Response to memorandum by Rowley and Dixon regarding U.S. Geological Survey report titled "Characterization of Surface-Water Resources in the Great Basin National Park Area and Their Susceptibility to Ground-Water Withdrawals in Adjacent Valleys, White Pine County, Nevada"

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U.S. Geological Survey, Carson City, Nevada: 2006

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Abstract

Applications pending for permanent permits to pump large quantities of ground water in Spring and Snake Valleys adjacent to Great Basin National Park (the Park) prompted the National Park Service to request a study by the U.S. Geological Survey to evaluate the susceptibility of the Park's surface-water resources to pumping. The result of this study was published as U.S. Geological Survey Scientific Investigations Report 2006-5099 "Characterization of Surface-Water Resources in the Great Basin National Park Area and Their Susceptibility to Ground-Water Withdrawals in Adjacent Valleys, White Pine County, Nevada," by P.E. Elliott, D.A. Beck, and D.E. Prudic. That report identified areas within the Park where surface-water resources are susceptible to ground-water pumping; results from the study showed that three streams and several springs near the eastern edge of the Park were susceptible. However, most of the Park's surface-water resources likely would not be affected by pumping because of either low-permeability rocks or because ground water is sufficiently deep as to not be directly in contact with the streambeds.

A memorandum sent by Peter D. Rowley and Gary L. Dixon, Consulting Geologists, to the Southern Nevada Water Authority (SNWA) on June 29, 2006 was critical of the report. The memorandum by Rowley and Dixon was made available to the National Park Service, the U.S. Geological Survey, and the public during the Nevada State Engineer's "Evidentiary Exchange" process for the recent hearing on applications for ground-water permits by SNWA in Spring Valley adjacent to Great Basin National Park. The U.S. Geological Survey was asked by the National Park Service to assess the validity of the concerns and comments contained in the Rowley and Dixon memorandum.

An Administrative Letter Report responding to Rowley and Dixon's concerns and comments was released to the National Park Service on October 30, 2006. The National Park Service subsequently requested that the contents with three minor changes to the Administrative Letter Report be released to the public. The first paragraph was revised to better explain how the memorandum was brought to the attention of the National Park Service and the U.S. Geological Survey and the purpose of the Administrative Letter Report. The second and third changes were minor word changes to the end of the first sentence at the top of page 11 and in the Summary statement, respectively. The Administrative Letter Report with these minor changes is reproduced herein.

Lastly, the National Park Service asked me to explain the difference between potentially and likely susceptible areas used in the report. Admittedly, the report did not clearly explain their usage. Potentially susceptible areas were used in the report to identify areas where (1) ground water interacts with water in the creeks but the connection between permeable rocks in the mountains with the basin fill is uncertain or where (2) ground-water interaction with water in the creeks is less certain but permeable rocks are connected with basin fill. Likely susceptible areas were used to identify areas in the mountains and valleys where ground-water interacts with water in the creeks or discharges as springs and permeable rocks are connected with basin fill. Likely susceptible areas are, therefore, more vulnerable to ground-water pumping.

United States
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October 30, 2006

Mr. Charles W. Pettee, Chief
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Fort Collins, CO 80525

Subject: Administrative Letter Report –Response to memorandum by Rowley and Dixon regarding U.S. Geological Survey report titled "Characterization of Surface-Water Resources in the Great Basin National Park Area and Their Susceptibility to Ground-Water Withdrawals in Adjacent Valleys, White Pine County, Nevada"

Dear Mr. Pettee:

This letter is my response to your request to assess comments contained in a memorandum sent by Peter D. Rowley and Gary L. Dixon, Consulting Geologists, to the Southern Nevada Water Authority (SNWA) on June 29, 2006 that was critical of a recent report we did for the National Park Service titled "Characterization of Surface-Water Resources in the Great Basin National Park Area and Their Susceptibility to Ground-Water Withdrawals in Adjacent Valleys, White Pine County, Nevada," by P.E. Elliott, D.A. Beck, and D.E. Prudic and published as U.S. Geological Survey Scientific Investigations Report 2006-5099." The memorandum by Rowley and Dixon was made available to the National Park Service, the U.S. Geological Survey, and the public during the Nevada State Engineer's "Evidentiary Exchange" process for the recent hearing on applications for ground-water permits by SNWA in Spring Valley adjacent to Great Basin National Park.

Before I begin my response, I would like to summarize the purpose and objectives of the study that led to the report. Applications pending for permanent permits to pump large quantities of ground water in Spring and Snake Valleys adjacent to Great Basin National Park (referred hereafter as the Park) prompted the National Park Service to request a study to evaluate the susceptibility of the Park's surface-water resources to pumping. Susceptible areas are defined as areas where ground water interacts with water in the creeks and where underlying rocks and deposits are sufficiently permeable to provide a connection with basin-fill deposits in the valley. The objectives were to assess the surface-water resources and to identify areas susceptible to ground-water pumping. Thus, the study was a simple vulnerability analysis.

The approach we took for the study was to install streamflow gages on the principal creeks draining the Park and on a spring at the Park's boundary near Lehman Caves. We classified the different groups of rocks and deposits into general categories on the basis of their permeability. Discharge along the creeks was measured at sites corresponding to changes in geology. Results from the study showed that most of the Park's surface-water resources likely would not be affected by ground-water pumping because of either low-permeability rocks (granite and quartzite) or because ground water is sufficiently deep as to not be directly in contact with the streambeds. The latter is the case for much of the southern end of the Park.

Rowley and Dixon listed four concerns regarding the report, which are:

1. "Its fundamental premise that data from seepage tests or stream gages can be used to pinpoint streams that might dry up from well pumping of groundwater miles away and hundreds of feet lower";

2. "Methodology problems that make some conclusions doubtful";

3. "Inaccurate application of geology"; and

4. "Poor writing that hinders understanding of the report".

My response to each concern is discussed sequentially in the following paragraphs.

Response to Rowley and Dixon's first concern " its fundamental premise that data from seepage tests or stream gages can be used to pinpoint streams that might dry up from well pumping of groundwater miles away and hundreds of feet lower":

A standard approach for evaluating stream interaction with ground water is the measurement of gains and losses along a stream using seepage tests and streamflow gages. Many studies that used measurements of gains and losses from seepage tests and streamflow gages are listed at the end of the letter. The references are but a few examples of such studies. Besides numerous studies that used seepage tests and streamflow gages to evaluate ground-water interactions with streams, a large body of literature has been written on stream depletion caused by ground-water pumping. Many of these studies also are listed in the references.

The work on stream depletion caused by ground-water pumping began with a famous publication by C.V. Theis (1940). Theis noted in this paper that the cone of depression around a well (or group of wells) will expand until the volume removed by pumping is replenished by an equal volume of increased ground-water recharge, decreased natural discharge, or a combination of both. Theis also noted that the cone of depression could extend miles from pumping wells; studies in areas of concentrated pumping confirm his statement.

We know from the ground-water flow equations for confined and unconfined flow (Fetter, 1994, p. 141–152) that a cone of depression can expand quickly for many miles soon after the well is pumped when the rocks are permeable and have minimal storage capacity. Similarly, a cone of depression will expand much slower when rocks are less permeable and have a high storage capacity. Consequently, the cone of depression from pumping in either Spring Valley or Snake Valley could extend up into the southern Snake Range and is dependent on the quantity and location of the pumping, the permeability and storage capacity of the various rocks and deposits, and areas of ground-water discharge or recharge that can be captured. Thus, Rowley and Dixon's contention that "it is a real stretch of the imagination to conceive of a cone of depression reaching miles and hundreds of feet up the flank of the Snake Range to where any stream within Great Basin Park exists" can only be correct if pumping in the adjacent valleys is less than what can be captured from evapotranspiration and the rocks in the mountains are impermeable, which means ground-water recharge in the mountains would be nil.

Four examples are used to illustrate why Rowley and Dixon's statement is incorrect. First, pumping from many wells for irrigation in Pahrump Valley in southern Nevada resulted in the demise of both Bennett and Manse Springs (Harrill, 1986, p. 22), and a recent reduction in ground-water pumping has resulted in the reemergence of flow at Manse Spring. Second, ground-water pumping from numerous wells has lowered the ground-water head over a large region south of Sacramento, California, and caused the Cosumnes River to become intermittent during fall salmon runs (Fleckenstein and others, 2004, Journal of Water Resources Planning and Management, v. 130, no. 4, p. 301–310). Third, cumulative pumping in the Arkansas River Valley in Colorado, including wells many miles from the river, lowered ground-water head and resulted in a marked decrease in streamflow of the Arkansas River in Kansas (Sophocleous, 2000, p. 27–43).

Fourth, pumping at the Lone Tree mine near Valmy, Nevada that commenced in 1992 resulted in a water-level decline of about 20 feet in 8 years at a monitoring well (well MIL2001-1) on Battle Mountain (the mountain, not the town) 10 miles south and 1,000 feet higher in elevation (Bureau of Land Management, 2003, p. 3–32). The well is in low-permeability rocks (Valmy Formation), and the mine and well are separated by several faults. Declines of more than 50 feet were observed at wells near Marigold mine and a couple of miles closer to Lone Tree mine. The observed declines occurred even though the Humboldt River and its flood plain are less than 3 miles to the north of Lone Tree mine (Prudic and others, 2003). Ground-water declines at Marigold mine are of particular interest because seldom do hydrologists have streamflow and ground-water data in the mountains to evaluate effects caused by ground-water pumping in adjacent valleys.

Rowley and Dixon failed to recognize when they stated “Seepage tests are valuable in water-rights adjudication, to define streamflow availability, and to assess and manage water resources” that streamflow depletion from ground-water pumping is a growing problem for water managers throughout the United States. The problem is highlighted by a recent court decision that awarded damages for the depletion of streamflow from ground-water pumping in the Arkansas River Valley of Colorado to the State of Kansas (Littleworth, 2003).

Response to Rowley and Dixon’s second concern “methodology problems that make some conclusions doubtful”:

Rowley and Dixon state that “seepage tests require error analysis so that the reader can be convinced that an apparent gain or loss in a reach exceeds the error associated with the measurement of that value.” A measure of error was provided for each set of synoptic discharges and is indicated in the headnote of table 4, pages 19–22 of the report. The terms “good, fair and poor” are not relative as implied by Rowley and Dixon. These terms are specifically defined related to standard USGS data collection protocols for stream discharge measurements. The term “good” refers to a measurement error that is less than 5 percent of the discharge, “fair” is between 5 and 8 percent, and “poor” is greater than 8 percent (Sauer and Myer, 1992). The percent range in measurement errors of the synoptic discharges also are stated on page 18 of the report, in addition to the statement of good, fair, and poor referenced by Rowley and Dixon in their memorandum.

Rowley and Dixon continue by stating “Nonetheless, the authors present many conclusions about losing or gaining reaches even though (a) the numbers from the lower measurement site are only slightly different from the upper site, (b) gains or losses made during a second seepage test contradict the first test, or (c) the so-called gains or losses do not make common sense based on the geology.” Darcy’s law (Fetter, 1994, p. 94–95) tells us that the exchange of water across the streambed is dependent on (1) the permeability of the streambed and underlying rocks and deposits, and (2) the head gradient between the stream and ground water, which is the head difference divided by the length from top of streambed to a particular point in the subsurface that corresponds to the ground-water head. No gain or loss can be attributed to an impermeable streambed or a zero head difference. Because streamflow measurements in our study are some distance apart, the lack of a gain or loss simply means that the sum of gains and losses along the streambed result in no net gain even though ground water is interacting with water in a creek, which is why we also measured specific conductance of the water. Although Rowley and Dixon were critical of specific conductance, specific conductance proved valuable in assessing ground-water interactions with the creeks. Additionally, the high-gradient creeks in and near the Park have sand and gravel beds that are permeable, thus places along the creeks with no net gain or loss between sites were indicative of ground-water heads that are close to the water level in the creek.

Rowley and Dixon apparently do not comprehend the reasoning behind the two sets of synoptic streamflow measurements; otherwise, there is no basis for them noting a contradiction in gains and loses between the first set of measurements during snowmelt runoff and the second set during low flow. The intent of making stream discharge measurements at spring snowmelt and then at low flow was to evaluate the effects of different stream discharges and ground-water conditions on gains and losses (described on page 3 of the report). Differences in head between a stream and ground water are what drive variations in gains and losses along a stream and these differences are known to change daily and seasonally. Gains and losses during spring snowmelt will almost certainly be different than the gains and losses during low flow. A stream that changes from gaining during snowmelt to losing during low flow or vice versa is an indication that ground water is in direct communication with the stream. Contrastingly, a stream, no matter its discharge, that consistently loses at nearly the same rate between measurement sites is a good indication that ground water is below the streambed and stream loss is not dependent on ground-water head but only on gravity drainage across the streambed (Niswonger and others, 2005, fig. 8).

Rowley and Dixon's statement that "the so-called gains or losses do not make common sense based on the geology" further illustrates their lack of understanding the basic principles of ground-water flow and interactions with streams. The gains and losses are not necessarily correlated to geology because they also are dependent on ground-water head. A good example of the relation between gains and losses and geology described in the report is Lehman Creek. A marked gain in discharge in Lehman Creek occurs in the vicinity where the Pole Canyon Limestone becomes capped by a less permeable rock (consolidated or cemented rock encountered at a depth of 104 feet in a test well ¼-mile downstream of Rowland Spring). Subsurface flow upslope of the capped limestone exceeds the capacity of the aquifer below the confining unit and causes ground-water heads to increase vertically and consequently, water to discharge at Rowland Spring and numerous seeps adjacent to Lehman Creek. This is akin to stormwater in a gutter that exceeds the capacity of a storm drain. Water in excess of the drain's capacity will simply continue flowing down the street. Two other good examples where gains and losses are related to geology and interactions with ground water are Snake Creek and South Fork Big Wash. Considerable detail was provided in the report (pages 36–43) to explain the rather complex gains and losses along these creeks and how they relate to geologic and ground-water conditions.

Response to Rowley and Dixon's third concern "inaccurate application of geology":

The comments regarding our application of the geology are unfounded and the criticisms are not substantiated by references to published material. Rowley and Dixon comment in several places on the antiquity of our published map sources; for instance, in stating "the geologic map was compiled from a 30-year-old reconnaissance map…" and made numerous references to "modern mapping" without stating a specific published source. The map of White Pine County (Hose and Blake, 1976) was used as a geologic base for the figures because the map was readily available in digital form and thus served as a convenient base layer for the figures. The text and references therein make it clear that we are aware of the wealth of recent studies of the Snake Range by Elizabeth Miller and her students at Stanford University. We also used unpublished USGS geophysical data to corroborate our field analysis. Although the modern mapping of Miller and colleagues has dramatically reinterpreted the nature and significance of faults in the Snake Range, the rock units, their descriptions, and locations have not changed appreciably since they were first described. We categorized the units broadly into rocks or deposits that were permeable and not permeable because that was our interest.

Rowley and Dixon express concerns about out treatment of the Cenozoic section stating, "the Tertiary rocks (Tr) unit consists of Tertiary basin-fill units that should be lumped with the QTs unit, and a Tertiary volcanic unit should have been mapped, even though it should appear only in cross sections." We agree that basin-filling rocks of Miocene and Pliocene (Tertiary) and younger age (Quaternary) may have a wide range of hydraulic properties and a number of ways could be imagined by which to subdivide them. Our intent in using the Tertiary rock unit was to capture the geologic relations shown so clearly at Big Wash and at Sacramento Pass where a tilted Miocene-aged section of relatively consolidated conglomerate is unconformably overlain by less consolidated alluvial fill. We agree that additional complexity could be present within the buried basin fill in Snake Valley, but unraveling the complexity of the basin fill was not part of or directly relevant to the study. Instead, we wanted to capture this first-order hydrogeologic distinction.

We considered the Tertiary rocks to be mostly permeable except for rocks and deposits that were well consolidated or cemented. We chose not to divide the Tertiary rocks and deposits because we were uncomfortable in drawing units on our cross sections where we think they may exist but have no real evidence. We recognized in our report that our Tertiary unit includes volcanic rocks. We concluded that given the subdued magnetic character of the valley fill in southern Snake Valley and the generally Oligocene age of many of the ash-flow tuffs, the Tertiary volcanic rocks would likely occur deep within the basin fill and not play a major role in the shallow subsurface shown on our geologic profiles along selected creeks.

Rowley and Dixon state that "the cross sections that show the geology are not the work of a professional geologist: in most places they are simplistic….in other places the sections are absurd." Rowley and Dixon certainly must realize the necessity to generalize complex geology for the purposes of hydrologic analysis. Second, Donald Sweetkind (U.S. Geological Survey, Geologic Discipline, Denver, Colorado) provided guidance in our development of the classification, geologic map, and geologic profiles along the selected creeks and reviewed the report. He also spent several days with us walking each selected creek where we discussed the profiles. The profiles are not geologic cross sections because they follow the creek and not a straight line. The sections are distorted in this regard because the length of the stream course is longer than a line on a map.

Rowley and Dixon assert that "high-angle faults….are not shown on the maps used in this study" and generally contend that we have ignored the presence and significance of high-angle faults. Rowley and Dixon are correct that we do not show high-angle faults on the geologic map compilation. We made a decision, for the sake of clarity, to omit the numerous faults in map view. Nonetheless, we have clearly shown several faults on our geologic profiles along Strawberry Creek, Snake Creek, and Big Wash. We included the low-angle detachment fault (décollement) on our geologic map because it was important for the interpretation of gains and losses and provides a reason why a water-diversion pipeline was placed along a mountain section of Snake Creek downstream of the granite outcrop. It was also important in explaining the lack of surface water in the North Fork Big Wash drainage in comparison with the many localized springs and areas of streamflow caused by the highly-faulted upper-plate rocks that outcrop over most of the South Fork Big Wash drainage.

Rowley and Dixon incorrectly state that “No range-front faults that are the cause for the uplift of the Snake Range are shown in the cross sections.” Detailed mapping in the Snake Range and fission-track dating studies by Elizabeth Miller (Stanford University) and colleagues have shown that uplift of the Snake Range is primarily the result of movement along the Snake Range detachment fault system. As such, our geologic profiles subscribe to the conceptual model of Miller and her student, Allen McGrew, which conclude that in many places the Snake Range detachment itself represents the range-bounding fault. This is essentially the geometry portrayed in our geologic profiles along Snake Creek and Big Wash. Similarly, our geologic profile along Strawberry Creek at the north end of the Park portrays a range-bounding fault separating the synorogenic rocks of the Sacramento Pass section from the bedrock in the uplands.

Range-bounding faults that are approximately perpendicular to the general flow of water from the mountains to the valleys are most important to ground-water flow when they abut low-permeability rocks against high-permeability rocks. Range-bounding faults typically result in a rapid thickening of basin fill on the valley side of the fault and often produce a drop in ground-water head. This drop in head is the result of an increase in transmissivity caused by a greater thickness of the more permeable basin fill compared with less permeable consolidated rocks on the upslope side of the fault. A drop in head will not occur across the fault when the consolidated rocks are more permeable than the basin fill. Thus, the lack of surface water in the southern part of the Park is because the permeability of the limestone rocks in the mountains exceeds that of the basin fill, which results in springs discharging along the edge of the valley floor where there is a marked decrease in permeability of the basin fill. Only the springs and creeks on the valley floor were mapped as being susceptible in this area because ground water is well below intermittent creeks in the mountains.

The relative abundance of surface water in the northern part of the Park is because consolidated rocks in the highest altitudes have a much lower permeability than the predominately limestone rocks to the south. Creeks that form in these areas flow to the adjacent valleys; each creek on its path to the valley encounters a variety of consolidated rocks and deposits, some permeable and some not. Only a small percentage of the northern part of the Park was determined susceptible because most of the region is underlain by consolidated rocks of low permeability. The small percentage that was mapped as being susceptible were places where ground water interacted with creeks that crossed permeable consolidated rocks and basin fill that abutted with the basin fill in the valley. Thus, the inference made by Rowley and Dixon that the range-front faults will limit the extent of ground-water head declines to the valleys is incorrect because it ignores areas where permeable consolidated rocks in the mountains abut permeable basin fill in the valleys.

Rowley and Dixon’s statement “In fact, the authors in places (p. 30, 32, 35, 36) make conclusions that these faults could not be crossed by the streams because they recognize no abrupt changes to a losing stream in the basin-fill deposits” is distorted. Our statements refer to profiles along creeks where we made measurements. We think any faults that increase the thickness of basin fill beneath Shingle Creek (page 30) occur near the beginning of the water-diversion pipeline. We think the same occurs near the beginning of the concrete aqueduct from combined Lehman and Baker Creeks (pages 32, 35, and 36). The pipelines and aqueducts are expensive to install and maintain and their presence indicates that streamflow losses increase somewhere near their beginning.

Finally, Rowley and Dixon state "Based on our geologic mapping and on geophysical profiles, we and some of the modern mappers showed faults that cross all profiles" then called into question our repeated measurements of streamflow; their assertion is incorrect. They apparently assume the faults always abut low-permeability consolidated rocks with high-permeability basin fill and that the mapping of faults is without error or uncertainty. The recent test well drilled ¼-mile downstream of Rowland Spring in the Lehman Creek drainage encountered the geology that we had indicated in our geologic profile. That profile, confirmed by the test hole, indicates no fault with vertical displacement between Lehman Caves and at least ¼-mile downstream of Rowland Spring. A fault with vertical displacement likely exists further downstream where the concrete aqueduct begins but, it would abut saturated and permeable Pole Canyon Limestone against saturated and permeable basin-fill deposits providing a continuous ground-water connection among Lehman and Baker Cave systems, Rowland Spring, and the basin fill.

Response to Rowley and Dixon's fourth concern "poor writing that hinders understanding of the report":

This concern is a matter of opinion; the report went through several technical reviews and one editorial review prior to publication.

Summary:

Peter Rowley and Gary Dixon's concerns and criticisms described in their memorandum to the Southern Nevada Water Authority are without merit. Their comments show that they do not understand basic principles of ground-water flow. Depletion of streamflow and springs caused by ground-water pumping has been documented in many parts of the country, including places in Nevada. The study for the Park was a simple vulnerability analysis of the surface-water resources. Its purpose was to identify areas in and near the Park that are susceptible to ground-water pumping. Susceptible areas in and near the Park are where ground water interacts with water in the creeks and where underlying rocks and deposits are sufficiently permeable to provide a connection with basin-fill deposits in the valley. Results from the study indicate that surface-water resources in most of the Park are not susceptible to ground-water pumping in the adjacent valleys. However, we identified a few areas within and near the Park's boundaries that are susceptible (potentially or likely); these areas warrant additional monitoring and study. The results presented in the report would have been the same no matter what government agency requested the study.

Sincerely,

David E. Prudic
Hydrologist

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