APPENDIX D

GROUNDWATER INFORMATION

Table of Contents

APPENDIX D1

EXPLANATION OF AQUIFER PROPERTIES

D1-1. DESCRIPTION OF AQUIFER PROPERTIES

The following text provides a brief explanation of each of the aquifer properties compiled on Table 5.6 of the Level 1, Phase II Assessment Report for WRIAs 55 and 57. The information within this Appendix supports information presented within Section 5.2.5 of the Level 1, Phase II Assessment Report for WRIAs 55 and 57.

- **Pump Rate or Well Yield** is a measure of how much water the wells completed within an aquifer produce and is expressed as a flow per unit of time (gallons per minute or gpm). Higher sustained well yields indicate an aquifer of higher productivity and vice versa.
- **Specific Capacity** is a measure of the performance of a well and is expressed as a flow rate per unit drawdown (gpm/ft). Specific capacity is a time dependant parameter until steady-state conditions are reached. It is also referred to as specific drawdown, expressed as a drawdown per unit flow rate (ft/gpm).
- **Transmissivity (T)** is a measure of the transmitting capacity of the aquifer and is expressed in units of L^2/T (ft^2/day for example). It is also often expressed as a volume capacity (gallons per day) per unit thickness of aquifer (ft). Transmissivity for an aquifer can be estimated from the specific capacity using the following empirical formula (Driscoll, 1986):

$$T = \frac{Q * x}{s}$$

Where,

T	=	transmissivity of the well (gallons per day / foot)
Q	=	yield of the well (gallons per minute)
s	=	drawdown in the well (feet)
x	=	1,500 for an unconfined aquifer and 2,000 for a confined aquifer

- **Hydraulic Conductivity (K)** is a vector quantity that describes the flow of groundwater through an aquifer. It has units of L/T (ft/day for example). As a vector, it has both a vertical and horizontal component. Hydraulic conductivity is used to determine the rate of groundwater movement. Vertical hydraulic (Kv) conductivity is not easily determined from well data. However, horizontal hydraulic conductivity (Kh) can be estimated using well test data by the following relationship:

$$Kh = \frac{T}{b}$$

Where,

T	=	transmissivity of the well (feet squared / day)
b	=	screened interval (feet)
Kh	=	horizontal hydraulic conductivity (feet / day)

Vertical anisotropy is the ratio of the horizontal hydraulic conductivity to the vertical hydraulic conductivity.

- For a confined aquifer, the storage term is referred to as the Specific Storage (Ss) and is defined as the volume of water that a unit volume of aquifer releases from storage under a unit decline in hydraulic head (Freeze and Cherry, 1979). Storativity for a confined aquifer is defined as:

$$S = S_s b$$

Where,

S	=	storativity or storage coefficient (dimensionless)
S_s	=	specific storage (1/feet)
b	=	aquifer thickness (feet)

The usual range for S_s is 0.005-0.00005.

- For an unconfined aquifer, the storage term is referred to as the **Specific Yield (S_y)** and is defined as the volume of water that an unconfined aquifer releases from storage per unit area of aquifer per unit decline in the water table (Freeze and Cherry, 1979). The storage coefficient for an unconfined aquifer is defined as:

$$S = S_s b$$

Where,

S	=	storage coefficient (dimensionless)
S_s	=	specific yield (1/feet)
b	=	saturated thickness of the aquifer

The usual range for S_y is 0.01-0.3.

Note that the higher values for specific yield versus specific storage reflect the fact that the releases from storage in unconfined aquifers represent an actual dewatering of the soil pores, whereas releases from storage in confined aquifers represent only the secondary effects of water expansion and aquifer compaction caused by changes in fluid pressure.

- **Porosity (n)** describes the ratio of the volume of voids to the total volume of the aquifer / aquitard material and is defined as:

$$n = \frac{V_v}{V}$$

Where,

n	=	porosity (decimal or % if multiplied by 100)
V_v	=	volume of voids (cubic feet)
V	=	total volume of aquifer / aquitard material (cubic feet)

The effective porosity is the porosity through which flow can occur. An understanding of porosity is required to estimate the volumes of water flowing through an aquifer or aquitard.

- **Linear Velocity (v)** describes the average horizontal velocity of groundwater flow through and aquifer or aquitard. Linear velocity has units and is defined as:

$$v = \frac{-Kh \times dh}{n \times dl}$$

Where,

Kh	=	horizontal hydraulic conductivity (feet / day)
n	=	porosity (decimal)
$\frac{dh}{dl}$	=	hydraulic gradient (dimensionless)

Where,

dh	=	change in hydraulic head (feet)
dl	=	horizontal distance (feet)

APPENDIX D2

GROUNDWATER SNAPSHOT AND HYDROGRAPH INFORMATION

APPENDIX D2 - GROUNDWATER SNAPSHOT INFORMATION

Table of Contents

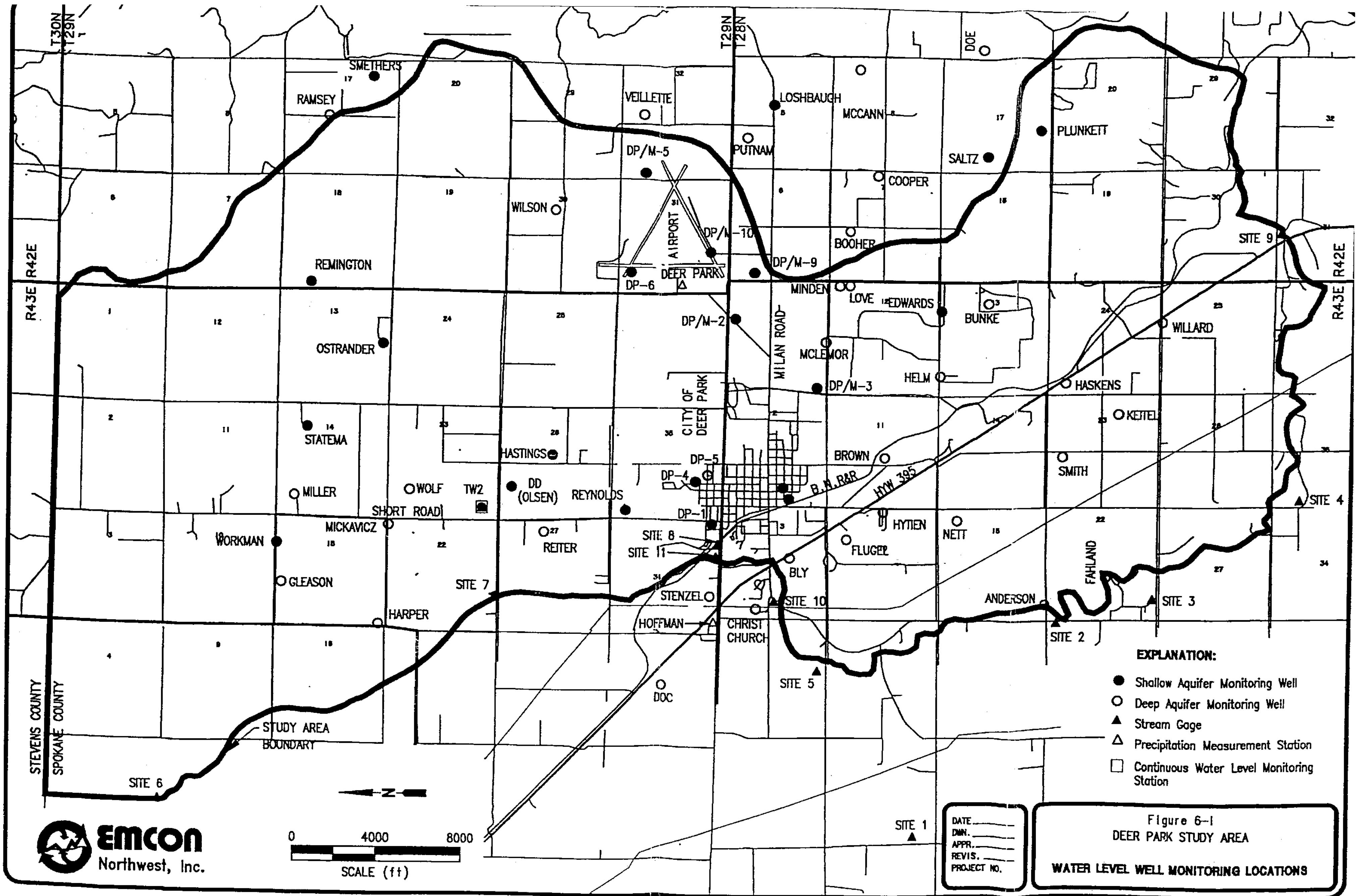


Figure 6-1
DEER PARK STUDY AREA

WATER LEVEL WELL MONITORING LOCATIONS

DEER PARK X2201C19 6-29-92

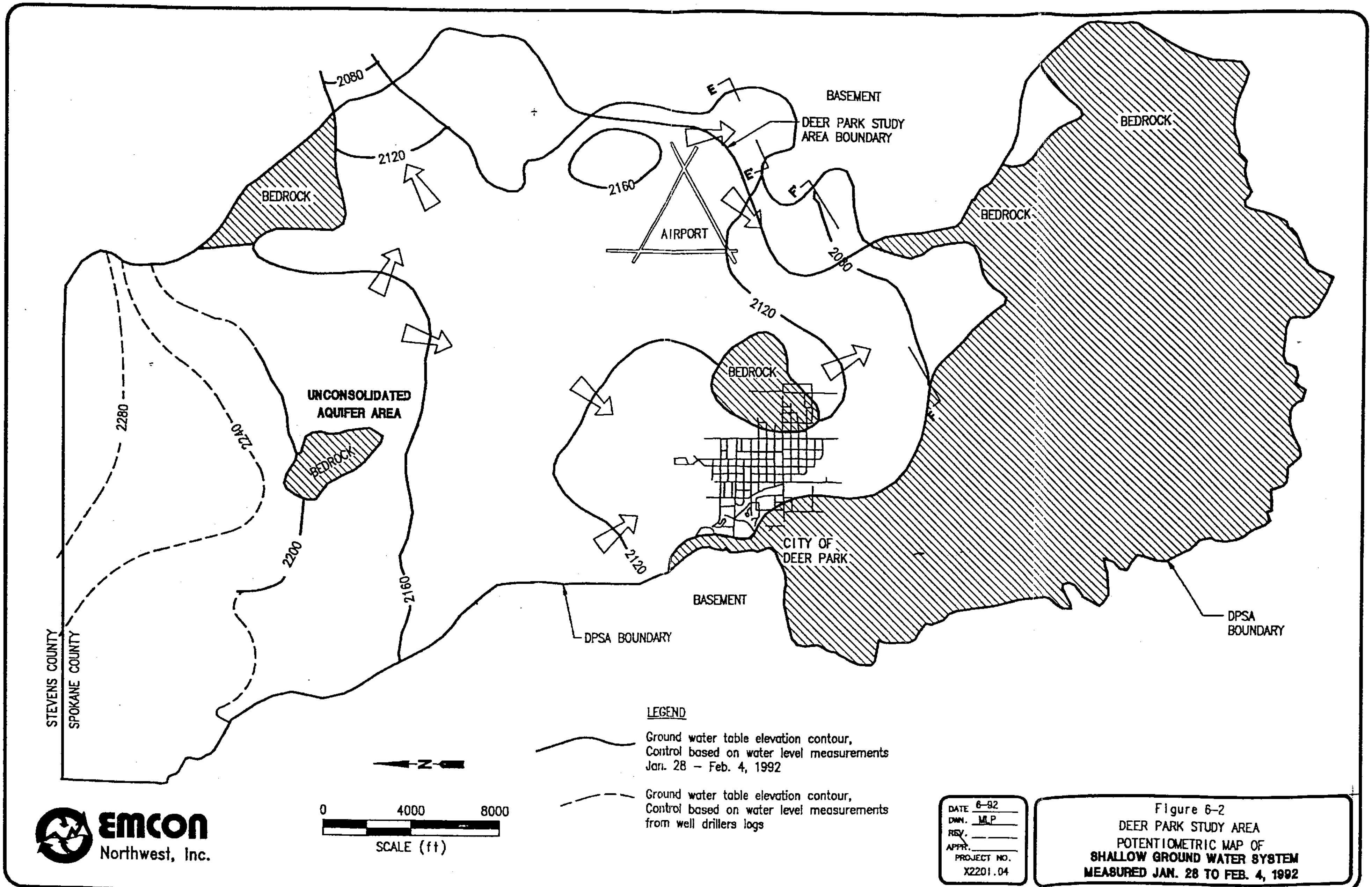


Figure 6-2
DEER PARK STUDY AREA
POTENTIOMETRIC MAP OF
SHALLOW GROUND WATER SYSTEM
MEASURED JAN. 28 TO FEB. 4, 1992

DEERPARK X2201C16 6-29-92

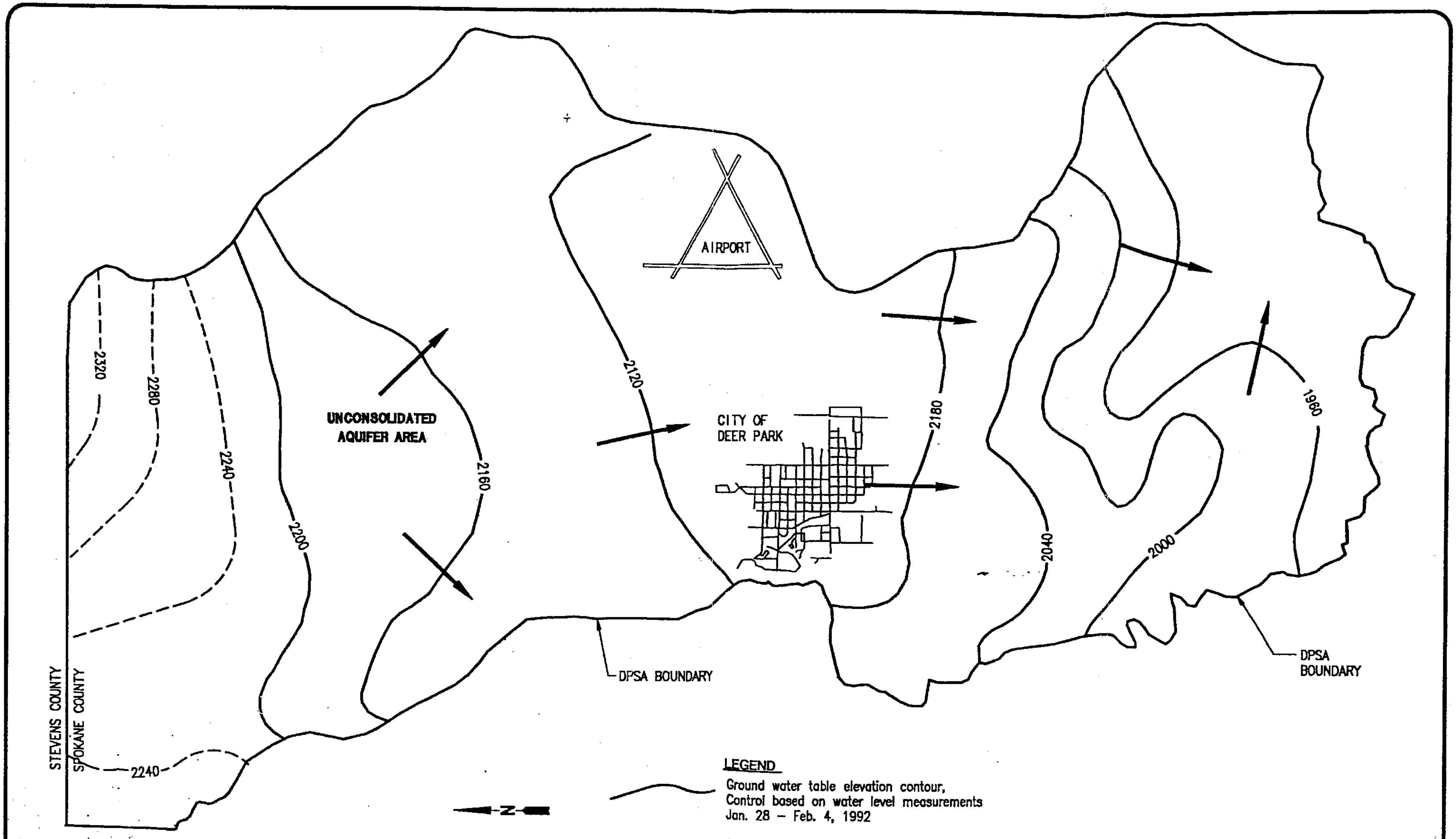


Figure 6-3
DEER PARK STUDY AREA
POTENTIOMETRIC MAP OF
DEEP GROUND WATER SYSTEM
MEASURED JAN. 28 TO FEB. 4, 1992

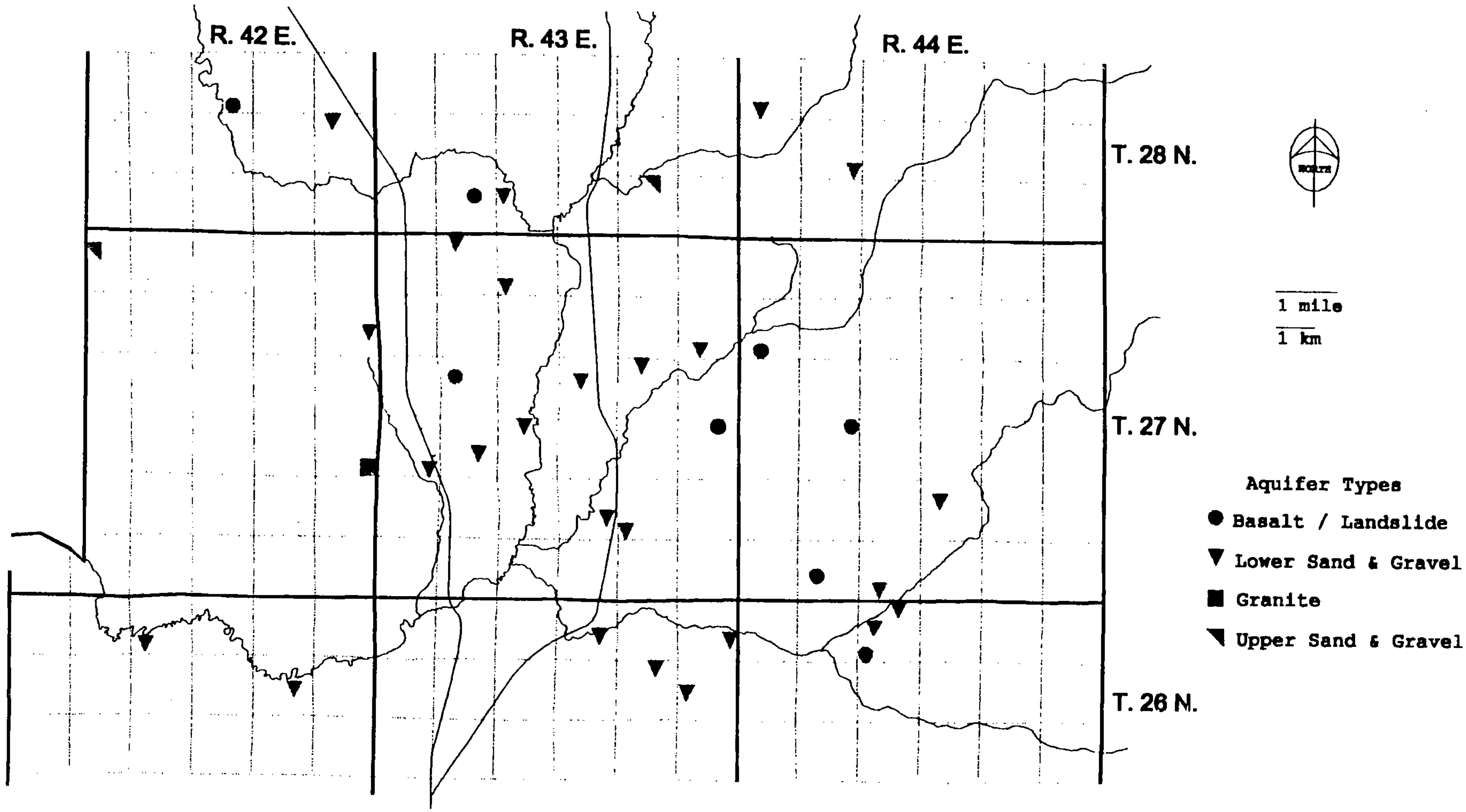
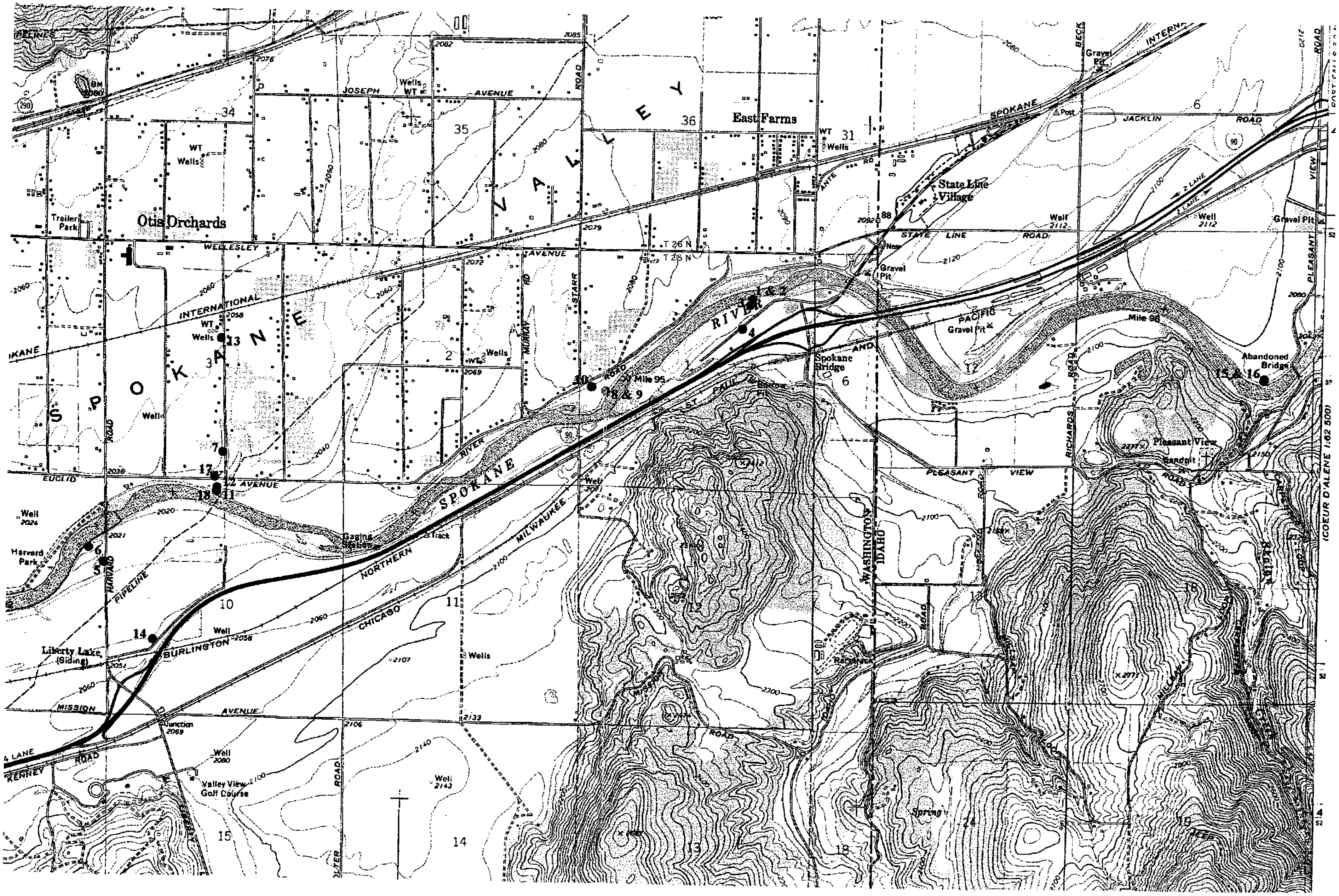
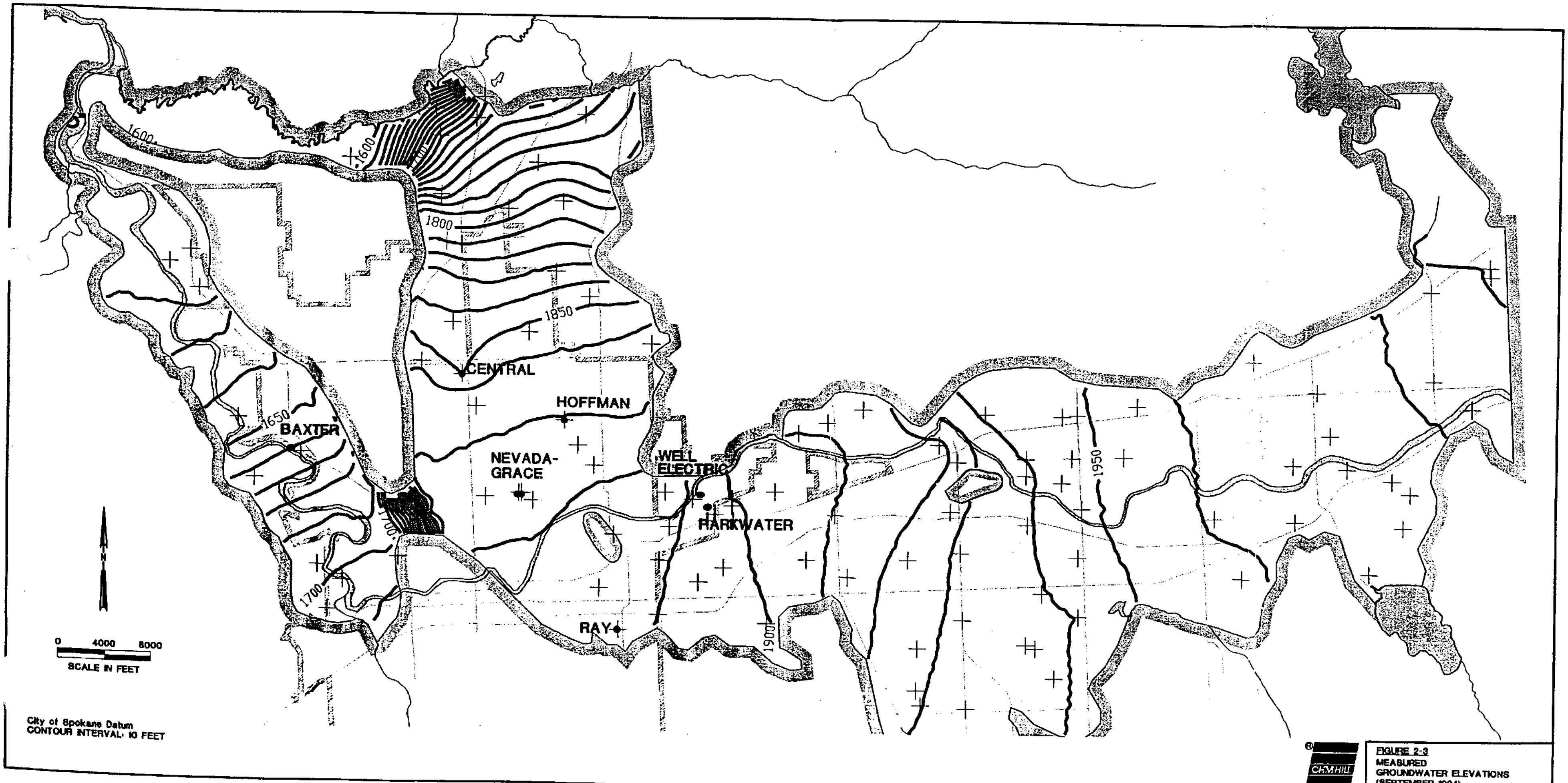


Figure 25. Location map of wells sounded for the depth to the water table in the study area, April - June, 1996.



SPOKANE VALLEY
Otis Orchards
East Farms
State Line Village
Trailer Park
Harvard Park
Liberty Lake (Siding)
Valley View Golf Course
Spokane Bridge
Abandoned Bridge
Pleasant View Sandpit
Gaging Station
Mile 95
Mile 98
SPOKANE RIVER
WASHINGTON
IDAHO
WELLESLEY AVENUE
JOSEPH AVENUE
EUCLID AVENUE
MISSION AVENUE
KENNEY ROAD
HARVARD ROAD
STARR ROAD
STATE LINE ROAD
JACKLIN ROAD
PLEASANT VIEW ROAD
RICHARDS ROAD
BURLINGTON NORTHERN
CHICAGO MILWAUKEE ST PAUL AND PACIFIC
INTERNATIONAL
PIPELINE
Gravel Pit
1 & 2
4
5
6
7
8 & 9
10
11
12
13
14
15 & 16
17
18
(COEUR D'ALENE 1:62 500)

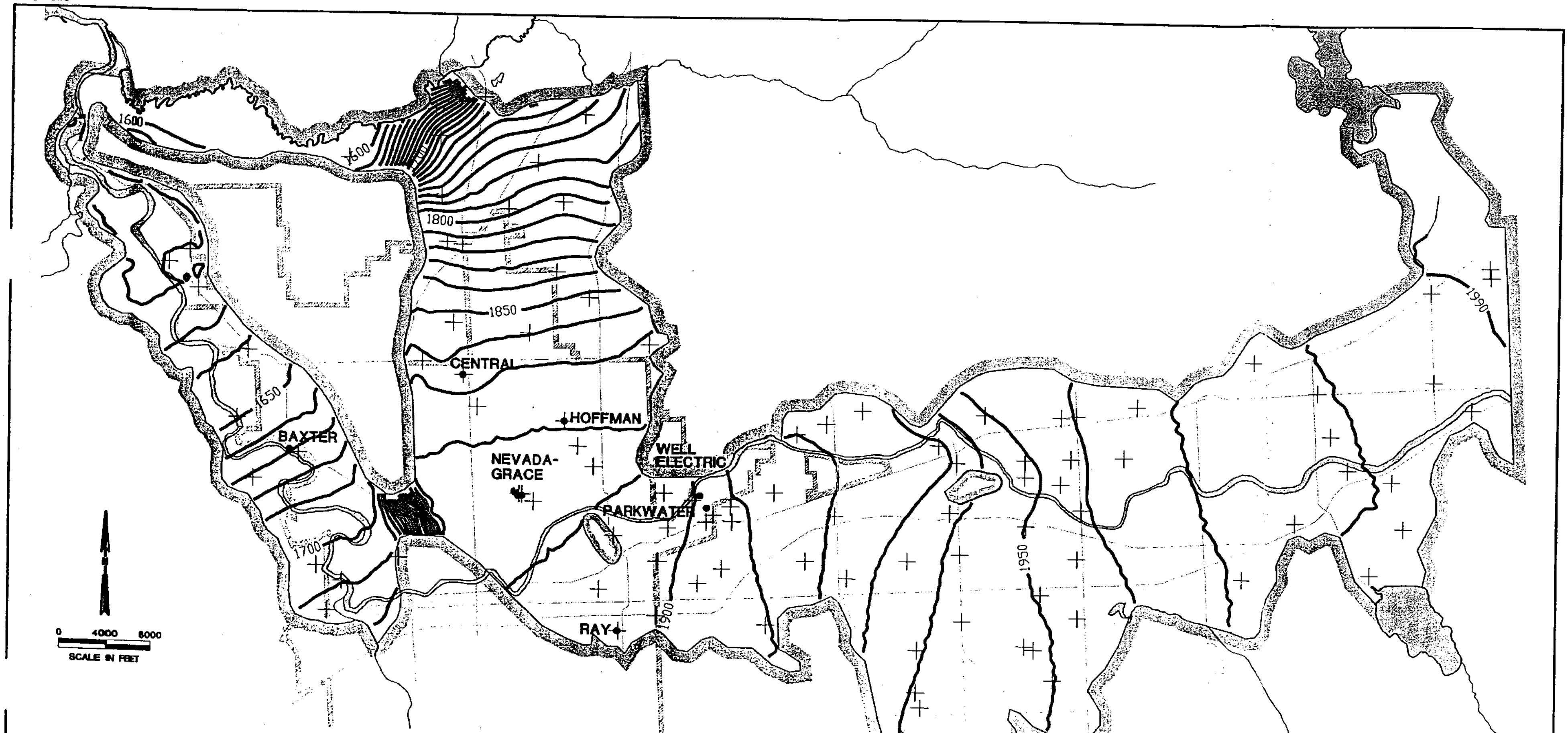
FIG-2-3.DWG



CH2M HILL

FIGURE 2-3
MEASURED
GROUNDWATER ELEVATIONS
(SEPTEMBER 1994)

FIG-2-4.DWG



City of Spokane Datum
CONTOUR INTERVAL- [illegible] FEET

CH2M HILL

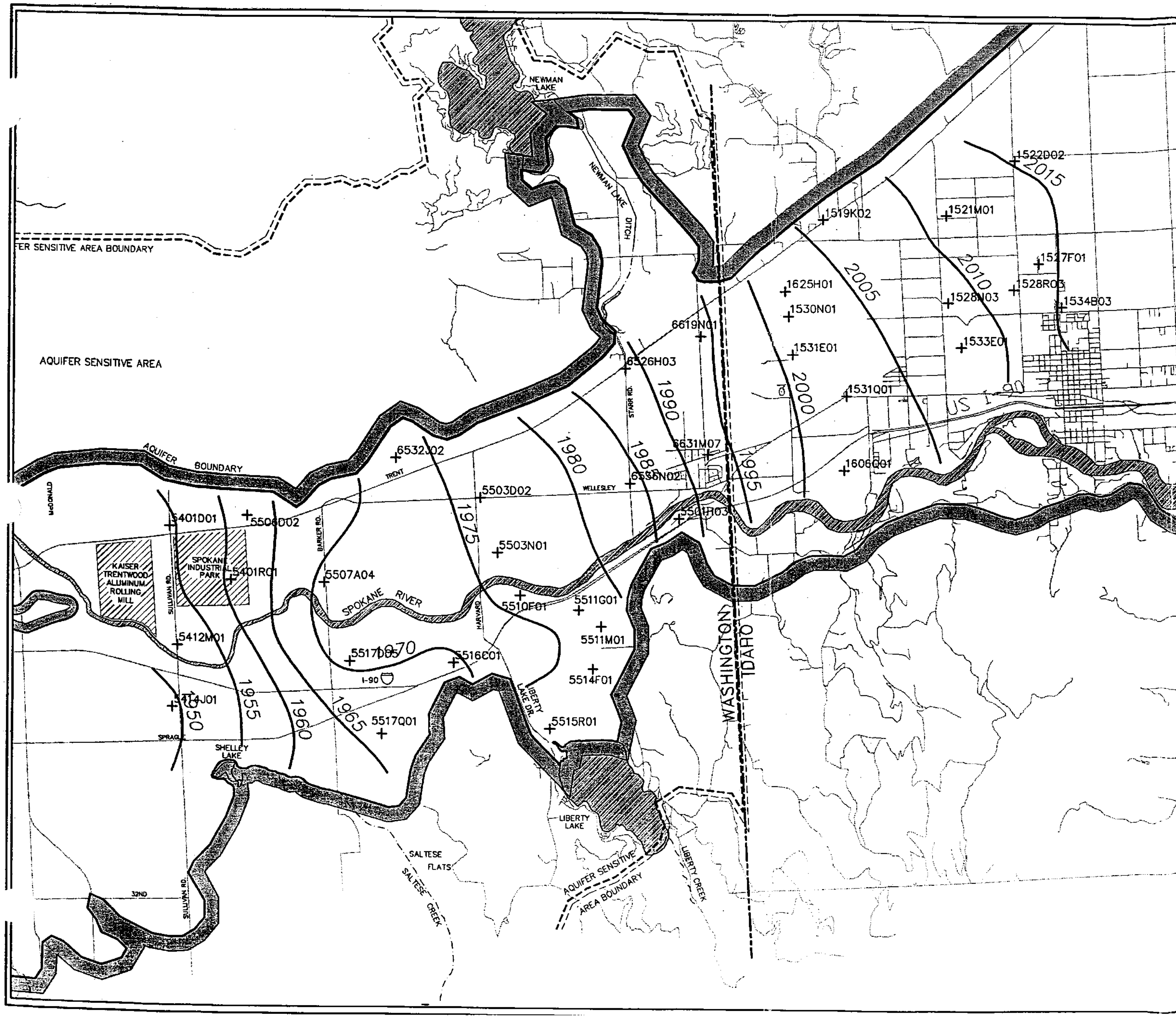
FIGURE 2-4
MEASURED GROUNDWATER ELEVATIONS
(APRIL 1995)

Table 2-1
Groundwater Depth and Elevation Data
September 1994 and April 1995
City of Spokane Wellhead Protection Program

Well ID	Well Owner	Well Name	Location (NAD 27)		Year	Depth	Depth to	Depth to	Diameter	Casing	Intake	Reference Point Elevation		Fall 1994				Spring 1995			
			Easting	Northing	Drilled	(ft bgs)	Top Open Interval (ft bgs)	Bottom Open Interval (ft bgs)	(inches)	Type	Type	(ft USGS)	(ft City)	Date	Depth to Water	Groundwater Elevations (ft USGS)	(ft City)	Date	Depth to Water	Groundwater Elevations (ft USGS)	(ft City)
5203H01	City of Spokane	Baxter well	2826906	271955	1945	124	93	122	144			1696.11		9/15/94		1647.27	1664.20	4/13/95		1647.15	1664.08
5203H02	City of Spokane	WWTP Mon Well	2827800	271500	1994	121			2	PVC	S	1697.05	1713.98	9/13/94	51.62	1645.43	1662.36	4/13/95	42.04	1655.01	1671.94
5203Q01	Riverside State Park	Equestrian Center	2823908.9	269247.62	1979	217			6	Steel	S	1769.37	1786.30	9/13/94	123.91	1645.46	1662.39	4/11/95	114.80	1654.57	1671.5
5213B01	Inland Empire Cold Storage		2835547.51	262572.3		208			41			1886.37	1903.30	9/14/94	195.45	1690.92	1707.85	4/12/95	186.00	1700.37	1717.3
5214C02	Central PreMix-Ft. Wright	Ft. Wright	2829378.98	261797.06		140	134	140	8	Steel	S	1772.06	1788.99	9/16/94	94.35	1677.77	1694.70	4/13/95	87.78	1684.34	1701.27
5214J01	Fairmont Cemetery Assoc.	Riverside Cemetery	2831607.99	260488.26		160	119	154	18	Steel	P	1712.54	1729.47	9/16/94	26.65	1685.89	1702.82	4/13/95	19.72	1692.82	1709.75
5223B01	City of Spokane	Indian Canyon Golf Course	2830364	257944	1931	59	45		6			1732	1749	9/15/94		1687.61	1704.54	4/13/95		1697.87	1714.8
5304B01	City of Spokane	Hoffman Well #1	2850739	274479	1937	231	222	227	198			2068	2085	9/15/94		1851.87	1868.80	4/11/95		1862.82	1879.75
5304B02	City of Spokane	Hoffman Well #2	2850739	274479	1936	216			126	Brick		2068	2085	9/15/94		1853.57	1870.50	4/11/95		1862.28	1879.21
5304G01	City of Spokane	NE Comm. Center (Hoffman MW)	2851980.87	272421.11	1994	195	182	192	2	PVC	S	2039.14	2056.07	9/21/94	182.10	1857.04	1873.97	4/11/95	174.22	1864.92	1881.85
5304R01	Miles Laboratory (Bayer)		2853386.19	270692.8		185						2020.73	2037.66	9/14/94	159.65	1861.08	1878.01	4/11/95	151.52	1869.21	1886.14
5307M01	City of Spokane	Trinity MW	2838136.8	266370.64		254						1895.40	1912.33	10/7/94	147.30	1748.10	1765.03	4/11/95	127.99	1767.41	1784.34
5308A01	City of Spokane	Grace Well	2847200	268203		124	85	119	144			1963	1980	9/15/94		1858.38	1875.31	4/11/95		1866.03	1882.96
5308A02	City of Spokane	Nevada well	2846955	268207		126			216			1960	1977	9/15/94		1854.37	1871.30	4/11/95		1862.19	1879.12
5308D01	WADOT, Mayfair complex	MW-1	2844108.69	267855.49		77	62	77	2	PVC	S	1929.24	1946.17	9/13/94	72.81	1856.43	1873.36	4/13/95	66.36	1862.88	1879.81
5309E04	City of Spokane	Marietta MW	2848176.65	267584.97	1994	101	86	96	2	PVC	S	1947.17	1964.10	9/14/94	87.60	1859.57	1876.50	4/11/95	80.23	1866.94	1883.87
5310P02	Spokane County (208 Well)	Spokane Community College	2855126.28	264762.84	1977	96	41	96	6		P	1910.42	1927.35	9/15/94	41.22	1869.20	1886.13	4/13/95	33.57	1876.85	1893.78
5311E01	Arbor Crest Winery	Hand dug well at plant	2859521.96	268503.34	1924	80			36			1938.65	1955.58	9/15/94	67.88	1870.77	1887.70	4/11/95	59.88	1878.77	1895.7
5311G01	City of Spokane	Old Well Electric (#1)	2862058.75	267806.98	1907	46.7			540	Brick		1904.92	1921.85	9/14/94	32.37	1872.55	1889.48	4/13/95	23.53	1881.39	1898.32
5311G06	City of Spokane	Well Electric #5	2862730	268280										9/15/94		1872.67	1889.60	4/13/95		1881.44	1898.37
5311H01	Spokane Airports	Old USGS, Well Electric area	2862103.31	267908.35		< 100						1935.36	1952.29	9/14/94	61.71	1873.65	1890.58	4/12/95	53.20	1882.16	1899.09
5311J05	City of Spokane	Hales Ale #1 Shallow (E)	2863896.64	266619.72	1994	80	62	72	2	PVC	S	1948.22	1965.15	9/16/94	70.18	1878.04	1894.97	4/12/95	60.78	1887.44	1904.37
5311J06	City of Spokane	Hales Ale #2 Inter. (M)	2863896.64	266619.72	1994	98	80	90	2	PVC	S	1948.83	1965.76					4/12/95	61.22	1887.61	1904.54
5311J07	City of Spokane	Hales Ale #3 Deep (W)	2863896.64	266619.72	1994	120	105	115	2	PVC	S	1948.71	1965.64					4/12/95	60.85	1887.86	1904.79
5311N01	Baker Commodities		2859891.45	265504.78		70			8			1903.94	1920.87	9/13/94	32.96	1870.98	1887.91	4/12/95	25.77	1878.17	1895.1
5311R01	Burlington Northern	Well south of offices	2863294.02	266029.44		104	69					1948.60	1965.53	9/13/94	70.98	1877.62	1894.55	4/11/95	61.48	1887.12	1904.05
5312C01	City of Spokane	Felts Field MW	2865483.25	267958.9	1994	80	65	75	2	PVC	S	1950.34	1967.27	9/14/94	66.52	1883.82	1900.75	4/12/95	57.41	1892.93	1909.86
5312E01	Middco Tool		2865436.7	267343.2		103						1952.06	1968.99	9/14/94	72.37	1879.69	1896.62	4/13/95	63.48	1888.58	1905.51
5312H01	Orchard Irr. Dist.	Well #1 (at office)	2869172.94	268572.27	1917	96	55	96	120			1946.81	1963.74	9/13/94	59.46	1887.35	1904.28	4/11/95	49.80	1897.01	1913.94
5312L03	Westco Apparel Service		2865565.09	266043.11		90			6	Steel		1948.42	1965.35	9/12/94	67.15	1881.27	1898.20	4/11/95	57.55	1890.87	1907.8
5313E01	Ponderosa Drilling		2864693.18	262018.43	1984	81	81		6		OH	1938.22	1955.15	9/12/94	57.55	1880.67	1897.60	4/11/95	48.05	1890.17	1907.1
5313K01	Acme Materials	Yardley Pit	2868798.48	260983.49		125	85	125	12	Steel	P	1901.60	1918.53	9/16/94	-5.00			4/10/95	6.98	1894.62	
5314E01	Spokane County (208 Well)	Central Premix - Yardley	2859032.44	262587.11	1977	211		211	6	Steel	OH	1941.75	1958.68	9/12/94	69.70	1872.05	1888.98	4/11/95	60.47	1881.28	1898.21
5314Q01	Union Pacific Railroad		2862603.47	260743.74		< 120			6			1936.67	1953.60	9/12/94	59.87	1876.80	1893.73	4/11/95	50.58	1886.09	1903.02
5316K01	Centennial Mills	Trent plant	2851831.09	260735.57	1935	65			36			1924.60	1941.53	9/15/94	60.05	1864.55	1881.48	4/12/95	52.64	1871.96	1888.89
5316R01	Playfair Racetrack		2853915.18	260132.05	1978	100	90	100	8		S	1935.71	1952.64	9/12/94	69.58	1866.13	1883.06	4/12/95	61.50	1874.21	1891.14
5322A01	City of Spokane	4th and Havana #1 - Shallow	2858984.32	257913.35	1994	62	47	57	2	PVC	S	1927.52	1944.45	9/16/94	54.37	1873.15	1890.08	4/12/95	45.67	1881.85	1898.78
5322A02	City of Spokane	4th and Havana #2 - Inter.	2859145.1	257910.43	1994	79	66	76	2	PVC	S	1927.58	1944.51	9/16/94	54.45	1873.13	1890.06	4/12/95	45.75	1881.83	1898.76
5322A03	City of Spokane	4th and Havana #3 - Deep	2859082.7	257908.1	1994	103	90	100	2	PVC	S	1927.49	1944.42	9/16/94	54.31	1873.18	1890.11	4/12/95	45.62	1881.87	1898.8
5322F01	City of Spokane	Ray St. well	2855441	256629	1941	77	54	77	252			1932	1949	9/15/94		1863.45	1880.38	4/12/95		1875.68	1892.61
5324G01	East Spokane WD	E Spok SO #1	2868519.08	257220.96	1946	147			58			2026.61	2043.54	9/13/94	144.15	1882.46	1899.39	4/12/95	134.18	1892.43	1909.36
5401D01	Trentwood Irr. Dist.	Trentwood #5	2895418.59	275571.53	68	159	110	145	16		P	2051.54	2068.47	9/13/94	119.71	1931.83	1948.76	4/11/95	108.03	1943.51	1960.44
5401R01	Spokane Industrial Park	Well #4	2899584.36	271949.05	1974	150	120	150	22	Steel	S	2018.01	2034.94	9/12/94	81.52	1936.49	1953.42	4/11/95	69.50	1948.51	1965.44
5402B01	Trentwood Irr. Dist.	Progress #6	2894105.59	275412.64		236	112	138				2036.75	2053.68	9/13/94	106.70	1930.05	1946.98	4/11/95	95.48	1941.27	1958.2
5402N01	Kaiser-Trentwood	MW-7	2891006	271690.52		< 125						2004.90	2021.83	9/13/94	81.55	1923.35	1940.28	4/11/95	72.78	1932.12	1949.05
5402R01	Kaiser-Trentwood	MW-4	2894986.38	271833.25		< 125						2015.92	2032.85	9/13/94	86.37	1929.55	1946.48	4/11/95	75.60	1940.32	1957.25
5403B01	Trentwood Irr. Dist.	Trentwood #4 McDonald	2887472.63	275518.24	1966	120	88	118	16	Steel	P	1991.46	2008.39	9/12/94	66.37	1925.09	1942.02	4/11/95	58.60	1932.86	1949.79
5404K03	Inland Empire Paper	MW in Plantes Ferry pit	2883497	272817		< 40						1925.03	1941.96	9/13/94	24.87	1900.16	1917.09	4/11/95	14.30	1910.73	1927.66
5404Q01	Trentwood El. School	Trent near Zoo	2885084.09	271337.95		< 125						1987.21	2004.14	9/12/94	81.90	1905.31	1922.24	4/11/95	73.23	1913.98	1930.91
5406A02	Pasadena Park Irr. Dist.	#4	2873644.53	274590.7		160	121	155	16			1984.16	2001.09	9/13/94	90.58	1893.58	1910.51	4/11/95	79.50	1904.66	1921.59
5406J03	Pasadena Park Irr. Dist.	#5 (New well)	2871087.28	273671.59	1993	180	145	180	20	Steel	S	1962.22	1979.15	9/13/94	69.73	1892.49	1909.42	4/11/95	59.48	1902.74	1919.67
5407R01	Farm Credit	Old USGS MW	2874445.56	266585.6	1979	120	60	120	6	PVC	S	1976.27	1993.20	9/13/94	82.53	1893.74	1910.67	4/10/95	72.23	1904.04	1920.97
5408B01	Millwood WD	Old Park Well	2875859.11	270434.65	1953	120	70	120	80	Steel	P	1950.07	1967.00	9/13/94	50.89	1899.18	1916.11	4/11/95	40.92	1909.15	1926.08
5409E01	Irvin WD	Montgomery	2880442.98	268789.36	1973	141	104	136	16	Steel	S	1968.51	1985.44	9/14/94	77.62	1890.89	1907.82	4/11/95	67.26	1901.25	1918.18
5409Q01	WADOT, Pines complex		2884542.1	267039.26	1991	< 125						1978.66	1995.59	9/13/94	68.20	1910.46	1927.39	4/10/95	57.02	1921.64	1938.57
5411G01	Kaiser-Trentwood	MW-5	2894111.77	269674.35		< 125						2009.55	2026.48	9/13/94	81.10	1928.45	1945.38	4/11/95	70.96	1938.59	1955.52
5411J01	Kaiser-Trentwood	MW-9	2891020.6	270216.49	1991	85	65	85	2	PVC	S	1977.18	1994.11	9/13/94	56.02	1921.16	1938.09	4/11/95	49.38	1927.80	1944.73
5411N02	Consolidated Irr. Dist. (CID)	Carder, 1B	2891146.02	265984.84	1987	176	117	162	10	Steel	S	1984.58	2001.51	9/14/94	62.50	1922.08	1939.01	4/10/95	51.20	1933.38	1950.31
5412M01	Central PreMix	SPK Co (208) - Sullivan	2895922.89	267421.85		< 150						1998.07	2015.00	9/12/94	67.27	1930.80	1947.73	4/10/95	55.73	1942.34	1959.27
5414J01	Vera Irr. Dist. #15	New #2 well	2895582.04	263204.61	1994	265	210	265	20	Steel	S	2044.27	2061.20	9/15/94	115.77	1928.50	1945.43	4/11/95	105.70	1938.57	1955.5
5415E01	Modern Electric	#5	2885443.86	263482.97	1947	158			75	Steel		2053.24	2070.17	9/14/94	138.69	1914.55	1931.48	4/11/95	127.75	1925.49	1942.42
5416E01	Modern Electric	#2	2880897.97	262839.1	1947	128			74	Steel		2012.16	2029.09	9/14/94	106.10	1906.06	1922.99	4/11/95	95.00	1917.16	1934.09
5417M01	Modern Electric	#4	2875586.92	261247.71	1947	114	114	130	66	Steel	S	2000.56	2017.49	9/14/94	101.96	1898.60	1915.53	4/11/95	91.35	1909.21	1926.14
5418F01	Spokane County WD #3	Vista and Broadway	2871918.34	262698.57		110	65	105				1965.59	1982.52	9/15/94	76.33	1889.26	1906.19	4/11/95	66.49	1899.10	1916.03
5421J01	Modern Electric	#3	2885680.84	257678.67		122						2022.43	2039.36	9/14/94	107.24	1915.19	1932.12	4/11/95	96.03	1926.40	1943.33
5421N01	Model Irr. Dist.	15th & Pierce, #1	2881810.2	255188.31	1911	183	166	183	84			2082.56	2099.49	9/13/94	171.79	1910.77	1927.70	4/11/95	160.28	1922.28	1939.21
5422R01	Vera Irr. Dist. #15	#3	2891101.39	255597.68	1908	257	210	257	20	Steel	S	2082.12	2099.05	9/15/94	162.40	1919.72	1936.65	4/11/95	150.90	1931.22	1948.15
5423C01	Vera Irr. Dist. #15	#7	2892461.04	260072.53		97						2017.96	2034.89	9/15/94	95.51	1922.45	1939.38	4/11/95	84.35	1933.61	1950.54
5423J03	Vera Irr. Dist. #15	#8/9 testwell	2895656.82	258099.39		210	188	208	6	Steel	P	2043.16	2060.09	9/15/94	119.75	1923.41	1940.34	4/11/95	108.05	1935.11	1952.04
5426D01	Vera Irr. Dist. #15	#5	2891923.97	255309.14	1910	170			72	Steel		2083.65	2100.58	9/15/94	163.44	1920.21	1937.14	4/11/95	151.91	1931.74	1948.67
5426L01	Vera Irr. Dist. #15	#4	2893587.66	252728.35	1910	163	130		72	Steel		2064.32	2081.25	9/15/94	143.35	1920.97	1937.90	4/11/95	131.38	1932.94	1949.87
5428M02	Model Irr. Dist.	#5	2881721.96	251563.34	1974	160	140	160	16	Steel	S	2009.40	2026.33	9/13/94	97.46	1911.94	1928.87	4/11/95	85.45	1923.95	1940.88

Table 2-1
Groundwater Depth and Elevation Data
September 1994 and April 1995
City of Spokane Wellhead Protection Program

Well ID	Well Owner	Well Name	Location (NAD 27)		Year	Depth	Depth to Top Open	Depth to Bottom Open	Diameter	Casing	Intake	Reference Point Elevation		Fall 1994				Spring 1995			
			Easting	Northing	Drilled	(ft bgs)	Interval (ft bgs)	Interval (ft bgs)	(inches)	Type	Type	(ft USGS)	(ft City)	Date	Depth to Water	Groundwater Elevations (ft USGS)	(ft City)	Date	Depth to Water	Groundwater Elevations (ft USGS)	(ft City)
5428P01	Model Irr. Dist.	#3	2882127.19	250257.12	1965	167	152	167	16	Steel	S	2031.08	2048.01	9/13/94	118.33	1912.75	1929.68	4/11/95	105.63	1925.45	1942.38
5428R01	Spokane County WD #3	32 & Pines @ Circle K	2886056	250027.07		132	113					2031.09	2048.02	9/14/94	114.22	1916.87	1933.80				
5501H03	Washington State Patrol	K001 WA St Patrol	2930196.9	276370.57	1970	165	155	165	8	Steel	S	2050.99	2067.92	9/12/94	94.17	1956.82	1973.75	4/11/95	81.57	1969.42	1986.35
5503D02	Otis Orchards School		2916639.09	277701.46	1953	137	100		8		P	2058.82	2075.75	9/12/94	109.30	1949.52	1966.45	4/12/95	96.90	1961.92	1978.85
5503N01	Coen		2917834.25	273952.17	1959	138	105	135	14		P	2048.18	2065.11	9/12/94	98.88	1949.30	1966.23	4/11/95	86.40	1961.78	1978.71
5506D02	Borjessan; Lloyd	Borjessan	2900686.05	276374.12	1973	177	162	177	10	Steel	S	2064.68	2081.61	9/12/94	126.33	1938.35	1955.28	4/11/95	113.41	1951.27	1968.2
5509B02	Jacklin, Gladice		2914609.03	271330.37	1976	147	137	146	10		P	2028.99	2045.92	9/12/94	81.57	1947.42	1964.35				
5510F01	Delp Place		2919352.67	271033.49	1930	85			48			2023.54	2040.47	9/14/94	73.65	1949.89	1966.82	4/10/95	61.20	1962.34	1979.27
5511G01	Bryant Motors		2923252.04	270058.18		< 150						2057.07	2074.00	9/12/94	106.37	1950.70	1967.63	4/10/95	93.39	1963.68	1980.61
5511M01	Kennert (North Well)	Simpson Rd, N. of Sprague	2924826.27	268952.13	1965	186	158	183	16			2110.48	2127.41	9/12/94	161.10	1949.38	1966.31	4/10/95	148.60	1961.88	1978.81
5514F01	Liberty Lake Improvement Dist.	Schultz well	2924259.3	266047.2		238	216	238				2143.25	2160.18	9/12/94	192.80	1950.45	1967.38	4/10/95	179.36	1963.89	1980.82
5515R01	Liberty Lake Improvement Dist.	Sprague well	2921346.21	261987.44	1961	155	110	155	48	Steel	P	2073.32	2090.25	9/12/94	123.85	1949.47	1966.40	4/10/95	102.83	1970.49	1987.42
5516C01	Inland Empire Paper	USGS Monitoring Well	2914841.85	266414.46		129						2056.43	2073.36	9/12/94	112.38	1944.05	1960.98	4/10/95	100.01	1956.42	1973.35
5517D04	Consolidated Irr. Dist. (CID)	Greenacres, 4D	2907493.19	266652.89	1964	229	152	217	20	Steel	S	2029.35	2046.28	9/14/94	85.10	1944.25	1961.18				
5517Q01	Spokane Gun Club		2909948.13	261528.12	1950	287	221	283	8	Steel	P	2046.02	2062.95	9/12/94	104.40	1941.62	1958.55	4/10/95	92.00	1954.02	1970.95
6219A01	Riverside State Park	Offroad Vehicle Park	2809279.61	286985.8	1978	303	293	303	6	Steel	S	1881.15	1898.08	9/13/94	265.65	1615.50	1632.43	4/11/95	261.60	1619.55	1636.48
6221C05	City of Spokane	North Landfill MW-K	2818288.87	288932.43		100	81	96	6	Steel	S	1665.50	1682.43	9/12/94	65.30	1600.20	1617.13	4/11/95	61.46	1604.04	1620.97
6221D04	City of Spokane	North Landfill MW-H	2816491.24	287854.7		66	47	62	6	Steel	S	1638.81	1655.74	9/12/94	38.43	1600.38	1617.31	4/11/95	34.78	1604.03	1620.96
6221K01	City of Spokane	North Landfill MW-E	2819031.5	285582.32		121	102	117	6	Steel	S	1658.76	1675.69	9/12/94	59.04	1599.72	1616.65	4/11/95	55.02	1603.74	1620.67
6227F01	Spokane County (208 Well)	North Landfill	2823406.78	280316.71	1977	126	51	126	6		P	1689.82	1706.75	9/13/94	77.82	1612.00	1628.93	4/11/95	64.05	1625.77	1642.7
6234N03	Fairmont Cemetery	Fairmont Cemetery Well	2822478.94	274409.69	1958	71	40		12	Steel		1643.63	1660.56	9/16/94	15.88	1627.75	1644.68	4/13/95	11.60	1632.03	1648.96
6303N01	Spokane County WD #3	Cherry	2852366.75	301177.57		180	135	180				1863.07	1880.00	9/13/94	120.60	1742.47	1759.40	4/12/95	117.85	1745.22	1762.15
6306H01	Morgan; Ron		2840500	303500		136						1666.89	1683.82	9/13/94	71.10	1595.79	1612.72	4/12/95	69.52	1597.37	1614.3
6307G04	Whitworth WD #2	#3B	2839902.43	299183.89	1979	200	180	200	20	Steel	S	1816.07	1833.00	9/14/94	115.51	1700.56	1717.49	4/12/95	110.05	1706.02	1722.95
6308C02	Acme Materials	Acme Farwell (Old Corral)	2843038.45	300750.53		< 100						1745.57	1762.50	9/13/94	34.55	1711.02	1727.95				
6309N01	Kaiser-Mead	TH-5	2848313	296973		< 175						1906.09	1923.02	9/13/94	145.50	1760.59	1777.52	4/12/95	144.85	1761.24	1778.17
6310K01	Spokane County WD #3	Market & Guy	2855246.69	298134.23		116	94	106				1902.40	1919.33	9/13/94	98.82	1803.58	1820.51	4/12/95	86.82	1815.58	1832.51
6316Q01	BPA NW	MW-3	2850570.68	293610.39	1991	165	140	160	2	Steel	S	1942.33	1959.26	9/13/94	154.65	1787.68	1804.61	4/12/95	153.90	1788.43	1805.36
6317J01	NW Pipeline Co.		2845885.37	292922.6	1961	248	228	243	6		P	1953.42	1970.35	9/14/94	177.15	1776.27	1793.20	4/12/95	174.38	1779.04	1795.97
6318B01	Whitworth College	New Well	2840062.42	294100.76	1986	282	252	282	16		S	1917.33	1934.26	9/13/94	171.98	1745.35	1762.28	4/12/95	168.75	1748.58	1765.51
6319A02	Whitworth Water Dist. #2	2A	2841879.37	289794.31	1979	228	180	220	20		S	1946.48	1963.41	9/14/94	154.34	1792.14	1809.07	4/12/95	149.49	1796.99	1813.92
6320D01	Whitworth Water Dist. #2	2B	2840576.3	289991.26	1962	286	253	286	16		S	1936.04	1952.97	9/14/94	143.46	1792.58	1809.51	4/12/95	138.22	1797.82	1814.75
6321J01	Acme Materials	Crestline well	2850046.78	287517.58	1980	238	213	233	8		S	2009.99	2026.92	9/14/94	194.46	1815.53	1832.46	4/12/95	189.95	1820.04	1836.97
6322N03	JB Richardson	Fisher Well	2852856.09	285310.28	1986	275	239	254	12	Steel	S	2017.71	2034.64	9/14/94	187.08	1830.63	1847.56	4/12/95	181.82	1835.89	1852.82
6327H01	Spokane Humane Society		2858219.13	281307.35	1976	225			6	Steel		1988.85	2005.78	9/15/94	140.25	1848.60	1865.53	4/12/95	132.62	1856.23	1873.16
6328M02	Ray Turf Farm		2847727.9	282156.47	1940	250			84			2051.75	2068.68	9/14/94	215.61	1836.14	1853.07	4/12/95	209.61	1842.14	1859.07
6330H02	Holy Cross Cemetary	New well	2841168.6	282952.76		310	270	310	18	Steel	S	2041.58	2058.51	9/15/94	215.75	1825.83	1842.76	4/12/95	204.00	1837.58	1854.51
6330P03	US West	MW-3	2838489.82	279537.28		234	214	234	4	PVC	S	2063.47	2080.40	9/15/94	224.44	1839.03	1855.96	4/12/95	217.49	1845.98	1862.91
6331A02	City of Spokane	Central Well #1	2841737	278376	1959	272	220	272	96			1866	1883	9/15/94		1832.82	1849.75	4/11/95		1845.98	1862.91
6331A03	City of Spokane	Central Well #2	2841737	278376	1959	272	220	272	96			1866	1883	9/15/94				4/11/95		1846.82	1863.75
6331J01	City of Spokane	Franklin Park MW	2843278.47	275663.14	1994	222	208	218	2	PVC	S	2058.84	2075.77	9/13/94	209.24	1849.60	1866.53	4/11/95	202.12	1856.72	1873.65
6432Q02	Pleasant Prairie WD		2876833.62	275785.43	1987	139	129	139	8	Steel	S	1988.44	2005.37	9/13/94	90.95	1897.49	1914.42	4/11/95	80.45	1907.99	1924.92
6525J01	Spokane County (208 Well)	Idaho Rd #2 (Near Trent Rd.)	2931709.11	287972.16	1977	190			6	Steel	OH	2103.72	2120.65	9/12/94	139.20	1964.52	1981.45	4/11/95	127.24	1976.48	1993.41
6526H03	Pentler; Virgil	Trent & Starr Rds	2926456.72	286574.43		< 150						2066.64	2083.57	9/12/94	108.22	1958.42	1975.35	4/11/95	95.75	1970.89	1987.82
6532J02	Schmidt; Wes	Schmidt Well	2910855.42	280374.9	1954	152			8			2098.79	2115.72	9/12/94	151.74	1947.05	1963.98	4/11/95	138.95	1959.84	1976.77
6536N02	Boshears; Dell	Boshears; Dell	2926808.8	278761.39		< 150						2069.45	2086.38	9/12/94	113.60	1955.85	1972.78	4/11/95	101.30	1968.15	1985.08
6619N01	Spokane County (208 Well)	Idaho Rd #1 (Beck)	2931620.14	288776.81		263			6	Steel	OH	2080.39	2097.32	9/12/94	117.22	1963.17	1980.10	4/11/95	104.35	1976.04	1992.97



LEGEND

+ LOCATION MONITORED

1970 GROUNDWATER ELEVATION CONTOUR

NOTE:
CITY OF SPOKANE DATUM, WHICH IS 16.92 FEET HIGHER THAN NAD 1927 DATUM.

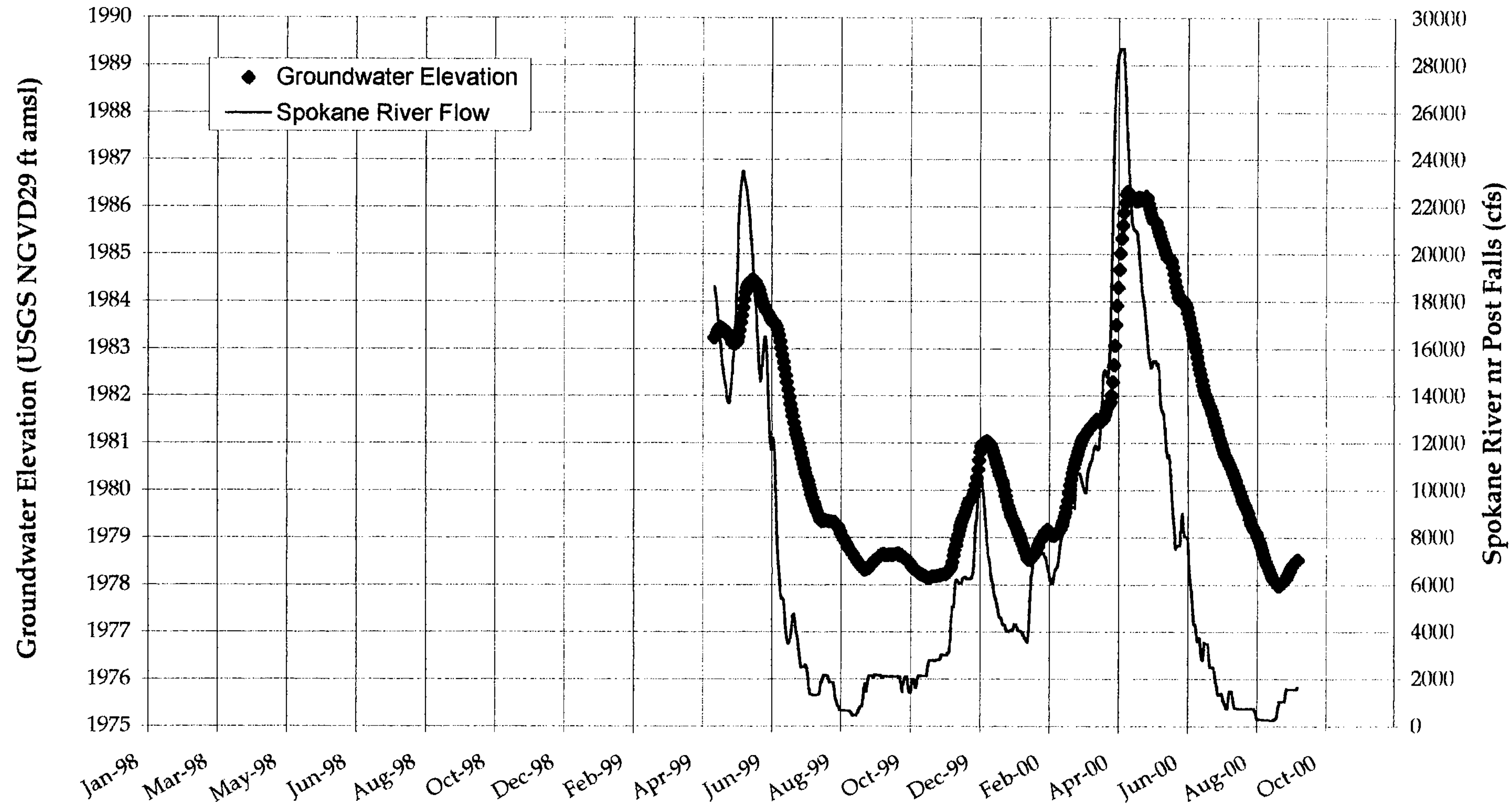
FIGURE 2-2
DATA COLLECTION POINTS AND WATER TABLE MAP FOR THE DISCRETE MONITORING EVENT
OCTOBER 30, 1996

CH2MHILL

APPENDIX D2 - GROUNDWATER HYDROGRAPHS

Table of Contents

Groundwater Hydrograph Information

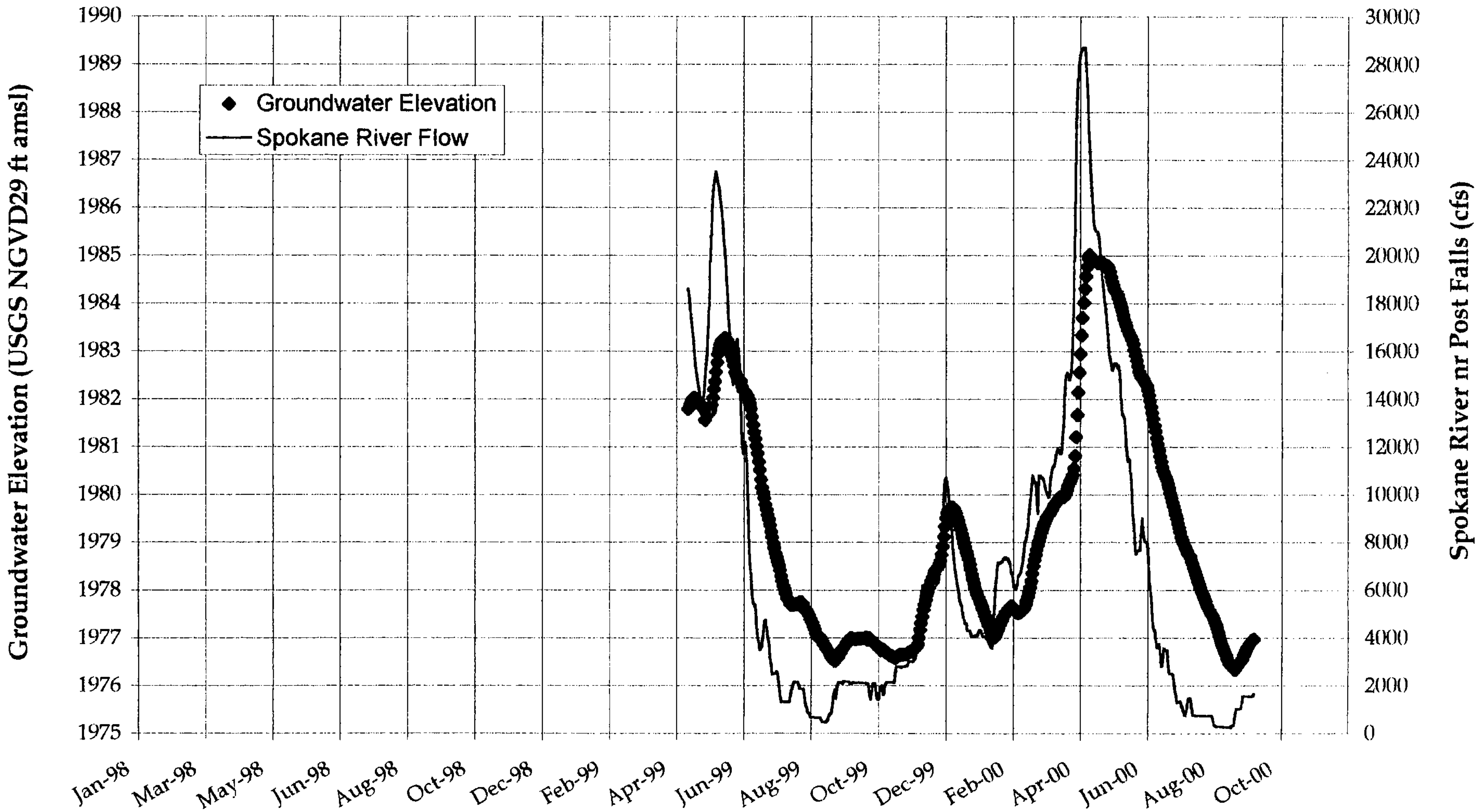


Data Source: Spokane County
Date Type : Daily averages from transducer data
Station Name: Idaho Road nr Pipeline
Station ID: 6525R01

FIGURE D2-1:
Idaho Road nr Pipeline Well
5/1999-9/2000

Spokane Co. / Level 1 Assess / WA

Golder Associates



Data Source: Spokane County
Date Type : Daily Averages
Station Name: CID-11 / Idaho Road Well
Station ID: 6631M07

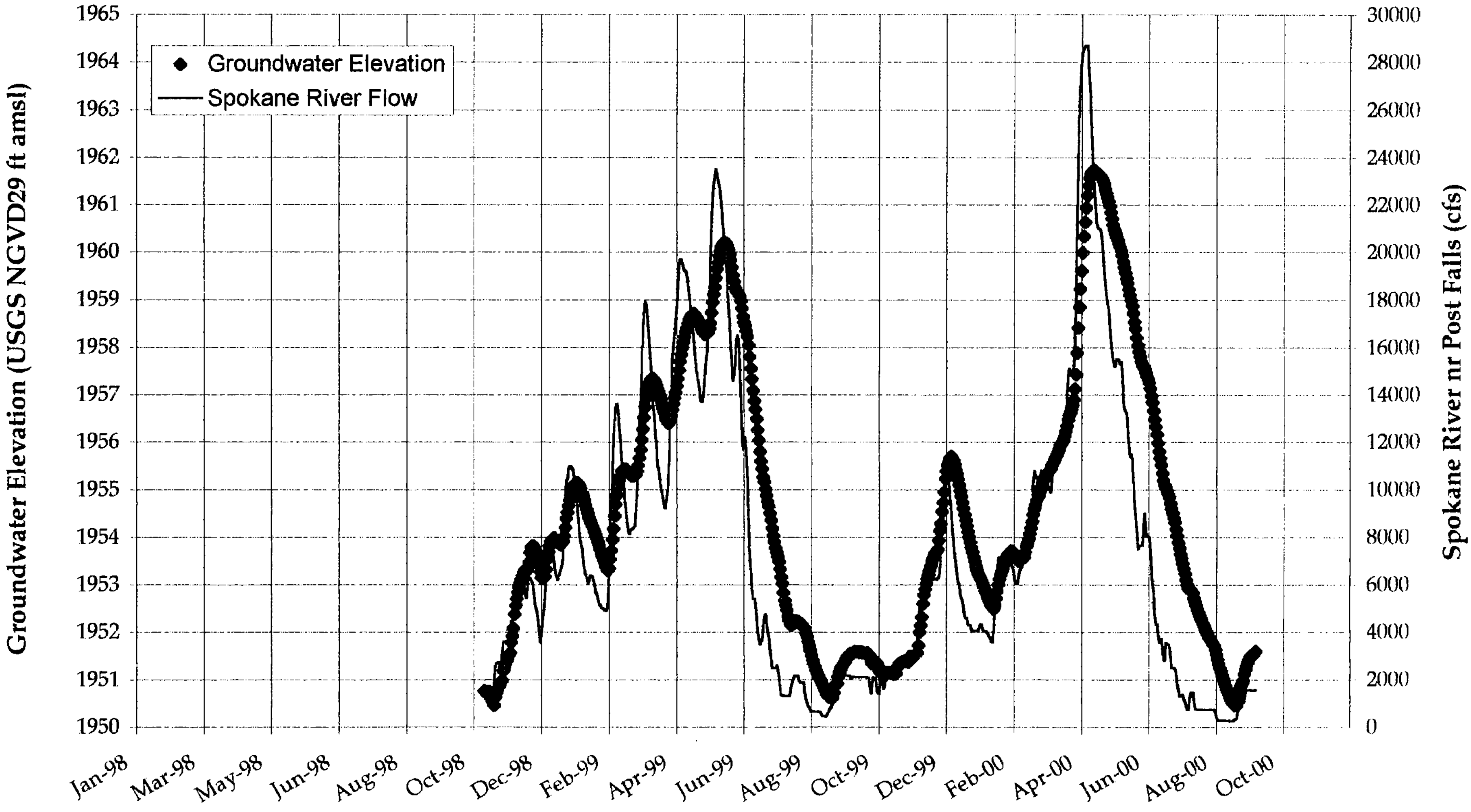
FIGURE D2-2:
CID 11 / Idaho Road
5/1999-9/2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-2 CID-11-idaho.xls/D2-2 hydro

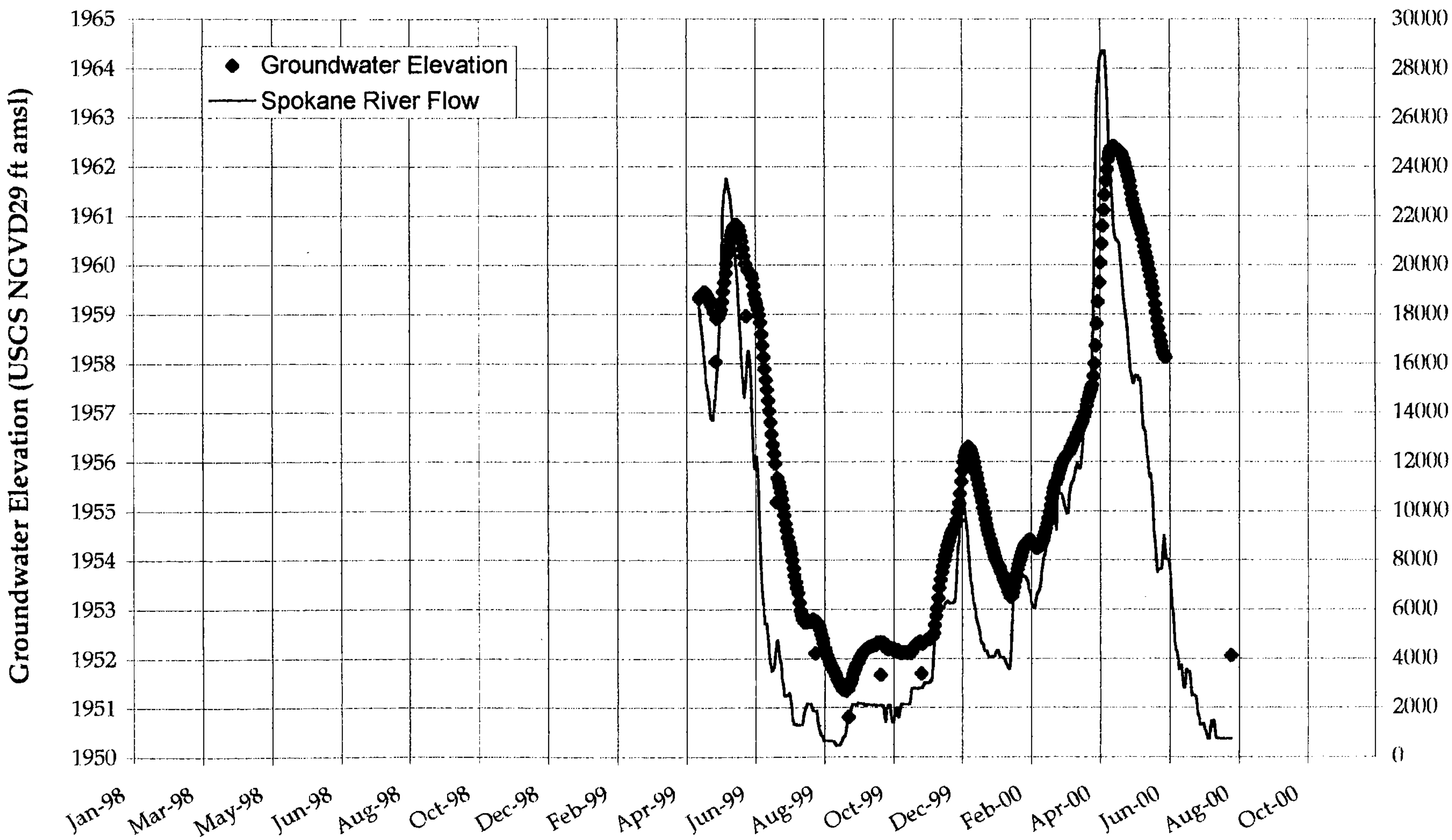


Data Source: Spokane County
Date Type : Daily averages from transducer data
Station Name: Barker Road North, Barker North
Station ID: 5507H01

FIGURE D2-3:
Barker Road North Well
(Barker North)
11/1998-9/2000

Spokane Co. / Level 1 Assess / WA

Golder Associates



Data Source: Spokane County
Date Type : Daily averages from transducer data
Station Name: Barker and Euclid, CID Barker North
Station ID: 5507A04

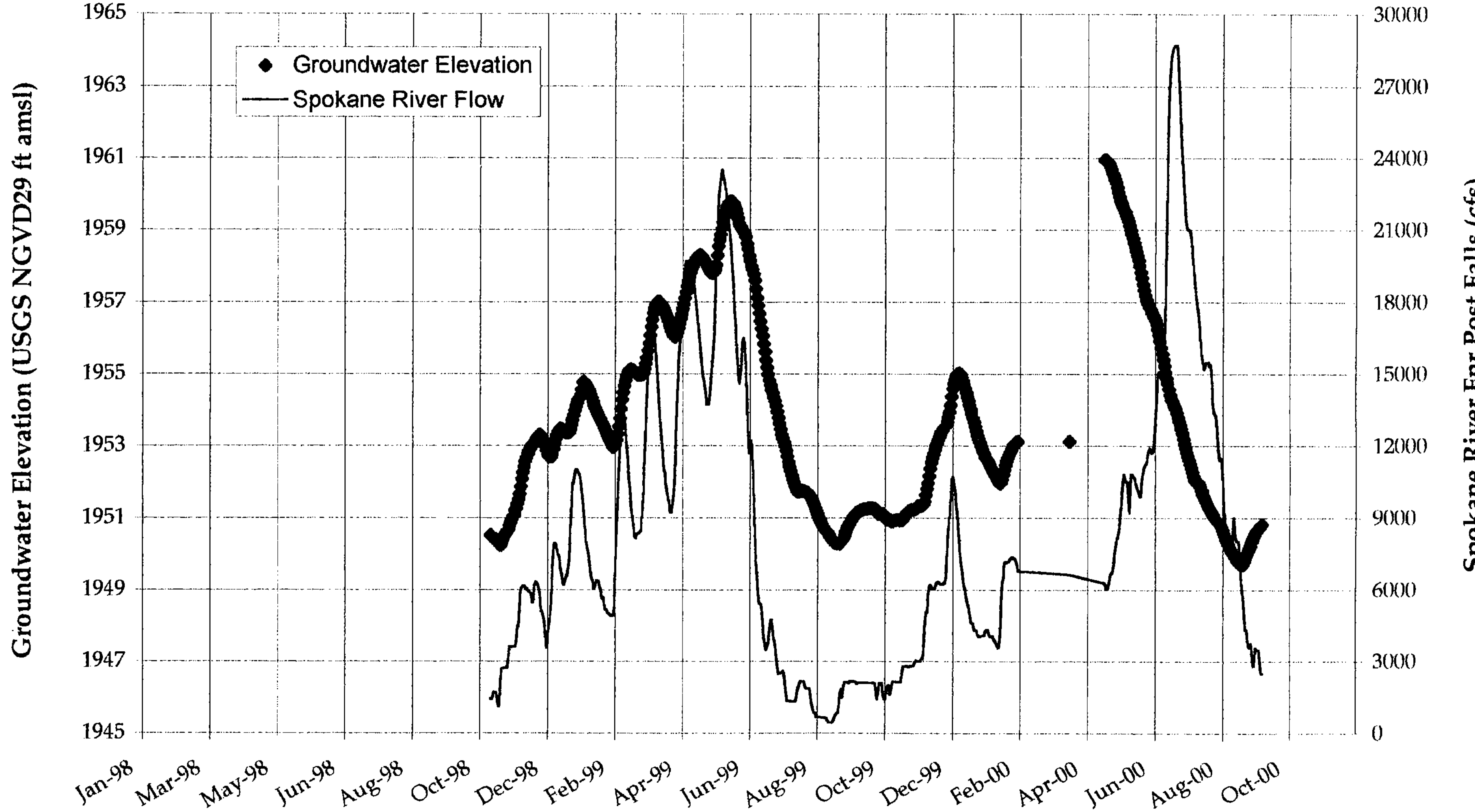
FIGURE D2-4:
Barker and Euclid Well
(CID Barker N)
5/1999-8/2000

Spokane Co. / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-4 barkereuclid.xls/D2-4 hydro



Data Source: Spokane County
Date Type : Daily averages from transducer data
Station Name: Barker and Centennial Trial S Well, Barker South 1
Station ID: 5508M02

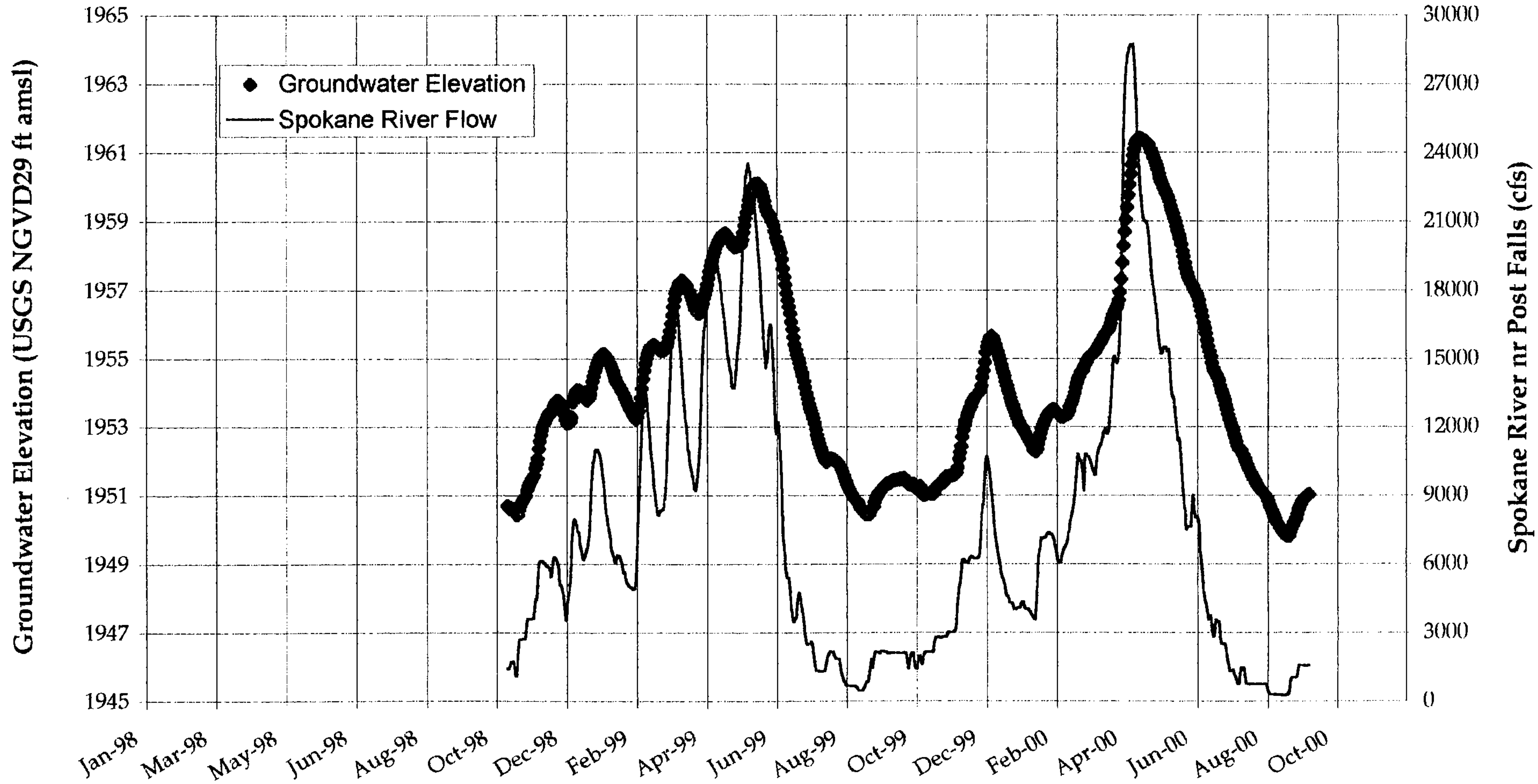
FIGURE D2-5:
Barker and Centennial Trail S Well
(Barker South 1)
11/1998-9/2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-5 barkercenttrailS.xls/D2-5 hydro

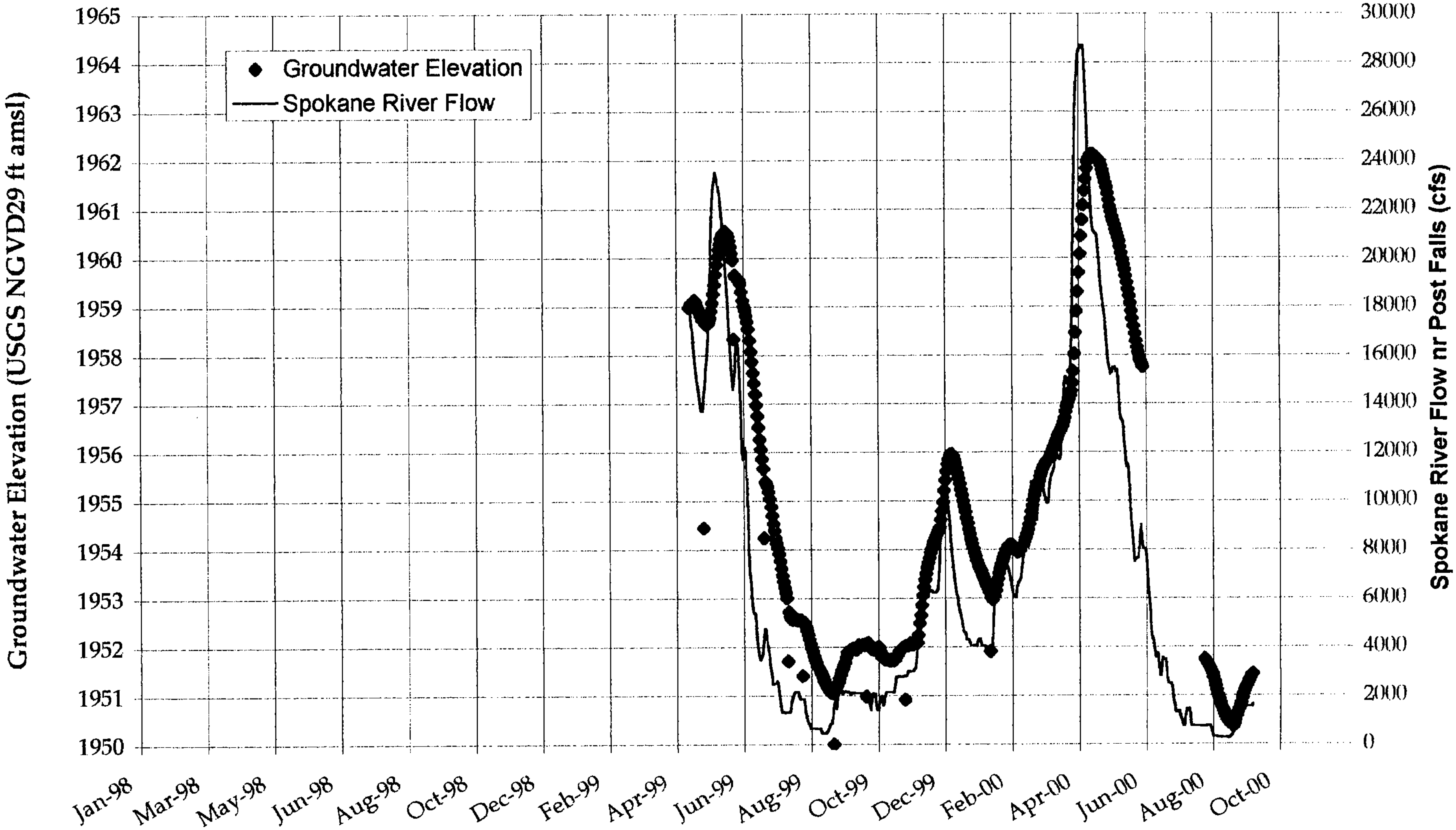


Data Source: Spokane County
Date Type : Daily Averages
Station Name: Barker and Centennial Trail N, Barker South 2
Station ID: 5508M01

FIGURE D2-6:
Barker and Centennial Trail North Well
(Barker South 2)
11/1998-9/2000

Spokane Co. / Level 1 Assess / WA

Golder Associates



Data Source: Spokane County
Date Type : Daily averages from transducer data
Station Name: Barker and Mission Well, CID Barker S
Station ID: 5517D05

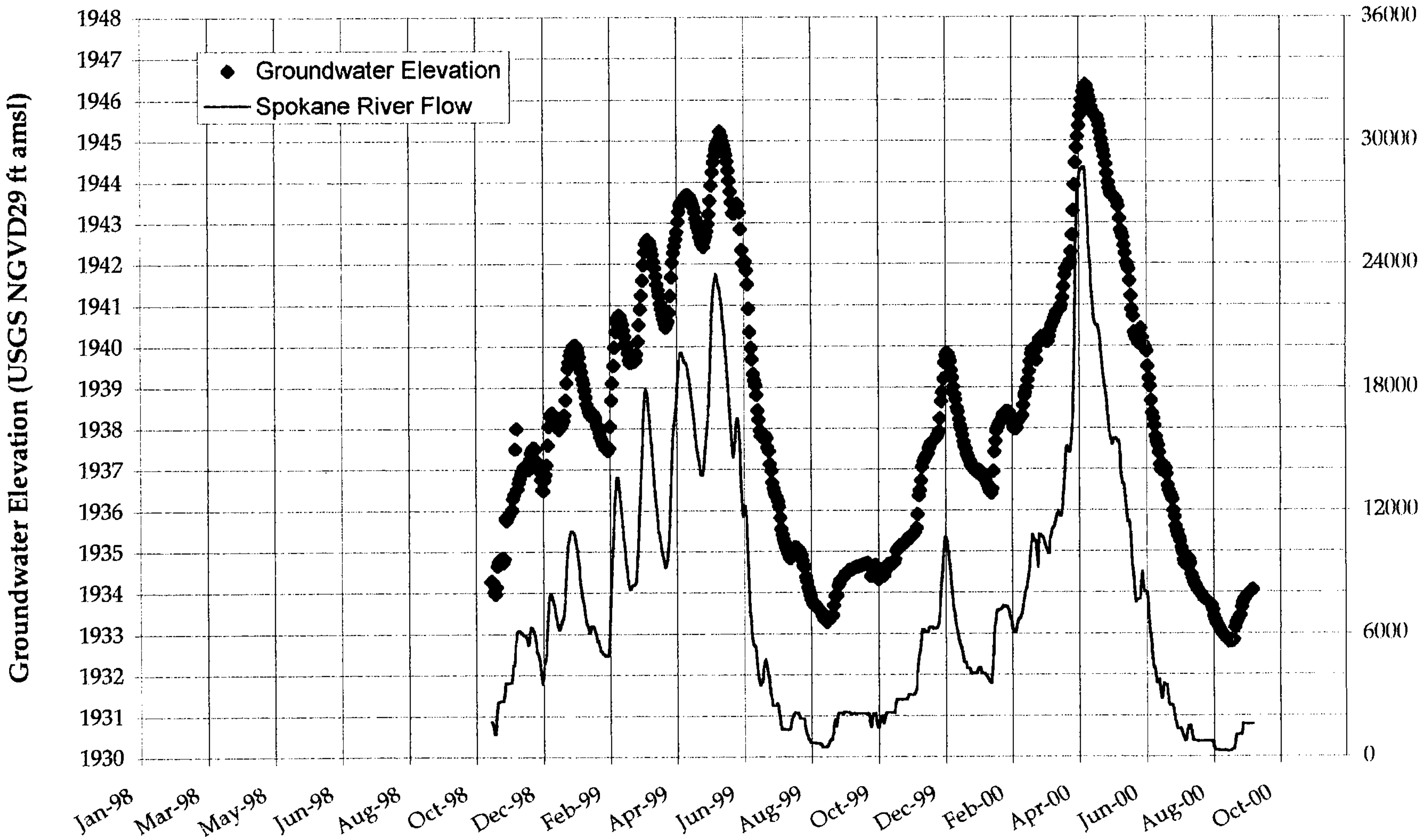
FIGURE D2-7:
Barker and Mission Well
(CID Barker S)
5/1999-9/2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-7 barkermission.xls/D2-7 hydro



Data Source: Spokane County
Date Type : Daily Averages from transducer data
Station Name: Sullivan South
Station ID: 5411R04

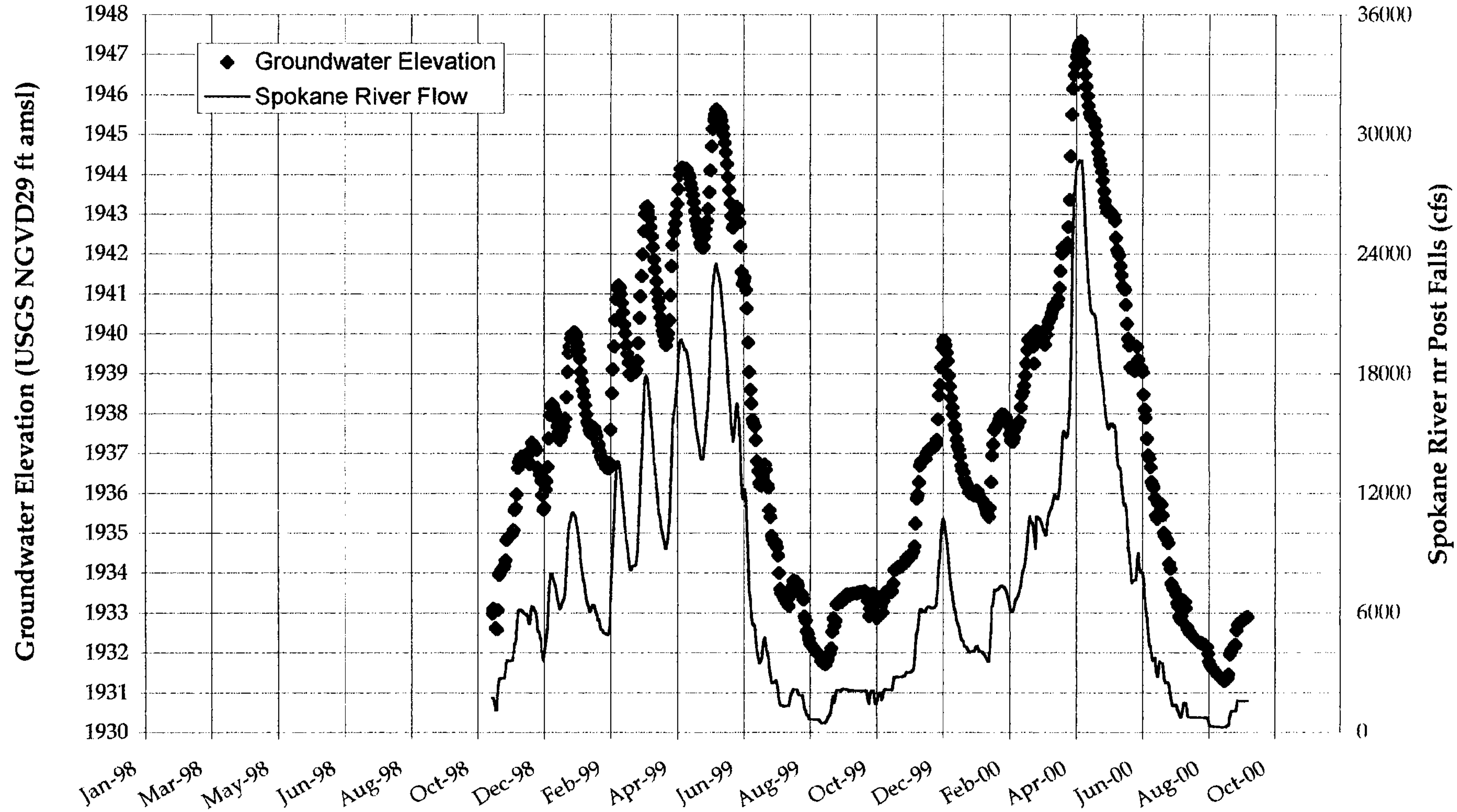
FIGURE D2-8:
Sullivan South Well
11/1998-9/2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-8 sullivanS.xls/D2-8 hydro

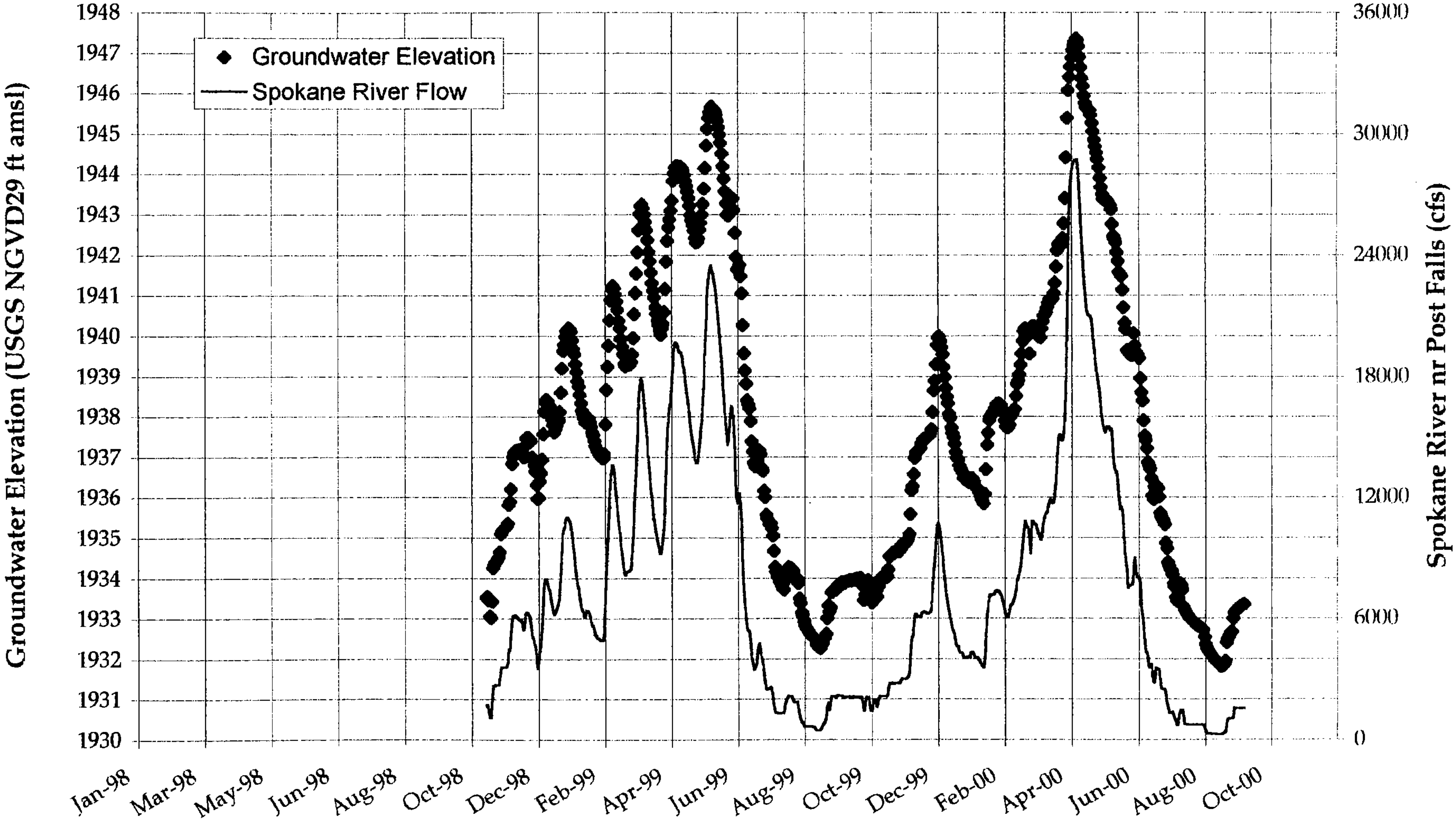


Data Source: Spokane County
Date Type : Daily averages from transducer data
Station Name: Sullivan Park South, Sullivan North 2
Station ID: 5411R03

FIGURE D2-9:
Sullivan Park South Well
(Sullivan North 2)
11/1998-9/2000

Spokane Co. / Level 1 Assess / WA

Golder Associates



Data Source: Spokane County
Date Type : Daily averages from transducer data
Station Name: Sullivan Park North, Sullivan North 1
Station ID: 5411R02

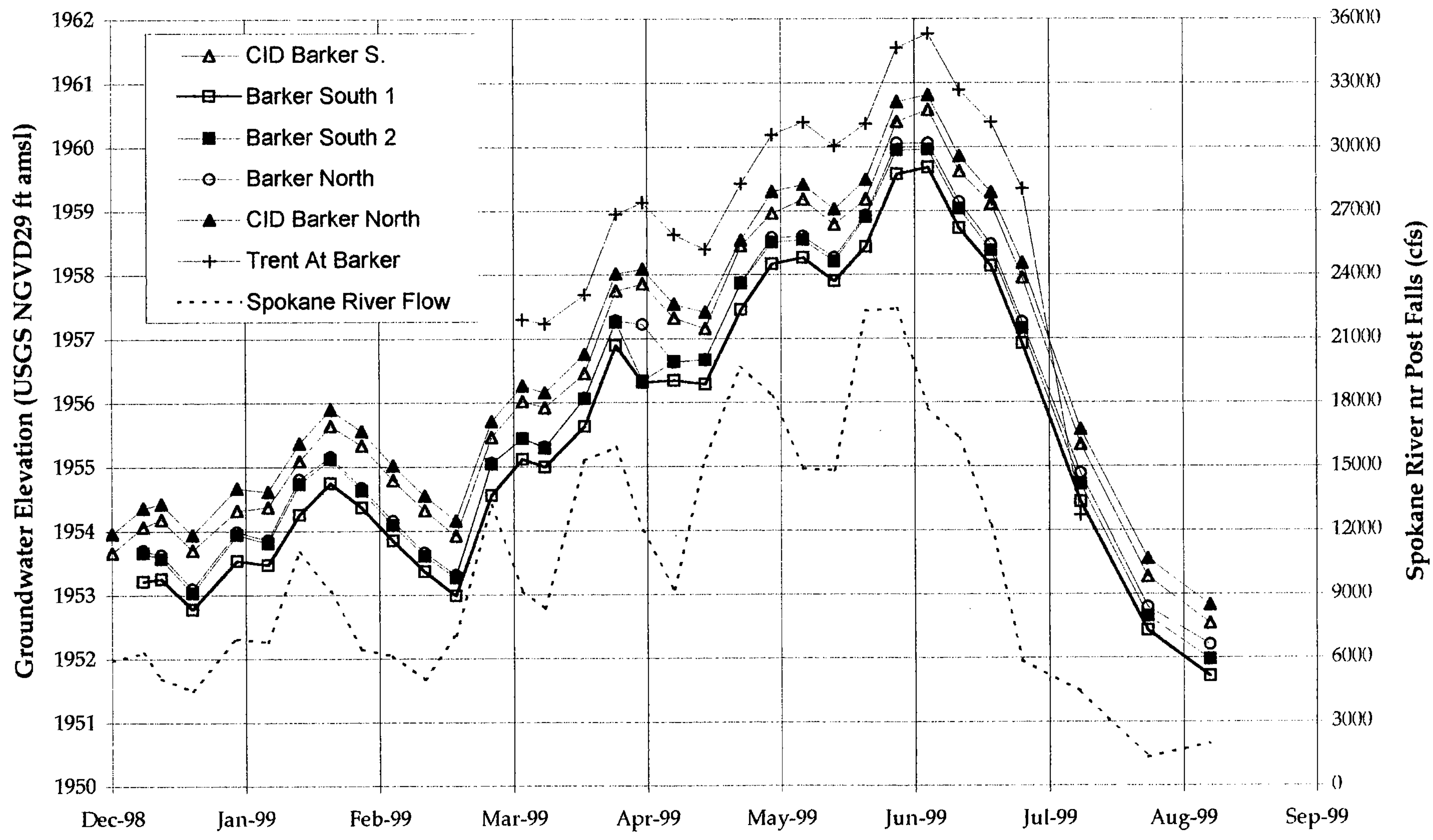
FIGURE D2-10:
Sullivan Park North Well
(Sullivan North 1)
11/1998-9/2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

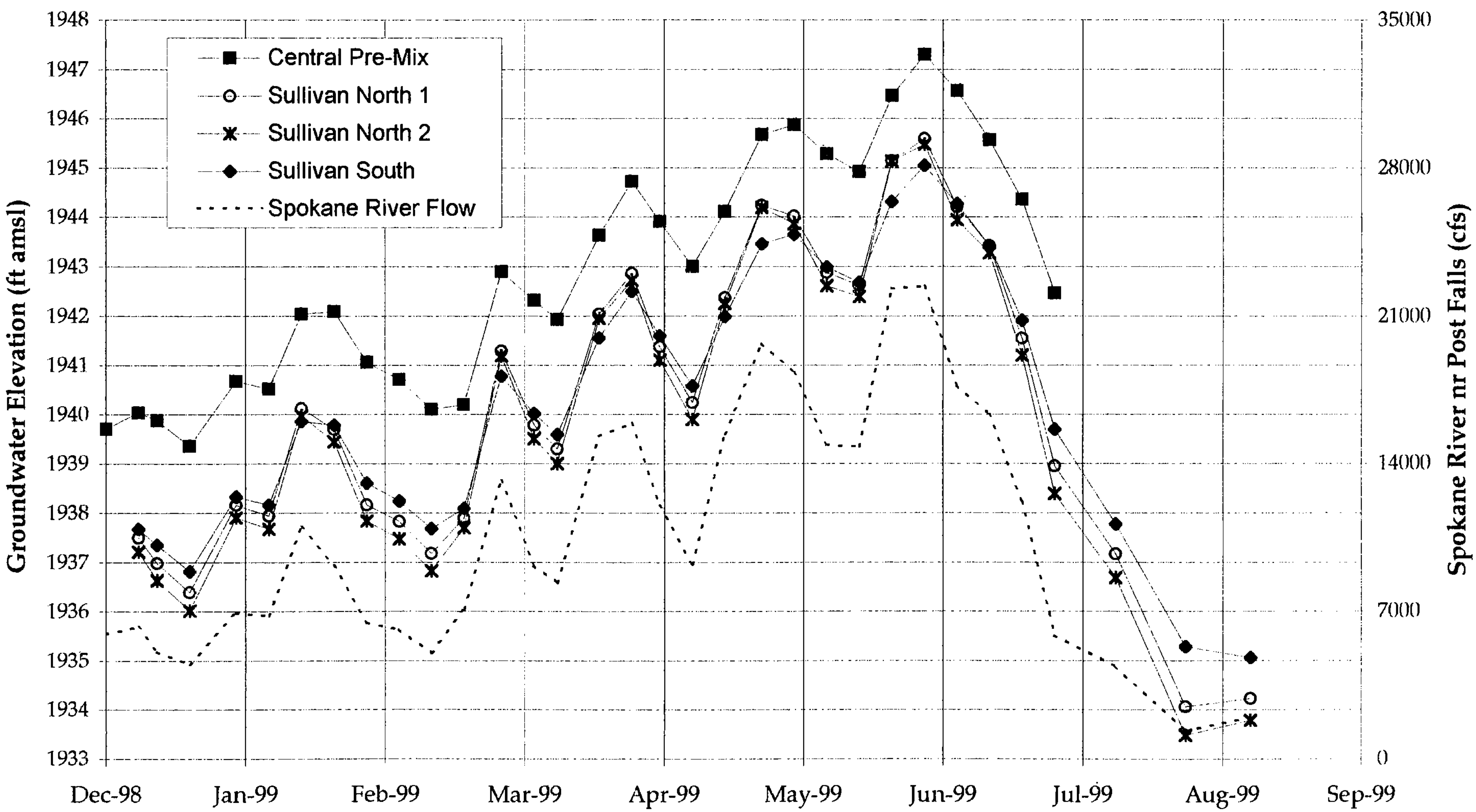
D2-10 sullivanpkN.xls/D2-10 hydro



Data Source: Spokane County **Date Type :** Weekly **Station Name:** Spokane County Baseline Monitoring **Station ID:** Barker Wells	**FIGURE D2-11:** **Spokane County Baseline** **Barker Wells** Spokane Co. / Level 1 / WA Golder Associates

013-1372.1100 April 13, 2001 well data.xls

D2-11to13 SR-SVRP.xls/D2-11 Barker



Data Source: Spokane County
Date Type : Weekly
Station Name: Sullivan Wells
Station ID: na

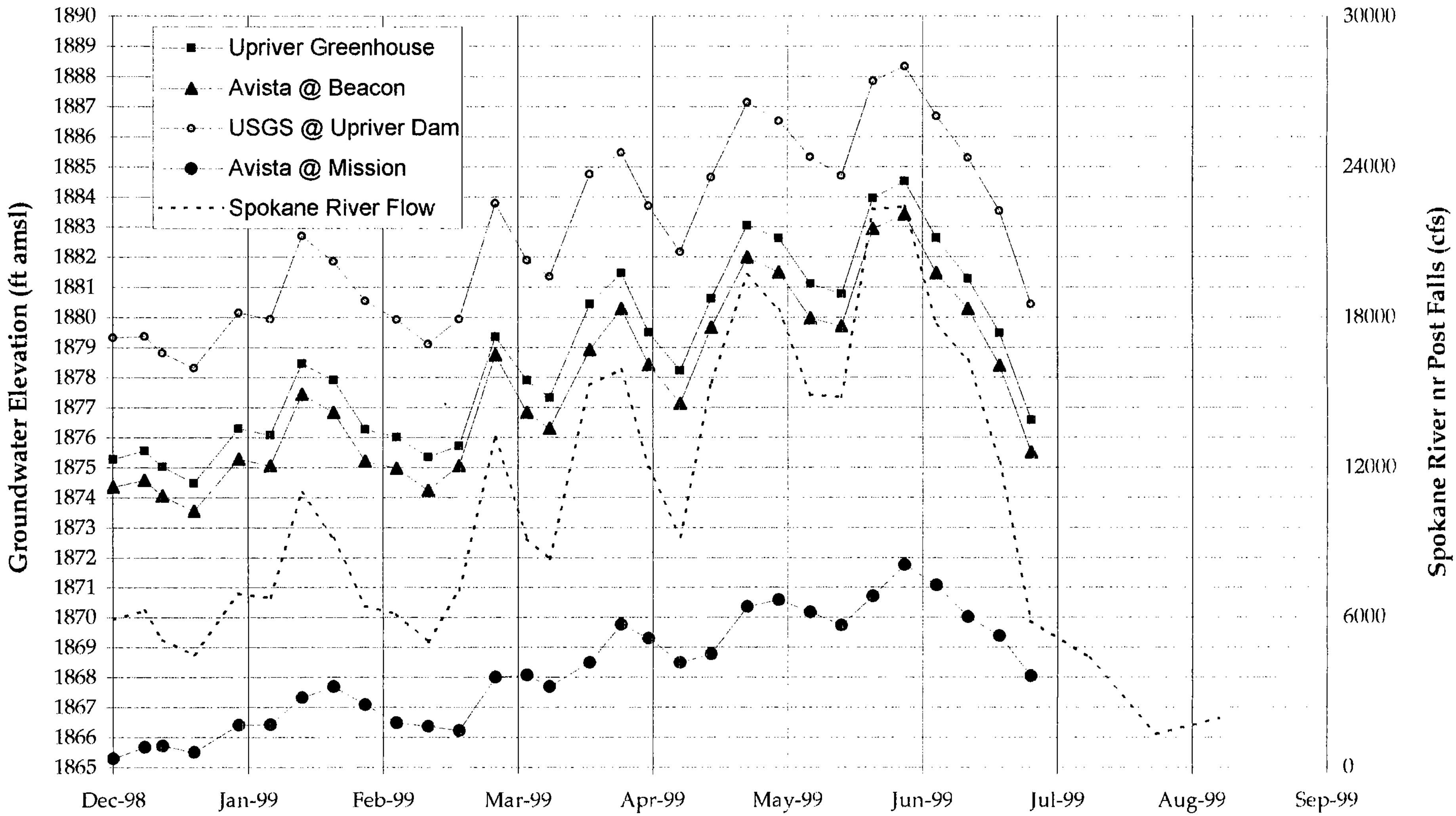
FIGURE D2-12:
Spokane County Baseline
Sullivan Wells

Spokane Co. / Level 1 / WA

Golder Associates

013-1372.1100 April 13, 2001 well data.xls

D2-11to13 SR-SVRP.xls/D2-12 Sullivan



Data Source: Spokane County
Date Type : Weekly
Station Name: Upriver Wells
Station ID: na

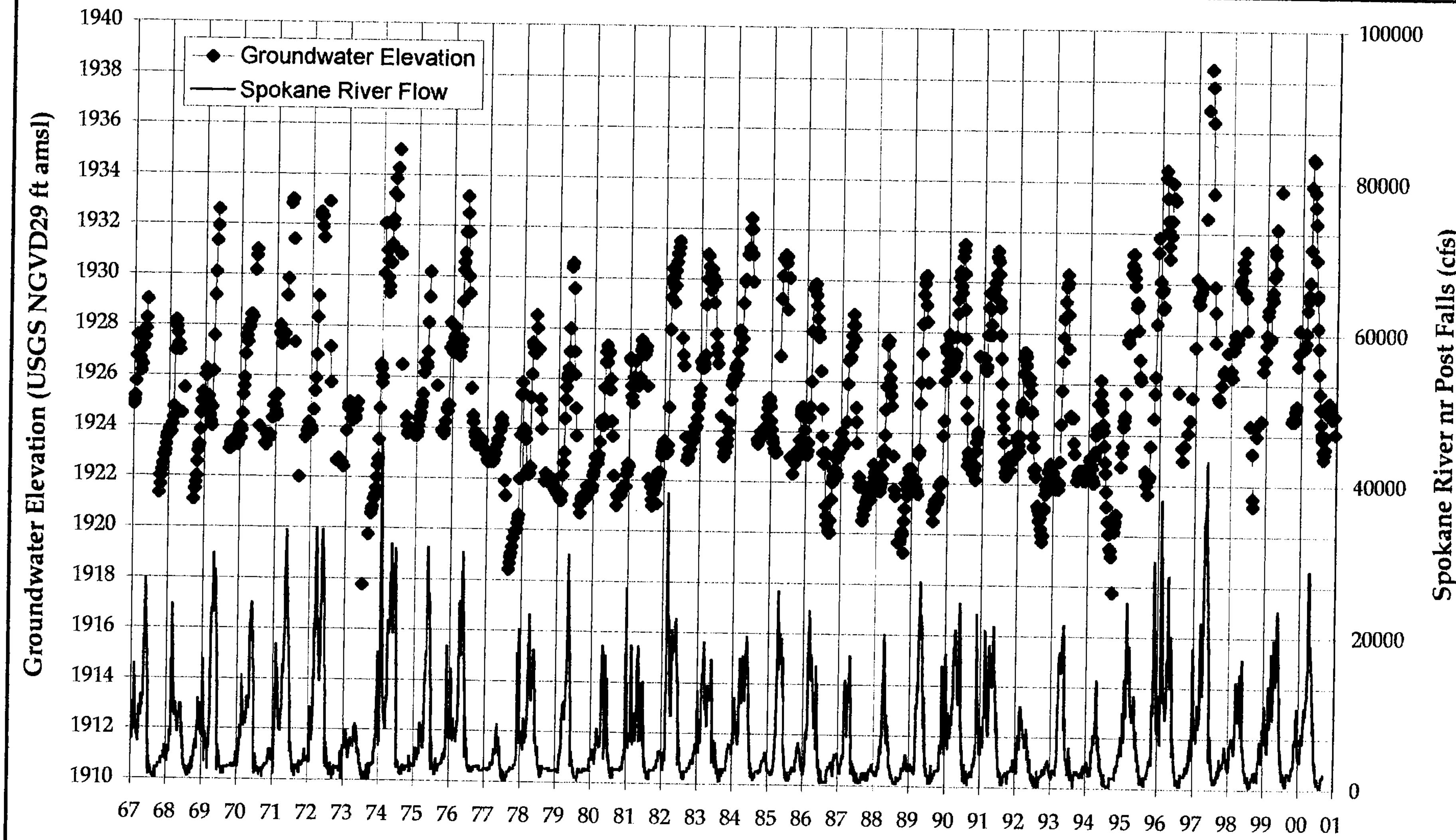
FIGURE D2-13:
Spokane County Baseline
Upriver Wells

Spokane Co. / Level 1 / WA

Golder Associates

013-1372.1100 April 13, 2001 well data.xls

D2-11to13 SR-SVRP.xls/D2-13 Upriver



Data Source: Vera Water District
Date Type : Weekly
Station Name: Vera Water District Well #1
Station ID: 5415J01

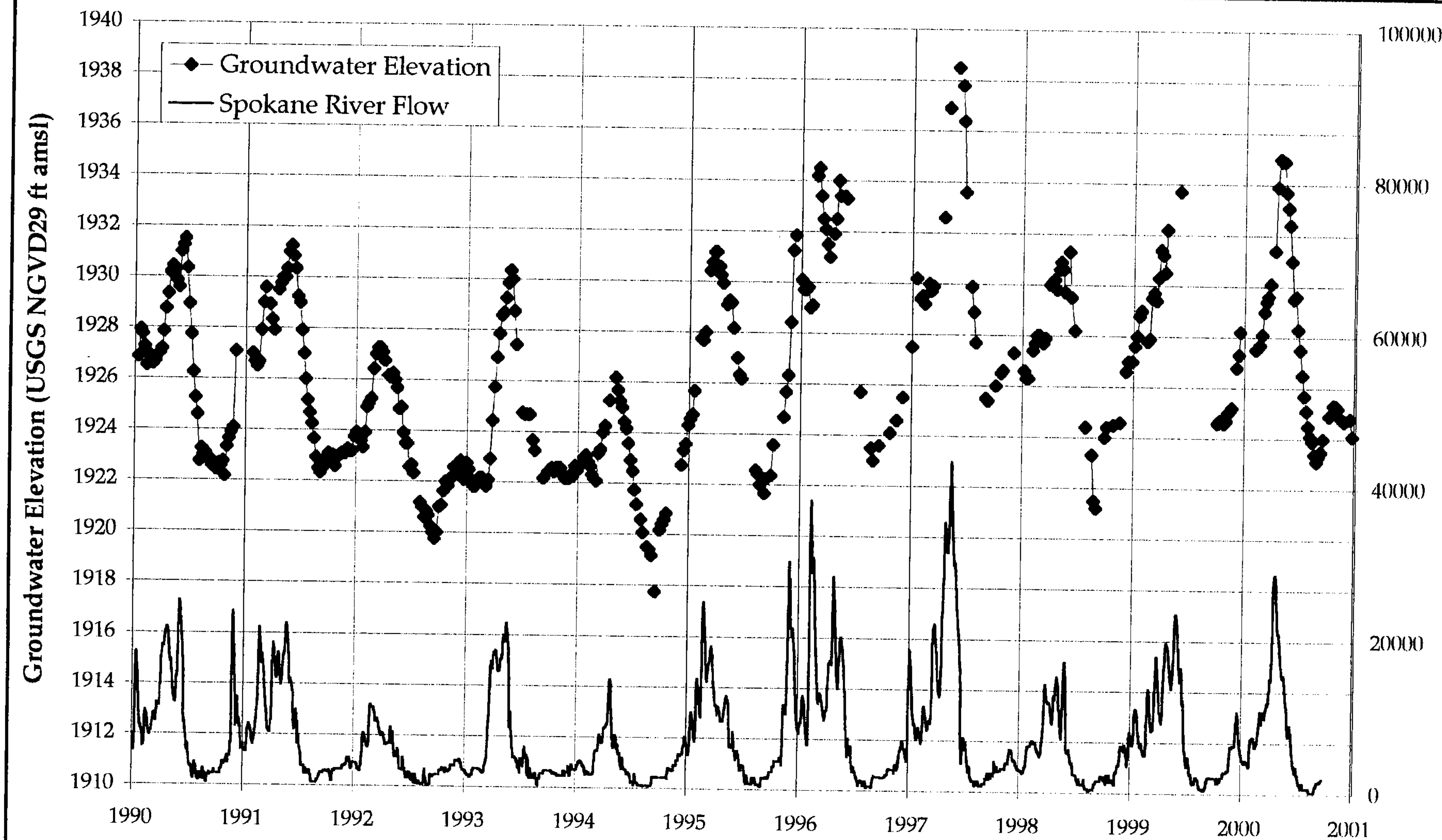
FIGURE D2-14:
Vera Water District Well #1
1/1967-12/2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-14to29 Vera.xls/D2-14 Vera #1 all



Data Source: Vera Water District
Date Type : Weekly
Station Name: Vera Water District Well #1
Station ID: 5415J01

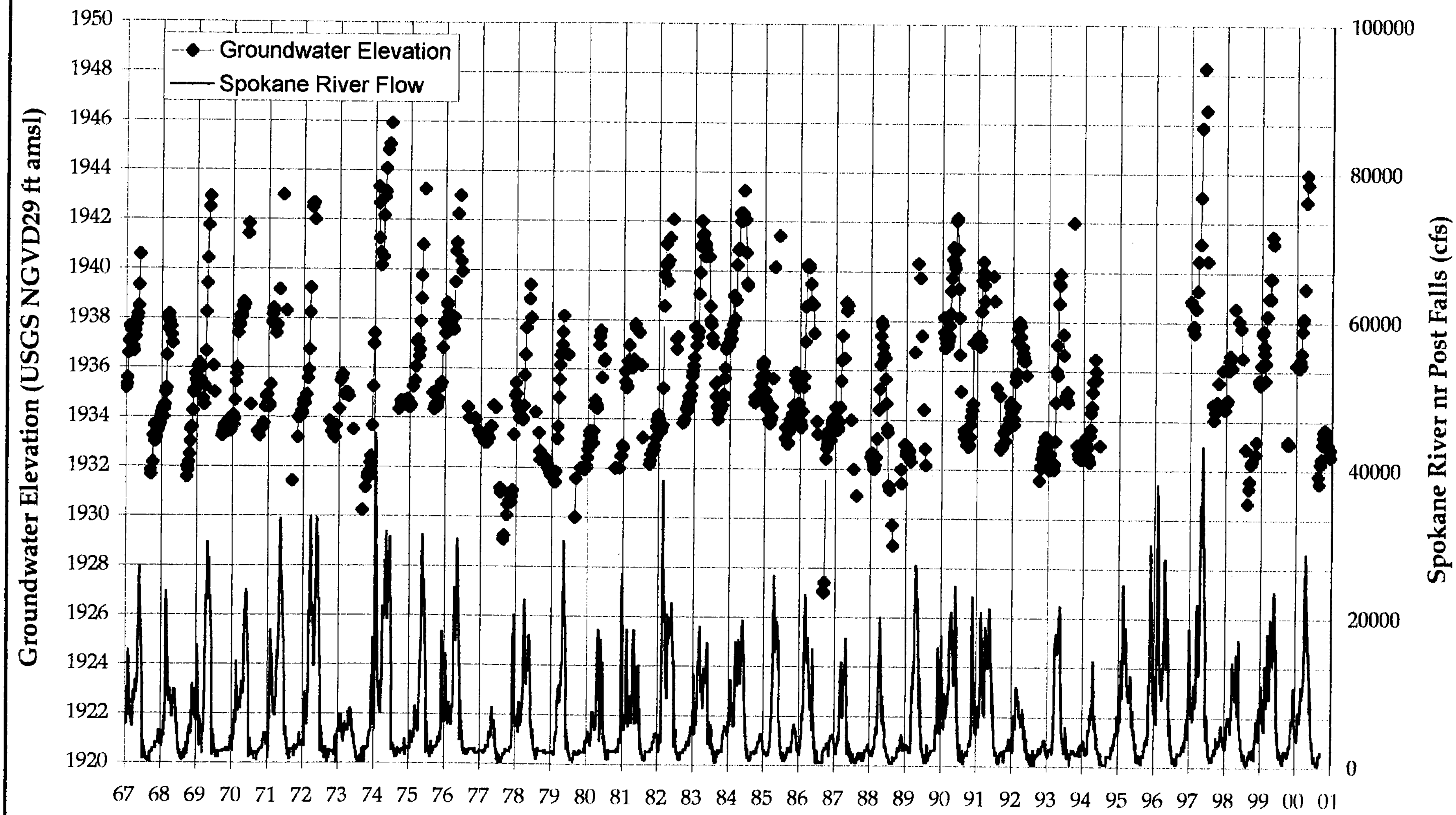
FIGURE D2-15:
Vera Water District Well #1
1990 - 2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-14to29 Vera.xls/D2-15 Vera #1 1990-2000



Data Source: Vera Water District
Date Type : Weekly
Station Name: Vera Water District Well #2
Station ID: 5413M01(1967-1994), 5414J01 (1994 - 2001)

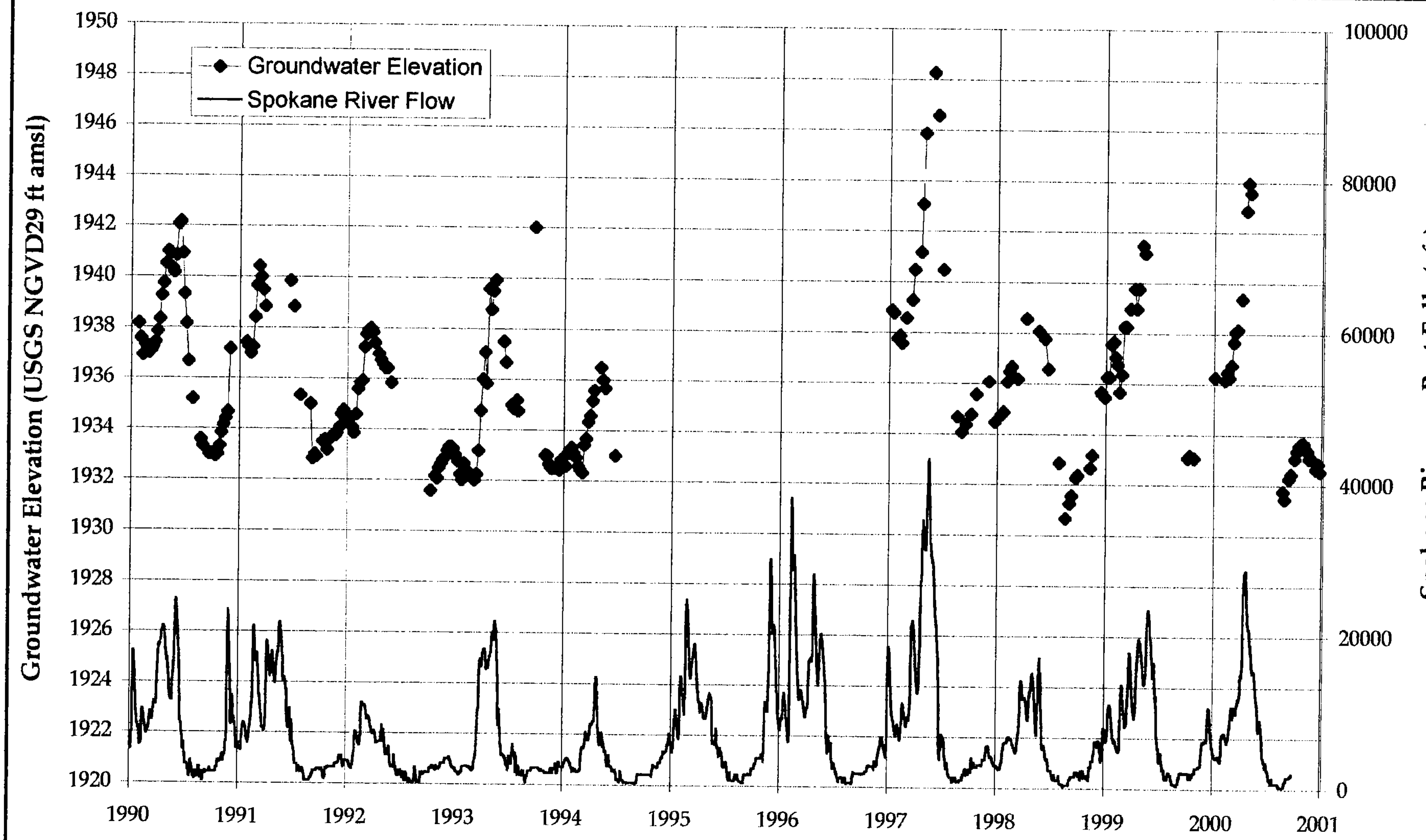
FIGURE D2-16:
Vera Water District Well #2
1/1967-12/2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-14to29 Vera.xls/D2-16 Vera #2 all



Data Source: Vera Water District
Date Type : Weekly
Station Name: Vera Water District Well #2
Station ID: 5413M01(1967-1994), 5414J01 (1994 - 2001)

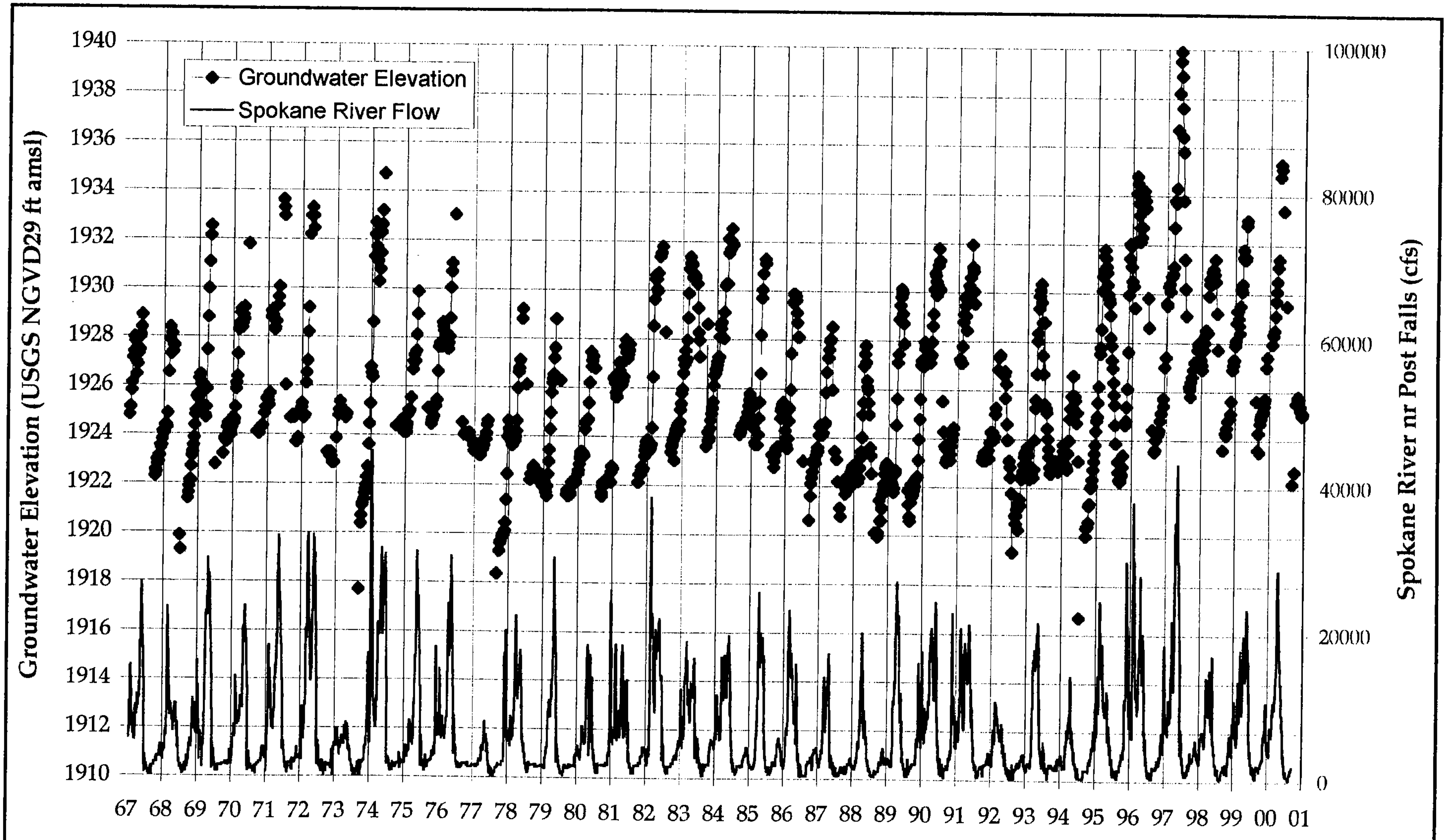
FIGURE D2-17:
Vera Water District Well #2
1990 - 2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-14to29 Vera.xls/D2-17 Vera #2 1990-2000



Data Source: Vera Water District
Date Type : Weekly
Station Name: Vera Water District Well #3
Station ID: 5422R01

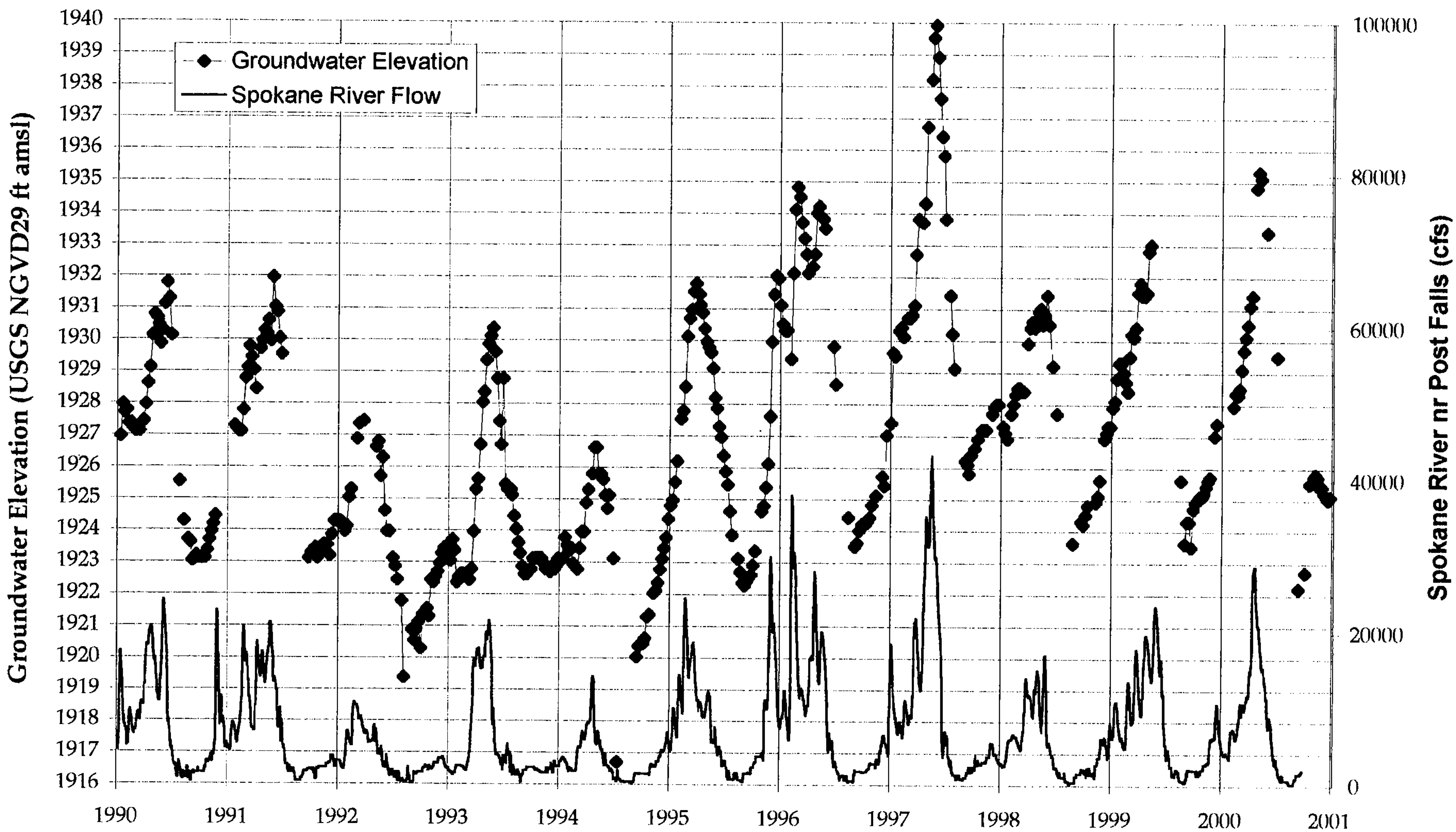
FIGURE D2-18:
Vera Water District Well #3
1/1967-12/2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-14to29 Vera.xls/D2-18 Vera #3 all



Data Source: Vera Water District
Date Type : Weekly
Station Name: Vera Water District Well #3
Station ID: 5422R01

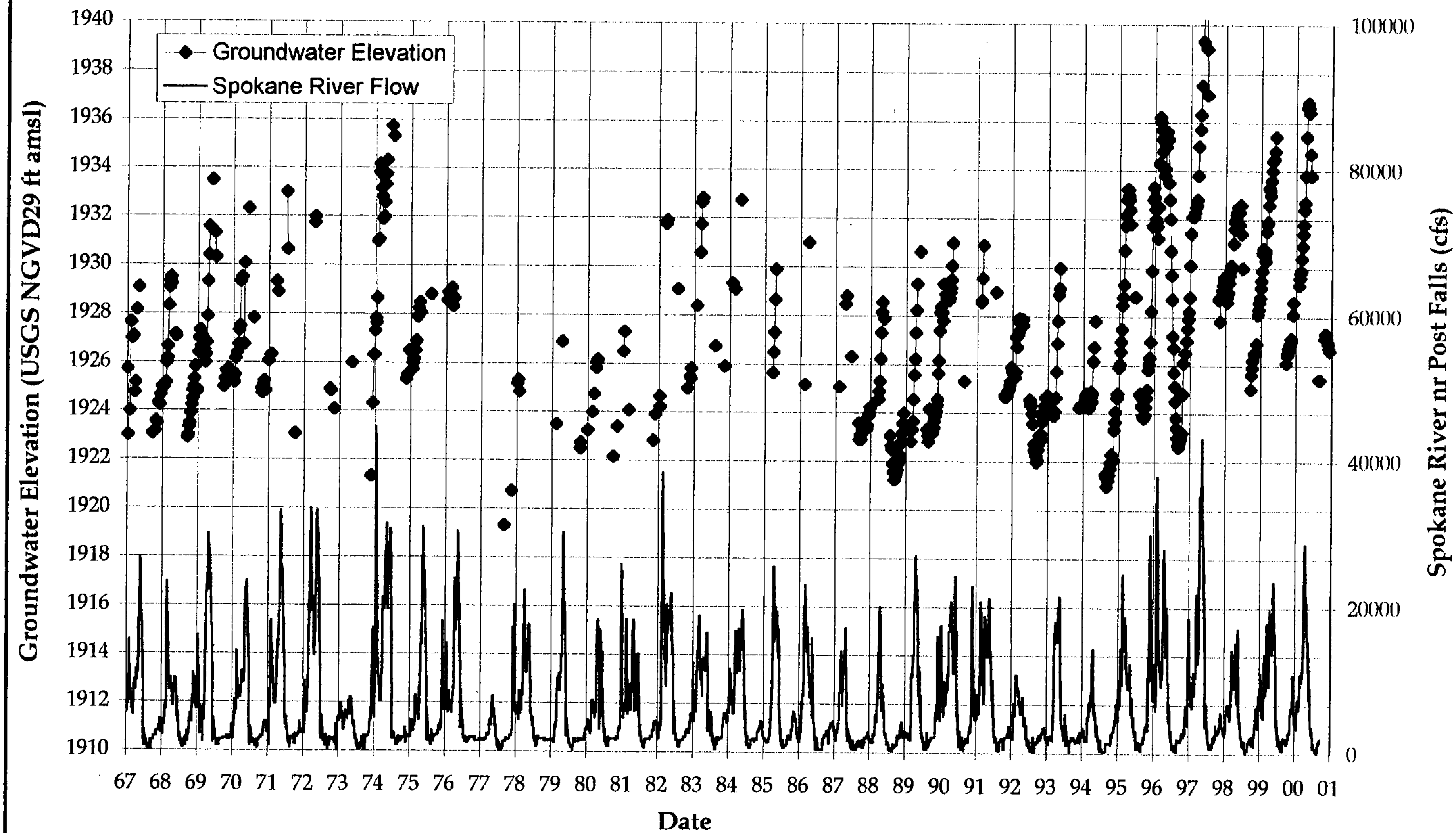
FIGURE D2-19:
Vera Water District Well #3
1990 - 2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-14to29 Vera.xls/D2-19 Vera #3 1990-2000



Data Source: Vera Water District
Date Type : Weekly
Station Name: Vera Water District Well #4
Station ID: 5426L01

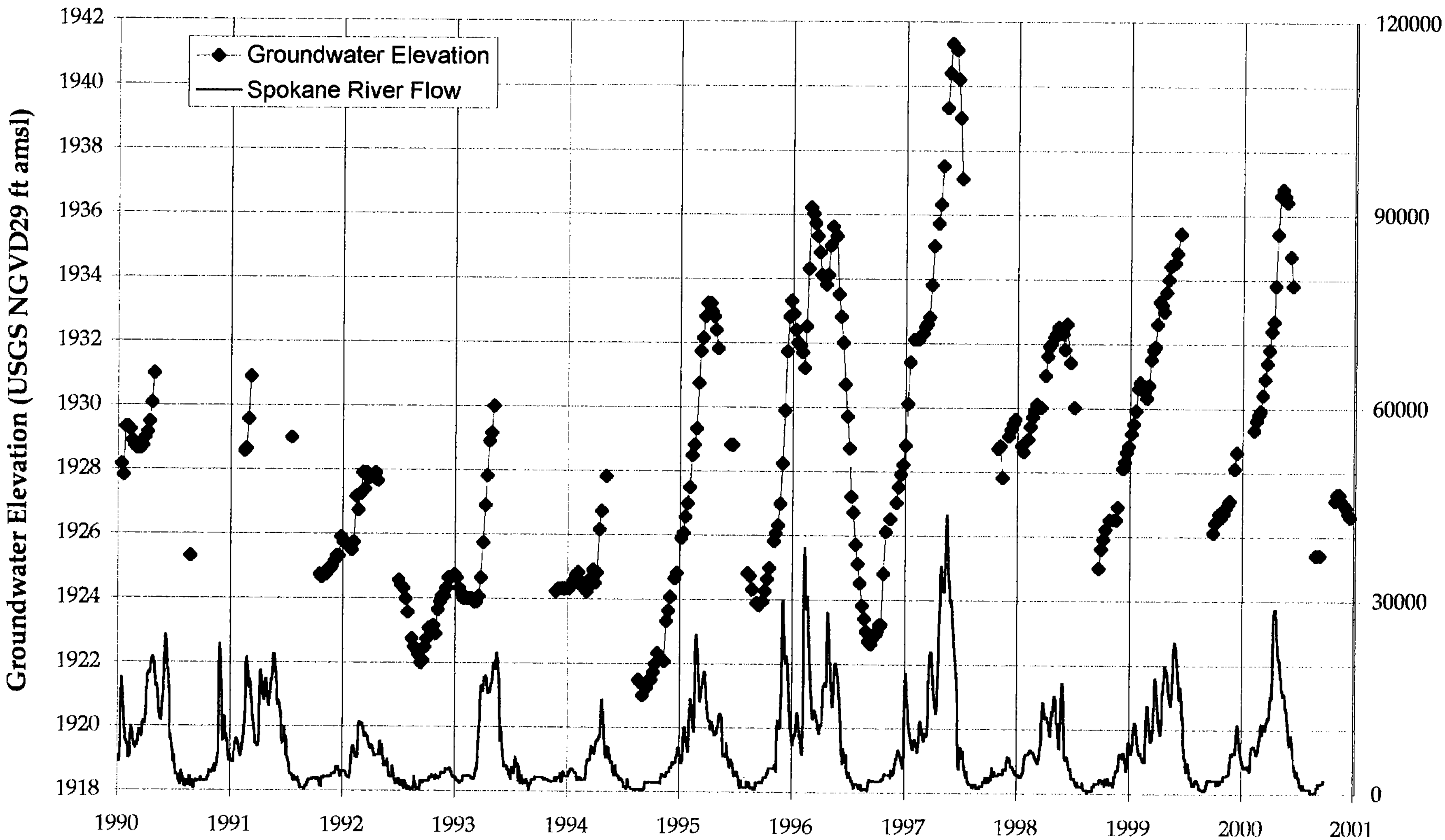
FIGURE D2-20:
Vera Water District Well #4
1/1967-12/2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-14to29 Vera.xls/D2-20 Vera #4



Data Source: Vera Water District
Date Type : Weekly
Station Name: Vera Water District Well #4
Station ID: 5426L01

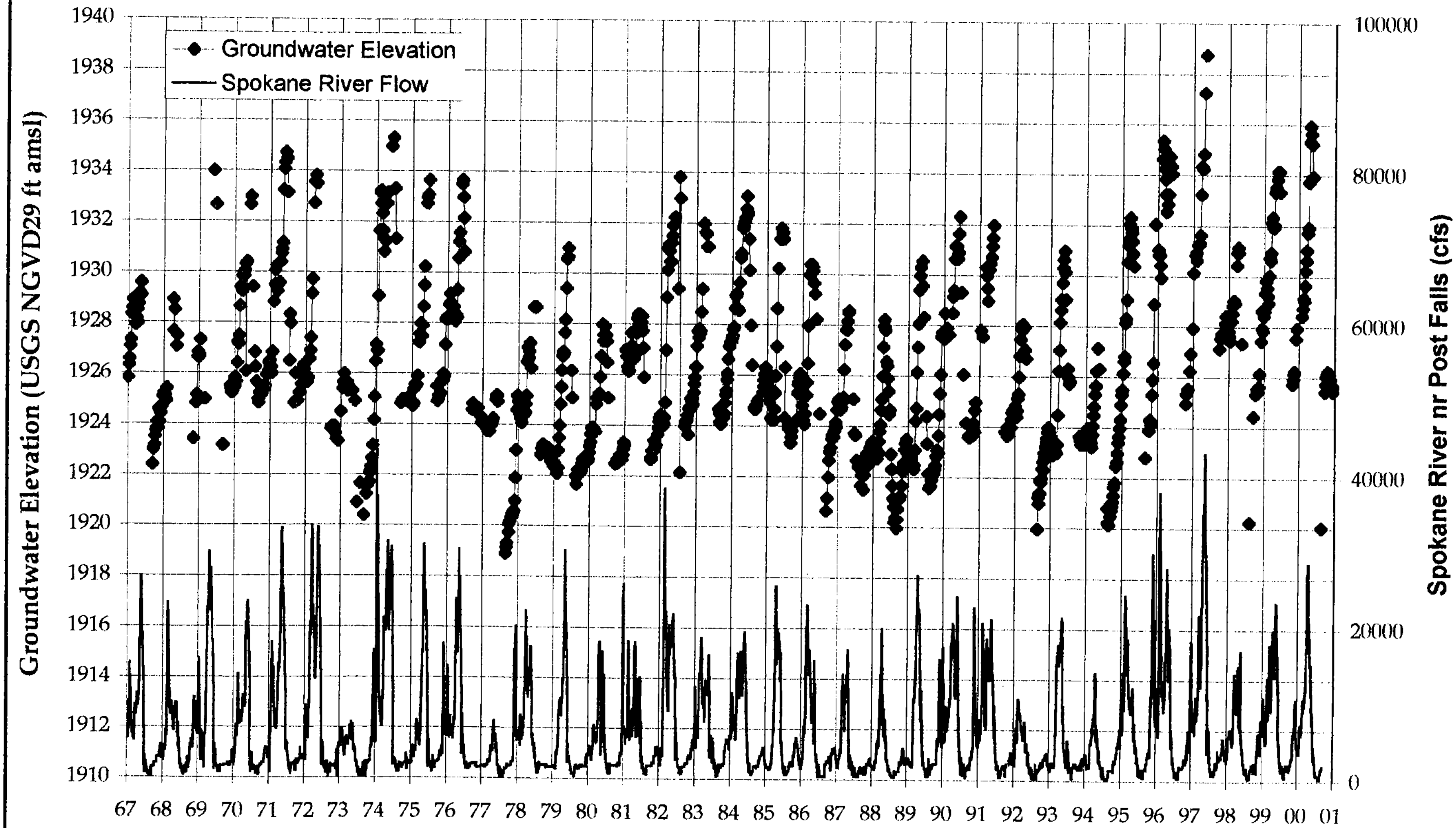
FIGURE D2-21:
Vera Water District Well #4
1990 - 2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-14to29 Vera.xls/D2-21 Vera #4 1990-2000



Data Source: Vera Water District
Date Type : Weekly
Station Name: Vera Water District Well #5
Station ID: 5426D01

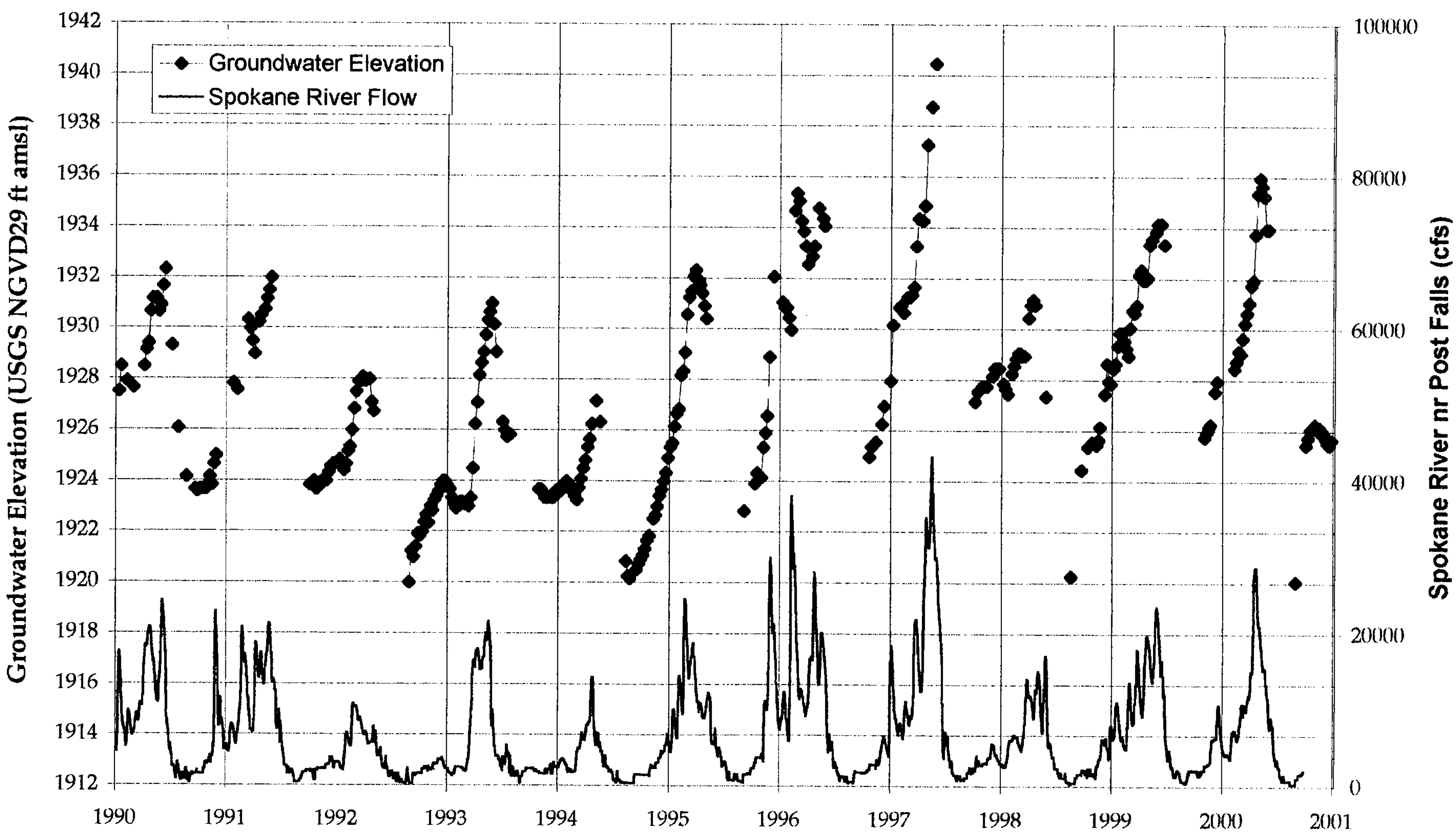
FIGURE D2-22:
Vera Water District Well #5
1/1967-12/2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-14to29 Vera.xls/D2-22 Vera #5

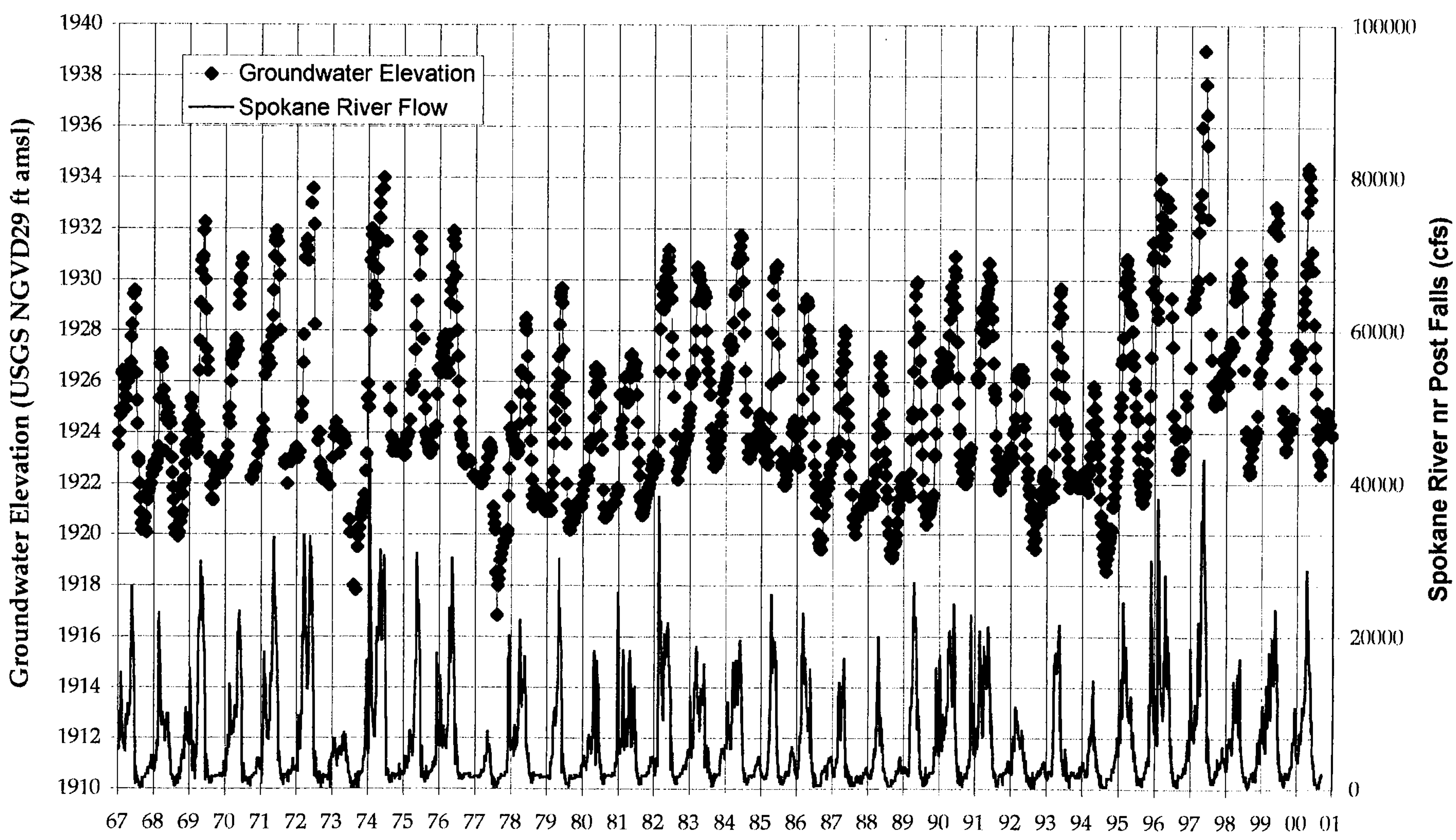


Data Source: Vera Water District
Date Type : Weekly
Station Name: Vera Water District Well #5
Station ID: 5426D01

FIGURE D2-23:
Vera Water District Well #5
1990 - 2000

Spokane Co / Level 1 Assess / WA

Golder Associates

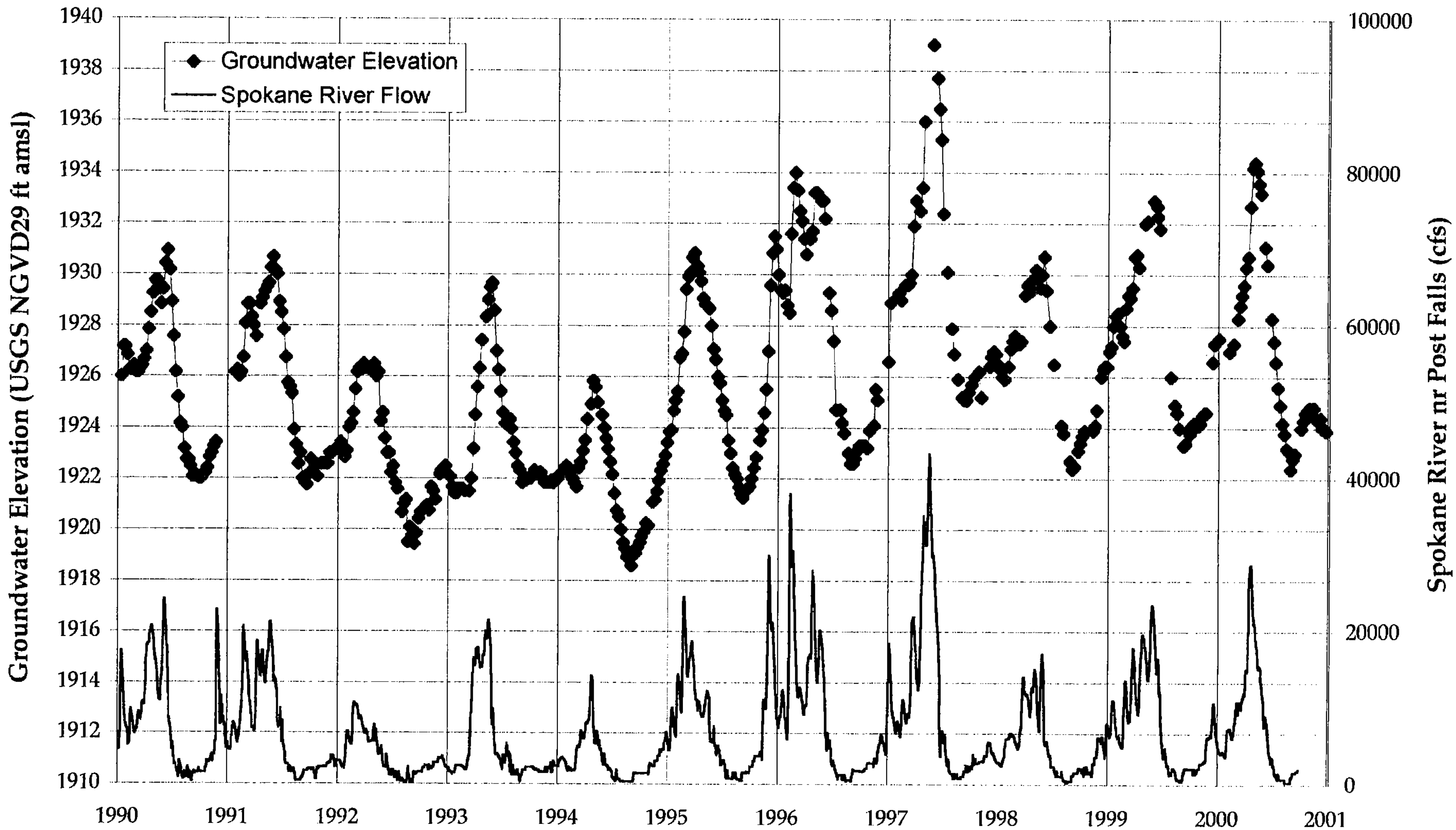


Data Source: Vera Water District
Date Type : Weekly
Station Name: Vera Water District Well #6
Station ID: 5422H02

FIGURE D2-24:
Vera Water District Well #6
1/1967-12/2000

Spokane Co / Level 1 Assess / WA

Golder Associates

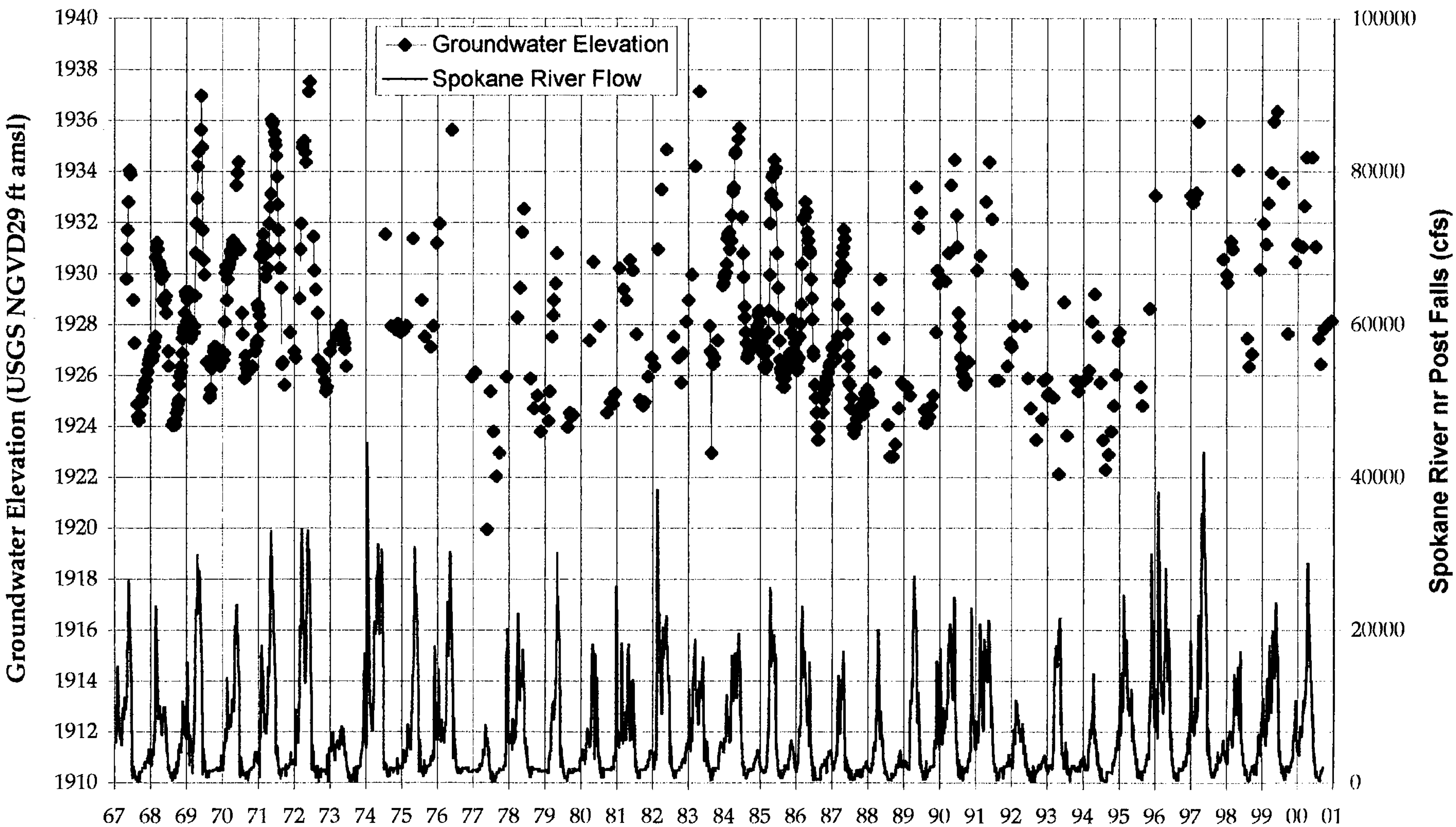


Data Source: Vera Water District
Date Type : Weekly
Station Name: Vera Water District Well #6
Station ID: 5422H02

FIGURE D2-25:
Vera Water District Well #6
1990 - 2000

Spokane Co / Level 1 Assess / WA

Golder Associates

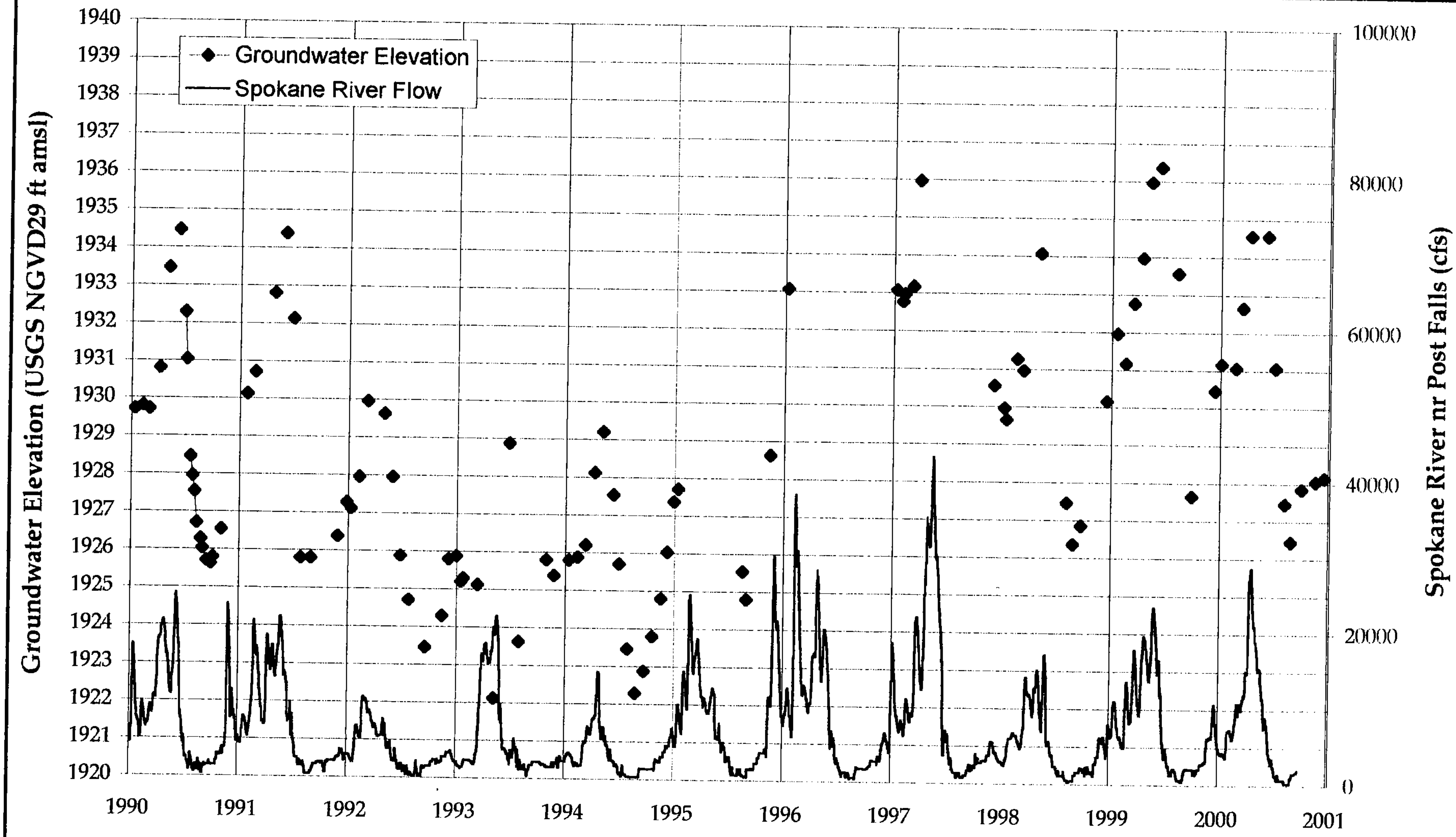


Data Source: Vera Water District
Date Type : Monthly
Station Name: Vera Water District Well #7
Station ID: 5423C01

FIGURE D2-26:
Vera Water District Well #7
1/1967-12/2000

Spokane Co / Level 1 Assess / WA

Golder Associates



Data Source: Vera Water District
Date Type : Monthly
Station Name: Vera Water District Well #7
Station ID: 5423C01

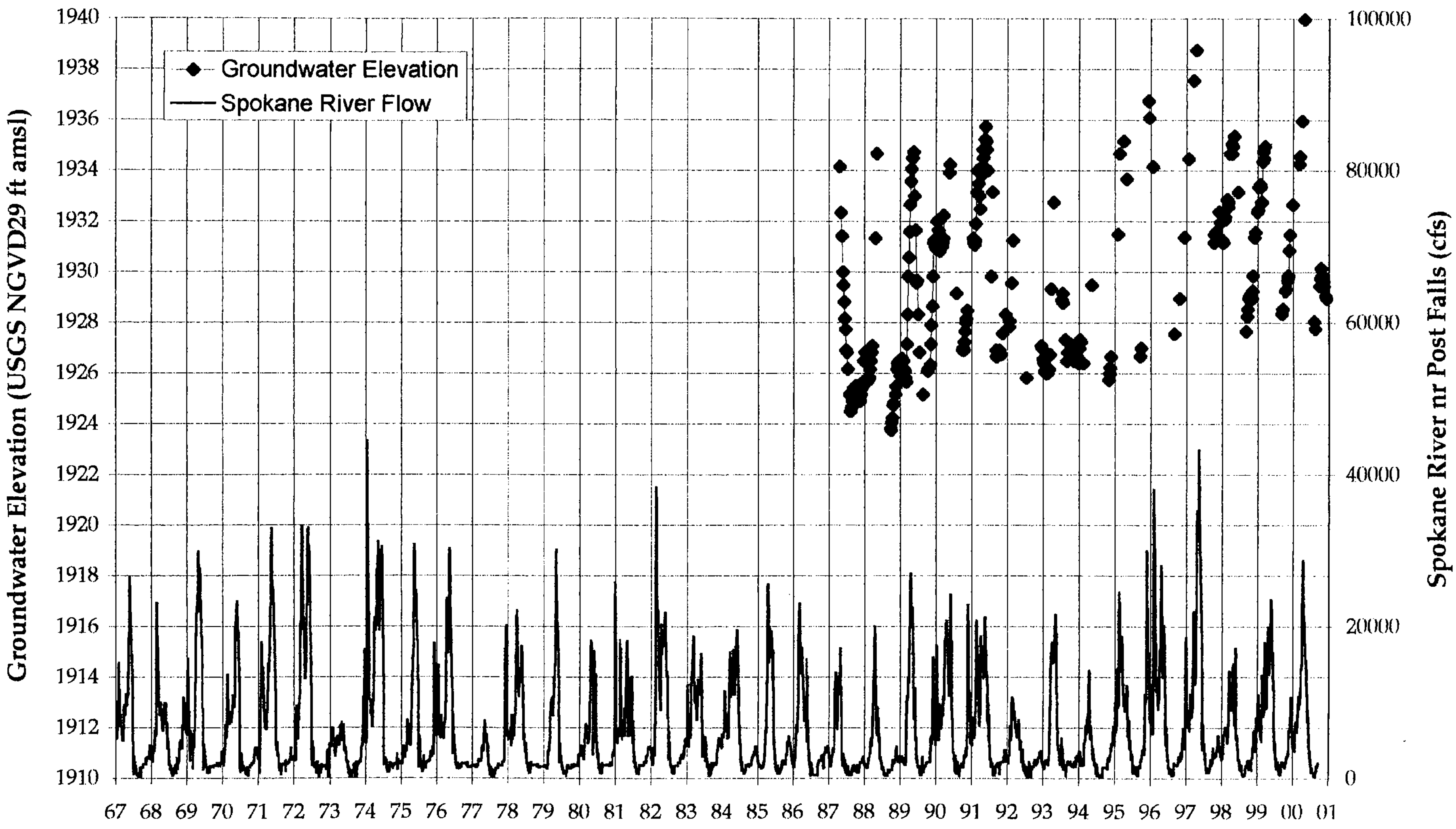
FIGURE D2-27:
Vera Water District Well #7
1990 - 2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-14to29 Vera.xls/D2-27 Vera #7 1990-2000



Data Source: Vera Water District
Date Type : Monthly
Station Name: Vera Water District Well #8
Station ID: 5423J03

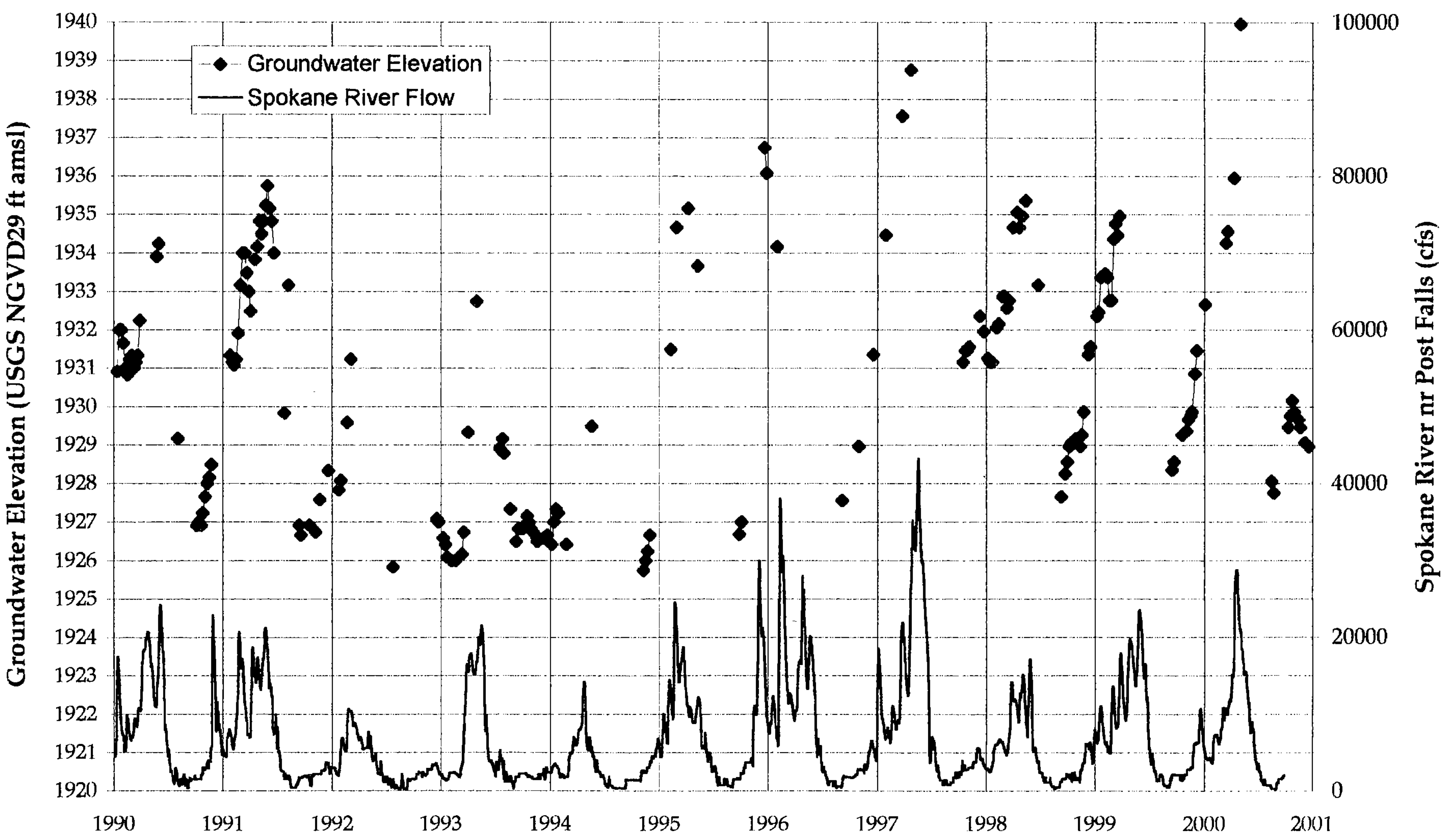
FIGURE D2-28:
Vera Water District Well #8
5/1987-12/2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-14to29 Vera.xls/D2-28 Vera #8



Data Source: Vera Water District
Date Type : Monthly
Station Name: Vera Water District Well #8
Station ID: 5423J03

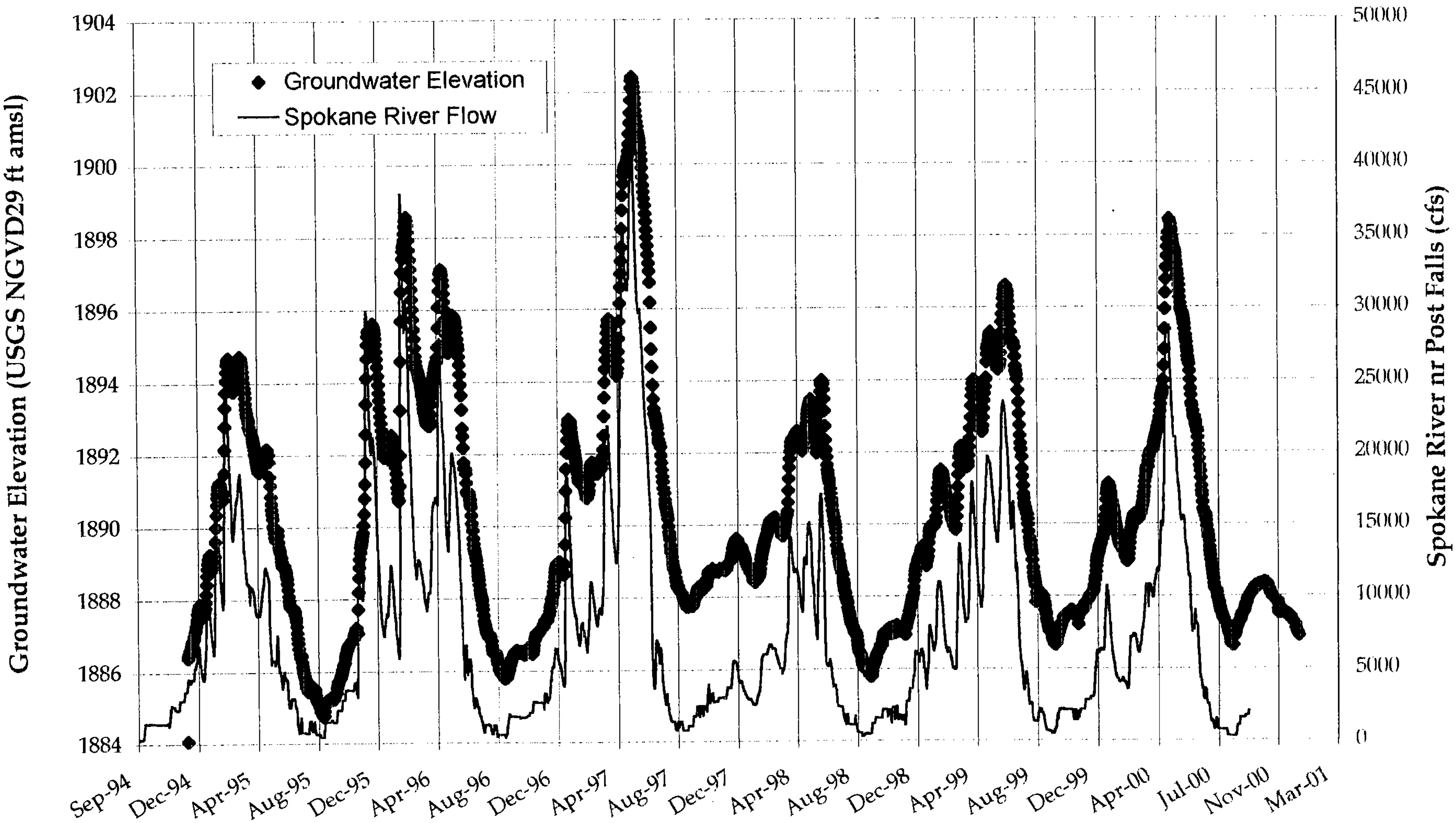
FIGURE D2-29:
Vera Water District Well #8
1990 - 2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-14to29 Vera.xls/D2-29 Vera #8 1990-2000



Data Source: City of Spokane
Date Type : Daily Averages from transducer data
Station Name: Felts Field Monitoring Well
Station ID: 5312C01

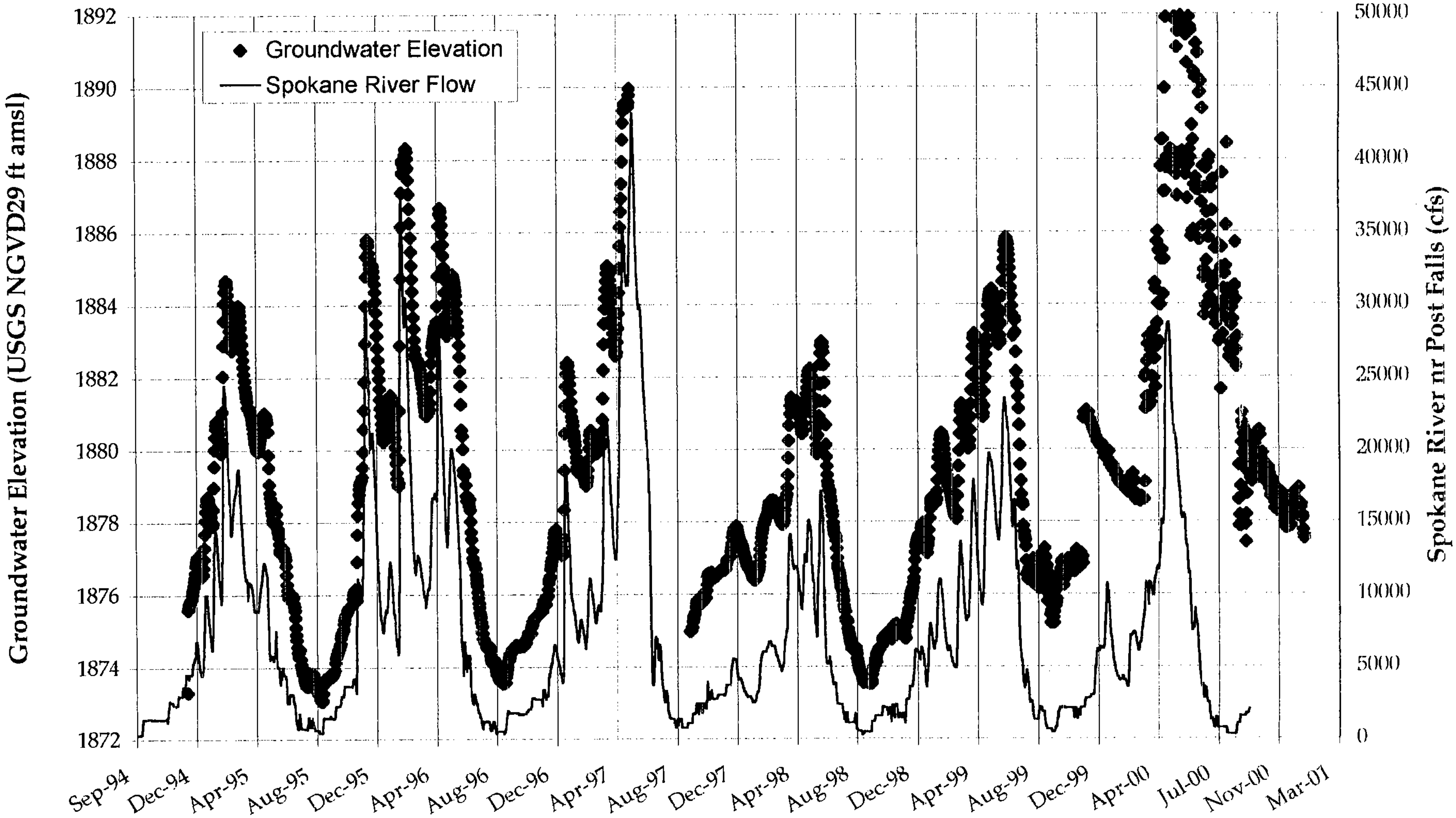
FIGURE D2-30:
Felts Field Monitoring Well
11/1994 - 1/2001

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-30to38 CityData.xls/D2-30 Felts Field Well



Data Source: City of Spokane
Date Type : Daily Averages from transducer data
Station Name: Central Pre-Mix at Yardley Monitoring Well
Station ID: 5314E01

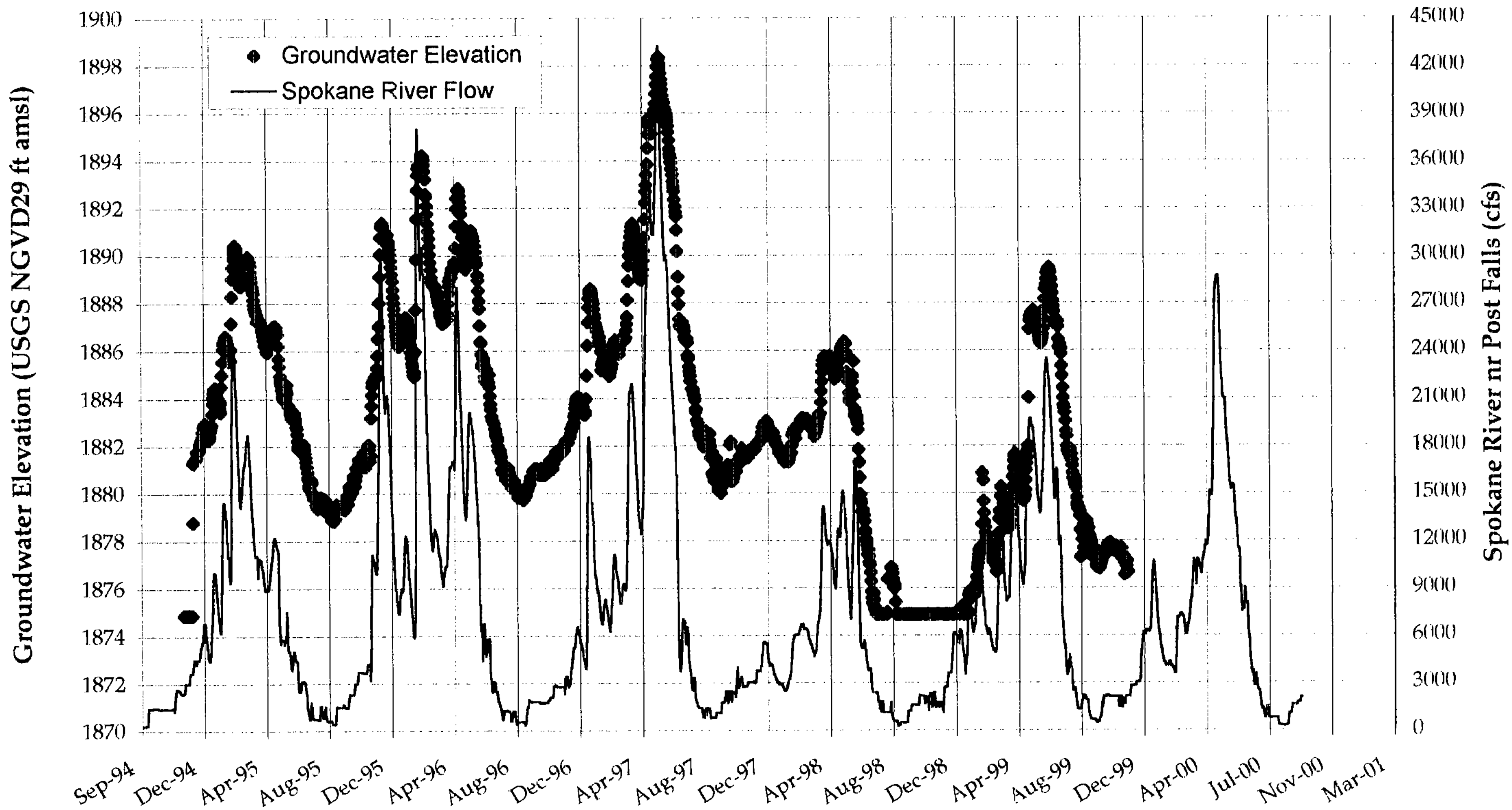
FIGURE D2-31:
Central Pre-Mix at Yardley Monitoring Well
12/1994 - 1/2001

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-30to38 CityData.xls/D2-31 Central Pre-Mix Yardley

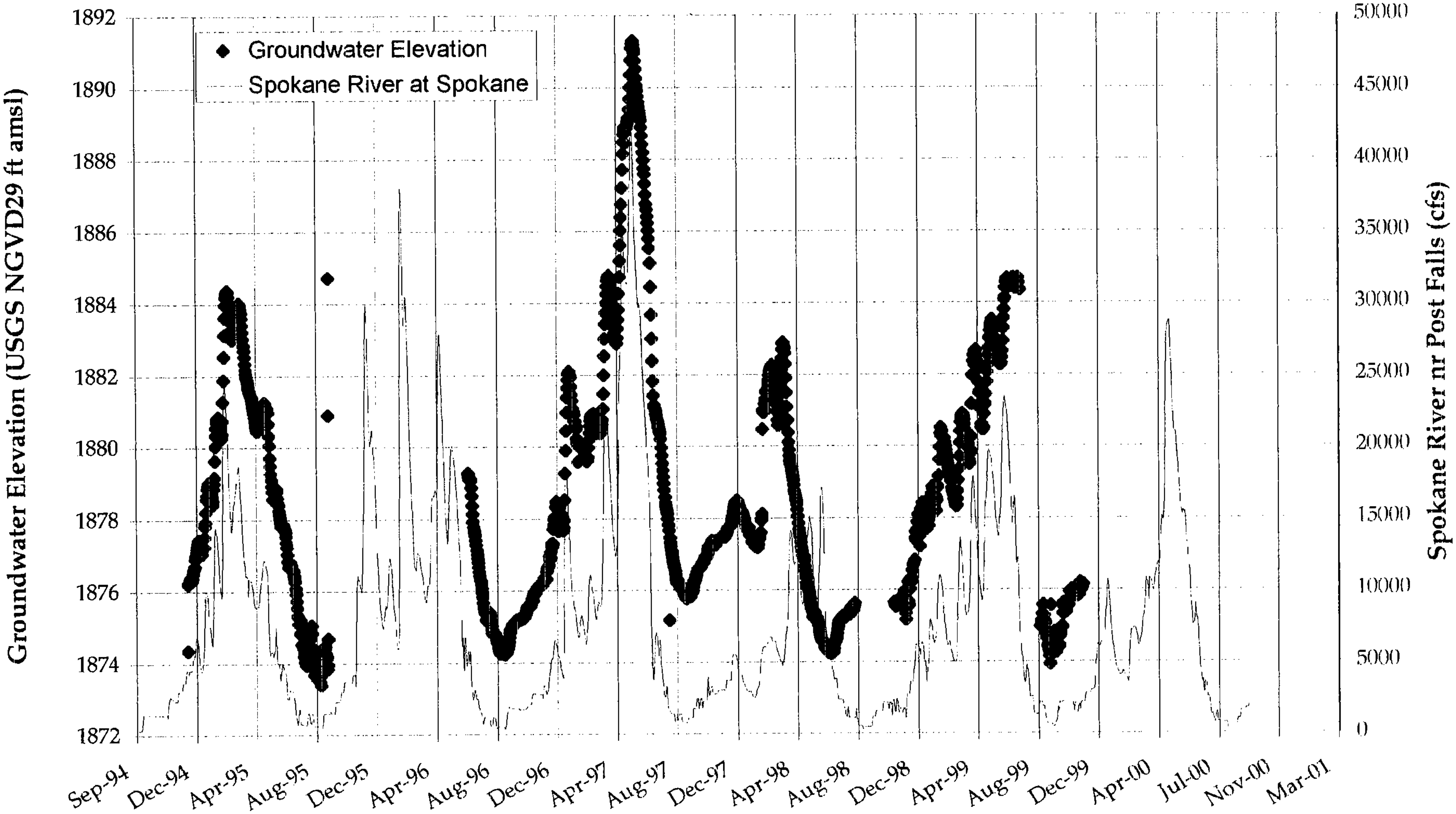


Data Source: City of Spokane
Date Type : Daily Averages from transducer data
Station Name: Hale's Nested Site - Mid Well, Monitoring Well
Station ID: 5311J07

FIGURE D2-32:
Hale's Nested Site - Mid Well
(Parkwater #2) Monitoring Well
11/1994 - 11/1999

Spokane Co / Level 1 Assess / WA

Golder Associates

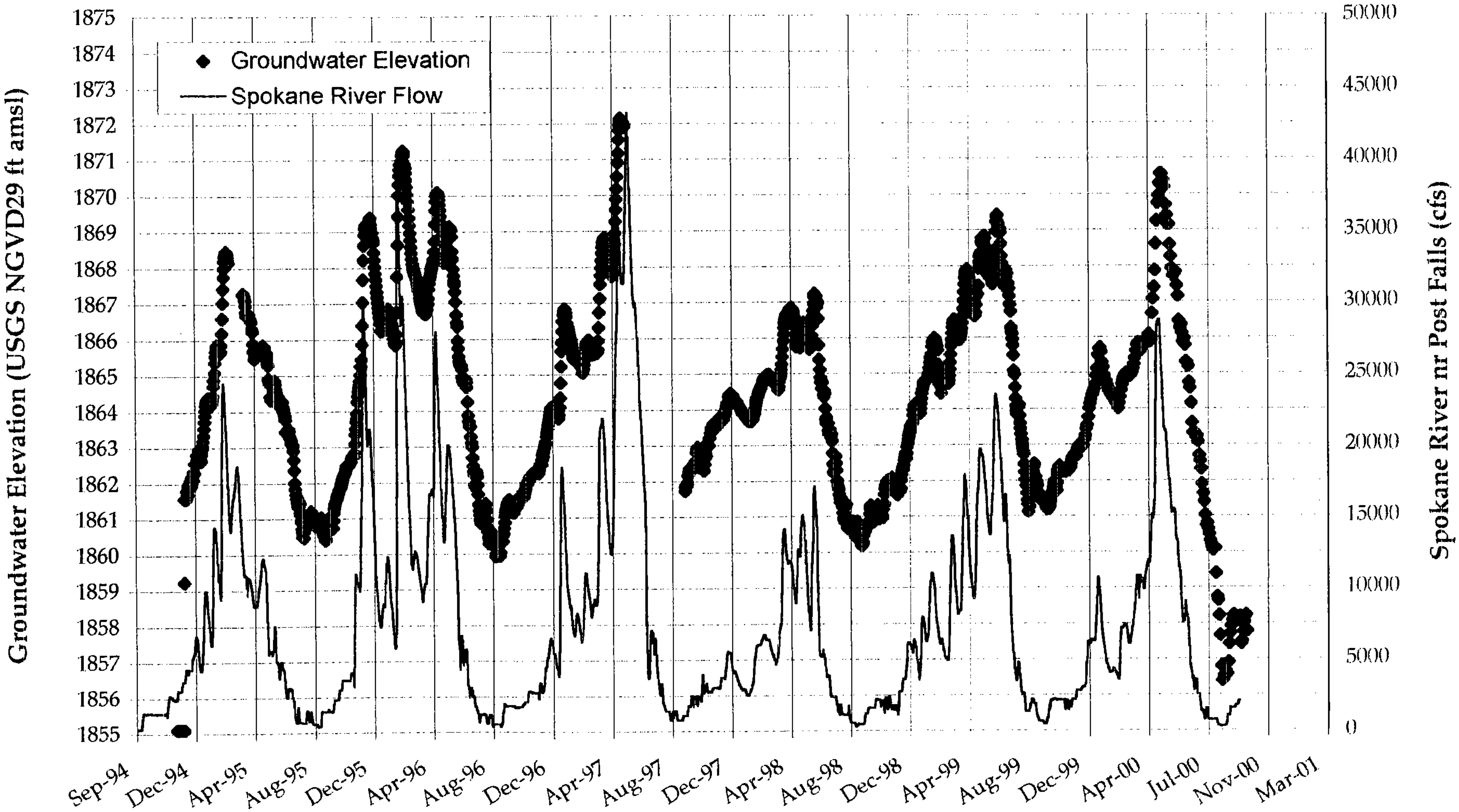


Data Source: City of Spokane
Date Type : Daily Averages from transducer data
Station Name: Third & Havanna Nested - Mid Well, Monitoring Well
Station ID: 5322A03

FIGURE D2-33:
Third & Havanna Nested - Mid Well
Monitoring Well
11/1994-11/1999

Spokane Co / Level 1 Assess / WA

Golder Associates



Data Source: City of Spokane
Date Type : Daily Averages from transducer data
Station Name: Nevada-Grace at Denver & Marietta, Monitoring Well
Station ID: 5308H01

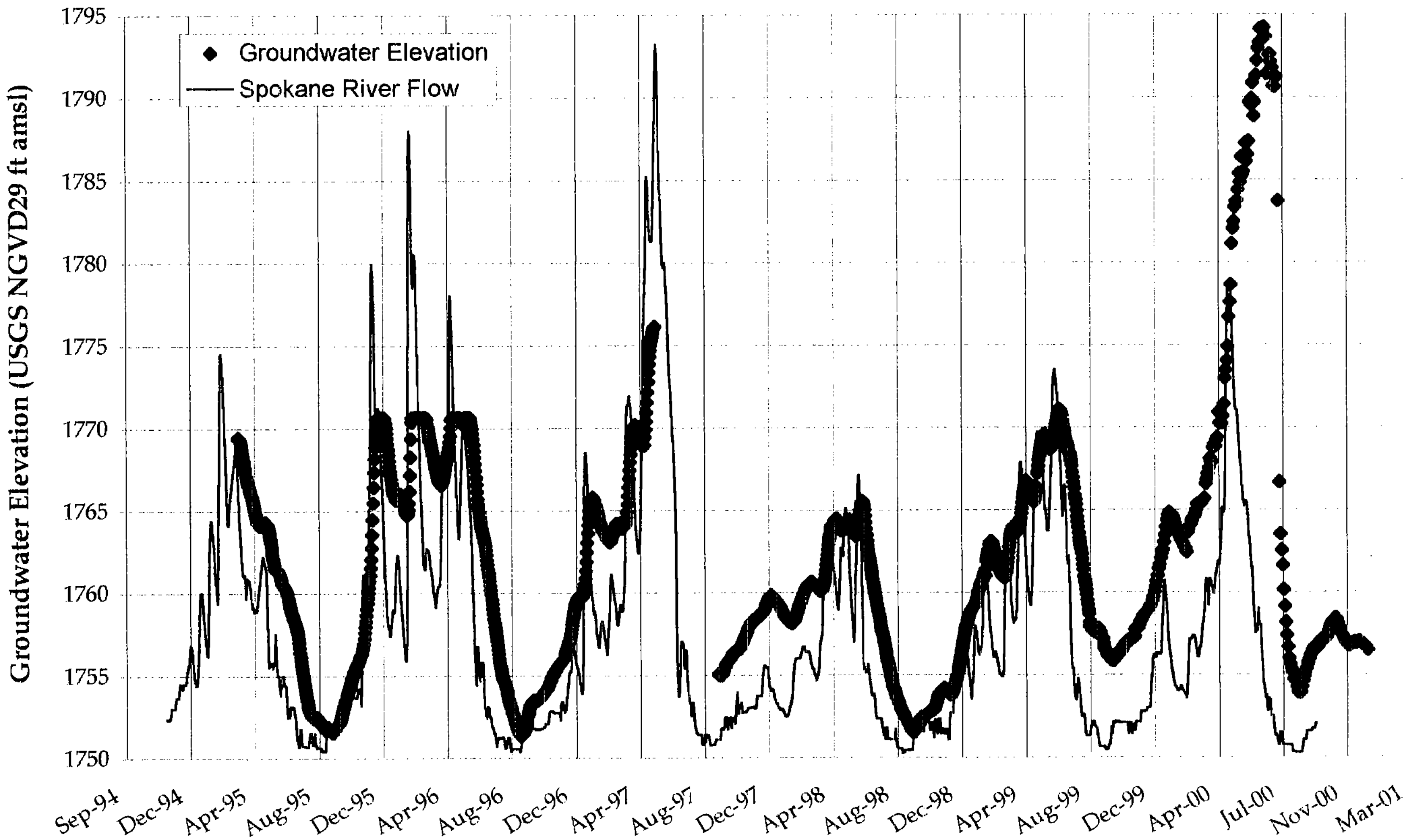
FIGURE D2-34:
Nevada-Grace at Denver & Marietta
Monitoring Well
11/1994 - 10/2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-30to38 CityData.xls/D2-34 Nevada Grace



Data Source: City of Spokane
Date Type : Daily Averages from transducer data
Station Name: Trinity School, Adams & Carlisle Monitoring Well
Station ID: 5307M01

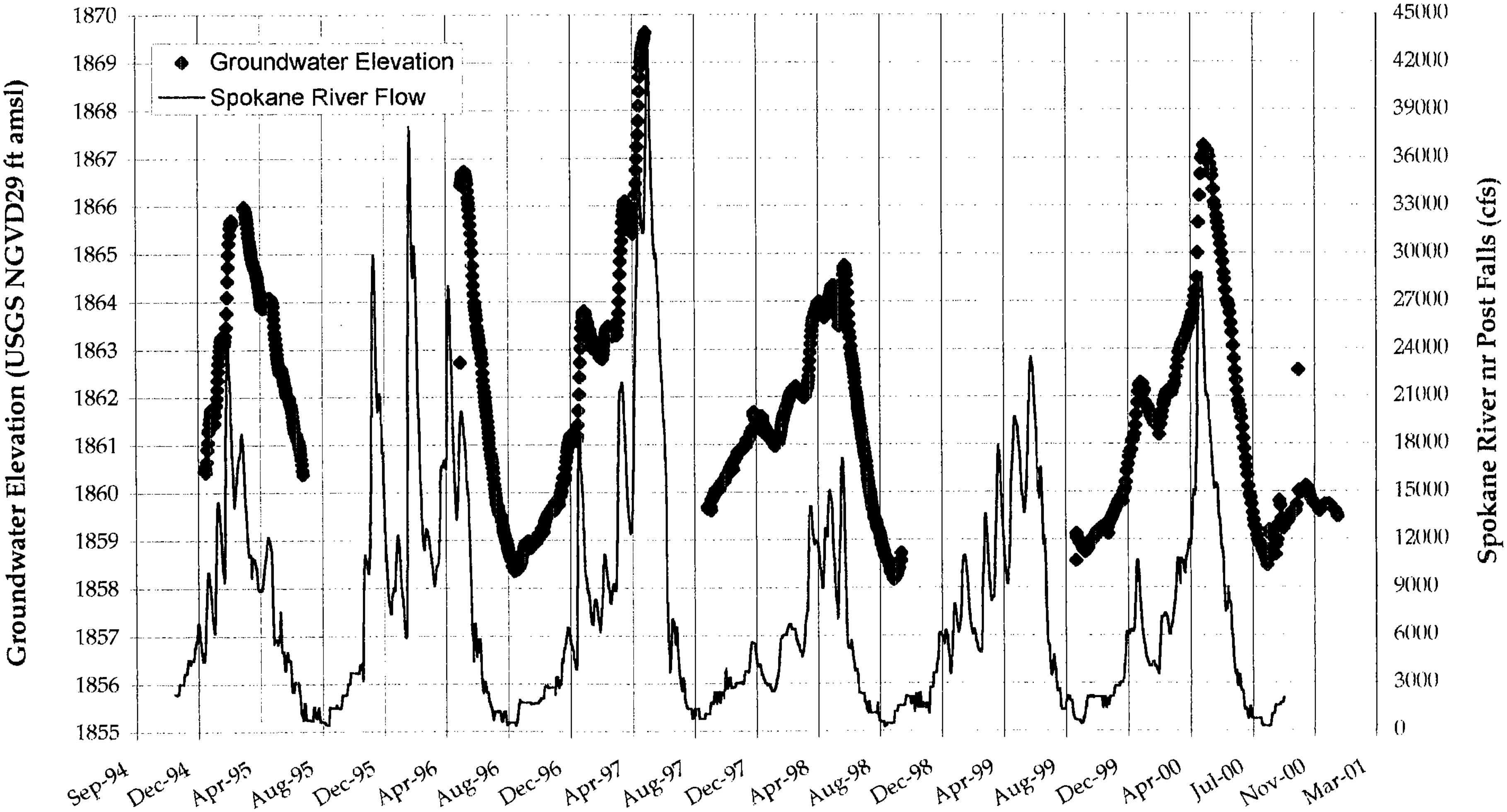
FIGURE D2-35:
Trinity School, Adams & Carlisle
Monitoring Well
3/1995 - 1/2001

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-30to38 CityData.xls/D2-35 Trinity School

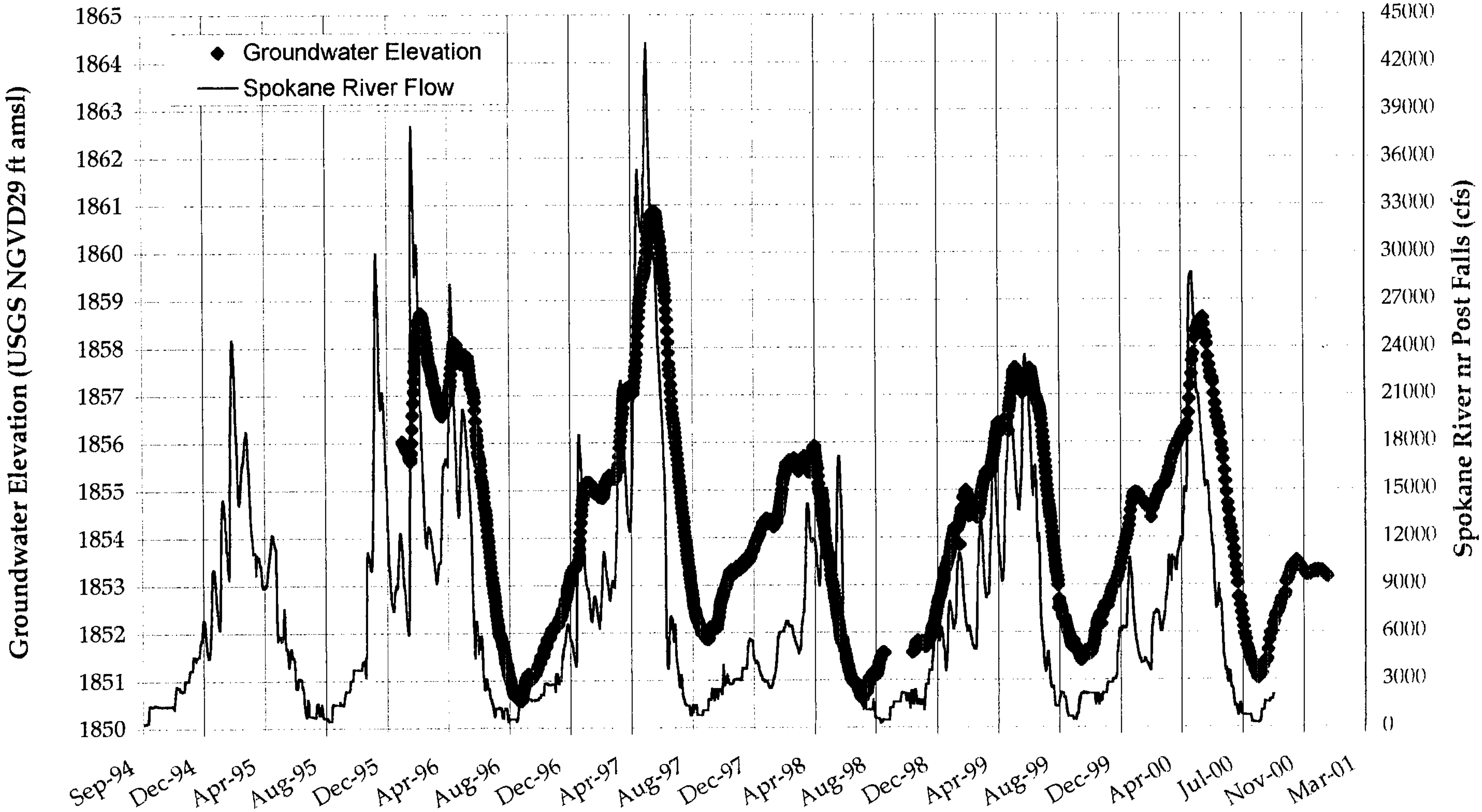


Data Source: City of Spokane
Date Type : Daily Averages from transducer data
Station Name: NE Community Center Monitoring Well
Station ID: 5304G01

FIGURE D2-36:
NE Community Center Monitoring Well
11/1995 - 1/2001

Spokane Co / Level 1 Assess / WA

Golder Associates



Data Source: City of Spokane
Date Type : Daily Averages from transducer data
Station Name: Franklin Park, Monitoring Well
Station ID: 5322A03

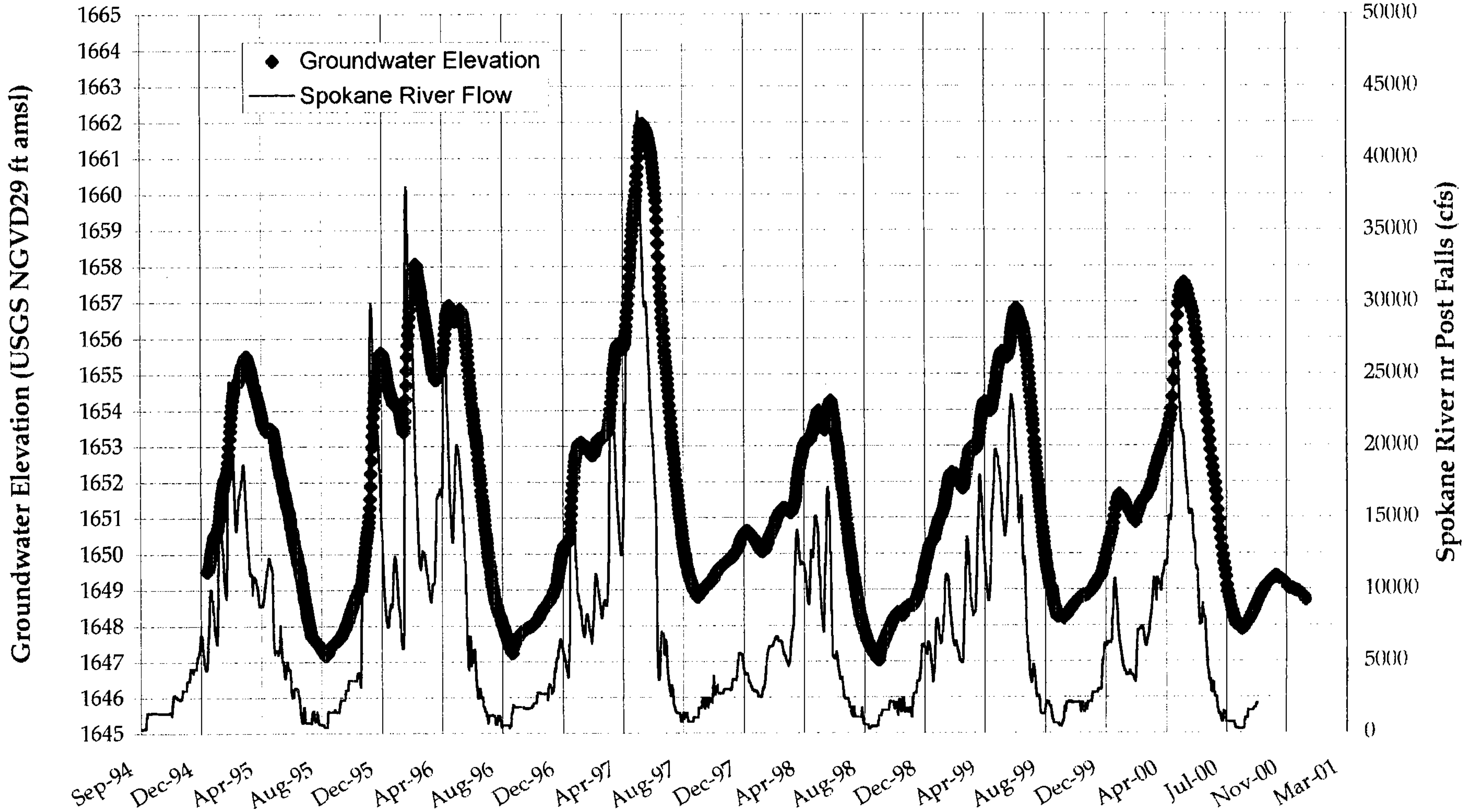
FIGURE D2-37:
Franklin Park Monitoring Well
1/1996 - 1/2001

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-30to38 CityData.xls/D2-37 Franklin Park



Data Source: City of Spokane
Date Type : Daily Averages from transducer data
Station Name: Wastewater Treatment Plant Monitoring Well
Station ID: 5202E01

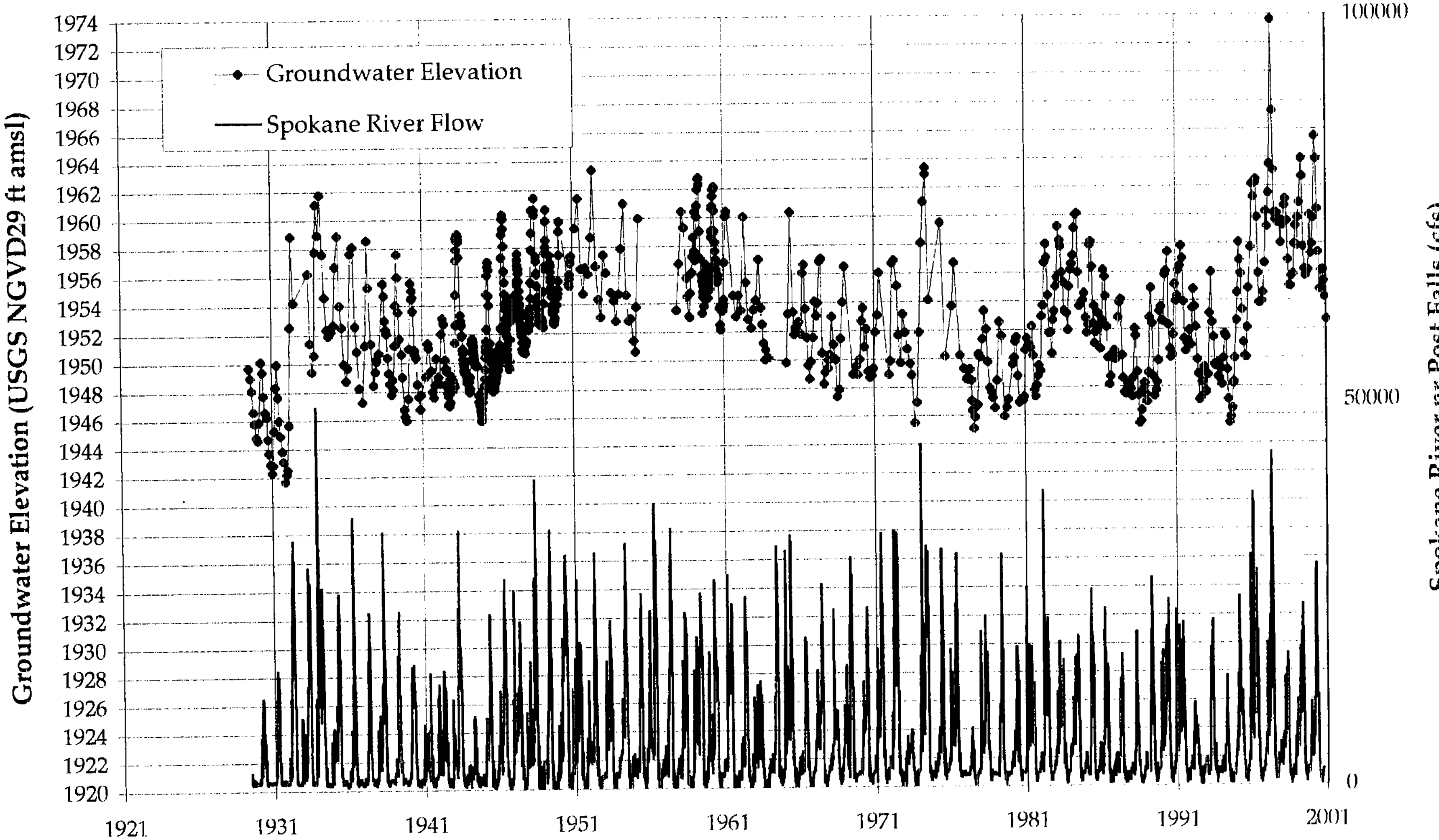
FIGURE D2-38:
Wastewater Treatment Plant Well
1/1995 - 1/2001

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-30to38 CityData.xls/D2-38 WWTP



Data Source: USGS
Date Type : Monthly
Station Name: Inland Empire Paper Well
Station ID: 5516C01

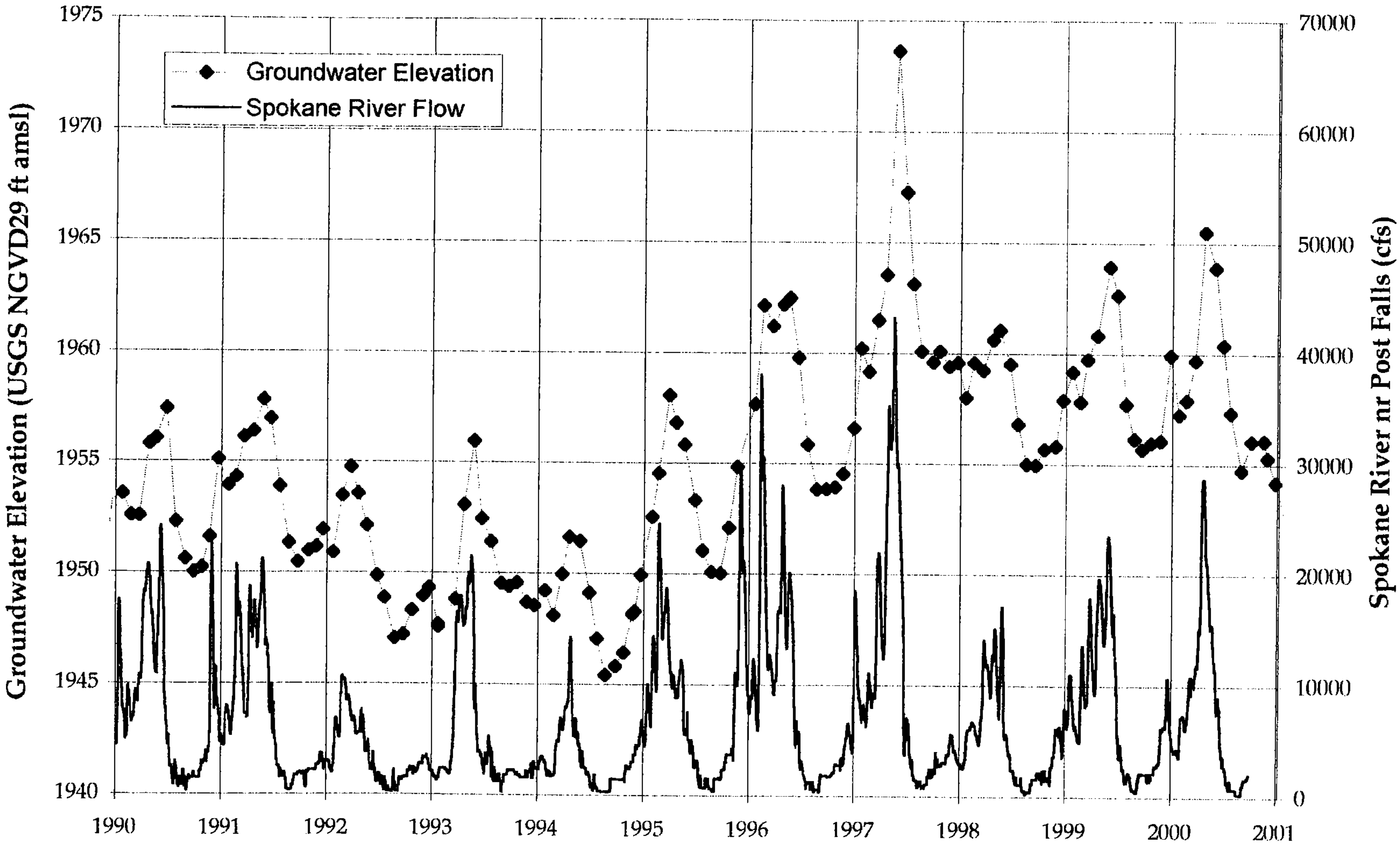
FIGURE D2-39:
Inland Empire Paper Well
7/1929-01/2001

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-39&40 inlandmonthly.xls/D2-39 hydro-1929-2001

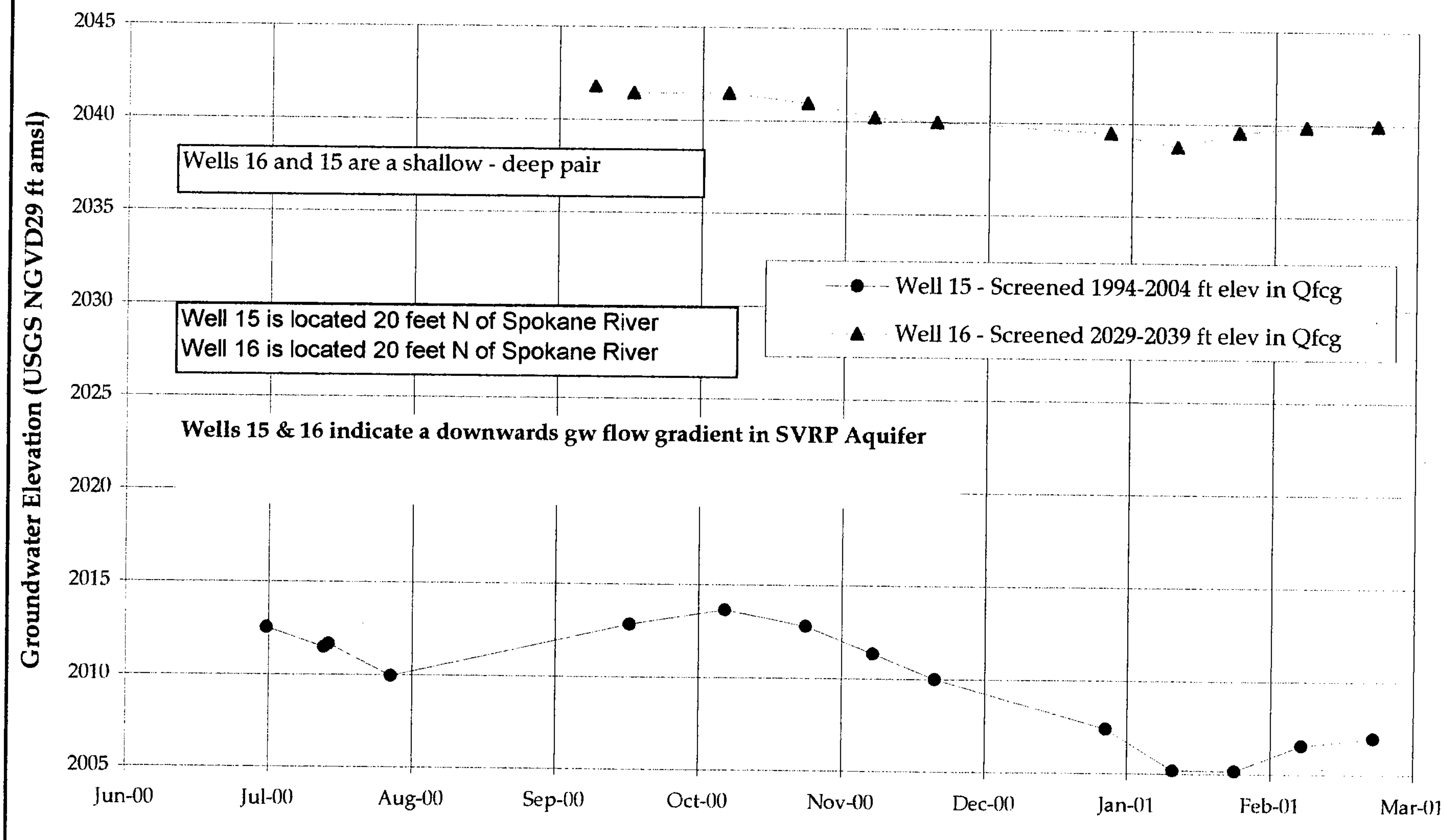


Data Source: USGS
Date Type : Monthly
Station Name: Inland Empire Paper Well
Station ID: 5516C01

FIGURE D2-40:
Inland Empire Paper Well
1/1990-12/2000

Spokane Co / Level 1 Assess / WA

Golder Associates



Data Source: USGS and Spokane County
Date Type : Weekly
Station Name: River Bend Road USGS Wells
Station ID: Well Nos 15 & 16

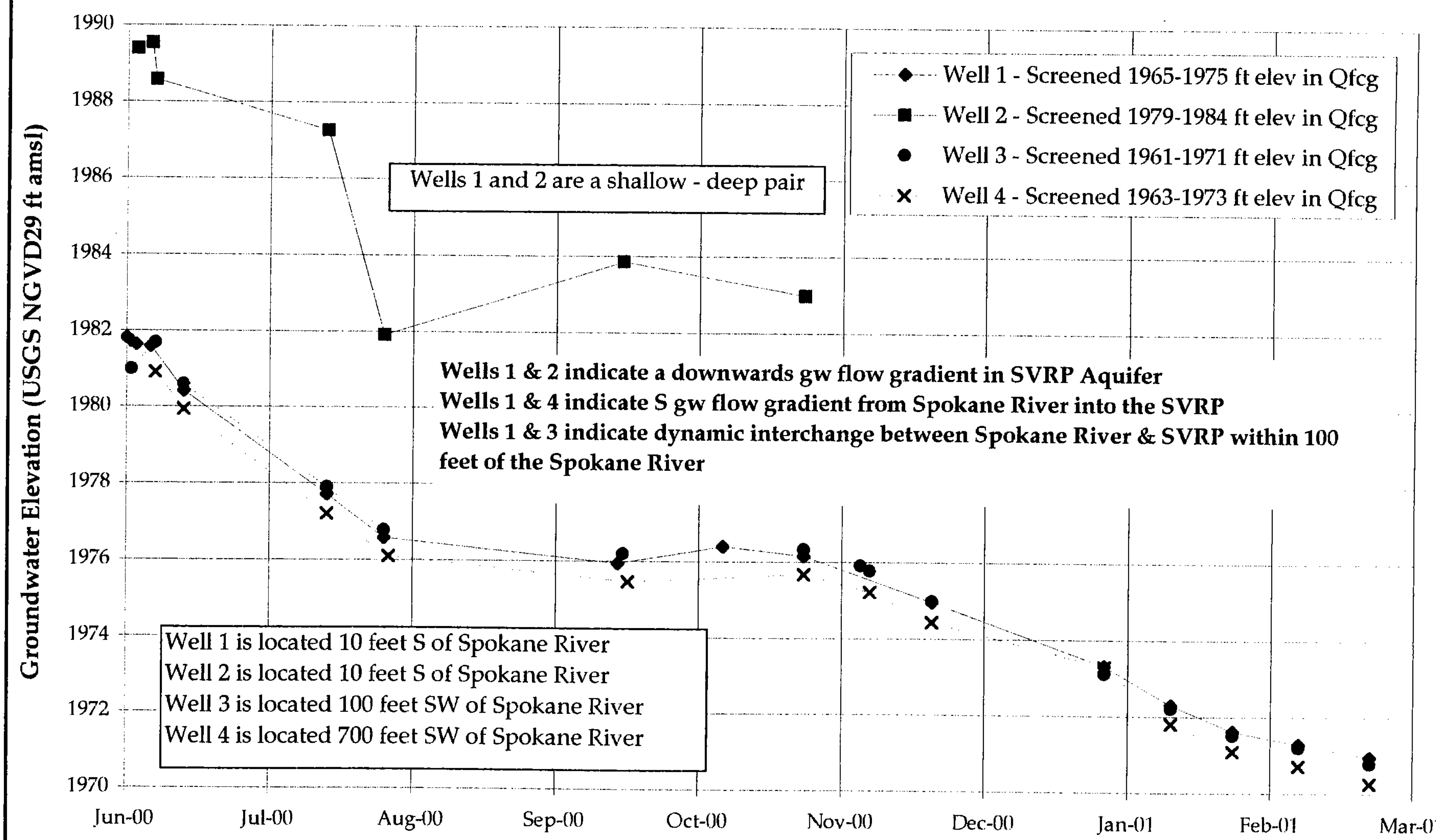
FIGURE D2-41:
USGS Wells 2000-2001
River Bend Rd, N of Spokane River

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-41to46 USGSnewwells.xls/D2-41 River Bend Rd



Data Source: USGS and Spokane County
Date Type : Weekly
Station Name: State Line USGS Wells
Station ID: Well Nos 1, 2, 3 & 4

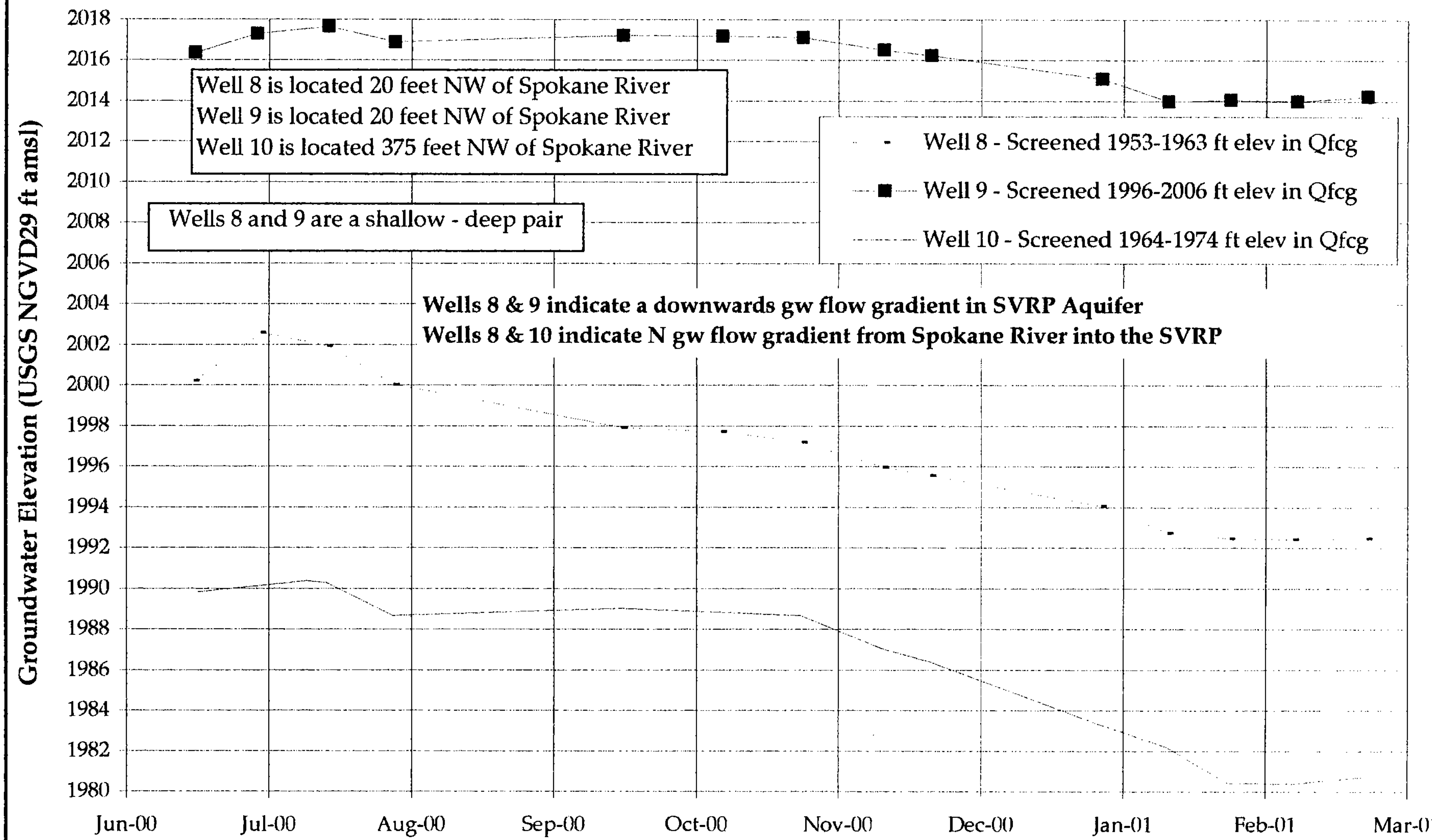
FIGURE D2-42:
USGS Wells 2000-2001
State Line, S of Spokane River

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-41to46 USGSnewwells.xls/D2-42 State Line

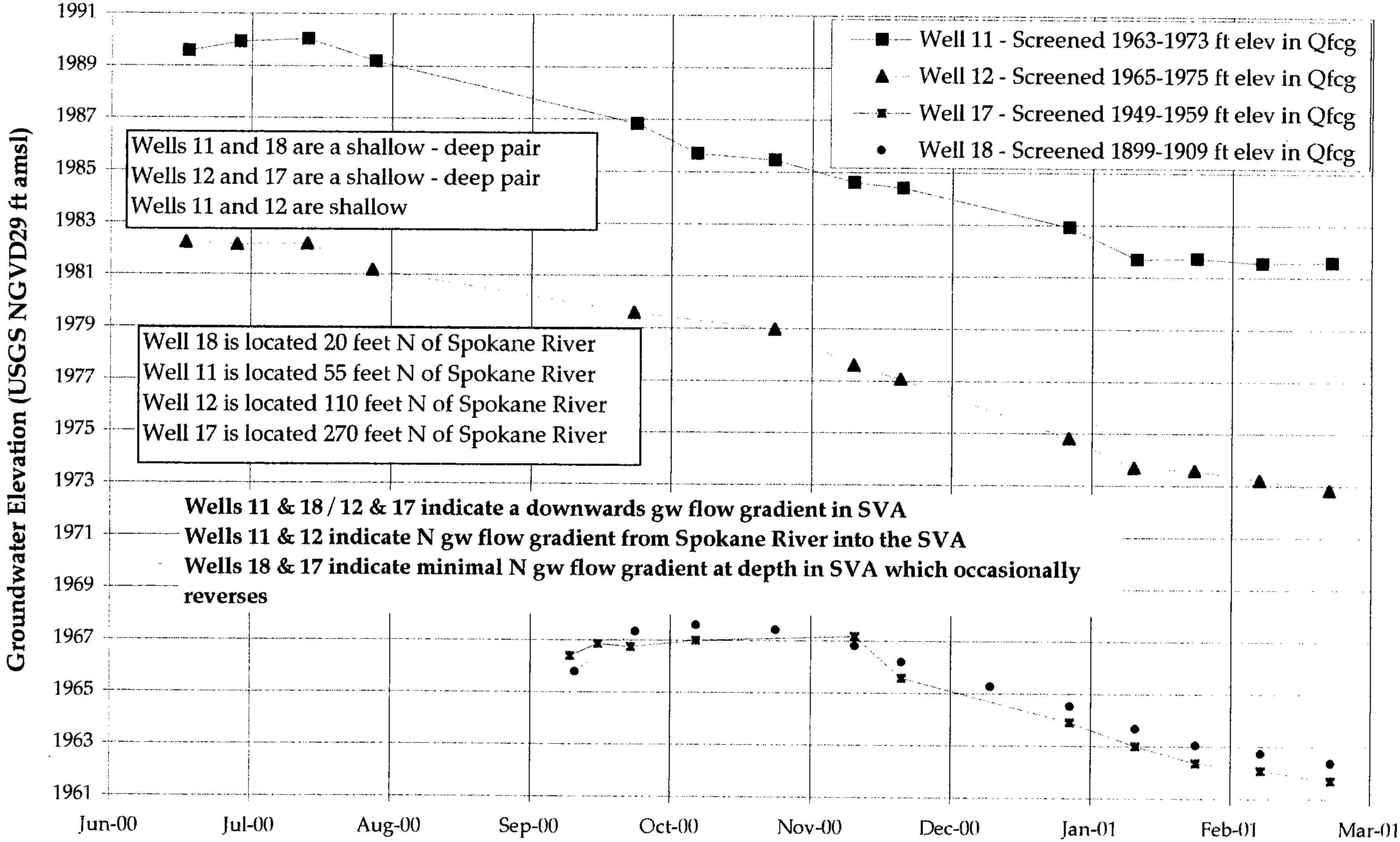


Data Source: USGS and Spokane County
Date Type : Weekly
Station Name: Starr Road USGS Wells
Station ID: Well Nos 8, 9 & 10

FIGURE D2-43:
USGS Wells 2000-2001
Starr Road, N of Spokane River

Spokane Co / Level 1 Assess / WA

Golder Associates



Data Source: USGS and Spokane County
Date Type : Weekly
Station Name: Euclid Ave USGS Wells
Station ID: Well Nos 11, 12, 17 and 18

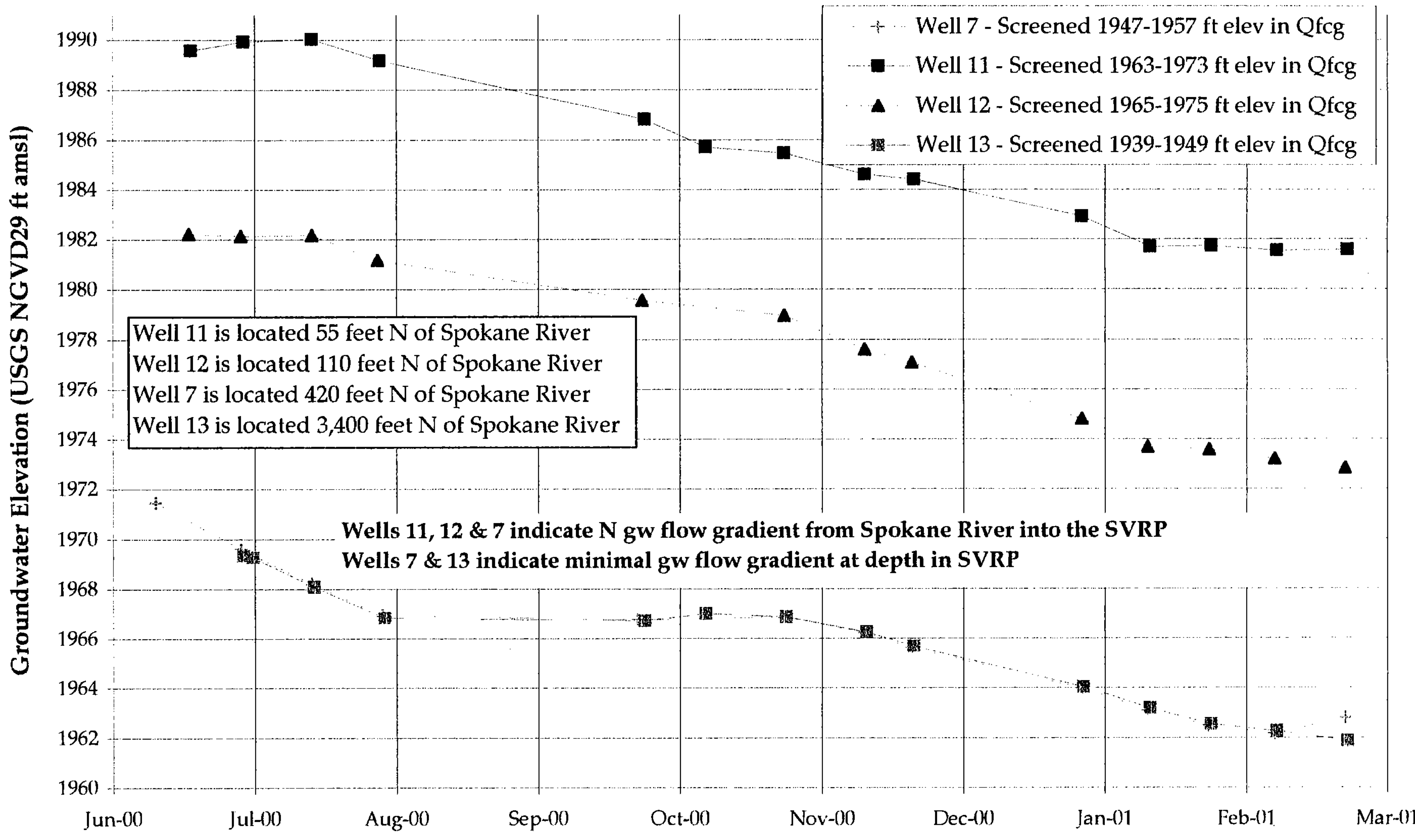
FIGURE D2-44:
USGS Wells 2000-2001
Euclid Ave N of Spokane River

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-41to46 USGSnewwells.xls/D2-44 Euclid Ave

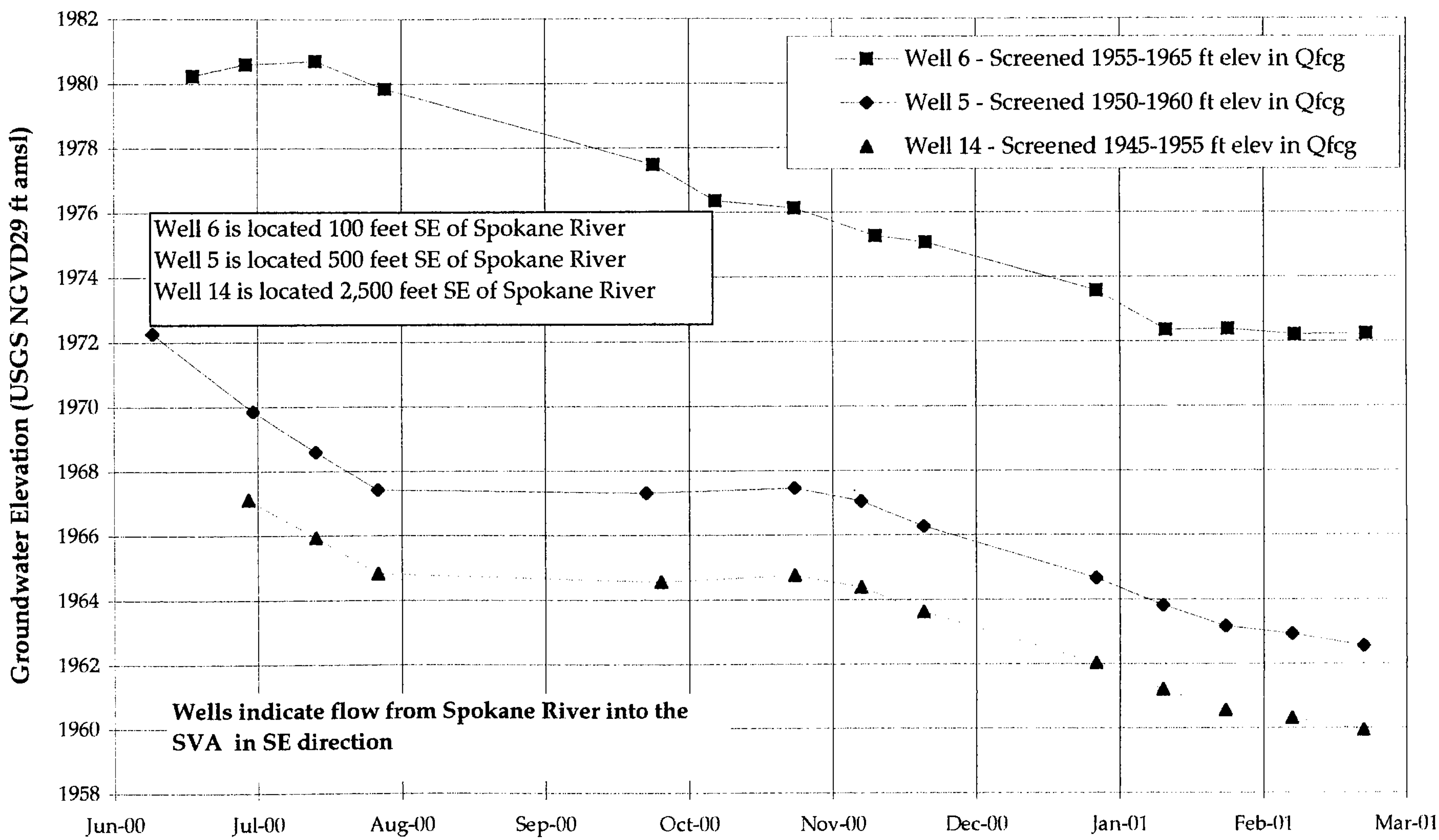


Data Source: USGS and Spokane County
Date Type : Weekly
Station Name: Lynden Road USGS Wells
Station ID: Well Nos 7, 11, 12 and 13

FIGURE D2-45:
USGS Wells 2000-2001
Lynden Road, N of Spokane River

Spokane Co / Level 1 Assess / WA

Golder Associates



Data Source: USGS and Spokane County
Date Type : Weekly
Station Name: Harvard Road USGS Wells
Station ID: Well Nos 14, 5 and 6

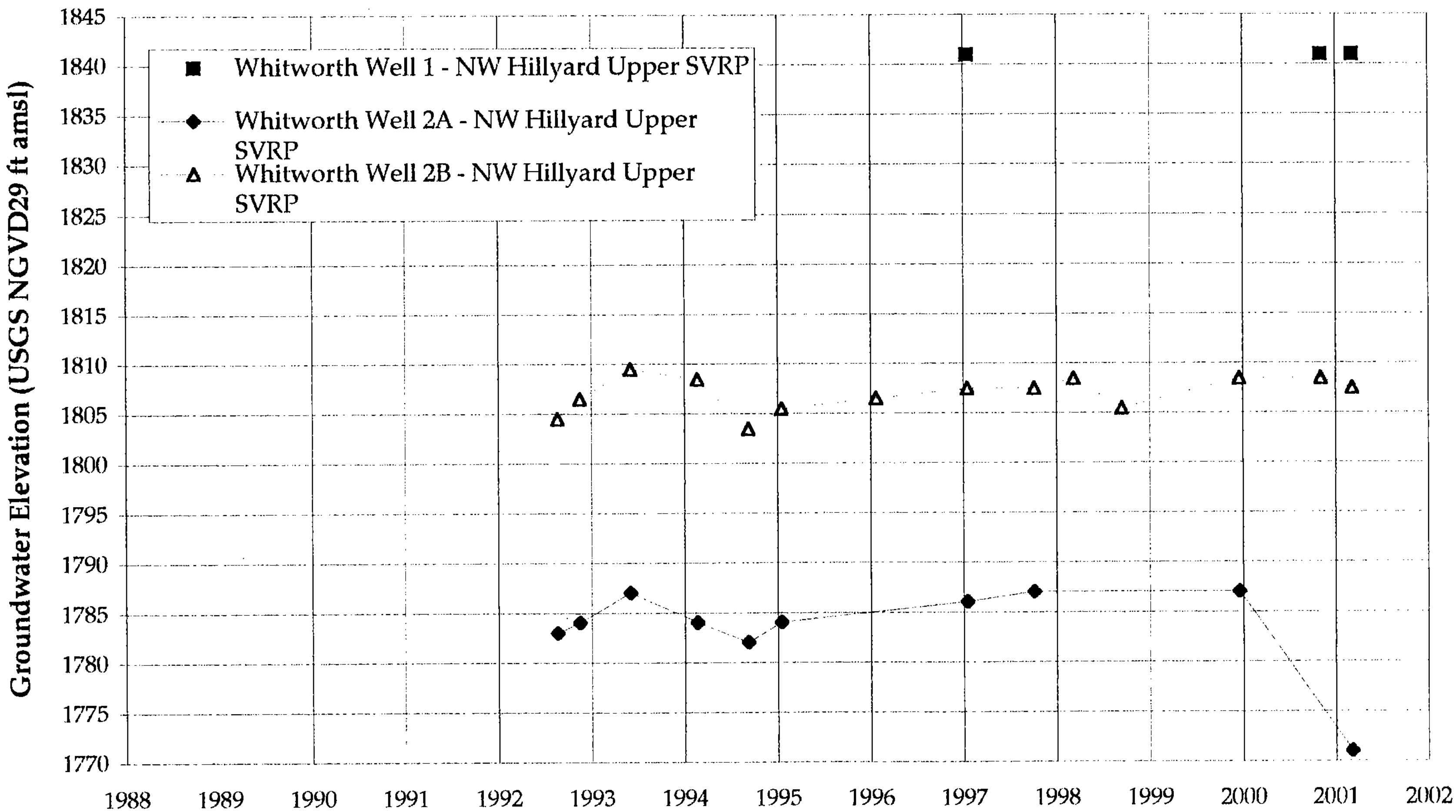
FIGURE D2-46:
USGS Wells 2000-2001
Harvard Road, S of Spokane River

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 April 13, 2001

D2-41to46 USGSnewwells.xls/D2-46 Harvard Rd



Data Source: Whitwoth Water District and Spokane County
Date Type : Randon Manual Measurements
Station Name: Whitworth Water District Well #s 1, 2A, 2B
Station ID: 6330F01, 6320D01, 6319A01
Note: Wells 1, 2A and 2B located northwest Hillyard Trough

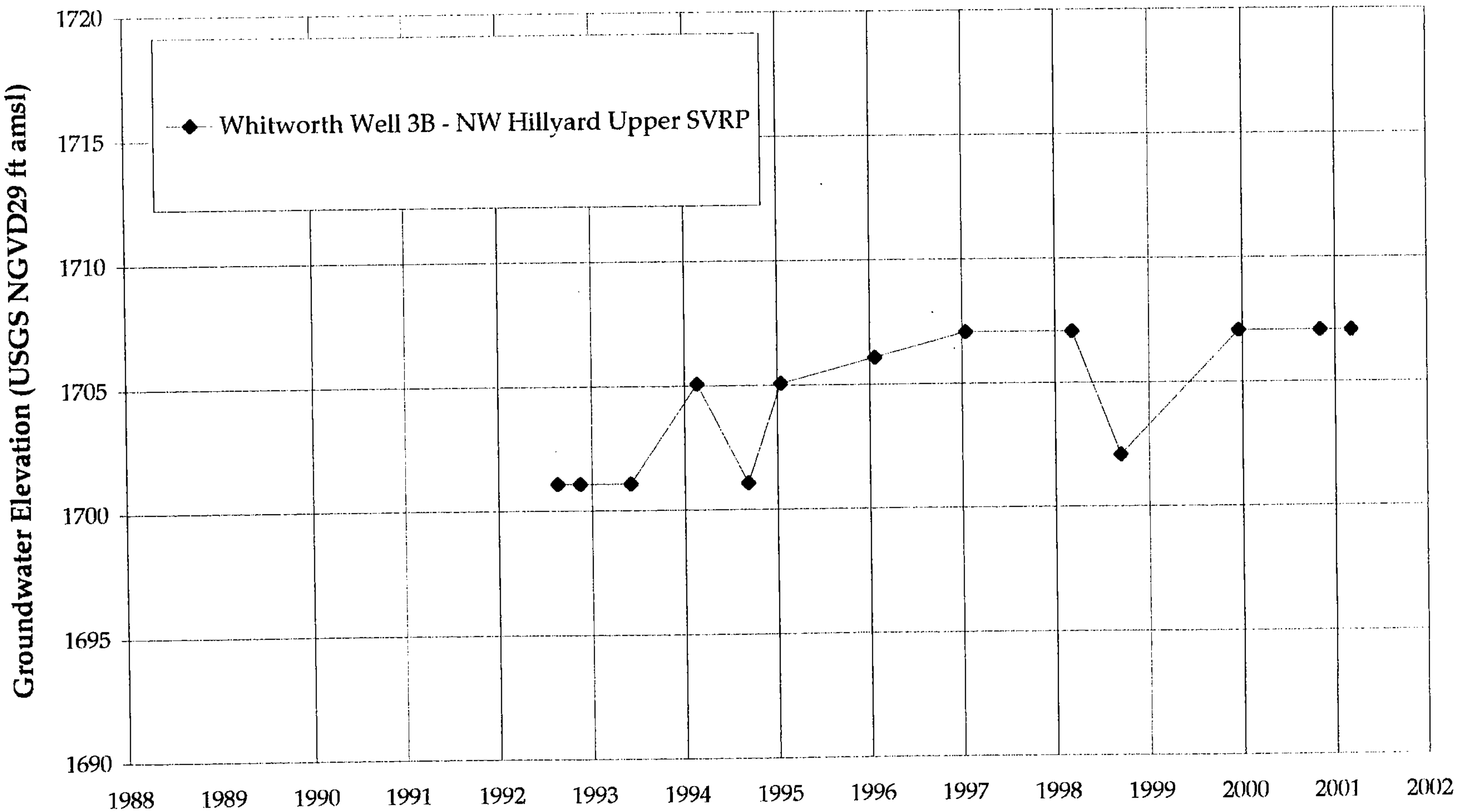
FIGURE D2-47:
Whitworth Water District Wells
#s 1, 2A, 2B
Static Levels 1988-2001

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-47to49 Whitworth.xls/D2-47 Whitworth 1,2A,2B

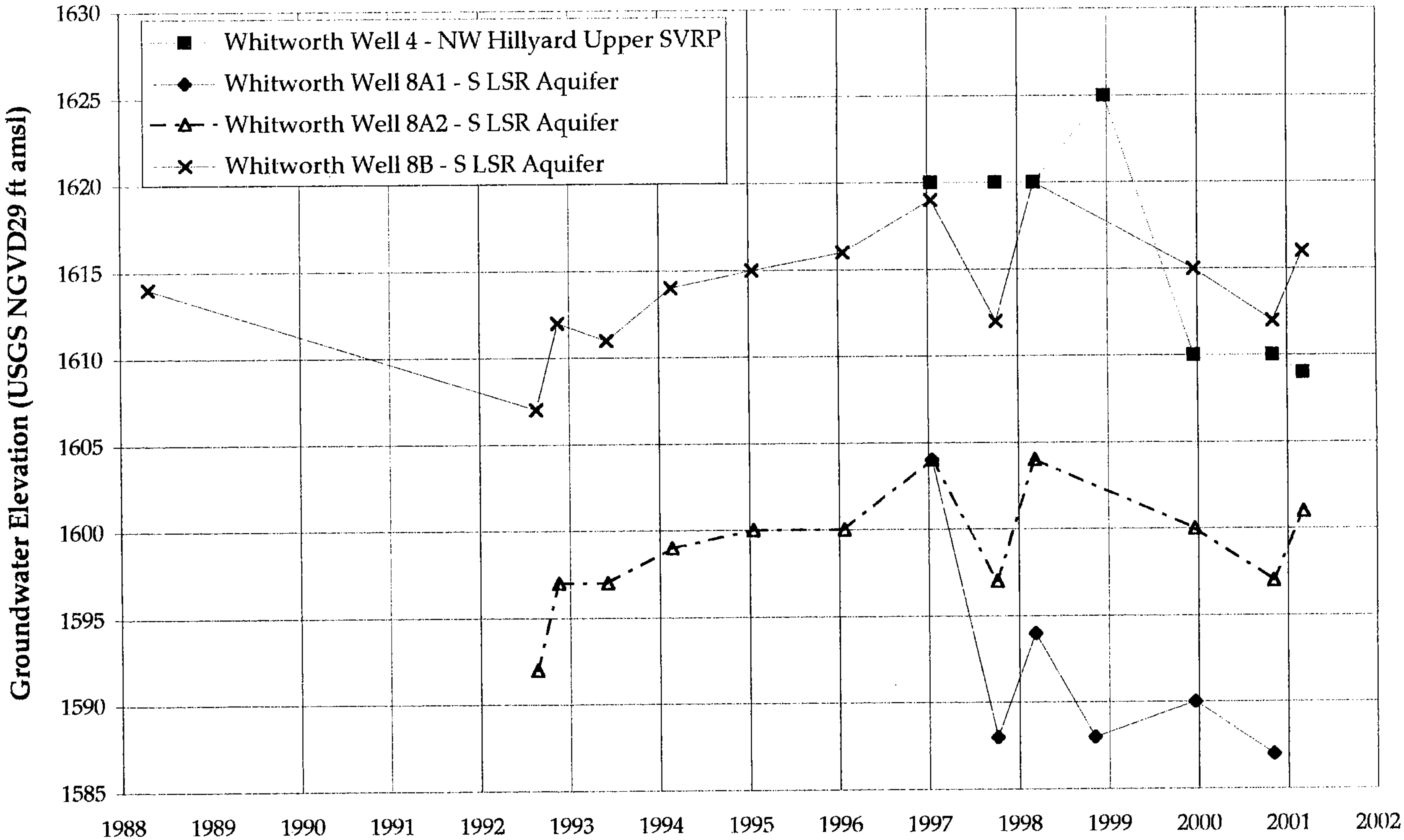


Data Source: Whitwoth Water District and Spokane County
Date Type : Randon Manual Measurements
Station Name: Whitworth Water District Well #s 3B
Station ID: 6307G01

FIGURE D2-48:
Whitworth Water District Wells
 # 3B
Static Levels 1992-2001

Spokane Co / Level 1 Assess / WA

Golder Associates



Data Source: Whitwoth Water District and Spokane County
Date Type : Randon Manual Measurements
Station Name: Whitworth Water District Well #s 4, 8A1, 8A2, 8B
Station ID: 6212L01, 7332H01, 7332H02, 7333E01
Note: Wells 8A1, 8A2 and 8B located north of Little Spokane River, just upstream of Dartford Creek.

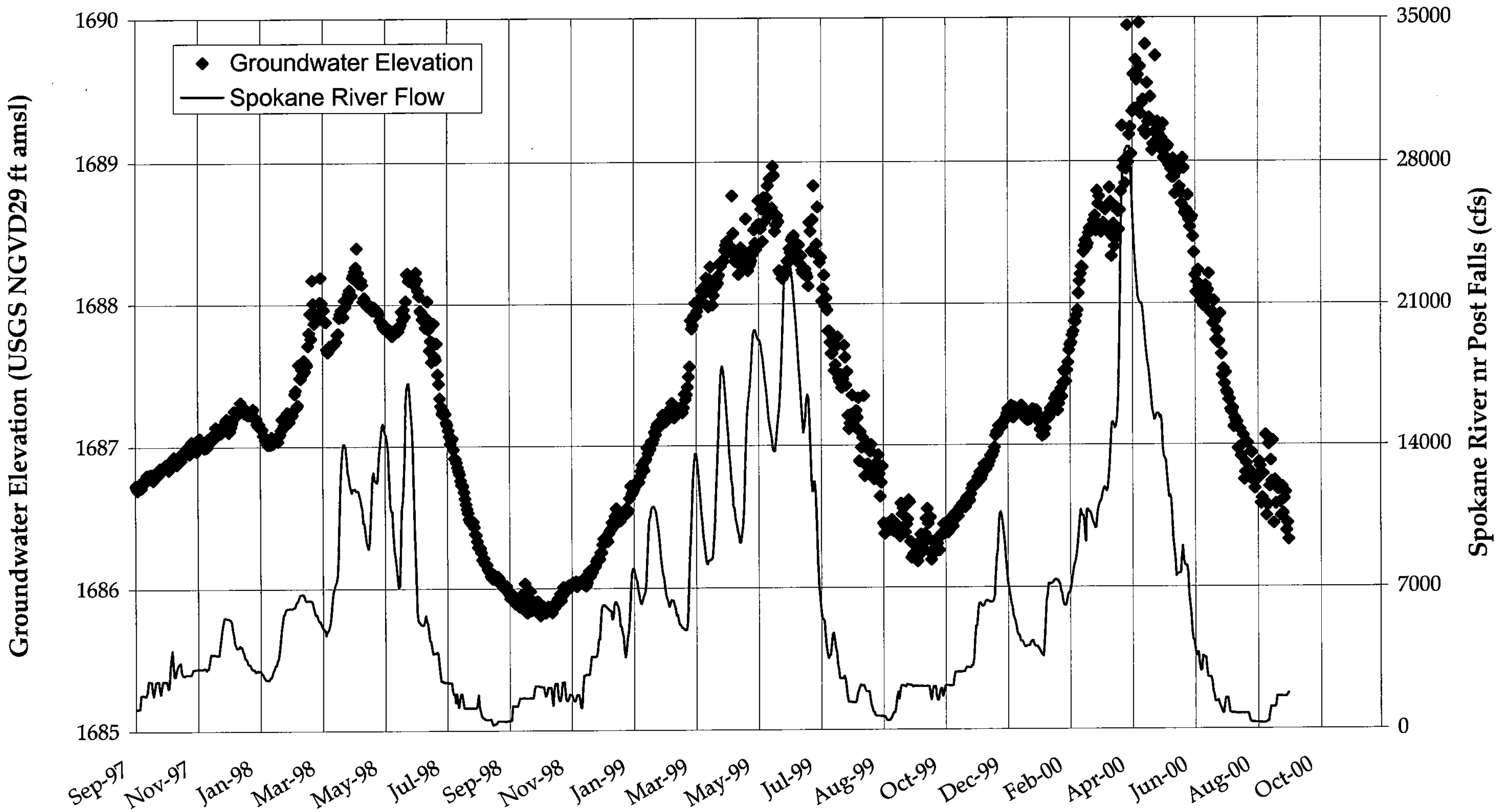
FIGURE D2-49:
Whitworth Water District Wells
#s 4, 8A1, 8A2, 8B
Static Levels 1988-2001

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-47to49 Whitworth.xls/D2-49 Whitworth 4,8A1,8A2,8B

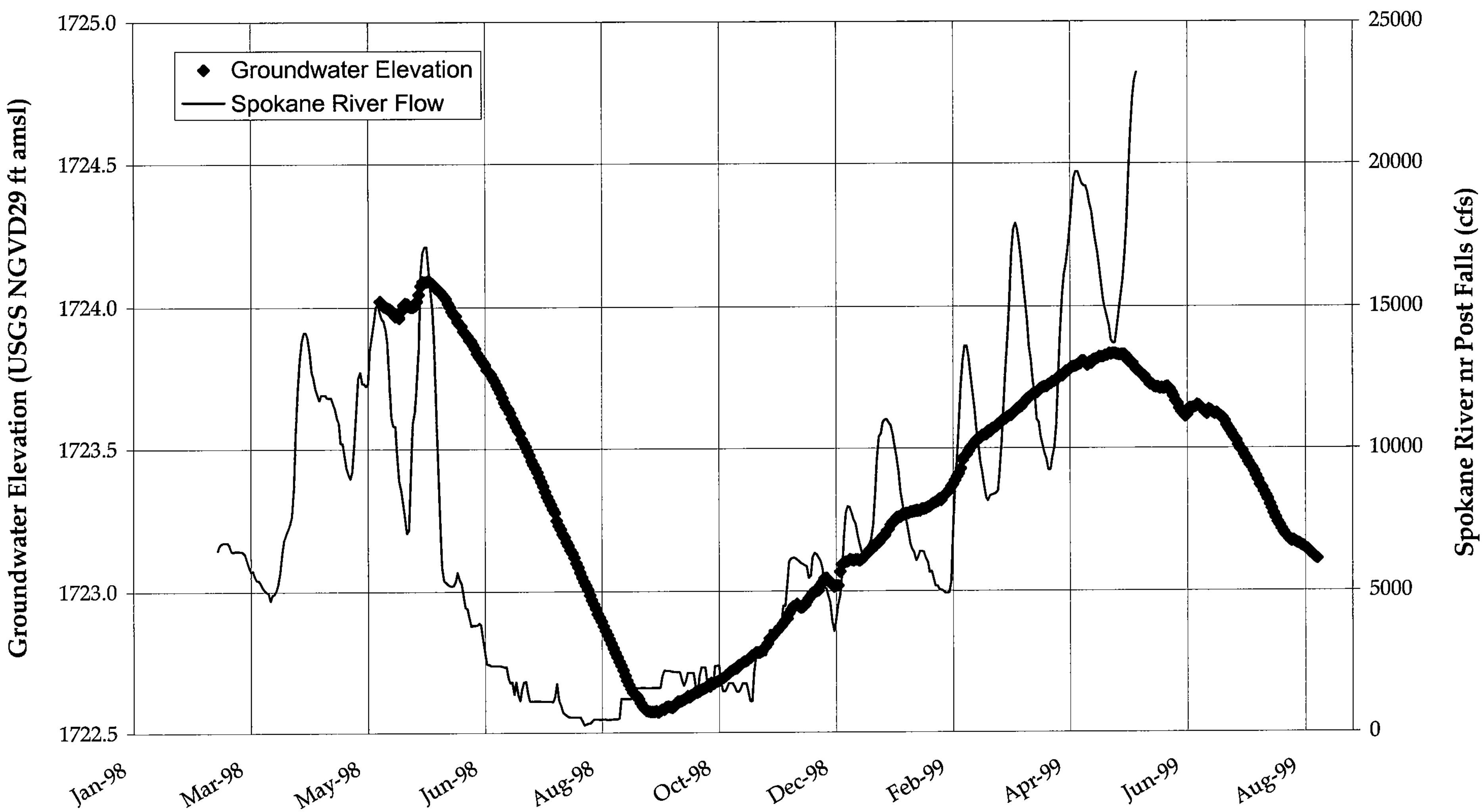


Data Source: Ecology
Date Type : Daily Averages
Station Name: Mayfair Well, Whitworth Water District Test Well
Station ID: 6308F02
Note: completed 452 - 462 ft bgs in the lower sands & gravels of N Hillyard Trough

FIGURE D2-50:
Mayfair Well
9/1997-9/2000

Spokane Co / Level 1 Assess / WA

Golder Associates



Data Source: Ecology
Date Type : Daily Averages
Station Name: Dakota Well, Spokane County Water District #3
Station ID: 6308B04
Note: completed 89 ft bgs in the upper sands & gravels of N Hillyard Trough

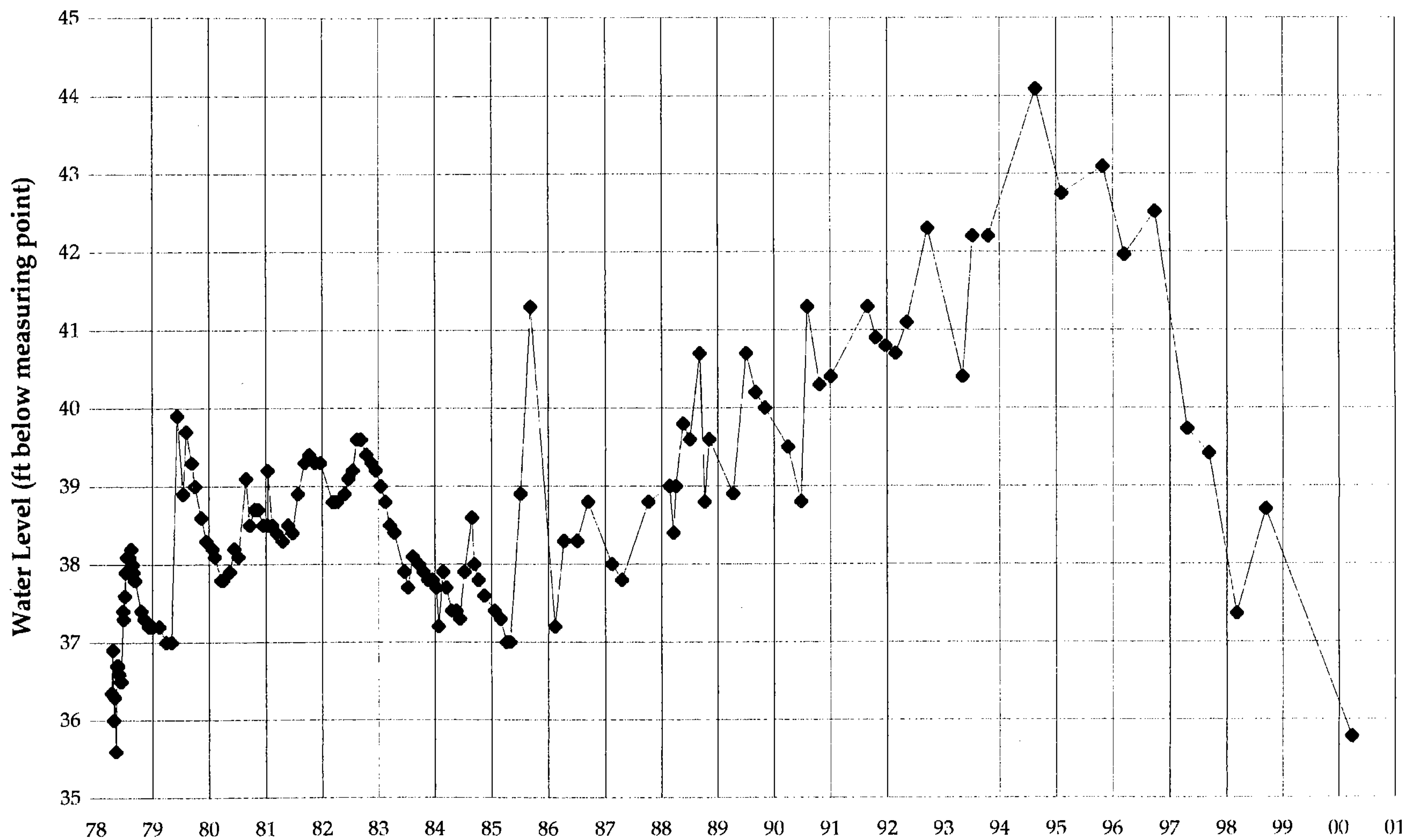
FIGURE D2-51:
Dakota Well
5/1998-8/1999

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-51 dakota.xls/D2-51 hydro



Da□a Source: Ecology
Date Type : Quartlery manual data
Station Name: Chatteroy Observation Well
Station ID: 8316D01

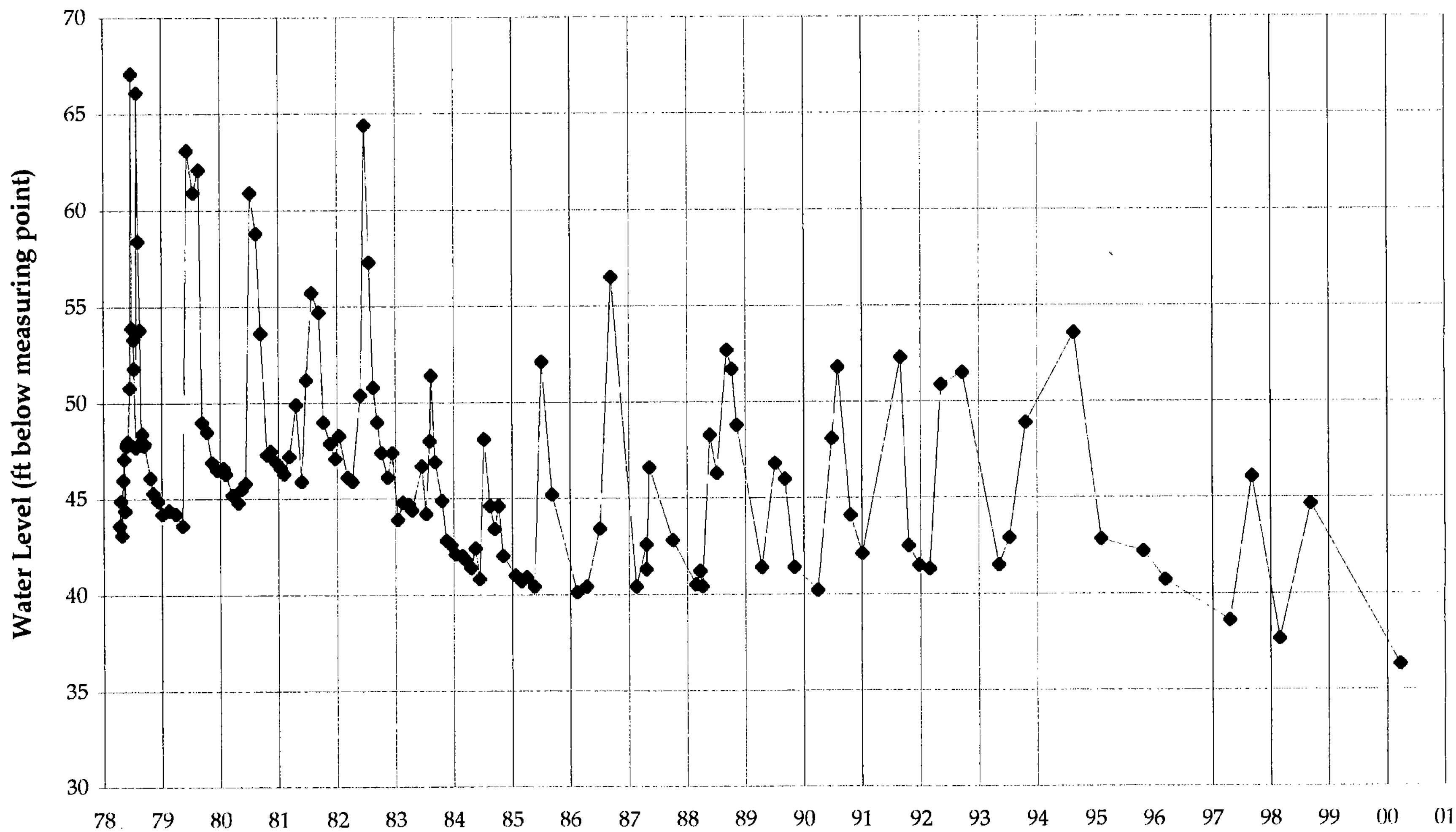
FIGURE D2-52:
Chatteroy Observation Well
4/1978 - 3/2000

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-52 chatteroyobwell.xls/D2-52 hydro

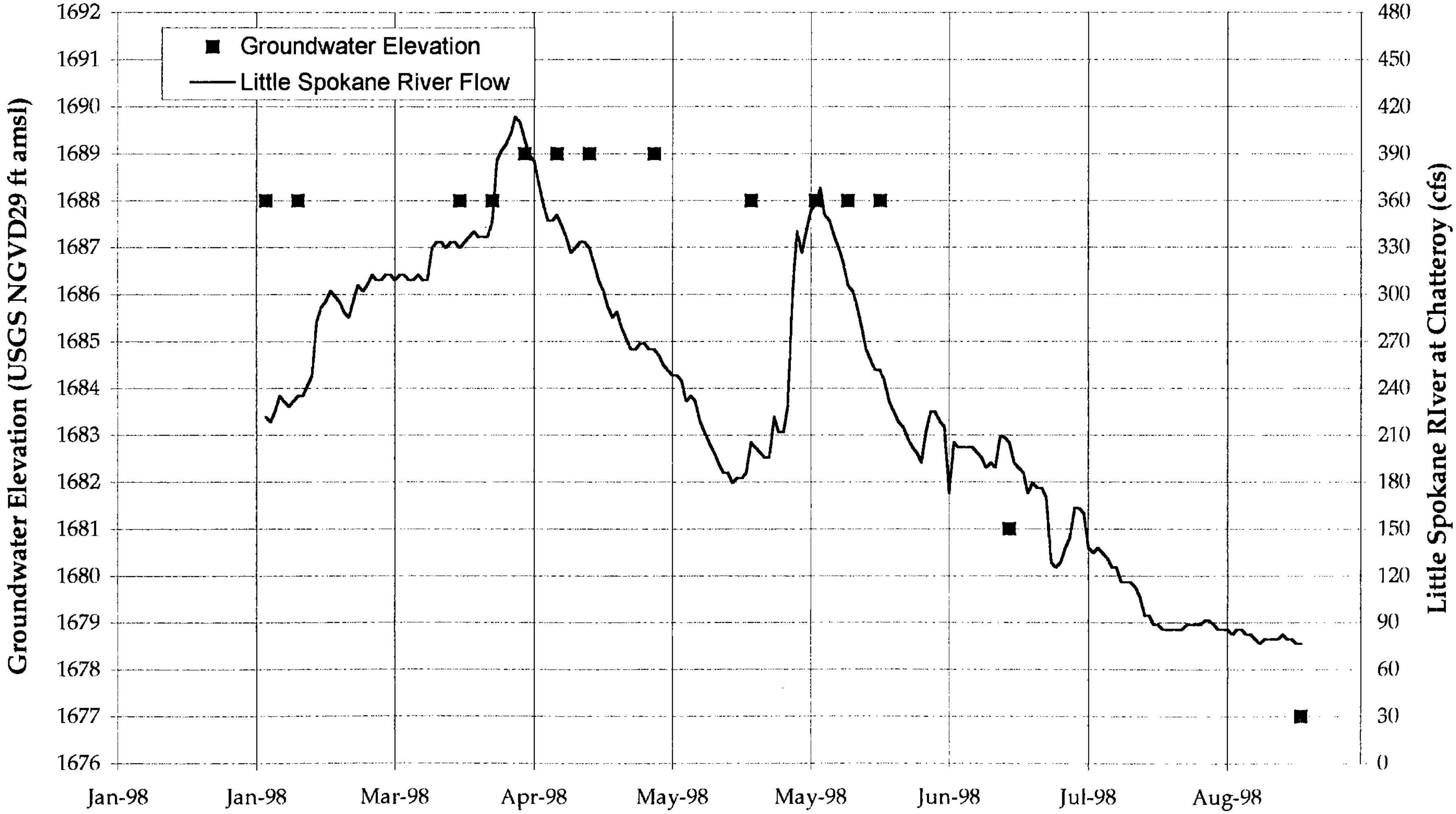


Da□a Source: Ecology
Date Type : Quarterly manual data
Station Name: Deer Park Observation Well
Station ID: 9233G01

FIGURE D2-53:
Deer Park Observation Well
4/1978-3/2000

Spokane Co. / Level 1 Assess / WA

Golder Associates



Data Source: Spokane County Water District #3
Date Type : Random
Station Name: Chatteroy Hills Well
Station ID: 8316D01

FIGURE D2-54:
Chatteroy Hills Well
2/1998 - 9/1998

Spokane Co / Level 1 Assess / WA

Golder Associates

013-1372.1100 March 30, 2001

D2-54 ChattaroyHills.xls/D2-54 hydro

APPENDIX D3

DESCRIPTION OF SPOKANE VALLEY RATHDRUM PRAIRIE AQUIFER GROUNDWATER FLOW MODELS

Table of Contents

D3-1. DESCRIPTION OF SPOKANE VALLEY RATHDRUM PRAIRIE AQUIFER GROUNDWATER FLOW MODELS

The following paragraphs present a review of the groundwater flow models of the SVRP Aquifer that have been developed primarily in support land of land development (i.e. groundwater supply) and to designate protection areas over aquifer zones that provide water to large water supply wells (i.e. groundwater quality protection). The information within this Appendix supports information presented within Section 5.2.7 of the Level 1, Phase II Assessment Report for WRIAs 55 and 57.

D3-1.1 Pluhowski and Thomas, 1968.

Pluhowski and Thomas (1968) completed a water balance equation for the Rathdrum Prairie with the Otis Orchard gaging station (above Liberty Bridge near Otis Orchard – station 1241950) as the outflow point. This gage is located on the Spokane River about two miles west of the Washington-Idaho state line. The water balance estimated 950 cfs of groundwater flow within the aquifer in the vicinity of the Otis Orchard gage and accounted for groundwater contributions from: 1) the Rathdrum Prairie (530 cfs); 2) Coeur d'Alene Lake and the Spokane River reach between Coeur d'Alene and Post Falls (250 cfs); 3) the Spokane River reach between Post Falls and Otis Orchards (120 cfs); and, 4) return flows from irrigated areas (50 cfs). The authors noted that groundwater contributions from the Rathdrum Prairie may be overestimated by as much as 200 cfs due to poorly understood groundwater flow conditions near Spirit Lake and Blanchard (located within the northwestern portion of the Rathdrum Prairie).

D3-1.2 Drost and Seitz, 1978.

Drost and Seitz (1978) completed the first comprehensive overview of the SVRP Aquifer to provide the EPA with technical data to support the aquifer's Sole Source status. The report compiles the existing information available for the aquifer and reviews estimates of recharge to and discharge from the aquifer. Based on the information available at this time, Drost and Seitz (1978) estimated that about 800 cfs of groundwater flow enters Washington at the Washington-Idaho state line.

D3-1.3 Bolke and Vacarro, 1981.

Bolke and Vacarro (1981) developed the first groundwater flow model of the Spokane Aquifer; a steady state (average annual) and transient (monthly discretization) two-dimensional finite element groundwater flow model for the Spokane Valley aquifer from Post falls to the confluence of the Little Spokane and Spokane Rivers. The purpose of the model was to assess the impacts of groundwater pumping on groundwater levels and stream flow. Data for model set up and calibration included: 1) water levels measured in 142 wells between march 1977 and May 1978 (Bolke and Vaccaro, 1979); 2) pumping records from 135 wells; 3) streamflow records for the Spokane and Little Spokane Rivers and Hangman Creek, and, 4) data and results from previous studies.

Lateral and vertical hydraulic conductivity were assumed to be the same for the geologic units.

The model boundary conditions are summarized below:

- Constant specified heads at the eastern boundary (based May 1977 to April 1978 field measurements);
- Constant discharge of the Spokane River, Little Spokane River and Hangman Creek;
- No-flow boundaries along the north and south limits of the aquifer except at nodes where hillside watersheds drain into the aquifer;
- Constant groundwater inflow at nodes where hillside watersheds drain into the aquifer based on data estimated by Drost and Seitz (1978);
- Constant specified heads at the western boundary (based May 1977 to April 1978 field measurements);
- Outcrops of basalt and crystalline basement within the model area were treated as areas of low transmissivity; and
- A no-flow boundary was used to define the base of the aquifer.

The main model inputs are summarized below:

- Average annual precipitation of 17.2 inches / month and 1977-1978 monthly values from the Spokane International Airport;
- Average annual evapotranspiration of 1.31 inches / month and monthly values based on a evapotranspiration equation developed by the U.S. Department of Agriculture (1967).
- Average annual 1977 pumping rate of 227 cfs applied to specific grid elements and distributed monthly based on available records;
- Constant specified heads ranging from 1,980 to 1,985 feet amsl at the eastern boundary;
- Constant specified heads ranging from 1,536 to 1,543 feet amsl at the western boundary;
- Constant discharge of the Spokane River at Post Falls of 5,383 cfs;
- Constant discharge of the Little Spokane River at Dartford of 229 cfs;
- Constant discharge of Hangman Creek to the Spokane River at 268 cfs; and.
- Total inflow at specified flow nodes of 269 cfs.

The table below summarizes the results of Bolke and Vaccaro's (1981) May 1977 to April 1978 model.

Bolke and Vaccaro (1981) Spokane Valley Groundwater Flow Model Results

	Contribution (cfs)
RECHARGE	
Precipitation minus Evapotranspiration	66
Groundwater Inflow Eastern Boundary	399
Subsurface Inflow (tributaries)	269
Leakage from the Spokane River	420
Land applied water	114
Septic systems	20
Total:	**1,288**
DISCHARGE	
Groundwater outflow at Nine Mile Dam	105
Groundwater pumpage	227
Groundwater Discharge to the Spokane River	702
Groundwater Discharge to the Little Spokane River	254
Total:	**1,288**

In a model simulation where wells were pumped at twice the estimated 1977 rates, the groundwater table within the Spokane Aquifer was lowered less than three feet during the one-year simulation period. However, the loss from the Spokane River to the Spokane Aquifer was simulated at about 150 cfs during the summer months and about 50 cfs during the remainder of the year. The contribution of the Spokane Aquifer to the Little Spokane River during the increased pumping run decreased by less than 10 cfs.

D3-1.4 Painter, 1991.

Painter (1991, unpublished) completed a mass balance approach based on previous investigations and accounting for all recharge into the Rathdrum Prairie aquifer. Painter estimated that 753 cfs of groundwater flowed into Washington across the state line. Inflow to the system from hillside lakes was simulated using an average yield of 0.59 cfs per square mile of tributary watershed per year. This average yield was estimated based on studies of recharge into the aquifer from the Spirit Lake tributary watershed (0.57 cfs / square mile of watershed), Twin Lakes watershed (0.79 cfs / square mile of watershed) and the Hauser Lake watershed (0.39 cfs / square mile of watershed). The sources of recharge to the Rathdrum Prairie aquifer are summarized below.

Painter (1991) Rathdrum Prairie Water Balance Model Results

Recharge Source (watershed name)	**Drainage** (square miles)	**Average Recharge** (cfs)	**Percent of Recharge**
Spirit Lake	39.0	22.3	3.0
Twin Lakes	31.4	25.0	3.3
Hauser Lake	21.1	8.2	1.1
Hidden Valley	12.3	7.3	1.0
Blanchard	106.4	62.2	8.3
Bayview / Kelso	25.3	14.8	2.0
Chilco Channel	69.4	40.6	5.4
Hayden Lake	64.0	37.8	5.0
Canfield	7.9	4.6	0.6
Lake Coeur d'Alene and Spokane River	3,718.0	230.0	30.6
Lake Pend Oreille	22,900.0	50.0	6.6
Rainfall	283.0	250.0	33.2
TOTAL		**753**	

D3-1.5 Buchanan and Olness, 1994.

Buchanan and Olness (1994) developed a groundwater flow model of the Spokane Valley portion of the SVRP Aquifer using the finite-difference MODFLOW code (McDonald and Harbaugh, 1988). The model was prepared for the Spokane County Water Quality Management Program and estimated a groundwater through flow at the state line of 320 cfs. This model was updated and linked to a Rathdrum Prairie model in 1999 (Buchanan, 1999).

D3-1.6 CH2M Hill, 1998.

CH2M Hill (1998) developed a three dimensional, steady state finite element groundwater flow model for the Spokane Aquifer (from the state line to the confluence of the Spokane and Little Spokane Rivers) for the City of Spokane's wellhead protection program. MicroFem (ver 3, Hemker and Nijsten 1996) was selected as the modeling software. The following data collection effort was completed to provide information with which to construct and calibrate the model:

- Installed 12 monitoring wells;
- Conducted aquifer pumping tests at two City production wells;

- Established a water level monitoring network from the Washington-Idaho state line to Nine-Mile Dam;
- Collected water level data in September 1994 and April 1995;
- Collected continuous water level data at nine monitoring wells;
- Conducted seismic reflection profiling across about 3 miles within selected areas of the City of Spokane; and,
- Reviewed well logs and entered about 300 well logs into a project database.

The model boundary conditions are summarized below:

- Specified flux at the state line;
- Specified heads (based on September 1994 field measurements) for the Little Spokane River valley and the lower reaches of Nine-Mile reservoir;
- Constant stage for the Spokane River;
- No-flow boundaries along the north and south limits of the aquifer except at nodes where hillside watersheds drain into the aquifer;
- No-flow boundaries (simulated by very low transmissivities) along the edges of Five-Mile Prairie, the Green Street Knoll and Pine Street Knoll;
- Specified flux at nodes where hillside watersheds drain into the aquifer; and,
- A no-flow boundary was used to define the base of the aquifer.

The main model input parameters are summarized below:

- Effective precipitation (precipitation minus evapotranspiration) was specified at 66 cfs across the study area using a distribution based on work completed by Olness (1991).
- Land applied water was recharged at a rate of 2.5 inches / year in areas of high population density (up to 6,000 persons / square mile), 1.0 inches / year in areas of moderate population density (about 1,000 persons / square mile), 0.25 inches / year in areas of low population density (about 100 persons / square mile) and 2 inches/ year for areas outside City limits where irrigation is known to occur.
- Septic recharge was modeled at 16 cfs.
- Pumping rate inputs are based on data provided by the purveyors and were varied seasonally.
- Hydraulic conductivity was simulated with 20 zones and varied between 7,000 ft/day in the eastern portion of the Spokane Valley Aquifer to 1,500 feet/day in the northern Hillyard Trough area. The hydraulic conductivity of sediments in the Trinity Trough was modeled at 120 feet /day.
- The horizontal hydraulic conductivity of aquifer materials was assumed to be ten times greater that the vertical hydraulic conductivity.

- The riverbed leakage rates were specified for 16 reaches of the Spokane River and allowed to vary during the model calibration process.

The model was calibrated to aquifer conditions measured in September 1994 and was verified by simulation of the aquifer conditions measured in April 1995. The table below summarizes the results of CH2M Hill's (1998) average annual steady state model for the Fall 1994 and Spring 1995 for the model area from the Washington-Idaho state line to the Little Spokane River.

CH2M Hill (1998) Spokane Valley Groundwater Flow Model Results

	Fall, 1994 (CFS)	**Spring, 1995** (CFS)
RECHARGE		
Precipitation minus Evapotranspiration	23	46
Groundwater Inflow Eastern Boundary	383	383
Subsurface Inflow (tributaries)	38	57
Leakage from the Spokane River	222	226
Land applied water	10	2
Septic systems	16	16
	692	730
DISCHARGE		
Groundwater outflow at Nine Mile Dam	-	-
Groundwater pumpage	220	125
Groundwater Discharge to the Spokane River	172	270
Groundwater Discharge to the Little Spokane River	300	335
	692	730

The following points summarize the main results of the water budget (CH2M Hill, 1998):

- The two main recharge components to the Spokane Aquifer are: 1) groundwater inflow at the state line; and, 2) leakage from the Spokane River.
- Areal recharge and recharge from tributary valleys to the Spokane Aquifer are relatively small contributions.
- The magnitude of groundwater flow through the Trinity Trough is insignificant in comparison to the overall water budget for the Spokane Aquifer.

D3-1.7 Buchanan, 1999.

This groundwater flow model was created using the finite-difference MODFLOW code (McDonald and Harbaugh, 1988) and represents the first regional groundwater flow model that extends any significant distance across the SVRP aquifer system from Idaho and into Washington. Although not suitable for highly resolved particle tracking and advective transport modeling, the model does function as a valuable tool in understanding the overall water balance of the aquifer system. The model is constructed using data gathered during years of work on the aquifer system in both Idaho and Washington (Bolke and Vaccaro, 1981; Painter unpublished, 1991; Buchanan and Olness, 1994; R&A Technical Consultants, 1997). In addition, the model considers the data generated in the delineation of wellhead capture zones for the City of Spokane and the Spokane Aquifer Joint Board (CH2M Hill, 1998; CH2M Hill, 2000).

The conceptual hydrogeologic model comprises a permeable sand and gravel aquifer within a bedrock valley. Recharge is primarily from lake and river leakage and areally distributed precipitation in Idaho. Discharge from the system takes place mostly to the Spokane River and Little Spokane River in Washington. The steady-state model is single-layer with 1,321 active cells defining the approximately 325 square mile surface area of the aquifer system. Each cell is a half-mile square.

The boundary conditions include constant head nodes corresponding to peripheral lakes and the Little Spokane River, river nodes representing the Spokane River and no-flow boundaries representing the bedrock of the valley sides.

Hydraulic conductivity is decreased from east to west, through the model domain with values of 1,500 to 50,000 feet per day used to represent the aquifer materials. Porosity is set to 20 percent (0.20) uniformly throughout the model domain. Recharge due to rainfall is applied to the top surface of each active cell in the model, and is estimated to be 25 percent of rainfall volume. Additional recharge from hillslopes and small basins adjacent to the aquifer is applied to the appropriate cells in the model with values taken from Painter (1991) and Bolke and Vaccaro (1982).

The final model yields an aquifer throughflow at the state line of about 390 cubic feet per second (cfs). This figure agrees with that of Bolke and Vaccaro's (1981) value of 453 cfs, Buchanan and Olness' (1994) 320 cfs and that of CH2M Hill (1998) of 380 cfs at the state line. Approximately 10 cfs of groundwater flow was estimated across the Trinity Trough.

D3-1.8 CH2M Hill, 2000.

The CH2M Hill (2000) groundwater model was created for the Spokane Aquifer Joint Board (SAJB), a group of 21 Class A water utilities, including the City of Spokane. The model updated the MICRO FEM groundwater flow model created for the City of Spokane in 1998. The purpose of the update was to expand the model domain, to incorporate new information and to delineate the capture zones to the SAJB wells for wellhead protection.

The new information collected for the CH2M Hill (2000) SAJB wellhead protection project included:

- An expanded water level monitoring (including at the State Line);
- Information from 15 new monitoring wells;
- An additional discrete and continuous water level monitoring event;
- New ground surveys;

- Additional aquifer testing;
- Seismic investigations in the central Spokane Valley;
- A review to confirm / refute deep confined aquifer system in the north Hillyard Trough and Little Spokane River Valley;
- A microgravity gradiometry survey of the north Hillyard Trough area;
- Transient electro-magnetics (TEM) in North Spokane
- Establishment of river stations and a well monitoring network of the Little Spokane River Basin between Dartford and Little Deep Creek; and,
- A geochemical evaluation (to determine if upper and lower portions of the SVA are distinguishable based on geochemistry).

The following adaptations were made to the City's wellhead protection model:

- The model grid was refined in the vicinity of the SAJB wells;
- The specified head nodes at the northern end of the Hillyard Trough were converted to variable head nodes so that capture zone delineations could be performed for 3 SAJB wells in this area;
- Recharge from the tributary valleys (which does occur in reality) was not simulated because of concerns that wellhead capture zones near the edges of the aquifer would be distorted;
- The following geologic boundaries were modified: : 1) the western boundary of a bedrock knoll in the vicinity of the Pines Road Walk-In-The-Wild Zoo; 2) the southern boundary of the Spokane Valley Aquifer in the vicinity of the East Spokane Water District wells #5 and #6; and, 3) the southern boundary of the SVA at Shelly Lake;
- Modifications of Spokane Valley Aquifer properties and river stage were made to the west of the Kaiser Aluminum Company Trentwood Rolling Mill (since the 1998 model did not correctly simulate groundwater flow directions in the western portion of the facility);
- The pumping rates for SAJB wells were made equal to annual water rights over 365 days per year;
- The pumping rates for the City of Spokane and private wells were set at rates equal to those in Fall 1994 simulation; and,
- All the SAJB wells and non-SAJB wells pumped simultaneously in the steady state model for a total pumping of 410 cfs or 184,000 gpm (about 1.75 times higher than City's model).

The model was recalibrated to aquifer conditions measured in September 1994. The table below summarizes the results of CH2M Hill's (1998) average annual steady state model for the Fall 1994 and Spring 1995 for the model area from the Washington-Idaho state line to the Little Spokane River.

CH2M Hill (2000) Spokane Valley Groundwater Flow Model Results

	1998 Model Fall, 1994 (CFS)	**2000 Model Fall, 1994** (CFS)
RECHARGE		
Precipitation minus Evapotranspiration	23	23
Groundwater Inflow Eastern Boundary	383	383
Subsurface Inflow (tributaries)	38	38
Leakage from the Spokane River	222	182
Land applied water	10	10
Septic systems	16	16
Total	**692**	**652**
DISCHARGE		
Groundwater outflow at Nine Mile Dam	-	-
Groundwater pumpage	220	220
Groundwater Discharge to the Spokane River	172	250
Groundwater Discharge to the Little Spokane River	300	182
Total	**692**	**652**

APPENDIX D4

SPOKANE RIVER – SVRP AQUIFER INTERACTION STUDIES

Table of Contents

D4-1. SPOKANE RIVER – SVRP AQUIFER INTERACTION STUDIES

The following paragraphs present a review of the Spokane River – SVRP Aquifer interaction studies that were reviewed as a component of the Level 1, Phase II Assessment of WRIAs 55 and 57. The information within this Appendix supports information presented within Section 5.3.1 of the Level 1, Phase II Assessment Report for WRIAs 55 and 57.

D4-1.1 McDonald and Broom, 1951.

McDonald and Broom (1951) published a preliminary analysis of Spokane River discharge records from the Post Falls Dam to Long Lake for the 1950 water year. They described the physical characteristics of some Spokane River reaches and identified them as either losing or gaining. This information was further developed by Broom (1951).

D4-1.2 Broom, 1951.

Broom (1951) computed annual stream gains and losses for the water year 1950 between gaging stations for seven reaches of the Spokane and Little Spokane Rivers. Broom divided the Spokane River into seven reaches from Post Falls, Idaho to the downstream end of Long Lake, Washington. The first six of these reaches (to Nine Mile Falls) are listed in Table 5.13. These reaches are illustrated on Figure 2 (taken from Gearhart and Buchanan, 2000) in Appendix D5. For the four Spokane River reaches located within WRIA 57, Broom's analyses characterized Reach 1 (Post Falls to Greenacres) and Reach 4 (Greene Street to Spokane) as losing and Reach 2 (Greenacres to Trent Bridge) and Reach 3 (Trent Bridge to Greene Street) as gaining.

D4-1.3 Drost and Seitz, 1978.

Drost and Seitz (1978) completed a Spokane Aquifer characterization report in which they cited the USGS's reanalysis of Broom's 1951 calculations. Between Post Falls, Idaho, and Greenacres, Washington, the USGS estimated an average annual loss of 80 cfs from the Spokane River to the Aquifer. The remainder of the Spokane River from Greenacres to Nine Mile Falls, was estimated to gain an annual average of 780 cfs from the Spokane Aquifer. The Drost and Seitz (1978) reanalysis is presented on Table 5.13 and illustrated on Figure 3 (taken from Gearhart and Buchanan, 2000) in Appendix D5.

D4-1.4 Bolke and Vacarro (1981)

Bolke and Vacarro (1981) further developed on Broom's 1951 losing / gaining analysis and divided the Spokane and Little Spokane Rivers from Post Fall to their confluence into 13 losing / gaining reaches. These reaches are illustrated on Figure 4 (taken from Gearhart and Buchanan, 2000) in Appendix D5. Bolke and Vacarro (1981) calculated a leakage coefficient for each of the reaches. The leakage coefficient is defined as the vertical hydraulic conductivity of the streambed divided by the thickness of the streambed:

$$C = \frac{Ks}{m}$$

Where,

C	=	streambed leakage coefficient
Ks	=	vertical hydraulic conductivity of the streambed (ft/sec)
m	=	thickness of the streambed

The table below summarizes the data that Bolke and Vaccaro (1981) used as input to their groundwater flow model from Post Falls to Hangman Creek. The data is also presented on Table 5.13.

Summary of Bolke and Vaccaro (1981) Spokane River Losses and Gains

River Reach	**Leakage Coefficient** (feet/second)	**Losing / Gaining** (cfs)
Post Falls to Greenacres	6.2×10^{-7}	- 50
Greenacres to Plantes Ferry (Irwin)	1.0×10^{-4}	+ 240
Plantes Ferry (Irwin) to Felts Field	6.2×10^{-7}	-40
Felts Field to Eastern Spokane	2.0×10^{-4}	+ 270
Eastern Spokane to Spokane Falls	6.2×10^{-7}	-200
Spokane Falls to USGS Spokane Gage	6.2×10^{-7}	+130

Based on the May 1977 to April 1978 data, Bolke and Vaccaro (1981) identified 6 losing and 5 gaining reaches along the Spokane River from Post Falls to the confluence with the Little Spokane River. In the model area between Post Falls and Hangman Creek, 3 losing reaches and 3 losing reaches were identified. The losing and gaining flows are summarized in the table above.

D4-1.5 Miller, 1996.

Miller (unpublished, 1996) used calcium concentrations in the Spokane River and Spokane Aquifer along with river stage to estimate the exchange between the Spokane River and the Aquifer. The study was based on the hypothesis that the main source of calcium to the river water is via groundwater discharge from the aquifer to the river. The following equation was used to estimate the volumetric exchange of water:

$$Q_o = \frac{(C_i Q_i + C_r Q_r - C_l Q_l)}{C_o}$$

Where,

Q_o = flow at the downstream end of a river reach
Q_I = flow at the upstream end of a river reach
Q_r = aquifer recharge to the river within the reach
Q_l = river loss to the aquifer within the river reach
C_o = concentration of the indicated parameter downstream
C_I = concentration of the indicated parameter upstream
C_r = concentration of the indicated parameter in groundwater adjacent to gaining reaches of the river
C_l = concentration of the indicated parameter in groundwater adjacent to losing reaches of the river

Miller estimated losses and gains for the six river reaches listed on Table 5.13. These reaches are illustrated on Figure 5 (taken from Gearhart and Buchanan, 2000) in Appendix D5. A summary of Miller's (1996) results is tabulated below.

Summary of Miller (1996) Spokane River Losses and Gains

<table>
<tr><th>River Reach</th><th>Low Flow</th><th>High Flow</th></tr>
<tr><td>Post Falls to Greenacres</td><td>- 207</td><td>- 319</td></tr>
<tr><td>Greenacres to Plantes Ferry (Irwin)</td><td>+ 206</td><td>+ 160</td></tr>
<tr><td>Plantes Ferry (Irwin) to Felts Field</td><td>Unquantified loss</td><td>Unquantified loss</td></tr>
<tr><td>Felts Field to Eastern Spokane</td><td>+ 209</td><td>+ 377</td></tr>
<tr><td>Eastern Spokane to Spokane Falls</td><td rowspan="2">+ 63</td><td rowspan="2">+ 122</td></tr>
<tr><td>Spokane Falls to USGS Spokane Gage</td></tr>
</table>

D4-1.6 CH2M Hill, 1998

The streambed leakage concept was used by CH2M Hill (1998) to simulate the river-aquifer interactions as a component of the groundwater flow model developed for the City of Spokane's wellhead protection program. CH2M Hill (1998) defined eleven losing / gaining reaches between Post Falls and Hangman Creek. The following is a summary of the CH2M Hill (1998) simulated streamflow losses and gains for the same reaches as those defined by Bolke and Vaccaro (1981) above. In comparison to both Bolke and Vaccaro's (1981) and Miller's (1996) models, the CH2M Hill (1998) model predicts an overall lower exchange of water (both losses and gains) between the Spokane River and Aquifer. The data is also presented on Table 5.13.

Summary of CH2M Hill (1998) Spokane River Losses and Gains

River Reach	Leakage Coefficient (feet/second)	Losing / Gaining Sept. 1994 (cfs)	Losing / Gaining Apr. 1995 (cfs)
Post Falls to Greenacres	5×10^{-7} to $2 X 10^{-6}$	- 136	- 171
Greenacres to Plantes Ferry (Irwin)	1.0×10^{-6} to 5×10^{-4}	+ 15	+ 59
Plantes Ferry (Irwin) to Felts Field	5×10^{-8} to 5×10^{-6}	- 17	+ 4
Felts Field to Eastern Spokane	1.0×10^{-3}	+ 149	+ 194
Eastern Spokane to Spokane Falls Spokane Falls to USGS Spokane Gage	5×10^{-6}	- 75	- 42

D4-1.7 CH2M Hill (2000)

As indicated in the summary table below, the updated CH2M Hill (2000) model for the SAJB, resulted in a further lowering of the overall exchange of water between the Spokane River and the Aquifer. The data is also presented on Table 5.13.

Summary of CH2M Hill (2000) Spokane River Losses and Gains

River Reach	Leakage Coefficient (feet/second)	CH2M Hill (1998) Losing / Gaining Sept. 1994 (cfs)	CH2M Hill (2000) Losing / Gaining Sept. 1994 (cfs)
Post Falls to Greenacres	5×10^{-7} to 2×10^{-6}	- 136	- 120
Greenacres to Plantes Ferry (Irwin)	2.0×10^{-6} to 5×10^{-4}	+ 15	+ 64
Plantes Ferry (Irwin) to Felts Field	5×10^{-8} to 5×10^{-6}	- 17	- 5
Felts Field to Eastern Spokane	1.0×10^{-3}	+ 149	+ 174
Eastern Spokane to Spokane Falls Spokane Falls to USGS Spokane Gage	5×10^{-6}	- 75	- 42

D4-1.8 Gearhart and Buchanan (2000).

Gearhart and Buchanan (2000) established five study sites between the Idaho-Washington state line and downtown Spokane: 1) State Line; 2) Barker Road; 3) Sullivan Road; 4) Upriver Dam; an, 5) Mission Avenue. The locations of these five sites are shown on Figure 6 (taken from Gearhart and Buchanan, 2000) in Appendix D5. Between December 1998 and July 1999 groundwater elevations in monitoring wells and river stage elevations were collected weekly at each of the five sites. The following paragraphs summarize the findings of this study.

At the State Line site, the groundwater elevation in the SVRP Aquifer was measured between 44 and 49 feet below the Spokane River stage. The State Line site is defined as a river losing site with an unsaturated zone between the river and the groundwater table.

At the Barker Road site, the groundwater elevation in the Spokane Valley Aquifer was measured between 20 and 26 feet below the Spokane River stage. The Barker Road site is defined as a river losing site with an unsaturated zone between the river and the groundwater table. A comparison of Spokane River flows near Post Falls with groundwater levels within the Barker Road wells indicated a one day to a few days lag time between rises and falls in the river flows in relation to corresponding rises and falls groundwater levels.

The Sullivan Road site is defined as a river losing and gaining site connected by saturated flow conditions. In the summer months, when river flows are low, groundwater levels rise above the river stage and groundwater flows from the aquifer to the river. Springs can often be seen along the Spokane River bank in this location during the summer months. As flows in the river increase, the river stage rises above the groundwater table and water flows from the river into the aquifer. A comparison of Spokane River flows near Post Falls within groundwater levels within the Sullivan Road wells indicated a 1 to 2 day lag time between rises and falls in the river flows in relation to corresponding rises and falls groundwater levels.

The Upriver Dam site is complicated by the dam pool, which is maintained at an elevation of 1,910 feet amsl. All measured groundwater elevations adjacent to the pool were below 1,910 feet amsl indicating that water flows into the aquifer in the vicinity of the pool. However, on the downstream side of the pool, the flow is likely reversed, with groundwater flowing from the Aquifer to the Spokane River.

The Mission Avenue site is defined as a river losing site connected by saturated flow conditions. During the period between December 1998 and June 1999, the river stage was between 1.5 to 4 feet higher than the groundwater table elevation within the well on the north side of the river. Since data was not collected at this site in July and August 1999, it was not possible to assess if the river gains flow during these low flow summer months.

Based on observations made at the five study sites, the Spokane River was divided into the five reaches illustrated on Figure 30 (taken from Gearhart and Buchanan, 2000) in

Appendix D5. Darcy's equation was used for each reach using riverbed areas estimated from aerial photographs. A riverbed hydraulic conductivity of 1 x 10^{-5} feet / sec was used for riverbed areas covered at low flow. A hydraulic conductivity of 1 x 10^{-4} feet / sec was used to characterize riverbed areas located between the low and high water levels. A one order of magnitude difference was assumed to account for the occurrence of silt within the low flow riverbed and sands within the riverbed between the high and low flow levels. These values were assigned based on a compilation of riverbed hydraulic conductivity data from a number of previous studies. These values are presented on Table 5.14.

The estimated volumetric exchanges between the river and aquifer at five reaches are summarized below.

Summary of Gearhart and Buchanan (2000) Spokane River Losses and Gains

Spokane River Reach	Losing / Gaining Dec. 1998 – July 1999 (cfs)	Flow Conditions
Reach 1 – State Line to Harvard Road	– 307 to – 47	Unsaturated
Reach 2 – Harvard Road to Barker Road	- 137 to – 29	Unsaturated
Reach 3 – Barker Road to Sullivan Road	- 28 to + 126	Transitional
Reach 4 – Sullivan Road to Trent Avenue	-88 to + 50	Saturated
Reach 4 –Trent Avenue to Plantes Ferry Footbridge	-53 to + 30	Saturated

Based on the 1998 to 1999 data, the change in the Spokane River SVRP Aquifer interaction from a generally losing to a generally gaining stream occurs between Barker Road and Sullivan Road. This is supported by unpublished field and flow data collected by Spokane County. The only other study described above that has similar reaches to the Gearhart and Buchanan (2000) study is the CH2M Hill (1998) groundwater model. CH2M Hill (1998) places the transitional zone between Sullivan Road and the Kaiser Trentwood site located about one mile downstream (west) of Sullivan Road.

D4-1.9 United States Geological Survey (ongoing).

The USGS is currently working on a Spokane River – Aquifer hydraulic connection study as a component of their National Water-Quality Assessment Program (NAWQA). The purpose of the study is to further improve the understanding of the groundwater / surface water interactions along the losing reach of the Spokane River between Pleasant View Road in Idaho and Harvard Road in Washington. The study also aims to investigate the impacts of the river on the water quality of the aquifer.

To date, the USGS NAWQA study has involved:

- compilation of a well inventory database;
- installation of 18 new wells;

- monitoring at the 18 new wells and 7 pre-existing wells;
- assessment of pressure and temperature responses in the wells as a result of flow changes in the Spokane River; and,
- investigation of the water quality differences between groundwater within the aquifer and the surface water of the Spokane River.

Since the work is ongoing, further description of the study and the study results will not be included within the Level 1 Watershed Assessment. However, the study results may be used for the model development stage of the WRIA 57 Assessment.