Influence of Canal Seepage on Aquifer Recharge near the New York Canal

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EXECUTIVE SUMMARY

The purpose of this study was to provide constraints on the interaction between surface water and ground water near the New York Canal (NYC). To accomplish this, spatial distributions of key hydrochemical parameters were analyzed with respect to aquifer stratigraphy.

Occurrence of tritium (^3H) in most of the ground water samples taken from the upper 200 to 300 feet of stratigraphic section near the NYC provides strong evidence of rapid recharge of Snake River Group aquifers. Ground water residence times range from several years in shallow, perched aquifers adjacent to the canal to approximately 100 years in deeper, confined or semi-confined aquifers. Elevated concentrations of nitrate (NO_3) and carbon dioxide (CO_2) in aquifers underlying irrigated fields west of the canal demonstrate the effect of flood-irrigation on ground water recharge. Ground water in aquifers east of the canal do not underlie irrigated land and do not exhibit elevated concentrations of NO_3 and CO_2. A ground water divide directly beneath the canal appears to minimize mixing of these waters.

Lack of ^3H and NO_3 and an abrupt decrease in conductivity (C_s) in ground water from wells that penetrate thick, blue clay layers at approximately 2,400 feet below mean sea level suggests that these aquifers do not receive substantial recharge from overlying ground water. Previous analysis of ground water ages suggest that these aquifers contain paleo-water and are part of a much larger, regional ground water system.

Our investigation provided the following primary conclusions:

1. Losses from and gains to the NYC correlate strongly with local stratigraphy.
2. Aquifers contained in the first few hundred feet of alluvial sediment near the canal are recharged by canal seepage and by percolating irrigation water where they are overlain by flood-irrigated fields.
3. Ground water in these shallow alluvial aquifers was recharged during the past 50 years.
4. Distinct geochemical signatures can be used to differentiate between ground water in shallow, alluvial aquifers and ground water in deeper, regional aquifers.
5. Contemporary surface water is not a major source of recharge to deep, regional aquifers beneath the NYC.

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1 INTRODUCTION

1.1 Background

Rapid population growth and changes in agricultural land use have contributed to increased ground water withdrawals in the Treasure Valley[1] during the past ten years. Public concerns about localized ground water declines in some areas of the Treasure Valley have prompted the Idaho Department of Water Resources (IDWR), United Water Idaho, Inc. (UWI), Ada and Canyon Counties, U.S. Geological Survey (USGS), U.S. Bureau of Reclamation (USBR), and a number of city governments to initiate the Treasure Valley Hydrologic Project (TVHP). The purpose of the TVHP is to develop a better understanding of ground water resources in the Treasure Valley and to evaluate how the ground water system will respond to long-term changes in regional hydraulic stresses. To accomplish these goals it is necessary to (1) understand and quantify the various sources of recharge to the regional ground water system and (2) accurately distribute inflows and outflows of water among the primary aquifer layers.

Canal seepage and deep percolation of irrigation water dominate the basin water balance (Urban and Petrich, 1998). Ground water mounding beneath the extensive canal system is often attributed to canal seepage. An analysis of seepage from the New York Canal (NYC) estimates that cumulative seepage rates range between 12% and 20% at canal flows of 439 to 980 cubic feet per second (cfs) (Berenbrock, 1999; Carlson and Petrich, 1999).[2] Carlson and Petrich (1999) conclude that (1) cumulative seepage rates are proportional to canal flow, and (2) seepage rates in various reaches of the canal are controlled largely by underlying geology and depth to ground water. The extent to which canal seepage mixes in the underlying aquifers is presently unknown; however, it is an important aspect of describing recharge to the regional ground water system.

Environmental tracers provide an excellent opportunity to address water movement in the subsurface (Clark and Fritz, 1997). Tritium (^3H) is particularly useful for understanding near-surface ground water flow. Large quantities of this radio-isotope of hydrogen were released into the atmosphere during nuclear bomb testing in the 1950s and 1960s. After these releases, concentrations of ^3H in the atmosphere diminished because of radioactive decay and removal by rain. Presence of ^3H in ground water allows ground water recharge during the period of 1960–2000 to be distinguished from

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[1] Treasure Valley is a socio-economic area that includes the entire lower Boise River watershed and extends south and west to the Snake River.

[2] Estimates of seepage from the NYC were obtained from flow measurements taken in 1997 and 1998 during periods of no diversion. These measurements are discussed by Berenbrock (1999) and Carlson and Petrich (1999).

ground water recharged prior to 1950. In some cases, more accurate estimates of ground water age can be obtained.

In addition to ^3H, measurements of nutrients and dissolved ions in ground water can be used to identify the recharge environment of ground water in some Treasure Valley aquifers. For example, the presence of nitrate greater than about 2 mg/L^{-1} is generally associated with agricultural applications of nitrogen fertilizer via deep percolation of irrigation water. Very low dissolved nitrate concentrations in seepage from the NYC contrast sharply with elevated nitrate concentrations in percolating irrigation water. The canal transports high-quality water from the upper Boise River drainage, and in its upstream reaches, has no surface water return flows. Thus, water seeping from the NYC contains very low concentrations of nitrate. Similarly, other dissolved constituents like chloride and sulfate can be used to distinguish sources of ground water recharge.

Dissolved CO_2 is also an indicator of the ground water recharge environment. The partial pressure of CO_2 in natural precipitation and in rivers and streams fed by natural precipitation is approximately $10^{-3.5}$ bar. This value is relatively constant because of equilibrium exchange with atmospheric CO_2. When water passes through the soil, however, the P_{CO_2} is enriched by microbial respiration. The value of P_{CO_2} in soil water is about 10^{-2} bar. Partial pressures of $>10^{-2.5}$ bar are strong evidence that the water did not originate as canal seepage.

1.2 Previous and Related Work

No previous work conducted in the Treasure Valley documents the extent of surface and ground water interaction associated with canal seepage. However, the results of several limited isotope geochemistry studies in the Boise area warrant review. Radiocarbon (^{14}C) ages of water sampled from the Amity, Mac, and Sunset West wells, which are all completed at depths of 400 to 500 feet in Idaho Group sediments beneath the NYC, show that these waters were recharged between 5,000 and 9,000 years ago (Hutchings and Petrich, 2001; Parliman and Spinazola, 1998). The existence of paleo ground water precludes a direct, dynamic connection to surface water. It is also unlikely that these aquifers are recharged by shallow, alluvial aquifers that are in direct connection with surface water. This temporal distinction is further supported by measurements of ^3H in ground water samples from five shallow wells adjacent to the NYC (USGS, unpublished data). These measurements suggest that downward movement of surface water originating from canal seepage and flood irrigation is limited to a depth of about 200 feet since the 1950s (D. Parliman, pers. comm.). Additional anecdotal evidence is found in the vertical distribution of nitrate (N) in Treasure Valley ground water. Occurrence of elevated N (>2 mg N/L^{-1}) is common in shallow aquifers but sparse in deeper aquifers (Parliman and Spinazola, 1998; Neely and Crockett, 1998).

The aforementioned studies are limited in scope and do not directly address ground water recharge. Nonetheless, they suggest that canal seepage and percolating irrigation water may be important sources of recharge to underlying shallow aquifers. Conceptually, these shallow aquifers discharge at nearby drains; however, downward hydraulic gradients beneath the NYC raise the question of whether these shallow aquifers supply water to deeper, regional aquifers.

1.3 Project Purpose and Objectives

The purpose of the present study was to provide additional constraints on the distribution of water balance data among principal aquifer layers and add to the reliability of canal seepage data. The specific objectives are to (1) measure key hydrochemical indicators in canal water and in ground water beneath the canal, and (2) use these indicators to trace water movement from the canal into underlying aquifers.

2 METHODS

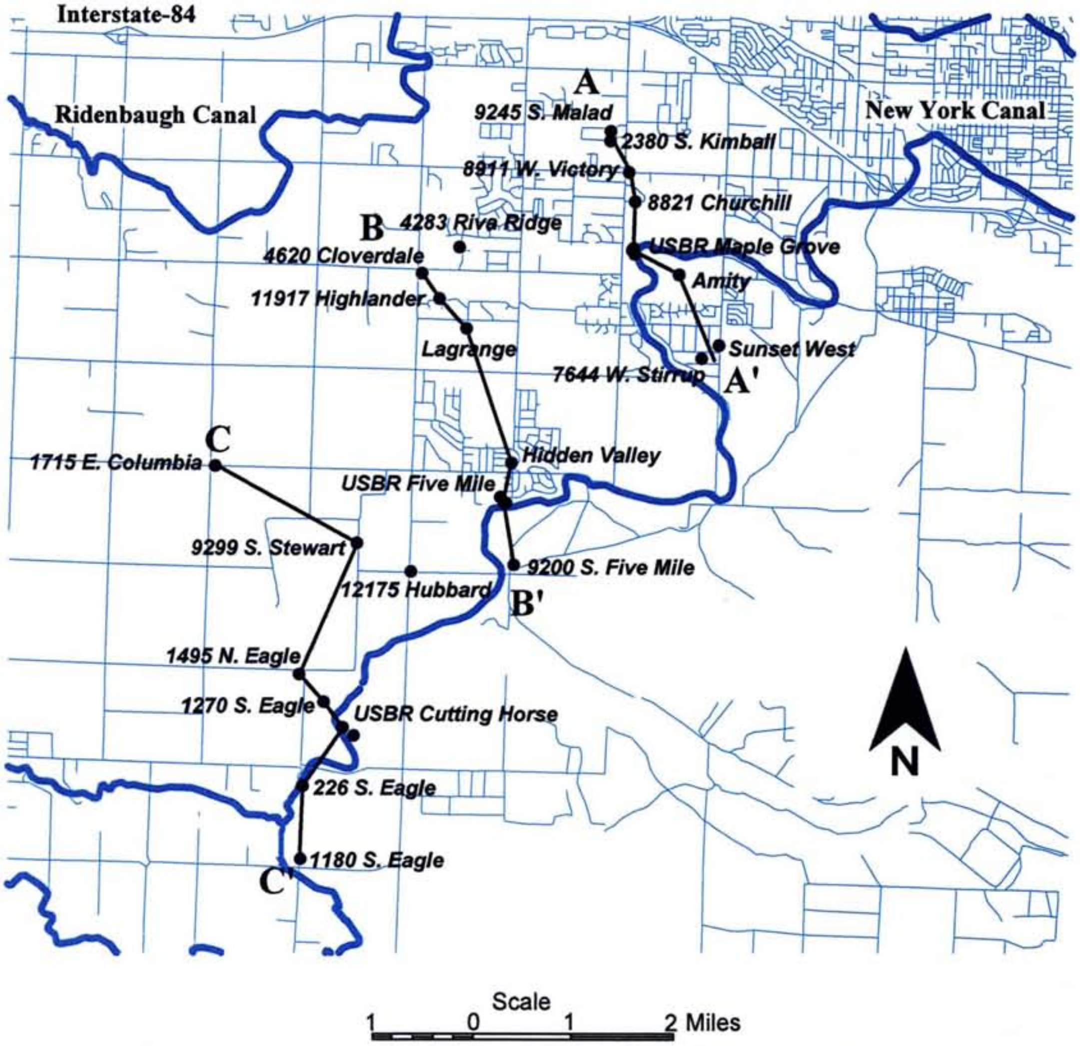
The objectives of this study required collection of ground water samples and measurement of a suite of dissolved constituents. Sampling well selection criteria, sampling procedures, chemical analyses, and the Quality Assurance (QA) plan are summarized below. The summary is followed by a detailed description of data analysis procedures. A complete listing of well information and water sampling data is given in Appendix A.

2.1 Well Selection

Twenty-eight wells adjacent to the NYC were selected for ground water sampling (Figure 1). The wells lie along three transects that bisect the canal and include eight recently drilled USBR monitoring wells. Fewer wells exist on the east side of the canal, resulting in a somewhat disproportionate coverage. The selected wells encompass a range of shallow and intermediate completion depths in aquifers underlying the canal. Most wells selected for sampling are pumped for domestic water supplies and meet the following depth criteria: (1) the top of the water-bearing zone (WBZ) is between 0 and 99 feet below ground surface (bgs) and the WBZ is less than 50 feet thick, or (2) the top of the WBZ is between 100 and 299 feet bgs and the WBZ is less than 200 feet thick. Drillers' logs were reviewed to insure that detailed lithologic information was available and that an adequate surface seal minimized the possibility for surface water leakage down the casing. Additional criteria included well accessibility and the presence of water level data.

2.2 Ground Water Sampling and QA/QC

The USGS (under contract with IDWR) obtained ground water samples from the wells shown in Figure 1. These wells were sampled within a 45-day period (to minimize temporal changes in ground water chemistry that could occur in shallow aquifers) beginning in March 1999. Sampling closely followed Standard Operating Procedures (SOPs) developed for IDWR's Statewide Ground Water Quality Program. Well sampling required completion of a field site inventory (SOP 1.00), well purging (SOP 3.00), equipment decontamination (SOP 4.00), sample collection (applicable parts of SOP 5.00), quality control sampling (SOP 9.00), sample labeling (SOP 8.00), and sample shipping (SOP 6.00). Quality control sampling consisted of two duplicate samples per each sampling effort, one equipment blank per month of sampling, and one blind reference of each analyte per month of sampling.



Well names correspond to data tabulated in Appendix 1. Lines A-A', B-B', and C-C' correspond to geologic cross-sections shown in Figure 3, Figure 4, and Figure 5.

Figure 1. Names and locations of NYC sampling wells.

The QA Plan for the Statewide Water Quality Monitoring Program was adopted to evaluate ground water sampling and analysis during this study. The plan ensured that date were (1) collected in a manner consistent with the research objectives, (2) accurately represented the actual ground water conditions, and (3) technically defensible. Applicable sections of the QA Plan as they applied to the analytes listed above are QA Objectives, Sampling Procedures, Quality Control (QC) Checks, and Calculation of Data Quality Indicators. Quality Assurance observations were conducted at the field and laboratory level. These observations included (1) previewing laboratory QA procedures prior to sample submission, (2) reviewing laboratory QA data upon receipt by project personnel, (3) observing field sampling techniques, and (4) evaluating QC data, including ion balances, precision of duplicate analyses, and accuracy of blind references.

2.3 Units of Measurement

All data, except isotopic measurements, are reported using International System of Units (SI).[3] For straightforward comparisons with previously reported data, ^3H measurements are reported in units of picoCuries per liter (pCi/L^{-1}).

2.4 Data Analysis

The contribution of surface water to aquifers underlying the NYC was examined by (1) creating and examining geologic maps and cross-sections showing permeable and impermeable stratigraphic units beneath the canal, and (2) correlating the stratigraphy to spatial distribution of C_s, ^3H, NO_3, SO_4, CO_2, and other geochemical indicators of recent surface water. Interpretation of subsurface geology was based on a detailed survey of driller's logs (using IDWR's WELL_LOG software) and on previous geologic mapping. The relative influence of canal seepage and percolating irrigation water was resolved by comparing concentrations of NO_3, SO_4, and CO_2 in different strata and at various distances from the canal. The P_{CO_2} in ground water was calculated from measurements of dissolved HCO_3^- and CO_3^-, and pH. This information was compared to measurements of canal seepage (Carlson and Petrich, 1999) and to water level measurements in shallow wells near the canal (Berenbrock, 1999).

A qualitative approach was employed to estimate ground water residence times in the shallow aquifers. The approach was based on known changes in atmospheric ^3H levels and on timing of agricultural development associated with Boise Project diversions. A thorough review of age interpretations of ^3H in ground water is given in Clark and Fritz (1998). Interpretations used for this study are summarized in Table 1. Substantial irrigation from diversions in the NYC and Mora Canal began in about 1911 with the construction of Arrowrock Reservoir (Warnick and Brockway, 1974; Higginsen, 1981). The acreage of irrigated land was comparatively small prior to construction of Arrowrock Reservoir; therefore, it is unlikely that surface water diversions were a major source of recharge prior to 1911. Large-scale commercial use of nitrogen fertilizer began after World War II; therefore, ground water containing NO_3-N concentrations greater than a few parts per million (ppm) most likely originated in the 1940s or later. Together, relative concentrations of ^3H and N place a limit on the age of ground water. For example, ground water containing 16 to 50 pCi/L^{-1} ^3H and 10 mg/L^{-1} NO_3-N is clearly modern and was recharged during the past ten years. In contrast, ground water containing <3 mg/L^{-1} ^3H and <2 mg/L^{-1} NO_3-N is older than

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[3] A reference of SI units can be found at http://www.unc.edu/~rowlett/units/sipm.html.

1940. Ground water containing <3 mg/L^{-1} ^3H and 5 mg/L^{-1} NO_3-N probably originated in the late 1940s.

^3H (pCi/L^{-1})	Interpretation
<3	Submodern water recharged before 1952
3-15	Mixture of submodern and modern water
16-50	Modern water recharged during the past ten years
50-100	Considerable proportion of recharge during the 1960s
>100	Dominant proportion of recharge during the 1960s

Table 1. Interpretation of ground water recharge based on ^3H concentrations (after Clark and Fritz, 1997).

3 GEOHYDROLOGY

3.1 Geologic Setting

Three general groups of sediment underlie the NYC in the first 1,000 feet of stratigraphic section. The groups consist of (1) Idaho Group lacustrine clays and sands overlain by (2) Snake River Group sediments and (3) Snake River Group basalts. The Idaho Group sediments were deposited during episodes of basin filling and lie below an erosional unconformity in the vicinity of the NYC. Idaho Group clays and sands are present at depths along the entire reach of the canal and appear to correlate with previously mapped Pliocene Idaho Group sediments (Burnham and Wood, 1992; Malde, 1991). Sand and clay units beneath the northeastern reaches of the NYC have similar positions and elevations as the Terteling Springs Formation, while sands and clays underlying the southwestern portion of the NYC appear to match the Glenns Ferry Formation.

The Snake River Group includes deposits that lie above the gravel and erosional unconformity. Thin terrace gravels of the upper Snake River Group appear to overlie the Idaho Group sand and clay units in much of the section. Tertiary Bonneville Point gravels and sands are believed to underlie younger Pleistocene terrace gravels near the eastern extent of the canal (Othberg, 1994). In these areas, alluvial gravel units occur to depths of approximately 600 feet bgs. In the western reaches of the canal the gravel units are considerable thinner and most likely correlate with gravels of the Tenmile terrace. Tenmile terrace gravels are believed to be Pliocene and Pleistocene in age (Othberg, 1994). In general, stratigraphic sequences appear to be more laterally continuous under the western portion of the study area than under the eastern portion. Pleistocene basalts cap the Tenmile gravel in the western portion of the study area. These basalts most likely erupted from local shield volcanoes such as Kuna Butte, Pickles Butte, and Powers Butte. Isolated basalt flows along the northeastern reaches of the canal likely correlate to basalts of the Gowen and Fivemile terraces. A generalized geologic map delineates Quaternary basalt flows and unconsolidated sediments in the upper section of the study area (Figure 2).

Several faults may affect water-bearing sedimentary units in central reaches of the canal (Figure 2). Map locations of the offset units are based on prior investigations and lithologic interpretation of well logs. One such fault, which occurs in section 19, Township 3 North, Range 2 East, is thought to represent the most recent period of faulting in the area (Burnham and Wood, 1992). This fault offsets Sunrise terrace gravels by approximately 1.5 feet. This small offset is unlikely to have an observable effect on ground water flow. Numerous faults with more substantial offset are documented in older sedimentary units (Burnham and Wood, 1992; Othberg, 1994).

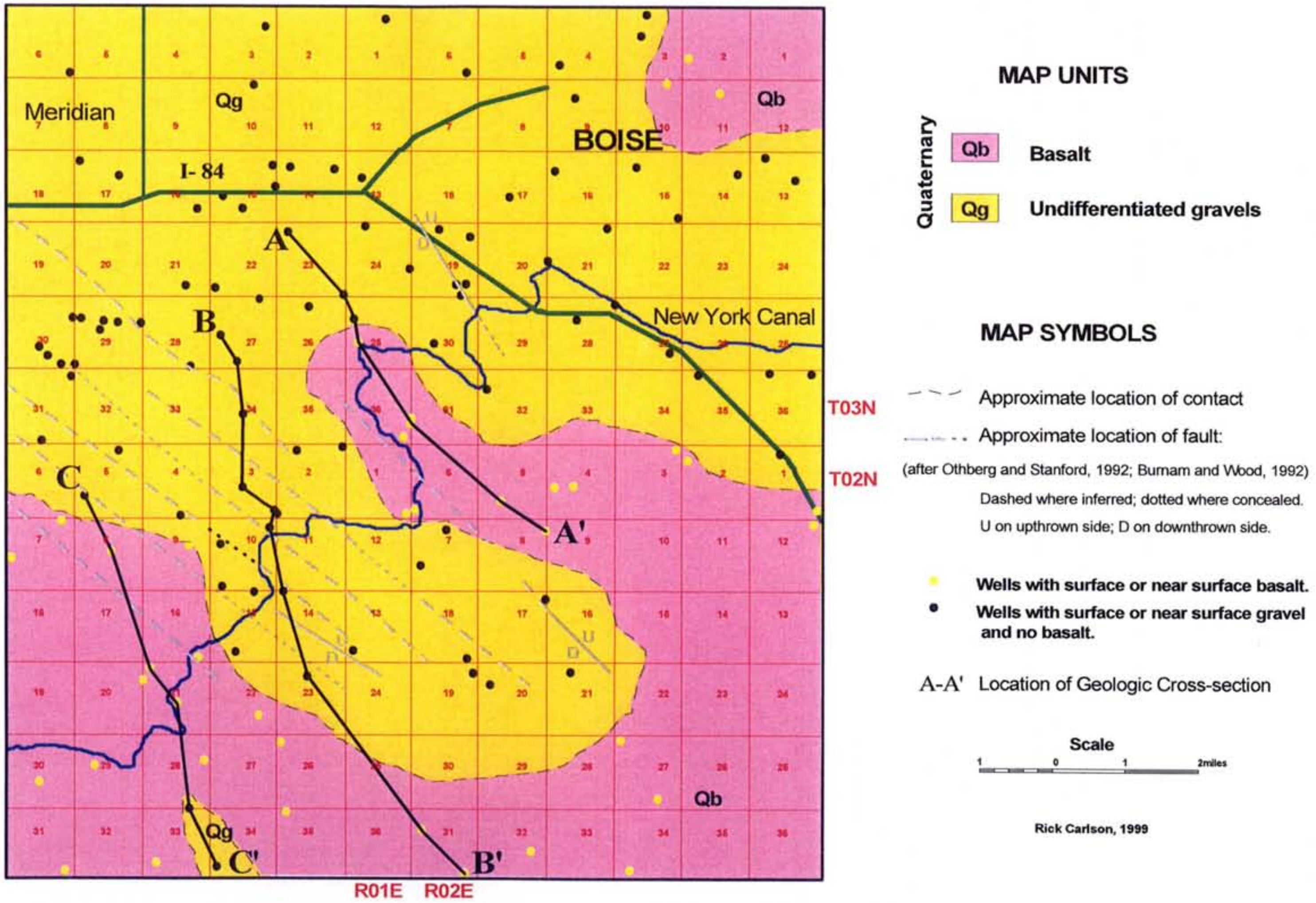

Figure 2. Map of surficial geology in the NYC study area emphasizing the occurrence of Quaternary Basalt and undifferentiated alluvial gravel. Cross-sections A-A', B-B', and C-C' are shown in Figure 3, Figure 4, and Figure 5.

3.2 Hydrostratigraphy

Geologic cross-sections constructed from well logs display more detail of the basalt and alluvium directly underlying the NYC (Figure 3, Figure 4, and Figure 5). These cross-sections are based on drillers' records of well cuttings. The most important hydrologic features of these cross-sections are clay beds intercalated into the coarser sand and gravel aquifer layers. At elevations above approximately 2,400 feet, the clay beds are between 10 and 20 feet thick and appear to be horizontally continuous on a scale of up to 2 or 3 miles. Below approximately 2,400 feet, individual beds range between 30 and 80 feet thick. In the Maple Grove cross-section, these beds are laterally continuous over distances greater than 6 miles (Figure 3). A similar series of continuous beds may exist in two wells below 2,500 feet in the Five Mile cross-section, although lack of deeper wells in the eastern portion of the cross-section makes this finding uncertain (Figure 4). These clay beds may play an important role in restricting vertical mixing of water between adjacent aquifer units.

Another important feature of the cross-sections is the location of faults. The fault locations are transferred from the surficial geologic maps of Othberg and Sanford (1992); as a result, the locations are approximate and the affected sedimentary units are not known. The point of locating these faults on the cross-sections is to show where lithologic offset may provide the hydraulic connection between aquifer units. No faults are mapped on the Maple Grove section, a single fault may bisect sediments of the Cutting Horse section, and numerous faults appear on the Five Mile section. Finally, surficial basalt is observed in all three cross-sections. The contact between the basalt and the underlying alluvium may provide highly permeable pathways through which water could rapidly move into deeper aquifers.

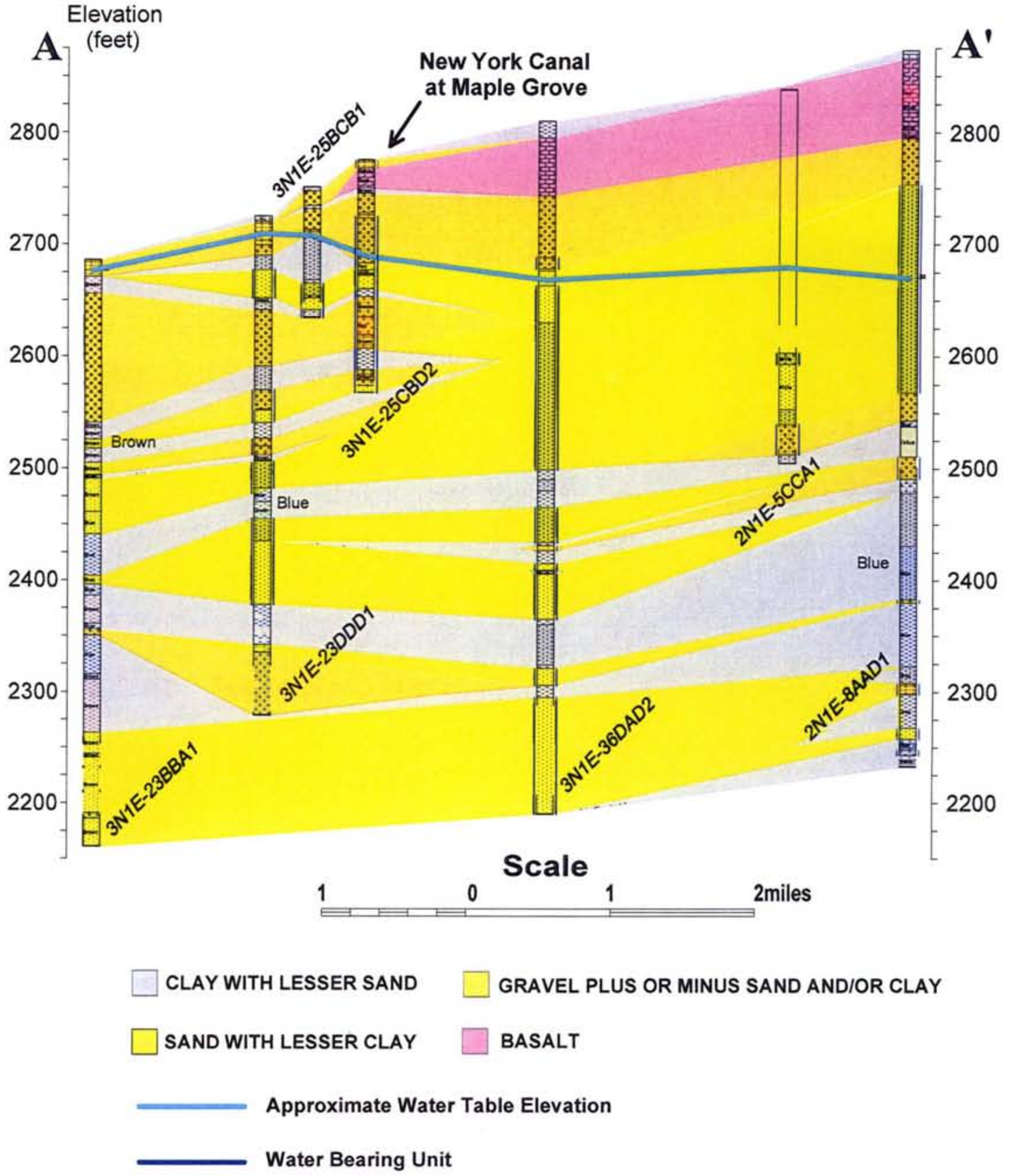

Figure 3. Geologic cross-section bisecting the NYC at Maple Grove Road. The location of A-A' is shown in Figure 2. Stratigraphy, water table, and occurrence of water are interpreted from drillers' logs.

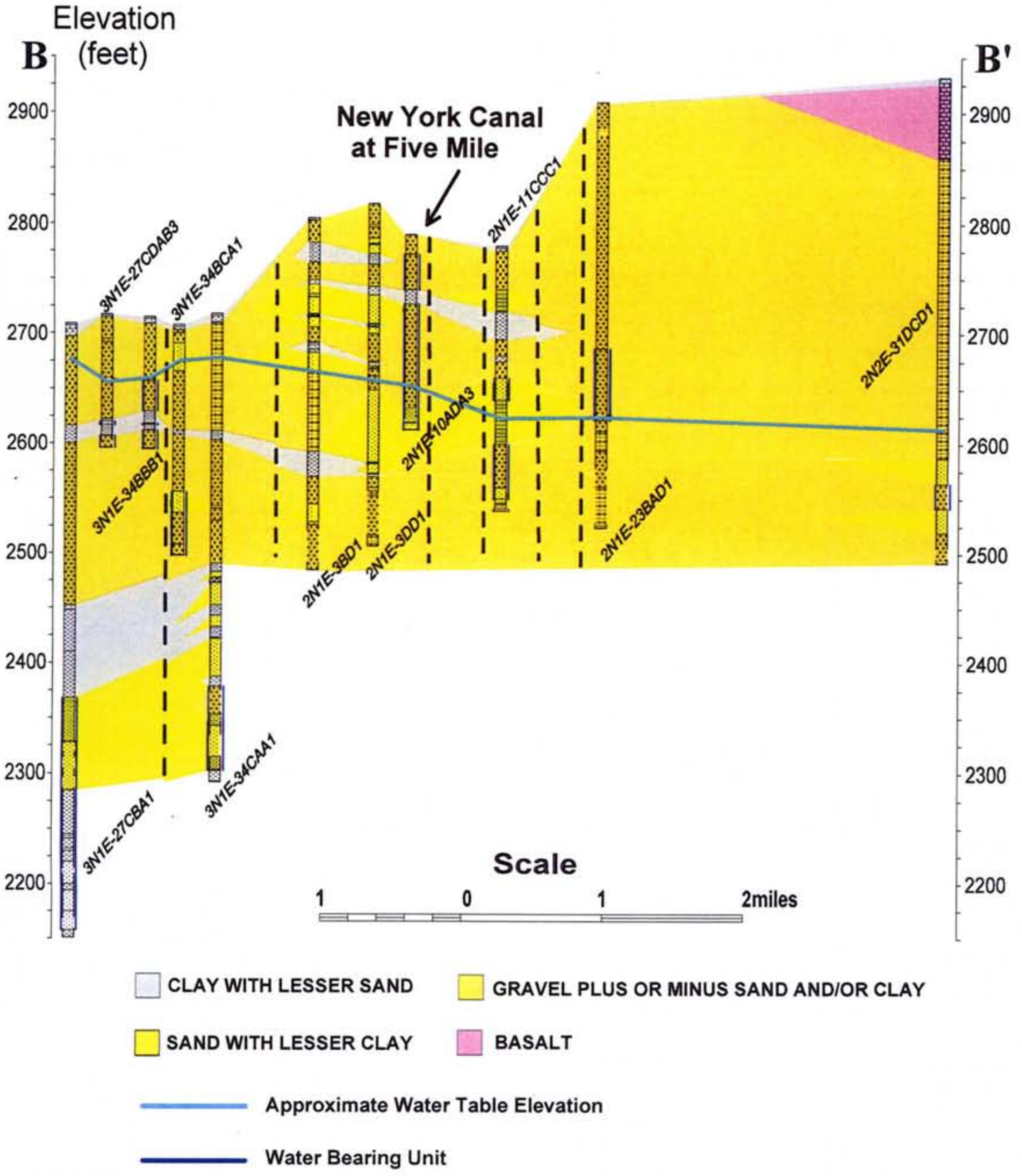

Figure 4. Geologic cross-section bisecting the NYC at Five Mile Road. The location of B-B' is shown in Figure 2. Stratigraphy, water table, and occurrence of water are interpreted from drillers' logs.

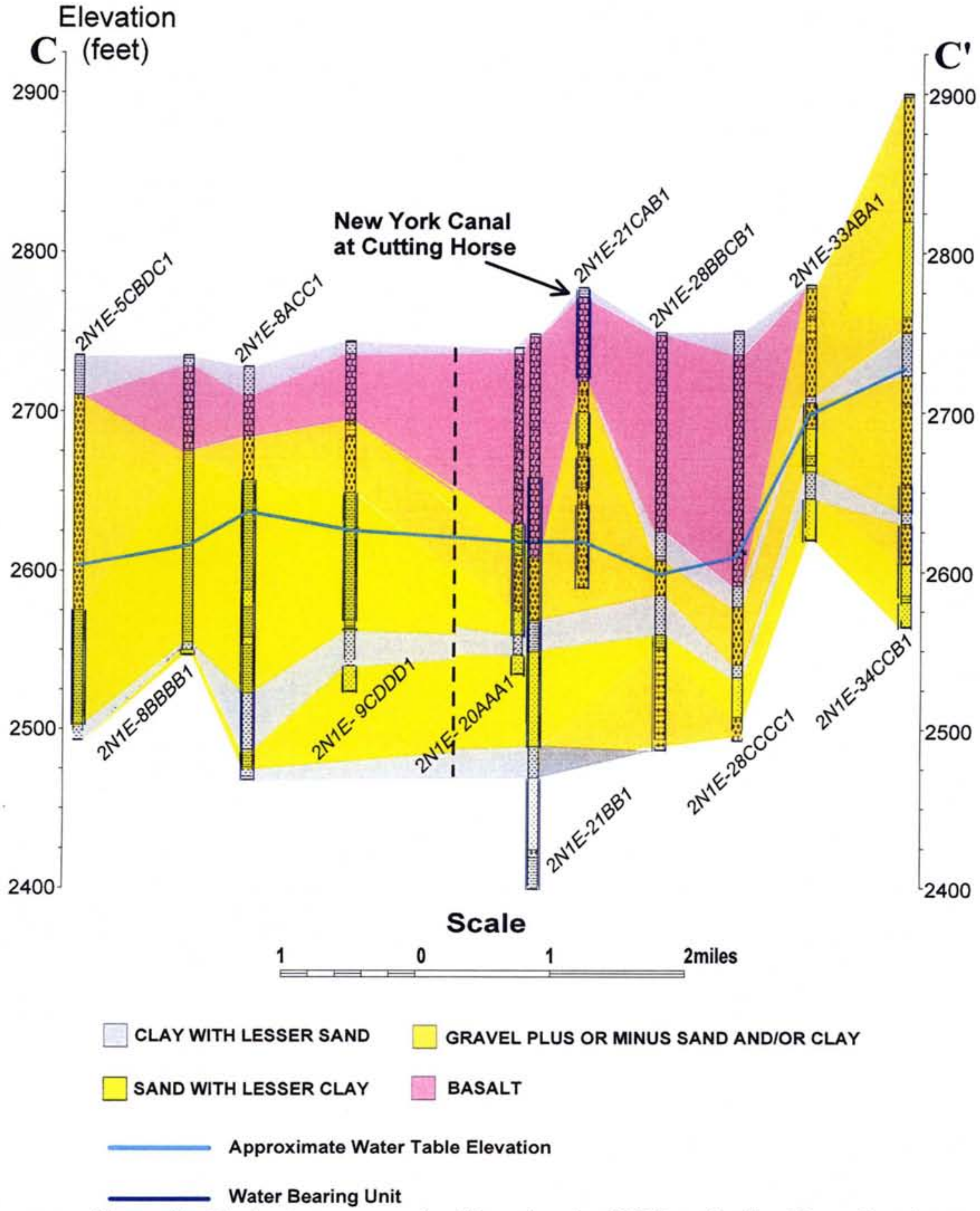

Figure 5. Geologic cross-section bisecting the NYC at Cutting Horse Road. The location of C-C' is shown in Figure 2. Stratigraphy, water table, and occurrence of water are interpreted from drillers' logs.

The shallowest aquifers that we sampled were penetrated by the USBR wells located within approximately 300 feet of the canal bank shown in the Maple Grove, Five Mile, and Cutting Horse cross-sections. These aquifers appear to be perched above shallow clay beds that occur at an elevation of approximately 2,675 feet and extend several miles northwest from the canal. Shallow clay zones are not ubiquitous in the first 50 to 100 feet of section beneath basalt flows. However, an unconfined aquifer clearly exists at approximately 160 feet beneath the canal at the USBR Cutting Horse well where the upper 20 to 60 feet of section at this location is comprised of basalt (Figure 5). Water levels in all of these shallow aquifers respond to changes in canal flow within a few days (Spinazola, pers. comm.). The dynamic character of the perched aquifers appears to be closely related to the shallow clay beds. Existence of perched ground water west of the canal at Maple Grove and Five Mile may reflect the gaining/losing character of the canal along the reaches upstream from these wells. The reach between Gowen Road and Cole Road lost 80 to 150 cfs in the four measurements taken at canal flows between 440 and 980 cfs (Carlson and Petrich, 1999). The Maple Grove well site lies in the middle of this reach, where the canal bends around a basalt outcrop (Figure 1 and Figure 2). In contrast, the reach between Cole Road and Hubbard Road, which encompasses the Five Mile well site, gained between 20 and 130 cfs over the same range of canal flows. Shallow clay extending west from beneath these reaches may conduct water recharged along the losing reaches back into the canal near the Five Mile well site.

The canal reach between Hubbard Road and Kuna Road, which includes the Cutting Horse well site, lost between 15 and 30 cfs. An unconfined aquifer zone lies directly beneath the NYC under the surficial basalt at this location (Figure 5). This aquifer appears to be perched above a clay layer at approximately 2,550 feet.

4 SPATIAL DISTRIBUTIONS OF GEOCHEMICAL TRACERS

A conceptual model of recharge processes near the NYC can be developed from the observed spatial distribution of geochemical tracers underlying the canal. Geochemical data from the shallow USBR wells (which penetrate perched aquifers in the upper 100 feet of section adjacent to the canal) are similar to data from surface water sampled in the canal at Diversion Dam (Table 2). Tritium concentrations in the shallow aquifers at the Maple Grove site are the same as the ^3H concentrations measured in canal water, showing that both the aquifer water and the source water are modern (Table 2, Figure 6). Low temperature, C_s, and SO_4 concentrations indicate that the water has not moved far from its recharge source. Concentrations of NO_3 are at background levels, while P_{CO_2} in canal water and in perched water at the Maple Grove site reflect atmospheric equilibrium.

Sampling Zone	Approx. elev. (feet)	^3H (pCi/L)	T (°C)	C_s (μS/cm)	NO_3-N (mg/L)	SO_4 (mg/L)	P_{CO_2} (bar)
Canal Water	surface	28	9	62	0.1	1.5	$10^{-3.3}$
Shallow/Perched	>2,675	26-33	11-14	83-175	0.1-0.3	1.6-9.8	$10^{-2.7}$-$10^{-3.4}$
Middle West	2,500-2,675	27-89	11-15	435-644	0.7-5.0	22-65	$10^{-2.2}$-$10^{-2.7}$
Middle East	2,500-2,675	32-49	13-14	119-330	0.2-2.3	6.1-21	$10^{-2.7}$-$10^{-3.4}$
Deep	2,400-2,500	<2.5-19	13-24	660-907	0.1-5.6	110-170	$10^{-2.3}$-$10^{-2.6}$
Regional	<2,400	<2.5-7	18-20	317-374	0.1-0.2	24-44	$10^{-2.4}$-$10^{-2.7}$

Table 2. Geochemical indicators of canal seepage and deep percolation and their relation to aquifer stratigraphy.

Similar relationships exist between canal water and shallow aquifers at the Five Mile and Cutting Horse sites (Figure 7 and Figure 8). There are two exceptions. First, P_{CO_2} of water from the shallow Five Mile and Cutting Horse USBR wells are between $10^{-2.7}$ and $10^{-2.8}$ bar, implying that some mixing occurs between canal seepage and percolating irrigation water in shallow aquifers adjacent to the canal. Second, conductivity in the Cutting Horse well is about 50 μS/L greater than observed at the two upstream locations. The increase is not large compared to C_s observed deeper in the section. Greater C_s at downstream locations suggests that downward seepage from the canal is not the only recharge process at work. A scenario that can explain these observations includes (1) recharge of the shallow aquifers by canal seepage in the Gowen Road to Cole Road losing reach, (2) a contribution of percolating flood-irrigation water from fields that boarder the canal, and (3) flow of this mixture back toward the gaining reaches.

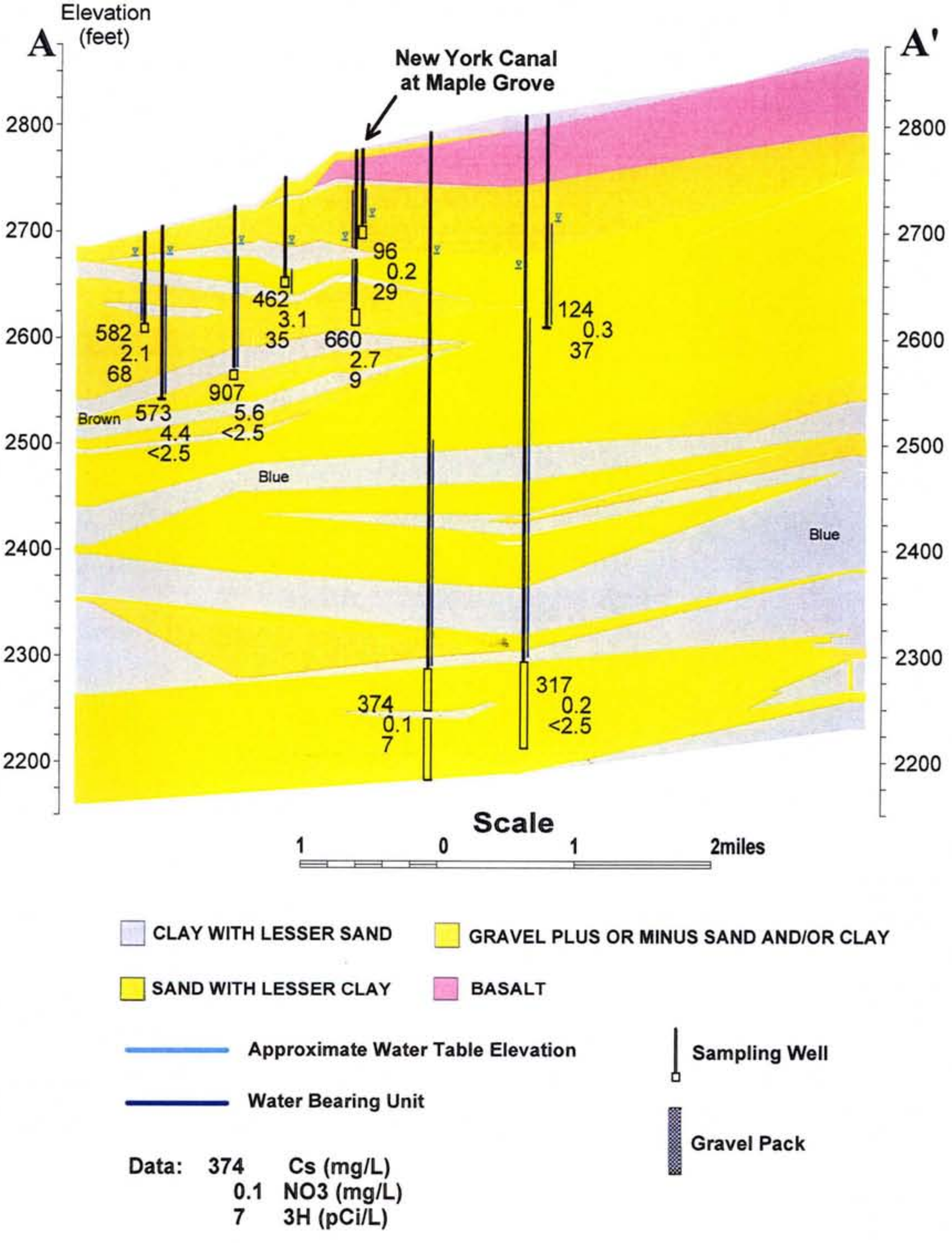

Figure 6. Ground water chemistry and aquifer stratigraphy near the NYC at Maple Grove Road. The geologic cross-section A-A' is shown in Figure 2. Names and locations of sampling wells are shown in Figure 1.

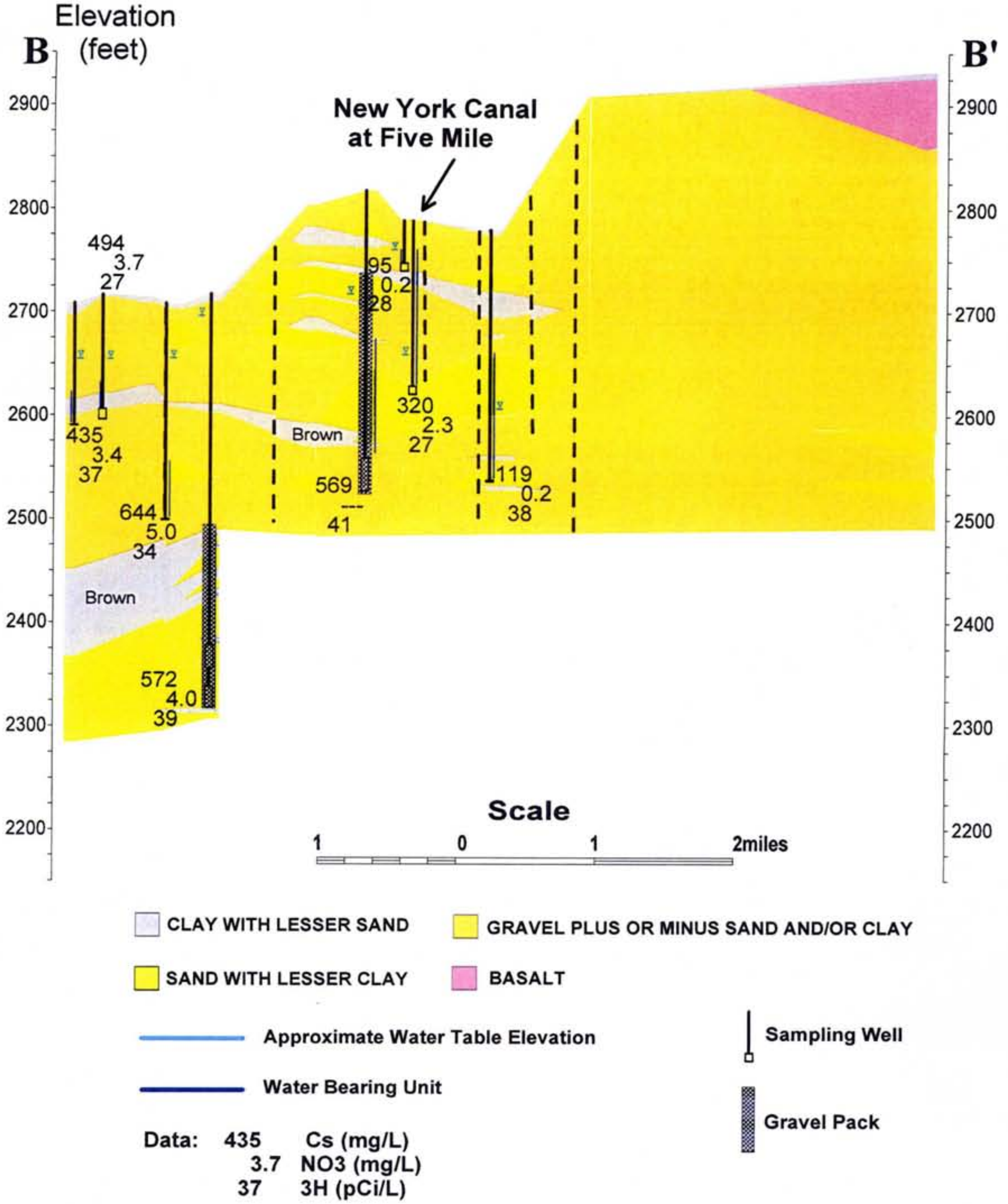

Figure 7. Ground water chemistry and aquifer stratigraphy near the NYC at Five Mile Road. The geologic cross-section B-B' is shown in Figure 2. Names and locations of sampling wells are shown in Figure 1

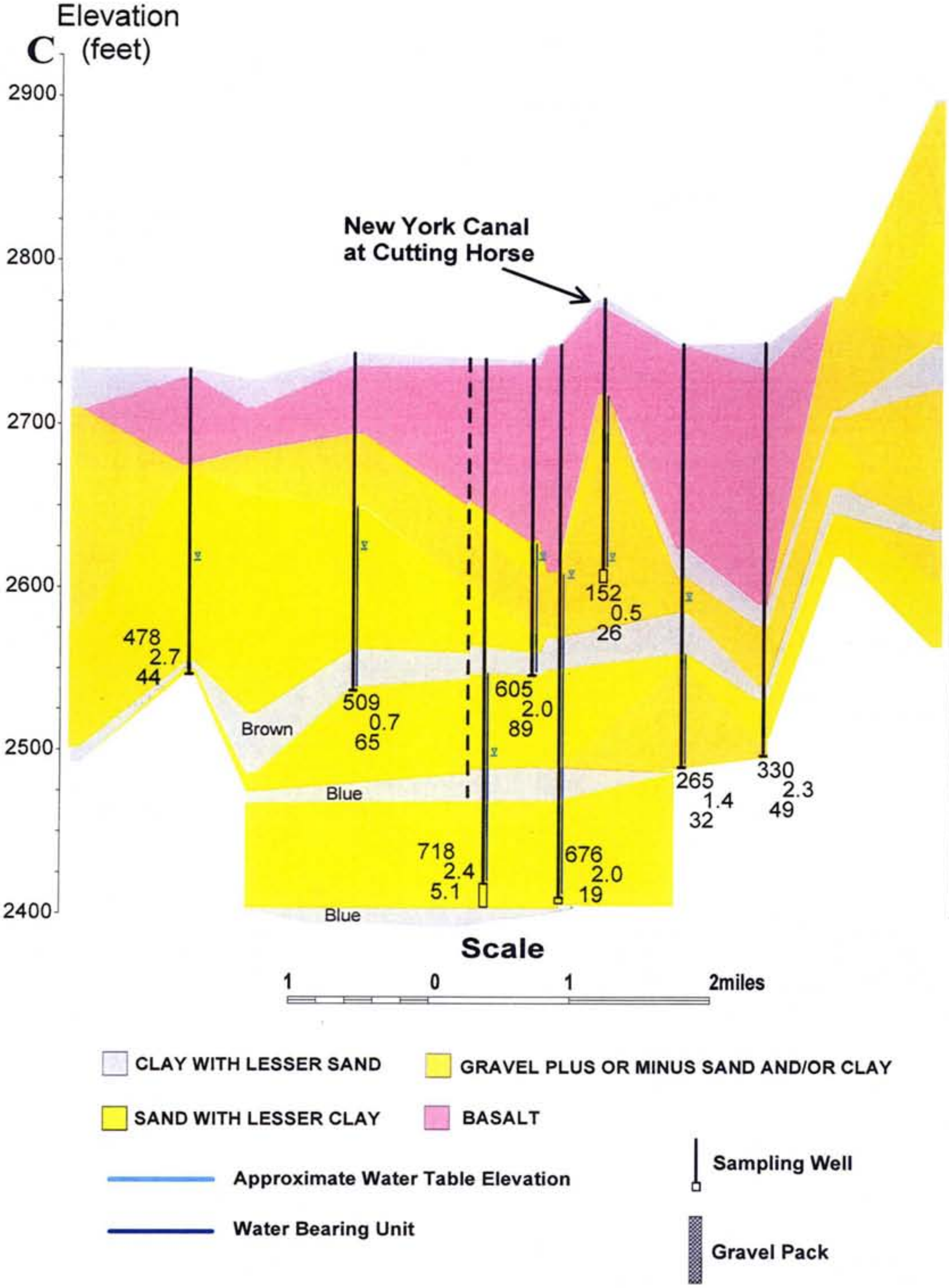

Figure 8. Ground water chemistry and aquifer stratigraphy near the NYC at Cutting Horse Road. The geologic cross-section C-C' is shown in Figure 2. Names and locations of sampling wells are shown in Figure 1.

Deeper aquifers west of the canal lie below the shallow clay beds. These waters exhibit a greater range of ^3H concentrations than is seen in the perched zones (Table 2). Ground water with ^3H concentrations greater than 50 pCi/L has received substantial contributions from recharge sources that originated during the 1960s (Clark and Fritz, 1997) (Table 1). Most waters below the 2,600-foot elevation in the Maple Grove cross-section are older than present recharge, with wells below the series of substantial clay layers at approximately 2,550 feet exhibiting ^3H below the detection limit of 2.5 pCi/L (Figure 7). Tritium concentration of less than 3 pCi/L is evidence of pre-1950s water (Clark and Fritz, 1997). Nitrate concentrations in these wells are between 2.1 and 5.6 mg/L, a range that likely reflects anthropogenic contributions via percolating surface water (Table 2, Figure 7). Elevated values of C_s and P_{CO_2} also implicate surface water percolation as a major contribution to ground water recharge. The combination of non-detectable ^3H and anthropogenic NO_3 constrains ground water residence times to between 50 and 90 years.

Similar distributions of geochemical indicators are seen in ground water aquifers between 2,500 and 2,600 feet in the Five Mile and Cutting Horse cross-sections (Figure 7 and Figure 8). One notable exception concerns ^3H in the Five Mile cross-section. Unlike the pattern of increasing then decreasing ^3H concentrations with depth observed in the Maple Grove and Cutting Horse sections, all wells west of the canal at Five Mile have ^3H concentrations between 27 and 41 pCi/L. This observation suggests that all waters contained in the stratigraphic aquifer zones are modern. Possible explanations for this apparent contradiction include (1) poor lateral continuity in horizontal clay zones, (2) faulting, and/or (3) poor well construction (i.e., extensive gravel packs or poor annulus seals). Each of these possibilities could allow vertical mixing of water between aquifer zones resulting in the observed distribution of ^3H concentrations. Nitrate concentrations between 3 and 5 mg/L and P_{CO_2} between $10^{-2.7}$ and $10^{-2.3}$ bar indicate that percolating surface water is the major source of recharge.

In contrast to aquifers west of the canal, ground water east of the canal in aquifers between 2,500 and 2,600 feet exhibit different characteristics. Most ground water samples east of the NYC exhibit ^3H values in the range of contemporary recharge, contain negligible NO_3, have conductivity similar to canal water, and exhibit P_{CO_2} values that reflect atmospheric equilibrium (Table 2, Figure 6, Figure 7, and Figure 8). This combination suggests that these aquifers do not receive major contributions from percolating irrigation water. Corroborating evidence is the fact that little or no irrigation occurs east of the canal where land surface elevations are greater than the canal elevation. We conclude from these observations that water in mid-level aquifers lying east of the canal are recharged solely by long-term seepage from the canal and that ground water mounding caused by canal seepage prevents mixing of waters west of the canal with those east of the canal.

Our analysis thus far has been confined to aquifers in the Snake River Group of sediments. To evaluate the relationship between ground water in the Snake River

Group and ground water in deeper aquifers we analyzed chemistry and isotope data from three United Water Idaho, Inc. (UWI) production wells. The Amity, Sunset West, and MAC wells penetrate a series of blue clay beds that lie between 2,300 and 2,400 feet (Figure 6). The data indicate that ground water below 2,300 feet is quite different from ground water in overlying aquifers. Specific conductance in the deeper aquifers is approximately one-half of the C_s measured in the overlying aquifers. Similarly, SO_4 is less than one-fourth and NO_3 is one-tenth of the corresponding values measured in the overlying aquifers. Tritium concentrations confirm that the water is sub-modern, while P_{CO_2} values suggest that these aquifers are recharged in a soil environment.

Movement of water from shallow aquifers into deeper, regional aquifers appears to be limited by clay aquitards. If the rate of leakage across these aquitards were substantial, then one would observe similar chemical analyses in aquifers above and below the clays. The abrupt decrease in C_s, SO_4, and NO_3 observed in the transition from the near-surface aquifers to the aquifers penetrated by the UWI productions wells suggests otherwise. It appears that the clay layers prevent downward movement of ground water despite a downward hydraulic gradient. This conclusion is supported by a 5,000- to 9,000-year range of ^{14}C age-dates in the Amity, Mac, and Sunset West wells (Hutchings and Petrich, 2001; Parliman and Spinazola, 1998). Superposition of contemporary ground water atop ground water of ancient origin, the existence of unique chemical characteristics, and the identification of a likely aquitard are convincing evidence that canal seepage and percolating irrigation water do not recharge the regional ground water system in the study area.

5 CONCLUSIONS

The purpose of this study was to provide constraints on the interaction between surface water and ground water near the NYC. Spatial distributions of key hydrochemical parameters were analyzed with respect to aquifer stratigraphy. Our investigation provided the following conclusions:

1 Losses from and gains to the NYC correlate strongly with local stratigraphy.

2 Aquifers contained in the first few hundred feet of alluvial sediment are recharged by canal seepage and by percolating irrigation water where they are overlain by flood-irrigated fields.

3 Ground water in these shallow alluvial aquifers was recharged during the past 50 years.

4 Distinct geochemical signatures can be used to differentiate between ground water in shallow, alluvial aquifers and ground water in deeper, regional aquifers.

5 Contemporary surface water is not a major source of recharge to deep, regional aquifers beneath the NYC.

6 REFERENCES

Berenbrock, C. 1999. Streamflow gains and losses in the Lower Boise River Basin, Idaho, 1996-97. U.S. Geological Survey Water-Resources Investigations Report 99-4105.

Burnham W.L. and S.H. Wood, 1992. Geologic map of the Boise South quadrangle, Ada County, Idaho. Idaho Geological Survey Technical Report Series. 28 p.

Carlson, R.A. and C.R. Petrich. 1999. New York Canal geologic cross-section, seepage gain/loss data, and ground water hydrographs: compilation and interim findings. Treasure Valley Hydrologic Project Open File Report. 6 p.

Clark, I. and P. Fritz. 1997. Environmental Isotopes in Hydrogeology. Lewis Publishers. New York. 328 p.

Higginson, R.K. 1981. Water and Power Resources Service Project Data. U.S. Government Printing Office. Denver. 1463 p.

Hutchings, J.J. and C.P. Petrich. 2001. Ground Water Recharge and Flow in the Regional Treasure Valley Aquifer System. Idaho Water Resources Research Institute Open File Report. 89 p.

Malde, H.E. 1991. Quaternary geology and structural history of Snake River plain, Idaho. in R.B. Morrison, ed., Quaternary non-glacial geology, conterminous United States. Boulder, Colorado, Geological Society of America. The Geology of North America K-2, p. 251-281.

Neely, K.W. and J.K. Crockett. 1998. Ground water quality characterization and initial trend analysis for the Treasure Valley Shallow and Deep Hydrologic Subareas. Idaho Department of Water Resources Water Information Bulletin No. 50, Part 3. 79 p.

Othberg, K.L. 1994. Geology and geomorphology of the Boise Valley and adjoining areas, Western Snake River Plain, Idaho. Idaho Geological Survey Bulletin 29. 54 p.

Othberg, K.L. and L.R. Stanford. 1992. Geologic map of the Boise Valley and adjoining area, Ada and Canyon Counties, Idaho: Idaho Geological Survey Technical Report 90-6, scale 1:24,000.

Parliman, D. J., and J. M. Spinazola. 1998. Ground-water quality in northern Ada County, Lower Boise River Basin, Idaho, 1985-96. U.S. Geol. Survey Fact Sheet FS-054-98.

Urban, S.M. and C.R. Petrich. 1998. 1996 water budget for the Treasure Valley aquifer system. Treasure Valley Hydrologic Project Research Report, Idaho Department of Water Resources, Boise, Idaho.

Warnick, C.C. and C.E. Brockway. 1974. A Case Study of Federal Expenditures on a Water and Related Land Resources Project: Boise Project, Idaho and Oregon. Idaho Water Resources Research Institute Open-File Report. 157 p.

APPENDIX A

Well Information and Water Sample Data

Glossary

DTW	depth to water
TWBZ	top of water-bearing zone
BWBZ	bottom of water-bearing zone

Well Name	LATd	LATm	LATs	LONd	LONm	LONs	T	R	Sec	Land Surf Elev ft	Total Depth ft	DTW ft	WL Elev ft	TWBZ ft	TWBZ Elev ft	BWBZ ft	BWBZ Elev ft
NYC_SW																	
7644 W. Stirrup	43	32	57	116	16	36	03N	01E	36DDB2	2800	200		2800	190	2610	200	2600
7644 W. Stirrup	43	32	57	116	16	36	03N	01E	36DDB2								
Sunset West	43	33	4	116	16	24	03N	01E	36DAD1	2810	620	120	2690	515	2295	603	2207
Amity	43	33	40	116	16	54	03N	01E	36ABB1	2798	675	120	2678	519	2279	670	2128
Maple Grove No. 3	43	33	50	116	17	26	03N	01E	25CCBA2	2780	207		2780	185	2595	207	2573
8821 Churchill	43	34	17	116	17	27	03N	01E	25BCB1	2751	117		2751	99	2652	110	2641
Maple Grove No. 1	43	33	53	116	17	27	03N	01E	25CCBA1	2780	100	68	2712	49	2731	115	2665
Maple Grove No. 2	43	33	52	116	17	28	03N	01E	25CCBA3	2780	98	72	2708	92	2688	98	2682
8911 W. Victory	43	34	32	116	17	32	03N	01E	25BBBB1	2730	170		2730	161	2569	166	2564
2380 S. Kimball	43	34	53	116	17	46	03N	01E	23DAB1	2715	173		2715	173	2542		
2380 S. Kimball	43	34	53	116	17	46	03N	01E	23DAB1								
9245 S. Malad	43	34	48	116	17	46	03N	01E	23DACD1	2718	96		2718	88	2630		
9200 S. Five Mile	43	31	7	116	18	45	02N	01E	11CCC1	2795	241		2795	239	2556	241	2554
9200 S. Five Mile	43	31	7	116	18	45	02N	01E	11CCC1								
Hidden Valley	43	32	0	116	18	49	02N	01E	03DDD1	2795	311		2795	140	2655		
Five Mile No. 2	43	31	39	116	18	52	02N	01E	10ADAA1	2790	78	29	2761	28	2762	56	2734
Five Mile No. 1	43	31	39	116	18	53	02N	01E	10ADAD1	2790	51	25	2765	38	2752	43	2747
Five Mile No. 3	43	31	42	116	18	56	02N	01E	10ADAC1	2790	177			158	2632	176	2614
Lagrange	43	33	9	116	19	24	03N	01E	34CAA1	2718	425			232	2486	415	2303
4283 Riva Ridge	43	33	51	116	19	31	03N	01E	27CDAB3	2717	121			110	2607	121	2596
11917 Highlander	43	33	24	116	19	44	03N	01E	34BCA1	2705	210			185	2520	210	2495
4620 Cloverdale	43	33	37	116	19	57	03N	01E	34BBB1	2715	120			103	2612	0	0
12175 Hubbard	43	31	2	116	19	58	02N	01E	15BBBB1	2770	335			319	2451	335	2435
Cutting Horse No. 2	43	29	36	116	20	35	02N	01E	21CAD1	2780	187			131	2649	187	2593
9299 S. Stewart	43	31	16	116	20	37	02N	01E	09CDDD1	2742	220			204	2538	0	0
Cutting Horse No. 1	43	29	40	116	20	43	02N	01E	21CAA1	2780	188			136	2644	188	2592
1270 S. Eagle	43	29	53	116	20	57	02N	01E	21BBDD1	2750	350			280	2470	330	2420
226 S. Eagle	43	29	9	116	21	10	02N	01E	28BBCB1	2770	263			198	2572	263	2507
1180 S. Eagle	43	28	31	116	21	10	02N	01E	28CCC1	2750	258			243	2507	258	2492
1495 N. Eagle	43	30	7	116	21	15	02N	01E	20AAAA1	2740	205			193	2547		
1715 E. Columbia	43	31	54	116	22	20	02N	01E	08BBB1	2740	188			185	2555		
2491 Beverly	43	34	51	116	16	6	03N	02E	19CBD1	2752	100	63	2690	100	2652		
2428 S. Liberty	43	34	45	116	15	36	03N	02E	19DBD1	2761	210	62	2699	165	2596		
2615 S. Liberty	43	34	41	116	15	39	03N	02E	19DCB1	2763	133	63	2700	127	2636		
2785 S. Liberty	43	34	38	116	15	40	03N	02E	19DCC1	2763	115	64	2699	110	2653		
2613 S. Liberty	43	34	42	116	15	38	03N	02E	19DCD1	2762	184	68	2694	178	2584		

Well Name	Sample Date	Pump Period min	Water Temp deg C	Field Cond uS/cm @ 25	Field pH	DO mg/L	Field Alk mg/L as CaCO3
NYC_SW	19991105		9	62	7.9	10.9	30
7644 W. Stirrup	19990429	35	12	124	8.1	8	48
7644 W. Stirrup	19990429						
Sunset West	19990421	20	20	317	7.8	1	120
Amity	19990421	>20	18	374	7.6	1	127
Maple Grove No. 3	19990412	30	15	660	7.6	5	93
8821 Churchill	19990315	37	13	462	8.0	8	203
Maple Grove No. 1	19990319	20	13	119	8.0	4	54
Maple Grove No. 2	19990319	30	12	96	8.0	4	42
8911 W. Victory	19990412	30	13	907	7.7	4	276
2380 S. Kimball	19990429	25	13	573	7.4	10	173
2380 S. Kimball	19990429						
9245 S. Malad	19990315	35	12	582	7.7	4	259
9200 S. Five Mile	19990412	25	11	121	8.3	5	48
9200 S. Five Mile	19990317	25	11	119	8.2	4	49
Hidden Valley	19990423	>20	14	569	7.7	7	221
Five Mile No. 2	19990319	30	12	95	7.4	6	41
Five Mile No. 1	19990319	25	7	83	7.3	6	37
Five Mile No. 3	19990414	85	12	320	7.6	5	85
Lagrange	19990423	>30	13	572	7.7	8	215
4283 Riva Ridge	19990317	>30	13	494	7.6	5	193
11917 Highlander	19990317	50	13	644	7.7	0	235
4620 Cloverdale	19990317	30	13	435	7.9	4	166
12175 Hubbard	19990316	20	15	718	7.8	5	208
Cutting Horse No. 2	19990414	25	14	175	7.5	5	69
9299 S. Stewart	19990316	15	14	509	7.8	7	245
Cutting Horse No. 1	19990414	20	13	152	7.5	5	63
1270 S. Eagle	19990517	>30	24	676	7.9	0	155
226 S. Eagle	19990316	25	12	265	7.8	3	113
1180 S. Eagle	19990318	27	15	330	8.2	4	130
1495 N. Eagle	19990316	25	13	605	7.8	3	235
1715 E. Columbia	19990316	30	12	478	7.8	5	176
2491 Beverly	19990622		14	1070	7.6		407
2428 S. Liberty	19990622		15	748	7.1		204
2615 S. Liberty	19990623		13	540	7.3		254
2785 S. Liberty	19990623		13	435	7.4		228
2613 S. Liberty	19990622		14	466	7.2		163

Well Name	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	HCO3 mg/L	Cl mg/L	SO4 mg/L	F mg/L	SiO2 mg/L	NO3-N mg/L	Fe ug/L	Mn ug/L	TDS mg/L	Hardness mg/L as CaCO3	d3H PiC/L
NYC_SW	7.7	0.95	3.3	0.64	38	0.39	1.5	0.23	15	0.128	14	4.9	75		28
7644 W. Stirrup	5.8	1.6	20	0.52	58	1.9	11	1	24	0.272	8.3	3	96	21	37
7644 W. Stirrup	5.8	1.6	20	0.52	58	2.8	11	1	24	0.259	6.2	3.3	97	21	34
Sunset West	27	5.7	33	1.3	150	8.5	24	0.38	32	0.182	10	3	204	91	2.5
Amity	33	8.9	32	1.4	160	9.7	44	0.53	31	0.104	5.5	13	237	120	7
Maple Grove No. 3	59	13	57	1.6	110	27	170	0.91	20	2.69	10	3	416	200	9
8821 Churchill	45	15	34	0.97	250	3	26	0.85	45	3.06	10	3	305	170	35
Maple Grove No. 1	15	3.5	4.1	0.73	66	0.5	2.3	0.35	30	0.232	10	17	91	53	29
Maple Grove No. 2	10	3.4	4.1	0.57	51	0.34	1.6	0.31	22	0.171	10	3	68	39	29
8911 W. Victory	92	23	79	2.5	340	32	120	0.41	25	5.55	10	23	568	320	2.5
2380 S. Kimball	55	14	42	4.1	210	28	64	0.33	39	4.4	17	7	370	200	2.5
2380 S. Kimball	54	14	41	2.4	210	29	64	0.33	39	4.52	16	5.6	368	190	2.5
9245 S. Malad	44	15	65	2.4	320	6.5	33	0.5	34	2.14	120	2.1	366	170	68
9200 S. Five Mile					58					0.187					
9200 S. Five Mile	7.8	1.1	17	0.42	60	2.4	6.1	0.61	18	0.201	110	19	84	24	38
Hidden Valley	41	7	75	1.4	270	9.1	44	0.39	38		10	3	349	130	41
Five Mile No. 2	12	1.6	3.8	0.66	50	0.73	2.4	0.27	18	0.241	10	3	65	37	28
Five Mile No. 1	11	1.4	3	0.54	45	0.66	2.2	0.18	13	0.148	5	3	55	33	33
Five Mile No. 3	28	7.1	29	0.61	100	12	40	0.57	20	2.27	10	3	197	99	27
Lagrange	41	6.9	71	1.5	260	9	44	0.38	37	3.96	10	3	358	130	39
4283 Riva Ridge	52	15	33	1	240	7.4	22	1	48	3.71	10	3	311	190	27
11917 Highlander	62	15	60	1.5	290	18	44	0.66	44	5.03	8.6	3	407	210	34
4620 Cloverdale	34	8.6	49	1.6	200	8.3	26	1	34	3.4	10	3	278	120	37
12175 Hubbard	85	7.8	60	2	250	30	110	0.19	30	2.35	43	3	458	240	5.1
Cutting Horse No. 2	14	7.1	10	1.3	84	2.5	9.8	0.44	26	0.695	7.5	1.9	116	65	27
9299 S. Stewart	63	14	31	1.8	300	3.2	21	0.4	25	0.676	10	3	309	210	65
Cutting Horse No. 1	13	6.9	7.5	1.2	77	2.1	6.8	0.42	25	0.513	10	3	103	60	16
1270 S. Eagle	30	0.89	122	0.79	190	30	140	0.69	27	0.05	78	39	446	79	19
226 S. Eagle	25	12	10	1.8	140	2.3	13	0.56	36	1.4	52	35	175	110	32
1180 S. Eagle	29	10	25	3.4	160	4.2	21	0.24	40	2.27	5.6	3	220	120	49
1495 N. Eagle	52	9.4	69	1.9	290	11	54	0.5	27	1.95	10	1.9	374	170	89
1715 E. Columbia	35	11	54	1.6	150	9.1	65	0.75	33	2.71	8.1	3	294	130	44
2491 Beverly					496	32				4.5					93
2428 S. Liberty					249	23				0.63					14
2615 S. Liberty					310	11				2.7					77
2785 S. Liberty					278	2.6				1.2					56
2613 S. Liberty					199	13				0.5					26

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