Appendix J
Modifications To Spokane Valley Regional Model

The regional model of the Spokane Valley aquifer is a three-layer steady-state finite-element model constructed using the Micro-Fem groundwater flow model (Hemker and Nijsten, 1996, Version 3). The model was constructed and calibrated during Phase I of the City of Spokane's wellhead protection program. The model was calibrated to hydrologic conditions that were measured during a four-day period in mid-September of 1994. During this period, groundwater elevations and river stages were at their approximate seasonal low levels, and the seasonal summer peak pumping season had just ended. Prior to delineating the capture zones for the City's wells, the model's calibration was checked by simulating hydrologic conditions during mid-April of 1995, which was a period of seasonal low pumping, seasonal high groundwater elevations and river stages. The construction and calibration processes for the original model used for delineating the City's capture zones are described in Section 3 and Appendix I of City of Spokane Wellhead Protection Program: Phase I – Technical Assessment (CH2M HILL, 1997).

Delineations of capture zones for the other members of the Spokane Aquifer Joint Board (SAJB) began after completion of the Phase I delineations for the City's production wells. The delineation work for the SAJB began with (1) localized spatial refinements of the model's finite-element mesh and (2) minor adjustments to the model's lateral and downgradient boundaries to accommodate the additional delineations. As the initial modifications were completed, the Kaiser Aluminum Company's Trentwood Rolling Mill facility and Mead facility joined the SAJB and requested that delineations be performed for their pumping wells. In addition, Kaiser provided hydrogeologic data from the Trentwood facility that indicated that the model needed adjustments in the vicinity of the facility. The specific information provided included:

- Discrete (non-continuous) measurements of the Spokane River stage at 19 surveyed measurement stations.
- Discrete (non-continuous) measurements of groundwater elevations beneath the facility.
- Hydraulic conductivity estimates for the portion of the aquifer beneath the facility.
- Results of a site-scale modeling effort.

This appendix describes the adjustments that were made to the regional model, including a re-calibration effort that was performed prior to delineating the SAJB capture zones.

J.1. Discrepancies Between Regional Model and Site Data

The hydrogeologic information from the Trentwood facility indicates that the original version of the regional model does not correctly simulate groundwater flow directions in the western portion of the facility. The original regional model simulates an east-to-west flow direction in this portion of the facility, whereas the actual flow directions indicated by the onsite monitoring well network exhibit a slight to moderate northeast-to-southwest component of flow throughout the year (including during the seasonal high and seasonal low water level periods). A site-scale groundwater flow model developed by Kaiser Aluminum Co. also predicted that groundwater flow directions in the western portion of the site would be expected to show a northeast-to-southwest component of flow, based on site-specific stratigraphic data and river stage data. The site-scale flow model and selected groundwater elevation data are presented and described by Hart-Crowser (1996).

The regional model was evaluated to identify changes that could be made to improve the simulated groundwater flow directions in the vicinity of the Trentwood facility. The evaluation process indicated that the model discrepancies could potentially be caused by the following:

- The representation of the river stage.
- The spatial extent of Pines Road Knoll and the node pattern used to represent the knoll and adjoining areas.
- The definition of the bedrock surface elevation, particularly north of Pines Road Knoll.
- The areal distribution of hydraulic conductivity.

In addition, the depth-specific assignments of pumping rates for pumping wells on the Trentwood facility were changed for the purpose of delineating capture zones. However, these changes were observed to have little effect on simulation results during model calibration.

J.2. Modifications To Regional Model

J.2.1 Procedure

Before refining the specifications of hydrogeologic parameter values in the model, the finite-element mesh was refined at the Kaiser Trentwood facility and in areas to the west (including Pines Road Knoll). The adjusted mesh is shown in Figure J-1. The refinement consisted of adding nodes in the following locations:

- At SAJB water supply wells.
- At the Kaiser-Trentwood facility.
- West of the Trentwood facility, including at and north of Pines Road Knoll.

Model parameters were then re-evaluated and changed as necessary based on the site-specific data from the Trentwood facility. Changes were made in an iterative fashion by changing one parameter value and re-running the model for the calibration period (mid-September 1994). Each model run was evaluated for its ability to reasonably simulate:

- Groundwater elevations and flow directions, particularly at the Trentwood facility.

- The aquifer water budget, including groundwater / surface water exchange rates between the Spokane River and the aquifer.

The changes that were made to the model during this re-calibration process are described below.

J.2.2 Representation of Spokane River Stage

The original regional model specified the river stage as having a uniform gradient between each station where stages were measured during the mid-September 1994 data collection period. In the vicinity of the Trentwood facility, the stations that were used to define the river stage were (from upstream to downstream) the Sullivan Road bridge (southeast of the site); Kaiser's staff gage at the water intake for the Trentwood facility (at the western edge of the site); and the East Trent Road bridge (northwest of the site).

Stage measurements were collected by Kaiser Aluminum at the staff gage and eighteen other surveyed stations on the Spokane River on August 23 and August 30, 1995. Data have also been collected on a more frequent basis at the staff gage. The stage measurements at the nineteen stations occurred during a period of seasonally low flows that was similar to the flow conditions during the mid-September 1994 data collection period (to which the original regional model was calibrated). Comparisons of the staff gage data indicate that the mid-September water levels were approximately ½ foot higher than during the two 1995 measurement events.

The data from the nineteen stations were used to refine the shape of the river stage profile adjacent to the Trentwood facility. The revised profile accounted for the presence of pools and rapids and was directly incorporated into the model. The revised profile was also checked by conducting a field reconnaissance to identify the locations of pools and rapids, the sizes of the various rapids, and the presence of other features (for example, bedrock outcrops, springs, vegetative growth patterns) that could affect hydrogeologic interpretations close to the river. The field reconnaissance and the data from the nineteen stations showed the following specific items of interest:

- A long pool is present adjacent to the eastern side of Pines Road Knoll. The pool occupies a 2,000-foot reach of the river. A 700-foot-long reach of steep rapids is present beginning at the downstream edge of the pool. The location of the transition point from a pool to rapids is consistent with geologic mapping, which suggests that this transition point may be the northeastern corner of Pines Road Knoll.
- The river stage profile in the original model was based on incorrect surveying data at the Sullivan Road bridge. The surveying error caused the river stage to be too high in the original model from Sullivan Road downstream to the Kaiser staff gage. The error was 8.17 feet at Sullivan Road, with a gradual decrease in the downstream direction. This error was confirmed in the field by re-surveying the measurement reference point on the Sullivan Road bridge.

The effect of the two observations above was to cause under-predictions of groundwater discharge rates to the river between Sullivan Road and the Kaiser staff gage in the original model.

J.2.3 Representation of Pines Road Knoll

Three aspects of the knoll's representation in the original model were modified.

1. A small number of nodes were used to represent the knoll and adjoining areas in the original model. The coarseness of the finite element mesh in these areas affected the predicted groundwater elevations and flow directions along the north side of the knoll. The density of nodes in the mesh was increased greatly at the knoll and in adjoining areas in order to minimize numerical influences on the simulated groundwater elevations and flow directions.

2. Visual observations of the river bank and available geologic maps indicate that the eastern edge of the knoll lies close to the Spokane River and forms the river's western bank in a limited reach near the Kaiser staff gage. The position of the eastern boundary was relocated during the mesh revision process.

3. The observed spatial variation of the river stage and the locations of rapids and flat pools suggest that the northeastern corner of Pines Road Knoll is situated at the northern (downstream) end of the pool. In the original version of the regional model, the northern edge of the knoll was simulated as lying several hundred feet further north.

J.2.4 Aquifer Base Elevation

The aquifer base elevation was modified north and west of the site vicinity based on detailed inspection of well logs in the area and on information from geophysical testing (a gravity survey conducted by Purves [1969]). The revised aquifer base elevation contour map is presented in Figure J-2. The specific changes to the base elevation are described below.

J.2.4.1 North of Pines Road Knoll

The original version of the regional model simulated an aquifer base elevation between 1700 feet NGVD and 1800 feet NGVD in this area. Gravity surveys conducted along East Trent Road and Pines Road suggests that the portion of the aquifer lying directly north of Pines Road Knoll is underlain by a north-south trending bedrock ridge (Purves, 1969). The ridge extends from the north side of Pines Road Knoll to the north side of the valley, where the river takes a 90 degree turn to the west and bedrock is visible in the river channel. The ridge separates the area to the west of Plantes Ferry Park and Pines Road Knoll from the area east of Pines Road and Pines Road Knoll.

The elevation of the bedrock forming the base of the aquifer along this ridge is uncertain. However, the geologic log for Irvin Water District's # 3 well suggests that the base of the aquifer lies at an elevation of about 1890 feet NGVD. Based on the well's location (approximately 1,500 feet north of Pines Road Knoll) and the presence of bedrock in the river channel north of the well (where the river turns 90 degrees), the bedrock elevation was redefined in the model as lying at an approximate elevation of 1890 feet NGVD in this area. This revised elevation is between 100 and 200 feet higher than was simulated in the original version of the regional model.

J.2.4.2 North of Kaiser Trentwood Facility

Geologic logs are available for four wells owned by the Trentwood Irrigation District due north of the Kaiser Trentwood facility. The geologic log for the northern-most well (Well #3) shows that the sand and gravel aquifer at Wellesley Road extends to a depth of 1880 feet NGVD, where the geologic contact consists of sand and brown clay underlying the gravel and sand deposits that constitute the aquifer. The bottoms of the District's three other wells lie at elevations ranging from about 1870 feet NGVD to 1910 feet NVGD and did not encounter the base of the aquifer.

Based on these well logs and the well logs available for the Kaiser Trentwood facility, the aquifer base elevation north of the facility was redefined as rising to as high as 1900 feet NGVD, which is approximately 100 feet higher than was specified in the original regional model. This change also caused smaller adjustments beneath and east of the Kaiser Trentwood facility.

J.2.5 Aquifer Saturated Thickness

The saturated thickness of the aquifer was redefined in the model based on the changes to the aquifer base elevation. The modified saturated thickness map is presented in Figure J-3. The principal revisions are:

- The saturated thickness is less than 50 feet along the bedrock ridge extending north from Pines Road Knoll, compared with approximately 150 feet to 200 feet in the original model.
- The saturated thickness ranges from approximately 50 to 150 feet directly north of the Kaiser Trentwood facility, compared with 150 to 200 feet in the original model.

J.2.6 Hydraulic Conductivity

The hydraulic conductivity zonation pattern was revised in the vicinity of Sullivan Road and the Kaiser Trentwood facility. The revisions were based on pumping test data from extraction wells located on the Trentwood facility and reevaluation of the spatial transition from high-permeability materials east of the facility to less permeable materials on the facility. The revised distribution is shown in Figure J-4. In the original regional model, the horizontal hydraulic conductivity was assumed to be uniform with depth throughout the valley. This assumption was retained in the revised model, except at the Trentwood facility where pumping test data indicate that the conductivity is lower by a factor of 2 to 6 at the base of the aquifer compared with the upper portion of the aquifer. Consequently, the hydraulic conductivity values in the deepest model layer at the Trentwood facility are two to six times lower than indicated in Figure J-4.

J.2.7 Transmissivity

The aquifer transmissivity was redefined from the revised saturated thickness and the revised hydraulic conductivity distribution. The revised aquifer transmissivity is presented in Figure J-5.

J.3. Results of Re-Calibration Process

J.3.1 Simulated Groundwater Elevations

The revised groundwater elevation contours for the Fall 1994 simulation are presented in Figure J-6, together with the measured contours. The simulated contours produced a more reasonable representation of flow directions in the vicinity of the Trentwood facility, as indicated by the southeast-to-northwest alignment of the contours just east of Pines Road Knoll and the Spokane River.

J.3.2 Simulated Water Budget

The changes to the model caused changes in the magnitudes of water exchanges between the aquifer and the Spokane River. These changes in turn caused changes to the overall water budget of the aquifer, including the water budgets within the two primary segments of the aquifer (the East Valley, which extends from the state line into the City and east of Five Mile Prairie; and the West Valley, which is the area west of downtown Spokane and west of Five Mile Prairie).

J.3.2.1 Groundwater / Surface Water Exchanges (Spokane River)

Table J-1 presents the revised water budget for the river for Fall 1994 conditions, including a comparison with the original regional model. The primary changes were:

- Between Sullivan Road and the East Trent Road bridge: (Northwest of the Kaiser Trentwood facility):
  - Revised model: Net gain of 76 cubic feet per second (cfs).
  - Original model: Net gain of 16 cfs.
  - Difference: Primarily attributable to the changes in the river stage, with a minor influence due to an increase in the riverbed conductance between Sullivan Road and the Kaiser staff gage (stations SPKRSUL and SPKRKAI in Table J-1).
- From Upriver Dam to the Monroe Street bridge: (Where the river leaves the aquifer and crosses onto bedrock):
  - Revised model: Net gain of 174 cfs from Upriver Dam to Greene Street, and net loss of 45 cfs from Greene Street to Monroe Street. This represents a net gain of 129 cfs from the dam to Monroe Street.
  - Original model: Net gain of 149 cfs from Upriver Dam to Greene Street, and net loss of 75 cfs from Greene Street to Monroe Street. This represents a net gain of 74 cfs from the dam to Monroe Street.

- Difference: Primarily attributable to an increase in the simulated groundwater elevation along and immediately up-gradient of this reach. The simulated elevations along this reach in the revised model are within + 1 foot of the measured elevations for Fall 1994 conditions.

As a results of the changes listed above, the revised model simulated a net gain of 68 cfs from the state line to the Monroe Street Bridge, versus a net loss of 64 cfs predicted by the original regional model. In the West Valley, both the original and revised models predict a net loss of 7 cfs from the river to the aquifer.

J.3.2.2 Aquifer Water Budget

Table J-2 summarizes the overall water budget for the original and re-calibrated models. The table lists the separate water budgets for the East Valley and Hillyard Trough; the West Valley (west of Five Mile Prairie and west of Trinity Trough); and the combined area. The changes are summarized as follows:

- East Valley. The changes in the magnitudes of the groundwater/surface water exchanges cause the following changes to the net groundwater flow through the East Valley and the individual components of the East Valley water budget:
  - River (Gaining Reaches): Groundwater discharges to the river increased by 78 cfs (from 172 cfs to 250 cfs).
  - River (Losing Reaches): Recharge of groundwater from the river decreased by 54 cfs (from 236 cfs to 182 cfs).
  - Net Groundwater Flow: The net groundwater flow through the valley as a whole decreased by 54 cfs (from 706 cfs in the original model to 652 cfs in the revised model). This is a 7.6 percent decrease compared with the 706 cfs flow predicted in the original model.
  - Other Water Budget Components: The groundwater discharge to the Little Spokane Valley decreased by 132 cfs (from 314 cfs to 182 cfs). This reduction equals the total water budget change for the Spokane River (78 cfs of additional groundwater recharge to the river and 54 cfs less leakage of river water to the aquifer).
- West Valley. The total recharge and total discharge are 139 cfs in the revised model, which is a 5.8 percent reduction compared with the 147 cfs predicted in the original model. This change occurs as a reduction in the recharge from the river at the southern end of the West Valley. This reduction causes an equal change in the discharge from the aquifer to the river in the northern end of the West Valley.
  - River (Gaining Reaches): Groundwater discharges to the river decreased by 20 cfs (from 145 cfs to 125 cfs).
  - River (Losing Reaches): Recharge of groundwater from the river also decreased by 20 cfs (from 152 cfs to 132 cfs).
  - Net Groundwater Flow: The net groundwater flow through the valley as a whole decreased by 20 cfs (from 706 cfs in the original model to 139 cfs in the revised model). This is a 12.6 percent decrease compared with the 159 cfs flow predicted in the original model.

- Other Water Budget Components: There were no other changes to the aquifer water budget in the West Valley because of the equal changes in the river /groundwater exchanges in gaining and losing reaches of the river.

- Entire Study Area. The total recharge and total discharge in the revised model (791 cfs) is 8.6 percent lower than the 865 cfs predicted in the original model. The only difference in aquifer recharge is leakage from the Spokane River. The differences in aquifer discharge are in the magnitudes of the discharge to the Spokane River and the discharge rate to the Little Spokane River Valley at the north end of Hillyard Trough.

J.4. References

CH2M HILL, 1997. *City of Spokane Wellhead Protection Program: Phase I – Technical Assessment*.

Hart-Crowser, August 21, 1996. *Site-Wide Groundwater Modeling Report: Kaiser Trentwood Works, Spokane, Washington.* Prepared for Kaiser Aluminum and Chemical Corporation.

Hemker, C.J., and G.J. Nijsten. 1996. *Groundwater Flow Modeling Using Micro-Fem, Version 3.*

Table J-1: Summary of Streamflow Gains and Losses
Original and Re-Calibrated Regional Models
Spokane Aquifer Joint Board (SAJB) Wellhead Protection Program

Reach	River Stage Measurement Station		Average River Width (ft)	Previous Investigations			Wellhead Protection Program (1994-1995)										Reach
				Bolke & Vaccaro (1981)		Broom (1951)	Streamflow Records [a]		Water Quality Study (Calcium) Miller (1995)		Calibrated MicroFem Model						
											Original Model			Revised Model			
	Upstream	Downstream		Leakage (sec^{-1})	Gain or Loss (cfs)	Gain or Loss (cfs)	Fall 1994	Spring 1995	Low Flow	Medium Flow	Leakage (sec^{-1})	Gain or Loss (cfs)		Leakage (sec^{-1})	Gain or Loss (cfs)		Reach
1	SPKRSTL	SPKRBAR	300			-78	-208	-442 [d]			5.0E-07	-45		5.0E-07	-45		1
2	SPKRBAR	SPKRSUL	200	6.20E-07	-50				-207	-319	2.0E-06	-91	-136	2.0E-06	-75	-120	2
3	SPKRSUL	SPKRKAI	150								*1.0E-06*	-7		*1.0E-03*	1		3
4	SPKRKAI	SPKRETR	150	1.00E-04	240	370					*5.0E-04*	22		*5.0E-04*	63		4
5	SPKRETR	SPKRPLF	200						206	160	*5.0E-06*	1	16	*5.0E-06*	12	76	5
6	SPKRPLF	SPKRARG	250								*5.0E-07*	-12		*5.0E-07*	-11		6
7	SPKRARG	SPKRUDF	400	6.20E-07	-40				Unquantified Loss		5.0E-08	-6	-18	5.0E-08	-6	-17	7
8	SPKRUDT	SPKRGRE	100	2.00E-04	270	566	312		209	377	1.0E-03	149	149	1.0E-03	174	174	8
9	SPKRGRE	SPKRMIS	250								*5.0E-06*	-38		*5.0E-06*	-26		9
10	SPKRMIS	SPKRSIR	300								*5.0E-06*	-22		*5.0E-06*	-11		10
11	SPKRSIR	SPKRMST	300	6.20E-07	-200				63	122	5.0E-06	-15	-75	5.0E-06	-8	-45	11
12	SPKRMST	SPKRUSG	200	1.00E-05	130	-39	-147	439	-57	-80	5.0E-06	-42		5.0E-06	-41		12
13	SPKRUSG	SPKRTJM	200	4.00E-06	-45						5.0E-06	-110	-152	5.0E-06	-91	-132	13
14	SPKRTJM	SPKRBAP	150	2.00E-06	-40	126					1.0E-05	50		1.0E-05	49		14
15	SPKRBAP	SPKR7ML	200	4.00E-06	50						1.0E-05	77		1.0E-05	71		15
16	SPKR7ML	SPKR9DF	750	1.00E-07	-40	21	81	1,102			1.0E-05	18	145	1.0E-05	5	125	16
STL to USG					**350**	**819**	**-43**	**1,099**	**214**	**260**		**-106**			**27**		
STL to MST					**220**	**858**	**104**		**271**	**340**		**-64**			**68**		
MST to 9DF					(b)	(b)	(b)	(b)	(b)	(b)		**-7**			**-7**		
USG to 9DF					**-75**	**147**	**81**	**1,102**	(c)	(c)		**35**			**34**		
Total (STL to 9DF)					**275**	**966**	**38**	**1,099**	(c)	(c)		**-71**			**61**		

Note: All values for flows, gains, and losses are in ft^3/second.

(a) Assumes that river flow rates at the stateline are identical to measured flows in the river at Post Falls.

(b) Flow rates were not estimated for this reach.

(c) Losses below USG station not computed for USGS historical data because of absence of USGS gage at 9DF station.

(d) Leakage from STL to BAR shown in "WHP Project" column for Spring 95 is uncertain because wide variation of flow occurred on 4/11/95. Rate varied from 9,780 to 12,300 cfs on that day (mean of 10,900 cfs).

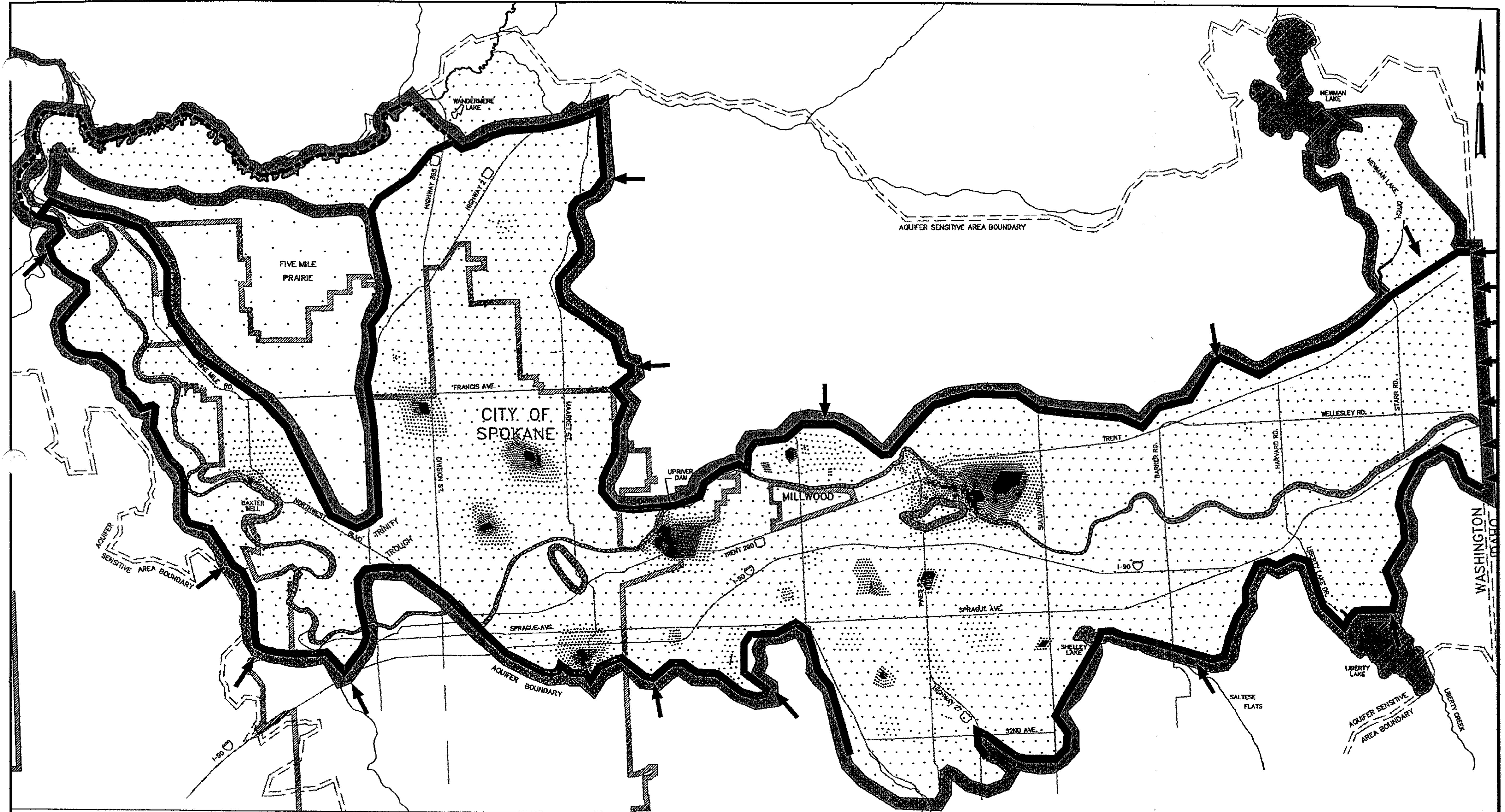
Table J-2: Comparison of Water Budgets From Original Calibrated Model, Re-Calibrated Model and Previous Investigators
Spokane Valley Aquifer
Spokane Aquifer Joint Board (SAJB) Wellhead Protection Program

	Drost and Seitz 1978 (Average Conditions)		Bolke and Vaccaro, 1983 (May 1977 - April 1978)		Original Calibrated Regional Model of Fall 1994 Conditions						Revised Calibrated Regional Model of Fall 1994 Conditions					
					East Valley / Hillyard Trough		West Valley		Entire Study Area		East Valley / Hillyard Trough		West Valley		Entire Study Area	
Component	**Rate (cfs)**	**Percent**	**(cf**	**Percent**	**Rate (cfs)**	**Percent**	**Rate (cfs)**	**Percent**	**Rate (cfs)**	**Percent**	**Rate (cfs)**	**Percent**	**Rate (cfs)**	**Percent**	**Rate (cfs)**	**Percent**
Recharge																
Precipitation minus evapotranspiration	50 [a]	4%	[i]	5%	23 [o]	3%	2 [o]	1%	25	3%	23 [o]	3%	2 [o]	1%	25	3%
Subsurface inflow	932 [b]	73%	[j]	31%	383 [p]	54%	2 [p]	1%	385	45%	383 [p]	54%	2 [p]	1%	385	49%
Subsurface inflow (tributaries)	210 [c]	17%	[j]	21%	38 [q]	5%	2 [q]	1%	40	5%	38 [q]	5%	2 [q]	1%	40	5%
Leakage from Spokane River	80 [d]	6%	[k]	33%	236 [r]	33%	152 [r]	96%	388	45%	182 [r]	26%	132 [r]	83%	314	40%
Land-applied water	[e]		[l]	9%	10 [s]	1%	1 [s]	1%	11	1%	10 [s]	1%	1 [s]	1%	11	1%
Septic systems	[e]		[l]	2%	16 [t]	2%	0 [t]	0%	16	2%	16 [t]	2%	0 [t]	0%	16	2%
Total Recharge	**1,272** [f]	**100%**		**100%**	**706**	**100%**	**159**	**100%**	**865**	**100%**	**652**	**92%**	**139**	**87%**	**791**	**100%**
Discharge																
GW discharge to Spokane River	780 [d]	61%	[k]	55%	172 [r]	24%	145 [r]	91%	317	37%	250 [r]	35%	125 [r]	79%	375	47%
Discharge to Little Spokane River valley	310 [d]	24%	[k]	20%	314 [u]	44%	--- [u]		314	36%	182 [u]	26%	--- [u]		182	23%
Groundwater pumping	127 [g]	10%	[m]	18%	220 [v]	31%	14 [v]	9%	234	27%	220 [v]	31%	14 [v]	9%	234	30%
Subsurface outflow at 9-Mile Dam	55 [h]	4%	[n]	8%	—		0 [w]	0%	0	0%	---		0 [w]	0%	0	0%
Total Discharge	**1,272** [f]	**100%**		**100%**	**706**	**100%**	**159**	**100%**	**865**	**100%**	**652**	**92%**	**139**	**87%**	**791**	**100%**

Explanations

(a) Difference between precipitation and evapotranspiration (Plate 4 of Drost and Seitz, 1978).
Original estimates by U.S. Geological Survey (J.V. Tracy, unpublished written communication, 1977).
(b) Drost and Seitz (1978) did not specify a subsurface groundwater flow rate across the state line.
Computed from Plate 4 of their report as the difference between total inflows to, and pumping loss from, Idaho portion of basin.
This assumes no change in groundwater storage and uses previous estimates of the water budget by Thomas (1963), Frink (1964), Pluhowski and Thomas (1968), and Hammond (1974).
Drost and Seitz (1978) did not specify a subsurface groundwater flow rate across the state line.
(c) Tabulated values given on Plate 4 of Drost and Seitz (1978). Original estimates by Tanaka (1975).
(d) Tabulated values given on Plate 4 of Drost and Seitz (1978). Original estimates by Tracy (1977) using analyses by Broom (1951) and long-term gauging station records.
(e) Not specified as a component of the water budget. Incorporated into groundwater pumping term.
(f) Listed as 1,320 ft^3/second for entire Rathdrum Prairie - Spokane Aquifer system by Drost and Seitz (1978).
(g) Estimated pumping in 1976. From U.S. Army Corps of Engineers (1976) and Dion and Lum (1977).
(h) Tabulated values given on Plate 4 of Drost and Seitz (1978). Original estimates by Tracy (1977).
(i) From Table 1 of Bolke and Vaccaro (1983). Assumes 21 inches annual precipitation over 135 mi^2 area.
Reported by Bolke and Vaccaro (1981) as 209 ft^3/second precipitation and 143 ft^3/second evapotranspiration.
(j) From page 17 of Bolke and Vaccaro (1983).
(k) Steady-state numerical flow model results (Figure 14 of Bolke and Vaccaro, 1981)
(l) From purveyors' water use records and assumed application rates (see Table 1 and page 17 of Bolke and Vaccaro, 1983).
(m) From inventory of water purveyors for 1977 (see Table 1 and page 16 of Bolke and Vaccaro, 1983).
(n) Steady-state numerical flow model results (Bolke and Vaccaro, 1981).
(o) Initially assumed equal to Bolke and Vaccaro (1981). Initially distributed according to west-to-east increase in precipitation (which ranges from 16 inches/year west to 24 inches/year east). Adjusted during calibration.
(p) Derived from K=7,000 ft/day, gradient of 7×10^{-4} ft/ft, and cross-sectional area of 6.9×10^{6} ft^2.
(q) From model calibration process. Assumed higher in spring than in fall because physical mechanism for aquifer recharge is surface water flow into aquifer from principal drainages in tributary valleys.
(r) Computed by model during calibration process. See Table XXX-1 for water budget summary in each river reach.
(s) Summer/fall recharge rate assumed equal to 2 inches/year basinwide, which is about 30 percent of estimated annual outdoor use.
Accounts for fallow land and irrigated commercial agricultural land. In urban and suburban areas, rates of land application are based on population density (100 persons/mi^2=0.25 inches/year, 1,000 persons/mi^2=1 inch/year, 6,000 persons/mi^2=2.5 inches/year, and City of Spokane=2.5 inches/year).
Rates assumed to be much lower in spring than in summer/fall. Not varied during calibration.
(t) Assumes 75 gpcd discharge in population zones 1-4 (as defined in MicroFem label file POPAG22.LBL). Densities in population zones are POPZONE1=100 persons/mi^2, POPZONE2=1,000 persons/mi^2, POPZONE3=6,000 persons/mi^2, POPZONE4=1,000 persons/mi^2.
Fixed in model (not varied during calibration).
(u) Model simulates discharge to Little Spokane River valley using fixed heads. Discharge to river itself is not directly simulated because a portion of the aquifer discharge is known to occur to springs upgradient of the river.
(v) Model input from field data collection activities conducted in September 1994 and April 1995. Not varied during calibration.
(w) 9-Mile Dam rests on bedrock. Model assumes no subsurface groundwater flow occurs beneath the dam.

SAJB_3-1.DWG 1/6/98



LEGEND

- SPECIFIED HEAD BOUNDARY
- NO-FLOW BOUNDARY
- SPECIFIED FLUX BOUNDARY

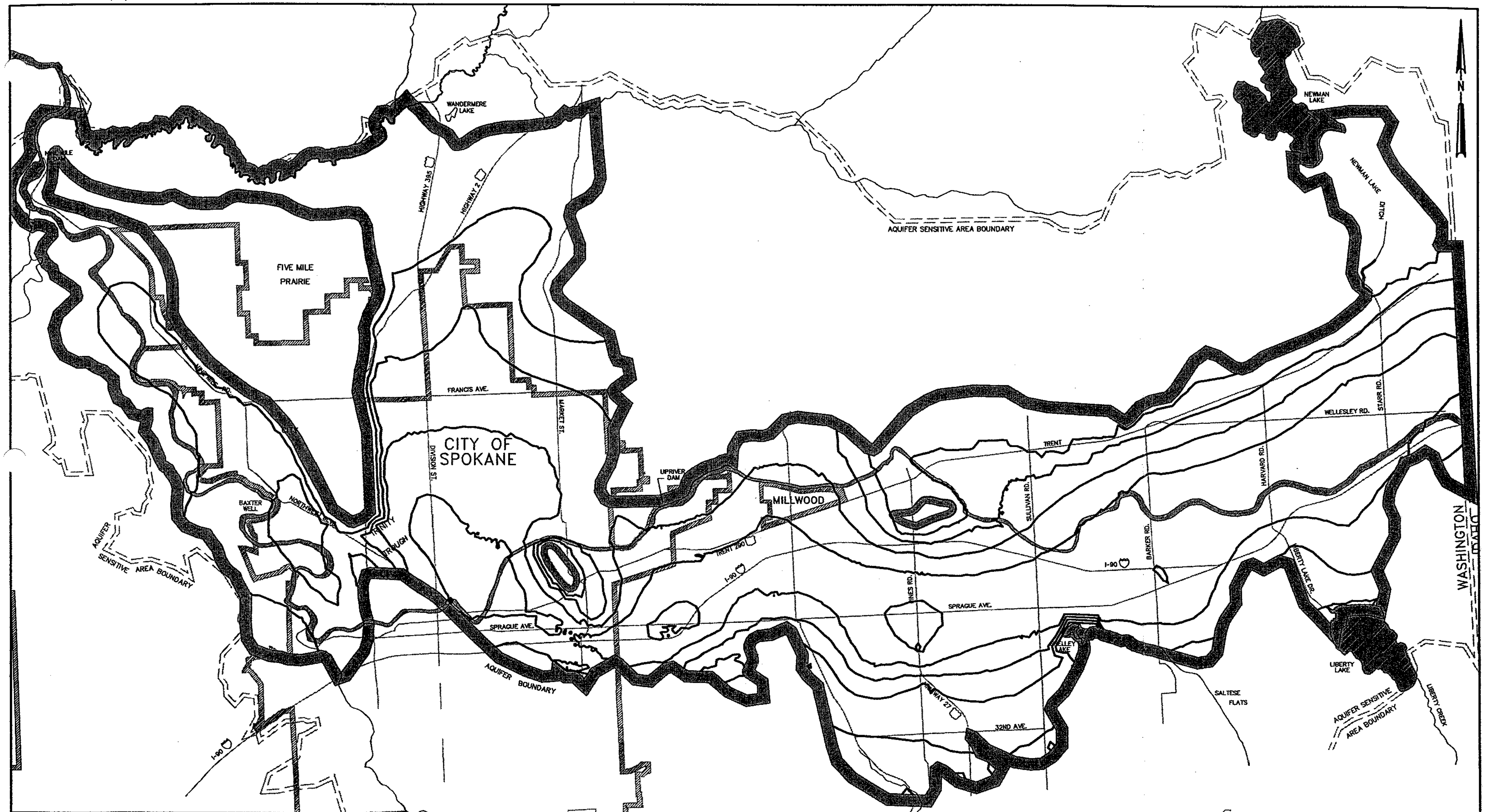
FIGURE J-1

MODEL MESH DESIGN AND BOUNDARY CONDITIONS

SPOKANE AQUIFER JOINT BOARD
DECEMBER 1997

CH2MHILL

SAJB_3-2.DWG 1/6/98



LEGEND

BASE CONTOUR (INTERVAL = 100 FT.)

FIGURE J-2

AQUIFER BASE ELEVATION

SPOKANE AQUIFER JOINT BOARD

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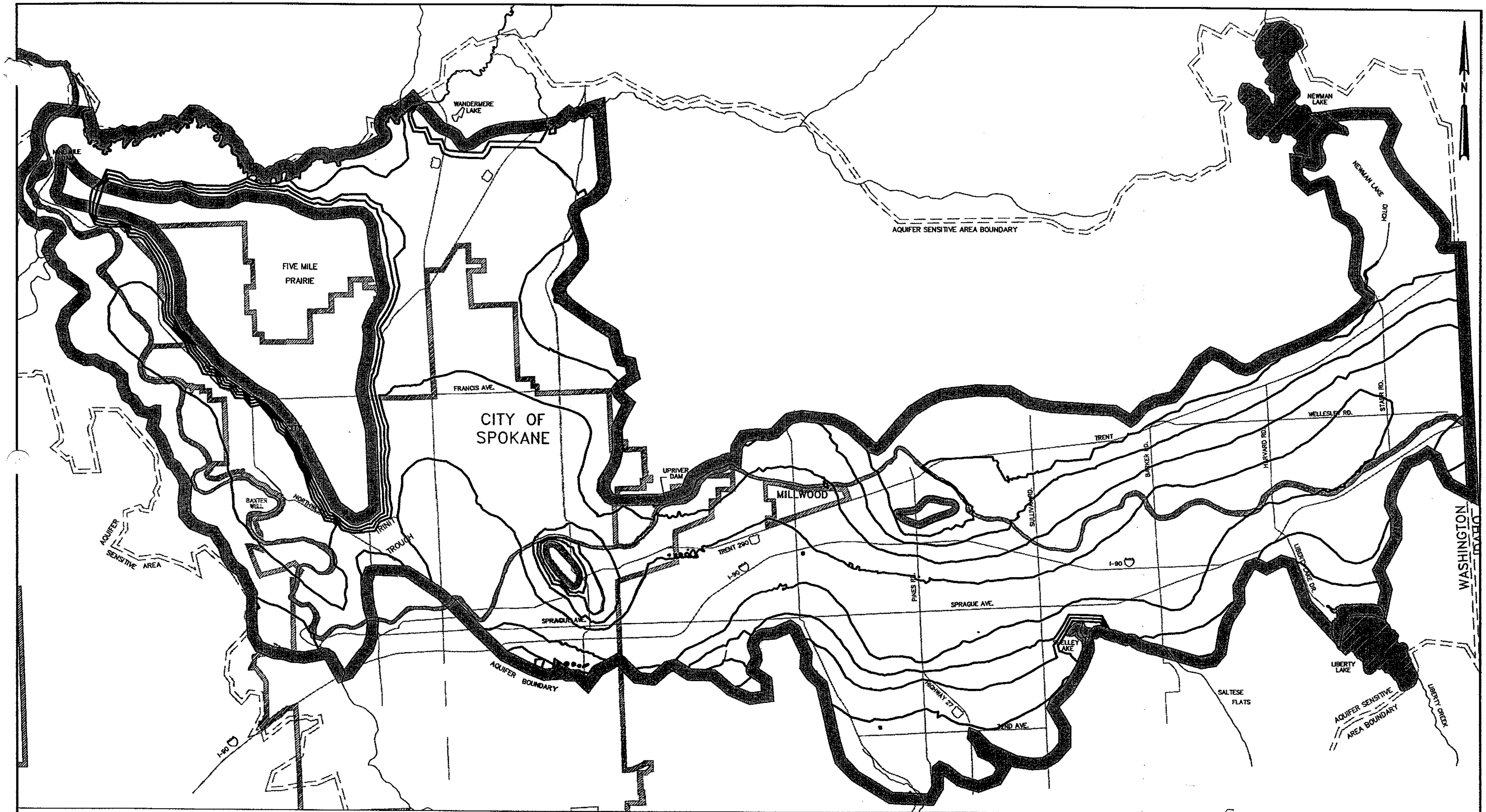
SAJB_3-3.DWG 1/6/98



LEGEND

AQUIFER CONTOUR

FIGURE J-3

AQUIFER SATURATED THICKNESS

SPOKANE AQUIFER JOINT BOARD
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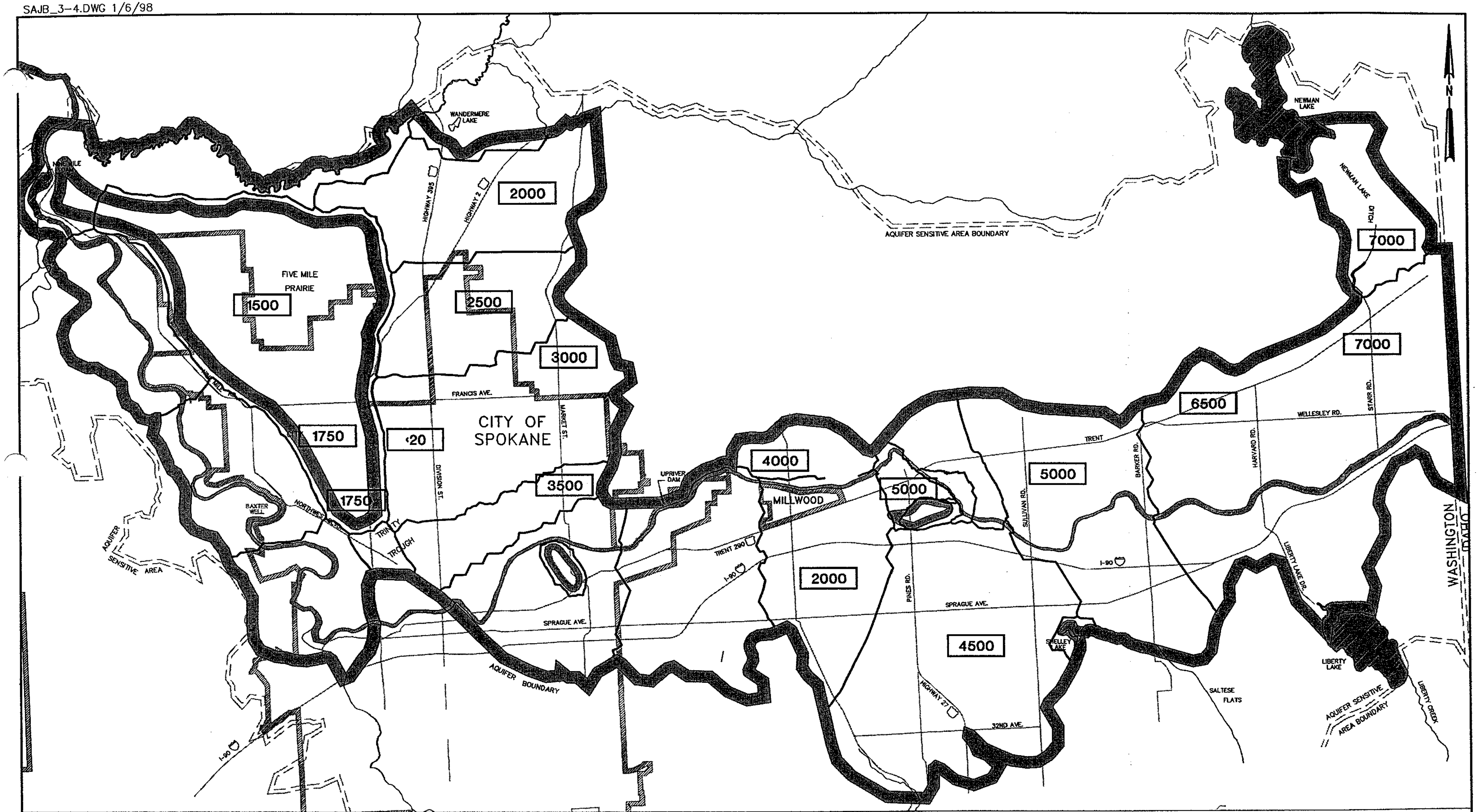
SAJB_3-4.DWG 1/6/98



LEGEND

HYDRAULIC CONTOUR

2500 MEASUREMENT UNITS ARE FEET/DAY

FIGURE J-4

HYDRAULIC CONDUCTIVITY ZONATION PATTERN

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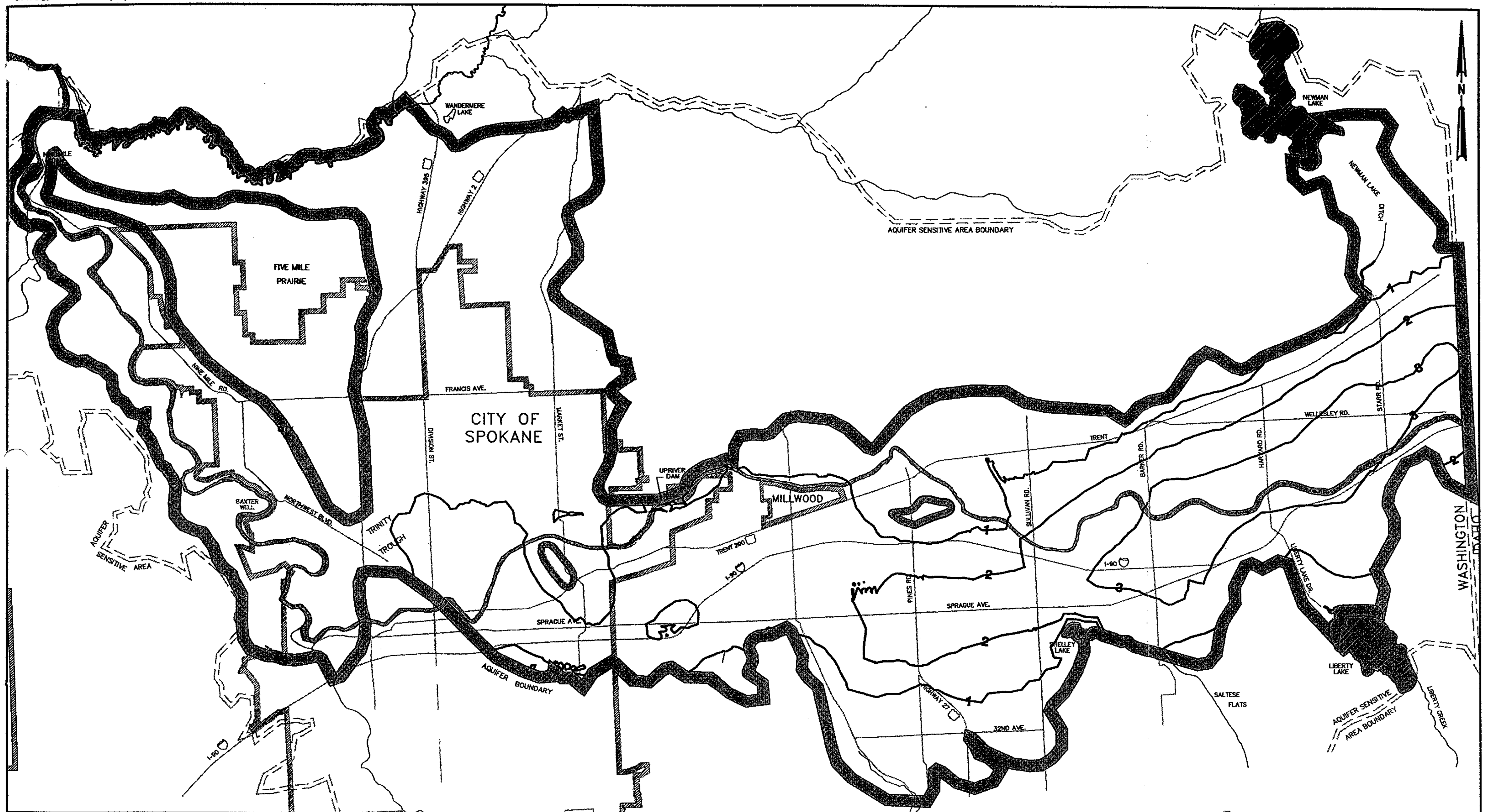
SAJB_3-5.DWG 1/7/98



LEGEND

—2— CONTOUR INTERVAL = 1 MILLION SQUARE FEET/DAY

FIGURE J-5

TRANSMISSIVITY DISTRIBUTION IN CALIBRATED MODEL

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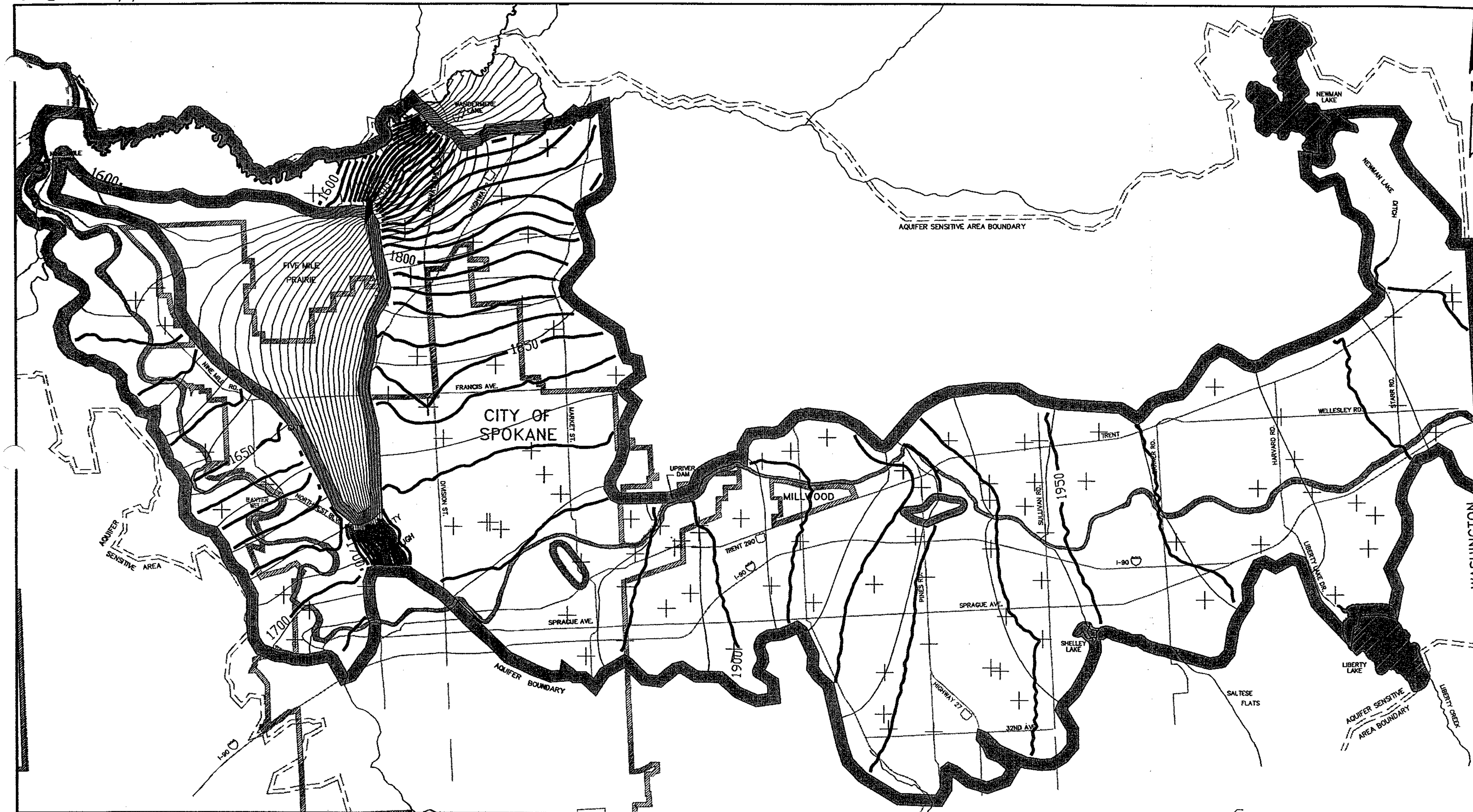
SAJB_3--6.DWG 1/7/98



LEGEND

1800 MEASURED CONTOURS

1600 SIMULATED CONTOURS

+ GROUNDWATER LEVEL OBSERVATION WELL

FIGURE J-6
COMPARISON OF
MEASURED AND SIMULATED
GROUNDWATER ELEVATIONS (SEPTEMBER 1994)

SPOKANE AQUIFER JOINT BOARD
DECEMBER 1997

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