535377

Analysis Report
Task 1A of AP-110
Identify Potash Holes Not Sealed Through the Culebra with Cement, and Units to Which the Culebra Might Be Connected

(AP-110: Analysis Plan for Evaluation of Culebra Water-Level-Rise Scenarios)

Task Number 1.4.1.1

Author: [signature] 5/18/04
Dennis W. Powers
Consulting Geologist
Date

Technical Review: [signature] 5/18/04
Richard L. Beauheim, 6822
Repository Performance Department
Date

QA Review: [signature] 5/18/04
Mario J. Chavez, 6820
Carlsbad Programs Group
Date

Management Review: [signature] 5/18/04
M.J. Rigali, 6822
Repository Performance Department
Date

WIPP:1.4.1.1:TD:QA-L:DPRP1:AP-110 Analysis Reports

Table of Contents
Task 1A of AP-110

Analysis Report for Task 1A, AP-110 Identify Potash Holes Not Sealed Through the Culebra With Cement, And Units To Which The Culebra Might Be Connected

Introduction

This analysis report has been prepared and submitted to meet the requirements of Task 1A of Analysis Plan AP-110 (Beauheim, 2003; effective 11/11/03) for evaluation of Culebra Water-Level-Rise Scenarios. The analyst is Dennis W. Powers, Ph.D., Consulting Geologist, Anthony, TX 79821.

The general area for this study comprises most of 12 townships, located in townships T21S to T24S, ranges R30-32E. Most of the data considered fall within the boundaries of the hydrological modeling domain (see Beauheim, 2003). The boundaries for subsequent tasks may be drawn differently to suit various needs, and an appropriate subset of the information provided in this report may be extracted for use. No unusual geological methods were applied in this program; estimates of Culebra depth from an existing structure contour map and reading topographic maps for location and elevation data are standard techniques.

Task 1A Elements

Four general steps are required to identify potash holes not sealed through the Culebra with cement and to identify units to which the Culebra might be connected:

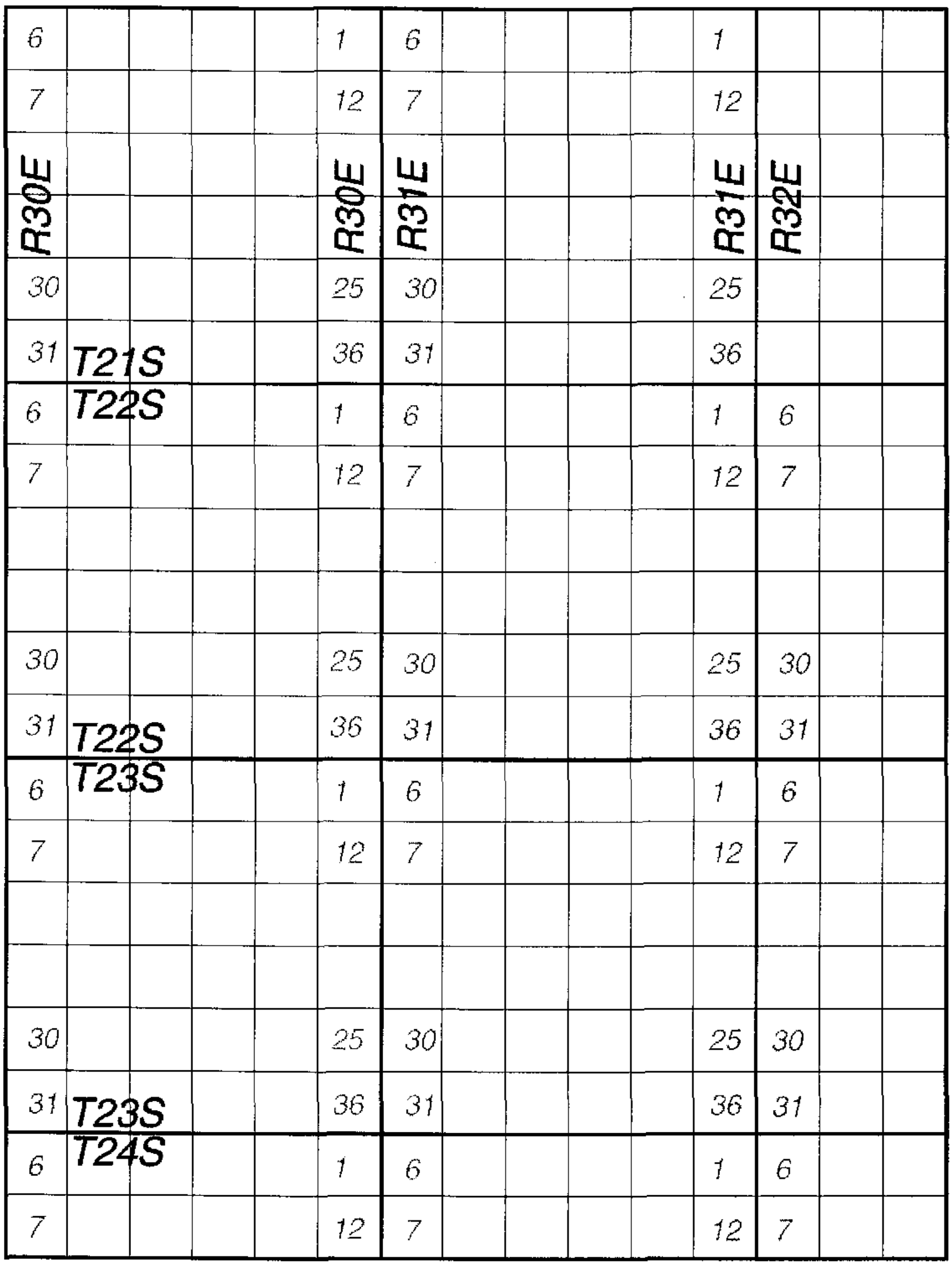
A) identify the set of potash drillholes within the area,
B) establish the cementing and casing records relevant to the Culebra,
C) establish or estimate the depth of the Culebra encountered in the drillhole, and
D) evaluate sealing of the Culebra by cement.

The initial source of data for steps A) and B) is the Delaware Basin drillhole database maintained by David Hughes, Washington Regulatory and Environmental Services (WRES). The sources of data for C) include previous work in support of Analysis Plan 088 (Powers, 2002, 2003) and some additional data collected from files at the U.S. Bureau of Land Management-Carlsbad. The depth to Culebra was estimated for a subset of drillholes based on the data on the map of Culebra elevation included in Powers (2002, 2003). Step D involved comparing the information on plugging with the information developed during step C.

Task 1A, Step A. The analysis plan calls for identifying potash drillholes for which the Culebra may not be isolated by cement. The domain of interest lies within the Delaware Basin, in the vicinity of the Waste Isolation Pilot Plant (WIPP). The drillhole database maintained by David Hughes is accepted as a record of reported drillholes within this area.

A Microsoft Access table, titled "NM 2000 Events," obtained from David Hughes, includes drillholes from potash exploration, water wells, WIPP drillholes, and earthquake data. (The original CD-ROM is attached and listed on page 12, *List of Electronic Files Submitted).* A usable subset of this table was developed by eliminating earthquake information. A further reduced subset includes drillholes only in 1) T21–23S, R30–31E, 2) T24S, R30-31E, sections 1–12, and 3) T21–24S, R32E, western half of each township (sections 4–9, 16–21, 28–33) (Fig. 1). This region is slightly larger than the general hydrologic domain (red rectangle on Fig. 2).

Figure 1 Task 1A AP-110
Initial Area of Selected Drillholes from "NM 2000 Events"



Dennis W. Powers, Ph.D.
Consulting Geologist
January 2004

The subset of drillholes from this region was further categorized or restricted as described in the next paragraph. It should be noted that the drillhole list includes water wells and WIPP drillholes, not just potash exploration drillholes. Some information included in the original Access table is unnecessary for this project and has been eliminated.

Two useful subcategories (Table 1) were established to limit the need to develop drillhole-specific data where it is not critical. The data table for this task (attached as "Table 1A for AP-110.xls") includes the subcategories as column L (Salado Dissolution Indicator) and column M (In Hydro Model Domain). The reasoning for the first category is that, in areas of Salado dissolution, the Culebra tends not to be isolated hydraulically and there are many vertical pathways resulting from karst, making borehole plugging likely to be irrelevant to the modeling exercise. Thus, the status of Culebra cementing in drillholes assigned indicator 1 may not have been evaluated. If modeling proves sensitive to this assumption, drillhole data along this margin can be reexamined. Drillholes outside the modeling domain are not expected to be included, and the status of cementing was only incidentally determined.

Table 1
General Drillhole Categories

Subcategory	Indicator	Discussion
Upper Salado halite is dissolved	0 = Salado is not dissolved 1 = upper Salado is dissolved	The indicator was assigned based on visual inspection of location relative to the Salado dissolution map; it is not precisely determined by borehole examination of thickness changes as was done by Powers (2002; 2003).
Drillhole is in modeling domain	0 = drillhole is not in modeling domain 1 = drillhole is in modeling domain	The indicator was assigned based on general visual inspection relative to the modeling domain; it was weighted somewhat toward including in the domain. This indicator was assigned mainly to assist in limiting data development and does not restrict including a drillhole in modeling.

Task 1A, Step B. The analysis plan calls for identifying the cementing and casing records for drillholes as a part of understanding the possible role of unplugged Culebra intervals. The source database, "NM 2000 Events," includes columns with information about drillhole casing and plugging (shown as columns U and T, respectively, in AP-110 Task 1A .xls). This information was evaluated and compared to Culebra intervals (see methods) to categorize Culebra plugging status in these drillholes. The cementing information is the focus, as potash drillholes are not commonly cased and left open.

The quality of the information in the database about plugging is considered good for this project. Spot checks of plugging information (records checked are indicated by a 1 in column S of AP-110 Task 1A.xls) showed good correspondence to file data at the Bureau of Land Management

(BLM) in Carlsbad, the original source consulted when the database was compiled. Some drillhole records in the database indicated no plugging information was available. All of these entries were either checked by consulting files at the BLM, or they were categorized as being in an area where plugging was not an issue (see methods). Drillhole files at BLM for some of these drillholes were found to include additional information on plugging that was used to revise Culebra plugging categories. Plugging information for the potash drillholes in the data set is considered to represent adequately the data available from the BLM; 85 drillhole files have no plugging information. Other data sources (e.g., company records) would have to be consulted to develop additional details, but there are few drillholes both in the modeling domain and outside the area affected by Salado dissolution that would be affected by the additional effort.

Task 1A, Step C. The Analysis Plan requires that the depth of the Culebra in the drillholes in the data set be established or estimated in order to evaluate the plugging effectiveness. Culebra depth was available from previous work (Powers, 2002, 2003), and these data were matched to the drillholes in the data set. Where Culebra depth was not available for a particular drillhole, it was estimated (a column for Culebra elevation in meters was added to "Table 1A for AP-110") based on information from surrounding drillholes and an elevation map of the top of Culebra (Powers, 2002, 2003) (see methods). Culebra depth was not estimated for a subset of drillholes in the area where upper Salado halite has been dissolved (see Methods) or where the drillhole is outside the model area. Estimated depths in AP-110 Task1A.xls have been differentiated by red numbers from depths obtained directly from drillhole data (black font).

Task 1A, Step D. The Analysis Plan requires evaluating the plugging of the Culebra in the potash drillholes in the data set. The plugging information for a number of drillholes was examined to establish a set of practical categories having characteristics expected to be helpful in modeling Culebra plugging. The categories and their characteristics are shown in Table 2. The categories established were initially applied to the drillholes in the hydrologic domain. Category 3 is commonly a temporary category, requiring an estimate of Culebra depth or more detailed checking of cement intervals relative to Culebra depth and reassignment to Category 2 or 4. Drillholes in areas of Salado dissolution were not commonly checked for cementing; it is assumed that karst has created vertical pathways throughout this area, rendering plugging of the Culebra moot in potash holes. Drillholes outside the modeling domain were also not further checked. Therefore, the data table will include drillholes in Category 3. Drillholes initially in Category 6 were further reviewed, and, as with Category 3, no further review was conducted if they fall in the area where Salado dissolution is considered significant. Drillholes in Category 6, but not in the modeling domain, were also not further reviewed. Three Category 6 drillholes remained and were further checked for plugging information at BLM.

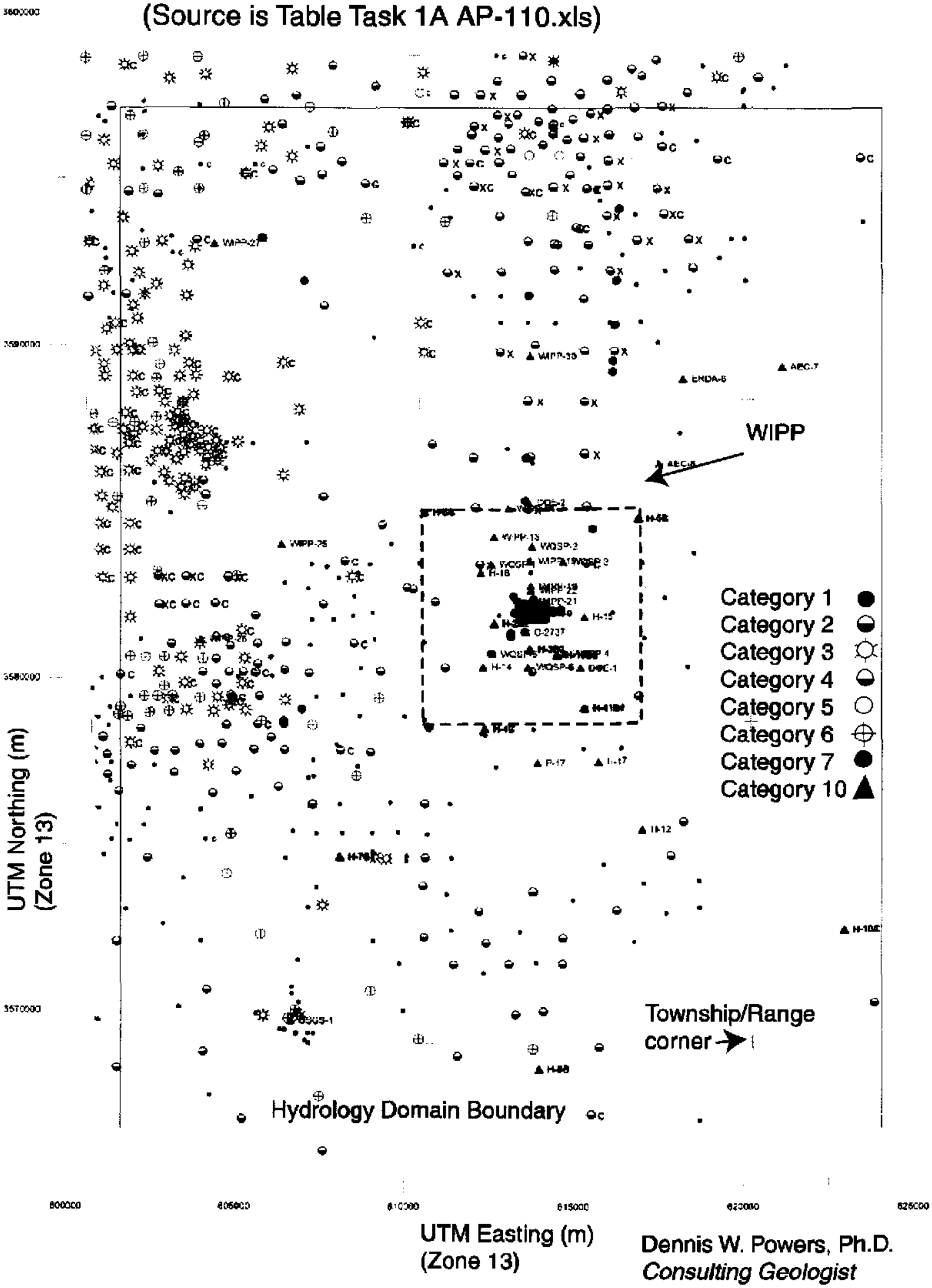
Some modifiers were added that are believed might be helpful (Table 2). Where significant casing has been left in the drillhole, the modifier "c" was assigned to a separate column (column O, Cement Evaluation Modifiers, in AP-110 Task 1A.xls). The modifier does not signify that the casing is at the stratigraphic position of the Culebra. The modifier "x" was assigned for a subset of either Category 2 or 4 where the cement top is very close to the stratigraphic position of the top of the Culebra. If the cement is at or within 3 ft above the stratigraphic top of Culebra, "x" was added to Category 2. If the cement is 1–3 ft below the stratigraphic top of Culebra, "x" was added to Category 4.

The drillholes and cement categories are plotted (Fig. 2) to show distribution within and adjacent to the hydrologic domain (red rectangle).

Table 2
Cementing Categories for Potash and Other Drillholes In the Hydrologic Domain

Cementing Category	Characteristics
1	Data indicate drillhole was cemented from total depth (TD) to surface
2	Data indicate that Culebra interval is completely cemented, with a high degree of certainty
3	Culebra intercepted by drillhole; cement intervals in drillhole; data not clear regarding cementing across Culebra interval [This category is generally a temporary category that is resolved with further checking; some drillholes remain in this category where the plugging history is considered irrelevant because of other factors.]
4	Culebra intercepted by drillhole; cement interval in drillhole does not match Culebra interval
5	Apparent open hole
6	Plugging information not available for drillhole
7	Drillhole is too shallow to intercept Culebra; plugging not considered
10	Drillhole is completed to Culebra for monitoring or water well; plugging not considered
c	This modifier for the basic category indicates that casing has been left in the drillhole; does not apply to surface marker casing; applied to categories 2–6.
x	This modifier for the basic category (either 2 or 4) indicates that the cement plug level is at, or within 3 ft above, the top of Culebra (2x) or is 1–3 ft below the top of Culebra (4x); both x and c modifiers may be attached for a single drillhole.

Figure 2 Task 1A AP-110
Composite map of Cement Evaluation Types
(Source is Table Task 1A AP-110.xls)



Dennis W. Powers, Ph.D.
Consulting Geologist
January, 2004

Methods

Several areas in developing the cement evaluation required that methods be applied to equivalent information among drillholes. Developing location coordinates is vital for data checking and later modeling exercises. It was necessary to estimate Culebra depth at drillholes where data were not available. Where cementing or plugging information provided cement amounts but not all depth information, it was appropriate to estimate the cemented interval. A method was used to develop necessary information for each of these areas.

The desired location information for each drillhole included UTM coordinates (NAD27). A surface or reference point elevation was also needed for some drillholes in order to estimate depth based on contour maps of Culebra elevation (see next paragraph). For the drillholes included in the final subset, UTM (NAD27) coordinates were available for many drillholes from the source database and from previous work on the Culebra (Powers, 2002, 2003). These coordinates were included. The source database from Hughes included New Mexico State Plane or Longitude and Latitude data for many drillholes. If one of these coordinate sets was available for a drillhole for which there was no existing UTM coordinates, the software Corpscon for Windows Version 5.11.08 was used to convert existing coordinates to UTM (NAD27) coordinates (see Powers, 2002, for a discussion of techniques and software background). For all drillholes without such a coordinate system, the UTM coordinates were derived following the methods in Powers (2002). The drillholes were marked on topographic maps according to the available information (Township, Range, Section, and distances from boundaries or corner markers). Transparent scales were used to determine the UTM coordinates from the existing 1000-m grid lines on topographic maps. Testing of the method (Powers, 2002) showed reproducible results within tens of meters, adequate for the purposes of this project. The UTM (NAD27) coordinates for all drillholes are shown in columns H and I of AP-110 Task 1A.xls. At the same time, elevation (in feet above mean sea level, NADV27) was estimated from the topographic map and is entered in column K (Elev(ft)2). As in the earlier exercise, Powers plotted and determined all locations and elevations. [*Note* that two columns (J and K) are provided for elevation data because there were different sources, such as the Hughes database and Powers (2002). Except for locations where Culebra depth was estimated by using Culebra structure maps, these data were provided for general information. They have not been further quality checked and are not used in calculations or assessment of cemented intervals.]

Depth to the top of the Culebra was available for many drillholes based on earlier work (Powers, 2002, 2003), and these data were converted to feet from meters (by dividing by 0.3048) and were incorporated into the selected subset of drillholes from the Hughes database as column R in AP-110 Task 1A.xls. These data are black numbers. For other drillholes, depth to Culebra was estimated and is shown in column R in red. These estimates were obtained in three ways:

A. For a few drillholes, depth in meters was estimated using the data from very close drillholes. Depths, in meters, are entered directly in column Q (Depth (m) Estimated and Directly Entered from Powers (2003)), and the calculated depths in feet are shown in red in column R. [There are a few depths entered in column Q where well names required visual matching with data in Powers (2002, 2003)].

B. For a few drillholes where it was more important, files at BLM were checked (noted by 1 in column S) and a depth to Culebra (ft) was entered directly into Column R, in red,

C. For other drillholes, the elements necessary to estimate depth are available: a surface or reference elevation at the drillhole and the structure contour map for the top of Culebra from Powers (2003). The process was carried out as follows:

1) the data table was sorted by location to locate drillholes around the location where top of Culebra is to be estimated,
2) surrounding drillholes were located on base maps of borehole identifiers (Drillhole ID Numbers rev 1-2-03.pdf; Powers, 2003) and elevations (Culebra elev rev 1-03-03 B. pdf; Powers, 2003),
3) the elevation of the top of Culebra (in meters above mean sea level (amsl)) was estimated by visual interpolation between structure contours, and this value is shown in column P [Culebra elevation (m amsl) interpolated from Powers (2003) map of Culebra and adjacent drillholes],
4) the elevation (in meters amsl) was converted to elevation in feet (amsl) by dividing the metric elevation by 0.3048,
5) the elevation in feet amsl was subtracted from the surface or reference elevation (ft amsl) (column J or K, as available) to obtain a depth (ft), and entered in column R (Depth (ft) to Top of Culebra) in red.

For most drillholes, the cementing data are reported as footage intervals. For a certain subset, some or all of the plugging data may be reported as a certain number of sacks of cement placed above a specified depth. To categorize the plugging status (column N, Cement Evaluation, in AP-110 Task 1A.xls) for such holes, the following method was used:

1) a sack of cement represents approximately 1 cubic foot volume,
2) a typical potash drillhole diameter is about 6 inches, but a 10-inch diameter would be assumed if it was not specified in the Hughes database,
3) Table 3 was developed (using Microsoft Excel 2002) to estimate the cemented interval when the plugging information has the general form "400': filled with 15 sacks of cement with water"; Table 3 provides an estimate of the cement height in a drillhole of a given diameter for a specified number of sacks of cement.
4) The plugging evaluation would be assigned to Category 2 if the computed top of cement, based on depth, number of sacks, and drillhole diameter, is tens of feet above the top of Culebra,
5) Category 4 was assigned if the top of cement was computed to be well below the top of Culebra,

Category 3 was assigned if the top of cement is calculated to be in the general area of Culebra top and the data about hole diameter or other variables are not detailed.

Table 3
General Computations of Cement Column (ft) in Boreholes of Varying Diameters

Dillhole Diameter (inches)	Sacks									
	10	20	30	40	50	60	70	80	90	100
	Cement Column Height in Drillhole (in feet)									
4.00	115	229	344	458	573	688	802	917	1031	1146
5.00	73	147	220	293	367	440	513	587	660	733
6.00	51	102	153	204	255	306	357	407	458	509
7.00	37	75	112	150	187	225	262	299	337	374
8.00	29	57	86	115	143	172	201	229	258	286
9.00	23	45	68	91	113	136	158	181	204	226
10.00	18	37	55	73	92	110	128	147	165	183
11.00	15	30	45	61	76	91	106	121	136	152
12.00	13	25	38	51	64	76	89	102	115	127
13.00	11	22	33	43	54	65	76	87	98	108
14.00	9	19	28	37	47	56	65	75	84	94

Assume: 1.00 cubic ft cement/sack
pi = 3.1416
Cement Column Height (ft) = (sacks * (volume/sack))/(drillhole volume/ft)
where drillhole volume/ft length = pi * radius (in ft) squared/1 ft

Data Sources and Quality Assurance

For the main records, a Microsoft Access Table titled "NM Events 2000" was obtained from David Hughes (WRES), and this table was accepted as a record of potash and other drillholes (exclusive of oil and gas exploration) for the study area. It was exported from Access as a Microsoft Excel table for paring down to the subset necessary for the project and for entering and manipulating additional data. Upon further investigation, two drillholes originally thought to be in the study area based on information in "NM Events 2000" are now believed to be located outside the study area, and Hughes has been notified of the apparent mislocation. These drillholes are I-E and I-330. In addition, the drillhole records "P_-01" through "P_-21" were removed from the exported Excel table as partial records of drillholes "P-01" through "P-21". They have been removed from this data set as unnecessary, and Hughes has been notified of this overlap.

Location data, depth to Culebra, and map data for the Culebra elevation from Powers (2002 or 2003) have been included and are accepted as correct.

Estimated Culebra depth, at locations where hole-specific data are not available, is distinguished in the data table by a red font so the estimates can be checked. Elevations taken from topographic maps are also distinguished, so that they can be checked if some question arises.

Microsoft Excel 2002 table "AP-110 Task 1A.xls" attached to this report as an electronic file shows the final assessment of Culebra plugging and supporting data.

Discussion
The source records have not been verified, and there are likely to be some discrepancies. Nevertheless, the data from various sources is considered very representative and reasonably complete for the study area. For example, a few drillholes have been eliminated because their location, as given in files, is very probably incorrect and they do not belong in the study area. Some may have been mislocated but are still included. The categories have been reasonably assigned, and they are consistent. Uncertainty in the relationship between cemented interval and Culebra depth is expressed by assigning to Category 3 or by adding the modifier "x" to Category 2 or Category 4. Lack of information is expressed by assigning the drillhole to Category 6.

The table "AP-110 Task 1A.xls" includes a number of columns derived from Hughes database that are preserved for general information. A few have been modified by information found in the BLM files. They are not further qualified for this project and have not been further checked. The principal data of concern for modeling are the UTM coordinates, Top of Culebra (ft), Cement Evaluation, and Cement Evaluation Modifiers. Other information permits detailed checking if particular drillholes become important.

Computers and Software
The following is a summary of the various personal computer technologies (software and hardware) used in the process of compiling source data for Task 1A of Analysis Plan AP-110. Two software applications were utilized in the creation, identification, and organization of drillhole data records: *Microsoft Access 2002* and *Microsoft Excel 2002.* A conversion program developed by the U.S. Army Corps of Engineers, *Corpscon for Windows 5.11.08,* was used to convert State-Plane coordinates (NAD 27) or Longitude/Latitude data into UTM (NAD 27) coordinates where location information was available in these coordinates. Plots and graphs were generated using *Grapher 3.03,* a two-dimensional graphing system developed by Golden Software, Inc. The graphic files were then imported into *Adobe Illustrator 8.0* for formatting, and finally exported as *Adobe Acrobat 5.0* files. Word processing needs were accomplished using *Microsoft Word 2002.* All software was run on a *Dell Inspiron 8200* with an operating system of *Microsoft Windows XP.*

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

Routine Calculations
Two routine calculations were made to support this work and the data columns are in Table "AP-110 Task 1A.xls.". The first is simple conversion of metric depths of Culebra (column "Interpolated Depth (m) from Powers (2003)") to English units ("Top of Culebra (ft)"). All conversions from meters to feet were done by dividing by the factor 0.3048. Several of these calculations were checked with the standard electronic calculator included as part of the Microsoft Windows XP operating system. Formula references have been removed from table "AP-110 Task 1A.xls" to avoid inadvertent changes. The second routine calculation was to convert the structural elevation of top of Culebra ("Culebra elevation (m amsl) from Powers (2003)") to depth to top of Culebra (ft). The formula used had the form [= cell ref 1 – (cell ref 2/0.3048)] where cell ref 1 is either the ELEV(ft) or ELEV(ft)2 column. Cell ref 2 is the column "Culebra elevation (m amsl) from Powers (2003)." Table 4 is a reduced subset showing the

conversion, which has again been checked by use of the electronic calculator that is part of Microsoft Windows XP. Formulas were again removed from the final table. Note that the units are rounded in Table "AP-110 Task 1A.xls," as there is no geological significance to the decimals.

Table 4
Computation of Depth (ft) to Top of Culebra from Reference Elevation (ft) and Elevation of Culebra (m)

ELEV(ft)	Culebra elevation (m amsl) from Powers (2003)	Top of Culebra (ft)	Computed value (ft)
3677	710	1348	1347.603675
3340	864	505	505.3543307
3390	835	650	650.4986877
3432	800	807	807.328084

For location data, it was desired to use UTM coordinates for drillholes and other features. A large number of the drillholes had locations in NM State Plane (NAD27) coordinates provided by David Hughes (WRES). These were accepted as given. Equivalent locations were not available for the potash data acquired for this project. The drillhole locations were plotted on topographic maps using standard township-range-section coordinates, and the UTM (NAD27) coordinates were then read from the map. Powers (2002) showed that locations obtained by this method checked within ± 50 ft or ± 15 m, which is about the best accuracy to be expected using maps and a scale. As these geological data are not particularly sensitive to that variation, it was deemed acceptable. All State Plane coordinates were converted to UTM (NAD27) coordinates using *Corpscon for Windows 5.11.08*. As for Powers (2002), to verify the conversion of State Plane to UTM coordinates, four locations in State Plane (NAD27) coordinates (left hand column below) were converted to UTM (NAD27) coordinates (right hand column below). Within the limits of reading a topographic map using an engineer's scale, these coordinates match, and they are identical to the results obtain previously (Powers, 2002). The coordinates checked were

Horizontal Datum: State Plane, NAD 27

State Plane X Y
CHECK1 650000 510000
CHECK2 650000 490000
CHECK3 670000 540000
CHECK4 630000 510000

Horizontal Datum: UTM, NAD27
Horizontal Zone: 13
Horizontal Units: Meters

UTM X Y
CHECK1 608404.72683 3585298.74965
CHECK2 608442.70416 3579204.01345
CHECK3 614442.41641 3594478.94431
CHECK4 602310.01957 3585260.74438

Corpscon is a standard tool for converting between these coordinate systems. Further testing was conducted by Powers (2002), and these tests were not repeated here; the software is the same as was used earlier.

Personnel

Dennis W. Powers did the geological interpretation and map construction. A resume is attached for information. Chris Mahoney (B.A., M.Ed.) assisted with data management and some quality checks of data transcription and calculations. Mahoney is employed as Technical Associate to Powers.

References Cited

Beauheim, R.L., 2003, Analysis Plan for Evaluation of Culebra Water-Level-Rise Scenarios AP-110: Sandia National Laboratories, 27 p.

Powers, D.W., 2002, Analysis report Task 1 of AP-088, Construction of geologic contour maps: report to Sandia National Laboratories, April 17, 2002 (ERMS# 522086)

Powers, D.W., 2003, Addendum 2 to Analysis report Task 1 of AP-088, Construction of geologic contour maps: report to Sandia National Laboratories, January 13, 2003 (ERMS# 525199)

List of Electronic Files Submitted

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

Main report file:	Task 1A Analysis Report for AP-110 5-18-04.doc (Word 2002)
Figures:	Task 1A for AP-110 Figure 1.pdf (Acrobat 5.0 file) Task 1A for AP-110 Figure 2.pdf (Acrobat 5.0 file)
Data source table:	AP-110 Task 1A.xls (Excel 2002)

As-received CD-ROM from David L. Hughes with Microsoft Access database: NM Events 2000

Resumé for Dennis W. Powers (Word 2002)