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Deer Park
Ground Water
Characterization Study
Preliminary Hydrogeologic
Summary Report

Prepared for

Spokane County

Draft Report

October 11, 1991

Prepared by

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Project X22-01.02

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1 INTRODUCTION

1.1 Purpose

This report summarizes existing geologic, hydrogeologic and ground water quality information for the Deer Park Basin (DPB) in Northern Spokane County, Washington. Information presented will guide the acquisition of additional data, and ultimately will be used for short- and long-term water resource planning and protection.

1.2 Scope of Work

The scope of work included:

- A literature search for previous geologic, hydrogeologic, and water supply studies
- Preparation of geologic maps, geologic cross-sections, and ground water flow maps for hydrogeologic characterization
- A state record search for ground water rights
- Evaluating overall water quality conditions
- Summarizing all study findings

1.3 Previous Studies

Limited geologic, hydrogeologic, and water quality studies have been completed in the study area. U.S. Geological Survey (USGS) topographic and geologic maps have been compiled and are available for the entire area. A study of the ground water resources and related geology of north-central Spokane and southeastern Stevens counties was completed by D. R. Cline in 1969. Several smaller scale studies have been completed since then. A hydrogeologic report was prepared by Century West Engineering (1983) as part of the City of Deer Park's Wastewater treatment and disposal facility plan. Anderson (1986) performed a hydrogeologic study of the Deer Park aquifer system focusing on nitrate contamination. Water supply studies completed for the City of Deer Park water municipality by CH2M Hill (1986 - 1987) include estimates of ground water resource potential. All studies have been compiled into a reference list in Section 7.

Studies that form the framework for the geologic summary of the study area include: Washington Division of Geology and Earth Sciences Open File Reports 80-3, 90-14 and 90-17 (McLucas 1980, Waggoner 1990, and Joseph 1990, respectively); Water Supply Bulletin No. 27 (Cline 1969); and Geological Survey Professional Papers 140-A and 806 (Pardee and Bryan 1925, and Miller and Clark 1975, respectively).

Driller's well logs for the DPB were obtained from the Washington State Department of Ecology. The geologic and hydrogeologic interpretations, shown in the cross sections (Section 3.1) and bedrock, and water level contour maps (Section 3.3 and 4.2, respectively) in this report were derived from the driller's logs. A copy of all the driller's well logs used for this report is presented in Appendix B.

2 STUDY AREA DESCRIPTION

The DPB is located in northeastern Spokane and southeastern Stevens counties, approximately 15 miles north of the City of Spokane. It is characterized by a broad open plateau with low-lying mountains to the north, west, and south, and a gentle rise to the east before it drops down to the Little Spokane river valley. Elevations in the DPB range from approximately 1,900 to 4,000 feet above mean sea level at Scoop Mountain, located on the western boundary of the basin. The basin is bisected north to south by Dragoon Creek, with small tributaries flowing from the northwest, west, and southwest into Dragoon Creek.

The Deer Park study area (DPSA) covers approximately 46 square miles and occupies the northeastern portion of the Deer Park Basin. It is bounded on the north by the Stevens County border, on the east by a surface watershed boundary between the Little Spokane River and Dragoon Creek, and on the south and west by Dragoon Creek (Figure 2-1).

The DPSA has a mild, arid climate during the summer months and a cold coastal-type climate in the winter. Precipitation is typically less than 20 inches per year at the Spokane International Airport, approximately 25 miles south of the DPB (1956 to 1985 annual record mean is 16.19 inches, Ruffner 1985). In the topographically higher areas north of Deer Park, precipitation may be more than 23 inches per year (Clayton PUD 1989-1990). Approximately 70 percent of the total annual precipitation falls between the first of October and the end of March, with about half of that as snow fall. Winter weather includes many cloudy or foggy days and below freezing temperatures. Snow depths occasionally reach several inches. Winter temperatures at the Spokane International Airport average 29°F, with summer temperatures averaging 66°F. The growing season usually extends from mid-April to mid-October. A summary of temperature and precipitation data from the Spokane International Airport is presented in Table 2-1.

The economy of the DPSA primarily is agricultural-based. The land use north of the City of Deer Park is approximately 43 percent agricultural with scattered residential dwellings. The land south of the city is approximately

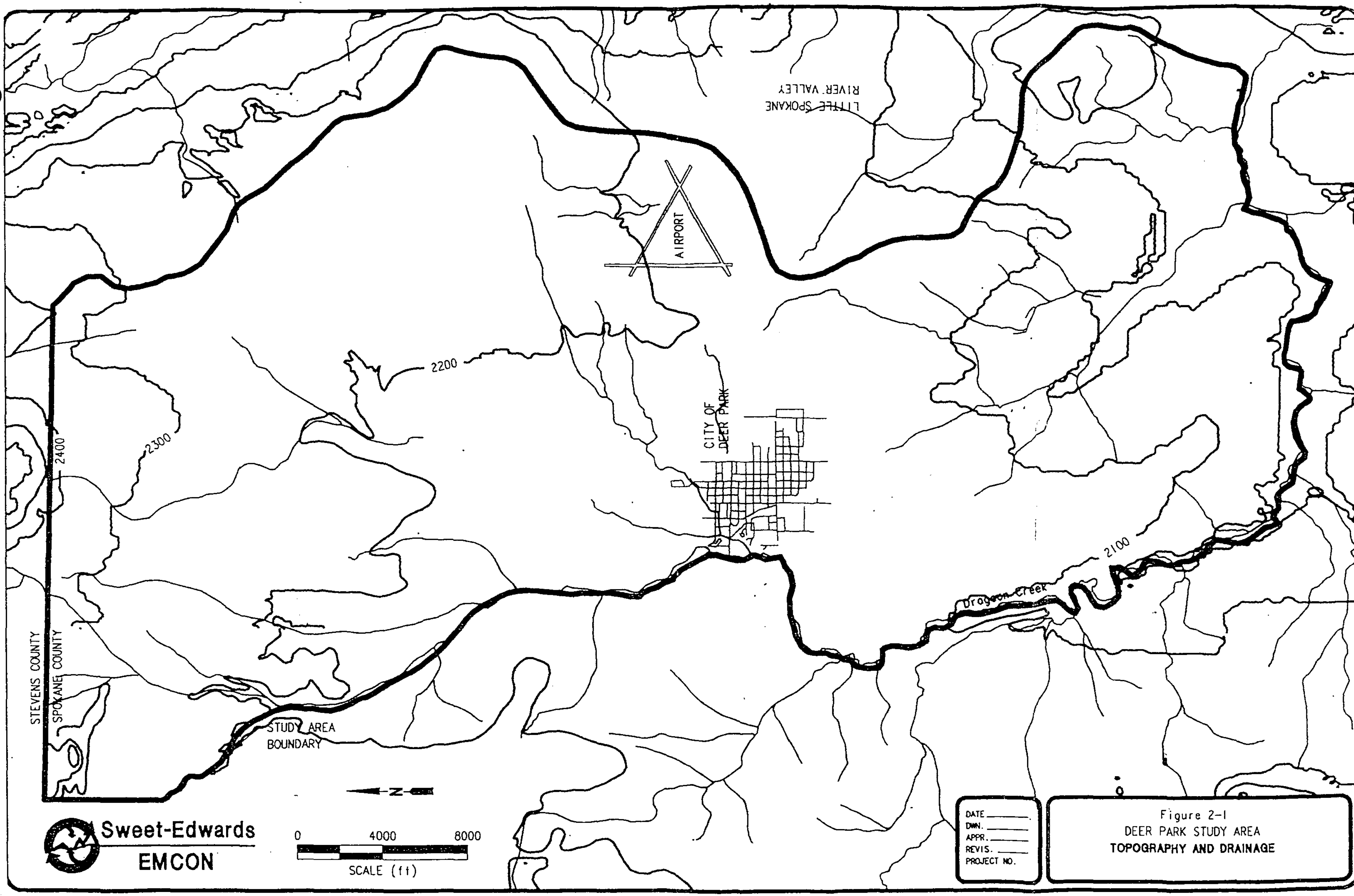

Figure 2-1
DEER PARK STUDY AREA
TOPOGRAPHY AND DRAINAGE

Table 2-1

Summary of Temperature and Precipitation From 1956 to 1985
Spokane International Airport

		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Average Temp.	Min	20.8	24.7	30.5	36.6	43.9	50.3	55.9	54.5	46.5	37.8	30.1	24.6	38.0
	Max	32.5	38.8	48.3	58.5	67.3	74.4	84.2	82.8	72.1	59.1	43.1	35.2	58.0
	Mean	26.6	31.8	39.4	47.5	55.6	62.4	70.10	68.7	59.3	48.5	36.6	29.9	48.0
Precip. (inches)	Min	0.75	0.40	0.31	0.08	0.54	0.16	0.01	0.01	0.03	0.05	0.34	0.60	11.21
	Max	4.96	3.94	2.56	2.62	3.74	3.06	1.85	1.83	2.05	2.33	5.10	5.13	21.51
	Mean	2.06	1.60	1.34	1.08	1.35	1.29	0.52	0.60	0.84	1.22	2.05	2.23	16.19
Snowfall (inches)	Min	4.6	0.7	0.1	0.1	0	0	0	0	0	0.0	0.1	0.5	14.2
	Max	48.7	28.5	15.3	6.6	3.5	0	0	0	0	3.9	23.7	42.0	89.0
	Mean	17.0	7.5	4.3	0.7	0.1	0	0	0	0	0.5	6.4	15.4	51.8

NOTE: From "Weather of U.S. Cities," 3rd ed., Vol. 2, Ruffner and Blair, Gale Research, Detroit, Michigan.

27 percent agricultural with numerous housing developments and small hobby farms.

Within the incorporated area of Deer Park, a small central business district exists in the western area, with a satellite commercial area developing in the southwest corner. The majority of the population is located in the western one-fifth of the incorporated area. The eastern portion is generally undeveloped except for the airport, scattered light industrial, and residential development.

The primary transportation corridors through the basin include Interstate 395 and the Burlington Northern Railroad. The Deer Park-Milan Road extends from the City of Deer Park east to State Highway 2 at Milan (Figure 2-2).

Beneficial uses of the Deer Park Basin aquifers include residential, agricultural, and commercial supplies. The quantity of water withdrawn for these purposes currently is not known.

There are seven public water suppliers in the DPSA, each using ground water sources. Additionally, there are hundreds of individual water wells using ground water sources.

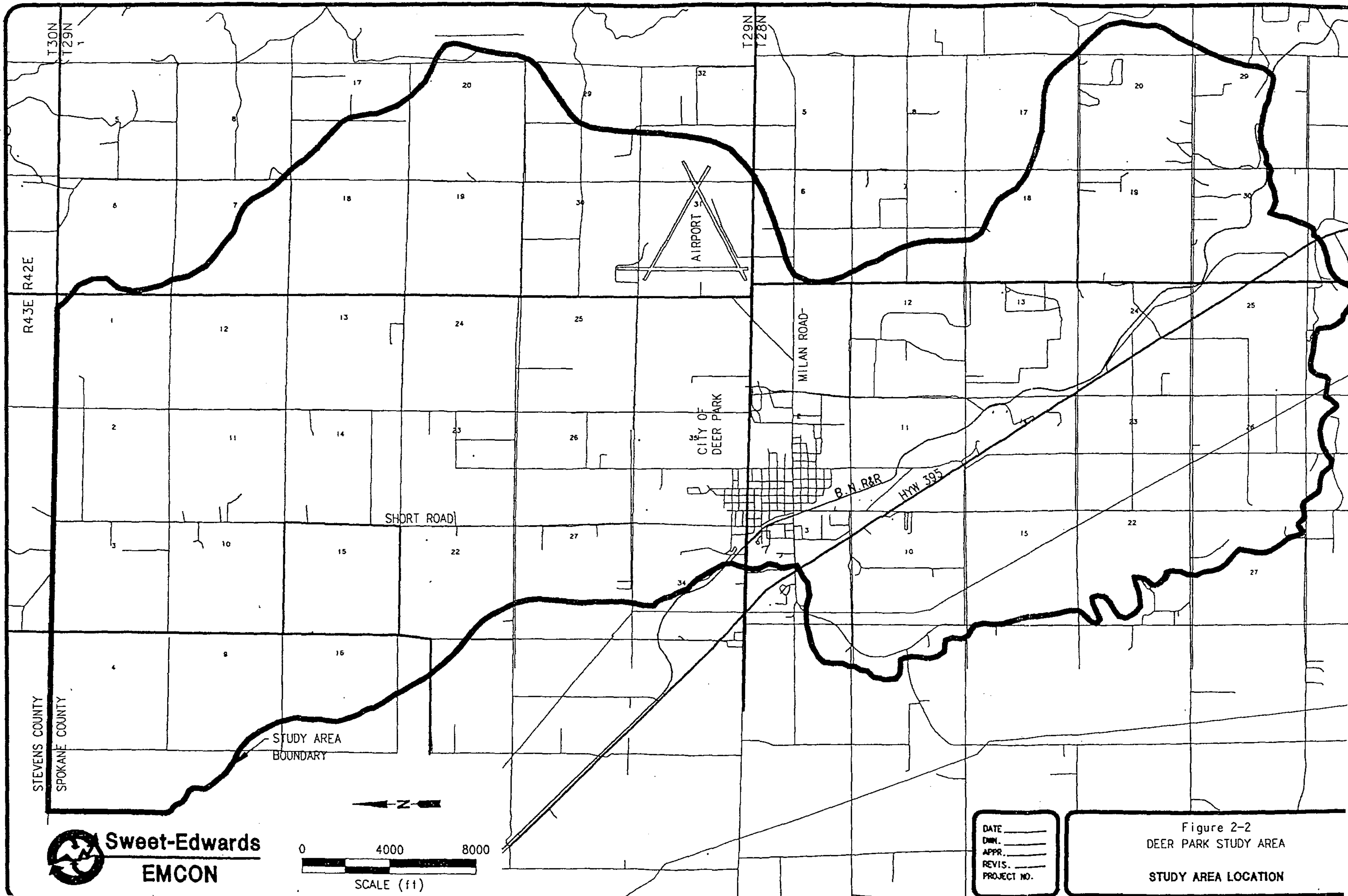

Figure 2-2
DEER PARK STUDY AREA

STUDY AREA LOCATION

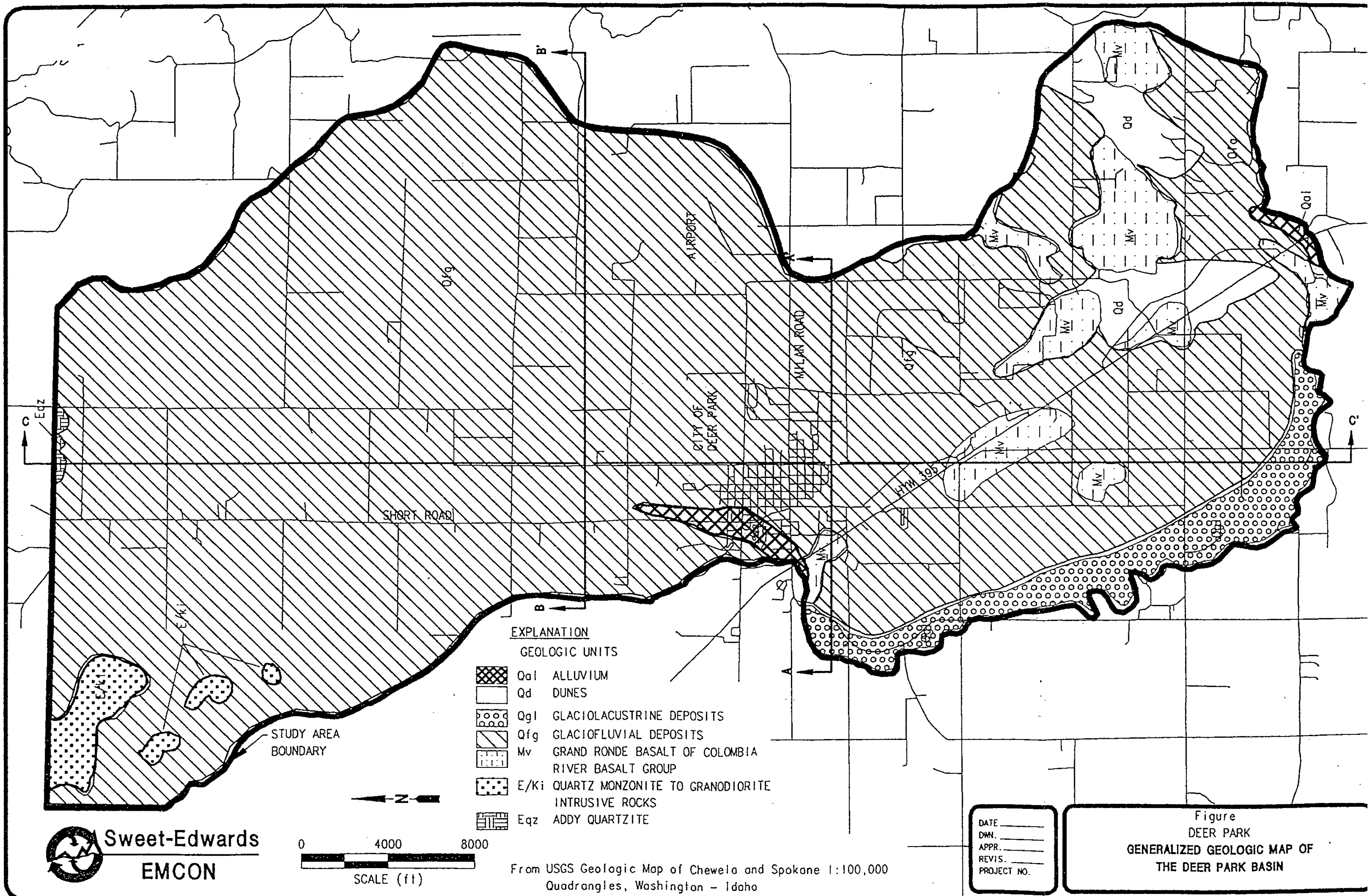

Figure
DEER PARK
GENERALIZED GEOLOGIC MAP OF THE DEER PARK BASIN

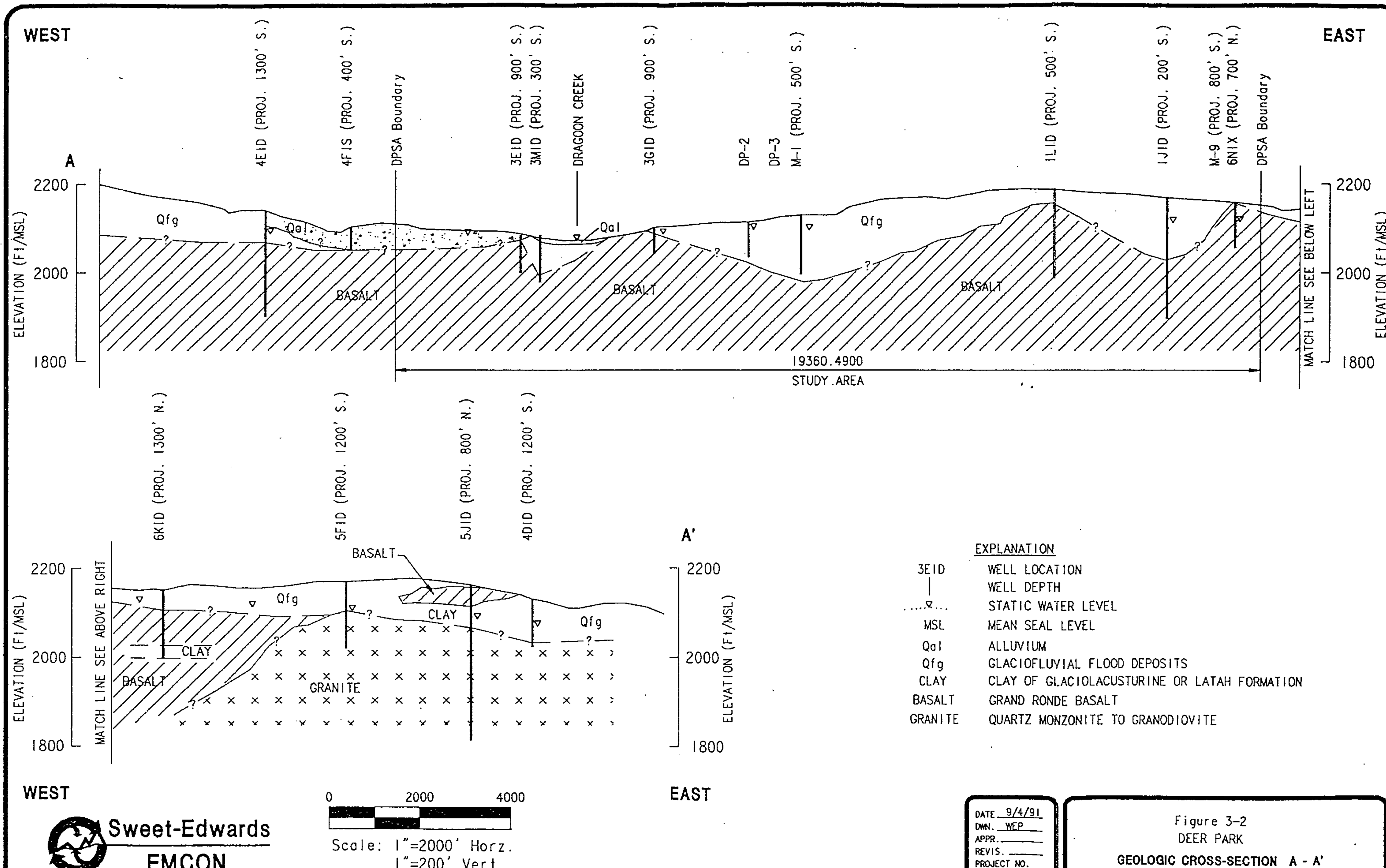

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Figure 3-2
DEER PARK
GEOLOGIC CROSS-SECTION A - A'

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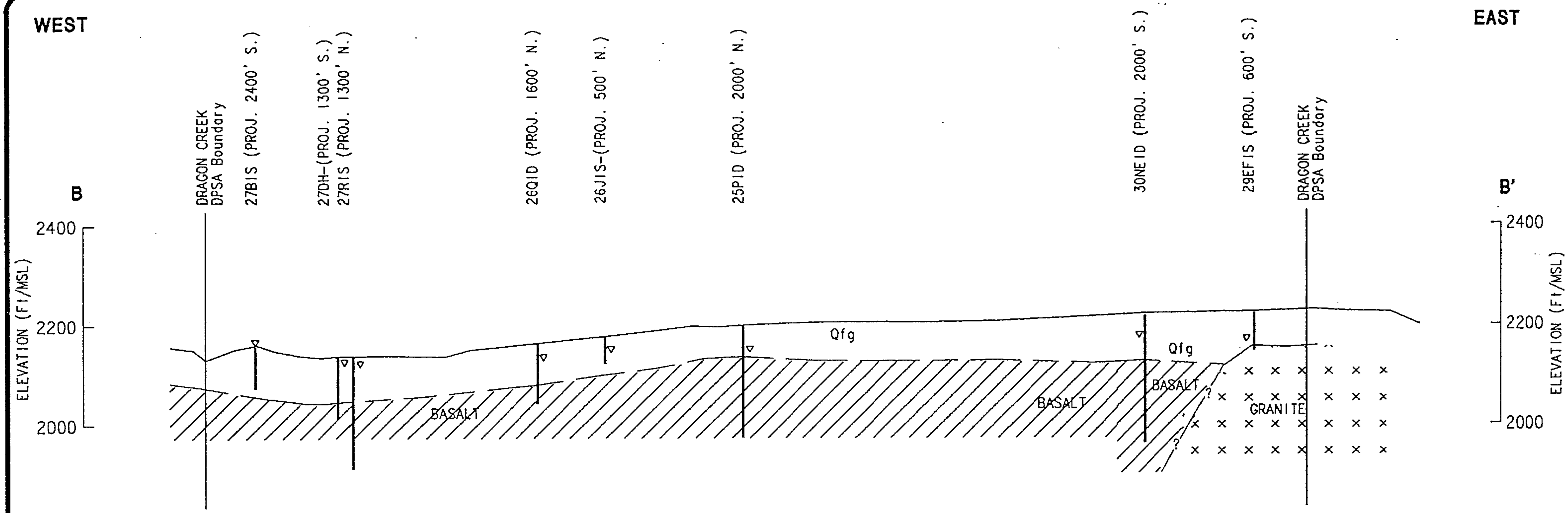

EXPLANATION

3EID	WELL LOCATION
|	WELL DEPTH
....▽...	STATIC WATER LEVEL
MSL	MEAN SEAL LEVEL
Qal	ALLUVIUM
Qfg	GLACIOFLUVIAL FLOOD DEPOSITS
BASALT	GRAND RONDE BASALT
GRANITE	QUARTZ MONZONITE TO GRANODIORITE

0 2000 4000

Scale: 1"=2000' Horz.
1"=200' vert.

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Figure 3-3
DEER PARK
GEOLOGIC CROSS-SECTION B - B'

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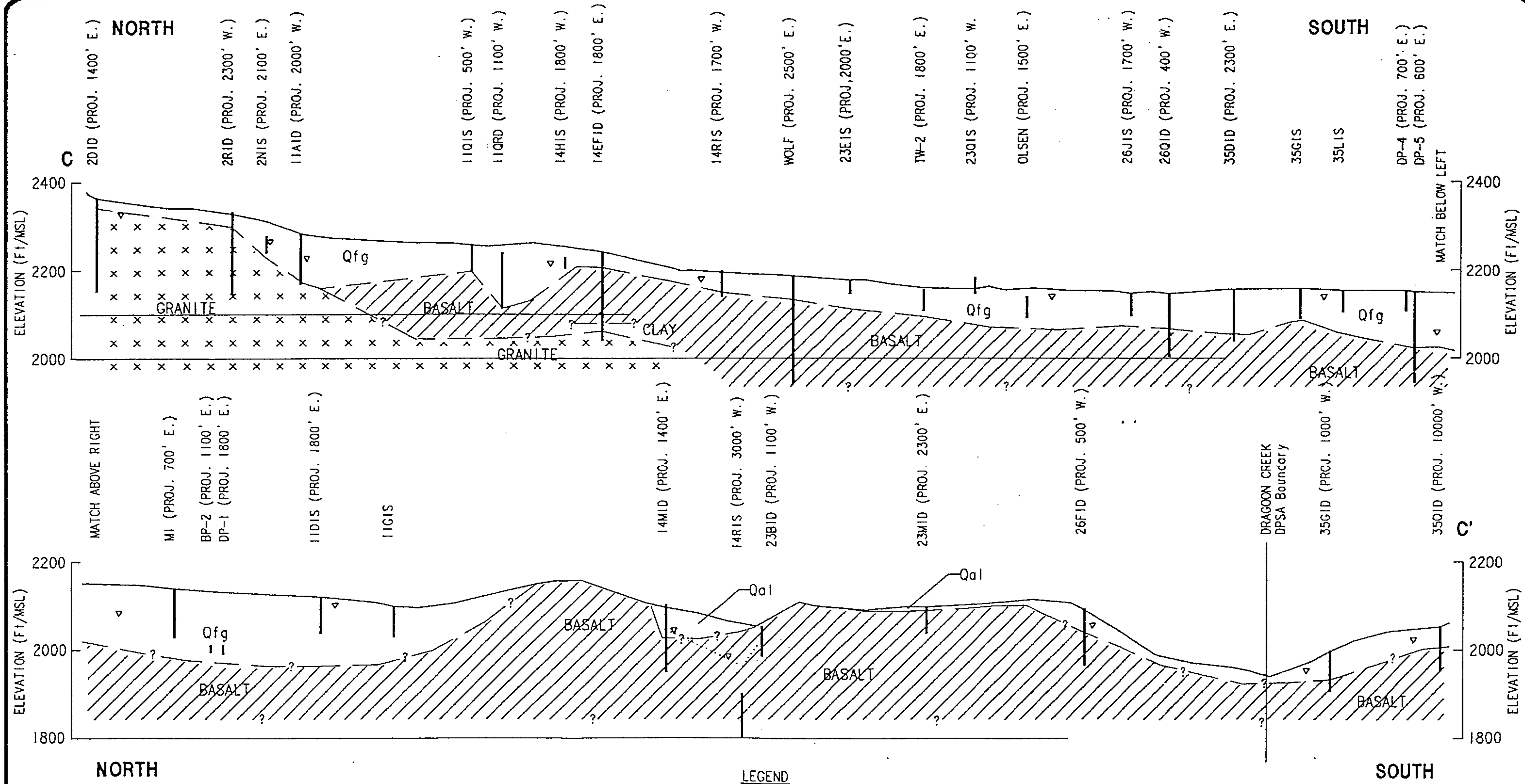

LEGEND

3E1D	WELL LOCATION
|	WELL DEPTH
▽	STATIC WATER LEVEL
MSL	MEAN SEAL LEVEL
Qal	ALLUVIUM
Qfg	GLACIOFLUVIAL FLOOD DEPOSITS
BASALT	GRAND RONDE BASALT
GRANITE	QUARTZ MONZONITE TO GRANODIOVITE

0 2000 4000

Scale: 1"=2000' HORZ.
1"=200' VERT.

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Figure 3-4
DEER PARK
GEOLOGIC CROSS-SECTION C - C

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Recent alluvial deposits occur along Dragoon Creek as thin, flat-lying sediments. Alluvium may be deposited on Pleistocene sediments or directly on the bedrock. Dune deposits consisting of reworked, wind-blown glaciofluvial and glaciolacustrine sands are encountered between the basalt mesas in the south-central portion of the study area.

3.2 Geologic History

The oldest rocks (1,600 to 550 million years ago), as shown in Figure 3-5, of the DPB are metasedimentary rocks of Precambrian to Cambrian age (Waggoner 1990). The metamorphic rocks of the "Belt Supergroup" form the mountains to the north of the basin and are composed of laminated siltite, argillite, quartzite, and minor impure carbonate-bearing clastic rocks (Waggoner 1990). During the Cretaceous Period (138 to 63 million years ago) and Eocene Epoch (55 to 38 million years ago), plutonic rocks intruded the metamorphic rocks of the Belt Supergroup in the vicinity of DPB (Miller and Clark 1975). These igneous rocks generally are composed of leucocratic, coarse-grained quartz monzonite to granodiorite (Joseph 1990) and compose the mountains to the northwest, west, and southwest of the basin. Following the intrusive periods, these rocks were deeply eroded and formed a northwest trending mountain range with a stream flow drainage to the lowlands in the southwest (USGS 1988).

During Miocene times (24 to 5 million years ago), the Latah Formation and basalt flows were deposited concurrently in the DPB. Basaltic flows of the Columbia River Group (Joseph 1990) were extruded across the land from the south and west (USGS 1988). These basaltic flows initially did not reach the DPB, but created a barrier west of Spokane. This basaltic barrier blocked major stream drainages, including the Columbia and Spokane rivers. East of the basalt barrier, an environment of quiet ponds, swamps, and slowly moving stream channels was created (Pardee & Bryan 1925). Within these swamps and ponds, sediments were deposited creating the Latah Formation. The Latah Formation consists of semi-consolidated sedimentary deposits of lacustrine and fluvial deposition and contains abundant fresh water fossils. During the deposition of the Latah Formation, a sequence of intermittent basalt flows over the barrier and into the Deer Park Basin, with subsequent deposition of the Latah Formation created interbedded deposits of sediment and basalt which overlie the older metamorphic and plutonic rocks.

During the Pleistocene Epoch (2 million to 100,000 years ago), periods of glacial advances and retreats scoured the existing land surface and deposited thick sequences of sediments on the underlying rocks. Glacial tongues of ice may have advanced as far south as Lake Eloika, located

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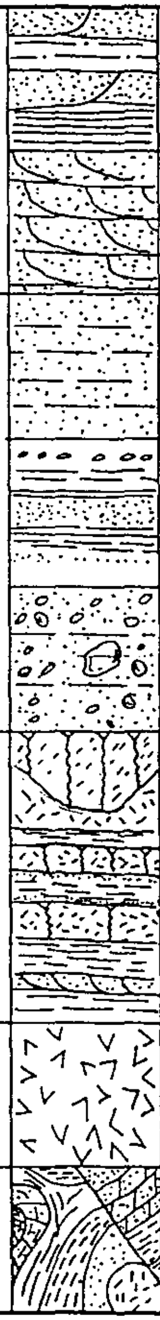
STRATIGRAPHIC SEQUENCE OF GEOLOGIC UNITS



Epoch	Age	Unit	Description
RECENT	Recent 12,000 – 0 Years	Alluvium	Stratified clay, silt, sand, and gravel
		Dunes	Wind deposited sand
PLEISTOCENE	12,000 – 2 Million Years Ago	Palouse Formation	Unstratified eolian silt, clay, sand, and ash loess deposits
		Glacial Lacustrine Deposits	Well bedded, clay, silt, and sand
		Glacial Fluvial Deposits	Poorly sorted sand, gravel, cobbles, and boulders
MIOCENE	5 – 24 Million Years Ago	Volcanic Rock	Basalt flows of the Columbia River Group, interbed and cap Latah Formation
		Latah Formation	Claystone, siltstone, and minor sandstone of lacustrine and fluvial origin
EOCENE TO LATE CRETACEOUS	38 – 100 Million Years Ago	Igneous Rocks	Coarse grained quartz monzonite to granodiorite
CAMBRIAN TO MIDDLE PROTEROZOIC	500 – 1,600 Million Years Ago	Metamorphic Rocks	Sequence of siltite, argillite, quartzite, and carbonate bearing clastic rocks of Belt Supergroup and Addy Quartzite

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Figure 3-5
DEER CREEK BASIN

GENERALIZED STRATIGRAPHIC COLUMN

approximately 5 miles northwest of Deer Park, as seen in deposition of glacial moraines (Cline 1969). The meltwater from the glaciers, however, had a greater effect on the contemporary topography in the Deer Park Basin, than did the advancing glacial ice.

Meltwater from the glaciers carried large quantities of silt, sand, and gravel and deposited these sediments as lacustrine or flood deposits in the DPB. The type of deposit was dependent on the changing environments of the Pleistocene Epoch. Glaciolacustrine deposits are primarily fine sand, silt, and clay, typifying sediments carried by slow moving water (Joseph 1990). Glaciofluvial deposits consist of a poorly sorted mixture of cobbles, gravel, and sand resulting from fast moving meltwater streams and multiple episodes of catastrophic outbursts from glacier dammed lakes (Joseph 1990). These glacial sediments filled the valleys and scoured into the underlying consolidated rocks.

During and following the glacial period, fine grained sands, silts, clays, and volcanic ash were transported by the wind and deposited on the highland mesas. These loess deposits comprise the Palouse Formation, and commonly mantle the Columbia River Basalt (Joseph 1990).

Recent post-glacial topographic erosion and deposition modifications have been minor; the wind and streams, however, have reworked the near surface sediments. Dune deposits formed by wind reworking the glaciolacustrine and glaciofluvial sediments consist of predominantly fine to medium sand grains (Joseph 1990). The dune deposits have a maximum thickness of 50 feet, though most are much thinner (Cline 1969). Recent alluvial deposits are reworked sediments along the streams, valley bottoms, and terraces and consist of silt, sand, and gravel (Joseph 1990).

3.3 Bedrock

Bedrock consisting of metamorphic and igneous rocks underlies the entire DPSA. The known depth to bedrock (granitic or basalt) in the study area ranges from land surface south of Deer Park, to 215 feet, approximately 5 miles north of Deer Park (T29N/R42E, Section 4). The average depth to bedrock in the northern portion of the study area ranges from 50 to 100 feet. The topography of the bedrock surface is highly irregular, and subterranean (buried) valleys, basins and mesas are present beneath the study area. One distinct valley is located under the western portion of the city of Deer Park. The buried valley trends north-northwest to south-southeast and is bounded on the east and west by mesas, approximately 120 feet above the low points in the buried valley bottom. A buried bedrock basin appears to exist beneath the area near the Airport. Figure 3-6 shows

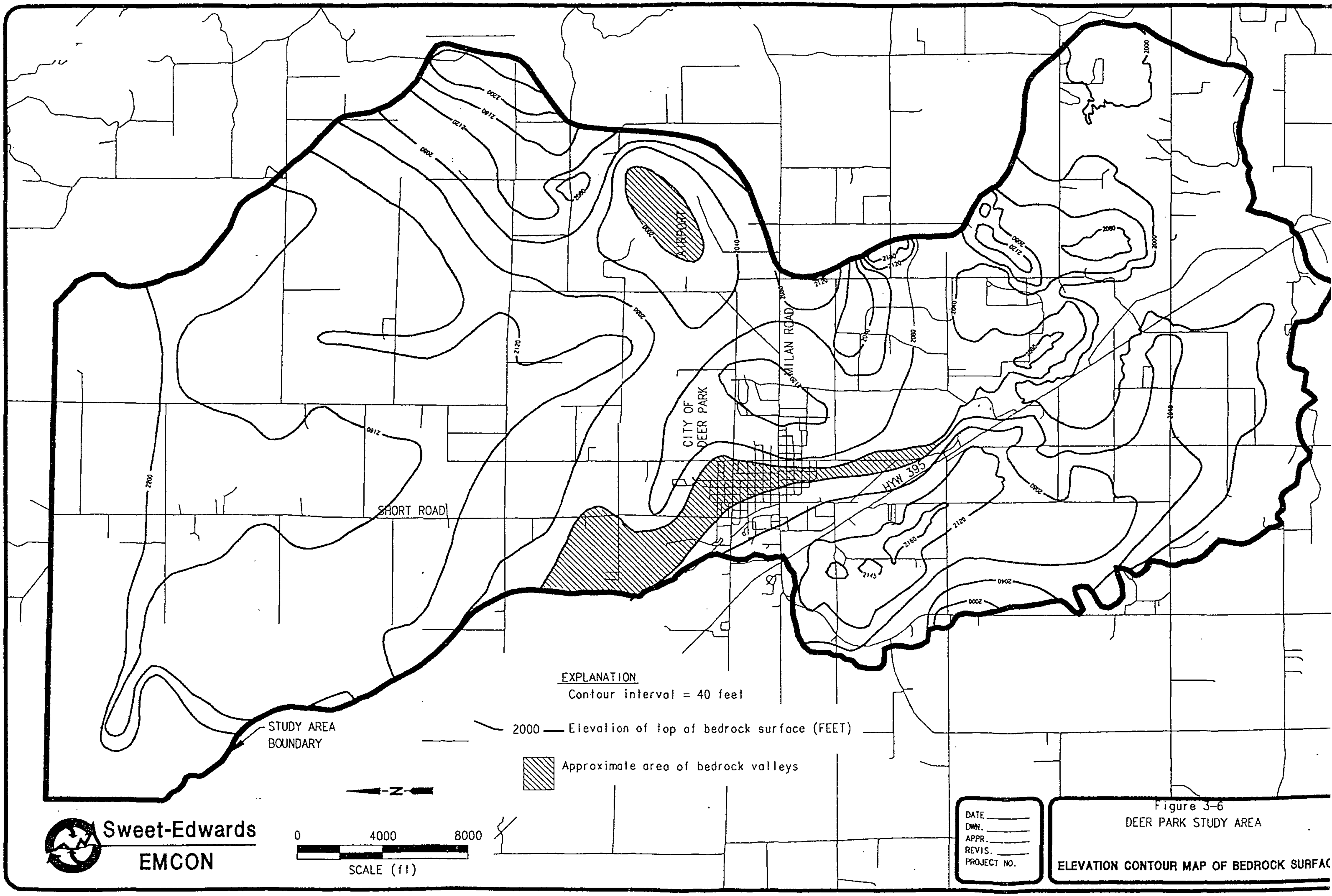

Figure 3-6
DEER PARK STUDY AREA
ELEVATION CONTOUR MAP OF BEDROCK SURFAC

the approximate elevations of the bedrock surface as derived from driller's logs and geologic maps.

3.3.1 Precambrian and Paleozoic Crystalline Rocks

Metamorphic rocks formed during the middle Proterozoic Era (800 to 1,600 million years ago) and lower Cambrian to Upper Proterozoic (550 to 800 millon years ago) are found along the northern margin of the DPB and extend north into Canada (Waggoner 1990). The older rocks of the "Belt Supergroup" consist of the Missoula Group, the Wallace Formation, the Ravalli Group, and the Prichard Formation. The metasedimentary rocks of the Belt Supergroup consist of siltite, argillite, quartzite, and minor impure dolomite- and carbonate-bearing clastic rock (Waggoner 1990). The Wallace Formation and the Revett Formation of the Ravalli Group are mappable units in the mountains on the northern border of the DPB (Waggoner 1990). The Addy Quartzite, deposited after the Belt Supergroup, consists predominantly of a thick sequence of quartzite, but has some significant amounts of siltite and argillite in the upper portions of the formation (Waggoner 1990). In the DPB, the Addy Quartzite only exists north of the study area as small blocks in the vicinity of the Belt Supergroup. The Belt Supergroup and Addy Quartzite are folded and broken by faults, have a general northwest strike, and dip primarily 30 to 60 degrees to the southwest (Waggoner 1990).

3.3.2 Plutonic Rocks

Nine plutons, representing three periods of plutonic activity, respectively 200, 100, and 50 million years ago, intruded the metamorphic rocks (Miller and Clark 1975). The plutonic rocks of the last two intrusive periods are exposed in numerous areas in the northwest, west, and southwestern mountains around the basin and have been logged by drillers at depth beneath the basin (Joseph 1990). These rocks, intruded during the Cretaceous Period (approximately 100 million years ago) and Eocene Epoch (approximately 50 million years ago), consist of leucocratic, coarse-grained quartz monzonite to granodiorite (Joseph 1990).

3.4 Latah Formation

The Latah Formation is a series of beds, primarily clay and shale, containing abundant fresh-water fossils. This formation only outcrops in a small area northeast of Deer Park, but it is recorded in numerous drilling logs across the basin and underlies much of the area. According to Pardee and Bryan (1925), during the Miocene Period (5 to 24 million years ago), the lava floods of the Columbia Plateau advanced from the south and west, but were held back from the Spokane area by a ridge in the vicinity of the Cheney, Marshal, and Medical lakes. The drainage into the Spokane area from the north and east was backed up by the lava, forming a broad alluvial plain containing lakes and swamps, over which streams meandered through sluggish channels toward the west. It was in this environment that the Latah Formation was deposited, creating a sequence of grey to tan to yellow-orange siltstone, claystone, and minor sandstone deposits (Waggoner 1990). The strata of the Latah Formation generally are thin-bedded to laminated, and exhibit local cross-bedding (Cline 1969). The backwater environment changed periodically as the basalt flows breached the protective ridge, creating a sequence of interbeds within, and a final cap on, the Latah Formation (Pardee and Bryan 1925).

The thickness of the Latah Formation is highly variable. It is influenced by the number of basalt interbeds and the degree of irregularity of the underlying surface. According to Cline (1969), the Latah Formation probably does not exceed a few hundred feet in thickness in the Deer Park area. The unit is not shown on the geologic cross sections (Figures 3.2 to 3.4) because of the difficulty in identifying it from well drilling reports. The lenses of clay shown on the x-cross sections probably represent the Latah Formation, but can not be distinguished from glaciolacustrine clays from the drillers' well logs.

3.5 Columbia River Basalt

During Miocene times, basalt of the Columbia River Group (Joseph 1990) was extruded across the area from the south and west (USGS 1988). Numerous flows are recorded in drilling well logs across the DPB, and the younger Grand Ronde Basalt, of the Columbia River Group, is present as surface outcrops in the south-central portion of the study area (Joseph 1990). The flows, which are commonly pillowed (water cooled) and interbedded with the Latah Formation, are typically 50 to 80 feet thick, but range up to 165 feet in thickness (Joseph 1990).

The combined thickness of the basalt flows may be as great as 350 feet, but at most places in the study area is 50 to 150 feet thick (Cline 1969).

3.6 Pleistocene Unconsolidated Sediments

During the Pleistocene Period (100,000 to 2 million years ago) glacial activities scoured the basalt landscape and deposited large quantities of sediments over the basalt surface. Glacial ice apparently did not reach into the study area, but Cline (1969) recorded morainal debris around Eloika Lake, located to the northwest of the study area. These morainal deposits were not, however, recorded by the USGS during their recent mapping of the area (Waggoner 1990). Most surficial sediments in the Deer Park Basin are glacial drift and flood deposits, including glaciolacustrine and glaciofluvial deposits. Small deposits of glacial loess are present in the basin, but not in the study area. Each of the deposits is described in the following sections.

3.6.1 Glaciolacustrine Sediments

The glaciolacustrine sediments are generally well laminated (varved) glacial lake deposits which overlie the consolidated deposits of the DPB. The sediments consist mostly of silt, sand, and clay, and contain some interbeds of fluvial gravel (Cline 1969). The deposits range in thickness up to 202 feet thick, according to well log information in the northeast corner of the study area (T29N/R43E, Section 29, Cline 1969).

3.6.2 Glaciofluvial Sediments

The glaciofluvial deposits in the study area were formed during the late Wisconsin outburst floods of glacial Lake Missoula (Waggoner 1990). The deposits consist of poorly sorted, subrounded-to-angular clasts of diverse lithologies (Waggoner 1990). The glaciofluvial deposits in the DPB are probably less than 200 feet thick, but can reach thicknesses up to 700 feet in other areas outside of the basin (Cline 1969).

3.6.3 Palouse Formation

The Palouse Formation consists of loess deposits transported and precipitated by the wind during and following periods of glaciation. The deposits consist of tan to brown silt, clay, fine sand, and ash (Joseph 1990). The loess deposits commonly mantle the tops of low hills and plateaus where erosion has been minimal. In the DPB, only one area of loess deposits has been mapped. The loess is located in the low mountains on the southern boundary of the basin (Waggoner 1990).

3.7 Recent Deposits

Post-glacial modifications of the topography by erosion and deposition have been minimal in the DPB. Some surface sediments, however, have been reworked by wind and streams to form dune and alluvial deposits. The consolidated rocks probably have undergone erosion due to mechanical weathering along roadside cuts and in the surrounding mountains, forming colluvial deposits. The weathering of consolidated rocks has, however, not produced deposits of significance as compared to the dune and alluvial deposits described below.

3.7.1 Dune Deposits

Dune deposits are located between the outcropping basalt in the south-central portion of the study area. They consist of predominantly fine to medium sand, mostly composed of quartz and basalt grains reworked from the older sedimentary rocks (Joseph 1990).

3.7.2 Alluvial Deposits

The alluvium consists of clay, silt, sand, and gravel, with some peat (Cline 1969). Limited of alluvial deposits are found next to the streams and valley bottoms of the study area.

4 GROUND WATER

This section describes the occurrence, movement, recharge, and discharge of ground water within the major geologic units in the study area. Although ground water occurs in most of the geologic units discussed in Section 3, quantities of ground water may not be sufficient for domestic or agricultural use. Physical conditions such as thickness, permeability, and layering determine the role of each unit in the overall ground water system.

4.1 Occurrence of Ground Water

Geologic materials that store and conduct ground water are considered to be aquifers. Ground water in the study area is extracted for multiple uses from the following geologic units: glaciofluvial deposits, glaciolacustrine deposits, the Latah Formation, basalt, and plutonic and metamorphic rocks. When evaluating the hydrologic characteristics of these geologic units, it often is more appropriate to talk in terms of hydrostratigraphic units. In this context, the geologic units can be described in terms of their role in the overall ground water regime. There are insufficient reliable data to draw accurate conclusions on ground water for each hydrostratigraphic unit in the study area; however, generalizations can be made.

In this study, the hydrostratigraphic units of the DPB have been divided into Pleistocene glacial and pre-glacial deposits, which consist of (1)a shallow unconsolidated sediment ground water system, and (2) a deeper semi-consolidated and consolidated rock ground water system. The shallow ground water system is restricted to Pleistocene glaciolacustrine and glaciofluvial deposits. The deep ground water system is composed of the ground water contained in the Latah Formation, basalt, plutonic, and metamorphic rocks.

4.2 Ground Water Flow Directions

Generalized ground water elevation contour maps have been constructed using water level information recorded on the logs of wells drilled in the DPSA. Since the water levels represent data from different seasons, and the location of wells are generally only accurate to the quarter-quarter section, the interpretation of regional ground water elevation contour patterns are only approximate. Ground water elevation for the shallow and deep ground water systems are shown on Figures 4-1 and 4-2, respectively. Both figures show only general ground water flow patterns. Local flow patterns may vary significantly. Wells used to prepare the water level contour maps are included in Appendix B.

The ground water elevation contour maps indicate the potentiometric surface, or the hydraulic head, in each aquifer. Ground water within the aquifer will rise in a well to the potentiometric surface. Ground water will flow perpendicular to the contour lines of the map. The ground water elevation map can be misleading, however, because the ground water systems occur in non-homogenous materials, and the potentiometric surface probably represents both unconfined (water table) and semi-confined/confined hydraulic conditions. In addition, ground water beneath the potentiometric surface may not always flow perpendicular to the contours shown on the map due to local permentations. These result from buried features such as basalt barriers, non-homogenous depositional sequences (silt, clay, and sand), or variable fracture patterns.

4.2.1 Shallow Ground Water System

In general, ground water in the shallow unconsolidated aquifer flows from the northwest to the southeast across the study area. On the eastern boundary of the study area, the ground water flow direction deviates and flows in an easterly direction toward the Little Spokane River. Based on limited well log data, basalt may form a barrier to ground water flow in portions of the shallow aquifer system.

In the south-central portion of the study area subterranean basalt outcrops which extend above the potentiometric surface of the unconsolidated aquifer may create a partial barrier to ground water flow within the aquifer. As shown on Figure 4-1, the buried basalt mesas create areas to the south and east of Deer Park where the glacial deposits are unsaturated. These basalt outcrops potentially act as barriers or diversions to ground water flow in the unconsolidated aquifer. Ground water can flow around the subterranean mesas and through the subterranean valleys, but the narrow areas between the mesas would tend to limit the flow quantity.

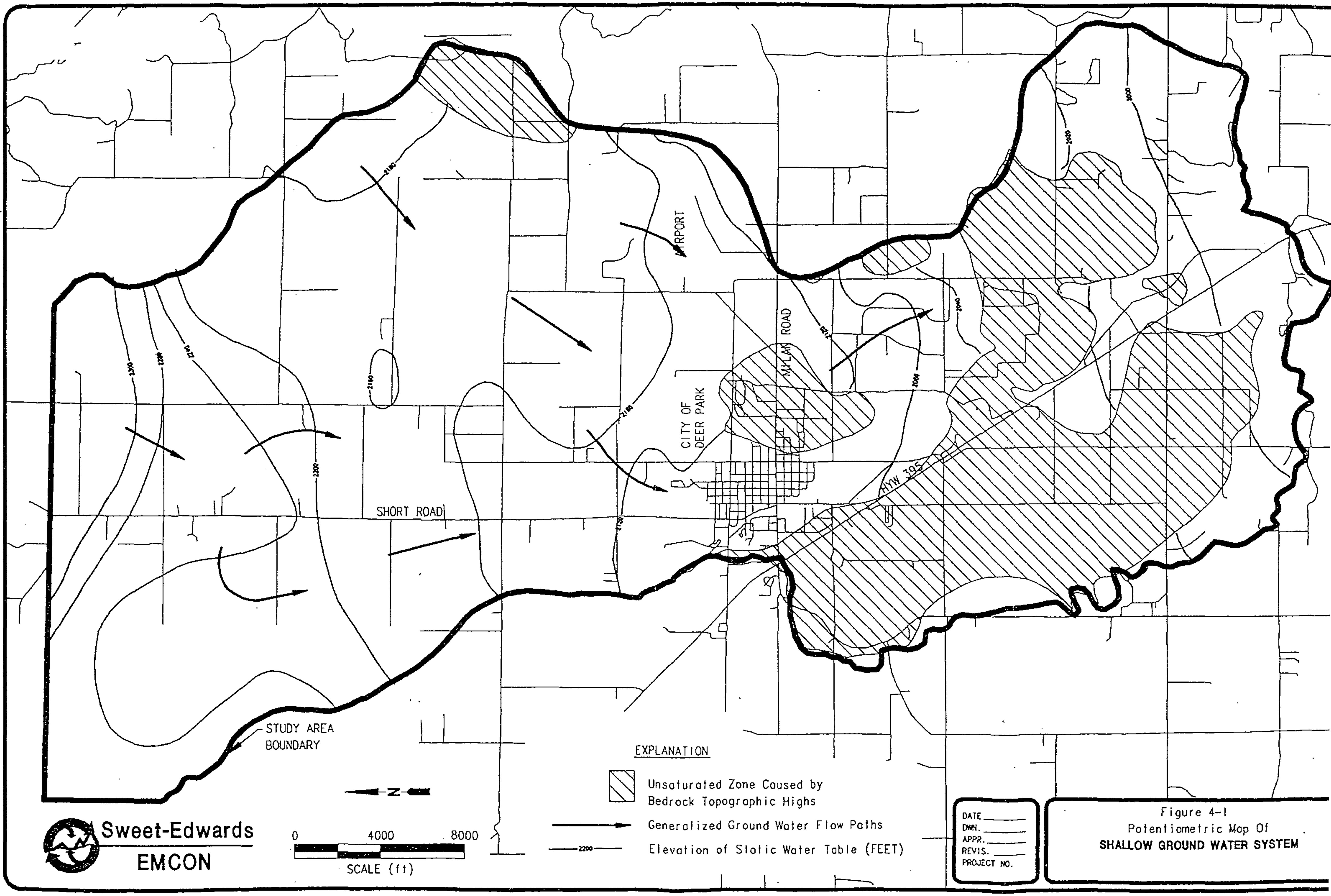

Figure 4-1
Potentiometric Map Of
SHALLOW GROUND WATER SYSTEM

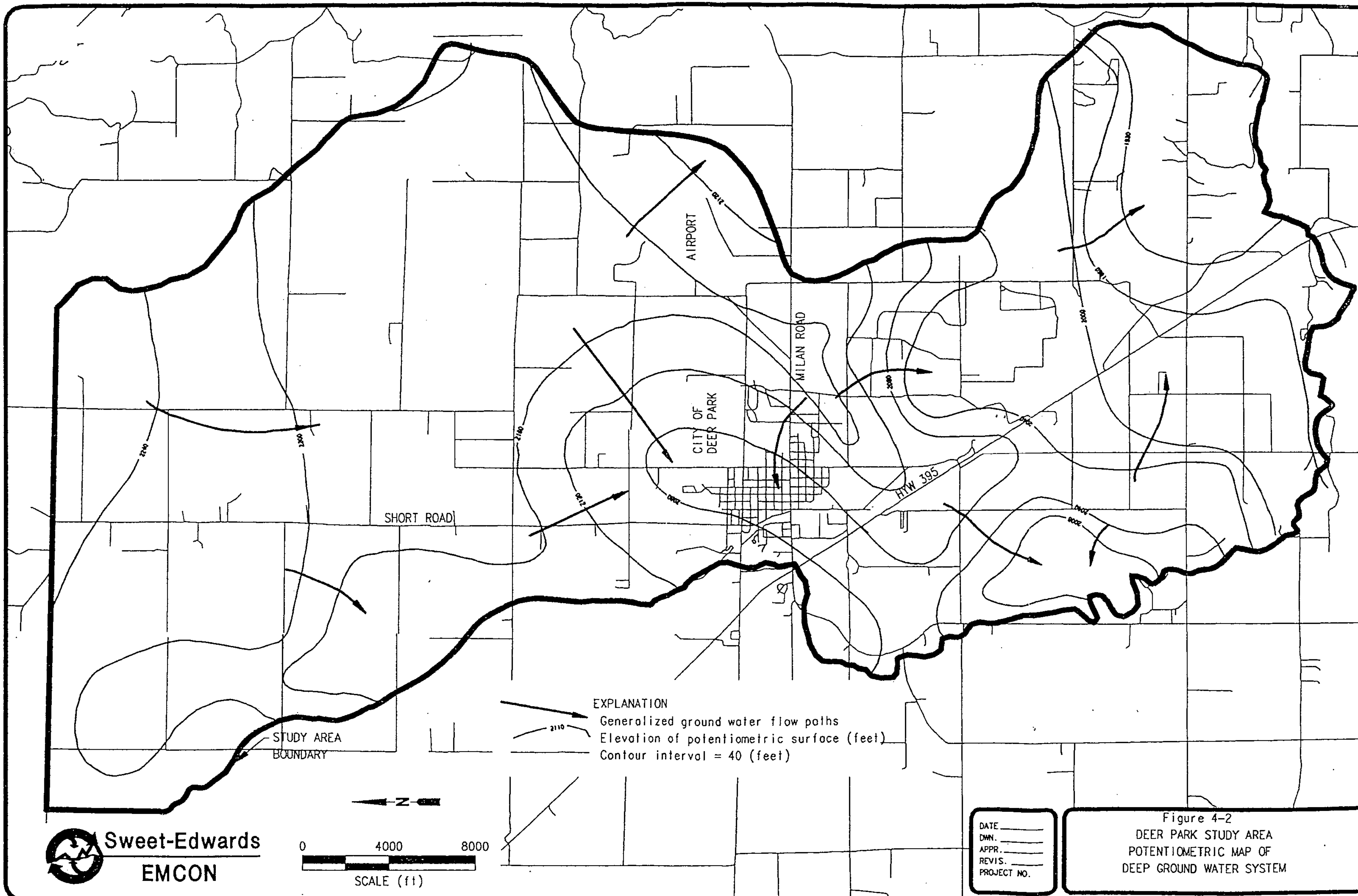

Figure 4-2
DEER PARK STUDY AREA
POTENTIOMETRIC MAP OF
DEEP GROUND WATER SYSTEM

4.2.2 Deep Ground Water System

Ground water flow in the deep ground water system generally flows from the northwest to the southeast. Two potentiometric surface depressions are located beneath the city of Deer Park and to the southwest (Figure 4-2). One potentiometric surface mound may be present to the southeast of the city.

These potentiometric depressions and mounds may be an expression of subterranean valleys and mesas which create local variations in the potentiometric surface, or result from local pumping. The depressions and mounds in the potentiometric surface create localized ground water flow patterns which deviate from the general direction of flow. As shown on Figure 4-2, ground water flows from high potential (the mounds) to low potential (the depressions) and creates localized flow to the northwest and southeast beneath and southwest of the city of Deer Park, respectively.

4.3 Major Hydrostratigraphic Units

The major hydrostratigraphic units of the DPSA occur within the Pleistocene glacial and pre-glacial sediments. In the DPSA the shallow unconsolidated ground water system is composed of Pleistocene glaciolacustrine and glaciofluvial deposits. The deeper ground water system is composed of the Latah Formation, basalt, plutonic, and metamorphic rocks. The metamorphic rocks located in the northern end of the DPB are grouped with the deeper ground water system because they store and transmit water similar to plutonic rocks; however, the metamorphic rock type is not logged by drillers in the boundaries of the DPSA.

The hydrostratigraphic units within each ground water system may either form barriers (aquitards) to ground water flow or readily store and transmit ground water (aquifers).

4.3.1 Shallow Ground Water System

Glaciofluvial Deposits. The glaciofluvial deposits are the most productive hydrostratigraphic unit in the region, and are the primary source of ground water for the areas in the north half of the study area. The ground water is generally under-water-table conditions (atmospheric pressure). The static water level commonly is found less than 10 feet below the surface, but is subject to seasonal fluctuations.

Ground water yields are relatively high, up to 1,700 gpm, from the glaciofluvial deposits. Ground water pumping tests conducted in 1987 for the city of Deer Park showed that transmissivity in the glaciofluvial deposits ranges from 5,400 gallons per day per foot (gpd/ft), in a well located at the "Former Saw Mill Site" on the northwest perimeter of Deer Park, to approximately 2,000,000 gpd/ft in the Olsen well located approximately 1.5 miles north of town (CH2M Hill 1987). Pumping rates in the test wells ranged from 90 to 620 gpm, but may yield as much as 900 gpm based on estimates from the Olsen well, (CH2M Hill 1987). A summary of the shallow aquifer characteristics is presented in Table 4-1.

The narrow bedrock valleys beneath the city of Deer Park contains a number of highly productive wells. The bedrock valley may represent a former fluvial (stream or river) channel where coarse materials were deposited. The coarse materials result in a more permeable and productive aquifer.

Table 4-1

Pumping Test Summary - Glaciofluvial Deposit

Well	Aquifer Thickness (feet)	Static Water Level (feet below ground level)	Date	Test Length (hours)	Pumping Rate (GPM)	Transmissivity (GPD/ft)	Storage Co-efficient
TW-1	45	4.59	2/27/87	4	90	5,400	-
TW-2	50	8.10	4/22/87	4	106	50,000-150,000	-
Olsen (West)	44	7.73	5/12/87	24	620	2,000,000	0.001

NOTE: All information based on pump testing data reported by CH2M Hill, 1987.

The glaciofluvial deposit is recharged from direct infiltration from precipitation, irrigation, surface water run-off, and ground water recharge from underlying hydrostratigraphic units. Seasonal water table surface fluctuations indicate direct infiltration is a major contributor to the aquifer; however, the fluctuations may be due in part to large quantities of ground water withdrawn for irrigation during the growing season.

Glaciolacustrine Deposits. Ground water in the glaciolacustrine deposits are generally stored in, and transmitted through, the interbeds of fluvial sands and gravel. Interbedded flat-lying deposits of silt and clay may act as aquitards within the deposits and confine the ground water transmission through the deposit. Ground water within the deposits is commonly encountered under artesian pressure by well drillers. The artesian pressure, combined with the fine sediments of the deposit is a source of what drillers term "quicksand" and is regarded as an undesirable unit for well completion.

Yields to wells tapping the glaciolacustrine deposits and underlying undifferentiated glacial deposits vary widely from 5 gallons per minute (gpm) to 600 gpm in a well located south of the Deer Park Basin (Cline 1969). Cline surveyed 25 wells that yielded over 50 gpm, with 10 wells, located adjacent and north of Deer Park, yielding 200 gpm or more, and one spring located to the north of the city yielding 75 gpm from glaciolacustrine deposits.

The glaciolacustrine deposit potentially is recharged from three sources: (1) direct infiltration from precipitation and surface run-off; (2) ground water leakage from the overlying glaciofluvial deposits; and (3) ground water recharge from underlying hydrostratigraphic units. The potential for ground water recharge from direct infiltration of precipitation and runoff is probably minor, resulting from the few areas which outcrop at the surface.

4.3.2 Deep Ground Water System

Basalt. Basalt underlies a large portion of the Pleistocene glacial deposits in the Deer Park Basin. Ground water in the basalt generally is stored and transmitted through interflow zones, joints, and fractures within the basalt. The interflow zones can provide the largest yields to wells located in the basalt. They consist of rubble zones above and below the solid rock body and of gravel deposited by streams on the lava flows which are subsequently covered with younger lava. The interflow zones generally run parallel to the basalt surface, and the joints generally run perpendicular to the flow trend. Where the basalt rests on low permeability formations, such as the Latah Formation, ground water yields are most likely produced from the fracture systems (Cline 1969).

Ground water yields in the basalt range from negligible amounts to sufficient quantities to supply domestic and stock needs. One well operated by the city of Deer Park (DP-5) yields up to 350 gpm (CH2M Hill 1986) from basalt deposits. The ground water is generally under artesian pressure, and some driller's logs report free-flowing wells at the surface in the Deer Park Basin.

In the southern half of the study area, most of the wells tap the basalt for domestic use.

The basalt flows are potentially recharged from direct infiltration of precipitation, stream discharge, and from overlying and underlying hydrostratigraphic units. The potential for ground water recharge from direct infiltration of precipitation and runoff is probably minor, due to the limited surface area of outcropping basalt in the study area and the potential for water to infiltrate through the relatively impermeable fractures and joints. Recharge from underlying hydrostatigraphic units is not documented, but is probable.

Latah Formation. This hydrostratigraphic unit is composed chiefly of clay and silt, with some sand and conglomerates. The clays and silts can act as aquitards. Due to the fine grained sediments and the flowing nature of the sands and conglomerates, the formation is generally not tapped for production. Wells which do extract ground water from the formation typically are screened and have yields of less than 35 gpm (Cline 1969).

Pre-Tertiary Basement Complex. The metamorphic and plutonic rocks of Pre-Tertiary age underlie the other formations in the study area and contribute ground water to many of the deep wells. Ground water in crystalline rocks generally is found in fractures and weathered zones near the surface of the formation. Yields to wells generally range from negligible to 35 gpm (Cline 1969).

Recharge of the hydrostratigraphic unit is from direct infiltration of precipitation and stream discharges, and from overlying units. The unit is exposed and forms many of the mountains surrounding the basin. These mountainous areas receive infiltration from precipitation and stream runoff. The bedrock complex underlying the basin, probably receives most of its recharge from overlying hydrostratigraphic units

4.4 Ground Water Rights

There are approximately 146 permitted ground water rights and 326 claims in the study area. The rights permit and prioritize the extraction of ground water for domestic, commercial, industrial, irrigation, stock, municipal, fire protection, fish propagation, or heat exchange uses. The water rights records do not provide information on the depths of wells or the geologic unit from which ground water would be extracted. The distribution of water right claims by section in the DPSA are shown on Figure 4-3. Approximately 31,000 ac-ft (over 1 billion gallons) of ground water are currently permitted to be withdrawn in the DPSA. Almost 75% of this

Time unit?

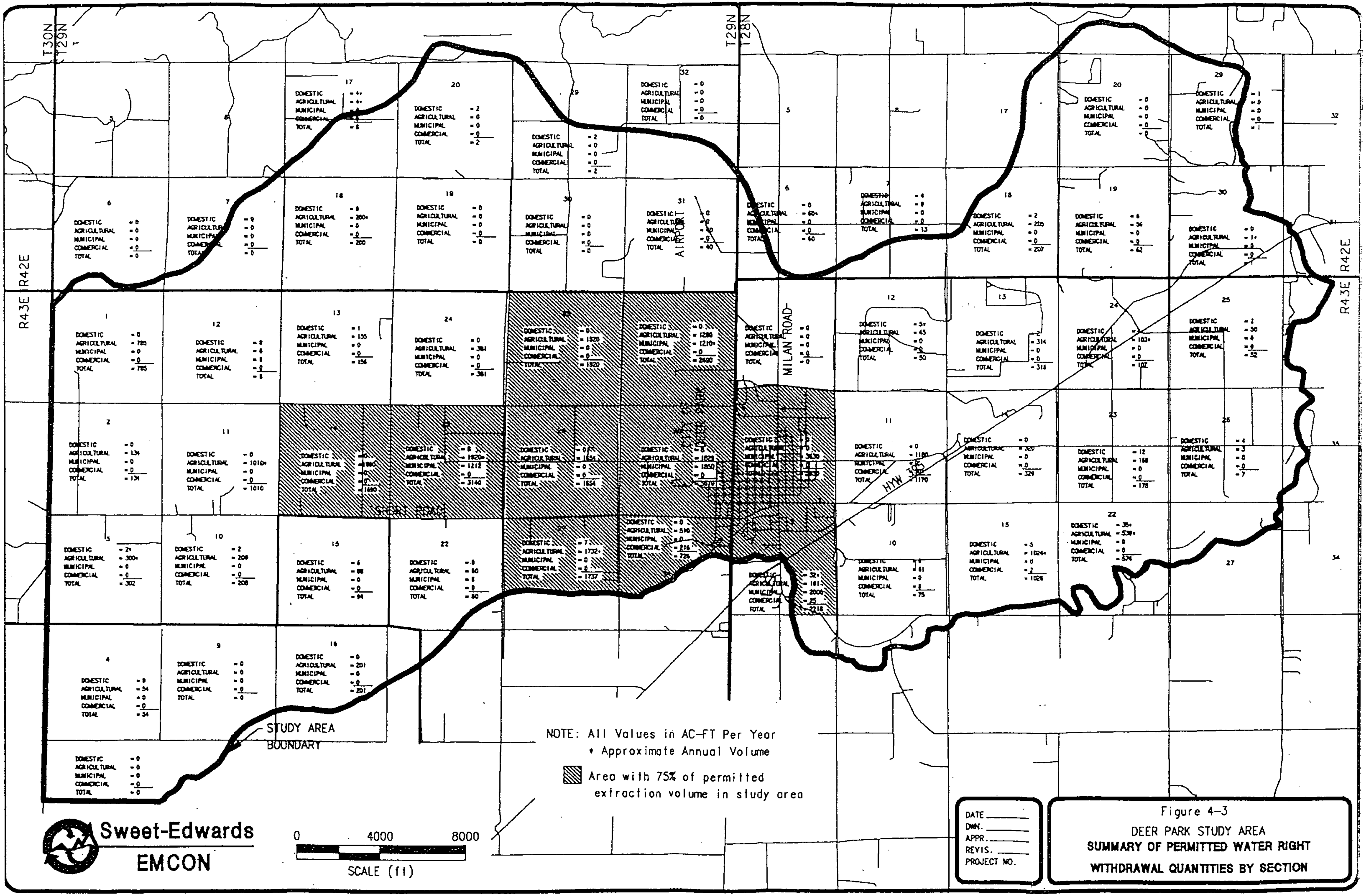

Figure 4-3
DEER PARK STUDY AREA
SUMMARY OF PERMITTED WATER RIGHT WITHDRAWAL QUANTITIES BY SECTION

potential extraction volume is from permitted rights concentrated in an eleven square mile area in and around the city of Deer Park (Figure 4-3).

The instantaneous extraction rates range from 5 to 2,000 gpm; annual extraction rates range from 1 to 1,280 acre-feet (326,000 to 417.28 million gallons). A summary of the approximate annual volumes permitted for the various uses is presented in Table 4-2. A copy of all water rights and claims currently on file with Ecology are presented in Appendix C.

Table 4-2
Summary of Water Rights and Claims

Summary of Established Water Rights					Water Uses[3]															
					Domestic[4]				Agricultural[5]				Municipal[6]				Commercial[7]			
Location[1]			#Claims[2]	#Permits[3]	#Uses	Annual Volume (AC-FT)	Source[8]		#Uses	Annual Volume (AC-FT)	Source[8]		#Uses	Annual Volume (AC-FT)	Source[8]		#Uses	Annual Volume (AC-FT)	Source[8]	
T	R	S					W	S			W	S			W	S			W	S
28N	42E	1	3	0																
28N	42E	2	3	3									3	3630	3+					
28N	42E	3	18	9	3	32*	4	1	5	161	4	1	3	2000	3+		1	25	1	
28N	42E	10	15	4	3	6	3		7	61.7	3						1	7.8		1
28N	42E	11	2	3					2	1160.61	2						1	10*	1	
28N	42E	12	3	3	3	5*	3		4	45.7	3									
28N	42E	13	1	12	1	2		1	3	314		1								
28N	42E	14	12	1					1	320		1								
28N	42E	15	11	6	3	5	1	2	5	1024*	3	2					1	2		
28N	42E	22	6	7	5	35.2*	5		9	539*	5	2								
28N	42E	23	18	8	6	12	6		9	166	6	1								
28N	42E	24	21	3	2	4*	2		3	103*	1	1								
28N	42E	25	9	1	1	2	1		2	50	1									
28N	42E	26	10	2	2	4	2		3	59	2									
29N	42E	1	5	1					1	785	1									
29N	42E	2	4	1					1	134	1+									
29N	42E	3	6	3	1	2*	1		4	300*	1	2								
29N	42E	4	7	1					1	54	1									
29N	42E	5	2	0																
29N	42E	9	8	0																
29N	42E	10	9	4	1	2	1		5	206	*4									
29N	42E	11	4	5					5	1010*	4	1								
29N	42E	12	1	0																
29N	42E	13	3	2	1	1	1		2	155	2									
29N	42E	14	5	5					6	1690	4	1								
29N	42E	15	8	3	3	6	3		4	88	3									
29N	42E	16	8	2					3	201	1	1								
29N	42E	22	7	1					1	60		1								
29N	42E	23	9	13	5	8	5		13	1920*	11	1	1	1210	1					
29N	42E	24	5	1					2	381	1									

Table 4-2
Summary of Water Rights and Claims
(continued)

Summary of Established Water Rights					Water Uses[3]															
					Domestic[4]				Agricultural[5]				Municipal[6]				Commercial[7]			
Location[1]			#Claims[2]	#Permits[3]	#Uses	Annual Volume (AC-FT)	Source[8]		#Uses	Annual Volume (AC-FT)	Source[8]		#Uses	Annual Volume (AC-FT)	Source[8]		#Uses	Annual Volume (AC-FT)	Source[8]	
T	R	S					W	S			W	S			W	S			W	S
29N	42E	25	2	2					2	1920	2									
29N	42E	26	2	3					3	1654	3									
29N	42E	27	2	4	2	7	2		6	1732*	3	1								
29N	42E	34	23	3					2	510.3	2						2	216	1	
29N	42E	35	13	13	5	8	5		14	1829.44	11		2	1850	2					
29N	42E	36	0	2					1	1280	1		1	1210*	1					
28N	43E	6	13	3					3	60*	3									
28N	43E	7	10	2	2	4	1	1	3	9	1	1								
28N	43E	18	3	2	1	2	1		3	205	1	1								
28N	43E	19	4	3	3	6	3		4	56	3									
28N	43E	20	5	0																
28N	43E	29	6	1	1	1		1												
29N	43E	6	1	0																
29N	43E	7	4	0																
29N	43E	17	0	2	2	4*		2	2	4*		1								
29N	43E	18	5	1					1	200*	1									
29N	43E	19	0	0																
29N	43E	20	1	0																
29N	43E	29	1	1	1	2	1													
29N	43E	30	0	0																
29N	43E	31	1	1									1	40	1					
29N	43E	32	0	0																

NOTE: * Approximate Annual Volume.

1 Locations based on township, range, and section.
2 Claims taken from Department of Ecology "Water Right Claims Register" dated 7/6/89.
3 Permits and water uses data taken from Department of Ecology "Recorded Water Rights," dated 1/15/91.
4 Domestic uses include single and multiple residential uses.
5 Agricultural uses include irrigation, stock water, and fish propagation.
6 Municipal uses include residential uses provided by wells owned by city of Deer Park.
7 Commercial uses include railway, miscellaneous commercial/industrial, heat exchange, fire protection, and power.
8 Source indicates whether water is obtained by well (W) or surface streams or springs (S) and total number of sources for each specific use.

5 GROUND WATER QUALITY

Ground water quality conditions in the DPSA have been studied periodically since the 1960s. Van Renbaush (1965) and Cline (1969) did limited sampling of ground water from the DPSA as part of regional water quality assessment studies. Extensive ground water sampling and testing was performed in the DPSA in the mid 1980s because of concern over nitrate contamination. Randall Anderson (Eastern Washington University thesis, 1986) in cooperation with the Spokane County Health District sampled up to 92 domestic and public water wells in the DPSA in April, June, August, September, October, and December, of 1986. The city of Deer Park's comprehensive water system plan (CH2M Hill, 1986) included an evaluation of the occurrence of nitrate and a number of other inorganic constituents in the DPSA ground water system. Nitrate impacts from activities at a poultry farm east of Deer Park were investigated in the late 1980s. The results of this investigation are part of a court settlement case and not available for review. Copies of historical DPSA water quality data reviewed for this report are included in Appendix D.

With the exception of elevated nitrates, overall ground water quality is good for the study area. Ground water quality can be impacted by both natural and man-made constituents (e.g. iron, nitrate, chloride etc.). The level of natural constituents can be impacted by both surface and subsurface conditions. Factors playing an important role in determining the concentration of natural constituents in ground water include:

- Aquifer permeability
- Amount of precipitation
- Concentration of leachable natural constituents in the soil or rock medium
- Age of ground water

Natural constituents are widespread, but they severely impact the water quality only in selected areas. The natural constituent levels are not expected to change significantly over time or with differing land uses.

Man-made constituents are generally restricted to areas of urban, industrial, agricultural, and transportation corridor land uses. Constituent levels and water quality may change with differing land use practices.

Natural and man-made constituents in ground water can affect both the aesthetic and health-related aspects of ground water (Primary and Secondary Drinking Water Standards, Washington State Water Quality Criteria, 1990). Secondary water quality standards regulate the allowable concentration of constituents affecting the aesthetic quality of water. For instance, iron is a secondary standard because it can affect the taste of water and also stain porcelain fixtures. Manganese tends to precipitate in pipes, reducing the ability to transmit water; this is a non-health related property, but still is undesirable. Primary drinking water standards refer to constituents that can impact human health. The most significant naturally occurring contaminant which can potentially impact human health in the DPSA is nitrate. Nitrate from agricultural activities and disposal of sewage (septic tanks) is a widespread chemical in the study area and can impact human health. A complete list of the primary and secondary water quality standards for ground water in Washington State is included in Appendix E.

The Basalt and Latah Formation deposits commonly have naturally elevated concentrations of iron and manganese because of lower pH and dissolved oxygen levels. In the study area, the location of naturally occurring constituents in ground water can be localized or widespread. For instance, organic material from existing or buried swamps or bogs will contain abundant peat. This may result in high levels of sulfur, iron, and manganese in ground water. These compounds are introduced into the ground water by weak organic acids which dissolve minerals in soils and rock.

Nitrates, sulfur, coliform bacteria, and man-made chemicals may be found in shallow ground water such as in the glaciofluvial deposits or where fractured basalt is present. The potential vulnerability of the study area's ground water resources to land use activities can be illustrated with a brief discussion of nitrate contamination in the study area.

5.1 Nitrate

Nitrate is an oxidized form of the element nitrogen. Nitrogen makes up about four-fifths or 80 percent of the gases in the earth's atmosphere and is an essential nutrient for the growth of all plants. Atmospheric nitrogen generally cannot be assimilated by plants; thus conversion to other forms must occur to support plant growth. In an environment where oxygen is abundant, conversion of nitrogen to nitrate is carried out by a variety of microorganisms in soil and water.

Nitrate is also formed by the complete oxidation of ammonium ions by soil or water microorganisms. Ammonia is abundant in most fertilizers, septic tank effluent, animal (e.g., livestock) wastes, and decomposing plant and soil organic matter.

Nitrate is highly soluble in water and can be carried into the soil by rainwater, irrigation water, surface runoff, and septic tank effluent. Up to a limit, growing plants can assimilate nitrate that enters the soil. If, however, the rate of nitrate application exceeds the uptake rate of plants, or if it is introduced to the soil below the plant root zone, excess nitrate will be present. The ability of a soil to remove or somehow absorb excess nitrate generally is quite limited. Because of its non-reactive nature, excess nitrate can be carried to ground water with water percolating through the soil column. Because of its high solubility, its resistance to removal in the soil, and almost universal presence, nitrate is a common contaminant of ground water. A U.S. Environmental Protection Agency 1987 survey indicated nearly 500 public water systems nationwide exceeded federal drinking water standard of 10 mg/l for nitrate (AWWA, 1987).

Nitrate is a natural component of many vegetables such as spinach, rhubarb, beets, cauliflower, and cabbage. Nitrate is also widely used as an additive in sausages, ham, bacon, hot dogs, and other cured or corned meats. While nitrates often are consumed by adults and children in food and food products, the presence of nitrate in drinking water can create a unique problem.

The maximum contaminant level for nitrate in drinking water is 10 mg/l. The maximum contaminant level was established to prevent any significant risk of a disorder known as methemoglobinemia (infant cyanosis). Methemoglobinemia can occur in infants under 5 months of age who have been given water or fed formula prepared with water having high concentrations of nitrates. Telltale symptoms include intestinal discomfort and cyanosis, a bluish or lavender tint to the skin caused by discolored blood.

Because an infant's gastric juices are less acidic than those of older children and adults, nitrate can be transformed to a closely related compound, nitrite, in the gastrointestinal tract. If nitrite is absorbed in an infant's bloodstream, it, like oxygen, reacts directly with hemoglobin. Because nitrite competes with oxygen for hemoglobin sites, it impairs the blood's ability to transport oxygen. While this can be a life-threatening disorder, however, methemoglobinemia is generally associated with drinking water nitrate levels far in excess of 10 mg/l.

5.1.1 Shallow Ground Water Quality

An evaluation of long-term trends in nitrate concentrations in the shallow ground water system of the DPSA shows some significant increases in nitrite levels between 1975 and 1988. Table 5-1 summarizes the nitrate levels for four city of Deer Park wells. Nitrate concentrations appear to have increased from less than 2.0 mg/l in 1975 to more than 8.0 mg/l by 1985. In the one well (DP-4), with data through July of 1989, the concentration of nitrate has remained near 8.0 mg/l. Results of a study by Anderson (1986), demonstrated that elevated nitrate levels (>5 mg/l) occur in some shallow wells within the city of Deer Park and to the west and east. Figure 5-1 shows the approximate location of wells having reported nitrate concentrations greater than 5 mg/l. The highest concentration of wells with elevated nitrate levels occur to the east of Deer Park in Township 28 N, Range 42E, Section 12 and Township 28N, Range 43E, Sections 6 and 7. Three wells in Section 12 have historical nitrate concentrations ranging from 158 to 250 mg/l. The source of excessively high nitrates in this area is probably from past manure disposal practices.

5.1.2 Deep Ground Water Quality

Although long-term trends in nitrate concentrations have not been established for wells completed in the deep aquifer, sampling data may indicate the level is increasing. Figure 5-1 shows areas southeast and southwest of Deer Park where a number of wells completed in the deep aquifer have nitrate concentrations up to 19 mg/l. As with shallow wells, seasonal fluctuations in nitrate concentrations of one order of magnitude (ten times) have been observed (see Appendix D).

Nitrate contamination in the deep aquifer probably is due to factors such as specific tanks and agricultural practices. The transmission of contaminated water from the shallow aquifer along the annular of poorly sealed wells could also be a contributing factor.

Table 5-1

Nitrate Concentrations in Shallow Aquifer City Wells

Date	DP-1	DP-2	DP-3	DP-4
May 1975	1.5	1.2		1.8
March 1981	5.4	3.8	4.0	4.2
April 1982			8.9	
December 1983			6.0	
January 1984			5.2	
May 1984			10.3	
October 1984		4.8	10.5	
January 1985	8.0	5.8	9.8	7.5
April 1985	8.3	6.5	9.6	8.0
July 1985	7.5	7.3	12.8	7.2
October 1985		10.5	10.2	8.8
January 1986			7.9	
April 1986			7.8	
July 1986			10.5	
October 1986			7.2	
January 1987			7.4	
March 1987			5.9	
June 1987			10.2	
January 1988			8.9	
May 1988			7.8	
July 1988			8.0	
October 1988			7.6	
July 1989			8.3	

NOTES: All concentrations are in mg/l.
Dates with no entry indicate no data available for that well.

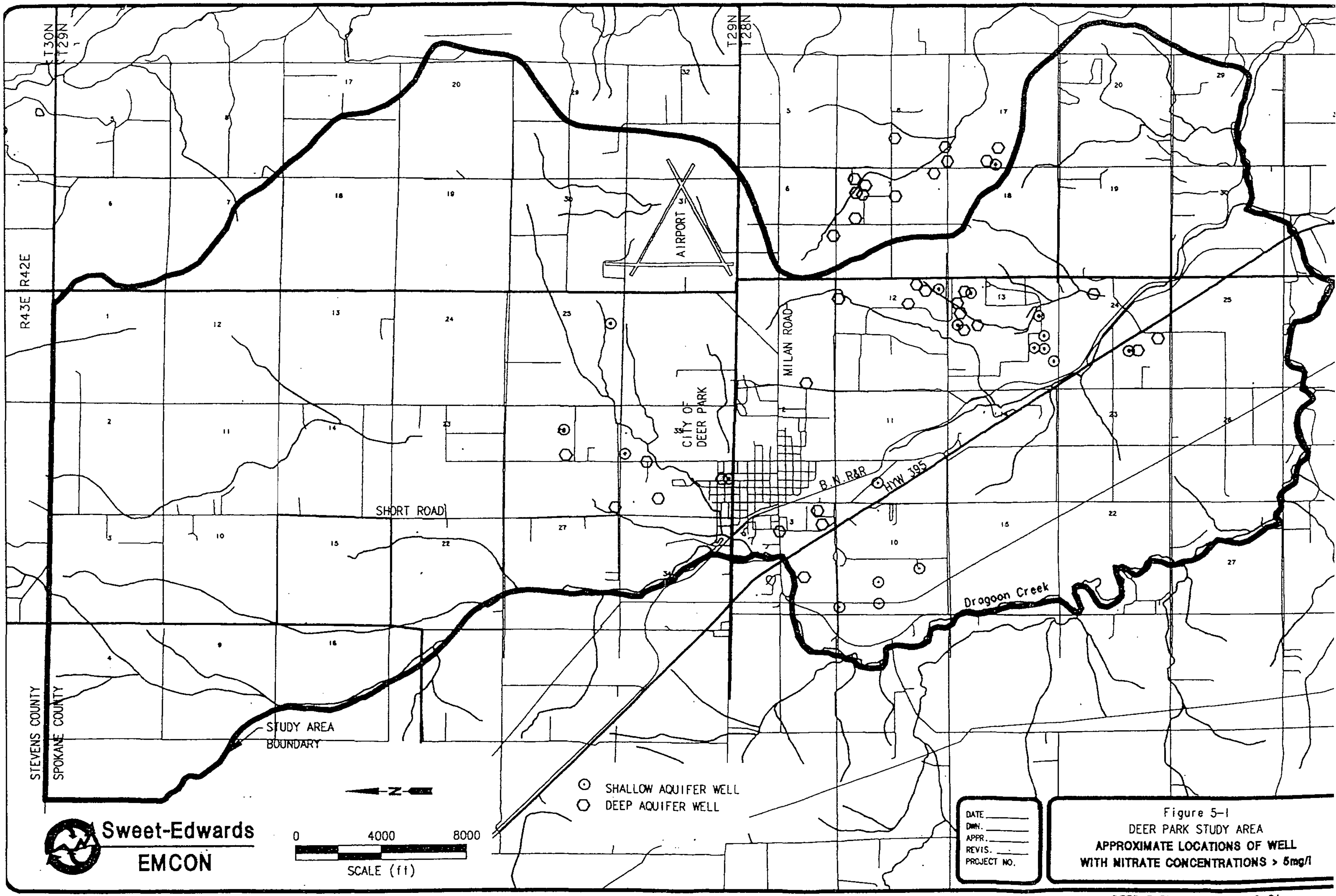

Figure 5-1
DEER PARK STUDY AREA
APPROXIMATE LOCATIONS OF WELL WITH NITRATE CONCENTRATIONS > 5mg/l

6 GLOSSARY OF COMMON HYDROGEOLOGIC AND WATER-RESOURCE RELATED TERMS AND ACRONYMS

Alluvium	Sediment such as clay, silt, sand, gravel, or other similar material deposited by running water.
Ammonia	A gas composed of NH_3 commonly used as fertilizers.
Aquifer	A body of rock or sediment able to store and conduct significant quantities of ground water.
Aquitard	A layer of rock or sediment that retards the flow of ground water to or from an adjacent layer of rock or sediment.
Argillite	An indurated claystone.
Artesian	Refers to ground water under sufficient hydrostatic head to rise above the aquifer containing it.
Basalt	Generally, any fine-grained, dark-colored, extrusive igneous rock.
Bedrock	A term for the solid rock that underlies soil or uncompacted sediments.
Braided Stream	A stream that divides into an interlacing network of channels and typically found in areas of heavy erosion.
Chloride	A compound of chlorine with one other positive element or radical.
Clastic	Rock fragments which have been moved from their place of origin.
Coliform Bacteria	Bacteria (*E. coli*) associated with human waste.

Colluvium	Loose clastic material usually found at the base of a hill or cliff.
Confined	A condition of an aquifer bounded above and below by lower permeability rock or sediment layers.
Contaminant	A naturally occurring or man-made compound that is undesirable or injurious and found in ground water.
Cross-bedding	Inclined laminations, deposited by currents.
Cross-section	A schematic representation of geologic layers as seen in a side view.
Cyanosis	A bluish coloration of the skin caused by lack of oxygen in the blood.
Discharge	Ground water that flows out of an aquifer into an adjacent aquifer or to the surface into a spring or river.
DOH	Washington Department of Health.
DPB	Deer Park Basin.
DPSA	Deer Park study area.
Drinking Water Standards	Federal or state water quality regulations that limit the contaminant levels of certain compounds for drinking water.
Ecology	Washington Department of Ecology.
Eolian	Sediments transported by wind action.
Erosion	The physical and chemical processes that remove and transport natural materials at the surface.
Fluvial	Deposits produced by river action.
Fossil	The remains or traces of animals or plants which have been preserved by natural processes.
Gastrointestinal	Of the stomach and intestines.

Geology	The study of earth materials, processes, and history.
Glaciofluvial	Deposits created from streams or floods flowing from glaciers.
Glaciolacustrine	Deposits created in lake environments from glacial silts and clays.
gmp	Gallons per minute.
GMA	Ground Water Management Act.
Granodiorite	Plutonic igneous rock containing at least twice as much Plagioclase Feldspar as Potassium Feldspar.
Ground Water	All water that is located below the surface; more specifically, subsurface water below the water table.
GWMMA	Ground Water Management Area.
GWMP	Ground Water Management Program.
Hazardous Waste	Federally regulated man-made waste that is ignitable, corrosive, reactive, or toxic.
Hydraulic Conductivity	The rate of flow of water through an area of permeable material at a constant pressure.
Hydraulic Connection	The condition in which two water-bearing layers or bodies may freely transmit water between them.
Hydrogeologic	Pertaining to subsurface water and water-bearing rock or sediment layers.
Hydrostratigraphy	The assemblage of layers of aquifers and aquitards.
Igneous	A type of rock solidified from molten material.
Impermeable	An adjective used to describe rock, soils, or sediments that impede the flow of water.
Infiltration	The downward movement of rain water or surface water into soil.

Interflow Zone	The zone between two basalt flows where, weathering, fracturing, and deposition of sediments create a permeable zone in an otherwise primarily impermeable environment.
Lacustrine	Lake environment.
Laminated	The layering or thin bedding in sedimentary rocks.
Leucocratic	A term applied to light-colored rocks.
Mesa	An elevated table land.
Mesozoic	A broad period of earth's history estimated to be 225 to 65 million years ago.
Metamorphic	A rock that has been physically and/or chemically changed from an original texture and/or composition, usually by very high temperatures or pressures below the earth's surface.
mg/l	Milligrams per liter; a unit of concentration in water equivalent to a part per million or 0.0001 percent.
mgd	Million gallons per day.
Microorganisms	Microscopic organisms such as any of the bacteria, protozoans, or viruses.
Nitrate	A compound commonly associated with domestic and agricultural waste.
Peat	A non-compacted deposit of organic material commonly developed from bogs or swamps.
Permeable	The condition under which water may be transmitted through rock or sediment.
Pleistocene	A period of earth's history estimated to be 2 million to 10,000 years ago.
Plutonic	A body of igneous rock which formed beneath the surface of the earth.

Pofentiometric Surface	The surface to which water will rise in an aquifer under hydrostatic pressure.
ppm	Part per million. A unit of concentration equivalent to 0.0001 percent.
Quartz Monzonite	A coarse-grained igneous rock with a high percentage of feldspar and quartz.
Quartzite	A granulose metamorphic rock consisting essentially of quartz.
Recent	Less than 10,000 years ago in earth's history.
Recharge	The process of absorption and addition of water to a layer of soil, rock, or sediment.
SDWA	Safe Drinking Water Act.
Sedimentary	A rock type formed from fragments of weathered natural material.
Siltite	An indurated siltstone.
Storage Coefficient	The volume of water released from storage per unit volume of porous medium per unit change in head.
Subterranean	Being beneath the surface of the earth.
Stratigraphic	Pertaining to the composition and position of layers of rock or sediment.
Tertiary	A period of earth's history estimated to have occurred between 2 and 65 million years ago.
Till	A complex non-layered mixture of clay, silt, sand, and gravel deposited directly by and underneath an active glacier.
Topographic	Pertaining to the general configuration of a land surface.

Transmissivity	The rate at which ground water flows through a certain thickness of aquifer under a certain pressure.
Unconfined	Ground water in an aquifer that is not covered by an impermeable layer.
Water Table	The subsurface level between the zone of saturation (ground water) and the zone of aeration.
Weathering	The destructive process(es) by which the atmosphere and surface water chemically change the character of a rock.

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