

8<sup>th</sup> Annual Española Workshop

The Link between Science and Water Policy

Ardyth Simmons, editor

New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech  
Socorro, New Mexico 87801

**Open-file Report 525**

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# 8<sup>th</sup> Annual Española Basin Workshop The Link between Science and Water Policy

March 3, 2009

Santa Fe, NM

Santa Fe Community College

## PROGRAM AND PRELIMINARY ABSTRACTS

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**Hosted by EBTAG** (Española Basin Technical Advisory Group)

An ad hoc group of technical people who represent government and academic organizations conducting geologic, geophysical, and hydrogeologic studies related to understanding of the Española groundwater basin.

City of Santa Fe

New Mexico Environment Department

Jemez Y Sangre Water Planning Council

Santa Fe County

Los Alamos National Laboratory

Española Basin Regional Planning Issues Forum (EBRPIF)

New Mexico Bureau of Geology and Mineral Resources

U.S. Geological Survey

New Mexico Office of State Engineer

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EBTAG web site: <http://esp.cr.usgs.gov/ebtag>

# The Link between Science and Water Policy

**8<sup>th</sup> Annual Española Basin Workshop: Tuesday, March 3<sup>rd</sup>, 2009**

Jemez Room, Santa Fe Community College, Santa Fe, New Mexico

**Galisteo Basin Fieldtrip: Wednesday, March 4<sup>th</sup>, 2009**

## DAY 1: PROGRAM

- 7:30-8:30 am **Registration**  
Pick up badges, programs and sign in; poster set up and viewing
- 8:30-8:45 am **Welcome and Introductory Remarks**  
*Who is EBTAG (Española Basin Technical Advisory Group) and why the Española Basin workshops?* Claudia Borchert, EBTAG chair
- 8:45-9:45 am **Case Study 1: How Domestic Wells Impact Water Resources of the Española Basin:**  
*A hydrogeologic perspective:* Jack Frost, Hydrologist, NM Office of State Engineer  
*A legal perspective:* Marcos Martinez, Assistant City Attorney, City of Santa Fe  
*A policy perspective:* Arianne Singer, Managing Attorney for the Northern Adjudication Bureau, Litigation and Adjudication Program, NM Office of State Engineer
- 9:45-10:00 am **Coffee Break**
- 10 -11:00 am **Case Study 2: Oil and Gas Drilling in the Española Basin area (Galisteo and Rio Arriba)**  
*A hydrogeologic perspective:* Alvis Lisenbee, PhD, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology  
*A policy perspective:* Karen Torres, Santa Fe County Hydrologist  
Lorenzo Valdez, Rio Arriba County Manager  
*A regulatory perspective:* Glenn von Gonten, Senior Hydrologist, Oil Conservation Division, New Mexico Energy, Minerals and Natural Resources Department
- 11-12:00 am **Case Study 3: City of Española Water Supply Dilemma**  
*A geologic perspective:* Dan Koning, NM Bureau of Geology and Mineral Resources  
*A hydrogeologic perspective:* Stephanie Moore/Bob Gray, Daniel B. Stephens & Associates  
*An options perspective:* Robert Fowlie, PE, Principal, CDM  
John Hernandez, Hernandez Consulting  
*A policy perspective:* Veronica Albin, City Manager, City of Española
- 12:00-1:30 pm **Lunch Break** (food available for purchase at the cafeteria next door)
- 1:30-2:30 pm **Collaborative 3-dimensional conceptualization and visualization of the Española Basin**  
*3-D Basin Model from Geophysics:* Tien Grauch, US Geological Survey  
*Pajarito Plateau model:* Greg Cole, Los Alamos National Laboratory  
*On the Relation between Geologic and Hydrologic Units - Four Examples:* Paul Davis, Envirologic, Inc.
- 2:30 - 4:30 pm **Poster Session**, North Jemez Room

## DAY 2: GALISTEO BASIN FIELD TRIP

- 8:30 am *Meet at AllSupps gas station at Hwy 14 and Hwy 599 (just south of the 599 exit of I-25)*
- 9 am - 1 pm Alvis Lisenbee and Karen Torres, Santa Fe County Hydrologist

## **Impact of Buckman Wells 10-13 Production on Water Levels in the Buckman Well Field Area**

BORCHERT, Claudia I.<sup>1</sup>, McCOY, Annie, and FINCH, Steve, <sup>1</sup>City of Santa Fe, 801 W. San Mateo Rd, Santa Fe, NM, 87505, [ciborchert@santafenm.gov](mailto:ciborchert@santafenm.gov)

As a condition of pumping water from the City of Santa Fe's Buckman Supplemental Wells 10-13 (BW10-13), the City monitors water levels in the Buckman area. Since the BW10-13 began producing water in October 2003, available data indicate that the past five years of pumping of BW10-13 have not significantly increased water-level declines. Additionally, water levels in the monitoring program area do not follow a consistent trend of decline, as projected by the hydrologic analyses during the permit application. Water levels in the area have been rising in 24 wells, holding steady in 2 wells, and declining in 11 wells. The water levels in 12 of the 13 Buckman production wells have been rising at rates ranging from 2 to 48 feet per year (ft/yr), likely due to less overall pumping and the distribution of pumping over a larger area. The water level in Buckman Well 11 has remained steady. During the same period, the water levels in 10 of the 16 USGS monitoring wells have been rising at rates ranging from 0 to 48 ft/yr. The water levels in 5 of the 6 USGS nested monitoring wells drilled north (Buckman) and south (Las Campanas) of BW10-13, have been declining at rates ranging from 0 to 19 ft/yr. In the nested wells, water level trends vary according to depth in the aquifer. The vertical distribution of groundwater heads also varies between the City and the Rio Grande. Of the eight private wells monitored, two show water-level rises in the range of 3 to 7 ft/yr, one shows no change in water level, and five show a decline of water levels ranging from -0 to 22 ft/yr. However, because the private well with the 22 ft/yr decline is one of the farthest from the pumping center, the decline is likely either the result of inaccurate data or drawdown effect from a more localized source. RG-30777, which is the closest private well to Buckman Well 13 has fluctuating water levels, but shows no decisive water-level change trend.

## **Expansion of the Pajarito Plateau Geologic Framework Model**

COBLENTZ, David, COLE, Greg, and JACOBS, Elaine P., EES Division, Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545, [coblentz@lanl.gov](mailto:coblentz@lanl.gov), [ejacobs@lanl.gov](mailto:ejacobs@lanl.gov), [gcole@lanl.gov](mailto:gcole@lanl.gov).

An on-going effort at the Los Alamos National Laboratory (LANL) has been the development and refinement of a 3D hydrostratigraphic model for the Pajarito Plateau in northern New Mexico that provides the framework for modeling groundwater flow and contaminant transport beneath the plateau. This model provides a detailed representation of stratigraphic units, facies, and volcanic flows. The model also allows flexible assignment of hydrogeologic properties and the construction of hydrogeologic models. The Pajarito Plateau Model is a component of the larger, lower-resolution model of the Española Basin that is used in regional groundwater studies.

The previous version of the model was constructed in 2005. This model covered the four geologic quadrangles in the vicinity of the LANL and contained 28 geologic units and subunits that embody the complex interfingering of sedimentary and volcanic rocks in this region of the Rio Grande rift system.

A new and expanded model of the Pajarito Plateau and adjacent Española Basin is currently being developed at LANL. This "2009 Model" covers twelve geologic quads and spans the Basin from the Jemez Mountains to the foothills of the Sangre de Cristo Mountains east of Santa Fe. Most of the geologic units of the 2005 Model are included in this update, with the addition of geologic information from the 8 new geologic quadrangle maps within the Española Basin (including a breakout of units within the older Miocene sediments of the Santa Fe Group, which are better exposed in the eastern portions of the model.) The 34 geologic units (increased from 24 in the 2005 Model) within the 2009 Model are constrained by outcrop information and a total of 330 drill holes (increased from 213 in the 2005 Model).

Here we present and discuss a comparison of the 2005 and 2009 Models, illustrating the expansion in spatial extent and geologic scope of the latest 3D geologic model of the Pajarito Plateau.

**New Geologic Framework Models for the Pajarito Plateau and Española Basin Regions**  
COLE, Greg; COBLENTZ, David, and JACOBS, Elaine, EES Division, Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545, [coblentz@lanl.gov](mailto:coblentz@lanl.gov), [ejacobs@lanl.gov](mailto:ejacobs@lanl.gov), [gcole@lanl.gov](mailto:gcole@lanl.gov).

A new set of geologic framework models is being developed to support environmental programs at Los Alamos National Laboratory. The models are at three scales, a high-resolution model for the laboratory site, a moderate-resolution model for the Southern Española Basin which encompasses the laboratory site and the city of Santa Fe, and a low-resolution model of the Española Basin, with a north-south range extending from the Abiquiu Reservoir to the Cochiti Reservoir. The high-resolution model will support drilling and cleanup activities at the laboratory; the moderate-resolution model encompasses all of the Buckman wells and can be used for groundwater studies extending well beyond the laboratory boundaries. The full Española Basin Model has a reduced set of hydrogeologic units and will be used to help define flow boundary conditions to the northern and eastern boundaries of the laboratory.

The high-resolution models consist of 11 basin sediment units, 3 basalt units and 20 units representing volcanic and erosional products of the Jemez Volcanic Field. The Española Basin Model consists of 7 regional units, which will “edge match” with the major units of the other models. Saturated and unsaturated alluvial units and a Precambrian basement unit will be added to all units when the regional model is completed.

These models have been developed through cooperation and the sharing of data with a number of organizations at the federal, state, and local levels, and through the collaboration and scientific contributions of numerous local geologists.

## **On the Relation between Geologic and Hydrologic Units—Four Examples**

DAVIS, Paul, A.<sup>1</sup>, KUVAEV, Andrey, A.<sup>2</sup>, POZDNIAKOV, Sergey, P.<sup>3</sup>, POZDNIAKOV, Irina<sup>3</sup>; <sup>1</sup>EnviroLogic Inc., 12127 Suite 4, State Highway 14 North, Cedar Crest, New Mexico, 87008, [p\\_davis@EnviroLogicInc.com](mailto:p_davis@EnviroLogicInc.com); <sup>2</sup>Shaneco Group, Moskvorechje Str.,4, Bld.3, Moscow, Russian Federation, 115 522; <sup>3</sup>Hydrogeological Department, Moscow State University, Leninskie Gory, Moscow 119899, Russia

Groundwater flow models are generally based on a geologic framework consisting of the spatial distribution of lithology and/or stratigraphy. The inherent assumption is that of a direct correlation between rock type and hydrologic properties. Here, four examples are examined: 1) the effect of the dipping beds of the Tesuque Formation on vertical hydraulic heads; 2) the effect of faults on simulated hydraulic heads; 3) a comparison of models that do and do not include lithosomes in the Santa Fe Formation; and 4) an analysis of the correlation between temperature and spinner log data with lithography for a Los Alamos production well.

The Tesuque Formation is known to dip approximately eight degrees to the northwest in the area of the Pojoaque River Basin. In addition, the Tesuque Formation is composed of interbedded silts, sands, clay, gravels, and intercalated volcanic ash beds that display strong anisotropy parallel to bedding versus perpendicular to bedding. The potential hydraulic impact of this anisotropy combined with the dipping of the Tesuque Formation was evaluated by comparing calibrated hydraulic heads from two steady-state models of the Española Basin and comparing model results to vertical head data. Gridding in one model aligns with the dip of the Tesuque Formation while the dip of the other model aligns with the slope of the water table. Vertical hydraulic head profiles reveal that the model that follows the dip of geology reproduces the field data, showing an increase in the hydraulic head with depth far to the east of the Rio Grande in an area where the other model shows either decreasing heads or constant heads with depth.

Using the model whose grid dips with the geology, the sensitivity of model results to the presence of faults as hydraulic barriers was investigated. Model results in this case were insensitive to the presence or absence of north-south trending faults. That is, the faults had a minimal effect on simulated water levels.

Next, results from the two models described above were compared to measured hydraulic heads in the Santa Fe embayment. In this region the model whose grid aligned with the water table included lithosomes to describe heterogeneity within the Tesuque Formation. The other model considers the Tesuque Formation as anisotropic but homogeneous in the Santa Fe embayment. Neither model was able to accurately reproduce measured hydraulic heads. The inherent calibration problem may be caused by heterogeneity but, in this case, not the heterogeneity associated with lithosomes.

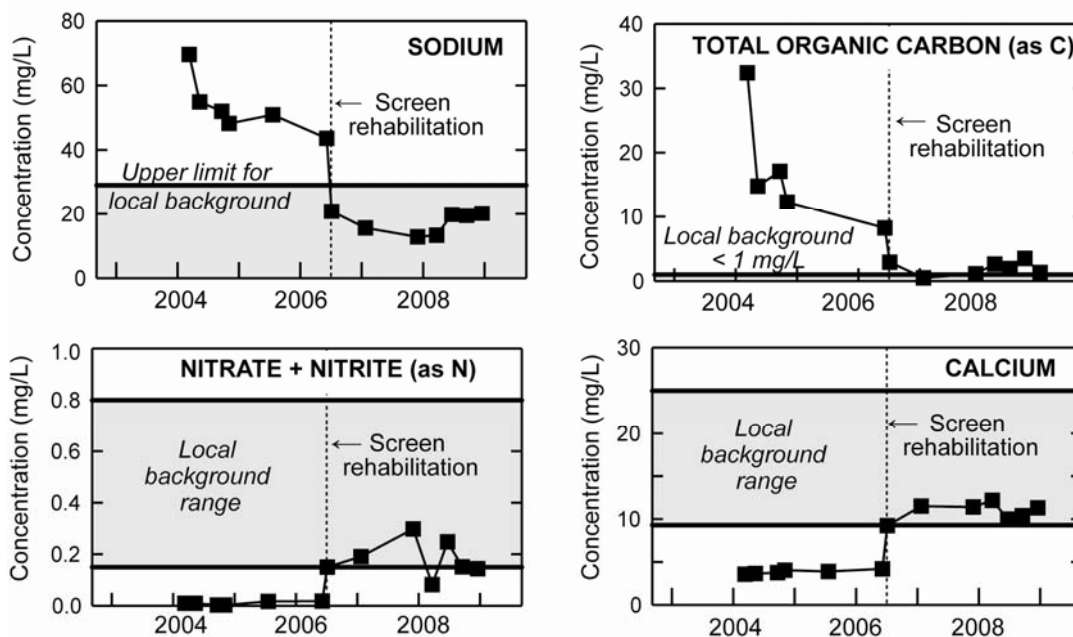
The last example involves the use of temperature and spinner logs to define contributing zones to one of the Los Alamos production wells, PM-2, and to compare the contributing zones to the observed lithology. The combined interpretation of these logs clearly delineated the zones of flow to PM-2 as well as the zones that contributed little or no water to the well. The results question our basic assumptions about the relation of geologically defined units and hydrologic units. In a subset of the units there are definable changes in flow to the well attributable to changes in lithology. However, for most of the well there is no correlation between lithology and flow. For example, over one section there is no change in inflow between a basalt layer and the adjacent overlying fanglomerate while in another section there are large differences in inflow rates within a single geologically defined unit.

## Data Reliability for Groundwater Monitoring Wells at Los Alamos National Laboratory

FABRYKA-MARTIN, June T.<sup>1</sup>, SIMMONS, Ardyth M.<sup>2</sup>, and LONGMIRE, Patrick<sup>1</sup>; <sup>1</sup>Los Alamos National Laboratory, Earth and Environmental Sciences Division, MS D462, Los Alamos, NM 87545, [fabryka@lanl.gov](mailto:fabryka@lanl.gov), [plongmire@lanl.gov](mailto:plongmire@lanl.gov); <sup>2</sup>Los Alamos National Laboratory, LANL Water Stewardship Project, MS M992, Los Alamos, NM 87545, [asimmons@lanl.gov](mailto:asimmons@lanl.gov)

In 2006, the Los Alamos National Laboratory (LANL) Water Stewardship Project initiated a systematic evaluation of chemical data collected from LANL's deep characterization wells on the Pajarito Plateau. This evaluation assessed which well screens were capable of providing reliable contamination data, and which screens were compromised as a result of incomplete removal of chemical products used downhole during well drilling, construction, and development. The results were incorporated into LANL's monitoring well network evaluations (*see related abstract by Katzman et al.*), in which screens that could not provide reliable data for key constituents were recommended for rehabilitation, conversion, or replacement. The data reliability evaluations also spurred LANL to implement significant changes in its well drilling, construction, and development practices for new wells, and in its groundwater sampling protocols, so as to improve data reliability of future water samples. The effectiveness of these measures is monitored in annual updates of LANL's interim facility-wide groundwater monitoring plan.

Data reliability for a water sample is assessed through examination of about 35 geochemical indicators in six performance categories: residual inorganic well drilling or construction chemicals, residual organic well drilling or construction chemicals, reducing conditions, adsorption onto clays used in well drilling or construction, disturbed carbonate-mineral system, and metal corrosion (e.g., see Figure 1). To document the process and to optimize efficiency and reproducibility of the results, the protocol is semi-automated as a software module linked to LANL's water-quality database.



**Figure 1. Trend plots for selected geochemical indicators in the upper screen at well R-20, showing improved data reliability following screen rehabilitation.** Sodium and total organic carbon concentrations are used to assess removal of residual drilling and construction products, nitrate + nitrite concentrations are used to evaluate redox conditions, and calcium concentrations are sensitive to disturbances to the carbonate-mineral system.



## **Española Groundwater Study**

FOWLIE, Robert, CDM

In 2007, the City of Española commissioned a study of its groundwater system to determine how it could best meet current and projected future water needs of its customers. The study was prepared in response to the City's concerns about the sustainability of its groundwater supply system in light of new EPA standards for arsenic and uranium and the desire to determine the best use of its San Juan-Chama water rights. The City had also expressed a strong interest in providing water to areas outside the City limits and also was interested in the possibility of becoming a regional water provider to communities outside of the Española planning area. To this end, the study evaluated the water production needs of the City's planning area for a twenty and forty year planning period.

While the City has 1000 acre-feet of surface water rights, it does not have the capacity to use water directly from the Rio Grande and has used its surface water rights to offset overages of its groundwater rights. The City is completely reliant upon groundwater for its water supply and obtains water from eight wells located throughout the City. However, only six of the eight wells were in operation due to arsenic, fluoride, and nitrate contamination in two of the wells. In addition, two of the six active wells had levels of arsenic that exceeded the EPA maximum contaminant levels (MCL) for arsenic, and two exceeded the MCL for uranium. The potential loss of these water sources represented over two-thirds of the City's water supply.

An evaluation of the City's future water requirements indicated that the City could meet its future water requirements in 40 years by installing three new groundwater wells. The study also showed that if the City placed Wells 4 and 7 into operation, it could delay constructing a new well until 2029. Constructing new wells in the Española area is problematic and potentially expensive since the Hydrogeologic Report that was conducted as part of the study indicated that arsenic and other contaminants of concern are prevalent throughout the area and new wells would most likely require treatment for arsenic and possibly for uranium and/or fluoride. Another recommended project was to evaluate modifications to existing Well No.9 which had been taken out of service due to low production and high levels of arsenic and fluoride. The proposed modifications consisted of drilling horizontal shafts in the alluvium near the surface to increase production. If this method of increasing production and improving water quality proved to be viable, the City would be able to bring a new well into production without having to incur the expense of drilling a new well.

To bring the existing wells into compliance with EPA Drinking Water Standards, the report recommended that the City install an arsenic treatment system at Well No.1 and blend water from Wells 2 and 3 to bring the wells into compliance with the EPA Arsenic Rule. To address nitrate contamination in Well 7 and arsenic and fluoride in Well 4, the study recommended installing a transmission main to blend these two wells at Tank No.4. Bringing Wells 4 and 7 into service would add an additional 0.6 MGD of production and would postpone the need for an additional well until 2029. The study also recommended the installation of a uranium treatment system at Wells 5 and 6.

At the same time the groundwater system was being evaluated, the City was also investigating the possibility of fully utilizing its surface water rights by constructing a surface water treatment plant on the Rio Grande. While the surface water plant would have allowed the City to exercise full consumptive use of its San Juan-Chama water rights and would have given the City a renewable water source, the City would still have needed the ground water system to supplement the plant to meet peak day demand. In addition, the groundwater system would also be needed as a backup source of water in the event the river water was of poor quality or during extreme drought conditions.

The cost of the surface water treatment plant was prohibitive with an estimated construction cost of \$13.7 million and the City did not have all of the necessary funding in place for the plant. In addition, the City was also looking at required improvements to the groundwater system with an estimated cost of \$4.5 million. Faced with these options and limited funding, the City elected to go forward with the improvements to the groundwater system.

## **Domestic Wells in the Española Basin, Santa Fe County, NM**

FROST, Jack P., NM Office of the State Engineer

Domestic wells account for roughly 20% of groundwater use in the Española geologic basin. Most of these wells occur outside municipalities, and are often used to develop more rural land. They are usually paid for up front, and may cost, equipped, \$30 to 50 per foot drilled (\$10,000 to \$30,000). With a few notable exceptions, most wells find adequate yields within 200 to 600 feet total depth. The NM OSE WATERS database is the only record of domestic wells in the area, and there are definite problems with locations and data. A sample of the basin, from the Galisteo watershed to north of Española contains about 6900 domestic wells, out of 9100 total water rights records. Domestic well water use in the basin is mostly unmetered, but has been estimated from 0.25 to 1.0 afy per year. The impact of these groundwater withdrawals depends on the well's density, location, depth to groundwater, aquifer properties, pumping rate and duration. In the semi-arid climate of the area, wells located outside of perennial stream valleys are believed to derive most of their water by storage depletion, intercepting regional groundwater flow-through and base-flow discharge to the Rio Grande. The magnitude of domestic well depletions compared to flows in the Rio Grande is too small to measure. In addition fluctuations in groundwater levels due to domestic wells are in general below detection within the current groundwater monitoring network.

## **Updated Geologic Framework Model of the Española Basin**

JACOBS, Elaine P., COLE, Greg, and COBLENTZ, David, EES Division, Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545, [ejacobs@lanl.gov](mailto:ejacobs@lanl.gov), [gcole@lanl.gov](mailto:gcole@lanl.gov), [coblentz@lanl.gov](mailto:coblentz@lanl.gov).

Understanding flow paths for water draining through the Española Basin is an important component to water quality and supply for the cities and communities located within its watershed. Several significant studies have looked at the geohydrology of the Española Basin over the years (Spiegel and Baldwin 1963; Griggs 1964; Purtymun and Johansen 1974; Coon and Kelley 1984; Hearne 1985; McAda and Wasiolek 1988; Anderholm 1994; Wasiolek 1995; Frenzel 1995; Keating et al. 1999; Keating et al. 2003). In 1999, Keating et al., created a basin scale model to define regional flow and boundary conditions for the regional aquifer. The model presented here updates the geologic framework of the Keating model by redefining the basin boundaries and incorporating the latest geologic map data. In the last ten years, new geologic mapping of 7.5 minute quadrangles in the Española Basin has been performed as part of the STATEMAP component of the National Cooperative Geologic Mapping Program, a geologic mapping initiative supported through a matching-funds grant program between the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) and the USGS. Boundaries for our new basin-scale model are designed to include the watershed for the basin as well as to capture possible subsurface flow coming from the Jemez Mountains. The goal of this geologic framework model is to provide a foundation for hydrogeologic studies looking at regional flow and boundary conditions.

The steps necessary in creation of a basin-scale model include: 1) determination of stratigraphic units to be used in creating surfaces; 2) input of all contact and cross-section data into digital format; 3) re-classification of stratigraphic units present on each 7.5 minute quadrangle to basin-wide units; 4) creation of structure contours for each stratigraphic surface/unit; 5) creation of surfaces using the ArcGIS (© ESRI Environmental Systems Research Institute, Inc.,) TopoGrid tool; 6) import of surfaces into EarthVision (© Dynamic Graphics) for 3D visualization. We are currently at step three in this process and expect to have a full model completed by August 2009.

Ten geologic map units are used in our geologic framework model with the goal of breaking out units with similar hydrogeologic qualities while striving to maintain a straightforward architecture. Alluvium is broken out into a saturated and unsaturated component in order to allow modeling of the alluvial aquifer. The Santa Fe Group and older sedimentary units are included as separate units in order to separate flow within the Santa Fe Group from deeper flow. Proterozoic crystalline rocks provide the bedrock surface.

Future goals with this model include refinement of the Santa Fe Group and the addition of a basin-scale fault block model. These additions could help the geologic framework reflect the anisotropy noted in the Tesuque Formation.

## **Groundwater Monitoring Well Network Evaluations and Optimizing the Locations of Additional Monitoring Wells at Los Alamos National Laboratory**

KATZMAN, Danny, BROXTON, David, E., VESSELINOV, Velimir, V., VANIMAN, David, T., BIRDSELL, Kay, H., FABRYKA-MARTIN, June, T., and LONGMIRE, Patrick, Water Stewardship Program, Mail Stop M992, Los Alamos National Laboratory, Los Alamos, NM 87545, [katzman@lanl.gov](mailto:katzman@lanl.gov)

Over the past two years Los Alamos National Laboratory conducted a series of monitoring well network evaluations at the direction of the New Mexico Environment Department (NMED) to evaluate the adequacy of the groundwater monitoring well network for providing 1) an understanding of the nature and extent of groundwater contamination, 2) support of Resource Conservation and Recovery Act (RCRA) monitoring requirements, where applicable, 3) monitoring data to evaluate conceptual models for contaminant transport, and 4) protection of water-supply wells and detection of potential offsite migration. Network evaluations were conducted for five areas of the Laboratory delineated by their geography as well as potential contaminant source areas and infiltration pathways. At this stage of the regulatory process, the network evaluations are intended to assess whether existing wells are adequate to monitor groundwater from these areas while ongoing site investigations are being conducted. Thus, recommendations arising from the monitoring well network evaluations capture the monitoring requirements for the 3- to 5-yr time frame while field investigations continue and before selection and implementation of the final remedies.

The approach used to evaluate the monitoring network involves examination of well and network performance in three main categories: 1) physical attributes of the wells, 2) geochemical performance of the wells, and 3) hydrogeologic attributes of the aquifer and well placement. The three categories are evaluated in the context of monitoring objectives and conceptual models of contaminant pathways as they relate to groundwater systems. The physical attributes of the well include isolation of multiple sampling zones, competency of annular fill, and other well construction factors. This analysis includes a review of factors such as screen depths and screen lengths in the context of the conceptual model for contaminant migration and site-specific monitoring objectives. Geochemical performance includes an assessment of how well groundwater samples represent conditions within the aquifer especially at wells installed with use of drilling fluid additives, particularly for site-specific contaminants. The evaluation of hydrologic attributes of the aquifer and well placement uses sampling data and a groundwater-transport model to trace the path of hypothetical mobile contaminants from locations where contaminants might break through to the regional aquifer. The transport model assesses the ability of the current well network to detect at least 95% of potential contaminants that might migrate toward a production well or pass beneath the Laboratory boundary.

The network evaluations identified deficiencies that are currently being addressed by the installation of additional monitoring wells. A total of ten new regional wells 1000 to 1400 ft deep are being installed to supplement the existing network of 51 regional monitoring wells. In addition, seven wells are being installed to depths of 600 to 800 ft to monitor intermediate perched groundwater in the vicinity of potential release sites. The adequacy of the monitoring well network is continually evaluated as new data become available. In addition to the wells installed as an outcome of the network evaluations, five regional wells and three intermediate perched groundwater wells are being drilled as part of ongoing investigations to characterize nature and extent of contamination including chromium and high explosives. Eventually, long-term monitoring recommendations will be tied to the evaluation and selection of remedial alternatives presented in Corrective Measures Reports for individual field sites.

## **Hydrogeology of the Española Area, Rio Grande Rift, North-central New Mexico**

KONING, Daniel J.<sup>1</sup>, ABY, Scott<sup>2</sup>, and FINCH, Steve<sup>3</sup>; <sup>1</sup> New Mexico Bureau of Geology and Mineral Resources; New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM 87801, [dkoning@nmt.edu](mailto:dkoning@nmt.edu), <sup>2</sup> Muddy Spring Geology, Box 488, Dixon, NM 87527, <sup>3</sup> John Shomaker and Associates, Inc., 2611 Broadbent Parkway, Albuquerque, NM 87107

The city of Española (population of ~10,000) straddles the Rio Grande near the middle of the Española Basin. The shallowest aquifer underlying the city is late Quaternary valley-fill alluvium, which may be as much as 30 m thick. This alluvium generally consists of sand and gravel at its base but fines upward into sand, silt, and clay. The Santa Fe Group underlies Quaternary alluvium and consists mainly of sandstone and siltstone with subordinate conglomerate and mudstone. Being Oligocene-Miocene in age, it obtains a thickness of approximately 2 km beneath the city. The Santa Fe Group deposits have been variably consolidated and cemented, the cementing agent generally being calcium carbonate. These deposits dip westward and northwestward due to associated tilting of the Española Basin half-graben.

Groundwater in the Quaternary alluvium flows southwards and in the Santa Fe Group towards the Rio Grande. For various lithostratigraphic units near Española, potential hydrologic differences were assessed by estimating hydraulic conductivities from aquifer test transmissivity values. These transmissivity values were obtained from pumping tests of wells (120-1,500 ft deep) screened across one or more of these lithostratigraphic units, which include Quaternary valley-fill and units in the Santa Fe Group. Depths of particular Santa Fe Group lithostratigraphic units vary with location due to faulting and west-tilting of the Española half-graben. These hydraulic conductivity values ranged over two orders of magnitude, from 0.1 to 34 ft/day. The Quaternary-age valley-fill has the highest hydraulic conductivity (K) values (range of 0.7 to 34 ft/day, averaging 10 ft/day). The Chamita Formation and middle to upper Ojo Caliente Sandstone of the Tesuque Formation may provide the most productive water-bearing zones in the Santa Fe Group proper (with most K values ranging from 0.7 to 7.3 ft/day), followed by a combined unit consisting of interbedded Ojo Caliente Sandstone-Cejita Members and underlying lithosome B of the Pojoaque Member of the Tesuque Formation (0.7 to 1.4 ft/day). In general, hydraulic conductivity values for the remaining lithostratigraphic units, located in a lower stratigraphic position, range from 0.1 to 2 ft/day, with lithosome B of the Pojoaque and Skull Ridge Members being on the higher end of that range. In general, hydraulic conductivity values seem to decrease with stratigraphically lower units. Other influences on hydraulic conductivity values and well yields include faults that act as barrier boundaries, stratified anisotropy from dipping beds, and secondary mineralization (cementation). This geologic complexity makes it difficult to locate zones favorable for the development of viable water supply wells.

## **Cross Sections and Geologic Map for the Eastern Española Basin, Rio Grande Rift, North-central New Mexico**

KONING, Daniel, J.<sup>1</sup>, GRAUCH, V.J.S.<sup>2</sup>, RODRIGUEZ, Brian D.<sup>2</sup>;

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We integrate several data sets to produce ten cross sections for the eastern Española Basin. The study area includes the foot of the Sangre de Cristo Mountains and extends as far west as Clara Peak and the town of White Rock. The northern boundary lies 3 km north of Embudo and the southern boundary passes through Santa Fe. Our study focuses on the internal stratigraphy of the Santa Fe Group, the Oligocene-Pleistocene basin-fill deposited during Rio Grande rifting. Volcanic flows, pre-rift strata, and top of Proterozoic basement are also shown. The cross sections trend W-E between Santa Fe and Española and NW-SE between Española and Embudo, which is generally orthogonal to bedding strike and fault trends. However, one cross-section is oriented NW-SE along Cañada Ancha, passing through the Buckman well field, and another trends NE-SW across Black Mesa northwest of Española. Subsurface stratigraphy and structure of the Santa Fe Group are interpreted using geologic map data, shown alongside the cross sections, in addition to data from borehole cuttings and down-hole geophysical logs. We apply a conceptual depositional model, derived from sedimentologic observations in the field, to depict internal Santa Fe Group stratigraphy below ~600 m depth. Depths to pre-rift strata and Proterozoic crystalline basement rocks are derived from synthesis of gravity, aeromagnetic, and magnetotelluric data, which are calibrated using available well data.

The cross sections illustrate the west-dipping, half-graben structure of the eastern Española Basin, with basin-fill thickness increasing westward from 0 to 2.4-3.1 km within the study area. The deepest parts of the basin coincide with secondary, intra-basinal half-grabens located west of the west-down Barrancos monocline and east of a series of faults with significant components of east-down throw (>350 m). In the study area, these intra-basinal half-grabens include the Velarde graben north of Española (bounded by the east-down Black Mesa fault and the west-down, left-strike-slip Velarde fault), the Santa Clara graben west of Española (bounded on the west by the east-down, oblique-slip Santa Clara fault), and the Cañada Ancha graben between Santa Fe and the Buckman well field. An inferred, largely concealed east-down fault separates the Cañada Ancha graben from a newly interpreted, north-plunging horst block to the west (approximately coinciding with the Caja del Rio plateau). A relatively non-faulted homocline extends 3.5-5.0 km eastward from the Barrancos monocline. The terrane between this homocline and the foot of the Sangre de Cristo Mountains is intensely faulted, with most faults showing east-down displacement and relatively minor throw (<150 m). The faulted, west-down Gabeldon monocline coincides with the foot of the Sangre de Cristo Mountains and a linear truncation of aeromagnetic patterns.

We differentiate 22 stratigraphic units in this study. Those deposited in the Rio Grande rift are grouped into three categories: 1) Pliocene coarse basin-fill and basalt-andesite volcanic flows, 2) Miocene upper coarse deposits (ca. 13.2-6 Ma), and 3) Oligocene-Miocene lower to middle deposits and mafic volcanic flows (26 to ~13.2 Ma).

### **Fate of Reservoir Releases to the Santa Fe River**

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A series of technical studies conducted under the direction of the City of Santa Fe were developed to assess the fate of potential releases of water in the Santa Fe River. Seepage studies and stream gage data were evaluated to determine the rate of loss for given flow rates in three reaches through the City of Santa Fe. Seepage rates for flows less than 10 cfs averaged 0.4 cfs/mile for the up-town and mid-town reaches, while the west-side reach averaged 0.2 cfs/mile. Using these loss rates, a release of 1,000 ac-ft/yr was evaluated for three release scenarios. If the 1000 ac-ft/yr were released at a constant rate of 1.38 cfs, the flows would not generally reach the Santa Fe River at the above St. Francis Bridge gage and therefore be too low for much of the Santa Fe River to develop the desired habitat. The three scenarios evaluated each had a peak flow (between 4.3 and 4.9 cfs) to represent spring runoff. In a scenario that mimics the natural hydrograph, flow will reach the St. Francis gage from April through mid-June and the Ricardo gage (near Frenchy's Park) from mid-May through mid-June. For two of the scenarios water reaches the St. Francis and Ricardo gages only during a one-month peak runoff, with a very small flow (0.2 cfs) at the St. Francis gage during the summer months. Flow rates at the Ricardo gage during the peak flows would be between 1.6 and 2.2 cfs. Seepage losses during peak flows through the west-side reach are estimated to be 1.5 cfs, which would leave a small amount of flow reaching the wastewater treatment plant during the peak flows. In each of these three scenarios, the seepage losses that have the potential for benefiting the local aquifer are about 900 ac-ft/yr.

## **Oil and Gas Drilling in the Española Basin (Santa Fe Embayment): a Hydrogeologic Perspective**

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Fifteen petroleum tests were conducted in the south end of the Santa Fe embayment in the 1970s and 1980s resulting in one small discovery of oil in a well near Galisteo Creek. This structurally deep area north of the Tijeras-Cañoncito fault system contains source rock (Cretaceous shale), reservoir rock (Cretaceous and Jurassic sandstone), potential structural traps (Laramide and Rio Grande rift folds and faults), seals (Jurassic or Cretaceous shale), and was heated during local igneous activity and deep burial in the Oligocene when structural traps were available. Therefore, it has all the critical factors necessary for an oil play. At shallower depths near the margins of the embayment the sandstone units are locally aquifers.

For most of the wells drilled to date, and for all of the recently proposed tests, Mesozoic rocks are reached beneath a cover of Paleogene strata to 1,300 m thick. The Paleocene-Eocene Diamond Tail Formation (Tdt: to 380 m) and the Eocene Galisteo Formation (Tg: to 940 m) consist dominantly of thick mudstone (green, gray, and maroon for the Tdt; red for the Tg) and coarse-grained sandstone and conglomerate (orange-tan in the Tdt; red and white in the Tg). The upper 50 m of the Galisteo consists of poorly sorted, coarse-grained, massively cross-bedded, tan sandstone. Volcaniclastic strata of the Eocene-Oligocene Espinazo Formation (to 90 m) comprise discontinuous, medium to very thick beds of tuff and debris flows (with clasts to 1 m) displaying varying degrees of consolidation. The generally limited porosity of all three units is enhanced by fracturing.

The Pliocene-Quaternary Ancha Formation lies with angular unconformity across older folded strata. The underlying Paleogene units form a broad, north-plunging, latest-Oligocene or younger syncline whose eastern fold limb is broken by a NNW-trending graben. The west limb is rotated to vertical by intrusions along the eastern flank of the Cerrillos igneous center.

A complicated history of Laramide deformation is revealed beneath the Diamond Tail Formation. Cretaceous strata form a large, open to the north anticline which extends the original margin of the Late Cretaceous-Paleocene San Luis uplift at least 34 km southward from the current Santa Fe Range mountain front. In late Paleocene the uplifted area foundered and through the Oligocene underwent a complicated history of subsidence, minor uplift, renewed subsidence and volcanic activity. The Tijeras-Cañoncito fault system was active during much of this time.



## **Geochemical Processes Controlling Chromium Transport in the Vadose Zone and Regional Aquifer, Los Alamos, New Mexico**

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The environmental aqueous geochemistry of Cr is of considerable interest to physical scientists and toxicologists in quantifying the fate and transport of this metal in surface and subsurface environments. Chromium(VI) solutions were released from cooling towers to a stream channel within Sandia Canyon at Los Alamos National Laboratory, NM from 1956 to 1971. These solutions have migrated to 293 m depth through the vadose zone, containing several saturated zones, to the regional water table. Anthropogenic concentrations of total dissolved Cr, mainly as Cr(VI), in the regional aquifer range between 0.15 to 15.77  $\mu\text{M}$ . The regional aquifer is characterized by calcium-sodium-bicarbonate solution, contains dissolved oxygen (0.09 to 0.22 mM), and has a circumneutral pH (6.8 to 8.3). Geochemical processes controlling the fate and transport of Cr in groundwater at Los Alamos include a combination of adsorption and precipitation reactions within aquifer systems. Vadose zone material containing hydrous ferric oxide, smectite, silica glass, and calcite widely range in their ability to adsorb Cr(VI) under basic pH conditions. Overall, the vadose zone at Los Alamos is relatively oxidizing, however, basalt flows are locally reducing with respect to Fe. Ferrous iron concentrated within the Cerros del Rio basalt has been shown through batch experiments to reduce Cr(VI) to Cr(III) resulting in precipitation of chromium(III) hydroxide. Regional aquifer material, consisting of silicates, oxides, and calcite, vary in the amount of Fe(II) available in reactive minerals to effectively reduce Cr(VI) to Cr(III). The results of our studies (1) directly assess the relationship between mineralogical characterization and transport behavior of Cr using site-specific hydrogeologic material and (2) provide site-specific adsorption and precipitation parameters obtained through the experiments to refine the fate and transport modeling of Cr within the vadose zone and regional aquifer. Natural attenuation of Cr at Los Alamos is a potential groundwater remediation option that needs to be fully assessed within Fe(II)-rich basalt and other aquifer material.

## **Integrated Approach for 3D Geology Rendering, Numerical Meshing and Modeling for Flow and Transport Studies, Pajarito Plateau, New Mexico**

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Los Alamos National Laboratory (LANL) has an extensive program devoted to understanding groundwater flow and transport beneath the Pajarito Plateau. One goal of this program is development of integrated and comprehensive modeling approaches that allow rapid creation of groundwater flow and transport models, representing entire or subsections of the Pajarito Plateau, on which physical processes over a wide range of spatial and temporal scales can be simulated.

Model integration requires three-dimensional rendering of a geologic framework model (GFM) representing hydrostratigraphic contacts and fault zones. This 3D volumetric representation of the hydrostratigraphy is reproduced into computational meshes on which the flow and transport simulations are performed and evaluated. Our approach maintains the geometry and topology of the hydrostratigraphic units while optimizing the computational mesh to ensure accurate and efficient simulations within computer and software memory constraints. The coverage and complexity of the computational mesh needed for flow and transport simulations at a given site depends on the relationships between conceptual understanding of groundwater flow and contaminant transport, and site specific details such as locations of monitoring wells and water supply wells.

The LANL modeling approach for building computational meshes utilizes flexible strategies necessitated by evolving complexity and continual assessments on parameter uncertainty and model predictions. Computational meshes generally evolve from relatively simple large regions (at the maximum spanning the entire Española Basin), to smaller focus areas with more detail and resolution (for example, the vadose zone and the regional aquifer at Sandia Canyon). The integrated modeling process involves the integration of a hydrogeologic setting, site characterization data, a computational mesh, numerical model, and evaluation of results. Here we show selected Pajarito Plateau area models to illustrate methods to develop numerical models in response to evolving needs of simulation scientists and program requirements.

## **A Hydrogeologic Perspective of Groundwater in and around the City of Española**

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Groundwater is available in and around the City of Española; however, the combination of limited data and complex geology has resulted in poor characterization of available supplies. The City has had problems with several constituents present in their production wells, including arsenic, fluoride, uranium, and nitrate.

Daniel B. Stephens & Associates, Inc. (DBS&A) conducted a hydrogeologic investigation of groundwater in the vicinity of the City of Española. The primary task performed as part of this investigation was a compilation and analysis of pertinent existing data. Because of the extremely limited data available, DBS&A recommended that the City collect water quality samples from eight of their supply wells to provide a recent snapshot of water quality; results of those samples were included as part of this study. DBS&A evaluated recent and historical water levels and water quality in City supply wells and in various wells within the study area where relevant water level and water quality data were available.

## **Rapid Recharge to Perched-Intermediate Groundwater Zones, Pajarito Plateau, Los Alamos, New Mexico (LA-UR-08-05882)**

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The Los Alamos National Laboratory continuously monitors groundwater levels and surface-water discharge at over 150 locations on the Pajarito Plateau. The resulting data sets were analyzed to help identify locations where surface water and shallow alluvial groundwater (generally <30 ft) recharge deeper perched-intermediate groundwater (approximately 200 to 700 ft bgs) zones. Runoff from snowmelt and summer rainstorms recharges the shallow alluvial groundwater. The vadose zone beneath the alluvial groundwater ranges in thickness from 600 to 1200 ft. Typical estimated annual infiltration rates vary spatially from <1mm/yr to 1000 mm/yr. However, localized rapid recharge can sometimes yield transient infiltration events that are detected 200 ft below ground surface within a few days. The recharge events are identified by the observed water-level fluctuations in perched-intermediate groundwater monitoring wells. Preliminary analysis of the data suggests that the mechanism for this rapid recharge is spatially-limited fracture flow through basalt and welded volcanic tuff. The rapid recharge has been observed at three separate areas in response to both snowmelt and stormwater runoff events. One recharge area located on the west side of the plateau is associated with a densely-welded, fractured, volcanic tuff that is also possibly faulted. Surface runoff and alluvial groundwater in drainages presumably infiltrates faulted and fractured tuffs, recharging perched-intermediate groundwater at depths of 600 to 700 ft. Two other areas of rapid infiltration occur on the eastern side of the plateau where thin nonwelded tuff and/or thin alluvium in canyon bottoms overlie highly fractured basalt. In these areas surface water and alluvial groundwater easily gain access to the shallow basalt beneath the canyon floor. Infiltration then takes place along fractures and recharges perched-intermediate groundwater within deeper basalt units. Identifying these areas is important for establishing an effective groundwater monitoring network and for refining conceptual models of infiltration mechanisms and contaminant pathways.

## **Utilization of Hydrogeologic Data for Planning and Regulating Oil and Gas Development within Santa Fe County**

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Due to public concerns about impacts of proposed oil and gas development to the economy, public facilities and services, the environment, cultural and archeological sites and the general public health, safety and welfare, Santa Fe County embarked on a comprehensive public planning process. The end product is an update to the Santa Fe County General Plan setting forth guiding principles and policy for managing oil and gas extraction and an Oil and Gas Ordinance setting forth standards and requirements.

Santa Fe County has recently benefited from the Bureau of Geology and Mineral Resources geologic mapping of several critical 7.5 minute quadrangles within the oil and gas planning area. This data was crucial in developing groundwater vulnerability, aquifer susceptibility and fault location layers for the Oil and Gas Suitability Analysis Model.

To address aquifer vulnerability or potential risk of contamination to the aquifer from a pollution source at or near the land surface the EPA DRASTIC (Aller, 1985) methodology was employed. A weighted raster-based map was created to rank the groundwater pollution potential, defined as the ease of which a contaminant can migrate to the groundwater table, utilizing influential hydrogeologic factors. These factors are depth to water, recharge, aquifer media, soil media, topography, unsaturated media, and hydraulic conductivity. Each factor has been assigned a relative weight with 5 being most significant and 1 as least influential.

Aquifer susceptibility was defined as the ease with which water enters and moves through an aquifer. To assist in the planning process the shallow saturated geologic units were ranked as good, moderate and low-producing aquifers. The aquifer ranking is based on lithology, reliability of supply, production of the wells and proximity to streams. Where data did not exist but the units are favorable for water production a fourth ranking was established to address a potential aquifer.

Due to major fault zones within the planning area a separate layer was created to treat proximity to faults as sensitive areas. Since it is largely unknown if faults located near proposed oil and gas development areas will behave as conduits to flow or barriers the creation of a separate data layer serves to require a higher level of analysis near known faults.

## **A Regulatory Perspective On OCD's Galisteo Basin Rulemaking**

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Executive Order 2008-004, issued by Governor Richardson on January 24, 2008, directed the Oil Conservation Division (OCD) to temporarily suspend the processing and granting of Applications for Permit to Drill (APDs) in Santa Fe County and the Galisteo Basin, directed executive agencies to work together to prepare a report, and directed the Energy, Minerals and Natural Resources Department (EMNRD) to ensure that no oil and gas drilling activity occurs in the Santa Fe County and the Galisteo Basin that would be contrary to the interests of the State of New Mexico and its citizens. Consequently, several agencies hosted an open house on March 29, 2008, and accepted public comments through April 17, 2008. On May 2, 2008, the Department of Cultural Affairs and the Department of Indian Affairs co-hosted a Tribal Information Session attended by the Pueblo of Tesuque, the Pueblo of San Ildefonso, the Pueblo of Santa Clara, the Pueblo of Sandia, the Pueblo of Picuris, and the Navajo Nation.

On June 24, 2008, the executive agencies issued the Report on the Galisteo Basin which highlighted areas of concern, including EMNRD's recommendations for special rules for Santa Fe County and the Galisteo Basin. On July 14, 2008, Governor Richardson issued Executive Order 2008-038 which extended the moratorium on oil and gas drilling in Santa Fe County and the Galisteo Basin until January 24, 2009, and directed OCD to investigate and begin drafting, if appropriate, rules and regulations to protect this fragile and ecologically sensitive area.

In December 2008 and in January 2009, the Oil Conservation Commission (OCC) held three days of hearings on OCD's application to add two new sections to its regulations. The goal of proposed rule 19.15.39.9 NMAC (Special Provisions) is to establish a new process for evaluating and regulating exploration and development in Santa Fe County and the Galisteo Basin. Presently, OCD evaluates and approves individual APDs administratively with no formal process for public notice or input and does not provide for participation by other governmental agencies. Under the new proposed rule, operators in Santa Fe County or the Galisteo Basin must have an approved exploration and development plan. Operators must provide information designed to inform OCD, other agencies, and the public on where and how they plan to operate in Santa Fe County and the Galisteo Basin. All applications will be set for public hearing and the operator must publish legal notice and mail a written notice to other potentially affected persons.

Proposed rule 19.15.39.10 NMAC (Additional Requirements) sets out "default" provisions that apply to any APD issued for a well in Santa Fe County or the Galisteo Basin. The provisions require operators to provide OCD and other agencies with information about fresh water and stipulate additional requirements to ensure that the environment is protected during any oil and gas operations.

Because OCD lacks specific statutory authority to address certain sensitive issues in Santa Fe County and the Galisteo Basin, other persons, including governmental agencies must review the information provided in the exploration and development application to determine whether the operator must comply with other relevant regulations and statutes. OCD's Galisteo Basin proposed rulemaking is designed to ensure that all persons are fully aware of any pending oil and gas operations in Santa Fe County and the Galisteo Basin before any operations begin. The OCC's decision on OCD's application is presently pending.

## **Petroleum Storage Tank Sites in the Española Basin and Risk to PVC Water Lines**

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There are 351 registered petroleum storage tank facilities with 149 confirmed releases in the Española Basin, both closed and currently active. Many of the confirmed release sites have or had monitoring wells, and data gained from site investigations are available for public review. Posters presented at the workshop will include maps of facilities in the cities of Española and Santa Fe. Also a map showing monitoring well locations associated with the confirmed release sites for the City of Santa Fe will be displayed at the workshop.

Petroleum hydrocarbon permeation of polyvinyl chloride (PVC) water supply lines has been documented in the literature, and an impacted community water line was encountered near a leaking underground storage tank (LUST) site. The problem was first noted when local residents of a small northern New Mexico village complained that their tap water smelled and tasted like gasoline. In response, NMED collected tap samples and sampled the two community water supply wells. The analysis of tap water samples detected extremely low levels of petroleum contamination. Water samples collected from four taps detected benzene concentrations of 1.5, 1.3, 1.1 and 0.2 µg/L, respectively, all below the drinking water standard for benzene of 5 µg/L. Petroleum hydrocarbons were not detected in the two community water supply wells or in taps upstream from the contaminated soil.

The stratigraphy in the vicinity of the impacted water line consists of Quaternary alluvium, generally consisting of well-graded sand and silt with discontinuous gravel, cobble, and boulder layers. The results of soil and soil vapor samples collected during a Geoprobe investigation indicated petroleum hydrocarbon contamination in soil for approximately 400 feet along each of the two PVC community water lines. BTEX concentrations in soil samples collected in the vicinity of the impacted part of the water line ranged from 7.69 to 670 mg/kg, and GRO results in the vapor samples from the same area ranged from 8,000 to 83,000 µg/L.

During excavation, NMED determined that the part of the PVC water line, installed in 1991, situated in contaminated soil had been permeated by petroleum hydrocarbons. The PVC pipe had brown staining, both inside and out. The PVC water line was deformed in the vicinity of the worst soil contamination. The deformation may have been due in part to high pressure in the water line. The PVC water line that was not lying in contaminated soil was not visually stained by petroleum hydrocarbons.

Site remediation included excavation and disposal of approximately 10,500 cubic yards of contaminated soil; replacement of approximately 800 feet of community PVC water lines with poly-wrapped ductile iron; and replacement of about 400 feet of roadway. Eight service lines were also replaced. Approximately \$2.6 million dollars from the Corrective Action Fund were spent. Follow-up tap sampling indicates that the project was a success. Benzene has been non-detect in tap water samples since the completion of the project.