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RECEIVED
MAY 31 2011
DEPARTMENT OF WATER RESOURCES

May 24, 2011

Renea Ridgeway, Paralegal
Office of the Attorney General
Natural Resources Division
Box 83720
Boise, ID 83720-0098

RE: ESPA Boundary Change
Our File No.: 19198.110020

Dear Renea:

Pursuant to the information meeting that was held by IDWR in Burley several weeks ago, I am submitting, on behalf of Southwest Irrigation District (SWID) and Goose Creek Irrigation District ("GC"), information compiled by the hydrologist for the two irrigation districts.

It is our understanding, that it is the intent of the department to assemble information that may be beneficial in moving forward or not moving forward with the Clear Springs Foods' Petition to enlarge the ESPA boundary. It is within that spirit that this information is furnished.

If the case goes into the formal process our clients reserve the right to supplement this material and/or provide new and additional material that may be then available.

It is obvious that to expand the boundary without taking into account other areas works a substantial hardship on SWID and GC.

It is recognized that both SWID and GC have been proactive in the mitigation and other efforts to be good stewards of the water in their respective areas. This has gone on for a number of years. To have some rulings now that adversely affects that without taking into account all of the data is not appropriate.

If we can furnish additional information at this level, after you've had a chance to review this, please advise and we will attempt to comply.

Very truly yours,

PARSONS, SMITH, STONE, LOVELAND & SHIRLEY, LLP

William A. Parsons

WAP/sw
cc: Goose Creek w/enc.
Brian Higgs wo/enc.
Enc.

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April 5, 2011

Renea Ridgeway
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Idaho Department of Water Resources
322 East Front Street
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Dear Renea,

On November 10, 2010, Clear Springs Foods through counsel petitioned the Idaho Department of Water Resources to amend Conjunctive Management Rule 50.01. The main purpose of the change in the rule is stated in the petition thusly:

"The report referenced in Rule 50 is nearly 20 years old and is not based upon the most recent data information regarding the proper hydrologic boundary of the ESPA."

"It is not reasonable for IDWR to continue to rely upon an outdated definition of the aquifer when it does not represent the best information available."

Changing the model boundaries has far reaching effects. Administration of water rights for ongoing water calls by the Spring Users and the Surface Water Coalition (SWC) are determined by the model boundaries. Irrigated acreage, manufacturing, and dairies are curtailed depending on the chosen model boundary.

South West Irrigation District (SWID) and Goose Creek Irrigation District (GC) protest this boundary change for many reasons. A few of the reasons are listed below.

1. The original model boundary was taken from the United States Geological Survey (USGS) report *Geohydrologic Framework of the Snake River Plain, Idaho and Eastern Oregon*, by R.L. Whitehead, 1986. When constructing the original model of the ESPA, Garabedian relied on the boundary chosen by Whitehead for the model (USGS Professional Paper 1408-F, *Hydrology and Digital Simulation of the Regional Aquifer System, Eastern Snake River Plain, Idaho*, by S.P. Garabedian). The Idaho Water Resource Research Institute (IWRRI) and Idaho Department of Water Resources (IDWR) followed the lead by Garabedian and maintained the Whitehead ESPA boundary for the first iteration of the ESPAM model with exception to the Murtaugh Area. The Murtaugh Area was not included due to the complex nature of the hydrogeology of the area.

   The problem with Garabedian, the IWRRI, the IDWR, and the modeling committee following the ESPA boundary chosen by Whitehead is, as Whitehead explained in his paper, "Where rocks equivalent in age to those in the plain extend beyond the plain's boundary (for example, where the boundary crosses the mouth of a tributary valley), a topographic contour was chosen to **arbitrarily** define the boundary." Arbitrary is fine for a large areal extent of the ESPA but not for

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water right administration. The mistake was made when no one from the IDWR investigated the position of the boundary and the implications of ***arbitrary*** curtailment prior to Conjunctive Management Rules and administration using the model.

Since then the boundary has been enlarged several times (Cosgrove et al., 1999; Johnson et al., 1999; Wylie, 2004). The boundary was moved for the convenience of the groundwater modelers, which is insufficient justification. Movement of the boundary by IDWR should have employed a rigorous scientific examination, which it did not. Any decision with such important ramifications must be made in the context of all existing scientific evidence.

2. SWID and GC have been concerned about their groundwater mitigation responsibility since the late 1980's. SWID began "soft conversions" (replacing groundwater irrigated acres with surface water) prior to any water call or model. In 2006, Water Well Consultants, Inc. (WWC) completed an extensive geochemical project to determine the volume of ESPA water pumped by SWID and GC irrigators.

   The project included sampling more than 65 locations throughout the SWID/GC area including samples taken from all the infiltrating sources and ESPA. Analysis was completed for pH, SC, Alkalinity, T, and major anions and cations.

   In addition, due to the complex nature of the geology and lack of control of the mixing of the groundwaters in the samples (infiltrated Snake River water with infiltrated mountain run-off) the results of the analyses were also presented for stochastic modeling.

   The results of the chemical study and the stochastic model agreed that wells in the northern end of the valley pump entirely ESPA water, wells near the Burley Irrigation District (BID) pump a mixture of ESPA and Oakley Fan water and wells in the southern portion of the Fan pump Oakley Fan water only.

   Combined, these totals state that approximately 15% of the water pumped by SWID/GC is SRPA groundwater. Of the 15% of SWID/GC wells that pump ESPA groundwater less than ½ of the acres have water rights junior to the Spring Users water rights. Therefore, only 7,000 acres should have been involved in any of the water calls instead of 85,000 acres which were called out according to the chosen model boundary.

3. Associated with the geochemical study WWC completed an extensive hydrogeological study of the groundwater in the aquifers beneath the Oakley Fan. Thousands of water levels and hydrographs of groundwater and surface water sources were analyzed for this study.

   The results identified a groundwater trough located in the northern end of the Fan. The trough is formed from the ESPA water and infiltrated BID water flowing south and meeting the Oakley Fan flowing north. The trough begins near where 600 South Road, Burley, meets the mountains and trends east northeast below the location where 900 West Road, Burley, crosses Highway 30. The trough continues west northwest and crosses under the Snake River at approximately 1000 West Road, Burley.

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The groundwater trough defines the hydrologic boundary of the ESPA; groundwater pumped north of the trough is ESPA water and groundwater pumped south of the trough is Oakley Fan water. The volume of groundwater pumped by SWID members north of the trough is 15% of the total groundwater pumped by SWID/GC perfectly agreeing with the geochemical analysis and the stochastic model. Stated again, of the 15% of the ESPA groundwater pumped by SWID/GC less than ½ is junior to the Spring Users water rights.

4. The proposed model boundary will include the entire Oakley Fan but maintain the Murtaugh Area outside the ESPA boundary. This is problematic for SWID/GC for 2 reasons.

   - Prior to 1997 SWID began soft conversions of groundwater irrigated acres bordering the BID's J Canal and groundwater irrigated acres in the Murtaugh Area. These soft conversions have grown to more 50,000 acre feet of surface water turning off 25,000 groundwater irrigated acres. In addition, SWID partnered with the West Cassia Pipeline in 2009 to convert another 7,000 acres from groundwater to surface water. Totaled, the SWID converts approximately 30,000 acres with 65,000 acre feet of surface water each year. These totals do not include the recharge injection.

     Since the arbitrary ESPA/model boundary does not include the Murtaugh Area SWID/GC receive no mitigation credit for their projects in that area. SWID/GC continue the conversions because it is the right thing to do to. The proposed boundary stops east of the Murtaugh Area which will continue to exclude the mitigation credit completed by SWID/GC.

   - The Oakley Canal Company utilizes all their rights to provide irrigation water to their membership. No water from the Fan reaches the Snake River and there is no water available for soft conversions. Some recharge injection is completed in the Cottonwood area but the volume is limited to Cottonwood Creek only.

     The proposed boundary adds more irrigated land within the Oakley Fan where there is no possibility for additional mitigation efforts.

5. The proposed ESPA boundary will bring more than 19,250 irrigated acres within the SWID/GC boundaries but will exclude the Murtaugh Area where approximately 35% of the SWID/GC mitigation effort is completed. SWID/GC demands that if the 19,250 acres in the southern end of the Oakley Fan are included in the model, the IDWR must also include the Murtaugh Area where the mitigation can and is being accomplished.

In Summary, SWID/GC can accept only 3 possible options.

1- Place the boundary of the ESPA as determined by the geochemical, stochastic, and hydrological studies determined as described in sections 2, 3, and 4 above.

2- Leave the boundary where it is currently described.

3- Expound the boundary to include the entire Oakley Fan as described in the mentioned petition **AND** include the entire Murtaugh Area using Rock Creek Road as the western boundary.

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SWID/GC will continue to complete and expand their mitigation efforts with or without credit from the administrating agencies. These districts realize that healing their aquifers will break the downward slope for the entire ESPA. However, credit must be given where credit is performed. The proposed boundary changes are neither scientifically determined nor advantageous to the districts completing the largest share of mitigation.

Please find enclosed copies of the documents listed in this letter.

Sincerely,

Brian Higgs

Brian Higgs, P.G.

APPENDIX A

Stochastic Analysis

of Groundwater Flows in the Oakley Fan Area

Stochastic Analysis of Groundwater Flows in the Oakley Fan Area

A.1 Introduction

Numerous methods have been proposed to model groundwater flow.. The extremely complex substrate patterns throughout the Snake River Aquifer make it particularly difficult to predict groundwater flow paths using fluid dynamics or diffusion analysis techniques. The most recent advances in computational fluid dynamics are unable to predict even the most simple underground water flow experiments. The difficultly in developing an accurate model is due to the unknown underground flow patterns.

Without a good understanding of the detailed flow channels within the SRPA, it is impossible to develop an accurate flow model that could be used to define sources of water in individual wells. The equations that define groundwater flow require a complete understanding of the boundary conditions and detailed hydrogeologic information of the lithology and groundwater gradients through which the flows occur. Viable boundary conditions and sufficient understanding of the flow medium is difficult to determine for the large Snake River Aquifer region.

Another approach for making an overall estimate of the complex and random patterns of chaotic water flows can be approximated through stochastic analysis. An overall prediction of random processes has been successfully achieved through Bayesian Statistics and Markov Processes as well as other statistical applications. The advantages of using a stochastic approach for modeling complex processes is the direct application of all information available, spatial and chemical as well as flow parameters such as level and rates, to develop a more accurate trending model of the flow phenomenon.

This Appendix documents a statistical analysis conducted on the Oakley Fan region for modeling the water usage from the Snake River Aquifer. The results show that, on average, less than 25% of the total water usage pumped from the Oakley Fan region probabilistically comes from the Snake River Aquifer. These results indicate that, on average, less than 15% of the water pumped from the Oakley Fan region statistically comes from the Snake River Aquifer due to seepage from the Snake River and other underground water sources.

A.2 Basis of Stochastic Approach

Underground water absorbs minerals as it flows through limestone, rhyolites, basalt, and alluvium substrates. The mineral content of underground water is a result of the general flow path through these specific substrates. Accurately measuring the mineral content of water taken from numerous wells in a region can be used to statistically determine the general groundwater flow direction and water sources.

A.3 Historical Analysis of the Oakley Fan Area

In 1988 the U.S. Geological Survey conducted a water resources investigation of the Oakley Fan area. The results are documented in a report produced by the U.S. Department of the Interior:

Hydrology of the Oakley Fan Area, South-Central Idaho, U.S. Geological Survey, Water-Resources Investitations Report 88-4065, Prepared in coorperation with the Southwest Irrigation District, published 1989.

The study documents selected wells in the area in addition to surface water streams. Pumpage from the area wells was determined with an estimation of recharge into the underground aquifer. Water levels, chemical content, and seasonal flows were measured and documented in the report. Most importantly, chemical analyses of the well water samples were spatially plotted in milliequivalents per liter on a diagram of the area. A copy of this chart is shown as Figure I in the Appendix to this report (where?).

Simple observation and analysis of the data shows spatial correlation. Observation shows that most wells near the Snake River, the northern boundary of the Oakely Fan region, are similar in major ion content. This area is either heavily affected by seepage from the river, irrigation return, or influence from the Snake River Aquifer. Smaller patterns, representing the chemical content of the water begin to appear about five miles south of the Snake River and continue into the southern most regions of the area. A few larger patterns can be seen within the southern cluster of wells. A simple analysis of well depth, hand written within the pattern diagram, show that a spatial correlation may be present.

Wells with within five miles of the Snake River have much higher major ion/dissolved solid concentrations than all other wells. In addition, a trend is visually apparent that the deeper a well is, the higher the dissolved solids content. Unfortunately, it is not known if the documented wells are sealed with casing or how deep the water samples were taken. However, the data shows a spatial correlation to well location and well depth.

Surface water samples from the local mountain streams, shown on the chart, also have low concnetrations of major ions/dissolved solids, similar to most wells in the region. It appears, from a simple visual spatial correlation, that much of the well water pumped from the Oakley Fan area is due to snow pack seepage from the local mountains and streams in the area. This visual correlation prompted a more thorough analysis.

These results indicate that water used by all shallow wells does not come from the Snake River Aquifer but a significant portion comes from snow seepage into the local mountain range. In addition, the smaller major ion concentrations of the deeper southern wells indicate that a significant portion of the pumped water is diluted with local stream or snow seepage. It was determined from these observations that a more accurate chemical measurement analysis and water flow model be developed.

A.4 Water Flow Analysis of the Oakley Fan Area

The State of Idaho Interior Department requires that one third (1/3) of the wells in each region be measured for water level and total pumped flow to regulate the Snake River Aquifer. A series of sixty five (65) locations were measured through out the growing summer season of 2006. Water samples taken from the measured wells were chemically analyzed at the University of Idaho Chemical Analysis Laboratory. Results of these data are listed in Table 1 of this Appendix.

A statistical analysis was conducted on the data to determine an overall stochastic model of the groundwater chemistry from the measured wells. The groundwater chemistry was related proportionally to a water flow model. The global model was summed for an overall model of the water flow throughout the Oakley Fan Aquifer. A spatial analysis was performed internal to the aquifer flow model to determine the total water flow coming from the northern boundary of the Oakley Fan Area or from the Snake River Aquifer. The results show that, on average, less than 30% of the Oakley Fan Area water comes from the Snake River Aquifer.

A.4.1 Groundwater Flow analysis of the Oakley Fan Area

Several statistical analyses were conducted on each parameter measured which included: specific conductivity, temperature, pH, alkalinity, fluoride, chloride, nitrate, sulfate, phosphate sodium, magnesium, potassium, and calcium content. A thorough Stepwise Regression analysis was performed to derive a global model of the data. Statistical product, cross-product, exponential, logarithmic, and reciprocal terms were used in the stepwise regression procedure.

Iterations using the stepwise regression procedure showed that scaling is required in the spatial data – an affect that is useful in evaluation of the aquifer. The Oakley Fan region is approximately 25 miles in latitude and 30 miles in longitude. The measured water elevations were between 2700 ft and 4700 ft. A spatial analysis shows that the depth of the measured data in the aquifer is less than 1.5% of the length or breadth. The very shallow region to be modeled creates an issue for any flow analysis in that determination of a vertical component would require extremely small elements. Stochastically, it is prudent to scale the area to depth such that each spatial characteristic can be statistically and numerically significant with each other. This observation notes that the spatial distortion of the aquifer is resistance to cross flow from the general trend. In other words, general fluid flow analysis would show that, in a non-restrictive channel such as a wide shallow river, cross flow is difficult against the overall stream flow. The overall fluid motion of the Snake River Aquifer is from the eastern Teton Range west-southwest to the Big Springs outcrop. A cross flow channel into a higher water elevation area, such as the Oakley Fan region is not likely to occur. It is similar to the flow of a smaller stream entering a larger river, some mixing occurs at the mouth of the stream, but does not flow significantly up the stream.

Numerous global trends are generated through a stepwise regression process for evaluation. A final global trend was selected which accounted for nearly 70% of the variation in the model of the Oakley Fan Aquifer. The scaled components of the spatial data were determined in down range, cross range, well elevation, and water depth. These components were translated from GPS coordinates based on a model boundary of 42.2 degrees latitude and 113 degrees longitude. The global trend model is listed below:

$$\begin{aligned}
\bmod el_i &= 13.32296 + 3.95353d^{-16}dR_i^3 - 6.5847d^{-16}cR_i^3 + 5.524193d^{-9}dT_i^3 + \\
&1.678842d^{-7} * cR_i * dT_i - 0.83071 * \log(cR_i) - 2.56d^{-14} * dR_i^2 * eL_i - \\
&1.0032d^{-10} * cR_i * dT_i^2 - 1.73499d^{-9} * eL_i * dT_i^2
\end{aligned}$$

where:

dR is the downrange, cR is the cross range, dT is the depth, and eL is the elevation of the i^{th} well

It is noted that a global model accounting for only 70% of the overall trend is relatively low. Statistically significant regression models are generally accepted with higher than 90% R^2, or much lower root mean square error. The relatively low fit to the global trend indicates the complexity of the water flow throughout the aquifer. The unknown substrate structure within the aquifer causes significant uncertainty in the data. Hence, a stochastic model, with relatively high variance, may still be the best approach to approximating any trends in the flow. General flow models or computational fluid dynamic models will not capture the stochastic variations. This also demonstrates the significant error that can exist in a single regression model without accounting for data variance such as the analysis conducted in the referenced study. The relatively large error band of the global trend indicates that the regression needs statistical account of the variation, such as a Kriging analysis.

A 3-dimensional plot of the global trend is shown below (Figure A-1). The spatial parameters have been normalized to non-dimensional parameters. Without normalization the global pattern would appear as a flat plate due to the ratio of down range and cross range to the depth of the aquifer as stated above.

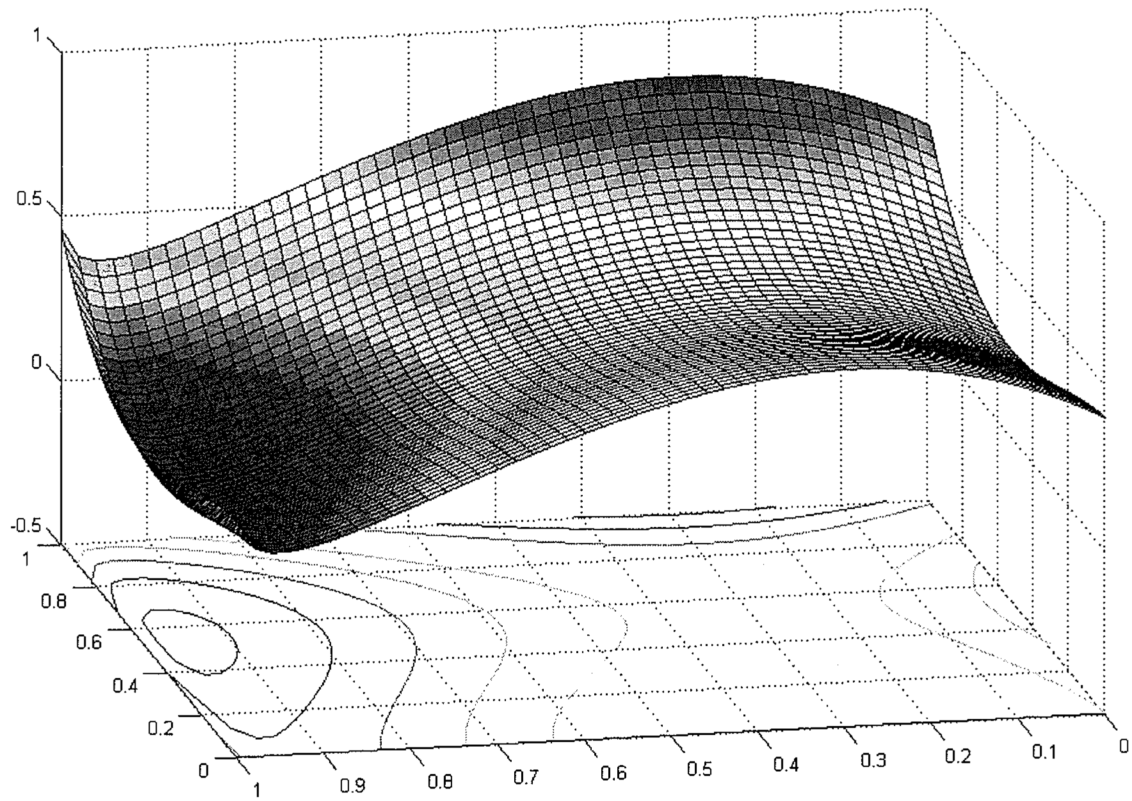


Figure A-1. Global model of Oakley Fan Aquifer data.

Visual inspection of the global trend indicates that the general trace of the Snake River has a significant affect in the ground water of the region. The high flow area, shown above in the red and yellow regions, aligns along the general trace of the Snake River. The global model also indicates that the flow from the northern Snake River boundary of the Oakley Fan Aquifer significantly reduces toward the southern area of the region. A contour plot of the global flow model is traced along the base of the diagram. Another verification of the flow model is the shape of the contour plot. Although the model is based on the chemical analysis of the tested water wells, the contour closely matches the trend of the water elevation levels documented in the Oakley Fan Area Hydrology report. This analysis indicates that, as expected, the global water flow within the aquifer generally flows down water elevation levels.

It is not known whether the increased underground flow is due to seepage from the Snake River or flow mixing of Snake River Aquifer with the Oakley Fan Area. The model shows that the flow north of the Snake River trend goes toward the Snake River Aquifer just as significant as toward the Oakley Fan Area.

This trend indicates that Snake River Seepage is the probable source for most of the cross flow trend into the Oakley Fan area and not the Snake River Aquifer.

Mathematical analysis of the model shows similar results to the above visual inspection as expected. However, the mathematical model does have a small positive cross range flow influence with respect to depth in the fifth term. The positive coefficient with depth in the term indicates that the deeper water source results in slightly higher cross flow content. In addition, the deeper the water source, the less likely the possibility that Snake River seepage has an effect. This term indicates that Snake River Aquifer water most likely does flow into the Oakley Fan Area only in significantly deep wells. This trend is supported by the USGS Hydrology report cited above. Similar chemical water content was detected in deep wells, even near the Snake River which differed from water in shallow wells.

A.4.2 Conclusion for Statistical Flow Model

The global model for the water flow does show some cross flow trend from the Snake River Aquifer to the Oakley Fan Area. The fifth term of the model accounts for less than 15% of the total model flow equation at the farthest well location. With this term, a conservative estimate can be made that less than 15% of the Oakley Fan Area water comes from the Snake River Aquifer.

A.5 Statistical Variation and Error Analysis

Applying a statistical analysis to an groundwater model can estimate the spatial variance and error of the estimated trend. Geologists have successfully used a statistical approach called Kriging to estimate the variation of a predicted model for a sporadically measured unknown underground region. Kriging is essentially a quadratic spatial correlation of the data variance that statistically predicts relationships between measured and estimated locations. Correlated as a flow model, Kriging can statistically relate the water flow between specific wells based on the mineral content of the water.

Kriging is used in this analysis to determine if a spatial correlation exists between wells. If a spatial correlation does not exist outside the global trend, then there is little likelihood that a physics based model can be accurately generated to predict the underground flow. If there is no statistical spatial correlation in the covariance between the water of various wells then the global trend shown above is the best solution that can be predicted.

A Kriging analysis was conducted using the chemical content and spatial coordinates of 65 sampled wells in the Oakley Fan Region. The Kriging approach, analysis, and results are presented in the following sections.

A.5.1 Kriging Analyses

Kriging techniques are used in geostatistics to interpolate sporadically sampled data over large regions. The broad success in Kriging has expanded into many applications including modeling of groundwater characteristics such as predicting potential well locations, well water levels, and mineral content. Similar stochastic applications have been applied to nearly all underground characteristics associated with complex patterns of rock or substrate regions that are nearly impossible to predict using other physics developed methods due to the unknown interstitial and boundary conditions.

A Kriging analysis develops a spatial model of medium characteristics based on measurements from sporadic locations. After developing a generalized function, Kriging theory effectively performs a linear least squares second order estimation of the interpolation variance between known points. The Kriging method is theoretically developed to minimize the variance of the interpolation prediction error.

Characteristics of selected locations within the measured field can be predicted based on the correlated variance interpolation from each of the measured points.

A Simple Kriging analysis was applied and assumes that a process model can be represented by:

$$Y(s) = x^T(s)\beta + U(s)$$

where:

$Y(s)$ is the process model,

$x^T(s)\beta$ is the estimated mean value of the model, and

$U(s)$ is a zero mean process with a predicted or known covariance function

The covariance function can be predicted from the known data points of the process. An assumption in this model is made that the covariance of the known data points represents the overall covariance of the process. The known covariance assumption is viable as long as the measured number of points to represent the model are sufficient to determine a standard deviation and the predicted locations are within, or interpolated, in the field of data, which are both valid in this application as over 60 wells were measured and are sporadically selected throughout the Oakley Fan area with measurements at the boundaries of the region.

Predicting the characteristics within the region at a specific point can be determined through a weighted linear combination of random variables:

$$\hat{U}(s) = \sum_{i=1}^{n} \lambda_i(s) U(s_i)$$

where:

$\hat{U}(s)$ is the weighted sum of the random variables at the measured locations

$\lambda_i(s)$ are the weights applied to each measured location

An overall model error can be estimated by selecting weighted values such that the weighted sum is close to the known model variability. Minimizing the expected mean square error results in weights calculated using (derivation shown in previous reference):

$$\lambda_s = C^{-1}(s_i, s_j)c(s_i)$$

where:

$C(s_i, s_j)$ is the spatial covariance matrix of measured data and

$c(s_i)$ is the covariance vector spatially determined from a selected point

The mean square prediction error of the Simple Kriging model can determined from:

$$\sigma_e^2 = \sigma^2 - c^T(s)C^{-1}(s_i, s_j)c(s_i)$$

where:

σ_e^2 is the mean square prediction error or Kriging variance

σ^2 is the model variance

A critical step in a Kriging analysis is to determine the spatial correlation of the data. A spatial correlation can be calculated by analyzing a variogram of a univariate data model. A variogram is a function describing the spatial dependence of a stochastic process. A close variogram regression ensures that the covariance is spatially related and that a Kriging analysis is an applicable stochastic model of the process. To ensure a non-singular inverse to the covariance matrix it is desired that the variogram regression take one of three forms:

$$\text{exponential variogram form} = \sigma_v^2\left(1 - e^{-3\frac{h}{R}}\right)$$

$$\text{Gaussian variogram form } = \sigma_v^2\left(1-e^{-3\left(\frac{h}{R}\right)^2}\right)$$

$$\text{spherical variogram form } = \sigma_v^2\left(\frac{3}{2}\frac{h}{R}-\frac{1}{2}\left(\frac{h}{R}\right)^3\right)$$

where:

σ_v^2 is the sil of the variogram,

R is the range of the variogram, and

h is the univariate covariance of the known data

In summary, a Kriging analysis takes three primary steps. First, a mean value, or global model, of the data is generated. Subtracting the mean value from the measured results produces a model covariance. Second, the model covariance is applied to a univariate variogram analysis. The univariate model is best fitted with a equation type selected from the following: exponential, Gaussian, or spherical. Good correlation of the univariate variogram ensures spatial correlation of the data and a valid Kriging analysis. Third, a Simple Kriging analysis is performed on all data points desired for prediction to the stochastic model. The overall weighted results are correlated to an integrated value.

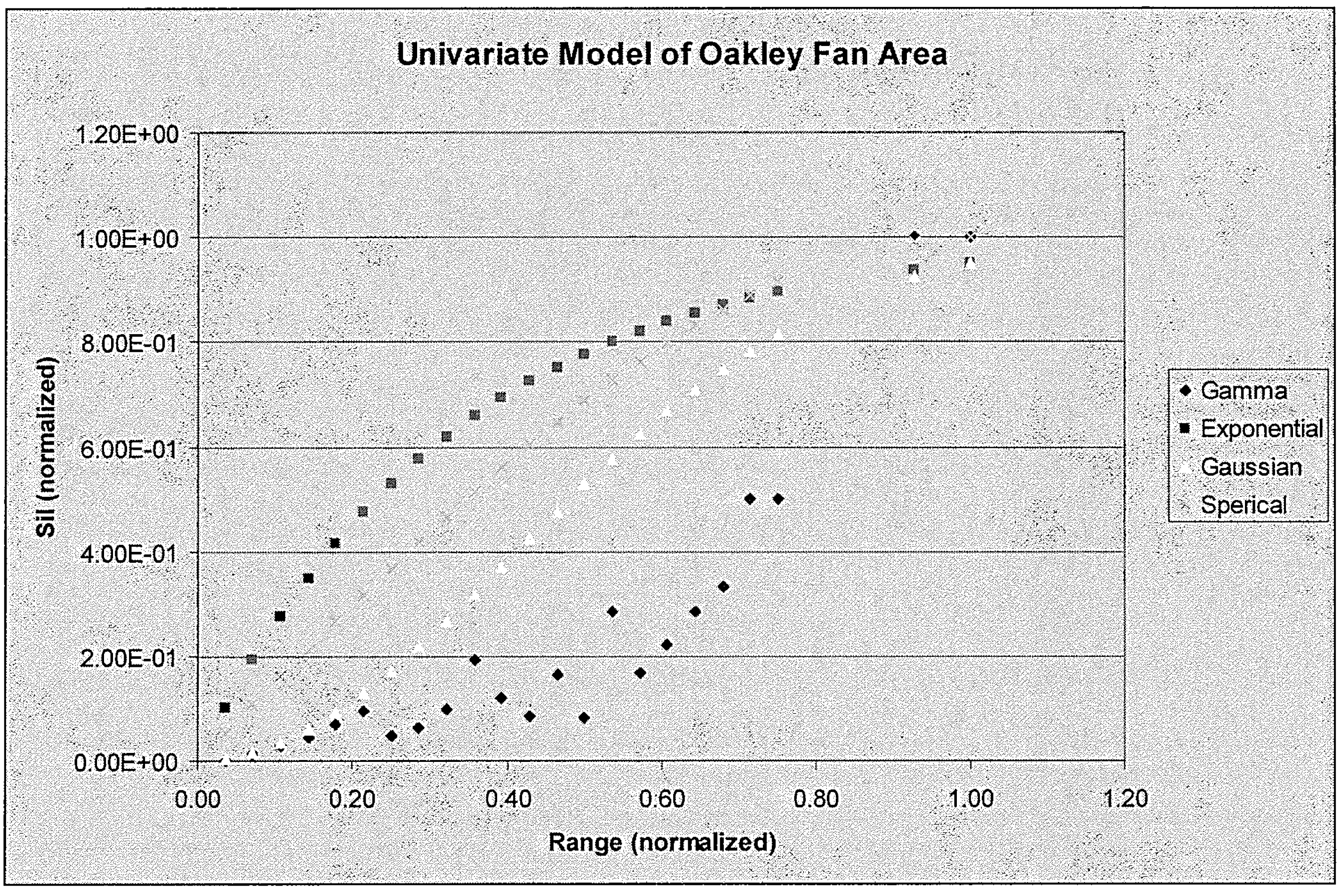
Another result of a Kriging analysis is that if a univariate variogram cannot be modeled, then it shows that there is no spatial correlation of the covariance. Without spatial correlation of the covariance, no mathematical model can better describe the remaining results. In other words, without spatial correlation, no physics based flow model, statistically derived flow function, or mathematically defined trend can better describe the general characteristics than the derived global trend. The following Kriging analysis shows that there is no little to no spatial correlation of the covariance in the flow model above.

Step 1 – Mean Value or Global Model

The global model was used to derive the groundwater chemistry covariance between the measured data and trend. GPS coordinates of each well as well as measured depths were also used to deriver the distance covariance matrices. These data were used in the following Kriging analyses.

Step 2 - Univariate Variogram

The cross range spatial characteristic was selected as the univariate parameter to determine the affect of total flow from the direction of the Snake River Aquifer. The covariance sum of the chemical model, or indicated flow parameter) was plotted against the cross range covariance. The variogram is generated by determining the covariance of the flow, or chemical variation, with respect to the univariate spatial parameter, or cross range. The univariate variogram is shown below:



As can be seen, the best possible fit to the data based on the three recommended univariate models cannot account for the spatial covariance. The result is that the data variation does not show a spatial trend that can be statistically correlated to an accurate model. The statistical result is that any model generated by physical, statistical, or mathematical trends can only be as accurate as the global trend presented above.

Step 3 - Kriging Analysis

There are 373 wells registered in the Oakley Fan Area listed in Table A-2 of this Appendix (where is it?). Over the past three years, these wells have been measured for flow rate multiple times during the pumping season. A total water volume pumped from the aquifer by each well has been estimated using measured water flow and overall power usage of the pump. GPS coordinates for each well are known as well as water elevation also listed in Table A-2.

The results of the univariate variogram show that there is not a valid spatial correlation to the data. The exponential, Gaussian, and spherical univariate forms are derived to avoid singular matrix calculations when taking the inverse of the covariance matrix. Numerous additional forms were attempted that had some correlation to the univariate model. All resulted in a singular matrix when attempting to determine the inverse. These results also corroborate that there is no valid spatial correlation in the covariance of the data.

A.5.2 Variation Estimate

An estimate of the variation about a predicted mean can be made by a simple average of the covariance. The average covariance in the data is about 25%. This estimate assumes that the variation is normally distributed which it cannot be as the standard deviation is higher than the predicted mean. However, adding this deviation to the mean represents a probable worst case cross flow estimate. The results is a 15% mean cross flow and 25% possible variation in the prediction resulting in a highest estimate of Oakley Fan Area water usage from the Snake River Aquifer of around 40%.

A.5.3 Conclusion

A global model of the groundwater flow was generated by correlating measured chemical content of the well water. The global model shows that, on average, less than 15% of the Oakley Fan Area groundwater comes cross range from the Snake River Aquifer.

A Kriging analysis of the data was conducted which showed that little to no spatial correlation of the covariance between the global trend and the measured data exists. This result indicates that the predicted global model is as good a predictor as can be derived.

Because a Kriging analysis proved no spatial correlation, a simple statistical variation was estimated to predict the highest probable cross range water flow trend. The results of the statistical analysis are a 15% mean cross flow and 25% possible variation in the prediction. This results in a range from essentially 0% to 40% for Oakley Fan Area water usage from the Snake River Aquifer.

Table 1. Wells sampled, general well information and major ion chemistry for wells used in stochastic analysis

	Date Sample Collected	Time Samples Collected	Well Number	Lat Long	Well Name	Charge balance error	Specific Conductivity µS/cm	Temp °C	pH
1	7/8/2006	18:50	A0006872	42°18'45" 114°01'13"		3.22%	250	24.6	7.56
2	7/8/2006	14:15	A0006732 A0002863	42°19'07" 113°51'04"		3.63%	575	15.5	7.09
3	7/18/2006	17:25	A0006860	42°20'01" 113°55'52"		5.43%	361	20.1	7.54
4	7/18/2006	10:55	A0006746 (Is this Pole #12S	42°21'05" 113°49'19"		4.07%	480	18.1	7.69
5	7/18/2016	13:20	A0006858	42°21'35" 113°57'44"		1.08%	275	24	7.76
6	7/18/2006		A0006852	42°21'43" 113°53'23"		4.59%	410	19.3	7.43
7	7/18/2006	12:50	A0006857	42°22'16" 113°55'48"		1.81%	417	19.2	7.54
8	7/8/2006	17:31	A0006888	42°22'28" 114°00'25"		0.05%	414	17.6	7.46
9	7/8/2006	16:32	A0005126 (Cranney)	42°22'52" 113°58'31"	Cranney	1.62%	174	32.3	7.94
10	7/8/2006	16:05	A0005132 (Wada)	42°22'53" 113°55'54"		2.63%	353	22.7	7.5
11	7/18/2006	9:15	A0005100	42°23'18" 113°54'12"		2.18%	420	19.8	7.39
12	7/18/2006	14:50	A0006939	42°23'18" 114°3'28"		0.22%	246	26.6	7.74
13	7/18/2006	10:00	A0005099	42°23'27" 113°51'05"		6.00%	422	18.4	7.49
14	7-13-06_17:14			42°23'54.9" 114°10'53.8"	Dry Creek	5.24%	130	23.2	8.42
15	7/17/2006	20:55	A0005114	42°23'55" 113°59'06"		3.40%	259	17.8	7.93
16	7/8/2006	17:40	A0005077 (Robinson)	42°24'10" 113°49'17"	Robinson	1.56%	295	19.6	7.57
17	7/18/2006	15:40	A0006933	42°24'37" 114°3'31"		2.28%	299	25.1	7.9
18	7/17/2006	21:25	A0006949	42°24'48" 114°1'43"		1.93%	381	20.7	7.93
19	7/17/2006	20:15	A0005113	42°24'57" 113°55'49"		0.03%	340	31.8	7.99
20	7/17/2006	19:50	A0005252	42°25'02" 113°53'27"		0.40%	777	19.2	7.71
21	7-13-06_18:56		A0006909	42°25'03" 114°07'38"		3.53%	1151	21.3	7.81
22	7-13-06_13:50		A0005019	42°25'03" 114°14'55"		0.67%	260	32.3	7.6
23	7-13-06_13:20		A0005162 (?51362)	42°25'10" 114°17'03"		1.22%	581	20.8	7.53
24	7/7/2006	16:50	A0005064	42°25'25" 113°46'23"		2.83%	290	17.2	7.44
25	7/17/2006	19:20	A0005281	42°25'28" 113°50'49"		4.14%	414	19.5	7.79
26	7/7/2006	16:15	A0005084	42°26'2" 113°44'36"	Wayment	4.40%	745	18.5	7.54
27	7/7/2006	14:50	A0002970	42°26'38.9" 113°39'38.4"	Stoker/Stanger	0.58%	420	24.1	7.68
28	7-10-06_18:15		A0005247	42°26'44" 113°53'25"		1.50%	781	17.1	7.76
1	7/10/2006_19:00		A0005259	42°26'44" 113°55'51"		4.08%	693	20.4	7.37
2	7-10-06_19:25		A0005262	42°26'46" 113°57'37"		3.41%	309	19	8.02
3	7-13-06_16:30		A0005038	42°26'47" 114°12'51"		1.70%	495	23.8	7.44
4	7-13-06_14:20		A0005043	42°26'47" 114°14'55"		1.92%	494	24.2	7.66
5	7/7/2006	19:10	A0005290	42°27'02" 113°50'32"		2.71%	447	16.7	7.83

Table 1. continued.

Well Number	Alkalinity mg/L CaCO3	Fluoride mg/L	Chloride mg/L	Nitrate as N mg/L	Sulfate mg/L	Phosphate as P mg/L	Sodium mg/L	Magnesium mg/L	Potassium mg/L	Calcium mg/L
1 A0006872	128.00	0.26	7.00	0.25	12.74	N.D.	10.10	7.34	3.36	42.44
2 A0006732 A0002863	172.00	0.12	84.92	4.00	34.59	N.D.	17.00	17.40	4.13	101.50
3 A0006860	142.00	0.35	29.12	1.31	18.62	N.D.	12.67	6.49	5.80	49.89
4 A0006746 (Is this Pole #12!	164.67	0.27	56.98	1.81	24.47	N.D.	12.76	10.85	3.95	71.26
5 A0006858	94.67	0.31	25.07	0.84	13.87	N.D.	10.09	3.30	5.52	40.99
6 A0006852	144.67	0.38	42.26	1.59	22.96	N.D.	14.50	7.23	5.72	58.17
7 A0006857	148.00	0.35	34.12	2.61	25.18	N.D.	14.11	7.54	6.05	61.86
8 A0006888	137.33	0.20	43.28	1.69	34.35	N.D.	16.94	9.74	4.49	63.17
9 A0005126 (Cranney)	76.00	0.45	6.98	0.16	5.30	N.D.	10.54	2.12	5.44	23.00
10 A0005132 (Wada)	132.00	0.38	34.03	1.85	19.96	N.D.	16.44	7.22	7.07	57.97
11 A0005100	132.67	0.36	49.48	1.89	28.29	N.D.	15.12	7.91	6.21	62.31
12 A0006939	114.00	0.38	8.48	0.23	9.81	N.D.	9.79	4.33	5.75	36.31
13 A0005099	143.33	0.33	44.02	1.96	27.54	N.D.	14.19	8.46	5.14	56.81
14	52.00	0.17	6.45	0.29	4.55	N.D.	10.75	2.85	4.16	13.68
15 A0005114	97.33	0.22	13.56	0.61	9.44	N.D.	7.56	4.94	3.56	31.62
16 A0005077 (Robinson)	129.33	0.42	22.68	0.52	8.75	N.D.	15.23	7.01	6.87	43.14
17 A0006933	122.67	0.44	19.21	0.40	15.47	N.D.	11.05	4.71	6.33	43.72
18 A0006949	130.67	0.35	20.43	1.57	19.66	N.D.	11.75	6.11	5.00	48.85
19 A0005113	125.33	1.42	16.30	0.51	12.26	N.D.	36.16	1.86	9.12	27.40
20 A0005252	188.67	0.33	72.67	4.66	51.77	N.D.	24.35	13.87	7.25	98.29
21 A0006909	158.67	0.29	177.69	4.76	121.31	N.D.	33.07	40.91	8.35	136.49
22 A0005019	78.00	0.45	14.71	0.68	10.90	N.D.	13.98	3.41	7.26	24.55
23 A0005162 (?51362)	146.67	0.43	30.68	1.92	73.74	N.D.	29.97	8.05	8.96	63.23
24 A0005064	88.00	0.12	38.91	1.24	14.37	N.D.	10.90	8.88	2.80	43.16
25 A0005281	146.00	0.42	25.73	1.04	18.75	N.D.	13.67	7.58	6.34	48.35
26 A0005084	109.33	0.18	184.67	3.61	42.40	N.D.	22.22	28.00	5.77	117.90
27 A0002970	143.33	0.48	49.72	1.67	33.79	N.D.	25.00	17.03	4.40	51.20
28 A0005247	206.00	0.24	60.49	4.15	58.30	N.D.	23.61	14.02	7.24	95.14
1 A0005259	178.67	0.25	68.34	0.97	50.91	N.D.	17.28	15.57	9.41	76.75
2 A0005262	83.33	0.17	26.36	0.80	15.15	N.D.	9.64	7.53	4.53	36.56
3 A0005038	84.00	0.37	60.09	1.60	41.36	N.D.	18.69	7.60	10.98	50.00
4 A0005043	113.33	0.31	48.32	1.84	32.66	N.D.	23.19	6.71	10.44	49.15
5 A0005290	162.67	0.14	44.36	2.64	37.14	N.D.	15.51	14.63	7.64	73.87

Water Table Determination of the ESPA Boundary

Water table maps are similar to contour maps of land elevations, depicting the surface that water levels in wells would rise to if drilled at that location. In an isotropic aquifer, groundwater flow is down the slope of the water table map (i.e. perpendicular to contour lines). Flow lines originate where water enters the aquifer and flow to where water is exiting the aquifer. Mounds in the water table map can be caused by leakage from streams and canals. A good example of mounding is shown on Figure 2 beneath the Murtaugh Lake area.

Several streams and rivers drain the mountains surrounding the Oakley Fan. Some of the water is impounded in reservoirs for use at a later time, some is injected to local aquifers, and some is utilized as it enters the valley. However, none of the surface water reaches the Snake River except during extremely high (wet) water years. All surface water is utilized and fully appropriated.

A water table map constructed using December 2006 water level data and is presented in Figure 2. The contour interval is 10 feet and arrows show the general direction of groundwater flow in beneath the SWID. On the south side, ground water flows generally northward beneath the Oakley Fan towards a ground water low created by pumping in the northeast part of the area. On the north side of the trough groundwater flows to the southeast toward the trough. The center of this low forms a northwest trending trough at an elevation of approximately 3,880 ft above mean sea level. The axis of the trough is approximately 600 South Rd. Groundwater flows northwest out the bottom of the trough.

Water table maps were constructed every 10 years from 1950 through 2006. The base of the trough is consistently within ½ mile of the trough shown in Figure 2. It may be expected that the trough would move north during high precipitation cycle and south during low precipitation cycles. However, since high precipitation cycles produce high influx from surface water streams and canals the centerline of the trough remains in the current location.

At the base of the water-level trough, groundwater from the Oakley Fan mixes with groundwater coming from the ESPA. This is represented schematically in Figure 3. The mixing zone may be up to several miles wide depending on the continuity of the layers and represents the boundary of the ESPA. The source of water pumped in any given well varies depending on the interconnection of the stratigraphy with the source zones, the hydraulic properties, well depth and open interval. As illustrated in Figure 3, a well drilled near the bottom of the trough may penetrate several zones of Oakley Fan water and ESRPA water thus pumping a mixture of both.

Based on the water levels, the boundary between the ESRPA and the Oakley Fan appears to be situated approximately along the axis of the water-level trough. The proposed position of the vertical SRPA boundary is shown on Figure 4 with the water table contours and the flow lines subdued.

Figure 5 is a profile of the land surface with the static water table. This figure is important to show the location of the groundwater trough in comparison to the river, BID, and A&B.

With the vertical boundary of the ESPA placed in the bottom of the water-level trough, 72 wells in the SWID pump an average of 26,656 acre-feet per year pump water from the ESRPA, or 18% of the total groundwater pumped by the SWID, comes from the ESPA. Of the 26,656 AF pumped only a small portion of the appurtenant acres are junior to the current spring user's call.

Water Table Map for the SWID

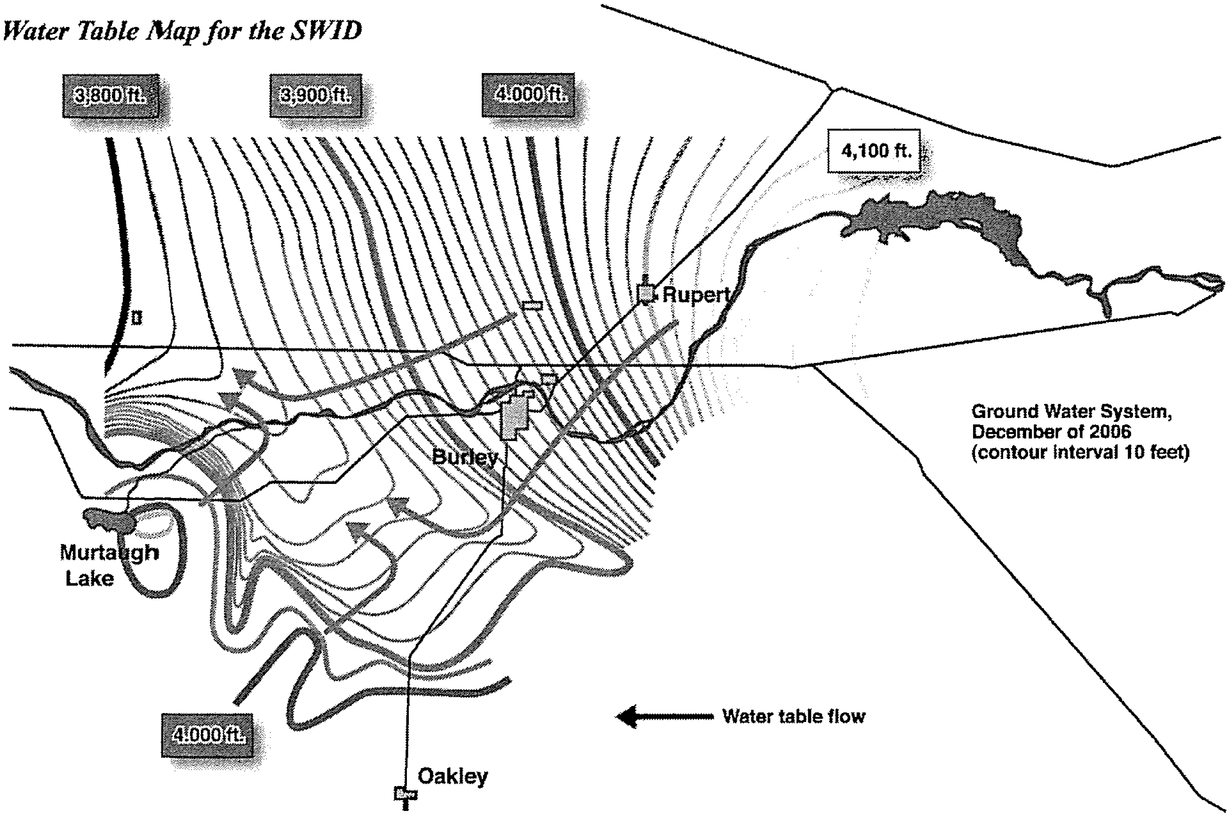


Figure 2. Water table map December 2006.

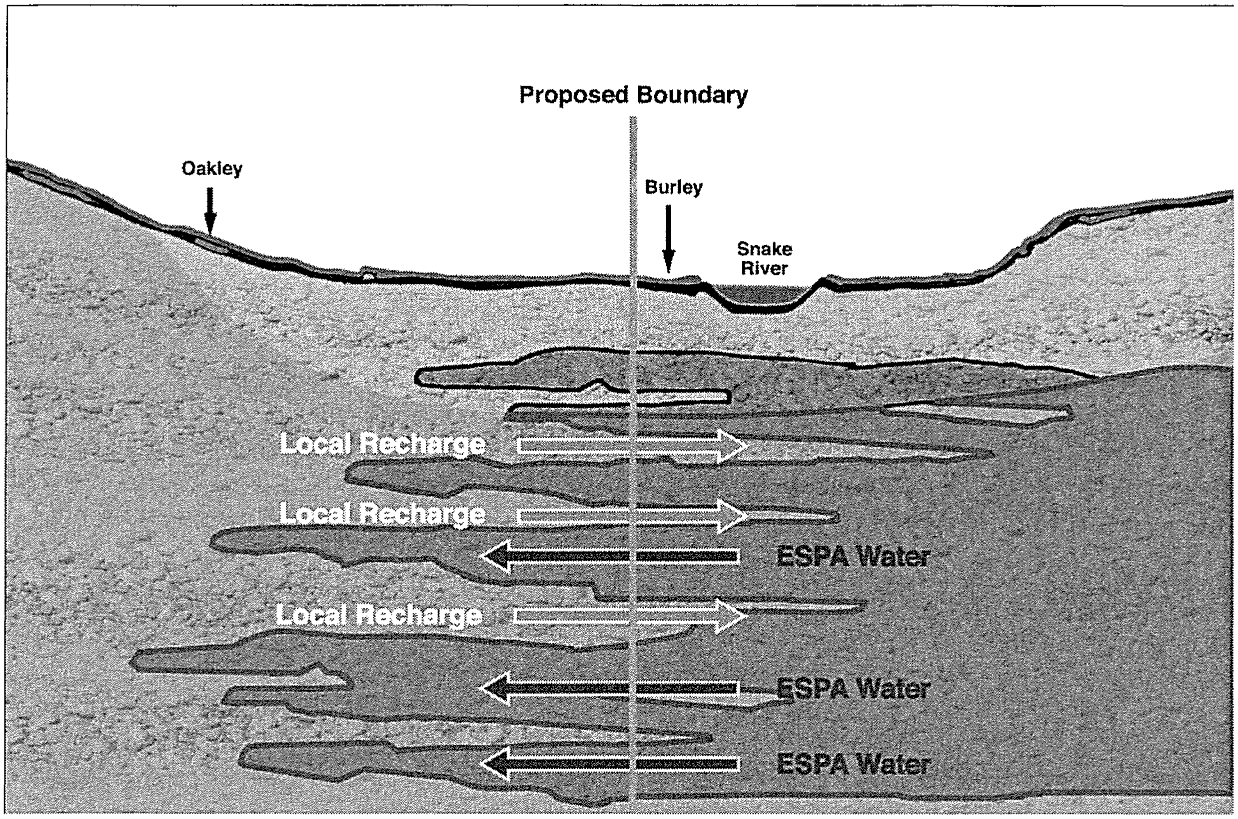
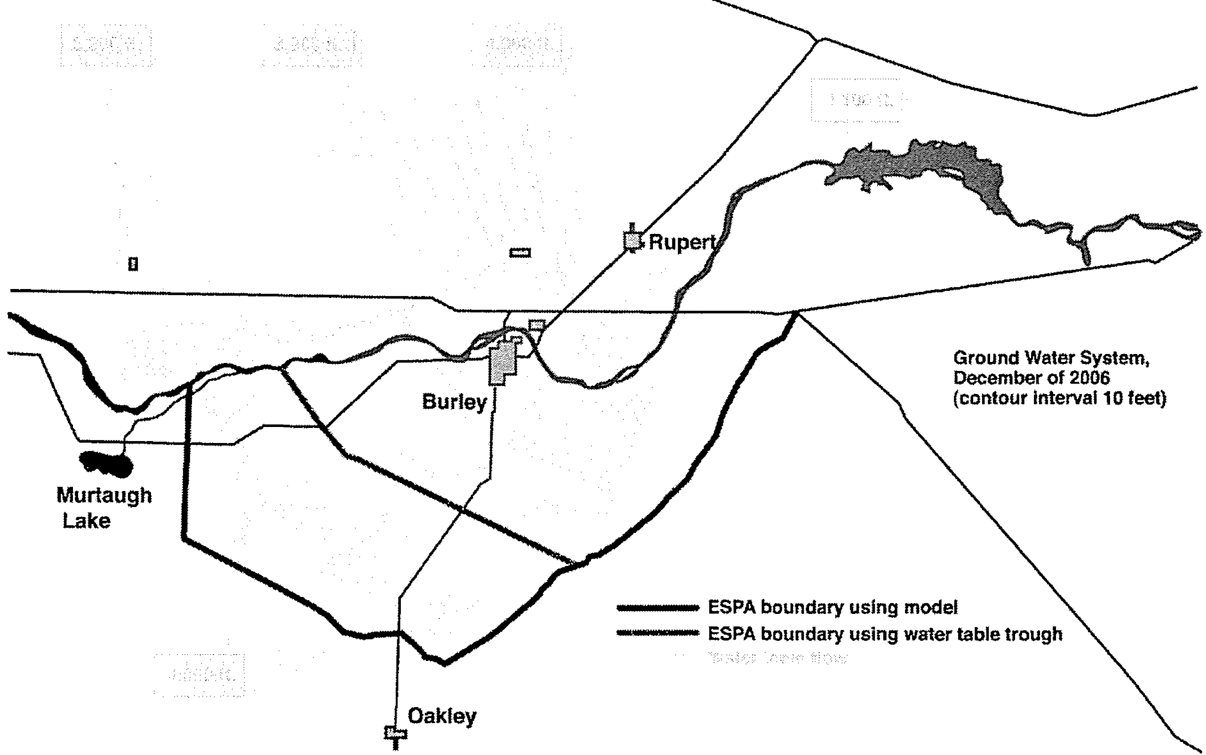


Figure 3. Zone of mixing of ESPA groundwater and Oakley Fan groundwater.

Water Table Map for the SWID



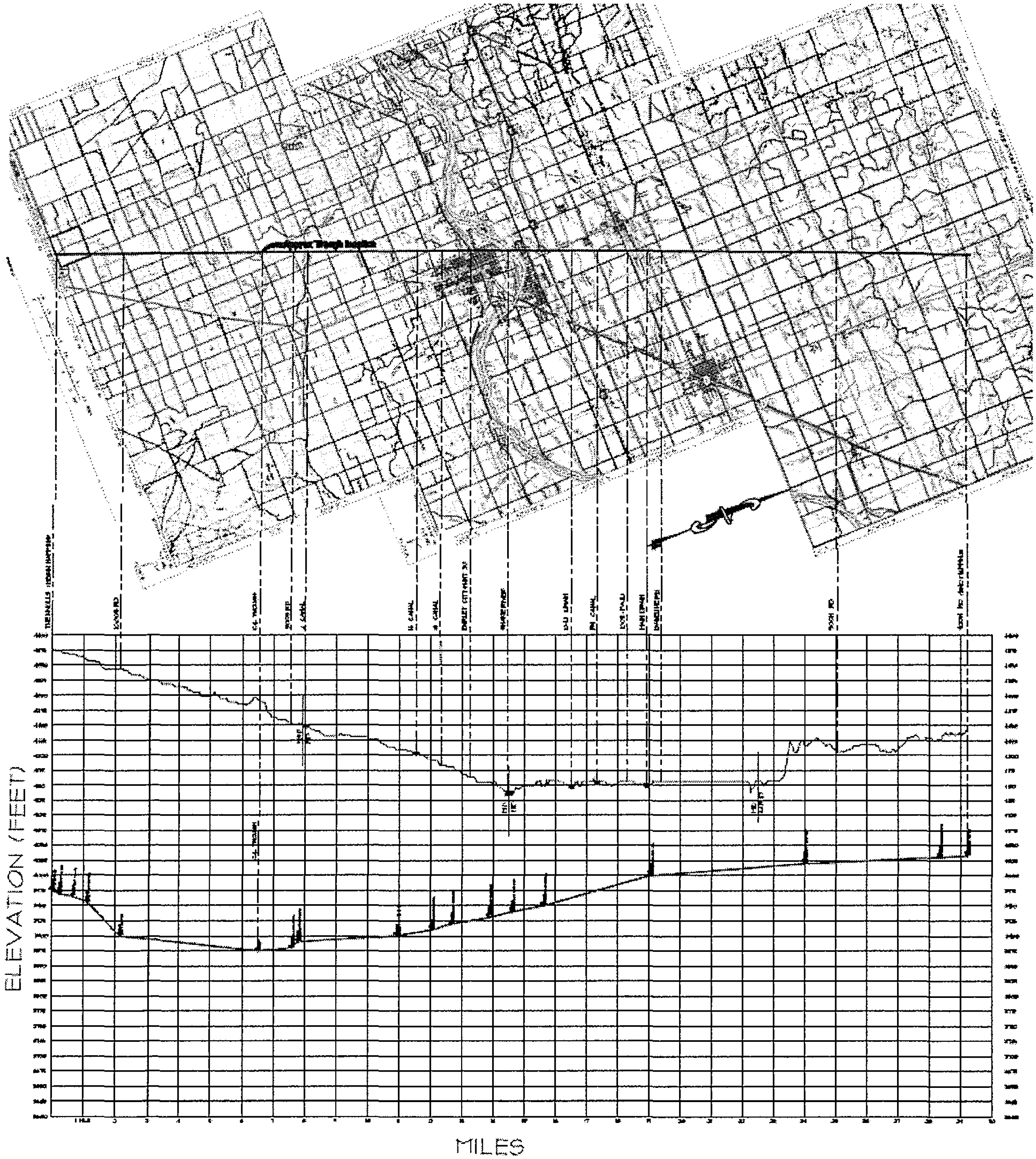


Figure 5. Profile with accompanying surface map.

4. Geochemical Analysis of Source Water Zones in the Vicinity of the Oakley Fan

Wells and surface water locations were sampled in and near the SWID in July 2006 to determine sources of water for the SWID (Figure 12 and Table 4). The goal of the geochemical evaluation was to determine the geographical areas within the SWID that pump water directly from the ESPA. Once the source of water is determined, then the impacts of ground water pumping within the Oakley Fan to water levels in the ESPA can be evaluated. Wells were sampled for temperature, pH, specific conductance, and major ions including calcium, sodium, potassium, magnesium, nitrate, chloride, sulfate, fluoride, alkalinity, and phosphate (Table 5).

4.1. Differentiation of Source Water in the SWID

Water sources are often differentiated using the relative proportions of the major ions or salinity (specific conductance). The relative abundance of major ions and salinity in water creates a chemical "fingerprint" for the water source that can be tracked in the aquifer and used to evaluate mixing with other waters. Differentiating the source of water for wells in the SWID is difficult because the relative proportions of the major ions are similar and show less contrast. This is shown graphically in the Piper Diagram (Figure 13). However, the principal problem with directly using anion concentrations to differentiate sources is that infiltrating irrigation water has overprinted many of the sampled wells. This problem is evidenced by the correlation of nitrate, a fertilizer, and specific conductivity (Figure 14). The influx of irrigation water makes it difficult to distinguish the sources of water based only on the concentrations of major ions because the irrigation return water typically has much higher amounts of dissolved solids compared to the water from the ESPA or locally derived water. Thus, in this area using just the major ion concentrations is inadequate to distinguish water sources. Another analysis is needed that accounts for the overprinting of infiltrating irrigation water.

A way to overcome the difficulties associated with using only the concentrations of the major ions is to use ratios of conservative anions, like chloride and sulfate, and plotting that ratio versus the specific conductance. Plotting the anion ratio should help reduce the difficulty in distinguishing water sources in areas affected by irrigation return because chloride and sulfate will increase in concentration as irrigation water evaporates but the ratio will remain the same (no removal mechanisms) or change slightly (some removal of sulfate) and trend on a predictable path. The anion ratio of chloride/sulfate should only be shifted marginally in comparison to the shift in anion concentrations due to the influx of irrigation return water. If reducing conditions occurred, then sulfate concentrations could be adversely affected and negatively impact this analysis. The ground water data indicate oxidizing conditions (elevated nitrate concentrations) in the aquifer so this is not considered to be a problem.

A plot of chloride/sulfate versus specific conductance and sized to nitrate concentrations enables the sources of water in the SWID area to be distinguished (Figure 14). However, water drawn from the Snake River is nearly identical to ESPA water in the area of interest in terms of anion concentrations and specific conductance. Since it is not possible to definitively differentiate between water from the Snake River and the ESPA, the two sources are treated as the same source. This may lead to an overestimate of the amount of water drawn from the ESPA.

The distinction of water sources in the SWID is based on the following:

- ESPA *Water*. The water from the ESPA is characterized by having a Cl/SO_4 ratio of 0.44 to approximately 1.2 and a specific conductance greater than 360 to 400 uS/cm based on background samples (Figure 14). These values are based on the trend defined by the Orton and Stevenson wells since these wells draw water primarily from the ESPA and are located in an area without agricultural influence (Orton) and with agricultural influence (Stevenson, see Figure 12 for locations of these wells). The upper limit for Cl/SO_4 of 1.2 for the ESPA water is estimated based on the highest background value of 1.07 at the Stevenson well. Some wells in the ESPA with a large irrigation return component could marginally exceed the upper limit of 1.2 and would also have higher nitrate and dissolved solid (higher specific conductance) concentrations.

- *Local Water.* Wells in the SWID that derive water from local sources are based on the following: 1) Cl/SO_4 values greater than 1 based on the chemistry of two wells near Oakley, deep background wells and local surface water that spans a ratio of 1 to 2.9, and/or 2) a specific conductance less than that for the ESPA or Snake River and/or 3) anion concentrations less than observed for background wells (Figure 14). Note that the pumping of local water and irrigating fields with that water could lead to the higher observed Cl/SO4 ratios (over 2 with elevated nitrate concentrations).

- *Mixed Water.* Wells that fall between the above ranges for the ESPA and local sources are in a mixing zone (Figure 14).

Based on the above criteria, the wells in the study area have been categorized as belonging to one of the above water sources in Table 6 and plotted on Figure 15. Based on the lines delineating water sources as shown on Figure 15, approximately 50 percent of the surface area within the SWID has local water sources; approximately 27 percent has mixed sources; and 23 percent has ESPA sources.

The above areas determined to be affected by the ESPA or local ground water sources may be skewed by infiltration from canals or other surface water bodies like Murtaugh Lake. As mentioned earlier, water from the Snake River can not be differentiated using the available data from water in the ESPA. Several wells located at the eastern and western fringes of the SWID may show influence from surface water bodies that owe their source to the Snake River. The chemistry of well (A0002970) on the eastern fringe of the SWID indicates mixing of ESPA and local water; however, this well is probably a mixture of local water and Snake River water since this well is located near the J Canal. Similarly, the influence of the ESPA may be overstated in the extreme western part of the SWID because of infiltration from Murtaugh Lake, injection wells, and canals since the source of water is the Snake River. Locations A0005054, A0005038, A0005073, A0013383, and A0006909 probably show influence from surface water rather than from the ESPA. The ground water mound near Murtaugh Lake in 2006 also supports the premise that local recharge maybe influencing the ground water chemistry near Murtaugh Lake (Figure 15).

4.2. ESPA North of the SWID

USGS ground water data from north of the SWID and from the A-B irrigation district north of the Snake River is shown for comparison to the data from the SWID (Table 7). These wells show the same high degree correlation between nitrate concentrations and specific conductance that the wells in the SWID show (compare figures 14 and 16). However, all the wells to the north of the SWID and in the A-B irrigation district plot in the ESPA are based on the plot of $C1/SO_4$ versus conductivity (compare Figure 14 and Figure 17). The USGS data locations for 2005 and 2006 are shown on Figure 18. The fairly uniform grouping of wells on Figure 17 for wells in the A-B irrigation district contrasts with the more variable pattern for the SWID district (Figure 14). The difference between the specific conductance and $C1/SO_4$ ratio plots for the SWID and A-B irrigation district strongly suggest that the SWID has multiple water sources (Local and ESPA).

4.3. Summary of Source Water Determination for the SWID

The geochemical data suggests that approximately 50 percent of the surface area within the SWID has local water sources; approximately 27 percent has mixed water sources; and 23 percent of the SWID area uses the ESPA. These percentages are based on the surface area of the SWID, but do not reflect the amount of pumping from each respective source zone.

In general, the geochemical evaluation agrees with the hydrogeologic data for ground water flow in the Oakley Fan area. However, there are two areas of disagreement: one on the eastern fringe of the SWID and one on the western fringe of the SWID near Murtaugh Lake. The water level data and surface water relations suggest that the eastern fringe of the SWID is probably a mixture of local water and Snake River water since the well in question is located near the J Canal. Similarly, the influence of the ESPA is probably overstated in the extreme western part of the SWID because of infiltration from Murtaugh Lake. Thus, the geochemical evaluation probably overstates both the SWID area with mixed water sources and with a ESPA source.

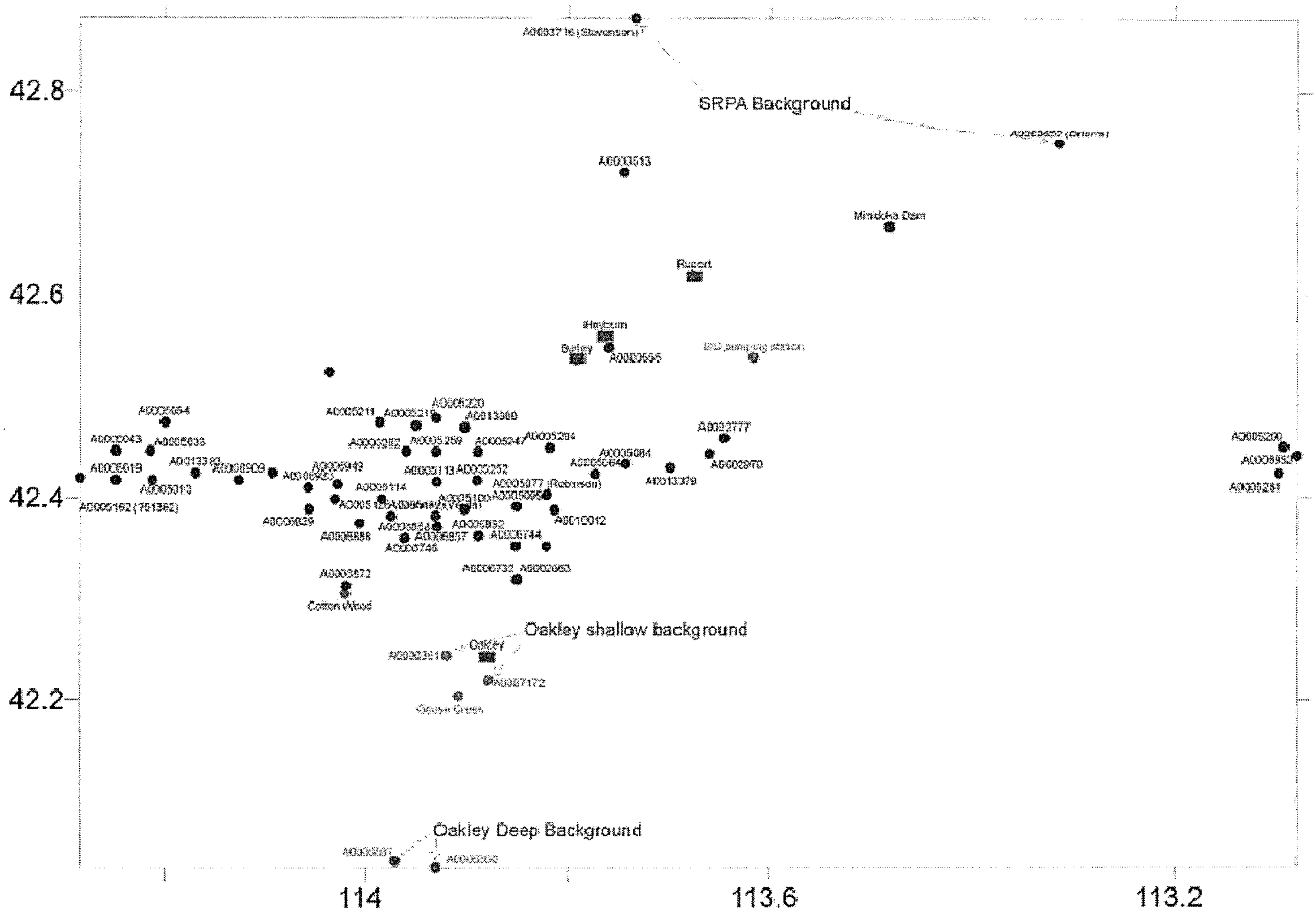


Figure 12. Locations ground water and surface water was sampled in SWID area.

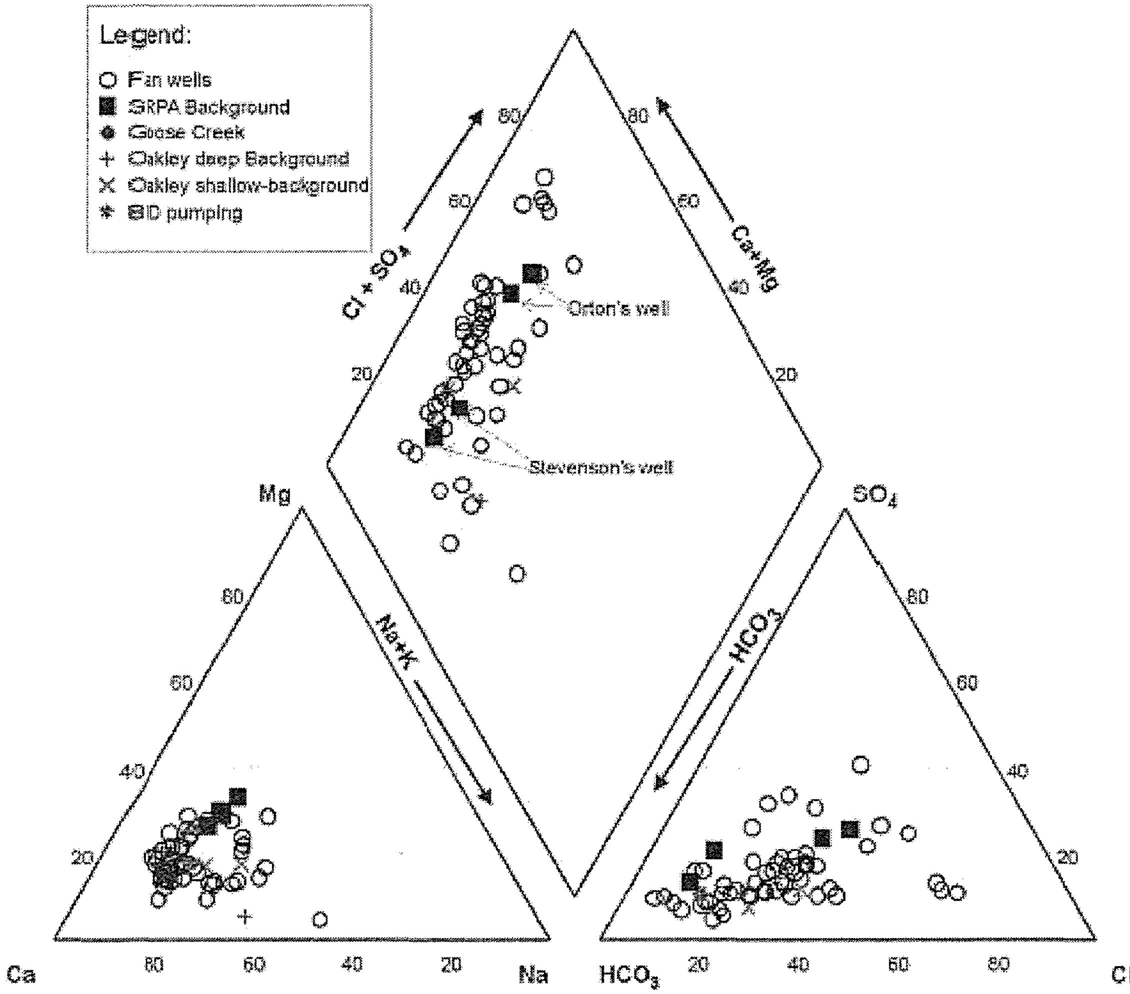


Figure 13. Piper diagram.

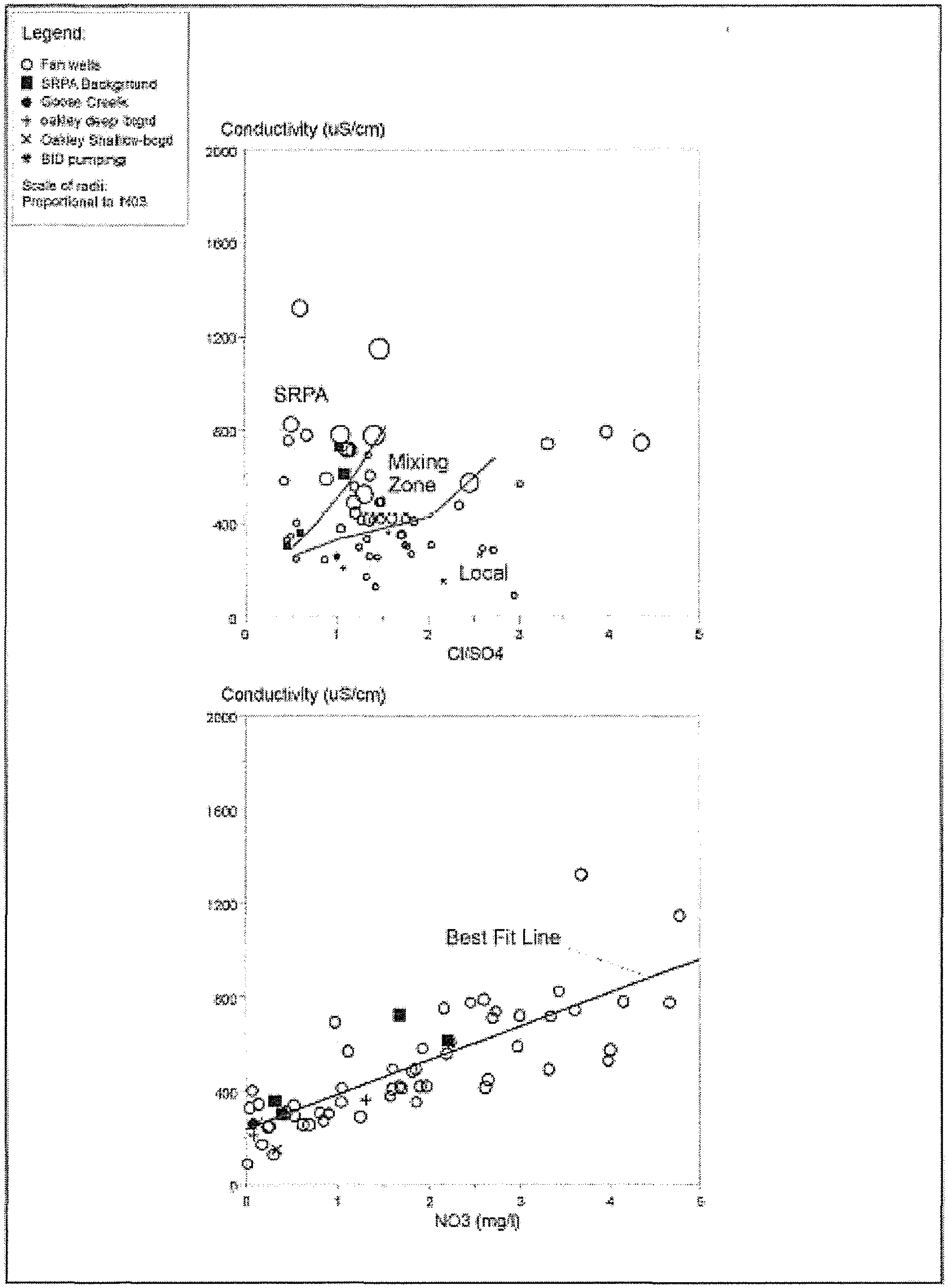


Figure 14. Plots of nitrate versus conductivity (specific conductance) and Cl/SO4 ratio versus conductivity with plot points proportional to the amount of nitrate.

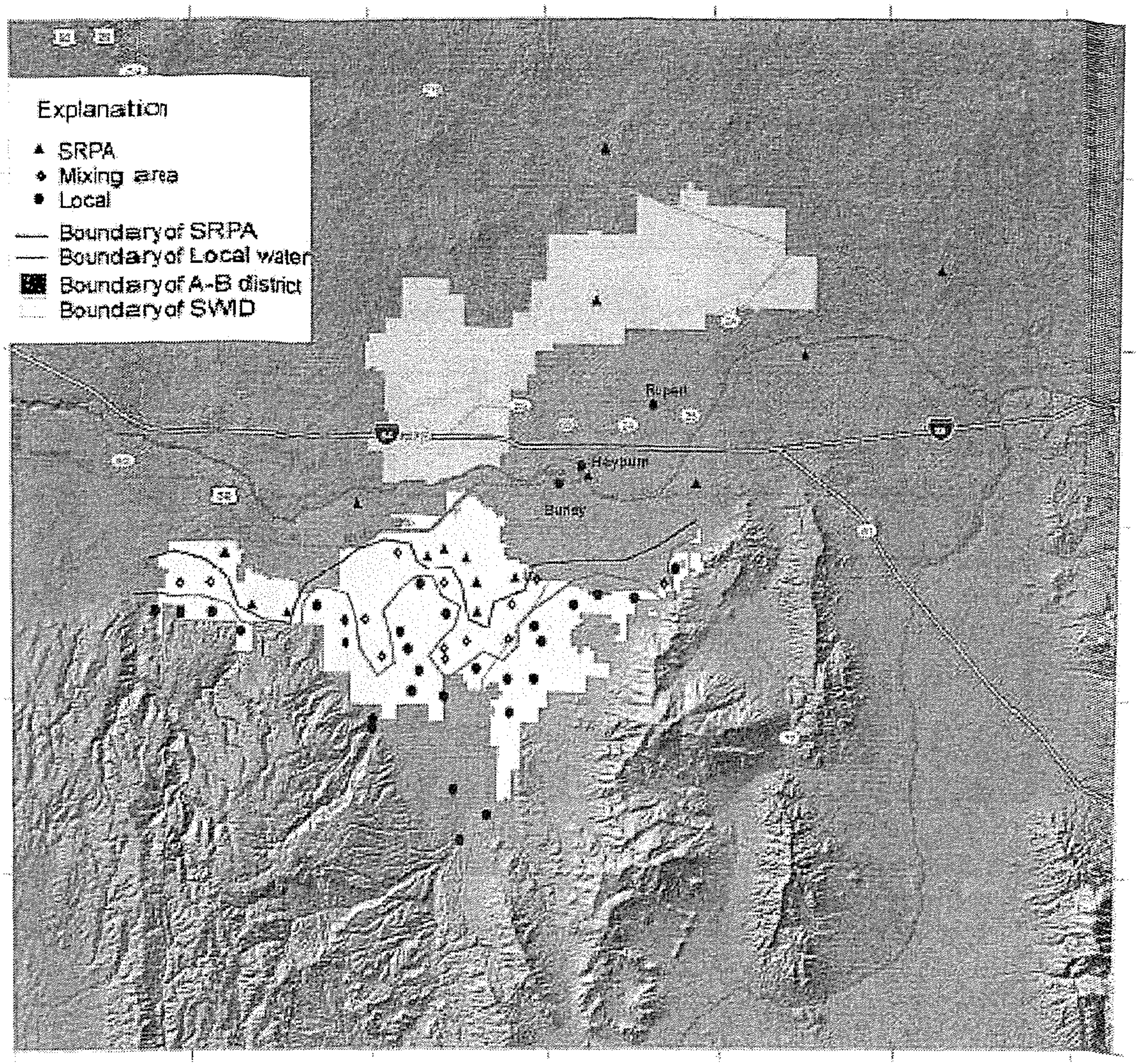


Figure 15. Approximate Boundaries of water sources for the SWID.

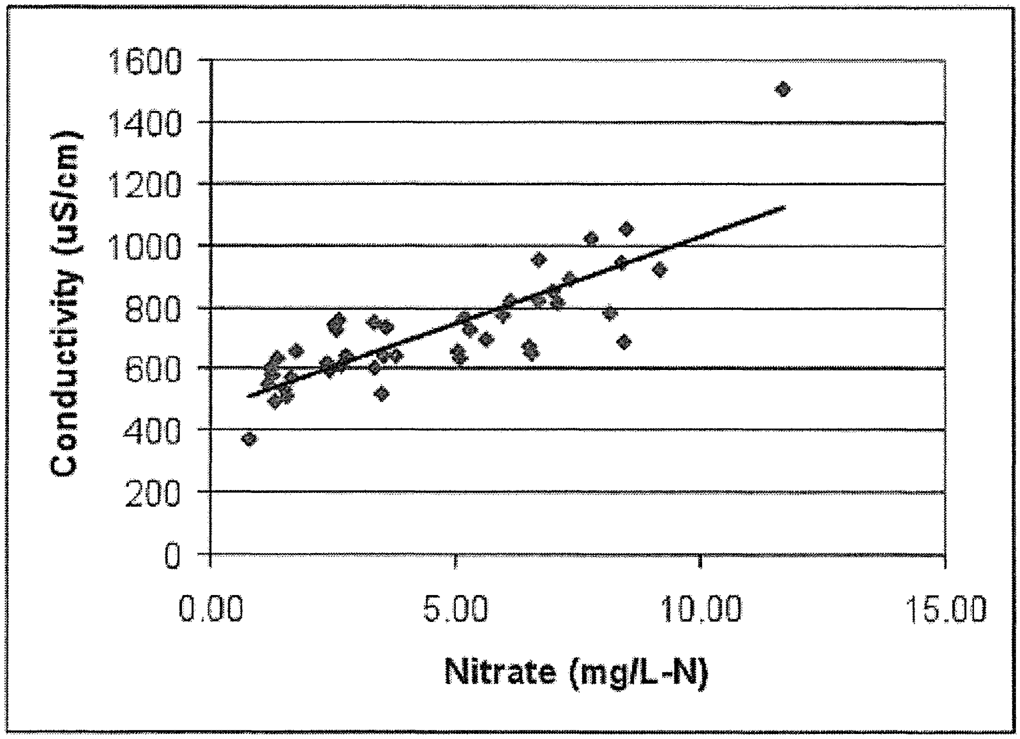


Figure 16. Correlation of nitrate concentrations with conductivity for USGS sampling locations north of the SWID (primarily in the A-B irrigation district).

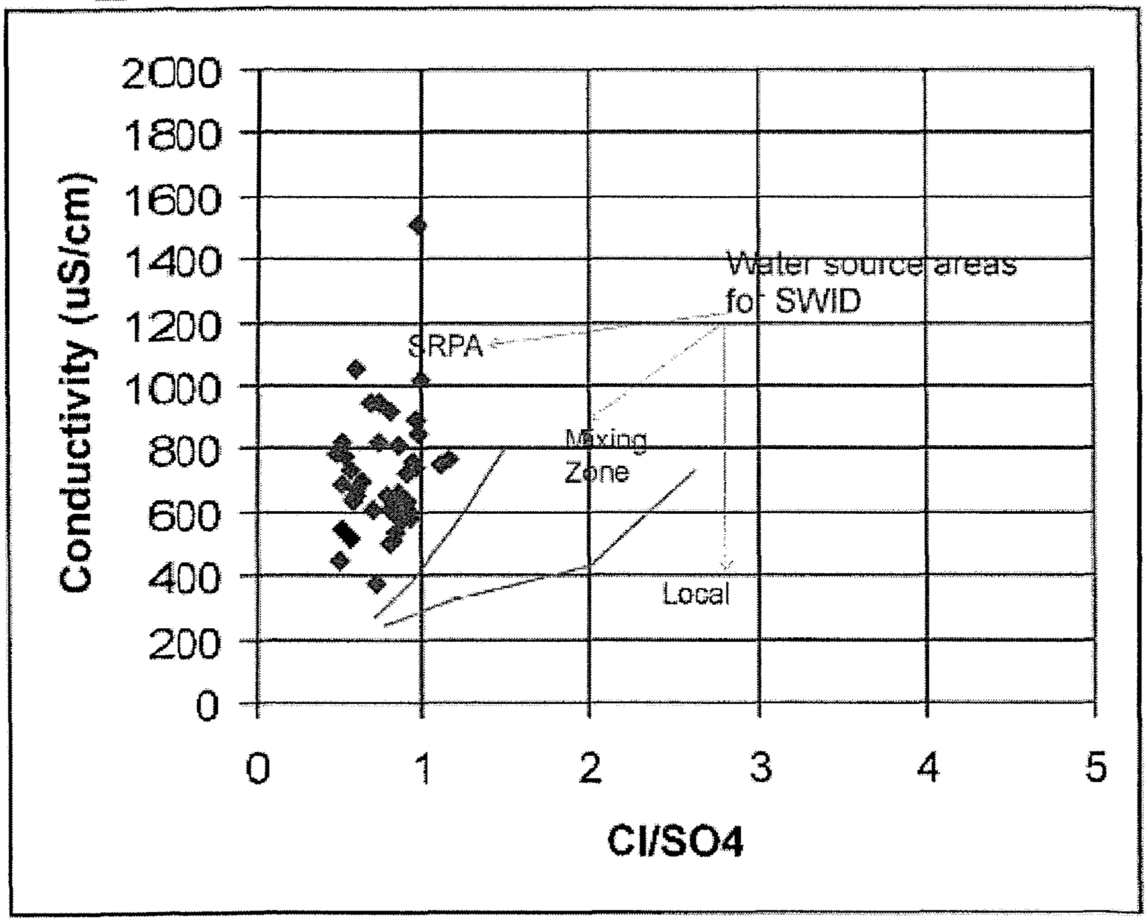


Figure 17. . Plot of Cl/SO4 versus conductivity for USGS data north of the SWID and from the A-B irrigation district.

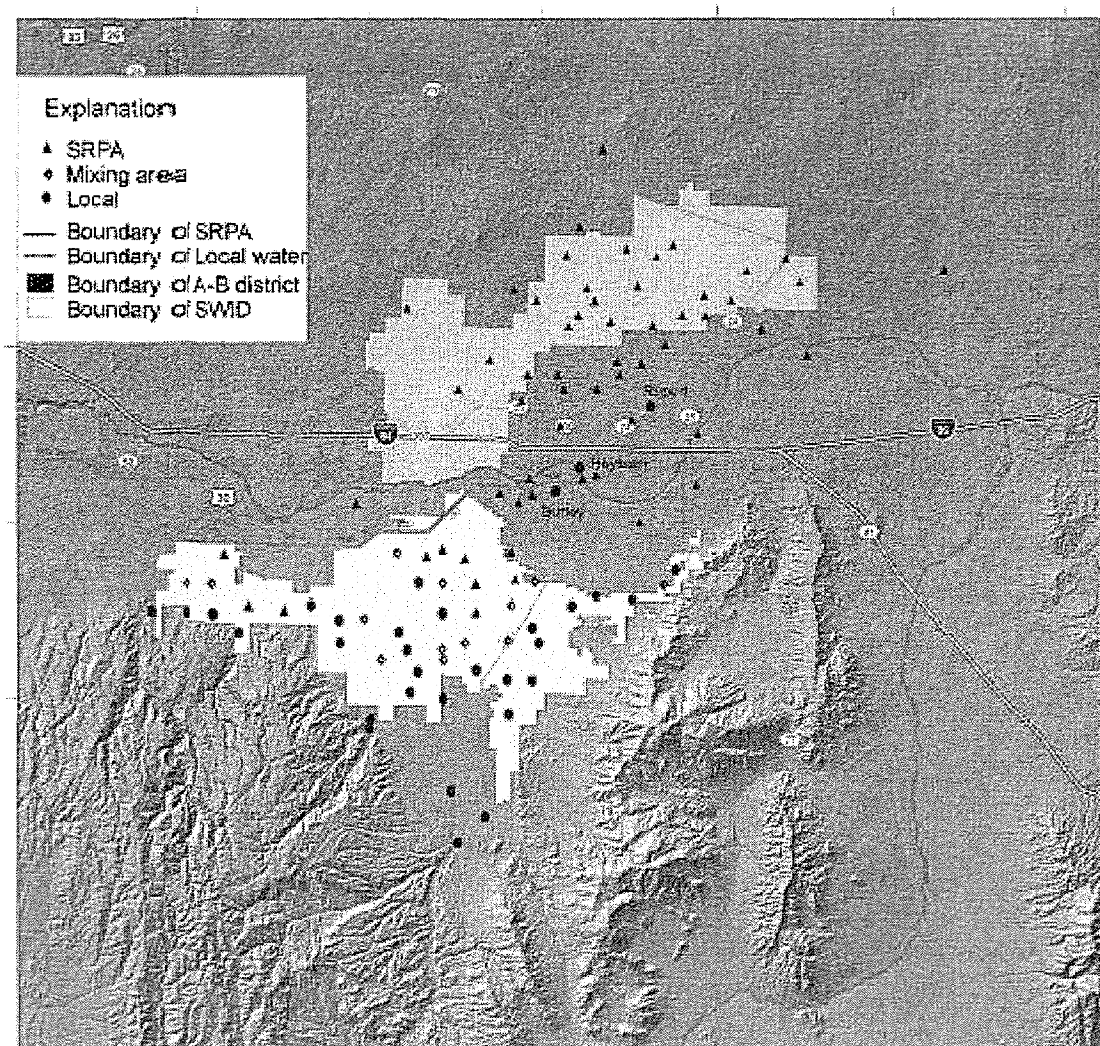


Figure 18. USGS sampling locations north of the SWID and locations sampled for the SWID with water sources indicated by the appropriate symbol.