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JUN 26 1997 Stoker 1993 56021

BEFORE THE NEW MEXICO WATER QUALITY CONTROL COMMISSION

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| IN RE: CONDITIONAL CERTIFICATION OF DRAFT NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) PERMIT NO. NM0028355 | ) |
| THE REGENTS OF THE UNIVERSITY OF CALIFORNIA and the UNITED STATES DEPARTMENT OF ENERGY, | ) |
| Petitioners. | ) |

DIRECT TESTIMONY OF
ALAN K. STOKER
ON BEHALF OF PETITIONERS
MARCH 31, 1993

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Q. PLEASE STATE YOUR NAME, POSITION AND BUSINESS ADDRESS.

A. My name is Alan Keith Stoker and I am employed by the University of California, Los Alamos National Laboratory (LANL). I am a Staff Member on the Hydrology Team of the Environmental Health Physics and Hydrology Section of the Environmental Protection Group (EM-8), which is part of the Environmental Management Division under the Associate Director for Operations. My business address is Mail Stop K 490, Los Alamos National Laboratory, Los Alamos NM, 87545

Q. WHAT IS YOUR EDUCATIONAL AND PROFESSIONAL BACKGROUND?

A. My Academic training includes the following Academic Degrees:

B.S. Physics, 1965, Occidental College,
M.S., Environmental Engineering, 1972, Stanford University, and
Engineer Degree, Environmental Engineering, 1975, Stanford University.

Other Graduate Work was completed at the University of Southern California and the University of California at Los Angeles. Various short courses include numerous professional training classes and seminars in areas including vadose zone hydrology, vadose zone monitoring, drilling technology, quantitative risk analysis, RCRA

requirements, project planning and management methodologies, team development, technical presentations, mainframe and PC computer applications, and Quality Assurance requirements and procedures.

My Professional Certification includes:

California State Board of Registration for Professional Engineers, EIT Certificate #35477 (Engineer in Training) 1974.

California State Community College Lifetime Certificate valid in several fields including Environmental Studies, Physics, and Mathematics, 1974.

Q. PLEASE SUMMARIZE YOUR RELEVANT EXPERIENCE WHICH QUALIFIES YOU TO SUBMIT TESTIMONY IN THIS CASE.

A. My professional background includes about 20 years in hydrogeology and environmental engineering, almost 19 of which have been at Los Alamos. From 1974 to the present I have been in what is now known as the Environmental Protection Group (EM-8). I now work as a technical staff member in environmental monitoring in technical field of hydrology. During my tenure in the group I spent seven years as deputy group leader. I have authored numerous publications, several with particular emphasis on

hydrogeology. Additional detail on my specific experience at Los Alamos is contained in EXHIBIT STOKER-1.

Prior to joining the Laboratory I was a Research Engineer at Stanford Research Institute, June 1973 to June 1974. I carried out water quality, wastewater treatment, and water resources development studies.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY

A. I will present the basis for understanding the hydrogeologic system in the Los Alamos environs. Hydrogeology deals with both surface and subsurface waters and their interactions with each other and geologic conditions. I will define the types of streams occurring in the area, describe the relationships between surface water and the various types of groundwater, and explain the major pathways by which discharges can be moved in the natural hydrologic system.

My testimony will demonstrate seven major conclusions. Expanded discussions of and evidence for each conclusion are provided in exhibits attached to this testimony. The major conclusions are:

1) The Los Alamos region is one of the most extensively studied and documented areas in New Mexico with regard to

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its hydrogeologic characteristics. Numerous published documents and articles document investigations during the last 50 years.

2) The vast majority of stream reaches within the Laboratory boundary are ephemeral, including all the locations into which NPDES regulated effluents are discharged. These ephemeral stream reaches produce little or no flow to the Rio Grande. Numerous documented professional observations of the nature of the streams date back to 1943 when the U. S. Army Corps of Engineers undertook a series of studies to develop a reliable water supply for Los Alamos.

3) The few perennial reaches of streams within the Los Alamos National Laboratory lands are not receiving waters for NPDES regulated effluents.

4) The stream-connected alluvial perched groundwaters in the bottoms of the canyons on the Pajarito Plateau are not continuous to the Rio Grande, and are not the source of the springs in White Rock Canyon.

5) The springs in White Rock Canyon of the Rio Grande are fed from the deep, regional main aquifer of the Los Alamos area. Several of these springs are responsible for the natural flow into the Rio Grande from three of the canyons.

6) The deep groundwater in the main aquifer of the Los Alamos environs has not been, and is not likely to be

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affected by infiltration of water from the surface of th· Pajarito Plateau.

7) There are no regular flows that extend from the Laboratory areas where NPDES-regulated effluents are released all the way to the Rio Grande arising from either natural flows, effluents, or other man-made releases. There are only two circumstances during which flow extends from the laboratory areas receiving NPDES discharges all the way to the Rio Grande:

> The first is during heavy snowmelt seasons when flow may extend all the way across the laboratory and on to the Rio Grande for periods of a few days to a few weeks in a few canyons.
>
> The second is during heavy thunderstorm runoff. This happens periodically in several canyons. The flows generally last no more than a few hours. The magnitude of the flows have been estimated by a standard numerical modelling technique developed by the Corps of Engineers.

The remainder of my testimony will be directed to elaborating on the reasons for these conclusions in summary fashion. I will refer to exhibits or other more detailed documents that illustrate or support the conclusions. The

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information in the testimony, exhibits, and documents represents the work of the entire Hydrology Team; that is who I include when I use the term "we." I will close the testimony with a canyon-by-canyon review of the most important hydrologic conditions in each that are relevant to this hearing.

Q. WOULD YOU PLEASE EXPLAIN THE BASIS FOR YOUR STATEMENT THAT THE LOS ALAMOS REGION IS EXTENSIVELY STUDIED AND DOCUMENTED ?

A. The Los Alamos region is one of the most extensively studied and documented areas in New Mexico with regard to its hydrogeologic characteristics. More than 600 published documents and articles document investigations made during the last 50 years. These sources are cited in an annotated bibliography of geologic, hydrogeologic, and environmental studies related to solid waste management units at LANL. This bibliography, entitled "Annotated Bibliography of Geologic, Hydrogeologic, and Environmental Studies Relevant to Solid Waste Management Units at Los Alamos National Laboratory," was originally submitted to the Environmental Protection Agency (EPA) and the New Mexico Environment Department (NMED) in September 1990. The full citation for this published document, and all others I will cite in my testimony, is included in a List of References provided as

EXHIBIT STOKER-2. Additionally, another copy of the bibliography and an update were submitted in 1993 in response to a document request from the NMED in this case. The bibliography and copies of the literature it describes are available for review in the Environmental Restoration (ER) Program's public reading room located at 2111 Trinity Drive, Building 2, Room 10, in Los Alamos.

Numerous documented observations of the nature of the streams and surface water occurrence date back to 1943 when the U. S. Army Corps of Engineers undertook a series of studies to develop a surface water supply for Los Alamos. Beginning in the late 1940s, the U. S. Geological Survey (USGS) provided direction for developing the more reliable groundwater supply wells. At the same time, the USGS started environmental monitoring of surface and groundwater for the newly-created Atomic Energy Commission. The USGS monitoring and hydrologic studies continued through the end of the 1960s. In 1969-1970, the environmental monitoring tasks were assumed by the predecessors of what is now the Environmental Protection Group (EM-8) at LANL.

Q. WHAT IS THE BASIS FOR YOUR CONCLUSION THAT MOST REACHES OF STREAMS WITHIN THE LOS ALAMOS NATIONAL LABORATORY ARE EPHEMERAL?

A. My own direct observations during my 18-plus year tenure at Los Alamos, coupled with: 1) an extensive familiarity with the documentation and observations of William D. Purtymun, who conducted hydrologic and monitoring studies in Los Alamos since 1959, first with the USGS and subsequently with the University of California (LANL); most of his reports are listed in the bibliography noted above (see EXHIBIT STOKER-2), and 2) by study of the documents produced for the U. S. Army Corps of Engineers and the Atomic Energy Commission in the 1940s and 1950s, including the earliest prepared by the Corps of Engineers in 1943 and three prepared by Black & Veatch Consulting Engineers in 1946, 1948, and 1951 (all cited in EXHIBIT STOKER-2).

Q. PLEASE EXPLAIN FURTHER WHAT YOU MEAN BY SAYING "MOST REACHES OF STREAMS ... ARE EPHEMERAL."

A. The portions, or reaches, of canyons on the Pajarito Plateau that are within the LANL boundary are dry for most of their length most of the time. These portions of the canyons flow only when spring snowmelt or precipitation, such as summer thunderstorms occur, and are technically termed "ephemeral." There are only a few reaches or portions of the canyons of limited length that have naturally flowing water supplied by springs or other groundwater that flow all the time in all years. These

portions or reaches of the stream channels are the only perennial reaches. There are also a few reaches that flow intermittently; that is, they may dry up during parts of the year.

Q. BECAUSE A CLEAR UNDERSTANDING OF THE TECHNICAL HYDROLOGY TERMS IS CRITICAL TO UNDERSTANDING THE APPLICABILITY OF THE NEW MEXICO STREAM STANDARDS, COULD YOU PLEASE FURTHER EXPLAIN THE TERMS YOU ARE USING BEFORE PROCEEDING ?

A. The terms are technical, and they are also defined within the legal framework of the New Mexico Stream Standards (hereafter Stream Standards) in Section 3-100. Accordingly, I am using terminology exactly in accord with definitions contained in the Stream Standards when they appear there, and supplemented by other professionally accepted technical usage as referenced in the Glossary of Geology published by the American Geological Institute (AGI), Washington, D.C., in 1972 (see EXHIBIT STOKER-2). This reference appears to be the source of most of the hydrologic definitions contained in Section 3-100 of the Stream Standards.

Some general points and assumptions must be emphasized: When using the term "flow," I use it exactly as given in the

Stream Standards at 3-100.N: "Flow, relative to the four definitions of streams herein, means natural flow ensuing from the earth's hydrologic cycle, i.e., atmospheric precipitation resulting in surface and, or, ground-water runoff." Note carefully the emphasis I have placed on the word "natural," which is the fundamentally operative part of the definition; "flow" in relation to the four stream definitions does not include effluents or other man-made discharges. Also, please keep in mind that the Stream Standards and AGI Glossary of Geology definitions indicate that the term "stream" may be used to refer to either an entire stream, or only to a reach of a stream when used in conjunction with the terms ephemeral, intermittent and perennial. When using the terms "ephemeral, intermittent, and perennial," I use them exactly as defined in the Stream Standards at 1-300.J., P., and CC., respectively. Other terminology is used either as defined in the Stream Standards (when the terms are defined there) or as given in the AGI Glossary of Geology. I have compiled the most important ones together for your convenience as EXHIBIT STOKER-3.

While realizing that we must always keep in mind the precise definitions, I will try to summarize the essential concepts of the three types of stream flow covered in the definitions:

"Perennial" is easy to understand. A perennial stream or reach of a stream flows all the time, all year, every year. It does not depend on changes in climate within a year or from one year to the next. Also, its surface is generally lower than the surface of the water table of the region adjoining the stream. This is the key; perennial flow depends on the input of some type of groundwater, most often from a spring or seep in or adjacent to the channel. In the case of Los Alamos the input of ground water is from the regional water table only in the case of springs located in or within a mile or so of White Rock Canyon of the Rio Grande. This is because the regional main aquifer lies hundreds of feet below the mesa tops and canyons of the Pajarito Plateau where the Laboratory facilities are located. Water supplying seeps and springs on the flanks of the Jemez Mountains at the western margin of the Plateau comes from localized bodies of perched groundwater of limited extent; and thus, is "perennial" in the strict sense of the Stream Standards definition only by depending on the exception provided by the clause "is generally lower than."

"Ephemeral" is also easy to understand. An ephemeral stream or reach of a stream flows only in response to

precipitation, such as thunderstorms, or snowmelt. This means the flow occurs only at specific times determined by climatological condi ons, for limited periods, often only very briefly. It never flows all year lon". Also, its "channel is always above the water table of the region adjoining the stream." This is the key; ephemeral flow does originate as groundwater; rather, it may feed or recharge groundwater. In the Los Alamos environs, the regional water table of the main aquifer lies hundreds of feet below all of the mesas and canyon bottoms. The water tables of the limited-extent, alluvial perched groundwaters within the canyon bottoms are also lower than the stream channels with very few exceptions.

"Intermittent" is more complicated. An intermittent stream or reach of a stream flows only sometimes. The flow may be from groundwater, as from springs or seeps from alluvial groundwater runoff, or from snowmelt or precipitation. However, water lost to either evaporation or seepage into the ground, uses up the available flow over varying distances. An example would be a reach of a stream below a spring. The spring might support perennial flow (flow all year, every year) for, say 1/2 mile. During the colder months of the year, when evaporation is lowest, flow of

the spring-fed stream might continue for another 1/4 mile. But as the weather warms, that extra length of flow would be gradually depleted, so that by mid-summer the extent of flow is only the perennial 1/2 mile. The extra 1/4 mile that flows only part of the year would be called an intermittent reach. (Such a situation occurs in the uppermost reaches of Los Alamos Canyon, above the Los Alamos reservoir.) Another example would be a reach of a stream that flows from snowmelt, but only when sufficient water has infiltrated the channel and recharged the alluvial groundwater so that the stream stays on the surface. As the snowmelt season goes on, the flow extends further and further down stream because less infiltration occurs. When the input of snowmelt water ceases, the surface flow may continue for a time in the more downstream reaches as water built up in the alluvium of the stream channel moves downgradient and returns to the channel. (Situations like this occur in both Los Alamos Canyon and Pajarito Canyon within the Laboratory Lands.) In intermittent flow, the adjacent groundwater may be either higher or lower than the stream flow, and often will be different at different times of the year.

The definitions also include the term "interrupted stream," at 3-100 Q. This refers only to an entire stream and not to

just a reach of the stream. Quite logically, the term interrupted stream simply means a stream that has reaches with differing characteristic flows. Specifically, the Stream Standards definition adopted the portion of the AGI Glossary of Geology definition that specifies a stream that has perennial reaches (flow all year, every year) with intervening intermittent (flow only at certain time of year) or ephemeral reaches (flow only in response to precipitation or snowmelt). If one also takes into account the aspect of the Stream Standards definition of "flow" that notes, "Natural in-stream flow may be interrupted or eliminated by dams and diversions," then a stream may be interrupted because of either man-made dams or diversions, or by natural geologic structure. In the Los Alamos environs, the natural geologic conditions resulted in the occurrence of interrupted streams prior to any works of man on the Pajarito Plateau. (Specifically, I refer to Guaje, Los Alamos, Pajarito, and Water Canyons.)

Q. WILL YOU PLEASE APPLY THESE DEFINITIONS TO THE STREAMS IN THE LOS ALAMOS AREA AND RELATE THEM TO THE LOCATIONS OF THE NPDES DISCHARGES ?

A. The map in EXHIBIT STOKER-4 (identical to Aronson-2A), which depicts the watersheds of the Los Alamos area, contains my conclusions. My conclusions were reached by

applying the Stream Standards definitions coupled with my own observations and my knowledge of other documented professional observations extending back to 1943, and documented anecdotal observations of stream conditions back to 1914 (see EXHIBIT STOKER-2).

The map illustrates the perennial reaches of the canyons with a solid blue line. Only four of the canyons contain perennial reaches within the Los Alamos National Laboratory boundary. These are Pajarito Canyon, Water Canyon, Ancho Canyon, and Chaquehui Canyon. Of these four reaches, note that three of them occur at a significant distance downstream, to the east, of any Laboratory facilities or NPDES discharge points.

Other perennial reaches occur outside of the Laboratory lands in the drainage areas of Guaje Canyon, Los Alamos Canyon, Sandia Canyon, Pajarito Canyon, Water Canyon (and its tributary Cañon del Valle), Ancho Canyon, and Chaquehui Canyon.

Within the Laboratory lands, perennial reaches in the lower portions of Ancho Canyon and Chaquehui Canyon are close enough to the Rio Grande that they extend to the Rio Grande without being depleted. In lower Water Canyon, the perennial reach is very short, and extends into an

intermittent reach that is also short, and does not extend to the Rio Grande. In Pajarito Canyon, about 1 mile east of State Road 501, a spring that has been called Homestead Spring, feeds a perennial reach a few hundred yards long. This is followed by an intermittent reach that flows varying distances depending on climate conditions.

Essentially all other reaches of canyons within the LANL boundary are ephemeral. That is, they flow naturally only briefly in response to precipitation or snowmelt in the immediate locality. Some other reaches are intermittent, especially those that flow during part of the year by temporary storage of snowmelt that recharges the alluvial perched groundwater and then supports flow for a somewhat longer period as groundwater runoff.

On a regional basis, that is considering the entire length of a stream, including the portions both within and outside the Laboratory, four of the canyons would be considered interrupted. These include Guaje Canyon, Los Alamos Canyon, Pajarito Canyon, and Water Canyon (including its tributary Cañon del Valle). These are interrupted because they have reaches that are perennial because of spring flow, one or more reaches that are intermittent because of the spring flow or temporary storage of infiltrated ephemeral flow, and one or more reaches that are ephemeral as a result of

precipitation. However, that does not affect the conclusion that the reaches within the Laboratory boundaries are ephemeral, excepting the reaches near the springs already noted.

The conclusion is that the great majority of reaches of canyons within the Laboratory are ephemeral. The map in EXHIBIT STOKER-4, which also depicts the locations of the NPDES-regulated discharges, shows that none of the NPDES discharges are are made into perennial reaches. This is basically the same conclusion contained in the EPA summary statement that "discharges are into various ephemeral streams which produce little or no flow to the Rio Grande." Certainly, none of the discharges extend into perennial reaches, which are the only reaches included in the definition of Segment 2-118.

Q. HAS THE DEVELOPMENT OF MAN-MADE DIVERSIONS SUCH AS THE LOS ALAMOS CANYON DAM, WHICH CREATED A RESERVOIR, AND THE WATER CANYON GALLERY DRASTICALLY CHANGED THE CHARACTER OF THE HISTORIC NATURAL FLOW IN THE CANYONS ?

A. The developments have had effect, to be sure; but, they have not changed the fundamental nature of the types of flow occurring in the canyons. I base this conclusion on the recorded observations of the professional hydrologists

assessing conditions for the Corps of Engineers in the early 1940s, and on their documented interviews with persons who had observed conditions on the Pajarito Plateau for many years. The Corps' 1943 report and three others prepared for them are cited in EXHIBIT STOKER-2.

I will briefly summarize their observations. In general, the Corps of Engineers hydrologists concluded that only six streams in the vicinity of Los Alamos had enough regular flow to even be considered for supplementing the water supply. The six included, from the south, Frijoles, Water, Pajarito, Los Alamos, Guaje, and Santa Clara. The Corps of Engineers immediately dismissed Frijoles and Santa Clara, the only two streams that flowed perennially to the Rio Grande, because they were already appropriated and too far away. The Corps of Engineers described the remaining streams as having small but generally constant flow in their upper reaches, with most of the water disappearing into the ground before going very far on the Pajarito Plateau. One hydrologic interpretation suggested that, "... a large portion of the flow of the streams soon disappears under the ground to appear near Rio Grande in the form of springs." We now know that the source of the springs is not related to the canyon surface flow, as will be discussed later; but it is worth noting that it is an easy mistake to be made from observation limited to the apparent surface phenomena.

A survey performed by the U. S. Geological Survey for the Corps of Engineers made the following observation about the canyons, "Except in periods of heavy runoff most of these slots (canyons) in the bench (Pajarito Plateau) are without surface water, although the headward portions of a few of them appear to have permanent streams for short distances before emerging from the Valle Mountain flank."

Anecdotal observations documented in the report include those of A. J. Connell, who was a forest ranger from 1914 to 1917, and then operated the Los Alamos Ranch School from 1917 until 1942. He noted that Guaje Canyon always flowed better than Los Alamos Canyon. He indicated that the school had obtained its water from a well in Los Alamos Canyon (evidently relatively near the school in the middle reach of Los Alamos Canyon) until 1922 when it dried up. This indicates that even before construction of the first small dam, perennial flow did not extend very far down the canyon. Furthermore, there was not sufficient perennial flow to recharge the shallow alluvial perched groundwater in Los Alamos Canyon roughly four miles downstream of the present reservoir. Because of this, in 1922 the school constructed a pipeline up Los Alamos Canyon to intercept the perennial flow in the upper reaches of the canyon.

Thus, even historically, the perennial flow in Los Alamos Canyon did not extend beyond the present reservoir, and intermittent flow did not consistently extend even down to the vicinity of the Ranch School, the present location of the center of the Los Alamos townsite.

In regard to the upper reaches of Water Canyon (i.e. west of State Road 501 and the present-day Laboratory boundary) the engineers noted that "This stream contains numerous small trout and several beaver dams and it is improbable that these would be present in a stream having no dry weather flow." They note that it typically had flow greater than that of Pajarito Canyon and "...from two to three times that of Los Alamos." This is the natural, perennial flow that occurred prior to construction of the Water Canyon Gallery. In spite of this documented much greater flow in Water Canyon, the report goes on to state, "Since the flow of Water Canyon sinks into the ground before leaving public lands, it is doubtful that any water rights have been taken there." (I have not been able to determine precisely where the public land boundary was at the date of this observation but it may be as far west as the boundary to the Ramon Vigil Grant, which is about where the present State Road 501 is located.) The engineers proposed installing a dam in the northerly drainage of Water Canyon into which the water from the spring that is now the gallery discharged. The

installation of the gallery ultimately intercepted most of this flow, thus reducing the length of perennial flow. However, Water Canyon did not flow far across the Pajarito Plateau even before any development. Accordingly, the basic character of the further downstream reaches was not altered.

Q. WHAT ABOUT THE STATEMENTS IN THE NMED REPLY FILED ON DECEMBER 21, 1992, IN THIS CASE, THAT FLOW REGULARLY OR CONTINUOUSLY OCCURS IN OTHER PORTIONS OF SOME OF THE CANYONS ? SOME OF THESE STATEMENTS, FOR EXAMPLE, OCCUR ON PAGES 26 (TWO INSTANCES IN BOTTOM PARAGRAPH), PAGE 27 (TOP PARAGRAPH), PAGE 31 (FIRST COMPLETE PARAGRAPH), PAGE 34 (FIRST COMPLETE PARAGRAPH), AND IN THE AFFIDAVIT OF PETER KEIM MONAHAN, INCLUDED AS THEIR EXHIBIT 2.

A. These other flows are not natural flows. Thus, the reaches or streams in which they occur are not perennial, ephemeral, intermittent, or interrupted within the meaning of the Stream Standards definitions, because of the specific definition of "flow" in 3-100.N that limits "flow" in relation to these other four terms to be natural. To quote the Stream Standards, "'Flow,' relative to the four definitions of streams herein, means natural flow ensuing from the earth's hydrologic cycle, i.e., atmospheric precipitation resulting in surface and, or, ground-water runoff."

I should point out that in some published documentation the terms "perennial" and "intermittent" have been applied in conjunction with descriptions of effluent discharges or other man-made releases. These were written without cognizance of the very precise meaning attached to the term "flow" by the Stream Standards. (In general hydrogeologic usage, the term flow is not so restrictive; see, for example, the AGI Glossary of Geology, cited in EXHIBIT STOKER-2.) However, within the precisely defined terminology of the Stream Standards, it is a non sequitur to speak of a "perennial discharge." Accordingly the documents will have to be viewed in light of whether they were written specifically to address the technical regulatory issues of this case, or rather, as is most often the case, were more general hydrologic discussions.

There is flow that regularly occurs in other locations because of discharge of effluents or other releases. In order to distinguish the non-natural character of these flows, I will use the term "effluent-supported" to mean flows ensuing from NPDES-permitted discharges, or "anthropogenic flows" to mean other man-made releases.

The major effluent-supported or anthropogenic flows are from sanitary sewage treatment plant discharges. For example, in

Pueblo Canyon, the effluent from the Los Alamos County-operated Bayo Sewage Treatment Plant (STP), creates an effluent-supported flow that extends across the DOE property and flows into Los Alamos Canyon essentially all the time; by early 1993, the effluent-supported flow extended through the entire lower reach of Los Alamos Canyon and into the Rio Grande continuously.

In Sandia Canyon, the main Laboratory STP discharge creates an effluent-supported surface flow that typically extends about 2 1/2 to 3 miles down the Sandia canyon channel, by which point it completely infiltrates the alluvium. This effluent-supported flow in Sandia Canyon does not extend to the Laboratory boundary.

In the lower reach of Cañada del Buey, the discharge from the Los Alamos County-operated White Rock STP creates a continuous, effluent-supported flow starting on Los Alamos County land that extends onto San Ildefonso Pueblo land to the confluence of Cañada del Buey and then on into the Rio Grande. In Los Alamos Canyon, release of water from the Los Alamos Reservoir via a pipeline that extends a short distance onto Laboratory property, may (during parts of the year when the reservoir is not discharging over its spillway) result in flow in the middle portion of the canyon

for several months. This occurred during the winter of 1992-1993, for example.

Q. YOU MENTIONED THAT SOME OF THE PERENNIAL FLOWS IN THE LOWER REACHES OF SOME OF THE CANYONS NEAR WHITE ROCK CANYON WERE FED BY SPRINGS. THE NMED REPLY FILED IN THIS CASE ON DECEMBER 21, 1992, SUGGESTS ON PAGE 31 (FIRST COMPLETE PARAGRAPH) THAT THOSE SPRINGS MAY BE FED BY EITHER NATURAL OR EFFLUENT-SUPPORTED FLOW SEEPING INTO THE ALLUVIUM IN THE CANYON BOTTOMS AND MOVING AS GROUNDWATER TO BE DISCHARGED AT THE SPRINGS. WILL YOU PLEASE EXPLAIN YOUR CONCLUSIONS ABOUT THE SOURCE OF THOSE SPRINGS ?

A. These springs in some of the stream channels leading into White Rock Canyon, as well as those in White Rock Canyon itself, are fed by the deep, regional main aquifer underlying the Pajarito Plateau. There are four important lines of evidence for this conclusion: their geologic points of origin, the discontinuity of the alluvium, the general chemical quality of the water, and the apparent age of the water. They are definitely not fed by the alluvial water in the stream channels.

Q. PLEASE EXPLAIN WHAT YOU MEAN BY "GEOLOGIC POINTS OF ORIGIN" ?

A. In order to provide a clear answer for anyone who may not be familiar with the geologic structure of the Pajarito Plateau, I first need to provide a brief description of the geologic setting and cross section of the Los Alamos area. A moderately detailed overview of the hydrogeologic environment is summarized in Chapter 2, "Installation Description," contained in the "Installation Work Plan for Environmental Restoration," Revision 2, published in November 1992 (see citation in EXHIBIT STOKER-2).

Q. WOULD YOU PLEASE DESCRIBE THE GEOLOGIC SETTING AND GEOLOGIC CROSS SECTION ?

A. The Laboratory is situated on the Pajarito Plateau on the east flanks of the Jemez Mountains and on the west side of the Rio Grande valley as shown in the figure provided as EXHIBIT STOKER-5. The Jemez Mountains are part of a volcanic field, which consists of more than 400 cubic miles of volcanic rocks erupted from numerous vents, including a giant caldera. Two major volcanic eruptions occurred about 1.5 and 1.13 million years ago deposited thick layers of the Bandelier Tuff. This tuff forms the Pajarito Plateau, a gently eastward-sloping surface dissected by numerous steep-sided canyons.

The next figure, provided as EXHIBIT STOKER-6 illustrates the geologic cross section through the Pajarito Plateau. Beneath the Bandelier Tuff, older volcanic rocks (especially basalts) and sedimentary deposits extend to great depths. These include the Puye Formation, and other sedimentary deposits of the Santa Fe Group. Additional details are contained in the Installation Workplan, cited earlier, a paper by Purtymun and Johansen, and several other publications by Purtymun and others listed as references in EXHIBIT STOKER-2.

Q. PLEASE DESCRIBE THE OCCURRENCE OF GROUNDWATER.

A. There are three basic types of groundwater found in the Los Alamos environs:

1) alluvial perched groundwater in the canyon bottoms;
2) perched groundwater in the recent volcanics (on the flanks of Jemez Mountains) and in the Puye Conglomerate and Basalts (beneath portions of Pueblo, Los Alamos, and Sandia Canyons), and
3) the regional Main Aquifer, partly in the Puye Conglomerate and mainly in Santa Fe group sediments.

I will discuss these in order.

Q. PLEASE DESCRIBE THE ALLUVIAL PERCHED GROUNDWATER

A. The bottoms of canyons of the Pajarito Plateau have deposits of alluvium that ranges in thickness to as much as 100 ft. The alluvium is generally composed of sedimentary deposits of widely ranging particle sizes, from clays to sands, gravels, and cobbles. Additional canyon-specific descriptions of the alluvial deposits is given in Chapter 2 of the Installation Workplan cited earlier and listed in EXHIBIT STOKER-2. Various reaches of the alluvium in some of the canyons contain perched groundwater.

Q. PLEASE DESCRIBE THE MOVEMENT OF WATER IN THE ALLUVIUM.

A. The alluvium is quite permeable. Surface flow in canyons infiltrates the alluvium until downward movement is impeded by the less permeable layers between the alluvial sediments and the tuff. This results in a buildup of a shallow alluvial groundwater body. Depletion by evapotranspiration and movement downstream in the alluvium or into the underlying rocks limits the horizontal and vertical extent of the alluvial water. Flow of the alluvial perched groundwaters is in a easterly, down-canyon direction.

Q. DOES THE PERCHED GROUND WATER IN THE ALLUVIUM EXTEND TO THE RIO GRANDE IN ANY OF THE CANYONS ?

A. No. None of the alluvial perched groundwater bodies are continuous from the plateau down to the Rio Grande. All of the canyons cross and cut through the basalts, where the alluvium thins and disappears. The lower reaches of some of the canyons also have alluvial deposits but they are not connected to the alluvium in the upstream reaches.

Q. WOULD YOU PLEASE DISCUSS THE PERCHED GROUNDWATER AT INTERMEDIATE DEPTHS ?

A. Perched ground water bodies occur in the conglomerates and basalts at intermediate depths beneath the alluvium in the middle and lower reaches of Pueblo and Los Alamos Canyons and in the reach of Sandia Canyon near the eastern Laboratory boundary. Depth to this perched ground water ranges from about 90 ft in the middle reach of Pueblo Canyon to about 450 ft in Sandia Canyon. The body in lower Pueblo Canyon near the confluence with Los Alamos Canyon has been studied in some detail. The potential for migration of perched water to the main aquifer is small based on chemical quality comparisons. Patterns of chemical quality and water level measurements indicate that the lower perched groundwater in Pueblo Canyon is hydrologically connected to the stream in Pueblo Canyon . Water from this perched groundwater discharges at the base of the basalt at Basalt Spring, which is off the Laboratory site in lower Los Alamos

Canyon on the San Ildefonso Pueblo. The rate of movement of the perched groundwater in this vicinity has been estimated at about 60 ft/day or about 6 months from recharge to discharge (see Abrahams 1966, and Purtymun 1981, cited in EXHIBIT STOKER-2). I note here that Basalt Spring is the only known discharge of the intermediate depth perched groundwater. Basalt Spring is not included in the group of springs in or near White Rock Canyon that are fed from the deep, regional main aquifer.

Some perched water occurs in volcanics on the flanks of the Jemez Mountains offsite to the west of the Laboratory. This water discharges in several springs (for example American and Armistead Springs) and supplies the gallery in Water Canyon.

Q. PLEASE DESCRIBE THE MAIN AQUIFER

A. The main aquifer of the Los Alamos area is the only aquifer capable of water supply. Water for the Laboratory, the communities of Los Alamos and White Rock, and Bandelier National Monument is supplied by deep wells in the main aquifer. The wells are located on the Pajarito Plateau and in Los Alamos and Guaje Canyons. Additional detail on the development of the water supply and the hydrologic characteristics of the main aquifer are contained in several

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1 references cited in EXHIBIT STOKER-2, including the
2 following titles: "Hydrologic Characteristics of the Main
3 Aquifer in the Los Alamos Area: Development of Ground Water
4 Supplies," and "Water Supply at Los Alamos: Current Status
5 of Wells and Future Water Supply,"
6
7 The surface of the main aquifer slopes eastward. The depths
8 to water below the mesa tops range from about 1,200 ft along
9 the western margin of the plateau to about 600 ft at the
10 eastern margin. The main aquifer is separated from the
11 alluvial perched groundwater and intermediate depth perched
12 water in the by 350 to 620 ft of tuff and volcanic
13 sediments.
14
15 Q. PLEASE DESCRIBE THE RECHARGE AND MOVEMENT OF WATER IN
16 THE MAIN AQUIFER.
17
18 A. Hydrologic data, mainly the eastward slope of the water
19 level in the main aquifer and knowledge of hydrologic
20 properties, indicate that the major recharge area for the
21 main aquifer under the Pajarito Plateau is west of the
22 Laboratory. The water in the aquifer moves generally
23 eastward toward the Rio Grande, where a part is discharged
24 into the river through numerous springs and seeps. This is
25 described in more detail in the documents titled
26 "Geohydrology of White Rock Canyon of the Rio Grande from

Otowi to Frijoles Canyon" and "Geohydrology of Bandelier National Monument, New Mexico," which are cited in EXHIBIT STOKER-2.

I believe this gives sufficient background to clearly address your question about the geologic origin of springs in the lower reaches of the canyons and in White Rock Canyon.

Q. PLEASE EXPLAIN THE GEOLOGIC ORIGIN OF THE SPRINGS.

A. The springs and seeps originate from the same geologic formations, the Puye conglomerate and the Santa Fe Group sediments, that produce water into test wells and supply wells that tap the main aquifer. The obvious springs with clear surface expression have been identified and grouped according to the formation of their origin: Group I comes out of the Totavi Lentil (of the Puye Conglomerate), Group II comes out of the coarse-grained Tesuque Formation (of the Santa Fe Group sediments), Group III comes out of the fine-grained Tesuque Formation (of the Santa Fe Group sediments), and Group IV originates in fine-grained Tesuque formation near basalt intrusions or faults. This is described in more detail in the document titled "Geohydrology of White Rock Canyon of the Rio Grande from Otowi to Frijoles Canyon" which is cited in EXHIBIT STOKER-2.

Q. PLEASE ELABORATE ON THE POINT THAT THE CANYON ALLUVIUM IS NOT CONTINUOUS ?

A. The alluvial materials present in the bottoms of canyons on the Pajarito Plateau are not directly connected with the alluvium at lower elevations closer to the Rio Grande and White Rock Canyon. Every one of the canyons tributary to the Rio Grande that crosses the Laboratory passes across and cuts through the basalts as they leave the Pajarito Plateau. Where they cut through the basalts the alluvium thins out and disappears for some distinctly observable reach. These locations are readily seen, for example, in Los Alamos Canyon near its confluence with Pueblo Canyon, in Cañada del Buey and Pajarito Canyon where they cross State Road 4 at the Laboratory boundary with White Rock, and in Water and Ancho Canyons where they cross State Road 4 in the southeastern portion of the Laboratory. Once the canyons reach a lower elevation, another reach of alluvium is generally found, but it is not continuous with the alluvium in the upper reaches.

Water would have to either 1) flow on the surface of the basalt reaches, or 2) follow some other subsurface pathway, perhaps through fractures in the basalt to reach the lower alluvium. The first case, surface flow, it is simply not

observed to occur frequently or for very long. The second case, subsurface movement through the basalt, is observed only in the connection between the alluvial perched groundwater in the lower portion of Pueblo Canyon and Basalt Spring in Los Alamos Canyon. I discussed this situation previously in conjunction with the intermediate depth perched groundwater.

Q. WOULD YOU PLEASE EXPLAIN WHAT THE CHEMICAL QUALITY OF THE SPRING WATER SHOWS ?

A. The chemical quality of the springs in the lower reaches of Sandia, Pajarito, Water, Ancho, and Chaquehui Canyons is very similar to the water extracted from the main aquifer through the deep wells. Conversely, the chemical quality of the water in the springs is quite different than the water that occurs in the stream channels or alluvium on the Pajarito Plateau. The conclusion is that the springs are fed by water from the regional main aquifer and not by surface or alluvial perched groundwater from the canyons.

Several figures, provided as EXHIBIT STOKER-7, illustrate this point. The figures are simple graphic representations of the concentrations of several major chemicals present in the water. Data was taken from the results of our routine

annual environmental monitoring (see citation in EXHIBIT STOKER-2).

One can simply compare the general shape of these figures to get an indication of similarity of the chemical makeup of water from the springs and the deep groundwater wells, and the contrasting different shape of the figures illustrating the chemical makeup of surface an alluvial perched water in the canyons.

Figure A (of EXHIBIT STOKER-7) shows the similarity of main aquifer water from supply well PM-1 and Sandia Spring, contrasted with the different quality of water from Sandia Canyon (SCS-3), Basalt Spring, and the Rio Grande. Figure B shows the similarity of main aquifer water from Pajarito Spring (4A) and the spring in Water Canyon (5AA), contrasted with the quality of alluvial perched groundwater in Pajarito Canyon at PCO-2 and PCO-3, and surface flow in Water Canyon at location BETA. Figure C shows the similarity of main aquifer water from Ancho Spring and several White Rock Canyon Springs between Ancho Canyon and Chaquehui Canyon (Springs 8A, 9, and 9A), contrasted with the quite different quality of surface flow in Water Canyon at location BETA. Figure D shows the similarity of main aquifer water from deep test wells DT-5A, DT-9, and DT-10, located near the middle of the Laboratory's southern boundary and Doe spring,

in Chaquehui Canyon, in contrast to the surface flow in Water Canyon at location BETA, which is quite near the three deep test wells along the southern boundary.

Q. WHAT DO YOU MEAN ABOUT THE APPARENT AGE OF THE WATER ISSUING FROM THE SPRINGS ?

A. We have analyzed samples of water from the springs by a well-known radiometric dating method and the results indicate the water is quite old.

Q. WOULD YOU PLEASE EXPLAIN HOW THIS METHOD WORKS ?

A. Basically, we have measured the tritium content of samples of the water from the springs. The low levels indicate the water must be at least many decades old. The measurements of tritium are made by extremely sensitive analytical methods. The interpretation is based on the equilibrium of contemporary precipitation with the sources of this radioactive element in the atmosphere. Tritium is a radioactive form (or isotope) of hydrogen. Tritium is present in the atmosphere both from natural production in the upper atmosphere by cosmic ray interactions and as a residual from worldwide atmospheric testing of thermonuclear weapons. Tritium is present in precipitation as part of the water molecule itself since it behaves chemically just like

ordinary stable hydrogen. As water from precipitation infiltrates the ground and moves down, the radioactive tritium is no longer replenished and gradually decays away. The proportion of the isotope remaining in a groundwater sample can be used with knowledge of the rate of decay, the radioactive half-life, to estimate how long the water has been isolated from the atmosphere, or "how old its is."

Q. HOW HAS THIS BEEN APPLIED TO THE SPRINGS IN AND NEAR WHITE ROCK CANYON ?

A. To date, low-detection-limit tritium analyses have been completed on samples from 12 springs in White Rock Canyon. The values for tritium in the water range from less than detectable to about 18 pCi/L. (The abbreviation "pCi/L stands for picoCuries per liter, a standard unit of measurement for expressing the frequency of radioactive emissions [picoCuries] in a specific volume of water [liter].) These values are all less than values for tritium in contemporary precipitation (about 30 to 60 pCi/L) and much less than the roughly 700 pCi/L that would be present now in water precipitated in northern New Mexico during 1962 and 1963, when tritium from worldwide atmospheric nuclear weapons testing was at its maximum. Additional detail is contained in EXHIBIT STOKER-8. The conclusion is that there cannot be any significant component of recharge from water

precipitated during the last several decades in the water issuing from the springs. The water is considerably older. This further confirms the lack of continuity of alluvium from plateau reaches of canyons to lower reaches.

Q: THE ISSUE THAT NOT ENOUGH IS KNOWN ABOUT THE HYDROLOGY OF THE PAJARITO PLATEAU IS FREQUENTLY RAISED BY THE NMED REPLY FILED IN THIS CASE ON DECEMBER 21, 1992. THE REPLY DESCRIBES DATA AS "INSUBSTANTIAL AND INCONSISTENT," ESPECIALLY ON PAGES 30 (BOTTOM PARAGRAPH) AND 31 (FIRST COMPLETE PARAGRAPH) IN RELATION TO THE SPRINGS THAT FLOW INTO THE RIO GRANDE. DO YOU BELIEVE THE DATA IS INSUBSTANTIAL AND INCONSISTENT ?

A: No. I believe that date are substantial and definitive. These four independent, separate lines of evidence are all complementary and contribute a high degree of confidence in the conclusion that the springs in the lower reaches of Sandia, Pajarito, Water, Ancho, and Chaquehui Canyons, as well as the others in White Rock Canyon, are fed by deep groundwater from the regional main aquifer. The data indicate they are not fed, even indirectly, by surface flow or alluvial perched groundwater moving from the ephemeral portions of the canyons on the Pajarito Plateau that receive NPDES-regulated discharges.

Q. THE SAME PARAGRAPHS IN THE NMED REPLY ALSO SUGGEST THE POSSIBILITY THAT DISCHARGES INTO THE CANYONS COULD PENETRATE ALL THE WAY TO THE MAIN AQUIFER, AND THEN ULTIMATELY CONTAMINATE THE RIO GRANDE AS DISCHARGE FROM THE SPRINGS YOU HAVE JUST SHOWN TO BE FED BY THE MAIN AQUIFER. DO YOU THINK THAT IS A VALID LINE :F REASONING ?

A. No. Several lines of evidence indicate that recharge to the main aquifer through the Pajarito Plateau cannot be significant. Three of the most important types of information are:

1) the geology, with hundreds of feet of dry volcanic deposits and sediments between the plateau surface and the top of the main aquifer,
2) the age of the water, as determined through radiochemical dating, and
3) the hydraulic response of the aquifer, as indicated by artesian conditions and water level fluctuations induced by barometric pressure variations, indicating a significant degree of confinement of the main aquifer.

The first type of information elaborated on in several of the documents already cited that are listed in EXHIBIT STOKER-2, the second is described in more detail in EXHIBIT

STOKER-8, and the third type is more recent, not-yet published data.

Q. ARE THERE ANY OF THE CANYONS THAT FLOW REGULARLY FROM WITHIN THE LABORATORY ALL THE WAY TO THE RIO GRANDE OTHER THAN THE PERENNIAL SPRING-FED REACHES YOU HAVE IDENTIFIED IN ANCHO AND CHAQUEHUI CANYONS ?

A. No, there are no regularly flowing streams that are continuous between the active Laboratory technical areas, including areas where NPDES-regulated effluents are discharged, and the Rio Grande in White Rock Canyon.

Q. DOES FLOW EVER EXTEND FROM WITHIN THE ACTIVE LABORATORY TECHNICAL AREAS TO THE RIO GRANDE ?

A. Yes. This occurs in response to two types of ephemeral flow situations: snowmelt and thunderstorm runoff. Snowmelt at times has extended all he way across the Laboratory lands, reaching the Rio Grande in a continuous, uninterrupted, surface flow in three canyons. These conclusions are based on observations by William D. Purtymun since about 1970 and my own observations since 1974.

In Los Alamos Canyon snowmelt runoff extends without interruption from the upper reaches above the reservoir all

the way to the Rio Grande for at least a few days, to a few weeks in wetter years. For example, this occurred five times during the 12 years from 1975 to 1986, inclusive. As described in the report titled "Transport of Plutonium in Snowmelt Run-off" (cited in EXHIBIT STOKER-2), snowmelt reached the Rio Grande a total of 205 days during the five runoff events, for an average of 41 days in each of those five years, but with a range of 11 to 78 days. This is about 11 percent of the days in the five years that snowmelt reached the Rio Grande, or about 4.7 percent of the total number of days in the 12 years.

The only other two canyons in which snowmelt has extended to the Rio Grande are Pajarito Canyon and Water Canyon. Since 1970, Pajarito Canyon snowmelt has reached the Rio Grande several times, but not as frequently as in Los Alamos Canyon. However, in Water Canyon snowmelt has reached the Rio Grande only once in the same period according to Mr. Purtymun's recollection.

Q. WHAT ABOUT THUNDERSTORM RUNOFF ?

A. Thunderstorm runoff extending from within the Laboratory's active technical areas to the Rio Grande happens periodically in more of the canyons. It is generally observed every year or two in one or more of

Guaje, Pueblo, Los Alamos, Sandia, Pajarito, Water, Ancho, and Chaquehui Canyons. The flows generally last no more than a few hours in response to major thunderstorms in July and August.

Q. DO YOU HAVE ANY QUANTITATIVE INFORMATION ON THE STORM RUNOFF FLOWS ?

A. There is limited gaging data in a few of the canyons from special studies, in Los Alamos and Mortandad canyons particularly, since the mid-1960s. Given all the competing demands for limited environmental monitoring resources, it has not been economically feasible to operate and maintain gaging stations in normally dry stream channels. However, because of changing conditions (such as the increased flow of effluent from the Los Alamos County-operated STP in lower Pueblo Canyon) we contracted with the USGS to operate continuous gaging stations in Pueblo and Los Alamos Canyons starting in the fall of 1991. So far, no significant runoff events have occurred to permit any quantitative interpretation. We expect to have the USGS install additional gaging stations in other major drainages to develop measurements over extended time periods for statistical analysis.

In the interim, we have turned to accepted, standard numerical simulation techniques. The work is described and results documented in detail in the 1992 report by Dr. Steve McL: , entitled "Determination of 100-year Floodplain Elevations at Los Alamos National Laboratory," and cited in EXHIBIT STOKER-2. Numerically simulated runoff flows were computed for all of the drainages in the Los Alamos area with the accepted HEC computer models developed by the Corps of Engineers. Extremely detailed input data on climatology and topography was utilized to ensure the best possible estimates. (This study was conducted primarily to define the 100-year floodplains for regulatory compliance with the Laboratory's RCRA/HSWA permit. It was submitted to the NMED, as are all compliance required documents.) The report documents the magnitude of flows in each drainage for a range of "return periods," or likelihoods of occurrence.

Q. WOULD YOU PLEASE SUMMARIZE YOUR CHARACTERIZATION OF EACH OF THE MAJOR CANYONS IN THE LOS ALAMOS AREA ?

A. I will refer you once again to the map in EXHIBIT STOKER-4, depicting the watersheds of the Los Alamos area, which illustrates the important conclusions of my testimony. Also, significant additional information is summarized in the report titled "Installation Work Plan for Environmental

Restoration," cited in EXHIBIT STOKER-2. Here I will only point out highlights of natural surface flow characteristics.

Guaje Canyon -- This is the largest single drainage, with a total area of about 26 square miles. It heads in the Sierra de Los Valles on U. S. Forest Service lands. None of Guaje Canyon proper is within the Laboratory boundary; but the facilities of the Guaje Water Supply Well Field are located in Guaje Canyon. Its tributary, Barrancas Canyon, drains part of the northeast portion of the Laboratory. Guaje Canyon then crosses San Ildefonso Pueblo lands to the point where it is tributary to Los Alamos Canyon within about a mile of the confluence of Los Alamos Canyon and the Rio Grande.

On a regional scale, Guaje is an interrupted stream. It has a perennial reach extending from springs upstream of the reservoir to some distance downstream from the Guaje reservoir, and an intermittent reach for an additional distance. Most of it, however, is ephemeral, and is dry most of the year in its lower reach before joining Los Alamos Canyon. Snowmelt does not reach the Rio Grande from Guaje.

Thunderstorm runoff from Guaje Canyon occasionally reaches the Rio Grande through Los Alamos Canyon. The estimated 24-hour runoff for a 2-year recurrence 6-hour event at the confluence with Los Alamos Canyon is about 8 acre-feet. This would be expected to flow on through a short reach of lower Los Alamos Canyon to the Rio Grande.

**Bayo Canyon** -- Bayo Canyon heads on the plateau on Los Alamos County lands. It has a total drainage area of about 4 square miles. Bayo Canyon extends across the northeast part of the Laboratory before it crosses San Ildefonso Pueblo lands the point where it is tributary to Los Alamos Canyon. There are no NPDES Discharges made into Bayo Canyon. There are no springs and no perennial reaches in Bayo Canyon. Bayo is entirely ephemeral. No significant snowmelt occurs in Bayo.

The estimated 24-hour runoff for a 2-year recurrence 6-hour storm is calculated to be less than 1 acre-foot near the eastern Laboratory boundary near the confluence of Bayo Canyon with Los Alamos Canyon; and that flow would not be expected to extend through Los Alamos Canyon to reach the Rio Grande.

**Pueblo Canyon** -- Pueblo Canyon heads on the flanks of the Sierra de Los Valles. It has a total drainage area of about

8.4 square miles. It originates on U. S. Forest Service lands, extends across Los Alamos County lands, and then crosses the northeast part of the Laboratory to the point where it is tributary to Los Alamos Canyon slightly west of the boundary between the Laboratory and San Ildefonso Pueblo. There are no perennial springs and no perennial reaches in Pueblo Canyon. Pueblo is entirely ephemeral.

Snowmelt from the upper reaches occasionally extends downstream as far as the townsite, but does not normally reach the Laboratory lands.

Continual, effluent-supported flow occurs essentially all the time in the lower reach of Pueblo Canyon because it receives discharge from the Los Alamos County-operated Bayo STP. This flow continues on into the lower reach of Los Alamos Canyon, and will be discussed further in the next section on Los Alamos Canyon.

The estimated 24-hour runoff for a 2-year recurrence 6-hour storm at the confluence of Pueblo Canyon with Los Alamos Canyon (within the Laboratory boundary) is about 4 acre-feet. Assuming continued saturation of the alluvium by discharge from the Los Alamos County-operated STP in Pueblo Canyon, this flow would probably extend through Los Alamos Canyon to reach the Rio Grande confluence.

**Los Alamos Canyon** -- Los Alamos Canyon heads on the flanks of the Sierra de Los Valles. It drains a total area of about 59 square miles (including its major tributaries). It originates on U. S. Forest service lands, and extends across the north central part of the Laboratory before entering San Ildefonso Pueblo lands a short distance downstream of the confluence with Pueblo Canyon.

On a regional scale, Los Alamos Canyon is an interrupted stream. There are several perennial springs in the upper reaches of Los Alamos Canyon and its tributary Quemazon Canyon. These upper reaches are perennial from the springs down to within a few hundred yards of the Los Alamos reservoir.

Snowmelt usually add enough water to the reservoir to overflow and support flow onto the Laboratory lands most years. Snowmelt extends downstream to the confluence with the Rio Grande in about half of the years; for example, between 1975 and 1986 snowmelt reached the Rio Grande during five of the years on a total of 205 days, averaging about 41 days a year during those five years or about 4.7 percent of the total number of days in the 12-year period.

The estimated 24-hour runoff for a 2-year recurrence 6-hour storm is 22 acre-feet at the confluence with the Rio Grande.

As noted in the discussion of Pueblo Canyon, discharge from the Los Alamos County operated Bayo STP results in effluent-supported flow that regularly continues on into the lower reach of Los Alamos Canyon. The effluent-supported flow combines with perennial flow from Basalt Spring on San Ildefonso Pueblo lands just east of the Laboratory Boundary. In 1992, the combined flow generally extended in Los Alamos Canyon to about the confluence with Bayo or Guaje Canyon. By early 1993, the alluvium had apparently become sufficiently saturated that the surface flow has extended to the Rio Grande most of the time during the first three months of 1993.

**Sandia Canyon** -- Sandia Canyon heads on the plateau within the Laboratory boundary. It has a total drainage area of about 5.7 square miles. The small drainage extends across the central part of the Laboratory. There are no perennial springs and no perennial reaches in Sandia Canyon within the Laboratory lands. Sandia is ephemeral within the Laboratory boundaries. No significant snowmelt occurs in Sandia Canyon.

The estimated 24-hour runoff for a 2-year recurrence 6-hour storm at the location where Sandia Canyon crosses State Road 4 is less than 1 acre-foot; this is not expected to extend to the confluence with the Rio Grande, about 4 miles further downstream.

A significant effluent-supported flow occurs in Sandia Canyon arising from the major discharge of treated sanitary sewage effluent. This typically extends about 2.5 to 3 miles downstream.

About 3 miles east of the Laboratory boundary, on San Ildefonso Pueblo lands, a perennial spring, known as Sandia Spring, supports a perennial flow for a few hundred yards. This flow does not normally reach the Rio Grande. The spring is fed by water from the main aquifer.

**Mortandad Canyon** -- Mortandad Canyon heads on the plateau. It has a total drainage area of about 5.9 square miles, or a total of 10.4 square miles including Cañada del Buey. The small drainage originates within the Laboratory, crosses the central part of the Laboratory, and extends across San Ildefonso lands down to the Rio Grande. There are no perennial springs and no perennial reaches in Mortandad Canyon; it is entirely aphemeral. No significant snowmelt occurs in Mortandad Canyon.

The theoretically estimated 24-hour runoff for a 2-year recurrence 6-hour storm at the Laboratory boundary with San Ildefonso is less than 1 acre-foot; this would not expected to extend to the confluence with the Rio Grande. The conservative nature of the calculated estimates can be judged from the fact that there has not been any continuous flow from the upper and middle reaches of Mortandad Canyon to or across the eastern Laboratory boundary with San Ildefonso Pueblo for the last 33 years.

Cañada del Buey joins Mortandad Canyon about 1/2 mile upstream from the confluence with the Rio Grande. Cañada del Buey is entirely ephemeral in character. The Los Alamos County-operated White Rock STP discharges into Cañada del Buey about 2 miles upstream of its confluence with Mortandad. This discharge results in effluent-supported surface flow that regularly extends to the Rio Grande.

The theoretically estimated 24-hour runoff for a 2-year recurrence 6-hour storm in the subdrainage of Cañada del Buey within the Laboratory boundary at the eastern Laboratory boundary is less than 1 acre-foot. The theoretically estimated 24-hour runoff for a 2-year recurrence 6-hour storm in all of Cañada del Buey at the Rio Grande is about 6 acre-feet.

**Pajarito Canyon** -- Pajarito Canyon heads on the flanks of the Sierra de Los Valles. It has a total drainage area of about 13.6 square miles including its major subdrainages known as Two-Mile Canyon and Three-Mile Canyon. It originates on U. S. Forest Service lands and extends across the south-central part of the Laboratory before entering Los Alamos County lands in White Rock.

On a regional scale, Pajarito Canyon is an interrupted stream. This is because there are several perennial springs in the upper reaches of Pajarito Canyon that support flow in a perennial reach followed by an intermittent reach to within about a half mile west of the Laboratory boundary. Pajarito Canyon then has an ephemeral reach extending downstream to a point about 1 mile east of the Laboratory boundary. At this point a spring, termed Homestead Spring, supports another perennial reach for at least several hundred yards, followed by an intermittent and/or ephemeral reach that may extend down to near its confluence with Three-Mile Canyon. Homestead Spring is probably groundwater runoff of alluvial perched water recharged from west of the Laboratory boundary; this inference is supported by a tritium measurement that indicates the water is not likely more than a couple decades old. Both Two-Mile and Three-

Mile Canyons are ephemeral and/or intermittent because of groundwater runoff of alluvial water recharged by snowmelt.

East of the confluence with Three-Mile Canyon, Pajarito Canyon is ephemeral the remainder of the distance across the laboratory, on east across Los Alamos County lands through White Rock and down to a point about 0.4 miles upstream from its confluence with the Rio Grande. At this point a large perennial spring, fed from the main aquifer, identified as Spring 4A, and commonly called Pajarito Spring, supports perennial flow the remainder of the distance to the confluence with the Rio Grande.

In most years snowmelt extends onto the Laboratory lands for periods ranging from a few days to a few weeks and may extend down to or below the confluence with Three-mile Canyon. Snowmelt occasionally extends downstream as far as the confluence with the Rio Grande. Bill Purtymun recalls a few times since about 1970 that this has occurred.

The estimated 24-hour runoff for a 2-year recurrence 6-hour storm at the Laboratory boundary with White Rock is 2 acre-feet; and at the confluence with the Rio Grande, about 6 acre-feet.

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1 **Water Canyon** -- Water Canyon heads on the flanks of the
2 Sierra de Los Valles. It drains a total area of about 19.5
3 square miles. It originates on U. S. Forest Service lands
4 and extends across the southern portion of the Laboratory
5 all the way to its confluence with the Rio Grande in White
6 Rock Canyon.
7
8 On a regional scale, Water Canyon is an interrupted stream.
9 This is because there are several perennial springs in the
10 upper reaches of Water Canyon, including both Armistead and
11 American Springs, and other springs in the upper reaches of
12 Cañon del Valle, the major subdrainage to Water Canyon, that
13 support perennial reaches followed by intermittent reaches
14 limited to the area west of the Laboratory boundary and
15 State Road 501.
16
17 In terms of the Stream Standards definitions based on
18 natural flow, Water Canyon, and its major tributary Cañon
19 del Valle, are ephemeral from the western Laboratory
20 boundary all the way across all the active technical areas,
21 and on east past State Road 4 down to a point below the
22 confluence with its tributary Potrillo Canyon. At this
23 point there is a small perennial spring, known as Spring
24 5AA, fed by the main aquifer that supports a very short
25 perennial reach. This flow does not extend to the Rio
26 Grande.

There is frequently some regular anthropogenic flow in part of Water Canyon extending from near the southwest corner of the laboratory boundary to a point slightly downstream of the confluence with its tributary Cañon del Valle. This is because all of the flow from the Water Canyon Gallery is contained and diverted through a pipeline to the microstrainer facility near State Road 501. When the water from the gallery is not used for industrial supply, it is released and flows through stormwater drainages back into the Water Canyon drainage.

Snowmelt in Water Canyon seldom extends downstream as far as the Laboratory boundary, but has on one occasion, as recalled by Mr. Purtymun, in the early 1970s extended all the way to the Rio Grande.

The estimated 24-hour runoff for a 2-year recurrence 6-hour storm at the confluence with the Rio Grande is about 2 acre-feet.

The tributary Potrillo Canyon, and its tributary Fence Canyon, are entirely ephemeral in character. The simulated runoff flows in these tributaries is not expected to reach the Rio Grande.

**Ancho Canyon** -- Ancho Canyon heads on the plateau within the Laboratory near the middle of the southern Laboratory boundary. It has a total drainage area of about 7 square miles. It extends across Laboratory lands all the way to its confluence with the Rio Grande.

Ancho is ephemeral within the active Laboratory technical areas and on to the east past State Road 4 to a point about 0.8 miles upstream from its confluence with the Rio Grande. At that point a perennial spring fed by the main aquifer, and known as Ancho Spring, supports a perennial flow all the way to the confluence with the Rio Grande. No significant snowmelt occurs in Ancho Canyon.

The estimated 24-hour runoff for a 2-year recurrence 6-hour storm at the confluence with the Rio Grande is about 1 acre-foot.

**Chaquehui Canyon** -- Chaquehui Canyon heads on the plateau in the southeastern corner of the Laboratory. It has a drainage area of about 1.5 square miles. It extends across Laboratory lands all the way to its confluence with the Rio Grande.

Chaquehui Canyon is ephemeral all the way down to a point about 1/2 mile upstream from its confluence with the Rio

Grande. At this point a perennial spring fed by the main aquifer, and known as Doe Spring, supports perennial flow for a short distance followed by a short intermittent reach. About 1/4 mile upstream from the confluence with the Rio Grande, flow from perennial Springs 9 and 9A support perennial flow that extends to the Rio Grande. No significant snowmelt occurs in Chaquehui Canyon.

The estimated 24-hour runoff for a 2-year recurrence 6-hour storm at the Rio Grande is less than 1 acre-foot; this is not expected to extend to the confluence with the Rio Grande.

DIRECT TESTIMONY OF ALAN K. STOKER
IN RE: CONDITIONAL CERTIFICATION OF NPDES PERMIT NO. NM0028355

EXHIBIT STOKER-1

Detailed Resume of Los Alamos Experience

DIRECT TESTIMONY OF ALAN K. STOKER
IN RE: CONDITIONAL CERTIFICATION OF NPDES PERMIT NO. NM0028355

Detailed Resume of Los Alamos Experience
for
Alan K. Stoker

February 1989 - Present; Staff Member, Hydrology Team, Environmental Protection Group. Responsible for hydrologic aspects of routine environmental monitoring program f LANL, including water soils, sediment monitoring, monitoring of perched alluvial aquifers and environmental and resource monitoring for main aquifer in Los Alamos Area. Also Project leader for special studies of extent of saturation and contaminant transport in Mortandad Canyon.

September 1988 to February 1989; Project Leader for Environmental Restoration Program, Environmental Surveillance Group and Division Office. Assigned to serve coordination and interface role between LANL and the DOE Environmental Restoration Program technical support office to implement remedial investigation of potential environmental contamination problems from past activities at Los Alamos.

February 1987 to September 1988; Staff Member, Environmental Surveillance Group. My principal assignments included water supply system review and evaluation, and preparation of a major environmental status report on a previously-classified, major experimental/waste disposal area at Los Alamos in anticipation of starting remedial investigation.

June 1986 to February 1987; Associate Group Leader for Environmental Assessments, Environmental Surveillance Group. In addition to administrative functions related to budget, accounting, and personnel management for Group Office, I provided technical management as Project Leader for entire Comprehensive Environmental Assessment and Response Program (CEARP) and oversight of the Los Alamos National Laboratory NEPA compliance activities.

January 1980 to June 1986; Deputy Group Leader, Environmental Surveillance Group. I shared management responsibility for group of 14-25 professional and 20-30 technical personnel including budget, accounting, personnel management, personnel evaluation, and programmatic oversight and direction of environmental monitoring programs, special studies, and applied technical support programs for DOE. Principal technical achievements including the following:

--Development of the Comprehensive Environmental Assessment and Response Program (CEARP). .

--Project Leader for Pantex Environmental Impact Statement. I had full management responsibility for preparation of the Environmental Impact Statement (EIS) for the DOE Pantex Plant near Amarillo, Texas

--Management direction for Contaminated Canyon Study. I oversaw preparation of the report of a major study under the DOE Formerly Utilized Sites Remedial Action Program (FUSRAP) on radioactive contamination in the interconnected Acid, Pueblo, and Los Alamos canyon system leading to the Rio Grande in the Los Alamos area. This included review of project design, management of field studies, review of relevant records and environmental data, and writing/compiling final 250 page report.

--Direction of Routine Environmental Surveillance Program for Los Alamos. This was a continuation of the previous assignment of supervising the conduct and evolution of the routine environmental monitoring program at Los Alamos. I increased efforts to include nonradioactive contaminants in program.

August 1978 to December 1980; Alternate Group Leader, Environmental Surveillance Group. This position was a shared management responsibility for the work of 12-14 professional and 18-20 technical personnel. My principal responsibilities were direction of environmental monitoring programs including the compilation, writing and editing of the annual monitoring report for Los Alamos. I had management oversight for revision and updating of the Los Alamos Draft EIS into a Final EIS and for the FUSRAP studies on Bayo and Acid, Pueblo, and Los Alamos Canyons.

March 1976 to August 1978, Section Leader, Environmental Surveillance Group. I managed the routine environmental surveillance program including principal writing and report compilation responsibility for 1977 and 1978 surveillance reports. I made major technical contributions to preparation of the Draft EIS for Los Alamos, published in July 1978. I participated as co-principal investigator in the resurvey and extensive remedial actions at Technical Area 1, the original Los Alamos site. This included field work, data interpretation, and report preparation.

June 1974 to March 1976, Staff Member, Environmental Surveillance Group. I prepared the Omnibus Environmental Assessment for Los Alamos, performed environmental impact field studies at the Los Alamos Hot Dry Rock Geothermal project at Fenton Hill, and participated in the routine Los Alamos environmental monitoring program.

DIRECT TESTIMONY OF ALAN K. STOKER
IN RE: CONDITIONAL CERTIFICATION OF NPDES PERMIT NO. NM0028355

# EXHIBIT STOKER-2

List of Documents Cited as References by Alan K. Stoker

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List of Documents Cited as References by Alan K. Stoker


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M. Gary, R. McAfee Jr., and C. L. Wolf, eds., Glossary of Geology, American Geological Institute, Washington, D. C., 1972.

J. H. Abrahams Jr. and W. D. Purtymun, "The Hydrology and Chemical and Radiochemical Quality of Surface and Groundwater at Los Alamos, New Mexico, U. S. Geological Survey Administrative Release, January 1966.

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W. D. Purtymun, R. J. Peters, and J. W. Owens, "Geohydrology of White Rock Canyon of the Rio Grande from Otowi to Frijoles Canyon," Los Alamos National Laboratory Report LA-8635-MS, December 1980.

W. D. Purtymun, "Hydrologic Characteristics of the Main Aquifer in the Los Alamos Area: Development of Ground Water Supplies," Los Alamos National Laboratory Report LA-9957-MS, January 1984.

W. D. Purtymun and A. K. Stoker, "Water Supply at los Alamos: Current Status of Wells and Future Water Supply," Los Alamos National Laboratory Report LA-11332-MS, August 1988.

W. D. Purtymun and H. Adams, "Geohydrology of Bandelier National Monument, New Mexico," Los Alamos National Laboratory Report LA-8461-MS, July 1980.

W. D. Purtymun, R. J. Peters, and M. Maes, "Transport of Plutonium in Snowmelt Run-off," Los Alamos National Laboratory Report LA-11795-MS, July 1990.

W. D. Purtymun, "Geohydrology of Acid-Pueblo and DP-Los Alamos Canyons, 1945 - 1975," Appendix A of "Radiological Survey of the Site of A Former Radioactive Liquid Waste Treathment Plant (TA-45) and the Effluent Receiving Areas of Acid, Pueblo, and Los Alamos Canyons, Los Alamos, New

Mexico," Los Alamos National Laboratory Report LA-8890-ENV (simultaneously issued as U. S. Department of Energy, Formerly Utilized MED/AEC Sites Remedial Action Program report DOE/EV-0005/30), May 1981.

Environmental Restoration Office, "Installation Description," Chapter 2, of "Installation Work Plan for Environmental Restoration", Revision 2, Los Alamos National Laboratory report LA-UR-92-3795, November 1992.

War Department, U. S. Engineer Office, Albuquerque District, "Report on Water Supply Los Alamos Project, Los Alamos, New Mexico," Albuquerque, New Mexico, 9 October 1943.

Black & Veatch Consulting Engineers, "Report on Water Supply, Power System, Sewage Disposal, Gas Supply; Los alamos Project, Los Alamos, New Mexico," Black and Veatch Consulting Engineers, Kansas City, Missouri, April 17, 1946.

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S. G. McLin, "Determination of 100-year Floodplain El ations at Los Alamos National Laboratory," Los Alamos National Laboratory report LA-12195-MS, August 1992.

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EXHIBIT STOKER-3

Compilation of Definitions

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## Compilation of Definitions

--Definitions of types of streams taken from NM Water Quality Standards (boldface) and supplemented with AGI Glossary of Geology (lightface, and also in brackets when combined with a NMWQS definition) as follows:

**J."Ephemeral Stream" means a stream or reach of a stream that flows briefly only in direct response to precipitation or snowmelt in the immediate locality; its channel bed is always above the water table of the region adjoining the stream.** [The term "may be arbitrarily restricted" to a stream that does "not flow continuously during periods of as much as one month" (Meinzer, 1923, p. 58). Cf. intermittent stream.]

**N. "Flow," relative to the four definitions of streams herein, means natural flow ensuing from the earth's hydrologic cycle, i.e., atmospheric precipitation resulting in surface and, or, ground-water runoff. Natural in-stream flow may be interrupted or eliminated by dams and diversions.**

**P. "Intermittent stream" means a stream or reach of a stream that flows only at certain times of the year, such as when it receives** [water] **flow from springs** [or from some surface source.], **melting snow, or localized precipitation. Syn: temporary stream, seasonal stream.** [(b) A stream that does not flow continuously, as when water losses from evaporation or seepage exceed that available streamflow. --cf ephemeral stream. Syn. temporary stream; seasonal stream]

**Q. "Interrupted stream" means a stream that contains perennial reaches with intervening intermittent or ephemeral reaches. Ant: continuous stream.** [, or a stream that contains intermittent reaches with intervening ephemeral reaches.]

**CC. "Perennial Stream" means a stream or reach of a stream that flows continuously throughout the year in all years: its upper surface, generally, is lower than the water table of the region adjoining the stream. Syn: permanent stream, live stream.**

--Definitions of Other Hydrogeologic Terms
Reference: Glossary of Geology, Ed. Margaret Gary, Robert McAfee Jr, and Caron L. Wolf. American Geological Institute, Wash. D.C. 1972

"Confluence" (a) A place of meeting of two or more streams; the point where the tributary joins the main stream; ..."

"continuous stream" A stream that does not have interruptions in space; it may be perennial, intermittent, or ephemeral, but it does not have wet and dry reaches.

"downstream" means toward, at, or from a point near the mouth of a stream; in a direction toward which a stream (or glacier) is flowing.

"effluent (adj.)" (b) A liquid discharged as a waste, such as contaminated water from a factory or the outflow from a sewage works; water discharged from a storm sewer or from land after irrigation.

"Ground-water runoff" The runoff that has entered the ground, become ground water, and been discharged into a stream channel.

"runoff" That part of precipitation appearing in surface streams. It is more restrictive than streamflow as it does not include stream channels affected by artificial diversions, storage, or other works of man.

"direct runoff" The runoff reaching stream channels immediately after rainfall or snowmelting.

"streamflow" A type of channel flow, applied to that part of surface runoff traveling in a stream whether or not it is affected by diversion or regulation.

"stream channel" The hollow bed where a natural stream of water runs or may run; the long, narrow, sloping, trough-like depression shaped by the concentrated flow of a stream and covered continuously or periodically by water.

"surface runoff" The runoff that travels over the soil surface to the nearest surface stream, runoff that has not passed beneath the surface since precipitation.

"snowmelt" The water resulting from the melting of snow.

"alluvial" Pertaining to or composed of alluvium (... clay, silt , sand, gravel, or similar unconsolidated detrital material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semisorted sediment in the bed of

the stream ... ), or deposited by a stream or running water ...

"aquifer" A body of rock that contains sufficient saturated permeable material to conduct water to yield economically significant quantities of water to wells and springs.

"ground water" That part of the subsurface water that is the zone of saturation, including underground streams.

"ground-water runoff" The runoff that has entered the ground, become ground water, and been discharged into a stream channel.

"perched ground water" Unconfined ground water separated from an underlying main body of groundwater by an unsaturated zone.

"subsurface water" Water in the lithosphere in solid, liquid, or gaseous form. It includes all water beneath the land surface and beneath bodies of surface water.

"unsaturated zone, vadose zone, zone of aeration" A subsurface zone containing water under less than that of the atmosphere, including water held by capillarity; and containing gasses generally under atmospheric pressure

"outfall" ... (b) the vent or end of a drain, pipe, sewer, ditch, or other conduit that carries waste water, sewage, storm runoff, or other effluent into a stream, ...

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EXHIBIT STOKER-4

Map of Los Alamos Watersheds

(Note: Figure Identical to Aronson-2A)

# Los Alamos National Laboratory Hydrology

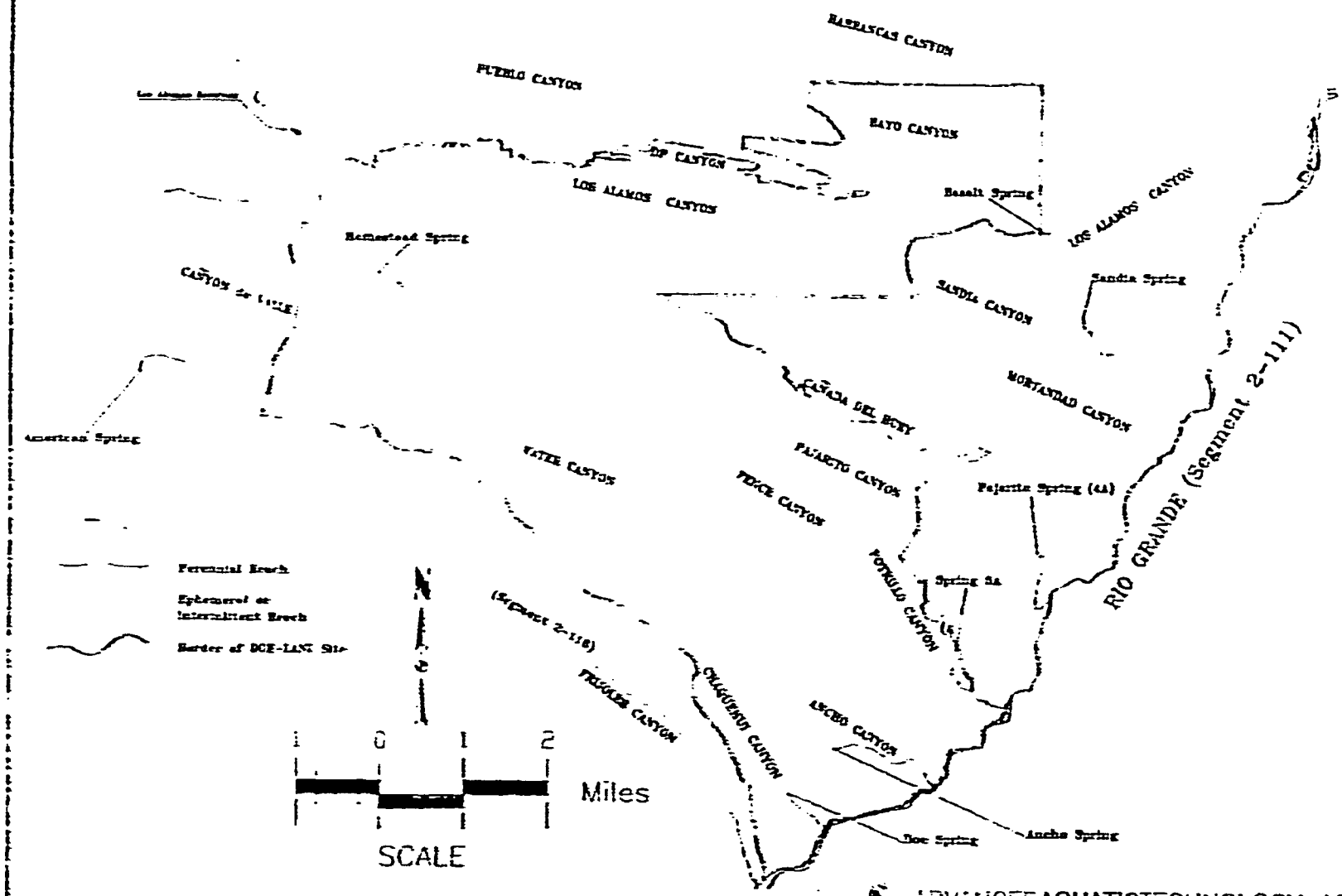


Exhibit 002-A

ADVANCED AQUATIC TECHNOLOGY ASSOCIATES, INC.

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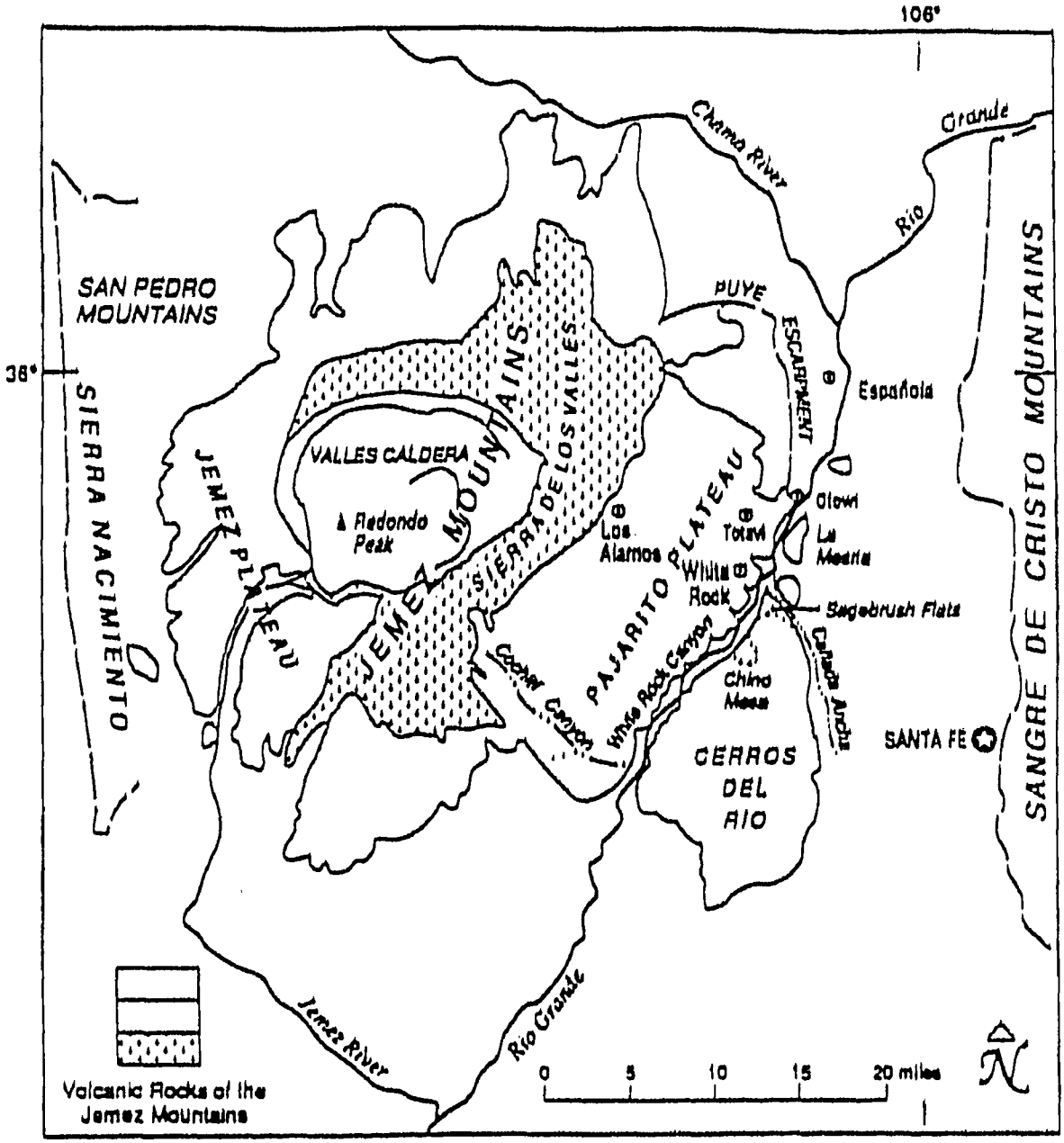
EXHIBIT STOKER-5

Figure of Los Alamos Geologic Setting




Los Alamos Geologic Setting

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EXHIBIT STOKER-6

Figure of Los Alamos Geologic Cross Section

## GEOLOGIC SECTION SHOWING STRATIGRAPHY AND STRUCTURE FROM THE SIERRA de los VALLES ACROSS THE PAJARITO PLATEAU TO THE RIO GRANDE

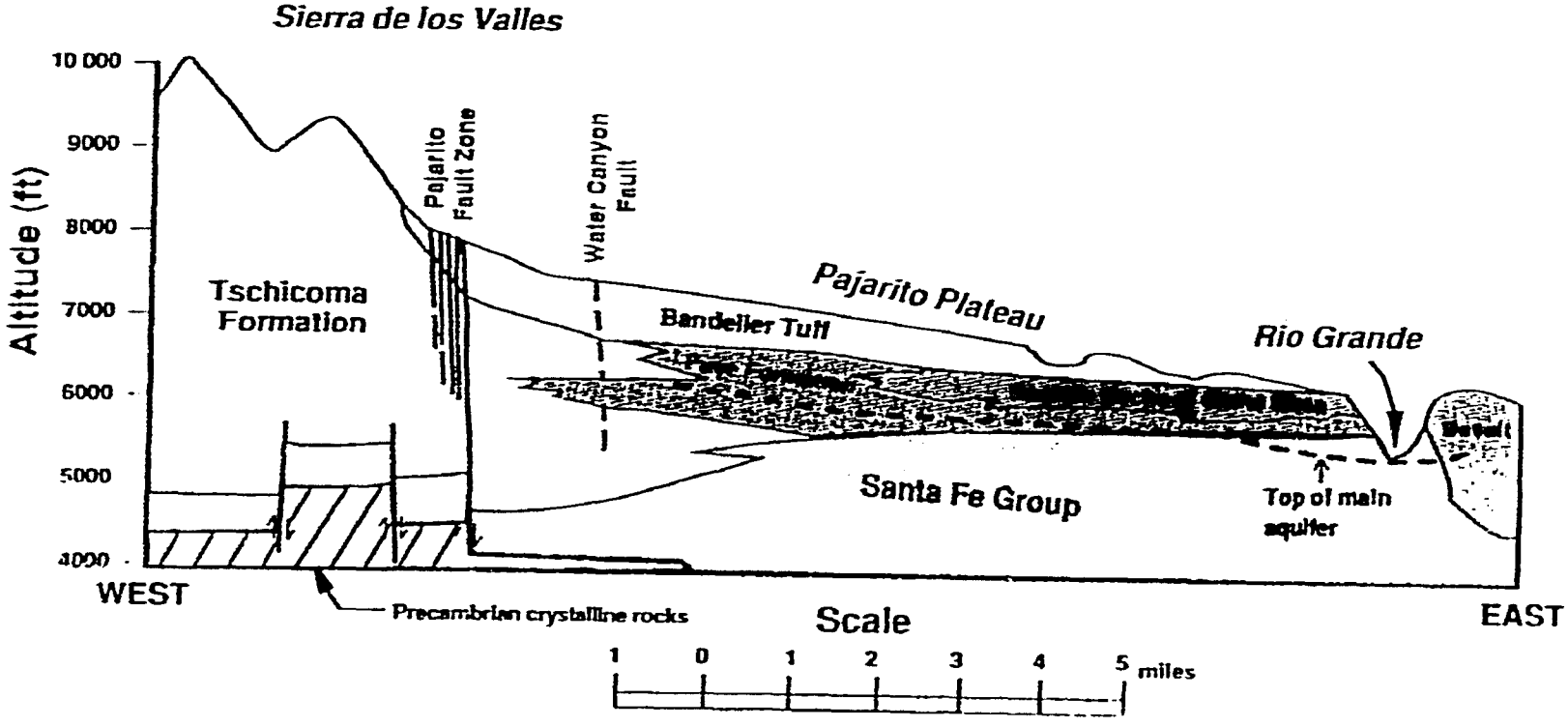

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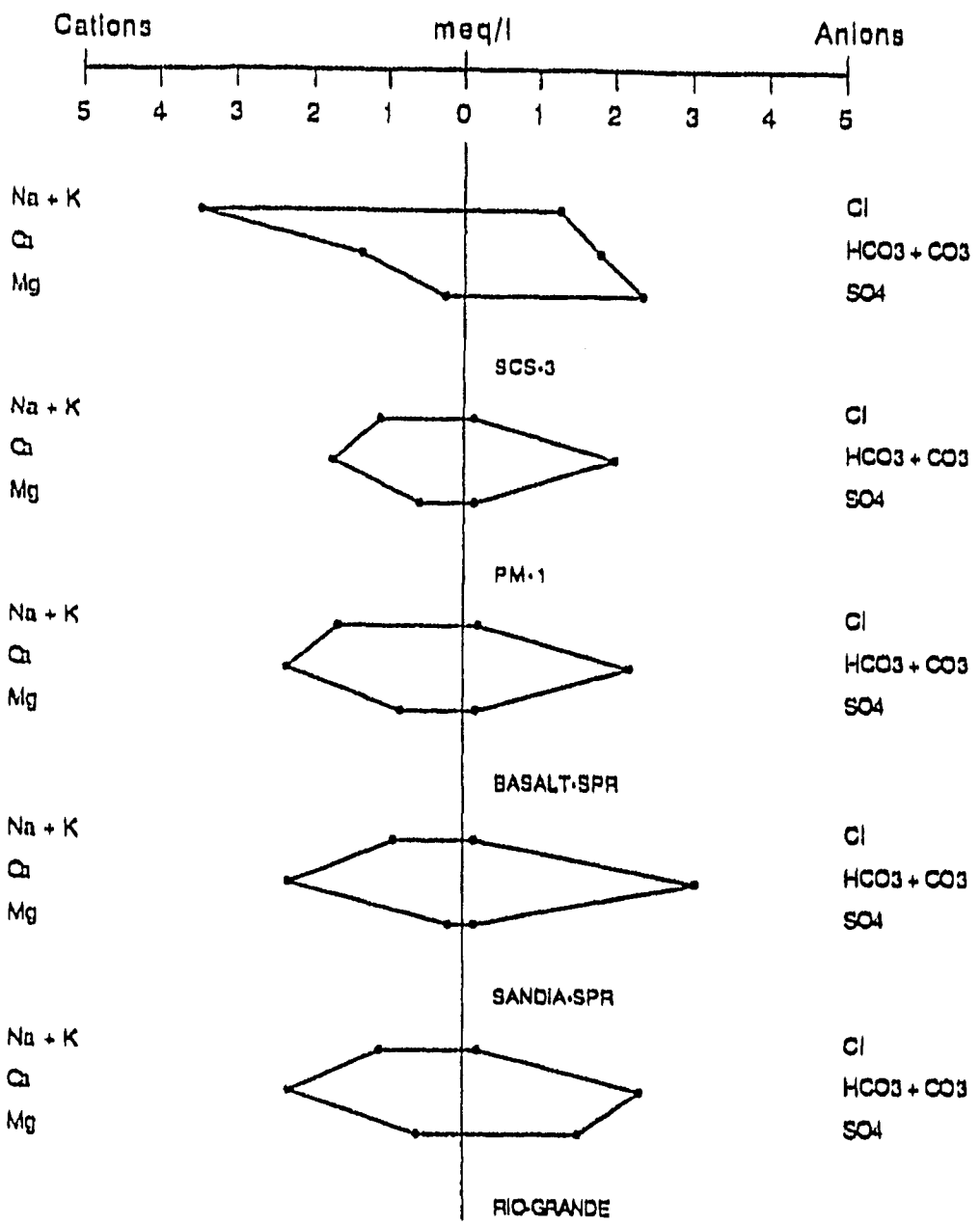
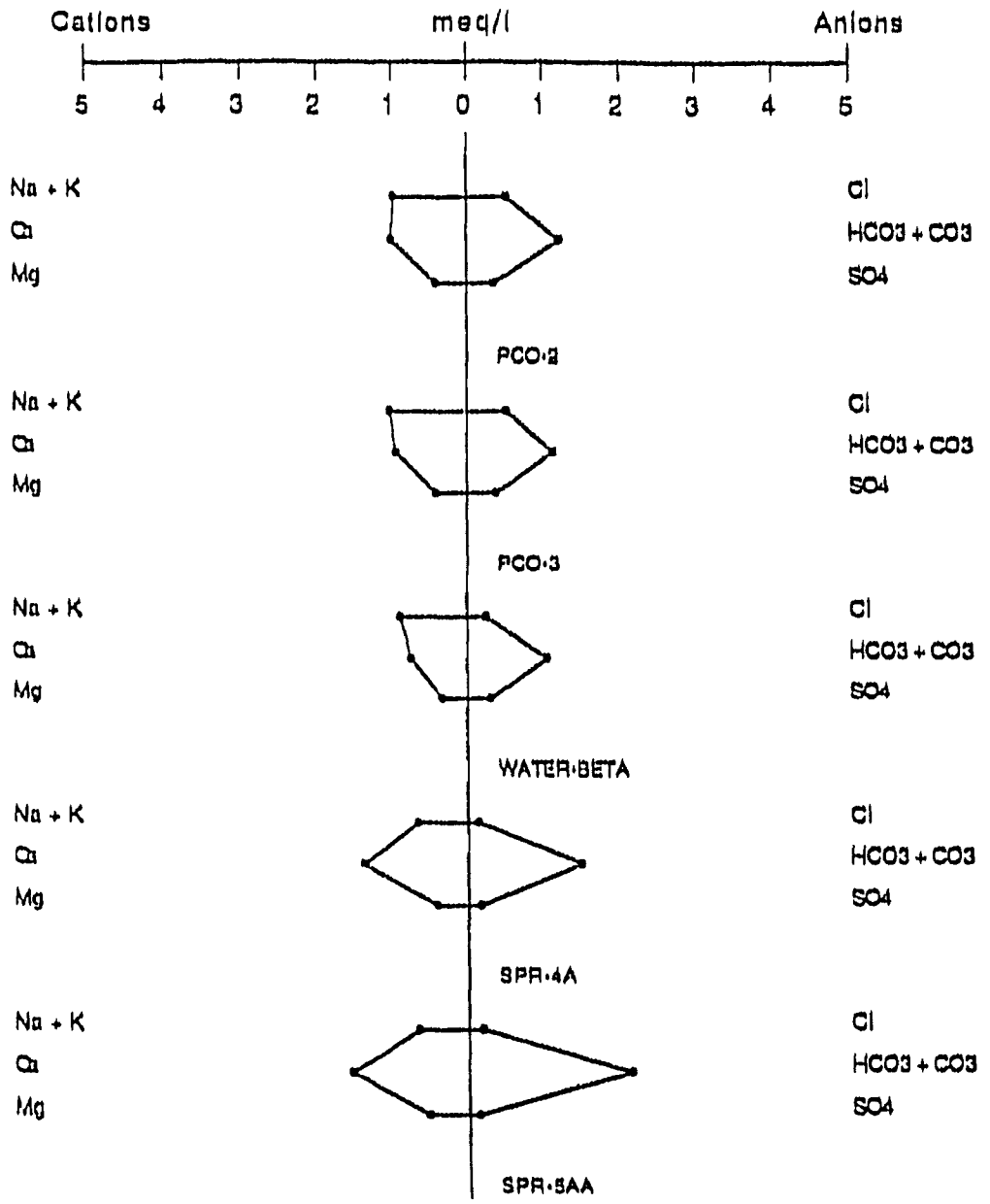
EXHIBIT STOKER-7

Figures Depicting Chemical Quality Comaprisons



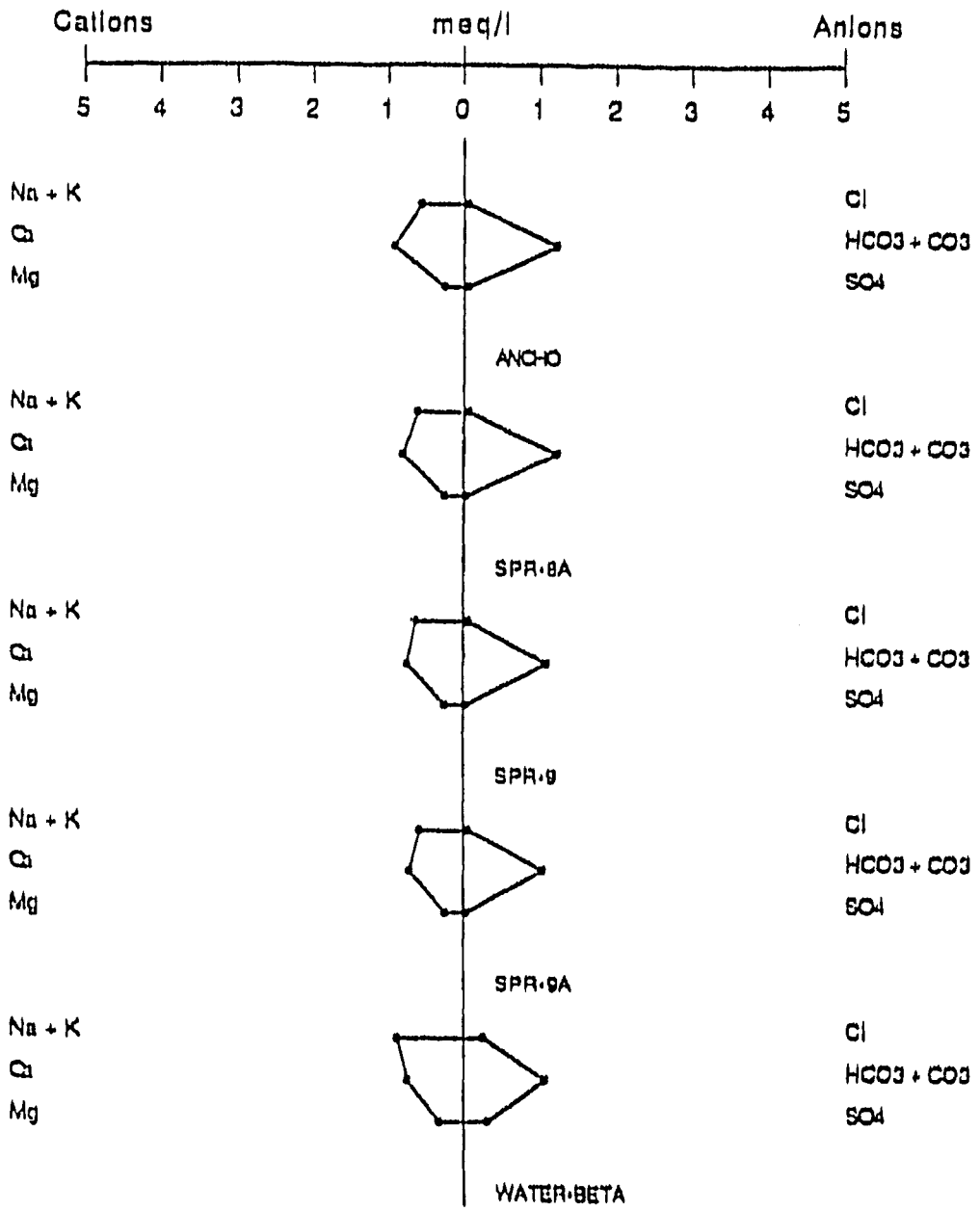

## Chemical Quality Comaprisons Figure A

- Main aquifer water from supply well PM-1 and Sandia Spring
- Surface water from Sandia Canyon (SCS-3) and the Rio Grande
- Intermediate perched water from Basalt Spring



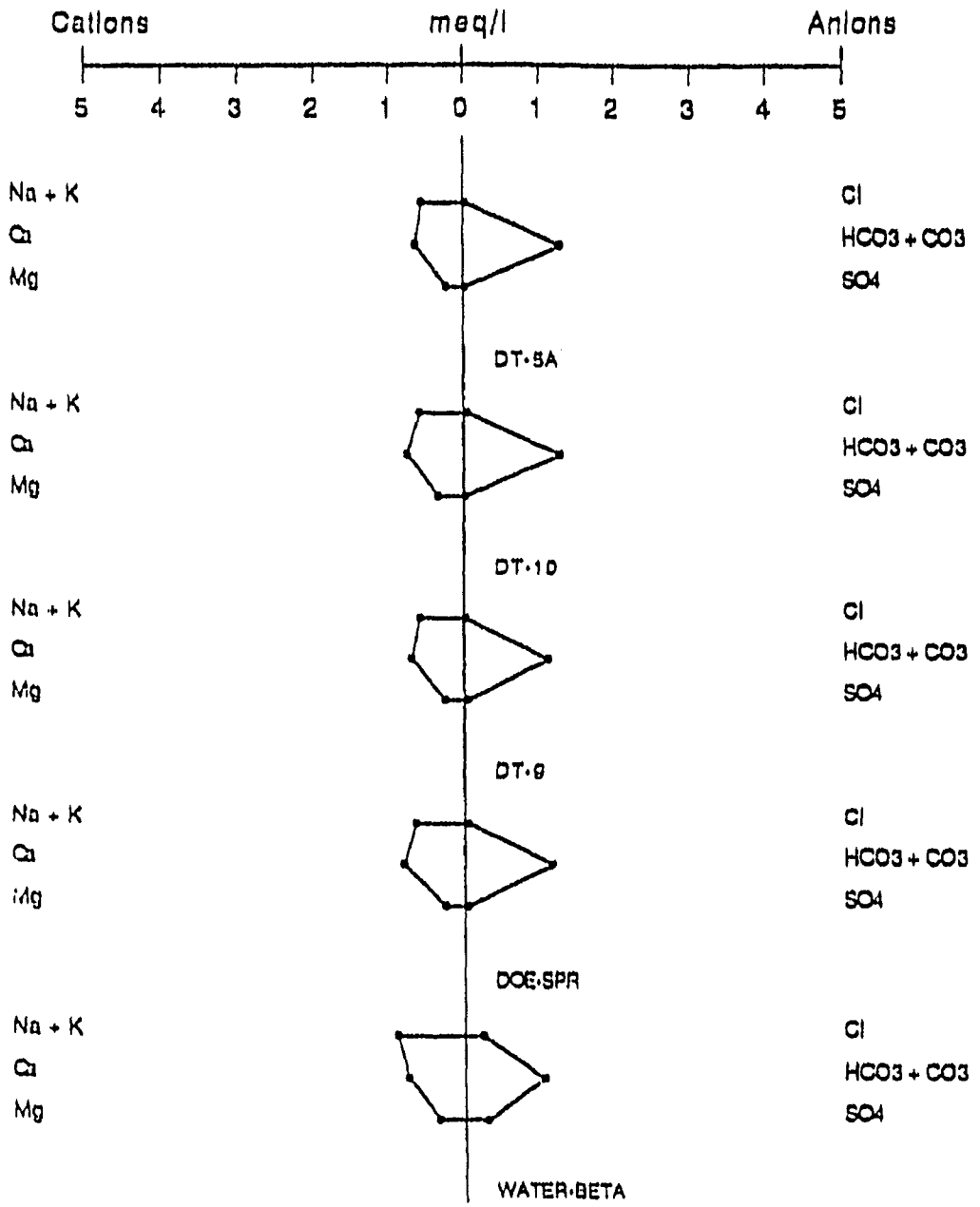

## Chemical Quality Comaprisons Figure B

- Main aquifer water from Pajarito Spring (4A) and Spring 5AA (Water Canyon)
- Alluvial perched groundwater in Pajarito Canyon at PCO-2 and PCO-3
- Surface flow in Water Canyon at location BETA.




## Chemical Quality Comaprisons Figure C

- Main aquifer water from Ancho Spring and Springs 8A, 9, and 9A (in White Rock Canyon between Ancho Canyon and Chaquehui Canyon
- Surface flow in Water Canyon at location BETA




## Chemical Quality Comaprisons Figure D

-Main aquifer water from deep test wells DT-5A, DT-9, and DT-10, and Doe spring, in Chaquehui Canyon

-Surface flow in Water Canyon at location BETA

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EXHIBIT STOKER-8

Description of Water Dating Methods

and Data Summary

geologically old carbon with no remaining carbon-14) the greater the estimated age will appear. The amount of dead carbon has been estimated by correlating values of carbon-14 with the stable isotope carbon-13 in each sample and calculating from a linear mixing model. The dating expert tells us that the true age is probably somewhere between the two estimates, probably closer to the minimum estimated age (Spangler 1992).

[a]Adaptation of text prepared in anticipation of publication of Environmental Surveillance Reports for calendar year 1991. Prepared by Alan K. Stoker, EM-8, March 25, 1993.

**References:**

Goff 1991: Personal communication between Alan K. Stoker (EM-8) and Fraser Goff (EES-1) (1991)

Spangler 1992: Personal communication between Alan K. Stoker EM-8, and Robert Spangler, Chem-Nuclear Geotech, Inc. Grand Junction Colorado (1992).

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# Description of Water Dating Methods and Data Summary[a]

by

Alan K. Stoker

The Hydrology Team of EM-8 is undertaking an effort to better understand the nature of recharge to the main aquifer in the Los Alamos area. As part of the environmental monitoring program and the groundwater protection management program, a series of special measurements was initiated in 1991 on selected water samples. This cooperative effort, involving researchers in the Laboratory's Earth and Environmental Sciences and Isotope and Nuclear Chemistry Divisions and staff from another DOE installation, is attempting to apply a range of geochemical techniques based on measurements of both radioactive and stable isotopes to help identify specific sources and estimate the age of water in the main aquifer. To date, low-detection limit tritium analyses have been completed on samples from 12 springs in White Rock Canyon and 5 samples from wells into the main aquifer (Goff 1991), and preliminary carbon-14 dating analyses have been made on samples from the same 5 wells into the main aquifer (Spangler 1992). These data are summarized in the following Table.

The values for tritium in the water range from less than detectable to about 7 pCi/L, with one value about 18 pCi/L. The highest value, for Doe Spring in Chaquehui Canyon, is a sample that must be collected in a pool in the stream channel after it has flowed over a rock face for some distance and thus is subject to mixing with some contemporary precipitation or contamination in the sediments. The values are all less than values for tritium in contemporary precipitation (about 30 to 60 pCi/L) and much less than the roughly 700 pCi/L that would be present now in water precipitated in northern New Mexico during the 1962-1963 period when tritium from atmospheric nuclear weapons testing was at its maximum. The conclusion is that there cannot be any significant component of recharge from water precipitated during the last several decades in the water from the main aquifer. The inference is that the water is considerably older.

Preliminary interpretation of carbon-14 data for samples from the same five deep wells indicates that the water ranges in age from about 1,000 years to more than 30,000 years (Spangler 1992). The results are tabulated at the bottom of the attached table. The results are presented as a range of values calculated by two different assumptions about the dissolution of carbonates from the rock matrix of the aquifer. The more dissolution of "dead" carbon (that is

## Low-Level Tritium Measurements in Groundwater Samples[a]

| Sample Location | Date of Sample | Tritium (as HTO) |
|---|---|---|
| *Springs in White Rock Canyon* | | |
| Spring 2 | Oct. 91 | 4.21+/-(0.36) |
| Spring 3 | Oct. 91 | 1.65+/-(0.39) |
| | Sept. 90 | 3.40+/-(0.29) |
| Spring 3B | Oct. 91 | 0.13+/-(0.29) |
| | Sept. 90 | 0.91+/-(0.29) |
| Spring 4A | Oct. 91 | 2.40+/-(0.39) |
| Spring 6 | Oct. 91 | 1.78+/-(0.32) |
| Spring 6A | Oct. 91 | 0.03+/-(0.29) |
| | Sept. 90 | 0.06+/-(0.29) |
| Spring 7 | Oct. 91 | 2.10+/-(0.29) |
| | Sept. 90 | 1.46+/-(0.29) |
| Spring 8 | Oct. 91 | 7.09+/-(0.55) |
| | Sept. 90 | 5.83+/-(0.29) |
| Spring 8B | Sept. 90 | 4.66+/-(0.29) |
| Spring 9A | Oct. 91 | 1.78+/-(0.29) |
| Ancho Spring | Oct. 91 | 4.21+/-(0.36) |
| | Sept. 90 | 3.40+/-(0.29) |
| Doe Spring | Sept. 90 | 17.71+/-(0.58) |
| *Wells In Main Aquifer* | | |
| Well LA-1B | Oct. 91 | 0.26+/-(0.29) |
| Well G-5 | Oct. 91 | 0.06+/-(0.29) |
| Well PM-1 | Oct. 91 | 1.65+/-(0.32) |
| Well PM-5 | Oct. 91 | 0.29+/-(0.29) |
| Test Well DT-5A | Oct. 91 | -0.23+/-(0.29) |

[a] Counting uncertainties are in parenthesis.

## Age of Main Aquifer water based on Carbon-14 Dating

| Sample Location | Date of Sample | Inferred Age Range[b] | |
|---|---|---|---|
| *Wells In Main Aquifer* | | *Maximum* | *Minimum* |
| Well LA-1B | Oct. 91 | >39,000 | >27,000 |
| Well G-5 | Oct. 91 | 10,900 | 6,110 |
| Well PM-1 | Oct. 91 | 14,000 | 5,620 |
| Well PM-5 | Oct. 91 | 5,140 | 1,040 |
| Test Well DT-5A | Oct. 91 | 4,560 | 1,810 |

[b] Age range inferred by calculations for maximum age assuming no carbonate dissolution, and for minimum age assuming linear dissolution of carbonates along flow path based on correlation of carbon-14 and carbon-13 values.

DIRECT TESTIMONY OF Alan Stoker
IN RE: CONDITIONAL CERTIFICATION OF
NPDES PERMIT NO. 0028355

STATE OF New Mexico )
) s.
COUNTY OF Los Alamos )

I have prepared the foregoing Direct Testimony of Alan Stoker, and it is true to the best of my knowledge, information and belief.

Before me this 30 day of March, 1993.

Alan Stoker

Subscribed, sworn to and acknowledged before me this 30 day of March, 1993.

Notary Public

My commission expires:
12/14/96