DEPARTMENT OF TRANSPORTATION
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771

10/25/06 BdMtg Item 10
303(d) List
Deadline: 10/20/06 5pm

Flex your power!
Be energy efficient!

October 11, 2006

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SWRCB
Executive Ofc.

State Water Resources Control Board
1001 I Street
Sacramento, California 95814

Dear Song Her:

Comment Letter-2006 Federal CWA Section 303 (d) List

The California Department of Transportation (Caltrans) District 9 reviewed the *"Proposed 2006 CWA Section 303(d) list of water quality limited segments"* issued by Lahontan RWQCB on September 15, 2006. We are concerned since it lists the following water bodies as "impaired" with "Highway/Road/Bridge Run-off" as a "potential source:"

- **Swauger Creek---Phosphorus**
- **East Walker River, below Bridgeport Reservoir----Nitrogen, Phosphorous, and Sedimentation/Siltation**
- **Bridgeport Reservoir----Nitrogen and Phosphorous**

Please clarify your meaning of "Highway." Is it being used in reference to a State Highway, County Highway, or some other type of roadway? Under California State Highway Code Section 24 a "State Highway" is defined as *"Any highway which is acquired, laid out, constructed, improved or maintained as a State highway pursuant to constitutional or legislative authorization."* Section 25 defines a "county highway" as being one in the jurisdiction of the County. Caltrans is the owner and operator of only State Highways and all other types of highways as defined by the Street and Highway Code are managed by other entities. We feel that your designation can be misconstrued as to whom the "Highway" may ultimately be referencing to as a "Potential Source." Caltrans owns and operates only Two State Highways within the same area as the aforementioned water bodies-US Route 395 and State Route (SR) 182.

On October 11 and 12, 2006 Lahontan RWQCB hosted a Grazing Workshop at Kings Beach, California regarding the regulation of grazing activities in the Lahontan Region. The public notice included the statement, *"Other grazing related water quality or beneficial use impairment include: nutrients (nitrogen and phosphorus), sediments, and habitat alterations."* If Lahontan has recognized that grazing activities contribute to nitrogen, phosphorus, and sediments then why is the Highway also being listed as a potential source?

The Bridgeport Valley is home to one of the largest cattle/livestock grazing areas in the Eastern Sierra (averaging 10,000 head of cattle in a season). Beside the statement in the public notice, numerous studies have also concluded that this form of agribusiness is a major source of nitrates, phosphates, and sediments to water bodies.

Additionally, Caltrans is aware of a Lahontan RWQCB study entitled, *"Groundwater Nutrient Loading to Bridgeport Reservoir" (January 2005).* It should be noted that this study was conducted in the summer months-when most ranching activity occurs in the Bridgeport Valley (See Attachment #1). This study indicates that the monitoring wells within the area were already testing high for these nutrients prior to reaching either US 395 or SR 182, with the major source originating from the central area of the Valley, where no State Highway is located. Finally, since this study was conducted during the summer months, snow and ice was not an issue so the materials that Caltrans uses for snow/ice removal would not be present at that time.

Regarding the listing of "Sedimentation/Siltation" for the "East Walker River, below Bridgeport Reservoir." Caltrans believes that "Highway/Road/Bridge Run-off", as a "potential source" is unlikely from any Caltrans' facilities. You should note that within this same area new home construction and infrastructure upgrades (i.e. unpaved roads, utilities, water treatment systems, etc) are occurring northerly of Bridgeport along SR 182 and the East Walker River, below Bridgeport Reservoir. Other resource agencies (USFS, BLM, and DFG), the County, and the local tribe could be contributing to this by approving new construction and infrastructure upgrades within their jurisdictions and without adequate runoff or stormwater mitigation plans in place. Within this area, Caltrans only operates two paved routes totaling approximately 34 miles of pavement, while other local agencies and governments operate, manage, and utilize over 300 miles of mostly unpaved roads in the same area. Additionally, Caltrans is the only road-operating agency within this area that is within the constraints of a Statewide NPDES Permit that guides all of our operations and stormwater management practices.

As mentioned earlier, Caltrans' operations are guided our Statewide NPDES Stormwater permit. Most of our ice and snow removal operations within the Bridgeport Valley utilize native material derived from local sources or the use of manpower and heavy equipment. We do not use either chemical or natural agents that contain high levels of either phosphates or nitrates, let alone use them in a regular manner throughout the year that could contribute to the levels you are currently reporting within the area.

In light of these facts and based upon the information provided by Lahontan, Caltrans thinks that although the 303(d) listing could be applicable to the Bridgeport Reservoir and its associated creeks and rivers, Caltrans and its daily operations are not contributing significant nutrients or sediments to be listed as a "Potential Source." Therefore, before your listing is finalized we expect to review the data that supposedly points to the State Highways (US 395 and SR 182) as a "Potential Source" of impairing these water bodies. If little proof is apparent, then we expect "Highway" to be removed as a "Potential Source" from this listing, if the State highway is the facility you are actually addressing.

I look forward to your response on this matter and if you have further questions feel free to contact me.

Sincerely,

Mark A. Heckman

MARK A. HECKMAN
District 9 NPDES Stormwater Coordinator

Attachment

c: Keith D. Jones, Caltrans – Headquarters
Paul Lambert, Caltrans- Headquarters
Lahontan RWQCB

Groundwater Nutrient Loading to Bridgeport Reservoir

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James Thomas
Clay Cooper
Ryan Powell
James Larson

January 2005

Prepared by
Division of Hydrologic Sciences, Desert Research Institute, University and Community College of Nevada

Prepared for
California Regional Water Quality Control Board, Lahontan Region. Contract No. 02-171-256-0

ABSTRACT

In 1994, Bridgeport Reservoir in Bridgeport Valley, California, was listed as impaired for nutrients, sediment, and siltation (Lahontan, 2003). The reservoir supports large algal blooms as a result of high concentrations of nitrogen and phosphorus (Entrix, 1998). The potential sources of nitrogen and phosphorus include: recycling of nutrients in the reservoir, streams flowing into the reservoir, and groundwater inflow to the reservoir. Groundwater flow and groundwater nutrient load to the Bridgeport Reservoir were estimated in this study. In Bridgeport Valley, four shallow wells were installed to evaluate aquifer parameters, groundwater hydraulic gradients, and nutrient concentrations. Additionally, five existing wells in the valley were sampled for water quality. Average total nitrogen groundwater loading to the reservoir for the upper 10 feet of the aquifer is estimated to be 134, 358, and 137 kg/yr, for the west, central, and east portions of Bridgeport Valley. Average total phosphorus groundwater loading to the reservoir is estimated to be 5.3, 74, and 45.4 kg/yr, for the west, central, and east portions of Bridgeport Valley. Average total orthophosphate as P groundwater loading to the reservoir is estimated to be 4.2, 63.4, and 31.4 kg/yr, for the west, central, and east portions of Bridgeport Valley.

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INTRODUCTION

Bridgeport Reservoir is located in Bridgeport Valley in eastern California (Figure 1). Perennial streams flowing into Bridgeport Valley and eventually into the reservoir include (from east to west) East Walker River, Virginia Creek, Green Creek, Robinson Creek, Buckeye Creek, and Swauger Creek. The outflow of Bridgeport Reservoir is the east fork of the Walker River that eventually flows into Walker Lake in western Nevada.

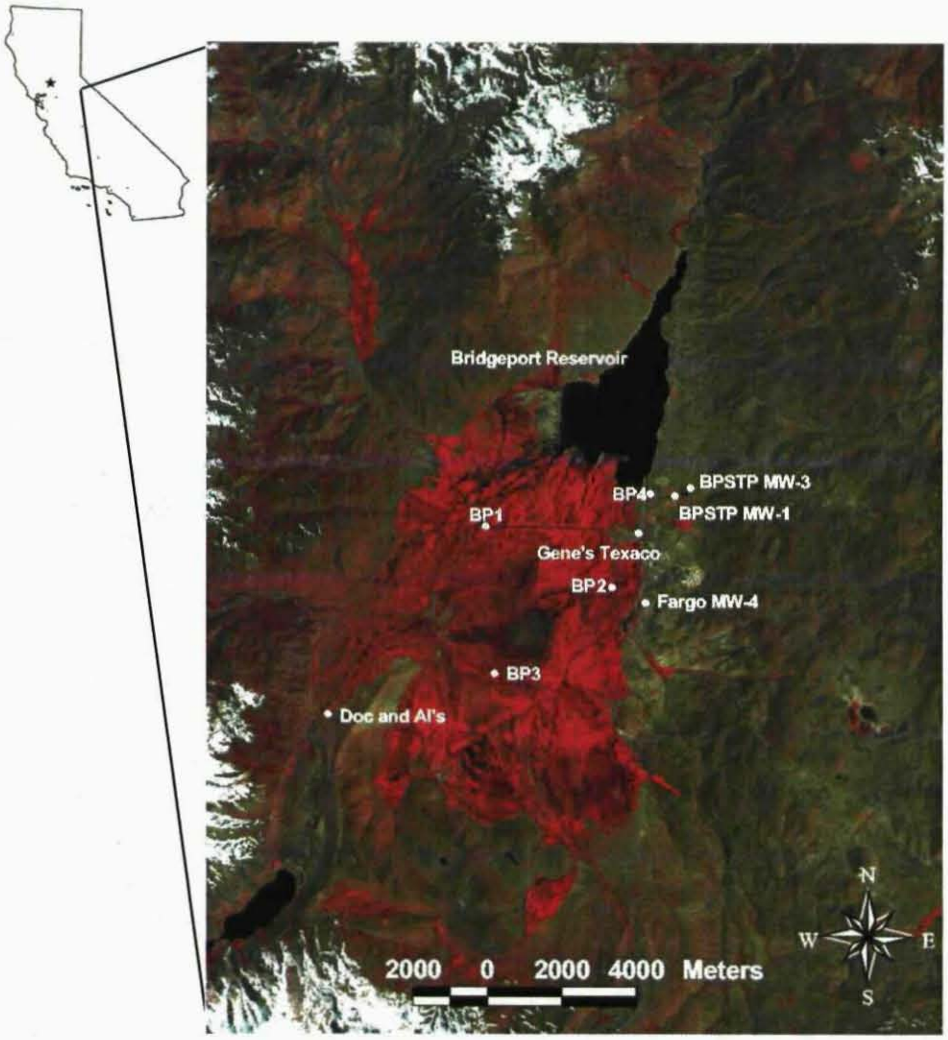

Figure 1. Map showing the location of Bridgeport Valley, California. Inset map shows the location of Bridgeport Reservoir and wells, the town of Bridgeport (area around Gene's Texaco), and Twin Lakes (lake in lower left of the figure is the northernmost of the two lakes).

In 1994, Bridgeport Reservoir was listed as impaired for nutrients, sediment, and siltation (Lahontan, 2003). Bridgeport Reservoir supports large algal blooms as a result of high concentrations of nitrogen and phosphorus (Entrix, 1998).

The sources of nutrient additions (nitrogen and phosphorus) to Bridgeport Reservoir include nutrients recycling within the reservoir and nutrients entering the reservoir via tributary streams and groundwater. Studies of nutrient loading from tributary streams and internal cycling of nutrients have been conducted; however, nutrient loading associated with shallow groundwater was not well characterized. The Lahontan Regional Water Quality Control Board (LRWQCB) funded this study to evaluate shallow groundwater flow and shallow groundwater nutrient contributions to Bridgeport Reservoir.

METHODOLOGY

Pre-field Activities

Drilling locations were selected by LRWQCB staff in consultation with the Desert Research Institute (DRI) and identified in the field during a trip to the Bridgeport, California, area in May 2004. Following the field visit, staff from DRI obtained encroachment permits from the California Department of Transportation (Caltrans) for wells LRWQCB-BP-1 and LRWQCB-BP-4 and from the Mono County Department of Public Works for wells LRWQCB-BP-2 and LRWQCB-BP-3. DRI also obtained well drilling permits from the Mono County Department of Environmental Health. As required by law, DRI marked the drilling areas in white paint and contacted Utility Service Alert prior to drilling. Copies of the well permits are presented in Appendix 1 and copies of the encroachment permits are presented in Appendix 2.

Drilling and Well Installation

Four shallow groundwater monitoring wells, designated LRWQCB-BP-1, LRWQCB-BP-2, LRWQCB-BP-3, and LRWQCB-BP-4, were installed under the direction of LRWQCB staff to support the Bridgeport Reservoir total maximum daily load (TMDL). Well locations are summarized below and presented in Figure 2.

- LRWQCB-BP-1 is located at the entrance of the Dressler Ranch, adjacent to U.S. Highway 395.
- LRWQCB-BP-2 is located on the south side of the first curve south of Bridgeport on Twin Lakes Road.
- LRWQCB-BP-3 is located near the entrance to Hunewill Ranch on the south side of Twin Lakes Road.
- LRWQCB-BP-4 is located on the west side of Highway 182 near the junction of Sage Brush Drive.

The LRWQCB contracted with DRI to arrange for drilling services. Desert Research Institute subcontracted with Andresen Exploration Drilling (Andresen) of Reno, Nevada, a California-registered drilling firm. Andresen utilized a CME-55 drilling rig equipped with nominal 6-inch-diameter hollow stem augers. Drilling and well installation was conducted under the supervision of a California-registered geologist (Tom Gavigan) employed by the LRWQCB.

Soil samples were collected at 5-foot intervals during drilling using a standard penetration sampler. Soil was described in accordance with the Unified Soil Classification System and recorded on boring logs (Appendix 3).

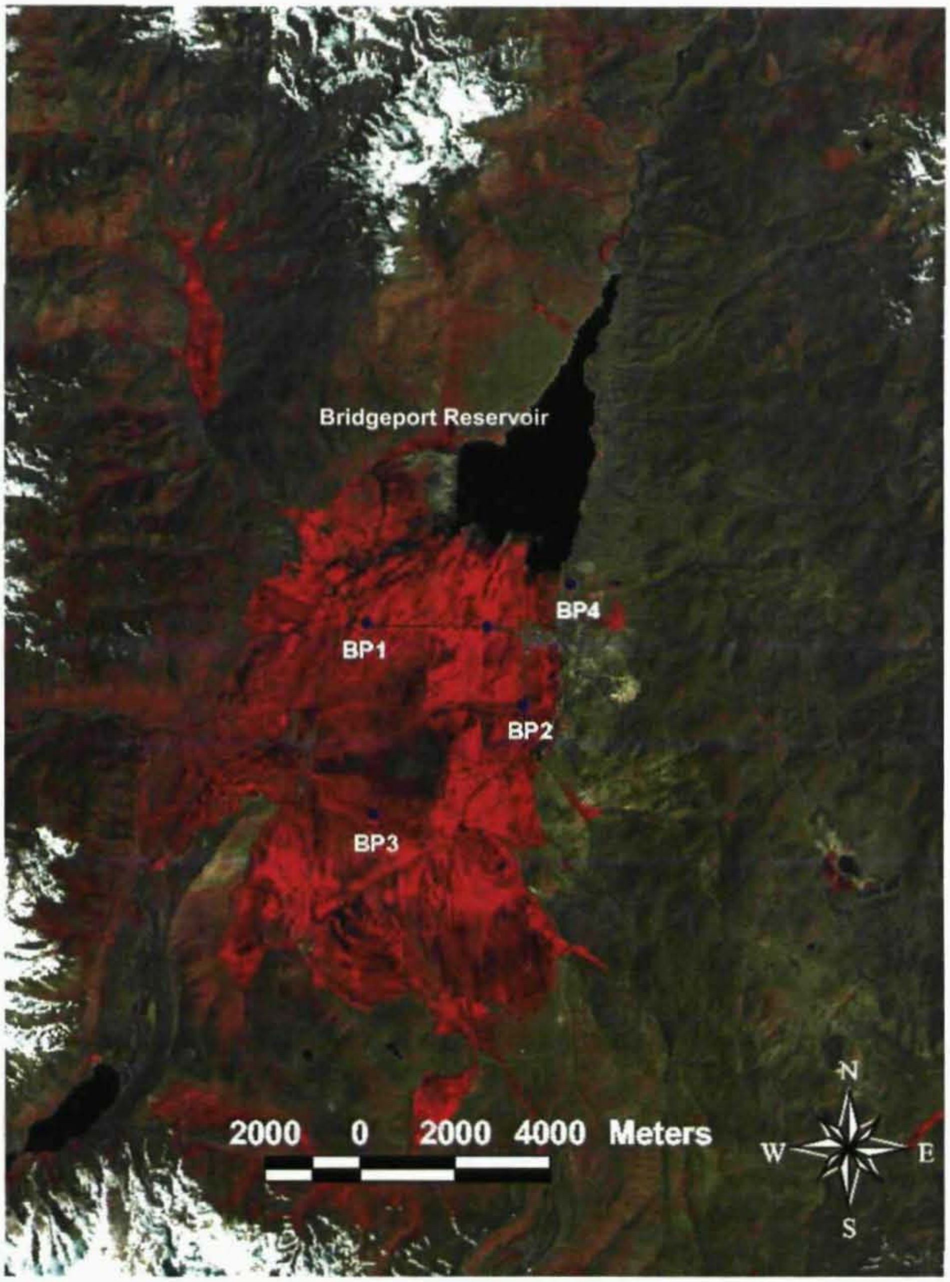

Figure 2. Location of wells drilled for this project. The blue marker without a well designation is the bench mark U914 used as a base station for GPS surveying.

Wells were constructed of 2-inch-diameter, flush-thread, schedule 40 PVC blank well casing and well screen with 0.020-inch machined slots. The well casing and screen were installed through the hollow stem augers. The augers were then removed from the borehole and formation sand collapsed around the well screen and casing. The remaining annular space was backfilled with a combination of Silica Resources, Inc. #6 sand, bentonite holeplug, and Type I/II Portland cement. The wells were completed at ground surface with flush-mount, traffic-rated manhole covers. Well construction details are presented on the boring logs in Appendix 3.

Well Development

Groundwater monitoring wells LRWQCB-BP-1 through LRWQCB-BP-4 were developed on August 24, 2004, to remove accumulated sediment and promote hydraulic connection with the aquifer. The wells were developed using a combination of bailing, surging, and pumping. The produced groundwater was monitored for pH, specific conductance, temperature, and turbidity. The wells were developed until the produced water was sufficiently clear, and the accumulated sediment had been removed from the well casing. Copies of the well development records are presented in Appendix 4.

Aquifer Testing

On August 25, 2004, slug tests were performed on wells LRWQCB-BP-1 through LRWQCB-BP-4 to estimate horizontal hydraulic conductivity of the shallow aquifer. A pressure transducer was inserted in the well and the water level was allowed to equilibrate. A slug was then rapidly lowered into the well and resulting water-level changes were recorded every second until the water level returned to the original value or the water level decline changed very slowly. The aquifer test data were analyzed using the Hvorslev method of analysis. A pumping test was also conducted in LRWQCB-BP-3. A pressure transducer was lowered to the bottom of the well; a small diameter 12V pump was then inserted into the well. The well was pumped at 7.3 L/m for a 15-minute period. These data were analyzed using the Theis nonequilibrium method. Plots of the slug test and pumping test are presented in Appendix 5.

Groundwater Sampling

Groundwater samples were collected from wells LRWQCB-BP-1 through LRWQCB-BP-4, along with an existing monitoring well at the former Fargo Unocal gas station (MW-4) on August 25, 2004. Four additional existing wells located in the Bridgeport Valley were sampled on September 7, 2004. The wells (Figure 3) are designated:

- Former Gene's Texaco MW-7,
- Doc and Al's resort well,
- Bridgeport sewage treatment plant (BPSTP) well MW-1, and
- BPSTP well MW-3.

Samples, except as noted below, were collected by DRI staff using a peristaltic pump and disposable tubing. The produced groundwater was monitored for pH, specific conductance, temperature, and turbidity. Samples collected for dissolved chemical species were filtered with 0.45-micron disposable filters. Field data sheets are presented in Appendix 6. Samples were placed in a cooler with ice and transported under chain-of-custody to the DRI Analytical Chemistry Laboratory. Samples from the monitoring wells at the BPSTP were collected by Bob Loding of Tri-state Water Operations, Inc., in DRI-supplied sample bottles and delivered to the DRI Analytical Chemistry Laboratory under chain-of-custody. Chain-of-custody forms are presented in Appendix 7.

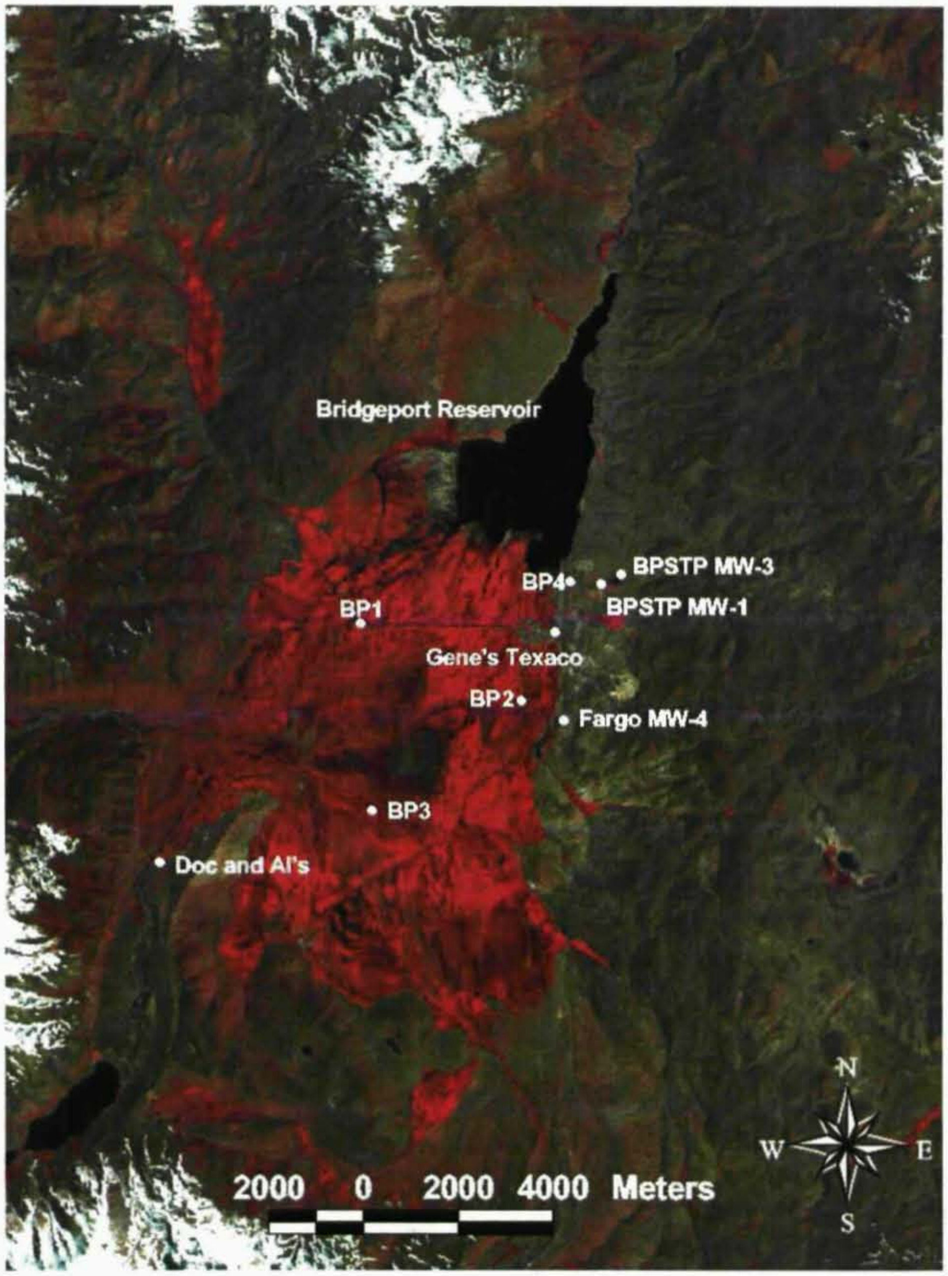

Figure 3. Location of wells sampled for this study in Bridgeport Valley.

Analytical Program

The analytical program consisted of nutrient and major ion analyses. The nutrients analyzed consisted of:

- nitrate as nitrogen (NO_3-N) (dissolved)
- nitrite as nitrogen (NO_2-N) (dissolved)
- total Kjeldahl nitrogen (unfiltered, TKN: organic nitrogen plus ammonium, total)
- total soluble Kjeldahl nitrogen (TKN_{sol}: organic nitrogen plus ammonium), (dissolved)
- ammonium as nitrogen (NH_4-N) (dissolved)
- total phosphorus (TP) (unfiltered)
- total dissolved phosphorus (TPsol) (dissolved)
- orthophosphate as phosphorus (PO_4-P) (dissolved)

The major ion analyses consisted of:

- calcium (dissolved)
- sodium (dissolved)
- magnesium (dissolved)
- potassium (dissolved)
- silica (dissolved)
- bicarbonate (dissolved)
- chloride (dissolved)
- sulfate (dissolved)
- specific conductance
- pH

The DRI Analytical Chemistry Laboratory is an EPA certified laboratory for low-level nutrient analyses. Analytic methods used for the above listed constituents are presented in Appendix 8.

Global Positioning System Survey

To determine the location and elevation of the four wells drilled for this project, a survey was conducted with Ashtech MarkII Pro differential global positioning system (GPS) units. The base GPS unit was set up over benchmark U914 along U.S. Highway 395 (Figure 2) west of Bridgeport (see Appendix 9 for details on this benchmark). The rover unit was set up on each well, with occupation times varying between 30 and 50 minutes, depending on the satellite geometry at the time of occupation. Data were post-processed using Ashtech Solution 2.70 software. Project accuracy was set at 0.02 meters in both the horizontal and vertical directions. Table 1 lists the well locations and elevations determined by this survey.

The reference point for the location and elevation of each well is the steel, traffic-rated cover plate for the well.

Table 1. Well location, elevation, and hydraulic data for shallow wells in Bridgeport Valley. Locations are in latitude and longitude, WGS 84. Symbol: NA, not available or not analyzed.

Sample Name	Degrees N Latitude	Decimal Minutes	Degrees W Longitude	Decimal Minutes	Hydraulic Conductivity (ft/day)	Surface Elevation (ft)
LRWQCB-BP-1	38	15.45193	119	16.25575	121	6,510.9
LRWQCB-BP-2	38	14.57958	119	13.97350	NA	6,485.0
LRWQCB-BP-3	38	13.26896	119	16.09679	82 (16*)	6,548.4
LRWQCB-BP-4	38	15.96415	119	13.32678	NA	6,469.7

*hydraulic conductivity determined by pumping test

RESULTS

Hydrogeology

Well LRWQCB-BP-1 is located near the entrance of the Dressler Ranch, adjacent to U.S. Highway 395. The Universal Transverse Mercator (UTM) coordinates are 4236828.277 m north, 301305.5 m east. The lithology encountered in the first 18 inches included poorly graded sand with gravel (dry and brown), consisting of 70 percent fine to coarse sand, 20 percent fine angular gravel, and 10 percent fines. At 10 feet, the soil became poorly graded sand (wet and light brown), with 70 percent fine to coarse sand, 15 percent fine to coarse subrounded gravel, and 10 percent fines. (See the well log in Appendix 3 for a more detailed description of the well lithology). The total depth of the well was 13.3 feet, and the initial depth to water was 3.5 feet. The screen interval ranged from 8.0 to 12.6 feet below land surface.

Well LRWQCB-BP-2 is located on the south side of the first curve from Bridgeport on the Twin Lakes Road. The UTM coordinates are 4235133.712 m north, 304595.042 m east. The lithology encountered in the top 18 inches was poorly graded sand with silt and gravel (light grayish brown), dry, 75 percent fine to coarse sand, 15 percent fine angular gravel, and 10 percent fines. Below that it consisted of poorly graded sand with gravel (grayish brown), moist, 70 percent fine to coarse sand, and 30 percent fine to coarse subrounded to rounded gravel. (See the well log in Appendix 3 for a more detailed description of the well lithology). The total depth was 17.5 feet boring, and 18.2 feet for the entire well. Depth to water was measured at 4 feet, and the screen interval ranged from 8.0 to 17.5 feet.

Well LRWQCB-BP-3 is located near the entrance to Hunewill Ranch on the south side of the Twin Lakes Road. The UTM coordinates are 4232784.931 m north, 301438.345 m east. The lithology consisted of poorly graded sand with silt and gravel (light brownish gray), dry to moist, with 75 percent fine to coarse sand, 15 percent subrounded gravel, and 10 percent fines in the first four feet. The next six feet had more sand and trace gravel, while the bottom 10 feet contained poorly graded sand with clay and gravel (brown), wet, and 70 to 90 percent fine to coarse sand, 10 to 15 percent fine to coarse, subrounded gravel, with decreasing fines. (See the well log in Appendix 3 for a more detailed description of the well lithology). The total drilled depth was 20.0 feet, and 19.4 feet for the constructed well. The depth to water was 15 feet, while the screen interval ranged from 9.2 to 18.7 feet.

Well LRWQCB-BP-4 is located on the west side of Highway 182 near the junction of Sage Brush Drive. The UTM coordinates are 4237671.917 m north, 305599.941 m east. The lithology consisted of poorly graded sand with silt (dark brown), dry to moist, 90 percent fine to coarse sand, 10 percent fines, and fine gravel in the top eight feet. The next 11 feet had increasing moisture, fine to coarse subrounded gravel, and only trace fines. The bottom 7.5 feet were more silt-like (grayish brown), wet, with 70 percent fine to medium sand, 25 percent low to medium plasticity fines, and only 5 percent fine to coarse, subrounded gravel. (See the well log in Appendix 3 for a more detailed description of the well lithology). The total depth was 26.7 feet. The screen interval was 16.4 to 25.9 feet.

Hydraulic Gradient

The hydraulic gradients (I) for the shallow aquifer in Bridgeport Valley were calculated from the water surface elevation measured in wells LRWQCB-BP-1 through LRWQCB-BP-4 and Bridgeport Reservoir. Water levels in the wells were measured on August 25, 2004, and December 27, 2004, to determine seasonal variations in water-level elevations. Water levels in three of the four wells dropped between August 25, 2004, and December 27, 2004; LRWQCB-BP-1 had a 1.95-foot decline, LRWQCB-BP-3 a 9.48-foot decline; and LRWQCB-BP-4, a 0.36-foot decline, whereas, LRWQCB-BP-2 had a 1.55-foot increase. The water-surface elevation of Bridgeport Reservoir also changed during this same time period. Although the reservoir level rose 1.02 feet between August 25, 2004, and December 27, 2004, the level dropped 9.3 feet after the August measurement, then rose 10.3 feet before the December measurement (see Figure 4). Even with the observed changes in water levels, the gradients from the wells to the reservoir did not change appreciably from season to season (see Table 2).

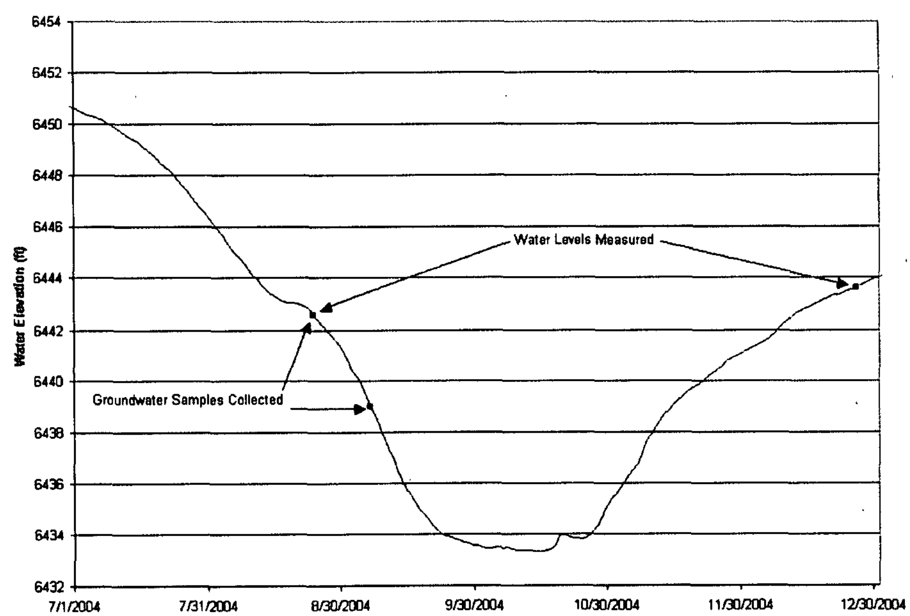

Figure 4. Bridgeport Reservoir water-surface elevations, July 1, 2004, to December 30, 2004. Also shown on the figure are the dates when water levels were measured and groundwater samples were collected.

Table 2. Groundwater gradients in Bridgeport Valley. Water-level elevations were measured in wells in September and December 2004. In each case, the water level of Bridgeport Reservoir was used with each corresponding well to determine the hydraulic gradient.

Well	Surface Elevation (ft)	Depth to Water (ft) 8/25/04	Water Elevation 8/25/04	Depth to Water (ft) 12/27/04	Water Elevation 12/27/04	Distance to Lake (ft)	Gradient 8/25/04	Gradient 12/27/04
LRWQCB-BP-1	6,510.9	3.57	6,507.4	5.52	6,505.4	8,231	0.0079	0.0075
LRWQCB-BP-2	6,485.0	5.81	6,479.2	4.26	6,480.7	7,864	0.0047	0.0047
LRWQCB-BP-3	6,548.4	6.58	6,541.8	16.06	6,532.3	18,999	0.0052	0.0047
LRWQCB-BP-4	6,469.7	15.72	6,453.9	16.08	6,453.6	1,095	0.0107	0.0091
Bridgeport Reservoir	n/a	n/a	6,442.2	n/a	6,443.6	n/a	n/a	n/a

Aquifer Testing

Hydraulic conductivity was measured for wells LRWQCB-BP-2 and LRWQCB-BP-3 using Hvorslav's piezometer method (Freeze and Cherry, 1979). A pressure transducer was placed below the static water level in each well and was connected to a datalogger. The water level was then measured for several minutes to establish a baseline level. A slug of a known displacement was rapidly placed in the well and the water level change was measured over time. A semi-log plot of $h(t)/h_o$, where h_o is the maximum head after the slug was introduced, was constructed and fit with a straight line. Hydraulic conductivity is calculated from $K = r^2 \ln(L/r)/2LT_o$, where r is the piezometer (inside) radius, L is the screen height, and T_o is the time at which $h(t)/h_o$ reaches 0.37. Table 3 shows the calculated hydraulic conductivity values from the two piezometer tests. The length of screen in both wells is 10 feet (see Appendix 10 for calculations).

In addition, a pumping test was performed on well LRWQCB-BP-3 to estimate hydraulic conductivity. As the depth to water is located very near the land surface, the aquifer is most probably unconfined. However, the methods to determine hydraulic conductivity on unconfined aquifers are not applicable to the data collected during the pumping test as (1) there is no observation well, and (2) the drawdown curve does not show a delayed yield response (characteristic of unconfined aquifers) because the pumping test lasted only 15 minutes. Therefore, the Theis nonequilibrium method (Freeze and Cherry, 1979) was used to analyze the data (see Appendix 10). This method is valid for confined aquifers; however, it is assumed that the duration of the test was short enough that little vertical flow occurred during the test, allowing this method to be utilized. The single hydraulic conductivity value is presented in Table 3, along with the arithmetic mean of the three methods.

Table 3. Values of hydraulic conductivity based upon Hvorslav's slug test method (wells LRWQCB-BP-2 and LRWQCB-BP-3) and an aquifer test (LRWQCB-BP-3*).

Well Name	Hydraulic Conductivity, ft/d
LRWQCB-BP-2	122
LRWQCB-BP-3	81
LRWQCB-BP-3*	16
Arithmetic Mean	73

*pumping test

Groundwater Nutrient and Major Ion Concentrations

Groundwater nutrient concentrations are presented in Table 4 and groundwater major ion data are presented in Table 5 (see Appendix 11 for Analytical Chemistry Laboratory data sheets). Total nitrogen (sum of NO_3-N + NO_2-N + TKN) ranged from 0.111 milligrams per liter (mg/L) at LRWQCB-BP-1 to 3.95 mg/L at Fargo MW-4. Nitrate was the dominant form of nitrogen in all wells except LRWQCB-BP-1, LRWQCB-BP-2, and BPSTP-MW-1, which were dominated by organic nitrogen. Total phosphorus concentrations ranged from 0.007mg/L at LRWQCB-BP-1 to 0.633 mg/L at Gene's Texaco MW-7. Laboratory data sheets are presented in Appendix 11.

Table 4. Nutrient data for groundwater in Bridgeport Valley. All values are reported in mg/L. Analyses include: NO_3-N (nitrate as N), NO_2-N (nitrite as N), TKN (total Kjeldahl nitrogen: organic nitrogen plus ammonium), TKN_{sol} (total soluble Kjeldahl nitrogen), NH_4-N (ammonium as N), TP (total phosphorus), TP_{sol} (total dissolved phosphorus), and OPO_4-P (orthophosphate as P).

Sample Name	Sample Date	NO_3-N	NO_2-N	TKN	TKNsol	NH_4-N	TP	TPsol	OPO_4-P
BP-1 Dressler	8/25/04	0.009	0.002	0.10	0.10	0.003	0.007	0.007	0.005
BP-2 1st Curve	8/25/04	0.014	0.002	0.58	0.57	0.15	0.160	0.159	0.011
BP-3 Hunewill	8/25/04	0.186	0.003	0.08	0.09	<.001	0.008	0.008	0.007
BP-4 Airport	8/25/04	0.74	0.010	0.07	0.15	<.001	0.523	0.525	0.501
MW-4 Fargo	8/25/04	3.64	0.045	0.26	0.20	<.001	0.441	0.437	0.424
Gene's Texaco MW-7	9/07/04	1.03	0.007	0.36	0.40	0.018	0.633	0.634	0.616
Doc and Al's	9/07/04	0.441	0.001	<.05	<.05	<.001	0.019	0.019	0.018
BPSTP MW-1	9/07/04	0.036	0.001	0.28	0.26	0.006	0.212	0.009	0.005
BPSTP MW-3	9/07/04	1.18	<.001	0.06	0.06	<.001	0.050	0.049	0.037

Table 5. Major ion data for groundwater in Bridgeport Valley. All major ion values are reported in mg/L.

Sample Name	Sample Date	EC (µS/cm)	pH	SiO_2	HCO_3	Cl	SO_4	NO_3	Na	K	Ca	Mg
BP-1 Dressler	8/25/04	100	7.50	18.3	51	0.7	5.6	0.009	4.11	1.95	12.3	1.94
BP-2 1st Curve	8/25/04	353	7.84	34.2	237	0.9	1.5	0.014	9.48	5.24	52.1	9.5
BP-3 Hunewill	8/25/04	119	7.37	28.5	61	0.8	6.8	0.186	4.14	2.94	13.3	3.45
BP-4 Airport	8/25/04	314	8.16	71.4	179	4.3	13.1	0.74	29.7	4.73	27.2	8.61
MW-4 Fargo	8/25/04	1225	7.93	96.3	383	46.6	303	3.64	44.4	5.93	15.2	2.92
Gene's Texaco MW-7	9/07/04	649	7.81	40.6	252	38.5	73.4	1.03	72.7	23.0	46.2	11.4
Doc and Al's	9/07/04	208	8.11	21.4	104	1.5	15.8	0.441	9.77	2.28	27.5	3.75
BPSTP MW-1	9/07/04	790	8.04	63.1	422	41.7	42.7	0.036	101	9.91	55.2	21.8
BPSTP MW-3	9/07/04	330	7.32	67.1	162	5.5	23.9	1.18	27.8	9.17	26.4	9.42

Nutrient Flux

Nutrient concentrations were used with hydraulic properties of the shallow aquifer and the groundwater gradient to the reservoir to estimate groundwater nutrient fluxes to the reservoir. First, the specific discharge to the reservoir was calculated using Darcy's Law:

$$q = KI \tag{1}$$

where q is the specific discharge, in ft/day; K is the hydraulic conductivity, in ft/day; and I is the hydraulic gradient (change in water level altitude over distance), in ft/ft.

Groundwater nutrient fluxes were then calculated by multiplying the specific discharge (q) by the average groundwater nutrient concentration:

$$F_n = q \times C \times 2.832 \times 10^{-5} \tag{2}$$

where F_n is the nutrient flux, in kg/(ft²/day); q is the groundwater flux, in ft/day; C is the nutrient concentration in mg/L; and 2.832×10^{-5} is the conversion factor to obtain kg/(ft²/day) from ft/day (q) and mg/L (C).

The resulting nutrient flux is the mass of the nutrient through a cross-sectional area for a unit of time, i.e., kg/(ft²/day). An average nutrient load was calculated from the nutrient flux information for a representative cross-sectional area of the shallow aquifer in which groundwater flows into the reservoir.

Nutrient concentrations in the sampled wells were quite variable. To estimate the nutrient flux to the reservoir, Bridgeport Valley was broken into three sections: the western section, which lies along the southwest side of the reservoir; the central portion, which lies near the town of Bridgeport along the south portion of the reservoir; and the eastern portion, which lies along the southeastern portion of the reservoir (see Figure 5). Since wells were not drilled in the northern and eastern side of the reservoir, nutrient flux estimates were not made for those sections.

West Area of Bridgeport Valley

The hydraulic gradient (I) for the west area of Bridgeport Valley ranged from 0.0047 to 0.0079 with an average value of 0.0063 determined by averaging the calculated gradients from LRWQCB-BP-1 and LRWQCB-BP-3 to Bridgeport Reservoir (Table 2). The calculated specific discharge (q), using the average hydraulic conductivity (K) value of 73 ft/day and average hydraulic gradient (I) of 0.0063 is 0.460 ft/day (168 ft/yr). Nutrient fluxes (F_n) can be calculated by multiplying the specific discharge (q) by the concentration of the nutrient (C). This value can be converted to kg/(ft²/day) by multiplying by 2.832×10^{-5}.

The nutrient flux calculations are made for the average concentration of the two samples (Table 1) and for the range in values. The total nitrogen groundwater flux (F_{NO3} +-F_{NO2} + F_{TKN}) ranges from 1.45 to 3.50×10^{-6} kg/(ft²/day) with an average value of 2.48×10^{-6} kg/(ft²/day). The flux of total dissolved phosphorus (FTP_{sol}) ranges from 0.091 to 0.104×10^{-6} kg/(ft²/day) with an average value of 0.097×10^{-6} kg/(ft²/day). The flux of orthophosphate as P (F_{OPO4}) ranges from 0.0651 to 0.0912×10^{-6} kg/(ft²/day) with an average value of 0.078×10^{-6} kg/(ft²/day). Orthophosphate is the readily bio-available portion of the total dissolved phosphorus.

Central Area of Bridgeport Valley

The hydraulic gradient (I) for the shallow aquifer in the central area of Bridgeport Valley was determined to be 0.0048 by averaging the gradients at LRWQCB-BP-2 (0.0047) and the gradient of 0.005 determined by Broadbent & Associates, Inc. (2003) at the former Gene's Texaco facility. The calculated specific discharge (q), using the average hydraulic conductivity (K) value of 73 ft/day and average hydraulic gradient (I) of .0048 is 0.350 ft/day (128 ft/yr).

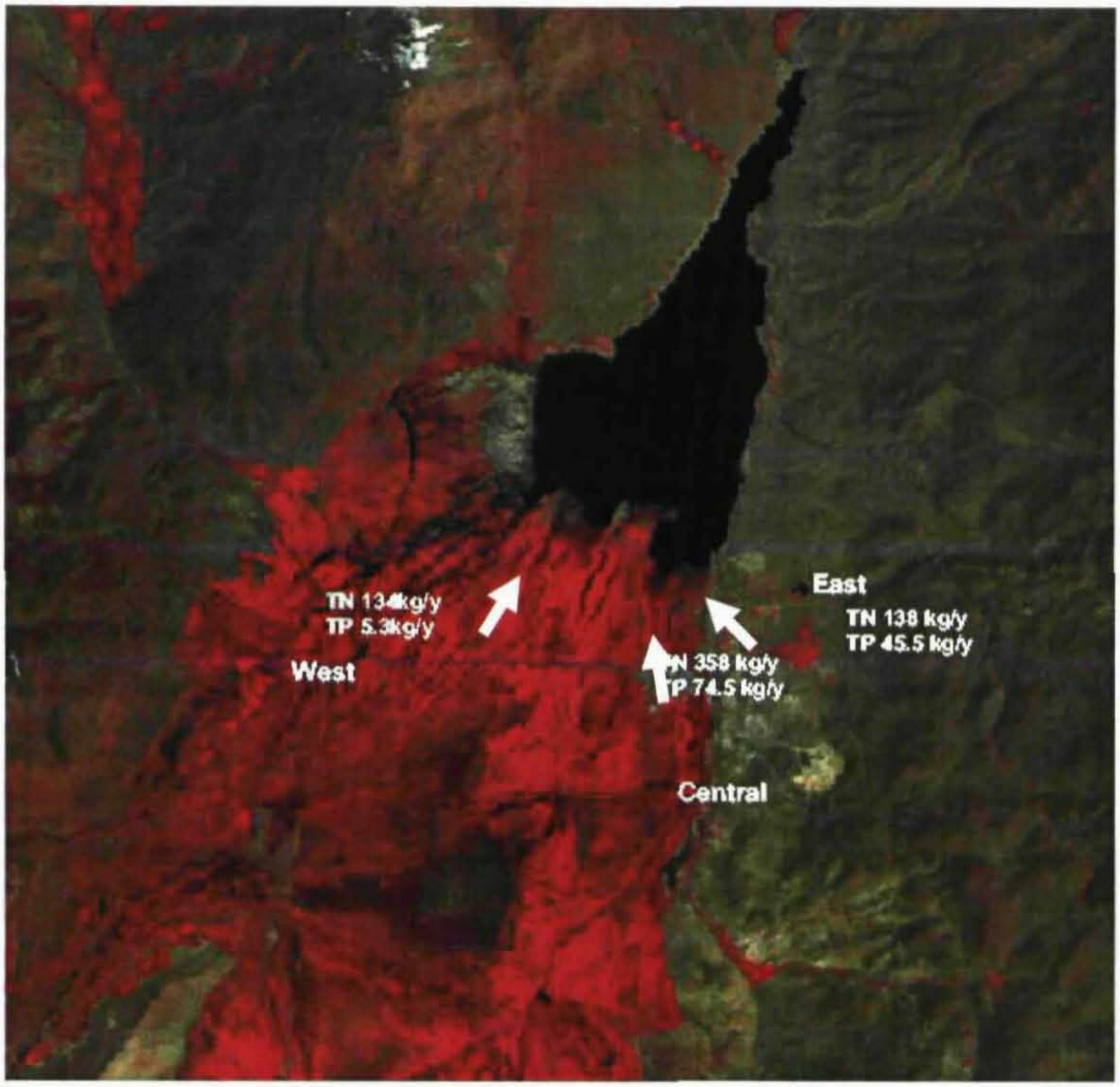

Figure 5. Total nitrogen and phosphorus groundwater loading to Bridgeport Reservoir for a shallow aquifer 10 feet thick. Arrows indicate direction of groundwater flow to the reservoir.

The nutrient flux calculations are determined from the average concentration of samples from Fargo MW-4, Gene's Texaco MW-7, and LRWQB-BP-4, and for the range in values. The total nitrogen groundwater flux ($F_{NO3} + F_{NO2} + F_{TKN}$) ranges from 5.91 to 39.1 x 10^{-6} kg/(ft^2/day), with an average value of 19.6 x 10^{-6} kg/(ft^2/day). The flux of total dissolved phosphorus (F_{TPsol}) ranges from 1.58 to 6.28 x 10^{-6} kg/(ft^2/day), with an average value of 4.06 x 10^{-6} kg/(ft^2/day). The flux of orthophosphate as P (F_{OPO4}) ranges from 0.109 to 6.11 x 10^{-6} kg/(ft^2/day), with an average value of 3.47 x 10^{-6} kg/(ft^2/day).

East Area of Bridgeport Valley

The hydraulic gradient (I) for the area by the east side of Bridgeport Valley was determined to be 0.010 by averaging the gradients at LRWQCB-BP-4 (Table 2). The calculated specific discharge (q), using the average hydraulic conductivity (K) value of 73 ft/day and average hydraulic gradient (I) of .010 is 0.73 ft/day (267 ft/yr).

The nutrient flux calculations are determined for the average concentration of the three samples (BPSTP MW-1 and -3 and LRWQCB-BP-4) and for the range in values. The total nitrogen groundwater flux (F_{NO3} + F_{NO2} + F_{TKN}) ranges from 6.55 to 25.7 x 10^{-6} kg/(ft^2/day), with an average value of 16.4 x 10^{-6} kg/(ft^2/day).The flux of total dissolved phosphorus as P (F_{TPsol}) ranges from 0.186 to 10.9 x 10^{-6} kg/(ft^2/day), with an average value of 4.02 x 10^{-6} kg/(ft^2/day). The flux of orthophosphate as P (F_{OPO4}) ranges from 0.103 to 10.4 x 10^{-6} kg/(ft^2/day), with an average value of 3.74 x 10^{-6} kg/(ft^2/day).

Nutrient Loads

To calculate nutrient loads (kg/day) from the shallow aquifer to Bridgeport Reservoir, a cross sectional area for the aquifer has to be assumed. The widths of the cross-sectional area for the three areas in Bridgeport Valley were estimated using a geographical information system. The width of the aquifer associated with the west portion of Bridgeport Valley was estimated to be 14,840 feet. The width of the central portion of Bridgeport Valley was estimated to be 5,000 feet and the width of the eastern portion of Bridgeport Valley was estimated at 2,300 feet (Figure 5). A saturated thickness for the shallow aquifer for groundwater flowing to the reservoir was assumed to range from 10 to 50 feet. The range of thickness was arbitrarily chosen to yield a range of estimated loads to the reservoir. Although the aquifer is likely much thicker than 50 feet, nutrient concentrations are likely different at deeper depths. The resulting cross-sectional area for the western portion of Bridgeport Valley ranged from 148,400 to 742,000 ft^2, the central portion of Bridgeport Valley ranged from 50,000 to 250,000 ft^2, and the eastern portion of Bridgeport Valley ranged from 23,000 to 115,000 ft^2.

The results of the load calculations are presented in Table 6. Although the west portion of the valley had the longest length of flow, it contained the smallest loads of total phosphorus and total nitrogen. The reason for this is that the wells that characterize this section had low nutrient concentrations. The largest load of total nitrogen and total phosphorus comes from the central portion of the study area.

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Table 6. Nutrient flux from the three areas in Bridgeport Valley. Nutrient flux estimates are based on a 10-foot and 50-foot thick saturated aquifer thickness. All values are reported in kg/yr.

Area of Valley	NO_3	NO_2	TKN	TKNsol	NH_4	TN	TP	TPsol	OPO_4
West Bridgeport Valley 10' thick	69	2	64	67	1.4	134	5	5	4
West Bridgeport Valley 50' thick	344	9	318	335	7	671	27	27	21
Central Bridgeport Valley 10' thick	283	3.3	72	71	10.2	358	75	74	63
Central Bridgeport Valley 50' thick	1,413	16	362	353	51	1791	372	371	317
East Bridgeport Valley 10' thick	113	0.7	24	27.2	0.5	138	46	34	31
East Bridgeport Valley 50' thick	566	3.5	119	136	2.3	688	227	1689	157
Total Load 10' thick	465	6	160	165	12	630	126	113	98
Total Load 50' thick	2,323	29	799	824	60	3,150	626	2,087	495

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