Analysis Report
Task 1D of AP-114
Collect Current and Historic Information on Water Levels and Specific Gravity in Potash Tailings Ponds within the Culebra Modeling Domain

(AP-114: Analysis Plan for Evaluation and Recalibration of Culebra Transmissivity Fields)

Task Number 1.4.1.1

Report Date: March 31, 2006

Author:	____________________________________ Dennis W. Powers Consulting Geologist	__________ Date
Technical Review:	____________________________________ Joseph F. Kanney, 6821 Performance Assessment Department	__________ Date
QA Review:	____________________________________ Douglas R. Edmiston, 6820 Carlsbad Programs Group	__________ Date
Management Review:	____________________________________ M.J. Rigali, 6822 Repository Performance Department	__________ Date

WIPP:1.4.1.1:TD:QA-L:AP-114 Analysis Reports

Table of Contents
Task 1D of AP-114

Table of Contents, continued

Analysis Report for Task 1D, AP-114
Current and Historic Information on Water Levels and Specific Gravity in Potash Tailings Ponds within the Culebra Modeling Domain

1.0 Introduction

This analysis report has been prepared and submitted to meet the requirements of Task 1D of Analysis Plan AP-114 (Beauheim, 2004; effective 10/11/04) for collecting current and historic information on water levels and specific gravity in potash tailings ponds within the Culebra modeling domain. The analyst is Dennis W. Powers, Ph.D., Consulting Geologist, Anthony, TX 79821.

Several lakes in the southern end of Nash Draw (Figure 1) exist today primarily because of brine effluent from operations by the Mosaic potash company. In two previous studies of water balances for this area (Geohydrology Associates, Inc., 1979; Hunter, 1985) the ponds or brine lakes that have developed in several low areas in the southern half of Nash Draw are understood to be wholly to partially (Laguna Grande de la Sal) due to the effluent from the Mosaic (formerly IMC) potash refinery located on the west central margin of Nash Draw. A now defunct refinery located west of Laguna Grande de la Sal was the first potash refinery in the basin, and it discharged into Laguna Grande beginning during the 1930s. Laguna Grande is downgradient from the study area and outside the boundaries.

The general area for this study south and west of the Waste Isolation Pilot Plant (WIPP) site is centered on the southeastern arm of Nash Draw (Figure 2), and it is the same as the study area for Task 1B (Powers, 2006). The boundaries to the west and south correspond to the limits used for earlier modeling; the northern and eastern boundaries include the southeastern arm of Nash Draw and an area beyond the apparent eastern extent of the draw. The Universal Transverse Mercator (UTM) (North American Datum 1927 - NAD27) western and eastern boundaries are at 601700 m Easting and 615000 m Easting, respectively. The UTM (NAD27) southern and northern boundaries are at 3566500 m Northing and 3582000 m Northing, respectively.

Within this study area, the focus is on three brine lakes or ponds, unofficially called Laguna Uno, Laguna Cuatro, and Laguna Cinco (Figures 1 and 2).

2.0 Specific Gravity Data and Methods

2.1 Current Specific Gravity Information. To obtain current information on specific gravity, Ed and Anne Schaub (Sandia National Laboratories) visited Lagunas Uno, Dos, Cuatro, and Cinco early in 2005 and recorded field measured specific gravity and temperature. The data are presented in Table 1 and shown in Figure 3. These locations were revisited December 6, 2005, to provide supplemental data (Table 2).

The specific gravity taken early in the year at these locations varies from a minimum of 1.0735 for the east side of Laguna Cinco to a high of 1.224 from Laguna Cuatro near the west side of this brine lake. The data for equivalent locations, taken in December, range from 1.0915 for the northeast side of Laguna Cinco from a spring to a high of 1.227 for brine from Laguna Dos.

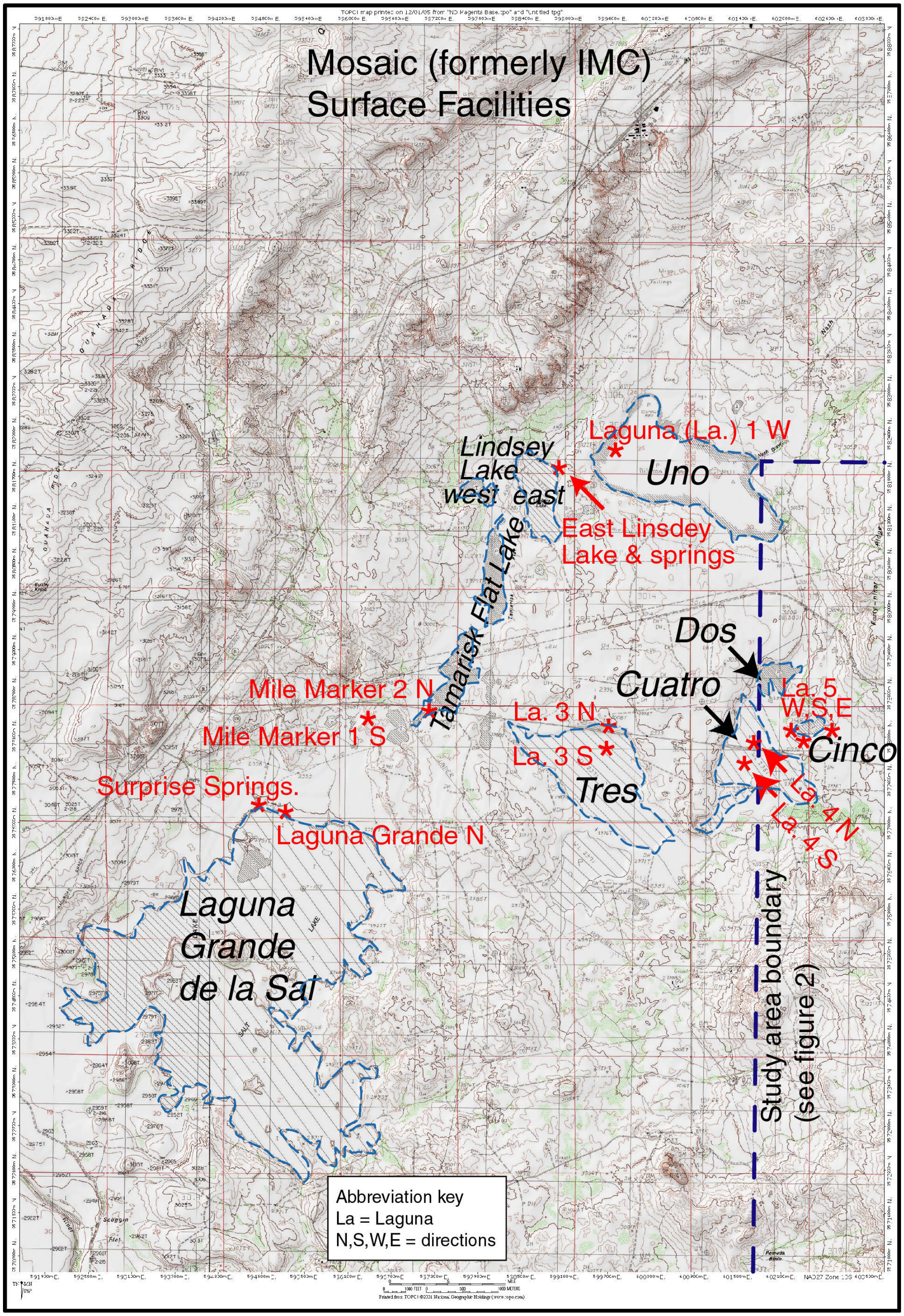

Figure 1. Brine ponds in southern Nash Draw. Red letters and asterisks identify general locations where historical specific gravity data have been collected since 1986. Major ponds are outlined with blue dashed lines.

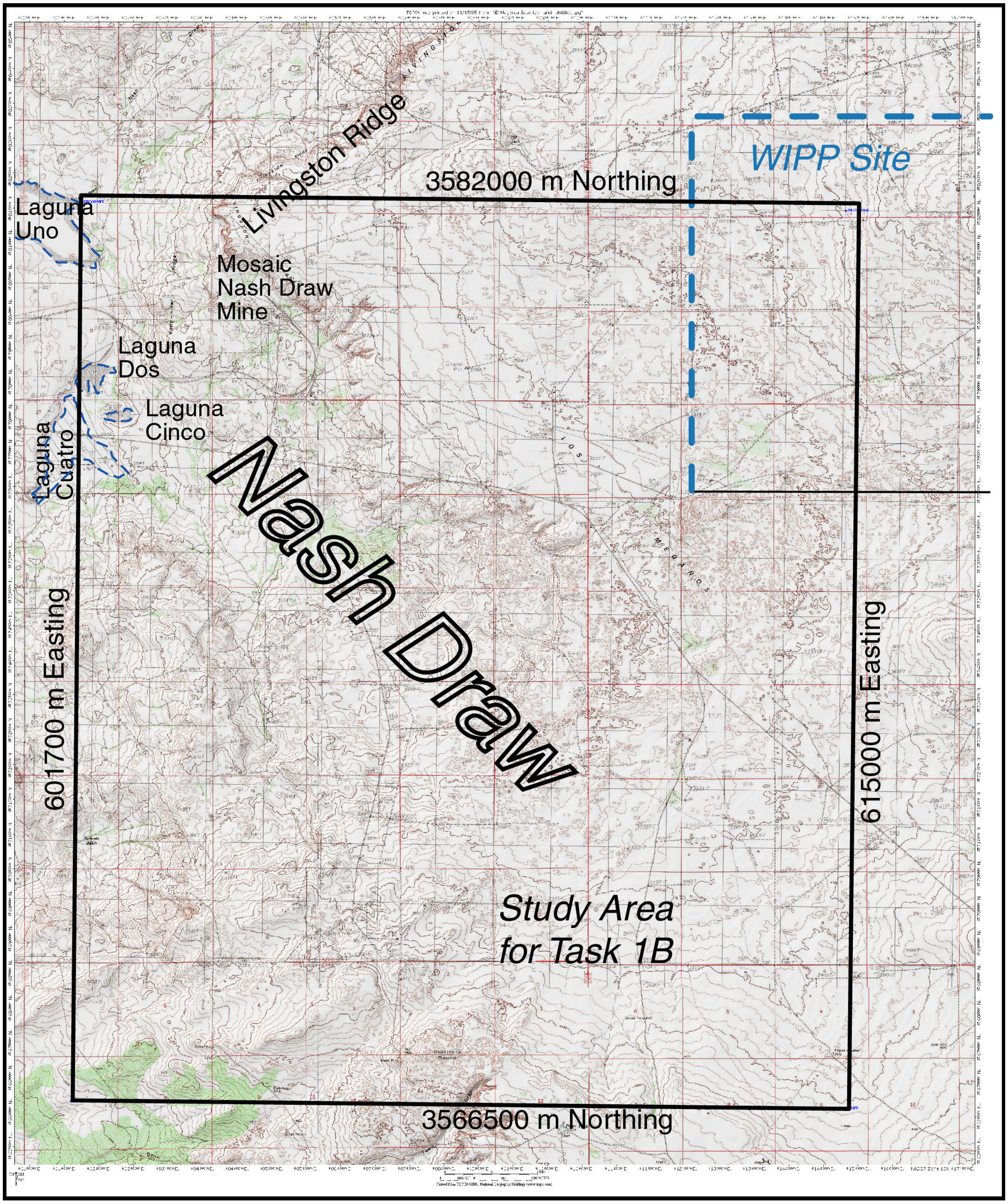

Figure 2 – Study area. The study area for Task 1B (Powers, 2006) shown in the black rectangle overlaps the southwestern part of the WIPP site (blue dashed outline) and is centered mainly on the southeastern arm of Nash Draw. Boundary limits are UTM (NAD27) coordinates in meters. Brine lakes described here as part of Task 1D occur in the northwestern corner of the study area.

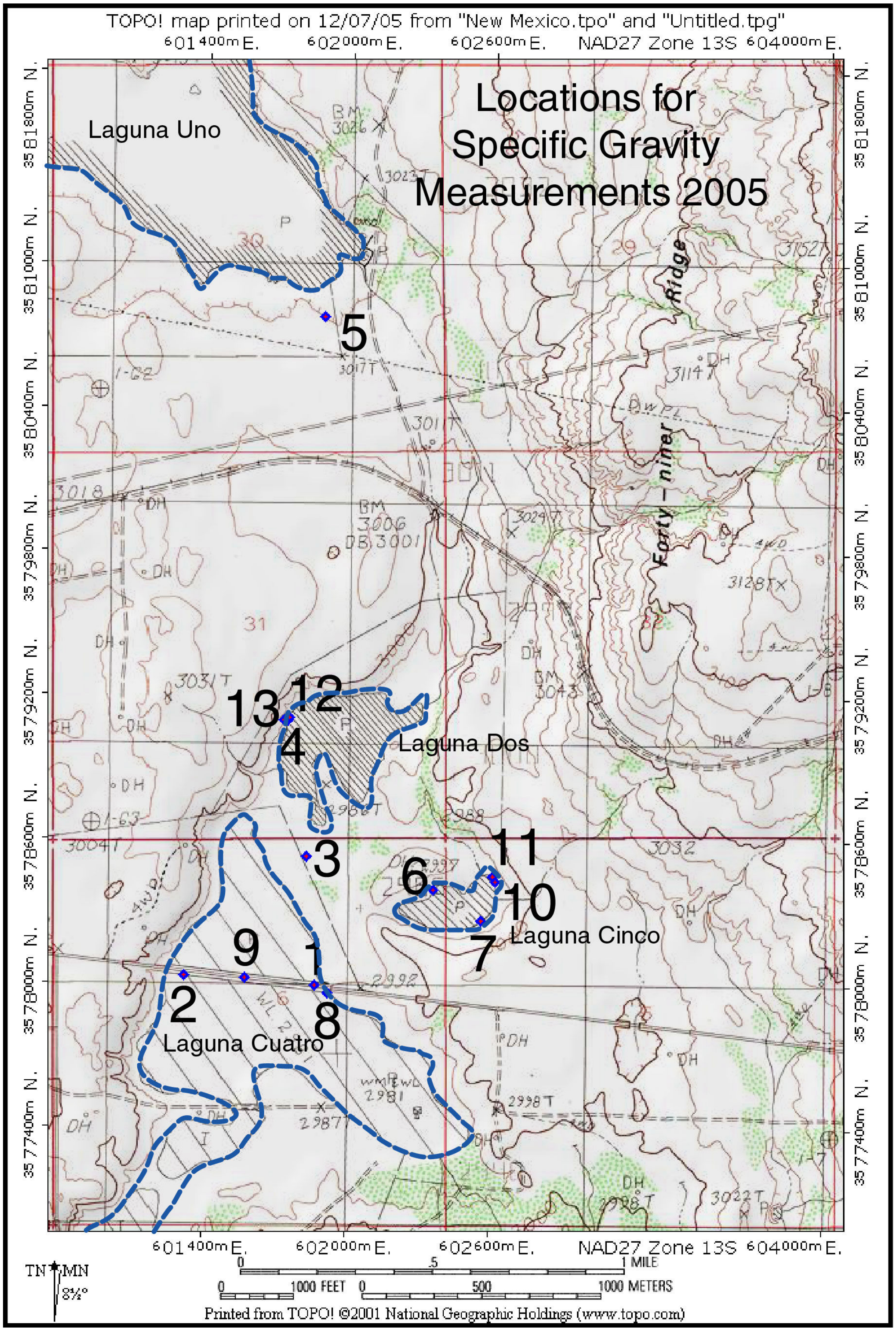

Figure 3 – Locations of specific gravity measurements. The locations are numbered according to the "sample #" listed in Tables 1 and 2. Locations 1-7 are approximately the same for both sample series listed in these tables.

Table 1
Specific Gravity Measured in Selected Nash Draw Brine Lakes - Early 2005

Date	Sample Name	Location	UTM X NAD27 (m)	UTM Y NAD27 (m)	Specific Gravity	Temperature (Degrees C)
2/9/2005	Sample 1	Laguna Cuatro N	601864	3577998	1.142	19.2
2/9/2005	Sample 2	Laguna Cuatro S	601317	3578038	1.224	22.4
2/9/2005	Sample 3	Laguna Dos S	601825	3578529	1.214	22.9
2/9/2005	Sample 4	Laguna Dos	601739	3579101	1.218	16.3
2/9/2005	Sample 5	Laguna Uno	601883	3580772	1.146	15.0
4/7/2005	Sample 6	Laguna Cinco W	602357	3578400	1.0755	16.7
4/7/2005	Sample 7	Laguna Cinco E	602623	3578350	1.0735	20.0

Table 2
Specific Gravity Measured in Selected Nash Draw Brine Lakes – Late 2005

Date	Sample Name	Location	UTM X NAD27 (m)	UTM Y NAD27 (m)	Specific Gravity	Temperature (Degrees C)
12/6/2005	Sample 1	Laguna Cuatro N	601864	3577998	1.188	8.2
12/6/2005	Sample 2	Laguna Cuatro S	601317	3578037	1.215	4.8
12/6/2005	Sample 3	Laguna Dos S	601824	3578534	1.221	15.2
12/6/2005	Sample 4	Laguna Dos	601742	3579101	1.225	11.1
12/6/2005	Sample 5	Laguna Uno	601884	3580779	1.187	10.2
12/6/2005	Sample 6	Laguna Cinco W	602357	3578400	1.0995	7.9
12/6/2005	Sample 7	Laguna Cinco E	602557	3578270	1.092	9.3
Additional Locations Measured 12/6/2005						
12/6/2005	Sample 8	Laguna Cuatro SE	601917	3577966	1.116	4.2
12/6/2005	Sample 9	Laguna Cuatro N Central	601570	3578029	1.22	5.2
12/6/2005	Sample 10	Laguna Cinco NE	602617	3578431	1.098	9.3
12/6/2005	Sample 11	Laguna Cinco NE Spring	602606	3578453	1.092	9.7
12/6/2005	Sample 12	Laguna Dos NW	601748	3579111	1.227	10.7
12/6/2005	Sample 13	Laguna Dos seep	601727	3579100	1.196	20.0

<u>2.2 Historical Data.</u> There are few sources of specific gravity data for these brine lakes. The most consistent set of data has been compiled from measurements taken at various times by me or colleagues since the early 1980s. An Excel® spreadsheet is submitted for the record package with these data (Historical Specific Gravity Data for AP-114 Task 1D.xls). Sampling locations referred to in the Excel® spreadsheet are consistent through time and are shown in red in Figure 1. These measurements were recorded in the field with Fisher Scientific hydrometers having individual ranges of 0.07 that overlap from one hydrometer to the next. I did not calibrate the hydrometers after purchase; measurements remained consistent with field evidence of brine concentration and are taken as adequate evidence of the range and change in composition. For example, specific gravity measured in the field in the range of ~1.23 was found for brines in contact with crystallizing halite and ~1.00 for tap water used to rinse equipment. These checks were informal and are not recorded in notebooks.

For Laguna Uno, eleven measurements between 1989 and 1994 along the west side of the brine pond averaged 1.236 specific gravity, with a narrow range between 1.212 and 1.247. These measurements are consistent with continued presence of halite in the lake substrate.

For Laguna Cuatro north (north side of NM 128), sixteen measurements between 1986 and 2001 averaged 1.231. This includes one measurement in 2000 where the upper limit of the available hydrometer was 1.19. The range is from 1.1955 and 1.244. The low end was the first measurement, in 1986. The average and most measurements are consistent with continuing presence of halite in this lake.

Laguna Cuatro south (south side of NM 128), thirteen measurements between 1988 and 2001 average 1.227, with a range between 1.176 and 1.242. The presence of halite in Laguna Cuatro south over this period is consistent with the average and most measurements of specific gravity.

Only four measurements from Laguna Cinco have been recorded. The average for these is 1.121. Two samples from the eastern side of the lake, near visible springs, were 1.1165 and 1.125. These were measured in April 2000 and June 2002, respectively. A sample along the south side of Laguna Cinco in April 2000 measured 1.1275, and a sample from the west side in June 2002 measured 1.175. Despite the modest differences in these measurements, additional notes show that the gypsum on the lake bottom was being degraded or dissolved in April 2002 and was sharp and well-formed in June 2002. Halite has not been observed crystallizing within the water in Laguna Cinco, although some halite efflorescence has been noted in the capillary zone above the strand line.

Measurements from other lakes in the vicinity generally confirm high specific gravities, with some temporary exceptions, that are consistent with the presence of crystalline halite in the substrate of all lakes except Laguna Cinco.

<u>2.3 Methods for Measuring Specific Gravity.</u> The current (2005) specific gravity data were obtained by Ed and Anne Schaub (Sandia National Laboratories) using hydrometers from Fisher Scientific, and the temperatures were measured using a Mannix Digital thermometer. The locations in February and April were obtained with a Garmin GPS12 unit, and the location

coordinates in December with a Garmin Etrex Vista unit. Data were recorded in WIPP Site Well Testing Scientific Notebooks #5 (February and April) and #7 (December), which include information on model and serial numbers for apparatus used. The temperature data are supplemental, as the specific gravity corrections for temperature are not essential. The location data are approximate (generally ± 4–5 m) and are fully adequate to show the general area of sampling. The hydrometers have calibration from the manufacturer.

As noted above the historical specific gravity data were acquired with Fisher Scientific hydrometers with overlapping ranges. They provide a general background with which to understand the current data.

3.0 Brine Elevation Data and Methods

3.1 Current Brine Elevation Survey. To obtain current information on water/brine elevations, Mel Pyeatt (New Mexico Registered Professional Land Surveyor #8510) was contracted to provide four reference elevations (Table 3, Figures 4 and 5), and they were obtained early in March 2005. These elevations of the brine/water range from a high of 917.402 m amsl for Laguna Uno to the lowest of 909.111 m amsl for the northern end of Laguna Cuatro (Table 3).

Table 3
Surveyed Elevations of
Selected Nash Draw Brine Lakes - Early 2005

Date	Sample Name	Location	UTM X NAD27 (m)	UTM Y NAD27 (m)	Elevation (m amsl)
3/2/2005	Survey 1	Laguna Uno	601693	3580763	917.402
3/2/2005	Survey 2A	Laguna Cuatro N	601762	3578380	909.111
3/2/2005	Survey 2B	Laguna Dos S	601886	3578388	910.037
3/2/2005	Survey 3	Laguna Cinco W	602196	3578293	910.341

3.2 Historical Brine Elevation Information. There are no equivalent historical records of brine levels within the lakes matching the historical specific gravity data. Notes provide some general ideas of modest changes in water level depending on season and rainfall events. These relate to low evaporation during the winter months, high evaporation during early summer, and higher rainfall during the late summer "monsoon" in southeastern New Mexico.

A limited study of local changes in brine lake levels is provided by Geohydrology Associates, Inc. (1979) based on data collected over a period of about 1 year. Stakes were driven in several of the ponds for a reference point 1 foot (~30 cm) above the brine level at the beginning, and the depth of water below the top of the stake was recorded a few times during the year and over short periods. For the most part, these changes are a few cm. The largest indicated change was nearly 0.5 m, recorded for East Lindsay Lake, which is out of our present area of concern.

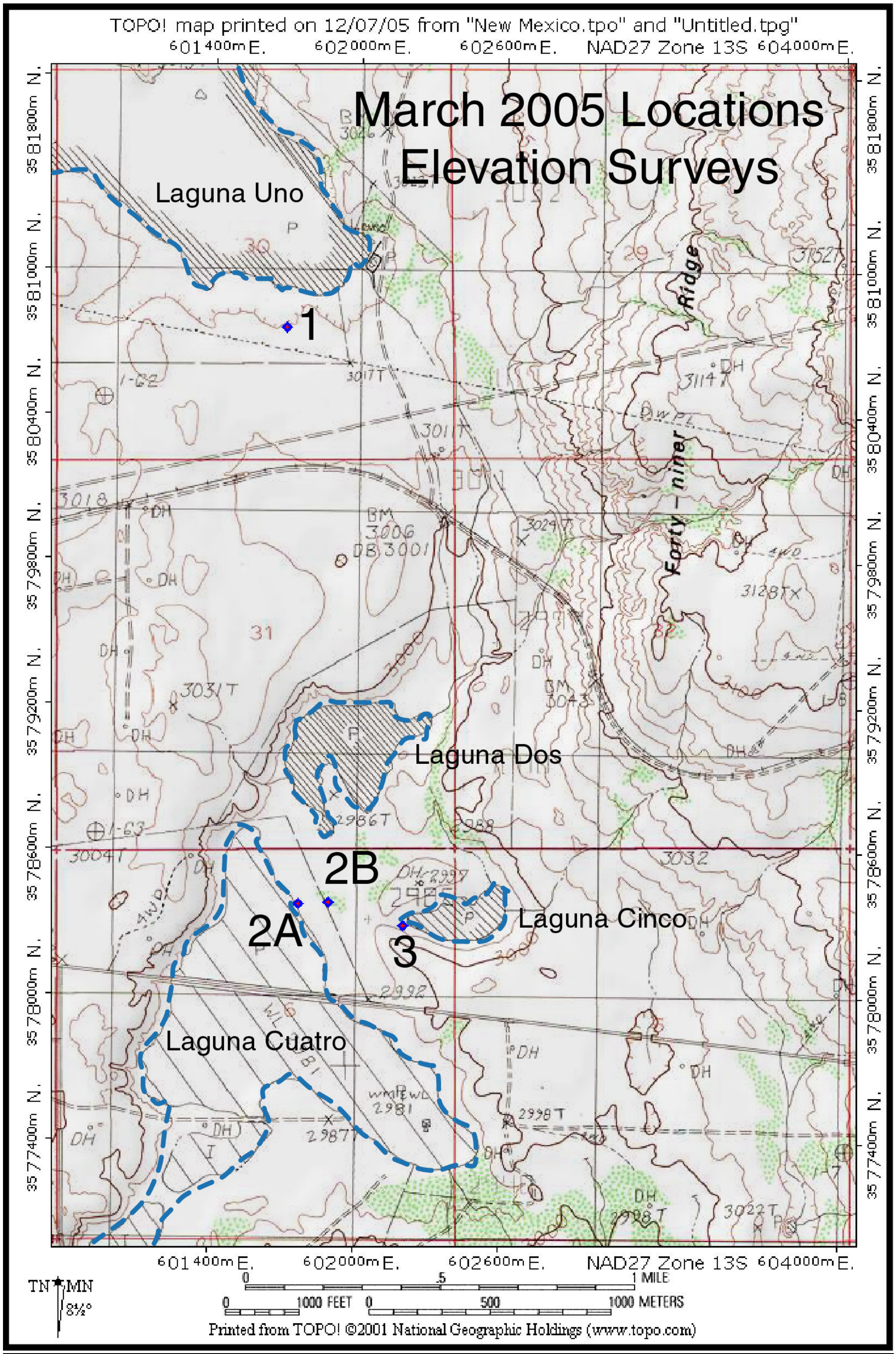

Figure 4 – Locations of brine lake elevation surveys. See Table 3 for location data and Figure 5 for a survey plat. Point 2B provides the elevation at the south end of Laguna Dos at higher water levels.

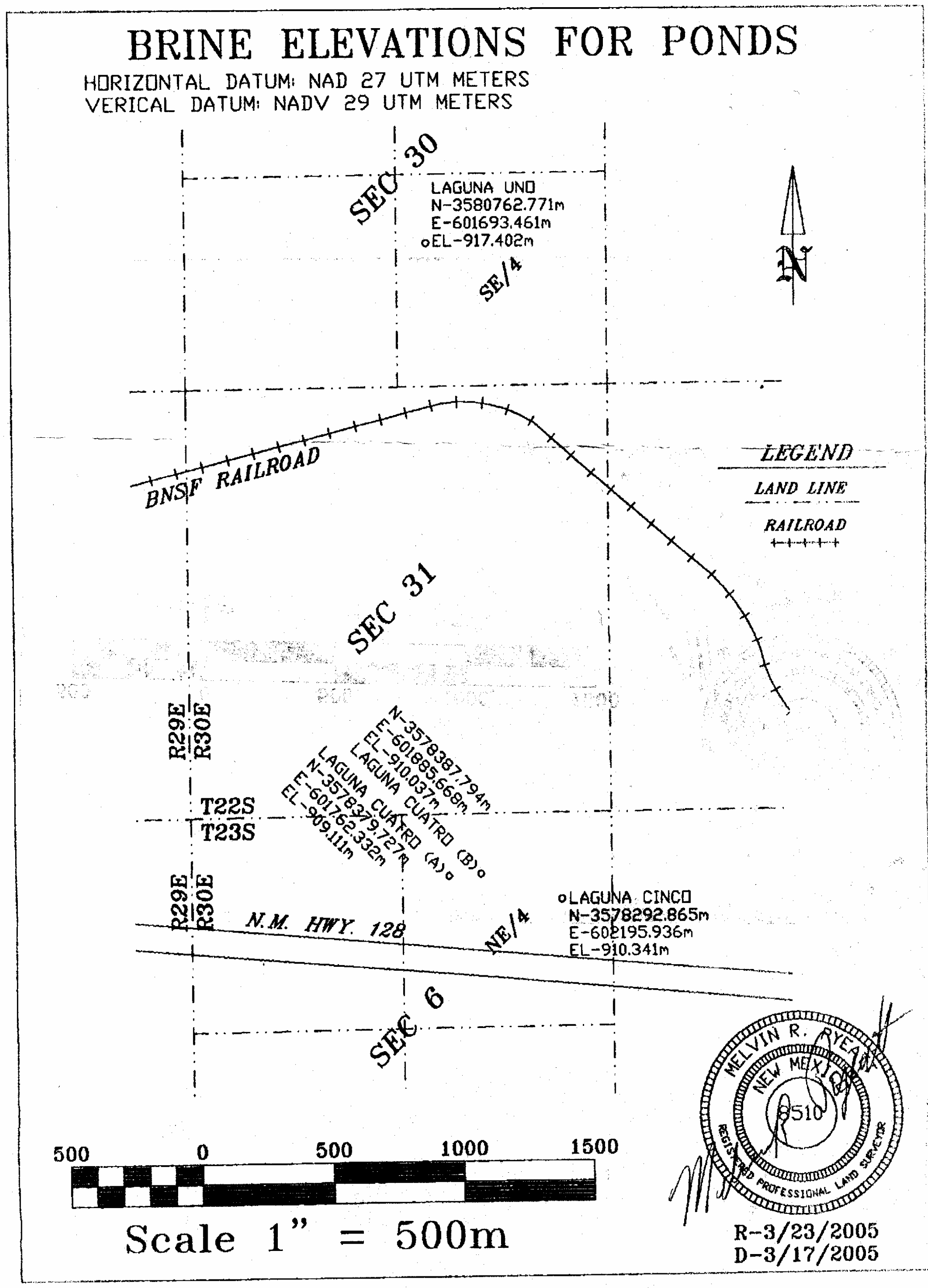

Figure 5 – Copy of survey plat by Melvin R. Pyeatt. The "Laguna Cuatro (B)" point is the southern edge of Laguna Dos, as it extends south to a slight rise that separates Laguna Dos from Laguna Cuatro. The survey was conducted March 2, 2005.

Aerial photographs provide a longer term indication of the changes that have occurred in some of the relevant lakes. In Figure 6, the aerial photograph for soil mapping used by Chugg et al. (1971) is compared to 1996 NAPP aerial photographs for Uno, Dos, Cuatro, and Cinco. The dates of the aerial photos used by Chugg et al. (1971) are not known very exactly, but they predate 1960, as there is no evidence of the roads and construction associated with Project Gnome. Concentric circles in the photograph are the remains of practice bombing targets left after WWII training that occurred in Carlsbad and elsewhere in the southwest. Nevertheless, there are some significant changes that occurred after these earlier aerial photographs were taken. Laguna Uno, now the catchment for the runoff effluent from the Mosaic potash refining plant, shows very little surface water in this early photograph, in contrast to the 1996 aerial photograph. Laguna Uno is an historically new collecting point for possible recharge of brine, although it has been significant for at least the last 30 years. The depth of Laguna Uno is not known, but topographic contours on the geologic map included in Vine (1963) suggest that, in the area covered by Laguna Uno, the deepest areas are about 2985 ft (<2990 and >2985 ft) or about 909.8 m amsl. The maximum change in water level over this period of time is therefore estimated to be about 7 m. In more recent years, the annual differential in elevation of the brine lake level in Laguna Uno is believed to be less than about 1 m, based on observations by Geohydrology Associates, Inc. (1979), supplemented by personal observations.

Water accumulated more persistently in Laguna Dos and Laguna Cuatro even before the major effects of the tailings effluent from the Mosaic mine (Figure 6). These lakes were significant in 1975, when I began traveling to the WIPP site area, but halite was not forming in them to my knowledge until late in the decade. Topographic details from Vine (1963) suggests that the fill/water depth has not exceeded about 3 m. The outlet at the south side of Laguna Cuatro south and the culverts connecting north and south lakes have not been disturbed for a number of years, and the water levels in Laguna Cuatro N and S are not believed to have changed by more than ~ ±1 m since about 1975. It does appear that Laguna Dos can vary somewhat more than Laguna Cuatro because of the topography dividing the two, but ±2 m likely bounds this change since about 1975.

Laguna Cinco is also persistent and has had increased surface area and depth since 1975, compared to the small areas of surface water in the early aerial photos (Chugg et al., 1971). There are limits to the rise in water from current levels before Laguna Cinco spills into Laguna Dos and Laguna Cuatro. Topography and wading surveys suggest that Laguna Cinco has raised at least 1 m, but likely not as much as 2 m, above the levels before 1960 (based on aerial photos in Chugg, 1971). Reconnaissance visits over several years indicate ±1 m is about the extent of changes since 1975. Laguna Cinco is fed by springs along the east and northeast side that yield water with much lesser specific gravity and few chlorides, to judge by the very limited halite efflorescence around the margins of the lake. Nevertheless, lake levels would appear to be influenced overall by the advance of effluent through the Laguna Cuatro and Dos areas, as Laguna Cinco levels have also risen, though salinity is still relatively low.

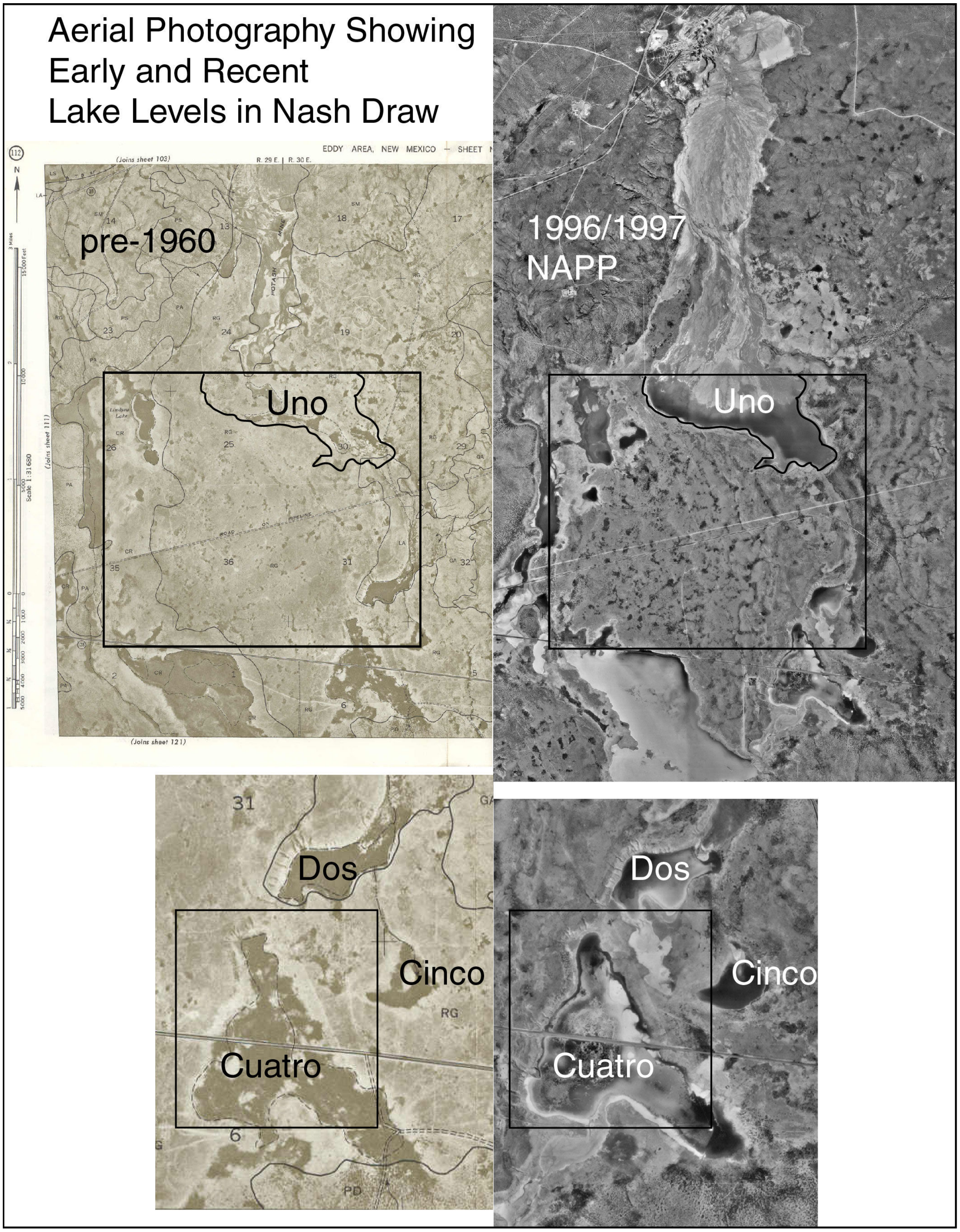

Figure 6 – Aerial photographs indicating historical changes in brine lakes. Squares show the corresponding points in photographs. The photos on the left are from Chugg et al. (1971; sheet 112) and pre-date 1960. The photos on the right are from the National Aerial Photograph Program (NAPP); this area is covered by photos 9615-12 (11/1/97) and 9611-51 (10/22/96).

<u>3.3 Methods for Brine Elevation Measurements.</u> The current (2005) elevations were obtained with the services of a professional registered surveyor.

Indications of historical water levels and their changes are not precise. They have been estimated from topographic data available from earlier maps (Vine, 1963) and compared to the extent of various brine lakes at differing times. They help to establish a reasonable range of variation, but they are limited.

4.0 Quality Assurance

Current information on specific gravity was obtained by Ed and Anne Schaub (Sandia National Laboratories) and recorded in scientific notebooks. Model or serial numbers are recorded in the notebooks. The current elevation data were obtained by a registered professional surveyor.

5.0 Computers and Software

The software used in this report is for the preparation of illustrations and the report. Illustrations have been prepared using *Adobe® Illustrator® 8.0* and *Adobe® Photoshop® 5.0.2*. The spreadsheet to report historical specific gravity data was prepared with *Microsoft® Excel® 2002* (10.6501.6626) SP3. Average historic specific gravity for different brine lakes was calculated using the AVERAGE function within Excel®. *Microsoft® Word 2002* was used for report preparation, and the final report file was prepared as a pdf using *Adobe® Acrobat® 6.0* version 6.0.3. All software has been registered to Dennis W. Powers.

All software was used on a *Dell® Inspiron® 8200* containing an Intel® Pentium® 4 2.00GHz Mobile CPU. The operating system is *Microsoft® Windows® XP* version 2002 with Service Pack 2 installed and registered to Dennis W. Powers.

Electronic files attached to this report are in Excel® 2002, Acrobat® 5.0, or Word 2002 formats.

6.0 Discussion

There are differences between the current (2005) specific gravity data and the historical data that are indicative of the effects of short term climatic effects. For example, the specific gravity (Table 1) from Laguna Uno obtained in February 2005 is only 1.146. This datum is anomalous compared to the historical data, and it is anomalous compared to the effluent from the tailings pile. The December 2005 data from the same location shows a somewhat higher specific gravity of 1.187; at this southeastern end of Laguna Uno, there is no evidence of halite being precipitated, consistent with the current data. Halite does fill the western end of Laguna Uno. During 2004, there were at least 2 significant rainfall events of >2.5 inches within 24–48 hours, with the latest in September of 2004. Runoff, non-brine springs that may be flowing into Laguna Uno, and reduced evaporation during the winter months likely contribute to this specific gravity reading. In addition, fresh water inflows can, and do, stratify on top of the brine and may not mix until wind has provided enough energy to cause mixing. An inspection of this lake in December 2005 did not indicate stratification at a shallow level. The area at the west end of Laguna Uno, where historic specific gravity data were obtained, is now (December 2005) dry, as solids from the tailings pile effluent have filled this area and restricted brine to the eastern part of the lake. Stratified brine, if it exists, is likely only in the deeper parts of the basin of Laguna Uno.

Laguna Dos is downgradient from Laguna Uno. Although there is no surface connection at this time, it seems likely from topographic data and aerial photographs (Figure 6) that there has been a connection in the past. It seems likely also that there is some subsurface connection through this area. At present (December 2005), there are numerous observable upwelling springs in the northwestern part of Laguna Dos, in the area where specific gravity was measured (Figure 3). Some have diameters of ~1 ft (Figure 7), and they are likely supplying hundreds of gallons per minute. A sample of one large upwelling near shore (Table 2, Sample 4) had a high specific gravity (1.225) and a moderate temperature (11.1 °C). A nearby sample (not from a spring) is Sample 12, with a slightly higher specific gravity of 1.227 and slightly lower temperature (10.7 °C).

Figure 7 – Springs in Laguna Dos (left) and Laguna Cinco (right). Another spring in Laguna Dos, closer to the shoreline, was sampled, measuring 1.225. The spring in Laguna Cinco was measured at 1.0915. See Table 2 for these and other measurements. The rate of flow is estimated to be in the hundreds of gallons per minute from such springs.

Along the west margin of Laguna Dos, numerous seeps trickle into the lake from about 1 to 3 ft above the current (December 2005) lake level. These seeps are estimated to range up to 2–5 gallons per minutes in many cases, while some are smaller. Sample 13 (Table 2) is representative, with a fairly high specific gravity (1.196) and a temperature of 20.0 °C. A temperature survey of several of these seeps showed a narrow range from about 19.8–20.1 °C. The specific gravity of these two sources (upwelling springs vs. seeps) are similar, but the temperatures are strikingly different.

There is only one obvious source for brine of this high specific gravity, and that is Laguna Uno. No other source has sufficient elevation or specific gravity to feed either source. Nevertheless, the specific gravity currently measured at the southeastern end of Laguna Uno is less than these springs and seeps.

The springs and seeps in Laguno Dos are being supplied by a reservoir that differs from the current conditions in Laguna Uno. I suggest that there is both recharged brine in the hydraulic system and, possibly, deeper brine within Laguna Uno that differs from the current surface conditions. The differing temperatures between seeps and springs suggest that there is some difference in the flow velocity if I assume that they are reflecting the same basic source. The temperature differences may reflect different times of recharge (colder, winter weather for the springs; warmer, summer weather for the seeps) and separated hydraulic systems. This is very complicated, and these data are certainly insufficient to sort out the differences. They provide a basis, however, for possible testing over a period by sampling for chemistry as well as monitoring temperature changes with time. Figure 8 illustrates some, but not all, of these differing conditions found late in 2005.

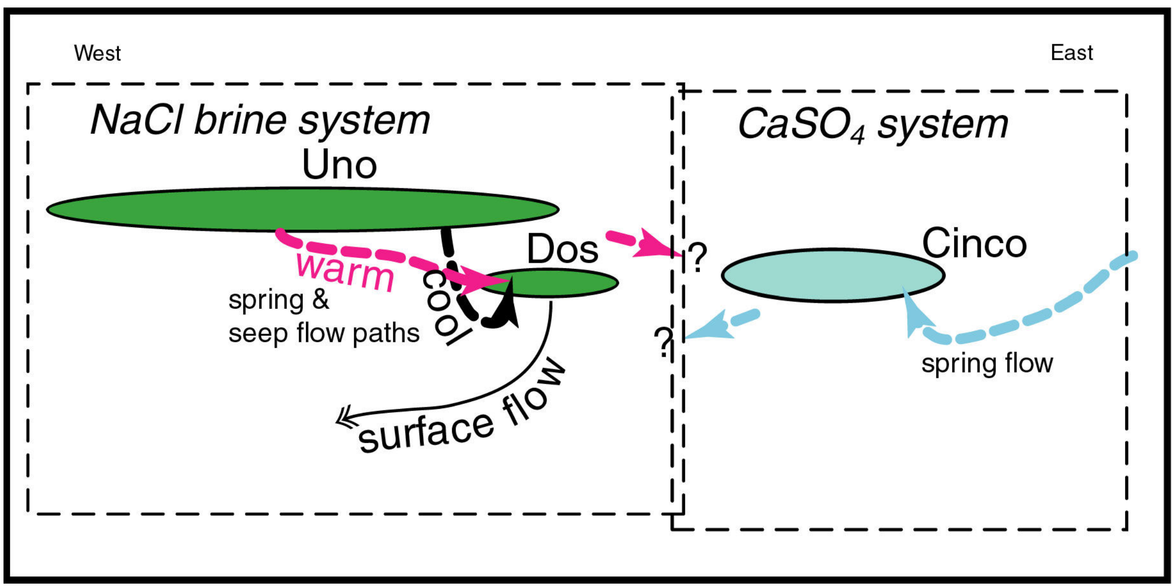

Figure 8. Diagrammatic concept of spring and seep flow. Laguna Uno, Dos, and other downgradient brine ponds are at or near saturation with respect to NaCl. Laguna Cinco has lower specific gravity and gypsum (sulfate) as a substrate. The NaCl system is maintained by potash tailings effluent into Laguna Uno. Laguna Cinco is recharged from karst in Rustler sulfate units. From Laguna Uno to Laguna Dos, there appear to be separate systems of cool flow that wells up in large springs in the bottom of Dos and warm seeps that travel in a shallower system.

Observed specific gravities at Laguna Cuatro also reflect the differences between areas with considerable seepage of lower salinity (lower specific gravity) along the eastern edge of the lake, at least, and the main flow of high specific gravity brine from Laguna Dos. This high specific gravity brine from Laguna Dos flows southward across the west central part of north Laguna Cuatro and through culverts near the location of Sample 9 (Table 2) into Laguna Cuatro south. Lower specific gravity water (especially Sample 8, but also Sample 1) from the east side of Laguna Cuatro is in contact with gypsum in the lake substrate at the eastern margin, and the water is seeping from eolian gypsite dunes to the east. It mixes with higher specific gravity water as it flows westward on both sides of NM 128.

As a consequence, I recommend that the brine specific gravity for Laguna Dos and Laguna Cuatro (both south and north) be considered 1.23 under typical conditions. Some modest excursions of part of the brine to values of 1.10 to 1.15 after significant rainfall can be considered if the modeling indicates any sensitivity to such changes. All of these lakes except Cinco maintain halite substrates, and a specific gravity of 1.10 to 1.15 cannot be considered an appropriate datum for long-term (last 25 years) modeling.

The 2005 values of Laguna Cinco are lower than the few historical measures, but they are likely indicating changes in chemistry in response to increased rainfall/recharge in the last couple years. Laguna Cinco appears to be much more dependent on the springs that have specific gravities much lower than for brine equilibrated with halite, as in other lakes. With recharge through evaporite (gypsum) karst systems in the Laguna Cinco area and to the east (see Powers, 2006), variations between about 1.07 and 1.15 are likely representative through wetter and drier years, respectively. These can be used as reasonable bounds if modeling shows that there is some sensitivity to these differences.

Elevation changes, both historic and recent, are relatively modest and likely do not exceed about ±1 m for most of these brine lakes through the course of any year. The more important question is likely to be the degree to which brine infiltrates.

The lakes within the study area are reported or observed to have springs feeding them. The differences in temperature at Laguna Dos between springs and seeps, and the lower salinity springs in Laguna Dos indicate significant differences in the hydraulic connections and/or sources for the water or brines. The springs and seeps are also points of discharge to the lakes. The local near-surface hydrologic system that feeds these springs must have higher pressures than is provided by the lake brine column. It is possible that brine pond infiltration is effective from Laguna Uno, but not very effective in Dos, Cuatro, or Cinco. Some of the infiltration may be more lateral than vertical. I remain uncertain about the local recharge from these lakes to the Culebra.

7.0 Personnel

Dennis W. Powers wrote this Task 1D report, summarized data, and reviewed aerial photos and other sources by which historical changes could be estimated. Current specific gravity data were acquired by Ed and Anne Schaub (Sandia National Laboratories). Current elevation data were obtained by Melvin R. Pyeatt, New Mexico Registered Professional Land Survey #8510. Some of the data (especially 1994 and 1995) reported for historical specific gravity data were obtained and recorded by Merrie Martin or Susan Pickering, accompanied in the field at different times by Les Hill, Mark Pickering, Andrew Orrell, and Lillie Austin. I appreciate their contribution because they volunteered at the time to supplement my information without any expectation of personal payoff.

8.0 References Cited

Beauheim, R.L., 2004, Analysis Plan for Evaluation and Recalibration of Culebra Transmissivity Fields AP-114: Sandia National Laboratories, 19 p.

Chugg, J.C., Anderson, G.W., King, D.L., Jones, L.H, 1971, Soil Survey, Eddy County, New Mexico: US Department of Agriculture Soil Conservation Service, in cooperation with New Mexico Agricultural Experiment Station.

Geohydrology Associates, Inc., 1979, Water-resources study of the Carlsbad potash area, New Mexico: report to Bureau of Land Management, Denver, CO.

Hunter, R.L., 1985, A regional water balance for the Waste Isolation Pilot Plant (WIPP) site and surrounding area: SAND84-2233, Sandia National Laboratories, Albuquerque, NM.

Powers, D.W., 2006, Analysis report Task 1B of AP-114, Identify possible area of recharge to the Culebra west and south of WIPP: report to Sandia National Laboratories, dated April 1, 2006 (ERMS# 543094).

Vine, J.D., 1963, Surface geology of the Nash Draw Quadrangle Eddy County New Mexico: Bulletin 1141-B, US Geological Survey, Washington, D.C.

9.0 List of Electronic Files Submitted

The following electronic files have been submitted for Task 1D:

Main report files: Analysis Report for Task 1D AP-114 Report 3-31-06.doc (Word 2002)
Analysis Report for Task 1D AP-114 Report 3-31-06.pdf (Acrobat® 5.0)

Figures as separate files: Task 1D for AP-114 Figure 1.pdf (Acrobat® 5.0)
Task 1D for AP-114 Figure 2.pdf (Acrobat® 5.0)
Task 1D for AP-114 Figure 3.pdf (Acrobat® 5.0)
Task 1D for AP-114 Figure 4.pdf (Acrobat® 5.0)
Task 1D for AP-114 Figure 5.pdf (Acrobat® 5.0)
Task 1D for AP-114 Figure 6.pdf (Acrobat® 5.0)
Task 1D for AP-114 Figure 7.pdf (Acrobat® 5.0)
Task 1D for AP-114 Figure 8.pdf (Acrobat® 5.0)

Data source table: Historical Specific Gravity Data for AP-114 Task 1D.xls (Excel® 2002)

Resumé for Dennis W. Powers (Word 2002)