RAS 14488

U.S. NUCLEAR REGULATORY COMMISSION
In the Matter of U.S. Army (Jefferson Proving Ground)
Docket No. 40-8838-MLA Official Exhibit No. 1.
OFFERED by: Applicant/Licensee Intervenor Save The Valley
NRC Staff Other ________
IDENTIFIED on ________ Witness/Panel ________
Action Taken: ADMITTED REJECTED WITHDRAWN
Reporter/Clerk ________

Save the Valley (Norris) Ex. 1

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	Docket No. 40-8838-MLA
U.S. ARMY	)	ASLBP No. 00-776-04-MLA
(Jefferson Proving Ground Site)	)	July 13, 2007

PREFILED DIRECT TESTIMONY AND EXHIBITS OF

CHARLES H. NORRIS, LPG

EXHIBITS CHN AND CHN-1

IN SUPPORT OF CONTENTION B-1

OF INTERVENOR SAVE THE VALLEY, INC.

DOCKETED
USNRC

October 25, 2007 (2:00pm)

OFFICE OF SECRETARY
RULEMAKINGS AND
ADJUDICATIONS STAFF

TEMPLATE = SECY-028

SECY-02

I. Qualifications

Q.001 Please state your name and business address.

A.001 My name is Charles H. Norris and my business address is 1928 E. 14th Avenue, Denver Colorado 80206.

Q.002 What is your educational background?

A.002 I received a B.S. degree with high honors and distinction in geology from the University of Illinois (Urbana-Champaign) in 1969. I received a MS degree in geology from the University of Washington (Seattle) in 1970, where I held a National Science Foundation fellowship. I worked toward a Ph.D. in geology at the University of Illinois (Urbana-Champaign) 1970-1972 and 1987 to 1992, completing all requirements except the dissertation and final defense.

Q.003 For whom do you work and in what capacity?

A.003 I work for Geo-Hydro, Inc. I am the founder and a principal in the company. I am a geologist and specialize in areas of hydrogeology, aqueous geochemistry, and numerical modeling of hydrogeology and geochemistry. I hold corporate positions of Vice President, Treasurer, and CEO.

Q.004 What is your professional background?

A.004 A copy of my resume has been provided to the Board and other parties previously and is attached to this testimony as Exhibit CHN-1. Briefly, I began professional work as a geologist in 1970 for Shell Oil Company, initially as an exploration geologist and eventually a petrophysicist. I worked for a number of companies in the oil industry between 1972 and 1981. In 1981, I started Emerald Gas and Oil, a small Colorado exploration company and worked there through 1986. In 1987 I returned to the University of Illinois (Urbana-Champaign) where I held a research faculty appointment with the Laboratory for Supercomputing in Hydrogeology. That position entailed hydrogeologic research, code development for Laboratory fluid-flow and geochemical models, liaison work with industry supporters, and teaching industry and academic short courses. From 1992 to 1996, I worked for HydroSearch, Inc., in Denver and in 1996 I started Geo-Hydro, Inc., where I work today. Since 1992 I have provided consulting services in geology and hydrogeology to a variety of industry, governmental and private clients. That work has included site characterization, site assessment, license review, compliance review, and modeling of fluid flow, geochemical reactions and processes, and fate and transport.

Q.005 Are you licensed to practice geology, hydrogeology and/or geochemistry?

A.005 I am a licensed Professional Geologist in six states, including Indiana, and a registered Environmental Professional in Colorado. Hydrogeology and geochemistry are considered specializations in geology for licensing purposes.

Q.006 Have you received any academic honors or professional recognition in your fields of study and practice?

A.006 I was awarded memberships in the academic honor societies of Phi Kappa Phi, Sigma Xi, and Phi Beta Kappa. I did graduate study under an NSF Fellowship. I am currently a member of the National Groundwater Association and the Colorado Ground-Water Association, where I have served as a Board member and as President. I have twice been invited to present to technical committees of the National Research Council of the

National Academies of Science. I recently completed a year-long appointment to a West Virginia quality assurance panel where I served with state, federal, and industry representatives evaluating aspects of permitting review by state regulators.

Q.007 Have you testified as an expert previously in any jurisdiction or proceeding?

A.007 Yes, in a variety of proceedings. I have been recognized as an expert in geology, hydrogeology, geochemistry and/or modeling before federal district courts (MO, WV), state district court (CO), a special commission (IL LLRW Commission), state regulatory agencies for environment or resources (TX, WY, IL, WV, OH, IN, PA, WV), and local hearing authorities in several states.

Q.008 Do you have a written summary of your education, employment, experience and background, and papers and presentations you have made over your career?

A.008 The copy of my resume attached as an exhibit to this testimony supplies such a summary.

Q.009 What materials have you reviewed and actions have you taken in preparation for your testimony?

A.009 I have reviewed the initial Field Sampling Plan (FSP) submitted to the Nuclear Regulatory Commission (NRC) by the Department of the Army (Army) in May 2005 for Depleted Uranium (DU) Impact Area Site Characterization at the Jefferson Proving Ground (JPG), Madison, Indiana, as well as the various addenda to the FSP which have been submitted subsequently. I have also reviewed:

- all of the available Environmental Radiation Monitoring (ERM) data from JPG;
- all of the geology and hydrogeology portions of documents and sources that have been disclosed by parties to this proceeding;

- weather records from and near the site, stream gauging data that is available by Internet for streams in the vicinity of JPG, and published topographic maps of the area around JPG;
- statistics related to analyses of radioactive isotopes, and
- techniques for field sampling and laboratory analysis of radioactive isotopes.

Q.010 What are the topics of your testimony?

A.010 I will testify on two general topics. The first general topic is the deficiencies of the hydrogeologic portions of the FSP, particularly those portions relating to the siting and installation of the various sampling stations for surface water, groundwater, and sediment. The second general topic is the deficiencies in the sampling and analysis protocols for those media. In both cases, the testimony will focus on the inability of the FSP, as a result of these deficiencies, to meet its charge to provide characterization of the Depleted Uranium (DU) site at Jefferson Proving Grounds that is adequate to support the fate and transport modeling required for purposes of the ultimate decommissioning of the site in accordance with NRC regulations.

II. Hydrogeologic Characterization

A. General Considerations

Q.011 As you understand it, what is the basic purpose of the hydrogeologic characterization activities in the FSP as modified in the addenda?

A.011 The hydrogeologic characterization activities must provide site-specific input data to the site modeling for JPG that accurately reflect the process(es), pathway(s), rate(s), and timing(s) of DU migration from the source areas to potential receptors both on- and off-site by water transport mechanisms.

Q.012 What types of water can transport DU?

A.012 Three types of water can transport DU: groundwater, surface water, and water in soils and rocks above and/or below zones with groundwater. This third water group is sometimes called soil-zone water, vadose water, or unsaturated-zone water. Groundwater at JPG consists of water moving through pores of saturated soil and rock and water moving through karst features in the rock. Surface water at JPG consists of channelized stream flow and unchannelized sheet wash and rill flow that occur in response to precipitation. Channelized stream flow has two components, flow in direct response to precipitation and flow from the discharge of groundwater to the stream.

Each of these three types of water can receive water (recharge) from or provide water (discharge) to the other two types of water. A given point of exchange between water types can reverse between recharge and discharge depending upon seasonal and event-related precipitation patterns.

Q.013 You introduced the term *karst features*. What do you mean by karst features?

A.013 Karst features are enlarged openings in earthen materials that result from water dissolving some of the materials as it moves through them. Karst is a term that originally applied solely to limestone and dolomite rocks, like those that form the bedrock at JPG. Karst features can occur in soils or rock but are usually best expressed in rock. The longer the conditions for karst development persist, the larger and more integrated the karst features become, and karst features typically come to dominate a groundwater flow system over geologic time. On the small-scale end of karst features are pores within rock that are enlarged and/or better connected due to the dissolution. On the large-scale end are major cave systems like Carlsbad or Mammoth. Under JPG and the DU area, there are shallow caves that are large enough to enter and survey. Between 1994 and 1997 some of these caves were mapped in a program unrelated to any of the current site characterization activities (Sheldon, Ray. 1997. Jefferson Proving Ground Karst Study). Parts of the karst system under JPG have surface expression as sink holes, which provide direct capture of surface water by the karst networks.

Q.014 How and when do karst features form?

A.014 Karst features may develop from the surface of the land and propagate downward. Karst features may also develop in the subsurface where two groundwater flows mix and then propagate in the direction of the combined flow. Karst features may form at any time after a limestone or dolomite layer has formed, when the proper chemical conditions exist. Hence, for the Ordovician and Silurian bedrock under the DU impact area (Regional Range Study (USACHPPM No. 38-EH-8220-03, JPG, IN, Sep 02, Sub-section 6.2.2, page 3 of 41)), there is a period of about 400 million years during which multiple karst networks may have developed, each with its own geometry. Such paleo-karst networks may be isolated or intersect with each other and with the shallow network that has been partially entered and mapped. Flow through such an anastomosing system can be extremely complex, even reversing directions depending upon seasonal or event-related precipitation patterns.

Q.015 For each of the water types you have described, what mechanisms are available to transport DU?

A.015 There are three mechanisms for each of the water types. First, there is transport by means of dissolved DU. Second, there is transport by means of entrained sediments that contain DU. Third, there is transport by means of suspended fine particles that contain DU.

Q.016 What factors influence the transport of dissolved DU?

A.016 Transport of dissolved DU is independent of water velocity. However, it is dependent upon water chemistry, since uranium is much more soluble in some water chemistries than others. Thus, it is important to track how water chemistry changes along any particular transport path or changes with time (*e.g.*, seasonally) at any particular point in the flow path.

Q.017 What factors influence entrained-sediment transport of DU?

A.017 The capacity of water to carry entrained sediments is a function of water velocity primarily; the greater the velocity the greater the capacity in terms of both particle size and total mass. For this reason, entrained sediments are a more important transport mechanism for surface water and for groundwater flowing in larger karst features than for unsaturated flow or saturated flow in soil and bedrock pores where velocity is typically much lower. Entrained sediments may include DU particles or soil particles that are contaminated with DU. Since entrainment is a function of velocity, the mass of entrained DU will change from place to place and from time to time depending upon transient variations in water velocity.

Q.018 What factors influence the suspended transport of DU?

A.018 Transport of DU in suspension is related to sediment entrainment. For very small particles or particles with near-neutral buoyancy, reduced velocity will not necessarily cause the particles to settle from water. DU contamination on such particles move with the water, analogously to dissolved DU, even at very slow rates of movement. Biological and organic particles and colloidal inorganic particles are two such carriers of DU. Physical or temporal changes along a particular flow path can change the suspended fraction of DU.

Q.019 What sources and types of hydrogeologic data are required to meet the needs of meaningful model of DU fate and transport from the DU impact area to potential receptors?

A.019 Meaningful fate and transport modeling requires the following types of data:

- Mapped critical pathways, presumably dominantly karst, of groundwater flow from source areas to discharge points, whether such discharge is within or outside JPG.
- Mapped points of major exchange between surface water and groundwater along streams, with sufficient measurements of that exchange to track temporal variations of quantity and direction of exchange.
- Measurements in groundwater of chemical parameters that control uranium mobility at places and times sufficient to establish spatial and temporal variability along each critical groundwater path.
- Measurements of dissolved and suspended DU concentrations in groundwater at

places and times sufficient to establish spatial and temporal variability along each critical groundwater path.

- Measurements of DU concentrations in sediments entrained by groundwater at places and times sufficient to establish spatial and temporal variability along each critical groundwater path. This will necessarily include periods of seasonally low flow, periods of seasonally high flow, and flushing events.
- Measurements in the streams of chemical parameters that control uranium mobility at places and times sufficient to establish spatial and temporal variability along each stream.
- Measurements of dissolved and suspended DU concentrations in streams at places and times sufficient to establish spatial and temporal variability along each stream.
- Measurements of DU concentrations in sediments entrained by streams at places and times sufficient to establish spatial and temporal variability along streams. This will necessarily include periods of seasonally low flow, periods of seasonally high flow, first-flush conditions, and, if they occur, during singular climate events such as a 25-year or rarer precipitation or drought event.
- Measurements of dissolved and suspended DU concentrations in unsaturated soils beneath DU penetrators at places and times sufficient to establish spatial and temporal variability for all soil types in the DU impact area.

B. Major FSP Hydrogeologic Elements

Q.020 What are the major elements of the hydrogeologic characterization in the FSP, as modified in the addenda, that you will address in your testimony?

A.020 My testimony will address the following seven major elements of the hydrogeologic characterization program:

- Fracture Trace Analysis
- Electrical Imaging Survey
- Gauging of Streams and Caves and Staging of Streams
- Well Location Assessment and Selection
- Well Installation and Assessment
- Surface Water Sampling
- Sediment Sampling

1. Fracture Trace Analysis

Q.021 What is a fracture trace analysis?

A.021 A fracture trace analysis is a study of remote sensing data from a site, such as aerial photographs or satellite imagery, in an effort to find the traces, the visible expressions, of fractures at or near the earth's surface.

Q.022 What are the major design elements of the fracture trace analysis as laid out in the FSP and related addenda?

A.022 The description of the JPG fracture trace analysis study is found in Subsection 5.2 of the FSP (parts of pages 5-1 and 5-2). As stated there, the premises behind the effort are two-fold. First, groundwater flow through sedimentary rocks is enhanced where rocks are fractured, particularly where fractures can be further enhanced through dissolution, *i.e.*, karst development, forming groundwater conduits. Second, some fractures can be seen as linear traces on aerial photographs. It is unstated but implied that mapping linear traces that are visible on the aerial photographs is mapping fractures and is equivalent to mapping groundwater conduits. Based upon the proposed program in the FSP, the major elements of the fracture trace analysis are as follows:

- Analysis will be based upon vintage (pre-JPG, black and white), stereo-paired aerial photographs,
- traces that are mapped on the aerial photographs will be quality ranked,
- traces will be transferred into an ArcView shape file for subsequent applications,
- the results of this analysis may be integrated with earlier USGS trace analysis work that included the area of this study (Greeman, 1981),
- after completion of the analysis, a one-day field verification and evaluation will be done by a geologist, and
- the stated use of the completed analysis is to "... further refine the areas or lines that will be completed as part of ..." the electrical imaging survey.

Q.023 Is this design for the fracture trace analysis adequate for purposes of JPG DU site characterization?

A.023 No, it is not.

Q.024 What are the deficiencies of that design for the fracture trace analysis?

A.024 What is described in the FSP is not a fracture trace analysis and it certainly does not identify groundwater conduits. It is an exercise in mapping lineaments. Lineaments are lines that can be observed on aerial photographs or similar media. Lineaments may represent the visible expressions of fracture. They may also represent other geologic features and they may represent non-geologic features. Of the subset of lineaments that are fractures, only a further subset may represent the solution-enhanced fractures sought as groundwater conduits. Beyond understating the complexity of a true,fracture trace analysis and overstating the understanding that will come from it, specific deficiencies of the fracture trace analysis in the FSP include the following:

- A fracture trace analysis can only identify fractures that have an expression on the surface of the earth. It cannot distinguish between simple fractures and solution–enhanced fractures that are part of karst networks. It cannot locate or assist in locating conduit systems that are not associated with fractures or that are associated with fractures that have no surface expression.
- Unless a bedrock fracture has propagated itself through the blanket of glacial sediments, it cannot be observed. Fracture trace analyses are most useful and applicable when bedrock is at the surface and fractures are relatively easily observed. That is not generally the case at JPG, where there is a widespread layer of (relatively) young glacial sediments that mantel the bedrock.
- Glacial sediments are often themselves fractured and traces of those fractures may have no bearing on the deeper bedrock fractures of interest. Previous characterization studies, summarized in the Regional Range Study (USACHPPM No. 38-EH-8220-03, JPG, IN, Sep 02, Sub-section 6.2.3.1, page 4 of 41), describe fracturing in the glacial tills at JPG.

- Limiting the analyzed imagery to pre-JPG aerial photographs is unduly restrictive and handicaps the interpreter. Vintage black and white, visible-spectrum photography conveys one set of information. But other spectra and other media can supplement that information greatly. For example, infrared photography more directly identifies features associated with groundwater discharges than does visible black and white. Color and false color imagery brings out features unnoticed in black and white. Side-scan and ground-penetrating radar provide yet different images and actual subsurface information, particularly valuable in a seeing through thin glacial sediments. All technology should be considered for use, and the best method(s) selected for the task and conditions. Sometimes that may be the oldest technology, but not in this case.
- Known surface expressions of groundwater conduits must be integrated into the analysis of the aerial photographs. In particular, the prior study of JPG karst features (Sheldon, 1997) mapped cave mouths and other entries at sink holes that must be integrated into the analysis.
- Integration of the earlier extensive work by the USGS (Greeman, Theodore K., 1981, Lineaments and Fracture Traces, Jennings County and Jefferson Proving Ground, Indiana, U. S. Geological Survey, Open-File Report 81-1120) should not be merely a "possible" element of this study. It is a must. That study is available and has been used in previous JPG studies, *e.g.*, Army's Final Responses to NRC's RAIs, November, 2004 (ML043360318). Because of the inherent subjectivity of the fracture trace analysis process, it is important to consider

differences between or among other trace analyses that used alternative methods, criteria, or data types. Important insights into the geology of a site result from comparing the multiple interpretations that derive from several analyses that use different criteria when they exist, as they do for this site with the USGS study.

- A one-day walk-over field visit by a geologist after the analysis has been completed is both too little and too late. Distinguishing the geologic meanings of lineaments identified from aerial photos is difficult, time consuming work, that should be done before, not after, the analysis is completed. The walk-over should also include areas off-road which include significant DU concentrations. It is not something that can be done in cursory fashion and, for an area of this size and with the risks of unexploded ordinance, it cannot be done adequately in a day.
- Mapping only linear traces in an area with rolling topography, as this area has, limits the analysis to vertical features, since only vertical features will produce a linear trace on a curved land surface. To the extent that the mapped traces may represent bedrock fractures, intersections of fractures that dip are likelier to develop major karst elements than are intersections of vertical fractures. Yet, potentially important dipping fractures would not be identified by the fracture trace analysis described in the FSP.

Q.025 Are any of these deficiencies corrected by later addenda to the FSP?

A.025. No, they are not.

Q.026 Of what significance are the deficiencies of the fracture trace analysis?

A.026 Pursuant to the FSP, an interpreted fracture trace is a mandatory criterion for the location of a groundwater characterization well (FSP Section 6.2, page 6-2, and Section 6.1, page 6-1 of the Well Location Selection Report, Site Characterization, SAIC, January, 2007). Since not all mapped traces will represent bedrock fractures and not all traces that represent bedrock fractures will be solution-enhanced conduits, relying on the fracture trace analysis absolutely will identify possible well locations for which there is no underlying geologic support. Of more concern, however, is the inverse. There are geologic settings that are of interest, and that may be critical for site characterization, that cannot be locations of characterization wells pursuant to the FSP because there will be no surface expression of their conduit systems. In particular, there are area karst networks that have developed independently of fractures or whose controlling fractures are too deep to reach the present day surface or are dipping rather than vertical. By limiting the locations of characterization wells to karst networks shallow enough to have vertical surface expression through the mantel of glacial till, the characterization is inherently biased, with no way to see or test for magnitude of that bias. In my opinion, this is a deficiency of critical significance to the adequacy of JPG site characterization.

2. Electrical Imaging Survey

Q.027 What is an electrical imaging survey?

A.027 An electrical imaging (EI) survey is a geophysical survey technique that measures some type of electrical response within the earth to an electrical signal transmitted at the surface of the earth. From the response, electrical properties of the earthen materials are calculated and from those properties inferences are drawn about the geological conditions of those materials. EI surveys are usually performed along a two-dimensional surface grid over an area of investigation in order to provide a three-dimensional map of the inferred subsurface geology.

For the EI survey described in the FSP, the transmitted signal is a direct current and the measured response is the voltage drop between pairs of electrodes measured along a line of electrodes away from the source. From the voltage drop, the resistivity of the rock along the line is computed. The FSP EI survey is not a grid application, so three-dimensional mapping of its results is not possible.

Q.028 What are the major design elements of the EI survey as laid out in the FSP and related addenda?

A.028 The EI survey description summary is found in the FSP in Subsection 6.1., on pages 6-1 and 6-2. Appendix B of the FSP describes the actually implementation of the survey in more detail. The FSP description was modified in Addendum 3 (July 2006) to the FSP in Section 3.

The starting premise for the EI survey is that the fracture trace analysis has, in addition to mapping visible-spectrum linear anomalies that represent bedrock fractures, identified "... possible areas of preferential flow pathways (groundwater conduits) ...", although this is not among the stated objectives of the fracture trace analysis as described in Section 5.2 of the FSP. The stated purpose for the EI survey on page 6-2 of the FSP is "... to refine the locations of the potential preferred groundwater flow pathways and to further characterize the subsurface features." The FSP also describes on page 4-2, in Table 4-1, an additional purpose of the EI survey, specifically that the "[s]urvey will be conducted to identify entry and exit pathways." The major elements and considerations for the EI survey are as follows according to the FSP on page 6-2:

- the "final design, location, and orientation of the geophysical investigation lines" is dependent upon the completion of the fracture trace analysis,
- electrodes are placed along each survey line,
- an electrical current is placed into the ground between two electrodes, and the resulting voltage drop is measured at successive pairs of electrodes of variable distances between them,
- from the voltage drop data, a two-dimensional model of the resistivity field is calculated and contoured for interpretation, where
- the premise for the interpretation is that areas of low electrical resistivity represent water-bearing zones of high conductivity, *i.e.*, they are groundwater conduits, and
- well locations will be picked only where (SAIC's) fracture trace analysis lineaments coincide with EI survey resistivity anomalies.

Following receipt of the results of the fracture trace analysis, Addendum 3 to the FSP formally designated the "final design, location, and orientation of the geophysical investigation lines" by positioning each line along an existing site road.

Q.029 Is this design for the EI survey adequate for purposes of JPG DU site characterization?

A.029 No, it is not.

Q.030 What are the deficiencies of that design for the EI survey?

A.030 The EI survey is deficient in its design elements, its interpretation premise, and its expectations of what the survey can provide toward the necessary characterization of the site. The design deficiencies include the following:

- The orientation of the EI survey lines were to have been determined based upon the final fracture trace analysis results. The fracture trace analysis results showed lineament traces overwhelmingly with a NE-SW or NW-SE orientation (Figure 3.1, page 3-2 of Addendum 3.). Geophysical methods, including electrical methods, are most precise and most reliable when survey lines are oriented normally to geologic features of interest or cultural features that may provide interference (see page B-3 of Appendix B of the FSP). The lines for the EI survey are shown on Figure 3.1, page 3-2 of Addendum 3. With a single exception, the orientation of the EI survey lines are oblique to the mapped fracture trace analysis lineaments. The result of this failure to orient the EI survey with respect to the lineament orientation is a loss of precision.
- EI results are best when lines are laid out as straight lines (Appendix B of the FSP, page B-3); however, EI Line 4 follows the sinuous path of D Road.
- The implementation of the EI survey as a series of isolated lines instead of a grid precludes using the EI survey as a tool to map the three-dimensional patterns of resistivity in the DU area. Rather than a three-dimensional map of potential groundwater conduits, there will be only a series of locations where individual

anomalies cross a road with a survey line along it.

The interpretation premise, that zones with high electrical resistivity represent low-permeability rocks that are unsaturated and that zones with low electrical resistivity represent high-permeability groundwater conduits, is an untested hypothesis for this site and is at best a weak hypothesis generally. It is inappropriately simplistic and cannot reasonably interpret the complexity that is inherent in a karst system. Deficiencies in that interpretive model include the following:

- While unsaturated carbonate bedrock will have high electrical resistivity, consistent with the hypothesis, that is true both when it has low permeability and when it contains a dry conduit awaiting the next thunderstorm. Depending upon conditions at the time of the EI survey, conduits may show high, not low resistivity.
- Minerals, not just groundwater, contribute to electrical conductivity in earth materials. Clay minerals, particularly when wet, are very conductive of electricity, whereas quartz or carbonate grains are not. Low-resistivity anomalies may represent the electrical signal of mineral content, not necessarily that of water-bearing conduits.
- Groundwater itself has highly variable electrical conductivity. Even within a local area such as the DU impact area, the specific conductance of groundwater varies more than 20-fold in the ERM data (MW-9 and MW-11, 2004 through 2006). Variations in the electrical resistivity may be unrecognized variations in groundwater quality, not variations in hydraulic conductivity of the rock.

- Slowly moving or stagnant groundwater may have higher electrical conductivity due to having had more time to react with minerals in the rock or soil. Slower moving water will increase the electrical response that is interpreted as a conduit.

Thus, a saturated karst network that has become plugged with clay-rich soil will exhibit high electrical conductivity (low resistivity) in an EI survey due to conductivity of the clay within the network and relatively high electrical conductivity of the groundwater moving slowly through the clayey soil. This feature does not function as a groundwater conduit because water does not preferentially move through it, but would be interpreted as a conduit by the FSP criteria for results from the EI survey. In contrast, consider a karst network that is a conduit for flow of rapidly infiltrating precipitation captured at a sink hole. Water moving through this karst network has the relatively low electrical conductivity of precipitation or surface run-off. The karst network may contain carbonate- or quartz-rich sand, but fine-grained, clay-rich sediments are largely moved through the conduit with the rapidly moving water. This karst network has no significant elements with high electrical conductivity. It would not reflect low electrical resistivity with EI and be unrecognized as a functioning conduit using FSP interpretive criteria.

The EI survey as proposed in the FSP is also deficient in its ability to achieve its stated expectations.. In particular, the expectation expressed in Table 4.1 on page 4-2 of the FSP cannot be achieved with the EI survey. The EI survey cannot identify entry and exit points of groundwater flow, even were the previously discussed simplistic interpretation premise of the FSP appropriate. The EI survey identifies where and at what depths resistivity anomalies occur under the roads covered by the survey. Combined with the fracture trace analysis, the EI survey identifies which mapped lineaments are associated with a resistivity anomaly at the point where the lineament crosses a road with a survey.

To determine entry and exit points of groundwater flow in conduits, first, one would have to determine which resistivity anomalies do function as conduits, second, those resistivity anomalies would have to be mapped, and third, the direction of flow within the mapped conduit would have to be determined. There has been no verification drilling to determine which type(s) of anomalies, if any, correspond to groundwater conduits and an EI survey that consists of isolated lines instead of a grid network cannot map any such anomalies even if they are conduits. At most there will be one point well control where a conduit crosses a road and flow direction cannot be determined from a single well (Wilson, John T., *et al.*, 2001, An Evaluation of Borehole Flowmeters Used to Measure Horizontal Ground-Water Flow in Limestones of Indiana, Kentucky, and Tennessee, 1999, United States Geological Survey, Water-Resources Investigations Report 01-4139).

Q.031 Of what significance are the deficiencies of the EI survey?

A.031 The FSP will locate groundwater characterization wells from a population of possible locations that are identified based upon a single criterion. The criterion for selection as a possible site for a characterization is that there be a low-resistivity anomaly in the EI survey data approximately coincident with where a mapped trace from the FTA crosses a road. For purposes of selection, the location of the EI anomaly needs to be within either

+/- 100 feet (precision of trace locations according to the Fracture Trace Report, page 3-1, as cited in Addendum 3 to the FSP) or +/- 200 feet (precision of trace locations according to the Well Location report, as cited in Addendum 4 to the FSP) of the mapped location of the trace.

There is the untested presumption that a low-resistivity anomaly on the EI survey where a mapped lineament crosses the road is the location of a groundwater conduit. A consideration of the electrical properties of groundwaters from the DU impact area and earthen materials associated with described in the mapped karst networks at JPG establishes that the untested presumption is unwarranted. There is no verification drilling to guide a realistic interpretation of the EI results with respect to what types of anomalies represent active conduits and, therefore, where active conduits do cross the road.

There is no mapping of resistivity anomalies, just the isolated lines along the roads. Hence, there is no knowledge of their horizontal or vertical orientation, persistence, or degree to which they bifurcate or merge with other anomalies. There is no ability to determine whether the anomaly begins at a sink hole within the DU area or begins or terminates at a stream inside or outside the DU impact area or JPG.

Without mapped conduits, the characterization of flow through the conduits, critical to meaningful fate and transport modeling, cannot be done. The EI survey in the FSP as modified by Addendum 3 does not provide such mapping and does not contribute to such mapping by supplementing other, independent data sources.

3. Gauging of Streams and Caves and Staging of Streams

Q.032 What are stream and cave gauging and stream staging?

A.032 Stream gauging is the measurement of the rate at which water flows past a point in the stream. Cave gauging is measuring the rate at which water flows past a point in the cave or from the mouth of a cave. Stream staging is the measurement of the height of the surface of a stream. Stream or cave gauging uses the water height (stage) as part of the computational process to determine flow rates. When water height is referenced to elevation, the water level measurement also serves as a control point for interpreting the nature of the exchange between ground- and surface water flow. Staging is sometimes done independently of gauging, particularly where understanding the rate of flow is not critical but the relationship between groundwater flow and surface water flow is ambiguous or may be transient.

Q.033 Where in the FSP and its addenda are the tasks of stream/cave gauging and stream staging described?

A.033 The FSP provides the initial description of the stream/cave gauging and staging tasks in Section 6.4, pages 6-29 through 6-31. Addendum 3, among other modifications, revises the FSP with respect to stream/cave gauging and staging in its Section 2, pages 2-1 to 2.4. The cave study at JPG (Sheldon, 1997) influenced the selection of caves to be monitored.

Q.034 What are the major design elements of the stream/cave gauging and stream staging

as laid out in the FSP and related addenda?

A.034 The following are the major design elements of the stream gauging and staging tasks, as described in the FSP:

- The objective is to evaluate surface water flows and discharges from groundwater to surface water.
- Two stream locations will have gauges installed; at the bridges where Morgan Road crosses Big Creek and where Morgan Road crosses Middle Fork Creek. (Morgan Road is also called West Recovery Road and marks the western side of the DU impact area.) Three cave locations are anticipated; two within the DU impact area that discharge into Big Creek and one that discharges into Middle Fork Creek, south of the DU impact area.
- Stream staging will be measured only at the two gauging locations.
- A minimum of one hydrologic year will be gauged/staged. Data will be collected electronically and downloaded quarterly
- Each gauging calculation will be recalibrated quarterly with field measurements of flow rate.
- An electronic precipitation recorder will installed at JPG as part of these tasks.

The following are the modifications to the major design elements of the stream gauging and staging tasks, as described in Addendum 3:

- The objective is changed. It is now to calculate and monitor surface water flows. The data will now be used to "estimate recharge to the aquifer." No definition is provided for "aquifer" as used in the statement of purpose.

- Five more locations for stream gauging are added, bringing the total to seven. The locations are shown in Addendum 3, on Figure 2-1 on page 2-2. The original two stream locations will have gauges installed; at the bridges where Morgan Road crosses Big Creek and where Morgan Road crosses Middle Fork Creek. The additional five locations are Big Creek at the eastern side of the DU impact area, the D Road bridge over Big Creek inside the DU impact area, and the East Recovery Road bridges over Middle Fork Creek and two tributaries to Middle Fork Creek south of the DU impact area.
- The two caves along Big Creek included in the FSP initally for gauging purposes are identified using the cave study nomenclature as BC-11 and BC-12 (Sheldon, 1997). The Middle Fork Creek cave is dropped from the FSP.
- Stream staging will be measured automatically at the seven gauging locations and manually where an unnamed stream north of Big Creek crosses West Recovery Road (Morgan Road), near E Road.
- The minimum period of record for automatic gauging/staging will be two hydrologic years, rather than one. Data collected at the automated stations will be downloaded monthly the first year and quarterly the second. There will be "periodic" measurements of stage from the manual station at the same time as the manual measurements at the automated stations.
- The gauging calculation will be recalibrated monthly for the first year and quarterly the second year, with field measurements of flow rate.
- The task to independently monitor precipitation is dropped. Precipitation records

from USFWS measured on the eastern side of the JPG will be used.

Q.035 Is this modified design for the stream/cave gauging and stream staging tasks adequate for purposes of JPG DU site characterization?

A.035 No, it is not.

Q.036 What are the deficiencies of that modified design for the stream/cave gauging and stream staging?

A.036 The deficiencies of the stream/cave gauging and staging design are three-fold. First, it is predicated on the previous and inadequate understanding of the site that the current characterization process is charged with replacing. It will simply add numbers to the previous, untenable site conceptual model. Second, the original and the revised stated objectives are largely irrelevant with respect to the information that is needed to allow meaningful modeling of exposures to DU transported from the impact area. Third, because of the timing and placement of the gauging and staging locations, these tasks will not provide the meaningful input that could help the groundwater characterization program correct these other two problems.

The existing site characterization was developed using a conceptual site model that did not consider the nature or importance of the karst development in the bedrock. That failure is a major element in the need for the supplemental characterization program that is described in the FSP as modified. As stated in the Well Location Selection Report, Site Characterization (SAIC, January, 2007), Section 4, page 4-1:

> Groundwater flow characteristics and flow pathways need to be evaluated in the DU Impact Area. Previous reports and studies at JPG focused on groundwater within the overburden (unconsolidated soil and sediments) above the bedrock and, in a few cases, in shallow bedrock. There was no specific acknowledgement [*sic*] of the unique properties of groundwater flow in a karst environment, such as exists at JPG.

When the DU impact area and the JPG are conceptualized without karst development in the bedrock, evaluating the groundwater and surface water hydrology of the sites is relatively straight forward. The headwaters of streams draining across the DU impact area are on JPG. Groundwater divides will coincide with surface water divides and headwaters of the groundwater flow system will coincide with surface water and topographic divides. Groundwater will flow toward and into local streams draining the area. Surface water entering the DU impact area will cross the DU impact area and leave the DU impact area as surface water on the downstream side. Groundwater that enters the DU impact area on the upstream side will leave the DU impact area on the downstream side as either groundwater or as surface water if it discharged to the stream within the confines of the DU impact area. Monitoring at the surface water flows upstream and downstream sides of the DU impact area will provide almost the whole story.

The FSP data-use objectives can be achieved using the pre-karst conceptual model of the site for the FSP stream gauging and staging tasks. Surface water flow measured at the downstream side of the DU impact area can be segregated into its surface flow and groundwater flow components using techniques such as base-flow separation. These are the data-use objectives of the original FSP.

Estimating recharge to the aquifer, the Addendum 3 data-use objective is more tenuous but possible using the pre-karst conceptual model. When site-specific precipitation is available, as it is at JPG, the total amount of water entering a drainage basin is known. The stream gauging records the total amount of surface water entering the DU impact area at the upstream edge and leaving the DU impact area at the downstream edge. Base-flow separation or a similar technique can be used to determine how much of the stream flow is surface flow and how much of surface water flow is discharge from groundwater. A comparison between the stream-flow components entering the impact area and leaving the impact area provides an indication of the net changes that are occurring within the impact area. Within the constraints of additional assumptions regarding groundwater underflow that passes the downstream surface water monitoring point and rates at which precipitation evaporates or is transpired by plants, the rate of precipitation recharge to groundwater can be approximated (the Addendum 3 use of the data).

The deficiency in the surface water gauging and staging tasks is that the premise of the current conceptual model is that there *is* karst flow underlying the JPG DU site. The objective of the characterization is the same, *i.e.*, provide the fate and transport modeling with an accurate description of how much groundwater flow is carrying how much DU how quickly from the impact area to the locations of potential exposure. But, groundwater no longer is conceptualized as simply moving toward and into the local streams, driven by in-basin topography. A karst network may discharge groundwater to the local stream. But, a karst network may recharge with water taken from the local stream, transport it through the karst system of the bedrock and discharge it back to the stream downstream of the surface water monitoring network. A karst network may also recharge with water taken from a local stream and discharge it to a stream in an entirely different basin. Karst groundwater and DU in or transported by that groundwater is undetectable by a gauging and staging system designed for non-karst hydrogeology when the karst system which actually exists discharges outside the confines of the surface water monitoring system.

This deficiency is further complicated because the interaction of a karst network and surface water drainage can and often does change temporally. Figure 1 shows a schematic of a simple karst network and how it can change with respect to its impacts on streams that it intersects. During high recharge conditions, groundwater in the karst network is recharged from precipitation and discharges to both streams. However, during low water flow conditions, the karst system recharges from precipitation and from the stream with the higher elevation and discharges only to the lower steam. Stream-flow separation of gauging data on either stream will produce an erroneous interpretation of the aquifer recharge unless the location and the transient nature of the karst interaction are known. The gauging and staging tasks proposed in the FSP and related addenda cannot account for even such a simple transient interaction and cannot, therefore, provide the data to the fate and transport model that is needed.

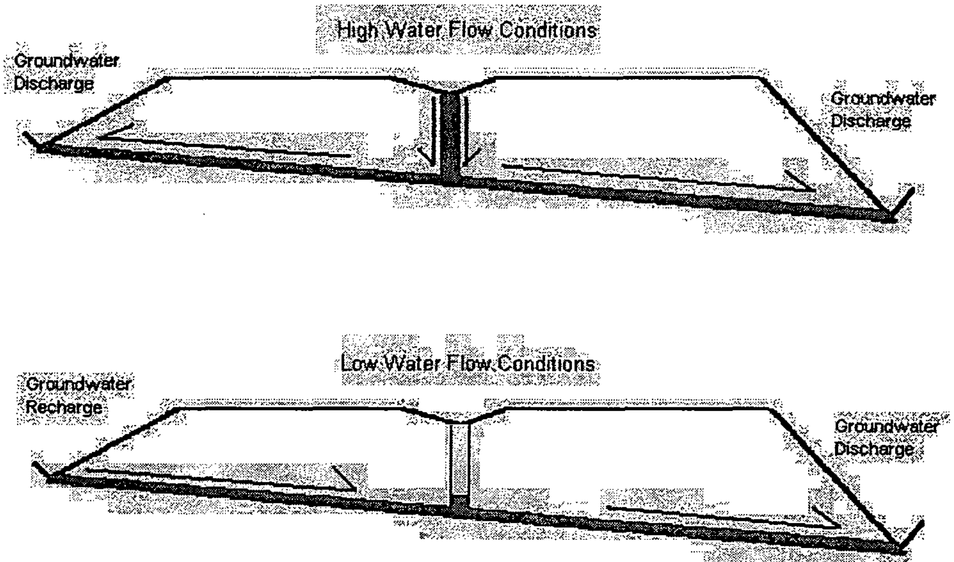

Figure 1. Reversible Exchange with Stream

Q.037 What is the significance of the deficiencies you identify and how can they be overcome?

A.037 The stream/cave gauging and stream staging activities in the modified FSP are not designed to document and quantify groundwater and surface-water interactions. Such a design is fundamentally needed to generate the data that are meaningful to the fate and transport modeling required to support site decommissioning. Achieving a design capable of supporting a decision on site decommissioning will require work not presently in the modified FSP.

An appropriately designed gauging and staging system would begin with stream surveys that identify areas where the stream interacts with major karst conduits that intersect it based upon changes in flow along reaches of the stream. Mapping where the stream shows major gains or losses identifies where significant karst systems are influencing surface water flows and vice versa. Tracking changes at those locations in the relative flow with variable recharge conditions establishes whether those conduits can provide DU transport routes that are not detectable by a given proposed surface and groundwater monitoring network. Such stream surveying definitively locates one end of groundwater conduits that demonstrably influence the groundwater hydrogeology, reducing the ambiguity of conduit location techniques that rely on indirect evidence such as visual expression or electrical resistivity. Once the points of stream-karst exchanges are identified, surface water gauging and staging locations can be selected that are designed document and quantify groundwater and surface-water interactions. Identifying and monitoring these exchange points is especially critical because the surface water locations that show continual or episodic discharges from groundwater may well lie outside the perimeter of the DU impact area, or even JPG.

4. Well Location Assessment and Selection

Q.038 Where in the FSP and its Addenda are the tasks associated with well location assessment and selection described?

A.038 The well location and assessment tasks are presented initially in Subsection 6.2 of the FSP. Addendum 4 modifies Subsection 6.2 of the FSP. Addenda 4, in turn, cites and relies upon the Well Location Selection Report, Site Characterization (SAIC, January,

2007) in developing its changes. Since the final well locations are directly dependent upon the results of the FTA and the EI survey, documents that subsequently describe, modify, or influence the adequacy of those programs also do so for the well location assessment and selection program. These include FSP Subsections 5.2 (FTA) and 6.1 (EI survey), FSP Addenda 2 and 3, the results of the EI survey (also in Well Location Selection Report, Site Characterization (SAIC, January, 2007)), and the results reported in the Fracture Trace Analysis (SAIC, June, 2006).

Q.039 What are the major design elements of the well location assessment and selection as laid out in the FSP and related addenda?

A.039 The following constitute the original FSP major design elements for well location assessment and selection:

- Wells will be installed in bedrock at locations where groundwater conduits are deemed likely to exist. Each location will potentially have two bedrock wells, completed at different depths, depending upon location-specific condition encountered while drilling.
- From ten to twenty locations of paired bedrock wells will be drilled. For budgeting purposes, ten was used.
- Well depths were estimated at 50 feet and 120 feet, subject to revision after the EI survey.
- No wells above bedrock are proposed to evaluate aquifers in unconsolidated sediments.
- Potential well locations will be where low-resistivity anomalies observed in the

EI survey coincide with lineaments mapped in the FTA. In the FSP, which was filed prior to the completion of the FTA, all EI survey lines are shown along site roads because the final orientation of the EI survey is subject to FTA results.

- Among potential well locations, the actual drilling locations will be those locations most likely to overlie conduits based upon locations of fracture traces, anomalies on the EI survey, evidence of greater depth to bedrock on the EI survey, and any known discharge(s) of groundwater from any fracture trace(s).

After modifications in response to the FTA, the EI survey, and Addenda 2-4, the following constitute major design elements for well location assessment and selection:

- Bedrock wells will be installed at locations where groundwater conduits are deemed likely to exist. Each location will potentially have two bedrock wells, completed at different depths, depending upon location-specific condition encountered while drilling.
- Nine locations of paired bedrock wells will be drilled.
- One location of paired wells is added to investigate an area of unusually thick unconsolidated sediment overlying the bedrock. Other wells in porous unconsolidated sediments may be installed, at the discretion of the Army.
- Bedrock well depths remain projected at 50 feet and 120 feet; the EI survey does not yet result in a prediction of depths to target anomalies at the picked locations.
- Thirteen potential bedrock well locations are identified where low-resistivity anomalies observed in the EI survey are within +/- 200 feet of lineaments mapped

in the FTA, the uncertainty of actual trace locations based upon Well Location Selection Report, Site Characterization (SAIC, January, 2007). Since lineament orientation from the FSP did not change EI survey locations or orientations, fracture traces are evaluated only where they cross roads.

- The selection criteria for proposed well locations among potential locations are changed to prioritize "... locations that are anticipated to provide coverage in possible flow directions from the DU Impact Area." (No indication is provided to suggest how groundwater flow directions are to be anticipated at locations, depths and in conduits yet to be drilled.) Depth of bedrock and groundwater discharge from fracture traces are no longer among the selection criteria.

Q.040 Is this modified design for the well location assessment and selection adequate for purposes of JPG DU site characterization?

A.040 No, it is not.

Q.041 What are the deficiencies of that design for the well location assessment and selection?

A.041 The following are among the deficiencies of the design for well location assessment and selection:

- The modified FSP does not require wells to be installed when aquifers are found in the unconsolidated sediments above the bedrock. Any such permeable zones that are encountered will have a fundamental impact on directions and rates of migration in the unconsolidated sediments and, therefore, similar impact on reduced attenuation of uranium migrating through the soils. Understanding these units will be fundamental to appropriately building the fate and transport model. Deferring installation of these wells to the discretion of the licensee is inappropriate.

- Wells are located using methodologies that may or may not be relevant to finding groundwater conduits at this site. The deficiencies of both the FTA and the EI survey as used at this site have been previously addressed. Inherently, a process that locates wells solely using two deficient methods, while excluding other methods and data, is itself flawed. Functionally, the resulting wells that are drilled are not characterization wells. They are very expensive verification wells to determine which subset of resistivity anomalies seen in the EI survey data do indicate and perhaps locate a few but far from all of the active groundwater conduits at this site.
- Groundwater conduits need to be mapped, not merely identified where they pass under site roads. Without mapping, the potential pathways of DU from the site to discharge points cannot be established. Further, over hundreds of millions of years of formation, karst networks that do exist and can be mapped may or may not be part of the contemporary conduit system through which the DU deposited at the site may move.
- Flow surveys of JPG streams as part of conduit mapping would allow site characterization to identify active conduits by identifying points on or reaches of streams that are receiving flow from or losing water to the groundwater conduits. The flow surveys are not part of the original FSP and are not modifications in the

addenda.

- Discharges from and recharges to groundwater conduits have not been located and used to locate (at a minimum) the mouths or headwaters of active groundwater conduits. The only use of observable conduit flow as a selection criterion for characterization well locations was dropped from the FSP (Section 6.2, page 6-4, selection criterion 2) with Addendum 4.
- The cave survey that was performed at JPG in the mid- to late 1990s is not fully and appropriately incorporated into the location and selection process. Almost two miles of caves were entered, surveyed and mapped during the JPG Karst Study (Sheldon, 1997). The karst study entered and mapped 19 caves in the Big Creek drainage basin. Among these caves the study surveyed 34 separate entrances and 3085 feet of caves large enough from human entry. Some of the mapped caves extend under the heart of the DU impact area. Along the reach of Big Creek within the DU impact area, the karst study entered and mapped 7 caves with an aggregate mapped length of 1679 feet and 13 separate entrances. The two longest accessible caves mapped in the Big Creek drainage basin are under the DU impact area, BC-07 with 436 feet and BC-08 with 617 feet. Each of these caves moves from Big Creek back toward heavily contaminated portions in the DU impact area as represented in Figure 2-5 on page 2-11 of the FSP. Each also has an entrance in a sink hole in the vicinity of the heavily contaminated areas. Figure 2 depicts the approximate locations of the mapped caves under the DU impact area.

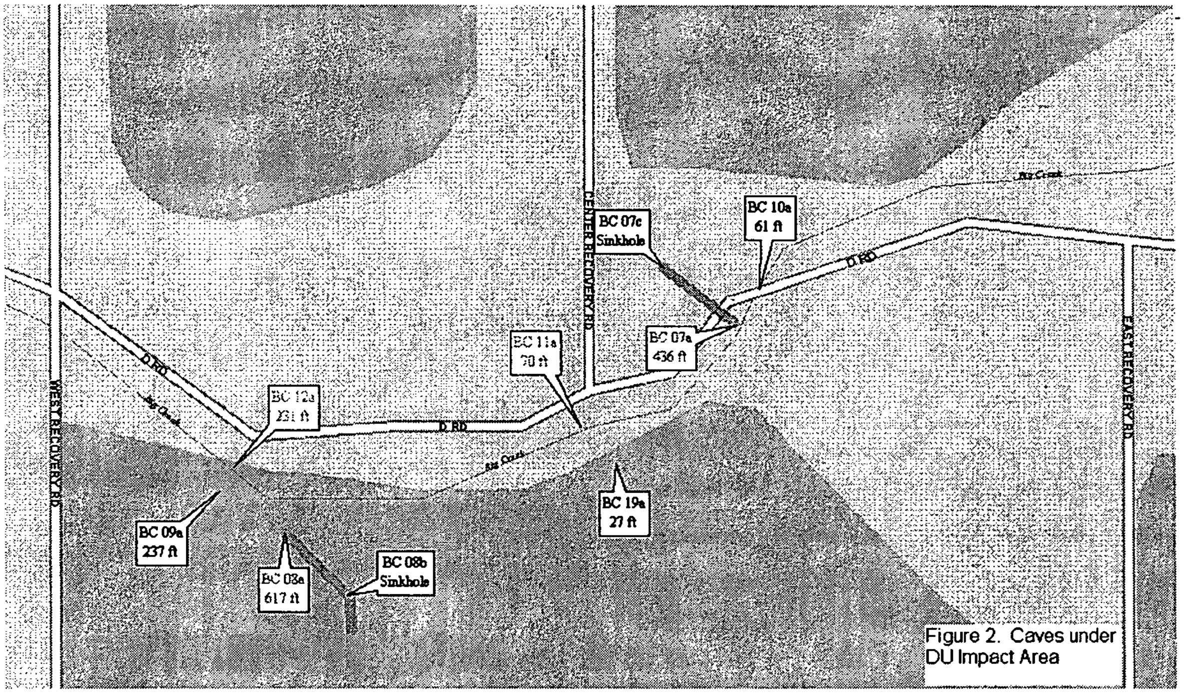

Figure 2. Caves under DU Impact Area

- Failure to verify the FTA/EI approach with the patterns and existence of known conduits and sink holes is an additional deficiency. Comparing the cave traces on Figure 2 with the fracture traces from the FTA (Figure 3-1, page 3-2 of Addendum 3) shows that the longest mapped cave under the DU impact area, BC-08, is not coincident with a fracture trace. Clearly the FTA doesn't identify all, if any, of major shallow groundwater conduits. The second longest mapped cave, BC-07, may

be associated with a fracture trace and the sink hole entrance may be associated with the intersection of two fracture traces. However, there is no low-resistivity anomaly on the EI survey where the fracture trace or the cave crosses the road and no EI survey was done around the intersection of the fracture traces away from the road. Clearly the resistivity anomaly criterion for the EI survey will not identify all major karst conduits. In combination, the criterion for well locations was unable to identify either of the most extensive, known karst conduits under the DU impact area.

The overriding deficiency of the design for locating and selecting the characterization wells is that the FSP program results in nine isolated data points with no practical way to use the data and no theoretical context within which to interpret it. Presume that one of the proposed wells finds an active groundwater conduit and the well is successfully completed in the conduit. Other than establishing that there is a conduit at that drilling location, what other meaningful information is there? Further presume that water quality is analyzed and water elevation measurements are taken from that well. Even presume the resulting data are accurate and precise within quality control protocols. The data still are not useful and it have no meaning for fate and transport modeling, because they have no systemic context for understanding.

To be useful for fate and transport modeling, to be meaningful with respect to testing and refining the conceptual site model, the data being collected be interpretable within the hydrogeologic context of the site. Where does this active conduit begin and where does it end? Is the conduit positioned to receive surface water runoff from the contaminated areas through a sink hole, from percolation through soils, or from stream loses upstream of any possible contamination? Where does the conduit empty? Does it empty to Big

Creek to the west or the Indian-Kentuck drainage to the east? Does it discharge inside or outside JPG boundaries? Is the characterization well sampling water near the head or near the mouth of this conduit? The fate and transport model needs the context provided by these answers before the information can appropriately used as input.

Q.042 Of what significance are these deficiencies in the well location assessment and selection?

A.042 Characterization wells can provide the information that is needed for fate and transport modeling only if their data are produced within a context of integrated hydrogeology that allows interpretive significance to be assigned to the data. That significance is based on the locations from which that data comes within the site-wide transport systems. The well selection process proposed in the FSP and related addenda confers none of those values on any data produced. Appropriate locations for groundwater characterization wells can be made only after groundwater conduits are mapped, after the subset of active contemporary conduits are identified from all conduits, and after recharge areas and discharge points of the active contemporary conduits are identified. Data from characterization wells installed at optimum positions within such conduits will contain the information and context needed by the fate and transport model to compute defendable exposure doses at times and places of interest. Data from the well locations selected by the modified FSP program cannot contribute to a defendable fate and transport modeling result.

5. Well Installation and Assessment

Q.043 Where in the FSP and Addenda are the tasks associated with well installation and assessment described?

A.043 The well installation and assessment tasks are presented initially in Subsection 6.2 of the FSP. Addendum 4 modifies Subsection 6.2 of the FSP. Addenda 4, in turn, cites and relies upon the Well Location Selection Report, Site Characterization (SAIC, January, 2007) in developing its changes. The final well installations are dependent upon the selected well locations, which, in turn, are directly dependent upon the results of the FTA and the EI survey. Therefore, documents that describe, modify, or influence the adequacy of those programs also do so for the well installation and assessment program. These include FSP Subsections 5.2 (FTA) and 6.1 (EI survey), FSP Addenda 2 and 3, the results of the EI survey (also found in Well Location Selection Report, Site Characterization (SAIC, January, 2007)), and the results report Fracture Trace Analysis (SAIC, June, 2006).

Q.044 What are the major design elements of the well installation and assessment as laid out in the FSP and related addenda?

A.044 The following constitute the original FSP major design elements for well installation and assessment, as described in Section 6.2.4 of the FSP on pages 6-5 through 6-21:

- All wells will be completed in bedrock.
- Conduit wells will be 4" PVC wells with 10-ft screens across the conduit interval and standard above-grade completions, completed in boreholes of 8-9 inch diameter.
- Air-rotary drilling will probably be used to install the wells, subject to unspecified

information obtained from the EI survey. Permanent outer casing will be installed across unconsolidated material. Soil and rock cuttings returned by air-rotary drilling will be logged.

- Water source for well completion will be documented free of DU.
- There will be no soil sampling or rock coring during drilling.
- There will be no geophysical logging of the boreholes during or after drilling, or through casing after drilling and/or well completion.
- Borehole depths are estimated at 50-ft and 120-ft below ground surface, pending results of EI study.
- A monitoring well will be completed only if there is sufficient water in the borehole at the time of drilling to support a monitoring well. If not, the borehole will be abandoned, subject to additional authorized drilling by Army.
- Well centralizers may be needed.
- Well development will be done between 2 and 7 days after installation using surge block and pumping/airlift.
- There will be no *in situ* permeability testing.
- No aquifer testing is scheduled.
- One round of water level measurements of all conduits wells, ERM wells and Range study wells will be made. Results will be contoured to establish flow directions if "... sufficient data points exist."

After modifications in response to Addendum 4 and the documents upon which

Addendum 4 relied, the following constitute major design elements for well installation and assessment. Changes to the FSP are noted with italics.

- Nine well pairs will be completed in bedrock and *one well pair will be completed in anomalously thick overburden.*
- Conduit wells will be *2" PVC wells* with 10-ft screens across the conduit interval and standard above-grade completions, completed in boreholes of *5.5-inch diameter*. (This reduced boring size has been further reduced during the active field program.)
- *Where overburden contains sufficient saturated, high-permeability sediments to support a well, Army will consider installing an overburden well.*
- *The unconsolidated materials will be drilled using hollow-stem augers and bedrock will be drilled using wire-line coring.*
- Water source for well completion will be *tap water or* a source previously documented for "suitability." The explicit reference to testing for DU has been dropped.
- *One well at each location will use split-spoons to collect samples through the unconsolidated sediments. Split-spoon sediment samples and bedrock cores will be examined and logged.*
- There will be no geophysical logging of the boreholes during or after drilling, or through casing after drilling and/or well completion.
- Borehole depths are estimated at 50-ft and 120-ft below ground surface, *even after results of EI survey.*

- A monitoring well will be completed only if there is sufficient water in the borehole at the time of drilling to support a monitoring well. If, not the borehole will be abandoned, subject to additional authorized drilling by Army. *A boring may also be abandoned if the permeability is too low.*
- Well centralizers *will* be needed, due to the smaller diameter configuration. *Also, well centralizers are not expected to be needed.* (This direct contradiction is discussed below.)
- Well development will be done between 2 and 7 days after installation using surge block and pumping or airlift.
- There will be no *in situ* permeability testing.
- No aquifer testing is scheduled.
- One round of water level measurements of all conduit wells, ERM wells and Range Study wells will be made. *Results are now represented as adequate to determine preliminary groundwater flow directions. These flow directions will "assist in the evaluation, selection, and frequency of surface water samples and locations. Included in this evaluation will be the selection of the wells for installation of recorders for groundwater stage data collection."* (It is presumed that all references to data from well staging and water level measurements will be expressed and evaluated as elevations relative to a common datum. If this is not the case, it would constitute an additional deficiency that is not discussed below.)

Q.045 Is this modified design for the well installation and assessment adequate for purposes of JPG DU site characterization?

A.045 No, it is not.

Q.046 What are the deficiencies of that design for the well installation and assessment?

A.046 There are six general deficiencies in the well installation and assessment program detailed in the FSP as modified by Addendum 4. One major deficiency of the original FSP was corrected by Addendum 4.

1. The modified FSP is deficient in the inconsistencies that make it uncertain what will or won't be done and what is or is not expected. For example, the original FSP states that because of the difference in diameter between the proposed 4-inch well and the 8-9-inch boring, centralizers will not be needed. Addendum 4 proposes smaller-diameter borings and wells. Addendum 4, Section 2.2.2.1, page 2-9, states, "The annulus between the screen assembly and the borehole will be small such that the use of centralizers will be necessary." However, Addendum 4, Section 2.2.5.4, page 2-12, states, "It is not anticipated that centralizers will be required during this well installation." Clearly, one of these statements cannot represent the expected method of installation.

2. The modified FSP is deficient by failing to set the depths of the targets to be drilled at each location. The original FSP used general estimates for the number of well pairs and the depths of the drilling targets, pending the results of the FTA and EI survey. Addendum 4 was completed with those results available. The EI survey results, upon which well locations were selected, showed a host of styles of resistivity anomalies, as

seen in Well Location Selection Report, Site Characterization (SAIC, January, 2007), Figures 5-1 through 5-5. Some anomalies were vertical. Some were dipping. Some extended to near the land's surface. Some were shallow. Some existed only at depth. However, the modified FSP changed nothing with respect to the depths of targets at each selected location; the targets remain the generic 50-feet and 120-feet.

3. The modified FSP is deficient by failing to require geophysical logging of the boreholes or characterization of the physical properties of the cores that will be taken. The decision to drill by coring that is part of Addendum 4 corrects a major deficiency of the original FSP, which did not even propose the recovery of intact rock or soil. However, the modified FSP proposes contemporaneous drilling and casing advancement, precluding many, but not all, geophysical measurements of rocks exposed in the borehole. Further, the modified FSP does not provide for geophysical evaluation of the cores beyond the visual descriptions of the recovered core. The opportunity to collect properties such as porosity, permeability, density, rock/soil radioactivity (natural or otherwise), and formation resistivity from, and vertical flow within, the borehole is irrevocably lost as a result of the drilling methods selected.

4. The modified FSP is deficient by failing to characterize the hydraulic properties of any of the soils and rocks drilled, including those of the conduit zones in which the wells will be completed. The original FSP specified there was no aquifer testing scheduled as part of the installation and assessment and that there would be no permeability testing of

the individual wells and Addendum 4 does not correct this failing.

5. The modified FSP is deficient by establishing criteria under which a boring will be abandoned without first establishing the context of the materials penetrated by the boring. The original FSP anticipates a boring will be abandoned if it does not produce sufficient water at the time of drilling (Section 6.2.4.3., page 6-12). A conduit that is dry at the time of penetration may well convey significant water and DU during seasonally high flow conditions or in response to precipitation events, conditions that can be established only when such events occur. Addendum 4 adds the criterion that a boring that does not encounter "adequate permeability" (Addendum 4, Section 2.2.6, page 2-13) will be considered for abandonment. Since no permeability testing is to be performed as part of the modified FSP, it is unclear how adequate or inadequate permeability can be established objectively and not capriciously. Further, although a conduit that is filled with fine sand, silt, and/or clayey sediments may have low hydraulic conductivity, a well in it can still provide important information for site characterization and fate and transport modeling, as is discussed later.

6. The modified FSP is deficient in its statement of intended uses of the data. Unlike the expectations in the original FSP, Addendum 4 asserts in Section 4.2, pages 4-3 and 4-4, that the evaluation of a single round of water levels (elevations) from the new characterization wells, the ERM wells and the Range Study wells,

> . . . will determine which, if any, of the existing wells are appropriately

> constructed and located for inclusion in ongoing characterization activities. In addition to determining if appropriate to be included, the types of uses (e.g., chemistry sampling, stage gauging) of the wells also will be evaluated. . . . Initial groundwater stage data will provide preliminary groundwater flow direction data that will assist in the evaluation, selection, and frequency of surface water samples and locations.

There is no scientific or technical basis to support the proposition that one can conclude anything about the usefulness or validity of including an existing well in ongoing characterization based upon an initial measurement of head levels in the new and existing wells. Any attempt to eliminate existing well locations or pre-determine what types of data should be collected from existing wells based upon such a round of water elevations will bias data that is collected toward a pre-conceived belief of what should be found. It epitomizes the classic error of accepting only data that support a preconceived hypothesis instead of allowing the hypothesis to evolve in response to a consideration of all of the data.

The Army will not be able to use the one-time water level elevation data to ". . .provide preliminary groundwater flow direction data . . ." The determination of groundwater flow directions at even a single moment in time requires measurements of water elevations at multiple locations along an available flow path. What the FSP as modified proposes is analogous to proposing to determine the flow direction(s) of water in a storm sewer based upon isolated measurements of water levels in the sewers without benefit of a map of the system.

The locations at which characterization well pairs are being installed cannot simply be assumed to be within a single conduit flow system. No conduit flow system has been or will be mapped as part of the modified FSP. Well locations were selected near where individual traces crossed site roads, not as locations within mapped conduit systems selected for their relevance to the transport of DU. All selected well locations cannot simply be assumed – and are not likely to be -- in a common karst conduit system. It is conceivable that each of the 18 bedrock wells will be completed in a karst conduit system that is hydraulically independent of the others; it is virtually certain that at least some of them will be. Moreover, water elevation data from the wells will not identify which, if any, of the wells area in a common conduit with any other well(s). That would require mapping conduits using aquifer testing, tracer surveys, or proper geophysical surveys, tasks that are not part of the FSP as modified.

Since it cannot produce valid flow direction interpretations, the initial round of groundwater elevation data cannot "assist in the evaluation, selection, and frequency of surface water samples and locations," as called for in Addendum 4.

Q.047 Of what significance are these deficiencies in the well installation and assessment?

A.047 1. The FSP provides the methods and protocols that will be used in the characterization program. Contradictory well installation procedures in the FSP allows arbitrary and inconsistent installation procedures to be instituted in the field by the Army and its consultant(s). It is fundamental in a characterization program that data from each well is obtained in a manner consistent with that of the other wells. Without that consistency, inter-well comparisons are flawed. With respect to the specific example cited, centralizers ensure filter packs surround the well on all sides, keeping sediments from entering the well and affecting either well function or chemical results. One cannot compare or interpret the well performances and water chemistries of the characterization wells when there may be inconsistencies and/or mistakes in their installations. Subsequently, the inputs needed for the fate and transport modeling will be denied the reliable sampling data for which the characterization was initially authorized and performed.

2. Nine well pairs are to be installed at locations that were picked based on an EI survey performed along the site roads. The modified FSP does not include an interpretation of the depth where individual conduits are expected based upon the EI survey results, as anticipated in the original FSP. The failure to integrate the EI survey information denies the rig geologist the knowledge of what to expect and at what depths, as well as an understanding of the nature of the resistivity anomaly at that well site. This invites well installations that miss conduits by simply failing to target them.

3. The modified FSP characterization program for new wells unnecessarily reduces the level of understanding of the geologic materials which are in and around the DU impact area and potentially associated with local conduits. Based upon my experience drilling, coring, and completing wells in similar sediments and rocks in similar settings, contemporary casing advancement with drilling or coring is seldom necessary. When

drilling precedes casing, an array of geophysical and optical measurements can be obtained from the borehole that allow detailed characterization of the physical properties that affect groundwater movement. If casing is needed to protect well installation, the casing can be run subsequent to drilling. However, even when casing must be advanced before logging can be performed, some geophysical techniques can be run through casing. With or without borehole geophysical logging, many of these rock and sediment properties can be obtained from the core that is to be taken. But, that data too will not be collected as part of the FSP programs. The result of this failure to measure and catalog the physical properties of the materials drilled is that the final interpretation of the geology that controls the hydrogeologic movement of DU will be based upon the speculative translation of visual characteristics into hydrogeologic properties or entirely non-site-specific data. That in turn means that the modeling of DU migration from the site by means of groundwater and hydrogeologic processes will be less accurate, less precise, and more uncertain, *i.e.*, unreliable.

4. Groundwater moves in response to the driving force of head changes along the path of flow and the permeability of the materials along the flow path. The modified FSP proposes to collect no information about the permeability of sediments or rocks through which borings are drilled and no information about the properties of the aquifer or conduits in which wells are completed. The incontrovertible result of that proposal is that the amount and speed of groundwater flow through the materials that are drilled cannot be determined. Without groundwater flow volumes and speeds, it is impossible to

model reliably the quantity, rate, and timing of DU transport in the subsurface.

5. Karst conduits do not necessarily convey groundwater continuously. Flow in some conduits may be low or zero between precipitation events or during the drier seasons of the year, as demonstrated in the JPG cave system study. Under normal conditions, the caves that were entered and surveyed were dry or had small streams running through them; the drained conditions allowed entry. That is not always the case, however, as illustrated by this entry for April 10, 1994:

> Bruce, Jacob, Keith Dunlap, and I met Jerry on site at 8:00 AM under extremely wet conditions. Big Creek was up about five feet above normal flow and five of the six caves surveyed were in full flood.

Penetrating and observing a successfully located conduit and finding the bore hole dry is not sufficient justification for abandoning the well, particularly for the shallower of the two wells at each pairing. To do so precludes measuring the conduit's ability to transport groundwater and associated DU during times and conditions when it does so.

The Addendum 4 addition of a plugging criterion of low permeability is similarly ill-conceived. There is the obvious problem of how one establishes insufficient permeability when permeability will not be measured as part of FSP activities. Notwithstanding that problem, low-permeability materials in karst conduits are common and are an important part of hydraulics of the system when they are permanent. The information from a well in such a conduit can provide a calibration point for understanding classes of anomalies in the EI survey. With a better EI survey, the information can assist in mapping the extent of such fill in that conduit network; head data for mapping gradients and flow directions in that conduit network, and water quality data that can help provide input parameters to the fate and transport model.

Sediments that plug a karst conduit can, however, be temporary at a given location. Deposited at times of low flow velocity, they are subject to scour and removal during flushing episodes of heavy precipitation and/or changes to seasonally high flow. Like a dry conduit, a conduit that is plugged at the time of drilling may be an important water conveyance under other hydrologic conditions. If plugging is episodic, the DU content of the transient sediments is of great importance. As with permeability measurements, not knowing the transient characteristics of the conduit flow systems precludes reliable modeling of the quantity, rate, and timing of DU transport in the subsurface.

6. The initial round of water level measurements will document whether groundwater moves up or down at the location of a pair of wells at the time of the water level measurements. The data will convey information about whether the groundwater in that particular conduit at the time of the water level measurements may (but not necessarily does) discharge to the local stream or whether it may (but not necessarily does) receive recharge from the local stream. But, without mapping of the karst conduits to identify where and if the conduits at a given well location connect, where and when they recharge, and where and when they discharge, temporal flow directions cannot be

determined. The FSP tasks do none of these things. That deficiency precludes adequate fate and transport modeling, for which one must know from where, to where, and under what conditions groundwater transports DU and DU-bearing sediments.

Any refinement of surface water sampling procedures, locations or timings based upon the invalid use of the initial groundwater elevation data, as anticipated by the modified FSP, would compound the flaws in the fate and transport model. Not only would groundwater flow with its DU content be misinterpreted and misrepresented in the modeled, any resulting changes to the surface water sampling would result produce the wrong locations to look for DU impacts from groundwater on surface water system.

6. Sediment Sampling

Q.048 What is sediment sampling?

A.048 Sediment sampling, as used in the FSP, is the collection of samples of sediments from stream banks above, within and, in only two cases, down stream of the DU impact area.

Q.049 Where in the FSP and its addenda are the tasks of sediment sampling described?

A.049 The FSP provides the initial description of the sediment sampling tasks in Section 6.6, pages 6-38 through 6-40. Section 6.6.1.1 states the expectation of an addendum, but that addendum has not been released. Details of sediment sampling protocols are provided in Sections 8.2 and 8.4 and in Appendix A of the FSP.

Q.050 What are the major design elements of sediment sampling as laid out in the FSP and related addenda?

A.050 The following are the major design elements of the sediment sampling task in the FSP:

- According to Section 6.6, sediment samples will be collected from the banks of Big Creek and Middle Fork Creek. At a minimum, samples will be collected where these creeks enter and leave the DU impact area and at their respective midpoints within the impact area. Collection sites will be where streams are shallow or where deposition is likely, such as at bends in the creeks. Additional locations will be sampled where a) creek banks are accessible and b) gamma scans exceed an arbitrary level greater than background. (It is believed the methodology for this scan can be found in Section 6.5, rather than in Section 6.2 as is referenced on page 6-38 of the FSP.)
- Alternatively, according to Sub-section 6.6.1.1, sediment samples will be collected at fourteen locations where surface water samples are collected. These locations are described as one where Big Creek crosses the western boundary of JPG; eight along Big Creek within the DU impact area, with four associated with spring/cave locations; one where Middle Fork Creek crosses the western boundary of JPG; and five along Middle Fork Creek within the JPG, with one associated with a spring/cave location.
- Sediment samples will be no less than 35 ounces (1000) grams, according to FSP Section 6.6 on page 6-18.
- Alternatively, sediment samples will be 8 ounces, according to Appendix A of the FSP, Section A.4, Table A.4-2, on page A.4-2.
- Locations for sediment sampling that are upgradient of possible DU

contamination, will be identified in an as yet unreleased addendum to the FSP.

- Sampling of sediments from ponds, lakes and lagoons is not anticipated.

Q.051 Is this design for the sediment sampling adequate for purposes of JPG DU site characterization?

A.051 No, it is not.

Q.052 What are the deficiencies of that design for sediment sampling?

A.052 A major deficiency of the sediment sampling program in the FSP is that there are actually two programs outlined that are largely inconsistent with each other. Neither of the programs fully addresses the rationale for the task that is provided in Sub-section 6.6.1 of the FSP on page 6.-38:

> Sediment can be contaminated by DU transported by surface water, water erosion, and contaminated groundwater flowing into ponds or streams. Contaminated sediment can enter the human food chain indirectly from incidental ingestion by livestock, fish, or game. In addition, biotic material adsorbing contaminants from the sediment also represents an indirect exposure route.

The exposure pathways that are described in that rationale establish the need to identify DU that has been, is being, or may be transported from the DU impact area to locations where receptors may be exposed. That transport may be as DU in ground- and/or surface waters that subsequently contaminates sediments at the point of exposure, or it may be the result of DU-contaminated sediments that are transported by ground- and/or surface waters to the point of exposure. With two exceptions, the locations that are described by either program are sediment sampling locations that are at or within the DU impact area, an area that is not representative of exposure locations. The two exceptions are locations at the western edge of the JPG. No locations for either program represent locations of exposure which must be modeled. There are, for example, no locations that sample sediments contaminated by DU in groundwater that is transported through karst conduits that discharge outside JPG.

The first program anticipates sampling at as few as six locations within or immediately adjacent to the DU impact area. These locations are first specified with geographic criteria (*i.e.*, streams at DU impact area boundaries and at midpoints within the impact area, and locations where stream banks area accessible) and then with technical (geologic/hydrologic) criteria (*i.e.*, areas of shallow water and/or deposition, and areas where bank sediments exhibit arbitrarily high gamma radiation). The description of the sediment sampling program does not indicate whether the geographic or technical criteria will take precedence where there is conflict. This program does not sample the sediments that are actively being transported from the DU impact area by ground- and surface water, or the rates of that transport. This program makes no effort to identify where DU-bearing sediments from the impact area have been deposited subsequent to being transported from the impact area by surface water. It samples only sediments that have been deposited within the DU impact area. This program makes no effort to establish where DU-bearing groundwater may be discharging outside the DU impact area and contaminating sediments. Even within the DU impact area, this program does not locate and sample either the sediments transported by karst conduits that discharge on site or sediments potentially being contaminated by discharging groundwater contaminated with DU.

The second program identifies 14 sediment sample locations; two specifically and 12 generically. These sites are co-located with 14 surface water sample locations described in Section 6.4 of the FSP. Beyond the criterion of sharing locations with surface water sampling, there are no criteria and no rationale provided for the selection of the 12 generic locations. There is no rationale provided that optimal locations for sediment samples will, or even can, coincide with optimal sampling locations for surface water. There is no discussion of whether the selection of the sediment sample or the surface water sample will have priority in the selection of a common location site if each is not optimal, or why. Based upon my decades of practice, I know of no geologic setting in which or reasons for which to expect that the best places to monitor surface water quality are also the best places, one-for-one, to monitor sediments.

Neither of the programs outlined in the FSP for sediment sampling proposes a methodology for sampling sediments that are actively being transported from the DU impact area to areas of potential exposure. The sediments that are being sampled are sediments that have been transported and deposited within the DU impact area or, in two cases for the second program, within the JPG. Depending upon details in an addendum yet to be released, the sediments that are sampled may even be sediments deposited prior to the use of DU in the impact area. Meaningful simulations of exposures by fate and transport modeling will require data on the rates of transport of DU from the source area to the location of exposure of interest, as well as the rate of accumulation at the exposure location. It requires sampling methods that capture sediments moving with streams and with discharges from caves under varying flow conditions. Such data cannot be generated from the type of sediment sampling programs that are described in the FSP, and the data from the programs in the FSP are not a surrogate for such data.

Q.053 What is the significance of those deficiencies?

A.053 As described in the FSP quotation cited above, exposure pathways associated with DU-contaminated sediments are complex. Exposure can occur directly through contact with, ingestion of, or inhalation of contaminated sediments. It can occur indirectly through the food chain or drinking water exposed to contaminated sediments. These complexities vary with the sources of DU that can contaminate the sediment and the means by which the contaminated sediment is moved from the point of contamination to the point of exposure. DU contamination in sediments can be particulates of the projectiles, adsorbed DU on sediments washed in where projectiles are weathering, or sediments contaminated by contact with DU-bearing ground- or surface water. DU-contaminated sediments may be found at multiple locations where surface-dominated erosion and deposition processes are moving and depositing them progressively downstream. They can also be found at locations unrelated to, and far removed from, surface transport deposits, where groundwater conduits discharge DU-contaminated water or sediments to the surface. Modeling the exposures from these complex processes and settings requires a sediment sampling program that collects data in a sufficient variety of locations to enable a projection of future impacts that are consistent with the complexities as observed to date. Neither of the programs outlined in the FSP attempt to or are capable of doing so.

7. Surface Water Sampling

Q.054 What is surface water sampling?

A.054 Surface water sampling, as used in the FSP, is the collection of samples of water from streams that drain across the DU impact area at locations above, within and down stream of the DU impact area and from water discharging from caves within the DU impact area.

Q.055 Where in the FSP and its addenda are the tasks of surface water sampling described?

A.055 The FSP provides the initial description of the surface water sampling tasks in Section 6.4, pages 6-29 to 6-31. Section 6.4.1 states the expectation of an addendum, but that addendum has not been released. Details of surface water sampling protocols are provided in Sections 8.2 and 8.4 and in Appendix A of the FSP.

Q.056 What are the major design elements of water samples sampling as laid out in the FSP and related addenda?

A.056 The following are the major design elements of the surface water sampling task in the FSP:

- According to Sub-section 6.4.1, surface water samples will be collected at fourteen locations where sediment samples are also collected. These locations are described as one where Big Creek crosses the western boundary of JPG; eight along Big Creek within the DU impact area, with four associated with spring/cave locations; one where Middle Fork Creek crosses the western boundary of JPG; and five along Middle Fork Creek within the JPG, with one associated with a spring/cave location.

- Sampling of surface water from ponds, lakes and lagoons is not anticipated.
- The volumes or surface water samples will be 100 ml, according to Sub-section 6.4.5 of the FSP.
- Alternatively, the volumes of surface water samples will be 1 of 100 ml (for uranium isotope analysis), 2 of 1 liter, and 3 of 500 ml, according to Appendix A of the FSP, Section A.4, Table A.4-3 on page A.4-2.

Q.057 Is this design for the surface water sampling adequate for purposes of JPG DU site characterization?

A.057 No, it is not.

Q.058 What are the deficiencies of that design for surface sampling?

A.058 A major deficiency of the surface water sampling program in the FSP is that the program does not address the rationale for the task that is provided in Sub-section 6.4 of the FSP on page 6.-29:

> Surface water can be contaminated by DU transported by water erosion as well as contaminated groundwater surfacing into ponds or streams. Contaminated surface water can enter the human food chain indirectly as livestock drinking water or directly through the drinking water supply, as discussed previously for groundwater. In addition, fish or other organisms indigenous to streams or ponds that contain contaminated water represent a pathway to potential receptors.

The exposure pathways that are described in that rationale establish the need to identify DU that has been, is being, or may be transported from the DU impact area to locations where receptors may be exposed. These are locations that are not proposed to be assessed in the surface water sampling program in the FSP. That transport may be as DU in surface water flowing to the point of exposure, or it may be the result of DU-contaminated groundwater that discharges at or above the point of exposure. With two exceptions, the locations that are described are surface water sampling locations that are at or within the DU impact area, an area that is not representative of exposure locations for fate and transport modeling. The two exceptions are locations at the western edge of the JPG. No surface water sampling locations represent especially critical locations of exposure which must be modeled. There are, for example, no locations that could sample surface water contaminated by DU in groundwater that is transported through karst conduits and discharges outside JPG.

The FSP surface water sampling program identifies 14 sample locations; two specifically and 12 only generally. These sites are co-located with 14 sediment sample locations described in Section 6.6 of the FSP. Beyond the criterion of sharing locations with sediment sampling, there are no criteria and no rationale provided for the selection of the locations. There is no rationale provided that optimal locations for surface water samples will, or even can, coincide with optimal sampling locations for sediments. There is no discussion of whether the selection of the surface water sample or the sediment sample will have priority in the selection of a common location site if each is not optimal, or why. Base upon my decades of practice, I know of no geologic setting in which or reasons for which to expect that the best places to monitor sediment are also the best places, one-for-one, to monitor surface water.

Q.059 What is the significance of these deficiencies?

A.059 As described in the FSP quotation cited above, exposure pathways associated with DU-contaminated surface water are complex. Exposure can occur directly through contact with or ingestion of contaminated surface water. It can occur indirectly through the food chain or through contact with, ingestion of, or inhalation of sediments that have become contaminated through contact with DU-bearing groundwater. These complexities vary with the means by which DU can contaminate the surface water and the means by which the contaminated surface water is moved from the point where it becomes contaminated to the point where exposure occurs. DU contamination in surface water can result from contact with particulates from the projectiles, contact with adsorbed DU on sediments washed into the stream from areas where projectiles are weathering, or from the discharge of DU-bearing groundwater to a stream, pond, or lake. DU-contaminated surface water may simply move progressively downstream or recharge groundwater conduits, only to discharge again to the surface downstream or in another drainage basin entirely. Modeling the exposures from these complex processes and settings requires a surface water sampling program that collects data in a sufficient variety of locations to enable a projection of future impacts that is consistent with the complexities that can be observed today. The program outlined in the FSP does not attempt to, and is not capable of doing so.

C. Interactive Considerations

Q.060 Do the design deficiencies of individual hydrogeologic sampling activities have broader implications for JPG site characterization purposes?

A.060 Yes, they do. No task of the FSP is independent of other tasks. Each task relies upon and, in turn, is relied upon by the other tasks, when such tasks are performed in a manner designed to provide feedback and refinement. That critical inter-relationship is not defined or developed in this FSP. The result is isolated sets of data that have no collective meaning, that do not improve understanding of the site, and that do not provide either the structure to the model or model inputs that allow a reasonable or realistic prediction of dose exposure at times and for receptors of interest.

The biggest change (and improvement) in the current conceptual site model over previous models is the recognition that the JPG and DU impact area are underlain by bedrock that has karst development and the recognition that conduits in that karst development will provide preferred pathways for groundwater flow. Those conduits for groundwater flow are similarly conduits for any DU that contaminates groundwater as well as DU-bearing sediments carried by the groundwater flow. Tracking the flows through those conduits from DU source areas to discharge locations is the primary characterization task that is required of the FSP as a result of the new conceptual site model. Everything else follows from that.

Finding a location to drill into a karst system is relatively easy. Determining flow paths through a karst system is extremely difficult. The latter task is what must be accomplished to meaningfully model the fate and transport of DU and the dose exposure that subsequently results. The FSP characterization program does not map open, interconnected conduits from source areas to discharge areas; it does not even attempt to do so. It attempts to penetrate disconnected points in the karst system and, even were that effort successful, does not have the means to integrate those points into a coherent picture of conduit flow. Absent that coherent picture, the ability to model the site in a meaningful way will be no better after this characterization program than before this program started.

Other portions of the FSP characterization program are similarly ill-conceived. They may provide data to the model, but that data has no conceptual validity or meaning. The locations of stream gauging are proposed without consideration of the meaningfulness of any data collected. Stream gauges above and below the intersections of karst conduits with the stream will tell whether and when that conduit feeds the stream or is fed by the stream. That information, in turn, helps map the conduit and, as importantly, the direction of flow through that conduit. That information cannot come from stream gauging locations that are selected to coincide with bridges and culverts under roads, as are those of the FSP.

Similarly, the surface water sampling and the sediment sampling are, for no technical reasons of data validity, co-located. And, in doing so, the FSP foregoes collection of meaningful data. Surface water sample locations logically should be selected at places where the hydrogeology may create different conditions or water quality. Surface water quality data collected at points of hydrogeologic significance feeds back information about the hydrogeologic feature. For example, surface water quality measured above and below the intersection with a conduit will convey information about the water quality in the conduit whether or not the conduit is itself sampled. Under this FSP, not only is significant data not collected, the failure to collect significant data robs the characterization program and the conceptual site model of refinement and improvement and denies the fate and transport model the ability simulate realistic dose exposures.

Sediment contamination is particularly synergistic and complex in areas influenced by karst development. Ground- and surface water can be contaminated by contaminated sediments with which they come in contact. Conversely, sediments can become contaminated by contact with contaminated ground-or surface water. With karst systems, contamination can cross between drainage basins or leapfrog downstream by groundwater that is contaminated discharging substantially downstream of problems associated with surface water. Sediment movement itself has an added dimension in karst terrain. In non-karst areas, sediments can be transported by surface water but not significantly by groundwater. With karst conduits, sediments can be moved through the subsurface just as they can by surface streams, transferring their contaminants to drainage basins that have no threat from sediments transported by surface water. Restricting sediment locations to surface water locations and having those locations almost exclusively in the DU source area imposes dual blinders on the characterization program. First, the restriction precludes identifying areas of contaminated sediments that already exist and which, by their existence help characterize the hydrogeology. Second, the wrong numbers go into the model that is to simulate dose exposures.

The overall objectives for the characterization program to be described by the FSP are to generate the necessary understanding of the site to allow a meaningful fate and transport model to be constructed and to generate the input parameters that are needed for that model to simulate likely doses to receptors of interest at times of interest. The FSP, even as modified by its addenda, simply will not accomplish those goals.

D. Corrective Actions

Q.061 What actions are required to correct the deficiencies sufficiently to produce an adequate characterization?

A.061 The primary focus of the FSP needs to be turned to identifying and mapping those portions of the karst system that constitute the interconnected groundwater conduit systems. At best, the combined responses of the FTA and the EI survey would only show where potential karst conduits cross under a road; they could not be used to map those conduits. In reality, the combined responses of these surveys as described under the existing FSP could not locate even the largest conduit known to exist under the DU impact area, conduits so large they are accessible for hundreds of feet to human entry.

A simpler, more practical approach is to start with direct evidence and measurements of conduits and map away from those known points. Sinkholes and surveyed caves are direct physical evidence of conduits and are a good starting point for mapping. Fracture orientations measured in bedrock exposures along streams can be integrated with cave orientations and sinkhole distributions to identify likely preferred orientations of karst features. Based upon these investigations, multi-spectra remote photography can look for correlative visible features, if any.

Groundwater conduits will discharge to or recharge from streams. Stream surveys that are made to identify locations or reaches of streams with significant gains or losses are indicative of conduit intersections with the stream. Observing these locations under differing flow conditions will establish any variability of the stream/conduit exchange that is time dependent. The stream/conduit intersections can be correlated with the previously mapped features to identify likely conduit positions away from the stream. Local geophysical investigations with appropriately oriented, fine grids can find and map the conduits away from the stream and identify intersecting conduits. EI surveying is one technique, but others such as seismic, penetrating radar or electrical induction are possible alternatives.

As conduits are mapped away from stream intersections, characterization wells can be installed into the conduits. The connection to the stream is often confirmed using dye or chemical tracer studies. Dye or chemical tracer studies can also be used to establish where a conduit discharges to a stream, whether it is a stream in a different basin or downstream of its recharge point in the same stream.

As with mapping conduits away from exchange points with streams, conduits can be mapped away from other known points. Mapping from or between sinkholes can be done in a manner similar to doing so from streams. Subsurface mapping can similarly be initiated from the ends of survey caves. Dye or chemical tracing can be a useful confirmation or exploration tool in these cases, too.

Starting the mapping with known conduits that are part of the groundwater system has the significant added advantage of helping calibrate the geophysical signatures with known features of interest. This allows tracking and mapping of those karst features known to be active conduits and can help avoid the inefficient drilling of expensive wells into karst features that are not groundwater conduits.

The result of this approach is that active karst conduits will have been mapped and they can be instrumented with wells. Optimum locations for surface water sampling, stream and cave gauging, and sediment sampling can then be selected based upon the conduit networks. These locations are selected to isolate the impacts of the hydrogeologic features that are controlling ground- and surface water flow and sediment transport. They, in turn, provide data into the fate and transport model that provide useful and meaningful constraints on that model, increasing the likelihood that the computed dose exposures will represent realistic estimates.

III. Sample Collection and Analysis Methods

Q.062 Where in the FSP and its addenda are the sample collection and analysis methods described for the various media being sampled?

A.062 The sample collection methods for the various media to be sampled are described in general terms in Section 6, Field Activities, of the FSP. Groundwater sampling is described generally in Sub-section 6.2; biota sampling in Sub-section 6.3; surface water sampling in Sub-section 6.4; soil sampling in Sub-section 6.5; sediment sampling in Sub-section 6.6; Kd-related sampling in Sub-section 6.7; and corrosion-related sampling in Sub-section 6.8. Section 8 of the FSP provides general discussions of the medium-specific sampling that will be done for purposes of quality control and assurance, descriptions of sample quantities and preservation requirements, and shipping and handling procedures.

Appendix A to the FSP, Quality Assurance Project Plan (QAPP), in part duplicates the aforementioned parts of Section 6 and Section 8, while adding some detail. Sub-section A-6.1 of Appendix A, Laboratory Analysis, references tables in Section A-4 for the analytical methods for each medium. These tables present listings of sample sizes and preservation protocols in addition to the analytical methods. Section A-3 contains a table with objectives of data quality, including reporting limits for alpha activity in each medium.

An addendum to describe these methods in more detail for specific media is planned but has not yet been released. However, my general understanding from past interactions with Army and SAIC personnel is that the they expect to follow basically the same methods used in the JPG DU Environmental Radiation Monitoring Program semi-annual sampling activities, except when a specific difference has been identified in the FSP or its addenda.

Q.063 What media are proposed to be sampled with the resulting data analyzed under the FSP?

A.063 Five general media are sampled and analyzed under tasks of the FSP for various purposes associated with site characterization: soil, sediment, groundwater, surface water and biota.

Q.064 What are the sample collection and analysis methods described in the FSP for each of these media?

A.064 For soil and sediment, samples will be a minimum of either 1000 grams or 8 oz (~225 grams), depending upon whether the Section 6 text of the FSP or Table A.4-2 is the controlling protocol. Samples will not be preserved. Any water collected with a sediment sample will be retained with the sample. Sediment samples will be collected from the top six inches of that medium. Soil samples will be collected as six-inch increments from the surface to a depth that shows gamma activity indistinguishable from background. No analyses for anything other than uranium is described and the QAPP reporting limit objective is 2 pCi/g, using the ASTM D3972-90M procedure for measuring alpha activity.

For groundwater and surface water the minimum sample size is 100 ml for uranium activity analyses, and the QAPP reporting limit objective is 1 pCi/L, using the ASTM D3972-90M procedure for measuring alpha activity. Appendix A specifies no filtering for water samples, but Section 6 alludes to possible filtering of groundwater. Appendix A, Table A.4-3, also specifies 1-Liter or 500 ml samples for laboratory analyses of other classes of constituents in the water, but does not identify the analytes individually and QAPP reporting limit objectives for non-radiologic analytes are listed as TBD, or to be determined.

For biota, see the testimony of STV witness Henshel.

Q.065 What in your opinion are the minimum requirements for media sampling and the subsequent analyses?

A.065 For each medium, the sampling needs to occur at the time(s), at the place(s), under the condition(s), and in sufficient quantity(ies) to produce data meaningful to the eventual task of modeling the site for fate and transport of DU out of the impact area and the computation of realistic dose exposures at places and times of interest. For each sample that is so collected, the analytical methodology must be capable of generating data of sufficient accuracy and precision to achieve those same results.

Q.066 In your opinion, are the sample collection and analysis methods described in the FSP adequate for purposes of JPG site characterization?

A.066 No, they are not.

Q.067 Are your concerns with sampling and analysis common to multiple media or are they specific to a single medium.

A.067 There are common elements of concern and there are elements that are medium specific. In general, the sampling protocols are medium-specific and the analytical concerns impact multiple media. However, there are times when sampling methods create inadequacies in the analytical results, as can occur, for example, when the sampling protocol specifies a sample that is too small to produce a reliable, meaningful analysis.

Q.068 What are common areas of concern among the various media with respect to analytical protocols?

A.068 The common areas of concern among the various media are related to DU in the samples. The most basic level of concern is whether the analysis can determine whether DU is in the sample and, if so, at what concentrations.

Q.069 Which of the media you listed are subject to the analytical concerns regarding DU detection in samples and establishing the DU concentration?

A.069 Each of the five media are subject to those concerns.

Q.070 Are there deficiencies in the analysis methods for DU?

A.070 Yes, both with respect to the detection of DU and with respect to measurement of the concentration of DU in the samples of each medium. There are two aspects with respect to each of these deficiencies. One aspect lies with the analyses themselves and the other lies with the interpretation of the analyses.

Q.071 What are the inadequacies with respect to the analyses of these samples?

A.071 The analyses that are run for uranium in these media samples are not chemical analyses of uranium. They are analyses that are based upon characteristic radioactive decay. Some samples are analyzed for gross gamma activity. An example of this is the criterion for adding new sediment sample sites at locations where a surface gamma scan exceeds the arbitrary increase over the "background" level, *i.e.*, the gamma scan where DU contamination is believed not to exist. For most samples, however, the analysis is the measurement of alpha activity.

For all samples which might represent migrating DU, the samples are analyzed for the alpha radiation attributable to three naturally occurring uranium isotopes; U-234, U-235, and U-238. Naturally occurring uranium has characteristic ratios among the alpha radioactivity levels of these isotopes. Depleted uranium has different characteristic alpha-activity ratios among these isotopes, as does enriched uranium. Thus, in theory, isotope analyses using alpha activity measurements can not only establish the total uranium activity, it can potentially distinguish among sources of that uranium.

Radioactive decay is a random process. Thus, the greater the number of nuclei, *i.e.*, the greater the mass of a radioactive isotope, and the longer the time period of the count, the greater the number of decays and the more precise the measure of the decay rate. In the case of multiple isotopes, the greater the precision of the individual isotope activities, the greater the precision in the ratios between isotopes and the surer one can be of interpretations based upon those ratios.

The analysis of samples for alpha activity of uranium isotopes proposed in the FSP is deficient because the size of the samples is too small to provide the mass necessary to provide count rates of sufficient precision to allow unambiguous identification of DU presence or concentrations at low levels of contamination. The reduced sample size is reflected in the large QAPP reporting-limit objectives for uranium isotopes.

Q.072 Why is it necessary to identify the presence of DU and establish its concentrations at low levels?

A.072 If the samples were being taken for purposes of compliance with a permit's effluent limitation, quantification of DU at low concentrations would not be important. Precision would only be needed at levels near the compliance standard. For the purposes of the FSP, however, it is both necessary and important. The objective of the FSP is not to compare current DU concentrations with a current compliance standard. The characterization objective of the FSP is to provide valid, site-specific data that allow a fate and transport model, whether RESRAD or some alternative program, to realistically and reliably predict the future movement and concentrations of DU at places removed from the sampling locations for the purposes of estimating dose exposures.

Whether the computations of a fate and transport model are predictive or speculative hinges upon whether the model is constrained with data specific to the site being modeled and whether there are data against which the model can be calibrated. For efforts like the modeling of the JPG for DU exposures to potential receptors off-site at some point in the future, finding hard data against which to calibrate the model's computations is essential. For calibration purposes, quantifying the existence of *any* DU in even a single medium greatly constrains the computational freedom of an otherwise uncalibrated model and moves the results of simulations from the realm of speculation toward that of reasonable prediction. Even establishing that DU does not exist in a medium above a very low detection threshold provides meaningful improvement over the condition of no DU above a high detection threshold.

Q.073 Can you offer an example of where small sample size interferes with the ability to identify DU or establish its concentration?

A.073 Yes. In the April, 2006 ERM report (ML062900028), the surface water samples collected from Big Creek at the downstream sides of both the DU impact area and JPG reported U-238/U-234 alpha-activity ratios above 3. These ratios exceed the threshold of 2 held as indicative of DU in the FSP (Sub-Section 2.3.1, page 2-14). Although that criterion was exceeded, the Army dismissed the significance of these data because of the statistical uncertainty associated with low count rates. The count rates are proportional to the mass of the sample analyzed. For these samples, the standard operating procedure for sampling groundwater and surface water is one gallon (ML062900028, Appendix A, page A-5). Based upon the field notes associated with the April 2006 sampling event

((ML062900028, Appendix B), the actual sample size was only 500 ml. The analysis was performed on a sample only about 1/9 that specified in the standard operating procedure. Had a sample of the specified size been analyzed, the count rates would have been substantially higher (approximately 9-fold) and the uncertainties substantially lower. In this case, unnecessarily low count rates, due to small sample size, produced uncertainties that allowed the Army to reject the indication of DU in the sample.

A critical deficiency of the FSP is that ground- and surface water samples will only be 100 ml, 1/5 that of the ERM samples that already exhibit uncertainties that cloud their interpretation. This deficiency is compounded by the high QAPP reporting limit objective for water of 1 pCi/L. For the cited ERM data, all individual isotope activities for surface water samples and most for groundwater samples are below the FSP reporting limit objective. The effect of the FSP analytical method, implemented by the small sample size and high reporting limit, is to reduce the resolution of the analyses, not increase it, thereby imposing blinders to the existence and concentrations of DU migrating from the DU impact area..

The situation is similar for soil and sediment samples. For solid samples, the FSP specifies samples of not less than 1000 grams in the main text. However, Appendix A of the FSP specifies sample sizes for solid media of 8 oz., less than 1/4 of the size stated in the FSP main text. If the smaller sample size prevails, the resolution of low concentrations of DU will also decline. Every unnecessary decline in the resolution of

DU concentrations results in an avoidable deficiency in data available for the modeling.

Q.074 What deficiencies exist that are specific to a particular medium with respect to sampling methods?

A.074 Sampling for groundwater and surface water must be explicit in requiring that samples being analyzed for uranium isotopes not be filtered. Filtering of water samples will remove suspended organic and inorganic particles moving with the water. Any DU on those particles will also be removed. The result will be an underestimate of DU transport from the source area in these media. As worded now, the FSP is inconsistent. Groundwater may be required to be filtered according to Sub-section 6.2.9 on page 6-23, and procedures are specified to do so. By contrast, Sub-section 6.4.5 on page 6-30 states that surface water will not be filtered.

Stream sediment sampling at present under the FSP consists of sampling sediments from locations on the banks of streams. With the exception of one location on each Big Creek and Middle Fork Creek at the west side of the JPG, these are sediments deposited by streams within the DU area, not sediments that are being transported from the DU impact area to potential areas of exposure. It is possible under the FSP, if samples are taken in the wrong places, *e.g.*, on the cut (outside) bank of a stream meander, that an FSP sediment sample may consist of sediments that pre-date DU use at the site. Streams are also not being sampled for sediments that are being actively moved by the streams. Since the FSP does not sample sediments being moved, it also cannot evaluate the load of uranium being transported from the DU impact areas to locations downstream, or establish how far those loads are moved.

There is no program in the FSP to monitor sediments that are transported with water moving through the karst conduits. There is no question that the karst conduits can and do receive sediments from the surface, as documented by the JPG karst investigation (Sheldon, 1997), which describes both animals and ordinance that were found in caves beneath sinkhole entrances, cave streams with beds of sediment, and even at least one stream that drains into the sink hole entrance to one cave. As presently written, the FSP does not sample sediments as they move through karst conduits and may authorize filtering of samples to remove suspended sediments. That effectively eliminates two of the three mechanisms that can transport DU through the groundwater conduits underlying the DU impact area and JPG. Such an approach is clearly deficient.

Each of these deficiencies has the potential to mask DU migration away from the DU impact area, precluding the ability to determine to where and at what eventual concentrations it will be found. Those are the types of data that are core to any attempt to compute dose exposures outside JPG by the site model.

The FSP provides no task associated with the soil sampling within the DU impact area that will address the potential for fractionation that occurs during projectile weathering and transport, modifying isotope ratios from those observed in intact, metallic DU. Fractionation sufficient to change isotope ratios has been demonstrated as an effect of redox reactions facilitated by micro-organisms (Rademacher, *et al.*, Experimentally Determined Uranium Isotope Fractionation During Reduction of Hexavalent U by Bacteria and Zero Valent Iron, Environ. Sci. Technol. 2006, 40, 6943-6948.). Just as alpha-recoil can alter uranium isotope ratios in some media with naturally occurring uranium, fractionation during weathering of projectiles within soils and migration of weathered DU through the soils may alter isotope ratios for mobile and residual DU from the ratios of the metallic uranium in the projectiles. Unless those changes are identified and tracked, one cannot know what isotope ratios in which medium will represent migrating DU. Missing DU or overestimating DU due to erroneous assumptions of isotope signature will introduce corresponding errors in the site modeling of exposures.

Q.075 What actions are required to correct these deficiencies?

A.075 With respect to isotope analyses, sampling and laboratory protocols should be established that will allow the identification and quantification of DU at levels that constitute 25% or more of the total uranium in the sample of any particular medium. This can be accomplished by collecting a sample of sufficient size and/or increasing the count rate window or both. Alternatively, the FSP could be rewritten to establish the isotope concentrations using chemical rather than, or in addition to, radiological methods.

Groundwater and surface water samples should be collected without filtering, to ensure that uranium moving with suspended sediments does not escape detection and measurement. Sampling for the suspended DU should also be performed over sufficient ranges of stream or conduit flow to establish temporal variations of suspended sediment transport and long-term totals.

Sediment sampling should be redefined in the FSP to focus on DU in sediments being transported by surface water and conduit groundwater, rather than DU in sediments that have been deposited in the DU impact area. As with suspended DU, sampling for DU-bearing sediments should also be performed over sufficient ranges of stream and conduit flow to establish temporal variations of sediment transport and long-term totals. In addition to measuring the temporal variability of sediment transport, the location(s) of where these sediments are deposited outside should be mapped.

As part of the FSP assessment of DU corrosion and weathered DU movement through soils, the task of studying any effects of fractionation should be added. If fractionation does make material changes to the isotope ratios in soil relative to the original projectile, appropriate adjustments to the DU isotope signature in downstream media needs to be recognized and included in the analysis of that data.

IV. Verification

I declare, under penalty of perjury, that the foregoing testimony is true and correct to the best of my knowledge, information and belief.

July 13, 2007

Charles H. Norris, PG

Exhibit CHN-1

PREFILED DIRECT TESTIMONY OF
CHARLES H. NORRIS, LPG

SAVE THE VALLEY, INC.
EXHIBIT CHN-1

Geo-Hydro, Inc.
1928 East 14th Avenue
Denver CO 80206
cnorris@geo-hydro.com

Charles H. Norris, P.G.
(303) 322-3171

SUMMARY OF QUALIFICATIONS

Thirty plus years of professional experience in geology, hydrogeology and management in the applied and theoretical geosciences. Experience includes performance, oversight review, or management of site assessment; RI/FS; computer modeling of fluid flow, contaminant transport, and geochemistry (applications and code development); policy and rule making procedures; aquifer evaluation; resource development; and litigation support; nationwide and internationally.

PROFESSIONAL EXPERIENCE

GEO-HYDRO, INC., Denver, Colorado, (1996-present), Principal, CEO, Vice-President
HYDRO-SEARCH, INC., Golden, Colorado, (1992-1996), Director of Hydrogeology
UNIVERSITY OF ILLINOIS, Urbana, Illinois, (1987-1992), Research Associate; Manager, Industrial Consortium for Research and Education for the Laboratory for Supercomputing in Hydrogeology
Consulting Hydrogeologist/Geologist, Champaign, Illinois and Denver, Colorado, (1980-1992)
MGF OIL CORPORATION, Denver, Colorado, (1985 - 1986), Manager Geological Engineering
EMERALD GAS AND OIL, Denver, Colorado, (1980 - 1986), President and Owner
PETRO-LEWIS CORPORATION, Denver, Colorado (1980), Districts Geologist
TENNECO OIL COMPANY, Denver, Colorado and Houston, Texas, (1977-1980), Senior Geological Engineer
AMOCO INTERNATIONAL OIL COMPANY, Chicago, Illinois, (1975-1977), Senior Geologist
SHELL OIL COMPANY, Houston and Midland, Texas, (1972-1975), Exploration Geologist

PROFESSIONAL REGISTRATIONS, MEMBERSHIPS, AND AFFILIATIONS

Professional Geologist: Illinois (# 196-001082), Indiana (# 2100), Pennsylvania (PG003994), Utah (#5532631-2250), Wisconsin (# 924), Wyoming (#2989)
Registered Environmental Professional (#5350), State of Colorado, Petroleum Storage Tank Fund

National Ground Water Association
Colorado Groundwater Association (Vice President 1999, President 2000, Past-President 2001)
Professional Geologists of Indiana (past)
The Colorado Mining Association (past)
Illinois Groundwater Association (past)
American Association of Petroleum Geologists (past)

Phi Beta Kappa, Phi Kappa Phi, Sigma Xi

EDUCATION

B.S., Geology, University of Illinois, High Honors and Distinction in Geology, 1969
M.S., Geology, University of Washington, National Science Foundation Fellow, 1970
University of Illinois, all but dissertation completed for Ph. D., Hydrogeology, 1992

PROJECT EXPERIENCE

RI/FS & GENERAL SITE INVESTIGATIONS

- Manager for technical assistance through a Technical Assistance Program (TAP) grant from PRPs to local citizens' group. Assistance through grant to provide assessment and feedback on site work products as they are developed and implemented, explain the remediation processes and activities to the citizens, and serve as technical liaison between citizens and remediation team.

- Modeler and hydrogeologic consultant at industrial tank farm adjacent to the Chicago Sanitary and Ship Canal in northeastern Illinois. Assess hydrogeologic data, interpret aquifer testing, and model groundwater flow in soil and fractured carbonate bedrock in area of DNAPL accumulation as part of site characterization and voluntary remediation design.

- Manager and Hydrogeologist of groundwater investigation at an industrial dump site adjacent to the Illinois River in north Central Illinois. Investigated fate and transport of 3-4 decades of disposal of mixed, hazardous industrial wastes at a non-engineered floodplain dump site. Expert testimony and legal support. Pre-trial settlement provided for installation of monitoring system in lieu of site characterization.

- Manager of groundwater flow modeling performed as part of the groundwater characterization effort and as part of the preliminary remedial designs. The site is a Superfund site involving both organic and metals contaminants at a wood treating facility in an urban area in Alabama adjacent to a major commercial waterway.

- Manager of groundwater flow modeling performed as part of the groundwater characterization effort and as part of the 90% and Final remedial designs. The site is a high profile Superfund site involving both organic and metals contaminants at a wood treating facility in Northern California.

- Technical Advisor assisting in the evaluation of aquifer properties and well performances for an extraction well field near Sacramento CA. A high volume pump and treat system for chlorinated solvents showed strong and anomalous decline in productivity. Detailed evaluation identified both possible causes and recommended operations changes to alleviate the problems.

- Technical Advisor assisting in the evaluation of aquifer properties and well performances for initial installation of a high volume extraction well field in Southern California. The chlorinated solvent plume associated with a Superfund site impacted a large area in a layered, heterogeneous groundwater basin managed intensively for public water supplies.

- Senior oversight and review in the evaluation of aquifer and soil properties, and the remediation of the soils contamination and groundwater impacts associated with compressor facilities of interstate gas transmission companies. Various projects and sites in western Colorado, Wyoming, and the Texas panhandle.

- Technical Advisor for the Remedial Investigation/Feasibility Study (RI/FS) of the Landfill Solids and Gases Operable Units at the Lowry Landfill CERCLA site located near Denver, Colorado. This project involves the characterization of the extent of potential contamination within the unsaturated zone adjacent to this high profile site. Work involves extensive coordination and interaction with multiple PRP groups as well as various regulatory agencies.

- Project Manager for independent oversight of a proposed low-level radioactive waste disposal site. Task was to develop technical and legal program for governmentally funded intervener's case as part of adjudicatory hearings on a high-profile, proposed disposal facility and involved identifying, retaining and educating legal staff, retaining a team of technical experts, negotiating fees, coordinating work product and presentations, providing liaison with citizen's groups, responding to press and integrating personal testimony on hydrogeology and modeling. Expert testimony and legal support.

LANDFILL SERVICES

- Project Manager and Hydrogeologist for a geologic and hydrogeologic assessment of existing water quality and off-site migration from existing licensed landfill near Joliet IL. Work includes groundwater flow modeling of remedial alternatives and groundwater impact assessments of various alternatives for submittal to IEPA.

- Project Manager and Hydrogeologist for a geologic and hydrogeologic assessment for siting of a proposed expansion for a hazardous waste landfill in Peoria County, Illinois. Expert testimony and legal support. Review identified errors in application, unaddressed contamination on facility property, and inappropriate modeling design and implementation.

- Project Manager and Hydrogeologist for a geologic and hydrogeologic assessment for siting of a proposed regional landfill by expansion of local landfill in Ogle County, Illinois. Expert testimony and legal support. Review identified in errors application, unaddressed existing leakage, and potential risk to public water supply. (Three hearings)

- Project Manager and Hydrogeologist for a geologic and hydrogeologic assessment for siting of a proposed regional landfill by expansion of local landfill in Kankakee County, Illinois. Expert testimony and legal support. Review identified errors in application, unaddressed existing off-site leakage, and inappropriate modeling design and implementation. (Two hearings)

- Project Manager and Hydrogeologist for a geologic and hydrogeologic assessment of a proposed regional landfill in Will County, Illinois. Expert testimony and legal support. Research documented numerous errors in application which resulted in underestimation of infiltration rates and potential migration rates. Identified evidence of sub-karstic migration pathway from site to nearby stream.

- Project Manager and Hydrogeologist for a geologic and hydrogeologic assessment of a proposed regional landfill expansion at East Peoria, Illinois. Research documented current leakage from the existing landfill into the regional unconfined aquifer within the cone of depression of the municipal water supply wells. In part as a result of the evaluation, the proposed expansion has been abandoned. Expert testimony and legal support.

- Project Manager and Hydrogeologist for a geologic and hydrogeologic assessment of a proposed regional landfill at Ottawa, Illinois. Provided testimony at county hearings identifying and documenting site-specific conditions that invalidated part of the ground water evaluation testing, necessitating the need to re-evaluate the groundwater flow system and redesign the monitoring system. Expert testimony and legal support.

- Project Manager and Hydrogeologist for a geologic and hydrogeologic assessment of existing municipal landfills and a proposed landfill redesign and expansion at Salem, Illinois. Provided testimony at city hearings documenting existing landfill leakage and identifying site-specific conditions that complicate the design of a reliable monitoring system. Expert testimony and legal support.

- Project Manager and Hydrogeologist for site evaluations of the geology and hydrogeology of several proposed municipal landfills and a landfill expansion in Bartholomew County, Indiana. The review of the expansion demonstrated inadequate monitoring of the existing facility. One proposed site showed possible, current ground water usage from under the proposed facility and conditions that may preclude state-level site approval.

- Project Manager and Hydrogeologist serving in consultation to the Board of Wayne County, Illinois, regarding a proposed expansion to a regional landfill. Investigation and oversight established viability of the physical site and improvements that were needed in operating procedures and monitoring efforts. Expert testimony and legal support.

- Project Manager and Hydrogeologist for an assessment of an existing regional municipal landfill at Urbana, Illinois. Principle problems included ground water contamination, unplugged well(s) within the facility boundary that penetrated the aquifer serving public water supplies and a monitoring system inadequate to evaluate the contaminant migration. Results of the evaluation include an expanded system of monitoring wells, improved protocols for ground water sampling and revised statistical procedures to determine background water chemistries.

- Project Manager and Hydrogeologist for a site assessment of a proposed municipal landfill expansion in west central Indiana. Established feasibility of using the engineering and design features of the expansion to prevent contamination from the pre-existing non-engineered facility.

- Project Hydrogeologist for a site assessment of a proposed saturated-zone, regional balefill in central Illinois. Principal problems involved the evaluation of the hydrogeologic characteristics of the strip mine spoils within which excavation would occur, the blasted mine bottom upon which the liners would be built and the materials available for liner construction. Expert testimony and legal support.

- Project Manager and Hydrogeologist for a site assessment of a proposed municipal landfill expansion in Livingston County, Illinois. Principal problems involved the evaluation of the impact of shallow coal tunnel mining beneath the site and reaction of waste leachate with unusual clay mineralogy important to waste isolation at the site. Expert testimony.

- Technical Reviewer of site assessment and re-assessment of a proposed inter-governmental regional landfill in central Illinois. Verified unanticipated, politically unacceptable risks to major aquifer system serving public water supplies. Assisted in drafting of technical policy statement that permitted new siting efforts to proceed in the jurisdiction. Expert testimony.

WATER RESOURCE EVALUATION & DEVELOPMENT

- Manager for ground water modeling effort associated with the development of a high-volume ground-water supply and delivery project in Colorado. The effort included investigating and evaluating a previously used, court-accepted model, adapting and updating the model, and applying the model to assess the impacts of a proposed private ground-water diversion project that would be the largest in the United States. Ongoing effort includes subsequent review of alternative proposed model and further litigation support.

- Manager for review of an application for an expansion of a large long-wall mine in southeastern Ohio. The review identified extensive unrecognized mining-related impacts to water supplies from historic mining and identified hydrologic risks to a unique old-growth forest adjacent to the proposed expansion, and resulted in an appeal of the application. Expert testimony and legal support.

- Manager for ground water modeling effort associated with the development of a surface reservoir designed for conjunctive use of ground and surface water to reduce peak ground water pumping demands in Denver metro area. The effort included investigating and evaluating a previously used, model, adapting and updating the model, and applying the model to assess the impacts of project on other water rights. Study is a component of the EIS.

- Project Manager for multi-company effort to model thermal loading of northern Nevada surface waters as a result of mine dewatering project. Successful liaison among technical staffs and regulators and modeling work for a high profile EIS resulted in approval of discharge permit.

- Project Hydrogeologist for the feasibility study of a small lake for a northern Illinois nursery, to be used for recreation, fishing and irrigation. Evaluated shallow and intermediate ground water and surface run-off, reviewed engineering design and directed ground and surface water sampling program to determine nutrient levels.

HYDROCHEMISTRY

- Principal Investigator for grant to research the geochemical implications of using alkaline addition as one means for preventing and/or remediating inorganic contamination resulting from acid mine/rock drainage. Empirical and modeling evidence showed conditions under which alkaline addition can cause or exacerbate contamination of some constituents of concern.

- Project Manager, hydrogeologist, geochemist for ongoing investigation of metals contamination of a trout stream in West Virginia. Impacts from natural and industrial sources , present and past, evaluated to segregate relative significance of various sources. Includes expert testimony and legal support.

- Project Geochemist and Hydrogeologist for evaluation and critique of modeling protocols used by USEPA for risk assessments performed as part of regulatory determinations for various solid wastes. Identified errors in methodology and input that had caused previous modeling to mischaracterize risks for settings with observed damage cases. Computer modeling.

- Geochemist and Hydrogeologist for evaluations of inorganic groundwater chemistry at an industrial RCRA site near Joplin MO. Federal lawsuit filed pursuant to PRP contribution and sources and timing of contamination. Was able to use geochemical interpretations to establish significant elements of aquifer characteristics and implications for contamination routes. Expert testimony.

- Project Hydrogeologist and Geochemist for evaluations of proposed coal combustion waste disposal as part of reclamation activities at surface coal mines in Southwestern Indiana. Ongoing efforts are targeted toward refining regulatory framework for disposal efforts, establishing effective characterization and monitoring programs and determining appropriate operation and engineering practices. Project involves extensive interdisciplinary effort and expert testimony.

- Project Geochemist for the investigation of the impacts of remediating acid mine drainage by installing bulkheads to flood exhausted mine working. Predictively modeled water chemistries in situ, within flooded mine, along flow paths and upon surface discharge. Assisted in preparation of testimony that resulted in permit approval for the San Juan County, Colorado project.

- Project Manager and Project Geochemist/Hydrogeologist for investigation of potential environmental impacts of disposal of coal combustion wastes (CCW) as part of a reclamation plan at a surface coal mine in northern New Mexico. Performed or directed geochemical, infiltration and flow modeling of the proposed project to identify optimum disposal methods and worst case impacts. Presentation to State resulted in approval of this precedent-setting project.

- Project Manager, Geochemist and Hydrogeologist for an investigation of a proposed disposal/construction project to build a central Illinois ski mountain from fly ash produced by a co-generating plant operated by a major food products manufacturer. The investigation involved overseeing an engineering review of project plans, a site investigation and evaluation, geochemical modeling of initial and final mineralogical composition of the mass and of the leachate chemistry and evolution and the impact on the hydrogeologic and structural integrity of the project. Expert testimony and legal support.

RELATED PETROLEUM INDUSTRY EXPERIENCE

- Project Manager for the environmental assessment of 82 Texas producing properties targeted for acquisition. Evaluations included site walk-overs, surface soil and liquid sampling, radiological monitoring and geoprobe sampling of soils and ground water. The assessments documented a multitude of impacts from both exempt and non-exempt wastes that, unrecognized, could have resulted in substantial financial exposure to the client.

- Project Geologist and Petrophysicist for an investigation of resource potential of coal bed methane in San Juan Basin of New Mexico and Colorado. Study focused on innovative log analysis techniques; formation water chemistries, production rates and disposal problems; well drilling, completion and re-completion practices; and detailed subsurface facies and structural mapping and stratigraphic correlation in shallow coal beds of Kirtland/Fruitland/Pictured Cliffs shoreline complex and relationships to overlying Tertiary sandstones.

- Developed a successful play in the Hunton and Mississippi Lime formations of northwest Oklahoma. The play recognized the secondary porosity systems of both formations (dolomitization and fracturing, respectively) and the genetic significance to each of the buried topography at the intervening unconformity.
- Managed a detailed reservoir study of a Cotton Valley gas field in east Texas that resulted in RRC approval of non-standard spacing based upon the recognition of secondary porosity and a dual-conductivity system that resulted from drape-induced fractures. The revised spacing both protected resource ownership and conserved the costs of infill drilling. Expert testimony and legal support.
- Project Geologist, Petrophysicist and Expert for various contested adjudicatory hearings apportioning oil and gas ownership. Cases involved primary recovery of both oil and gas and secondary recovery of oil. Accepted as expert (geology, hydrogeology, and/or geological engineering) in Oklahoma, Texas, and Wyoming.

Additional Professional Experience

- Invited presenter to National Research Council of the National Academy of Sciences, Committee on Mine Placement of Coal Combustion Wastes.
- Appointed member of a Quality Assurance Committee under the West Virginia Department of Environmental Protection. The committee, comprised of representatives of state and federal regulators, industry , and interveners, was charged with a year-long review of state mining applications and approval practices relative to mining under the state and federal surface mining laws.
- Invited presenter to National Research Council of the National Academy of Sciences, Subcommittee on Alternatives, Study on Coal Waste Impoundments.
- Project Manager and Hydrogeologist for the review of Proposed and Revised Proposed Criteria for the Siting of a Low Level Radioactive Waste Disposal Facility in Illinois. Evaluation was targeted toward both technical content and processes of selection. Testimony and written comments led to significant improvements and flexibility in the Criteria as finally published.
- Project Hydrogeologist testifying at hearings before the Illinois Pollution Control Board on regulatory language for the Illinois Ground Water Protection Act. Contributed major conceptual and specific language changes to the final promulgated rules for Ground Water Quality Standards and Regulations for Existing and New Activities with Setback Zones and Regulated Recharge Areas. Expert testimony and legal support.
- Project Hydrogeologist and Log Analyst for three applications to U.S. EPA for permits to continue deep well disposal of hazardous wastes in east central Illinois and southern Ohio. Project required evaluation of geophysical logging data to determine injection zone and confining layer properties, regional flow systems, chemical interactions of the waste stream with the native rock and the ability of the injection system to isolate the waste from the environment.

Reports, Presentations, and Publications

Norris, Charles H., 2005, "Water Quality Impacts from Remediation Acid Mine Drainage with Alkaline Addition", draft version released to National Research Council of the National Academy of Sciences, Committee on Mine Placement of Coal Combustion Wastes, Geo-Hydro, Inc., Denver CO, July 3, 2005

Norris, C. H., "notes from the front... Overview of three sites", invited paper before National Research Council of the National Academy of Sciences, Committee on Mine Placement of Coal Combustion Wastes, Evansville IN,

March, 2005.

Norris, Charles H., 2004, "Environmental Concerns and Impacts of Power Plant Waste Placement in Mines", Presented at Harrisburg PA, May 4-6, 2004. Published in Proceedings of State Regulation of Coal Combustion By-Product Placement at Mine Sites: A Technical Interactive Forum, Kimery C Vories and Anna Harrington, eds, by U. S. Department of Interior, Office of Surface Mining, Alton IL, and Coal Research Center, Southern Illinois University, Carbondale IL.

Norris, C. H., "Developing Reasonable Rules for Coal Combustion Waste Placement in Mines. Why? When? Where? How?", USEPA Contract 68-W-02-007, IEI Subcontract 7060-304, Invited paper at USEPA MRAM meeting, Rosslyn VA, September, 2003.

Norris, C. H., "So, You think You're a Geologist? (F. Kafka to A. Liddell, In Wonderland)", Colorado Ground Waster Association Monthly Meeting,, Denver CO, September, 2002.

Norris, C. H., "Assessment of the Anker Energy Corporation proposal for mining and reclamation, Upshur County, West Virginia." Independent evaluation on behalf of Anker Energy Corporation and West Virginia Highlands Conservancy , July, 2002.

Norris, C. H., "Coal Combustion Waste: Coming soon to a neighborhood (and maybe a faucet) near you." Colorado Ground Waster Association Monthly Meeting,, Denver CO, May, 2001.

Norris, C. H., "Slurry-to-ashes, and ashes-to . . . A case of a coal company and citizens working together to evaluate alternatives." Invited paper before National Research Council of the National Academy of Sciences, Subcommittee on Alternatives, Study on Coal Waste Impoundments, St. Louis MO, June, 2001.

Norris, C.H., and C. E. Hubbard, "Use of MINTEQA2 and EPACMTP to Estimate Groundwater Pathway Risks from the Land Disposal of Metal-Bearing Wastes", for Environmental Technology Council, submitted as public comment to USEPA on regulatory determination for Fossil Fuel Combustion Wastes, May, 1999.

Norris, C.H., "Report on the Determination of Intermittent Streams and the Potential Impacts of Valley Fill on Area Drainages, Southern West Virginia", expert report for litigation prepared for Mountain State Justice, Inc, Charleston WV, March, 1999.

Norris, C.H., "Report on the Geology and Hydrogeology of the Caterpillar Levee Site with an Evaluation of Potential Pathways on- and off-site for the Movement of Solid and Hazardous Wastes", expert report for litigation prepared for Citizens for a Better Environment, Chicago IL, March, 1998.

Norris, C.H., "Dr Pepper, Biorhythms, and the Eight-Hour Pumping Test ", Colorado Ground Waster Association Annual Meeting, Golden CO, December, 1997.

Norris, C.H., "Characterizing Ash Composition and (vs.) Projecting Environmental Impact for Purposes of Permitting CCW Disposal ", Coal Combustion By-Products Associated with Coal Mining - Interactive Forum, Southern Illinois University at Carbondale, Carbondale IL, October, 1996.

Norris, C.H., "Geochemical Modeling". Co-instructor for Short Course on Hydrogeologic Issues Related to Mine Permitting, Reclamation and Closure, SME Annual Convention, Phoenix AZ; March, 1996.

Norris, C.H., An Improved Method for Middle Time Analysis of Slug and Bail Test. Unpublished. 1994.

Norris, C.H., "Evolution of the Landfill", presentation as part of a Telnet program, *Garbage Dilemma Educational Series*, sponsored by Illinois Farm Bureau and Cooperative Extension Service of the College of Agriculture, University of Illinois, Urbana, Illinois, April 20, 1992.

Norris, C.H., "Technical Analysis or Political Acceptability: The Domesticated Fowl or its Ovum", Solid Waste

Management and Local Government Workshop, sponsored by Institute of Government and Public Affairs, University of Illinois, Urbana, Illinois, Jan-Apr, 1992.

Norris, C.H., Report on the Geology and Hydrogeology [of the] SWDA Proposed Landfill Site, Township 8 North, Range 6 East, Section 31, Bartholomew County, Indiana, for Central States Education Center, Champaign, Illinois, 1991.

Norris, C.H., Hydrogeology and Modeling of the Proposed Illinois Low Level Radioactive Waste Disposal Site at Martinsville, Illinois; testimony before the LLRW Siting Commission, October and November, 1991, Martinsville, Illinois.

Norris, C.H., Ground Water Quality Standards for the Illinois Ground Water Protection Act; testimony before Illinois Pollution Control Board, Chicago, Illinois; February, May, October and December, 1990; May, 1991.

Norris, C.H., Hearing on a Petition for a Special Use Permit for the Construction of a Ski Mountain in Oakley Township, Macon County, Illinois; testimony before the Macon County Zoning Board of Appeals; February 16, 1990.

Norris, C.H., Hearing on a Solid Waste Disposal Permit for the Siting of a Municipal Landfill for Streator, Illinois; testimony before the Livingston County Board; August 6, 1990.

Norris, C.H., In the matter of the Gallatin National Company Proposed Balefill, Fulton County, Illinois, written comments to the Illinois Environmental Protection Agency, Springfield, Illinois, 1990.

Norris, C.H., 1990, Log Analysis of the Allied Chemical Corporation Waste Injection Well, Danville, Illinois, for Alberto Nieto, Champaign, Illinois.

Norris, C.H., 1989, Log Analysis of the Cabot Corporation Waste Disposal Wells, Tuscola, Illinois, for Alberto Nieto, Champaign, Illinois.

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