HWA GEOSCIENCES INC.
Geotechnical & Pavement Engineering • Hydrogeology • Geoenvironmental • Planning & Permitting • Inspection & Testing

February 6, 2007

Mark Sadler
City of Everett
Department of Public Works
3200 Cedar Street
Everett, Washington 98201

Subject: **IRON, MANGANESE & ARSENIC BACKGROUND INVESTIGATION**
Everett Landfill/Tire Fire Site
Everett, Washington

Dear Mark:

This report summarizes the HWA GeoSciences Inc. (HWA) investigation to determine background concentrations of iron, manganese, and arsenic at the Everett Landfill.

INTRODUCTION

Cleanup levels for iron, manganese, and arsenic were not established at the time of the Everett Landfill/Tire Fire Site Consent Decree preparation. These compounds were known to exist at elevated concentrations at and near the landfill, therefore the Compliance Monitoring and Contingency Plan (CMCP) specified determination of background concentrations after the evaluation monitoring period (which ended in April 2004) for subsequent use as clean up levels during Performance Monitoring (year 2005 to 2010). After the evaluation monitoring period, it was determined that the existing upgradient wells installed in order to establish background concentrations did not adequately represent conditions at and near the landfill, as they are located in a different hydrogeologic environment. In addition, iron, manganese, and arsenic concentrations in the shallow aquifer did not correspond to the distribution of these elements in the deep aquifer (HWA, 2004 & HWA, 2005).

The upgradient monitoring wells MW-33 and MW-35, although thought to be hydraulically connected to the deep aquifer beneath the landfill, are installed in a different hydrogeologic formation than the deep aquifer wells within and down gradient of the landfill. The upgradient deep aquifer wells MW-33 and MW-35 are screened in dense glacial sand, overlain by a stiff silt layer (Transitional Beds). The deep monitoring wells within and down gradient of the landfill are installed in loose alluvial sand, overlain by soft alluvial silt and peat. In some locations, wood waste and naturally occurring woody debris occurs above the loose sand. Naturally occurring organic material (peat and woody debris) and wood waste produce a low oxygen (anaerobic) environment with reducing conditions. This type of environment tends to mobilize metals, such as iron, manganese, and arsenic, which would otherwise remain insoluble. Reducing conditions, caused by the anaerobic decomposition of

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organic material, are also often encountered within and down gradient of landfills (HWA, 2004).

Iron and manganese concentrations in the upgradient background monitoring wells (MW-33, MW-34, and MW-35) are one to three orders of magnitude less than the concentrations measured in wells at and down gradient of the landfill. Calculation of background values from the upgradient wells for use as cleanup levels would therefore be inappropriate.

Iron, Manganese, and Arsenic Concentrations Near The Landfill

The reducing conditions encountered within and down gradient of the Everett Landfill are encountered area-wide in the alluvial sediments east, south, and north of the landfill. Analytical results from investigations at the nearby Simpson Site indicate high iron, manganese, and arsenic concentrations are present throughout the low-lying areas adjacent to the Snohomish River. The Simpson site is located south of the Landfill and formerly had pulp, paper, plywood and saw mills on it. HWA detected iron concentrations in shallow ground water during the Brownfields Riverfront Stormwater Site Selection Study at the Simpson site ranging from 6,730 to 80,500 µg/l; manganese ranging from 846 to 3,640 µg/l, and arsenic up to 31 µg/l (HWA, 2003). ERM detected arsenic in four monitoring wells completed in the shallow aquifer at the Simpson site in 1992, at concentrations of 8.77, 10.3, 14.4, and 15 µg/l (ERM, 1993). GeoEngineers detected dissolved arsenic in a monitoring well completed in the shallow aquifer at a property north of the landfill at a concentrations of 81 µg/l (GeoEngineers, 1997). Some of these iron, manganese, and arsenic concentrations are higher than detected within the landfill and leachate collection system. Figure 1 shows the location of these sites.

IRON, MANGANESE, AND ARESENIC BACKGROUND STUDY SCOPE

In order to establish meaningful background values, ground water sampling in a similar hydrogeologic environment, but outside the potential influence of the landfill, was performed. Due to the landfill's unique geologic position (occupying the entire width of the alluvial valley between the river and glacial uplands), the investigation included installation and sampling of three new monitoring wells (MW-40, MW-41, and MW-42), located side, or cross-gradient of the landfill, and in similar geologic conditions. The scope of that work was outlined in the HWA *Iron, Manganese & Arsenic Background Investigation* letter dated January 27, 2005, and was based on discussions and concurrence with the Department of Ecology. Figure 1 shows the landfill and surrounding areas. Figure 2 shows the approximate locations of the three background monitoring wells.

Monitoring Well Installation

On June 28-29, 2005 Cascade Drilling, under subcontract to HWA, drilled and installed three ground water monitoring wells at the locations shown in Figure 2. The monitoring wells were drilled and constructed according to State of Washington Department of

Ecology (Ecology) Minimum Standards for Construction and Maintenance of Wells (Chapter 173-160 WAC). All field work was supervised by an HWA geologist. The wells were completed in alluvial sands of the upper portion of the deep aquifer, below the alluvial silt and peat aquitard. The wells were developed to improve hydraulic connection and water clarity, by surging with a surge block and bailing or pumping. Each well was developed for approximately 0.5 hour. Appendix A contains boring logs with geologic and well completion details.

Ground Water Sampling

HWA conducted nine rounds of ground water sampling over a period of one year (July 2005 to July 2006) to obtain a statistically significant sample size, and account for any seasonal variation. Sampling methods were in accordance with the existing Sampling and Analysis Plan, which was amended to include the new wells. HWA submitted the samples to the Everett Environmental Laboratory for analysis of dissolved iron, manganese, and arsenic. HWA also measured field parameters, including pH, temperature, dissolved oxygen, and specific conductivity. HWA measured ground water levels at each of the monitoring wells for inclusion in the performance monitoring ground water gradient evaluation, and to evaluate seasonal ground water level changes.

Figure 3 shows the ground water level hydrograph for the monitoring period. Ground water levels in MW-40 and MW-41, located near the River, appeared to follow a typical pattern of higher ground water elevation in the fall and winter months, with an annual variance of approximately 10 feet. Ground water levels in MW-42, located inland of the River, appeared vary by approximately 2.5 feet over the year, and were generally lower in the fall and winter months.

Figures 4 and 5 show the deep aquifer ground water gradients measured during semi-annual performance monitoring (July 2, 2005 and February 2, 2006). Ground water elevation data from MW-40 and MW-41, located near the River, were not used to contour ground water elevations, as these wells are subject to tidal influence. Ground water gradients in the deep aquifer are generally towards the east, toward the Snohomish River.

Results

Table 1 summarizes the analytical results. Appendix B contains the laboratory reports. MW-40 had the highest iron and manganese concentrations, ranging from 3,740 to 29,000 micrograms per liter (µg/l) for iron, and 881 to 8,080 µg/l for manganese. MW-40 had the highest arsenic concentrations, ranging from 13 to 26 µg/l. Arsenic was not detected in MW-40 and 41 above laboratory reporting limits during the one year monitoring period.

HWA performed statistical calculation of natural background values for the three new wells per Chapter 173-340-709 WAC of the Model Toxics Control Act (MTCA) and Ecology *Statistical Guidance for Ecology Site Managers* (Ecology, 1992). Background levels were calculated based on:

- The upper 90th percentile, or four times the 50th percentile, whichever is lower, for lognormally distributed populations;
- the upper 80th percentile, or four times the 50th percentile, whichever is lower, for normally distributed populations; or
- the non-parametric 90th percentile, or four times the 50th percentile, whichever is lower, for populations displaying neither lognormal nor normal distributions.

Tables 2 and 3 summarize the results.

Table 1
Background Monitoring Results

		Metals			Field Parameters			
Date	Well	As (µg/l)	Fe (µg/l)	Mn (µg/l)	pH	SC (uS/cm)	DO (mg/l)	Temp. (^{0}C)
7/19/2005	MW-40	<2	28,800	8,080	5.44	12,130	0.15	14.1
	MW-41	<2	2,660	1,830	5.88	13,490	0.15	15.0
	MW-42	17	4,520	448	6.31	327	0.14	14.9
9/1/2005	MW-40	<2	20,900	2,220	5.21	2,010	1.56	14.4
	MW-41	<2	1,950	1,580	5.28	12,700	2.00	14.2
	MW-42	21	5,840	425	5.20	296	1.77	15.5
10/13/2005	MW-40	<2	24,900	6,580	6.46	11,250	0.40	13.0
	MW-41	<2	6,120	651	6.61	2,900	0.22	12.9
	MW-42	20	6,310	441	6.81	321	0.19	14.2
11/23/2005	MW-40	<10	28,800	6,620	6.76	12,800	0.15	11.8
	MW-41	<10	2,910	1,520	7.03	12,090	0.15	12.0
	MW-42	25	6,590	439	7.20	202	0.15	13.3
1/11/2006	MW-40	<4	21,600	2,000	6.64	2,970	0.56	11.9
	MW-41	<4	1,730	1,700	6.73	13,430	3.21	11.9
	MW-42	23	6,700	428	6.73	366	0.37	12.8
2/27/2006	MW-40	<4	29,000	5,120	6.51	5,820	0.85	11.9
	MW-41	<4	847	1,860	6.82	13,480	9.29	12.2
	MW-42	20	6,330	419	6.83	266	0.35	12.4
4/4/2006	MW-40	<4	4,880	881	6.83	1,153	0.81	12.4
	MW-41	<4	3,630	1,040	6.71	8,450	1.15	12.5
	MW-42	13	3,780	428	6.63	446	2.00	12.8
5/19/2006	MW-40	<4	3,740	1,010	6.96	886	1.38	12.8
	MW-41	<4	6,860	528	6.81	2,616	1.90	12.9
	MW-42	26	7,360	431	7.02	282	1.00	13.1
7/12/2006	MW-40	<4	20,000	1,780	6.58	840	0.18	12.6
	MW-41	<4	5,360	970	6.53	2,220	0.33	13.1
	MW-42	24	7,290	430	6.64	268	0.26	14.1

As – Arsenic
Fe – Iron
Mn – Manganese
<n – not detected at the laboratory reporting limit shown

Table 2
Statistical Summary of Results by Well (µg/l)

	MW-40			MW-41			MW-42		
	As	Fe	Mn	As	Fe	Mn	As	Fe	Mn
Mean	ND	20,291	3,810	ND	3,563	1,298	21	6,080	432
Lognormal mean	ND	22,710	4,080	ND	3,737	1,327	21	6,108	432
Standard deviation	ND	9,718	2,782	ND	2,098	509	4	1,206	9
Median	ND	21,600	2,220	ND	2,910	1,520	21	6,330	430
Minimum	ND	3,740	881	ND	847	528	13	3,780	419
Maximum	ND	29,000	8,080	ND	6,860	1,860	26	7,360	448

ND - analyte not detected above laboratory reporting limits during one year monitoring period

Table 3
Statistical Summary of Results All Wells (µg/l)

	As MW-42	As	Fe	Mn
Distribution	N	NP	LN	NP
Mean	21	9.7	9,978	1,847
LN mean	21	9.9	10,272	1,788
Standard deviation	4	8.7	9,337	2,143
Median	21	4	6,310	1,010
Minimum	13	2	847	419
Maximum	26	26	29,000	8,080
90th percentile			**23,687**	
80th percentile	**24.8**			
4 x 50th percentile	84	**16**	26,623	**4,040**
NP 90th percentile		24.2		6,588

N - Normal distribution
LN - Lognormal distribution
NP – Distribution is neither normal nor lognormal (non parametric)
Background - Based on upper 90th percentile for lognormally distributed populations, upper 80th percentile for normal distributions, and 4 x 50th percentile for non-normal/lognormal distributions

Due to the large number of arsenic values below detection limits in all three wells (18 out of 27, or 67%), HWA also evaluated the arsenic background level based on only MW-42 results, which displayed a normal distribution, for comparison purposes. The 80th percentile value for MW-42 data (24.8 µg/l) is very close to the 90th percentile based on the non-parametric method for all three wells, (24.2 µg/l). This value is also near the maximum detected value (26 µg/l) which is typically used to establish upper confidence limits for populations with greater than 50% non-detects. Note the 50th percentile for this population is heavily skewed by the large number of non-detects, and is below the practical quantitation limit. Establishment of the background value based on four times the 50th percentile is therefore very conservative. HWA recommends establishment of an arsenic background value of 25 µg/l, based on the methods described above.

DISCUSSION

The Ecology *Statistical Guidance for Ecology Site Managers* (Ecology, 1992) defines natural background concentrations as not influenced by human activity or due to human activity but widespread (e.g., PCBs). Natural background concentrations can be used to establish cleanup standards where no regulatory standard exists, or to replace MTCA cleanup standards where the natural background is higher. Area background concentrations are typically attributed to human activities unrelated to the site in question, but are widespread in the area of interest. Area background concentrations may be used to replace Method A or B cleanup standards, but can not exceed Method C values.

Iron, manganese, and arsenic concentrations in ground water at the Everett Landfill site are considered to represent natural background conditions, as their presence is due to the reducing environment in ground water associated with natural peat deposits, and no direct or man-made source of these elements is known at or near the site.

Due to the percentile approach for determining background concentrations, compliance data can be expected to exceed the calculated background concentration based on the percentile used (e.g., if background is based on the 90^{th} percentile, 10 percent of the compliance data will likely exceed). Evaluation of compliance data is therefore based on an allowable frequency and magnitude of exceedances, as follows (Ecology, 1992):

- Frequency of exceedance: no more than 20% of compliance samples should exceed the background value
- Magnitude of exceedance: the maximum allowable exceedance is 2 times the background value

Iron and Manganese

Iron and manganese concentrations in the three new background monitoring wells (MW-40, MW-41, and MW-42) varied considerably by well. High variability of iron and manganese concentrations among point of compliance wells has also been observed, and suggests some localized redox conditions across the down gradient edge of the landfill and near the River (HWA, 2004).

Iron and manganese concentrations in wells MW-40 and MW-41, located near the River, were generally higher, with the highest average and maximum concentrations detected in MW-40. Iron and manganese concentrations detected in the background monitoring wells were similar or higher than in landfill deep aquifer point of compliance wells MW-36, MW-37, MW-38, and MW-39, located down gradient of the Landfill. Data tables for the point of compliance wells can be found in the HWA *Performance Monitoring Annual Report* (HWA, 2006). Table 4 summarizes the iron and manganese concentrations in the point of compliance wells to date.

Table 4
Point of Compliance Wells
Iron & Manganese Concentrations (μg/l)

	MW-36		MW-37		MW-38		MW-39	
	Fe	Mn	Fe	Mn	Fe	Mn	Fe	Mn
Minimum	255	26	20,327	598	1,560	219	18	206
Maximum	18,000	852	29,900	956	4,850	384	3,780	430
Average (mean)	14,354	644	24,620	702	3,556	283	2,147	335

Manganese concentrations measured in the point of compliance wells to date have not exceeded the manganese background concentration calculated above of 4,040 μg/l. Iron concentrations measured in point of compliance wells MW-36, MW-38, and MW-39 have not exceeded the iron background concentration 23687 μg/l.

Iron concentrations in MW-37 have consistently (7 times out of 12) exceeded the iron background concentration, but have not exceeded twice that amount. Monitoring well MW-37 has recently been determined to not be representative of deep aquifer conditions and will be abandoned. Recent investigations into elevated chloride concentrations in this well have demonstrated the influence of river water in the well (HWA, 2006b).

Arsenic

Arsenic concentrations also varied considerably between the three new background monitoring wells, with no detections in MW-40 and MW-41, and concentrations of 13 to 26 μg/l detected in MW-42.

Arsenic concentrations measured in the point of compliance wells (MW-36, MW-37, MW-38, and MW-39) to date have not exceeded the background concentration calculated above of 16 μg/l. Data tables for the point of compliance wells can be found in the HWA *Performance Monitoring Annual Report* (HWA, 2006). Table 5 summarizes the arsenic concentrations in the point of compliance wells to date.

Table 5
Point of Compliance Wells
Arsenic Concentrations (μg/l)

	MW-36	MW-37	MW-38	MW-39
Minimum	4	<2	ND	<2
Maximum	14.7	3	ND	8
Average (mean)	8.5	**	ND	3.4

ND - analyte not detected above laboratory reporting limits during monitoring period
** detected once at 3μg/l

Arsenic has been detected in three interior wells, seven network wells, three compliance wells, and the two leachate lift station vaults, at concentrations ranging from 3 to 16 µg/l. Elevated arsenic concentrations (above 6 µg/l, the highest detection limit used), have been limited to the easternmost wells (MW-24, MW-28, MW-30, MW-32, MW-36, MW-37, and MW-39), which include the point of compliance wells (MW-36, MW-37, and MW-39) in which arsenic has been detected at concentrations up to 14.7 µg/l. Elevated arsenic concentrations (above 6 µg/l) have not been detected in the leachate lift station vaults, suggesting its occurrence in other wells is the result of mobilization from soils or increased solubility due to reducing conditions in ground water. In two shallow/deep monitoring well pairs, arsenic concentrations were generally higher in the deep well than in the shallow well (MW27/MW-28 and MW-25/MW-30), suggesting a source not associated with the landfill.

SUMMARY / CONCLUSIONS

In general, it appears iron, manganese, and arsenic may not be reliable indicators of landfill impacts to ground water in this vicinity, due to elevated and variable area background conditions, and the landfill's unique geologic position (occupying the entire width of alluvial valley between the river and glacial uplands).

Based on calculation of natural background values for iron, manganese, and arsenic, Table 6 summarizes the proposed background-based cleanup levels for iron, manganese and arsenic at the landfill:

Table 6
Proposed Background-Based Cleanup Levels (µg/l)

	As	Fe	Mn
Background CUL	25	23,687	4,040
2 x Background	50	47,374	8,080

Evaluation of compliance data is based on an allowable frequency of exceedance of 20%, and a maximum value of two times the background value (Ecology, 1992).

The point of compliance monitoring data collected to date are in currently in compliance with these background-based cleanup standards, with the exception of monitoring well MW-37, which has recently been determined to not be representative of deep aquifer conditions, and will be abandoned.

Future analytical results should also be evaluated for changes or trends over time at each well. Any observed trends over time will be correlated to precipitation, ground water, or River levels to account for potential confounding variables. Control charts may also be used for appropriate sample populations.

HWA recommends sampling MW-40, MW-41, and MW-42 for all compliance parameters for the next two rounds (1/07, 7/07) instead of MW-33 and MW-35. Based

on the results, MW-33 and MW-35 (deep upgradient wells), and MW-34 (shallow upgradient well) can be abandoned.

REFERENCES

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HWA GeoSciences, Inc., August 22, 2003, *Brownfields Riverfront Stormwater Site Selection Study, Simpson Site, Everett, Washington*, Prepared for City of Everett.

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HWA GeoSciences, Inc., September 11, 2006, *MW-37 Chloride Investigation, Everett Landfill, Everett, Washington*, Prepared for City of Everett.

Washington State Department of Ecology Toxics Cleanup Program, 1992, *Statistical Guidance for Ecology Site Managers (& MTCAStat 3.0 Software, revised 1997),* Publication 92-54, August, 1992.

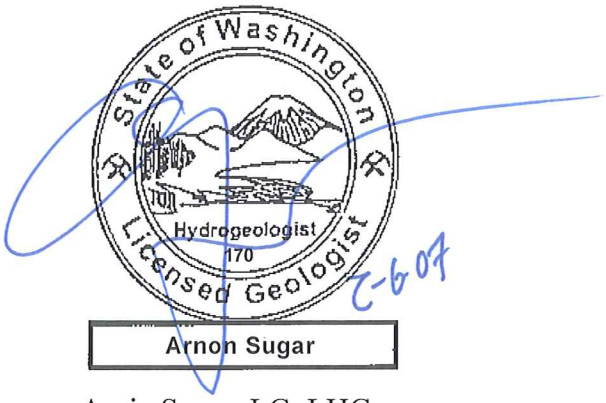
LIMITATIONS

The conclusions expressed by HWA are based solely on material referenced in this report. Observations were made under the conditions stated. Within the limitations of scope, schedule and budget, HWA attempted to execute these services in accordance with generally accepted professional principles and practices in the area at the time the report was prepared. No warranty, expressed or implied, is made. Experience has shown that subsurface soil and ground water conditions can vary significantly over small distances. It is always possible that contamination may exist in areas that were not sampled. HWA's findings and conclusions must not be considered as scientific or engineering certainties, but rather as our professional opinion concerning the significance of the limited data gathered and interpreted during the course of the assessment.

This study and report have been prepared on behalf of the City of Everett, for the specific application to the subject property. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, nor the use of segregated portions of this report.

We appreciate the opportunity to provide services on this project. Please feel free to call me if you have any questions or need more information.

Respectfully submitted,
HWA GeoSciences Inc.



Arnie Sugar, LG, LHG
Vice President

cc: John Keeling, Washington State Department of Ecology
3190 160th Avenue SE, Bellevue, WA 98008-5452

HWA GEOSCIENCES INC.

EVERETT LANDFILL
EVERETT, WASHINGTON

SITE AND EXPLORATION PLAN

DRAWN BY KS	FIGURE NO. 1
CHECKED BY PP	
DATE 10.17.06	PROJECT NO. 98165

REV 00 EFK 10/17/06

BASE MAP PROVIDED BY:
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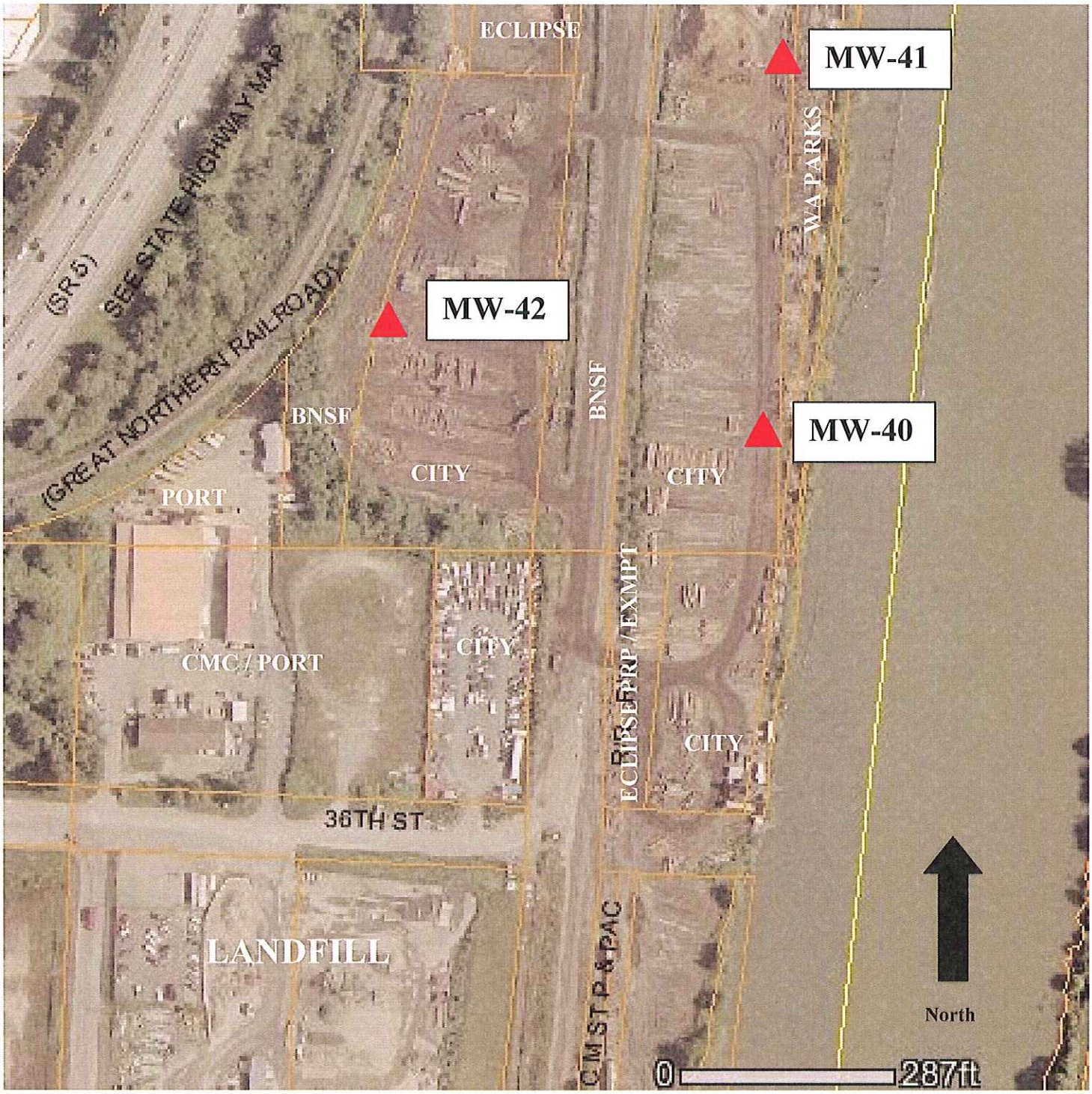


▲ Fe, Mn, As BACKGROUND MONITORING WELL

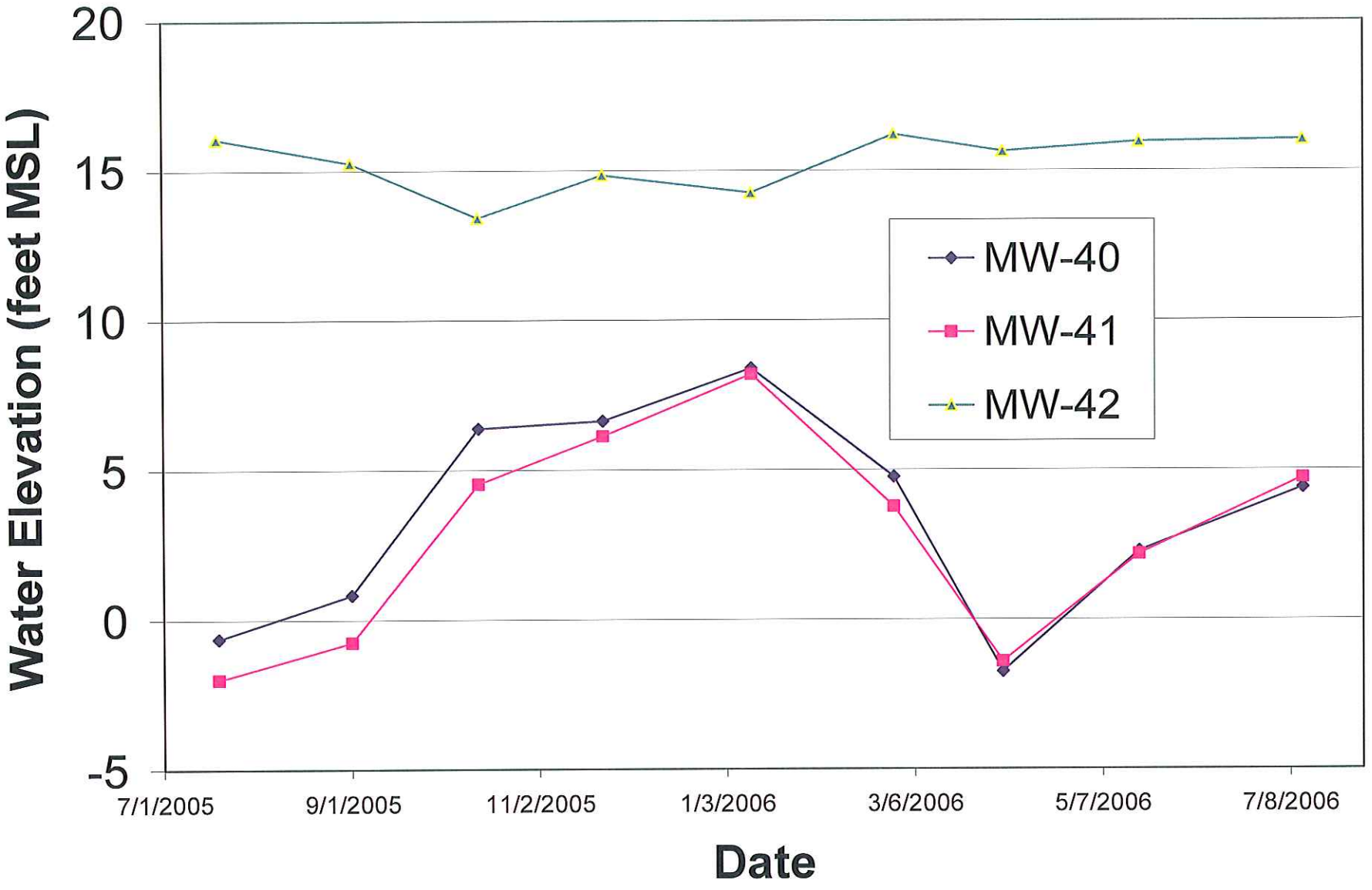
HWA GeoSciences Inc.

Fe, Mn, As BACKGROUND MONITORING LOCATIONS

Fe/Mn/As BACKGROUND STUDY
EVERETT LANDFILL
EVERETT WASHINGTON

FIGURE NO.
2

PROJECT NO.
98165 640



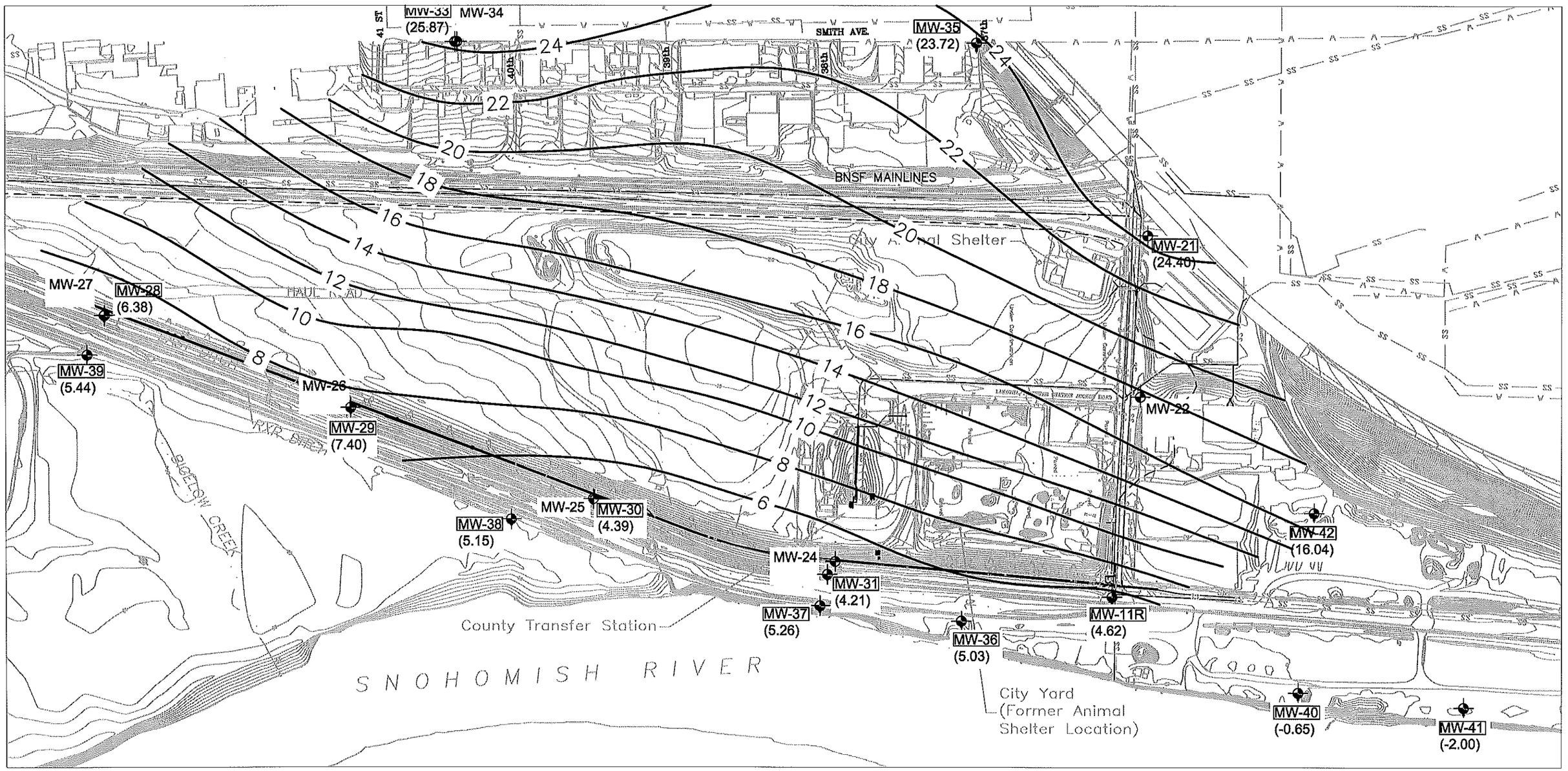
HWA GeoSciences Inc.

GROUND WATER ELEBVATION HYDROGRAPH

EVERETT LANDFILLL
EVERETT WASHINGTON
Fe/Mn/As BACKGROUND STUDY

FIGURE NO. 3

PROJECT NO. 98165-640



LEGEND

MW-12 — SHALLOW MONITORING WELLS

MW-12 — DEEP MONITORING WELLS

8 — GROUND WATER ELEVATION CONTOUR

0' 100' 200' 300' 600'

SCALE: 1"=300'

REFERENCE : Base map provided by Floyd & Snider Inc.

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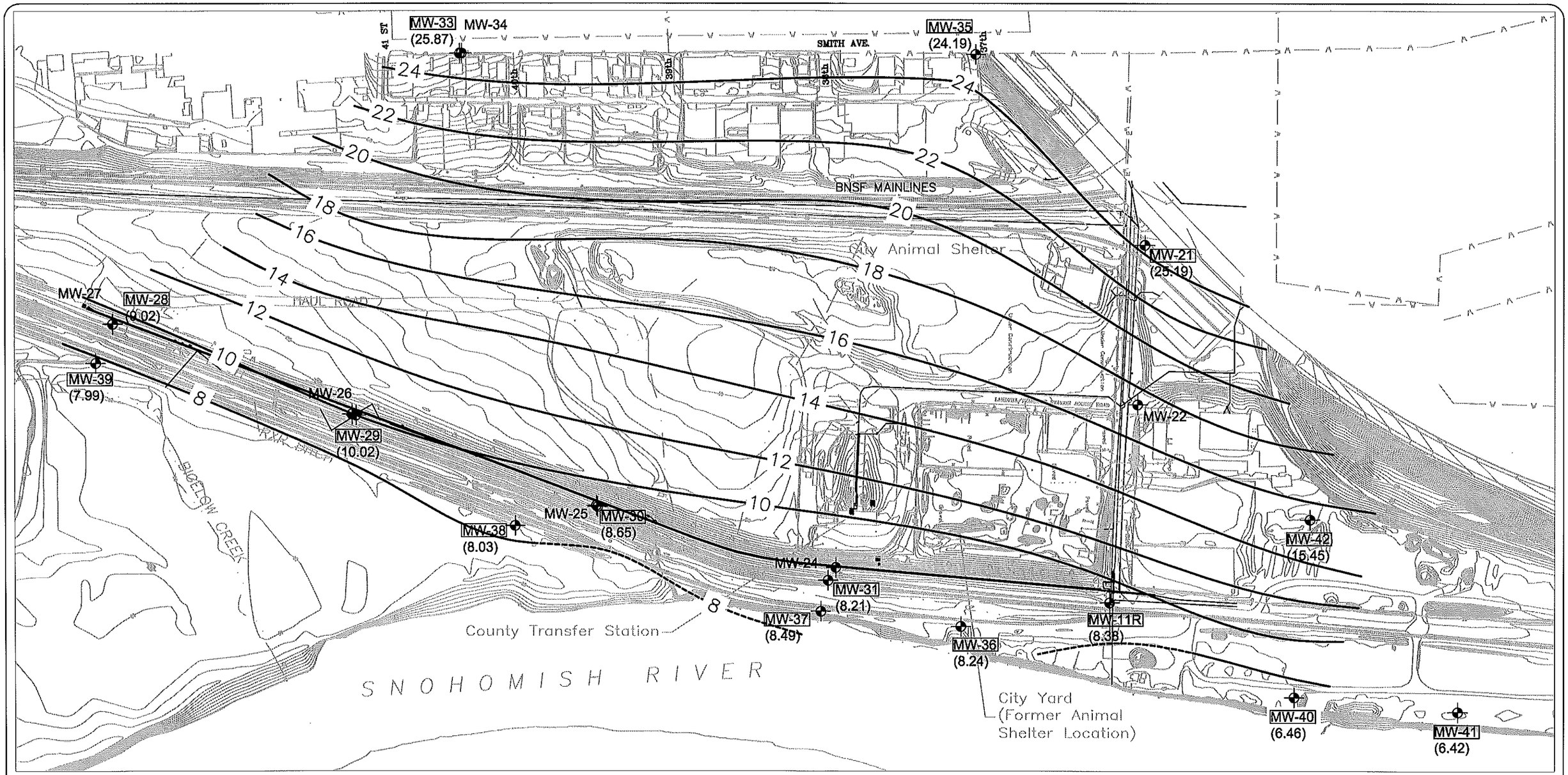
HWA GEOSCIENCES INC.

EVERETT LANDFILL
EVERETT, WASHINGTON

DEEP AQUIFER
GROUNDWATER GRADIENT
JULY 2, 2005

DRAWN BY	EFK
CHECKED BY	PP
DATE	07.02.06
FIGURE NO.	4
PROJECT NO.	98165-100



LEGEND

MW-34 — SHALLOW MONITORING WELLS

MW-40 (6.46) — DEEP MONITORING WELLS

— 8 — GROUND WATER ELEVATION CONTOUR

0' 100' 200' 300' 600'

SCALE: 1"=300'

REFERENCE : Base map provided by Floyd & Snider Inc.

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HWA GEOSCIENCES INC.

EVERETT LANDFILL
EVERETT, WASHINGTON

DEEP AQUIFER
GROUNDWATER GRADIENT
FEBURARY 2, 2006

DRAWN BY EFK	FIGURE NO. 5
CHECKED BY PP	
DATE 02.01.06	PROJECT NO. 98165-100