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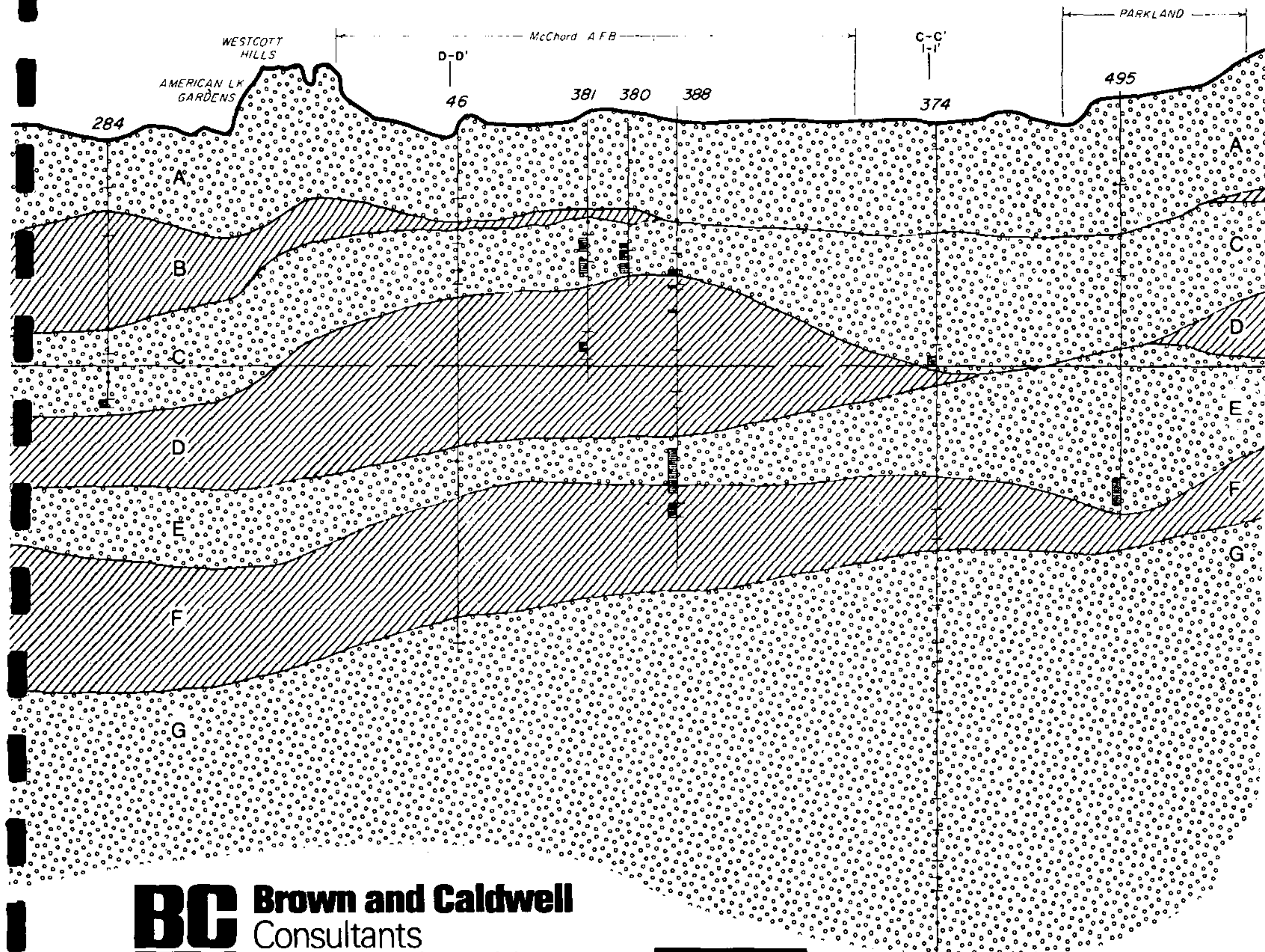
VER/CHAMBERS CREEK BASIN GROUND WATER MANAGEMENT PROGRAM AND ENVIRONMENTAL IMPACT STATEMENT

TECHNICAL APPENDICES



Brown and Caldwell
Consultants
In Association with
ADOLFSON ASSOCIATES, INC.
SWEET-EDWARDS/EMCON, INC.
ROBINSON & NOBLE, INC.
TRIANGLE ASSOCIATES

WASHINGTON STATE DEPARTMENT OF ECOLOGY

MARCH 1990

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TECHNICAL APPENDICES

Prepared for

Clover/Chambers Creek Basin
Ground Water Advisory Committee

Tacoma-Pierce County Health Department,
Lead Agency

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Washington State Department of Ecology
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Centennial Clean Water Fund

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APPENDIX A

FINAL
STORMWATER EVALUATION
CLOVER/CHAMBERS CREEK BASIN
GROUND WATER MANAGEMENT PROGRAM

by

Adolfson Associates, Inc.

February, 1990

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EXECUTIVE SUMMARY

CLOVER/CHAMBERS CREEK BASIN

GROUND WATER MANAGEMENT PROGRAM

A study was conducted in the Clover/Chambers Creek (CCC) Basin to evaluate the impacts of subsurface disposal of stormwater to ground water. Due to the highly permeable, gravelly nature of the soils in the CCC Basin, subsurface disposal of stormwater has been highly utilized. Specifically, a monitoring program was designed to determine the pollutant removal effectiveness of open-bottomed drywells that have been extensively utilized in Pierce County for over 30 years.

Literature Search:

A literature search, including studies of the Nationwide Urban Runoff Program (NURP); Fresno, California; Spokane, Washington; and Missoula, Montana were reviewed. These studies agreed that stormwater is a source of contaminants, but differ in their conclusions regarding the magnitude of the problem.

Monitoring Sites:

A monitoring program was set up to identify the impacts of subsurface disposal of stormwater to ground water. This program included the selection of two drywells to represent typical or average land use conditions within the basin. Sites selected were Koreana Plaza and Mt. Tacoma Drive. These two sites met the desired criteria: located in sewered areas to avoid impacts from septic tanks; located in residential or commercial areas; draining catchment areas of 3 to 10 acres; and acceptable for drilling. Monitoring wells were drilled at these sites to allow sampling of the shallow ground water system.

Tracer injection was performed to confirm that the monitoring wells were directly connected to the drywells. Lithium chloride and sodium chloride tracers were utilized for this confirmation. The tracer compounds were added to the drywells during simulated storm conditions, and then monitored in the monitoring wells. Due to the anomalously high levels of lithium in the background ground water samples, results using lithium chloride were inconclusive. Sodium chloride was used as the determining tracer. Ground water flow at both sites is very channelized, and not all of the wells were in direct hydraulic connection to the drywell.

Storm Sampling:

The drywells were sampled during or immediately following a storm event when stormwater depth in the drywell reached two feet. Nine storms were sampled between February 1988 and April 1989. Monitoring wells were sampled during storm events when a 0.2-foot increase in ground water level was observed. Conductivity and pH were field measured. All other parameters (chemical oxygen demand, nitrate-nitrogen, ortho-phosphorus, arsenic, copper, lead, zinc, fecal coliform, priority pollutant organics) were analyzed by Columbia Analytical Services Inc., in Longview Washington.

Additional ground water samples were obtained at the end of the rainy season to determine if seasonal variations could be detected. The results of these samples were generally consistent with those of the previous sampling events.

Results:

Due to the complicated site hydrology at both monitoring sites it was difficult to draw specific conclusions regarding the attenuation of contaminants in the drywells. There was substantial variability among the data, both from storm to storm and from monitoring location to monitoring location for nearly all parameters.

Ground water quality results indicated that metals appear to be migrating into the shallow ground water system from the drywells. Metals concentrations, particularly copper and lead, were relatively high in most of the monitoring wells. It appears likely that stormwater discharged from the drywells is flushing particulates through the vadose, or unsaturated, zone into the ground water system. Data indicates that particulates can migrate through the gravelly substrata with minimal attenuation. Conductivity varied widely from storm to storm, and nitrate concentrations were lower in the stormwater samples than in the ground water samples. Very few priority pollutants were detected during the monitoring program.

Recommendations:

Results of the study indicated that a stormwater control program should be implemented to control the chronic levels of particulates and reduce the impacts from acute spill events. Recommendations were made for a Pilot Drywell design study, which is currently being implemented. The Tacoma-Pierce County Health Department, in association with the Pierce County Department of Public Works, received a Centennial Clean Water Program Grant in July 1989 from the Department of Ecology. This Pilot Program will evaluate three alternative drywell designs at three locations in Pierce County. The designs include provisions for particulate removal and containment of small-volume spills. The drywells were installed in January and February, 1990; monitoring results will be available in the summer of 1990.

STORMWATER EVALUATION
CLOVER/CHAMBERS CREEK BASIN

Subsurface disposal of stormwater runoff is widely utilized in areas with permeable or porous soils, including the Clover/Chambers Creek Basin (CCCB). Although studies have been conducted throughout the country under a variety of conditions to determine the impact of this practice upon ground water quality, there has been little study in the Pacific Northwest. Therefore, an evaluation of the impact of subsurface disposal of stormwater to ground water quality was conducted in the Clover/Chambers Creek Basin.

Prior to discussing the results of the investigations within the CCCB, a summary of other runoff evaluations is included. Following is a brief summary of those studies characterizing runoff in situations similar to those in the CCCB.

Literature review of runoff quality

Numerous studies have been conducted characterizing stormwater runoff quality, however, few have analyzed the relationship between runoff quality and ground water quality. Following is a discussion of the major recent studies characterizing runoff, with particular emphasis upon those evaluations of addressing impacts to ground water.

NURP. Probably the most extensive study evaluating stormwater quality was the Nationwide Urban Runoff Program (NURP) conducted by the Environmental Protection Agency (EPA) in the early 1980's (EPA, 1983). This project involved 28 separate monitoring projects around the country, including Bellevue, Washington and Eugene, Oregon. Results from the study indicated that urban runoff flows and concentrations of contaminants are quite variable; substantial variations in constituent concentrations occur within a particular event and from one event to the next at a particular site. Because of this high variability among the data, the results for all the sites were analyzed collectively, to yield Event Mean Concentrations (EMCs), defined as the total constituent mass discharge divided by the total runoff volume. The major overall conclusions of the NURP study were as follows:

> Heavy metals, especially copper, lead and zinc, are by far the most prevalent priority pollutant constituents found in urban runoff.
>
> Organic priority pollutants were detected less frequently and at lower concentrations than the heavy metals. The most commonly found organic constituent was the plasticizer bis (2-ethylhexyl) phthalate, followed by the pesticide 2-hexachlorocyclohexane.

Coliform bacteria were present at high levels and frequently exceeded EPA water quality criteria for surface water as well as drinking water.

Table 1 summarizes the NURP data for selected parameters, averaged for all 28 sites monitored. The data are summarized according to land use type, although the NURP researchers concluded that event-to-event variability eclipsed site-to-site variability. The highest EMCs appear to occur in the residential sites, however, this bias may be due to the fact that 39 residential sites were monitored, compared with 10 commercial sites and 4 industrial sites.

Table 1. Ranges of Means, Event Mean Concentrations (mg/l) Nationwide Urban Runoff Program

Parameters	Residential (39 sites)	Commercial (10 sites)	Industrial (4 sites)	Open (8 sites)
NO3 + NO2-N	0.4 - 9.5	0.4 - 1.2	0.7 - 1.4	0.2 - 1.5
BOD	0 - 28	0 - 19	0 - 14	0 - 2
Total copper	0 - 0.3	0.01 - 0.1	0.03 - 0.04	0.04-0.05
Total lead	0.03 - 2.7	0.05 - 0.4	0.1 - 0.1	0.009- 0.2
Total zinc	0.05 - 1.4	0.04 - 1.4	0.2 - 2.7	0.1 - 0.1

Conventional contaminants in stormwater are well documented, but toxic constituents, including priority pollutants and toxic metals, have not been extensively monitored. NURP researchers concluded that there was generally minimal health risk to humans associated with urban runoff-borne organic priority pollutants. Concentrations of most organic constituents monitored in the NURP study were generally below the detection limits. As a group, toxic metals were by far the most prevalent priority pollutant detected in the NURP study. Lead concentrations were detected at levels above 2 mg/l at some sites.

Fresno, California. A study conducted as part of the NURP program in Fresno, California (Brown and Caldwell, 1984) attempted to determine the impact of stormwater percolation basins on ground water quality. (Soils conditions in this study were considerably different than those found in the Clover-Chambers Creek basin. The Fresno study area was underlain by loams and sandy loams with relatively high organic content, which have higher pollutant removal ability than the Steilacoom gravels of the CCC basin (because of increased density and organic content). This study revealed that the concentrations of conventional constituents were significantly higher at the industrial sampling site, with lowest concentrations observed at the residential sites. The study concluded that major cation, anion, and nutrient concentrations in the regional ground water system were greater than the concentrations in the recharged runoff. Concentrations of lead, zinc, iron and manganese were significantly higher in runoff than in the regional ground water system, but these constituents were removed in the basin soils.

Spokane, Washington. A Spokane study determined that in general, loadings to ground water from commercial runoff were approximately double that of residential runoff (Miller, 1984). It should be noted that the Spokane study had a limited number of sampling sites (3 sites during 7 storms).

Miller concluded that pollutant concentrations were higher in the upper, shallow ground water system than in the deeper ground water system, and he attributed the contamination of the upper aquifer largely to stormwater recharge.

Missoula, Montana. A study conducted in Missoula, Montana, (Wogsland, 1988) determined that runoff quality varies considerably, both temporally and spatially. Factors contributing most significantly to the variability included: length of antecedent dry days, land use, and the season. (Missoula has an extensive road salting program during the winter which significantly affects runoff or snowmelt quality). Wogsland concluded that the unsaturated or vadose zone is a major source of cations and anions, and that concentrations in runoff increased during percolation through the vadose zone. Therefore, Wogsland determined that pollutant loads to the aquifer were higher than would be estimated from runoff loading alone. All parameters increased with depth, on the order of several hundred to several thousand percent. Chloride increased over 500 percent within the first 8 feet of depth, nitrate increased by 600 percent, and total dissolved solids increased over 1000% in 8 feet of depth. Constituents were higher at commercial sites, probably because of increased road surfaces and resulting increased salted areas during the winter. Increasing nitrate concentrations with increasing depth in the vadose zone were attributed to nitrification of reduced forms of nitrogen present in runoff. Trace metals were largely attenuated in the upper portion of the vadose zone, likely due to adsorption, precipitation and coprecipitation, and oxidation/reduction by metal hydroxides, organic material and clay minerals.

Summary of literature reviewed

Stormwater has been identified as a source of contaminants to ground water quality, however, researchers differ in their conclusions regarding the magnitude of the problem. Potential for contamination varies according to subsurface conditions, rainfall characteristics, land use types, and other factors such as roadway type and use. Recent research has not evaluated the potential long-term or cumulative impacts from subsurface disposal of runoff. Long-term deposition of sediments, particularly particulates with significant metals concentrations, could be major contributors of contaminants to the shallow ground water system.

STORMWATER DISPOSAL IN THE CLOVER/CHAMBERS CREEK BASIN

Because of the highly permeable nature of the gravelly soils in the Clover/Chambers Creek basin, subsurface disposal of stormwater has been widely utilized. Stormwater generated in the southern basin, particularly in the Lakewood and Parkland areas, is discharged almost exclusively to the subsurface, largely through drywells, which are essentially open-bottomed manholes. Residential, commercial and industrial areas utilize drywells for stormwater disposal.

Soils in the areas with high densities of drywells are largely Steilacoom Gravels, a locally special type of recessional outwash deposit. Steilacoom Gravels are composed of a consistently coarse gravel with interstitial sand, and are largely lacking in fines and organic material. Studies have shown that soils with a higher percentage of silt and clay, rather than sand, have higher cation exchange capacities and can better attenuate migrating contaminants (Salo, Harrison, and Archibald, 1986; Nightingale, 1987). Because soils in the CCC basin are largely lacking in silts and clays, their contaminant removal capacity was unknown, but predicted to be low. It was suspected that contaminants in urban runoff could migrate through the gravels into the ground water with little attenuation. Therefore, a study was designed to determine the impact of subsurface discharge of stormwater to ground water quality. Specifically, a monitoring program was designed to determine the pollutant-removal effectiveness of the drywells in the Steilacoom Gravels. Following is a description of the monitoring program and a summary of the results.

Site selection

Two drywells were selected for the monitoring program. Criteria for the monitored drywells were as follows:

1) Located in sewered areas;

2) Located in residential or commercial areas;

3) Generally typical of drywells in basin, i.e., not located in "worst case" type of basin with known high levels of contamination;

4) Drainage area of 3 to 10 acres;

5) Acceptable restrictions to drilling (overhead wires,

utility conflicts, traffic considerations etc.)

Pierce County Public Works staff performed an initial screening of potential sites, which was followed up by a consultant field investigation. The drywells selected for monitoring were located in commercial areas along South Tacoma Way and Mt. Tacoma Drive, in the Lakewood area, as illustrated on Figure 1.

<u>Koreana Plaza.</u> The drywell located at 9312 South Tacoma Way (Koreana Plaza) drains an area of approximately 3.5 acres, which is roughly 90 percent impervious. The drywell drains a quarter-mile section of South Tacoma Way, the Koreana Plaza parking lot, and the commercial strip adjacent to South Tacoma Way. The drywell is 2 feet in diameter and 10 feet deep, draining into Steilacoom Gravels. Stormwater disposal in the surrounding area is entirely to the subsurface. Figure 2 illustrates the site and monitoring well configuration.

Figure 3 illustrates the site gradients, which were calculated following drilling for the monitoring wells. Based upon preliminary contour estimates, it was determined that an additional well was needed to ensure that at least one well was downgradient of the drywell. These contours were refined with additional data obtained during the stormwater monitoring. Five two-inch diameter PVC monitoring wells were drilled at approximately 35-foot depths in the shallow aquifer system. The drywell was designated DW-2; monitoring wells were designated CC-4, CC-5, CC-6, CC-7,and CC-9. The drywell generally drained within 45 minutes of filling. Ground water velocities were calculated to be between 29 and 290 feet per day; subsequent field investigations indicated velocities of approximately 160 feet per day.

Lithologic descriptions and well details are included in Appendix B.

<u>Mt. Tacoma Drive.</u> The drywell at the intersection of Mt. Tacoma Drive and Bridgeport Way drains roughly 1.75 acres of commercial area, including a section of Bridgeport Way. Figure 4 illustrates the site and monitoring wells. The drywell is two feet in diameter and ten feet deep, draining into Steilacoom Gravels. Stormwater disposal in the surrounding area is entirely to the subsurface; approximately 30 drywells are located within a one-half mile radius of the monitoring wells. Three two-inch PVC monitoring wells were drilled in areas calculated to be downgradient from the drywell, and one well was drilled in the area calculated to be upgradient. The drywell was designated DW-1; monitoring wells were designated CC-1, CC-2, CC-3, and CC-8. Contour intervals were calculated following drilling and refined during the stormwater monitoring; Figure 5 illustrates the site contours. As illustrated on Figure 5, the site

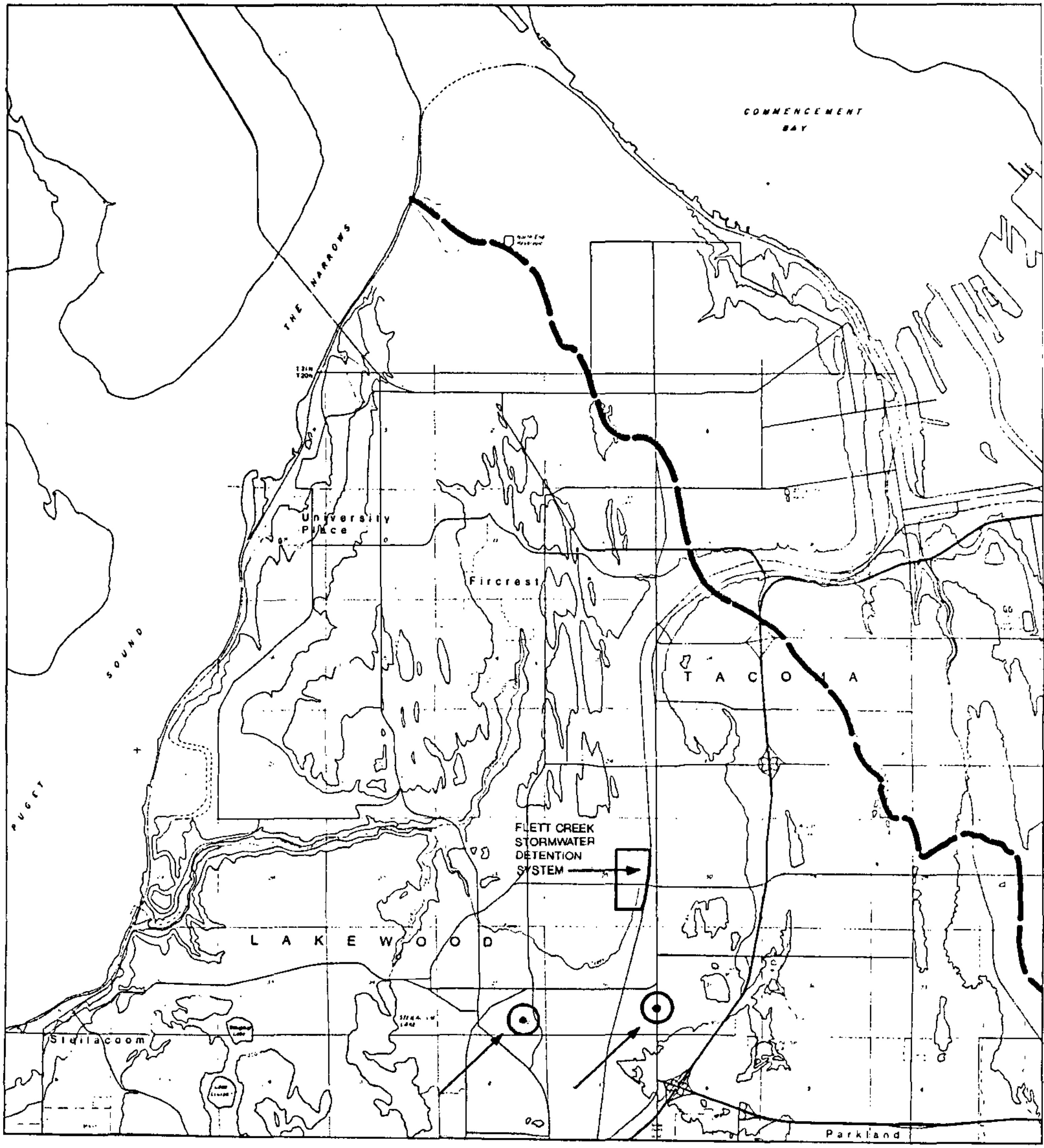
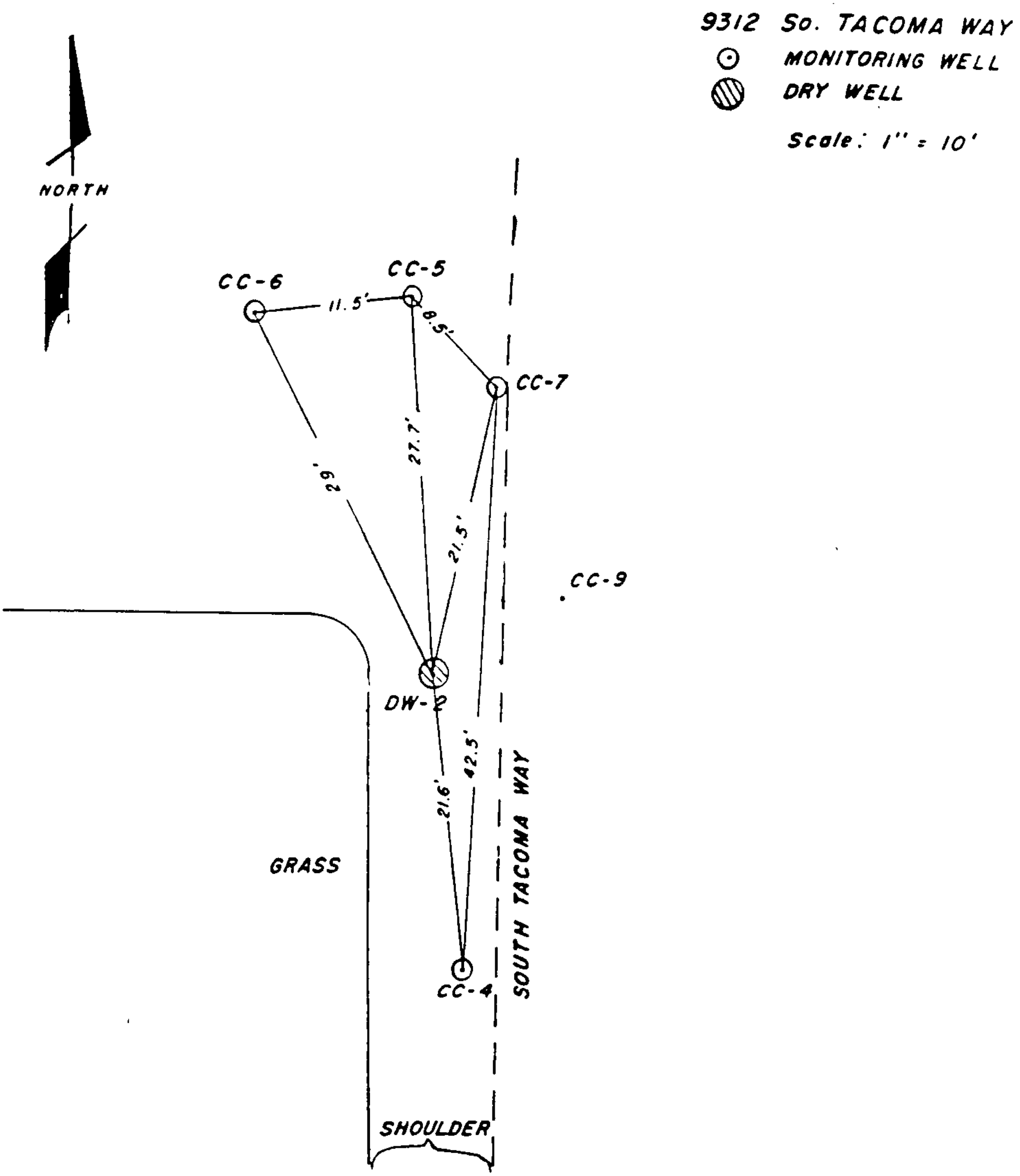
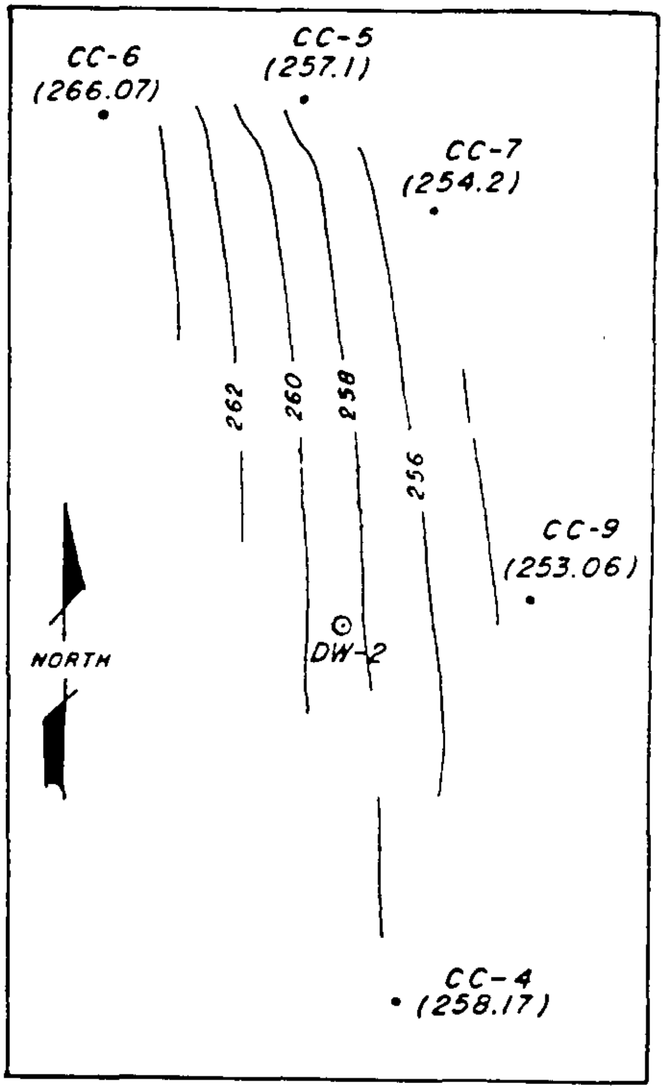


Figure 1. Location of Drywell Monitoring Sites



9312 So. TACOMA WAY
MONITORING WELL
DRY WELL
Scale: 1" = 10'
NORTH
CC-6
CC-5
CC-7
CC-9
DW-2
CC-4
11.5'
8.5'
29'
27.7'
21.5'
42.5'
21.6'
GRASS
SOUTH TACOMA WAY
SHOULDER

Gradient 0.6 ft / ft



SOUTH TACOMA WAY

WATER TABLE SURFACE PLOT 5/14/86

Scale: 1" = 10'

FIGURE 3

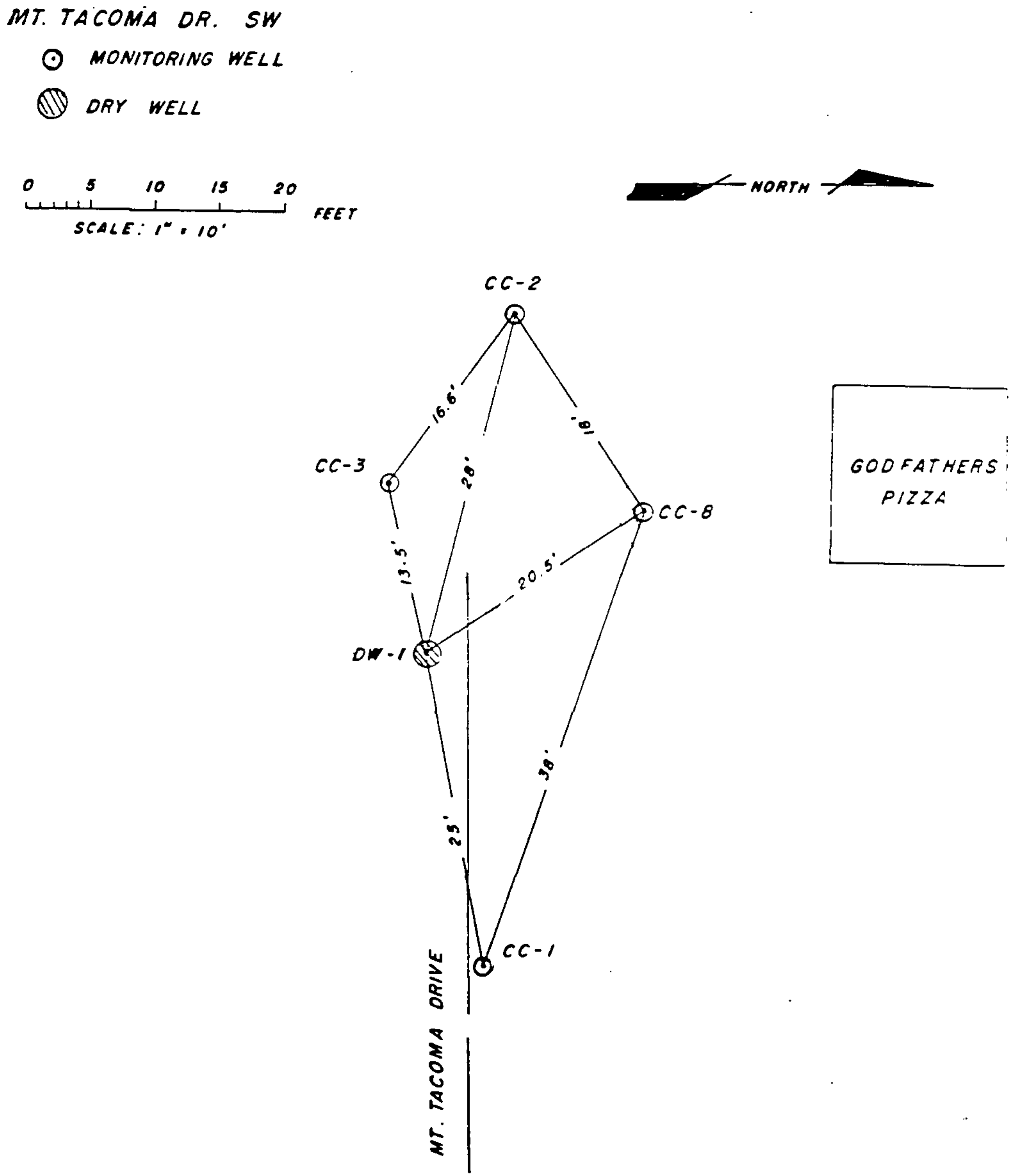
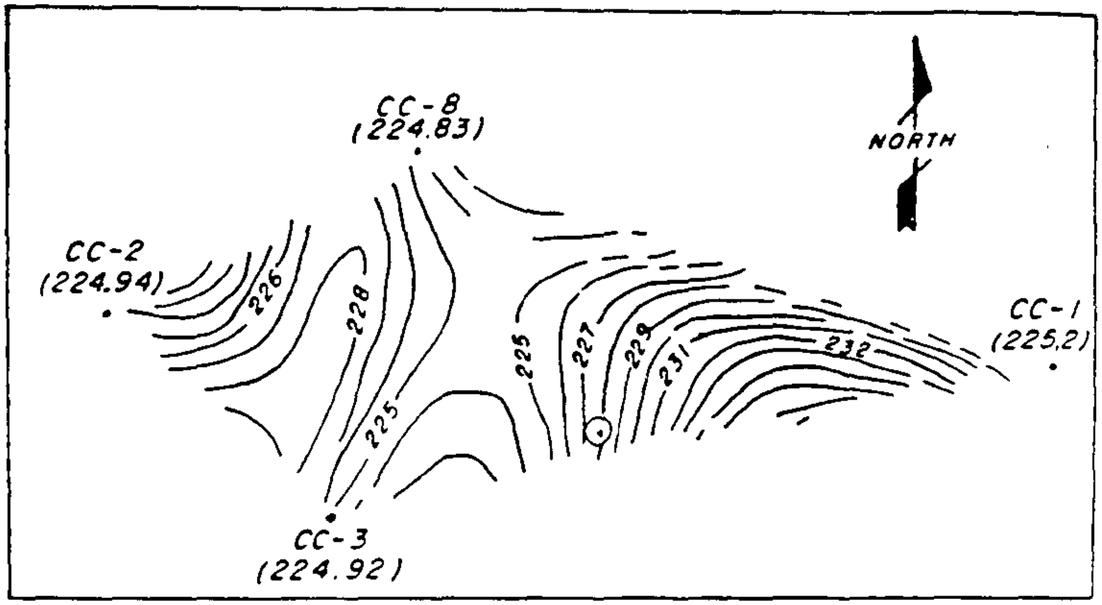

MT. TACOMA DR. SW
MONITORING WELL
DRY WELL
0 5 10 15 20
FEET
SCALE: 1" = 10'
NORTH
CC-2
16.6'
28'
18'
CC-3
CC-8
GODFATHERS PIZZA
13.5'
20.5'
DW-1
38'
25'
CC-1
MT. TACOMA DRIVE

FIGURE 4

Gradient 0.67 – 1.0 ft/ft



MOUNT TACOM DRIVE
WATER TABLE SURFACE PLOT 9/8/86
Scale: 1" = 10'

hydrology is extremely channelized. Estimated ground water velocities were approximately 1.5 feet per day. It is interesting to note the difference in ground water velocities between the two sites, which are both located in Steilacoom Gravel.

Rainfall

Rainfall was measured with individual raingages at each site, but the raingages were continually vandalized. Therefore, rainfall was measured at the Chambers Creek Wastewater Treatment Plant, located approximately 3 miles from the monitoring sites. Typical annual rainfall at the Chambers Creek Wastewater Treatment Plant in Lakewood during 1987 was 33.86 inches; this compares with the average annual rainfall at the treatment plant of 37.79 inches. Total rainfall from January through May of 1988, the period of stormwater monitoring, was 18.5 inches. January and February totals were below the annual average, but March, April and May were above the annual average monthly totals, by as much as 2 inches.

Drywell cleaning

Three storms were sampled in the drywells in their existing conditions, which were filled with several inches of sediment. The drywells were cleaned by Public Works staff after three storms, and results in the monitoring wells following the subsequent storm were compared with the previous results. The drywells drained considerably slower following the drywell cleaning, probably because of the disruption of the sediments in the drywell.

Currently, Pierce County spreads the sediments removed from catch basins and drywells on County-owned lands, located throughout the County. Approximately 6,000 to 20,000 pounds of sediment per day are removed from drywells. Because the sediments are applied to the land surface and therefore receive treatment from surface vegetation and the upper soil horizon, the potential for migration of pollutants into the ground water system is much lower than that associated with the drywells themselves. Much of the pollutant load in the sediments is associated with the particulate phase, which has very low mobility through the soil horizon. However, there is no data in Pierce County to determine the potential impact of surface-applied sediments to the ground water system.

Tracer sampling

In order to confirm that the monitoring wells were directly connected to the drywells, a tracer was added to the drywells which was sampled in the monitoring wells.

Lithium Tracer. The tracer, lithium chloride (LiCl), was injected into the drywells in early February and March, 1988. Lithium was selected as a tracer material because it typically occurs at very low levels in the ground water system. A detailed description of the tracer injection and sampling methodology is included in Appendix C. Based upon the estimated range of travel velocities for stormwater in Steilacoom gravels, the monitoring wells were sampled at intervals estimated to fall within the upper and lower limits of time necessary for the stormwater to reach the monitoring wells.

Background levels of lithium were higher than anticipated in all the wells, up to 1.15 mg/l in well CC-3 at the Mt. Tacoma Way site. These anomalously high levels made tracer detection difficult, and resulted in inconclusive results. Background levels of lithium were consistently higher in ground water at the Mt. Tacoma Way site, where they ranged from 0.6 mg/l to 1.15 mg/l, than at the Koreana site, where background levels ranged from 0.02 mg/l to 0.6 mg/l. The occurrence of lithium at the levels encountered in the CCC aquifer is an anomalous situation, since lithium normally occurs in ground water at less than the detection limit. The source(s) of the lithium is unclear, although, it is found naturally in the environment. There are no metal plating companies or other industrial sources in the vicinity of the wells. The former Lakewood Industrial Park Sewage Treatment Facility is upgradient of the Mt. Tacoma Drive site, along with Lakewood General Hospital. Both of these dischargers were connected to the recent regional sewerage project (ULID 73-1), but may continue to contribute contaminants to the ground water system.

The concentrations of lithium detected in the monitoring wells were not conclusive at either site, and did not allow correlation between the drywells and the monitoring wells. The background sample, taken one month prior to the injection of lithium, was generally higher than the samples taken following the injection. Well CC-9 showed an increase approximately 3 hours after the lithium injection, but no other increases were noted. Following review of the data, it was determined that the lithium was probably not detected because dilution at the sites was higher than anticipated (up to a factor of 1000 to 1), and that the quantities of water added to flush the drywells (25 gallons) was inadequate to move the lithium into the ground water system within the time of sampling.

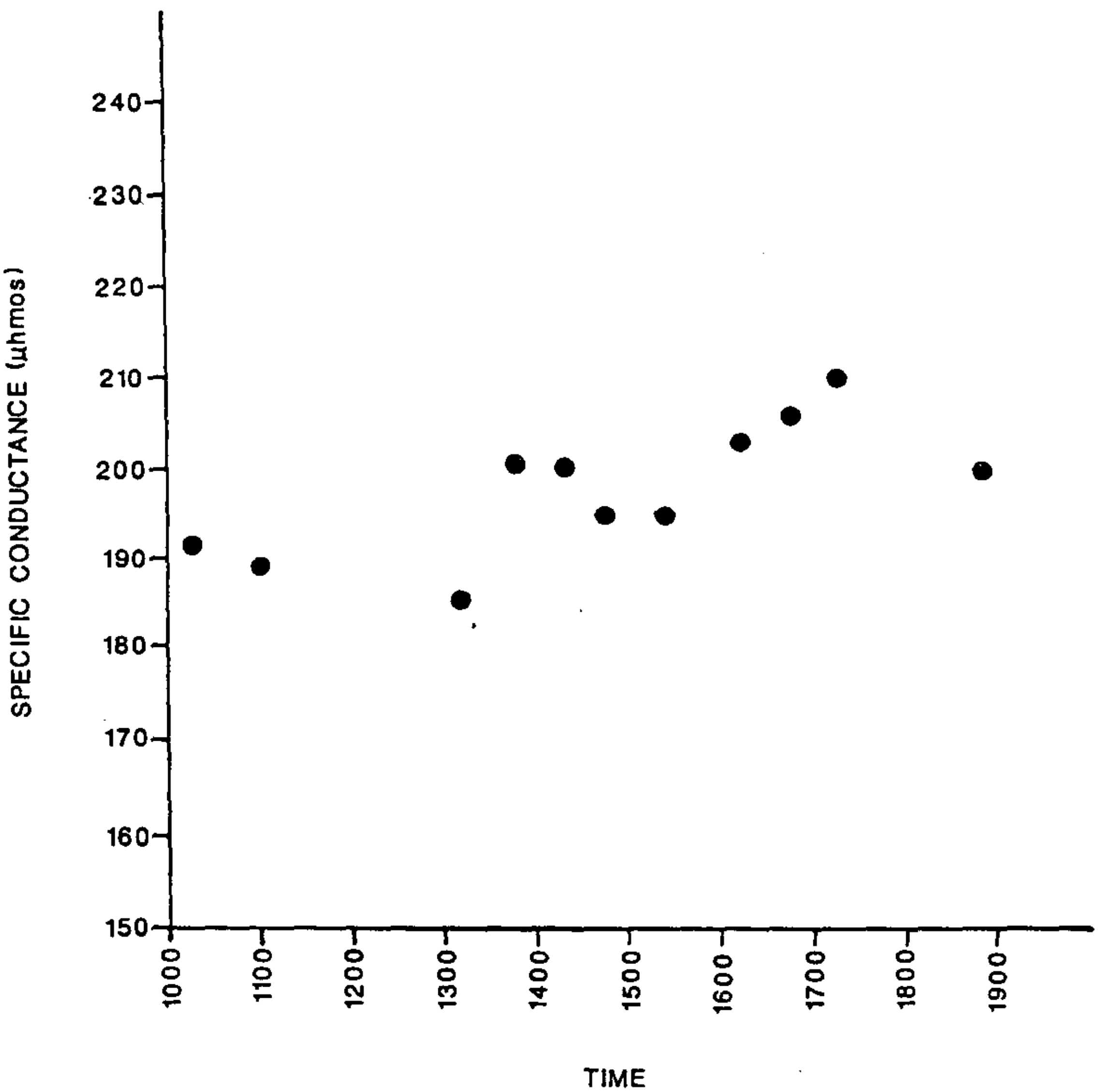
Upon review of water level data and monitoring results, it was determined that it was unlikely that the monitoring wells at the Mt. Tacoma Drive site were directly located in the drywell (DW-1) plume. Ground water flow, as indicated in Figure 5, is highly channelized at this site, and the monitoring wells do not appear to be hydraulically connected to the drywell. The microchannelization at the site is a complex phenomenon, and does not allow direct correlation between the drywell and the ground water quality reflected in the monitoring well. Because the monitoring wells are located in an area with dense utilization of drywells, monitoring results appear to reflect a localized response to subsurface disposal of stormwater and other non-point sources of contamination, rather than the specific response to a single drywell.

Sodium Chloride Tracer. After examining the lithium monitoring data, it was determined that additional sampling was needed to confirm a direct hydraulic connection between the drywell and the monitoring wells at the Koreana Plaza site. On July 17, 1988, a sodium chloride (NaCl) solution was added to the drywell at Koreana Plaza (DW-2) and flushed with fresh water. Approximately 100 gallons of NaCl solution was added to the drywell, with a measured conductivity of approximately 70,000 umhos. This solution was flushed through by the addition of 2000 gallons of fresh water. Conductivity changes were monitored on the half hour in the monitoring wells. Conductivity increases were noted in CC-4, CC-7 and CC-9, as illustrated on Figures 6 through 9. It was assumed that increases in conductivity greater than 20 percent during the course of the sampling indicated the influence of the NaCl solution. CC-4 began to show conductivity increases 5 hours following the sampling; CC-7 began to increase conductivity 3 hours after the NaCl injection; and CC-9 began to increase 3 hours after the NaCl injection. The influence of the NaCl injection was still noticeable 24 hours later.

Based upon the conductivity results, it was determined that monitoring wells CC-7 and CC-9 are directly connected to the drywell; CC-4 appears to be influenced by the drywell; and CC-5 and CC-6 are not hydraulically connected to the drywell. The stormwater appears to exit the drywell in a radial manner, creating a mound of stormwater migrating into the ground water system. The hydrology at the Koreana site is also channelized, although not to the extent as that seen at the Mt. Tacoma Drive site. The channelization at the Koreana site is illustrated by the independent behavior of CC-5 and CC-6 when compared with the other monitoring wells, which are less than 20 feet away.

Stormwater sampling

The drywells were sampled during or immediately following a storm event when at least 2 feet of water depth accumulated in the drywell. DW-2 typically drained completely within 45 minutes, while DW-1 required several hours to drain. Prior to sampling, the depth to ground water in each of the monitoring wells was measured using an ACTAT 300 Olympic Well Probe or similar instrument. All samples, except Fecal Coliform, were shipped to Columbia Analytical Services (CAS) in Longview, Washington for analysis. Fecal coliform samples were hand delivered to the Tacoma-Pierce County Health Department (TPCHD) for analysis. Due



Sweet-Edwards EMCON

CLOVER CHAMBERS CREEK
GROUND WATER MANAGEMENT PLAN

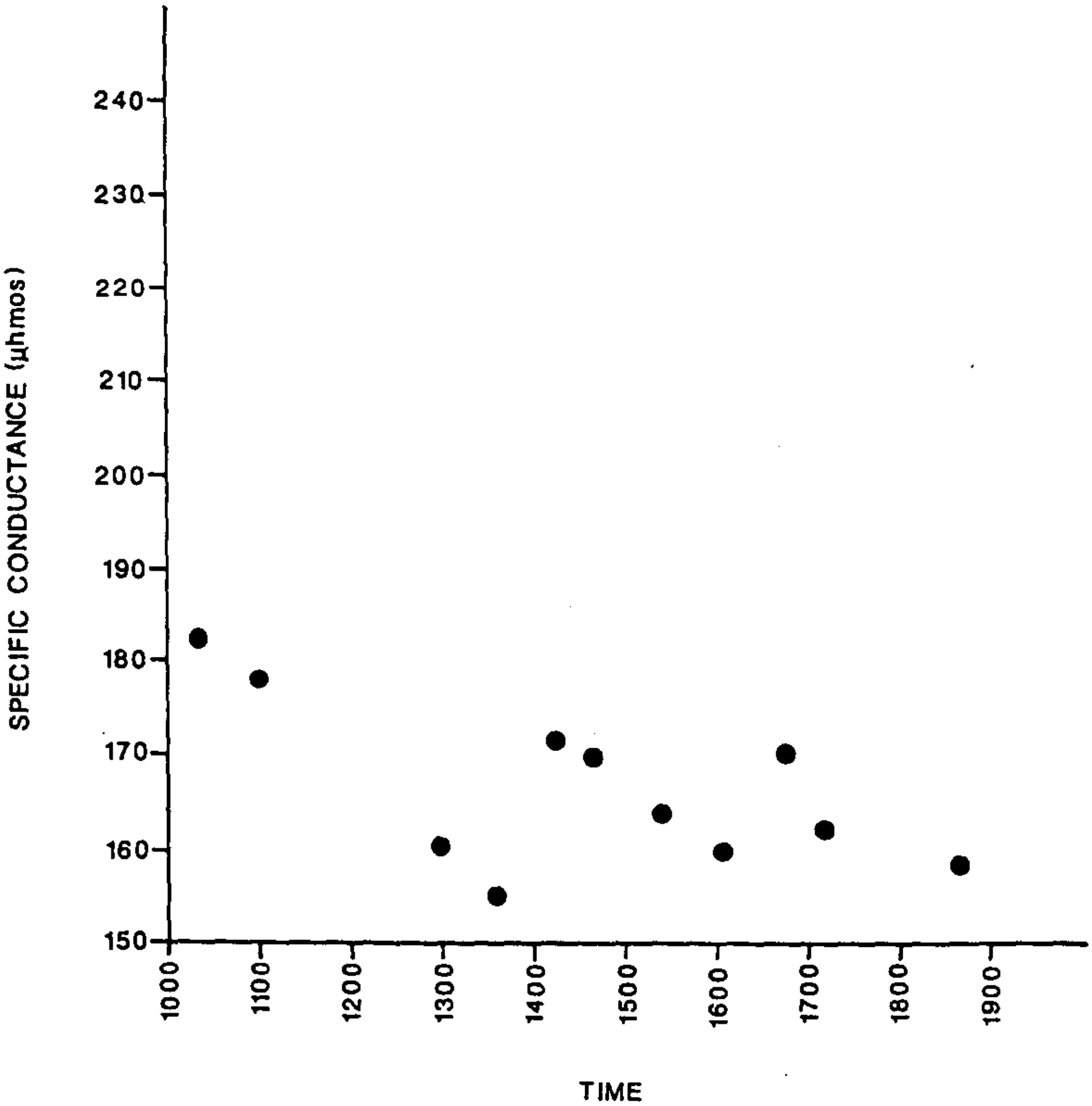
SODIUM CHLORIDE TRACER RESULTS

WELL CC-4 7/17/88

FIGURE 6

PROJECT NO. S0213.01

KUKER-RANKEN INC./106857



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EMCON

CLOVER CHAMBERS CREEK
GROUND WATER MANAGEMENT PLAN

SODIUM CHLORIDE TRACER RESULTS

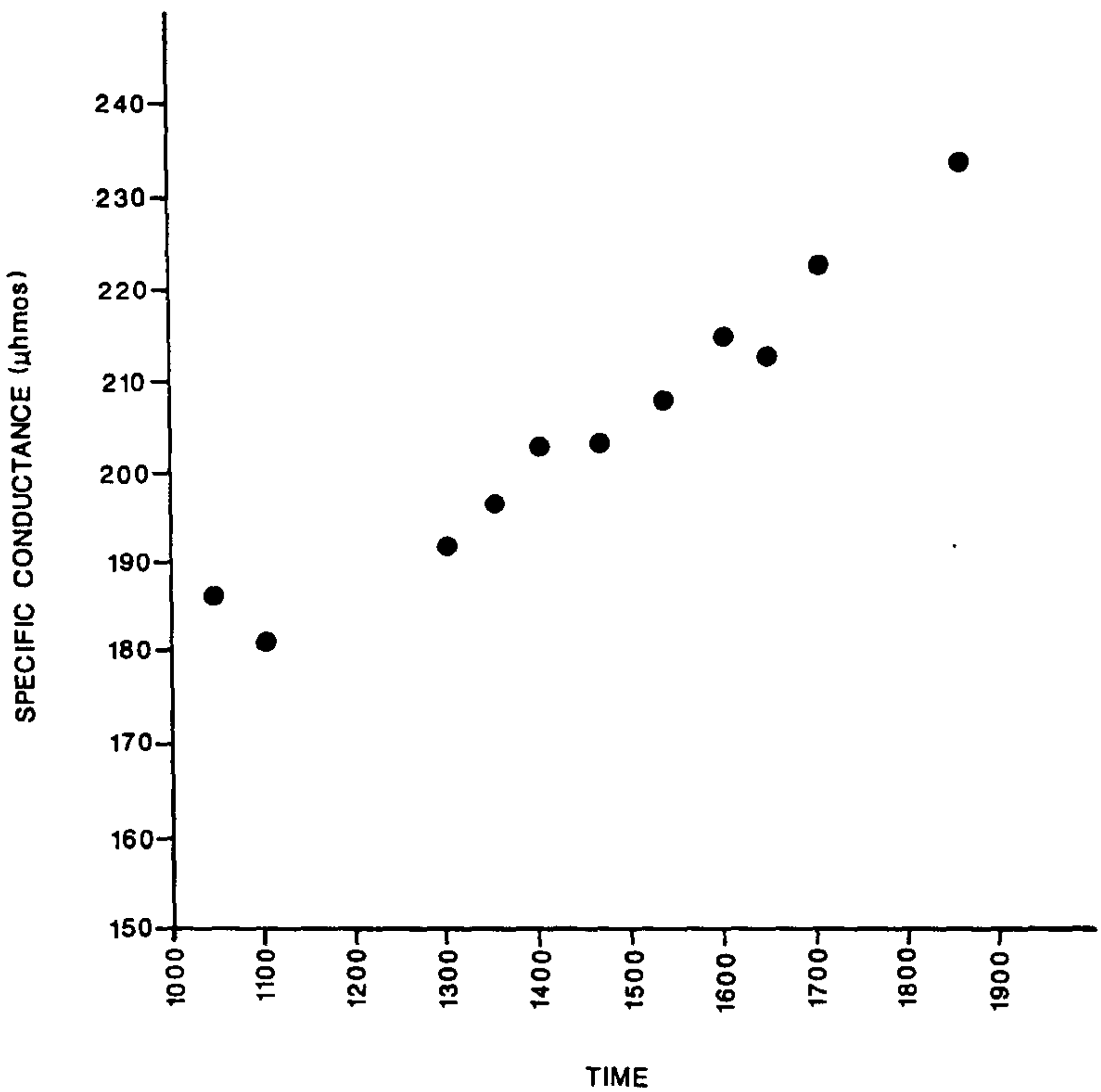
WELL CC-5

7/17/88

FIGURE 7

PROJECT NO. S0213.01

KUKER-RANKEN INC./106857



Sweet-Edwards EMCON

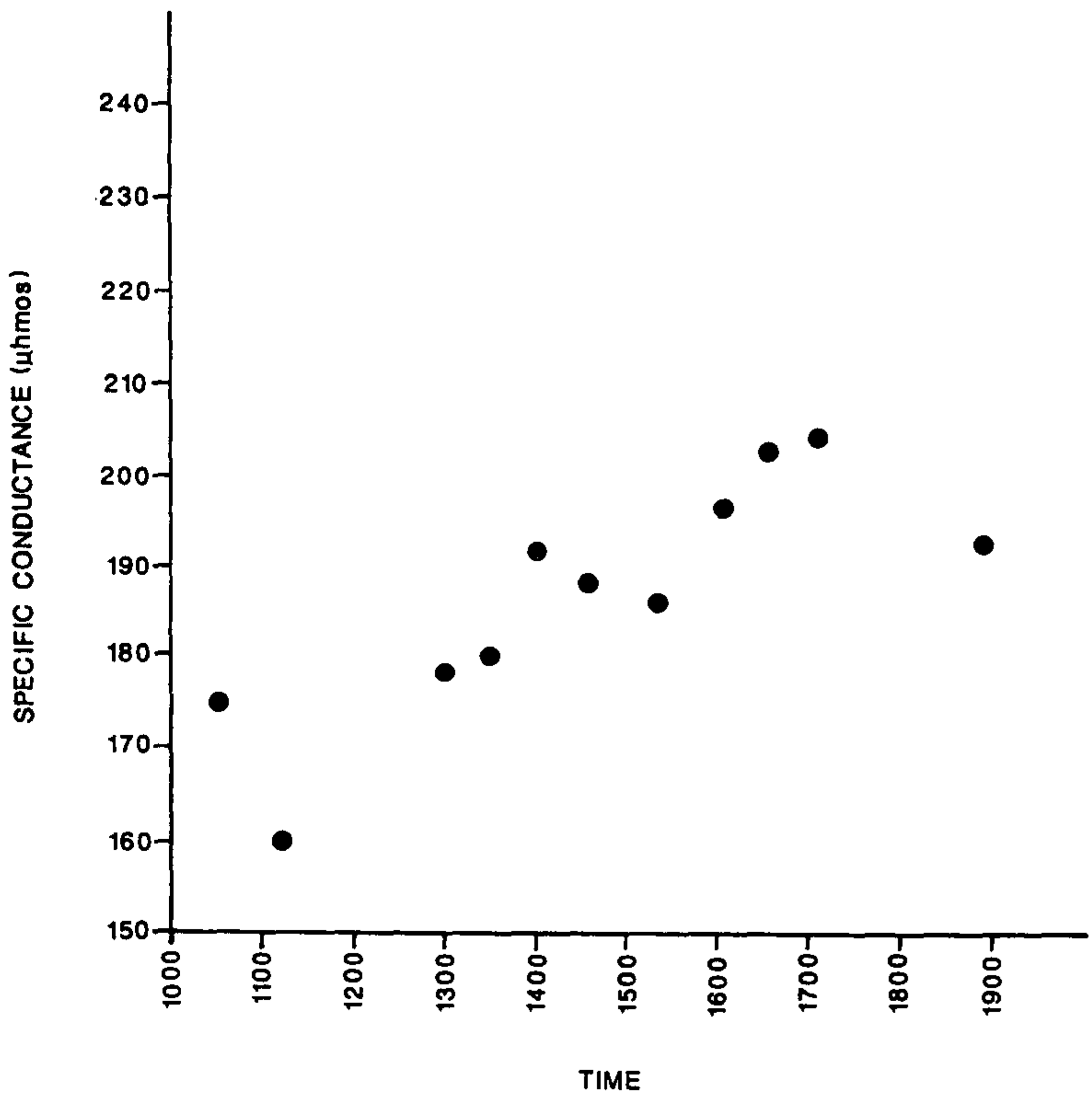
CLOVER CHAMBERS CREEK
GROUND WATER MANAGEMENT PLAN

SODIUM CHLORIDE TRACER RESULTS

WELL CC-7 7/17/88

FIGURE 8

PROJECT NO. S0213.01



Sweet-Edwards
EMCON

CLOVER CHAMBERS CREEK
GROUND WATER MANAGEMENT PLAN

SODIUM CHLORIDE TRACER RESULTS

WELL CC-9 7/17/88

FIGURE
9

PROJECT NO.
S0213.01

KUKER-RANKEN INC./106857

to a holding time limitation of 24 hours and the fact that the TPCHD will not accept samples on Fridays, coliform samples were not always obtained.

Ground water samples were obtained from the monitoring wells after a minimum of 0.2 foot increase in water levels were observed. The increase in ground water levels during or immediately following rainfall events was considered to indicate the direct influence of stormwater. Ground water samples were collected after removing approximately one pore volume from each well with a double check valve Norton Teflon bailer. Monofilament line was used to lower the bailer into the wells. Specific conductance (umhos), pH, and temperature were measured prior to collecting ground water samples. Conductivity and pH were measured using a DSPH-3 pH/Conductivity meter.

Samples were analyzed for: halogenated volatile organics (EPA Method 601); dissolved and total arsenic, copper, lead, and zinc; nitrate-nitrogen; COD; ortho-phosphate; Benzene, Toluene, and Xylene (BTX); and Fecal Coliform. Analyses for Base/Neutral/Acid Extractable Organics (EPA Method 625) were performed on samples taken May 2, 1988.

Storms were sampled on March 4, March 8, March 23, May 2, and May 13, 1988. 24-hour rainfall accumulations on those dates were 0.18 inch; 0.67 inch; 0.43 inch; 0.22 inch and 0.6 inch, respectively. In addition, dry weather samples were taken on September 7, 1988, following 35 days where no rainfall event accumulated more than 0.08 inches, to determine dry weather conditions.

RESULTS

Tables 2 and 3 illustrate a summary of the monitoring results for each of the sites. Geometric means are shown for each monitoring well and drywell, along with the range of values detected. Following is a discussion of the results for each parameter analyzed.

Water levels

Water levels in all nine monitoring wells followed a similar pattern in fluctuation, as illustrated on Figures 10 and 11 ; water levels reached low levels during the last week of March, reached the highest levels during the first two weeks of May, and then dipped to the lowest levels of the monitoring period during September. Rainfall accumulations were below normal during January and February, above normal averages during March, April and May, approximately average for June, and well below average for July, August and September. Ground water levels during the 9 months of monitoring fluctuated by as much as 10 feet. Highest

TABLE 2
SUMMARY, STORMWATER MONITORING RESULTS
MT. TACOMA DRIVE
(mg/l)

	STATIONS				
Parameter	CC-1	CC-2	CC-3	CC-8	DW-1
pH					
mean	6.58	6.52	6.65	6.77	6.9
range	5.7-7.8	6.1-7.7	6.1-8.2	6.3-7.9	6.5-7.5
Conductivity (umhos)					
mean	160	172	124	213	68
range	116-198	145-350	70-180	153-317	43-153
COD					
mean	24.9	13.3	22.1	14.7	61.1
range	ND-449	ND-289	14-31	ND-82	38-97
NO-3-N					
mean	2.0	0.94	0.67	1.2	0.10
range	1.2-2.5	0.13-3.0	0.08-3.3	0.12-3.4	0.03-0.18
Ortho-p					
mean	0.21	0.03	0.22	0.19	0.04
range	ND-1.9	ND-0.17	ND-0.78	ND-0.69	0.01-0.17
Arsenic					
mean (d)	ND	ND	ND	0.002	ND
range (d)	ND	ND	ND	ND-0.012	ND
mean (t)	0.02	0.006	0.02	0.013	ND
range (t)	ND-0.06	ND-0.02	0.01-0.02	0.01-0.02	ND
Copper					
mean (d)	0.006	0.02	0.02	0.04	0.01
range (d)	ND-0.03	ND-0.03	ND-0.03	ND-0.62	ND-0.02
mean (t)	0.37	1.26	0.83	0.71	0.01[b]
range (t)	0.1-1.1	0.16-11.9	0.78-0.90	0.32-1.57	0.01[b]
Lead					
mean (d)	ND	0.001	0.002	0.134	0.012
range (d)	ND	ND-0.006	ND-0.006	ND-0.670	0.007-0.035
mean (t)	0.14	0.32	0.158	0.226	0.05[b]
range (t)	0.07-0.27	0.7-2.5	0.15-0.17	0.17-0.30	0.05[b]

Zinc					
mean (d)	0.011	0.02	0.02	0.04	0.09
range (d)	ND-0.07	ND-0.06	ND-0.04	ND-0.29	0.08-0.11
mean (t)	0.36	0.86	0.89	0.63	0.16[b]
range (t)	0.03-6.8	0.03-14.0	0.80-0.99	0.33-1.20	0.16[b]
Fecal coliform (detected levels, MPN/100 ml)	2.2	2.2	16	2.2	16[a]
bis (2-Ethylhexyl) Phthalate	ND	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND	ND

All mean values reported are geometric means

[a]Inadequate number of samples for geometric mean

[b]Only one sample analyzed

(d) Indicates dissolved metals concentrations

(t) Indicates total metals concentrations

TABLE 3
SUMMARY, STORMWATER MONITORING RESULTS
KOREANA PLAZA
(mg/l)

	STATIONS					
Parameter	CC-4	CC-5	CC-6	CC-7	CC-9	DW-2
pH						
mean	7.5	7.47	7.4	7.3	7.43	7.2
range	6.5-8.5	6.5-8.7	6.8-8.8	6.4-8.5	6.7-8.0	7.0-7.6
Conductivity (umhos)						
mean	224	173	204	195	188	113
range	186-314	160-214	131-291	163-230	154-251	83-212
COD						
mean	50	18	32	28	23	91
range	2-301	9-39	16-52	11-87	1-108	2-2242
NO_3-N						
mean	0.25	1.92	0.57	0.41	0.8	0.22
range	0.02-1.7	0.68-2.8	0.02-2.2	0.06-3.7	0.1-3.4	0.03-0.64
Ortho-p						
mean	0.14	0.16	0.14	0.25	0.08	0.13
range	ND-1.1	0.02-1.3	0.06-0.28	0.03-5.6	ND-0.21	0.04-0.49
Arsenic						
mean (d)	ND	ND	ND	ND	ND	ND
range (d)	ND	ND	ND	ND	ND	ND
mean (t)	0.010	0.002	0.01	0.005	0.001	ND
range (t)	0.005-0.016	ND-0.006	0.01-0.02	ND-0.009	ND-0.007	ND
Copper						
mean (d)	0.02	0.01	0.01	0.02	0.004	0.021
range (d)	ND-0.06	ND-0.02	ND-0.03	0.02-0.02	ND-0.01	ND-0.04
mean (t)	0.20	0.31	0.22	0.17	0.07	0.02
range (t)	0.01-0.59	0.18-0.59	0.21-0.23	0.06-0.33	ND-0.23	0.01-0.035

Lead						
mean (d)	0.003	0.002	ND	ND	ND	0.03
range (d)	ND-0.012	ND-0.014	ND-0.002	ND	ND	ND-0.225
mean (t)	0.06	0.10	0.14	0.098	0.07	0.123
range (t)	0.004-0.151	0.05-0.19	0.12-0.16	0.067-0.138	ND-0.27	0.086-0.177
Zinc						
mean (d)	0.01	0.01	0.03	0.02	0.004	0.06
range (d)	ND-0.16	ND-0.06	ND-0.07	ND-0.07	ND-0.02	0.02-0.27
mean (t)	0.019	0.22	0.28	0.36	0.11	0.19
range (t)	0.012-0.64	0.13-0.37	0.23-0.34	0.18-0.66	ND-0.35	0.16-0.22
Fecal coliform						
range	ND-5.1	ND-9.2	ND-16	ND-2.2	ND-2.2	ND-16.0
bis (2-Ethylhexyl) Phthalate	0.026	0.011	0.009-0.023	ND	ND	ND

All values reported are geometric means

(d) Indicates dissolved metals concentrations

(t) Indicates total metals concentrations

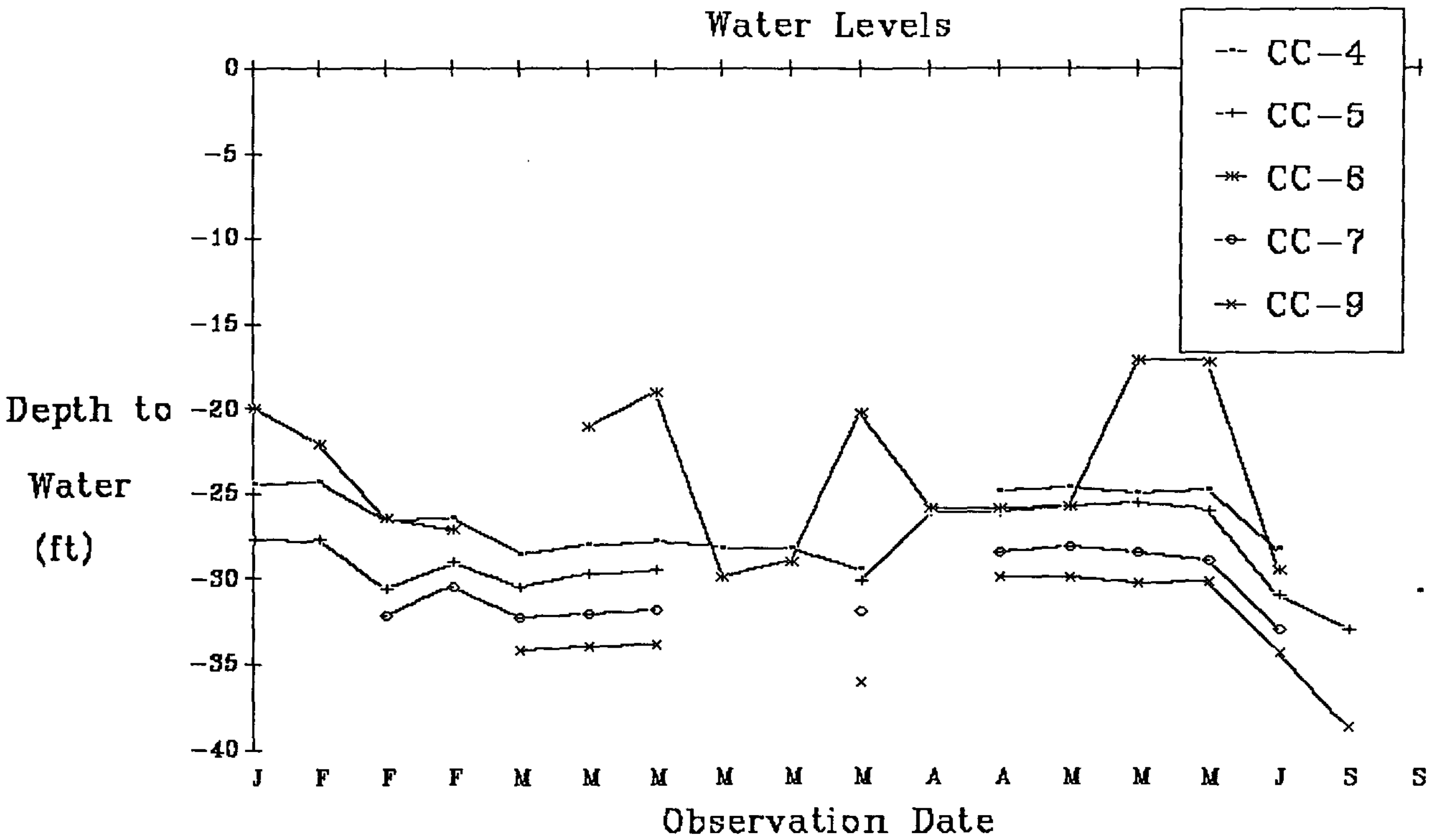


Figure 10. Depth to Ground Water, Koreana Plaza Site

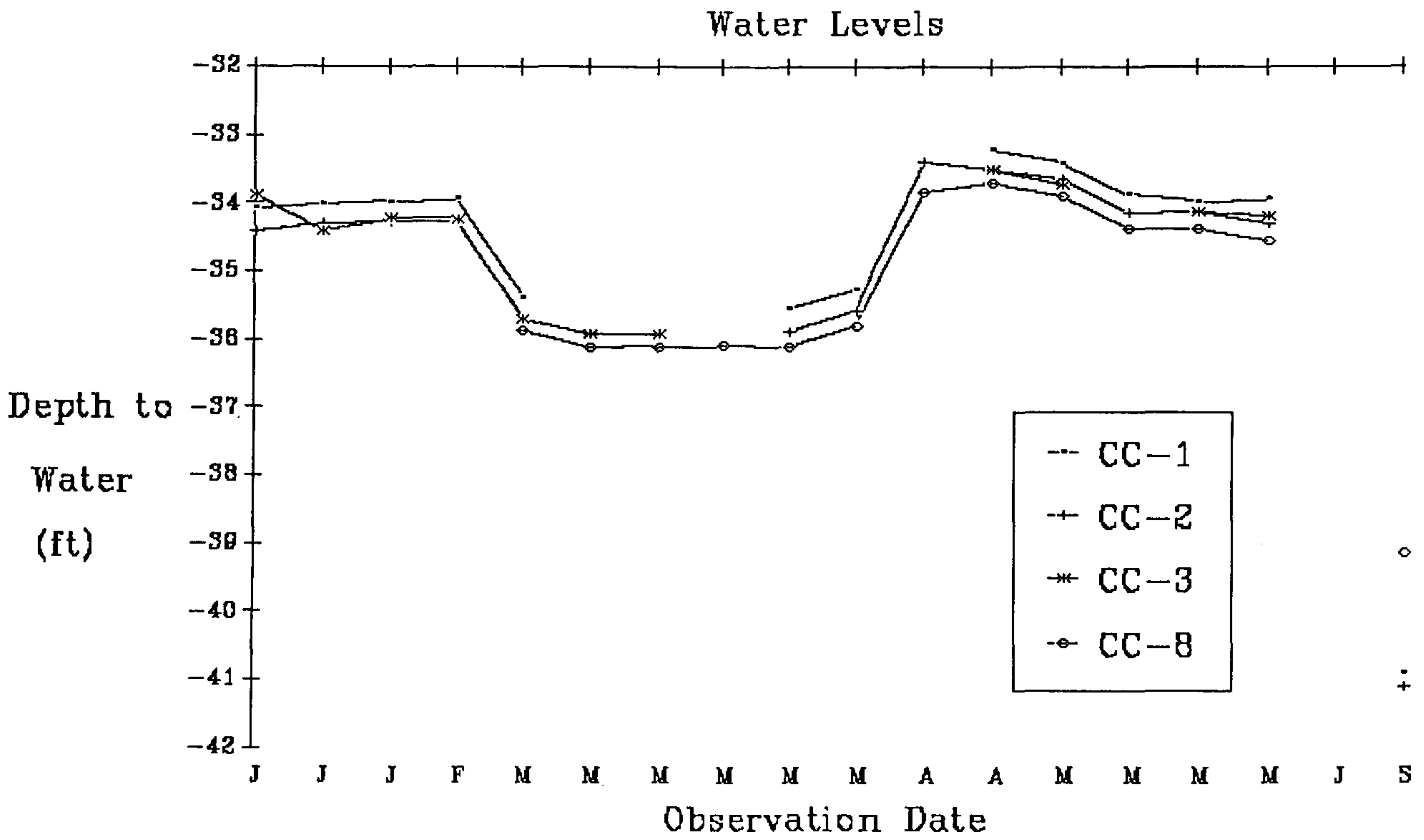


Figure 11. Depth to Ground Water, Mt. Tacoma Drive Site

levels of fluctuation were observed in well CC-6 at the Koreana Plaza site, which increased in water level by over 6 feet within 3 hours of the onset of a storm event in April, and fluctuated by a total of 10 feet between January and September, 1988.

pH

pH is the hydrogen ion concentration. It is an important parameter because it directly affects the toxicity of various compounds, particularly low pH enhances solubility of metals.

Koreana Plaza. pH values in DW-2 ranged from 6.94 to 7.67. The monitoring wells were relatively consistent in mean pH values, with geometric means ranging from 7.39 to 7.53. pH values varied with sampling dates in the monitoring wells by as much as 2 pH units or more. All of the monitoring wells had the highest pH values observed on the first storm, which occurred on February 3, 1988. pH values in February ranged from 7.7 to 8.8 in the monitoring wells, which was significantly higher than would be anticipated from values monitored in Lakewood Water District Wells in January and February, 1984, and exceeds the pH for Steilacoom gravels which typically ranges from 6.1 to 6.5. These high pH values appear to reflect a source of alkalinity in the ground water or soils, but this source is currently not identified. Possible sources include past practices by the Gypsum Board Operators along the railroad tracks and Pierce Transit, and calcium leaching from concrete product use in the area. The trend of high pH in the early monitoring results was not observed in the drywell, indicating that the high pH values were reflecting ground water conditions unrelated to the stormwater inputs. Differences in pH between CC-7 and CC-9 (the wells hydraulically connected to the drywell) and the other monitoring wells were not significant.

Mt. Tacoma Drive. pH values in DW-1 ranged from 6.45 to 7.53, with a mean of 6.89. Mean values in the monitoring wells were consistently lower than the pH values measured at Koreana Plaza, ranging from 6.5 to 6.89. Similar to the results at Koreana Plaza, the February 3 ground water samples had the highest pH of all the samples obtained, by as much as 2 pH units. Subsequent storm-related ground water samples were within a range of 20 percent variability. Apparently, the factor influencing pH in the ground water is regional in nature, because it occurred at both sampling sites.

Conductivity

Koreana Plaza. Conductivity values in the ground water samples varied considerably from event to event, however, the drywell was consistently lower in conductivity than the ground water samples. The mean conductivity in DW-2 was 108 umhos, with values ranging from 90 to 212 umhos. Monitoring wells ranged in mean conductivity values from 172 to 228 umhos. The variability from sampling date to sampling date overrides any correlations relating input at the drywell and impacts to conductivity in the ground water. Dilution of stormwater by ground water is estimated to be up to 1000 to 1 in wells CC-7 and CC-9, therefore any changes in conductivity resulting from stormwater inputs are likely masked by dispersion. However, stormwater appears to be lowering localized ground water conductivity levels.

Mt. Tacoma Drive. Mean conductivity in DW-1 was 68 umhos, with a range from 43 to 153 umhos. The variability among conductivity values from event to event was less than that measured at the Koreana Plaza site, but still substantial. The variability among the monitoring wells on each sampling date illustrates the channelized nature of ground water flow at this site. Mean conductivity values were lowest at CC-3 (124 umhos) and highest at CC-8 (216 umhos).

Chemical oxygen demand

Koreana Plaza. Chemical oxygen demand (COD) varied considerably among storms in DW-2, from 2 to 2242, with a geometric mean of 91. Detected COD levels at the Koreana site are illustrated on Figure 12. COD values measured in monitoring wells CC-7 and CC-9 were highest following the March 4 storm, which may indicate the influence of stormwater. Prior to the March 4 storm, 16 days had elapsed with 24-hour accumulated rainfall less than 0.1 inches. High COD values, which coincide with high metals values measured in both the drywell and monitoring wells following this storm, may reflect a "first flush" effect. The high COD detected in the drywell on March 23 was not observed in wells CC-7 and CC-9, however, samples were taken in the wells less than 2 hours following the onset of the storm, and based upon subsequent velocity calculations, it is not likely that the stormwater had reached the monitoring wells by this time. Mean COD values detected in CC-7 and CC-9 were 28.3 and 27.7, respectively. Highest COD values were measured in CC-4 on March 4.

Mt. Tacoma Drive. The mean COD value in DW-1 was 61, with a detected range from 38 to 92. COD values detected in the monitoring wells, illustrated on Figure 13, were lower than those detected at the Koreana Plaza site. Mean values ranged from 12.9 to 23.3. Overall, there was less variability in COD values among events at this site than that observed at the Koreana Plaza site.

Nitrate-nitrogen

Koreana Plaza. The mean nitrate-nitrogen (NO_3-N) concentration in DW-2 was 0.19 mg/l, with a range from 0.03 to 0.37 mg/l. The drainage area to the drywell is 100 percent commercial, with only minimal grassed areas. Sources of NO_3-N in the Koreana Plaza

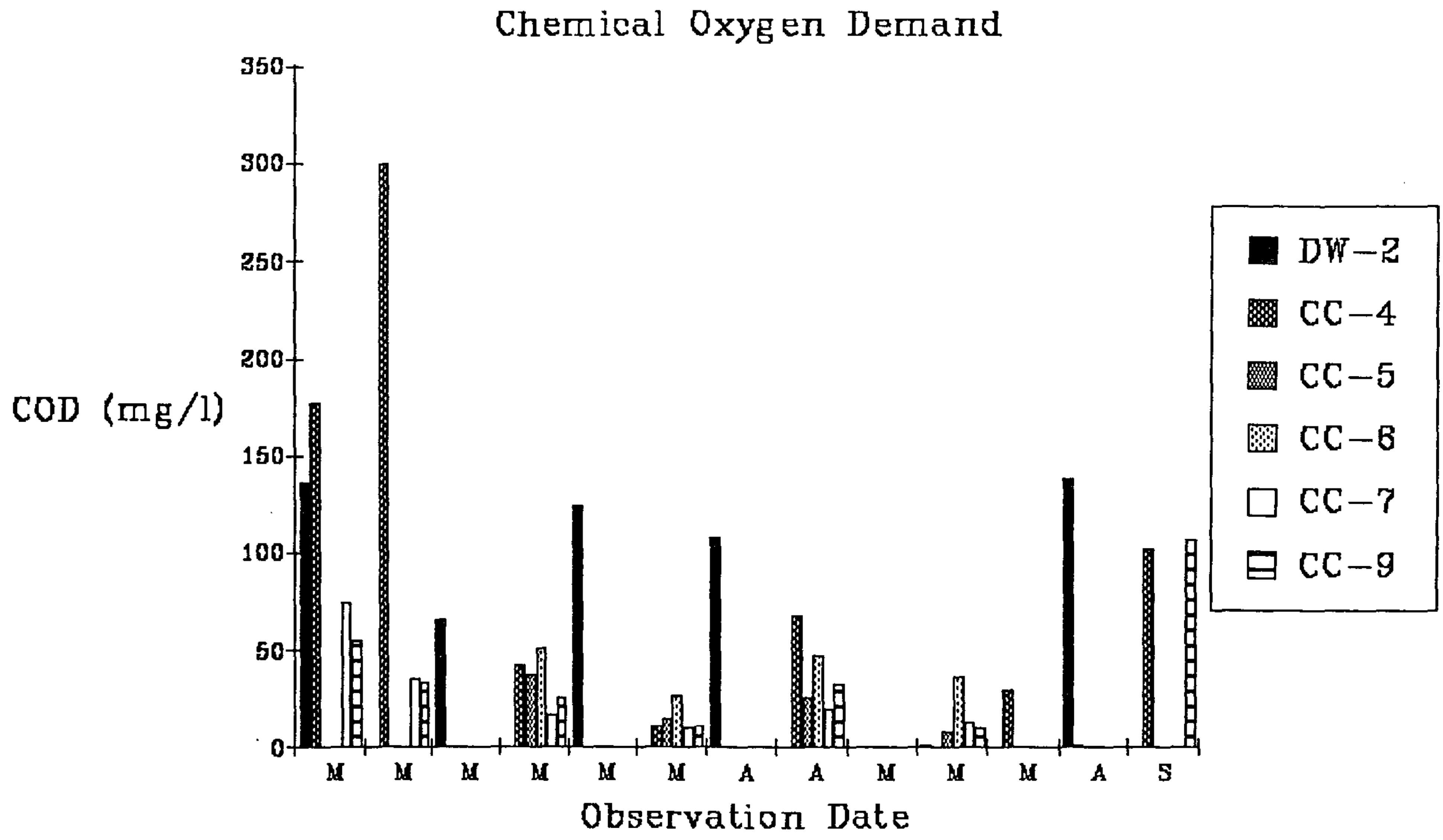


Figure 12. COD, Koreana Plaza Site

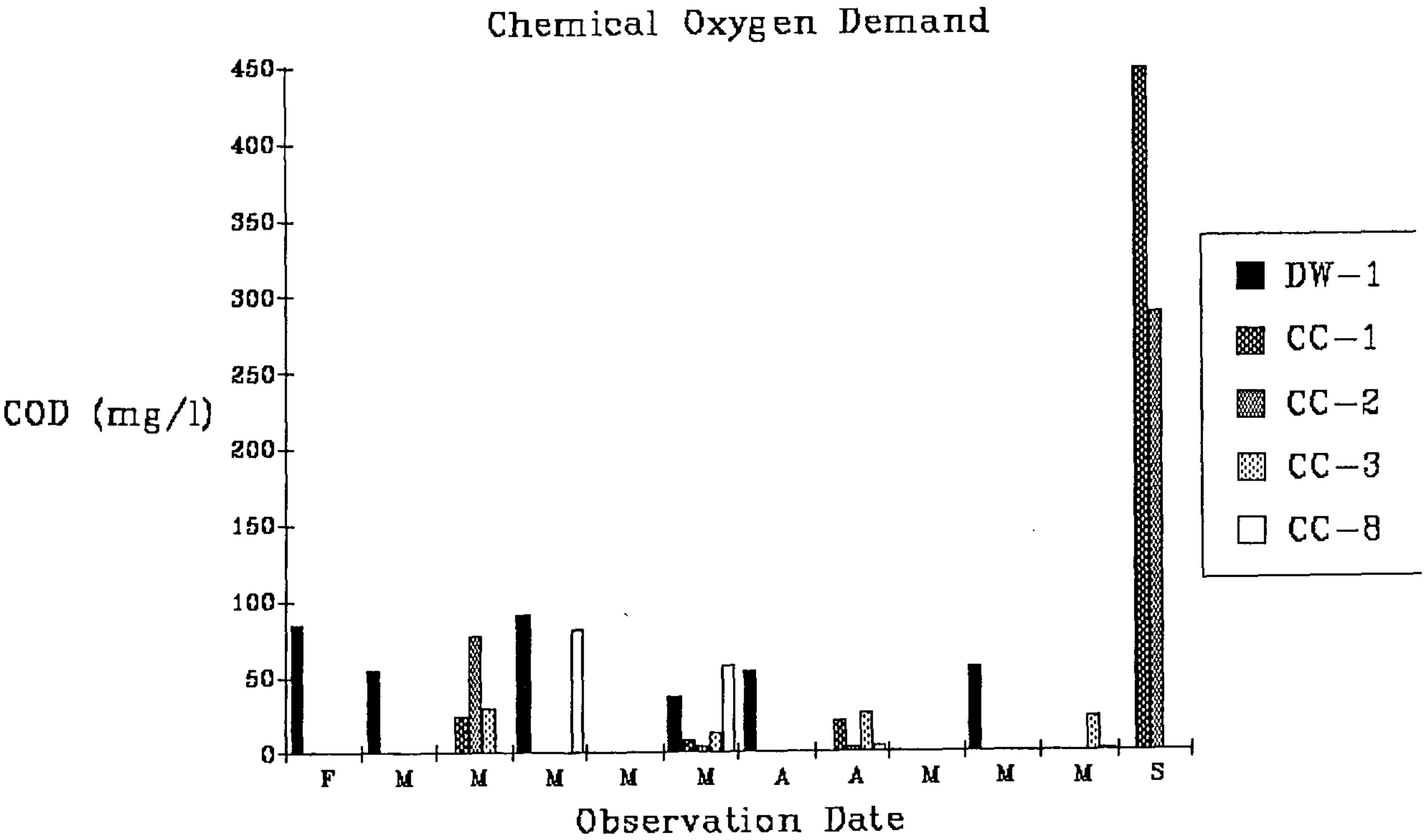


Figure 13. COD, Mt. Tacoma Drive Site

basin are largely atmospheric washout. Nitrate concentrations in ground water frequently exceeded the concentrations in the stormwater, particularly in late March when ground water NO3-N concentrations elevated from less than 0.5 mg/l to 1.0 mg/l and greater, up to nearly 4.0 mg/l in May. Nitrate concentrations in the monitoring wells are illustrated on Figure 14. As shown on the Figure, wells CC-7 and CC-9 were consistently high in NO3-N concentrations at the end of the monitoring period. This does not appear to be a result of input from the drywells, which had substantially lower concentrations during the same period. A possible explanation may be the heavy rains at the end of March following a long, unusually dry winter. Heavy rains at this time may have flushed accumulated nitrate through the ground water system, resulting in the elevated concentrations, which exceeded the typical background levels for the area. At any rate, the nitrate concentrations appear to indicate a regional phenomenon rather than site-specific contributions from the drywells monitored. Data from the Lakewood Water District obtained during the 1984 and 1985 CCC monitoring program indicated background nitrate concentrations ranging from 2.6 mg/l to 4.5 mg/l in the shallow aquifer. Seasonal trends were not indicated in the Lakewood wells.

It was not possible to determine nitrate attenuation (or lack of attenuation) in the drywells because of the low concentrations in the monitored stormwater. Based upon the data collected, stormwater contributions seem to be diluting background ground water nitrate concentrations at the sites monitored.

Mt. Tacoma Drive. Monitoring wells at the Mt. Tacoma exhibited a similar phenomenon as that measured at the Koreana Plaza site: nitrate levels rose significantly at the end of March. Although nitrate levels were lower at the Mt. Tacoma Drive site, the occurrence of a similar phenomenon suggests that the influence is regional rather than site-specific. Figure 15 illustrates the nitrate concentrations at the Mt. Tacoma Drive site. Because of the low nitrate concentrations in the stormwater at this site, stormwater is actually diluting the ground water nitrate concentrations. This dilution of ground water by stormwater would be less evident in areas with higher runoff nitrate concentrations. However, literature sources rarely illustrate runoff with nitrate concentrations exceeding 3.0 mg/l, which is the mean background concentration in the Lakewood shallow aquifer.

Ortho-phosphorus

Ortho-phosphorus values were low in both stormwater and ground water at both sites. Levels in the ground water were slightly higher than the drywell samples, however, both sites were predominantly commercial with few sources of phosphorus in their

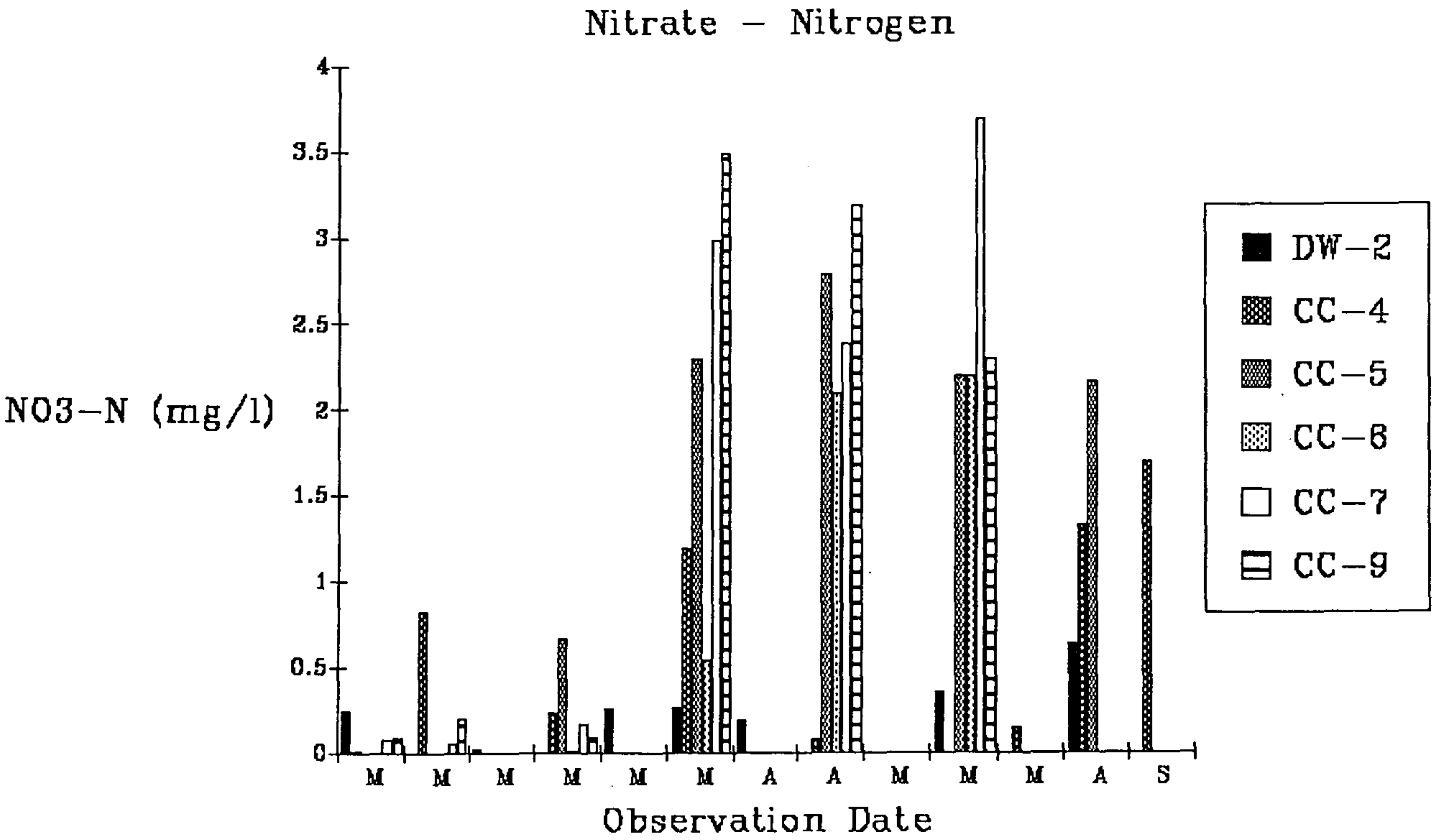


Figure 14. Nitrate–Nitrogen Concentrations, Koreana Plaza Site

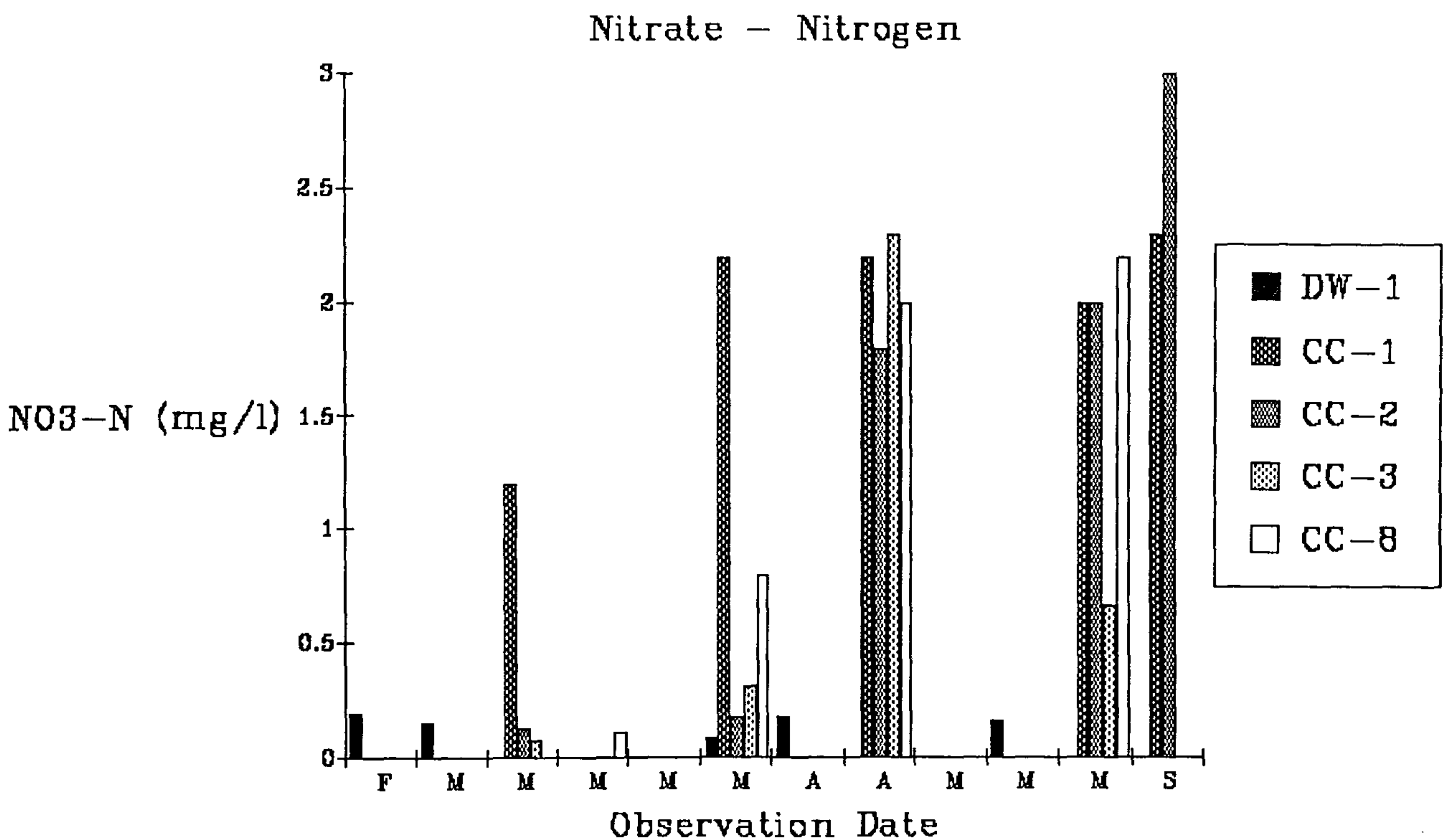


Figure 15. Nitrate-Nitrogen Concentrations, Mt. Tacoma Drive Site

respective tributary drainage areas. Sources of phosphorus in the ground water include unleaded gasoline stored in underground storage tanks.

Arsenic

Koreana Plaza. Arsenic was not detected in the drywell samples, but was detected in small concentrations in the ground water samples in CC-4, CC-5, CC-6 and CC-7. The highest levels were detected in CC-4 following the March 4 storm, which is thought to represent a first flush following a 16-day antecedent dry period. The arsenic detected in CC-4 reflects upgradient contributions, likely stormwater. Stormwater disposal in the upgradient area is almost exclusively to the subsurface.

Mt. Tacoma Drive. Dissolved arsenic was not detected in the drywell samples, but was detected once in well CC-3 (total arsenic) and twice in well CC-8. Concentrations were 0.012 mg/l and less, except for the sample taken during dry weather conditions, which measured total arsenic at 0.062 mg/l. The sample was taken in September, 1988, following over a month with no runoff-producing rainfall events. The high arsenic levels may reflect reduced dilution in the extreme low water period which was measured at this time (the water level was approximately 7 feet lower than the subsequent measurement, taken in May).

Copper

Koreana Plaza. Most of the drywell samples were analyzed for dissolved copper, while several of the ground water samples were analyzed for total copper, making comparison of results difficult. A storm sample taken in August showed total copper concentrations to be approximately twice the dissolved copper concentration in the drywell. Figure 16 illustrates the dissolved copper concentrations in the monitoring wells and drywell. Mean (geometric) total concentrations in CC-4, CC-7, and CC-9 were 0.20, 0.24, and 0.076 mg/l, respectively. CC-9 has the highest degree of dilution, and the lower copper concentrations are likely reflecting this dilution. Total copper concentrations appear to receive little attenuation in the drywell. It appears likely that accumulated copper particulates in the drywell sediments are flushed through the system by stormwater, resulting in often higher concentrations in the ground water than the drywell itself. Cleaning the drywell resulted in no apparent differences in ground water concentrations of copper. The highest total copper concentrations measured in CC-5 and CC-9 occurred in September, during the low flow, non-storm monitoring; this may reflect reduction of dilution. Dry weather sampling produced copper concentrations approximately comparable to winter samples in

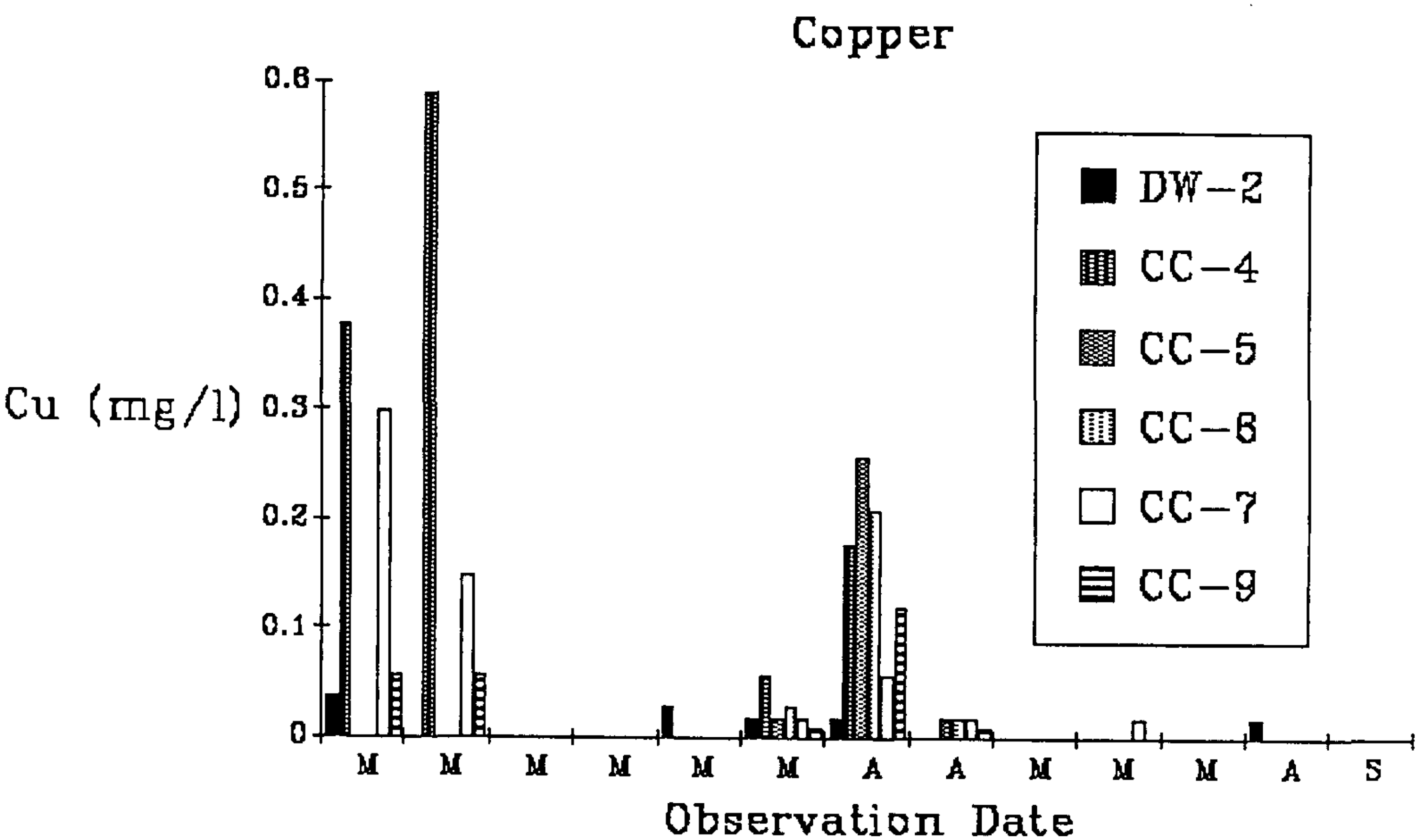


Figure 16. Dissolved Copper Concentrations, Koreana Plaza Site

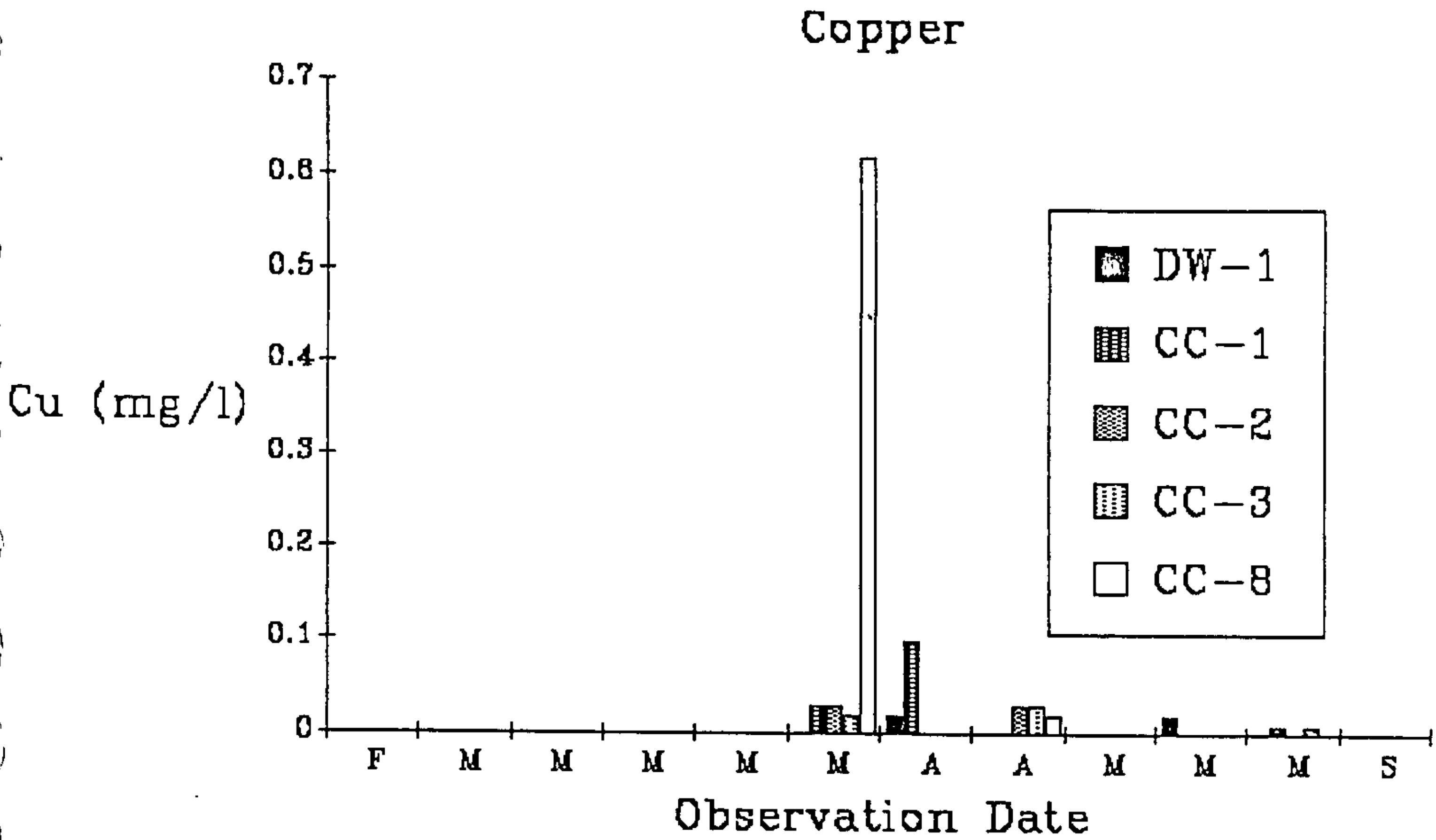


Figure 17. Dissolved Copper Concentrations, Mt. Tacoma Drive Site

CC-4. Wells CC-6 and CC-7 were dry during the September sampling.

Mt. Tacoma Drive. Dissolved copper concentrations were generally lower than the Koreana measured levels in both the drywell and the monitoring wells at this site, with a few notable exceptions. Well CC-3 had a total copper concentration of 0.78 mg/l on April 29, when lead and zinc concentrations were similarly elevated. Of particular interest were the results from the dry weather sampling, which indicated total copper concentrations of 1.1 mg/l and 11.9 mg/l in monitoring wells CC-1 and CC-2, respectively. The State Maximum Contaminant Level (MCL) for copper is 2.4 mg/l as a secondary standard. Previous copper concentrations in these wells were less than 0.05 mg/l, so the dry weather results were surprising. Re-analysis of the samples indicated that the results were not due to laboratory error. Additional analyses are being conducted to determine the source of the elevated copper concentrations in monitoring wells CC-1 and CC-2. Review of the boring log for CC-2 (Appendix B) indicates oily deposits at 15-20 feet. These deposits may indicate previous contamination from surface activities or from petroleum products and/or street dirt associated with stormwater. These contaminants may become increasingly evident in the ground water in extremely low water conditions such as that occurring in September, when dilution is minimal. Figure 17 illustrates dissolved copper concentrations at the Mt. Tacoma Drive site.

Lead

Lead is of particular interest in the ground water system because of the public health implications. Although the current Drinking Water Standard for lead is 0.05 mg/l (50 ug/l), EPA has recommended that the standard be reduced to 0.005 mg/l total lead in source waters; distribution systems with concentrations greater than 0.01 mg/l will be required to install treatment systems (personal communication, L. Woodruff, July, 1988). Although there are numerous sources of lead in industry, automobile by-products are the greatest source of particulate lead, including exhaust particulates and tire/brake wear. Stormwater and ground water samples were analyzed for dissolved as well as total lead. Although lead concentrations are typically associated largely with the particulate phase, it was desirable to determine if the potentially more mobile dissolved constituents were moving through the ground water system.

Data from wells in the Lakewood Water District were analyzed to determine general background water quality for lead. Although the Lakewood wells are generally completed at a minimum depth of 100 feet, they do represent the shallow aquifer. No lead was detected in any of the Lakewood shallow wells in recent testing (personal communication, Bob Forster, November, 1988).

Koreana Plaza. Dissolved lead was measured in DW-2 at 0.225 and 0.159 mg/l, respectively, on March 4 and March 20. Figure 18 illustrates lead concentrations at the site. It can be assumed that total lead concentrations were higher than this, since lead is typically associated to a much higher degree with particulates than the dissolved fraction (Galvin and Moore, 1982). Total lead was measured at 0.177 mg/l on August 16, when dissolved lead was measured in the drywell at 0.05 mg/l.

Total lead concentrations were substantially higher than the proposed EPA Drinking Water Standard on more than one date at all of the monitoring wells. CC-4 had a mean total lead concentration of 0.057 mg/l, with individual event concentrations ranging as high as 0.151 mg/l. CC-5 had a mean total lead concentration of 0.062 mg/l; dissolved lead was lower than the detection limit on three out of four sampling dates but was measured at 0.014 mg/l in May. Dissolved lead was not detected in well CC-6, but the single analysis for total lead was 0.161 mg/l. Monitoring wells CC-7 and CC-9, the two wells downgradient from the drywell, had mean total lead concentrations of 0.098 and 0.063 mg/l, respectively. Individual concentrations of total lead in CC-7 were as high as 0.138 mg/l; total lead concentrations in CC-9 were measured as high as 0.091 mg/l (dry weather sample; the highest storm sample was 0.069 mg/l). There was no apparent difference in ground water concentrations following the drywell cleaning.

Both dissolved and total lead concentrations were detected in the ground water samples, however, total lead concentrations were significantly higher. This is a departure from most of the studies reviewed in the literature, which generally find little or no particulate lead in the ground water system. The data at Koreana Plaza indicates that the significant portion of lead in the ground water at these sites is associated with the particulate fraction. Particulates appear to be moving through at least the uppermost layers of the ground water system, and are present at levels substantially greater than the Drinking Water Standard within a 15 foot radius of the drywell. Lead was measured in the monitoring wells during non-storm conditions, following over a month without a runoff producing event. This seems to indicate that lead in the particulate phase is present during non-storm as well as storm conditions in the uppermost levels of the aquifer. Again, lower levels of dilution during the dry season may account in part for the higher lead measurement.

Lead was detected in the monitoring wells not directly connected to DW-2, indicating that lead is fairly widespread in the localized ground water system. The most readily identifiable source of this lead is subsurface disposal of stormwater. As previously mentioned, there are numerous drywells upgradient of this site, however, the nearest drywell to CC-5, a well with a

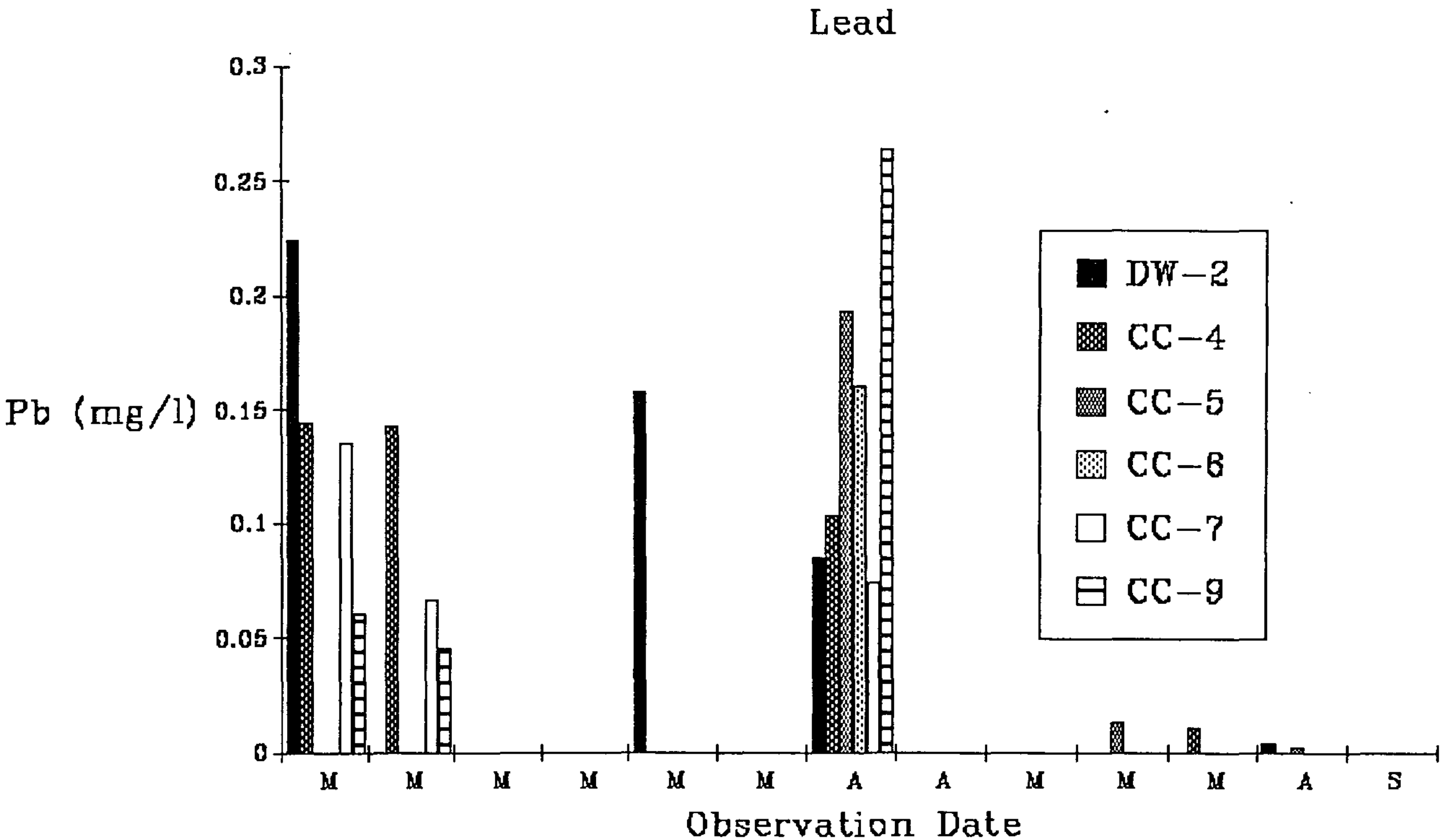


Figure 18. Dissolved Lead Concentrations, Koreana Plaza Site

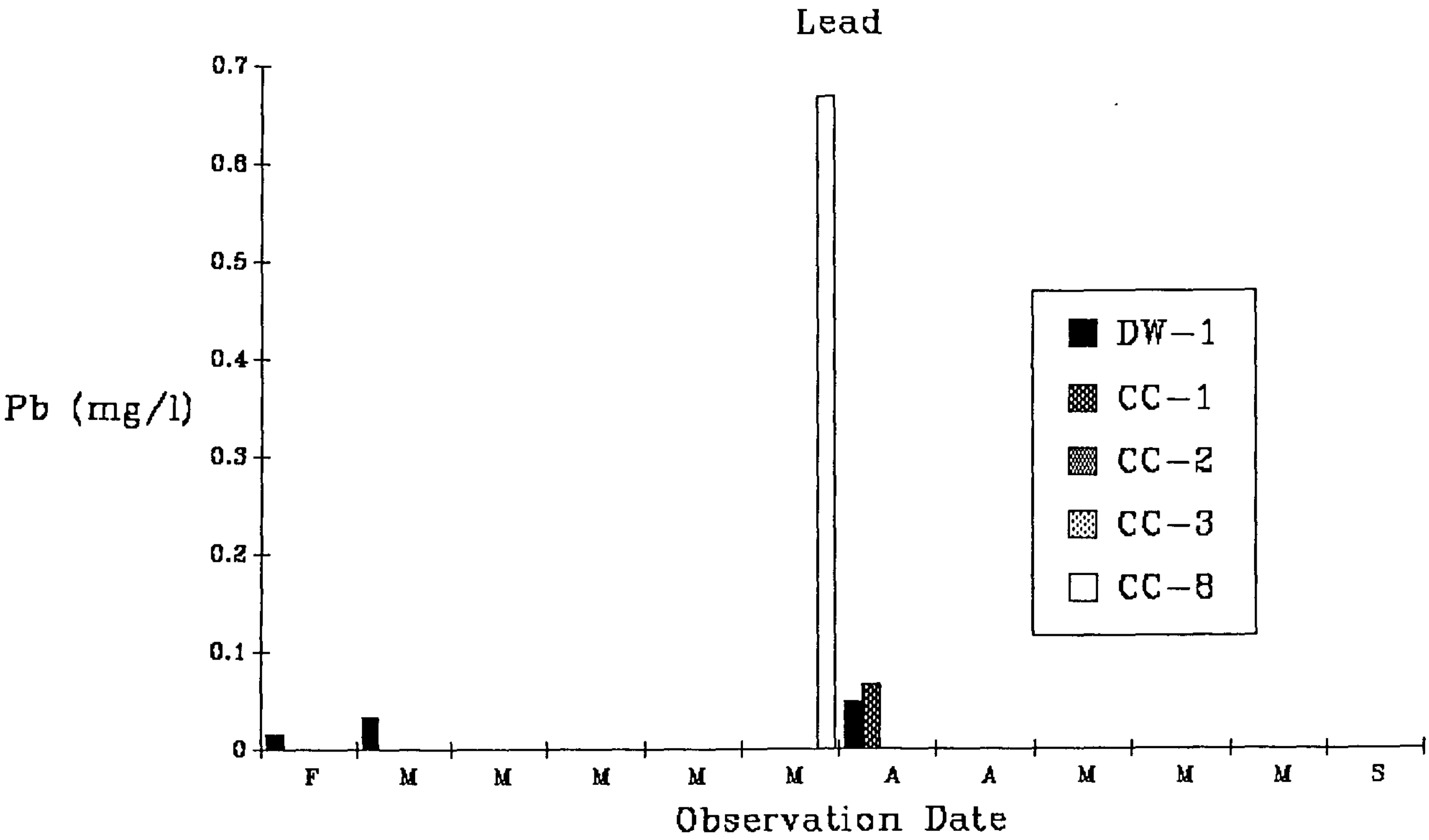


Figure 19. Dissolved Lead Concentrations, Mt. Tacoma Drive Site

detected total lead concentration of 0.194 mg/l, is approximately one hundred fifty feet away. Although lead concentrations in street dust and urban runoff are anticipated to decline in the future as usage of leaded gasoline decreases, the persistence of lead particulates in the ground water system may continue to be seen. Particulates in the drywell itself and in the underlying soil column will likely continue to be flushed into the ground water system by stormwater migrating downward.

Mt. Tacoma Drive. Dissolved lead concentrations in DW-1 were lower than those measured at the Koreana site, but detectable, and are illustrated on Figure 19. Total lead concentrations at all monitoring wells were substantially greater than the EPA Drinking Water Standard. Dry weather ground water samples taken in September, 1988, indicated extremely high total lead levels in CC-2, and substantially higher levels in CC-1. Both wells were previously low in metals concentrations. CC-2 was particularly high in lead, with a concentration of 2.5 mg/l which is 500 times the proposed drinking water standard. The high levels are apparently not related to direct storm discharges but may reflect previous stormwater-related lead deposition that became more apparent during periods of reduced dilution.

Dissolved lead levels were generally below 0.005 mg/l. There was one exception, at well CC-8 following the March 23 storm. Dissolved lead in CC-8 was measured at 0.67 mg/l. As previously stated, monitoring well CC-8 is not hydraulically connected to DW-1, and therefore is not reflecting specific inputs from this drywell. However, CC-8 is located in an area with dense utilization of drywells and highly channelized flow; this high concentration likely represents stormwater inputs from adjacent drywells. Review of the boring log for CC-8 (Appendix A) indicates oily deposits at approximately 15 - 20 feet. These deposits are similar to those described for CC-1, and may indicate deposition associated with stormwater, since there is no other apparent source in the vicinity. CC-8 was dry during the dry weather sampling.

Zinc

Koreana Plaza. Dissolved zinc concentrations in DW-2 were comparable to dissolved lead concentrations. Figure 20 illustrates dissolved zinc concentrations at Koreana Plaza wells. On the sampling occasion where both dissolved and total zinc concentrations were analyzed, dissolved zinc was less than 20 percent of the total zinc concentration. Monitoring wells CC-4 and CC-7 had the highest concentrations of total zinc in ground water; both of which are influenced by DW-2. CC-9 had lower concentrations of zinc, however, CC-9 has the highest rate of dilution. Zinc appears to be migrating in the shallow ground water system; stormwater is the most likely source of this zinc.

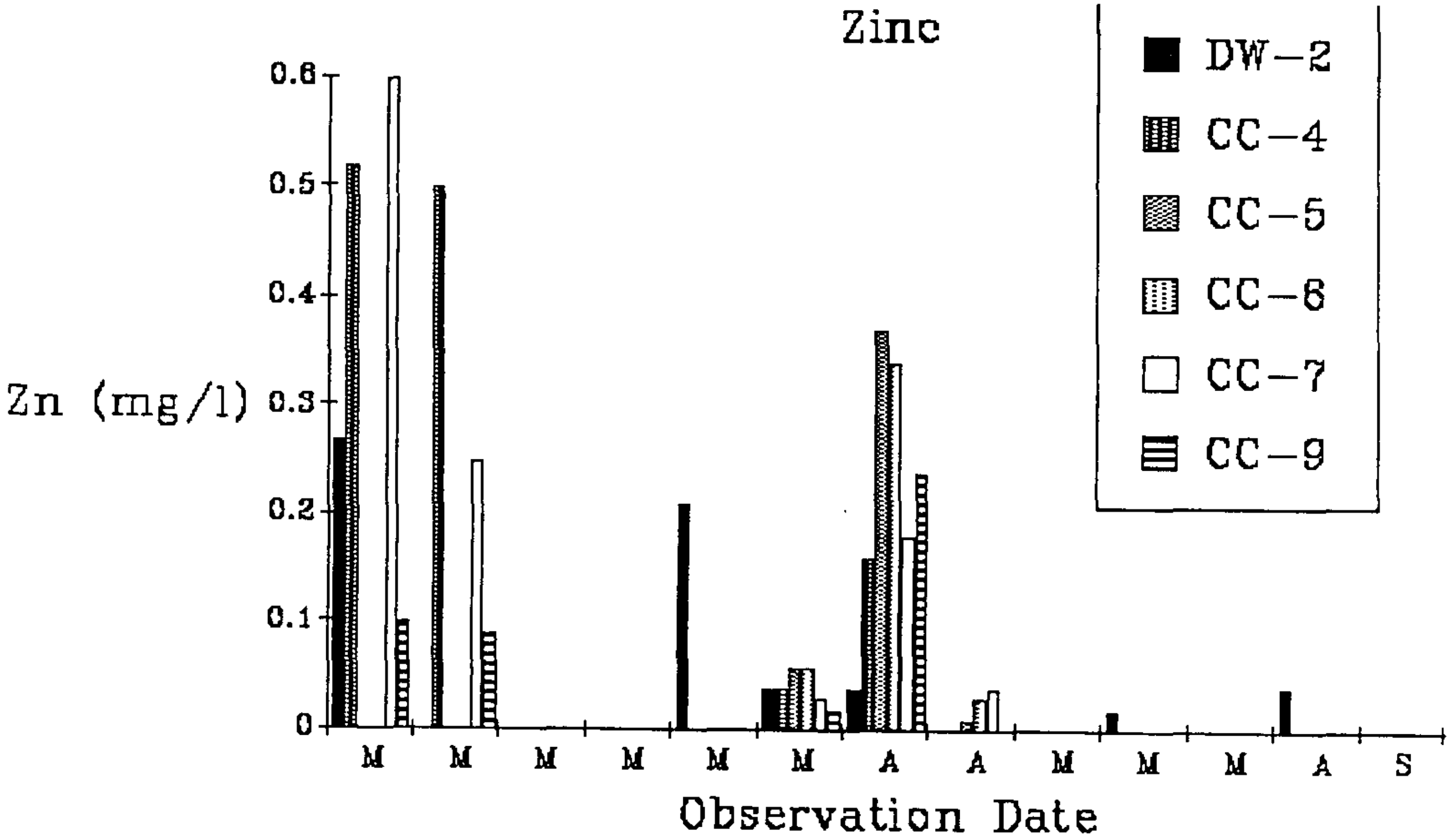


Figure 20. Dissolved Zinc Concentrations, Koreana Plaza Site

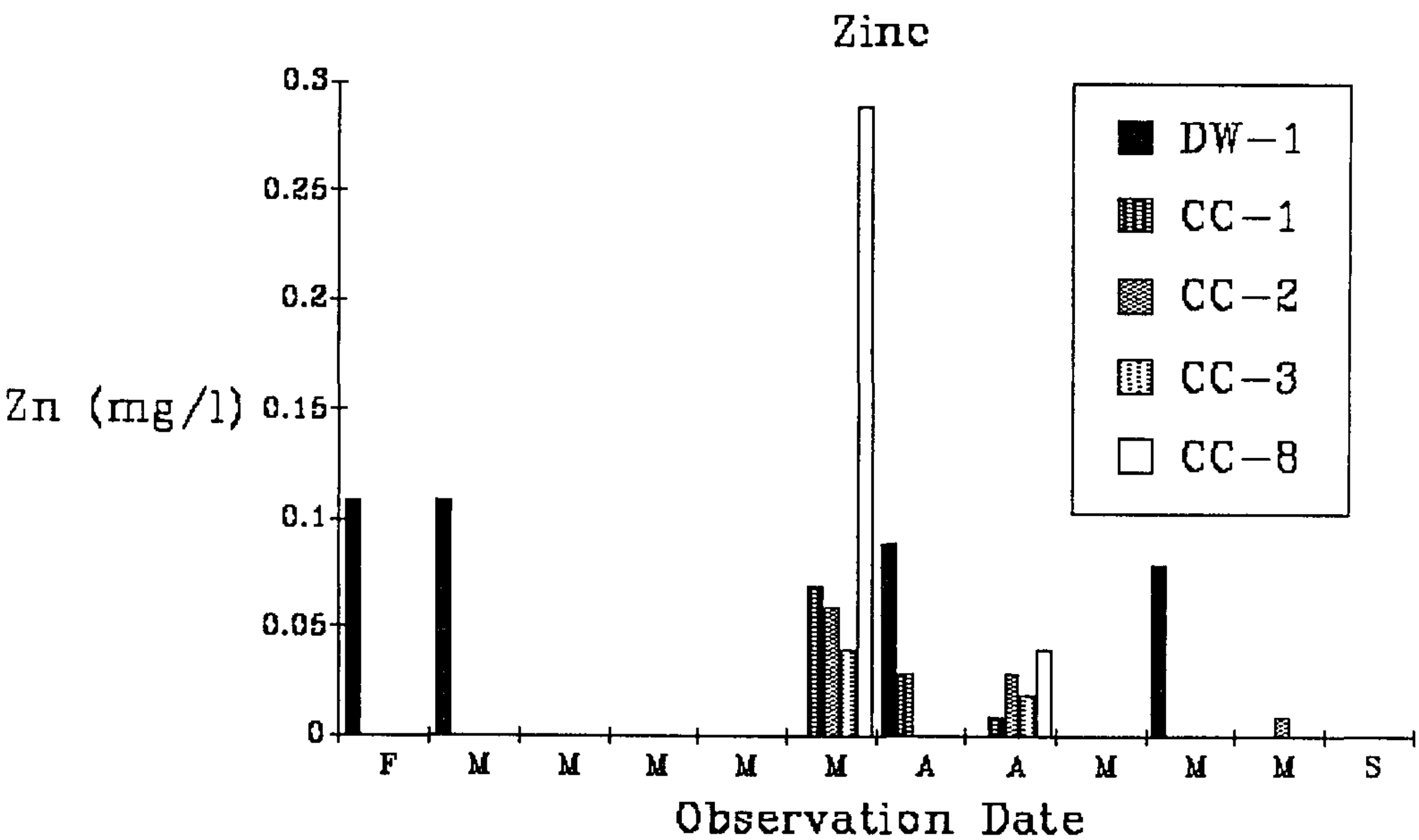


Figure 21. Dissolved Zinc Concentrations, Mt. Tacoma Drive Site

Mt. Tacoma Drive. Both dissolved and total zinc levels were lower in the Mt. Tacoma Drive drywell and monitoring wells than in the Koreana Plaza wells, except for extremely high levels in CC-1 and CC-2 during September, 1988. Total Zinc concentrations were 6.8 mg/l and 14.0 mg/l, respectively; the State Maximum Contaminant Level (MCL) for zinc is 5.0 mg/l. The detected dry weather levels are an anomaly in that previous zinc concentrations in these wells were less than 0.10 mg/l. Zinc was present at relatively high levels at wells CC-8 and CC-3, indicating that zinc is moving through the uppermost ground water system in particulate and dissolved fractions. Figure 21 illustrates dissolved zinc concentrations at this site.

Fecal coliform

Koreana Plaza. Fecal coliform organisms were detected in DW-2 at greater than 16 organisms/100 ml on three sampling occasions. Fecal coliform organisms were detected in monitoring wells CC-4, CC-5, CC-6, CC-7, and CC-9 on more than one sampling occasion, generally at or near the detection limit of 2.2 organisms/100 ml. The Drinking Water Standard for coliform bacteria is 1 organism per 100 ml. Coliform levels in wells CC-7 and CC-9 were no higher than the levels in wells not directly connected to the drywell. It appears than some attenuation of fecal coliform may be occurring in the drywell, but concentrations of fecal coliform organisms in the monitoring wells are not influenced by the drywell, indicating there is migration of the bacteria originating from other sources in the upper layers of the shallow aquifer. It is difficult to determine attenuation in the drywell, because fecal coliform concentrations in the runoff were very low.

Mt. Tacoma Drive. Fecal coliform organisms were detected in two storm samples, and in at least one sample in each of the monitoring wells, at very low levels. Since the monitoring wells are not believed to be directly connected to the drywell, these coliform concentrations reflect localized levels of bacterial contamination.

Priority pollutants

There were no volatile organics detected in any of the storm or ground water samples. Base/Neutral/Acid Extractable Organics analyses were performed, with no detected constituents at the Mt. Tacoma Drive site. Well CC-4 at the Koreana Plaza site had detected levels of bis(2-ethylhexyl) phthalate, as did well CC-5 and CC-6. Apparently, these levels reflect localized regional trends, rather than a direct influence from DW-2. Phthalates are prevalent in the environment, and were detected in Lakewood-area ground water during the organics sampling program conducted as part of the CCC Geohydrologic Study in 1985 (Brown and Caldwell, 1985). There is no human health criterion for bis (2-ethylhexyl) phthalate, but the recommended human health criteria for diethylhexyl phthalate, which is a very similar compound, is 10 mg/l.

ADDITIONAL GROUND WATER SAMPLING

APRIL, 1989

An additional set of ground water samples was obtained at the end of the rainy season. The purpose of this monitoring was to determine if seasonal variations could be detected, or if increasing ground water levels affected the results. Storm water samples were not obtained; the ground water samples were taken following a storm event.

The monitoring wells at the Koreana Plaza site, and the Mt. Tacoma Drive site were sampled on April 3, 1989. Prior to sampling, the depth to ground water in each of the monitoring wells was measured using an ACTAT 300 Olympic Well Probe. Ground water levels were the lowest on record for this project, and are summarized below. Previous water level elevations are summarized in Appendix D. Ground water levels measurements were not obtained from monitoring wells CC-4 and CC-7 because the wells could not be opened at the time of the site visit.

TABLE 4. GROUND WATER LEVELS, APRIL 3, 1989
(Feet below ground surface)

MT. TACOMA DRIVE SITE

Well number	Depth to Ground water
CC-1	30.60
CC-2	30.81
CC-3	30.81
CC-8	30.84

KOREANA PLAZA SITE

Well number	Depth to Ground water
CC-4	--
CC-5	23.04
CC-6	17.26
CC-7	--
CC-9	27.93

Ground water samples were collected after bailing approximately one pore volume with a double check valve Teflon bailer. Monofilament line was used to lower the bailer into the wells. Specific conductance (umhos), and pH were measured prior to collecting each ground water sample using a DSPH-3 pH/Conductivity meter.

Samples were analyzed for: dissolved and total arsenic, copper, lead, and zinc; nitrate-nitrogen; COD; ortho-phosphate; and Fecal Coliform. All samples, except Fecal Coliform, were shipped to Columbia Analytical Services (CAS) in Longview, Washington. Fecal coliform samples were hand delivered to the Tacoma-Pierce County Health Department (TPCHD).

Stormwater samples were collected on April 3, 1989 with a 24-hour rainfall accumulation of 0.54 inches. Antecedent rainfall was 1.86 inches, with 7 previous days of rain with at least 0.10 inch of rain. February and March had accumulated rainfall of 2.87 and 7.08 inches, respectively.

RESULTS

The sample analysis results were generally consistent with the results of the previous sampling events. Summarized below are the findings, by site, with the final sampling round data included. Sampling data are summarized in Tables 2 and 3.

pH

Koreana Plaza. The monitoring wells were relatively consistent in mean pH values, with geometric means ranging from 7.3 to 7.5. pH values measured in April, 1989 ranged from 7.24 to 7.61. The high pH values measured throughout the monitoring period appear to reflect a source of alkalinity in the ground water or soils, but this source has not been identified.

Mt. Tacoma Drive. The pH values of the Mt. Tacoma Drive monitoring wells were consistently lower than the pH values measured at Koreana Plaza, ranging from 6.5 to 6.8. Values measured in April, 1989 ranged from 6.59 to 6.94, which were consistent with previous values.

Conductivity

Koreana Plaza. Monitoring wells ranged in mean conductivity values from 173 to 224, with April readings ranging from 131 to 190 umhos. The 131 umhos value measured at monitoring well CC-6 in April was the lowest value recorded for that well, but is within the range of values typically recorded in the basin. The variability from sampling date to sampling date overrides any correlations relating input at the drywell and impacts to conductivity in the groundwater. This data is consistent with the previously collected data.

Mt. Tacoma Drive. Mean conductivity values were lowest at CC-3 (124 umhos) and highest at CC-8 (213 umhos). April data ranged from 125 to 155 umhos, again with lowest values measured at CC-3, and highest values measured in well CC-8.

Chemical Oxygen Demand (COD)

Koreana Plaza. Mean COD values detected for the entire sampling period in CC-7 and CC-9 were 28 and 23 mg/l respectively. Monitoring well CC-7 was not sampled in April, 1989, as previously described. COD measured in CC-9 was 28 mg/l, and the other wells ranged between 16 and 29 mg/l for the April sampling. Mean COD values in the site monitoring wells ranged from 18 to 50 mg/l.

Mt. Tacoma Drive. COD values detected in the monitoring wells were slightly lower than those detected at the Koreana Plaza site. Mean values ranged from 15 to 25 mg/l. April values ranged from 18 to 36 mg/l. Overall, there was less variability in COD values among events at this site than that measured at the Koreana Plaza site during the year of sampling.

Nitrate-Nitrogen

Koreana Plaza. Mean average nitrate-nitrogen concentrations ranged from 0.25 to 1.92 mg/l. April values ranged from 0.84 in monitoring well CC-6 to 2.6 mg/l in monitoring well CC-9. The higher nitrate concentration in CC-9 may reflect a flush of nitrate in the shallow ground water system due to regional contributions from on-site septic systems.

Mt. Tacoma Drive. Nitrate-nitrogen values measured in April, 1989, ranged from 2.5 to 3.3 mg/l, somewhat higher than concentrations observed at the Koreana Plaza site. Nitrate concentrations appeared to be up to one milligram/liter higher in April than had previously been noted at this site, and may reflect the increased movement of regionally-contributed nitrate in the shallow ground water system.

Ortho-Phosphorus

Koreana Plaza. The mean average concentrations of ortho-phosphorus measured in the shallow ground water at this site ranged from 0.08 to 0.25 mg/l during the initial analyses. Values reported from the April sampling ranged from 0.05 to 0.18 mg/l, within the range of event-to-event variability. A trend similar to that observed for nitrate-nitrogen was not observed.

Mt. Tacoma Drive. The mean average concentrations measured in the shallow ground water during the initial monitoring ranged from 0.03 to 0.22 mg/l. April 1989 values ranged from 0.09 to 0.18 mg/l. Ortho-phosphorus did not exhibit a similar phenomenon to nitrate-nitrogen; highest concentrations were not measured during the highest water levels. Water level did not have a significant effect upon ortho-phosphorus levels in ground water at the two sites monitored.

Arsenic

Koreana Plaza. Dissolved arsenic was not detected in any of the monitoring wells during the monitoring program, including during the April 1989 sampling. Mean total arsenic concentrations ranged from 0.001 to 0.10 mg/l. Total arsenic was detected in monitoring well CC-6 (0.022 mg/l) in the April sampling. State and Federal water quality standards suggest a maximum contaminant level of 0.05 mg/l.

Mt. Tacoma Drive. Dissolved arsenic was not detected in any of the monitoring wells at this site. Mean total arsenic concentrations detected in the ground water ranged from 0.006 to 0.02 mg/l, with April sampling values ranging from 0.018 to 0.024 mg/l.

Copper

Koreana Plaza. Mean dissolved copper concentrations detected in the ground water ranged from 0.004 to 0.02 mg/l. Of the wells sampled in April, dissolved copper was detected only in monitoring well CC-6. Mean total copper concentrations in ground water at this site ranged from 0.07 to 0.31 mg/l. April values ranged from 0.093 in monitoring well CC-9 to 0.586 mg/l in monitoring well CC-5. The April value was the highest recorded in monitoring well CC-5. The movement of particulates through the vadose zone is indicated by the relatively high concentration of total copper in the shallow ground water system.

Mt. Tacoma Drive. Mean dissolved copper concentrations monitored in ground water ranged from 0.006 to 0.04 mg/l. Dissolved copper was not detected in the April 1989 ground water samples. Measured mean total copper concentrations ranged from 0.37 to 1.26 mg/l. April sample values ranged from 0.451 in monitoring well CC-1 to 1.57 mg/l total copper in monitoring well CC-8, which was higher than the values obtained from the Koreana Plaza site. State and Federal water quality standards suggest a maximum contaminant level of 1.0 mg/l. As previously described, the detected levels of total copper, which tends to associate with the particulate fraction, indicates movement of particulates from the drywell through the vadose zone into the shallow ground water system.

Lead

Koreana Plaza.

Both dissolved and total lead concentrations were detected in the ground water samples at this site, however, total lead concentrations were substantially higher. Dissolved lead was detected in monitoring wells CC-4, CC-5, and CC-6, with mean concentrations ranging from below the detection limit to 0.003

mg/l. During the April sampling, dissolved lead was detected in monitoring well CC-6, at 0.002 mg/l. Mean total lead concentrations ranged from 0.06 to 0.14 mg/l. Total lead detected in the April sampling ranged from 0.070 to 0.115 mg/l.

Mt. Tacoma Drive. Dissolved lead concentrations ranged from 0.001 to 0.134 mg/l in the shallow ground water system, but was not detected in monitoring well CC-1. In the April sampling, dissolved lead was detected in monitoring wells CC-2 and CC-3, both at concentrations of 0.006 mg/l. Mean total lead concentrations in the monitoring wells during the initial sampling program ranged from 0.14 to 0.226 mg/l. Detected levels of total lead in April ground water samples ranged from 0.131 mg/l in CC-1 to 0.295 mg/l in CC-8.

Zinc

Koreana Plaza. Dissolved zinc was not detected in the April, 1989 samples at this site. Mean total zinc concentrations ranged from 0.019 to 0.36 mg/l over the entire monitoring program; total zinc concentrations measured in the site monitoring wells ranged from 0.092 to 0.234 mg/l in the April samples.

Mt. Tacoma Drive. Mean dissolved zinc concentrations ranged from 0.01 to 0.04 mg/l in ground water samples obtained prior to April, 1989. Dissolved zinc was not detected in the April ground water samples. Mean total zinc concentrations ranged from 0.36 to 0.89 mg/l in the previous samples; ground water concentrations in April 1989 ranged from 0.226 mg/l in monitoring well CC-1 to 1.20 mg/l in monitoring well CC-8, concentrations which are higher than the samples collected at the Koreana Plaza site. Throughout the sampling, the Mt. Tacoma Drive site ground water generally had higher concentrations of total zinc than the Koreana site.

Fecal Coliform

The detection level for fecal coliform bacteria is 2.2 organisms/100 ml, as measured by MPN dilution methods. The drinking water standard for fecal coliform is 1 organism/100 ml.

Koreana Plaza. Fecal coliform bacteria were noted above the detection limit in monitoring wells CC-6 and CC-9. These wells had measurable fecal coliform concentrations in several samples. Fecal coliform bacteria were detected in the April, 1989 ground water samples in monitoring wells CC-6 and CC-9 at greater than 16.0, and 2.2 organisms/100 ml respectively.

Mt. Tacoma Drive. Fecal coliform bacteria were consistently noted in monitoring well CC-3 throughout the monitoring program. Fecal coliform bacteria were reported to be greater than 16.0

organisms/100 ml in the April, 1989 samples. Fecal coliform bacteria were not detected at any of the other monitoring wells during the course of the monitoring program.

SUMMARY

Ground water samples taken in April, 1989 at the Mt. Tacoma site had generally higher nitrate concentrations than those measured during the rainy period. Ground water samples obtained at the Koreana Plaza site were generally similar in nitrate-nitrogen concentrations as those previously recorded.

Total lead concentrations in the April, 1989 ground water samples were elevated at both sites, as were copper and zinc concentrations. This indicates that dilution is apparently not taking place with increasing ground water levels. The high ground water table may be moving nitrates emanating from septic tanks through the system. The relatively high lead levels are likely due to resuspension of particulate lead in the vadose zone, since ground water lead concentrations are generally higher than concentrations measured during this investigation in the stormwater. This lead has probably been deposited in the vadose zone over a period of decades.

SUMMARY OF MAJOR CONCLUSIONS

Following is a summary of the general conclusions regarding the impact of stormwater to ground water from two drywells in the Clover/Chambers Creek Basin. It should be noted that these results summarize a limited sampling program (eleven storm events over 14 months) at two commercial sites in the Lakewood area, and cannot be considered representative of all land use, terrain, and soil types. The sites were not selected to represent worst case conditions, but were intended to represent typical, or average conditions.

Because of complicated site hydrology at both the Koreana Plaza and Mt. Tacoma Drive sites, it was difficult to draw specific conclusions regarding the attenuation of contaminants in drywells. However, it can be concluded that non-point sources are resulting in elevated levels of contaminants in the shallow aquifer, primarily metals. Metals, particularly lead, appear to be migrating or have been migrating in the shallow ground water system from the drywells. Drinking Water Standards for zinc, copper and lead were exceeded in the monitoring wells.

There was substantial variability among the data, both from storm to storm and from station to station for nearly all parameters, precluding the ability to draw statistically significant conclusions.

Conductivity varied widely from storm to storm, and was generally at least twice as high in the ground water as in the drywells (stormwater).

Nitrate concentrations in the stormwater samples at the two study area drywells were lower than ground water nitrate concentrations in most of the wells. At the Koreana Plaza site, nitrate levels increased significantly in all the monitoring wells at the end of March, coincident with the lowest water levels. This appears to be a correlation with regional ground water concentrations resulting from low dilution rather than input from the drywell, which had consistent nitrate concentrations throughout the monitoring program. The source of nitrate is likely either runoff/infiltration from upgradient areas, or is reflecting a subsurface "first flush" of adsorbed particles which are likely remaining in the soil profile from recent utilization of septic tanks in the area.

Metals concentrations were relatively high in monitoring wells CC-4, CC-7, and CC-9 during the first storms monitored. This may reflect a "first flush" effect following two rainless weeks. Arsenic was detected in CC-4 and CC-7, and was not detected in the drywell. Copper, lead and zinc concentrations exceeded Drinking Water Standards in wells CC-1 and CC-2 during the dry weather sampling in September, following over a month with no runoff event. These high concentrations may reflect previous metals depositions in the soil column that became more evident with decreased dilution.

The only priority pollutants detected in the ground water monitoring were bis(2-ethylhexyl) phthalate and phenanthrene, which were detected in the shallow ground water system at very low levels. No priority pollutants were detected in stormwater samples obtained during this analysis. Phthalates are common in the environment, and have been detected previously in Clover-Chambers Creek basin ground water. Priority pollutants did not appear to be a chronic problem associated with runoff at the sites monitored.

Dilution by ambient ground water at the South Tacoma Way site is substantial; greatest dilution is occurring in well CC-9.

Ground water flow at both sites is channelized, but the Mt. Tacoma Drive site is extremely channelized.

RECOMMENDATIONS

Although the stormwater and ground water data collected were difficult to analyze because of complicated hydrology and highly variable results, several trends were indicated. Based upon a review of the data collected in the Clover/Chambers Creek Basin as well as review of recent studies regarding the risk of stormwater to ground water quality, it can be concluded that drywells pose a threat to ground water in the Clover/Chambers Creek Basin through two major avenues: as a source of runoff-borne metals directly transported through the vadose zone into the ground water system; and as a direct conduit for hazardous materials spills to enter the ground water system.

This study identified that total and dissolved metals are entering the ground water system and are present in the upper aquifer at levels significantly greater than Drinking Water Standards. These high levels of metals appear to be entering the ground water system through the drywell system, transported by the discharge of the stormwater itself and flushing of adsorbed particulates in the soil system.

Drywells can serve as a conduit for ground water contamination by spilled hazardous materials because there appears to be little attenuation of materials in the upper soil layers. Therefore, materials spilled in the drywell can be expected to migrate into the ground water system with little or no attenuation, particularly dissolved constituents.

Recommended Stormwater Control Program

The stormwater control program should have two major components: control of chronic levels of particulates, particularly metals, and control of acute events or spill control.

Particulate control. New installations of drywells in residential areas should include grass percolation areas, including up to 100 feet of vegetated swales prior to discharge of stormwater to drywells. If possible, this design should be incorporated into commercial facilities. Backfill materials for installed drywells should include fine-grained sands for increased filtration.

Spill control/runoff containment. The goal of spill control/runoff containment is to prevent contaminant-carrying runoff from entering the soil or ground water system. Spills can occur during the processing, storage, and transport of hazardous materials. The first step in this process is to identify those facilities that are affected by the transport, storage, and processing of hazardous materials. Previous studies (Brown and Caldwell, 1985) indicate a definite link between land use types and risk of spills. Areas discharging stormwater to the subsurface should be characterized according to risk of spill/leak of hazardous materials. This includes an estimate of the number of vehicles transporting hazardous materials, and an inventory of the industries/businesses storing, using and transporting hazardous materials. Following this inventory, it will be possible to estimate the relative risk to ground water from the various sources in the recharge area, and establish priorities for containment/spill control. Containment measures to be considered for implementation include such features as: on-site detention/holding facilities; control systems for pavement, platforms, floors, curbs and gutters; leakage controls for pipes and tanks; emergency holding facilities; detention treatment facilities; and supplemental holding facilities.

Phase II recommendations

Phase II of the Stormwater Evaluation should include preparation of recommended design guidelines for drywells and vegetated swales. The Phase II effort should also include a characterization of risk to ground water from transport, storage, and use of hazardous materials, followed by a recommended plan for Spill Control/Runoff Containment. Implementation of a Pilot Program with accompanying monitoring is not recommended at either the Mt. Tacoma Drive or Koreana Plaza sites at this time. It is felt that the monitoring effort necessary to detect direct impacts associated with mitigation measures is beyond the budget limitations of this project.

Implementation of Phase II recommendations

The Tacoma-Pierce County Health Department, in cooperation with the Pierce County Department of Public Works, received a Centennial Clean Water Program Grant from the Department of Ecology in July, 1989. The purpose of the grant was to install and monitor the pollutant-removal effectiveness of alternative drywell designs. Three alternative drywell designs, including a design utilizing a grass-lined swale, were developed and installed in Pierce County in early 1990. Six storms will be monitored. Stormwater will be sampled as it enters the drywell, and subsequently monitored at three points within the system, including the underlying shallow ground water system. The drywells were designed to increase particulate removal, as well as provide a measure of containment for small-volume spills.

During design of the facilities, AAI and Brown and Caldwell worked closely with the Department of Ecology and Pierce County Public Works Maintenance staff, to ensure that the drywells would provide the most cost-effective measure of particulate removal while being easy to install and maintain. The Department of Ecology has applied to the Environmental Protection Agency for funds to conduct long-term monitoring of the systems. Monitoring will begin in February, 1990; preliminary results will likely be available in the late spring or early summer of 1990. Based upon the results, Pierce County Department of Public Works will select the most cost-effective design for County-wide implementation.

APPENDIX A

RISK TO GROUND WATER
FROM TRANSPORTATION-RELATED SPILLS

CLOVER/CHAMBERS CREEK BASIN
GROUND WATER MANAGEMENT PROGRAM

APPENDIX A

RISK TO GROUND WATER FROM TRANSPORTATION-RELATED SPILLS

There are numerous sources of contaminants within the CCC basin that could potentially enter the ground water system via the stormwater disposal system. Non-point, or diffuse sources including chronic stormwater loadings, enter the ground water system either through direct subsurface discharge or through seepage through the soil profile. Point sources, including large-volume spills, can enter the ground water system through direct discharge or infiltration through soil.

The presence of highly permeable soils throughout much of Pierce County has resulted in extensive utilization of subsurface disposal for stormwater. Figure A-1 illustrates stormwater disposal facilities in the CCC basin.

The Tacoma-Pierce County Health Department (TPCHD) undertook a 13-month ground water monitoring program to determine potential impacts to ground water from chronic stormwater loading. The results of that study are discussed in the body of this report. Previous investigations have determined that risk of transportation-related spills pose a potentially significant risk to ground water quality, particularly in areas with dense industrial development (Brown and Caldwell, 1986). Therefore, it was determined that it would be beneficial to identify transportation-related sources of spills within the CCC basin, and determine the relative risk to ground water associated with these sources. By identifying the relative risk of hazardous materials spills that could enter the ground water via the stormwater system, we can establish priorities for mitigation and/or control measures. Following is a discussion of the various sources of contaminants transported through the CCC basin and their relative risk to ground water. It is acknowledged that risks from transportation facilities represent only one of several sources of risk to ground water, such as agricultural runoff, pesticide/herbicide application, and on-site sewage disposal, but because of the relative land use distribution within the CCC basin and previous work which identified transportation-related risks as significant, this study focused upon that area.

SPILLS FROM TRANSPORTATION FACILITIES

Truck Transportation

Roadways in the basin are important to ground water quality because accidents involving vehicles transporting hazardous materials can result in spills that can enter and contaminate the ground water system. The major arterials located within the CCC

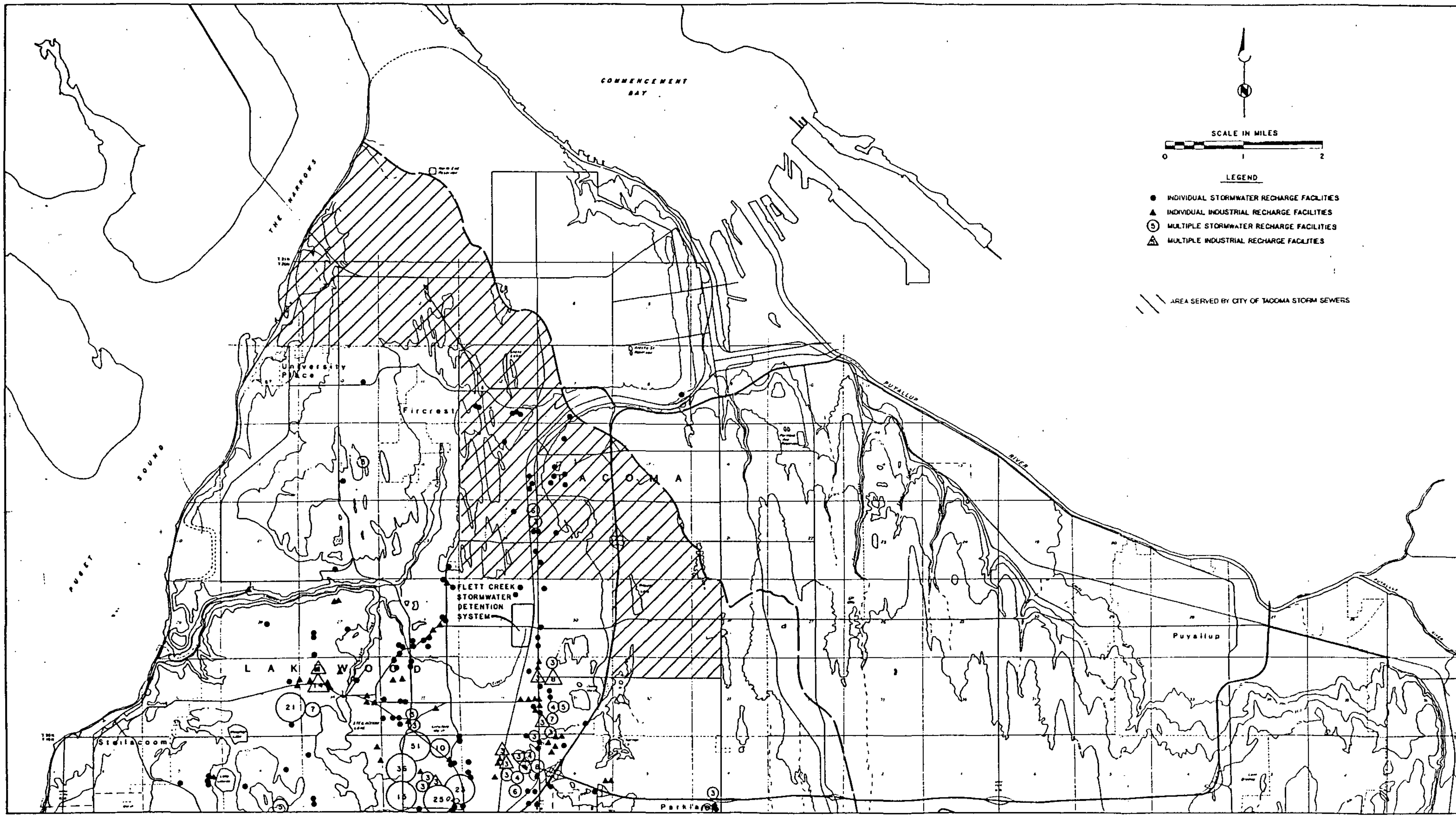


Figure A-1 Stormwater Facilities

basin include: Bridgeport Way; South Tacoma Way; Gravelly Lake Drive; Pacific Highway Southwest; Steilacoom Boulevard; 112th Avenue; Spanaway Loop; and Lakewood Drive/Orchard. Figure A-2 illustrates the major roadways in the district. Traffic counts are available for these roadways from various years (1983 to 1988), and are summarized in Table A-1. Traffic counts were provided by the Pierce County Public Works Department. All counts represent Annual Average Daily Traffic.

Truck traffic is important to the evaluation of potential for ground water contamination because trucks carry significant quantities of hazardous materials which can be spilled during an accident. Water quality impacts from these transportation-related spills can occur either through direct percolation of contaminants into the soil, discharge from drywells, or by transport through stormwater conveyance systems. The majority of stormwater within the CCC basin is routed to drywells or other subsurface disposal facilities. Any spill occurring on roadways within the basin served by drywells or infiltration facilities is likely to enter the ground water system.

Hazardous Material Transport in the CCC Basin. In order to determine the types of materials most likely to be spilled, it is necessary to determine the type, relative frequency and volume of material transported through the CCC basin. A breakdown of the types of materials transported by trucks travelling through the basin was not available for this investigation. To develop our estimates, we used national figures developed by the Department of Transportation, in addition to data prepared by the Oregon Public Utilities Commission (similar data is not available from the WSDOT). Ten percent of the average daily vehicle traffic was assumed to be truck traffic. (Percentage of truck traffic typically varies from six to 12 percent; ten percent was assumed to be an approximate average for the CCC basin roadways.) Ten percent of the total truck traffic was assumed to be transporting hazardous materials, which is consistent with national estimates (U.S. Department of Transportation, June 1985).

The hazardous materials most frequently transported by truck are petroleum products, including gasoline, diesel, and other flammable liquids. A review of the types of industries located in the CCC basin indicates that this breakdown is appropriate. In Oregon, petroleum products constitute up to 60 percent of the hazardous materials transported by truck. Corrosives are the next most-commonly transported material, but constitute less than 15 percent of the loads. Other regulated materials (ORM) constitute the third most commonly transported materials, constituting approximately 9 percent of the loads. ORM constitutes material not meeting any definitions of the other hazardous material classes, but "poses an unreasonable risk to health and safety when transported."

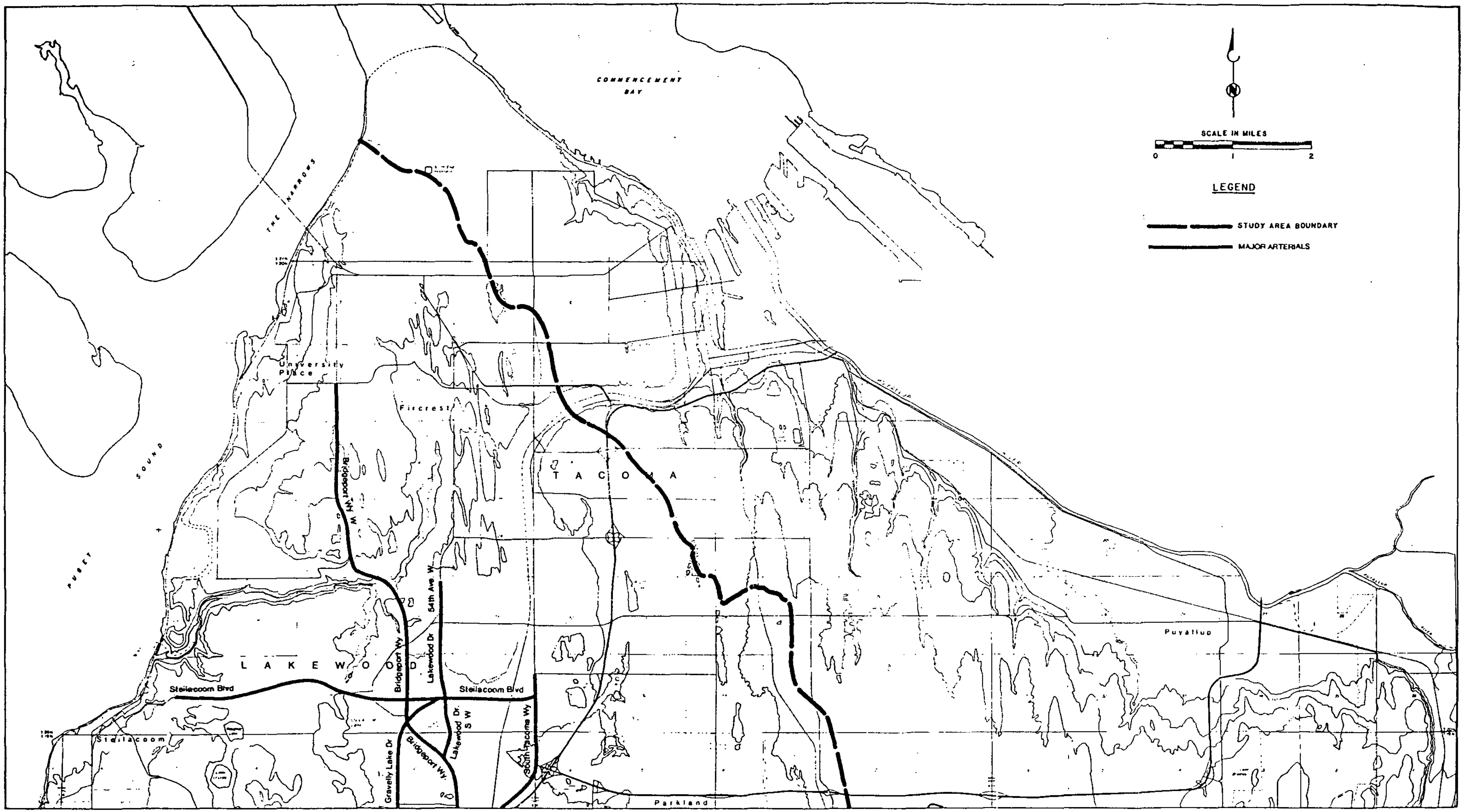


Figure A-2 Basin Roadways
(North Half)

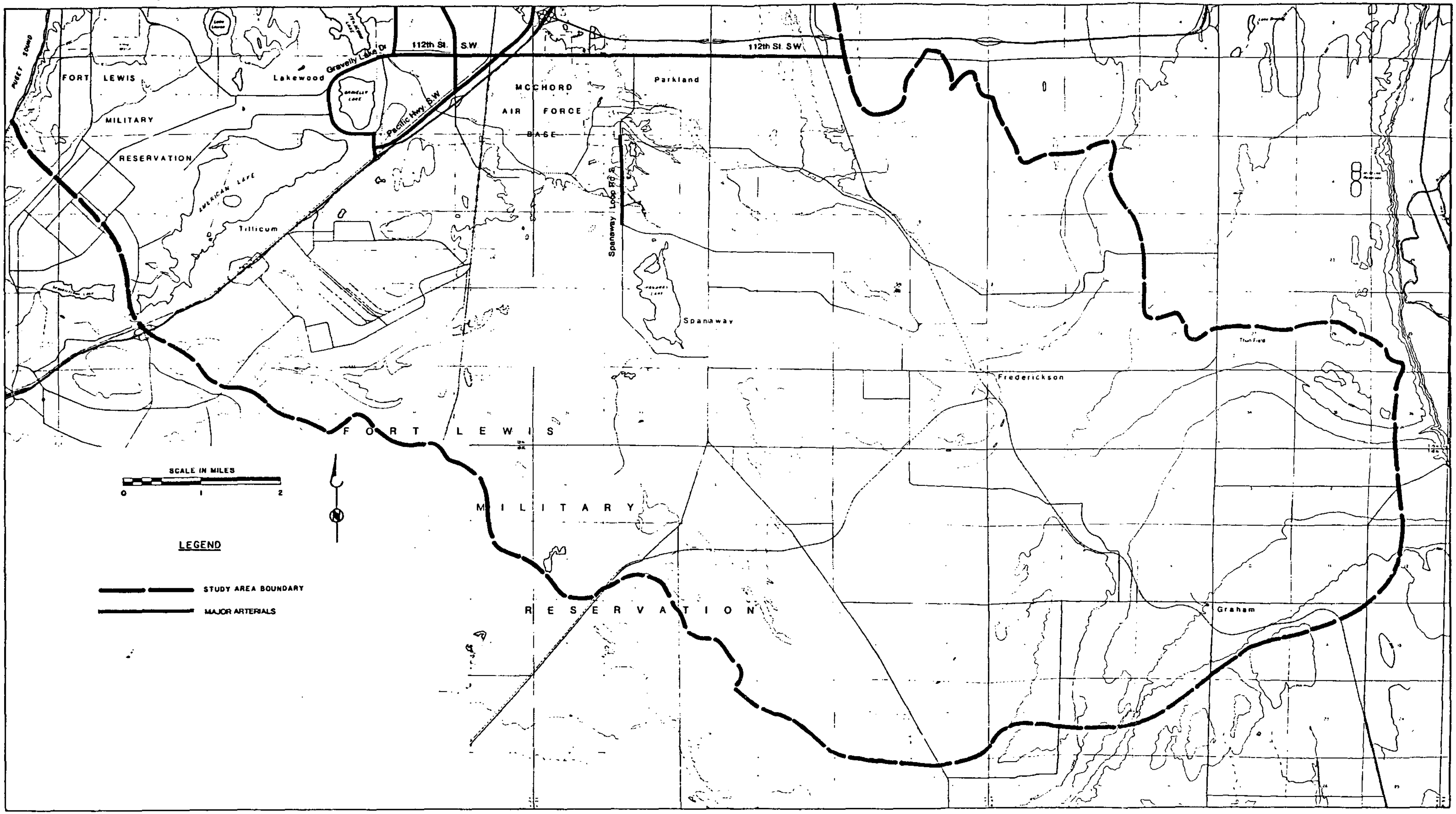


Figure A-2 Basin Roadways
(South Half)

The range of chemicals that could enter the ground water system via stormwater is nearly unbounded and includes such widely disparate contaminants as metal cations, dissolved anions, toxic organic solvents, petroleum derivatives, fertilizer and pesticides, and viral or bacterial pathogens. To make our analysis manageable, we grouped the wide range of contaminants into three broad classifications depending upon the physical properties (density and solubility) that govern their interaction with, and movement through, the ground water environment. These categories are:

Hazardous Material Type 1 (HM-1). Dissolved, water coincident materials.

Hazardous Material Type 2 (HM-2). Light, generally insoluble floating materials, characterized by petroleum products.

Hazardous Material Type 3 (HM-3). Dense, non-soluble sinking compounds, characterized by solvents.

These categories are not exhaustive, nor are they mutually exclusive. However, they do represent the most commonly-found chemical species, especially in industrial areas, and represent the three basic ground water contamination pathways.

Each major roadway within the CCC basin was characterized according to the types of materials likely to be transported along it. This information is summarized in Table A-2.

<u>Accident Rates.</u> Transport of hazardous materials in the CCC basin is typically of little concern to ground water quality unless there is an accident which results in a release of the transported materials. The highest accident rates occur on signalized arterials with speeds between 30 and 40 mph (U.S. Department of Transportation, June 1985). According to 1983 accident data compiled by the U.S. Department of Transportation, 46 percent of urban large truck accidents occurred on roads with speed limits between 30 and 40 mph. For single-axle trucks, the second highest accident category was the 25 mph or less zone (32 percent), while for multi-axle trucks, the second highest rate of accidents occurred in the 55 mph zone (28 percent). Roadways within the CCC basin fall into all of the speed categories at various locations. Figure A-3 illustrates speed limits on area roadways.

Accident rates for roadways within the CCC basin have not been computed. Accidents on several basin roadways were summarized by Pierce County Public Works staff, for roadways within Pierce County. Similar figures have not been compiled by the City of Tacoma for the area inside the incorporated Tacoma city limits. Calculating accident rates using numbers supplied by the Pierce County results in significantly lower rates than accident rates

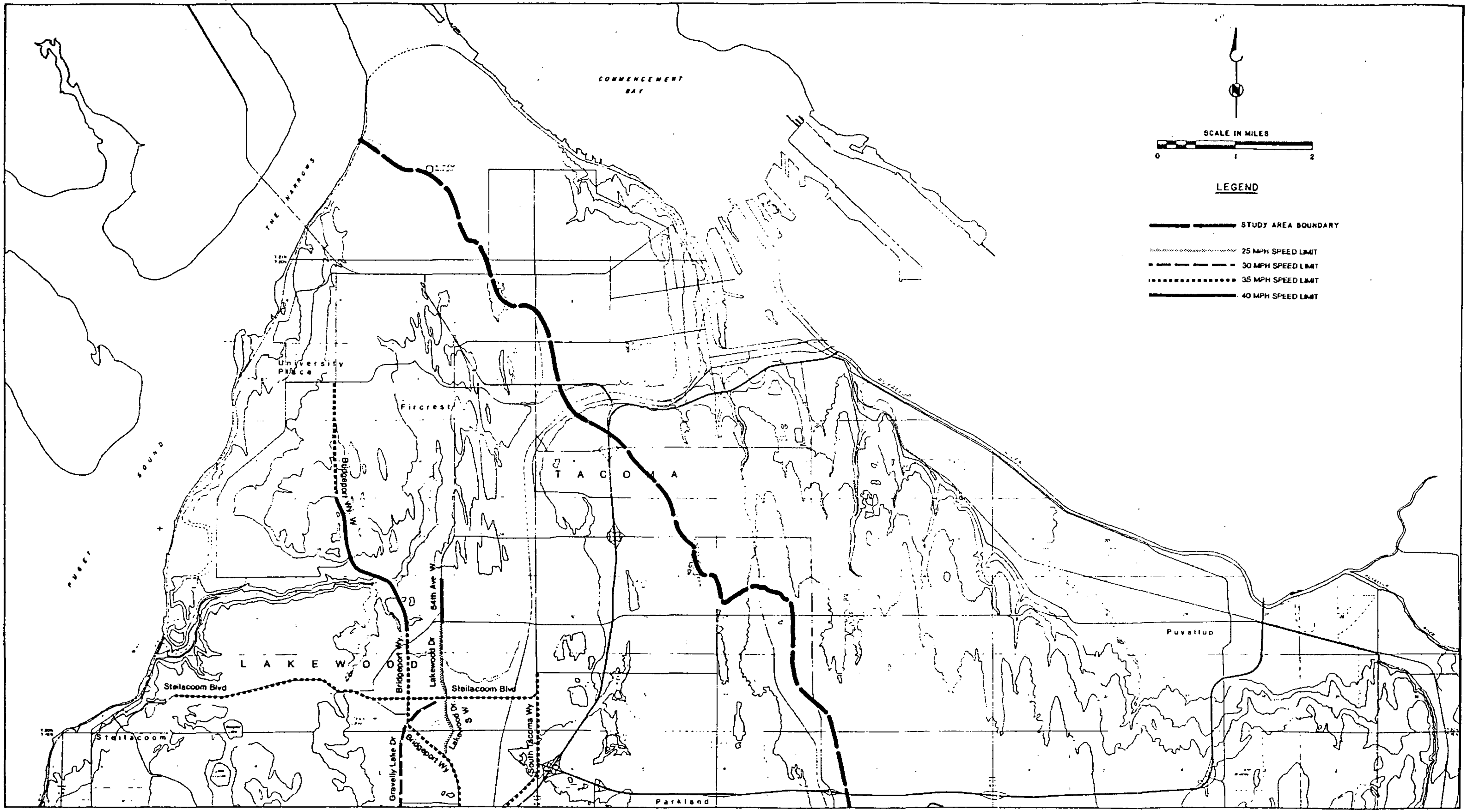


Figure A-3 Roadway Speed Limits
(North Half)

31-B

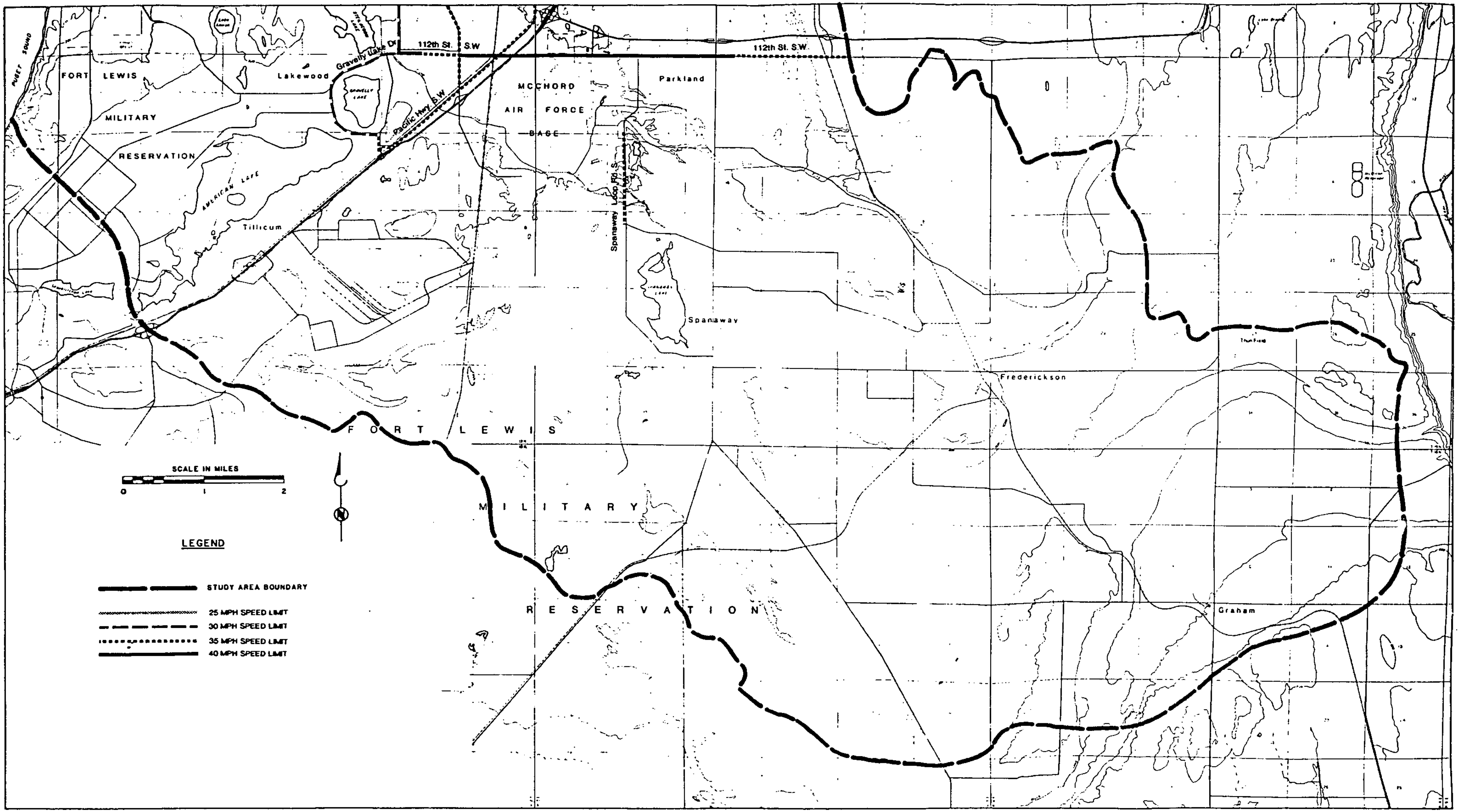


Figure A-3 Roadway Speed Limits
(South Half)

RISK ASSESSMENT CLOVER\CHAMBERS CREEK

TABLE A-1 - TRAFFIC COUNTS

STREET NAME	NUMBER OF MILES	AVG TOTAL TRAFFIC	TRUCK TRAFFIC*	HAZ MAT TRUCKS**
Bridgeport	7.5	18,620	1,862	186
S. Tacoma Way	2.5	24,492	2,449	245
Gravelly Lk Dr	3.0	19,572	1,957	196
Pacific Hwy SW	1.25	13,000	1,300	130
Steilacoom	2.25	19,882	1,988	199
112th Street	7.25	6,611	661	66
Spanaway Loop	1.30	11,124	1,112	111
Lakewood\Orchard	2.25	10,566	1,057	106

COMMENTS:

* Truck Traffic estimated to be 10% of Total Traffic

** Hazardous Material Trucks estimated to be 10% of Truck Traffic

RISK ASSESSMENT CLOVER\CHAMBERS CREEK

TABLE A-2 - SUMMARY OF HAZARDOUS MATERIALS

STREET NAME	HM-1	HM-2	HM-3
Bridgeport	15	70	15
S. Tacoma Way	5	85	10
Gravelly Lk Dr	10	70	20
Pacific Hwy SW	15	70	15
Steilacoom	20	70	10
112th Street	10	70	20
Spanaway Loop	20	70	10
Lakewood\Orchard	5	75	20

COMMENTS:

Numbers are expressed in estimated percentages.

calculated for SR 7 within the CCC basin by the Washington Department of Transportation (WDOT). It is unclear whether there is a disparity in accident reporting methodology between the two agencies, or if some other reason is contributing to the difference, such as substantially lower accident occurrence on CCC basin roadways. For this analysis, accident rates supplied by the Washington State Department of Transportation were utilized, because of the wider data base, and the similarity of roadway conditions on SR 7 to those found on CCC basin roads. Also, portions of SR 7 for which specific accident rates are available are located within the CCC basin.

Accident rates are based upon accidents per million vehicle trips per mile. For example, assuming an accident rate of 3.0 for a given roadway, for every one million vehicles that pass over that mile of roadway, there will be 3.0 accidents. The designated accident rates apply to all vehicles, not just trucks. Accident data specific to trucks was not available within the CCC basin. National data indicate that trucks have a higher accident rate than automobiles, however, because local data are not available, for this analysis the overall accident rate was used for trucks.

Accident probability is computed as accident rate multiplied by roadway length, and is expressed as accidents per million vehicle mile on a particular segment of roadway. For those roadways within the CCC basin where specific accident rates were not provided, we assumed that traffic volumes were uniform throughout the roadway section within the basin. Therefore, accident probabilities were considered uniform throughout the length of the roadway, which is likely an overly simplistic generalization. Roadways with the highest probability of an accident can be identified using this methodology, however, specific areas of high risk such as particular intersections will not be identified. This estimate includes only the probability that an accident will occur, and does not include the probability that a spill will result from an accident. The likelihood of spill occurrence is discussed below.

Spill Potential. Not all accidents occurring on CCC roadways will result in a release of hazardous material. The Department of Ecology has compiled records of spills within the CCC basin, which do not include transportation-related spills. The WSDOT does not have records of truck-related hazardous material spills, or the percentage of accidents involving trucks transporting hazardous materials that result in spills. Our research indicates that this data has not been compiled in Washington. The information was compiled by the Oregon Department of Transportation for 1987, however. During 1987 there were 38 accidents involving vehicles transporting hazardous materials, accounting for 2.3 percent of the total truck accidents during that year. Twenty-one percent of these accidents resulted in release or spill of hazardous materials. Flammable and combustible liquids (mostly petroleum products) resulted in 68 percent of the spills, and 89 percent of the spills occurred on rural arterials and highways.

Based on the Oregon research, we have assumed that 25 percent of the truck accidents occurring on the CCC basin arterials may result in spills of hazardous material. The likelihood of an accident involving the spill or release of hazardous materials along the basins major roadways is estimated in Table A-3.

South Tacoma Way has the highest probability of a spill, resulting from the highest truck volume and relatively high accident probability. It appears probable that an accident involving a spill of hazardous materials will occur along the portion of South Tacoma Way in the CCC basin within the next 7 to 15 years. (Assuming that 10% of the accidents resulted in a spill results in one spill every 15 years; assuming that 25% of the accidents result in a spill causes a probability of one spill every 7 years). Following South Tacoma Way in hazardous material accident probability is Gravelly Lake Drive, with a high probability of a hazardous material spill within the next 8 to 20 years. Those sections of Bridgeport Way and Pacific Highway South within the basin have a high probability of a hazardous material spill from a truck accident within the next 10 to 20 years. The remaining roadways analyzed have minimal risk of spills, with the probability of an accident resulting in a spill occurring once every 40 to 100 years.

High priority areas. The Clover/Chambers Creek Geohydrologic Study (Brown and Caldwell, 1985) identified areas of varying environmental sensitivity within the CCC basin, based upon the level of geohydrologic protection for ground water supplies. Higher sensitivity occurs where protective impermeable layers are absent. Spills occurring in areas where there is direct hydraulic continuity between the uppermost aquifer (Hydrostratigraphic Layer A) and the lower aquifer (Hydrostratigraphic Layer C) represent the greatest threat to ground water supplies.

Those roadways with the highest accident/spill probability located within areas where an impermeable layer is absent represent the greatest risk to ground water, should a spill occur. These roadways, including sections of South Tacoma Way, Lakewood/Orchard; 112th; Spanaway Loop; SR 7; and SR 512 (no traffic volumes are available but accident rates are likely comparable to SR 7). These roadways are illustrated on Figure A-4, which also illustrates the Environmental Sensitivity.

Railroads

Transportation facilities include railroads as well as roadways. Railroads are of concern because of the potential for railway

RISK ASSESSMENT CLOVER\CHAMBERS CREEK

TABLE A-3 - ACCIDENT PROBABILITY

STREET NAME	ACCIDENT RATE	% HAZ MAT ACCIDENTS	HAZ MAT SPILL PROBABILITY
Bridgeport	6.6	1 acc/2.3 yr/mile	1 spill/9.2 yr
S. Tacoma Way	6.7	1 acc/1.6 yr/mile	1 spill/6.4 yr
Gravelly Lk Dr	6.7	1 acc/2.1 yr/mile	1 spill/8.4 yr
Pacific Hwy SW	6.7	1 acc/3.1 yr/mile	1 spill/12.4 yr
Steilacoom	6.7	1 acc/2.6 yr/mile	1 spill/10.4 yr
112th Street	6.7	1 acc/5.4 yr/mile	1 spill/21.6 yr
Spanaway Loop	6.7	1 acc/2.8 yr/mile	1 spill/11.2 yr
Lakewood\Orchard	6.7	1 acc/1.8 yr/mile	1 spill/7.2 yr

COMMENTS:

Hazardous Material Spill Probability estimated to be 25% of accidents involving hazardous materials

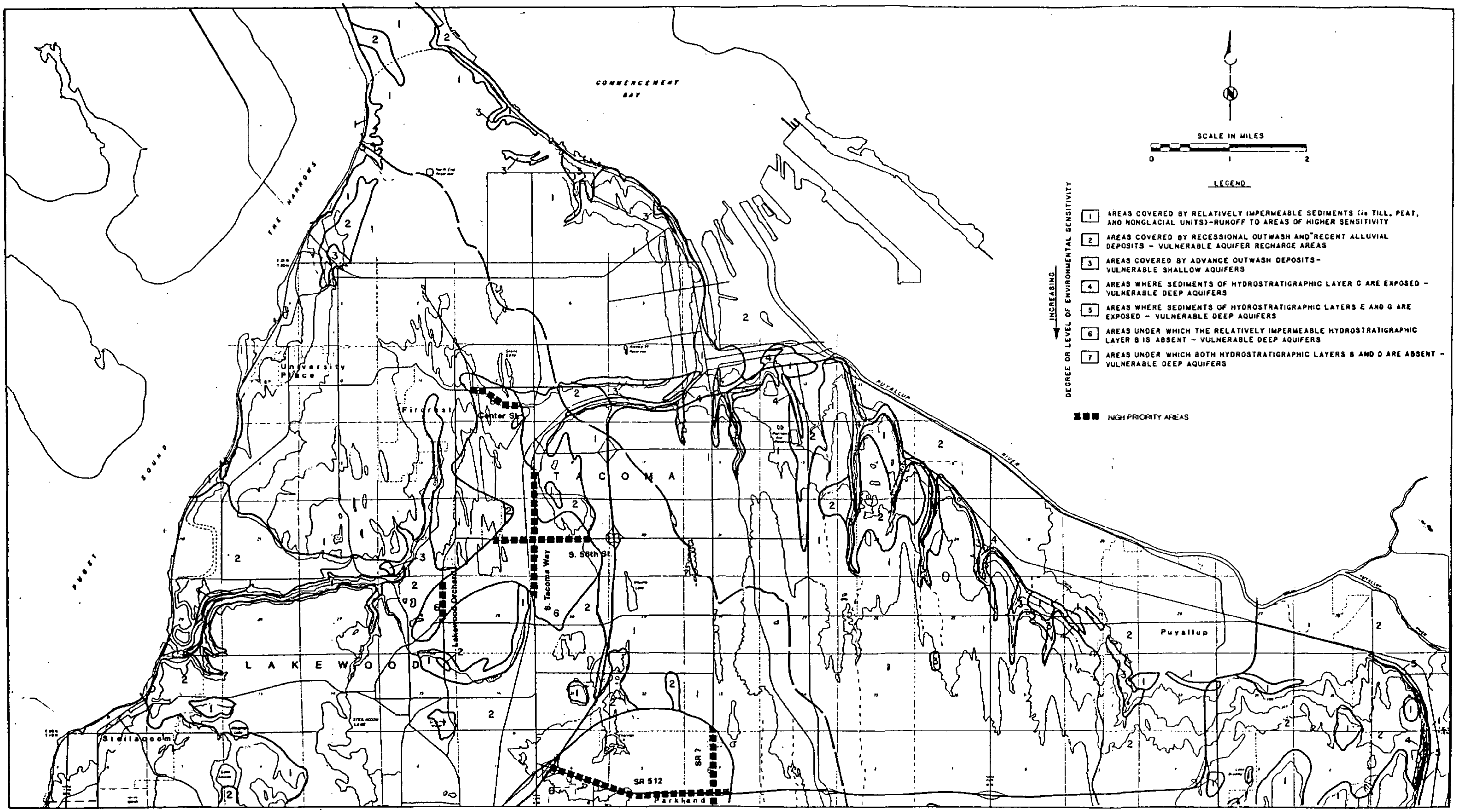
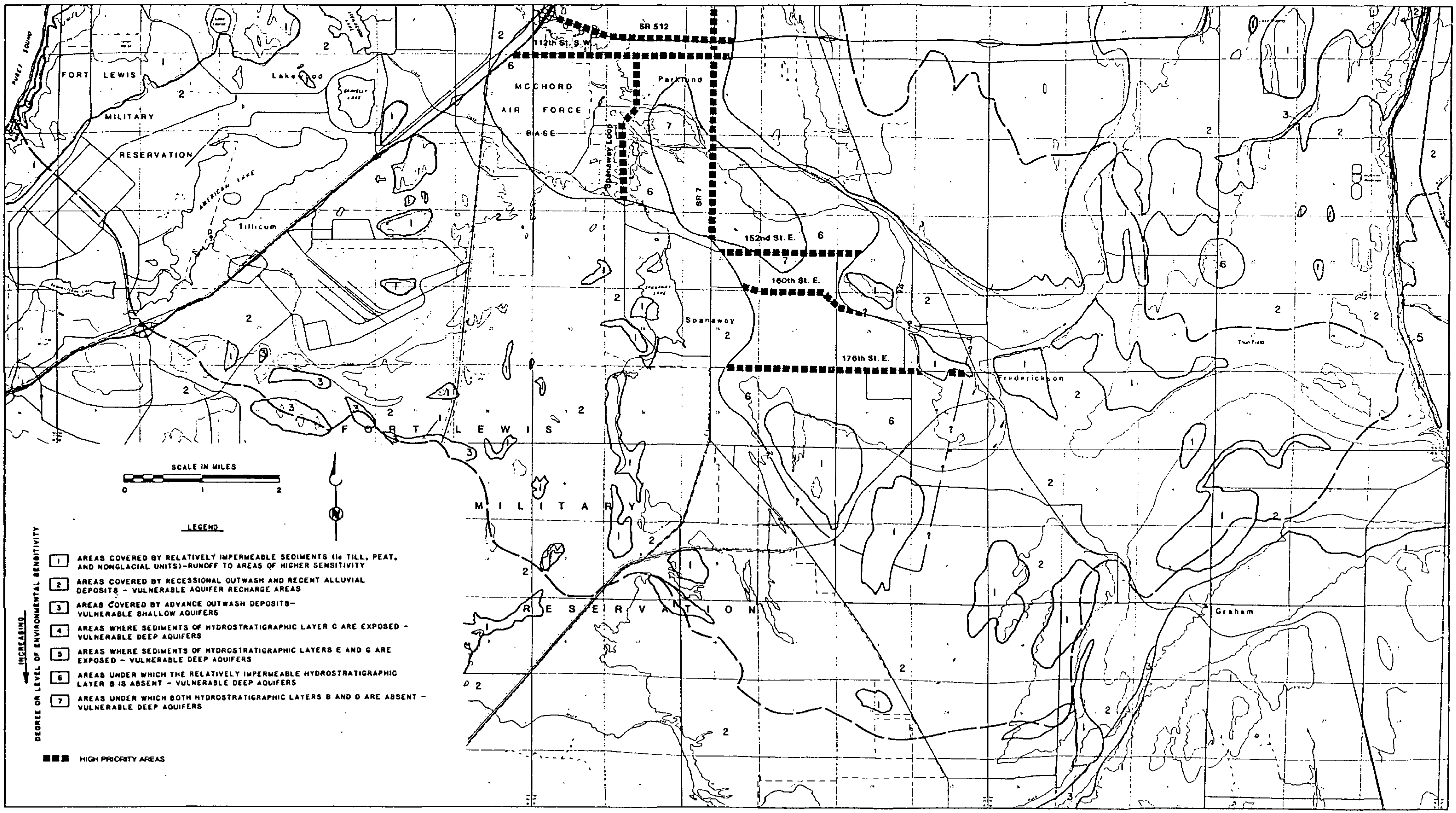


Figure A-4 Environmental Sensitivity (North Half)



FigureA-4 Environmental Sensitivity
(South Half)

accidents such as derailments or collisions which can result in spills of hazardous materials. Railway tanker cars have a capacity of up to 20,000 gallons, and are frequently used to carry hazardous materials.

The major railway line through the CCC basin is Burlington Northern. This line is reported to be the main freight line between Seattle and Vancouver, Washington, and has a train frequency of approximately 60 to 80 trains per day. There is another rail line, the Burlington Northern Old Prairie Line that serves mainly as a switching line for Fort Lewis and McChord Air Force Base, as well as other industries. Burlington Northern Railroad officials report that there have been "incidents" within the area, but they have no records of these spills and/or incidents.

The Burlington Northern Old Prairie Line is of greatest potential risk to ground water quality in the CCC Basin because it serves industries and military operations, and also includes significant portions within the highly Environmental Sensitive Areas. Typically, switching activities occur at low speeds, reducing the potential for accidents, but spills can still occur. It is possible to make only qualitative assessments regarding the risk to ground water from railroad activities because of the lack of accident data or information regarding transported materials, but railroad activities within the Environmentally Sensitive Areas (Areas 6 and 7 shown on Figure A-4) can be considered a moderate risk.

Airports

McChord Air Force Base has a military airport at its facility. This airport has numerous military jets tied down on-site, and has on-site storage of aviation fuel. There is a risk of fuel spills during airplane fueling, tank filling, and in the event of an accident. Historical water quality problems have resulted from on-site leaks and spills of aviation fuel at McChord AFB.

Spill Response

The environmental impact of a spill can depend in a large part upon the response and remedial action taken. The first course of action typically taken in the event of a spill is a call to 9-1-1, in which the local fire department responds. Depending on the conditions and location of the spill, the Tacoma/Pierce County Health Department, Pierce County Emergency Management, Department of Ecology, State Patrol, or the Coast Guard are notified. Within the CCC basin, there are several fire districts, including: District # 2, Lakewood; District #3, University Place; District #6, Parkland; District #7, Spanaway; and Midland.

In the event of a spill within the basin, Fire Department staff arrive on the scene, identify the material, and determine the next step of action, which could include containment and removal, or notification of other agencies with increased capability for hazardous material response.

The local fire departments and the Tacoma-Pierce County Health Department maintain records of spills and spill responses.

On-Site Sources of Contaminants

The risk of hazardous material spills from on-site activities or land use developments results from loading/unloading, underground and below-ground storage facilities' leaks, and process or operating leaks. Spills can infiltrate directly into the soil or be washed into the storm drainage system and enter either a drywell or other surface water system. The greatest risk is associated with industrial and commercial hazardous materials users. Nearly all industries use some quantity of solvents, degreasers, petroleum products (fuels), etc. Even small commercial operations such as dry cleaners and auto repair shops store small quantities of hazardous materials on site. The biggest concern in terms of large-quantity hazardous material spills are major industrial users who store large quantities of raw materials or waste materials on-site.

The Department of Ecology has recorded 11 hazardous material spills within the CCC basin since approximately mid-1987. Of these, one spill was of hazardous material type 1 (HM-1), four were of hazardous material type 2 (HM-2), and three were of hazardous material type 3 (HM-3).

According to Oregon DEQ spill records from 1983 to 1985, between 33 and 46 percent of the hazardous materials spills reported each year were due to offloading and in most cases attributed to operator error, equipment failure, or overfilling.

On-site equipment failure is a major potential source of hazardous material contamination for those industrial activities storing large quantities of such material. The most likely source of contamination is tank failure. For most existing underground storage tanks, a leak can continue undetected for years. The average life span of an underground storage tank is estimated at 17 to 18 years. An American Petroleum Institute Survey found that after 20 years, nearly 90 percent of all petroleum tanks surveyed had leaked or failed. (Most of these tanks were single-walled steel.) Most of the storage tanks, including gasoline and fuel tanks, older than about 15 years are likely to be leaking at the present time or will be leaking soon. Above ground storage tanks have a lower probability of undetected failure because spills or leaks are visible.

Fifty-five gallon drums and smaller containers are the size most often used to store corrosive materials such as acids, bases, and solvents. These containers can be dropped during transport and offloading. Although a 55-gallon spill may seem small compared to a 2000-gallon tanker truck, highly concentrated materials (such as solvents, acids or corrosives) often contained in the drums can have significant impact upon ground water quality.

In summary, on-site storage and transfer practices represent a major source of the on-site spills of hazardous materials. Within the CCC basin, the areas of most concern are those industries located within the Environmentally Sensitive Areas illustrated on Figure A-4.

Industries of Concern

A wide variety of industrial and commercial hazardous material users are present in the CCC basin. These industries were illustrated on Figure 4-3, Potential Sources of Contamination, in the Clover/Chambers Creek Geohydrologic Study (Brown and Caldwell, 1985). The greatest concentration of industries using hazardous materials is along South Tacoma Way. Businesses in this area have recently fallen under a City of Tacoma ordinance regulating the storage and disposal of hazardous materials. This ordinance, regulating the South Tacoma Channel, focuses upon underground storage tanks as opposed to small quantity hazardous materials users. The risk of spills from use, storage and loading of small quantities of hazardous materials continues to exist. The area of greatest potential risk is that portion of South Tacoma Way located within the high Environmental Sensitivity designation (illustrated on Figure A-4). Spills in Environmentally Sensitive Areas 6 and 7 are likely to directly enter the ground water system in areas where Hydrostratigraphic Layer B is absent, thus having the potential to contaminate both the shallow and deeper aquifer.

RISK OF GROUND WATER CONTAMINATION

The relative risk of ground water contamination from potential sources with the Clover/Chambers Creek Basin is discussed below. The sources will be described according to potential for ground water contamination (significant, moderate, low); this potential will be compared with the potential hydrogeologic sensitivity (i.e., potential to enter ground water system).

NON-POINT SOURCES

Non-point sources of contamination contribute contaminants in a diffuse, widespread manner. Although the individual contaminant contributions may not be significant, the additive effect can be substantial. Following is a discussion of the major non-point sources of contamination in the Clover/Chambers Creek Basin.

Runoff

Based upon recent research conducted by the Tacoma-Pierce County Health Department (Adolfson Associates, Brown and Caldwell, and Sweet-Edwards/EMCON, 1989), chronic, day-to-day runoff discharged to drywells in the CCC basin enters the shallow ground water system with minimal attenuation. Particulates appear to be migrating through the vadose zone, including lead, copper and zinc. There was no indication in the study that attenuation of constituents contained in runoff was occurring prior to entering the shallow ground water system. Therefore, it appears that materials discharged to basin drywells enter the ground water system with minimal attenuation.

Stormwater disposal can become a point source of contamination if a spill or leak of a hazardous material occurs within the drainage area. This occurrence represents a significant risk, and is described in more detail in the following discussion regarding point source contamination.

POINT SOURCES

Point sources of contamination are single sources or events that discharge significant quantities of contaminants to the receiving environment. In the CCC basin, point sources of most concern are associated with accidental releases of contaminants through a leak or spill.

Transportation-Related Spills

As discussed earlier, there is a relatively high probability of an accident, resulting in the spill of hazardous materials, occurring on one of the basin's major transportation arterials within the next ten years. Should an accident occur, it is likely that some portion of the hazardous material will enter a drywell. The fate of the spilled material will depend largely on the remedial response, location of the spill (slope, soil conditions, etc.), weather conditions, and the quantity and type of material spilled. There are numerous factors that can affect the outcome of such a spill. Based upon our review of area roadway accident statistics, we feel that transportation spills represent a significant risk to ground water in the CCC basin. The material most likely to be spilled is gasoline or other petroleum products, followed by numerous soluble and insoluble chemicals, including solvents.

High risk roadways. Table A-4 summarizes the basin roadways according to relative risk to ground water. South Tacoma Way, between South 62nd Street and South 72nd Street, represents the

RISK ASSESSMENT CLOVER\CHAMBERS CREEK

TABLE A-4 - SUMMARY OF ROADWAY RISK POTENTIAL

HIGH RISK ROADWAYS

South Tacoma Way
Lakewood Drive/Orchard Street

MODERATE RISK ROADWAYS

Gravelly Lake Drive
Bridgeport Way
Pacific Highway South
Steilacoom Boulevard
Spanaway Loop Road

LOW RISK ROADWAYS

112th Avenue

highest risk to ground water in the area because of the high density of industries in the area, high traffic volume, and high environmental sensitivity. Review of accident rates and traffic volumes indicate that there is a high probability of at least one accident occurring involving a hazardous material spill within the next 7 to 15 years. The material most likely to be involved in the spill is HM-2, (light insoluble organics, largely petroleum products), based upon review of existing industries in the area. A spill of even a small quantity of hazardous materials in this area could have disastrous impacts upon ground water. This area is the highest priority for spill containment measures.

Lakewood Drive/Orchard Street, between South 62nd and South 72nd Streets represents the next priority in implementation of spill containment/control measures. Similar to South Tacoma Way, the dense utilization of industries served by drywells, with a high volume of truck traffic combines to present a high risk to ground water.

Moderate risk roadways.

Gravelly Lake Drive and Bridgeport Way fall into the Moderate Risk Category, with a high probability of having a hazardous material spill within the next 10 years, but they are located in less environmentally sensitive areas.

Other moderate risk roadways within the basin include: Pacific Highway South, Steilacoom Boulevard, and Spanaway Loop Road. These roadways have a probability of having a hazardous material spill within the next 10 to 20 years. Spanaway Loop Road should be highlighted, however, because it is located in the high Environmental Sensitivity category. The estimated hazardous material spill probability is approximately once every 11 years; considering the level of accuracy of some of the data utilized, this roadway could conservatively be considered high risk.

Low risk roadways.

The single roadway within the basin characterized as low risk is 112th Street. This roadway has an estimated probability of having a hazardous material spill within approximately 22 years. 112th Avenue is located in the highest risk category according to the hydrostratigraphy, but it has a lower probability of a hazardous material spill associated with a transportation accident.

SUMMARY

There are several sources of contaminants within CCC basin that pose a relatively high risk to ground water. These sources include several basin roadways. Roadways within the high risk category are recommended for additional analysis to determine potential measures for mitigation, including spill containment and/or control.

APPENDIX B

BORING LOGS

GROUND WATER MONITORING WELLS
STORMWATER EVALUATION

CLOVER/CHAMBERS CREEK BASIN
GROUND WATER MANAGEMENT PROGRAM

Sweet-Edwards/EMCON, Inc.
Ground Water, Engineering, Waste Management, & Drilling Services

14590 N.E. 95th • Redmond, WA 98052-2251
Office (206) 881-0415 • FAX (206) 867-1104

March 14, 1988
Project No. S02.13-01.05

Mr. Kirk Sinclair
Department of Ecology
7272 Cleanwater Lane, MS LU-11
Olympia, WA 98504-6811

Re: Resource Protection
Well Report

Dear Kirk:

Enclosed are two (2) Resource Protection Well Reports, which include nine (9) boring logs, completed for the Clover/Chambers Creek Ground Water Management Plan. On February 25, 1988, Sweet-Edwards/EMCON (SE/E) received approval from Bill Miller to submit boring logs with well details completed on our Boring Log form (SEA-300-02a) with one WDOE reporting form completed for each drilling site.

If you have any questions or comments, please call either myself at (206) 572-3099 or Jim Bailey at (206) 881-0415.

Respectfully submitted,
Sweet-Edwards/EMCON, Inc.

[signature] for
Denise E. Mills
Hydrogeologist

DEM:kk
enclosures
cc: Lisa Adolfson; SE/E, Redmond
Jim Bailey; SE/E, Redmond
Gerritt Rosenthal; SE/E, Kelso

RES PRO-L.314

RESOURCE PROTECTION WELL REPORT

START CARD NO. 016957

PROJECT NAME: Clover | Chambers Ck GWMP*

WELL INDENTIFICATION NO. See attached logs

DRILLING METHOD: Hollow Stem Auger

DRILLER: Eric Hansen

FIRM: Tacoma Pump & Drilling Co.

SIGNATURE: ER HANSEN

CONSULTING FIRM: Sweet-Edwards/EMCON

REPRESENTATIVE: Denise Mills

LOCATION: T 20N, R 2E, SEC. 35

DISTANCE: 10 FT. FROM N/(S) SECTION LINE

2,850 FT. FROM (E)/W SECTION LINE

DATUM: See attached logs

WATER LEVEL ELEVATION: See attached logs

INSTALLED: See attached logs

DEVELOPED: 1/28 - 2/5/88 (surge/bail)

*GWMP = Ground Water Management Plan

AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	NOTE: Four 2-inch dia. PVC monitoring wells were installed at this location. These wells are designated CC-1, CC-2, CC-3, and CC-8. Lithologic descriptions and as-built well details for each of these wells are attached (Form SEA-300-02a).	

SCALE: 1" = 10 ft

Sweet, Edwards & Associates, Inc.

BORING LOG

PROJECT Clover/Chambers Creek Ground Water Management Plan **Page** 2 **of** 5

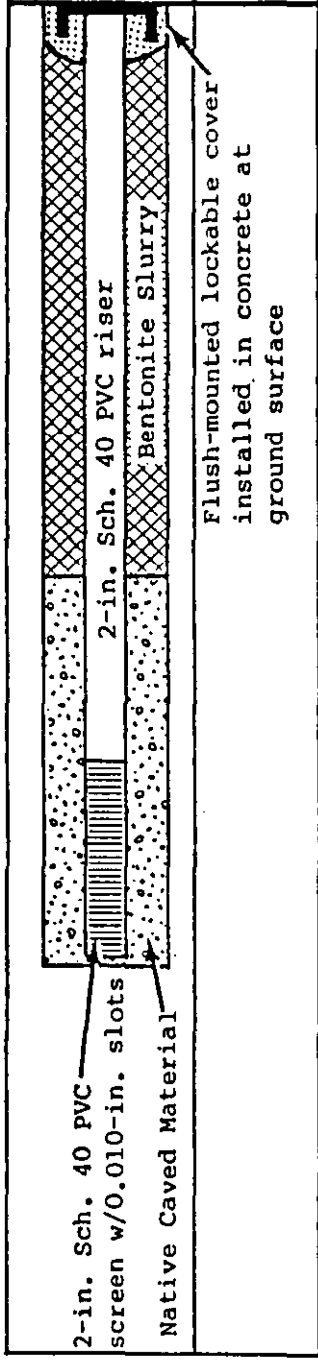
Location Near intersection of Mt. Tacoma Dr. SW and Bridgeport Way **Boring No.** CC-1

Surface Elevation 260.59 ft. (USGS) **Drilling Method** Hollow Stem Auger

Total Depth 50 feet **Drilled By** Tacoma Pump & Drilling Co.

Date Completed 1/26/88 **Logged By** D.E. Mills

WELL DETAILS:



DEPTH (FEET)	SAMPLE NO.	SAMPLE TYPE	PERMEABILITY TESTING	SYMBOL	LITHOLOGIC DESCRIPTION	WATER QUALITY
0–9				GP	0-4" Asphalt 4"-9 ft. GRAVEL, brown, dry, med to coarse, subrounded-rounded; trace fine sand and silt	
10				GP	9-11 ft. Sandy GRAVEL, brown, dry, fine, subrounded	
20, 30				GW	11-39 ft. GRAVEL, brown, dry, fine to coarse, subrounded; trace silt	
40				SP-SM	37-50 ft. Gravelly SAND with silt, tan, saturated, very dense; med to coarse. Gravel to 1", rounded.	
50					Bottom at 50 ft.	

SEA-300-02a

Sweet, Edwards & Associates, Inc.

BORING LOG

PROJECT Clover/Chambers Creek Ground Water Management Plan **Page** 3 **of** 5

Location Near intersection of Mt. Tacoma Dr. SW and Bridgeport Way

Boring No. CC-2

Surface Elevation 260.62 ft. (USGS)

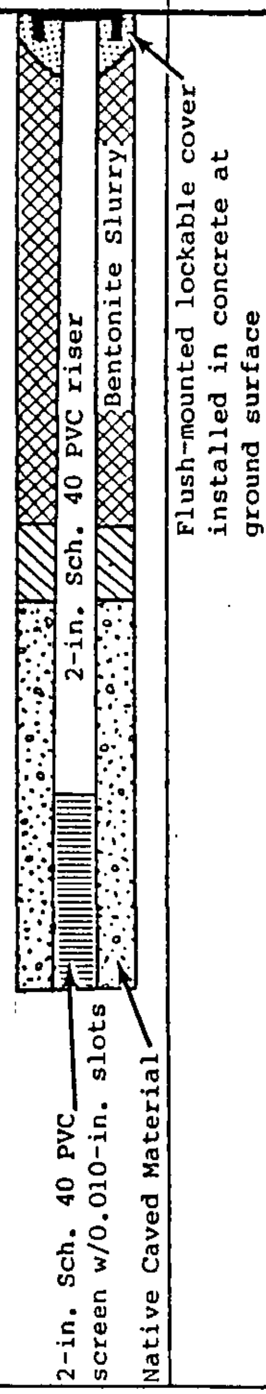
Drilling Method Hollow Stem Auger

Total Depth 50 ft.

Drilled By Tacoma Pump & Drilling Co.

Date Completed 1/27/88

Logged By D.E. Mills



WELL DETAILS	PENETRATION TIME/RATE	DEPTH (FEET)	SAMPLE NO.	SAMPLE TYPE	PERMEABILITY TESTING	SYMBOL	LITHOLOGIC DESCRIPTION	WATER QUALITY
		0					0-4" Asphalt	
						GP	4"-40 ft. GRAVEL, brown, dry, trace silt, fine to coarse, variable sizes with depth. Rounded.	
		10					— greasy coating on gravel from 10-15 ft.	
		20					— increased sand content at 23 ft.	
		30					— oily odor at 30 ft., oily coating on gravel	
		40				SP	40-50 ft. SAND, grey, saturated, fine to med. Trace gravel to 1", rounded.	
		50					Bottom at 50 ft.	

Sweet, Edwards & Associates, Inc.

BORING LOG

PROJECT Clover/Chambers Creek Ground Water Management Plan **Page** 4 **of** 5

Location Near intersection of Mt. Tacoma Dr. SW and Bridgeport Way

Boring No. CC-3

Surface Elevation 260.63 ft. (USGS)

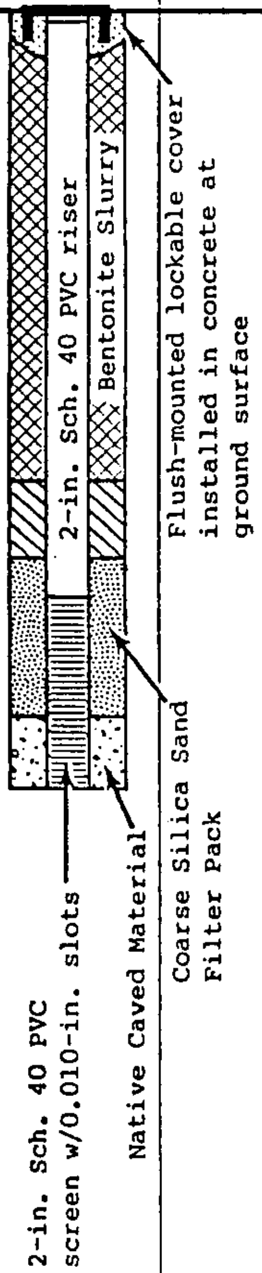
Drilling Method Hollow Stem Auger

Total Depth 40 ft.

Drilled By Tacoma Pump & Drilling Co.

Date Completed 1/27/88

Logged By D.E. Mills



WELL DETAILS	PENETRATION TIME/RATE	DEPTH (FEET)	SAMPLE NO.	SAMPLE TYPE	PERMEABILITY TESTING	SYMBOL	LITHOLOGIC DESCRIPTION	WATER QUALITY
		10				GP	0-4" Asphalt 4"-22 ft. Sandy GRAVEL, light brown, dry, fine to med, rounded — large boulder at 13 ft.	
		20						
		30				GP	22-35 ft. GRAVEL, brown, dry, with sand. Trace 5" cobbles — increasing fine sand and silt content with depth	
		40				GP	35-40 ft. ? Sandy GRAVEL, ? dark grey, saturated, trace silt	
							Bottom at 40 ft.	

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BORING LOG

PROJECT Clover/Chambers Creek Ground Water Management Plan **Page** 5 **of** 5

Location Near intersection of Mt. Tacoma Dr. SW and Bridgeport Way

Boring No. CC-8

Surface Elevation 260.71 ft. (USGS)

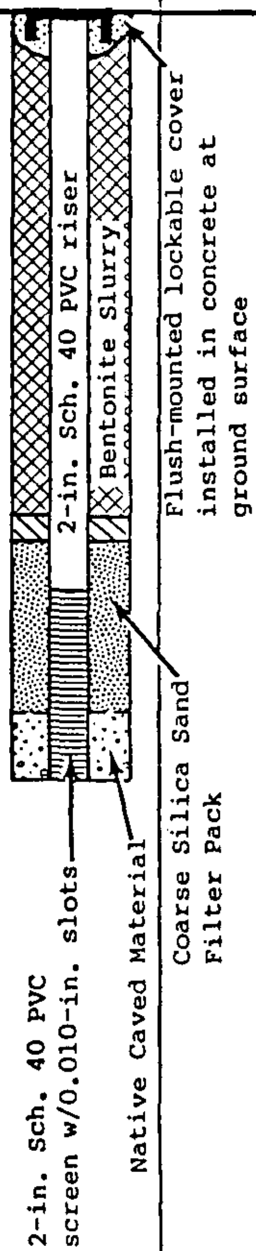
Drilling Method Hollow Stem Auger

Total Depth 40 ft.

Drilled By Tacoma Pump & Drilling Co.

Date Completed 2/2/88

Logged By D.E. Mills

WELL DETAILS	PENETRATION TIME/RATE	DEPTH (FEET)	SAMPLE NO.	SAMPLE TYPE	PERMEABILITY TESTING	SYMBOL	LITHOLOGIC DESCRIPTION	WATER QUALITY
							0-4" Asphalt	
							4"-25 ft. GRAVEL to Sandy GRAVEL, brown, dry, med to coarse. Variable ratios of sand trace silt	
		10				GP		
							boulder (?) at 15 ft.	
							oily between 15 and 20 ft.	
		20						
						?	25-40 ft Sandy GRAVEL, brown, moist, fine to med gravel, sand fine to coarse. Trace silt.	
		30				GP		
		40					Bottom at 40 ft.	

RESOURCE PROTECTION WELL REPORT

START CARD NO. 016956

PROJECT NAME: Clover/Chambers Ck GWMP*

WELL INDENTIFICATION NO. SEE ATTACHED LOGS

DRILLING METHOD: HOLLOW STEM AUGER

DRILLER: ERIC HANSEN

FIRM: TACOMA PUMP & DRILLING CO.

SIGNATURE: Eric Hansen

CONSULTING FIRM: SWEET-EDWARDS/EMCON

REPRESENTATIVE: Denise Mills

LOCATION: T 20N, R 2E, SEC. 36

DISTANCE: 100 FT. FROM N/(S) SECTION LINE

50 FT. FROM (E)/W SECTION LINE

DATUM: SEE ATTACHED LOGS

WATER LEVEL ELEVATION: SEE ATTACHED LOGS

INSTALLED: SEE ATTACHED LOGS

DEVELOPED: 1/28 - 2/5/88 (surge/bail)

*GWMP = Ground Water Management Plan

AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	NOTE: Five 2-inch dia. PVC monitoring wells were installed at this site. These wells are designated CC-4, CC-5, CC-6, CC-7, and CC-9. Lithologic descriptions and well details for each of these wells are attached (Form SEA-300-02a).	

SCALE: 1" = 10 ft

ECY 050-12

Sweet, Edwards & Associates, Inc.

BORING LOG

PROJECT Clover/Chambers Creek Ground Water Management Plan **Page** 2 **of** 6

Location 9312 S. Tacoma Way

Boring No. CC-4

Surface Elevation 282.94 ft. (USGS)

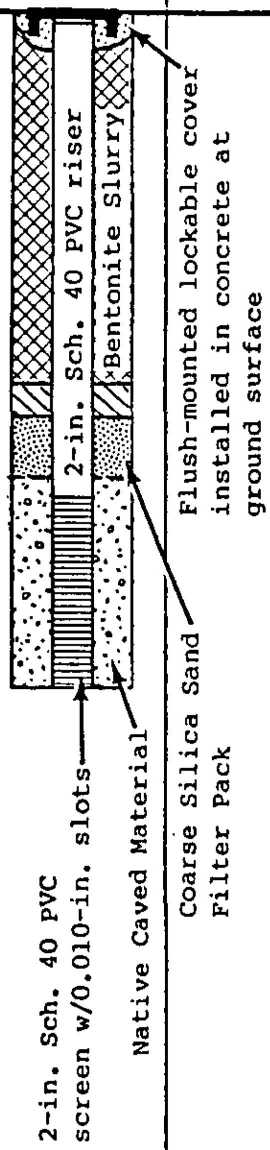
Drilling Method Hollow Stem Auger

Total Depth 35 ft.

Drilled By Tacoma Pump & Drilling Co.

Date Completed 1/28/88

Logged By D.E. Mills



WELL DETAILS	PENETRATION TIME/RATE	DEPTH (FEET)	SAMPLE NO.	SAMPLE TYPE	PERMEABILITY TESTING	SYMBOL	LITHOLOGIC DESCRIPTION	WATER QUALITY
		0–26 (10, 20)				GP	0-4" Asphalt 4"-26 ft. GRAVEL to Sandy GRAVEL, brown, dry, fine to med, rounded	
		26–35 (30)				SM	26-35 ft. Interbedded Silty SAND and clayey to sandy SILT, grey, saturated, dense. Trace gravel	
		40					Bottom at 35 ft.	

SEA-300-02a

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BORING LOG

PROJECT Clover/Chambers Creek Ground Water Management Plan **Page** 3 **of** 6

Location 9312 S. Tacoma Way

Boring No. CC-5

Surface Elevation 283.07 ft. (USGS)

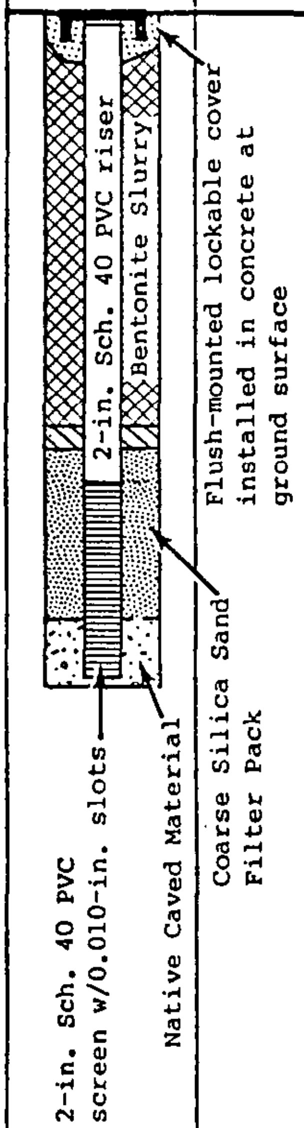
Drilling Method Hollow Stem Auger

Total Depth 35 ft.

Drilled By Tacoma Pump & Drilling Co.

Date Completed 1/29/88

Logged By D.E. Mills



WELL DETAILS	PENETRATION TIME/RATE	DEPTH (FEET)	SAMPLE NO.	SAMPLE TYPE	PERMEABILITY TESTING	SYMBOL	LITHOLOGIC DESCRIPTION	WATER QUALITY
		0–27.5 (10, 20)				GP	0-4" Asphalt 4"-27.5 ft. GRAVEL and Sandy GRAVEL, brown, dry, rounded	
		27.5–35 (30)				SM	27.5-35 ft. Silty SAND, grey, saturated. Interlayered with sandy silt, variable silt/sand ratios. Tan near the top.	
		40					Bottom at 35 ft.	

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BORING LOG

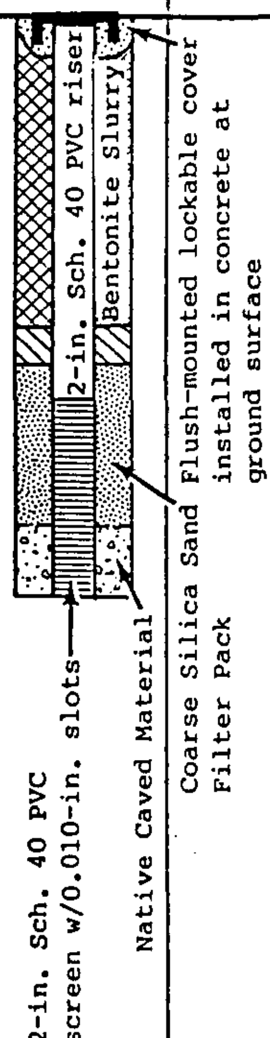
PROJECT Clover/Chambers Creek Ground Water Management Plan **Page** 4 **of** 6

Location 9312 S. Tacoma Way | **Boring No.** CC-6

Surface Elevation 283.34 ft. (USGS) | **Drilling Method** Hollow Stem Auger

Total Depth 30 ft. | **Drilled By** Tacoma Pump & Drilling Co.

Date Completed 1/29/88 | **Logged By** D.E. Mills



WELL DETAILS	PENETRATION TIME/RATE	DEPTH (FEET)	SAMPLE NO.	SAMPLE TYPE	PERMEABILITY TESTING	SYMBOL	LITHOLOGIC DESCRIPTION	WATER QUALITY
							0-4" Asphalt 4"-29 ft. GRAVEL and Sandy GRAVEL, brown, dry. Variable ratios of sand and gravel	
							29-30 ft. Silty SAND with gravel, grey, saturated, fine to med sand, trace coarse gravel to 1-1/2", rounded	
							Bottom at 30 ft.	

SEA-300-02a

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BORING LOG

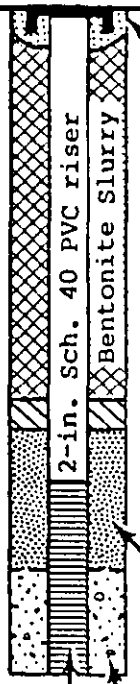
PROJECT Clover/Chambers Creek Ground Water Management Plan **Page** 5 **of** 6

Location 9312 S. Tacoma Way **Boring No.** CC-7

Surface Elevation 283.10 ft. (USGS) **Drilling Method** Hollow Stem Auger

Total Depth 30 ft. **Drilled By** Tacoma Pump & Drilling Co.

Date Completed 1/29/88 **Logged By** D.E. Mills

WELL DETAILS	PENE-TRATION TIME/RATE	DEPTH (FEET)	SAMPLE NO.	SAMPLE TYPE	PERME-ABILITY TESTING	SYMBOL	LITHOLOGIC DESCRIPTION	WATER QUALITY
						GW	0-2" Asphalt 2"-9.5 ft. GRAVEL, brown, moist, med to coarse. Small cobbles to 5" dia.	
		10				GP	9.5-23 ft. Sandy GRAVEL, brown, moist, fine to med. Sand is med to coarse	
		20				SM	23-28 ft. Silty SAND, grey, moist, dense (?). Trace gravel	
		30				ML	28-35 ft. Sandy SILT with clay, grey, saturated, fine sand. Trace fine gravel. Silty sand beds are common	
		40					Bottom at 30 ft.	

Sweet, Edwards & Associates, Inc.

BORING LOG

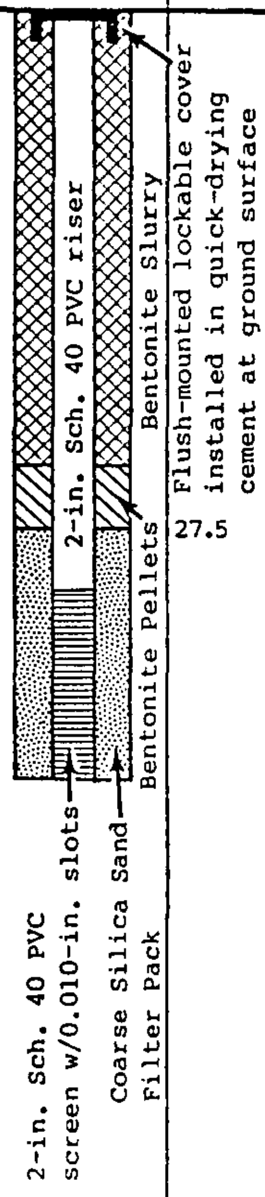
PROJECT Clover/Chambers Creek Ground Water Management Plan **Page** 6 **of** 6

Location 9312 S. Tacoma Way **Boring No.** CC-9

Surface Elevation 283.23 ft. (USGS) **Drilling Method** Hollow Stem Auger

Total Depth 40 ft. **Drilled By** Tacoma Pump & Drilling Co.

Date Completed 2/25/88 **Logged By** L.B. Adolfson

WELL DETAILS	PENETRATION TIME/RATE	DEPTH (FEET)	SAMPLE NO.	SAMPLE TYPE	PERMEABILITY TESTING	SYMBOL	LITHOLOGIC DESCRIPTION	WATER QUALITY
						GP	0-4" Asphalt Cover 4"-10 ft. GRAVEL, brown, dry, rounded, coarse, some fine sand and silt	
		10				GP	10-12 ft. Sandy GRAVEL, brown, moist, rounded, trace silt	
						GP	12-26 ft. Sandy GRAVEL, some silt, greyish brown, moist, slightly cohesive, rounded gravel	
		20						
	27.5					ML	26-40 ft. Sandy SILT, greyish brown, saturated, fine sand, trace fine gravel, trace clay (?)	
		30						
		40					Bottom at 40 ft.	

APPENDIX C

TRACER INJECTION AND STORM SAMPLING METHODOLOGY

BY

SWEET-EDWARDS/EMCON

M E M O R A N D U M

TO: Molly Adolfson
Gerritt Rosenthal

FROM: Denise Mills
Lisa Adolfson LBA

DATE: July 7, 1988

RE: Clover/Chambers Creek GWMP
Tracer Injection and Storm Sampling

TRACER INJECTION

Mt. Tacoma Drive S.W.

On February 9, 1988 at 8:30 a.m., a solution of lithium chloride (LiCl) was injected into the dry well (DW-1). The depth of water in the dry well prior to adding the LiCl was 2.5 feet from ground surface. A solution of LiCl was made by dissolving 2.5 kg of dry LiCl in 9.5 gallons of water. The electrical conductance of this solution was 8,010 umhos/cm.

Koreana Plaza

On March 4, 1988 at 14:10, a solution consisting of 1.25 kg LiCl and 5 gallons of water was added to the dry well (DW-2). The electrical conductance of the solution was 114,400 umhos/cm. DW-2 had less than 6 inches of water standing in the drywell prior to adding the LiCl solution. After adding the LiCl, an additional 25 gallons of water was injected to ensure distribution of the tracer in the surrounding gravels.

TRACER SAMPLING

Mt. Tacoma Drive S.W.

Background LiCl samples were obtained on February 2 to 3, 1988. After tracer injection, LiCl samples were collected on February 18, 25, and March 7, 1988. Travel time for storm water was estimated to be between 13 and 18 days (velocity estimated at 1.5 ft/day), for interlayered silt and sandy silt. Samples were obtained after bailing approximately 1 pore volume from each well.

Koreana Plaza

Background LiCl samples for wells CC-4, CC-5 and CC-7 were obtained on February 3, 1988. A background sample for CC-6 was obtained on February 5 due to it bailing dry on February 2. CC-9 background sample was collected on March 3, 1988 due to the later construction date. Travel velocities for storm water traveling through Steilacoom gravel was estimated to be between 29 and 290 ft/day.

After injection, three wells were "continuously" sampled for LiCl. CC-4 (upgradient) was sampled at 15:45 and 18:00 on March 4; 10:30 on March 5; and 17:00 on March 7. CC-7 (side gradient) was sampled at 15:10 and 17:50 on March 4; 10:00 on March 5; and 16:40 on March 7. CC-9 (downgradient) was sampled at 14:44, 15:30 and 17:45 on March 4; 9:30 on March 5; and 16:25 on March 7. Samples were obtained after bailing approximately 1 pore volume from each well.

STORM SAMPLING

The dry wells were sampled during or soon after a storm event when there was sufficient water in the dry well to obtain a sample. The dry well at Koreana Plaza (DW-2) drained very rapidly (approximately 45 minutes) and some storms were missed. The dry well at Mt. Tacoma Drive drained much more slowly.

Prior to sampling, the depth to water was measured using an ACTAT 300 Olympic Well Probe or similar instrument.

All samples, except Fecal Coliform, were shipped via Greyhound to Columbia Analytical Services (CAS), Longview, Washington. Fecal coliform samples were hand delivered to the Tacoma-Pierce County Health Department (TPCHD), Tacoma, Washington. Due to the short holding time (24 hours), and the fact that TPCHD will not accept samples on Fridays, coliform samples were not always obtained.

Samples from the monitoring wells were obtained after at least a 0.2 foot increase in water levels were observed. Samples were collected after bailing approximately 1 pore volume with a double check valve Norton Teflon bailer. Monofilament line was used to lower the bailer into the wells. Field parameters of pH, specific conductance (umhos) and temperature (^{o}C) (when available) were measured before collecting each sample. PH and conductivity were measured using a DSPH-3 pH/conductivity meter.

Immediately after collection, samples were placed on ice ($4^{o}C$) and remained at $4^{o}C$ until shipment to the analytical laboratory.

Equipment decontamination consisted of washing with a dilute non-phosphate detergent (liquinox) solution (when visibly dirty), followed by a distilled water rinse, a methanol rinse and a final distilled water rinse.

Samples for dissolved metals were filtered using a disposable Sample Pro .45 micron nitrocellulose filter. Water was bailed into an intermediary holding container and filtered using a Geopump 2 peristaltic pump.

Samples were analyzed for: halogenated volatile organics, (EPA Method 601); dissolved arsenic, copper, lead, zinc; nitrate nitrogen; COD; ortho-phosphate; BTX; and Fecal Coliform. Samples for Base/Neutral/Acid, (EPA Method 625) were added on May 3, 1988.

APPENDIX D

MONITORING RESULTS

MT. TACOMA DRIVE SITE - LITHIUM RESULTS

* * WELL CC-1 * *

SAMPLE DATE	TIME	LITHIUM (ppm)	COMMENTS
02-Feb-88	13:10	0.58	BACKGROUND SAMPLE
18-Feb-88	13:30	0.13	
25-Feb-88	17:30	0.23	
07-Mar-88	14:30	0.01	

* * WELL CC-2 * *

SAMPLE DATE	TIME	LITHIUM (ppm)	COMMENTS
02-Feb-88	12:00	0.71	BACKGROUND SAMPLE
18-Feb-88	12:40	0.12	
25-Feb-88	16:45	0.27	
07-Mar-88	15:15	0.14	

* * WELL CC-3 * *

SAMPLE DATE	TIME	LITHIUM (ppm)	COMMENTS
02-Feb-88	11:15	1.15	BACKGROUND SAMPLE
18-Feb-88	14:00	0.80	
25-Feb-88	17:00	0.34	
07-Mar-88	15:30	0.49	

* * WELL CC-8 * *

SAMPLE DATE	TIME	LITHIUM (ppm)	COMMENTS
03-Feb-88	9:45	1.09	BACKGROUND SAMPLE
18-Feb-88	13:15	0.05	
25-Feb-88	16:30	0.05	
07-Mar-88	15:00	0.04	

KOREANA PLAZA SITE - LITHIUM RESULTS

* * WELL CC-4 * *

SAMPLE DATE	TIME	LITHIUM (ppm)	COMMENTS
03-Feb-88	8:00	0.64	BACKGROUND SAMPLE
04-Mar-88	15:45	0.25	
04-Mar-88	18:00	0.09	
05-Mar-88	10:30	0.15	
07-Mar-88	17:00	0.01	

* * WELL CC-5 * *

SAMPLE DATE	TIME	LITHIUM (ppm)	COMMENTS
03-Feb-88	8:30	0.51	BACKGROUND SAMPLE

* * WELL CC-6 * *

SAMPLE DATE	TIME	LITHIUM (ppm)	COMMENTS
05-Feb-88	14:30	0.02	BACKGROUND SAMPLE

* * WELL CC-7 * *

SAMPLE DATE	TIME	LITHIUM (ppm)	COMMENTS
03-Feb-88	8:15	0.16	BACKGROUND SAMPLE
04-Mar-88	15:10	0.13	
04-Mar-88	17:50	0.17	
05-Mar-88	10:00	0.06	
07-Mar-88	16:40	0.03	

* * WELL CC-9 * *

SAMPLE DATE	TIME	LITHIUM (ppm)	COMMENTS
03-Mar-88	14:00	0.04	BACKGROUND SAMPLE
04-Mar-88	14:44	0.04	
04-Mar-88	15:30	0.05	
04-Mar-88	17:45	0.19	
05-Mar-88	9:30	0.12	
07-Mar-88	16:25	*	

MT. TACOMA DRIVE SITE
WATER LEVELS

* * WELL CC-1 * *

DEPTH TO WATER (FT)	DATE	TIME	COMMENTS
34.09	28-Jan-88		
34.03	29-Jan-88	9:00	BAILED 1 PORE VOL., SILTY
33.98	30-Jan-88	13:30	
33.95	01-Feb-88		REMOVED 3.5 GALS, VERY SILTY
35.39	09-Mar-88	12:00	
35.56	25-Mar-88	11:47	
35.29	26-Mar-88	10:30	
33.24	30-Apr-88	16:15	
33.42	03-May-88	16:03	
33.89	13-May-88	14:30	
33.88	14-May-88	13:21	
33.95	16-May-88		
40.92	06-Sep-88	12:55	
30.60	03-Apr-89	12:30	

* * WELL CC-2 * *

DEPTH TO WATER (FT)	DATE	TIME	COMMENTS
34.41	28-Jan-88		
34.31	29-Jan-88	9:10	BAILED 1 PORE VOL., SILTY
34.28	30-Jan-88	13:30	
34.27	01-Feb-88		REMOVED 3.5 GALLONS, VERY SILTY/SANDY
35.68	09-Mar-88	13:00	
35.89	25-Mar-88	11:40	
35.59	26-Mar-88	10:30	
33.41	29-Apr-88	19:05	
33.51	30-Apr-88	18:00	
33.66	03-May-88	15:22	
34.17	13-May-88	14:36	
34.13	14-May-88	13:18	
34.29	16-May-88		
41.10	06-Sep-88	13:25	
30.18	03-Apr-89	13:20	

* * WELL CC-3 * *

DEPTH TO WATER (FT)	DATE	TIME	COMMENTS
33.87	28-Jan-88		
34.40	29-Jan-88	9:20	BAILED 1 PORE VOL., SILTY
34.23	30-Jan-88	13:30	
34.24	01-Feb-88		REMOVED 1.5 GALLONS, VERY SILTY/SANDY
35.71	09-Mar-88	12:40	
35.94	20-Mar-88	22:30	
35.93	21-Mar-88		
35.95	21-Mar-88	14:35	
35.91	21-Mar-88	11:35	
33.51	30-Apr-88	17:00	
33.74	03-May-88	16:17	
34.13	14-May-88	13:25	
34.19	16-May-88		
-	06-Sep-88	13:40	DRY
30.81	03-Apr-89	14:15	

* * WELL CC-8 * *

DEPTH TO WATER (FT)	DATE	TIME	COMMENTS
35.88	09-Mar-88	12:15	
36.13	20-Mar-88	22:32	
36.11	21-Mar-88		
36.10	23-Mar-88	14:21	
36.12	25-Mar-88	11:30	
35.82	26-Mar-88	10:30	
33.85	29-Apr-88	19:03	
33.72	30-Apr-88	17:30	
33.92	03-May-88	15:20	
34.39	13-May-88	14:33	
34.39	14-May-88	13:16	
34.55	16-May-88		
39.14	06-Sep-88	13:20	
30.84	03-Apr-89	12:58	

* * DRY WELL - 1 * *

DEPTH TO WATER (FT)	DATE	TIME	COMMENTS
2.5	09-Feb-88	8:30	ADDED LITHIUM CHLORIDE
	04-Mar-88	11:30	2.80 FEET STANDING IN DRYWELL
	09-Mar-88	10:50	1 FOOT STANDING IN DRYWELL
	20-Mar-88	22:30	APPROXIMATELY 2 FEET STANDING IN DRY WELL
	21-Mar-88		DRY
	23-Mar-88	14:45	3.2 FEET STANDING IN WELL
	25-Mar-88	11:50	3 FEET STANDING IN WELL
3.8	29-Apr-88	19:00	
4.1	03-May-88	16:45	5.4 FEET STANDING IN WELL
5.2	14-May-88	13:30	

KOREANA PLAZA SITE
WATER LEVELS

* * WELL CC-4 * *

DEPTH TO WATER (FT)	DATE	TIME	COMMENTS
24.43	30-Jan-88	13:00	
24.36	01-Feb-88		REMOVED 2 PORE VOLS, VERY SILTY/SANDY
26.61	02-Feb-88	16:50	MAY NOT HAVE RECOVERED FROM BAILING 2/1/88
26.52	10-Feb-88	7:10	
28.56	04-Mar-88	14:20	
27.99	08-Mar-88	15:41	
27.86	09-Mar-88	10:25	
28.22	20-Mar-88	9:46	
28.25	21-Mar-88	10:37	
27.98	23-Mar-88	10:32	
30.97	23-Mar-88	13:27	
24.95	30-Apr-88	13:50	
24.68	03-May-88	13:35	
24.98	13-May-88	12:55	
24.77	14-May-88	11:56	
28.32	17-Jul-88	09:50	
30.69	16-Sep-88	12:09	

* * WELL CC-5 * *

DEPTH TO WATER (FT)	DATE	TIME	COMMENTS
27.65	30-Jan-88	13:00	
27.73	01-Feb-88		BAILED 4 GALLONS, VERY SILTY/SANDY
30.60	02-Feb-88	16:50	
29.09	10-Feb-88	7:18	
30.50	04-Mar-88	14:20	
29.70	08-Mar-88	15:48	
29.55	09-Mar-88	9:00	
29.80	23-Mar-88	10:28	
30.53	23-Mar-88	13:24	
26.13	29-Apr-88	18:34	
26.10	30-Apr-88	13:32	
25.77	03-May-88	12:11	
25.58	13-May-88	11:12	
25.97	14-May-88	13:04	
30.97	17-Jul-88	09:55	
32.87	06-Sep-88	11:40	
23.04	03-Apr-89	10:39	

* * WELL CC-6 * *

DEPTH TO WATER (FT)	DATE	TIME	COMMENTS
19.98	30-Jan-88	13:00	
22.09	01-Feb-88		BAILED 6 GALLONS, VERY SILTY, GREY
26.46	02-Feb-88	16:50	
27.09	10-Feb-88	7:20	
21.14	08-Mar-88	15:52	
19.10	09-Mar-88	8:30	
30	20-Mar-88	9:46	APPROXIMATE READING
29.03	21-Mar-88	10:33	
23.50	23-Mar-88	10:00	
17.16	23-Mar-88	12:56	
25.91	29-Apr-88	18:32	
25.92	30-Apr-88	13:30	
25.80	03-May-88	12:10	
17.22	13-May-88	11:10	
17.27	14-May-88	13:02	
29.45	17-Jul-88	09:50	
-	06-Sep-88	11:34	DRY
17.26	03-Apr-89	10:00	

* * WELL CC-7 * *

DEPTH TO WATER (FT)	DATE	TIME	COMMENTS
32.21	02-Feb-88	16:50	
30.47	10-Feb-88	7:15	
32.25	04-Mar-88	14:20	
32.03	08-Mar-88	15:45	
31.80	09-Mar-88	9:25	
31.96	23-Mar-88	11:44	
28.51	30-Apr-88	14:45	
28.15	03-May-88	12:12	
28.45	13-May-88	12:50	
28.90	14-May-88	11:53	
32.99	17-Jul-88	09:55	
-	06-Sep-88	12:06	DRY

* * WELL CC-9 * *

DEPTH TO WATER (FT)	DATE	TIME	COMMENTS
36.40	25-Feb-88		BEFORE DEVELOPMENT
34.07	03-Mar-88	13:17	BEFORE DEVELOPMENT
34.18	04-Mar-88	14:20	
34.01	08-Mar-88	16:47	
33.88	09-Mar-88	10:00	
36.10	23-Mar-88	12:30	
29.97	30-Apr-88	15:15	
29.96	03-May-88	14:00	
30.28	13-May-88	13:40	
30.17	14-May-88	12:32	
34.28	17-Jul-88	10:00	
38.74	06-Sep-88	12:20	
27.93	03-Apr-89	11:20	

* * DRY WELL - 2 * *

DEPTH TO WATER (FT)	DATE	TIME	COMMENTS
	04-Mar-88	10:30	1.6 FEET STANDING IN DRY WELL
	04-Mar-88	14:00	ADDED LITHIUM CHLORIDE + 25 GALLONS WATER
	20-Mar-88	21:50	APPROXIMATELY 1 FOOT STANDING IN DRY WELL
	21-Mar-88	10:30	TRACE WATER IN DRY WELL
6.7	29-Apr-88	18:00	APPROXIMATELY 3 FEET STANDING IN DRY WELL
7.3	03-May-88	12:30	APPROXIMATELY 2.5 FEET STANDING IN DRY WELL
7.2	14-May-88	13:00	
	06-Sep-88	11:30	DRY

MT. TACOMA DRIVE SITE - FIELD PARAMETERS

* * WELL CC-1 * *

DATE	pH	CONDUCTIVITY (UMHOS)	TEMPERATURE
02-Feb-88	7.77	165	10.7
25-Feb-88	6.22	156	-
18-Feb-88	6.59	167	-
07-Mar-88	6.37	190	-
09-Mar-88	6.45	198	-
26-Mar-88	5.68	166	-
30-Apr-88	7.45	159	-
03-May-88	6.09	116	12
16-May-88	6.24	160	-
06-Sep-88	6.87	159	-
03-Apr-89	6.94	136	-

* * WELL CC-2 * *

DATE	pH	CONDUCTIVITY (UMHOS)	TEMPERATURE
02-Feb-88	7.70	149	10.9
25-Feb-88	6.25	151	-
18-Feb-88	6.43	165	-
07-Mar-88	6.19	156	-
09-Mar-88	6.65	164	-
26-Mar-88	6.07	185	-
30-Apr-88	6.79	171	-
03-May-88	6.20	145	-
16-May-88	6.55	350	-
06-Sep-88	6.34	183	-
03-Apr-89	6.71	138	-

* * WELL CC-3 * *

DATE	pH	CONDUCTIVITY (UMHOS)	TEMPERATURE
02-Feb-88	8.22	108	8.9
25-Feb-88	6.10	164	-
18-Feb-88	6.47	171	-
07-Mar-88	6.30	180	-
09-Mar-88	6.94	123	-
26-Mar-88	6.48	71	-
30-Apr-88	7.23	167	-
03-May-88	6.21	124	12
16-May-88	6.20	70	-
03-Apr-89	6.59	125	-

* * WELL CC-8 * *

DATE	pH	CONDUCTIVITY (UMHOS)	TEMPERATURE
02-Feb-88	7.89	153	12.8
25-Feb-88	6.46	259	-
18-Feb-88	6.53	193	-
07-Mar-88	6.48	238	-
09-Mar-88	6.81	214	-
26-Mar-88	6.40	317	-
30-Apr-88	7.07	210	-
03-May-88	7.16	174	-
16-May-88	6.30	228	-
06-Sep-88	6.79	253	-
03-Apr-89	6.70	155	-

* * DRY WELL DW-1 * *

DATE	pH	CONDUCTIVITY (UMHOS)	TEMPERATURE
17-Feb-88	6.52	92	-
04-Mar-88	6.93	153	-
09-Mar-88	6.45	45	-
03-May-88	7.08	54	14
13-May-88	7.53	43	16

COMMENTS:

1. (-) Indicates sample was not tested for that parameter.

KOREANA PLAZA SITE - FIELD PARAMETERS

* * WELL CC-4 * *

DATE	pH	CONDUCTIVITY (UMHOS)	TEMPERATURE	COMMENTS
03-Feb-88	8.49	207	12.9	
04-Mar-88	-	209	-	
04-Mar-88	7.34	186	-	
05-Mar-88	-	220	-	
07-Mar-88	7.42	210	-	
09-Mar-88	8.01	228	-	
23-Mar-88	7.68	230	-	
30-Apr-88	7.16	314	-	
03-May-88	6.54	240	13	
14-May-88	7.76	259	15	
16-Aug-88	-	192	-	
06-Sep-88	7.54	227	-	

* * WELL CC-5 * *

DATE	pH	CONDUCTIVITY (UMHOS)	TEMPERATURE
03-Feb-88	8.73	161	12.7
09-Mar-88	6.98	190	-
23-Mar-88	7.23	140	-
30-Apr-88	6.49	214	-
03-May-88	7.77	160	13
13-May-88	7.65	180	14
16-Aug-88	-	169	-
06-Sep-88	7.49	164	-
03-Apr-89	7.32	190	-

* * WELL CC-6 * *

DATE	pH	CONDUCTIVITY (UMHOS)	TEMPERATURE
03-Feb-88	8.80	181	11.3
09-Mar-88	8.16	149	-
23-Mar-88	6.52	280	-
23-Mar-88	6.78	230	-
30-Apr-88	6.86	291	-
03-May-88	7.64	243	13
13-May-88	7.46	187	14
03-Apr-89	7.24	131	-

* * WELL CC-7 * *

DATE	pH	CONDUCTIVITY (UMHOS)	TEMPERATURE
03-Feb-88	8.54	202	13.2
04-Mar-88	7.85	185	-
07-Mar-88	7.06	173	-
09-Mar-88	7.51	230	-
23-Mar-88	7.48	190	-
30-Apr-88	6.53	224	-
03-May-88	6.43	163	13
13-May-88	7.54	205	14

* * WELL CC-9 * *

DATE	pH	CONDUCTIVITY (UMHOS)	TEMPERATURE
03-Mar-88	7.72	192	-
04-Mar-88	7.53	225	-
04-Mar-88	7.41	178	-
04-Mar-88	7.52	177	-
05-Mar-88	6.65	190	-
07-Mar-88	7.17	179	-
09-Mar-88	7.56	162	-
23-Mar-88	7.68	190	-
30-Apr-88	6.72	251	-
03-May-88	7.50	165	13
14-May-88	7.95	188	15
16-Aug-88	-	186	-
06-Sep-88	7.70	223	-
03-Apr-88	7.61	154	-

* * DRY WELL DW-2 * *

DATE	pH	CONDUCTIVITY (UMHOS)	TEMPERATURE
04-Mar-88	7.03	212	-
08-Mar-88	6.94	83	-
23-Mar-88	7.28	90	-
13-May-88	7.67	87	16
16-Aug-88	-	132	-

COMMENTS:

1. (-) Indicates sample was not tested for that parameter.

1. (*) Indicates that the sample result was below the detection limit.

2. (TU) Indicates that the test was unsuitable due to excess debris in the sample.

3. (-) Indicates sample analysis not performed for this analyte.

4. (T) Indicates sample was analyzed for total metal concentration.

5. (D) Indicates sample was analyzed for dissolved metal concentration.

6. (J) Indicates an estimated value when result is less than specified detection limit.

7. (M) Indicates an estimated value of analyte found and confirmed by analyst, but with low spectral match parameters.

MT. TACOMA DRIVE SITE - STORM WATER ANALYSIS

* * DRY WELL DW-1 * *

SAMPLE DATE	TIME	COD	NITRATE NITROGEN	ORTHO PHOSPHATE	ARSENIC	COPPER	LEAD	ZINC	FECAL COLIFORM	bis (2-Ethylhexyl) Phthalate	Phenanthrene
17-Feb-88	13:00	86	0.2	0.17	*	*	0.018	0.11	TU	-	-
04-Mar-88	11:30	56	0.16	0.08	*	*	0.035	0.11	-	-	-
09-Mar-88	10:50	92	0.01	0.05	-	-	-	-	TU	-	-
23-Mar-88	14:45	38	0.09	0.01	-	-	-	-	>16	-	-
29-Apr-88	18:00	54	0.18	0.01	* T * D	0.01 T 0.02 D	0.050 T 0.007 D	0.16 T 0.09 D	-	-	-
03-May-88	16:45	-	-	-	-	-	-	-	>16	2J	*
13-May-88	14:45	57	0.17	0.07	*	0.02	*	0.08	-	2M	2M

* * WELL CC-1 * *

SAMPLE DATE	TIME	COD	NITRATE NITROGEN	ORTHO PHOSPHATE	ARSENIC	COPPER	LEAD	ZINC	FECAL COLIFORM	bis (2-Ethylhexyl) Phthalate	Phenanthrene
07-Mar-88	14:30	26	1.2	0.48	-	-	-	-	TU	-	-
26-Mar-88	15:30	9	2.2	1.4	*	0.03	*	0.07	-	-	-
30-Apr-88	16:30	22	2.2	*	* T * D	0.10 T * D	0.069 T * D	0.03 T 0.01 D	-	-	-
03-May-88	16:15	-	-	-	-	-	-	-	<2.2	*	*
16-May-88	16:10	*	2.0	0.22	*	*	*	*	-	*	*
16-May-88	DUPLICATE	7	1.9	0.06	*	*	*	*	-	*	*
06-Sep-88	13:00	449	2.3	-	0.062 T	1.1 T	0.27 T	6.8 T	0	-	-
03-Apr-89	13:00	36	2.5	0.10	0.018 T * D	0.451 T * D	0.131 T * D	0.226 T * D	<2.2		

* * WELL CC-2 * *

SAMPLE DATE	TIME	COD	NITRATE NITROGEN	ORTHO PHOSPHATE	ARSENIC	COPPER	LEAD	ZINC	FECAL COLIFORM	bis (2-Ethylhexyl) Phthalate	Phenanthrene
07-Mar-88	15:15	78	0.13	0.17	-	-	-	-	TU	-	-
26-Mar-88	16:30	6	0.18	0.04	*	0.03	*	0.06	-	-	-
30-Apr-88	18:00	5	1.8	*	* T * D	0.16 T 0.03 D	0.071 T * D	0.07 T 0.03 D	-	-	-
03-May-88	15:50	-	-	-	-	-	-	-	<2.2	*	*
16-May-88	15:00	*	2.0	0.05	*	*	*	0.01	-	*	*
06-Sep-88	13:30	289	3.0	-	* T	11.9 T	2.5 T	14.0 T	0	-	-
03-Apr-89	13:45	19	2.7	0.09	0.020 T * D	1.06 T * D	0.178 T 0.006 D	0.646 T * D	<2.2		

* * WELL CC-3 * *

SAMPLE DATE	TIME	COD	NITRATE NITROGEN	ORTHO PHOSPHATE	ARSENIC	COPPER	LEAD	ZINC	FECAL COLIFORM	bis (2-Ethylhexyl) Phthalate	Phenanthrene
07-Mar-88	15:30	31	0.08	0.1	-	-	-	-	TU	-	-
26-Mar-88	17:00	14	0.32	0.71	*	0.02	*	0.04	-	-	-
30-Apr-88	17:00	27	2.3	*	0.011 T * D	0.78 T 0.03 D	0.169 T * D	0.99 T 0.02 D	-	-	-
03-May-88	16:30	-	-	-	-	-	-	-	>16	*	*
16-May-88	16:50	25	0.67	0.78	*	0.01	*	*	-	*	*
03-Apr-89	14:15	18	3.3	0.09	0.024 T * D	0.900 T * D	0.147 T 0.006 D	0.801 T * D	>16.0		

* * WELL CC-8 * *

SAMPLE DATE	TIME	COD	NITRATE NITROGEN	ORTHO PHOSPHATE	ARSENIC	COPPER	LEAD	ZINC	FECAL COLIFORM	bis (2-Ethylhexyl) Phthalate	Phenanthrene
07-Mar-88	15:00	-	-	-	-	-	-	-	TU	-	-
09-Mar-88	12:15	82	0.12	-	-	-	-	-	-	-	-
26-Mar-88	15:50	58	0.80	-	0.012	0.62	0.670	0.29	-	-	-
30-Apr-88	17:30	6	2.0	*	0.008 T * D	0.32 T 0.02 D	0.173 T * D	0.33 T 0.04 D	-	-	-
03-May-88	15:30	-	-	-	-	-	-	-	<2.2	*	*
16-May-88	15:40	*	2.2	0.69	*	*	*	*	-	*	*
16-May-88	DUPLICATE	3	2.2	0.14	*	*	*	*	-	*	*
06-Sep-88	13:20	-	-	-	-	-	-	-	0	-	-
03-Apr-89	13:30	20	3.4	0.18	0.021 T * D	1.57 T * D	0.295 T * D	1.20 T * D	<2.2		

* * FIELD BLANK * *

SAMPLE DATE	TIME	COD	NITRATE NITROGEN	ORTHO PHOSPHATE	ARSENIC	COPPER	LEAD	ZINC	FECAL COLIFORM	bis (2-Ethylhexyl) Phthalate	Phenanthrene
07-Mar-88	16:00	*	*	0.02	-	-	-	-	0	-	-
09-Mar-88	10:40	*	0.03	0.02	-	-	-	-	0	-	-
03-May-88	16:00	-	-	-	-	-	-	-	<2.2	*	*
13-May-88	13:30	8	0.51	*	*	*	*	*	-	*	*
06-Sep-88	13:45	*	*	-	* T	* T	* T	* T	0	-	-
03-Apr-89	14:00	*	*	*	* T * D	* T * D	* T * D	* T * D	<2.2		

COMMENTS:

1. (*) Indicates that the sample result was below the detection limit.

2. (TU) Indicates that the test was unsuitable due to excess debris in the sample.

3. (-) Indicates sample analysis not performed for this analyte.

4. (T) Indicates sample was analyzed for total metal concentration.

5. (D) Indicates sample was analyzed for dissolved metal concentration.

6. (J) Indicates an estimated value when result is less than specified detection limit.

7. (M) Indicates an estimated value of analyte found and confirmed by analyst, but with low spectral match parameters.

KOREANA PLAZA SITE - STORM WATER ANALYSIS

* * DRY WELL DW-2 * *

SAMPLE DATE	TIME	COD	NITRATE NITROGEN	ORTHO PHOSPHATE	ARSENIC	COPPER	LEAD	ZINC	FECAL COLIFORM	bis(2-Ethylhexyl) Phthalate
04-Mar-88	10:30	137	0.25	0.12	*	0.04	0.225	0.27	-	-
08-Mar-88	11:15	67	0.03	0.11	-	-	-	-	TU	-
20-Mar-88	21:50	125	0.27	0.49	*	0.03	0.159	0.21	>16.0	-
23-Mar-88	11:25	2242	0.28	0.24	*	0.02	*	0.04	>16.0	-
29-Apr-88	19:00	109	0.20	0.04	* T * D	0.02 T 0.02 D	0.086 T * D	0.16 T 0.04 D	-	-
03-May-88	12:30	-	-	-	-	-	-	-	>16	**
13-May-88	11:30	2	0.37	0.06	*	*	*	0.02	-	**
16-Aug-88	18:07	139	0.64	0.21	*T *D	0.035 T 0.020 D	0.177 T 0.005 D	0.219 T 0.041 D	-	-

** WELL CC-4 **

SAMPLE DATE	TIME	COD	NITRATE NITROGEN	ORTHO PHOSPHATE	ARSENIC	COPPER	LEAD	ZINC	FECAL COLIFORM	bis(2-Ethylhexyl) Phthalate
04-Mar-88	15:45	122	0.02	0.18	0.009 T	0.32 T	0.138 T	0.39 T	-	-
04-Mar-88	18:00	234	0.03	1.1	0.016 T	0.44 T	0.151 T	0.64 T	-	-
05-Mar-88	10:30	301	0.83	0.41	0.015 T	0.59 T	0.144 T	0.50 T	-	-
09-Mar-88	10:25	43	0.24	0.63	-	-	-	-	0	-
23-Mar-88	11:00	12	1.2	0.08	*	0.06	*	0.04	<2.2	-
30-Apr-88	15:45	69	0.09	0.03	* T	0.18 T	0.104 T	0.16 T	-	-
					* D	* D	* D	* D		
03-May-88	13:50	-	-	-	-	-	-	-	5.1	9
14-May-88	12:15	31	0.15	0.20	*	*	0.012	*		26
16-Aug-88	18:38	2	1.34	0.07	*T	0.011 T	0.004 T	0.012 T	-	-
					*D	* D	* D	* D		
06-Sep-88	12:15	103	1.7	-	0.008 T	0.36 T	0.053 T	0.19 T	0	-

* * WELL CC-5 * *

SAMPLE DATE	TIME	COD	NITRATE NITROGEN	ORTHO PHOSPHATE	ARSENIC	COPPER	LEAD	ZINC	FECAL COLIFORM	bis(2-Ethylhexyl) Phthalate
09-Mar-88	9:00	39	0.68	0.49	-	-	-	-	0	-
23-Mar-88	10:15	16	2.3	1.3	*	0.02	*	0.06	9.2	-
30-Apr-88	14:30	27	2.8	0.02	* T * D	0.26 T 0.02 D	0.194 T * D	0.37 T 0.01 D	-	-
03-May-88	13:20	-	-	-	-	-	-	-	<2.2	*
13-May-88	12:40	9	2.2	0.16	*	*	0.014	*	-	11
16-Aug-88	18:25	*	2.17	-	*T *D	0.176 T * D	0.052 T	0.134 T	-	-
06-Sep-88	11:45	-	-	-	0.006 T	0.35 T	0.003 D 0.075 T	* D 0.27 T	0	-
03-Apr-89	11:00	29	2.4	0.05	*T *D	0.058 *D	0.109 *D	0.162 *D	<2.2	

* * WELL CC-6 * *

SAMPLE DATE	TIME	COD	NITRATE NITROGEN	ORTHO PHOSPHATE	ARSENIC	COPPER	LEAD	ZINC	FECAL COLIFORM	bis(2-Ethylhexyl) Phthalate
09-Mar-88	8:30	52	0.02	0.28	-	-	-	-	TU	-
23-Mar-88	10:15	39	0.11	0.17	*	0.03	*	0.05	5.1	-
23-Mar-88	12:56	16	1.0	0.18	*	0.03	*	0.07	16.0	-
30-Apr-88	13:45	48	2.1	0.06	0.010 T * D	0.21 T 0.02 D	0.161 T * D	0.34 T 0.03 D	-	-
03-May-88	12:50	-	-	-	-	-	-	-	-	23
13-May-88	12:00	43	2.2	0.11	*	*	*	*	-	9
13-May-88	DUPLICATE	32	2.2	0.10	*	*	*	*	-	12
03-Apr-89	10:30	16	0.84	0.18	0.022 T * D	0.233 T 0.016 D	0.155 T 0.022 D	0.234 T * D	>16.0	

** WELL CC-7 **

SAMPLE DATE	TIME	COD	NITRATE NITROGEN	ORTHO PHOSPHATE	ARSENIC	COPPER	LEAD	ZINC	FECAL COLIFORM	bis(2-Ethylhexyl) Phthalate
04-Mar-88	15:10	87	0.06	5.6	0.009 T	0.33 T	0.133 T	0.66 T	-	-
04-Mar-88	17:50	64	0.12	0.22	* T	0.28 T	0.138 T	0.55 T	-	-
05-Mar-88	10:00	37	0.06	0.62	0.005 T	0.15 T	0.067 T	0.25 T	-	-
09-Mar-88	9:25	18	0.18	0.19	-	-	-	-	0	-
23-Mar-88	11:55	11	3.0	0.10	*	0.02	*	0.03	<2.2	-
30-Apr-88	15:00	21	2.4	0.03	* T	0.06 T	0.075 T	0.18 T	-	-
					* D	0.02 D	* D	0.04 D		
03-May-88	13:30	-	-	-	-	-	-	-	<2.2	*
03-May-88	DUPLICATE	-	-	-	-	-	-	-	<2.2	*
13-May-88	13:00	14	3.7	0.16	*	0.02	*	*	-	*

* * WELL CC-9 * *

SAMPLE DATE	TIME	COD	NITRATE NITROGEN	ORTHO PHOSPHATE	ARSENIC	COPPER	LEAD	ZINC	FECAL COLIFORM	bis(2-Ethylhexyl) Phthalate
04-Mar-88	14:44	42	0.11	0.11	* T	0.03 T	0.053 T	0.05 T	-	-
04-Mar-88	17:45	70	0.09	0.05	* T	0.08 T	0.069 T	0.15 T	-	-
05-Mar-88	9:30	35	0.21	0.16	* T	0.06 T	0.046 T	0.09 T	-	-
09-Mar-88	10:00	27	0.1	0.21	-	-	-	-	0	-
23-Mar-88	12:40	12	3.5	*	*	0.01	*	0.02	<2.2	-
30-Apr-88	15:30	34	3.2	0.04	* T * D	0.12 T 0.01 D	0.265 T * D	0.24 T * D	-	-
03-May-88	14:00	-	-	-	-	-	-	-	<2.2	*
13-May-88	13:00	11	2.3	0.12	*	*	*	*	-	**
16-Aug-88	18:55	1	3.39	0.06	*T *D	* T * D	* T * D	* T * D	-	-
06-Sep-88	12:30	108	3.4	-	0.007 T	0.23 T	0.091 T	0.35 T	0	-
03-Apr-89	11:30	28	2.6	0.08	*T *D	0.093 T * D	0.070 T * D	0.092 T * D	2.2	

COMMENTS:

1. (*) Indicates that the sample result was below the detection limit.
2. (TU) Indicates that the test was unsuitable due to excess debris in the sample.
3. (-) Indicates that the sample was not analyzed for that analyte.
4. (T) Indicates sample was analyzed for total metal concentration.
5. (D) Indicates sample was analyzed for dissolved metal concentration.
6. (**) Indicates sample for that analyte was broken in shipment.

APPENDIX B

TASK 5.5 REPORT

ON-SITE WASTE PROGRAM EVALUATION

APPENDIX B

ON-SITE WASTE PROGRAM EVALUATION

ADOLFSON ASSOCIATES, INC.

INTRODUCTION

As recently as 1985, the unincorporated portions of the Clover/Chambers Creek (CCC) Basin represented one of the largest unsewered population centers in the United States. On-site sewage disposal systems, typically smaller on-site systems with flows of less than 3,500 gallons per day, served a population of about 150,000 residents. Ground water quality problems resulting from the proliferation of on-site sewage disposal systems forced Pierce County to construct a public sewer system to serve the more heavily urbanized portions of the CCC Basin such as Lakewood, Parkland, and Spanaway. However, the less densely populated portions of the basin lying to the east of Parkland and Spanaway remain largely unsewered. In these areas, about 40,000 residents are currently served primarily by smaller on-site sewage disposal systems. In addition, until the Pierce County sewer system is extended into this area, any new development must be served by on-site systems.

The purpose of this report is to assess the effectiveness of the regulatory framework governing the use of smaller on-site sewage disposal systems in protecting the ground water quality of the Clover/Chambers Creek Basin.

INSTITUTIONAL FRAMEWORK

The Washington Department of Ecology (Ecology), the Washington Department of Health (DOH), and the Tacoma-Pierce County Health Department (TPCHD) are all involved in regulating the use of on-site sewage disposal systems in the Clover/Chambers Creek Basin. Under WAC 173-216, the State Waste Discharge Permit Program, Ecology is responsible for the direct regulation of systems with common point flows of 14,500 gallons per day or greater. DOH directly regulates the construction of intermediate sized systems with between 3,500 and 14,500 gallons per day. The Tacoma-Pierce County Health Department controls the use of smaller on-site sewage systems, those with daily flows of under 3,500 gallons. However, to some extent both Ecology and DOH serve in essentially an oversight capacity in the conduct of the TPCHD smaller on-site system program.

State involvement in local on-site programs is a relatively recent phenomenon. Prior to 1976, regulation of smaller on-site systems in Washington State was generally left to the discretion of local government. January of 1976 was the effective date of the Rules and Regulations of the State Board of Health for On-Site Sewage Disposal (WAC 248-96). WAC 248-96 established minimum standards for on-site sewage systems in Washington State including soil, lot size, and horizontal setback requirements.

Local boards of health may adopt regulations, but these must be at least as stringent as the regulations passed by the State Board of Health and must be reviewed and approved by DOH. DOH is responsible for administering WAC 248-96.

The involvement of Ecology in the oversight of the TPCHD smaller on-site system program is a unique situation that applies only to the Clover/Chambers Creek Basin. As a result of their concern over the degradation of surface and ground water quality in the CCC Basin, Ecology issued a docket order in 1972 under authority of the State Water Pollution Control Act (RCW 90.48) banning new small lot-size development in the basin served by on-site sewage systems. In response, the Pierce County Commissioners formed Utility Local Improvement District (ULID) 73-1 and began development of a sewage collection and treatment system that would eventually serve much of the communities of Lakewood, Parkland, and Spanaway. Once the ULID was formed, Ecology began relaxing their original construction ban, replacing it with special soil depth standards and requirements for county maintenance of larger on-site systems in the basin. The most recent modification of the Ecology Order, Docket Number DE 74-57, (5th Amendment, July 1978), is still in effect in the unsewered portions of the CCC Basin.

The Tacoma-Pierce County Board of Health began maintaining local on-site sewage system rules and regulations long before the Ecology Docket Order was imposed or WAC 248-96 became effective. The local rules and regulations have been modified on a number of occasions since the mid-1970's in an attempt to reflect the changing requirements in state law, particularly WAC 248-96, as well as to accommodate new technology. The most recent version of the On-Site Sewage Disposal Rules and Regulations of the Tacoma-Pierce County Board of Health was approved in June of 1987. The Tacoma-Pierce County Health Department is responsible for administration and enforcement of the local rules and regulations.

For simplicity, throughout the remainder of this report the Department of Ecology Docket Order 74-57 will be referred to as the Ecology Order, the Rules and Regulations of the State Board of Health for On-Site Sewage Disposal (WAC 248-96) will be referred to as the DOH regulations, and the On-Site Sewage Rules and Regulations of the Tacoma-Pierce County Board of Health will be referred to as the TPCHD regulations.

POTENTIAL GROUND WATER QUALITY IMPACTS OF ON-SITE SEWAGE DISPOSAL SYSTEMS

On-site disposal of sewage in the unincorporated portions of the Clover/Chambers Creek Basin has historically been accomplished almost exclusively through the use of septic tanks and gravity drainfields. The purpose of the septic tank is to separate suspended solids in the waste stream from the residual liquid known as effluent, provide storage for those solids, and to provide an environment for their anaerobic decomposition. The effluent passes from the septic tank to a drainfield, typically a series of interconnected gravel filled trenches containing 4-inch diameter perforated pipes. Under ideal circumstances, the effluent is distributed evenly throughout the drainfield and released to the surrounding soil where it is treated and absorbed.

Unfortunately, soils differ substantially in the ability to treat and absorb effluent. Some soils, such as coarse sands, are highly permeable and thus have a substantial capacity to accept effluent but are not efficient in removing contaminants. Other soils, such as clays or clay loams, are extremely efficient in filtering or attenuating contaminants but are limited in the ability to accept effluent. Failure of a drainfield to function properly has traditionally been considered only in terms of a loss in the absorptive or disposal capacity of the soil rather than inadequacies in treatment efficiency. That is, according to the common definition, drainfield failure occurs when the volume of effluent entering the drainfield exceeds the absorptive capacity of the surrounding soils resulting in the release of sewage to the ground surface or a backup in the building plumbing draining to the septic tank. From a practical point of view, this form of failure represents the easiest to monitor and regulate since it represents the most obvious manifestation of sewage system difficulties, particularly from a visual and olfactory standpoint.

Neither the DOH or the TPCHD on-site disposal regulations contain a definition of what legally constitutes failure of a system, however, both explicitly prohibit any surface discharge of sewage (WAC 248-96-050) (TPCHD, Sec. 4 Sub. II). Thus, the operative definition of failure in both the state and local regulations is consistent with the traditional definition.

From a ground water protection standpoint, however, failure occurs when the on-site disposal system and the soils surrounding the system lack the capability to adequately treat contaminants present in the effluent prior to reaching an aquifer. This form of failure is difficult to detect on an individual basis and is more often observed through an overall deterioration of ground water quality in a geographic area from the cumulative effects of many different systems. Therefore, impacts from on-site sewage disposal systems are commonly considered a form of non-point pollution. The TPCHD regulations (Sec. 4 Sub. III.) state that on-site sewage disposal systems shall be

> "operated and maintained in a manner that ... does not cause changes in ... ground water characteristics detrimental to their beneficial use",

However, on a practical basis, this requirement is difficult to enforce considering the extent and expense of the geohydrologic studies that would be necessary to identify the individual system or systems responsible for deterioration of ground water quality in a given area; if indeed, an on-site waste disposal system is responsible for the problem at all.

Rather than attempting to deal with ground water contamination from on-site sewage disposal systems after the fact, the operational stance of the Department of Ecology, DOH, and TPCHD is to attempt to minimize the potential for ground water contamination through tightly controlling system design and construction practices as well as regulating the spatial distribution or density of such systems. That is, the goals are to establish and implement design and installation requirements that facilitate long term disposal and treatment of sewage (WAC 248-96-011) (TPCHD, Sec. 1 Sub. II. C) and to allow installation of on-site sewage systems only on parcels of land that have a

> "sufficient amount of area and proper soils in which sewage can be retained and treated properly on-site" (TPCHD, Sec. 18 Sub. I.).

To effectively analyze the adequacy of the state and local regulatory programs in achieving these goals, it is necessary to evaluate the factors that determine the efficiency of a soil in treating or removing the suite of contaminants commonly present in septic tank effluent.

<u>Treatment Efficiency</u>

Treatment efficiency is largely a function of soil particle size and hydraulic loading characteristics. Soils dominated by large particles (coarse textured soils) typically are less effective than those composed of finer particles (fine textured soils) in removing contaminants from septic tank effluent. When sewage is initially applied to gravity drainfields installed in coarse textured soils, weaknesses in treatment efficiency associated with particle size are compounded by the establishment of a saturated flow regime. Effluent will accumulate at the lowest point in the drainfield and will enter the soil under saturated flow conditions characterized by rapid movement through large soil pores. Saturated flow conditions limit the contact of septic tank effluent with soil particle surfaces that is necessary for treatment mechanisms to operate.

In addition, a septic tank that is discharging to a drainfield by gravity, cannot provide temporal or quantitative balancing of inputs of effluent to the drainfield. For example, residential water use tends to be sporadic with peaks between about 7 to 10 in the morning and 5 to 7 in the evening. During these periods, effluent is entering the drainfield at a rate essentially equivalent to the rate of water-use in the home. The resultant flow into the soil will tend to be in concentrated slugs, again favoring saturated flows through large soil pores.

Saturated flows will persist in a gravity drainfield until the system matures and a crust develops at the drainfield/soil interface. The crust is composed of solids filtered from the septic tank effluent, accumulated biomass from the growth of microorganisms, precipitated insoluble metal sulfides (particularly ferrous sulfide), and excretions of slimy polysaccharide gums from some soil bacteria (EPA, 1977). The crust inhibits the movement of effluent through the drainfield/ soil interface and results in a more even release of effluent across the drainfield bottom.

Even though effluent will build-up or pond in the drainfield, the mature crust will restrict the rate of effluent infiltration preventing saturated flow through the underlying soils. As a result, unsaturated flow conditions are established in the soil column favoring movement of effluent through smaller, more tortuous pores. This results in greater exposure of the effluent to soil particle surfaces and longer effluent/soil particle contact time. These conditions promote treatment efficiency by enhancing purification processes such as physical filtration, biochemical reactions, and adsorption processes (ibid).

Ironically, the progressive formation of the crust, also known as a clog mat, and the associated reduction in infiltration capacity, have historically been considered to be a sign of impending system failure. In fact, the term "creeping failure" has been applied to this phenomenon (Otis et. al., 1977). In the past, a presumption was made by most practitioners that crust development would intensify over time until the drainfield was no longer capable of transmitting effluent to the surrounding soil. This incorrect presumption was largely responsible for the widely held misconceptions concerning the lack of viability of the on-site sewage disposal system as a permanent form of sewage disposal. In point of fact, soils do not clog to zero hydraulic conductivity but instead will reach a stabilized, long term equilibrium acceptance or infiltrative rate (Machmeier, 1975). Thus, if on-site sewage systems are sized to reflect the lower long term equilibrium acceptance rate of a soil instead of the higher initial pre-crust acceptance rate, they should be capable of operating satisfactorily on an indefinite basis. Additionally, operation of a drainfield with a mature crust enhances treatment efficiency by maintaining unsaturated flow conditions through the soil profile.

It would appear then, that a conventional septic tank and drainfield is least effective in terms of treatment efficiency during the period between initial system startup and the point at which a mature crust has developed. The actual time necessary for the crust to reach maturity is variable and is dependent upon such factors as soil texture, wastewater (hydraulic) loading, and the pattern of effluent application (Mc Gauhey and Winneberger, 1964) (Hargett et. al., 1981). Dense crust formation can occur in just a few months or can take well over a year (ibid). Crust formation in coarse textured soils extends much more deeply into the soil column and is less dense than a crust forming in fine textured soils. Thus, the period of time elapsing between system startup and the development of a significant reduction in soil infiltrative capacity and concomitant establishment of unsaturated flow conditions is considerably longer in coarse textured soils than in fine textured soils (Mc Gauhey and Winneberger, 1964).

However, the period prior to crust formation during which saturated flow conditions operate can be avoided entirely through pressure distribution of the septic tank effluent. Rather than distributing effluent by gravity through a standard 4 inch diameter pipe, effluent can be pumped (or siphon dosed) through small diameter pipe, usually 1-2 inches, perforated and sized in such a manner as to allow uniform, low head, discharges throughout the drainfield. The volume of each dose of wastewater received by the drainfield can also be controlled by adjusting the pump cycle and providing an adequately sized pump chamber. Through the application of pressure distribution technology, unsaturated flow conditions can be maintained from the very start of system operation resulting in improved initial treatment efficiency, especially in coarse textured soils (Converse et. al., 1974).

<u>Pollutant Removal Mechanisms</u>

The contaminants that are commonly associated with domestic sewage are nitrates, bacteria, viruses, phosphorus, chlorides, and trace organic chemical compounds; particularly solvents associated with commercial cleaning products (Brown and Caldwell, 1985). Nitrate is often considered to be the most significant contaminant of domestic wastewater due to its relatively high water solubility and mobility within the soil column as well as its public health significance (Brown et. al., 1977).

Nitrate. Nitrate is formed when ammonia released from the septic tank is oxidized in the unsaturated soils below the drainfield. Nitrate is a drinking water contaminant that is associated with methemoglobinemia in infants, also known as blue baby disease, a condition that reduces the ability of a baby's blood to carry oxygen. The maximum contaminant level (MCL) for nitrate in drinking water is 10 mg/l expressed as nitrogen.

Most of the existing studies concerning the ability of soil to remove nitrogen from sewage involve land-surface application of wastewater as opposed to subsurface application that occurs with septic tanks and drainfields. The primary difference is that land-surface application forces wastewater to pass through the root zone where it is available for plant uptake while subsurface application usually releases wastewater below much of the root zone. Factors normally involved in denitrification or chemical reduction of nitrate, including nitrate adsorption and chemodenitrification, are believed to have negligible impacts on effluent nitrate concentrations below drainfields, especially in coarse textured soils. As a result, nearly the entire nitrogen contribution of the septic tank can be available to ground water in the form of nitrate.

The estimated waste load of nitrate expressed as nitrogen in domestic sewage is 11.2 grams per capita per day (Siegrist et. al., 1977) or about 27 pounds per year for a family of three, the average number of occupants of a single family residence in the unsewered portion of the Clover/Chambers Creek Basin. This is roughly equivalent to the anticipated annual nitrate contribution to ground water resulting from the use of lawn fertilizers in a one acre area with suburban residential land-use (Flipse et. al., 1984). If the nitrate generated annually by one single family residence was mixed evenly with the estimated annual precipitation recharge received by an acre of land in the Clover/Chambers Basin (annual precipitation minus potential evapotranspiration) (Cooperative Extension, 1968), the average concentration of nitrate-nitrogen in the recharge would be about 10 mg/l. Thus, assuming that little or no removal of nitrate will occur in a column of coarse textured soil, densities of housing in the CCC Basin greater than one unit per acre served by conventional on-site sewage systems would probably result in nitrate-nitrogen levels in the recharge that exceed the MCL for nitrate in drinking water on an annualized basis.

While no appreciable denitrification can be anticipated through the use of conventional on-site sewage systems installed in coarse textured soils, evidence suggests that the denitrification capability of on-site sewage disposal systems in such soils can be significantly enhanced through relatively simple modifications to the drainfield. By combining the pressure distribution technology discussed previously with slow filtration of effluent through at least two feet of fine to medium sand (USDA texture) placed under a drainfield, nitrate levels can be reduced prior to the entry of effluent into the surrounding native soils. In studies of systems in the State of Wisconsin utilizing similar technology, mean reductions in nitrate levels of 44 percent were observed (Hill, 1979). No explanation was offered as to the precise mechanisms involved in that reduction. However, the conditions necessary for nitrate removal from sewage as a result of biological denitrification have been documented and those conditions should be present in a sand filtration/pressure distribution system. Those conditions include conversion of ammonia-nitrogen to nitrate-nitrogen (i.e. nitrification must occur before denitrification can occur), migration of the nitrate through a zone where oxygen is depleted, and the availability of an organic carbon source in the anaerobic zone as an energy source for the denitrifying organisms (Lance, 1974).

A properly designed pressurized drainfield will result in unsaturated flow of effluent through the two foot sand layer providing ample opportunity for oxidation of the ammonia-nitrogen, a process that will occur rapidly under such conditions. This provides the first of the three conditions necessary for denitrification under the drainfield.

When installed in coarse textured gravelly sands such as those which occupy much of the Clover/Chambers Creek Basin, the fine to medium sand fill underlying the pressure distribution system will have a much greater capillary attraction for the percolating wastewater than the larger pored, surrounding native soil material. Consequently, as long as unsaturated flow conditions are maintained, effluent will travel preferentially through the fill until it reaches the interface with the native soils. At that point, the greater capillary potential of the smaller pored, relatively fine textured fill checks the downward flow of wastewater creating a zone of saturation and oxygen depletion in the fill at its interface with the native soil. Effluent will be prevented from passing from the saturated zone within the fill to the surrounding native soil until all of the adhesive and cohesive forces of the fill at the interface have been satisfied (Gardner, 1964). Thus, the second condition for denitrification has been met.

Finally, the septic tank effluent itself provides an abundant quantity of organic carbon for utilization by denitrifying organisms (Bezdicek, 1979). This satisfies the third and final condition necessary for denitrification to occur.

This type of enhanced nitrogen removal can be achieved through the use of several soil absorption configurations. These include construction of an above-ground mound/fill system in accordance with published DOH guidelines or through lining the bottom of a standard drainfield trench or bed with a minimum of two feet of fine to medium sand.

Bacteria. A second parameter of concern associated with domestic septic tank effluent is bacteria. Concentrations of fecal coliform bacteria in septic tank effluent normally range from between 3,000 to 6,000 organisms per milliliter (Tyler et. al., 1977). While this type of bacteria is associated with only mild forms of illness, it is considered to be an indicator of the potential presence of more highly pathogenic organisms. Owing to differences in soil temperature, native microbial populations, soil texture, and thickness of the unsaturated zone, bacterial treatment efficiencies of individual soils can vary widely. However, it is believed that most bacterial contamination is removed from septic tank effluent within the first three feet of unsaturated material surrounding the drainfield (ibid). As little as 20 inches of a fine textured soil such as a silt loam may effectively remove coliform bacteria at low rates of wastewater application (Ziebell et. al., 1975). Removal mechanisms include filtering action, die off by attrition of nutrients, and the action of materials toxic to the bacteria that are either naturally present in the environment or produced by the organisms themselves (Tyler et. al., 1977).

Coarse textured soils, such as glacial outwash deposits, present a special problem in terms of bacterial treatment efficiency. Based on studies of the potential for ground water contamination of the Rathdrum aquifer in the Spokane area, at least 20 and possibly up to 50 feet of vertical travel through coarse textured, unsaturated outwash deposits may be necessary to remove bacterial contamination from septic tank effluent (Crosby et. al., 1968). While it is not possible to accurately quantify estimated bacterial loadings to an aquifer associated with on-site sewage disposal systems, it is possible to make a qualitative assessment of risk. Bacterial pollution would be of greatest concern in areas where ground water is encountered at relatively shallow depths, where coarse textured soils such as glacial outwash derivatives are present, and where on-site sewage system densities are highest.

Soil removal of bacteria from domestic wastewater is most effective when unsaturated flow regimes exist resulting from either the presence of a mature crust or through controlled effluent application (EPA, 1977). As was the case with nitrates, bacterial removal in coarse textured soils can be greatly enhanced through the use of sand filtration and pressure distribution. Application of such technology has resulted in removal rates of as high as 99.5 percent of total coliform and 99.9 percent of fecal coliform organisms (Harkin et. al., 1979).

Viruses. Unlike bacteria, comparatively little information is available concerning the risks posed by viruses in septic tank effluent. While viral contamination of ground water associated with the operation of on-site sewage systems has been documented, some researchers believe the presence of viruses in septic tank effluent to be infrequent and that between 90 and 100 percent of viral organisms present in raw wastewater are retained or inactivated in the septic tank (Hill, 1979). The high rate of removal in the septic tank is attributed to digestion of viruses by proteolytic enzymes as well as entrapment and precipitation in the sludge. However, free and suspended particle-sorbed viruses will occasionally be released due to turbulent conditions in the tank (EPA, 1977).

Once in the soil, viral removal will occur as a result of the combined effects of sorption, inactivation, and retention. Generally, viruses are rapidly adsorbed to solid surfaces as they enter the soil and once adsorbed, are inactivated in a spontaneous process that is temperature dependent, being most effective at higher temperatures. The spontaneous inactivation process will normally operate unless saturated flow conditions prevent contact between viruses and soil particles (ibid). Of the documented cases of ground water borne viral disease outbreaks associated with on-site sewage system operation, most involved situations where either the ground water table was close to the level of the bottom of a drainfield that had been installed in coarse textured soils, or some underlying geologic condition such as fissured limestone existed promoting saturated vertical flows that allowed the rapid entry of effluent into ground water (Yates, 1985). Once in ground water, horizontal viral movement of as much as 213 feet has been observed (ibid).

By maintaining unsaturated flow conditions and providing a treatment medium capable of rapid entrapment of viruses, sand filtration with uniform, low-level wastewater application rates should substantially improve treatment efficiency where natural conditions prove inadequate (Hill, 1979). Crust maturation in a drainfield should also dramatically improve viral removal efficiency.

Phosphorus. Phosphorus compounds are also present in wastewater. However, unlike viruses, bacteria, and nitrates, phosphorus does not represent a significant public health consideration. Because phosphorus is a biostimulant and can induce rapid growth or blooms of algae and phytoplankton, it does have significant environmental effects when released to surface water systems. Total phosphorus concentrations in septic tank effluent generally range between 6.25 and 30 mg/l (Peavy and Groves, 1977). Phosphorus accumulation in ground water beneath septic systems is rare since it is rapidly immobilized in soils with a pH of less than 7 by sorption reactions or by formation of insoluble phosphate precipitates of aluminum or iron. The soils of western Washington, including those of the Clover/Chambers Creek Basin, are typically high in aluminum and iron and tend to be at least slightly acidic. Aluminum and iron cations become solubilized in the presence of low pH septic tank effluent. The secondary aluminum and iron compounds that form with available phosphates from the septic tank effluent are only slightly soluble and precipitate in the soil (Hausenbuiller, 1978).

Accumulation of phosphorus in ground water does occasionally occur as a result the operation of on-site sewage disposal systems that have been installed in, or just a few inches above, a water table or by systems installed in very coarse soils that are receiving high rates of wastewater application (EPA 1977). The risk associated with the latter situation would be particularly great during initial system operation if the systems receiving the high rates of wastewater application utilized gravity distribution. As pointed out previously, operation of gravity systems prior to formation of a mature crust permits saturated flow conditions to prevail providing rapid access of percolating effluent to underlying ground water.

Chlorides. As with phosphorus, chlorides are present in septic tank effluent but generally not in quantities that present a risk to public health. Chloride content in domestic septic tank effluent ranges from 37 and 101 mg/l (Peavy and Groves, 1977). The maximum contaminant level for chloride in drinking water is 250 mg/l, the approximate quantity necessary to produce a noticeable salty taste.

Like nitrate ions, chloride ions are negatively charged particles, or anions, and are not reactive with the cations that are typically present in the soil profile. Thus, chlorides are not highly susceptible to electrochemical adsorption by soil particles and can migrate freely through the soil column in solution (Hausenbuiller, 1978). Therefore, significant attenuation of chloride would not be anticipated during movement through the vadose zone, particularly under saturated flow conditions (Peavy and Groves, 1977).

While chlorides in septic tank effluent do not represent a significant threat to public health, their presence in ground water can still be significant. Just as coliform bacteria serve as indicators for the potential presence of pathogenic organisms, chlorides, because of their high mobility and ease of detection, in a sense, serve as indicators of the potential presence of other mobile chemical compounds that are more difficult and expensive to identify in ground water such as volatile organic chemicals.

Organic Chemicals. Historically, studies of the impacts of septic tanks and drainfields on ground water quality have focused on parameters that were commonly perceived to represent the most significant threat to public health, specifically bacteria and inorganic chemicals such as nitrates. Monitoring of both ground and surface water supplies used by public water systems has been oriented largely towards these parameters as well. Widespread concern over the presence of organic chemicals in water supplies, particularly in ground water, has been a relatively recent phenomenon. Although EPA is in the process of setting MCLs for about 40 organic compounds (Culp, 1988), MCLs currently exist for only a handful of organic chemicals. Requirements for widespread monitoring of organic chemicals in public water supplies are only now being implemented. Consequently, the extent of ground water contamination associated with non-point sources such as on-site sewage disposal systems is not well documented.

The relative complexity and high cost of organic chemical analysis techniques have probably also contributed to the paucity of data concerning the relationship between organic chemicals, on-site sewage disposal systems, and ground water quality. Additionally, little is known about the occurrence of organic chemicals in septic tank effluent or the ability of subsurface absorption systems such as drainfields to trap, degrade, or remove them.

One of the few definitive studies of low-level organic chemical concentrations in septic tank effluent was conducted in the Lakewood area of the Clover/Chambers Creek Basin by the University of Washington in 1980 (De Walle et. al., 1982). In that study, the influent and effluent of a 33,000 gallon septic tank serving 97 residences was monitored daily for volatile organics during a one week period. One of the most frequently observed compounds and the one observed at the highest levels was toluene with an average influent concentration of 34.6 ug/l, average effluent concentrations of 38.8 ug/l, and a peak concentration of 56.9 ug/l. The suspected source of the toluene entering the septic tank was cleaning solvents and paint thinners.

Influent levels of toluene and other volatile compounds such as tetrachloroethane, trichloroethylene, benzene, and ethylbenzene were observed to be considerably higher on weekends than weekdays. Presumably, the higher weekend levels of those contaminants were related to increased discretionary household maintenance activities such as house painting and cleaning and related use of paints, thinners, degreasers, and toilet bowl cleaners. Essentially no removal of volatiles was found to occur in the septic tank, particularly with higher molecular weight compounds, and no attempt was made to determine the fate of these compounds once the septic tank effluent entered the drainfield.

However, it is known that ground water underlying soils with a low organic carbon content and a relatively coarse texture are susceptible to contamination from halogenated hydrocarbons associated with overlying land-use activities (Brown and Caldwell, 1985). These halogenated hydrocarbons include such compounds as toluene, 1,1,2,2-tetrachloroethane, 1,2 dichloroethane, tetrachloroethylene, and trichloroethylene. The ability of halogenated hydrocarbons, particularly solvents, to migrate rapidly in coarse textured soils from the ground surface to ground water with percolating recharge is well documented in the Clover/Chambers Creek Basin. The contamination of Tacoma Wells 9-A and 12-A and of Lakewood Wells H-1 and H-2 were the result of improper chemical disposal practices at nearby commercial and industrial establishments (EPA, 1984) (EPA, 1985).

While typically, organic chemicals in septic tank effluent from domestic sources are not present in sufficient quantities to impact ground water, this is not necessarily true of effluent originating from commercial and industrial facilities (Brown and Caldwell, 1985). In any facility where solvents, degreasers, paints, fuel products, and other potentially hazardous compounds are used or handled during normal operations there is a potential for deliberate or unintentional disposal of such materials through sinks, toilets, or floor drains. EPA has identified a number of types of commercial and industrial establishments where toxic or hazardous organic compounds may be used during normal operations including dry cleaners, auto repair shops, wood processing and preserving facilities, paint manufacturers and applicators, machine shops, and pesticide applicators. Discharges from on-site sewage systems serving these types of establishments may pose a significant threat to ground water quality.

EVALUATION OF POLICIES AND REGULATIONS

From the previous section, it is apparent that there are a number of critical factors affecting the degree to which on-site sewage disposal systems will impact ground water quality. Those critical factors include soil and on-site sewage system treatment efficiency, system density or the volume of sewage discharged in a given area, and wastewater characteristics. The purpose of this section is to evaluate the effectiveness of the existing state and local rules and regulations in addressing those critical factors as they apply to the excessively permeable soils of the Clover/Chambers Creek Basin.

General Provisions

Both the DOH (WAC 248-96-011 (1)) and the TPCHD (Sec. 1 Sub. II. A) Rules and Regulations contain identical declarations of purpose concerning the issue of water quality both stating that the

> "purpose of these regulations is to assure protection of public health by minimizing public health effects of on-site sewage disposal systems on surface and ground water".

The DOH regulations (WAC 248-96-025) also contain a specific provision requiring that local rules must include special standards for areas within their jurisdiction identified as having type 1 (coarse textured, excessively permeable) soils. The level of control exerted by such special standards is to be

> "commensurate with the degree of protection deemed necessary for the underground source of drinking water by the [local] health officer and the department [DOH]".

It is not clear whether this requirement is applicable to ground waters that are not currently used as drinking water supplies but are potentially capable of serving that purpose in the future. However, it most certainly applies to any portion of a ground water aquifer presently utilized for domestic supply.

Water supply wells are located within virtually every section of land contained within the Clover/Chambers Creek Basin (Brown and Caldwell, 1985) and the shallow or "A" hydrostratigraphic unit, including the Steilacoom gravels, is the portion of the aquifer that is most heavily developed for water supply purposes. Therefore, the special standards requirement of the DOH regulations should apply to any portion of the basin where type 1 soils are encountered.

The Ecology Order, imposed in response to a perceived threat to surface and ground water quality from the use of on-site sewage systems in the Clover/Chambers Creek Basin, also requires the enforcement of special standards concerning systems installed in type 1 soils within the Clover/Chambers Creek Basin. Accordingly, the recently adopted TPCHD regulations incorporate the DOH and Ecology requirements pertaining to the construction of on-site systems in type 1 soil.

Provisions Concerning Treatment Efficiency

The treatment efficiency provided by an on-site sewage disposal system in type 1 soil is dictated by a number of conditions including flow regime, trench depth, wastewater application rates, and vertical separation. The provisions of the state and local on-site sewage disposal regulations concerning each of these conditions is described in detail below.

Flow Regime. For a number of contaminants associated with domestic wastewater, treatment efficiency is dependent upon maintenance of an unsaturated flow regime within the treatment media. The nature of the flow regime is largely dictated by wastewater loading (application rate) and the method of application specified in applicable design and construction standards. Since the DOH regulations do not contain specific design and construction standards, their development is left to the discretion of local government. However, DOH maintains review and approval authority over any locally promulgated standards.

The design and construction standards contained within the TPCHD regulations (Sec. 24) identify the gravity-fed drainfield as the conventional subsurface disposal technology. Use of this conventional technology would suggest that low treatment efficiency, saturated flow regimes would be anticipated in the soil column under these systems until a mature crust has formed.

However, as will be discussed in more detail later, use of conventional drainfields in portions of the Clover/Chambers Creek Basin with type 1 soil is primarily limited to relatively low density developments of one living unit per acre or less than one living unit per acre. Developments on type 1 soils in the basin with densities greater than this amount will require the use of pressure distribution and sand filtration or an equivalent level of treatment (TPCHD, Sec. 18 I. B. 3).

The health department also has discretionary authority to require the use of pressure distribution, but not sand filtration, for systems at densities of one living unit per acre or less than one unit per acre if, in the judgement of the local health officer, adequate treatment may not be provided by the excessively permeable native soils before effluent reaches ground water (TPCHD, Sec. 24 VI. J). However, in the absence of definitive geohydrologic information on each site, the health department may have difficulty enforcing that requirement on a sporadic or case by case basis without appearing arbitrary or capricious.

Trench Depth. Another construction practice affecting treatment efficiency is trench depth. The depth of a standard drainfield trench is one foot. Depending upon placement of the distribution pipe within the trench, between 6 and 9 inches of drainrock normally lie between the pipe invert and the trench bottom. Although the TPCHD regulations (Section 24 IV. F) state that the practice generally will not be allowed in excessively permeable soils, it does not absolutely preclude the option of installing additional drainrock under the distribution pipe in exchange for a reduction in drainfield length. This practice deepens the drainfield trench placing it closer to underlying ground water. It also involves, at least initially, disposal of wastewater over a much smaller trench bottom area. This can result in an increase in the hydraulic head exacerbating the problem of saturated flow conditions (Kropf, Laak, and Healy, 1977).

The deep trench drainfield configuration may not present a problem or may even be advantageous in a deep, fine textured soil of low permeability and high treatment efficiency. However, there is little justification for use of this type of system in coarse textured soils overlying a drinking water aquifer, particularly if the effluent is distributed by gravity.

Wastewater Application Rates. Effluent application rates or loading rates are presented in Appendix A of the TPCHD regulations. The application rates prescribed in Appendix A range from .45 gallons of wastewater per square foot of drainfield bottom per day in a fine textured soil, such as a silt loam, to 1.2 gallons per square foot per day in type 1 soil.

These rates are consistent with application rates recommended in the literature and by EPA for the long term equilibrium operation of a drainfield (Otis et. al., 1977) (EPA, 1980). In equilibrium operation, the rate of wastewater application is equivalent to the ultimate infiltrative or acceptance capacity of the soil surrounding the drainfield at crust maturity. EPA qualifies their recommendations regarding application rates, however, suggesting that in coarse sands and gravels the drainfield trench should be underlain with at least two feet of fine to medium sand.

Drainfields are sized by dividing the estimated volume of wastewater expected to be generated by the residence or facility to be served by the on-site system by the appropriate application rate for the textural quality of the soil found at the installation site. This calculation will yield the total square footage of required trench bottom area. The bottom area is then divided by the standard trench width of 3 feet to yield the total linear feet of required drainfield.

For the design of gravity-fed drainfields, the TPCHD regulations (Sec. 17 I.) require residential wastewater flows to be estimated at a rate of 150 gallons per bedroom per day or 75 gallons per capita per day (assumes 2 occupants per bedroom). Thus, a 3 bedroom home with an estimated wastewater flow of 450 gallons per day located in an area with type 1 soil would require 125 linear feet (375 square feet of bottom area) of drainfield.

For systems using pressure distribution, the TPCHD regulations (Sec. 17 I.) allow a reduction in estimated flow from 150 gallons per bedroom per day to 120 gallons per bedroom per day (60 gallons per capita per day). As a result of this change in estimated flow, the amount of drainfield bottom area available to accept effluent from a typical pressure distribution system is about 20 percent less than a gravity system serving an equivalent residence or facility. The rationale behind this reduction in estimated flow is not provided in the regulations. A review of the literature suggests that little technical justification exists for the reduction since, there is no substantive evidence that the ultimate or long term infiltrative capacity of a soil is affected by the method of wastewater application (Hargett et. al., 1981).

Studies of actual wastewater generation indicate that while the average person creates about 45 gallons of wastewater per day, the range is between 8 and 101 gallons per capita per day (EPA, 1980). At 75 gallons per capita per day there is only about a 3 percent probability that design flows will be exceeded; at 60 gallons per capita per day, that probability increases to about 13 percent (ibid). If trench bottom area represented the only infiltrative surface available, this reduction might represent a significant loss in design safety margin. However, the design standards do not credit the infiltrative capacity of the on-site sewage system trench sidewall, a capacity some researchers consider quite significant (Otis et. al., 1977).

For example, if the 125 linear foot drainfield described above was downsized based on the 120 gallon per bedroom per day design factor, a 100 linear foot drainfield with 300 square feet of bottom area would result. This amounts to a reduction in 75 square feet of bottom area. However, at least that much sidewall area is available to compensate for the loss in bottom area absorptive capacity. Counting only the sidewall area between the pipe invert and the drainfield bottom in a standard one foot deep trench, at least 100 square feet of additional infiltrative surface is available for absorption, about a third of the total bottom area. Thus, the conservative "bottom area only" design approach appears to offset the loss in design safety margin created by allowing a reduction in per capita flow estimates when pressure distribution is used.

Vertical Separation. The final condition affecting the treatment efficiency of an on-site system and the surrounding soil is the travel distance or vertical separation between the subsurface absorption system bottom and the underlying water table. The DOH regulations (WAC 248-96-100 (2)) require a 3-foot vertical separation but provide a broad categorical exemption allowing a reduction to one foot if the plans and specifications for the system are developed by a professional engineer, a registered sanitarian, or an on-site sewage system designer certified by the local jurisdictional health authority.

The TPCHD regulations (Sec. 15. III. A) essentially adopt the one foot separation as the minimum standard. Since the TPCHD regulations require that all systems be designed by a professional engineer, registered sanitarian, or certified designer, the one foot standard is not in conflict with the DOH requirements.

The Ecology Order (Para. 3 d(3)) prescribes a three foot vertical separation for systems installed in type 1 soils. Since the Ecology vertical separation requirements are the most stringent, they supercede those of both DOH and TPCHD.

Considering the high mobility of conservative or non-reactive anions such as nitrate or chloride in the soil column and the ineffectiveness of type 1 soils in removing coliform bacteria over short travel distance, the advantage of the three foot vertical separation over one foot is not clear. The affect of vertical separation on treatment efficiency in type 1 soil is certainly not of the magnitude of other conditions such as flow regime or wastewater application rates.

On-Site System Density

Gross Density and Lot Size. The second critical factor governing the impact of on-site sewage disposal systems on ground water is the density of those systems in a given area. The DOH standards establish some rather definitive limits on density. Densities are expressed in residential unit volumes per acre. A unit volume is defined by DOH as 450 gallons of effluent per day, the estimated quantity of wastewater generated by a 3 bedroom home (248-96-090(1)). The maximum number of residential unit volumes allowed per acre is 3.5 or a total of 1570 gallons of wastewater per acre per day (WAC 248-96-090(1)(b)(i)).

In the DOH regulations, allowable density is determined through establishing a minimum gross land area for each unit volume of sewage. Gross land area is defined as the

> "lot area which is bounded by the centerline of adjoining road or street right-of-ways within the boundaries of the proposed development" (WAC 248-96-020(7)).

DOH provides two options for establishing gross land area termed Method I and Method II. Method I prescribes a specific gross land area on a variable scale based on soil conditions and the source of water. For developments to be served by a public water system, gross land areas range from 12,500 square feet in medium sand to 1 acre for type 1 soil. Other soil types require gross land areas of between 15,000 and 22,000 square feet (WAC 248-96-090(1)(a)).

The DOH Method II is much more ambiguous than Method I. Gross land area requirements are not clearly spelled out but are determined, within certain limits, by consideration of a variety of factors concerning the site including soil conditions, impacts on ground water, topography, geology, climatic conditions, and area growth patterns (WAC 248-96-090(1)(b)(i)). These factors must be analyzed by the developer's engineer or designer and the results incorporated into a report used to justify a proposed gross land area.

The gross land area proposed under Method II cannot exceed 3.5 units per acre. If the Method II report indicates that type 1 soils exist at the site, gross land area can only be reduced to below one acre under certain unspecified conditions. DOH was to have published guidelines outlining those conditions by July 1, 1984 but to date, the guidelines have not been completed (WAC 248-96-090(1)(b)(ii)). Consequently, interim provisions that were to remain in effect until the completion of the guidelines govern this situation. Those provisions allow reductions below one acre only if mound systems, sand filters, or equivalent technology are used to treat the wastewater. However, even with use of such enhanced treatment technology, minimum gross land area per unit volume of sewage cannot be less than one-half acre (WAC 248-96-090(1)(b)(ii)).

For residential wastewater, the doubling of density allowed with the use of enhanced treatment appears justified on the basis of the data presented in the previous section regarding the performance of systems utilizing pressure distribution and sand filtration. With even the most limiting of parameters, nitrate, removal levels should approach 50 percent.

The procedures used by the health department for determining allowable density parallel those of DOH to a large degree, however, some distinct differences do exist. While the health department's Method I requirements (Sec. 18 IV. A) differ only slightly from those of DOH, the Method II procedures involve a two tiered process with a point system formula for determining gross land area (lot size) (Sec. 18 IV. C) and a separate ground water impact evaluation for determining allowable gross density (Sec. 18 I. C).

The point system attempts to provide uniform evaluation criteria for the most significant factors required in a DOH Method II justification report such as soil texture, depth to water table, annual precipitation, and method of storm water disposal. Points are assigned within each category. For instance, 5 points are granted if annual precipitation is less than 45 inches per year, minus 5 points if precipitation is between 45 and 70 inches per year, and minus 10 points if precipitation is greater than 70 inches per year. The total points determine the minimum lot size with the highest positive point total resulting in the lowest land area requirement (Sec. 18 IV. C. Table 2). Through this system it is possible to arrive at a minimum gross land area of as little as 9,600 feet.

On the surface, the 9,600 square foot lot size appears to be in conflict with the DOH regulations (WAC 248-96-090(1)(b)(i)) establishing 12,500 square feet as the minimum allowable gross land area. However, DOH approved the TPCHD regulations on the basis that the second tier of the local Method II process maintained actual densities within the limits set forth in the state requirements regardless of actual lot size (Lenning 1988, Personal Communication).

The health department determines density almost exclusively on the basis of the potential for ground water contamination. Allowable densities are most heavily restricted in areas with the greatest potential for adverse impacts on ground water (Sec. 18 I. C). The health department regulations classify the effectiveness of native soil and geologic structures in sheltering underlying ground water from contamination in terms of three general categories: protective, partially protective, and non-protective.

Protective and partially protective conditions involve either deep, fine or medium textured surface soils or the presence of extensive glacial till or clay subsurface stratas separating the first aquifer developed for drinking water purposes from the ground surface. Non-protective conditions are generally characterized by coarse textured surface soils and the lack of any significant confining layer between the ground surface and the shallowest developed aquifer. In the Clover/Chambers Creek Basin non-protective conditions are more clearly defined as

> "Areas with type 1 soils in sensitivity levels 2 through 7 as defined in the Clover-Chambers Creek Basin Geohydrologic Study, July 1985 (Sec. 18 I. B. 3)".

During the course of the Clover/Chambers Creek Geohydrologic Study the entire basin was mapped on a scale of 1 to 7 based upon the relative sensitivity to ground water contamination (Brown and Caldwell, 1985, Figure 5-30). Level one areas are the least sensitive, being overlain by tills or other relatively impermeable deposits, while levels 2 through 7 represent areas covered primarily by recessional outwash.

Because the Clover/Chambers Creek Basin ground water system is composed of a number of successive aquifer units, a high level of concern exists over the potential for migration of contaminants from shallow aquifer units into deeper units that are more heavily utilized for public water supply. The level of sensitivity between 2 and 7 rises as the vulnerability of deeper aquifer units increases. At level 7, the two major regional aquitards are absent, potentially allowing contaminants introduced at the ground surface to penetrate into some of the deepest portions of the aquifer system.

In portions of the basin considered non-protective, densities are limited to one unit per acre with conventional systems and two units per acre if sand filtration and pressure distribution technologies are employed (Sec. 18 I. A). With sand filtration and pressure distribution, the relatively small gross land areas (lot sizes) determined under the Method II point system may still be acceptable provided overall density of the development remains at the prescribed two unit per acre level. For example, individual lots in a subdivision may be only 9,600 square feet but sufficient land area must remain undeveloped to prevent gross densities from exceeding two units per acre. This can be accomplished through preserving large greenbelt areas or establishing a community playground on a portion of the property.

Where low housing densities are dictated by type 1 soil conditions, this clustered, small lot style of development is favored by developers over diffuse, large lot developments because it limits the distance and, therefore, the cost of necessary road construction as well as water and power extensions. It also allows greater flexibility for further property development should public sewers become available in the future.

Planning agencies and sewer utilities also favor the clustered development approach. Forcing development to occur on lots of between about 15,000 square feet and five acres may foreclose upon the option of future sewer expansion. The ultimate population that could be accommodated at such a low housing density could probably not economically support sewer expansion and, once the original dwelling has been constructed on each site, lots of this size cannot easily be further subdivided to accommodate additional dwellings.

The practice of residential cluster development may have some moderate impact on shallow ground water in the immediate vicinity of the development. Under a worst case scenario, all portions of a given acre within a subdivision could be utilized entirely as residential lots of 9,600 square feet. In that case, the effective density would be 4.5 units per acre. Using nitrate-nitrogen as a yardstick and assuming a 44 percent reduction of nitrate with use of sand filtration and pressure distribution (Hill, 1979), the effective density would be reduced to 2.5 units per acre. The resulting annual nitrate-nitrogen contribution to the aquifer from on-site sewage disposal systems would be roughly 67.5 lbs. per year per acre. Thus, the annualized average nitrate content in the aquifer recharge would be 25.7 mg/l in the most heavily developed areas. Presumably, this would be offset by adjacent areas of undeveloped property contributing nitrate-poor recharge.

<u>Community Systems</u>. A more significant risk of ground water contamination than that from cluster development is posed by

the use of community on-site sewage systems. With a community system, a number of residences or facilities are served by a single system. The Tacoma-Pierce County Health Department regulates systems serving up to 9 living units or producing wastewater flows of up to 3,500 gallons per day.

In a development of detached single family dwellings, a number of these community systems could be installed in close proximity to each other. For example, consider a mobile home park development of 33, 3 bedroom units on about 17 acres of land served by community systems located in a common area. To stay within local jurisdiction, the 14,850 gallon total daily wastewater flow from the development would need to be divided among 5 separate systems, each receiving less than 3,500 gallons per day. Using health department drainfield design and setback requirements (Sec. 24 IV.), approximately 10,000 square feet of land area would be needed to accommodate a drainfield to serve each 3,499 gallon increment of daily wastewater flow. About 4.3 such fields could be placed adjacent to each other on one acre of land. At this rate, even allowing for the improved treatment efficiency of sand and pressure, nitrate-nitrogen loadings would be equivalent to about 18 unit volumes per acre or 486 lbs. of nitrate-nitrogen per acre per year.

Thus, with use of community systems, even though the overall density of a development remains within the two unit per acre limit, impacts on shallow ground water might be anticipated in close proximity to the disposal area. Considering that a community system can be legally located within 100 linear feet of an operating drinking water well (WAC 248-96-100), those impacts could be substantial. Similar adverse impacts could also be expected with larger community systems receiving over 3,500 gallons per day (common point flow) installed under the jurisdiction of DOH and the Department of Ecology. The risk of ground water contamination associated with community systems could be even more pronounced in situations where those systems are serving commercial or industrial facilities producing wastewater containing contaminants more harmful than those normally found in residential sewage.

<u>Wastewater Characteristics</u>

With the exception of a few special requirements for disposing of greases in wastewater from restaurants, neither the DOH regulations, the Ecology Order, or the Tacoma-Pierce County Health Department regulations draw any distinction between residential wastewater and wastewater of a commercial or industrial origin. This remains the case despite the fact that some commercial and industrial facilities produce an effluent that is much stronger than that originating from typical residential developments, particularly in terms of heavy metals and organic compounds.

Discharges or waste disposal practices at large facilities that handle significant amounts of hazardous materials would generally be regulated under the State Waste Discharge Program (WACs 173-240 and 372-24) or the federal Resource Conservation and Recovery Act (RCRA). However, the waste disposal practices of many small facilities are not closely monitored. A 1985 survey of the Clover/Chambers Creek Basin identified a significant number of commercial and industrial facilities that were served by on-site sewage disposal systems and were not regulated under the State Waste Discharge Program or RCRA. These facilities included twenty auto body shops, eleven dry cleaners, two fuel oil companies, five self service laundries, four machine shops, six pesticide applicators, two paint suppliers, ten printers, three radiator shops, fifteen transmission shops, and one wood manufacturer (Brown and Caldwell, 1985). Although, about one-half of these establishments have subsequently been connected to public sewers it is possible that their drainfields may continue to release undegraded compounds to the ground water for years.

SUMMARY

With two state agencies and one local agency involved in the process of regulating on-site sewage disposal practices in the Clover/Chambers Creek Basin, some problems with inconsistency among the various programs might be anticipated. However, because the recently adopted Tacoma-Pierce County Health Department regulations appear to have captured the intent of both the DOH regulations and the Ecology Order, conflicts have been avoided.

It is obvious that the regulation and control of on-site sewage disposal systems in the basin has developed into a relatively sophisticated process. But, since on-site sewage disposal is being more widely accepted as a permanent form of wastewater management, it is essential that systems are designed and constructed in such a way as to promote satisfactory long term operation and to minimize ground water and other environmental impacts.

The basic design and construction standards as well as the density requirements for individual residential systems appear sound and are consistent with accepted best management practices. Minor modifications, such as further limiting the use of deep trench systems in type 1 basin soils might be appropriate, but beyond that, few other adjustments appear necessary.

However, two significant problems with the existing regulatory framework are apparent; the failure to deal with the potential for adverse ground water impacts from community systems and the lack of provisions to control potentially hazardous commercial and industrial wastewater flows. Since the concern over community systems is primarily their impact on ground water in the immediate vicinity of a development rather than over regional or basin wide impacts, the most appropriate strategy may be to spread the disposal systems over a wider area. Required distances separating individual drainlines could be increased. Setbacks from wells and property lines could be extended. Concentration of multiple community systems could limited by establishing special setbacks between systems or possibly by requiring dedicated drainfield replacement areas to be reserved between systems.

The second problem may be more difficult to address. Requiring all new commercial and industrial developments to be served by sewers would be the most effective solution but since sewers are not readily available in all portions of the basin, this would amount to a moratorium in unsewered areas. In addition, effluent from commercial facilities such as business offices, banks, and some retail establishments are no more deleterious than residential wastewater. A more reasonable approach might be to require sewers for types of commercial or industrial development that pose the greatest apparent risk to ground water such as dry cleaners, auto repair facilities, and machine shops.

Another option would be to impose special permit conditions on commercial or industrial developments to be served by on-site sewage systems. These conditions could include installation and testing of up and down gradient monitoring wells, periodic effluent monitoring, and posting of a performance bond or other financial assurances to cover the cost of any remedial measures deemed necessary as a result of on-site sewage system operation.

A final option, one that could be implemented individually or in concert with other strategies, would be an educational program aimed at modifying the behavior of waste handlers. Such an outreach program could help facility operators identify materials that are potentially threatening to ground water if introduced into an on-site sewage disposal system. In addition, information could be provided concerning proper waste disposal methods, and opportunities for waste recycling. While the options discussed previously focused on the problem of new commercial or industrial facilities, this approach could be applied to new as well as existing facilities.

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September 11, 1989
U-29796

MEMORANDUM

To: Jane Hedges, Senior Environmental Health Specialist, Health Dept.

From: Don Perry, Director of Utilities

Subject: Clover Chambers Creek Basin Technical Review of "Smaller On-site Sewage Disposal System Regulations: Assessment of Effectiveness in Protecting Ground Water

On page 5, the last sentence says that an on-site system could operate satisfactorily for an indefinite period. However, the economic cost for sizing facilities for the equilibrium acceptance rate of the soil is extremely high. Operationally speaking, the soils will plug ultimately so that the "leaching treatment section" will have to be replaced.

On page 7, the nitrate discussion seems to overlook natural generators of nitrogen (alder trees, clover, etc.), man-made fertilizers for farming and homeowners, lawns, manure, etc. It would appear that even with on-site systems taking out some of the nitrate that there is strong reason to believe that the groundwater will exceed 10 mg/l.

On Page 8, using of 44% or 50% removal for nitrate based on the 1979 Hill reference is very suspect at this point. With no systems built and in use to prove this can be done consistently operationally for the long term, I would be most concerned at using any nitrate removal especially. We must remember that there are over 40,000 residents on old systems which were not designed to remove nitrates.

We recommend commercial/industrial facilities must pretreat all their wastes (as they would have to do before it went into the Wastewater Treatment Plant) before entering the environment (i.e. a "leaching field").

On Page 18, the tone of the last paragraph of Vertical Separation could be changed to justify importing 3 feet of good material rather than attacking the 3 vs. 1 foot separation.

Also on page 18, the last paragraph is in conflict with the Public Works Department having sole use of the street right-of-way for storm water treatment and the covenant on all plats mandating all storm drainage for the plat is to be handled on the plat lots The above two items are in conflict with the use of the "lot area bounded by the centerline" of the road.

On page 19, second to the last paragraph, it appears to be a totally inappropriate conclusion that may lead to the aquifer to exceed 10 mg/l of nitrate because of all sources of nitrate.

On page 21, the last paragraph comment - generally, lots over one acre make justification for sewers on an economic basis difficult. It is a developer(s) option to cluster development which is supported by planning departments. Pierce County Utilities Department is neutral on the subject of clustering.

On page 22, the top paragraph - because of roads, you can "only" get 3.6 units to the acre not the 4.5 units shown for 9600 square foot lots. Using 44% nitrate removal is most questionable; and also overlooks other sources of nitrogen already commented on.

Summary Comments on Page 24

First paragraph - I am not a lawyer but I wouldn't come to the same conclusion reached here based on the information supplied in the report.

Second paragraph - Definitely wouldn't define on-site sewage disposal to be a permanent form of wastewater management without defining what you call permanent.

Last Paragraph - Pretreat all wastes before being discharged to the environment

Page 25, last paragraph - The Health Department must also have an active sampling and monitoring program along with education.

DTP/Misc-1/2

RESPONSE TO
COMMENTS ON
TASK 5.5 REPORT
ON-SITE WASTE PROGRAM EVALUATION

The following are responses to the comments received from Don Perry concerning the Task 5.5 Report entitled "Smaller On-Site Sewage Disposal System Regulations: Assessment of Effectiveness in Protecting Ground Water".

Comment 1 (Re Page 5): The notion that soils "will plug ultimately so that the leaching treatment section [of the on-site sewage system] will have to be replaced" is rooted in what is commonly referred to as the creeping failure theory. That particular theory was widely accepted until the early to mid-1970s when it was turned around by the findings of extensive research into this subject. The creeping failure theory asserts that a subsurface absorption system will cease to function over time as a result of the development of a clog mat at the interface with the surrounding soil.

The hydraulic conductivity of a soil at its interface with the subsurface absorption system is definitely impaired as a clog mat forms, but is not reduced to zero. Conductivity of the soil at the interface will eventually stabilize at a long term equilibrium acceptance rate. A subsurface absorption system will function properly as long as the amount of effluent being applied to the soil surface does not exceed the long term equilibrium acceptance rate.

With an unsaturated soil, the long term equilibrium acceptance rate is largely dependent upon soil texture and will generally fall within a predictable range. For the types of soils that are suitable for installation of subsurface absorption systems under the DSHS and TPCHD regulations, that predictable range is between about 0.45 and 1.2 gallons per day per square foot (gpd/sq ft). Porous silt loams and loams represent the low end of this spectrum while medium and coarse sands are at the high end. Sandy loams and fine sands reach equilibrium acceptance rates of approximately 0.60 and 0.79 gpd/sq ft respectively.

These application rates are now nationally accepted as proper design criteria for subsurface absorption systems. The EPA Design Manual for On-Site Wastewater Treatment and Disposal Systems (1980) recommends these application rates to assure that systems are designed based on the rate of infiltration through a mature clog mat.

There is, of course, some site specific variability in the long term acceptance rate of a soil. That is, a sandy loam will not accept effluent at a rate of precisely 0.60 gpd/sq ft. It could be slightly higher or lower than that value. For that reason, subsurface absorption systems that are designed based on the TPCHD standards are not sized precisely according to the recommended rates. As pointed out in the text of the Task 5.5 Report, the TPCHD design standards have several built-in safety factors that result in functional application rates that are considerably more conservative than the recommended long term acceptance rates. Because the TPCHD regulations ignore the infiltrative capacity of the sidewall and use a relatively high per-capita wastewater generation estimate of 75 gallons per day, the chances of actual wastewater flows exceeding the equilibrium infiltrative capacity of a subsurface absorption system are quite low.

The health department implemented a requirement that all on-site systems must be designed based on long term acceptance rates over 10 years ago. In fact, that requirement was in effect nearly 2 years prior to the release of the EPA Design Manual.

As a result of this requirement, the length of a subsurface absorption system necessary to serve a 3-bedroom single family residence increased from a range of 50 to 150 linear feet of 3-foot wide trench to a range of between 125 to 330 linear feet. Contrary to the assertion in Comment 1, while the requirement for larger subsurface absorption systems has increased the cost of their construction, such systems have certainly remained within the realm of economic feasibility.

There are some excellent references concerning long term acceptance rates that will more completely explain this phenomenon. Two that are recommended are "Design and Construction of Soil Absorption Trenches and Beds," by R.J. Otis, G.D. Plews, and D.H. Patterson (Proceedings of the Second National Home Sewage Treatment Symposium, American Society of Agricultural Engineers, 1977) and "Long Term Acceptance Rates of Soils for Wastewater," by J.L. Anderson, R.E. Machmeier, and M.J. Hansel (Proceedings of the Third National Symposium on Individual and Small Community Sewage Treatment, American Society of Agricultural Engineers, 1981). EPA has published a number of documents concerning this subject as well.

Comments 2 and 3 (Re Pages 7 and 8): Because these two comments both deal with the issue of nitrate, they will be addressed in the same response.

This report was never intended to provide a calculation of total nitrogen contribution to ground water from all sources. The information that was presented concerning nitrate contributions from individual on-site systems was provided primarily for purposes of comparison with nitrate loading values that were developed later in the document for community on-site systems.

In residential areas of the CCC Basin, the total nitrate input to ground water from all sources is roughly 112 kg/hectare/year. On-site sewage systems at densities of one unit per acre or two units per acre with sand filtration and pressure distribution account for about 30 kg/hectare/year or 26 percent of that amount.

The portion of the nitrate load that originates from natural sources is about 12 kg/hectare/year. This natural input has resulted in a background nitrate level in basin ground water of about 0.25 mg/l (NO_3-N). On a proportionate basis, 112 kg/hectare/year should result in nitrate concentrations in ground water of roughly 2.3 mg/l (NO_3-N).

A complete breakdown of CCC Basin nitrate loading is presented in Table 1.

Table 1. Clover/Chambers Creek Basin Nitrate Loading

Source	Loading (kg/hectare/yr)	Percent
Atmospheric (Based on Tacoma, WA)	5.4	4.8
Biological habitat (Douglas fir/oak/mixed shrub)	6.7	5.9
Residential lawn fertilizer use	63.0	55.9
On-site sewage systems (one unit per acre or two units with sand and pressure)	30.0	26.6
Lawn watering (assume nitrogen levels in water of 1.6 mg/l)	5.0	4.4
Dogs and cats	2.7	2.4
Total	112.8	

(Flipse et. al., 1984) (Sweet/Edwards, 1978) (Uttomark et. al., 1980)

The comment that there is "strong reason to believe that ground water will exceed 10 mg/l [of NO_3-N]" due to the cumulative impacts of all sources of nitrate in a low density, residential area served by on-site sewage disposal systems is without foundation. Concern that nitrate levels will exceed the maximum contaminant level was certainly valid in the urbanized portions of the basin during the mid-1970s when housing densities as high as 18 units per acre were being allowed on community on-site sewage systems. However, low density, single family residential developments are not as likely to create a significant impact without an unusually large source of nitrogen being present, such as a confined animal keeping operation or a manure spreading operation. These types of agriculturally oriented land-uses occur in only very limited portions of the basin and are not well tolerated in residential areas.

If indeed there is "strong reason to believe" that nitrate levels in ground water will exceed 10 mg/l due to on-site sewage system use, then water samples taken just prior to the sewering of Lakewood, Parkland, and Spanaway should have demonstrated wide-spread exceedence of the maximum contaminant level for nitrate. These areas represented the most heavily urbanized un-sewered portions of the basin and had housing densities far above the one to two units per acre that are currently allowed. However, a review of water quality data from the period between 1975 and 1982 conducted as part of the Clover/Chambers Creek Geohydrologic Study revealed that nitrate levels in two-thirds of all samples taken during that period were less than 1.8 mg/l (NO_3-N). A majority of those samples were from the urbanized portions of the basin. In spite of the high concentrations of on-site systems that existed in a number of areas of the basin, the highest value observed during the period was 6.1 mg/l (NO_3-N)(Brown and Caldwell, 1985).

This is not intended to suggest that a nitrate level of 6.1 mg/l does not suggest a serious problem. However, it should put the potential impacts of two dwelling units per acre with enhanced on-site sewage treatment facilities (pressure distribution and sand filtration) in better perspective.

Concerning the statement that "there are over 40,000 residents on old systems that were not designed to remove nitrates", it should be noted that pressure distribution and sand filtration requirements were imposed in the Clover/Chambers Creek Basin in 1979. That means that all houses built during the last 10 years in the unsewered portion of the basin were subject to those requirements. The largest currently unsewered portion of the basin is the eastern one-third which was only sporadically developed prior to the 1980s. There are some un-sewered, high density developments such as Southwood still present in the basin that warrant careful scrutiny in terms of their potential impact on ground water. However, in our opinion it would be misleading to suggest that on-site sewage systems in the entire unsewered area, or even a significant portion of it, represent a high level of nitrate contamination risk.

With regard to the comment concerning the use of the 44 percent nitrate removal efficiency estimate when using sand filtration and pressure distribution, we have found no substantive technical data to refute the Hill reference. The document written by Robert C. Hill that was referenced in the Task 5.5 Report was prepared for the State of Wisconsin and was based on studies conducted by the University of Wisconsin at Madison. During those studies, the treatment efficiency of on-site sewage systems that utilized sand filtration and pressure distribution were monitored over an approximately 10 year period.

Other studies on long term operation of such systems suggest even higher removal efficiencies. For instance, the Oregon Department of Environmental Quality indicates that a 50 percent removal can be expected based on the performance of systems in that state. The most recent research data suggests that removal efficiencies of over 80 percent can be attained with similar technology (Lenning, 1989).

Comment 4 (Re Pretreatment): Good suggestion.

Comment 5 (Re Page 18): It was not the intent to dismiss the 3-foot separation requirement. It was pointed out that, considering the type of soil that is present in the basin, vertical separation, per se, is not a critical factor in the protection of ground water. This is important because it would be a mistake to presume that ground water is being protected through adherence to rigid vertical separation requirements.

In the text, the benefits of placing sand filter material under drainfields installed in excessively permeable soils were emphasized; however, your suggestion has merit.

Comment 6 (Re Page 18): The lot size definition that was presented comes from Washington Administrative Code Chapter 248-96. We believe that a county can pass regulations that are more restrictive than a WAC, but we do not believe that the Public Works requirements, in their present form, necessarily supersede the WAC.

Comment 7 (Re Page 19): This comment is essentially a reiteration of Comments 2 and 3. Based on the available literature, we cannot find support for the conclusion that nitrate levels in CCC Basin ground water underlying areas with low density residential land use will exceed 10 mg/l due to the combination of all nitrate sources.

Comment 8 (Re Page 21): The information concerning economic feasibility was provided by Pierce County Utilities staff.

Comment 9 (Re Page 22) The statement, "under a worse case scenario, all portions of a given acre could be entirely utilized as residential lots of 9,600 square feet", was considering usable lot area only, not roads.

If the configuration of a subdivision places lots in two contiguous, parallel rows (back yard touches back yard), the area occupied by the lots would be entirely utilized for residential purposes. Roads would not be a factor. Therefore, the effective density could be as high as 4.5 units per acre.

We have assumed that the concern expressed in this comment concerning the estimated 44 percent removal of nitrate through use of sand filtration and pressure distribution is a reiteration of Comments 2, 3, and 7. The University of Wisconsin based the 44 percent figure on exhaustive research on the pollutant removal efficiency of sand filtration and pressure distribution systems. To date, we have seen no data that refutes their conclusions.

We have seen evidence that suggests that levels of removal higher than 44 percent can be expected with pressure distribution and sand filtration technology. The Oregon Department of Environmental Quality concluded that nitrate removal efficiencies in such systems is probably closer to 50 percent. Dave Lenning of the Washington State Health Department indicates that the most recent research suggests removal efficiencies of over 80 percent can be achieved through similar technology.

The Rules and Regulations of the State Board of Health for On-Site Sewage Disposal (WAC 248-96) are based on the same anticipated removal efficiency.

<u>Comment 10</u> (Re Page 24, First Paragraph): Since the TPCHD regulations are in many cases simply a re-statement of the Washington State Health Department (formerly DSHS) regulations and since the TPCHD regulations were reviewed and approved by the State Health Department in 1987, a conclusion that they do not meet the intent of the DSHS regulations is somewhat paradoxical. If the TPCHD regulations are somehow in conflict with the State Health Department regulations, that department has a legal responsibility to reject the local regulations.

Regarding consistency with Ecology requirements, the TPCHD regulations incorporate the 3-foot separation requirement of the Ecology Docket Order. That is about the only significant provision of the current version of the Docket Order. In recent years, Ecology has basically relied on strict adherence to the State Health Department regulations for protection of the CCC Basin aquifer.

<u>Comment 11</u> (Re Page 24, Second Paragraph): This comment relates to Comment 1 (re Page 5). The longevity issue was addressed in our previous comment.

Use of the term "permanent" in this context can be defined as meaning that an on-site sewage disposal system should function properly for at least as long as the functional life of a typical house. Again, the great preponderance of scientific evidence supports the concept of long-term equilibrium operation of subsurface absorption systems.

The stated philosophy of EPA, FHA, Department of Ecology, and the State Health Department is that on-site sewage disposal systems are a viable, long-term form of sewage disposal.

Comment 12 (Re Page 24, Last Paragraph): This is a reiteration of Comment 4. We fully agree with the concept of pretreatment of commercial/industrial wastewater.

Comment 13 (Re Page 25, Last Paragraph): We view the need for a sampling and monitoring program as being part of a comprehensive small quantity waste generator program that deals with both sewered and unsewered areas.

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APPENDIX C

QUALITY ASSURANCE/QUALITY CONTROL PLAN
FOR WATER QUALITY SAMPLING AND ANALYSIS

CLOVER/CHAMBERS CREEK GROUND WATER
MANAGEMENT PROGRAM

Prepared by

BROWN AND CALDWELL CONSULTING ENGINEERS

For

TACOMA-PIERCE COUNTY HEALTH DEPARTMENT

APRIL 1988

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CHAPTER 1

INTRODUCTION

This Quality Assurance/Quality Control Plan (QA/QC Plan) is based on the Gig Harbor Peninsula Quality Assurance Project Plan program and includes the principal elements detailed in the Washington Department of Ecology (WDOE), December 1986 Quality Assurance Interim Guidelines.

This document includes Quality Assurance (QA) procedures for ground water sample collection, analysis, and reporting for the Clover/Chambers Creek Ground Water Management Program (CCC GWMP) to the Tacoma-Pierce County Health Department (TPCHD). The goals of this document are:

- To ensure that high-quality, verifiable data are collected.
- To encourage cost-effective use of resources.
- To ensure that data are usable by Ecology and other state and local agencies.

Three types of data will be used in characterizing ground waters of Clover/Chambers Creek: (1) previously collected data, (2) data collected during this project from existing wells (primarily domestic and municipal wells), and (3) data collected from monitoring wells constructed during this project.

The general criteria to be used to evaluate ground water data for inclusion in the CCC GWMP data base will be as follows:

1. Previously collected data: Wells will have Water Well Report Forms that include location information (to quarter-quarter section) and well depth; sample data will indicate the name and/or agency of the person who collected the sample and the laboratory that performed the analysis. Data more than 20 years old will be included in a separate file.

2. Existing wells to be sampled as part of this project: Same information as for No. 1, above. In addition, the Water Well Report Form will indicate the depth of the screened or open portion of the well, the casing material, and the elevation and horizontal location of the top of the casing. Additional information associated with

existing wells chosen for sampling will be included if available. Note: Some existing wells included in the Clover/Chambers Creek Ground Water Management Program may require surveying by a licensed surveyor at the responsibility of the TPCHD.

3. Monitoring wells to be drilled for data collection during this project: Same information as in No. 2, above. In addition, the wells will be surveyed by a licensed surveyor to an established National Geodetic Datum. Also, the wells will meet the minimum information requirements listed in Ecology's Design and Construction Guidelines for Monitoring Wells (WAC 173-162).

Data gathering activities will be specified in detail in the Clover/Chambers Creek Data Management Plan.

CHAPTER 2

PROJECT DESCRIPTION

Project Goals

The Clover/Chambers Creek Ground Water Management Program (CCC GWMP) is an integrated approach to ground water management. The primary goal of the project is to implement a credible, defensible and successful ground water management program.

The key objectives to achieving this goal include:

- Refine characterization of the basin's land use activities, hydrogeology and ground water quality sufficient to develop a sound ground water management program
- Augment water level and quality data base to better focus goals and objectives of ground water management program.
- Determine the pollutant load entering the subsurface disposal system.
- Determine the pollutant-removal capacity of existing subsurface stormwater disposal systems (drywells) for priority contaminants in the CCC Basin.
- Evaluate the need for and potential effectiveness of runoff control and/or treatment.
- Initiation of the actual management/decision making process by the GWAC and Pierce County
- Development of the institutional and funding foundation to carry on management activities after this project is completed

Scope of Work

This project includes nine (9) tasks:

Task 1: Public information and involvement

Task 2: Background data collection, land and water use activities

Task 3: Background data collection, hydrogeology

Task 4: Data collection plan and quality assurance plan

Task 5: Data collection and analysis

Task 6: Development and selection of alternatives

Task 7: Implementation plan development

Task 8: Preparation of the draft Clover/Chambers Creek Ground Water Management Program

Task 9: Public review and program adoption

Task 5, data collection and analysis, will be the principal task requiring strict QA/QC. Monitoring well construction, stormwater and ground water sampling, and sample analysis will be the principal efforts requiring QA. Tasks 2 and 3, which involve the evaluation of large quantities of data, will also require QA for assessing data precision, accuracy and completeness (Chapter 8) and comparability of data bases.

Water Quality Sampling

This project includes stormwater sampling for four precipitation events and ground water sampling by Sweet-Edwards/EMCON and Molly Adolfson Consulting in the Clover/Chambers Creek Basin.

Drywell Sampling. Two existing subsurface stormwater disposal systems (drywells) selected to be representative of composite land use categories will be evaluated. In order to avoid potential interfering effects from septic tanks, commercial transportation areas served by sanitary sewers will be selected. All drywells evaluated will be located in areas with shallow ground water (approximately 30 feet deep) in order to represent "worst case" conditions in terms of potential ground water contamination. Runoff entering each drywell will be monitored for the following constituents:

Conductivity
COD
Temperature
Fecal coliform
Nitrate-nitrogen
Ortho-phosphorus
Arsenic, Copper, Lead, Zinc
Chlorinated volatile organics
Benzene, toluene, and xylene (BTX)
Fecal coliform

Puyallup (outside basin boundary)
Fircrest
Summit
Fruitland Mutual

Testing parameters for the purveyors' ground water systems are included in Table 2-1. Efforts will be made to incorporate data from these wells where feasible, recognizing, however, that not all purveyors will be testing for many of these parameters during the time frame of this study.

Table 2-1. Minimum Monitoring Requirements for Group A Systems[b]

System Group	Sample type	Minimum number of samples required[a]
A	Bacteriological	Dependent on population served.
	Inorganic chemical and physical (primary and secondary)	One complete analysis per source or well field every 36 months.
	Trihalomethanes	Systems with 10,000 or more population only. 1 per plant every 12 months.
	Corrosivity	1 per plant or well field.
	Pesticides	As directed by the Department.
	Radionuclides	Once every 48 months or as directed by the Department of Health.

[a]These are the minimum requirements. Additional monitoring may be required by the Department of Health.

[b]Group A; systems with 15 or more service connections, regardless of the number of people, OR 25 or more people per day for 60 or more days per year.

CHAPTER 3

PROJECT ORGANIZATION AND RESPONSIBILITIES

This section outlines the Quality Assurance Project Organization for the Clover/Chambers Creek Ground Water Management Program. Figure 3-1, Clover/Chambers Creek Ground Water Management Program Quality Assurance Project Organization, shows schematically the QA project plan. Below, we describe the specific responsibilities of the project QA team.

<u>Jane Hedges, Lead Agency Project Manager</u>

Lead agency responsibilities for review and approval of QA Project Plan. Responsible for ensuring that QA Project Plan is carried out to the full extent and that data collected meet the specified data quality objectives.

<u>Elizabeth Phinney, Ecology Project Officer</u>

Lead person in Ecology responsible for project performance, review of project QA needs and problems, and approval of appropriate QA corrective actions as needed.

<u>Brent Barrett, Water Quality Program Technical Advisor</u>

Assists Ecology Project Officer in reviewing QA Project Plans and data submitted. Also may assist in tracking fulfillment of WA Project Plan provisions.

<u>Marilyn Blair, Water Resources Program Technical Advisor</u>

Assists Ecology project officer in reviewing QA project plans and data submitted. Also may assist in tracking fulfillment of WA project plan provisions.

<u>Molly Adolfson, Adolfson Associates, Inc.</u>
<u>Task 5 Project Manager and Project QA Coordinator</u>

Oversees field, laboratory, and data analysis, and QA activities to ensure that project performance complies with QA Project Plan. Approves and implements necessary corrective action and adjustments to accomplish project objectives. Promptly notifies GWMA Project Manager, Project Coordinator, and Ecology Project Officer of any corrective action or adjustments made to schedules or procedures. Submits QA results with sampling data and other documentation as described under Sections 5, 7, and 11 on a regular basis (depending on the project schedule).

Jack Warburton, Brown and Caldwell, Project Coordinator

Acts as liaison between agencies and contract personnel.

Gerritt Rosenthal, Sweet-Edwards/EMCON Field Operations QA Officer

Tracks QA activities relative to field sampling and analysis to ensure compliance with QA Project Plan. Conducts inspections of sampling procedures, field analyses, and documentation in conjunction with QA Project Plan specifications. Verifies that laboratory results of field blanks, duplicates, spikes, and standard reference materials are being used to evaluate and eliminate any potential sample contamination. If problems are discovered, reports these immediately to the Task 5 Project Manager.

Steve Merrill, Brown and Caldwell, Data Management QA Officer

Establishes computerized Data Management System and updates data base of QA results and sampling data on a regular basis.

Steve Vincent, Columbia Analytical Laboratory QA Officer

Tracks QA activities and sample results from the laboratory. Evaluates laboratory adherence to procedures required in the QA Project Plan. When problems are discovered, reports these immediately to the Project QA Coordinator. Submits reports to the Project QA Coordinator on a specified time basis (time frame dependent on project schedule).

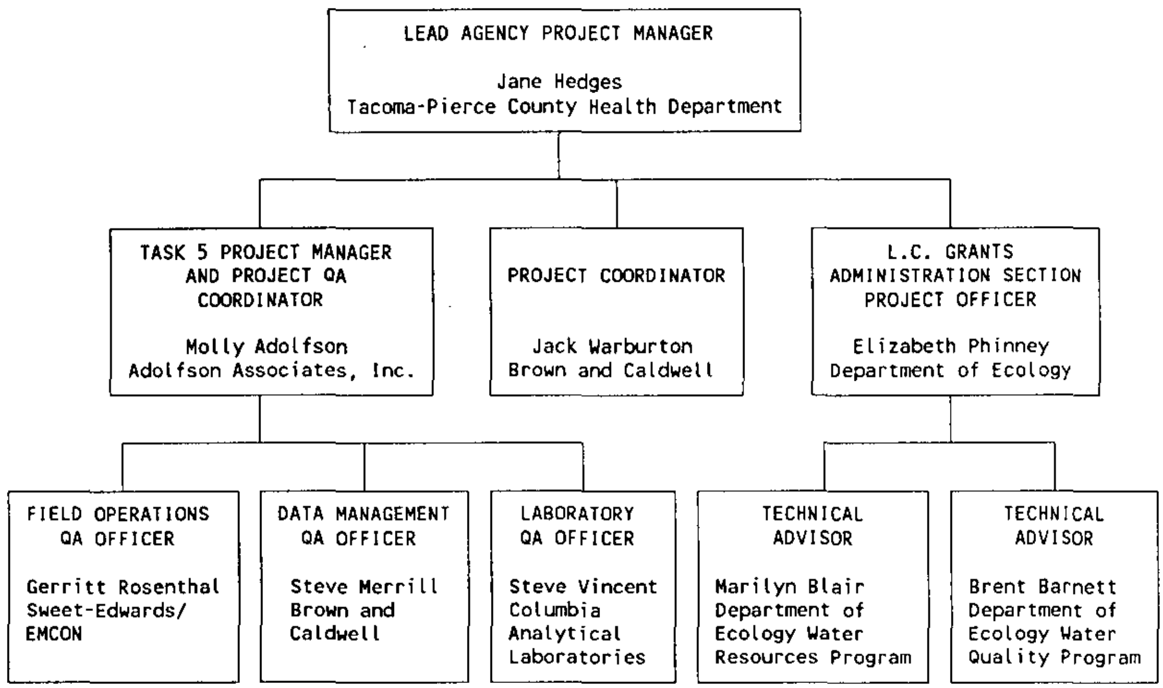

Figure 3-1. Clover/Chambers Creek Ground Water Management Program Quality Assurance Project Organization

CHAPTER 4

OBJECTIVES FOR MEASUREMENT DATA

Quality Assurance is the mechanism to provide for control and evaluation of data quality throughout the course of study for the Clover/Chambers Creek Ground Water Management Program. The procedures and guidelines outlined in this Quality Assurance Project Plan (QAPP) will be used to evaluate the quality of both qualitative and quantitative data that will be obtained during he study and ultimately used for ground water management decisions. Consistency in methods of sampling, analysis, data evaluation and reporting will be a high priority in this investigation. Quality Assurance goals for detection limits, accuracy, precision and completeness are shown in Table 4-1, Data Quality Objectives.

Table 4-1. Data Quality Objectives

Matrix	Parameter	Detection			Precision	Com-plete-ness	Preferred method	Reference
		Units	Limit	Accuracy				
Ground water	<u>Organics</u>							
	Volatile organics	µg/l	a	b	+20%	95%	EPA Method 624	Federal Register 40 CFR Part 136
	Base neutrals and acids	µg/l	a	b	+20%	95%	EPA Method 625	"
	Organochlorine pesticides and PCBs	µg/l	a	b	+20%	95%	EPA Method 608	"
	Polynuclear aromatic hydrocarbons	µg/l	a	b	+20%	95%	EPA Method 610	"
	<u>Field Analyses</u>							
	pH	standard pH units	NA	+0.1	+0.1	95%	EPA Method 150.1	U.S. EPA 1979
	Specific conductance	umhos/cm	1.0	+5%	+5%	95%	EPA Method 120.1	"
	Temperature	degrees C	4	+0.1	+0.1	99%	EPA Method 170.1	"
	<u>Inorganic Tests</u>							
	Chloride, sulfate, nitrate, nitrite, ammonia	µg/l or mg/l	a	+10%	+10%	95%	EPA Methods c, d	U.S. EPA 1979
	Chemical oxygen demand							
	Total organic carbon	µg/l	0.5	+10%	+10%	95%	EPA Method 415.1	"
	Metals	µg/l or mg/l	a	+20%	+20%	95%	EPA Methods c, d	"

[a] Dependent on individual compound.
[b] Dependent on individual compound.
[c] Methods for Chemical Analysis of Water and Wastes, U.S. EPA, 1983.
[d] Federal Register 40 CFR Part 136.

CHAPTER 5

SAMPLING AND FIELD MEASUREMENT

Drilling and Borehole Logging

Drilling for the installation of ground water monitoring wells will be performed utilizing hollow stem auger or air rotary drilling methods. All drilling will be under the direct supervision of a driller licensed in the State of Washington. Drilling equipment will be steam cleaned prior to drilling the first hole, and between borings if the on-site geologist determines that subsurface conditions have been encountered which could compromise the validity of the water quality samples taken from the wells.

All drilling activities will be supervised by a SE/E geologist. A continuous log of subsurface soils will be prepared for each boring location. Each boring log will include the following information:

- Name and location of project.
- Boring number, well number and/or gas probe number.
- Drilling contractor, drilling method and sampling method.
- Detailed description of soil samples and drill cuttings including designation according to the Unified Soil Classification System (USCS).
- Start and finish of drilling.
- Date and time of water level measurements.

Monitoring Well Installation

Monitoring wells will be constructed with the following materials:

- Schedule 40 2-inch diameter PVC well casing.
- Ten feet of 2-inch diameter, 0.002-inch machine slotted PVC well screen with threaded end cap.
- Natural gravel pack or 8-12 silica sand.

- Bentonite pellets/bentonite chips and/or bentonite powder.
- Flush mounted surface security casing with locking cap.

Upon the completion of each boring, a single completion monitoring well will be installed in each boring. Each monitoring well will consist of Schedule 40, 2-inch diameter flush threaded PVC screen and riser pipe. All screen will be factory slotted with 0.020-inch size slots. If appropriate, an annular gravel pack will be placed around and extend approximately 2 feet above and 2 feet below the screened interval. A bentonite seal will be emplaced from 2 feet above the top of the screen to ground surface. Bentonite pellets and bentonite chips will be used as a seal beneath the water table and bentonite powder mixed as a dense slurry above the water table. After the completion of each well the screened zone will be developed using a combination of pumping and surging techniques.

Notification will be given to the Department of Ecology in the event that the completion design of any monitoring well or gas probe has to be significantly changed as a result of subsurface conditions encountered while drilling.

Well Development

Following installation of each monitoring well, the well's screen zone will be developed by pumping, bailing and/or surging until the discharge water is free of sediment and non-turbid, or field measurements of pH, temperature, and conductivity have stabilized or show no further improvement.

Surveying

All installed wells will be surveyed by a registered surveyor. Each well will be surveyed in accordance with the following guidelines:

- All wells (new and existing) used for the measurement of ground water surface elevations shall be surveyed for vertical elevation. The basis for all elevations shall be a recognized USGS datum. The top of the well casing shall be surveyed to the nearest 0.01 foot. A mark shall be placed on the well casing indicating the location which was surveyed. Vertical surveys shall be of third-order accuracy.

Hydrogeologic Measurements

Depth to water measurements will be obtained with an ACTAT Olympic Well Probe or similar instrument. Water levels will be measured to the nearest 0.01 foot. Well probes will be calibrated using a steel measuring tape. The indicator probe will be rinsed with distilled water prior to use in each well. All measurements will be taken from a marked surveyed point on the top of the PVC monitoring well casing. Each measurement will be recorded on Field Sampling Data Sheets and will include the date and time of measurement. Water level measurements taken in a single data set will be taken over as short a time period as possible to reduce the potential influence of water level fluctuations.

Tracer Analysis for Ground Water Flow Verification

As part of the Clover/Chambers Creek QA/QC Program, tracers will be used to provide positive tracking of ground water flow between dry wells and downgradient monitoring locations. To assist in siting monitoring wells during drilling, sodium chloride slugs of approximately 100,000 ppm concentration will be injected in aqueous solution into the dry well before and during drilling each site. During and upon completion of well development, conductivities will be measured. Subsequent downgradient well locations will be selected on the basis of relatively higher conductivities and the direction of ground water flow determined ground water levels.

During storm events, known quantities of sodium chloride will be injected in aqueous solution into the dry well and water in the monitoring wells will be tested for increases in lithium concentration over a period of 3 days to 4 weeks.

Injection concentration will approximate 100,000 ppm and downgradient detections are anticipated in the 1 to 100 ppm range. Detection testing sensitivity is approximately 0.01 ppm using standard AA techniques. Initial samples will be taken prior to injection to determine ambient lithium levels. Sample collection will be by standard shallow ground water techniques with normal quality assurance protocols. It should be noted that the test is performed to evaluate the rate of aquifer travel and to provide a direct negative/positive evaluation of drywell influence on individual wells and quantification of lithium levels and is not critical to the analysis.

Sampling and Field Measurement

Sample Container Preparation and Preservatives. All sample containers will be prepared and provided by Columbia Analytical Laboratories as follows:

1. Coliform bacteria will be collected in a sterile whirl pack bag.

2. COD, nitrate-nitrogen, and phosphorus will be collected in polyethylene sampling bottles which have been rinsed with deionized distilled water and preserved with sulfuric acid to a pH of less than 2.

3. Metals will be collected in polyethylene sampling bottles which have been washed with dilute nitric acid, rinsed with deionized distilled water, and preserved in nitric acid to a pH of less than 2.

4. Volatile organics will be collected in EPA approved 40 ml glass vials with Teflon septa caps; these vials will be heated in a muffled furnace prior to use.

Samples will be preserved as per recommendations given in Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March, 1979. The type and size of container used for each parameter, and any preservative will be recorded on a field sampling data sheet.

Field Instrument Calibration and Maintenance. Time-sensitive parameters, i.e., temperature, pH and specific conductance, will be measured in the field at the time of sample collection. Field instruments will be calibrated using known standard solutions a minimum of twice daily. Calibration, procedures, date and time will be recorded in instrument log books. Conductivity and pH measurements will be obtained using a DSPH 2 meter. Calibration will be performed daily with known standards. Backup instruments will be available in the event of a malfunction. Instrument maintenance will be performed as necessary by the manufacturer.

Sampling Procedure. Purging stagnant water from well casings prior to ground water sampling will be accomplished with two general methods. Monitoring wells will be purged with either dedicated positive displacement pumps or with a 1.5-inch diameter, 10-foot long PVC bailer. A Field Well Record will be filled out for each well during the first sampling period (see Appendix A).

The general ground water sampling procedure will be as follows:

- Measure static water level with a calibrated electric water level meter

- Purge a minimum of three storage water volumes or until pH and conductivity stabilize. Storage water volume will be calculated according to V = 3.14 x R2 x L where V = volume, R = well radius and L = length of static water in well

- Measure and record field parameters of pH, conductivity and temperature

- Filter samples for dissolved metals analysis using 0.45-micron in-line filter system

- Transfer ground water to sample containers with a minimum of agitation and ensure head space is not present in samples for volatile organics analysis (VOA)
- Label samples and document activities including weather, purge rate, etc.
- Deliver or ship samples to analytical laboratory within 24 hours of collection.
- Follow chain-of-custody procedures as outlined below.

All field activities and data are to be entered on a Field Data Sheet for each site (see Appendix A).

Quality Control Samples

Quality control samples consisting of field blanks, transport blanks and duplicate samples will be included in each sampling event.

Duplicate ground water samples will be obtained by alternately filling like sample bottles for two sample sets until all containers are full. Approximately ten percent of ground water samples will be collected as duplicates.

Field blanks (method blanks) will be taken for each separate sample bottle type and analyzed in the laboratory with the other samples. Field blank samples will be obtained following equipment decontamination by collecting distilled water that has passed through the sampling equipment. This process is performed to check contamination of sampling equipment. Field blanks will be tested at a rate of approximately 1 in every 20 samples (5 percent).

Transport blanks will be provided by the analytical laboratory, accompany the shipment of sample bottles to the site, and will return to the laboratory for analysis with the sample shipment. Each type of sample bottle will be filled with de-ionized water at the laboratory and will not be opened until its return to the laboratory for analysis. Transport blanks will be taken at a rate of 1 on every 20 samples or one per sampling event, whichever is greater.

Sample Labeling, Shipping and Chain-of-Custody

Sample Labeling. Sample containers will be labeled as much as possible prior to sample collection. Sample container labels will be completed immediately following sample collection. Container labels will include the following information:

- sample number
- name of collector
- data and time of collection
- place of collection
- type of preservative used

Sample Shipping. Samples will be shipped to Columbia Analytical Laboratory using the following procedure:

- Sample containers will be transported in a sealed ice chest or other suitable container. Care will be taken to secure the drainage hole at the bottom of the cooler in case of sample container leakage.

- Glass bottles will be separated in the shipping container by absorbent material to prevent breakage.

- Ice will be placed in separate plastic bags and sealed.

- All sample shipments will be accompanied by a Chain-of-Custody Laboratory Analysis Request Form(s) (see Appendix). The sealed envelope containing the Chain-of-Custody Forms will be enclosed in a plastic bag and taped to the inside lid of the cooler.

- Signed and dated chain-of-custody seals will be placed on all coolers prior to shipping.

- The consultant's office, name, and address will be placed on the container.

Chain-of-Custody. Upon transfer of sample possession to subsequent custodians, a Chain-of-Custody Form will be signed by the persons transferring custody of the sample container. Upon receipt of samples at the laboratory, the shipping container seal will be broken and the condition of the samples will be recorded by the receiver. Chain-of-Custody records will be included in the analytical report prepared by the laboratory.

Sweet-Edwards/EMCON's Field Sampling Data/Chain-of-Custody forms will be used during ground water sampling for this study. Copies of these forms are included in the appendix. These sheets provide documentation of the following information:

- Project name
- Location and sampling source
- Time and date of sampling
- Pertinent well data, e.g., depth-to-water
- Sampling method, e.g., dedicated pump
- Preservation, if any
- Log number of each sample, volume and type of container
- Weather

- Field measured parameters, e.g., pH, temperature, specific conductance
- Sample storage
- Comments, e.g., appearance of sample
- Total number of bottles at station

Decontamination Procedures

All drilling equipment will be steam cleaned prior to drilling the first boring at a given site. Steam cleaning of drilling equipment between borings will be required if monitoring wells for ground water sampling are to be installed.

All non-dedicated ground water sampling equipment will be thoroughly decontaminated prior to sample collection at each well. The following treatments will be sequentially used for equipment decontamination:

- Non-phosphate detergent wash
- Distilled water rinse (double rinse)
- Reagent methanol rinse
- Distilled water rinse (double rinse)

Plastic sheeting will be used to cover work surfaces at each ground water sampling location. Diluted HCl and methanol will be stored in separate, labeled containers and will be treated in an appropriate manner. If conditions involving high concentrations of oils or gases are encountered, hexane may be substituted for the methanol rinse.

Documentation

Accurate documentation of field activities will be maintained using field logs, field data forms, correspondence records and photographic slides. Entries will be made in sufficient detail to provide an accurate record of field activities without reliance on memory.

Field log entries will be dated and include a chronologic description of task activities, names of individuals present, names of visitors, weather conditions, etc. All entries will be legibly entered in ink and will be signed.

When photographs are taken, the project number, date, picture number and a description of the photograph will be entered on a photography log form (see Appendix A).

CHAPTER 6

ANALYTICAL SYSTEM

The analytical laboratory system to be used in the CCC study is Columbia Analytical Services, 1317 South Thirteenth Avenue, Kelso, Washington, 98626 (telephone (206) 577-7222). Columbia Analytical Services is certified under the EPA Contract Laboratory Program (CLP) for inorganic analyses. In addition, the lab is certified for drinking water analysis by the State of Washington. As part of standard laboratory procedure, the lab holds their raw data which will be available for review during the course of the project. The Quality Management Plan employed by CAS is included as an attachment. This plan provides details relevant to equipment, personnel, calibration and maintenance procedures, analytical methods, QA/QC checks and other information necessary to the QAPP. This information outlines CAS's Standard Operating Procedures that will be used in this study.

CHAPTER 7

DATA MANAGEMENT, REDUCTION, VALIDATION AND REPORTING

A project-specific Data Management Plan has been prepared to address the data sources, data processing and data applications for the Clover/Chambers Creek Ground Water Management Program. Raw data generated in the field or received from analytical laboratories will be entered into a computerized data base for management. Criteria for analytical data validation includes checks for internal consistency, transmittal errors, laboratory protocol and overall adherence to the QAPP. Tables 7-1 and 7-2 outline the laboratory report documentation necessary for data validation. Quality control sample results and information documented on field sampling forms will be used to interpret and evaluate laboratory and field analytical results.

Table 7-1. Recommended Documentation for Independent QA Review of Data on Organic Substances (WDOE, 1986)

1. Analyzes of the requested priority pollutant acids, bases, neutrals (including PCBs and pesticides), and chemically similar compounds should be reported as follows:

   a. Sample concentrations reported in proper units (e.g., ug/l) to the appropriate number of significant figures on standard data sheets.

   b. Lower limits of detection of undetected values reported for each compound on a sample-by-sample basis.

   c. Internal standard recoveries for analyses using method recovery standards (including isotope dilution GC/MSO), reported on the data sheets as percent recoveries.

   d. Ancillary information, including the actual spike level of any recovery standards, final volume of the extract, and injection volume.

   e. A statement in the cover letter describing any significant problems in any aspect of sample analysis (e.g., instrument malfunctions, software problems during quantification).

2. Other documentation that will be made available on request includes the following:

   a. The reconstructed ion chromatogram for each sample (or for each sample fraction if the extract has been analyzed in distinct chemical fractions).

   b. GC/ECD chromatograms for pesticide/PCB analyses, with identification of peaks used for quantitation and any confirmation chromatograms.

   c. Complete data for all method blanks, reported as absolute mass of each blank contaminant determined; samples associated with each blank should be indicated.

   d. Raw data quantitation reports, including tabulated results (identification, GC/MS scan number/retention time, area and quantity) for compounds in each sample analyzed by GC/MS.

   e. A statement in the cover letter describing how standard calibration curves were generated and applied to the samples for quantitation (and access to laboratory records of standard calibration curves for possible inspection).

   f. A tabulation on standard data sheets of instrument mass detection limits.

Table 7-2. Recommended Documentation for Independent QA Review of Data on Inorganic Substances (WDOE, 1986)

To minimize the amount of backup information provided, only the "raw" instrument readings for duplicate and spike analyses are requested. Additional backup information would only be required if a review of the QA sample data indicated the need. Data reports from the laboratory should include:

1. Sample concentrations reported in proper units to the appropriate number of significant figures.
2. Method blank data associated with each sample.
3. Quantity of sample digested and final dilution volume.
4. Instrument detection limit for each element (denoting method of detection).
5. Method detection limit.
6. Summary of all deviations from the prescribed methods.
7. Background corrections used (e.g., Zeeman).
8. Spiked sample results with associated calibration procedures and instrument readings.
9. Results from all reference materials analyzed with samples.
10. All problems associated with the analyses.

CHAPTER 8

DATA PRECISION, ACCURACY AND COMPLETENESS

Precision

Precision is a measure of data variation when more than one measurement is taken on the same sample. The precision estimate for duplicate measurements can be expressed as the relative percent difference (RPD):

$$RPD = \frac{(c_1 - c_2)}{c} \times 100$$

where

c_1 = concentration for replicate #1
c_2 = concentration for replicate #2
c = mean concentration

Acceptable precision limits are based on past data bases as defined by the EPA. Laboratory duplicate measurements will be obtained once per round of ground water samples.

Accuracy

Accuracy of laboratory analysis is assessed by measuring standard reference material and spiked samples. Standard reference materials are utilized to calibrate laboratory measurement instruments.

Spike recovery is determined by splitting a sample into two portions, spiking one portion with a known quantity of a constituent of interest, and analyzing both portions. Spike recovery is expressed as percent recovery:

$$\text{Percent Recovery} = \frac{c}{c_s} \times 100$$

where

c = measured concentration increase
c_s = known concentration increase

Acceptable spike recovery limits are based on past data sets as defined by EPA.

Completeness

Completeness is an estimate of the amount of valid data obtained from the analytical measurement system for a given set of data. The percent completeness is defined as the number of samples analyzed that meet the data quality goals divided by the total number of samples analyzed multiplied by 100.

CHAPTER 9

PERFORMANCE AND SYSTEM AUDITS

Performance and system audits are designed to assess the capability of the measurement systems.

An on-site review of field quality assurance procedures will be conducted by a the Sweet-Edwards/EMCON field operations QA Officer. The SE/E QA Officer will observe and document field activities and present findings/recommendations to the Task 5 Manager in a summary report. Appropriate auditor recommendations will be incorporated into field procedures at the discretion of the Task 5 Manager.

Analytical laboratories contracted for this study will be required to participate in performance and system audits conducted by the National Enforcement Investigating Center (NEIC) or consistent with the USEPA Environmental Monitoring Systems/Support Laboratories. The results of these audits will be made available to the Task 5 Manager.

CHAPTER 10

CORRECTIVE ACTION

Corrective action measures generally lie within two areas of project management: (1) concerns associated with sample collection, sample handling, equipment failures, data processing, data management, and/or data analysis; and (2) non-conformance or non-compliance of analytical laboratories with QA requirements.

The Task 5 manager will be kept informed of all potentially major quality assurance problems. The Task 5 manager will be notified immediately by telephone should a field or laboratory quality assurance problem arise that may potentially jeopardize the use of collected data. Corrective action will be taken by the Task 5 manager when field methods are determined to be inappropriate or analytical data found to be outside predetermined limits of acceptability. Corrective actions may include a procedural change, additional performance and system audits, meeting with laboratory personnel, retesting of existing samples or resampling, and in extreme cases obtaining a new subcontractor. The TPCHD (Lead Agency Project Manager) will be notified should procedural corrective action not be satisfactory. All data validation problems and solutions will be documented.

CHAPTER 11

QUALITY ASSURANCE REPORTING

Monthly progress reports of the Clover/Chambers Creek Ground Water Management Program project will be submitted by the Task 5 Project Manager to the TPCHD. The Washington Department of Ecology will in turn be kept informed of project progress by the TPCHD.

The monthly progress reports submitted by Molly Adolfson Consulting will include all pertinent information regarding quality assurance goals for data acquisition, analysis, and management. In addition to providing a summary of activities and general program status, the monthly reports will include the following if appropriate:

- Results of system and performance audits.
- Recommended and/or implemented corrective action activities.
- Results regarding data accuracy, precision and completeness.
- Procedural changes for collecting data.
- Status and recommendations for any unresolved problems.

Major project reports will include a separate section on Quality Assurance that summarizes performance audit results and analytical data accuracy, precision and completeness.

APPENDIX A

FIELD DATA SHEETS

Sweet, Edwards & Associates, Inc.

BORING LOG

PROJECT ____________ Page ___ of ___

Location ____________ Boring No. ____________

Surface Elevation ____________ Drilling Method ____________

Total Depth ____________ Drilled By ____________

Date Completed ____________ Logged By ____________

WELL DETAILS	PENE-TRATION TIME/ RATE	DEPTH (FEET)	SAMPLE		PERME-ABILITY TESTING	SYMBOL	LITHOLOGIC DESCRIPTION	WATER QUALITY
			NO.	TYPE				

Sweet, Edwards & Associates, Inc.

Well Testing Record

Sheet ______ of ______

☐ Pumping Well No. ____________

☐ Observation Well No. ____________

Test Conducted from ____________ to ____________

Well Location ____________

Static Water Level ____________

Measuring Point ____________

Elevation of Measuring Point ____________

Project ____________

Job No. ____________

Measuring Instruments:

Discharge Rate ____________

Water Level ____________

Well Depth ____________

Screened Interval ____________

Inspector/Engineer/Geologist ____________

DATE / TIME	PUMPING PERIOD					RECOVERY PERIOD						COMMENTS
	TIME HOURS, MINUTES SECONDS	TOTAL TIME ELAPSED (MIN)	DEPTH TO WATER (FEET)	MEASURED DRAW-DOWN (FEET)	MEASURED DIS-CHARGE (gpm)	TIME HOURS, MIN, SECONDS	TOTAL TIME ELAPSED, t (MIN)	TIME SINCE PUMP STOPPED t (MIN)	RATIO t/t'	DEPTH TO WATER (FEET)	RESIDUAL DRAWDOWN (FEET)	

Sweet, Edwards & Associates, Inc. • P.O. Box 328 • Kelso, WA 98626

Field Well Record

WELL No. ________
PROJECT

Owner of record ______________________ State No. ________
Tenant ______________________ Other No. ________
Address ______________________

Type Community ☐ Domestic ☐ Irrigation ☐ Monitor ☐ Other ________

Location County ________ Basin ________

U.S.G.S. Quad. ________ ___¼ ___¼ ___¼ Sec.___ T___ R___ W.M.

Description ______________________

Measuring point elev.____ ft./datum ________ /description ________
which is ____ ft. above/below land surface, determined from ________
Ground elev.____ ft. D.T.W.____ ft. Potentiometric elev.____ ft. Well depth____ ft.
Condition ______________________ Casing dia.____ in.
Perforations/Screen ______________________
Chief Aquifer ________ Depth to Aq. top____ ft./bot.____ ft.
Type of material ________ Perm. rating____ Thickness____ ft.
Gravel packed? Yes ☐ No ☐ Depth to Gr. top____ ft./bot.____ ft. Seal ________

Driller ________
Date drilled ________ Method ________
Log filed? Yes ☐ No ☐ Open ☐ Conf. ☐

Pump Yield____ gpm Pumping level____ ft.
Type ________ Make ________ H.P.____

Water Analysis Primary ☐ Secondary ☐
Priority ☐ Other ________
Water levels available? Yes ☐ No ☐
Period of Record: Begin ______ End ______
Collecting agency ________
Prod. Rec. ____ Pump Test ____ Yield ____

Sketch

Remarks ______________________

Recorded by: ________ Date: ________

Sweet, Edwards & Associates, Inc.
Kelso, WA (206) 423-3580
Redmond, WA (206) 881-0415

Field Sampling Data

LOCATION/ADDRESS ______
PROJECT NAME ______ # ______
CLIENT/CONTACT ______

Well or Surface Site Number ______
Sample Designation ______
Date, Time ______
Weather ______

HYDROLOGY MEASUREMENTS:

(Nearest .01 ft.)	Elevation	Date, Time	Method Used (M-Scope Number or Other)

WELL EVACUATION:

Gallons	Pore Volumes	Method Used	Rinse Method	Date, Time

Surface Water Flow Speed ______, Measurement Method ______, Date, Time ______

SAMPLING:

Sample	Date, Time	Method	Volume (ml)	Container Type	Depth Taken (feet)	Field Filtered (yes,no)	Preserva-tive	Iced (yes,no)	Sampler Cleaning Method
									Non-Phosphatic detergent wash
									H2O rinse
									MeOH rinse
									Distilled H2O rinse

FIELD WATER QUALITY TESTS:

Pore Vol. Number	pH	Conductivity	Temp	Eh				

NOTES:

Total # of Bottles: ______ Signature: ______

Sweet, Edwards & Associates, Inc.
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Redmond, WA (206) 881-0415

Chain of Custody / Laboratory Analysis Request

DATE ____________ PAGE ______ OF ______

PROJECT ____________ # ____________

CLIENT INFO.
CONTACT ____________

ADDRESS ____________

TELEPHONE# ____________

SAMPLERS NAME ____________ PHONE# ____________

SAMPLERS SIGNATURE ____________

ANALYSIS REQUESTED — GENERAL CHEMISTRY (Specify) — OTHER (Specify)

SAMPLE I.D.	DATE	TIME	LAB I.D.	TYPE	BASE/NEU/ACID ORGAN. GC/MS/625/8270	VOLATILE ORGANICS GC/MS/624/8240	HALOGENATED VOLATILE ORGANICS 601/8010	PHENOLICS 604/8040	POLYNUCLEAR AROMATIC 610/8310	TOTAL ORGANIC CARBON (TOC) 415/9060	TOTAL ORGANIC HALIDE (TOX) 9020	EP TOX/TCLP METALS (Circle One)	METALS (TOTAL) (See Special Inst.)	TCLP ORGANICS	pH, COND ALK	NO_3/NO_2, Cl SO_4	Ca, Mg, Na, K							NUMBER OF CONTAINERS
1.																								
2.																								
3.																								
4.																								
5.																								
6.																								
7.																								
8.																								

Relinquished By Sweet, Edwards & Assoc.	Relinquished By	Relinquished By	PROJECT INFORMATION	SAMPLE RECEIPT
Signature	Signature	Signature	Shipping I.D. No.	Total No. of Containers
Printed Name	Printed Name	Printed Name	VIA	Chain of Custody Seals
Firm	Firm	Firm	Project	Received in good condition
Date/Time	Date/Time	Date/Time		LAB NO.

Received By	Received By	Received By	SPECIAL INSTRUCTIONS/COMMENTS
Signature	Signature	Signature	
Printed Name	Printed Name	Printed Name	
Firm	Firm	Firm	
Date/Time	Date/Time	Date/Time	

DISTRIBUTION: WHITE - return to originator; YELLOW - lab; PINK - retained by originator.

SEA-400-05

PROJECT PHOTO LOG

Sweet, Edwards & Associates, Inc.

Sheet ______ of ______

PROJECT NO: ______________________
PROJECT NAME: ______________________
PROJECT LOCATION: ______________________
CLIENT: ______________________
PHOTOGRAPHER: ______________________

Slides _____ Prints _____ Negatives _____

SITE CATEGORY (CHECK ONE):

- ☐ Chemical Plant
- ☐ Sanitary Landfill
- ☐ Sludge
- ☐ Hazardous Waste
- ☐ Fabrication Facility
- ☐ Water Supply
- ☐ Woodwaste
- ☐ Wood Treatment
- ☐ Light Industry
- ☐ Metal Plating
- ☐ Other ______________________

TYPE OF WORK:

Geotechnical Exploration
- ☐ Test Pits
- ☐ Drilling
- ☐ Mapping
- ☐ Waste Characterization

Water Quality Monitoring
- ☐ Drilling
- ☐ Well Installation
- ☐ Ground Water Sampling
- ☐ K-testing
- ☐ Surface Monitoring
- ☐ Surface Sampling

Gas Monitoring
- ☐ Drilling
- ☐ Well Installation
- ☐ Recovery Systems
- ☐ Sampling

Water Supply
- ☐ Drilling
- ☐ Well Installation
- ☐ Aquifer Testing
- ☐ Sampling
- ☐ Pump Installation

Other
- ______________
- ______________
- ______________
- ______________
- ______________

PHOTO NO.	DATE	DESCRIPTION

PHOTO NO.	DATE	DESCRIPTION

METHODS FOR COLUMBIA ANALYTICAL

NOT INCLUDED IN THIS DOCUMENT

APPENDIX D

COMPUTER DOCUMENTATION

APPENDIX D

COMPUTER DOCUMENTATION

The purpose of this effort was to establish a verifiable and consistent data base to use as a baseline for well information and water quality data of ground water wells within the Clover/ Chambers Creek Basin. As part of the data collection and analysis for this program, data bases compiling known sources of well information and water quality data on wells in the Clover/Chambers Creek Basin was developed by Dr. Steve Merrill of Brown and Caldwell.

This data base was compiled from three separate data sources, including the U.S. Geological Service STORET data, the 1985 CCC Basin study, and Department of Ecology WATSTORE data. These data bases were merged through transition programs which made the data source configurations compatible.

The well information files include data on USGS well number, location, water level, owner, date of construction, etc., in the format specified by WDOE. USGS data for the sections encompassed by the study was obtained and converted into a data base format using Dbase III. Cross-checking was conducted by overlaying the data from the 1985 Geohydrologic Study (Brown and Caldwell) to the newly developed data base to eliminate duplicate entries. Well locations were also verified by longitude and latitude. Entries with inappropriate locations (outside the study area) were removed from the data base.

The water quality files contain:

- Well number
- Station number
- Latitude
- Longitude
- Record number
- Sample dates
- Sampling depth
- Parameter code number
- Parameter concentration
- Parameter flag

Once the data were sorted and verified, the final data bases were turned over the the Tacoma-Pierce County Health Department for use as a baseline of well information and water quality data for wells within the Clover/Chambers Creek Basin. This baseline will be used for determining trends of water quality parameters which are sampled and tested in the future. Refer to Appendices C and E for additional information on data analysis and manipulation.

APPENDIX E

DATA COLLECTION AND ANALYSIS PLAN

CLOVER/CHAMBERS CREEK GROUND WATER MANAGEMENT PROGRAM

Prepared by

BROWN AND CALDWELL CONSULTING ENGINEERS

For

TACOMA-PIERCE COUNTY HEALTH DEPARTMENT

JANUARY 1989

TABLE OF CONTENTS

SECTION 1

INTRODUCTION

This section provides a brief synopsis of the Clover/Chambers Creek (CCC) basin background leading to the development of a Ground Water Management Plan (GWMP).

Background

In the early 1980's the Tacoma-Pierce County Health Department (TPCHD) began to study documented ground water quality problem areas in the central Pierce County area of the CCC basin. These problem sites included: the Thun Field Landfill, the McChord Air Force Base, and Lakewood. A regional study was also conducted by the Washington State Department of Social and Health Services. As a result of debate arising from these studies, between 1983 and 1985 a comprehensive geohydrologic investigation of the CCC basin was conducted.

The results of the study identified several wells with significant contamination. In addition, the study indicated trends toward increased contaminants in some areas. The study recommended the establishment and implementation of a ground water management program in order for the CCC basin aquifer to continue to reliably provide drinking water which meets health standards.

In September 1985, TPCHD developed a 14 point plan to initiate an aquifer protection/management program for the CCC basin and other aquifers in the county; at this time TPCHD also established a Ground Water Management Task Force. This task force now functions as the Ground Water Advisory Committee (GWAC), under Washington State Substitute House Bill 232, RCW 90.44.440 (passed in late 1985 giving the Washington State Department of Ecology the responsibility to work with local governments to establish ground water management areas in accordance with WAC 173-100).

In May 1987, a petition for Sole Source Aquifer Designation was submitted by the TPCHD to the U.S. EPA in accordance with the Sole Source Aquifer Petitioner Guidance published by U.S. EPA in February of the same year.

The scope for the GWMP was developed in the fall of 1987. Work on the GWMP was initiated by Brown & Caldwell in association with Molly Adolfson Consulting, Sweet Edwards/EMCON, Robinson & Noble, and Triangle Associates under the direction of the TPCHD.

The Clover/Chambers Creek Ground Water Management Program (CCC GWMP) represents an integrated approach to ground water management. The primary goal of the project is to implement a credible, defensible and successful ground water management program by focusing on filling data gaps identified in the 1985 CCC Study and developing ground water management alternatives.

The key approaches to achieving this goal include:

- refining the characterization of the Basin's land use activities, hydrogeology and ground water quality sufficiently to develop a sound technical base for the ground water management program,
- augmenting the water level and quality data base to better focus the goals and objectives of the ground water management program,
- determining the pollutant load entering the subsurface through stormwater disposal systems (drywells) and on-site sewage disposal systems,
- evaluating the need for, and providing recommendations for, further study of the effectiveness of stormwater runoff control and/or treatment,
- initiating a management/decision making process by the GWAC and Pierce County, and
- developing the institutional and funding foundation to carry on management activities after the GWMP study is completed.

Purpose of the Data Collection and Analysis Plan

This plan and the Scope of Work present the goals, objectives, and approach to data collection and analysis for the Clover/Chambers Creek Ground Water Management Program (CCC GWMP). The plan serves as a companion document to both the Data Management Plan (DMP) dated January, 1988, and the Quality Assurance/Quality Control Plan (QA/QC) dated April, 1988. The DMP covers the management and format of the varied types of data necessary to complete the Clover/Chambers Creek Ground Water Management Program, and the QA/QC Plan includes the procedures for sample collection, analysis and reporting for the program.

Goals and Objectives

The principal goals and objectives of this study's Data Collection and Analysis Plan (DCAP) are:

- to complete and refine the data collection needs outlined in the Scope of Work.

- to summarize the background and sources of existing data upon which the current GWMP study is based;
- to identify the data deficiencies of the existing data;
- to provide a context and clear rationale for proposed data collection;
- to establish local guidelines for the coordination of data collection efforts; and
- to meet the requirements of the Washington State Department of Ecology (Ecology) and provide Ecology with an accurate ground water data base in the prescribed format

Approach to the GWMP Scope of Work

There is a fundamental difference between a comprehensive data collection program and a monitoring program. A data collection program provides a context for the collection of data over a long period of time for characterizing an environment and providing the necessary background information to address future problems. Whereas, a monitoring program has more specific goals: to characterize ambient conditions or detect changes in the environment.

There is a considerable amount of overlap in the types of data obtained for a scientifically sound data analysis program and for a monitoring program. However, in local political jurisdictions, it is difficult to justify the expense of a comprehensive data collection program which, to many, may appear to be simply collecting data for the sake of collecting data. For this reason, it has traditionally been the role of large government institutions, such as the United States Geological Survey, to implement comprehensive data collection and analysis programs.

The 1985 CCC Study and the current GWMP Scope of Work have both identified the data base resulting from the 1985 CCC Study as largely sufficient; and have also identified specific data gaps in areas such as stormwater. Thus, the current phase of the CCC basin study focuses on developing stormwater recharge data and ground water management alternatives.

In the Clover/Chambers Creek Ground Water Management Program, the most important consideration in the approach to data collection is that efforts to collect additional data should primarily be focused on filling information gaps necessary to support management strategies recommended by the Ground Water Management Task Force and the Ground Water Advisory Committee. In view of the limited project budget, any attempt to collect substantial amounts of new data will be at the expense of development of management options to achieve the study's objectives as set forth in the Scope of Work.

In this study four types of data will be used to further characterize the ground waters of the Clover/Chambers Creek basin as a basis for developing ground water management alternatives: (1) previously collected data, (2) data collected during this project from existing wells (primarily domestic and municipal wells), and (3) data collected from monitoring sites established during this project, (4) consolidation of WATSTOR (USGS) and STORET (Ecology) data not previously evaluated.

Task 5, Data Collection and Analysis, includes the principal activities for generating new technical data. Monitoring well construction, stormwater and ground water sampling, and sample analysis will be the principal activities of this task. Tasks 2 and 3 involve the evaluation of large quantities of background data.

Data reporting and management activities are specified in detail in the CCC Data Management Plan. The general criteria to be used to evaluate ground water data for inclusion in the CCC GWMP data base will be as follows:

1. Previously collected data: Wells must have Water Well Report Forms that include location information and identifier (to quarter-quarter section) and well depth; sample data must indicate the name and/or agency of the person who collected the sample and the laboratory that performed the analysis. Data more than 20 years old will be included in a separate file. Cross checking between WATSTOR and STORET data must be conducted, duplicate well data must be flagged and eliminated. Water level and hydrogeologic data must be included wherever available.

2. Existing wells to be sampled as part of this project: Same information as for No. 1, above. In addition, the Water Well Report Form must indicate the depth of the screened or open portion of the well, the casing material, and the elevation and horizontal location of the top of the casing. Additional information associated with existing wells chosen for sampling must be included if available. Note: Some existing wells included in the Clover/Chambers Creek Ground Water Management Program may require surveying by a licensed surveyor at the request of the Tacoma-Pierce County Health Department.

3. Monitoring wells to be drilled for data collection during this project: Same information as in No. 2, above. In addition, the wells must be surveyed by a licensed surveyor to an established National Geodetic Datum. Data must be collected from the wells to meet the requirements

of Ecology's Interim Guidelines for Data Collection from Wells Used in Ground Water Management Programs (October 30, 1987).

Amendments to the GWMP Scope of Work

The process of identifying data gaps or deficiencies in the existing information was conducted both in the process of providing conclusions and recommendations in the 1985 CCC Study and subsequently during the development of the Scope of Work for the current CCC GWMP. Specific tasks of the current study were developed to fill data deficiencies identified in the 1985 CCC Study work.

There are additional data gaps which have been identified and/or amplified as the GWMP development has progressed. These include: the need to further characterize nonpoint source contamination to the shallow aquifer; and the frequency, occurrence and distribution of accidental spills.

Two distinctly different types of data will be developed in this study: **technical data**, which directly augments the existing CCC Geohydrologic Study database (Task 5), and **background data**, which is evaluated and incorporated in a format that can be utilized during implementation of the GWMP and in the future. In the process of updating and collecting data, all of the tasks require assessment of data precision, accuracy, and completeness/ comparability of data bases (which is addressed in the QA/QC and Data Management Plans).

As the project progresses further and options are developed for the GWMP, data deficiencies which have not yet been identified, are likely to arise. In addition, new data deficiencies are likely to become apparent as the ground water data base is used by TPCHD and Ecology. These data gaps will be addressed over the course of the project to meet the goals and objectives of the CCC DMP. It is anticipated that not all data gaps will be filled, given the budgetary and schedule limitations remaining for this specific study. However, one of the goals of the study is to develop an on-going process so that data gaps may be filled as they are identified.

SECTION 2

SUMMARY OF EXISTING DATA SOURCES

With regard to data collection for the CCC Basin, much has already been accomplished since the process of developing a ground water management program began in 1978. An extensive geohydrologic study and a data base management program for the Basin have already been completed. Regulations and land use plans developed since the early 1980s have begun to reflect the need to protect this critical resource.

Guide to Existing Data Sources

For this study, data collection is predicated upon several previous studies and policies including the original CCC Geohydrologic Study (1982 to 1985); the Coordinated Water System Plan (draft completed in 1986; passed by the County Council and accepted by DSHS in 1988), the establishment of the South Tacoma Ground Water Protection District (developed between 1984 and 1987; passed by the City Council in 1988); the establishment of a Ground Water Management Task Force (1986); and the petition for Sole Source Aquifer designation (1988). The relationship of these activities to the existing study is represented graphically in Figure 1.

The following narrative provides a summary of each of the enumerated studies and policies.

The 1985 CCC Geohydrologic Study. The purpose of the CCC Geohydrologic Study was to provide a technical basis for decisions and implementation of solutions by state and local entities regarding regional water management and land use planning. The study was a regional investigation and as such was not intended to provide solutions to site-specific problems. However, as a result of the regional investigation site-specific ground water quality areas were identified. The study was conducted to accomplish the following objectives:

- Make a comprehensive assessment of the geohydrology of the study area.
- Define boundaries of the regional aquifer system.
- Determine present ground water quality.
- Determine the rate of deterioration of ground water quality.

- Examine the relationship between ground water quality and land use activities.

- Compile land use data and establish an on-going program to update the land use data base under the jurisdiction of the County Health Department, and the City and County Planning Departments.

- Determine what effects future land use activities may have on ground water resources.

- Develop a framework for a comprehensive ground water management plan which included institutional (management, planning and educational), enforcement (monitoring, reporting and regulations), capital (dedicated monitoring, sewer system expansion), and study elements (small quantity hazardous waste generators, stormwater control feasibility, artificial aquifer recharge evaluation, additional hydrogeologic studies).

- Identify major data gaps - these are discussed in summary form in Chapter 2 of the 1985 report and provided a basis for the development of the Scope of Work for the current study.

The 1985 CCC Geohydrologic Study's data collection was based on a modified form of the monitoring methodology outlined by the Environmental Protection Agency's (EPA) Environmental Monitoring and Support Laboratory. The EPA methodology is primarily directed toward source monitoring, which focuses on measurements relating to pollution and methods of waste disposal contributing to pollution.

The monitoring methodology for the CCC Basin included 15 steps:

1. Select area or basin for monitoring.

2. Identify potential pollution sources, causes, and methods of waste disposal.

3. Identify potential pollutants.

4. Define ground water usage.

5. Define hydrogeologic situation.

6. Study existing ground water quality.

7. Evaluate infiltration potential for wastes at the land surface.

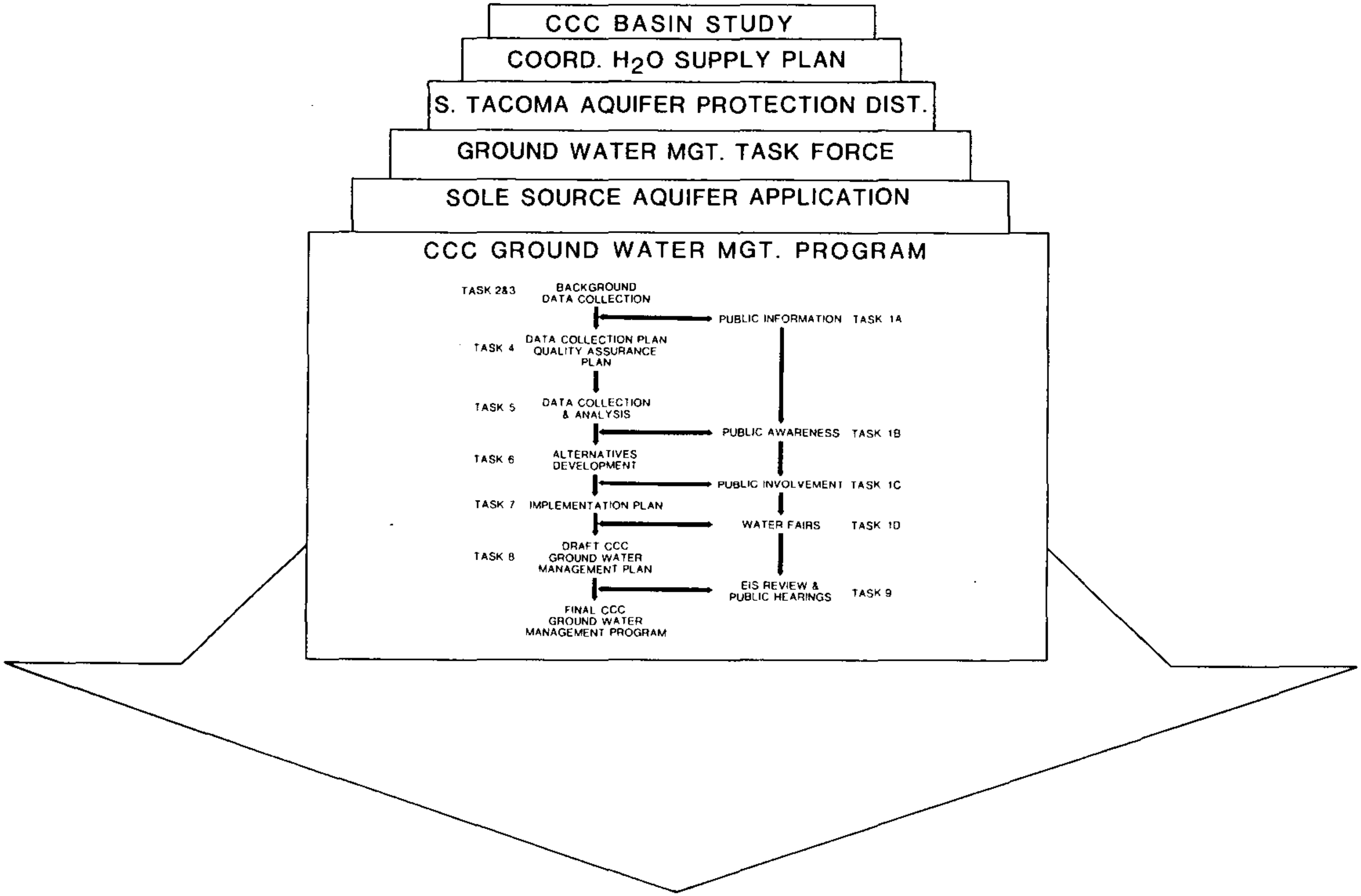

Figure 1 Clover/Chambers Creek Basin--Continuity

8. Evaluate mobility of pollutants from the land surface to the water surface.

9. Evaluate attenuation of pollutants in the saturated zone.

10. Identify priority monitoring areas (EPA--prioritize sources and causes).

11. Evaluate existing monitoring methods.

12. Establish monitoring approach (EPA--establish alternative monitoring approaches.).

13. Select and implement the monitoring program.

14. Review and interpret monitoring results.

15. Summarize and transmit monitoring information.

Appendix VII of the CCC Geohydrologic Study (July, 1985) outlines the step-by-step approach of the monitoring methodology used in the study, providing for an orderly and comprehensive data collection system. This data collection strategy included all of the relevant geohydrologic and land use factors which must be accounted for in establishing the relationship between land use activities and water quality.

Coordinated Water System Plan. The Coordinated Water System Plan established public water system service area boundaries, established uniform water system design standards, and coordinated public water system planning. It also identified current and future public water supply needs and assessed the capability of available ground and surface water resources to meet those needs.

South Tacoma Ground Water Protection District. The Tacoma City Council established this district as a means of protecting ground water quality in South Tacoma, the location of the City of Tacoma's primary wellfield. The ordinance creating the district established special requirements for the construction, maintenance and operation of underground chemical storage tanks in south Tacoma.

Ground Water Management Task Force. Based on a recommendation of the Tacoma-Pierce County Health Department, the Mayor of Tacoma and the Pierce County Executive established a task force to begin the process of developing a ground water management program for the Clover/Chambers Creek Basin. The task force created in 1986, later formed the nucleus of the Clover/Chambers Creek Ground Water Advisory Committee after the basin was designated a Ground Water Management Area by Ecology under provisions of WAC 173-100.

Tacoma-Pierce County Health Department Sole Source Aquifer Petition. The Tacoma-Pierce County Health department prepared and submitted to EPA a petition for the designation of the Clover/Chambers Creek Basin as a Sole Source Aquifer under provisions of the Safe Drinking Water Act. The petition, prepared in accordance with Sole Source Aquifer Designation, Petitioners Guidance (U.S. EPA, February, 1987), established the total amount of basin ground water currently used for drinking water supplies and evaluated the ability of alternative drinking water supplies to replace the Clover/Chambers Creek Basin Aquifer.

In addition to studies and policies, the current study is relying heavily on the ground water data bases provided by the USGS WATSTORE and Ecology's STORET. During the course of the study these data bases will be combined and integrated with the existing ground water data base developed in the 1985 CCC Study to provide a consistent, proofed data base for use in future ground water management activities. These sources of existing data provide the basis for the development of a system adequate for the input of ground water data generated in this study and in the future.

Reference Summary

The following is a brief list of references of the more important existing data sources for the CCC Basin. A more thorough reference list is provided in Appendix I of the 1985 CCC Geohydrologic Study. In addition, Appendix II of the same report provides a comprehensive "Literature Search and Bibliography".

1. Brown and Caldwell Inc., Clover/Chambers Creek Basin Geohydrologic Study, Prepared for Tacoma-Pierce County Health Department, July 1985. WDOE Project Manager: Carol Fleskes. Hard copy of project available from WDOE: Barbara Carey.

2. Economic and Engineering Services, Inc., Coordinated Water System Plan; regional supplement for Pierce County. Prepared for Pierce County Planning and Natural Resources Management Department, May 1988.

3. Economic and Engineering Services, Inc., Tacoma Water System Plan Volume 1-4. Prepared for Tacoma Water Division, December 1980.

4. Hart Crowser and Associates Inc. Ground Water Resource Evaluation for Pierce County, Washington. Prepared for Pierce County Planning and Natural Resources Management Department as an adjunct to Coordinated Water System Plan, November 1984.

5. Hart Crowser and Associates Inc. Ground Water Resource Evaluation Existing and New Supply Areas, Tacoma, Washington, 1986.

6. Molly Adolfson Consulting, Sweet Edwards and Associates, and Brown and Caldwell Inc., Clover/Chambers Creek Aquifer Petition for Sole Source Designation, Prepared for Tacoma-Pierce County Health Department, January 1988.

SECTION 3

HYDROGEOLOGIC DATA COLLECTION

Introduction

Due to the extensive hydrogeologic component of the 1985 CCC Study, the hydrogeologic component of the current project is limited. The project focuses primarily on developing a better understanding of the upper, shallow aquifer; revising and updating the CCC 1985 Study in a format readily usable in the GWMP and utilizing the data generated from purveyors and specific studies such as the Tacoma Wells to further define the deeper aquifer. The purpose of this aspect of the management program is to provide concise, easy-to understand hydrogeologic characterization in support of management plan development.

The purposes of the hydrogeologic data collection and refinement in this study are to:

- Refine hydrogeologic characterization within the CCC Basin.
- Augment water level and quality data base to better focus goals and objectives of ground water management program.
- Determine the pollutant loads entering the subsurface via existing on-site disposal systems and stormwater disposal systems (drywells).
- Evaluate the need for, and potential effectiveness of, stormwater runoff control/treatment.
- consolidation and rectification of the USGS WATSTORE with Ecology STORET data format as defined in the Data Management Plan.

Data Collection and Analysis, Parties Responsible and Use of the Hydrogeologic Data (parameters and procedures are covered in the QA/QC Plan)

- Developing a better understanding of the shallow aquifer will consist of characterizing the distribution and thickness of glacial till. Basic data on the till (depth, thickness, and location) has already been entered into the TPCHD's data management system. Characterization of the till involves retrieval of the data and analysis; this will be conducted by Robinson and Noble.
- Review of water utility reports (consulting team).

- Federal agency hydrogeologic data (consulting team).

- Tacoma Utilities Test Well Drilling Project. This project involves drilling a series of test wells in the South Tacoma Aquifer, testing the water levels, aquifers and water quality. The information will be incorporated in Parts I and II of the DMP.

- Hidden Valley (Thun Field Landfill) Hydrogeologic Study. This project includes well drilling, water sampling, water level investigations and the effects of the landfill on the CCC Basin.

- Firgrove Water Company Well. This will include activities by Firgrove Water Company in drilling a new test well, plus the water sampling and water level measurements involved. This information will be incorporated in Parts I and II of the DMP.

- Tacoma-Pierce County Geohydrologic Evaluations. This match source includes geohydrologic evaluations done for land use activities. Applicable technical data will be incorporated into Part III of the DMP.

Ground Water Management Area Boundaries

Boundaries selected for the Clover/Chambers Creek Aquifer - Ground Water Management Area (CCCA-GWMA) are based on hydrologic flow conditions and are shown in Figure 1 (foldout pocket map). The CCC drainage basin is divided into eight subbasins based on surface topography including: the American Lake Subbasin; Chambers Creek Subbasin; Flett Creek Subbasin; Leach Creek Subbasin; University Place Subbasin; Clover Creek Subbasin; North Fork Subbasin; Spanaway Lake Subbasin. The overall basin and subbasins are based on:

- Ground water divides for the shallow ground water system.

- Ground water divides for the deep ground water system.

- Topographic divides for the CCC drainage basin.

The boundaries are defined in more detail in Chapter 5 of the 1985 CCC Geohydrologic Study. A brief description justifying the boundaries from a hydrogeologic perspective is outlined below.

Eastern Boundary. The eastern boundary of the CCC aquifer system trends northwest to southeast. Throughout most of its length this boundary is coincident with the CCC drainage basin divide. A water table map of the shallow ground water system shows that the dominant ground water divide for the shallow flow system lies close to the drainage basin boundary.

The hydrologic boundary definition for the deep ground water system is more complex than for the shallow ground water system. The eastern basin boundary includes all areas which might result in surficial recharge or westerly subsurface flow to the CCCA as interpreted from potentiometric maps. These boundaries are not well defined since many of these areas may lie outside the study area in the Cascade foothills.

Southeastern Boundary. The southeastern boundary of the CCCA is the shallow water table divide which trends southwest to northeast, northwest of Muck Creek Valley. Potentiometric maps indicate the presence of this divide in both the shallow and deep flow systems. In the shallow flow system this divide appears to be slightly more to the southeast than in the deeper flow system. Using a conservative approach, the boundary was drawn along the shallow flow system divide. This divide passes through Patterson Spring, the headwaters of Muck Creek. The southeastern boundary follows Muck Creek along its southwest traverse. Potentiometric data indicate that Muck Creek is a recharge/discharge boundary for the shallow ground water system and a ground water potentiometric divide for the deep flow system.

Southwestern Boundary. The southwestern boundary extends from Muck Creek northwest to Puget Sound at the Fort Lewis Military Base. Potentiometric data for this area are limited; however, the available water table data indicate that ground water flow in the shallow ground water system parallels the drainage basin divide along the southwest boundary; therefore, contaminated recharge or subsurface flow southwest of the drainage basin divide would not impact water northwest of the drainage basin divide. The deep ground water system flows to the southwest along most of this boundary, however it is possible that a northerly ground water flow component is present southeast of Section 34, T 18N, R 2E. Consequently, in this area the boundary has been located further south to ensure that all surficial recharge and all subsurface flow in the deeper ground water system is either parallel to the boundary or to the west and southwest.

Western Boundary. The western boundary of the CCCA is Puget Sound extending from the Fort Lewis Military Base in the Lakewood area in the south to the Tacoma Narrows in the north. Puget Sound serves as a discharge zone for both the shallow and deep ground water systems.

Depth Boundary. The absolute base of the CCC basin is a tertiary-age bedrock located at depths up to 2000 feet below ground surface. The base of the CCC aquifer is a low permeability geologic unit ranging from approximately 400 to 600 feet below the ground surface. Although data are sparse for this unit, it appears to be present beneath most of the basin and serves as a regional barrier to ground water flow.

Data Analysis and Products

- Existing DMS data converted to dBase III Plus in an IBM-compatible format. Augmented water quality/level data base incorporating data gathered in this task.

- Structural contour/isopach (thickness) map of glacial till.

- Updated basin boundary maps, hydrostratigraphic and potentiometric maps.

- Task 3 report which integrates hydrogeologic information presented in the 1985 Clover/Chambers Creek Study, Sole Source Aquifer Petition, and Pierce County Coordinated Water System Plan and includes maps and illustrations characterizing the hydrogeology of the CCC Basin.

SECTION 4

GROUND WATER QUALITY DATA COLLECTION

Introduction

The 1985 Clover/Chambers Creek Geohydrologic Study identified subsurface disposal of stormwater as a potential source of contamination to the ground water system. Although the 1985 study identified stormwater as a possible source of contaminants to the CCC Basin ground water system, the fate of those contaminants upon reaching the ground water system remained undetermined. Pollutant removal occurring in the drywells themselves and in the surrounding gravelly soils was identified in the Scope of Work of the current study to be an area requiring further data collection.

Generally, it is difficult to separate stormwater-related loading from loading contributed by septic tanks without carefully controlled experimental conditions because drywells are often located in areas where subsurface conditions are also conducive to septic tank operation. Therefore, the Scope of Work for this investigation proposed a controlled monitoring program to determine what contaminants were being transported into the drywells and what level of attenuation is achieved with vertical depth and horizontal distance from the drywell. From the investigation of subsurface disposal of stormwater, appropriate measures are being developed for stormwater management that will balance ground water quality and quantity issues.

Data Collection and Analysis, Parties Responsible and Use of the Ground Water Quality Data

This project includes stormwater sampling and ground water sampling by Sweet-Edwards/EMCON and Molly Adolfson Consulting in the Clover/ Chambers Creek Basin. This section also describes parameters and procedures which are also covered in the QA/QC Plan.

Drywell Sampling. Two existing subsurface stormwater disposal systems (drywells) were selected to be representative of composite land use categories. In order to avoid potential interfering effects from septic tanks, commercial areas served by sanitary sewers were selected. All drywells evaluated were located in areas with shallow ground water (approximately 30 feet deep) in order to represent "worst case" conditions in terms of potential ground water contamination.

Drywell monitoring site selection criteria were as follows: located in a sewered area; located in residential or commercial areas; generally typical of drywells in basin, i.e. not located in "worst case" type of basin with known high levels of contamination; drainage area of 3 to 10 acres; acceptable restrictions to drilling. TPCHD staff performed an initial review of potential sites, which was followed by a consultant field investigation. The drywells selected (Mount Tacoma Way site and Koreana Plaza site) are located in commercial areas along South Tacoma Way and Mt. Tacoma Drive in the Lakewood area. For site figures refer to the November, 1988 Stormwater Evaluation for the CCC Basin Ground Water Management Program.

Runoff entering each drywell was monitored for the following constituents:

Conductivity

COD
Temperature
Fecal coliform
Nitrate-nitrogen
Ortho-phosphorus
Arsenic
Copper
Lead
Zinc
Chlorinated volatile organics
Benzene, toluene, and xylene (BTX)

Ground Water Sampling. The focus of the ground water sampling program was to collect:

- background data
- storm related indicator data
- contaminant data
- tracer data
- hydrologic data

One monitor well was drilled upgradient of each drywell and three to four monitor wells were drilled at varying depths and horizontal distances downgradient of each drywell. These monitor wells were sampled for the previously-listed parameters to determine the extent and rate of vertical and horizontal pollutant migration from each drywell.

Seven storm events of varying intensity were sampled at the Mt. Tacoma Way drywell site; eight storm events were sampled at the Koreana Plaza drywell site. The monitor wells were sampled prior to and following six measurable precipitation events at the Mt. Tacoma Way wells and nine events were sampled at the Koreana Plaza Wells. One dryweather sample was taken to determine non-storm related concentrations in the ground water. The purpose of this sampling strategy was to enable identification of the specific compounds entering the drywell and the level of pollutant attenuation attained within the drywell as well as with distance from the drywell. Volatile chlorinated organics and BTX fractions were analyzed only during two events.

Tracers (lithium-chloride and sodium chloride) were added to the drywells during simulated storm conditions and monitored in the wells to provide a positive indication of detection and flow direction, as discussed in the Sampling and Field Measurement section of the QA/QC Plan. All monitoring points were surveyed and accurate measurements taken of water levels during monitored events to provide for close hydrologic control over flow direction prediction.

Tacoma-Pierce County Health Department Sampling. Existing sample sites include:

1. Six off-site domestic/public wells outside the Thun Field Landfill. These wells are sampled quarterly for the majority of primary and secondary drinking water parameters. Temperature, pH, and conductivity will be measured in the field during each period.

2. Contract sample collection sites for bacteriological parameters may include the following community well systems (the frequency of sample collection is usually quarterly, but varies from once per month to annually, depending on class of water system):

Community Well Systems
- Country Water
- Frederickson
- Bethel Water Company
- Lemmay
- Mountain Highway Apartments
- Rainier Villa
- Kentucky Fried Chicken
- Av-Mar Court
- Forest Glen
- American Lake Gardens
- Ponderosa
- Bethel High School
- Bethel Junior High School
- Shining Mountain Elementary School
- AMA Timber
- O'Brien
- Frontier Park
- Pinewood Glen
- Loveland
- Country Acres
- Rancho Villa
- Zuver

Water Purveyor Sampling. Local water purveyors with either Class 1 or Class 2 systems in the Clover/Chambers Creek Basin scheduled for ground water sampling as part of the CCC GWMP include:

Local Water Purveyors
- City of Tacoma
- Firgrove
- Lakewood
- Parkland
- Spanaway
- S.E. Tacoma Mutual
- Richardson Water Company (multiple systems)
- McChord
- Ft. Lewis
- Puyallup (outside Basin boundary)
- Fircrest
- Summit
- Fruitland Mutual

Testing parameters for the purveyors' ground water systems are included in Table 4-1. Efforts will be made to incorporate data from these wells where feasible, recognizing, however, that not all purveyors will be testing for many of the parameters during the time frame of this study.

Table 4-1. Minimum Monitoring Requirements for Class 1 and Class 2 Systems

System class	Sample type	Minimum number of samples required[a]
1	Bacteriological	Dependent on population served.
	Inorganic chemical and physical (primary and secondary)	One complete analysis per source or well field every 36 months.
	Trihalomethanes	Systems with 10,000 or more population only. 1 per plant every 12 months.
	Corrosivity	1 per plant or well field.
	Pesticides	As directed by the Department.
	Radionuclides	Once every 48 months or as directed by the Department.
2	Bacteriological	Dependent on population served.
	Inorganic chemical and physical (primary and secondary)	One complete analysis per source every 36 months.
	Trihalomethanes	As required by the Department.
	Corrosivity	1 per plant or well field.
	Pesticides	As directed by the Department.
	Radionuclides	Once every 48 months or as directed by the Department.

[a]These are the minimum requirements. Additional monitoring may be required by the Department.

Refer to the Data Management Plan for details on the following:

Part I -Water Well Construction and Water Level Information.
Part II -Coding Instructions for Water Quality Data.
Part III -Other Ground Water Information
Part IV -Land Use Data
Part V -Soils Data
Part VI -Hydrostratigraphic Layer Data

Data Collection Activities

- Documentation of water quality problems that have occurred following completion of the 1985 Clover/ Chambers Creek Study.

- Water Purveyor Sampling including pertinent water quality testing by area purveyors. Applicable data will be incorporated into Part III of the DMP.
- Characterization of stormwater facilities in CCC Basin and remainder of Pierce County.
- Characterization of runoff from NURP studies, local studies.
- Methods of mitigating pollutant loading from stormwater.
- Costs of stormwater mitigation measures; potential effectiveness of pollutant abatement for major pollutant categories.
- Recent water quality problem areas or "hot spots" where water quality standards have been exceeded within the CCC Basin.
- Ground water quality and quantity monitoring data for the CCC Basin.

Study Area

Refer to section 3 for an overall description of the study area.

Data Analysis and Products

- Estimate of stormwater-generated pollutant loading to the ground water system in the CCC Basin.
- Estimate of pollutant-removal capacity of two existing drywells in the CCC Basin and estimated cost-effectiveness of alternative stormwater control methods.
- Revised Executive Summary documenting affected jurisdictions, historic and current water quality problems in the CCC Basin, and study efforts completed to date (completed March 1988).
- Map illustrating Water Quality Problems, presented as an overlay to Figure 5-30 of the 1985 Clover Chambers Creek Study (completed June 1988).

SECTION 5

LAND AND WATER USE DATA COLLECTION

Introduction

Land use data was collected and compiled into a regional data base as part of the 1985 CCC Study (refer to study objectives described in section 2). As part of the study, an on-going mechanism for updating the data base was established under the jurisdiction of the County Health Department in conjunction with the City and County Planning Departments.

Quantification and a thorough understanding of the Basin's total available ground water resource and water use is a major element of any successful ground water management program. However, it is important to recognize the following:

- Insufficient data are currently available to meaningfully quantify the available ground water resource. Current deep drilling programs for the City of Tacoma, Thun Field, and the military bases will contribute to our understanding of the deeper ground water resources. Resource quantification will, however, require additional information about aquifer interaction, regional ground water flow, subsurface recharge, and discharge.

- Resource quantification will have to remain a goal, a product of the on-going program implemented under the ground water management program.

- Adequately determining the available resource will be a costly and long-term effort spanning several years.

- One of the objectives of the current project is to ensure that the final management program includes the procedures and methodology for determining the total available resource.

Data Collection and Analysis, Parties Responsible and Use of the Water Resource Data

- Tacoma Utilities Test Well Drilling Project. This project involves drilling a series of test wells in the South Tacoma Aquifer, testing the water levels, aquifers and water quality. The information will be incorporated in Parts I and II of the DMP.

- Hidden Valley (Thun Field Landfill) Hydrogeologic Study. This project includes well drilling, water sampling, water level investigations and the effects of the landfill on the CCC Basin

- Firgrove Water Company Well. This will include activities by Firgrove Water Company in drilling a new test well, plus the water sampling and water level measurements involved. This information will be incorporated in Parts I and II of the DMP.

- Tacoma-Pierce County Geohydrologic Evaluations. This match source includes geohydrologic evaluations done for land use activities. Applicable technical data will be incorporated into Part III of the DMP.

For parameters and procedures of water level data collection refer to the QA/QC Plan.

Study Area

For Study area boundaries refer to Section 3.

Data Analysis and Products

- Task 2 report which is a "Problem Statement" documenting affected jurisdictions, historic and current water quality problems in the CCC Basin, and study efforts to date (completed March 1988).

- Map illustrating Water Quality Problems, presented as an overlay to Figure 5-30 of the 1985 CCC Study (completed June 1988).