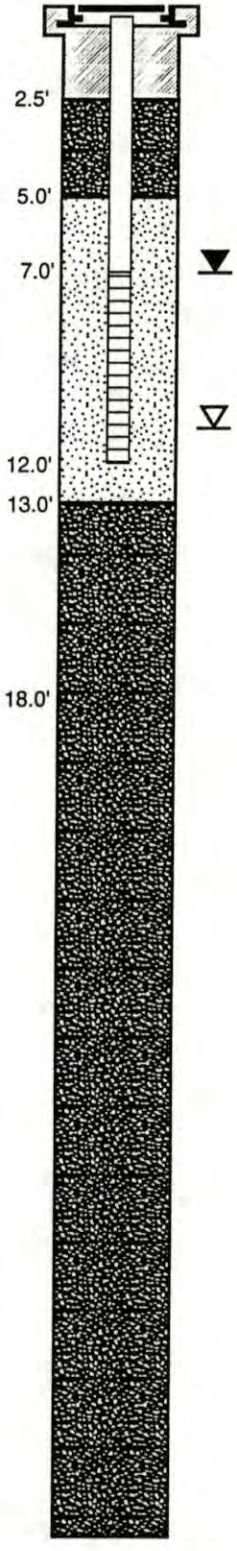
PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
512108mw.cdr	15,512.108	JFL/ALW	4 April 95		

Equipment AP 1000 Dual Wall

Top of Casing Elevation 311.96 feet

Start Date 5/3/94

Well Construction Summary



Blows per Foot	Depth (feet)	Sample	
	0		BROWN SILTY SAND (SM) very dense, moist; with some gravel and a trace of organics (Fill).
	5		
40/6"	10		BROWN SANDY SILT (ML) hard, wet; mottled, with some gravel.
	15		GRAY SILTSTONE, moist, moderately consolidated, flaggy, low hardness, friable to weak, little weathering.
	20		Moisture content increases.
	25		
	30		
	35		GRAY BROWN SANDY SILT (ML) medium stiff, wet.
	40		GRAY SANDY SILTSTONE, moist, well consolidated, flaggy, moderately hard, strong, fresh.

AGI TECHNOLOGIES

Log of Well PZ-6 (0-40')

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE **C9a**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
512108mw.cdr	15,512.108	JFL/ALW	4 April 95		

Equipment AP 1000 Dual Wall

Top of Casing Elevation 311.96 feet

Start Date 5/3/94

Blows per Foot | Depth (feet) | Sample

45.0'

40

45

50

55

60

65

70

75

80

DARK GRAY SILTSTONE, poorly to well consolidated, shaley, low hardness, weak, fresh.
Boring terminated on 5/3/94.
Groundwater encountered at 11 feet during drilling.

AGI TECHNOLOGIES

Log of Well PZ-6 (40-45')

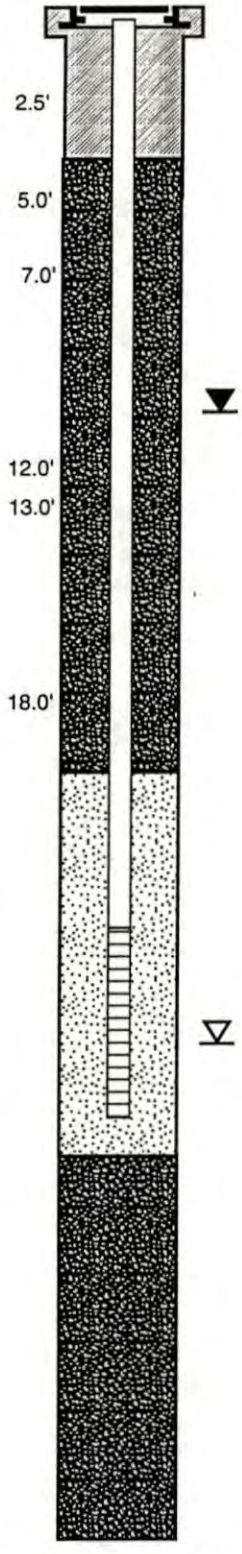
Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE C9b

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	JFL/ALW	4 April 95	TMM		

512108mw.cdr

Well Construction Summary



Equipment: AP 1000 Dual Wall

Top of Casing Elevation: 311.16 feet

Start Date: 5/2/94

Blows per Foot	Depth (feet)	Sample	
	0		GRAY BROWN SILTY SAND (SM) dense, moist; with some gravel (road base).
	5		DARK BROWN SANDY SILT (ML) very hard, moist; with some gravel, gravel is siltstone.
			GRAY SILTSTONE, well consolidated, flaggy, moderately hard, weak, fresh.
50/5"	10		
	15		Becomes moist, with some fine to coarse sand, and a trace of shell fragments.
			Without shell fragments.
	20		
	25		Becomes strong.
			Becomes moderately strong.
	30		With some friable zones and micaceous seams.
			Becomes weak.
	35		
	40		

AGI TECHNOLOGIES

Log of Well PZ-7 (0-40')

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

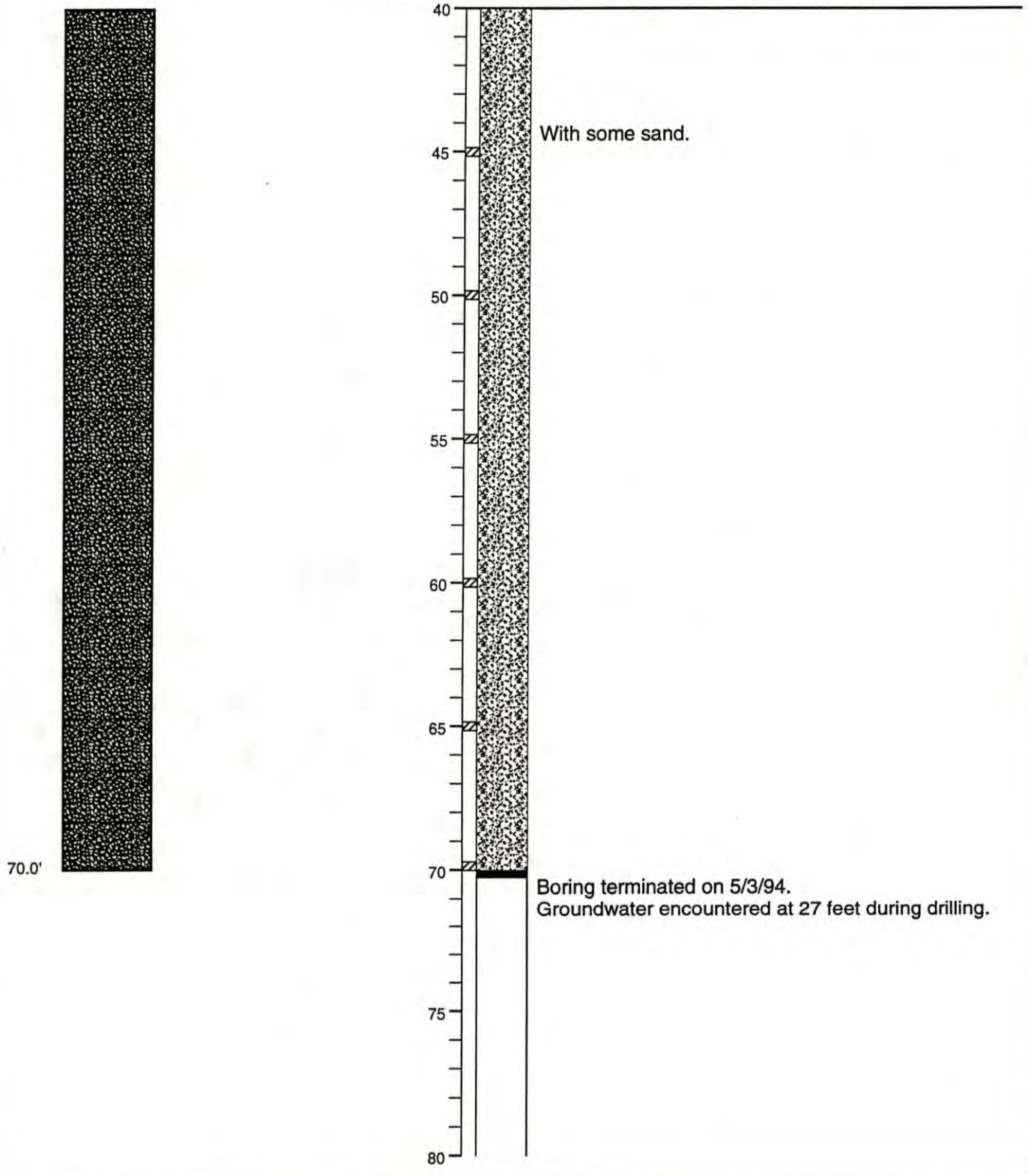
PLATE C10a

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
512108mw.cdr	15,512.108	JFL/ALW	4 April 95	TMM	

Equipment: AP 1000 Dual Wall

Top of Casing Elevation: 311.16 feet

Start Date: 5/2/94



Log of Well PZ-7 (40-70')

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE C10b

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	JFL/ALW	4 April 95	TMM		

512108mw.cdr

AGI TECHNOLOGIES

Equipment AP 1000 Dual Wall

Top of Casing Elevation Abandoned Start Date 5/3/94

Blows per Foot	Depth (feet)	Sample	
	0		GRAY BROWN SILTY SAND (SM) dense, moist; with some gravel (Fill).
	5		
	10		DARK GRAY SILTSTONE, moderately consolidated, flaggy, low hardness, weak, fresh.
	15		
	20		
	25		Becomes well consolidated.
80	30		With shell fragments.
			Bedding becomes shaley, with fine dark gray micaceous laminations.
	35		Occasional shells, petrified wood.
			GRAY PEBBLE SANDSTONE CONGLOMERATE, moderately consolidated, flaggy, medium hard, weak, fresh.
120	40		Boring terminated on 5/3/94.
			Groundwater not encountered during drilling.

AGI TECHNOLOGIES

Log of Boring G-24 (Abandoned)

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE C11

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	/JFL/ALW	4 April 95	TMM		

512108m2.cdr

AGI TECHNOLOGIES

APPENDIX D

Cap Runoff Chemistry Evaluation and Surface Water Chemistry

APPENDIX D

Cap Runoff Chemistry Evaluation and Surface Water Chemistry

CAP RUNOFF CHEMISTRY

Cap runoff samples taken at location L-1 on December 2, 1993 indicated a specific conductivity of 850 micromhos per centimeter (µmhos/cm), a hardness of 400 milligrams per liter (mg/L), and sulfate of 270 mg/L. Other anionic and cationic species were not detected at concentrations that would be expected to affect the specific conductivity. Two different calculation methods were used to determine whether the sources of the high specific conductivity were sulfate and hardness.

The first method is an empirical relationship between total dissolved solids (TDS) and specific conductivity (SC). This approximate relationship is TDS = 0.64 SC, where TDS is in units of mg/L and SC is in units of µmhos/cm (G. Tchobanoglous and F. L. Burton, Wastewater Engineering: Treatment, Disposal, and Reuse, 1991, McGraw-Hill, New York, p. 1145). Assuming that hardness and sulfate represent the majority of the TDS, the calculated SC is 1,000 µmhos/cm, which is the same order of magnitude as the reported value of 850 µmhos/cm.

The second method calculates the specific conductivities associated with hardness and sulfate. The specific molar conductivity of sodium bicarbonate ($NaHCO_3$) was used to represent hardness and the specific molar conductivity of magnesium sulfate heptahydrate ($MgSO_4 \cdot 7H_2O$) was used to represent sulfate (R. C. Weast, Handbook of Chemistry and Physics, 56th Edition, 1975, CRC Press, Cleveland, p. D218 - D267). These selections were made based on geochemistry and data availability. The specific conductance of a solution of magnesium sulfate heptahydrate with 270 mg/L sulfate was calculated to be 570 µmhos/cm. The specific conductivity of a solution of sodium bicarbonate with a hardness (measured as calcium carbonate) of 400 mg/L was calculated to be 280 mg/L. These data add to a total of 850 µmhos/cm, which compares well to the observed value for the surface water. Selection of different indicator chemicals for sulfate and hardness would have given different numbers, but the result would be the same order of magnitude.

These results show that the specific conductivity associated with the Cathcart Landfill surface water is attributable to sulfate and hardness. The data also show that even though the concentration of hardness is greater than that of sulfate, the sulfate is the major source of the high specific conductivity.

SURFACE WATER CHEMISTRY

Surface water chemistry plots are provided in the following **Plates D-1** through **D-20**. Surface water chemistry results for the fourth quarter 1994 round are presented in **Tables D-1** through **D-3**.

AGI TECHNOLOGIES

Table D–1
General Parameters – Surface Water
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Parameter	Detection Limit	Date Sampled	Sample I.D. A	A–1	B	B–1	D	D–1	F	J	North Pond
pH		11/94	6.9	6.7	6.9	NA	NA	6.8	6.8	6.7	NA
		11/17/94	NA	NA	NA	NA	NA	7.3	NA	NA	NA
		12/02/94	6.2	6.2	NA	6.2	6.5	NA	6.2	7.2	6.8
		12/09/94	NA	NA	NA	NA	6.9	NA	6.7	NA	NA
Total Organic Cargon (mg/L)	1.0	11/94	7.5	4.8	5.5	NA	NA	45	8.2	7.5	NA
	1.0	11/17/94	NA	NA	NA	NA	NA	10	NA	NA	NA
	1.0	12/02/94	3.6	3.1	NA	7.5	8.0	NA	3.5	3.5	8.8
	1.0	12/09/94	NA	NA	NA	NA	11	NA	3.8	NA	NA
Chemical Oxygen Demand (mg/L)	10	11/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10	11/17/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10	12/02/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10	12/09/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
Biochemical Oxygen Demand (mg/L)	10	11/94	ND	ND	ND	NA	NA	ND	ND	ND	NA
	10	11/17/94	NA	NA	NA	NA	NA	ND	NA	NA	NA
	10	12/02/94	ND	ND	NA	ND	ND	NA	ND	ND	ND
	10	12/09/94	NA	NA	NA	NA	ND	NA	ND	NA	NA
Chloride (mg/L)	1.0	11/94	7.8	3.5	2.5	NA	NA	48	5.2	5.4	NA
	1.0	11/17/94	NA	NA	NA	NA	NA	6.7	NA	NA	NA
	1.0	12/02/94	6.5	8.3	NA	5.7	4.9	NA	6.0	6.0	4.5
	1.0	12/09/94	NA	NA	NA	NA	4.5	NA	6.5	NA	NA
Conductivity (μmhos/cm)	0.5	11/94	140	200	440	NA	NA	1,500	580	540	NA
	0.5	11/17/94	NA	NA	NA	NA	NA	710	NA	NA	NA
	0.5	12/02/94	170	160	NA	140	640	NA	200	150	650
	0.5	12/09/94	NA	NA	NA	NA	630	NA	170	NA	NA
Hardness (mg/L)	1.0	11/94	44	73	170	NA	NA	580	250	240	NA
	1.0	11/17/94	NA	NA	NA	NA	NA	340	NA	NA	NA
	1.0	12/02/94	51	37	NA	36	260	NA	57	65	270
	1.0	12/09/94	NA	NA	NA	NA	230	NA	45	NA	NA
Ammonia Nitrogen (mg/L)	0.005	11/94	0.007	0.24	0.029	NA	NA	0.15	0.018	0.085	NA
	0.005	11/17/94	NA	NA	NA	NA	NA	0.016	NA	NA	NA
	0.005	12/02/94	0.010	0.013	NA	0.012	0.011	NA	ND	ND	0.029
	0.005	12/09/94	NA	NA	NA	NA	0.14	NA	ND	NA	NA

AGI TECHNOLOGIES

Table D–1
General Parameters – Surface Water
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Parameter	Detection Limit	Date Sampled	Sample I.D. A	A–1	B	B–1	D	D–1	F	J	North Pond
Nitrate + Nitrite Nitrogen (mg/L)	0.01	11/94	2.0	0.35	0.53	NA	NA	1.3	0.85	1.3	NA
	0.01	11/17/94	NA	NA	NA	NA	NA	2.6	NA	NA	NA
	0.01	12/02/94	3.7	4.2	NA	5.4	1.5	NA	3.8	3.6	1.6
	0.01	12/09/94	NA	NA	NA	NA	1.7	NA	3.9	NA	NA
Nitrite Nitrogen (mg/L)	0.001	11/94	0.004	0.025	0.009	NA	NA	0.011	0.002	0.002	NA
	0.001	11/17/94	NA	NA	NA	NA	NA	0.011	NA	NA	NA
	0.001	12/02/94	0.004	0.003	NA	0.002	0.004	NA	0.004	0.004	0.009
	0.001	12/09/94	NA	NA	NA	NA	0.001	NA	0.001	NA	NA
Sulfate (mg/L)	10	11/94	25	49	74	NA	NA	300	200	200	NA
	10	11/17/94	NA	NA	NA	NA	NA	24	NA	NA	NA
	10	12/02/94	19	46	NA	5.2	200	NA	17	47	230
	10	12/09/94	NA	NA	NA	NA	200	NA	34	NA	NA
Total Coliforms (cfu/100 ml)	1	11/94	450	73	63	NA	NA	ND	60	75	NA
	1	11/17/94	NA	NA	NA	NA	NA	1	NA	NA	NA
	1	12/02/94	75	41	NA	20	1	NA	26	24	ND
	1	12/09/94	NA	NA	NA	NA	1	NA	6	NA	NA
Turbidity (NTU)	10	11/94	4.4	3.8	9.3	NA	NA	26	1.4	1.2	NA
	10	11/17/94	NA	NA	NA	NA	NA	0.84	NA	NA	NA
	10	12/02/94	2.4	4.8	NA	0.60	2.2	NA	1.5	1.6	1.0
	10	12/09/94	NA	NA	NA	NA	0.50	NA	0.60	NA	NA

Notes:

NA – Not analyzed.
ND – Not detected.
mg/L – Milligrams per liter.
μmhos/cm – Micromhos per centimeter.

AGI TECHNOLOGIES

Table D–2
Total Metals – Surface Water
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Metal	Detection Limit (mg/L)	Date Sampled	Sample I.D. A	A–1	B	B–1	D	D–1	F	J	North Pond
Arsenic	0.001	11/94	ND	0.001	ND	NA	NA	0.002	ND	ND	NA
	0.001	11/17/94	NA	NA	NA	NA	NA	ND	NA	NA	NA
	0.001	12/02/94	ND	ND	NA	ND	0.001	NA	ND	ND	ND
	0.001	12/09/94	NA	NA	NA	NA	0.001	NA	0.001	NA	NA
Barium	0.003	11/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	0.002	11/94	ND	ND	0.007	NA	NA	ND	ND	ND	NA
	0.002	11/17/94	NA	NA	NA	NA	NA	ND	NA	NA	NA
	0.002	12/02/94	0.003	0.004	NA	0.002	0.002	NA	ND	ND	0.002
	0.002	12/09/94	NA	NA	NA	NA	ND	NA	ND	NA	NA
Chromium	0.006	11/94	ND	ND	ND	NA	NA	ND	ND	ND	NA
	0.006	11/17/94	NA	NA	NA	NA	NA	ND	NA	NA	NA
	0.006	12/02/94	ND	ND	NA	ND	ND	NA	ND	ND	ND
	0.006	12/09/94	NA	NA	NA	NA	ND	NA	ND	NA	NA
Copper	0.002	11/94	ND	0.003	0.005	NA	NA	ND	0.006	0.007	NA
	0.002	11/17/94	NA	NA	NA	NA	NA	0.009	NA	NA	NA
	0.002	12/02/94	ND	0.002	NA	0.006	0.008	NA	ND	ND	0.004
	0.002	12/09/94	NA	NA	NA	NA	0.002	NA	ND	NA	NA
Iron	0.01	11/94	0.27	0.42	0.50	NA	NA	2.5	0.09	0.12	NA
	0.01	11/17/94	NA	NA	NA	NA	NA	0.07	NA	NA	NA
	0.01	12/02/94	0.13	0.29	NA	0.06	0.18	NA	0.14	0.11	0.07
	0.01	12/09/94	NA	NA	NA	NA	0.06	NA	0.30	NA	NA
Mercury	0.0002	11/94	ND	ND	ND	NA	NA	0.0005	ND	ND	NA
	0.0002	11/17/94	NA	NA	NA	NA	NA	0.0008	NA	NA	NA
	0.0002	12/02/94	ND	0.0004	NA	ND	ND	NA	0.0005	ND	ND
	0.0002	12/09/94	NA	NA	NA	NA	ND	NA	0.0003	NA	NA
Manganese	0.002	11/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nickel	0.01	11/94	ND	ND	0.01	NA	NA	0.02	ND	ND	NA
	0.01	11/17/94	NA	NA	NA	NA	NA	0.01	NA	NA	NA
	0.01	12/02/94	ND	ND	NA	ND	ND	NA	ND	ND	ND
	0.01	12/09/94	NA	NA	NA	NA	0.01	NA	ND	NA	NA

AGI TECHNOLOGIES

Table D–2
Total Metals – Surface Water
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Metal	Detection Limit (mg/L)	Date Sampled	Sample I.D. A	A–1	B	B–1	D	D–1	F	J	North Pond
Lead	0.001	11/94	0.001	0.001	ND	NA	NA	0.001	ND	0.001	NA
	0.001	11/17/94	NA	NA	NA	NA	NA	ND	NA	NA	NA
	0.001	12/02/94	0.001	0.001	NA	ND	ND	NA	ND	0.010	0.010
	0.001	12/09/94	NA	NA	NA	NA	0.003	NA	0.002	NA	NA
Selenium	0.001	11/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
Silver	0.01	11/94	ND	ND	ND	NA	NA	ND	ND	ND	NA
	0.01	11/17/94	NA	NA	NA	NA	NA	ND	NA	NA	NA
	0.01	12/02/94	ND	ND	NA	ND	ND	NA	ND	ND	ND
	0.01	12/09/94	NA	NA	NA	NA	ND	NA	ND	NA	NA
Zinc	0.002	11/94	0.010	0.020	0.081	NA	NA	0.11	0.066	0.042	NA
	0.002	11/17/94	NA	NA	NA	NA	NA	0.016	NA	NA	NA
	0.002	12/02/94	0.014	0.019	NA	0.009	0.014	NA	0.030	0.024	0.018
	0.002	12/09/94	NA	NA	NA	NA	0.023	NA	ND	NA	NA

Notes:

mg/L – Milligrams per liter.
NA – Not analyzed.
ND – Not detected.

AGI TECHNOLOGIES

Table D–3
Volatile Organic Compounds – Surface Water
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Compound	Detection Limit (µg/L)	Date Sampled	Sample I.D. W–1 µg/L
Chloromethane	5.0	11/94	ND
	5.0	12/94	NA
Vinyl Chloride	5.0	11/94	ND
	5.0	12/94	NA
Bromomethane	5.0	11/94	ND
	5.0	12/94	NA
Chloroethane	5.0	11/94	ND
	5.0	12/94	NA
Trichlorofluoromethane	1.0	11/94	ND
	1.0	12/94	NA
1,1–Dichloroethylene	1.0	11/94	ND
	1.0	12/94	NA
Acetone	20	11/94	ND
	20	12/94	NA
Carbon Disulfide	1.0	11/94	ND
	1.0	12/94	NA
Methylene Chloride	1.0	11/94	3.0 B
	1.0	12/94	NA
1,2–Dichloroethylene	1.0	11/94	ND
	1.0	12/94	NA
1,1–Dichloroethane	1.0	11/94	ND
	1.0	12/94	NA
Vinyl Acetate	10	11/94	ND
	10	12/94	NA
2–Butanone (MEK)	10	11/94	ND
	10	12/94	NA
Chloroform	1.0	11/94	ND
	1.0	12/94	NA
1,1,1–Trichloroethane	1.0	11/94	ND
	1.0	12/94	NA
Carbon Tetrachloride	1.0	11/94	ND
	1.0	12/94	NA
Benzene	1.0	11/94	ND
	1.0	12/94	NA
1,2–Dichloroethane	1.0	11/94	ND
	1.0	12/94	NA
1,1,2–Trichloroethene	1.0	11/94	ND
	1.0	12/94	NA
Bromodichloromethane	1.0	11/94	ND
	1.0	12/94	NA
1,2–Dichloropropane	1.0	11/94	ND
	1.0	12/94	NA
4–Methyl–2–Pentanone	10	11/94	ND
	10	12/94	NA

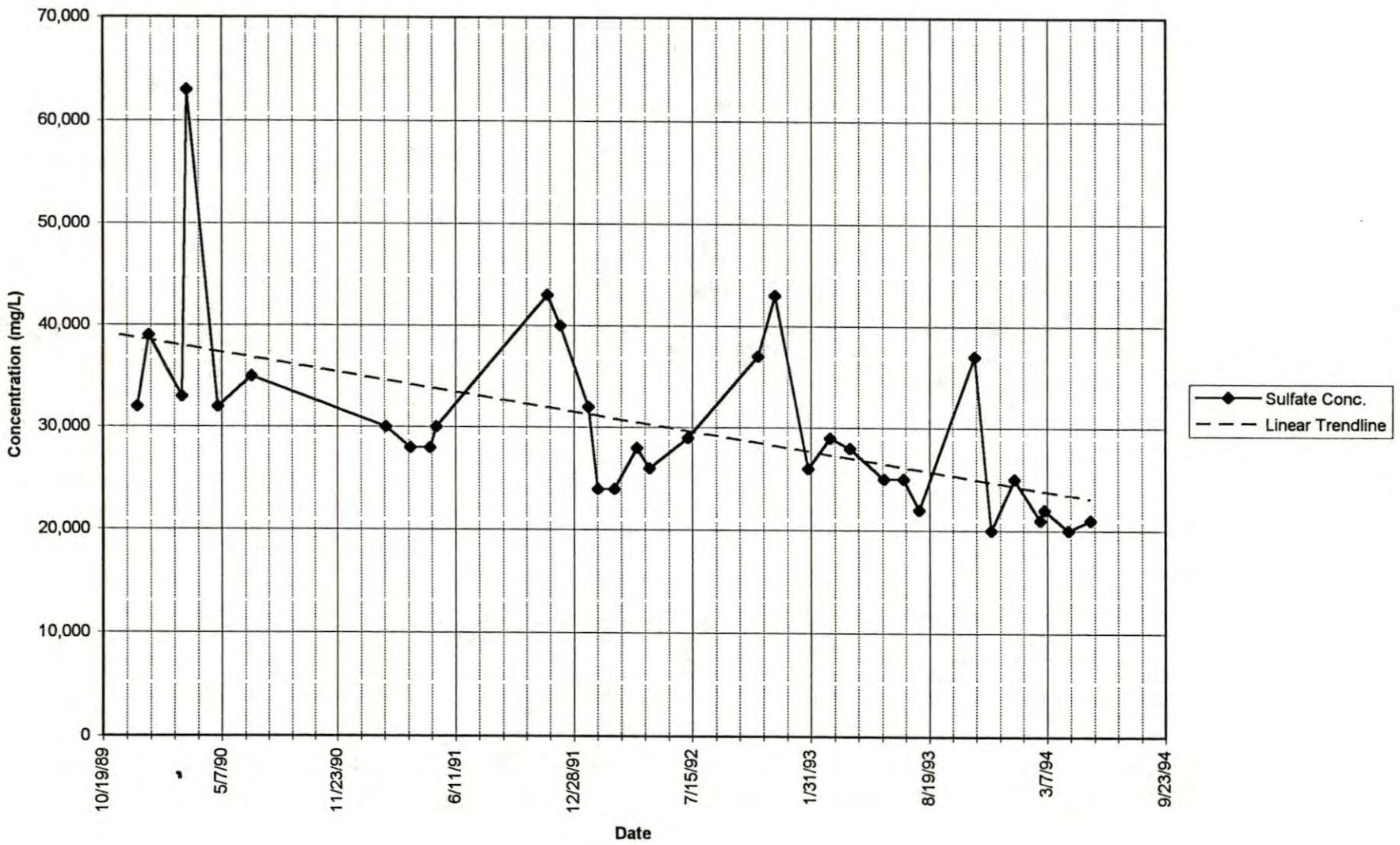
AGI TECHNOLOGIES

Table D–3
Volatile Organic Compounds – Surface Water
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Compound	Detection Limit (µg/L)	Date Sampled	Sample I.D. W–1 µg/L
Toluene	1.0	11/94	1.2
	1.0	12/94	NA
cis–1,3–Dichloropropene	1.0	11/94	ND
	1.0	12/94	NA
1,1,2–Trichloroethane	1.0	11/94	ND
	1.0	12/94	NA
Tetrachloroethylene	1.0	11/94	ND
	1.0	12/94	NA
2–Hexanone	10	11/94	ND
	10	12/94	NA
Chlorodibromomethane	1.0	11/94	ND
	1.0	12/94	NA
Chlorobenzene	1.0	11/94	ND
	1.0	12/94	NA
Ethylbenzene	1.0	11/94	ND
	1.0	12/94	NA
Total Xylenes	1.0	11/94	1.2
	1.0	12/94	NA
Styrene	1.0	11/94	ND
	1.0	12/94	NA
Bromoform	1.0	11/94	ND
	1.0	12/94	NA
1,1,2,2–Tetrachloroethane	1.0	11/94	ND
	1.0	12/94	NA
trans–1,3–Dichloropropene	1.0	11/94	ND
	1.0	12/94	NA
p–Dichlorobenzene	1.0	11/94	ND
	1.0	12/94	NA

Notes:

NA – Not analyzed.
ND – Not detected.
µg/L – Micrograms per liter.



Sulfate at Location A - Garden Creek

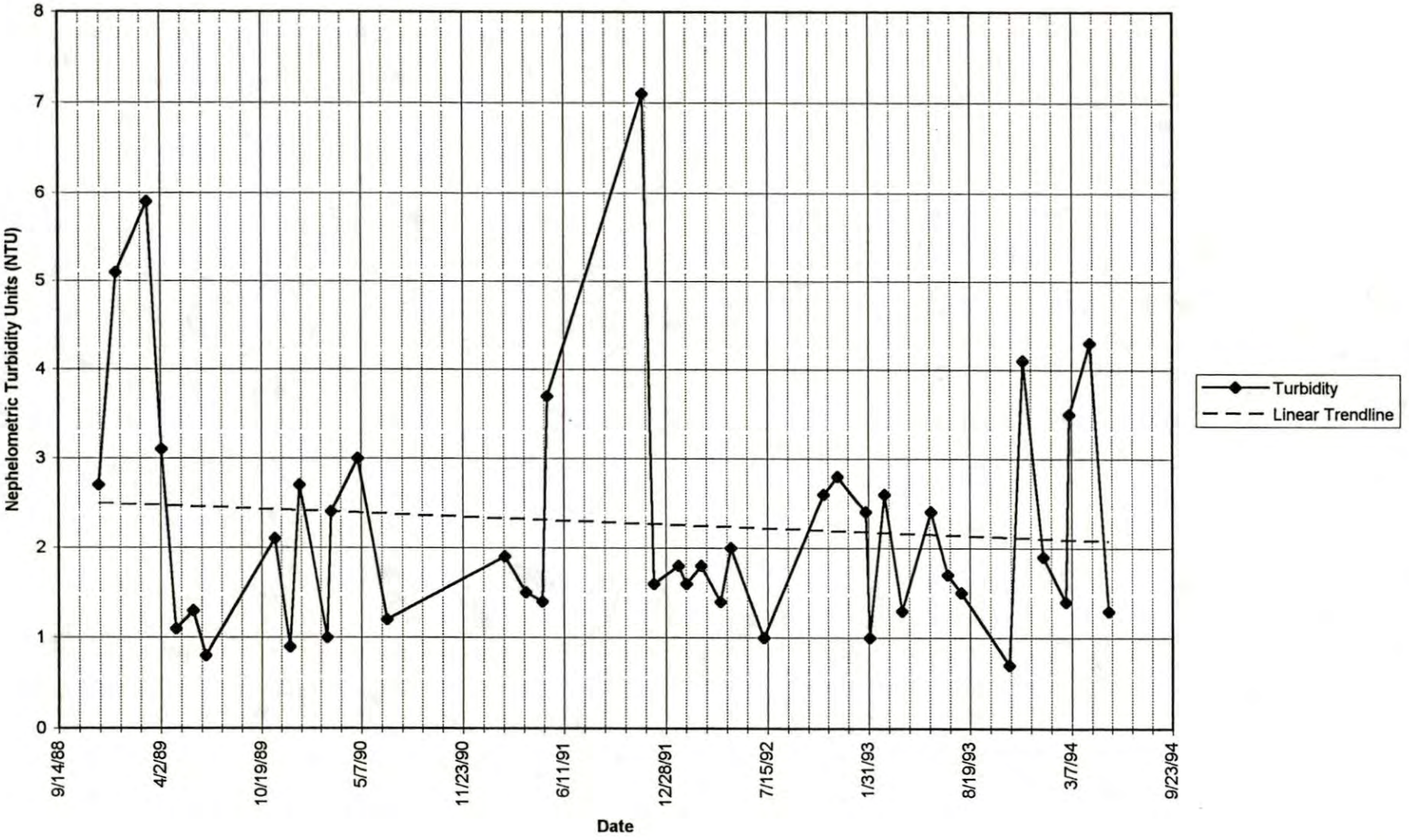
Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

AGI TECHNOLOGIES

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMM		

PLATE **D1**



AGI TECHNOLOGIES

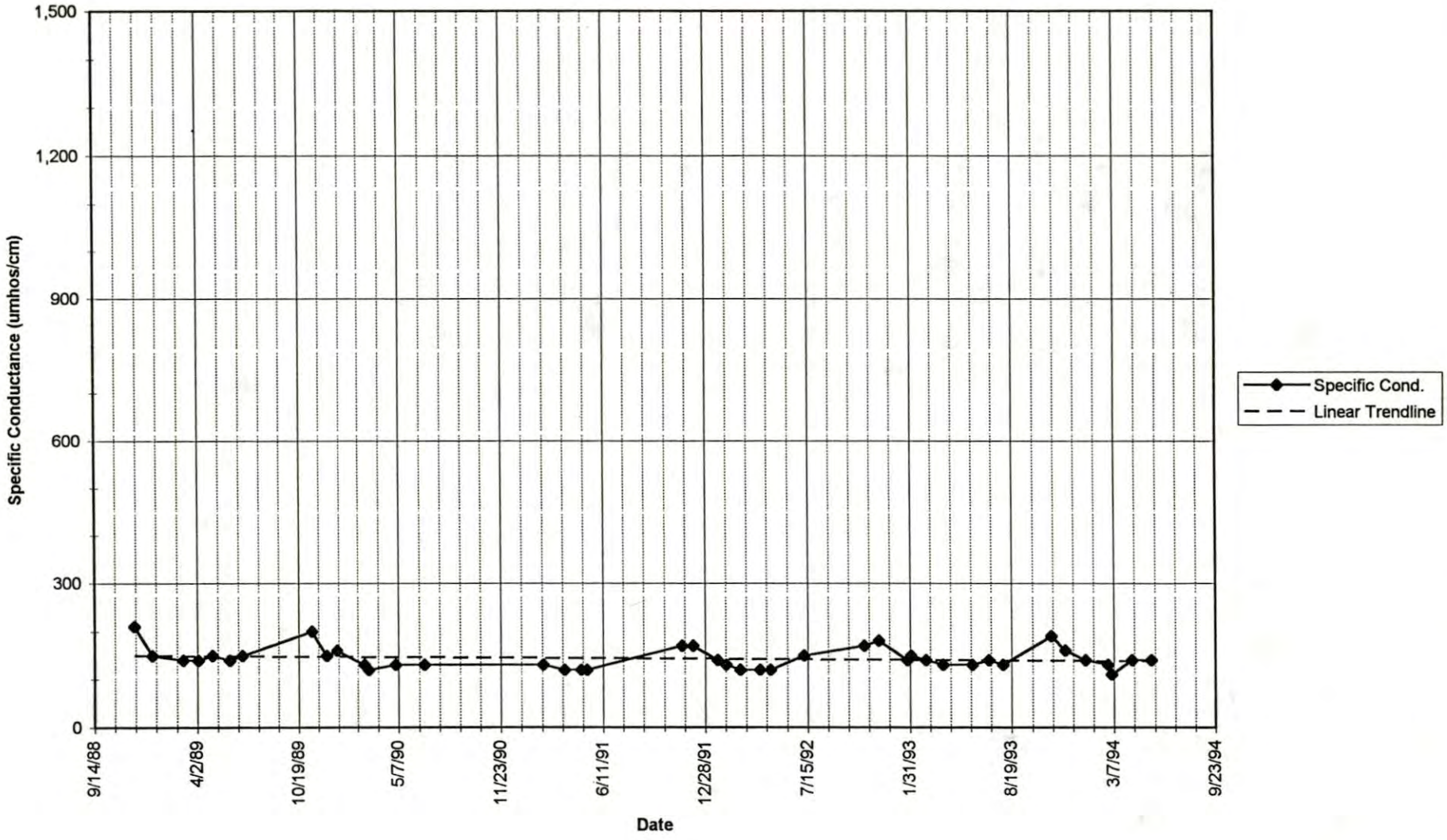
Turbidity at Location A - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **D2**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMM		



AGI TECHNOLOGIES

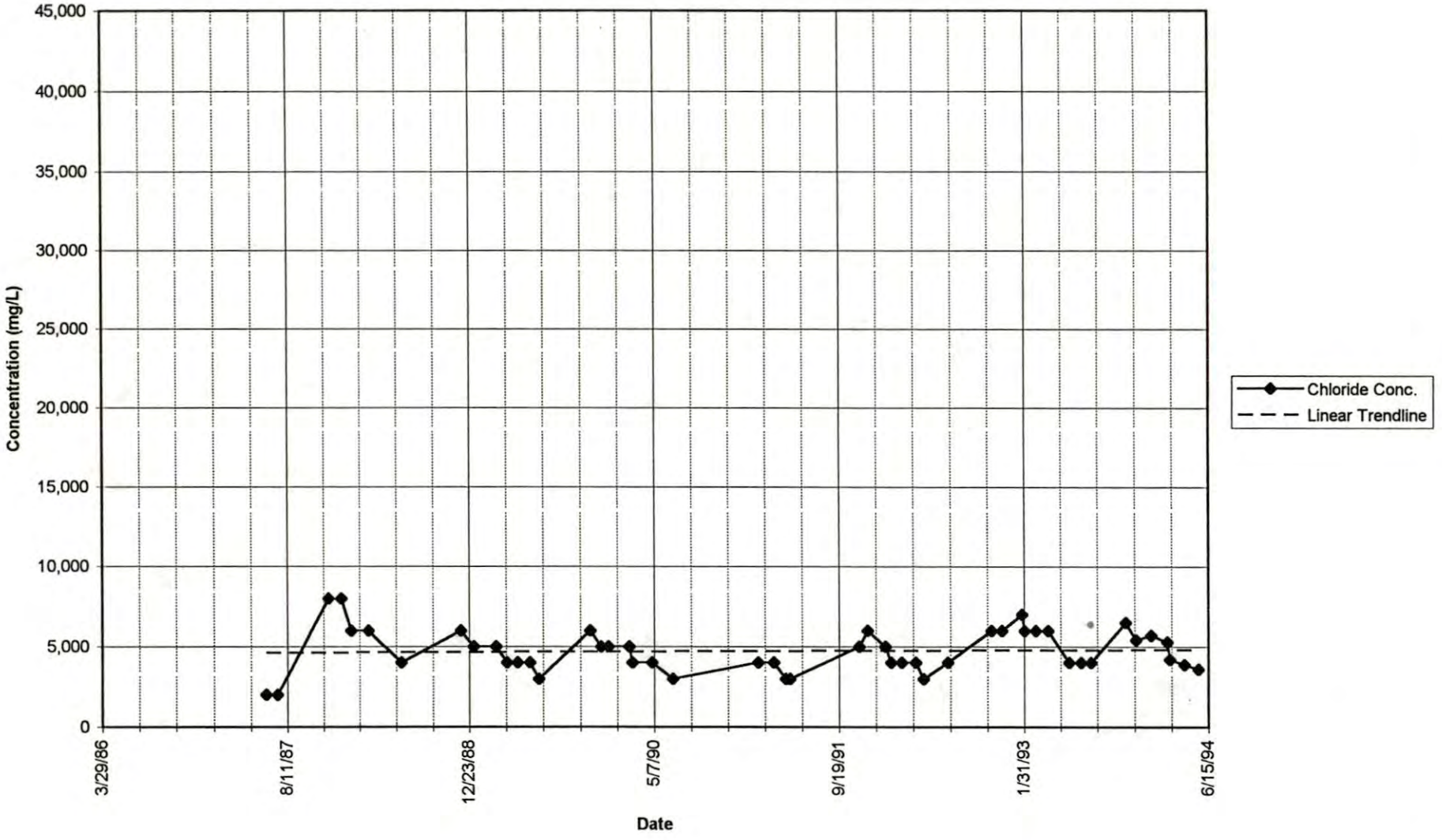
Specific Conductance at Location A - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE: **D3**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMM		



Chloride Concentration at Location A - Garden Creek

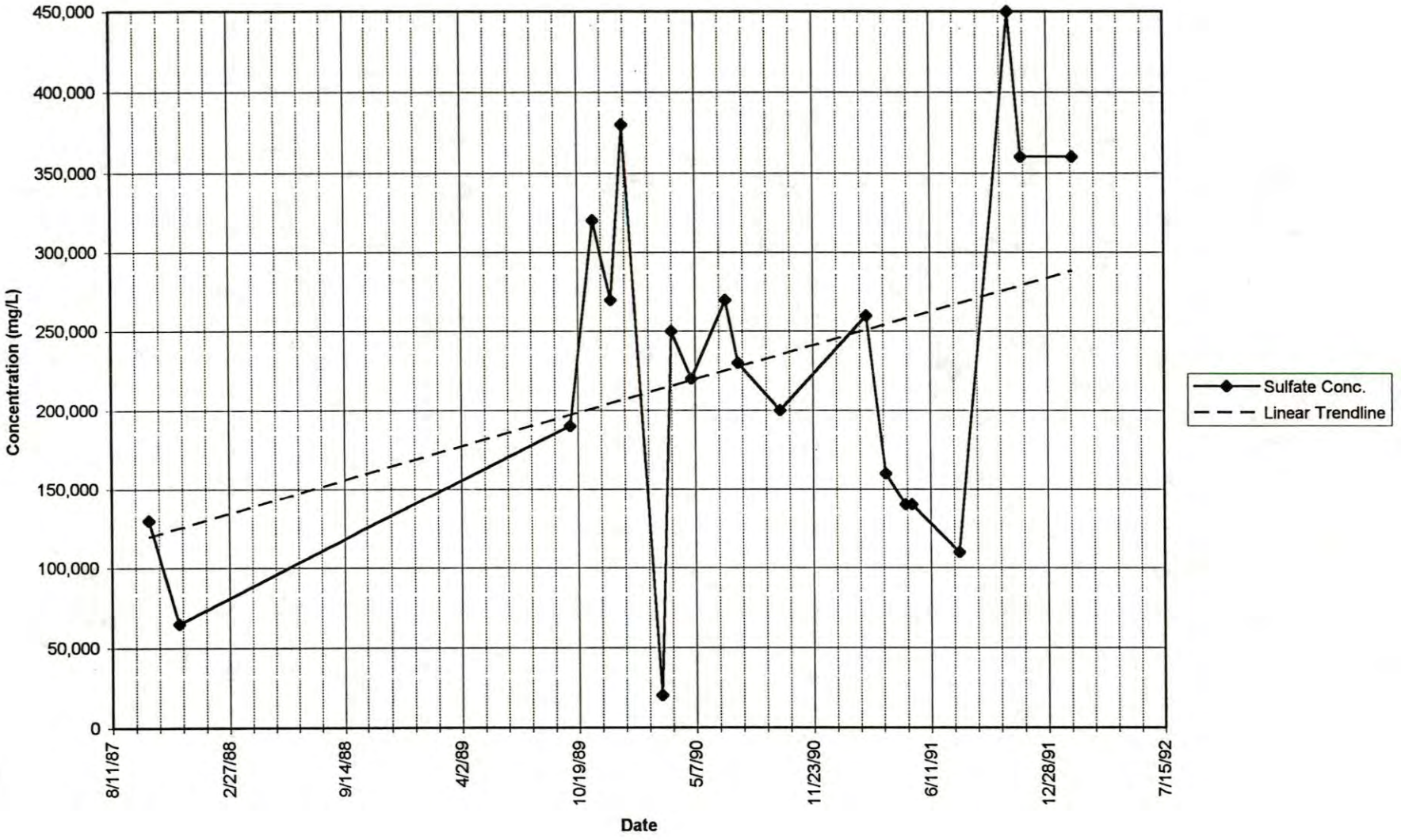
Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

AGI TECHNOLOGIES

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95			

PLATE **D4**



AGI TECHNOLOGIES

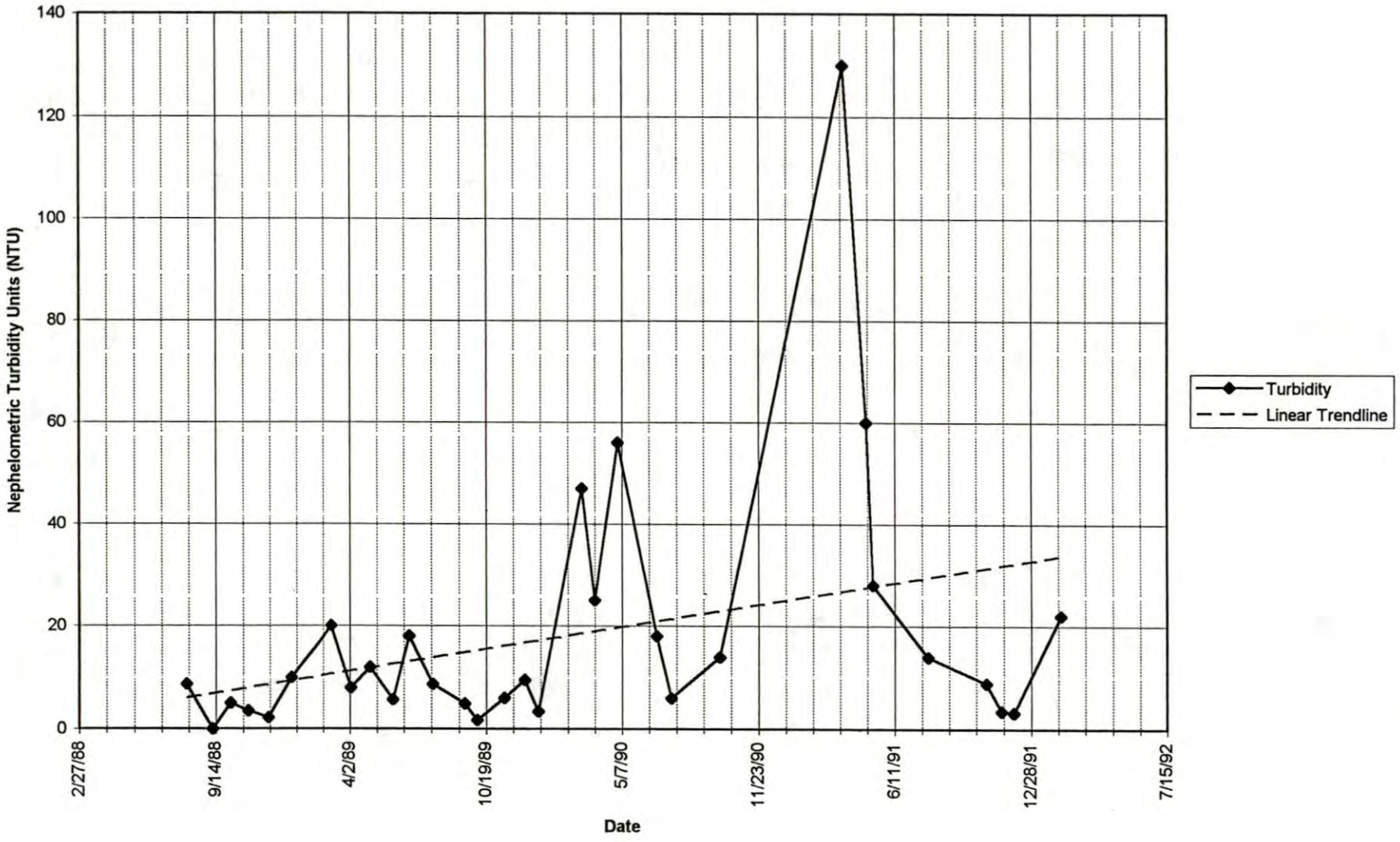
Sulfate at Location C - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **D5**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMM		



AGI TECHNOLOGIES

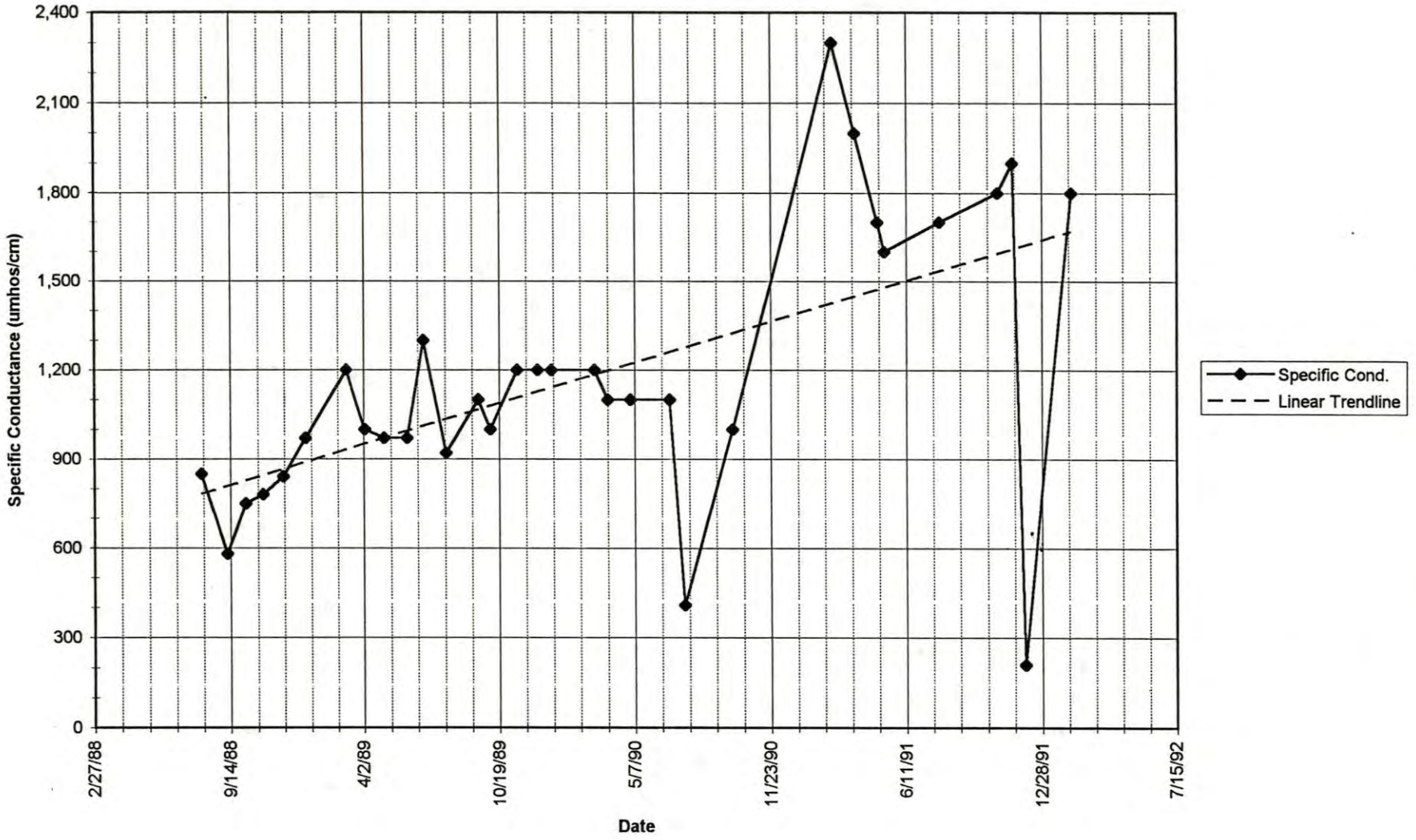
Turbidity at Location C - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **D6**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMM		



AGI TECHNOLOGIES

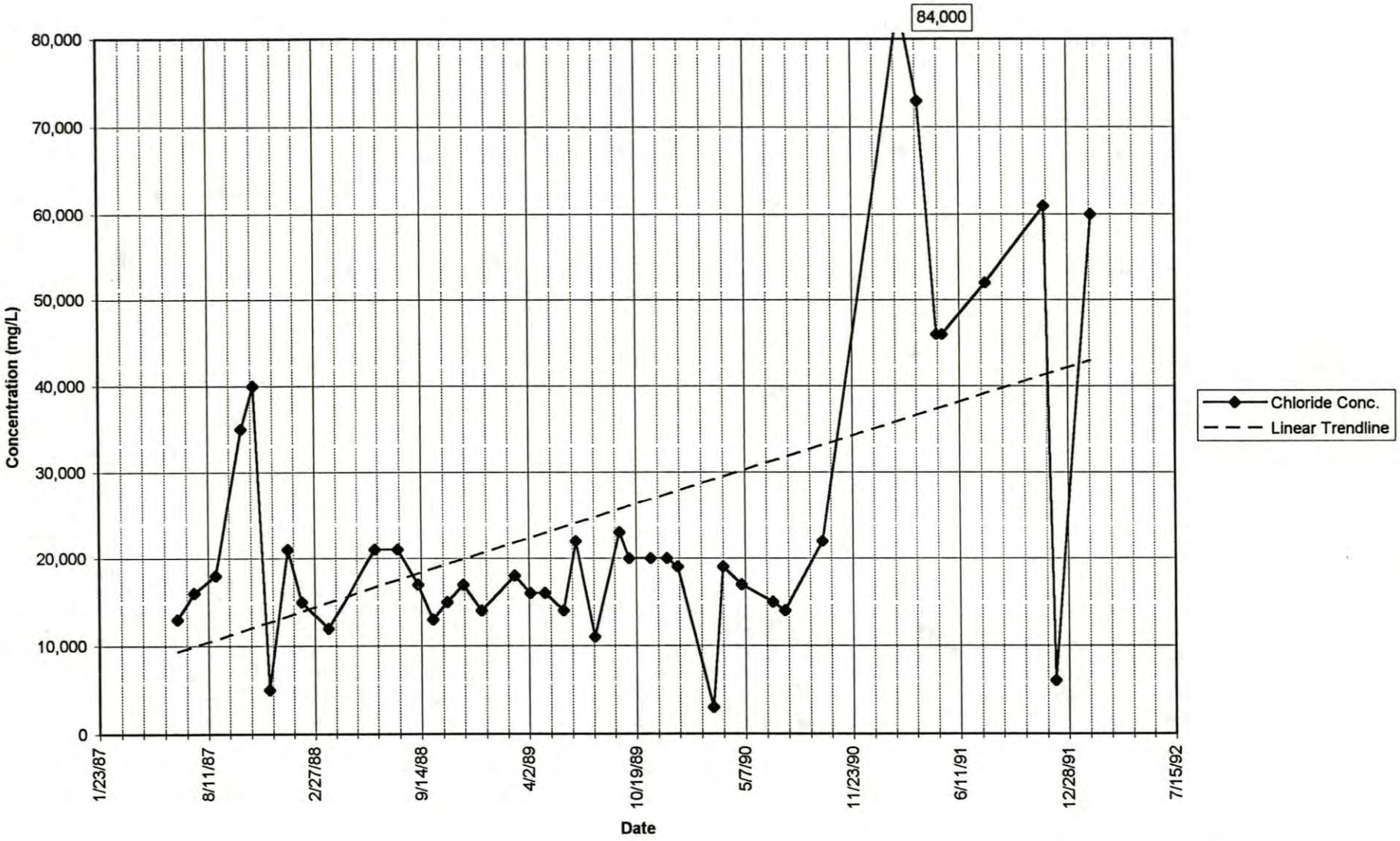
Specific Conductance at Location C - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **D7**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMM		



AGI TECHNOLOGIES

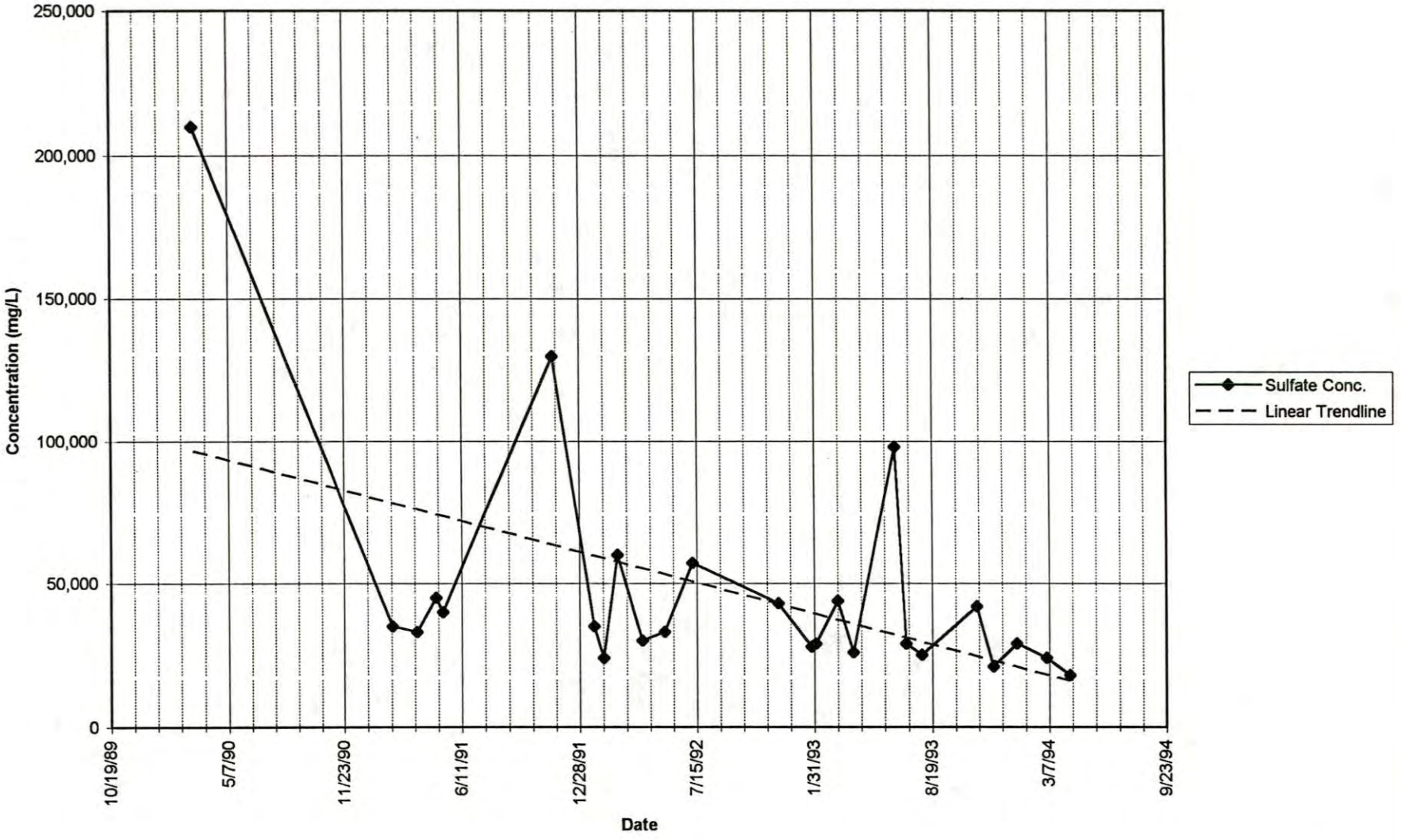
Chloride Concentration at Location C - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE: **D8**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95			



AGI TECHNOLOGIES

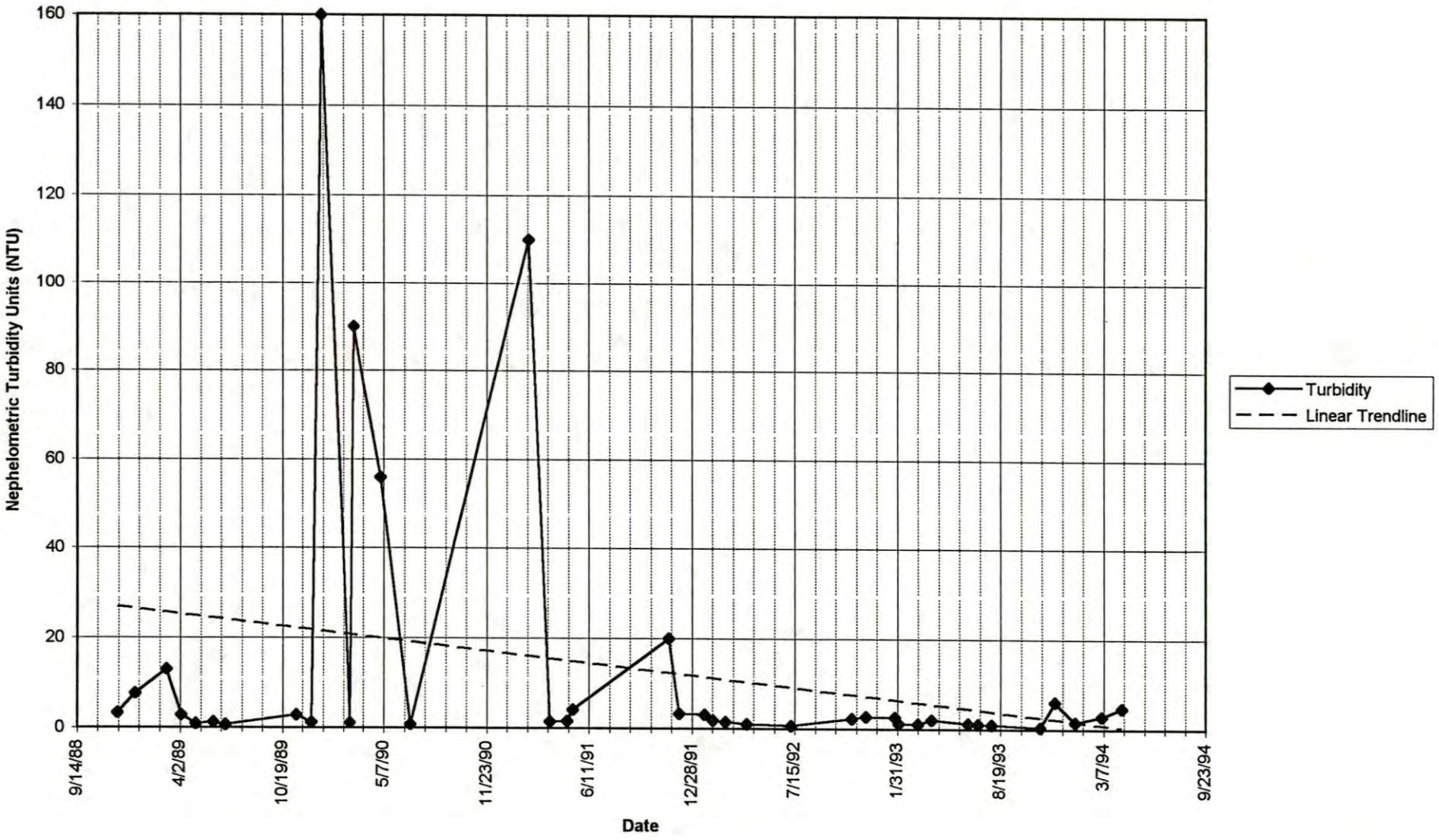
Sulfate at Location F - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE: **D9**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMM		



AGI TECHNOLOGIES

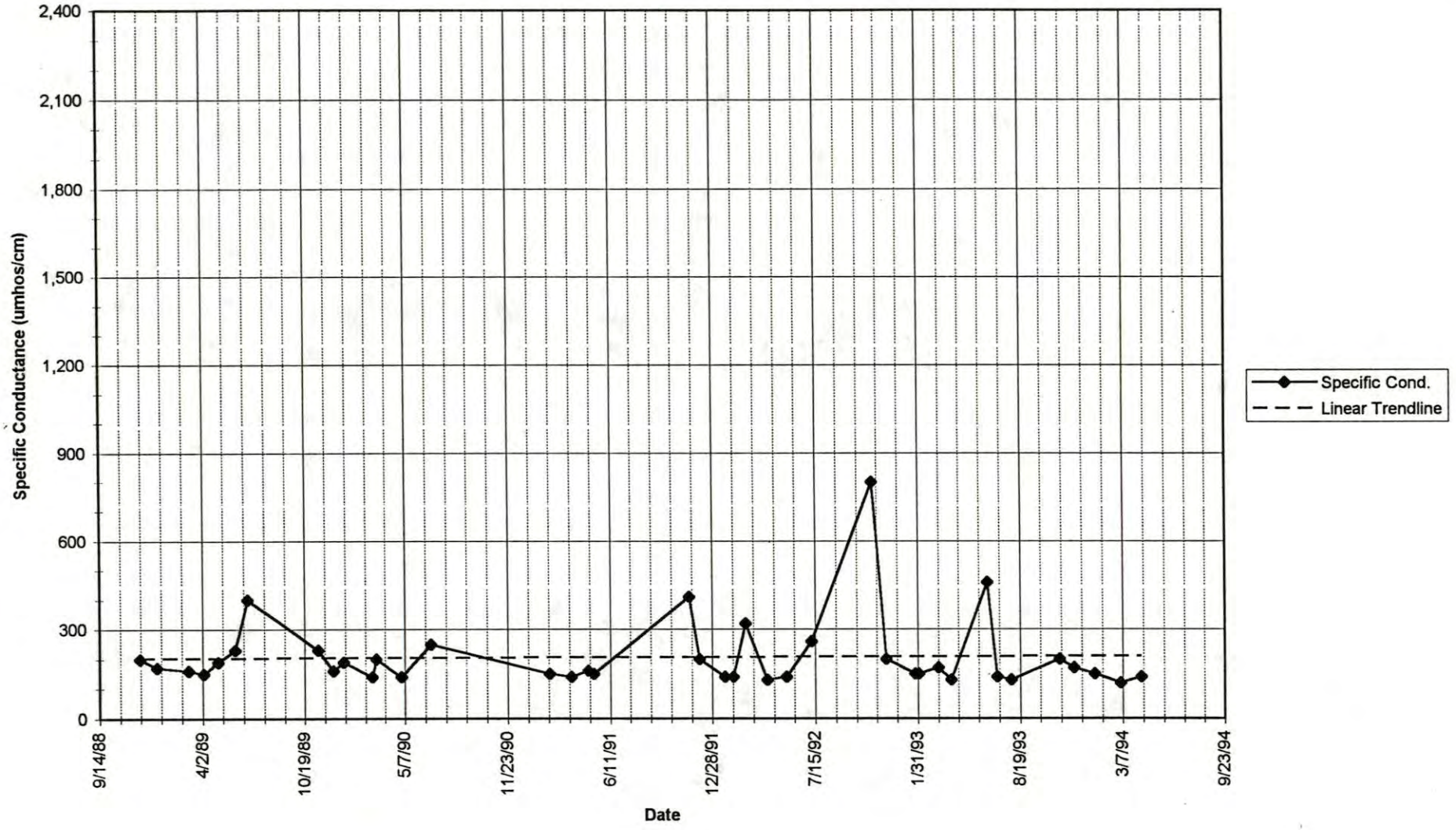
Turbidity at Location F - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **D10**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95			



AGI TECHNOLOGIES

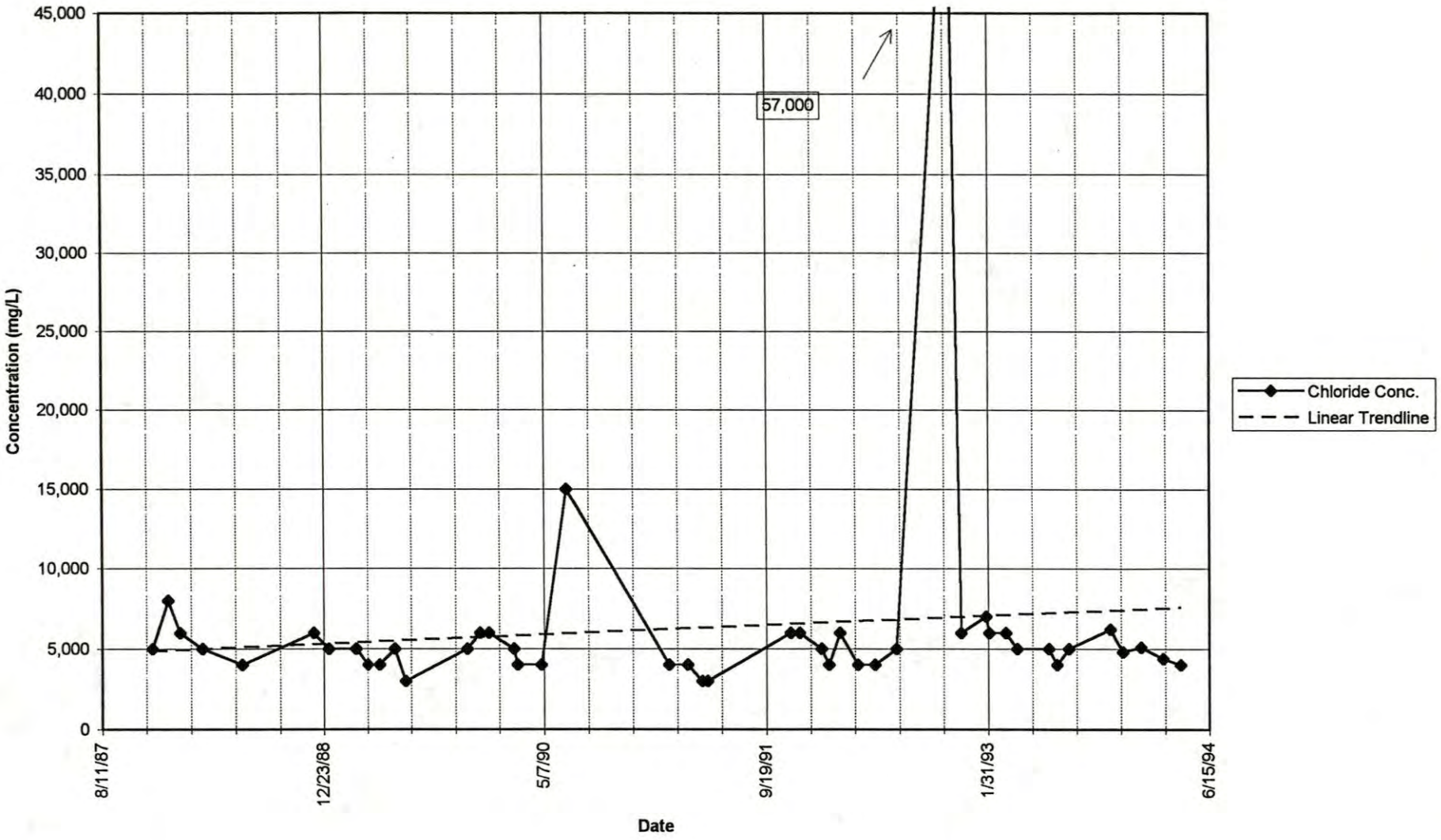
Specific Conductance at Location F - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **D11**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMM		



AGI TECHNOLOGIES

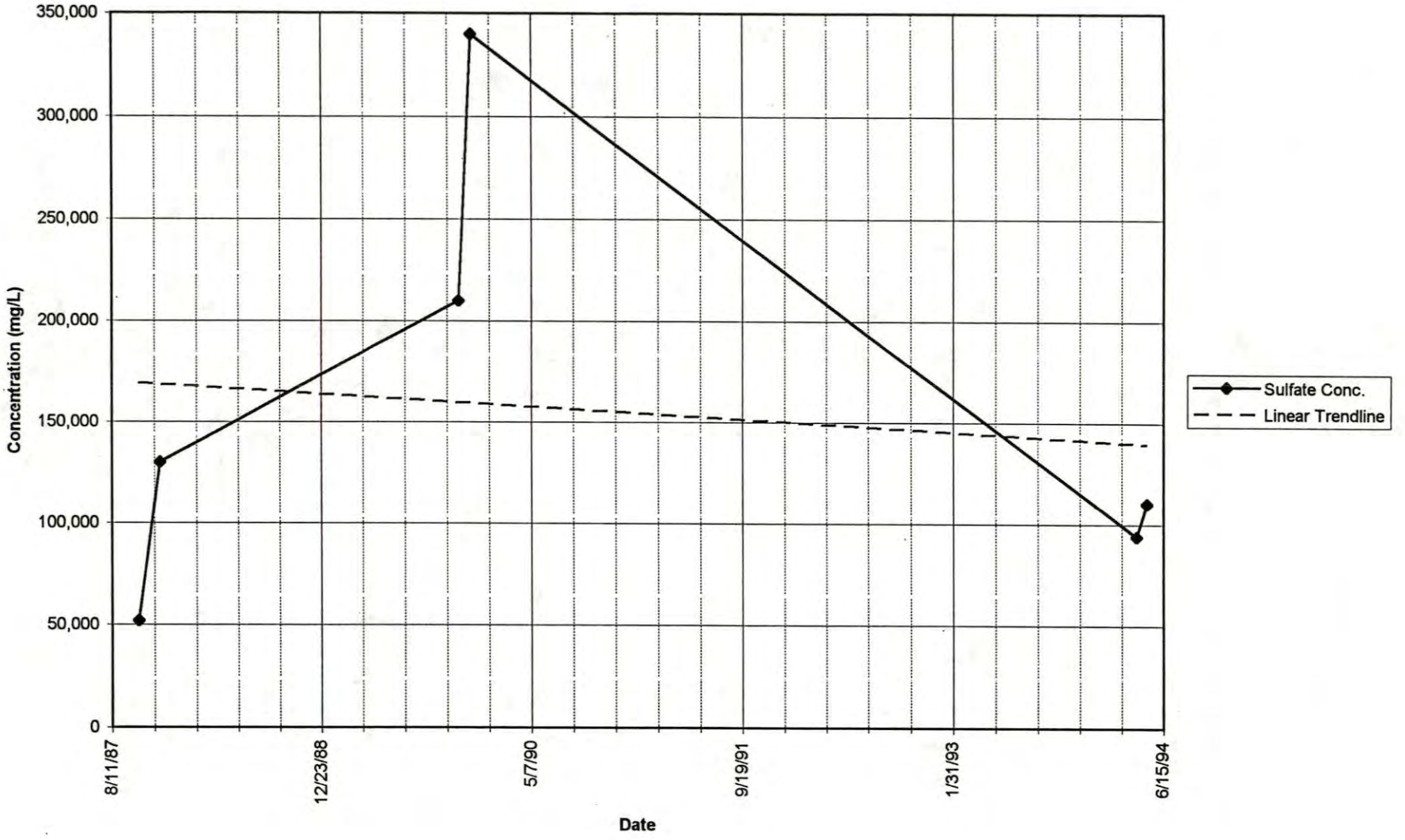
Chloride Concentration at Location F - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **D12**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	JMM		



AGI TECHNOLOGIES

Sulfate at Location D - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **D13**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMH		

AGI TECHNOLOGIES

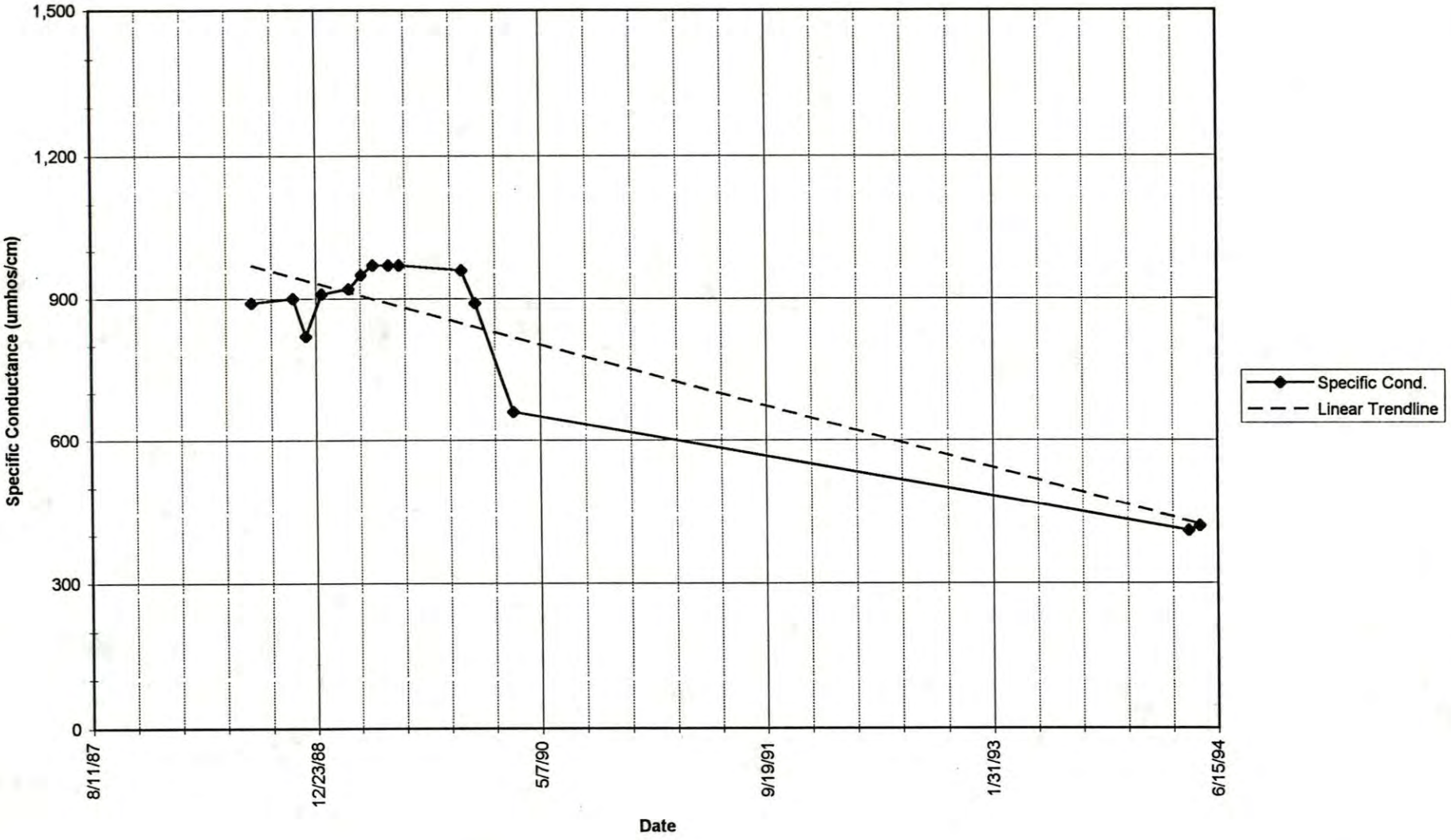
Turbidity at Location D - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **D14**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMH		



AGI TECHNOLOGIES

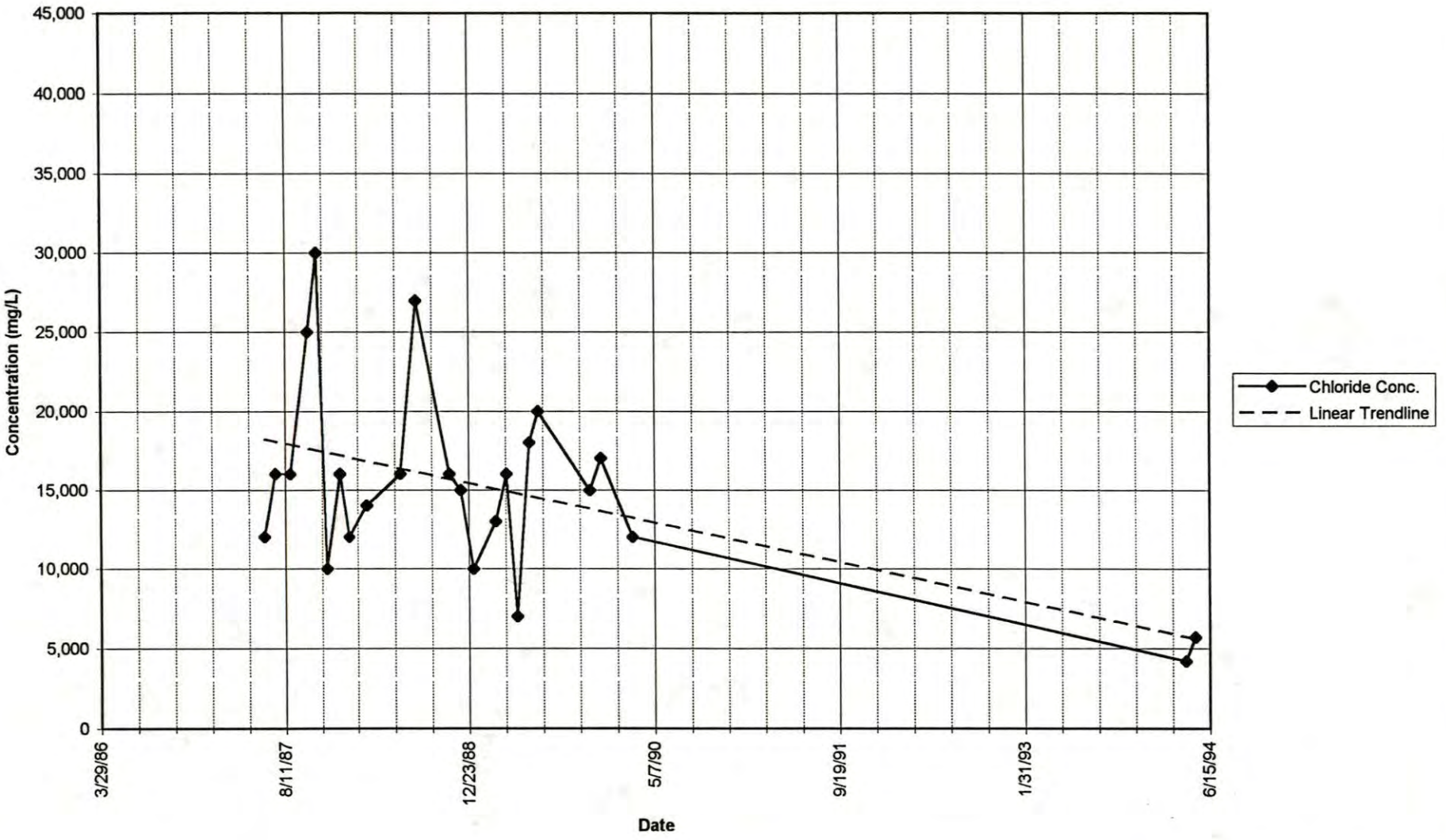
Specific Conductance at Location D - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **D15**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMM		



AGI TECHNOLOGIES

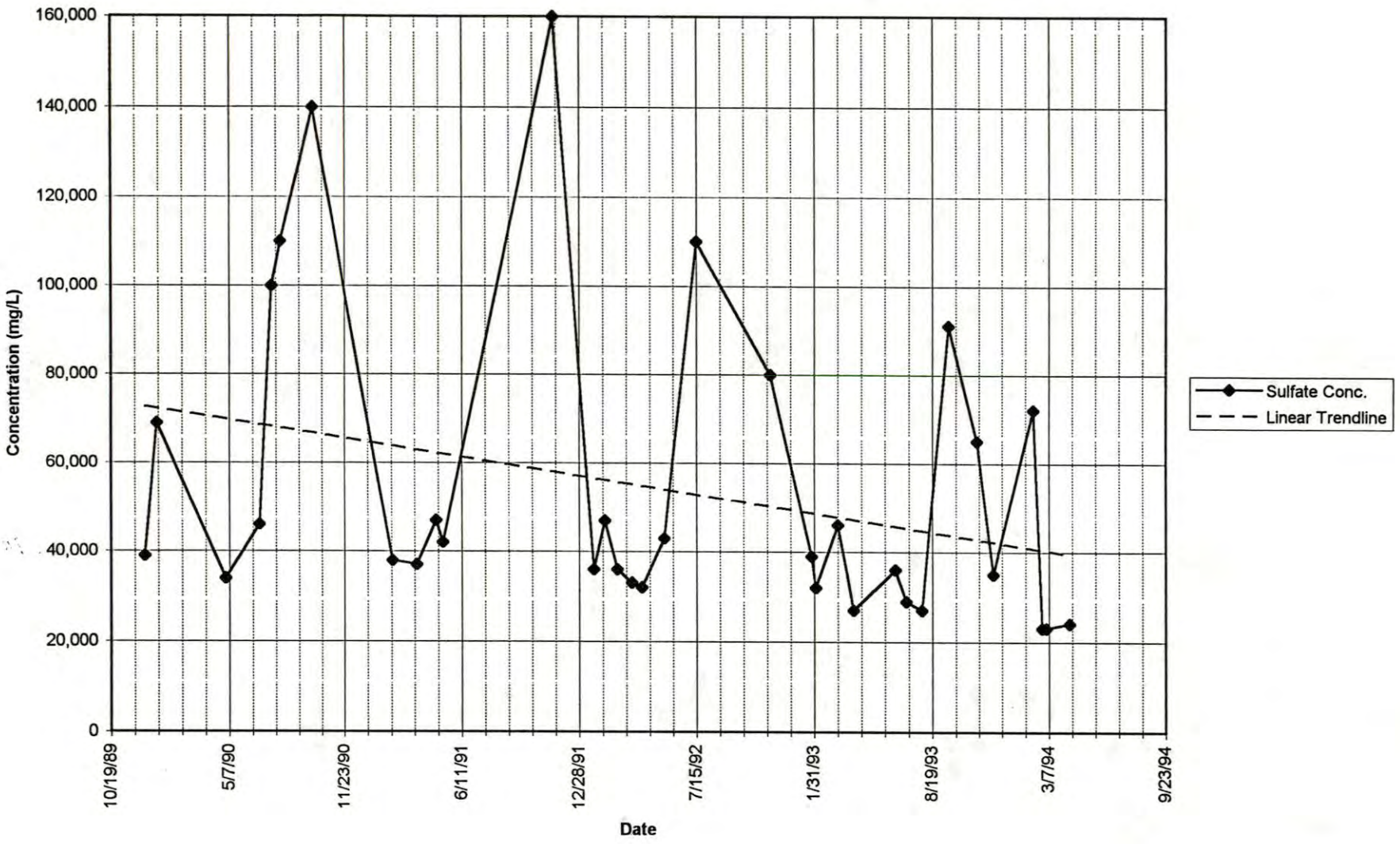
Chloride Concentration at Location D - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE: **D16**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMM		



Sulfate at Location J - Garden Creek

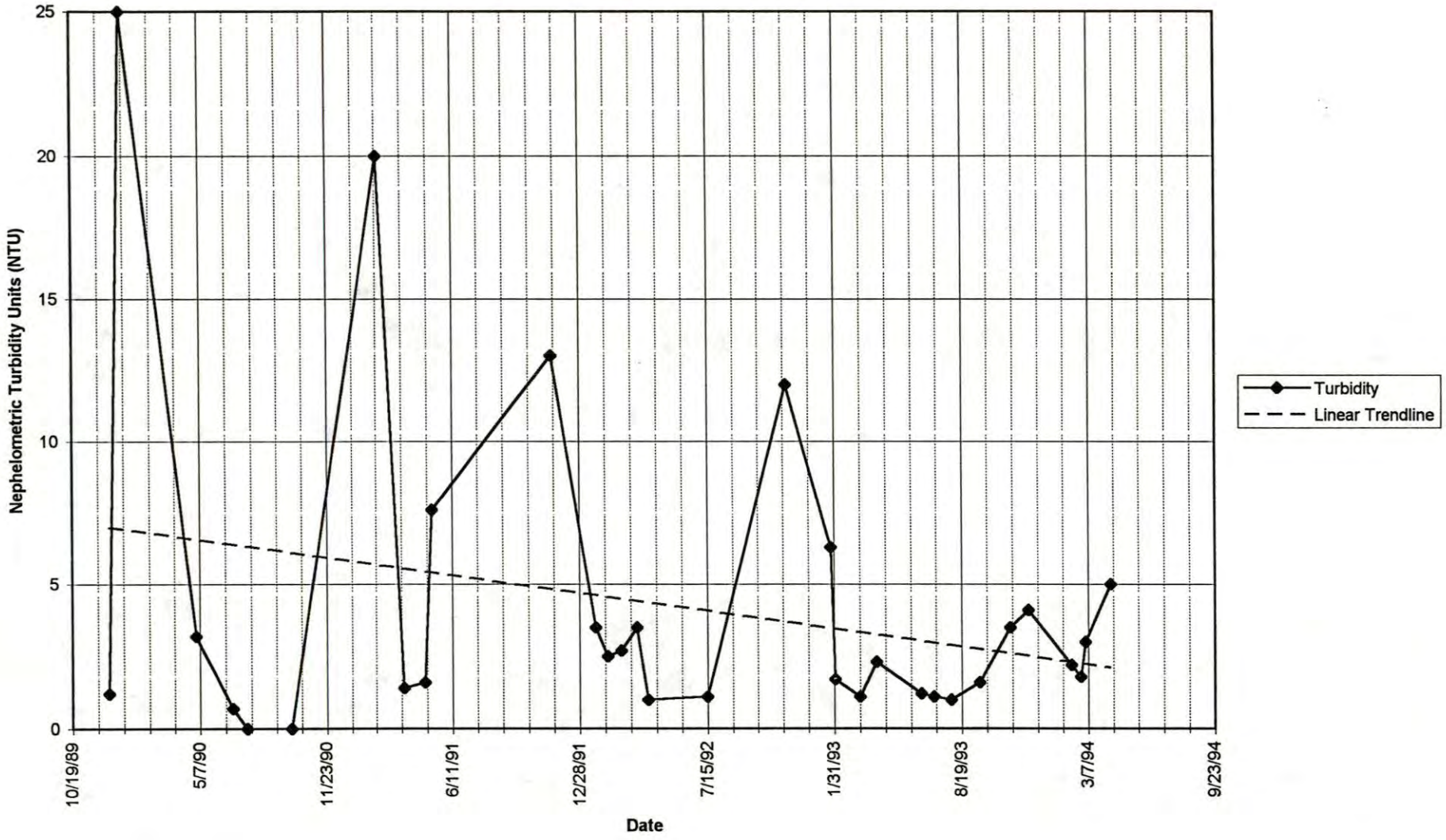
Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

AGI TECHNOLOGIES

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMM		

PLATE: **D17**



AGI TECHNOLOGIES

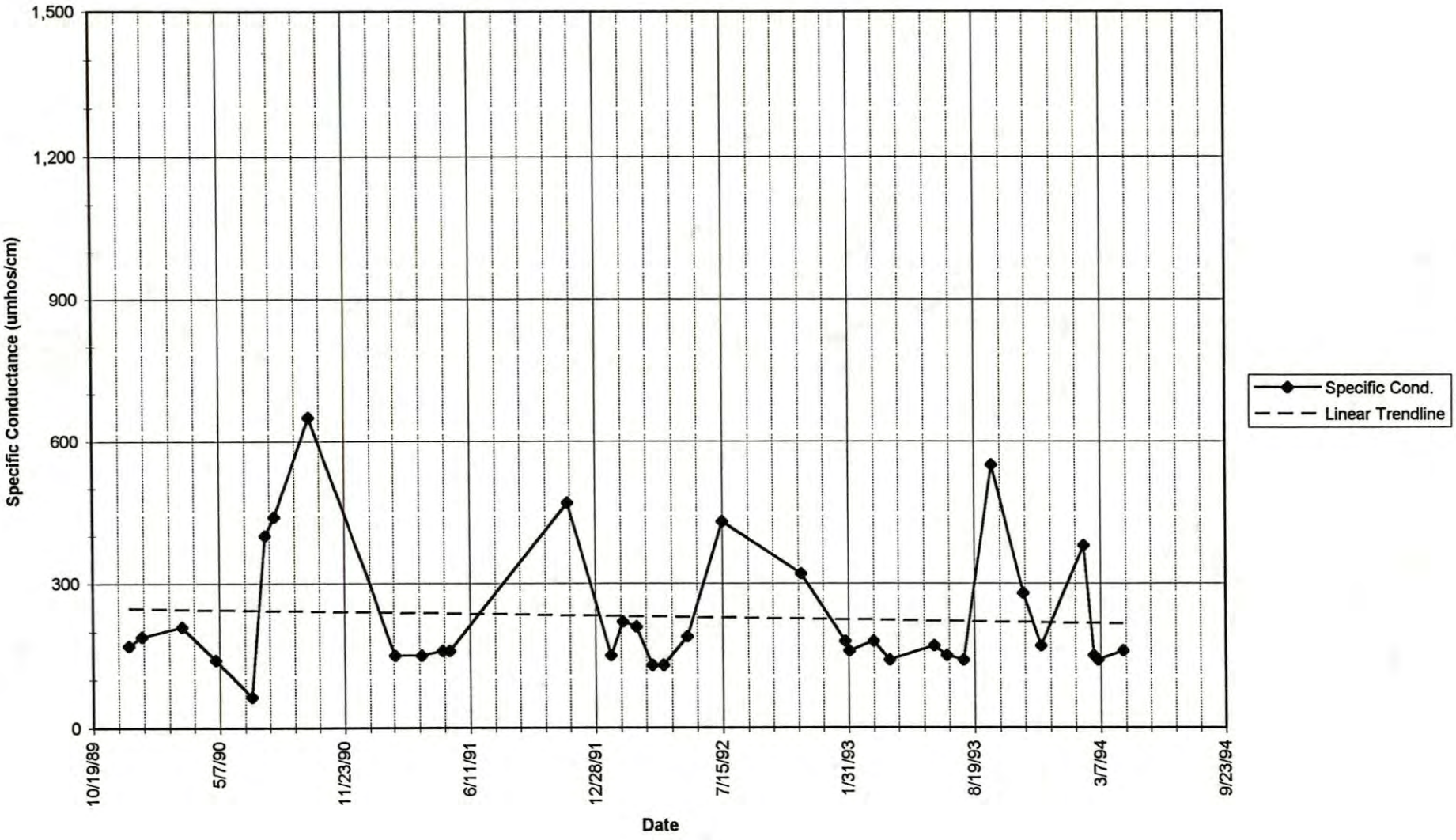
Turbidity at Location J - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE: **D18**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMM		



AGI TECHNOLOGIES

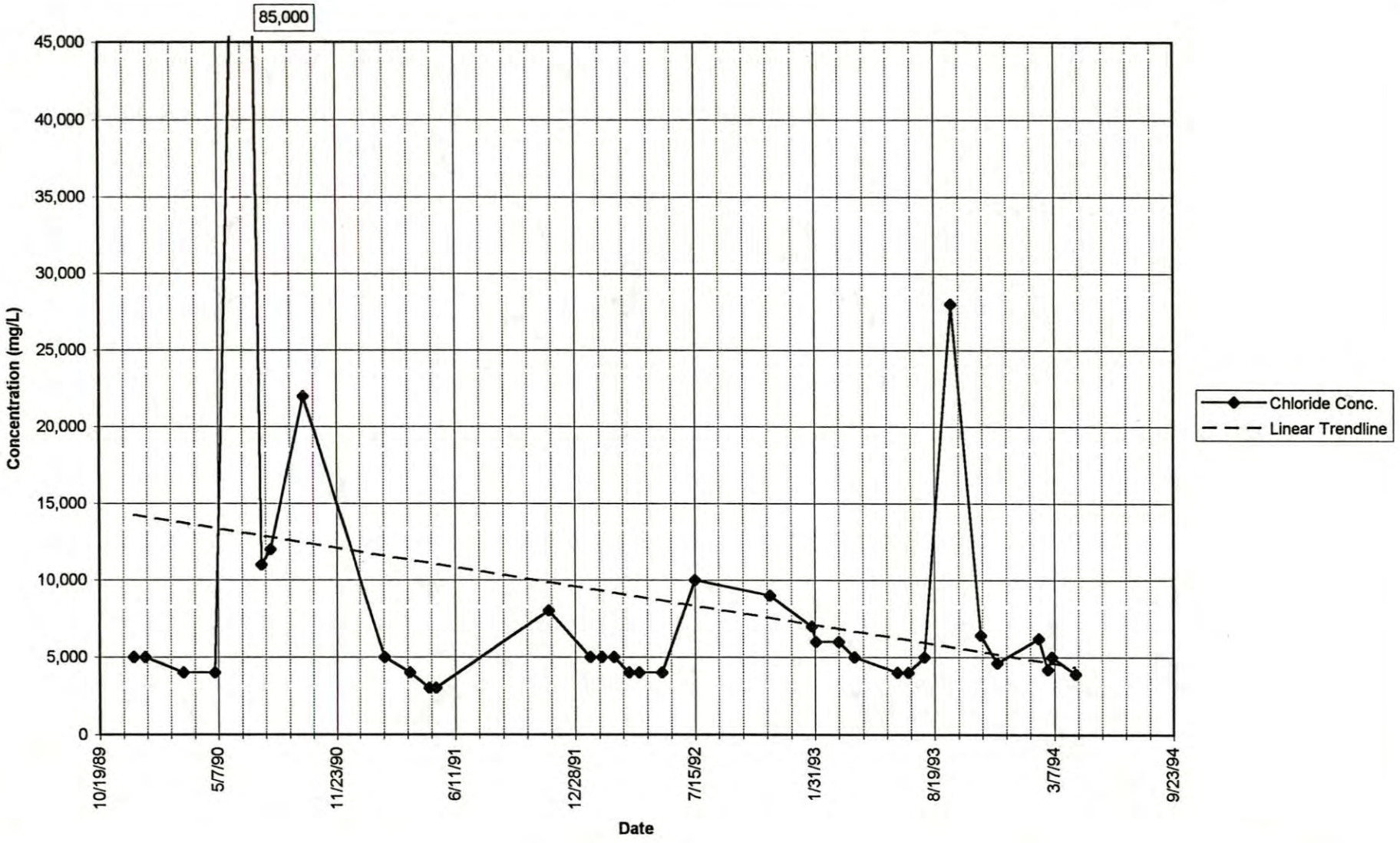
Specific Conductance at Location J - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **D19**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	JMM		



AGI TECHNOLOGIES

Chloride Concentration at Location J - Garden Creek

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **D20**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	6 Mar 95	TMM		

APPENDIX E

Well Information and Groundwater Elevation and Flow Diagrams

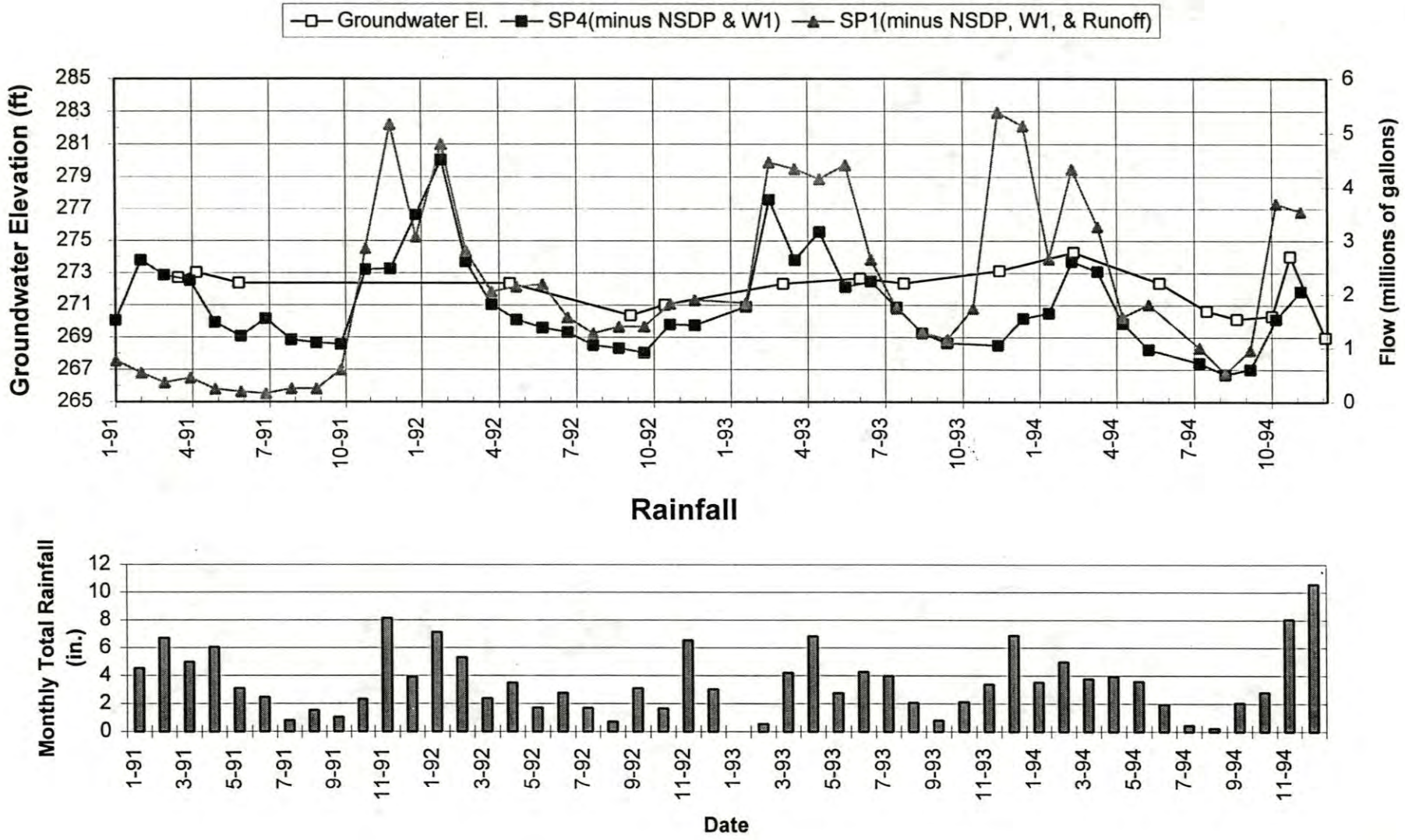
AGI TECHNOLOGIES

Table E–1
Well and Piezometer Coordinates and Reference Elevations
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Well No.	Coordinates		Top of Casing Elevation [a] (ft MSL)
	Northing	Easting	
G 1 A	321629.24	1324867.65	229.00
G 1 D	321638.17	1324885.65	229.96
G 2 D	321545.76	1325188.30	242.10
G 3	321467.49	1325426.66	270.37
G 4	320273.18	1324618.21	285.22
G 4 S	320264.49	1324668.28	286.52
G 5 A	321318.36	1325073.57	241.01
G 6 A	321441.59	1324948.06	242.51
G 6 B	321426.79	1324942.96	246.24
G 7 D	318161.15	1324644.56	336.10
G 7 S	318172.26	1324643.30	335.66
G 8 D1	321817.92	1325164.62	222.02
G 8 D2	321817.22	1325182.63	221.62
G 9 D	321275.75	1325193.71	274.60
G 9 S	321273.63	1325177.96	273.08
G 10 D	321254.31	1324950.50	268.32
G 10 S	321254.03	1324925.32	266.94
G 11 S	321467.94	1324722.20	250.74
G 12 D	320695.94	1324718.72	285.28
G 13 D	321600.06	1324674.85	232.17
G 14 D	319998.52	1325720.47	329.58
G 14 S	320002.03	1325710.77	328.76
G 15 S	318137.72	1325752.35	327.13
G 16 S	321332.98	1325019.89	238.90
W1	321336.65	1325043.79	239.07
W2	321330.53	1325081.10	238.78
PZ1	320849.23	1325615.77	318.84
PZ2	320434.25	1325607.60	319.63
PZ3	319617.98	1325603.21	324.18
PZ4	318983.87	1325600.88	323.18
PZ5	318487.52	1325367.24	311.16
PZ6	318491.00	1325253.97	311.96
PZ7	318527.91	1325036.29	311.16

Notes:

a) Elevations referenced to Mean Sea Level of NGVD 1929.



AGI TECHNOLOGIES

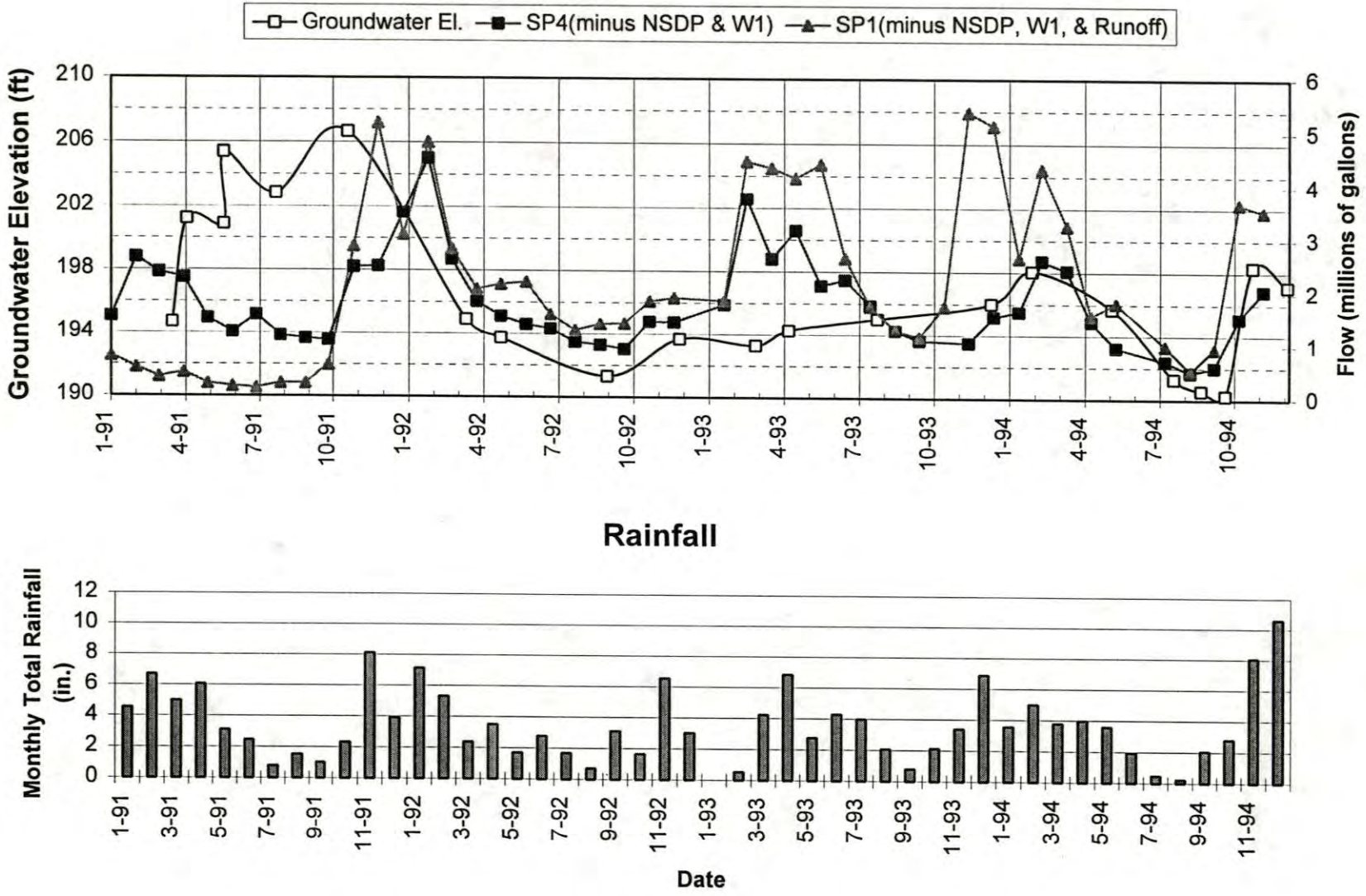
Groundwater Elevation with Precipitation - Well G-4A

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **E-1**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	TMM		



AGI TECHNOLOGIES

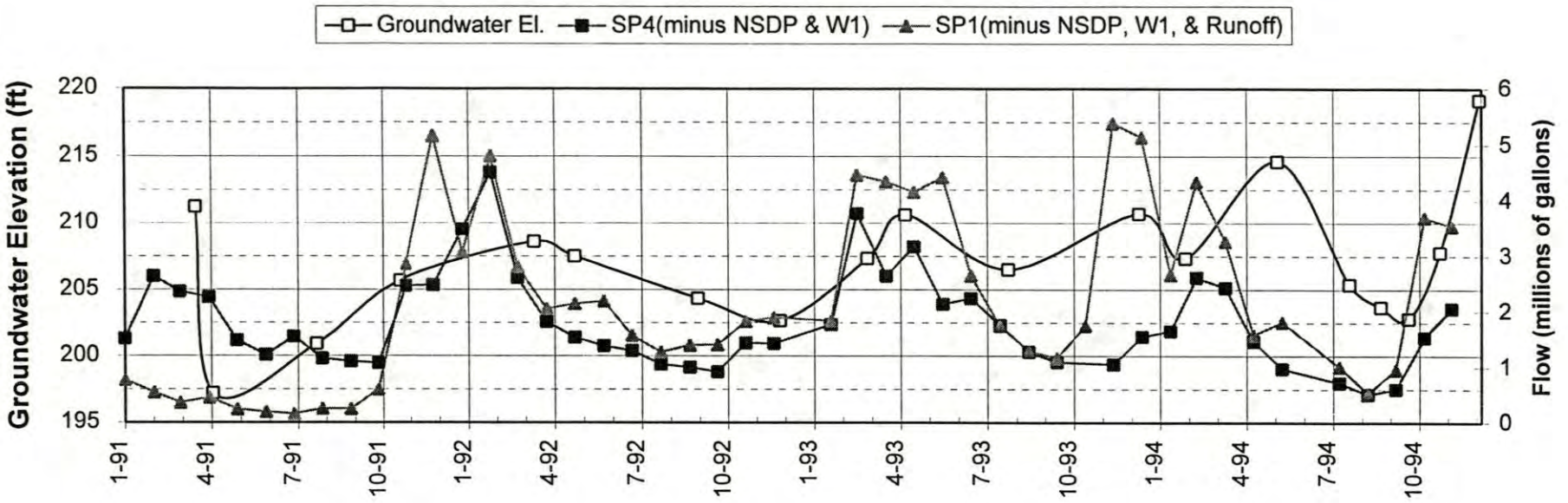
Groundwater Elevation with Precipitation - Well G-8D1

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

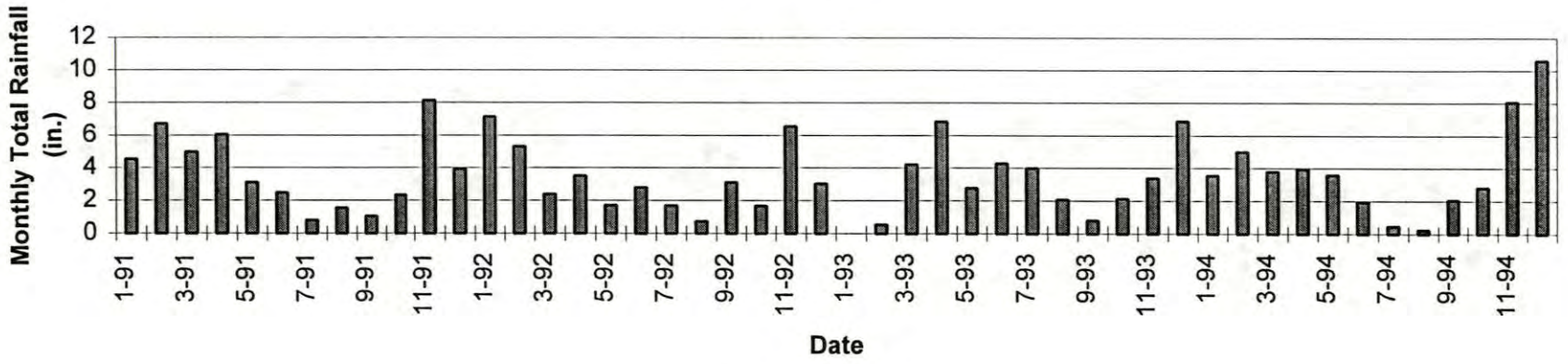
Snohomish County, Washington

PLATE **E-2**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	TMM		



Rainfall



AGI TECHNOLOGIES

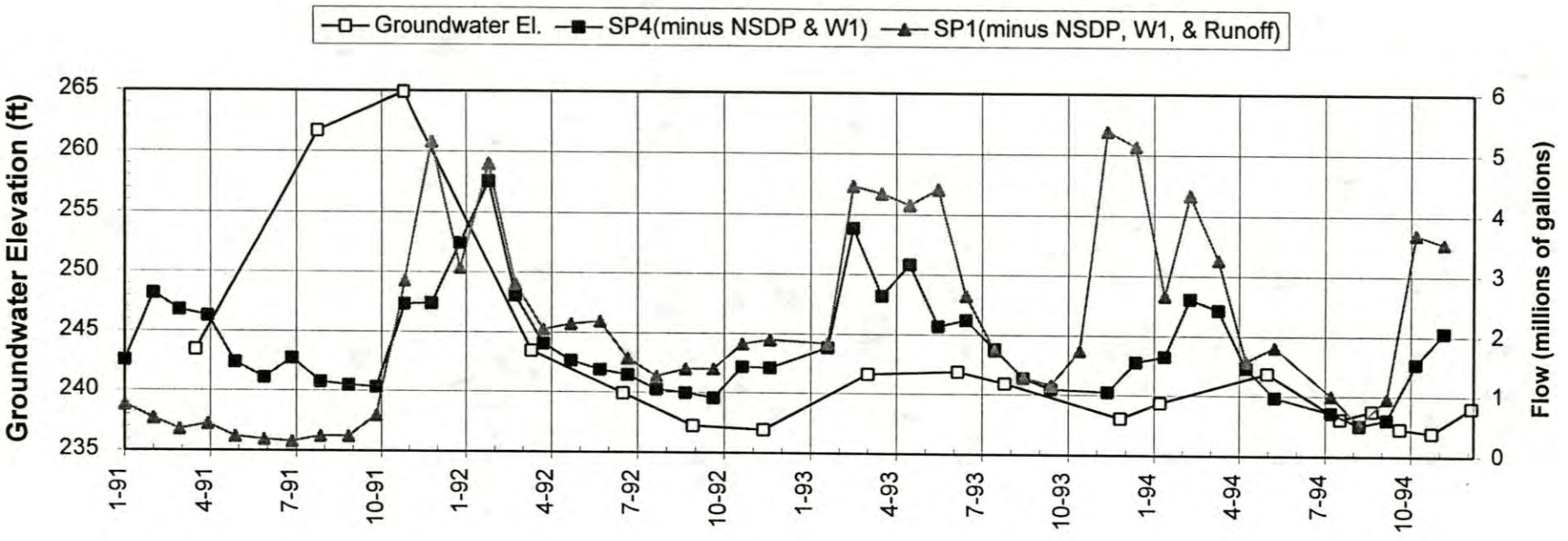
Groundwater Elevation with Precipitation - Well G-8D2

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

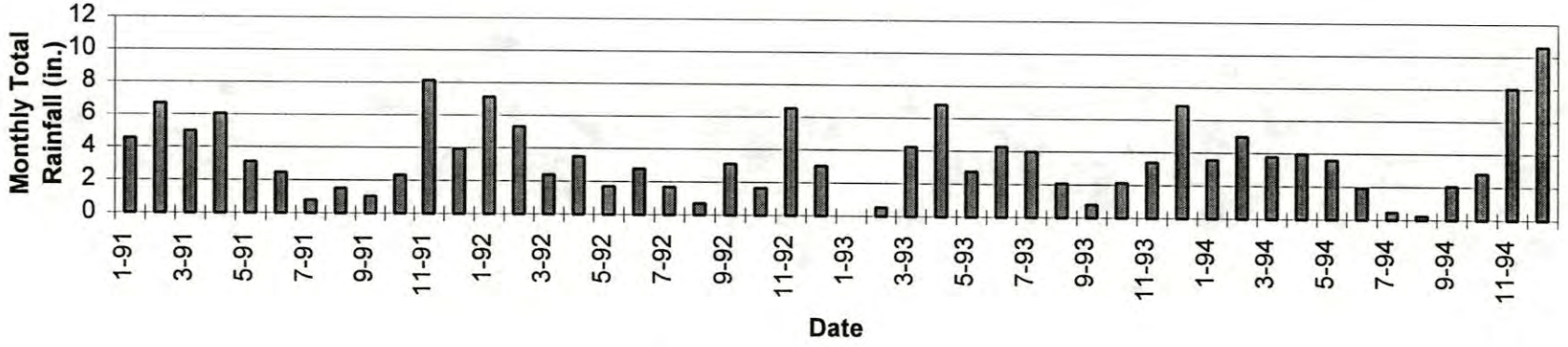
Snohomish County, Washington

PLATE **E-3**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	TMM		



Rainfall



AGI TECHNOLOGIES

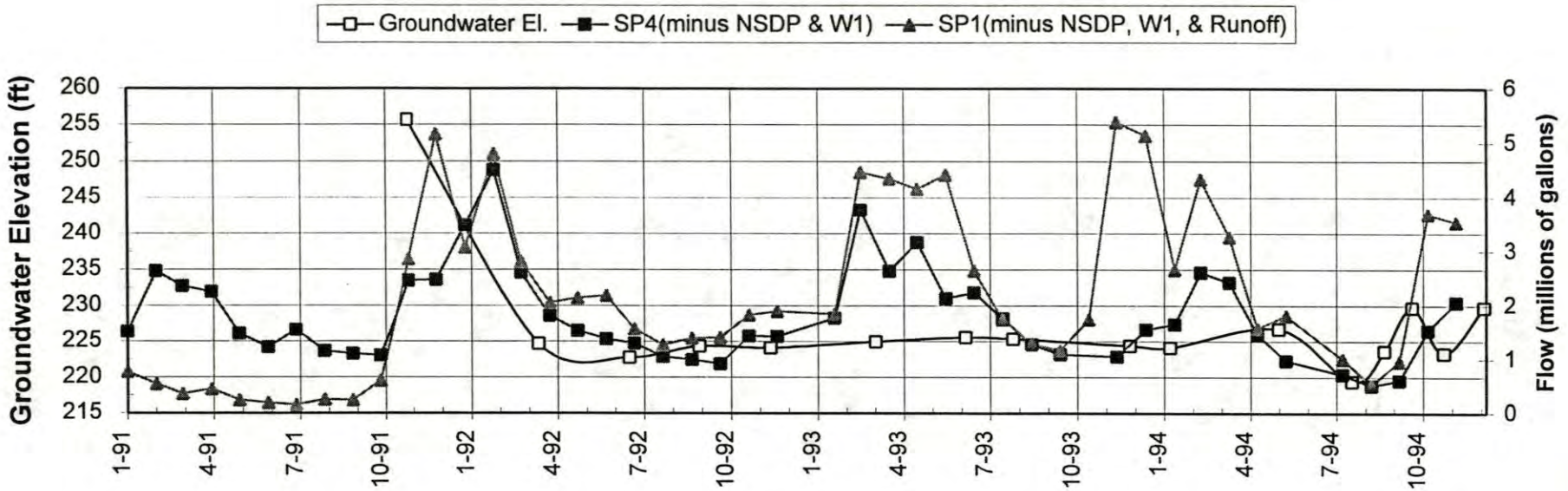
Groundwater Elevation with Precipitation - Well G-9S

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

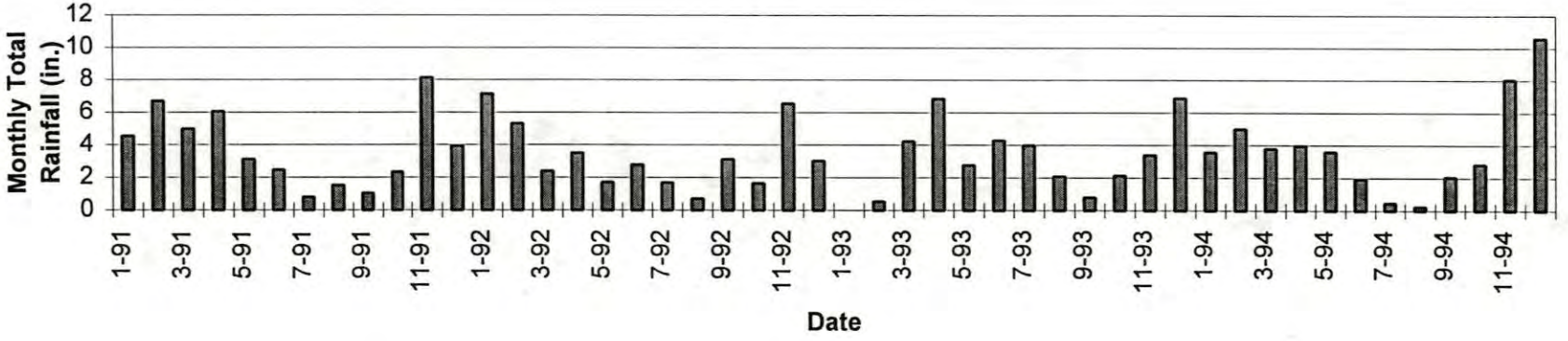
Snohomish County, Washington

PLATE **E-4**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	TMM		



Rainfall



AGI TECHNOLOGIES

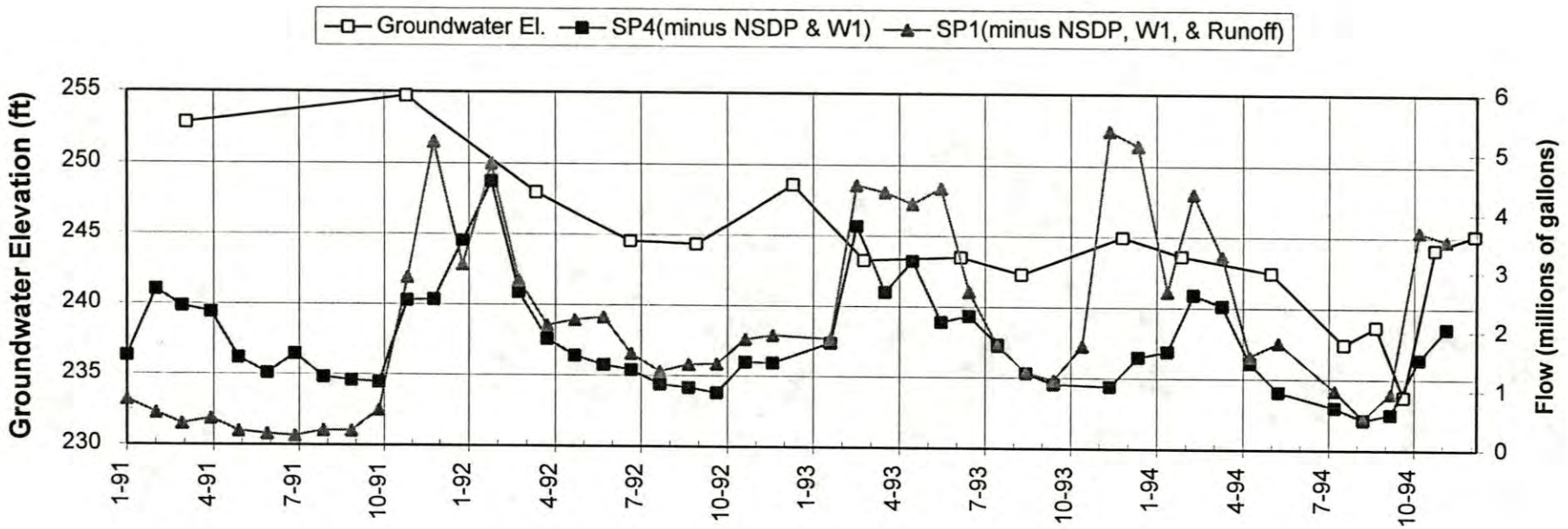
Groundwater Elevation with Precipitation - Well G-9D

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

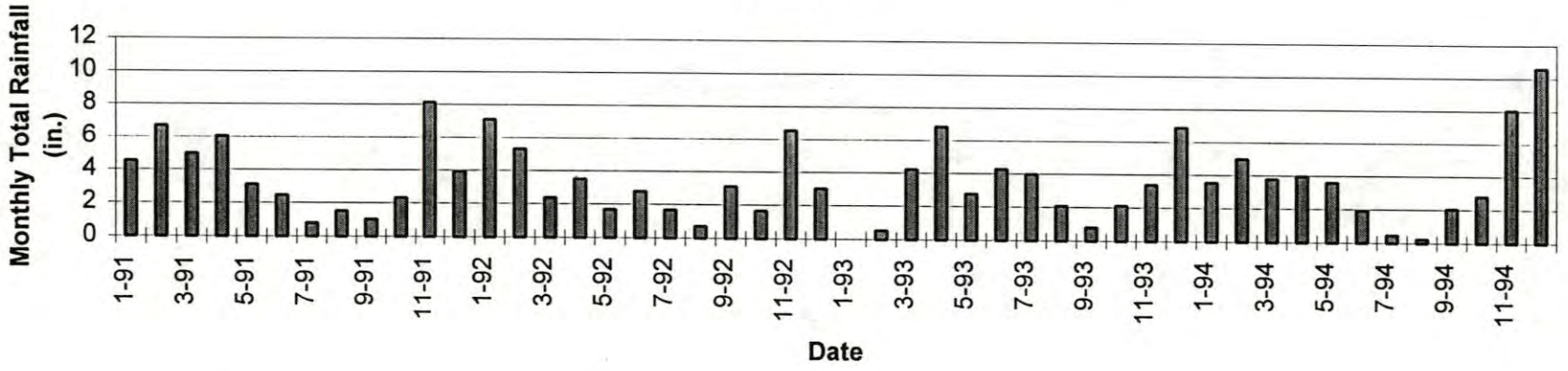
Snohomish County, Washington

PLATE **E-5**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	TMM		



Rainfall



AGI TECHNOLOGIES

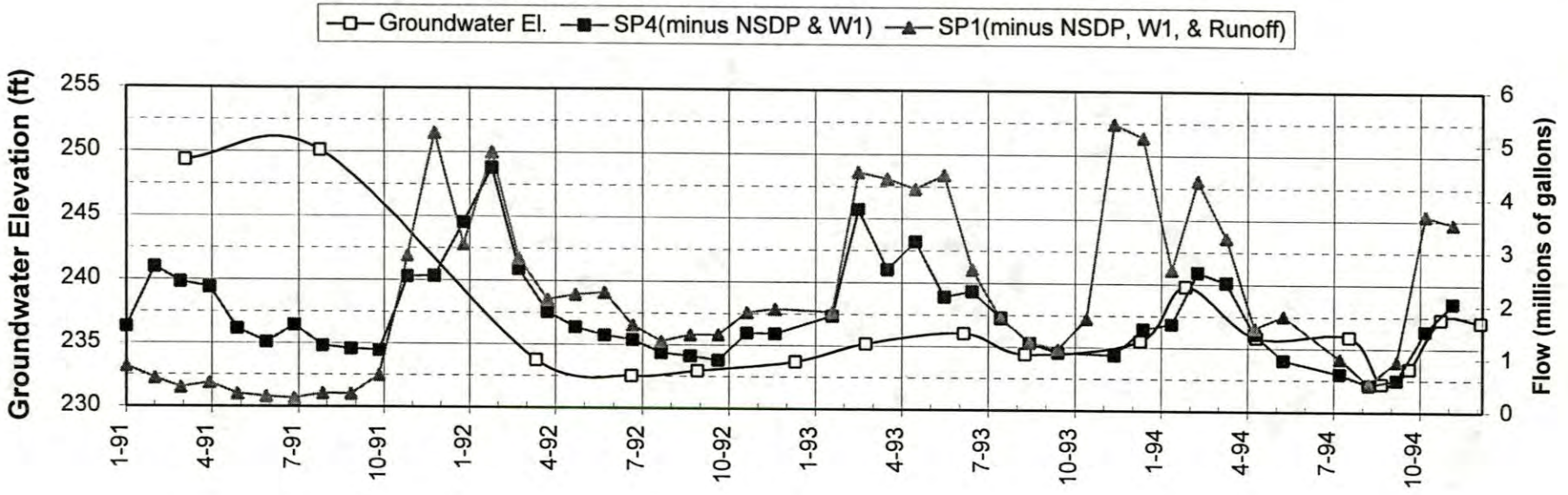
Groundwater Elevation with Precipitation - Well G-10S

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

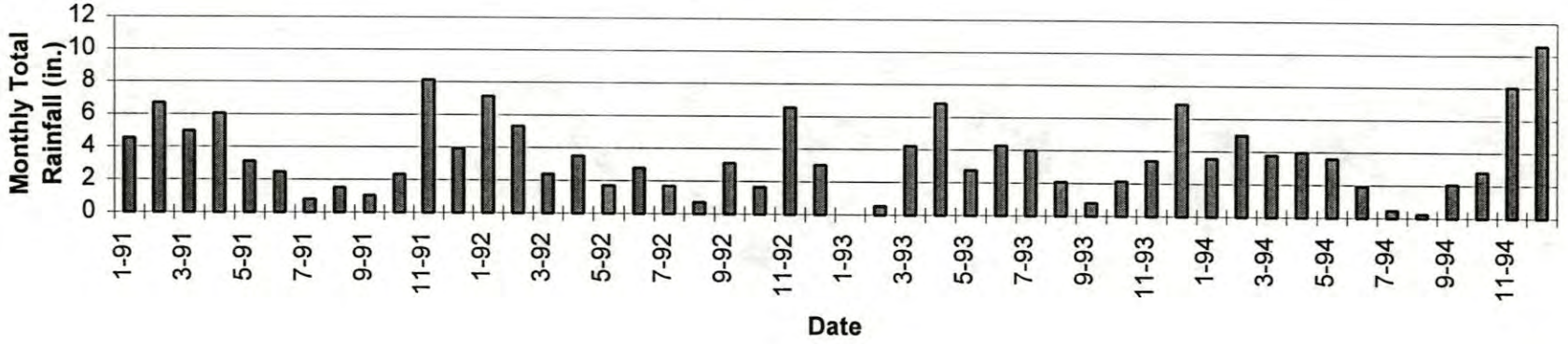
Snohomish County, Washington

PLATE **E-6**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	JMM		



Rainfall



AGI TECHNOLOGIES

Groundwater Elevation with Precipitation - Well G-10D

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **E-7**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
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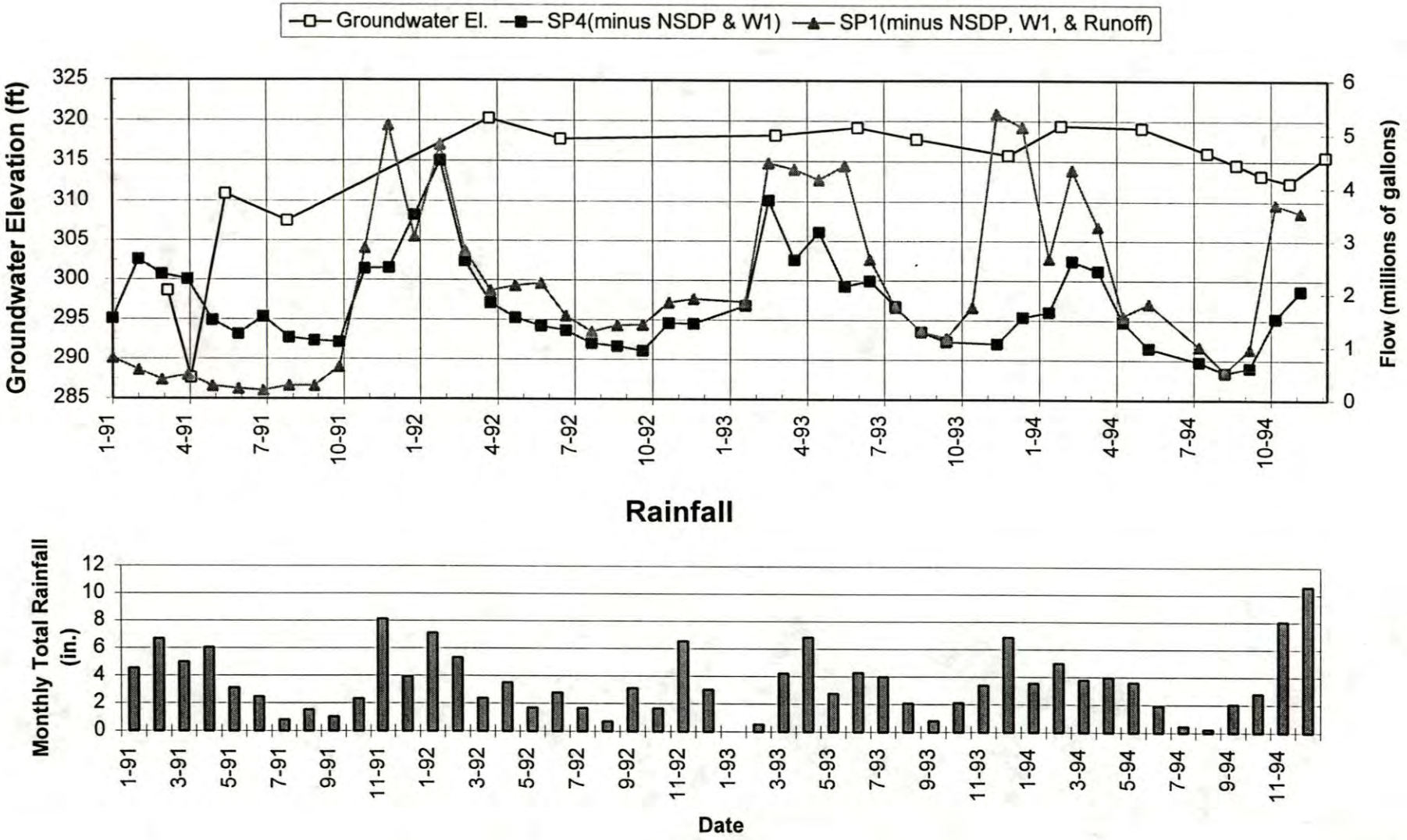


AGI TECHNOLOGIES

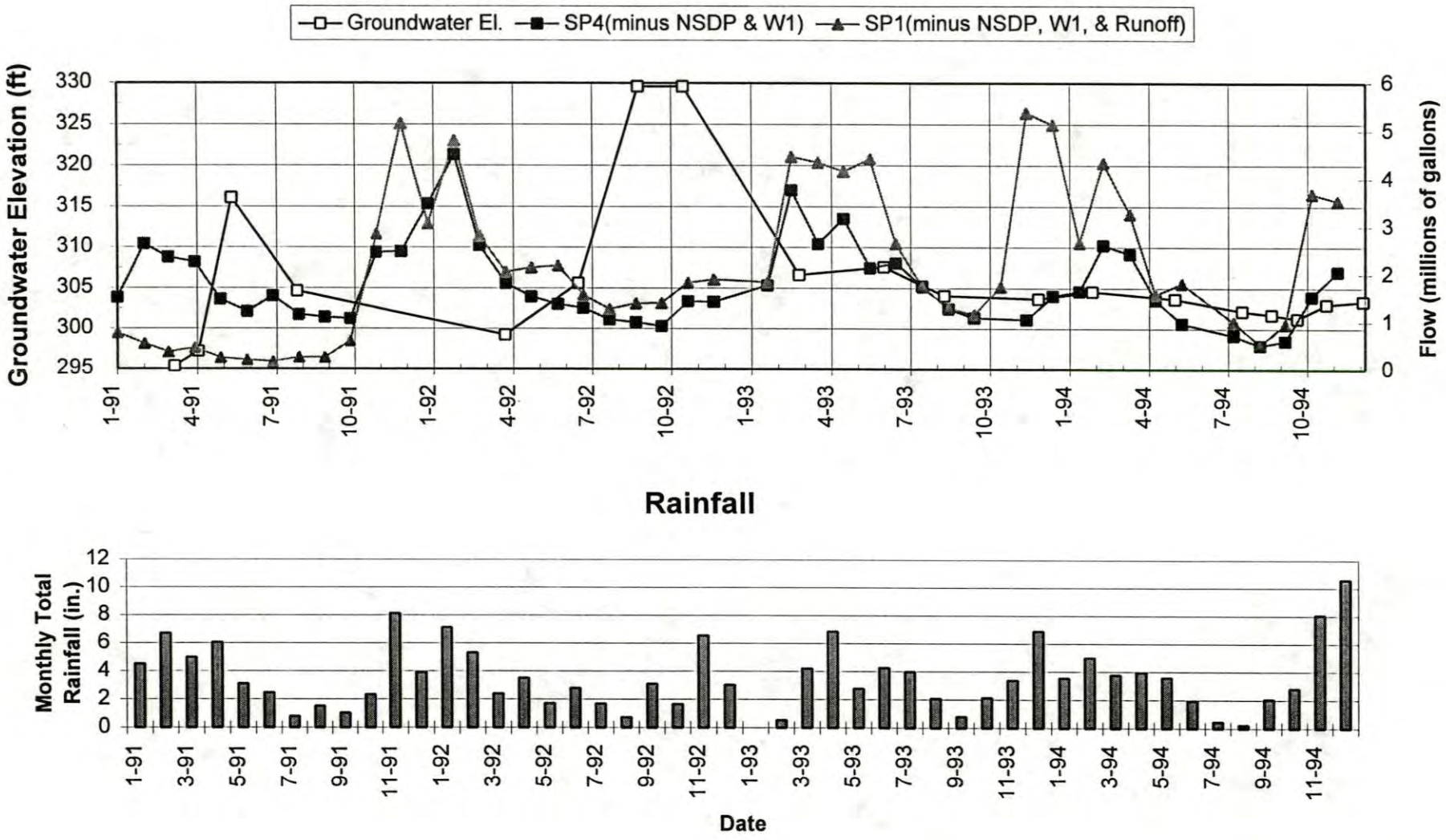
Groundwater Elevation with Precipitation - Well G-14S

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **E-8**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95			



AGI TECHNOLOGIES

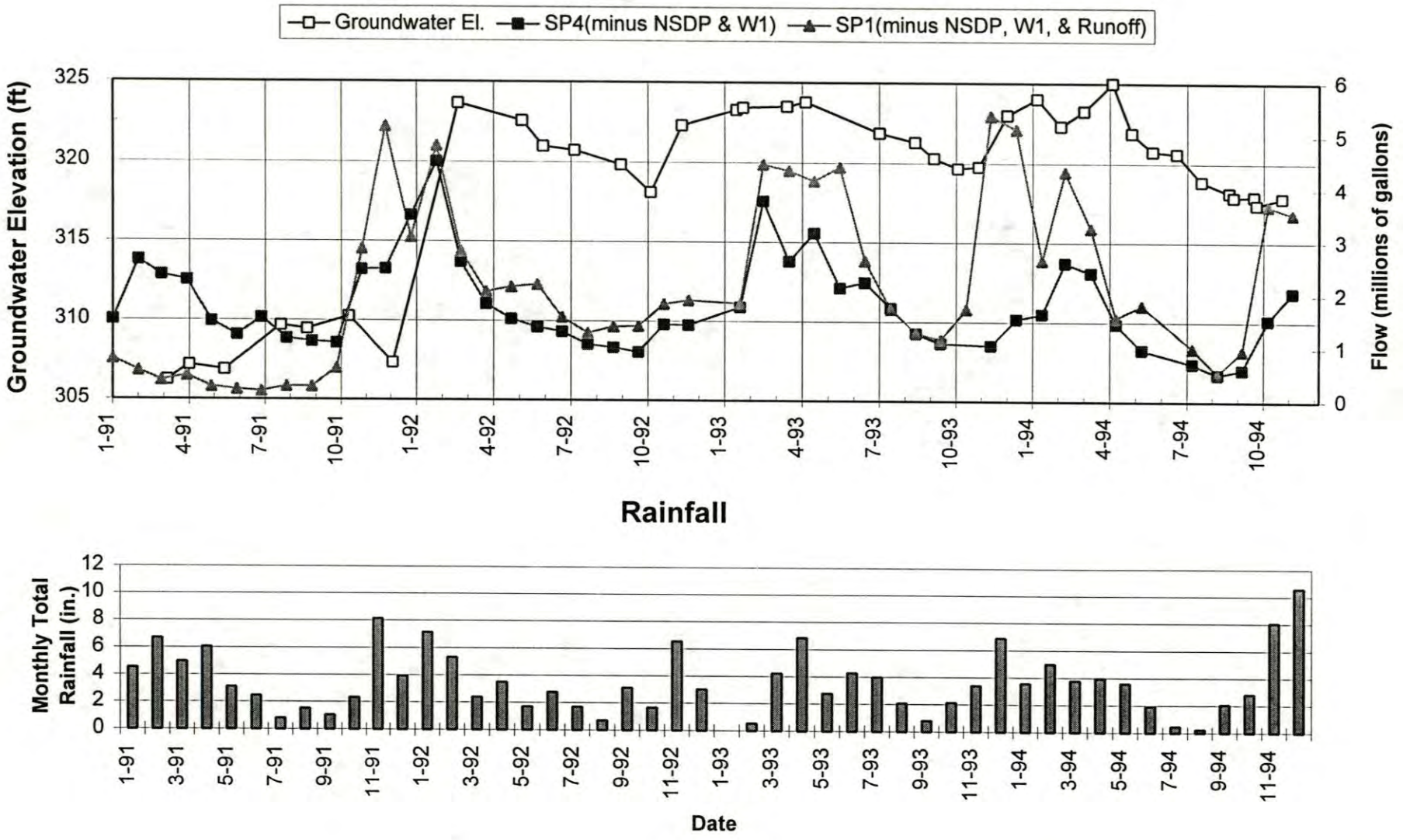
Groundwater Elevation with Precipitation - Well G-14D

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **E-9**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	TMM		



AGI TECHNOLOGIES

Groundwater Elevation with Precipitation - Well G-15S

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **E-10**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	TMM		

APPENDIX F

Groundwater Chemistry Evaluation and Quality Assurance

APPENDIX F

Groundwater Chemistry Evaluation and Quality Assurance

AGI Technologies (AGI) evaluated groundwater chemistry trends based on plots of concentration with time provided by Snohomish County (the County). Detection limits were not available and our evaluation is therefore based primarily on direct interpretation of the plots.

Upgradient (background) trends were used for comparison to the extent possible to identify potential impacts on groundwater chemistry downgradient of Cathcart Landfill. G-15S and G-7D were considered background wells for the shallow and deep groundwater zones, respectively.

The following assumptions were made to evaluate the groundwater chemistry plots provided by the County.

- Chloride Ln detection limit is 0 over time period evaluated.
- Sulfate Ln detection limit is 0 over time period evaluated.
- Nitrate values below -2.3 are assumed to be in error and have been adjusted to -2.3 for comparison purposes.
- Ammonia Ln detection limit is -4.6 over time period evaluated.
- Arsenic Ln detection limit is -5.99 over time period evaluated.
- Barium Ln detection limit is -4.6, then becomes -6.5.
- Chromium Ln detection limit is -5.99 over time period evaluated.
- Cadmium Ln detection limit is 0, then becomes -6.9.
- Lead Ln detection limit is -5.9, then -5.32, then -7.6".
- Mercury Ln detection limit is -9.9, then becomes 0.
- Zinc Ln detection limit is -6.9 over time period evaluated.
- Total coliform Ln detection limit is 0 over time period evaluated.

The following summarizes chemical analyte-specific trends noted in groundwater chemistry over the time period March 1988 through May 1994 for monitoring wells at the landfill. Gross trends are observed in concentration versus time plots provided by the County. **Plates F-1** through **F-7** are plots of shallow zone groundwater chemical concentrations over the review period for G-1A, G-6A, G-8D1, G-9S, G-10S, and G-15S; **Plates F-8** through **F-14** plot deep zone groundwater chemistry data for G-1D, G-6B, G-7D, G-8D2, G-9D, and G-10D. Well specific chemical trends over the referenced time period are as follows:

SHALLOW GROUNDWATER ZONE WELLS

G-15S (Background):	Chloride concentrations have become *higher* since approximately July 1993. Sulfate *increases*. Ammonia *decreases*. Chromium *decreases*. Total coliform *decreases* to non-detection.
G-01A:	Sulfate *increases*.
G-4:	No available data after June 1992.
G-04A:	Chloride *increases*.

G-5A:	No available data after 1989.
G-6A:	Chloride *increases* slightly.
	Conductivity *decreases* very slightly.
G-6S:	No data after November 1991.
G-7S:	Zinc *decreases*.
G-08D1:	Chloride *increases*.
	Conductivity *increases*.
G-09S:	Chloride *increases*.
	Sulfate *increases*.
	Conductivity *increases* slightly.
G-10S	Chloride *increases*.
	Sulfate possible *increase*.
	Conductivity *increases*.
	Ammonia *increases*.
	Zinc possible slightly *increase*.
	Total coliforms show higher concentrations and erratic.
G-11S:	Chloride *increases*.
	Nitrate *decreases*.
	Zinc *increases*.
G-14S:	Chloride *increases*.
	Nitrate *increases*.

DEEP GROUNDWATER ZONE WELLS

G-07D (Background):	Chloride has been detected since September 1993.
	Conductivity *increases* slightly.
	Arsenic has been detected since approximately January 1993.
	Chromium *decreases* to non-detection during last 3 rounds of available data.
	Metals generally peaked early 1991 to August 1991.
	Zinc appears to *decrease* since January 1992.
G-01D:	Chloride concentrations *higher* after landfill closure.
	Nitrate concentrations *higher* after landfill closure.
	Arsenic decreases.
	Total coliform hits are *higher* after landfill closure.
G-02D:	Nitrate *increased* until September 1993, then *decreased* during last 4 rounds of data reviewed.
	Total coliform concentrations become *higher* after January 1991.
G-06B:	Chloride *increases*.
	Sulfate *increases*.
	Nitrate generally *increases*.
	Ammonia *decreases*.
	Lead *decreased* to non-detection during last 3 rounds of data reviewed.
	Zinc *decreases*.
G-06D:	Not sampled after November 1991.
G-09D:	Ammonia slightly *increases*.
	Zinc concentration appears to cycle.
G-10D:	Chloride *increases* since October 1989.
	Ammonia *increases* since October 1990.

G-12D:	Chloride *increases* since early 1991.
	Sulfate *increases* very slightly.
G-13D:	Chloride *increases* slightly during last 3 rounds.
G-14D:	Chloride *increases*.
	Arsenic appears to *decrease* slightly.
	Barium *decreases* slightly.

Groundwater chemistry results for the fourth quarter 1994 round are presented in **Tables F-1, F-2,** and **F-3.**

AGI TECHNOLOGIES

Table F–1
General Parameters – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Parameter	Detection Limit	Date Sampled	Sample I.D. G–1A	G–1D	G–2D	G–3	G–4A	G–6A	G–6B	G–7S	G–7D
pH		10/94	NA	NA	NA	NA	5.8	NA	7.8	6.1	9.1
		11/94	NA	8.8	8.7	NA	NA	5.0	7.7	6.3	9.3
		12/94	7.3	NA	NA	7.7	NA	5.4	8.0	6.5	9.4
Total Organic Cargon (mg/L)	1.0	10/94	NA	NA	NA	NA	ND	NA	ND	5.8	1.2
	1.0	11/94	NA	1.7	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chemical Oxygen Demand (mg/L)	10	10/94	NA	NA	NA	NA	22	NA	29	32	ND
	10	11/94	NA	11	ND	NA	NA	NA	NA	NA	NA
	10	12/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloride (mg/L)	1.0	10/94	NA	NA	NA	NA	5.4	NA	37	1.9	1.9
	1.0	11/94	NA	18	5.5	NA	NA	9.4	28	2.0	2.4
	1.0	12/94	1.5	NA	NA	7.5	NA	9.4	33	2.1	2.1
Conductivity (μmhos/cm)	0.5	10/94	NA	NA	NA	NA	550	NA	1,700	500	630
	0.5	11/94	NA	940	570	NA	NA	960	1,700	650	630
	0.5	12/94	340	NA	NA	290	NA	650	1,500	540	580
Ammonia Nitrogen (mg/L)	0.005	10/94	NA	NA	NA	NA	0.009	NA	0.027	0.028	0.12
	0.005	11/94	NA	0.20	0.15	NA	NA	NA	NA	NA	NA
	0.005	12/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate + Nitrite Nitrogen (mg/L)	0.01	10/94	NA	NA	NA	NA	ND	NA	0.68	ND	0.71
	0.01	11/94	NA	ND	7.3	NA	NA	NA	NA	NA	NA
	0.01	12/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrite Nitrogen (mg/L)	0.001	10/94	NA	NA	NA	NA	0.006	NA	0.001	ND	0.035
	0.001	11/94	NA	0.005	0.012	NA	NA	NA	NA	NA	NA
	0.001	12/94	NA	NA	NA	NA	NA	NA	NA	NA	NA

AGI TECHNOLOGIES

Table F–1
General Parameters – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Parameter	Detection Limit	Date Sampled	Sample I.D. G–1A	G–1D	G–2D	G–3	G–4A	G–6A	G–6B	G–7S	G–7D
Sulfate (mg/L)	10	10/94	NA	NA	NA	NA	67	NA	200	150	100
	10	11/94	NA	46	100	NA	NA	420	240	270	71
	10	12/94	78	NA	NA	38	NA	260	300	240	78
Total Coliforms (cfu/100 ml)	1	10/94	NA	NA	NA	NA	3	NA	<2	ND	ND
	1	11/94	NA	4	2	NA	NA	NA	NA	NA	NA
	1	12/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
Turbidity (NTU)	10	10/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10	11/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10	12/94	NA	NA	NA	NA	NA	NA	37	26	31

Notes:

ND – Not detected.
mg/L – Milligrams per liter.
µmhos/cm – Micromhos per centimeter.

AGI TECHNOLOGIES

Table F-1
General Parameters – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Parameter	Detection Limit	Date Sampled	Sample I.D. G-8D1	G-8D2	G-9S	G-9D	G-10S	G-10D	G-11S	G-12	G-12D
pH		10/94	NA	NA	NA	NA	NA	NA	NA	NA	8.9
		11/94	NA	NA	NA	NA	NA	NA	NA	NA	9.0
		12/94	9.3	9.5	8.6	8.6	6.5	6.8	2.7	9.2	
Total Organic Cargon (mg/L)	1.0	10/94	NA	NA	NA	NA	NA	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA	23
	1.0	12/94	NA	NA	ND	ND	ND	3.2	NA	NA	NA
Chemical Oxygen Demand (mg/L)	10	10/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10	11/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10	12/94	NA	NA	19	15	41	32	NA	NA	NA
Chloride (mg/L)	1.0	10/94	NA	NA	NA	NA	NA	NA	NA	NA	6.4
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA	6.1
	1.0	12/94	3.5	3.7	7.8	16	87	80	34	6.0	NA
Conductivity (μmhos/cm)	0.5	10/94	NA	NA	NA	NA	NA	NA	NA	NA	1,000
	0.5	11/94	NA	NA	NA	NA	NA	NA	NA	NA	970
	0.5	12/94	430	470	1,500	860	2,300	2,400	1,500	890	NA
Ammonia Nitrogen (mg/L)	0.005	10/94	NA	NA	NA	NA	NA	NA	NA	NA	0.19
	0.005	11/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.005	12/94	NA	NA	0.24	0.078	0.27	0.64	NA	NA	NA
Nitrate + Nitrite Nitrogen (mg/L)	0.01	10/94	NA	NA	NA	NA	NA	NA	NA	NA	ND
	0.01	11/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.01	12/94	NA	NA	ND	0.097	ND	ND	NA	NA	NA
Nitrite Nitrogen (mg/L)	0.001	10/94	NA	NA	NA	NA	NA	NA	NA	NA	0.039
	0.001	11/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.001	12/94	NA	NA	0.002	0.009	0.004	0.004	NA	NA	NA

Table F–1
General Parameters – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Parameter	Detection Limit	Date Sampled	Sample I.D. G–8D1	G–8D2	G–9S	G–9D	G–10S	G–10D	G–11S	G–12	G–12D
Sulfate (mg/L)	10	10/94	NA	NA	NA	NA	NA	NA	NA	NA	230
	10	11/94	NA	NA	NA	NA	NA	NA	NA	NA	190
	10	12/94	60	60	310	180	360	370	170	210	NA
Total Coliforms (cfu/100 ml)	1	10/94	NA	NA	NA	NA	NA	NA	NA	NA	ND
	1	11/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
	1	12/94	NA	NA	<2	<2	ND	ND	NA	NA	NA
Turbidity (NTU)	10	10/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10	11/94	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10	12/94	NA	NA	NA	NA	NA	NA	NA	36	NA

Notes:

ND – Not detected.
mg/L – Milligrams per liter.
μmhos/cm – Micromhos per centimeter.

AGI TECHNOLOGIES

Table F–1
General Parameters – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Parameter	Detection Limit	Date Sampled	Sample I.D. G13D	G–14D	G–15S
pH		10/94	NA	NA	7.7
		11/94	NA	NA	8.4
		12/94	9.2	9.4	8.4
Total Organic Cargon (mg/L)	1.0	10/94	NA	NA	ND
	1.0	11/94	NA	NA	NA
	1.0	12/94	ND	ND	NA
Chemical Oxygen Demand (mg/L)	10	10/94	NA	NA	19
	10	11/94	NA	NA	NA
	10	12/94	11	19	NA
Chloride (mg/L)	1.0	10/94	NA	NA	2.2
	1.0	11/94	NA	NA	2.3
	1.0	12/94	3.8	2.2	2.1
Conductivity (μmhos/cm)	0.5	10/94	NA	NA	950
	0.5	11/94	NA	NA	390
	0.5	12/94	510	400	400
Ammonia Nitrogen (mg/L)	0.005	10/94	NA	NA	0.020
	0.005	11/94	NA	NA	NA
	0.005	12/94	0.14	0.15	NA
Nitrate + Nitrite Nitrogen (mg/L)	0.01	10/94	NA	NA	ND
	0.01	11/94	NA	NA	NA
	0.01	12/94	ND	0.020	NA
Nitrite Nitrogen (mg/L)	0.001	10/94	NA	NA	0.005
	0.001	11/94	NA	NA	NA
	0.001	12/94	0.005	0.007	NA

AGI TECHNOLOGIES

Table F–1
General Parameters – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Parameter	Detection Limit	Date Sampled	Sample I.D. G13D	G–14D	G–15S
Sulfate (mg/L)	10	10/94	NA	NA	39
	10	11/94	NA	NA	38
	10	12/94	95	16	59
Total Coliforms (cfu/100 ml)	1	10/94	NA	NA	ND
	1	11/94	NA	NA	NA
	1	12/94	<2	<2	NA
Turbidity (NTU)	10	10/94	NA	NA	NA
	10	11/94	NA	NA	NA
	10	12/94	NA	NA	5.5

Notes:

ND – Not detected.
mg/L – Milligrams per liter.
µmhos/cm – Micromhos per centimeter.

AGI TECHNOLOGIES

Table F–2
Dissolved Metals – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Metal	Detection Limit (mg/L)	Date Sampled	Sample I.D. G–1D	G–2D	G–4A	G–6B	G–7S	G–7D	G–9S	G–9D	G–10S	G–10D	G–12D
			mg/L										
Arsenic	0.001	10/94	NA	NA	0.001	0.001	0.003	0.004	NA	NA	NA	NA	0.001
	0.001	11/94	0.001	0.008	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.001	12/94	NA	NA	NA	NA	NA	NA	0.001	0.007	ND	0.001	NA
Barium	0.003	10/94	NA	NA	0.004	ND	0.004	ND	NA	NA	NA	NA	ND
	0.003	11/94	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.003	12/94	NA	NA	NA	NA	NA	NA	0.005	ND	0.007	ND	NA
Cadmium	0.002	10/94	NA	NA	ND	ND	ND	ND	NA	NA	NA	NA	0.003
	0.002	11/94	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.002	12/94	NA	NA	NA	NA	NA	NA	0.002	ND	ND	ND	NA
Chromium	0.006	10/94	NA	NA	ND	ND	ND	ND	NA	NA	NA	NA	ND
	0.006	11/94	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.006	12/94	NA	NA	NA	NA	NA	NA	ND	ND	ND	ND	NA
Copper	0.002	10/94	NA	NA	ND	ND	ND	ND	NA	NA	NA	NA	0.002
	0.002	11/94	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.002	12/94	NA	NA	NA	NA	NA	NA	ND	0.004	ND	ND	NA
Iron	0.01	10/94	NA	NA	7.6	0.07	0.03	0.08	NA	NA	NA	NA	0.04
	0.01	11/94	0.09	0.12	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.01	12/94	NA	NA	NA	NA	NA	NA	0.01	0.13	0.03	0.02	NA
Mercury	0.0002	10/94	NA	NA	ND	ND	ND	ND	NA	NA	NA	NA	ND
	0.0002	11/94	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.0002	12/94	NA	NA	NA	NA	NA	NA	ND	0.0002	ND	ND	NA
Manganese	0.002	10/94	NA	NA	6.3	ND	1.7	0.003	NA	NA	NA	NA	0.002
	0.002	11/94	0.007	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.002	12/94	NA	NA	NA	NA	NA	NA	1.0	0.018	7.3	1.4	NA
Nickel	0.01	10/94	NA	NA	ND	ND	ND	ND	NA	NA	NA	NA	ND
	0.01	11/94	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.01	12/94	NA	NA	NA	NA	NA	NA	0.04	ND	0.02	ND	NA
Lead	0.001	10/94	NA	NA	ND	ND	ND	ND	NA	NA	NA	NA	ND
	0.001	11/94	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.001	12/94	NA	NA	NA	NA	NA	NA	ND	ND	ND	ND	NA

AGI TECHNOLOGIES

Table F–2
Dissolved Metals – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Metal	Detection Limit (mg/L)	Date Sampled	Sample I.D. G–1D	G–2D	G–4A	G–6B	G–7S	G–7D	G–9S	G–9D	G–10S	G–10D	G–12D
			mg/L										
Selenium	0.001	10/94	NA	NA	ND	ND	ND	ND	NA	NA	NA	NA	ND
	0.001	11/94	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.001	12/94	NA	NA	NA	NA	NA	NA	ND	0.001	ND	ND	NA
Silver	0.01	10/94	NA	NA	ND	ND	ND	ND	NA	NA	NA	NA	ND
	0.01	11/94	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.01	12/94	NA	NA	NA	NA	NA	NA	ND	ND	ND	ND	NA
Zinc	0.002	10/94	NA	NA	ND	0.003	ND	ND	NA	NA	NA	NA	0.005
	0.002	11/94	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.002	12/94	NA	NA	NA	NA	NA	NA	0.008	0.006	0.005	ND	NA

Notes:

mg/L – Milligrams per liter.
NA – Not analyzed.
ND – Not detected.

AGI TECHNOLOGIES

Table F–2
Dissolved Metals – Groundwater
Snohomish Co. Public Works Dept./Cath
Snohomish County, Washington

Metal	Detection Limit (mg/L)	Date Sampled	Sample I.D. G–13D	G–14D	G–14D	G–15S
			mg/L			
Arsenic	0.001	10/94	0.001	NA	NA	0.001
	0.001	11/94	NA	NA	NA	NA
	0.001	12/94	0.001	0.002	NA	NA
Barium	0.003	10/94	NA	NA	NA	ND
	0.003	11/94	NA	NA	NA	NA
	0.003	12/94	ND	0.003	NA	NA
Cadmium	0.002	10/94	NA	NA	NA	ND
	0.002	11/94	NA	NA	NA	NA
	0.002	12/94	ND	ND	NA	NA
Chromium	0.006	10/94	NA	NA	NA	ND
	0.006	11/94	NA	NA	NA	NA
	0.006	12/94	ND	ND	NA	NA
Copper	0.002	10/94	NA	NA	NA	0.003
	0.002	11/94	NA	NA	NA	NA
	0.002	12/94	0.002	0.003	NA	NA
Iron	0.01	10/94	NA	NA	NA	0.05
	0.01	11/94	NA	NA	NA	NA
	0.01	12/94	0.78	0.57	NA	NA
Mercury	0.0002	10/94	NA	NA	NA	ND
	0.0002	11/94	NA	NA	NA	NA
	0.0002	12/94	0.0003	0.0004	NA	NA
Manganese	0.002	10/94	NA	NA	NA	0.009
	0.002	11/94	NA	NA	NA	NA
	0.002	12/94	0.020	0.008	NA	NA
Nickel	0.01	10/94	NA	NA	NA	ND
	0.01	11/94	NA	NA	NA	NA
	0.01	12/94	ND	ND	NA	NA
Lead	0.001	10/94	NA	NA	NA	ND
	0.001	11/94	NA	NA	NA	NA
	0.001	12/94	0.001	ND	NA	NA

AGI TECHNOLOGIES

Table F–2
Dissolved Metals – Groundwater
Snohomish Co. Public Works Dept./Cathc
Snohomish County, Washington

Metal	Detection Limit (mg/L)	Date Sampled	Sample I.D. G–13D	G–14D	G–14D	G–15S
			mg/L			
Selenium	0.001	10/94	NA	NA	NA	0.001
	0.001	11/94	NA	NA	NA	NA
	0.001	12/94	ND	ND	NA	NA
Silver	0.01	10/94	NA	NA	NA	ND
	0.01	11/94	NA	NA	NA	NA
	0.01	12/94	ND	ND	NA	NA
Zinc	0.002	10/94	NA	NA	NA	0.003
	0.002	11/94	NA	NA	NA	NA
	0.002	12/94	ND	ND	NA	NA

Notes:

mg/L – Milligrams per liter.
NA – Not analyzed.
ND – Not detected.

AGI TECHNOLOGIES

Table F–3
Volatile Organic Compounds – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Compound	Detection Limit (µg/L)	Date Sampled	Sample I.D. G–1D	G–2D	G–4A	G–6B	8 G–7S	9 G–7D	G–9S	G–9D
			µg/L							
Chloromethane	5.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	5.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	5.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Vinyl Chloride	5.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	5.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	5.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Bromomethane	5.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	5.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	5.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Chloroethane	5.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	5.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	5.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Trichlorofluoromethane	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
1,1–Dichloroethylene	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Acetone	20	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	20	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	20	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Carbon Disulfide	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Methylene Chloride	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	1.0 B	1.1 B	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	1.2 B	1.4 B
1,2–Dichloroethylene	1.0	10/94	NA	NA	4.2	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND

AGI TECHNOLOGIES

Table F–3
Volatile Organic Compounds – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Compound	Detection Limit (µg/L)	Date Sampled	Sample I.D. G–1D	G–2D	G–4A	G–6B	8 G–7S	9 G–7D	G–9S	G–9D
			µg/L							
1,1–Dichloroethane	1.0	10/94	NA	NA	1.8	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Vinyl Acetate	10	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	10	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	10	12/94	NA	NA	NA	NA	NA	NA	ND	ND
2–Butanone (MEK)	10	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	10	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	10	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Chloroform	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
1,1,1–Trichloroethane	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Carbon Tetrachloride	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Benzene	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
1,2–Dichloroethane	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
1,1,2–Trichloroethene	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Bromodichloromethane	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND

AGI TECHNOLOGIES

Table F–3
Volatile Organic Compounds – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Compound	Detection Limit (µg/L)	Date Sampled	Sample I.D. G–1D	G–2D	G–4A	G–6B	8 G–7S	9 G–7D	G–9S	G–9D
			µg/L							
1,2–Dichloropropane	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
4–Methyl–2–Pentanone	10	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	10	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	10	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Toluene	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
cis–1,3–Dichloropropene	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
1,1,2–Trichloroethane	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Tetrachloroethylene	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
2–Hexanone	10	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	10	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	10	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Chlorodibromomethane	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Chlorobenzene	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Ethylbenzene	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND

AGI TECHNOLOGIES

Table F–3
Volatile Organic Compounds – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Compound	Detection Limit (µg/L)	Date Sampled	Sample I.D. G–1D	G–2D	G–4A	G–6B	8 G–7S	9 G–7D	G–9S	G–9D
			µg/L							
Total Xylenes	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Styrene	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
Bromoform	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
1,1,2,2–Tetrachloroethane	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
trans–1,3–Dichloropropene	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND
p–Dichlorobenzene	1.0	10/94	NA	NA	ND	ND	ND	ND	NA	NA
	1.0	11/94	ND	ND	NA	NA	NA	NA	NA	NA
	1.0	12/94	NA	NA	NA	NA	NA	NA	ND	ND

AGI TECHNOLOGIES

Table F–3
Volatile Organic Compounds – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Compound	Detection Limit (µg/L)	Date Sampled	Sample I.D. G–10S	G–10D	G–12	G–12D	G–13D	G–14D	G–14D	G–15S
			µg/L							
Chloromethane	5.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	5.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	5.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Vinyl Chloride	5.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	5.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	5.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Bromomethane	5.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	5.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	5.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Chloroethane	5.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	5.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	5.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Trichlorofluoromethane	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
1,1–Dichloroethylene	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Acetone	20	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	20	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	20	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Carbon Disulfide	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Methylene Chloride	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	1.9 B	2.5 B	NA	NA	1.4 B	ND	1.0 B	NA
1,2–Dichloroethylene	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA

AGI TECHNOLOGIES

Table F–3
Volatile Organic Compounds – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Compound	Detection Limit (µg/L)	Date Sampled	Sample I.D. G–10S	G–10D	G–12	G–12D	G–13D	G–14D	G–14D	G–15S
			µg/L							
1,1–Dichloroethane	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Vinyl Acetate	10	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	10	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	10	12/94	ND	ND	NA	NA	ND	ND	ND	NA
2–Butanone (MEK)	10	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	10	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	10	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Chloroform	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
1,1,1–Trichloroethane	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Carbon Tetrachloride	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Benzene	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
1,2–Dichloroethane	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
1,1,2–Trichloroethene	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Bromodichloromethane	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA

AGI TECHNOLOGIES

Table F–3
Volatile Organic Compounds – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Compound	Detection Limit (µg/L)	Date Sampled	Sample I.D. G–10S	G–10D	G–12	G–12D	G–13D	G–14D	G–14D	G–15S
			µg/L							
1,2–Dichloropropane	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
4–Methyl–2–Pentanone	10	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	10	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	10	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Toluene	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
cis–1,3–Dichloropropene	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
1,1,2–Trichloroethane	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Tetrachloroethylene	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
2–Hexanone	10	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	10	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	10	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Chlorodibromomethane	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Chlorobenzene	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Ethylbenzene	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA

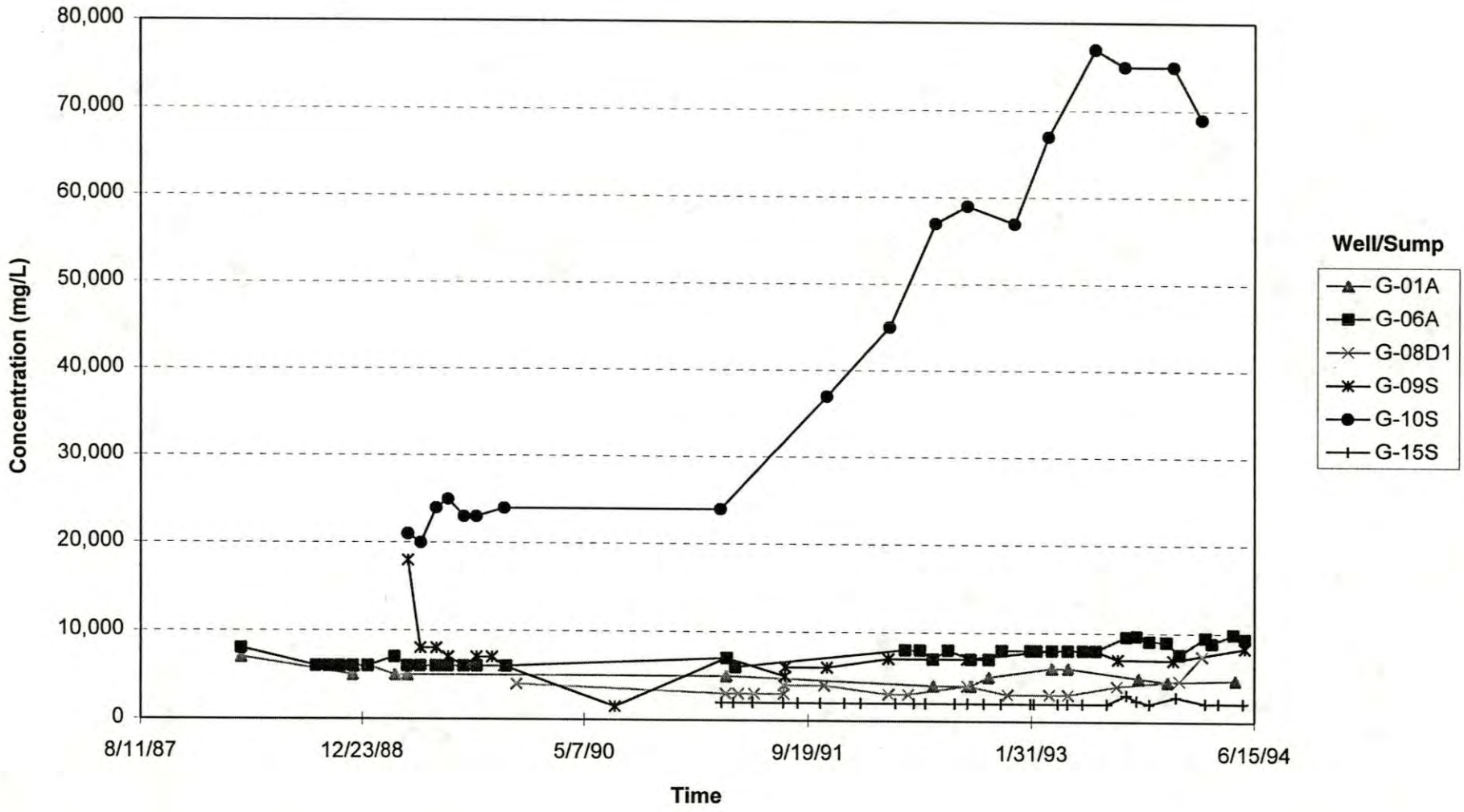
AGI TECHNOLOGIES

Table F–3
Volatile Organic Compounds – Groundwater
Snohomish Co. Public Works Dept./Cathcart Landfill
Snohomish County, Washington

Compound	Detection Limit (µg/L)	Date Sampled	Sample I.D. G–10S	G–10D	G–12	G–12D	G–13D	G–14D	G–14D	G–15S
			µg/L							
Total Xylenes	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Styrene	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
Bromoform	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
1,1,2,2–Tetrachloroethane	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
trans–1,3–Dichloropropene	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA
p–Dichlorobenzene	1.0	10/94	NA	NA	NA	ND	NA	NA	NA	ND
	1.0	11/94	NA	NA	NA	NA	NA	NA	NA	NA
	1.0	12/94	ND	ND	NA	NA	ND	ND	ND	NA

Notes:

B – Compound detected in method blank; possible laboratory contaminant.
ND – Not detected.



AGI TECHNOLOGIES

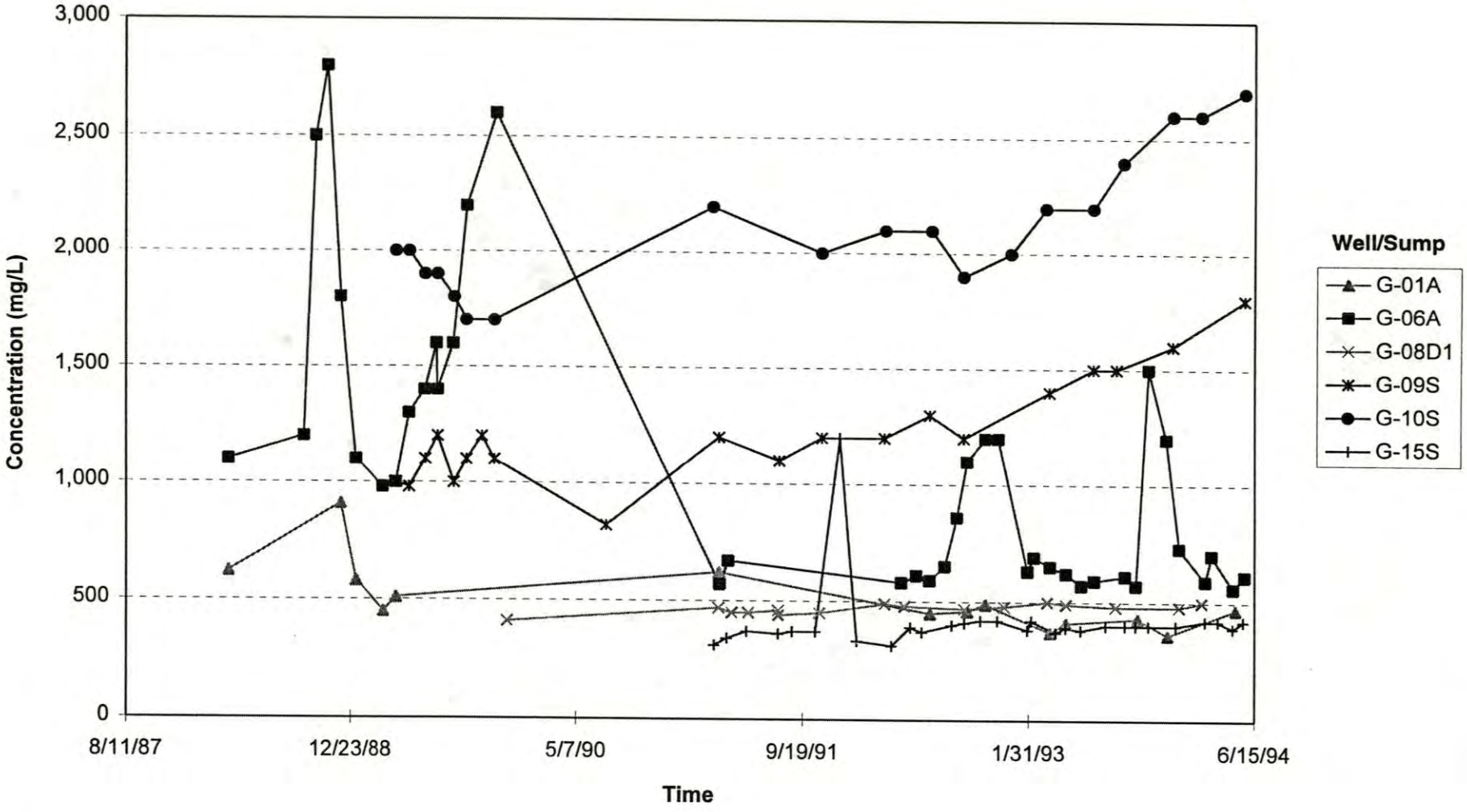
Chemistry Trends: Chloride - Shallow Groundwater Zone

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **F-1**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	TMM		



AGI TECHNOLOGIES

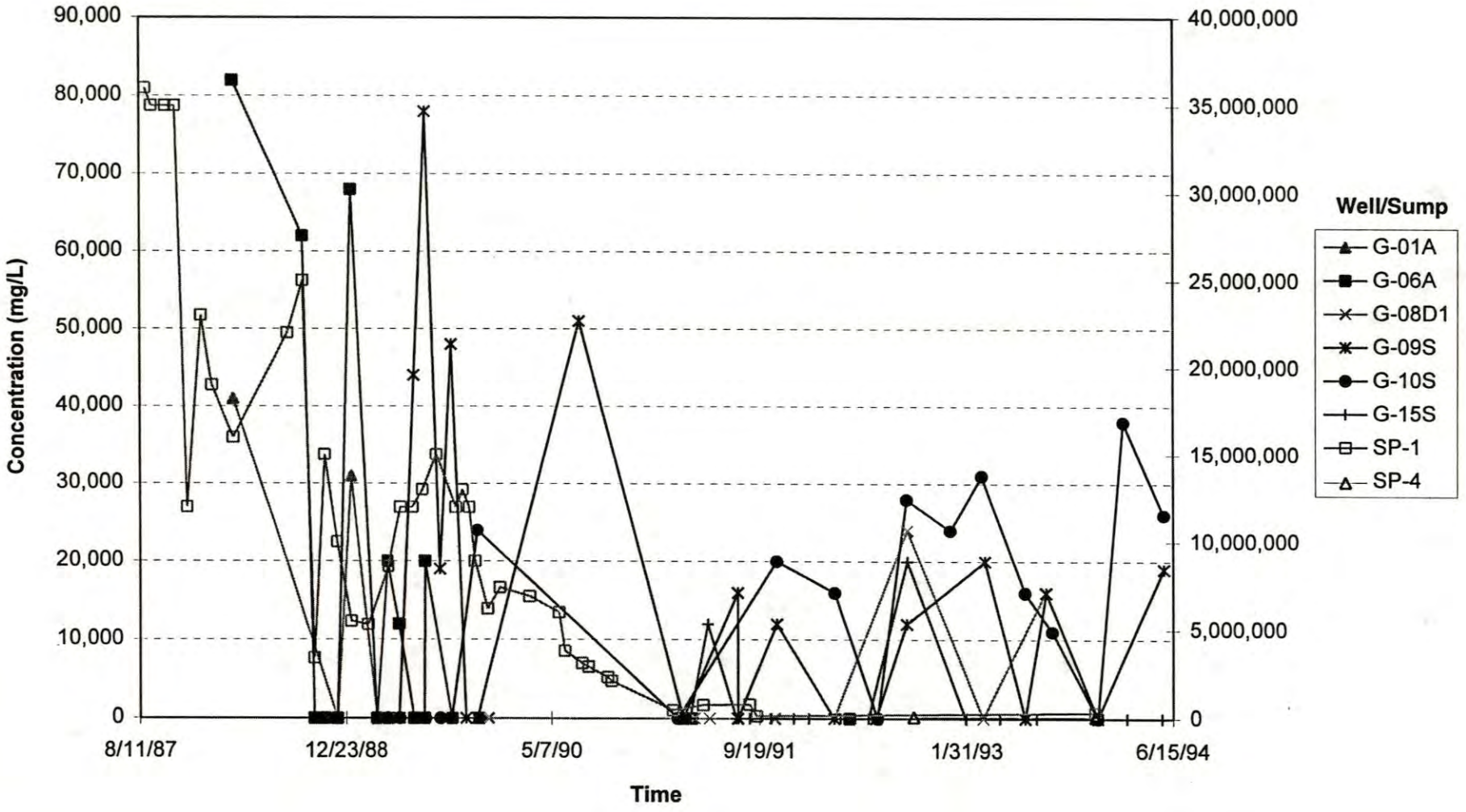
Chemistry Trends: Conductivity - Shallow Groundwater Zone

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **F-2**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	TMM		



AGI TECHNOLOGIES

Chemistry Trends: COD - Shallow Groundwater Zone

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **F-3**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
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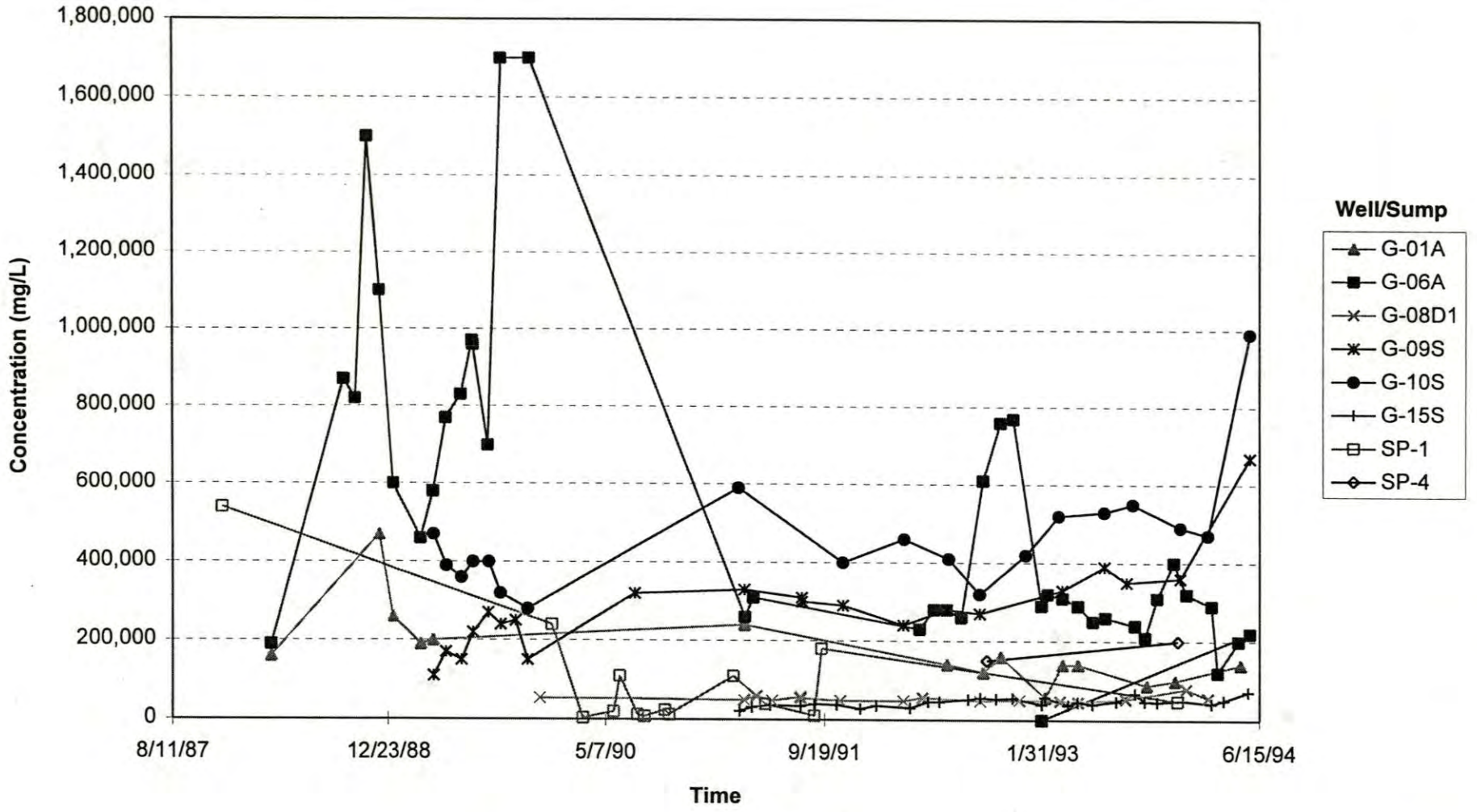


AGI TECHNOLOGIES

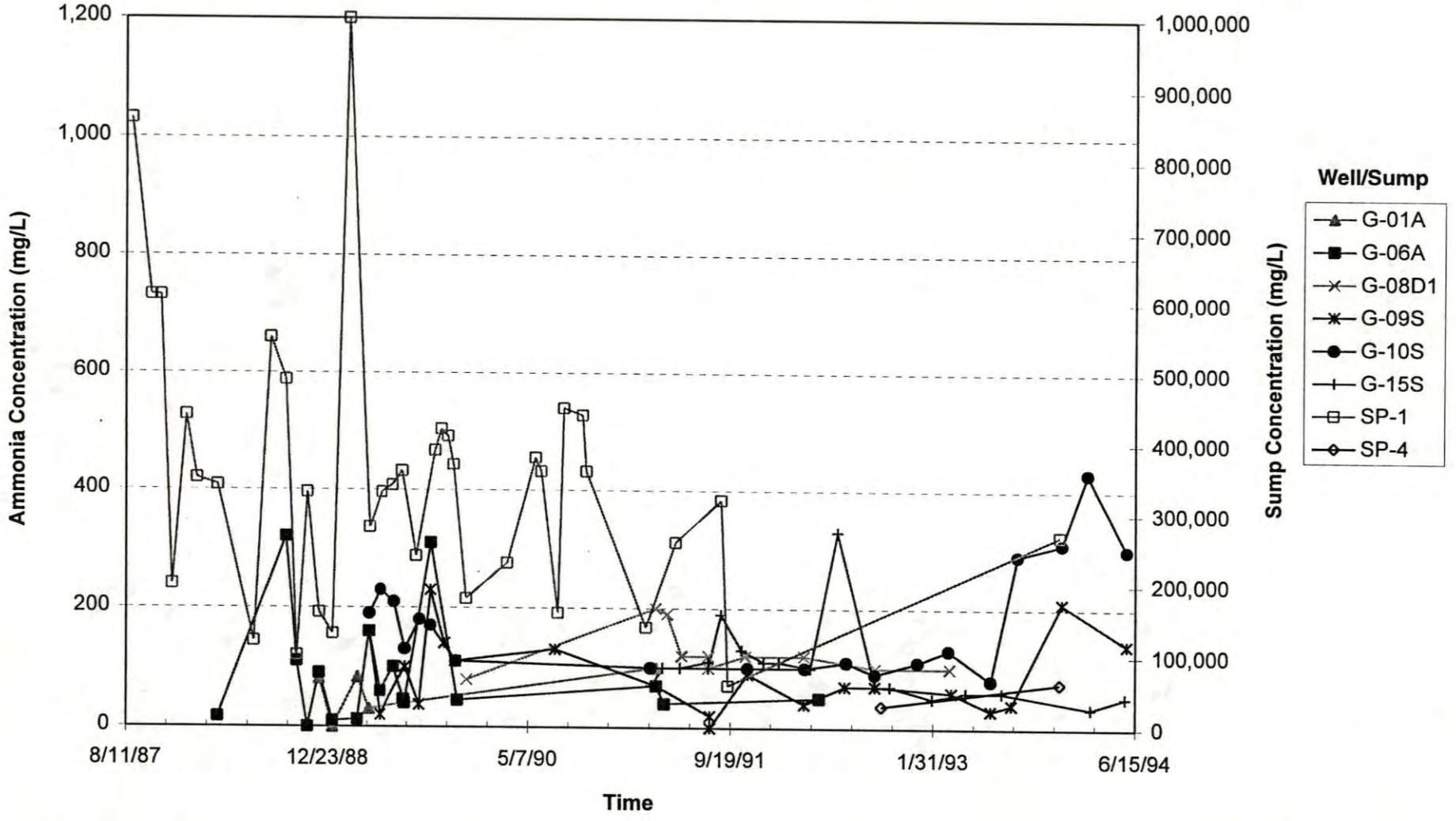
Chemistry Trends: Sulfate - Shallow Groundwater Zone

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **F-4**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	TMM		



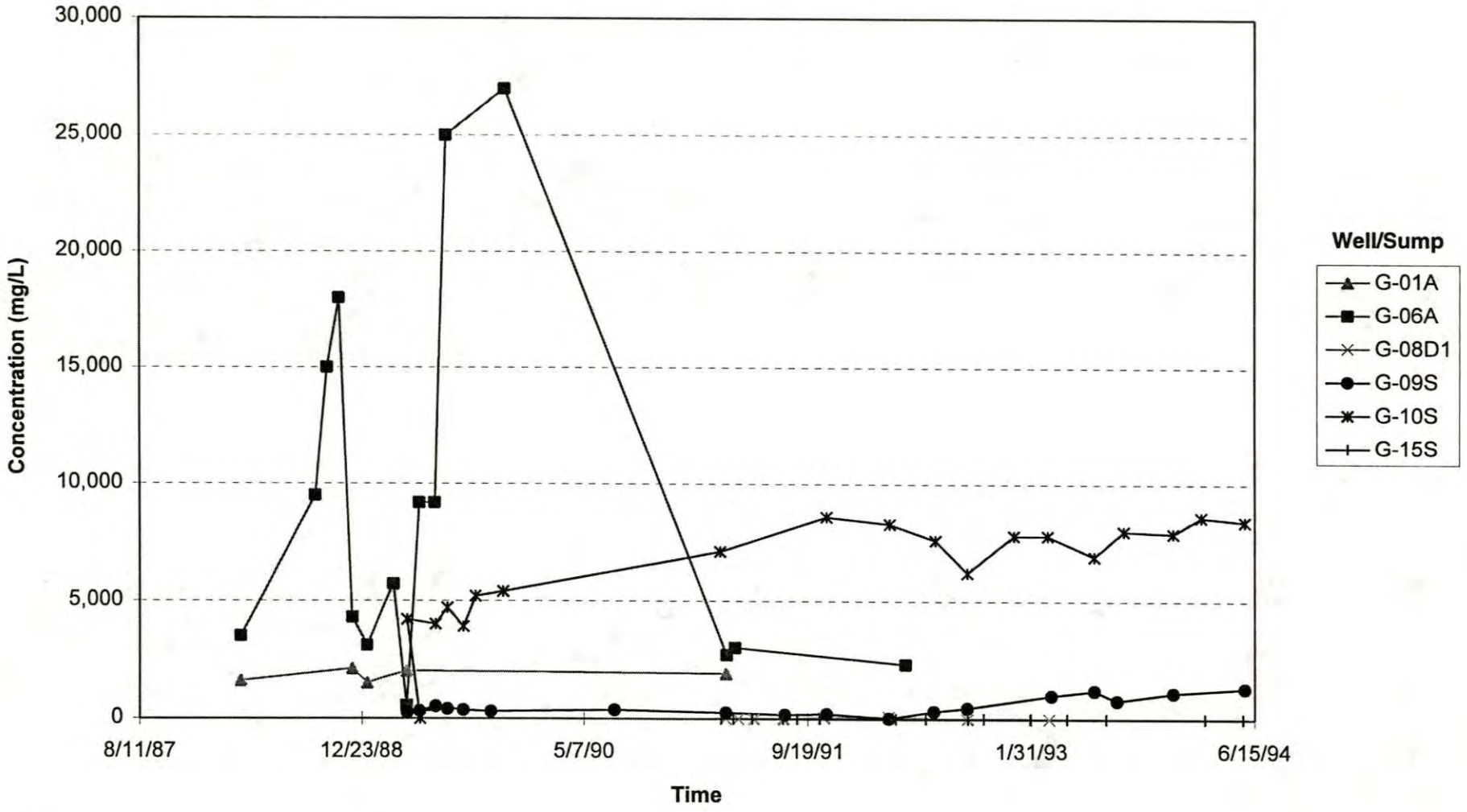
Chemistry Trends: Ammonia - Shallow Groundwater Zone

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **F-5**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	TMM		



Chemistry Trends: Manganese - Shallow Groundwater Zone

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

AGI TECHNOLOGIES

PLATE **F-6**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
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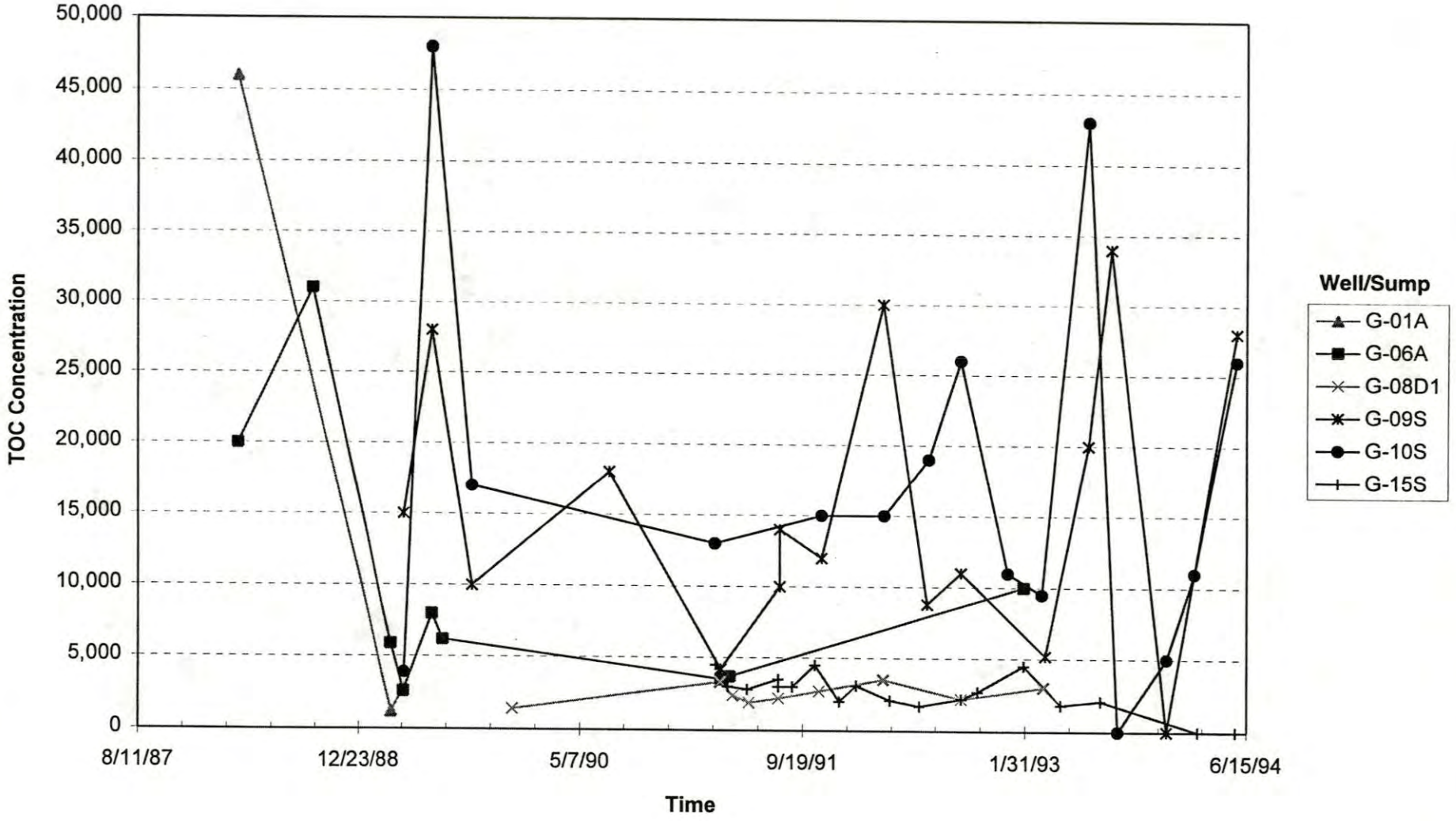


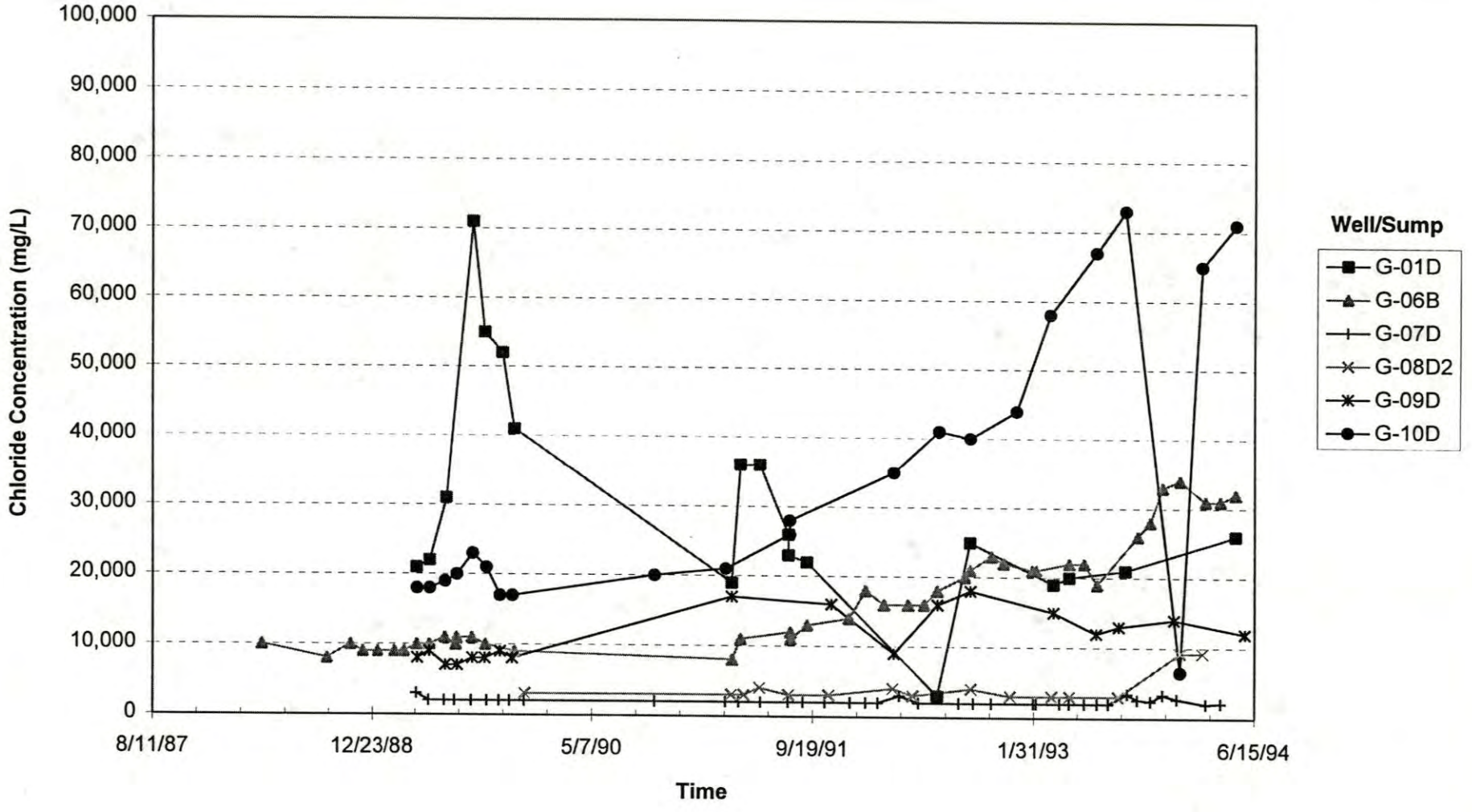
AGI TECHNOLOGIES

Chemistry Trends: TOC - Shallow Groundwater Zone

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE **F-7**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	TMM		



AGI TECHNOLOGIES

Chemistry Trends: Chloride - Deep Groundwater Zone

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE **F-8**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
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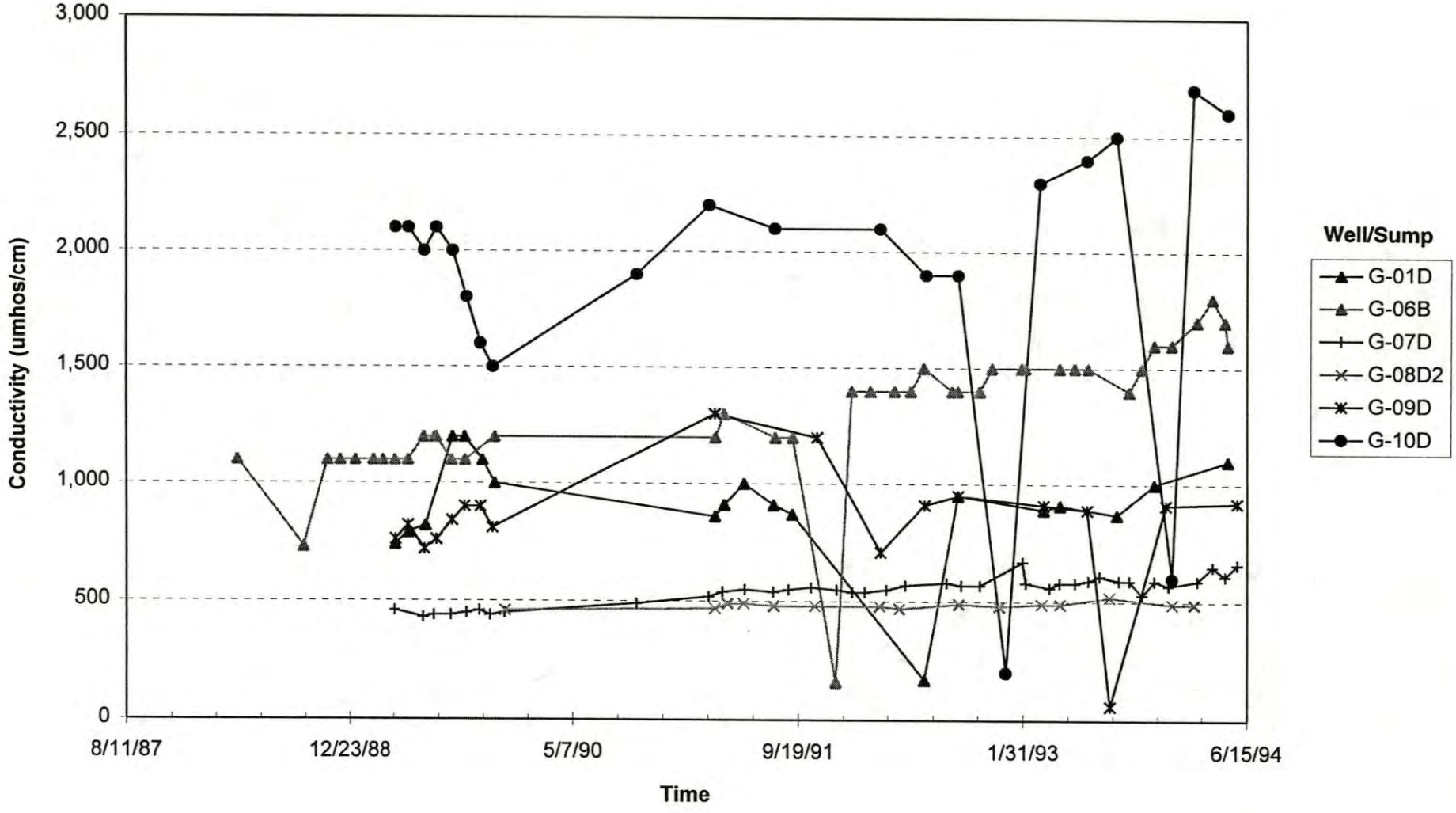

AGI TECHNOLOGIES

Chemistry Trends: Conductivity - Deep Groundwater Zone

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **F-9**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
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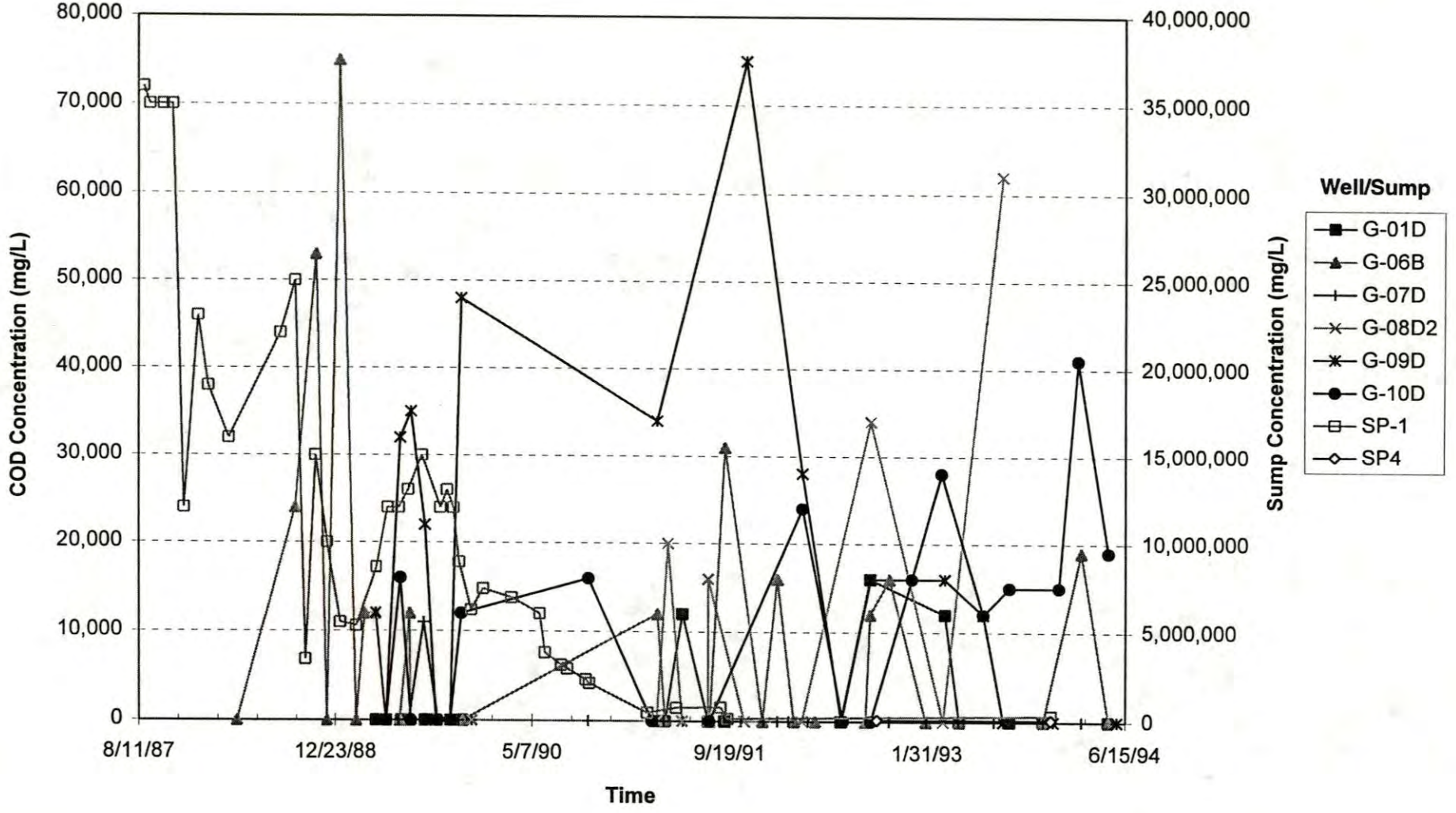


AGI TECHNOLOGIES

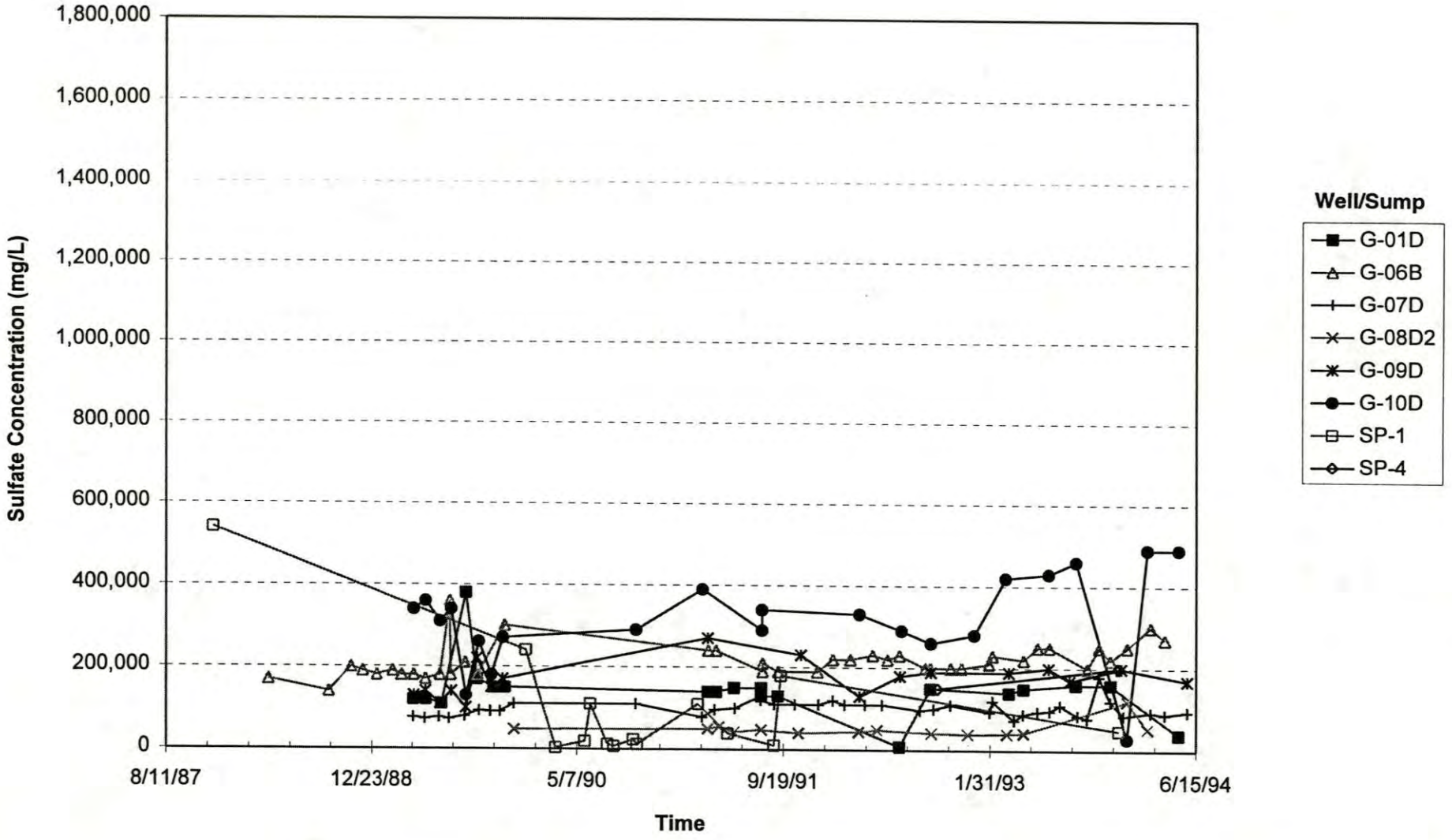
Chemistry Trends: COD - Deep Groundwater Zone

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **F-10**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	JMM		



AGI TECHNOLOGIES

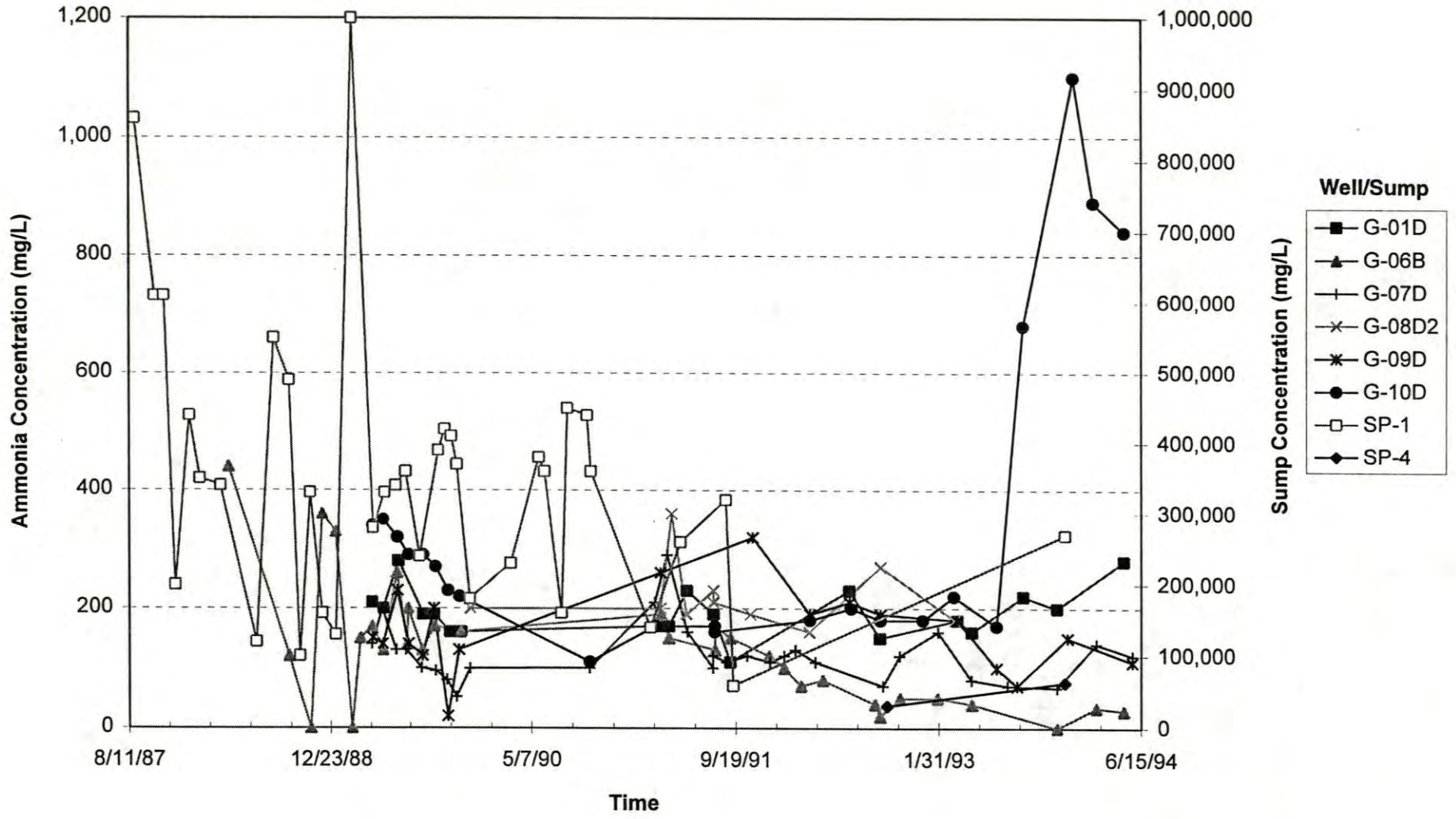
Chemistry Trends: Sulfate - Deep Groundwater Zone

Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **F-11**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95			



Chemistry Trends: Ammonia - Deep Groundwater Zone

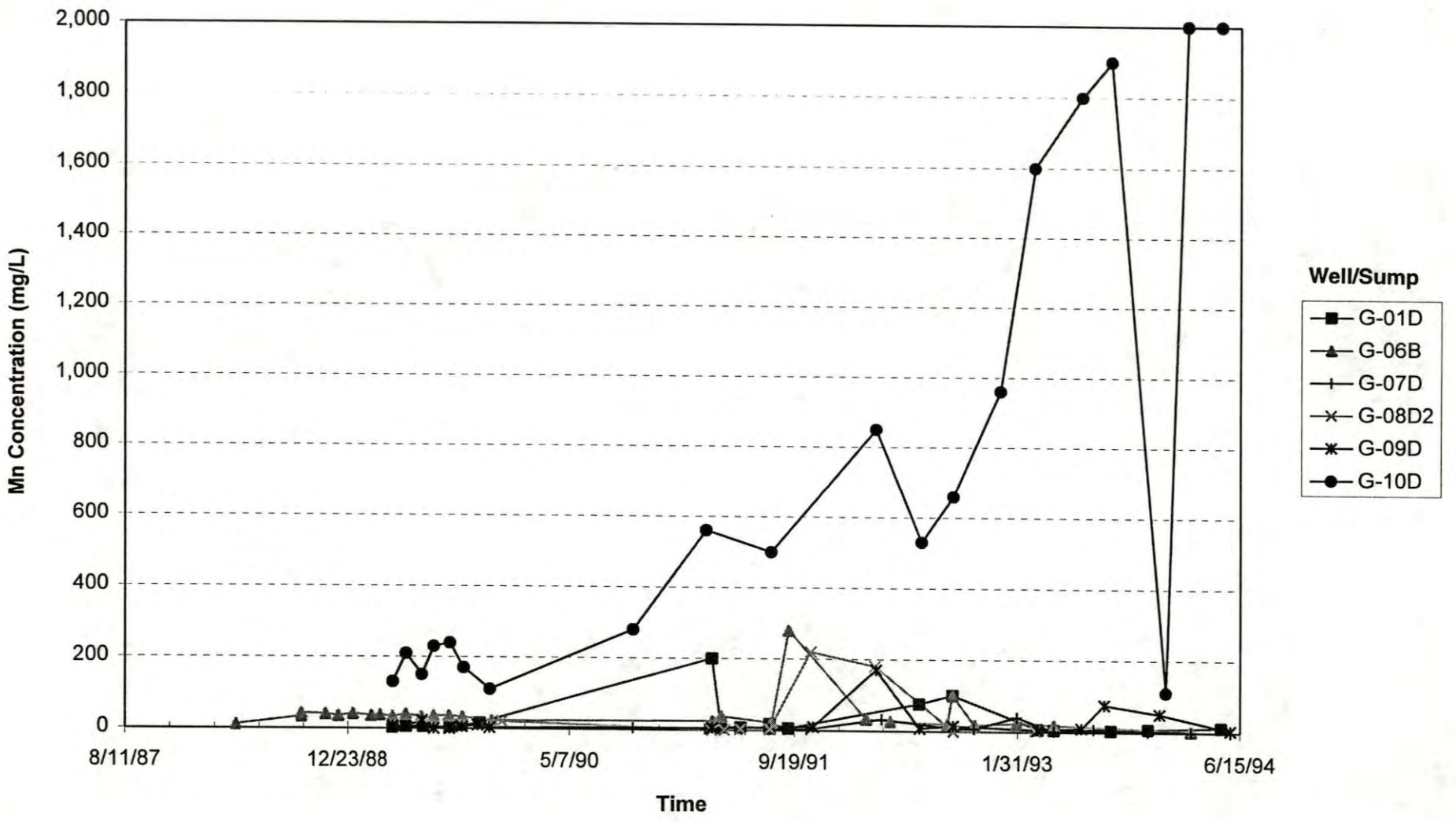
Snohomish Co. Public Works Dept./Cathcart Landfill Phase II

Snohomish County, Washington

PLATE **F-12**

AGI TECHNOLOGIES

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	TMM		

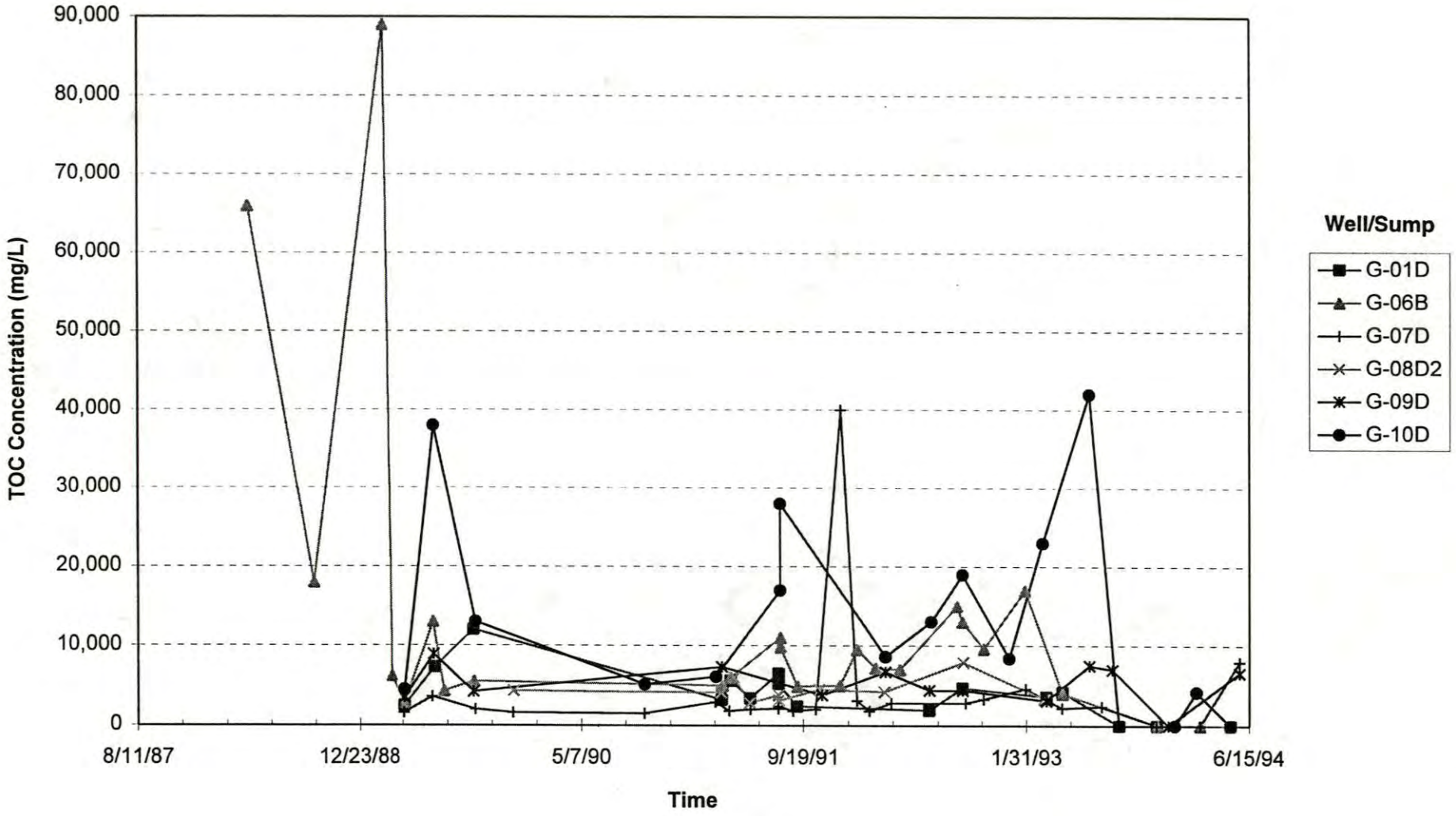


AGI TECHNOLOGIES

Chemistry Trends: Manganese - Deep Groundwater Zone
Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

PLATE **F-13**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95			



Chemistry Trends: TOC - Deep Groundwater Zone
Snohomish Co. Public Works Dept./Cathcart Landfill Phase II
Snohomish County, Washington

AGI TECHNOLOGIES

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
15,512.108	DFF	7 Mar 95	TMM		

PLATE **F-14**

AGI TECHNOLOGIES

CHEMICAL DATA QUALITY REVIEW

Project Name: Snohomish County/Cathcart Landfill
Project No.: 15,512.108

AGI performed a general chemical data quality review of third quarter 1994 groundwater sampling results for the Cathcart Landfill. Results of associated laboratory method blanks, matrix spike/matrix spike duplicate (MS/MSD) percent recoveries and relative percent differences (RPDs), surrogate spike percent recoveries, accompanying chromatography, methods of analysis, and holding time requirements were evaluated. Findings are summarized below.

The laboratory reports reviewed are:

AmTest File No.	Date Collected	Matrix	Sample Identification
94-A017918	09/22/94	Water	500 SLMS, 600 SP-1, 601 SP-4, Trip Blank
94-A017678	09/20/94	Water	174-G-15S, 175 G-7S, 176 G-7D, 177 G-12
94-A015633	08/23/94	Water	162 G-13D
94-A015040	08/12/94	Water	152 G-15S, 153 G-7S, 154 G-7D, 155 G-12D, 156 G-8D1, 157 G-8D2, 158 G-6B, 159 G-11S
94-A014941	08/11/94	Water	144 G-2D, 145 G-1D, 146 G-9S, 147 G-9D, 148 G-10S, 149 G-10D, 150 G-14S, 151 G-14D
94-A014872	08/11/94	Water	140 NSDP, 138 G-3A, 141 G-4A
94-A013995	07/27/94	Water	120 G-6A, 123 NSDP
94-A013497	07/19/94	Water	G-12, G-1D, G-6B
94-A013210	07/13/94	Water	2 G-15S, 3 G-7S, 4 G-7D

AmTest File No. = AmTest identification number of first sample listed on the report.

METHODS OF ANALYSIS

Parameter	Technique	Method
pH	Electrometric	EPA 150.1
Alkalinity (as CaCO3)	Titrimetric	EPA 310.1
Hardness (as CaCO3)	Gravimetric	EPA 130.2
Chloride	Titrimetric	EPA 325.2
Conductivity	Electrometric	EPA 120.1
Sulfate	Turbidimetric	EPA 375.4
Total Coliforms	Membrane Filter	SM 9222B[a]
Fecal Coliforms	Membrane Filter	SM 9222D[a]
Chemical Oxygen Demand	Colorimetric	EPA 410.4
Biochemical Oxygen Demand	Electrometric	EPA 405.1
Total Organic Carbon	Oxidation	EPA 415.1

Parameter	Technique	Method
Ammonia Nitrogen	Colorimetric	EPA 350.1
Total Oil and Grease	Spectrophotometric	EPA 413.2
Total Cyanide	Titrimetric	EPA 335.2
Ortho-Phosphate	Colorimetric	EPA 365.2
Nitrate & Nitrite Nitrogen	Colorimetric	EPA 353.2
Nitrite Nitrogen	Spectrophotometric	EPA 354.1
Total Suspended Solids	Gravimetric	EPA 160.2
Metals[b]	ICP, AA, Cold Vapor	EPA 200 Series
Volatile Organic Compounds (VOCs)	GC/MS	EPA 624
Total Volatile Suspended Solids (TVSS)	Gravimetric	EPA 160.4[c]
Turbidity	Nephelometric	EPA 180.1
Semivolatile Organic Compounds	GC/MS	EPA 625
Pesticides and PCBs	GC/ECD	EPA 608

Notes:

a - Standard Methods for the Examination of Water and Wastewater.
b - Includes arsenic, barium, cadmium, chromium, copper, iron, mercury, magnesium, manganese, nickel, lead, selenium, silver, and zinc.
c - Method not identified; assumed to be EPA 160.4.

The laboratory has grouped analytical parameters in their reports. For ease of presentation, these groupings (listed below) are used in this data quality review.

Bacteriological (BACT):	SM 19222B, SM 1922D
Conventionals (CONV):	EPA Methods 120.1, 130.2, 150.1, 160.2, 160.4, 180.1, 310.1, 325.2, 335.2, 350.1, 353.2, 354.1, 365.2, 375.4, 405.1, 410.4, 413.2, 415.1
Metals (MET):	EPA Methods 200.7, 206.2, 239.2, 245.1, 270.2
Organics (ORG):	EPA Methods 608, 624, 625

LABORATORY QUALITY CONTROL

Method Blanks : Analytes were not detected at or above their associated method detection limit (MDL) in any blanks except as follows:

ORG

AmTest File No. 94-A014872: Methylene chloride was detected in the blank at 1.0 μg/L, and in associated sample 141 G4-A at 3.8 μg/L. The methylene chloride results for sample 141 G4-A should be flagged U, considered not detected, and the methylene chloride MDL considered to be elevated to 3.8 μg/L for this sample batch.

AmTest File Nos. 94-A014941 and 94-A013210: Methylene chloride (a common laboratory contaminant) was detected in the method blank by EPA Method 8260, a VOC method comparable to EPA 624, at 1.0 μg/L and 2.0 μg/L, respectively. Methylene chloride was not detected in any associated samples.

Metals

AmTest File No. 94-A017918: Zinc was detected in the blank at 0.006 mg/L, and in associated sample 601 SP-4 at 0.019 mg/L. The zinc result for sample 601 SP-4 should be flagged U and considered not detected.

AmTest File No. 94-A013497: Selenium and zinc were detected in the blank at 0.001 mg/L; zinc was detected in associated samples G-12 and G-6B at 0.002 mg/L. Both sample detections of zinc should be flagged U and considered not detected.

AmTest File No. 94-A013210: Iron was detected in the blank at 0.01 mg/L; iron detections in associated samples are considered not affected and data flagging is not recommended.

Matrix Spike/Matrix Spike Duplicates: Matrix spike (MS)/matrix spike duplicate (MSD) information is not provided for the following AmTest file numbers: 94-A017678, 94-A015633, 94-A014872, and 94-A013995. Other reports provide matrix spike/matrix spike duplicate percent recovery data, but laboratory control limits are not reported, and in some case, matrix spike concentrations are not reported. Without this information, it is difficult to assess laboratory performance. MS/MSD data were evaluated against EPA guidelines where possible; see the following discussions:

Pesticides and PCBs

AmTest File No. 94-A017918: Laboratory control limits were not available. MS and MSD recoveries of aldrin and p,p'-DDT fell below EPA advisory limits for a similar analytical method. AGI recommends the County obtain AmTest control limits for this parameter so a more comprehensive evaluation can be performed.

CONV

AmTest File No. 94-A015040: MS and MSD recoveries were reported for chloride and sulfate analyses. Spike concentrations were reported to be 50 and 100 mg/L, respectively, or 50 and 100 times the MDL. When spike concentrations are this high, percent recovery may not be an accurate indication of laboratory accuracy during analysis of samples with low analyte concentrations.

AmTest File No. 94-14941: Spike concentrations for TOC, chloride, ammonia-nitrogen, and sulfate ranged from 40 to 100 times the analyte MDL. See discussion above. Nitrate + nitrite-nitrogen and nitrite-nitrogen spike concentrations were 25 and 12.5 times the associated MDL, and are considered acceptable.

Metals

AmTest File No. 94-A014941: Spike concentrations were reported to range from 0.5 to 1 mg/L, or 50 to 500 times the analyte MDL. See CONV discussion above.

Duplicates : Duplicate sample information was provided for CONV and MET in 94-A015040, 94-A014941, 94-A013497, and 94-A013210. Duplicate sample information was not provided for other AmTest file numbers. Duplicate sample analysis is required by some of the EPA methods performed and should be provided with all laboratory reports. These data are used to evaluate laboratory precision. AGI recommends the laboratory be requested to provide these data.

Blank Spikes : Blank spike results were not provided.

Surrogates : Surrogate spike percent recoveries were provided for ORG analyses; however, laboratory control limits for acceptable recoveries were not provided. Without this information, it is difficult to assess laboratory performance on individual samples. Reported recoveries generally fell within EPA accepted limits for similar analytical methods, and are thus considered to indicate satisfactory laboratory performance.

HOLDING TIMES

Analysis dates were provided for most samples. If not provided, the date of report issuance was used to verify holding time compliance. Holding time requirements were met except as follows:

TVSS

Amtest File No. 94-A017918: Samples 600 SP-1 and 601 SP-4 were analyzed one day outside of holding time. Both reported results should be flagged UJ to indicate it is estimated there are no detections at the stated detection limit.

pH

Recommended holding time is specified to be immediate. Analyses for pH outside of holding time occurred as follows: 94-A017918 (samples held 6 days), 94-A017678 (sample held 2 days) 94-A015040 (analysis date not reported), 94-A013497 (samples held 2 days), and 94-A013210 (samples held 2 days). Results for samples held 2 days or more may have been affected, and should be considered estimated values.

Fecal Coliform

AmTest File No. 94-A014872: Date of analysis for this parameter is listed as 8/10/94, 2 days past the sample collection date of 8/10/94. Recommended holding time for this parameter is 6 to 9 hours. It is not clear from the laboratory report whether the analysis was begun or completed on 8/10/94. If it was begun on 8/10/94, sample results were likely compromised, and should be regarded as estimated. AGI recommends clarifying this issue with the laboratory.

AmTest File Nos. 94-A013995 and 94-A013497. Dates of analysis for this parameter are listed 7/28/94 and 7/20/94, respectively, which is likely a minimum of 17 hours past the sample collection times. See discussion above.

FIELD QUALITY CONTROL

Trip Blanks : One trip blank was analyzed, associated with AmTest File No. 94-A017918. Methylene chloride was detected at 1.7 μg/L. Associated samples 600 SP-1 and 601 SP-4 contained methylene chloride at 1.5 and 3.3 μg/L, respectively. The associated method blank was free of contamination. Because the methylene chloride detections are all approximately the same concentration, it is not likely the trip blank was contaminated during sample shipment or storage. Since the trip blank is prepared in the laboratory and methylene chloride is a common laboratory contaminant, it was likely introduced during preparation, preservation, or analysis. Associated sample detections may have been similarly affected and are therefore flagged (J) and regarded as estimates.

A trip blank should be included and analyzed with each shipment of water samples to be analyzed for VOCs for complete data quality assessment.

Field Blanks : Were not analyzed.

Field Duplicates : Were not analyzed.

Rinsate : Were not analyzed.

The various field quality control samples listed above can provide a means to evaluate field procedures, including equipment decontamination, and field precision. Implementation of a field data collection quality control program is recommended during any sampling rounds for which data quality assessment will be performed.

SUMMARY

Data were reviewed based on available quality control information. Additional quality control data were not requested by the County or AGI. Data were generally considered acceptable, with the following exceptions:

The following analytes are considered not detected due to laboratory contamination:

Methylene chloride in sample 141 G4-A
Zinc in samples 601 SP-4, G-12, and G-6B

Fecal coliform results in Am Test File Nos. 94-A014872, 94-A013497, and A013995 should be considered estimated unless it can be determined that analyses were begun within recommended holding time.

pH results in AmTest File Nos. 94-A017918, 94-A017678, 94-A015040 (analysis date not reported), 94-A013497, and 94-A013210 should be considered estimated unless it can be determined they were analyzed within approximately 24 hours of collection.

TVSS results for samples 600 SP-1 and 601 SP-4 should be flagged UJ and considered estimated nondetections due to holding time exceedance.

Methylene chloride results for samples 600 SP-1 and 601 SP-4 are flagged (J) and regarded as estimates due to contamination in the associated trip blank.

Note that QC data were not available for all analyses performed, and it was not always possible to determine relevance of the provided QC data to laboratory performance on environmental samples.

For complete analytical data validation, AGI recommends the County consider requesting that future sample analysis reports include complete quality control data in the form of method blank results, matrix spike/matrix spike duplicate percent recoveries and RPDs, duplicate sample RPDs, blank spike percent recoveries where applicable, surrogate spike percent recoveries, and all associated laboratory control limits and matrix spike concentrations.

AGI
TECHNOLOGIES

CHEMICAL DATA QUALITY REVIEW

Project Name: Snohomish County/Cathcart Landfill
Project No.: 15,512.108

AGI Technologies (AGI) performed a general chemical data quality review of fourth quarter 1994 surface and groundwater sampling results for the Cathcart Landfill. Results of associated laboratory method blanks, matrix spike/matrix spike duplicate (MS/MSD) percent recoveries and relative percent differences (RPDs), surrogate spike percent recoveries, accompanying chromatography, methods of analysis, and holding time requirements were evaluated. Findings are summarized below.

The laboratory reports reviewed are:

AmTest File No.	Date Collected	Matrix	Sample Identification
94-A019149	10/11/94	Water	8G-7S, 9G-7D
94-A019630	10/18/94	Water	17 G-15S, 18 G-12D, 19 G-6B
94-A020182	10/27/94	Water	111 NSDP
94-A020186	10/27/94	Water	110 G-4A
94-A020442	11/01/94	Water	115 A, 116 A-1, 117 B, 118 J, 119 F
94-A021112	11/15/94	Water	44 D-1
94-A021114	11/15/94	Water	43 W-1
94-A021217	11/17/94	Water	49 D-1
94-A021550	11/23/94	Water	52 G-15S, 53 G-7S, 54 G-7D, 55 G-12D
94-A021717	11/29/94	Water	60 G-1D, 61 G-2D
94-A021851	11/30/94	Water	63 G-6B, 64 G-6A
94-A021912	12/01/94	Water	67 G-13B, 68 G-14B, 69 G-14D
94-A021965	12/02/94	Water	150 A-1, 151 A, 152 B-1, 153 F, 154 D, 155 NSPD, 156 I, 157 J
94-A022408	12/09/94	Water	68 F, 69 D
94-A022800	12/14/94	Water	76 G-15S, 77 G-7S, 78 G-7D, 79 G-12, 80 G-6B
94-A022927	12/16/94	Water	82 G-9S, 83 G-9D
94-A023123	12/20/94	Water	90 G-10S, 91 G-10D
94-A023199	12/21/94	Water	85 G-11S, 86 G-8D1, 87 G-8D2
94-A023797	12/29/94	Water	172 G-1A, 173 G-6A, 174 G-3

AmTest File No. = AmTest identification number of first sample listed on the report.

METHODS OF ANALYSIS

Parameter	Technique	Method
pH	Electrometric	EPA 150.1
Hardness (as CaCO3)	Gravimetric	EPA 130.2
Chloride	Titrimetric	EPA 325.2
Conductivity	Electrometric	EPA 120.1
Sulfate	Turbidimetric	EPA 375.4
Total Coliforms	Membrane Filter	SM 9222B[a]
Fecal Coliforms	Membrane Filter	SM 9222D[a]
Chemical Oxygen Demand	Colorimetric	EPA 410.4
Biochemical Oxygen Demand	Electrometric	EPA 405.1
Total Organic Carbon	Oxidation	EPA 415.1
Ammonia Nitrogen	Colorimetric	EPA 350.1
Nitrate & Nitrite Nitrogen	Colorimetric	EPA 353.2
Nitrite Nitrogen	Spectrophotometric	EPA 354.1
Metals[b]	ICP, AA, Cold Vapor	EPA 200 Series
Volatile Organic Compounds (VOCs)	GC/MS	EPA 624
Turbidity	Nephelometric	EPA 180.1

Notes:

a - Standard Methods for the Examination of Water and Wastewater.
b - Includes arsenic, barium, cadmium, chromium, copper, iron, mercury, manganese, nickel, lead, selenium, silver, and zinc.

The laboratory has grouped analytical parameters in their reports. For ease of presentation, these groupings (listed below) are used in this data quality review.

Bacteriological (BACT):	SM 19222B, SM 1922D
Conventionals (CONV):	EPA Methods 120.1, 130.2, 150.1, 180.1, 325.2, 350.1, 353.2, 354.1, 375.4, 405.1, 410.4, 415.1
Metals (MET):	EPA Methods 200.7, 206.2, 239.2, 245.1, 270.2
Organics (ORG):	EPA Method 624

LABORATORY QUALITY CONTROL

Method Blanks : Analytes were not detected at or above their associated method detection limit (MDL) in any blanks except as follows:

ORG

AmTest File Nos. 94-A019149, 94-A019630, and 94-A020186: Methylene chloride (a common laboratory contaminant) was detected in the method blank by EPA Method 8260, a VOC method comparable to EPA 624, at 2.0 µg/L, 5.0 µg/L, and 1.0 µg/L, respectively. Methylene chloride was not detected in any associated samples.

AmTest File No. 94-A021114: Methylene chloride was detected in the blank at 2.0 µg/L, and in associated sample 43 W-1 at 3.0 µg/L. The methylene chloride results for sample 43 W-1 should be flagged U, considered not detected, and the methylene chloride MDL considered to be elevated to 3.0 µg/L for this sample batch.

AmTest File No. 94-A021717: Methylene chloride was detected in the blank at 5.0 µg/L and in associated samples 60 G-1D and 61 G-2D at 1.0 and 1.1 µg/L, respectively. These sample results should be flagged U, considered not detected, and the methylene chloride MDL considered elevated to 5.0 µg/L for this sample batch.

AmTest File No. 94-A021912: Methylene chloride was detected in the blank at 4.0 µg/L and in associated samples 67 G-13D and 69 G-14D at 1.4 and 1.0 µg/L, respectively. These sample detections should be flagged U, considered not detected, and the methylene chloride MDL considered elevated to 4.0 µg/L for this sample batch.

AmTest File No. 94-A022927: Methylene chloride was detected in the blank at 2.0 µg/L and in associated samples 82 G-9S and 83 G-9D at 1.2 and 1.4 µg/L, respectively. These sample detections should be flagged U, considered not detected, and the methylene chloride MDL considered elevated to 2.0 µg/L for this sample batch.

AmTest File No. 94-A023123: Methylene chloride was detected in the blank at 1.0 µg/L and in associated samples 90 G-10S and 91 G-10D at 1.9 and 2.5 µg/L, respectively. These sample detections should be flagged U, considered not detected, and the methylene chloride MDL considered elevated to 2.5 µg/L for this sample batch.

Metals

AmTest File Nos. 94-A020442, 94-A021912, and 94-A021965: Copper was detected in the blank at 0.006, 0.005, and 0.006 mg/L, respectively, and in associated samples 116 A-1; 117 B, 118 J, 119 F, 67 G-13D, 68 G-14D, 69 G-14D, 150 A-1, 152 B-1, 154D, 155 NSPD, and 157 J at similar concentrations. The copper results for these samples should be flagged U and considered not detected.

AmTest File No. 94-A02112: Copper was detected in the blank at 0.002 mg/L, but not in the associated sample. Data are not considered to be affected.

AmTest File No. 94-A021114: Iron and zinc were detected in the blank at 0.01 and 0.005 mg/L, respectively; iron and zinc detections in associated sample 43 W-1 are considered not affected and data flagging is not recommended.

AmTest File No. 94-A021217: Copper and zinc were detected in the blank at 0.002 and 0.005 mg/L, respectively; copper and zinc were detected in associated sample 49 D-1 at 0.009 and 0.016 mg/L, respectively. These results should be flagged U and considered not detected.

AmTest File No. 94-A021717: Copper was detected in the blank at 0.005 mg/L. Copper was not detected in associated samples. Data are not considered to be affected.

Matrix Spike/Matrix Spike Duplicates: Matrix spike (MS)/matrix spike duplicate (MSD) information is not provided for the following AmTest file numbers: 94-A020182, 94-A021112, 94-A021114, 94-A021217 (MS/MSD for ORG only), 94-A021851, 94-A022408, 94-A022800, 94-A022927 (MS/MSD for ORG only), 94-A023199, and 94-A023797. Other reports provide matrix spike percent recovery data, but laboratory control limits are not reported, and in some cases, matrix spike concentrations are not reported. Without this information, laboratory performance cannot be completely assessed. MS/MSD data were evaluated against EPA guidelines where possible; see the following discussions:

CONV

AmTest File No. 94-A020442: MS percent recoveries were reported for TOC, chloride, ammonia nitrogen, nitrate/nitrite nitrogen, nitrite nitrogen, and sulfate analyses. Spike concentrations were reported to be between 25 and 50 times the MDL. When spike concentrations are this high, percent recovery may not be an accurate indication of laboratory accuracy during analysis of samples with low analyte concentrations.

AmTest File No. 94-A021550: MS percent recoveries were reported for chloride and sulfate analyses. Spike concentrations were reported to be 50 and 200 mg/L, respectively, or 50 and 200 times the MDL. See discussion above.

Metals

AmTest File No. 94-A020442: Spike concentrations were reported to range from 0.025 to 1 mg/L, or 25 to 500 times the analyte MDL. See CONV discussion above.

Duplicates : Duplicate sample information was provided for CONV and MET in 94-A020442, 94-A021550, 94-A021912, and 94-A021965. Duplicate sample information was not provided for other AmTest file numbers. Duplicate sample analysis is required by some of the EPA methods performed and should be provided with all laboratory reports. These data are used to evaluate laboratory precision. AGI recommends the laboratory be requested to provide these data for complete data quality review.

Blank Spikes : Blank spike results were not provided.

Surrogates : Surrogate spike percent recoveries were provided for ORG analyses; however, laboratory control limits for acceptable recoveries were not provided. Without this information, laboratory performance on individual samples cannot be completely assessed. Reported recoveries generally fell within EPA accepted limits for similar analytical methods, and are thus considered to indicate satisfactory laboratory performance.

HOLDING TIMES

Analysis dates were provided for most samples. If not provided, the date of report issuance was used to verify holding time compliance. Holding time requirements were met except as follows:

pH

EPA recommends holding time for pH analysis be immediate. Analyses of pH outside of holding time occurred as follows: 94-A019630 (samples held 2 days), 94-A021112 (sample held 2 days) 94-A021851 (samples held 2 days), 94-A021965 (samples held 3 days), 94-A022408 (samples held 3 days), and 94-A022927 (samples held 3 days). Results for samples held 2 days or more may have been affected, and should be considered estimated values.

Total Coliform

AmTest File Nos. 94-A019149, 94-A019630, 94-A020442, 94-A021717, 94-A021912, 94-A022927, and 94-A023123: Dates of analysis for this parameter are listed as 1 day past sample collection dates. Recommended holding time for this parameter is 6 to 9 hours. It is not clear from the laboratory reports whether the analysis was begun or completed on the listed dates. If it was begun on the listed dates, sample results were likely compromised, and should be regarded as estimated for future sampling rounds. The County may want to consider clarifying this issue with the laboratory.

FIELD QUALITY CONTROL

Trip Blanks : Were not analyzed

A trip blank should be included and analyzed with each shipment of water samples to be analyzed for VOCs for complete data quality assessment.

Field Blanks : Were not analyzed.

Field Duplicates : Were not analyzed.

Rinsate : Were not analyzed.

The various field quality control samples listed above provide a means to evaluate field procedures, including equipment decontamination, and field precision. Implementation of a field data collection quality control program is recommended during any sampling rounds for which data quality assessment will be performed.

SUMMARY

Data were reviewed based on available quality control information. Additional quality control data were not requested by the County or AGI. Data were generally considered acceptable, with the following exceptions:

The following analytes are considered not detected due to laboratory contamination:

Methylene chloride in samples 43 W-1, 60 G-1D, 61 G-2D, 67 G-13D, 69 G-14D, 82 G-9S, 83 G-9D, 90 G-10S, and 91 G-10D

Copper in samples 116 A-1, 117 B, 118 J, 119 F, 67 G-13D, 68 G-14D, 69 G-14D, 150 A-1, 152 B-1, 154D, 155 NSPD, 157 J, 49 D-1

Zinc in sample 49 D-1

Total coliform results in Am Test File Nos. 94-A019149, 94-A019630, 94-A020442, 94-A-21717, 94-A021912, 94-A022927, and 94-A023123 should be considered estimated unless it can be determined that analyses were begun within recommended holding time.

pH results in AmTest File Nos. 94-A019630, 94-A021112, 94-A021851, 94-A021965, 94-A022408, and 94-A022927 should be considered estimated unless it can be determined they were analyzed within approximately 24 hours of collection.

Note that QC data were not available for all analyses performed, and it was not always possible to determine relevance of the provided QC data to laboratory performance on environmental samples.

For complete analytical data validation, AGI recommends the County consider requesting that future sample analysis reports include complete quality control data in the form of method blank results, matrix spike/matrix spike duplicate percent recoveries and RPDs, duplicate sample RPDs, blank spike percent recoveries where applicable, surrogate spike percent recoveries, and all associated laboratory control limits and matrix spike concentrations.

APPENDIX H

Landfill Hydrologic Budget Analysis

APPENDIX H

Landfill Hydrologic Budget Analysis

The hydrologic budget analysis is summarized in Section 4.3. Details regarding formulation of the analysis are presented below.

BASIS FOR ANALYSIS

Monthly mean SP-1 flow data are the basis for the hydrologic budget analysis. Available information indicates all landfill fluids are routed through SP-1 prior to conveyance to the Pretreatment Facility. After correction for inflow to SP-1 from the North Pond and extraction well W-1 pumping, SP-1 is assumed to represent total flows discharging from the landfill.

Total landfill flows, as quantified at SP-1, are based on total sump pumping time converted by the County to total daily flows. County personnel have indicated these rates are calibrated on a periodic basis. It should be noted that the hydrologic budget assumes these flow values represent actual field conditions. Any error associated with the SP-1 flow values are carried through the analysis.

CONCEPTUAL MODEL

To determine relative magnitudes of groundwater inflows to the CLF, the landfill was conceptualized as a rectangular box with primary dimensions equal to those of the landfill, as shown on **Figure 22.** Horizontal inflows to the landfill occur at the south, east, and west faces of the model; upward inflow (upwelling) occurs at the model floor. Outflow from the model occurs at the north face and SP-1 (underdrain and leachate collection system).

As stated in Section 3.3.2, inflows to the landfill likely originate as:

- groundwater throughflow
- infiltrating Garden Creek flow loss
- infiltrating east side drainage ditch loss
- infiltrating South Pond loss
- construction features which reportedly exist in the vicinity of the South Pond

Flow contributions from each of these sources enters the landfill through one of the faces of the model.

FORMULATION OF ANALYSIS

The flow inflow/outflow balance was formulated as follows:

inflow: west face + south face + east face + cap runoff (directed into SP-1) + internal leachate + upwelling =

outflow: [underdrain + leachate outflow (SP-1)] + north face

Both wet and dry season flows were evaluated. The dry season was evaluated using SP-1, precipitation, and hydraulic gradient data from August and September 1994, which were the driest months of the year. Dry season flow magnitudes were assumed to represent baseline, or minimum conditions. The wet season was evaluated using data from November and December 1994; these were the most recent and wettest months available at the time of the analysis.

The following are more detailed formulations of the hydrologic budget equations for the two seasons:

Dry Season

$$GW_{south} + GW_{east} + GW_{west} + GW_{upwell} + internal\ leachate = SP\text{-}1 + GW_{north}$$

where GW_{south}, GW_{east}, GW_{west} and GW_{north} were calculated as described above, internal leachate generation was assumed, and SP-1 flows were from the County's database. GW_{upwell} was the unknown parameter.

Wet Season

$$GW_{south} + GW_{east} + GW_{west} + GW_{upwell} + internal\ leachate = SP\text{-}1 + GW_{north} - (R - ET) * f$$

where the same conditions described above exist and

R = rainfall
ET = evapotranspiration
and f = the fraction of the landfill's surface water routed to SP-1 (95%).

During November 1994, surface water was routed to SP-1 for 24 days. No surface water entered SP-1 during December, and the above equation was reduced to that used for the dry season analysis.

The various flows were determined as follows:

Surface Water : Surface water flow rates were measured at various locations along Garden Creek using existing V-notch weirs and the new weirs installed in 1994, the South Pond weir, and several culverts. Flow measurements were made between October 31 and December 19, 1994. These data are presented in **Table 1** of the text.

Cap Runoff : Cap runoff was estimated based on the difference between total rainfall and total evapotranspiration calculated for the cap using the Penman equation. This volume of surface water runoff was removed from the SP-1 flow volume for the periods of interest.

Groundwater Flows : The hydrologic budget analysis employed groundwater inflow through five flow faces: the west, south, east, and north walls of the landfill, and the landfill floor. Each of the faces comprised up to three hydrogeologic flow regimes: siltstone, till and fill, and alluvium. Siltstone, till, and fill are included in each of the faces; alluvium, which comprises the former Garden Creek channel, was included only in the south and north faces. The landfill floor was assumed to comprise only siltstone. Groundwater through each of these units was estimated based on the Darcy formula, as follows:

$$Q = K \times i \times A$$

where
- Q = groundwater flow (cubic feet per second)
- K = hydraulic conductivity of the medium (feet/second)
- i = hydraulic gradient (vertical head difference per horizontal distance)
- A = effective saturated cross sectional area of the medium

Groundwater flow through the siltstone, till/fill, and alluvium was calculated based on hydraulic gradients determined based on water elevation differences between monitoring wells in proximity to the respective face. Groundwater elevations were obtained from monthly water levels measured by the County. Hydraulic conductivity values are based on the previous investigations for the CLF and adjoining RLF (*AGI: Summary Hydrogeologic Report for the Regional Landfill, 1995*) or were assumed based on known lithologic properties. Hydraulic parameters for the various units are summarized in **Table 3** of the text.

Considerations for groundwater flow through each landfill face are discussed below.

West Face : Groundwater inflow across the west face of the landfill occurs as seepage through the siltstone and shallow flow in the fill and till. As shown on the groundwater contour maps (**Figures 15 through 18**), groundwater flows toward the landfill at an oblique angle along the west side; the hydraulic gradient (water table slope) into the west face is therefore relatively low. The rate of groundwater seepage across the west face was assumed to be constant along its entire length.

Garden Creek flows parallel to the west side of the landfill along its entire length. Water infiltrating from the creek likely percolates downward until it reaches the water table and enters the groundwater. Due to reasons just described, some of this water likely does not flow toward the landfill. Additionally, the increase in groundwater flow across the west face caused by losses from Garden Creek is calculated in terms of increased saturated thickness in the Darcy formula presented above. Maximum loss measured along Garden Creek during wet season flow was approximately 3 gpm along its entire length along the landfill. Given the large saturated area of entire west face, the contribution from Garden Creek as groundwater flow across the west face is considered insignificant.

Garden Creek losses could enter the landfill through other pathways such as construction features; however, no such pathway has been identified.

South Face : Groundwater flow through the Garden Creek watershed flows directly into the south face of the landfill. Local sources of groundwater recharge at the landfill's south face include groundwater flow through the watershed, surface water infiltration from the South Pond and the south reach of Garden Creek, and physical flow pathways associated with landfill construction features that may still exist at the landfill's south end. These sources all contribute to movement of water across the south face of the landfill.

Groundwater flow across the south face occurs in the alluvium (original Garden Creek channel), till, and siltstone. The alluvium likely contributes the greatest magnitude of flow across the south landfill face. The till and siltstone likely allow markedly less flow due to their low hydraulic conductivities.

Surface water collected by the South Pond causes an increase in the pond water level between dry and wet seasons. As water elevations increase, hydraulic head at the pond base also increases, causing water to infiltrate into groundwater. This recharge to groundwater flow is assumed to contribute a significant portion of the flow across the south face of the landfill. County personnel have noted that the pond has never drained completely; this indicates the pond is likely an expression of the water table. Consequently, as long as surface water flows into the pond, it provides continuous recharge to the groundwater flowing toward the south face.

As described above, maximum loss measured along Garden creek during wet season flow was approximately 3 gpm for its entire length along the landfill. Based on this volume, it is unlikely the portion of the creek along the south face of the landfill contributes significantly to flows across the south face.

East Face : Groundwater inflow across the east face of the landfill consists of seepage through the bedrock and shallow flow in the fill and till. The groundwater divide, which generally corresponds to the topographic ridge east of the landfill, is relatively close to the east face. The hydraulic gradient here is therefore higher than at the west face. The rate of groundwater seepage was assumed to be constant across the entire east face.

Some portion of surface water infiltrating from the east side drainage ditch may enter groundwater; however, this process is likely identical to that described above for Garden Creek. The contribution to groundwater from the east side drainage ditch is therefore assumed to be insignificant.

Groundwater Upwelling : Groundwater upwelling cannot be measured due to lack of direct access to water and leachate levels at the base of the landfill excavation. Construction records indicate the integrity of the membrane liner was compromised during construction. This factor, coupled with chemical and volumetric evidence of commingling of leachate and groundwater, indicates that there is likely upward groundwater flow through the landfill base.

In the hydrologic budget analysis, groundwater upwelling was solved for as the unknown factor. As described above, all other inflows and outflows through the landfill faces were estimated based on hydraulic properties determined by the watershed balance, and SP-1 values were known. Because the surface area of the landfill base is on the order of 3 million square feet, upwelling across this face is likely significant.

Internal Leachate Generation : Additional water is contributed by internal leachate drainage resulting from refuse consolidation over time and delayed drainage of water trapped in the refuse after capping. The internally generated leachate volume was estimated at 5 gpm assuming no precipitation inflow through the landfill cap.

North Face : In addition to SP-1, the north face of the landfill constitutes a groundwater outflow pathway. This outflow is partitioned into the same three flow regimes as the south end of the landfill: the alluvial channel, till, and siltstone. Conditions are similar at both faces, except that the north face likely has a higher hydraulic gradient across it.

RESULTS

Estimated inflows and outflows for the 1994 dry (August and September) and wet (November and December) seasons are summarized in **Table 4** of the text. Relative magnitudes of these inflows for both seasons are illustrated in the pie diagram shown on **Figure 23** of the text.

Results of the analysis demonstrate the following:

- Groundwater upwelling is responsible for the largest share of inflow to the landfill. During December 1994, upwelling inflows were estimated to be approximately 70 gpm. In terms of the total flow rate, this inflow appears relatively high compared with the landfill faces. However, the corresponding flux rate for the upwelling term is approximately 2.5×10^{-5} gpm per square foot of landfill floor, based on landfill excavation dimensions of 3,000 feet (length) by 900 feet (width). December flux rates for the west and east faces are approximately 7×10^{-6} and 1×10^{-5} gpm.

- Inflow through the south landfill face is significant relative to the other faces. South face inflows are likely higher than the other faces due to flow through the alluvium and the relatively continuous recharge to groundwater from the South Pond.

SUMMARY

Our analysis indicates landfill inflows are ordered, from most to least significant, as follows:

1. Groundwater upwelling
2. South face inflow
3. Internal leachate drainage
4. East face inflow
5. West face inflow

Based on results of the watershed and landfill hydrologic budget analyses, we conclude the following:

- The results of the landfill hydrologic budget analysis indicate groundwater upwelling is significant. During the dry season, approximately 16 gpm of water enters the landfill excavation and exit through SP-1. Wet season groundwater upwelling may exceed 70 gpm.

- Flow through the alluvial channel at the south face of the landfill is also likely a large quantity. During the dry season, south face groundwater flow is approximately 4 gpm; during the wet season, this flow increases to approximately 14 gpm.

- Groundwater flows across the east and west faces of the landfill are not significant relative to the south face and upwelling inflows. The east and west face flows range from 0.1 gpm from the east and 0.4 gpm from the west during the wet season. Calculations for these flow values assume uniform flow through the till or bedrock along the entire length of the east and west faces.

- Internal drainage of leachate may be a significant source of landfill fluids, although it is currently impossible to quantify the volume contributed.