SUMMARY OF THE RELATIONSHIP BETWEEN KNOWN TEPHRA DEPOSITS, TEPHRA ISOPACHS, AND TOPOGRAPHY AT LATHROP WELLS VOLCANO, NEVADA

Prepared for

U.S. Nuclear Regulatory Commission
Contract NRC–02–07–006

Prepared by

Marius Necsoiu
Donald Hooper
Roland Benke

Center for Nuclear Waste Regulatory Analyses
San Antonio, Texas

August 2008

CONTENTS

Section Page

FIGURES

ACKNOWLEDGMENTS

This report was prepared to document work performed by the Center for Nuclear Waste Regulatory Analyses (CNWRA®) for the U.S. Nuclear Regulatory Commission (NRC) under Contract No. NRC–02–07–006. The studies and analyses reported here were performed on behalf of the NRC Office of Nuclear Material Safety and Safeguards, Division of High-Level Waste Repository Safety. This report is an independent product of CNWRA and does not necessarily reflect the views or regulatory position of NRC.

The authors wish to thank Kevin Smart for technical review and Gordon Wittmeyer for programmatic review, Sharon Odam for word processing support, and Lauren Mulverhill for editorial review.

QUALITY OF DATA, ANALYSES, AND CODE DEVELOPMENT

DATA: Data and information contained in this report meet quality assurance requirements described in the CNWRA Quality Assurance Manual. The data and information used in support of this report are from documents published by the U.S. Department of Energy, its contractors, and supporting organizations for the Yucca Mountain Project. The respective sources of these documents should be consulted for determining the level of quality assurance.

ANALYSES AND CODES: Calculations were checked as required by Quality Assurance Procedure (QAP)–014, Documentation and Verification of Scientific and Engineering Calculations, and recorded in a scientific notebook. Generation of figures was aided by the use of controlled versions of ArcGIS® 8.3 (Environmental Systems Research Institute, Inc., 2004), Arc/Info™ 7.0.2 (Environmental Systems Research Institute, Inc., 2003), ArcView® 3.2 (Environmental Systems Research Institute, Inc., 1999), and ENVI 4.1 (ITT Industries Corporation, 2004).

References

Environmental Systems Research Institute, Inc. “ArcGIS 8.3.” Redlands, California: Environmental Systems Research Institute, Inc. 2004.

———. “Arc/Info 7.0.2.” Redlands, California: Environmental Systems Research Institute, Inc. 2003.

———. “ArcView 3.2.” Redlands, California: Environmental Systems Research Institute, Inc. 1999.

ITT Industries Corporation. “ENVI 4.1.” White Plains, New York: ITT Industries Corporation. 2004.

1 INTRODUCTION AND OBJECTIVES

To prepare for an Appendix 7 meeting on the U.S. Department of Energy (DOE) Fortymile Wash Ash Redistribution (FAR[1]) model, Center for Nuclear Waste Regulatory Analyses (CNWRA®) and U.S. Nuclear Regulatory Commission (NRC) staffs participated in a fluvial redistribution workshop on September 27, 2007. At the request of NRC, CNWRA staff used a digital elevation model to analyze the topography (i.e., surface slopes) in the region surrounding the Lathrop Wells volcano. The results of the slope analysis were presented on maps, which also displayed existing DOE information. Specifically, the maps included DOE isopachs, estimating the original tephra-fall deposit thickness, and DOE tephra thickness data from field measurements (Appendix A).

The DOE tephra redistribution model (FAR model) calculates the mass and concentration of tephra and any potentially entrained waste transported from the upper drainage basin to the Reasonably Maximally Exposed Individual (RMEI[2]) location by hillslope and fluvial processes (Sandia National Laboratories, 2007a). This is accomplished within the model by using a spatially distributed analysis of the hillslopes and channels of the drainage basin upstream from the fan apex. The model assumes that primary tephra and waste deposited on the landscape is remobilized and transported toward the RMEI location if it falls on steep slopes or in active channels. A spatially distributed analysis of slope and stream characteristics is performed using the input Digital Elevation Model (DEM[3]). These values are then compared to critical slope and drainage density values on a pixel-by-pixel basis to integrate the total mass of tephra and waste mobilized from the drainage basin.

Before the remobilized tephra and waste would be deposited at the RMEI location, they would be transported through the alluvial channel system where mixing with uncontaminated channel sediments leads to dilution. Mixing occurs during flood events as sediment and tephra are entrained from the bed, mixed by turbulent flow, and redeposited on the bed. The depth to which tephra and channel sediment are mixed is the scour depth. If the scour depth is more than the tephra thickness, the entire tephra thickness is entrained. The dilution factor at each point (i.e., the fraction of channel sediment composed of tephra in each channel pixel) is calculated using the local thickness of remobilized tephra and the local scour depth. To model the dilution effect, remobilized tephra is routed through the channel system. Remobilized tephra and uncontaminated channel-bed sediments are routed using a bifurcation routing algorithm. This approach to modeling dilution is similar to classic models widely used in the mineral exploration and contaminant-transport literature.

As a part of prelicensing interactions, an Appendix 7 meeting on the DOE FAR model was held on January 8, 2008, in Las Vegas, Nevada. By informing questions NRC and CNWRA staffs asked at the meeting, the CNWRA analysis contributed to a better understanding of the DOE model, technical basis, and results. These prelicensing activities were performed under the Redistribution of Radionuclides in Soil Integrated Subissue.

The presentation of CNWRA analysis results was refined to address NRC and CNWRA feedback received after the meeting. Site labels were revised for clarity, and fluvial channels were added. This administrative item documents the resulting set of figures from the CNWRA analysis. Each figure is also briefly described. Satellite image data were used to investigate the specific DOE sites where tephra thickness measurements were performed. Brief remarks from this investigation are provided in Appendix B.

[1] FAR = Fortymile Wash Ash Redistribution.
[2] RMEI = Reasonably Maximally Exposed Individual
[3] DEM = Digital Elevation Model

2 FIGURES AND DATA PRESENTATION

2.1 Figure Descriptions

NRC and CNWRA staffs used the following figures to better understand the DOE model and to determine whether the critical slope angle approach implies that water will never remobilize tephra deposited on slopes less than the critical angle. Only wind is presumed to cause remobilization on relatively flat surfaces. Staffs will ascertain whether this is the correct DOE model description and whether this is consistent with other analogs (e.g., Sunset Crater, Cerro Negro, Parícutin). Additional staff discussion includes model uncertainty for the relationship between scour depth, discharge, and tephra thickness across the catchment basin.

Figure 1 displays computer-generated ephemeral stream courses (blue) superimposed on an IKONOS® satellite image of the region surrounding Lathrop Wells volcano (yellow triangle). Additional information and data from DOE studies are also superimposed on the image, including an isopach map (yellow lines) and individual field measurement locations (labeled with black identification numbers on a blue background). The isopach map is an estimate of the thickness (in centimeters) of the original tephra-fall deposit. Individual DOE field locations for tephra thickness measurements are numbered, color-coded circles. Each color corresponds to a range of thickness values and when superimposed on the isopach map helps identify outliers or points with anomalous tephra thickness. The inset map shows the final two DOE field sites located in the distal region of the fall deposit. The DOE isopach map and tephra thickness data are from Sandia National Laboratories (2007b, Figure C-2c). Appendix A specifies the locations and thicknesses of tephra gathered from DOE field work (Krier, 2003). The detailed overlay of the drainage network is included to demonstrate the proximity or relationship of individual field locations to ephemeral stream channels. DOE field teams often followed stream channels (this practice was mentioned at the Appendix 7 meeting) to facilitate the identification of tephra deposits. This practice may also be useful in the potential search for buried or undocumented deposits of tephra.

Figure 2 is a slope map of the area surrounding Lathrop Wells volcano (yellow triangle) with coarse slope scale (in degrees). Additional DOE input is also superimposed on the image, including the isopach map (yellow lines) with estimated tephra thickness values given in centimeters and individual field measurement locations. The field measurement sites are labeled with black identification numbers on a blue background and are color-coded to represent a range of thickness values. When superimposed on the isopach map, this color-coding helps identify outliers or points with anomalous tephra thickness. The DOE isopach map and tephra thickness data are from Sandia National Laboratories (2007b, Figure C-2c).

A slope map of the Lathrop Wells region with marked areas of interest is produced for Figure 3. Slope angle (degrees) is indicated with a fine scale on this map. Figure annotation has been simplified for clarity. The circled areas are regions of potential interest because they may or may not contain tephra based on their local slope angle. The DOE tephra redistribution model assumes that primary tephra and waste are remobilized and transported if they fall on steep slopes (exceeding a critical slope value) or in active channels. Regions A and B identify near-vent (proximal) locations with shallow surface slopes of less than 8°. Region C represents a near-vent area with steeper surface slopes (between 8 and 20°) and a thick original tephra deposit (based on the DOE isopach map). Regions D and E indicate additional areas with steep surface slopes up to 45 degrees and an original tephra deposit thickness that mostly varies between 50 and 100 cm [1.6 and 3.3 ft] based on the DOE isopach map.

Figure 4 displays the computer-generated ephemeral stream courses superimposed on the detailed slope map of the Lathrop Wells region. Figure annotation has been simplified for clarity, but DOE tephra thickness measurement sites are included for reference and are the same as in previous figures. The DOE isopach map and tephra thickness data are from Sandia National Laboratories (2007b, Figure C-2c).

2.2 Image and Topographic Datasets

Figure 1 is an IKONOS 1-m PAN/MSI orthorectified image showing the optical satellite data used in this analysis. The image was acquired September 2001, and the geodetic model is the North American Datum of 1983 (NAD83). For topographic analysis to create slope maps and shaded relief perspectives, the digital elevation model employed U.S. Geological Survey 10-m National Elevation Data, shown in Figures 2–4.

2.3 DOE Field Site Description

Appendix A describes the locations and thicknesses of tephra gathered from DOE field work (Krier, 2003) on the Lathrop Wells volcano tephra sheet and from previous scientific notebooks.

Appendix B contains brief remarks on the DOE field sites for tephra thickness measurements.

3 REFERENCES

Krier, D. "Locations and Thicknesses of Tephra (Ashfall) From Lathrop Wells Cone, Nevada." SN–LANL–SCI–286–V2. Yucca Mountain Project. Los Alamos, New Mexico: Los Alamos National Laboratory. p. 19. April 14, 2003.

Sandia National Laboratories. "Redistribution of Tephra and Waste by Geomorphic Processes Following a Potential Volcanic Eruption at Yucca Mountain, Nevada." MDL–MGR–GS–000006. Rev. 00. Las Vegas, Nevada: Sandia National Laboratories. December 2007a.

——-. "Characterize Eruptive Processes at Yucca Mountain, Nevada." ANL–MGR–GS–000002. Rev. 03. Las Vegas, Nevada: Sandia National Laboratories. February 2007b.

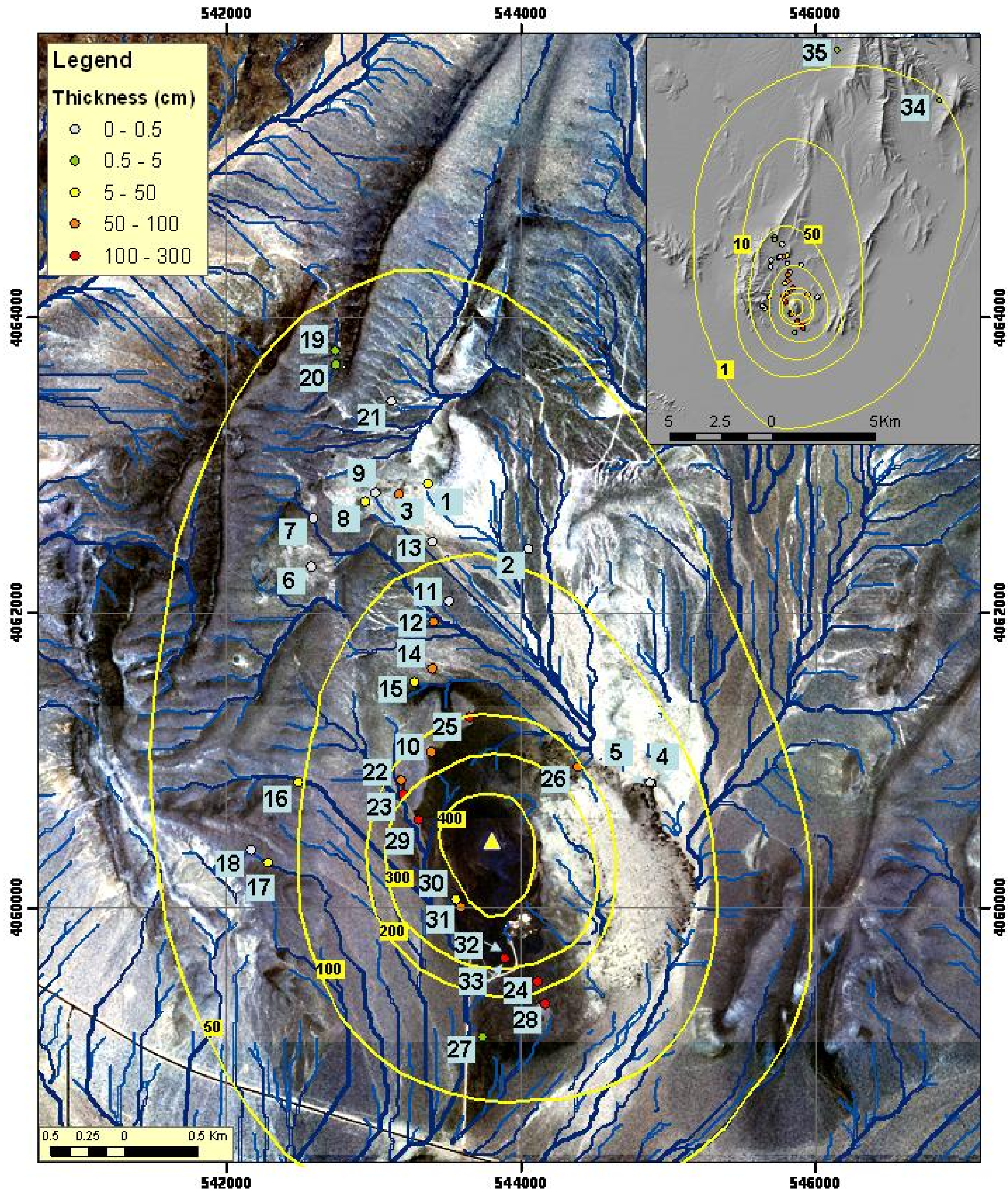

Figure 1. Computer-Generated Ephemeral Stream Courses (Blue) Superimposed on an IKONOS Satellite Image of the Region Surrounding Lathrop Wells Volcano (Yellow Triangle). An Isopach Map (Yellow Lines) From Sandia National Laboratories (2007b) and Individual Field Measurement Locations (Labeled With Black Identification Numbers on a Blue Background) (Krier, 2003) Are Also Superimposed on the Background Image. The Inset Map Shows Two Additional DOE Field Sites Located in the Distal Region of the Fall Deposit. Further Detail Is Given in the Text.

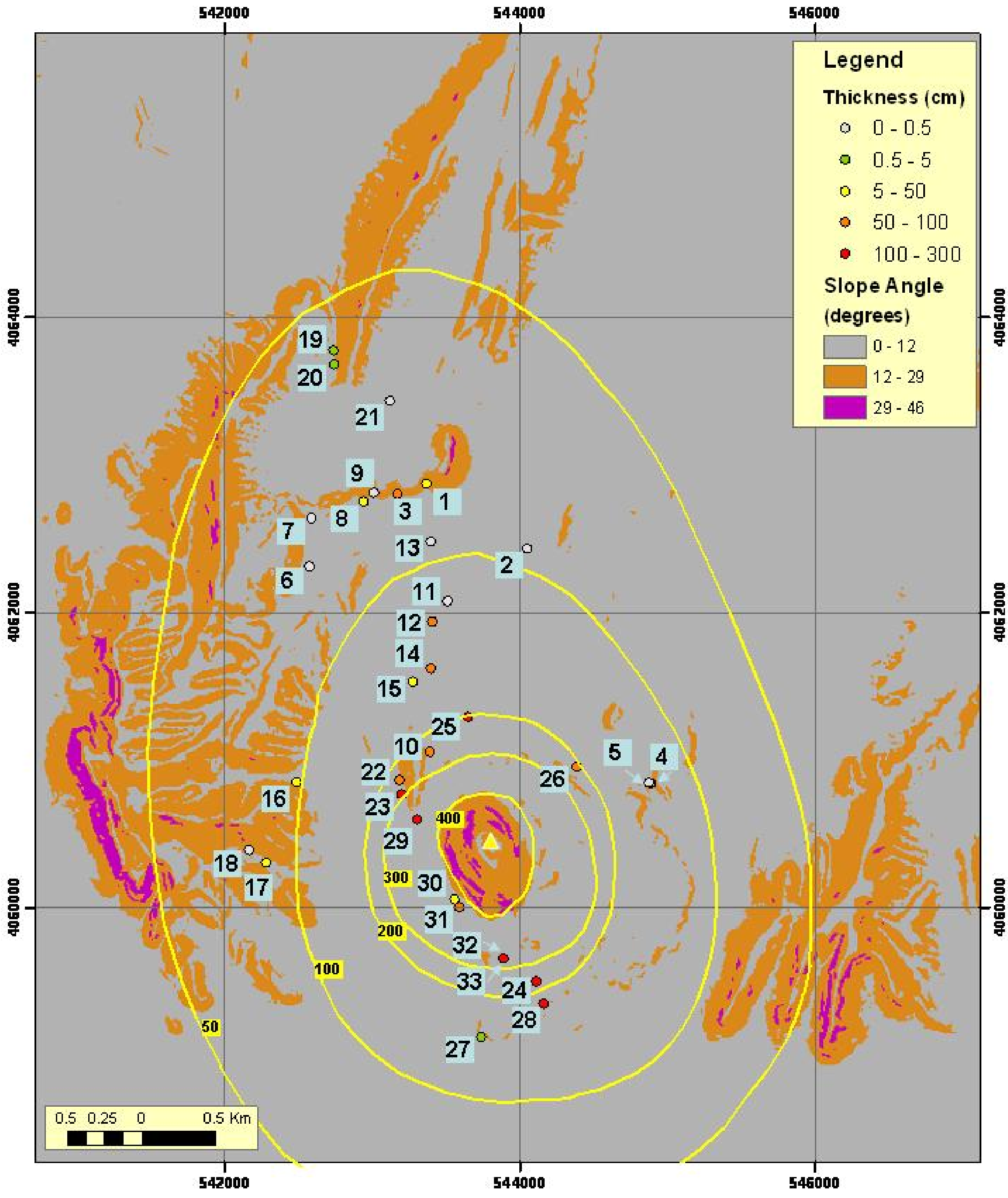

Figure 2. Tephra Thickness Information Superimposed on a Coarse-Scale Slope Map (in Degrees) of the Area Surrounding Lathrop Wells Volcano (Yellow Triangle). Further Detail Is Given in the Text.

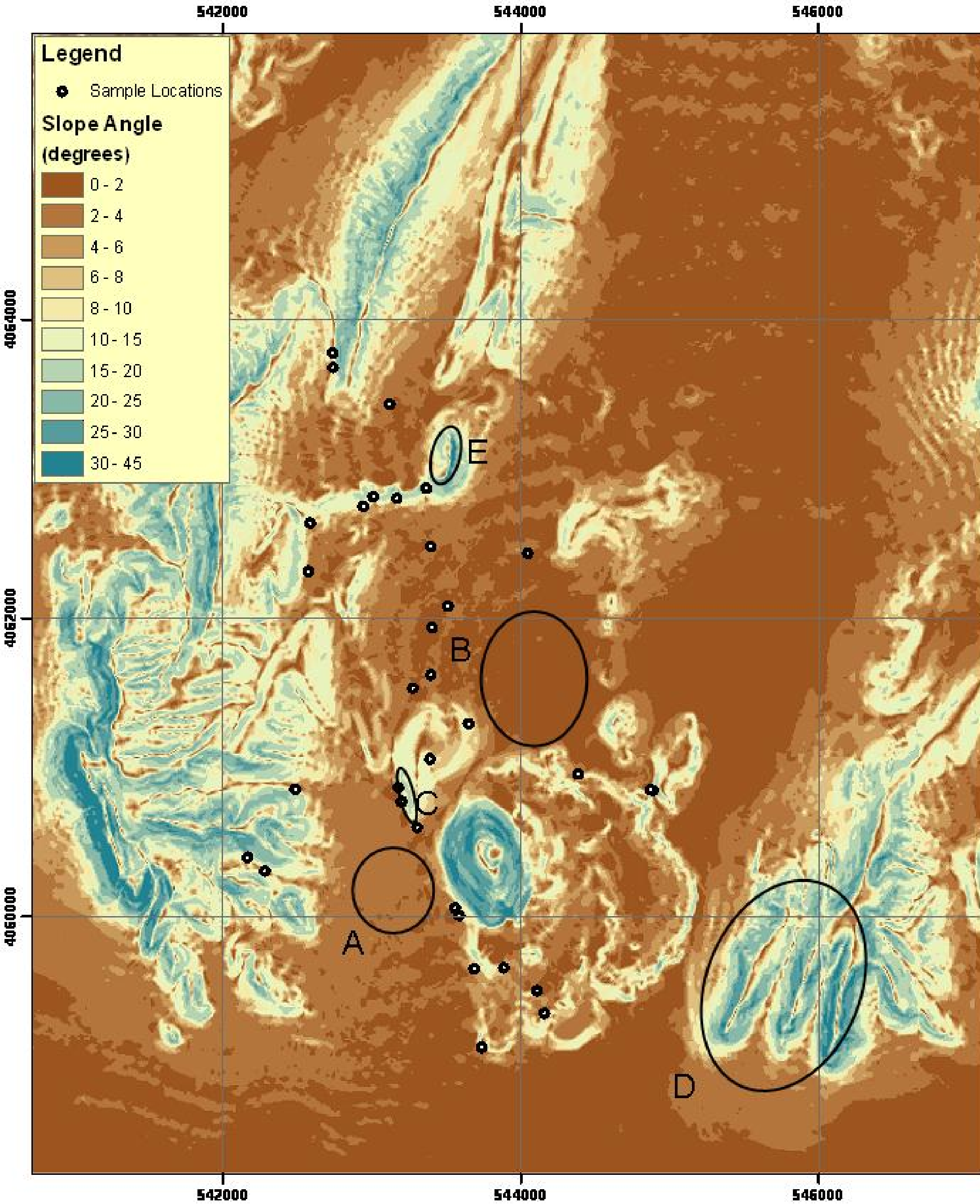

Figure 3. A Fine-Scale Slope Map (in Degrees) of the Lathrop Wells Region With Circled Areas Representing Regions That May or May Not Contain Tephra Based on Their Local Slope Angle. Figure Annotation Has Been Simplified for Clarity. Further Detail Is Given in the Text.

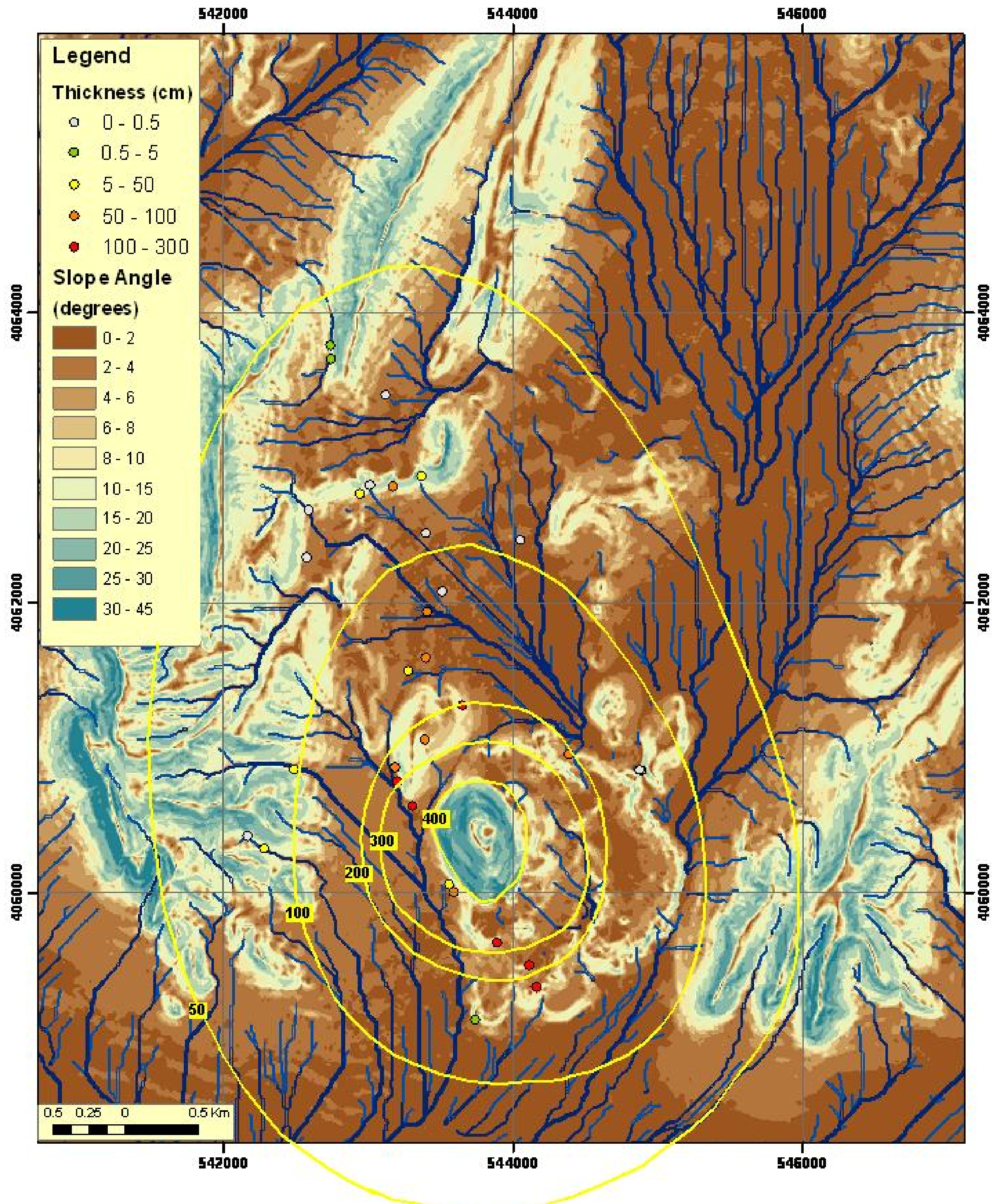

Figure 4. Computer-Generated Ephemeral Stream Courses Superimposed on the Detailed Slope Map of the Lathrop Wells Region. Figure Annotation Has Been Simplified For Clarity, but the DOE Isopach Map and Tephra Thickness Measurement Sites Are Included for Reference and Are the Same as in Previous Figures. Further Detail Is Given in the Text.

APPENDIX A

Appendix A. Locations and Thicknesses of Tephra (Ashfall) From Lathrop Wells Cone, Nevada									
ID*	Lat_dms†	Lat_dd‡	Lon_dms§	Lon_dd‖	Elev_ft¶	Elev_m#	Thick_cm**	SN_Page††	Comments
1	36 42 44.3	36.71230556	116 30 55.3	−116.51536111	2,920	890.0	48	10	North edge of south Crater Flat, base exposed
2	36 42 30.0	36.70833333	116 30 27 8	−116.50772222	2,803.7	854.6	0	10	DEM‡‡ elevation
3	36 42 42.1	36.71169444	116 31 03.2	−116.5175556	2,915	888.5	80	15	North edge of south Crater Flat, base exposed
4	36 41 38.2	36.69394444	116 29 54.4	−116.498444444	2,745	836.7	16	16	Under lava flow, base exposed
5	36 41 38.4	36.69400000	116 29 55.0	−116.49861111	2,663	811.7	0	18	
6	36 42 26.3	36.70730556	116 31 27.3	−116.52425000	2,958	901.6	0	19	
7	36 42 36.9	36.71025000	116 31 26.7	−116.52408333	2,973	906.2	0.01	20	Detrital, base exposed
8	36 42 40.4	36.71122222	116 31 12.4	−116.52011111	2,905	885.4	10	21	Base exposed, top eroded?
9	36 42 42.4	36.71177778	116 31 09.7	−116.51936111	2,907	886.1	0.01	21	Reworked
10	36 41 45.4	36.69594444	116 30 54.7	−116.51519444	2,814	857.7	85	22	Hydrovolcanic, no base exposed; approximate thickness
11	36 42 18.6	36.70516667	116 30 49.7	−116.51380556	2,820	859.5	0	25	0.58-m [1.9-ft] deep pit
12	36 42 14.0	36.70388889	116 30 53.9	−116.51497222	2,825	861.1	70	25	10-cm [4-in] “salt/pepper” at base; base exposed
13	36 42 31.6	36.70877778	116 30 54.1	−116.51502778	2,837	864.7	0	26	
14	36 42 03.7	36.70102778	116 30 54.3	−116.51508333	2,838	865.0	55	27	LWVC–95–T3; EES–13–LV–02–93–09, S. Wells, scientific notebook, p. 24
15	36 42 00.8	36.70022222	116 30 59.2	−116.51644444	2,821	859.8	36	28	Base exposed, top eroded
16	36 41 38.9	36.69413889	116 31 31.2	−116.52533333	2,869	874.5	10	33	Base exposed, reworked top
17	36 41 21.2	36.68922222	116 31 39.5	−116.52763889	2,801	853.7	8	35	Reworked
18	36 41 24.1	36.69002778	116 31 44.2	−116.52894444	2,844	866.9	0.01	35	Reworked
19	36 43 13.7	36.72047222	116 31 20.4	−116.52233333	2,968	904.6	1	39	Western mountains, reworked
20	36 43 10.6	36.71961111	116 31 20.3	−116.52230556	2,964	903.4	1	39	Western mountains, reworked
21	36 43 02.6	36.71738889	116 31 05.1	−116.51808333	2,989	911.0	0.01	40	
22	36 41 39.2	36.69422222	116 31 03.1	−116.51752778	2,788	849.8	90	45	Mssv§§ under hydrovolcanic, base not exposed
23	36 41 36.1	36.69336111	116 31 02.4	−116.51733333	2,755	839.7	110	46	Base exposed
24	36 40 54.8	36.68189497	116 30 26.0	−116.50722050	2,696.4	821.9	255	58	DEM ‡‡elevation; boneyard; base not exposed
25	36 41 53.0	36.69805556	116 30 44.2	−116.51227778	2,796	852.2	120	26	Base exposed
26	36 41 41.9	36.69496972	116 30 14.7	−116.50407740	2,730.6	832.3	55	27	Trench T–3, EES–13–V–02–93–09 (S. Wells, SP–9 of B.M. Crowe)
27	36 40 42.6	36.67851142	116 30 41.1	−116.51140360	2,599.8	792.4	3	90	Trench SP–7A, under lava; B.M. Crowe TWS–EES–13–LV–11–89–07
28	36 40 49.9	36.68051977	116 30 24.0	−116.50666600	2,673.7	814.9	148	52	LW–95–13; notebook G.A. Valentine TWS–EES–5–6–93–01

Appendix A. Locations and Thicknesses of Tephra (Ashfall) From Lathrop Wells Cone, Nevada (continued)									
ID*	**Lat_dms†**	**Lat_dd‡**	**Lon_dms§**	**Lon_dd‖**	**Elev_ft¶**	**Elev_m#**	**Thick_cm****	**SN_Page††**	**Comments**
29	36 41 30.5	36.69180444	116 30 58.2	−116.51616140	2,751.7	838.7	181	57	QW–13; notebook B.M. Crowe TWS–EES–13–LV–01–93–05
30	36 41 13.0	36.68693631	116 30 48.1	−116.51335590	2,685.2	818.5	47	33	TP–1; notebook B.M. Crowe TWS–EES–13–LV–01–93–05
31	36 41 11.2	36.68644711	116 30 46.9	−116.51303820	2,679.0	816.6	54	35	TP–2; notebook B.M. Crowe TWS–EES–13–LV–01–93–05
32	36 40 59.6	36.68322837	116 30 43.0	−116.51193520	2,647.8	807.0	304	41	TP–8; notebook B.M. Crowe TWS–EES–13–LV–01–93–05
33	36 40 59.8	36.68328006	116 30 35.0	−116.50971170	2,703.5	824.0	212	45	TP–11; notebook B.M. Crowe TWS–EES–13–LV–01–93–05
34‖‖	36 46 49.9	36.78051835	116 25 52.0	−116.43109940	3,532.9	1,076.8	1	54	Busted Butte, west side; B.M. Crowe TWS–EES–13–LV–01–93–05, p. 54
35‖‖	36 48 10.9	36.80302287	116 29 13.5	−116.48707790	3,606.8	1,099.4	1	4–24	Solitario Canyon trench TB, 16.5 km [10.3 mi] north of Lathrop Wells cone (Perry and Bowker, 1998¶¶).

*ID = identification number
†Lat dms = latitude in degrees, minutes, seconds
‡Lat dd = latitude in decimal degrees
§Lon dms = longitude in degrees, minutes, seconds
‖Lon dd = longitude in decimal degrees
¶Elev ft = elevations (ft) with one decimal are from digital elevation model; other elevations are hand-held Global Positioning System
#Elev m = conversions of feet to meters
**Thick_cm = tephra thickness in centimeters
††SN Page = page numbers from Scientific Notebook SN–LAN–SCI–286–V1, unless noted. Krier, D. “Locations and Thicknesses of Tephra (Ashfall) From Lathrop Wells Cone, Nevada.” SN-LANL-SCI-286-V1. Yucca Mountain Project. Los Alamos, New Mexico: Los Alamos National Laboratory. 2003.
‡‡DEM = Digital elevation model
§§Mssv = Massive
‖‖Points 34 and 35 have assumed thicknesses of 1 cm [0.4 in]. Locations having trace amounts of ash are given a 0.01-cm [0.004-in]-thickness for contouring purposes.
¶¶Perry, F.V. and L.M. Bowker. “Petrologic and Geochemical Constraints on Basaltic Volcanism in the Great Basin.” Volcanism Studies. Final Report for the Yucca Mountain Project: LA–13478. Los Alamos, New Mexico: Los Alamos National Laboratory. 1998.

APPENDIX B

Appendix B. Remarks on the Department of Energy Field Sites for Tephra Thickness Measurements	
Site ID	
1	Surrounding regions of steep slopes adjacent to small flat area; small drainage dissecting a small mesa
2	Small drainage in a flat terrain in the alluvial basin
3	Similar to Site 1 in a drainage dissecting the mesa
4	In sandy fluvial channel (jeep trail) that borders northeast lava flow field; sample taken from bank of channel
5	In sandy fluvial channel (jeep trail) that borders northeast lava flow field; sample taken from the flat central portion of channel
6	Series of shallow channels draining a portion of the alluvial basin; however, flat-lying terrain
7	Within a wash (if location is accurate)
8	Bank of small drainage channel
9	Within a large drainage channel
10	Sample taken from a nearby hill to the northwest and separated from Lathrop Wells cone by a wash; flat terrain here has an accumulation of tephra
11	Flat terrain of the alluvial basin floor
12	This location can be characterized as part of the alluvial basin with the sample collected from the side of a relatively uneroded interfluve (like a "remnant island") in a broad, braided drainage
13	Sampled from the bank of well-defined drainage channel
14	Sampled along the margin of a patch of tephra
15	Sampled along the margin of a patch of tephra. Locations 14 and 15 are remnant patches of tephra that have been modified (eroded, reworked) to some extent, but neither fully buried nor stripped away by erosion.
16	Near the margin of a braided drainage channel
17	Bottom of a large channel
18	Bottom of a large channel; sample taken from what appears to be a cutbank
19	In a fluvial channel at the base of a long ridge; ridge and channel have same orientation; smaller drainage pattern is perpendicular to this
20	In a fluvial channel at the base of a long ridge; ridge and channel have same orientation; smaller drainage pattern is perpendicular to this
21	Roughly in an interfluve in a small dissected alluvial basin
22	North-northwest of the cone as a remnant patch of tephra at the base of a ridge; opposing drainage patterns on opposite sides of the tephra
23	North-northwest of the cone as a remnant patch of tephra at the base of a ridge; opposing drainage patterns on opposite sides of the tephra
24	South-southeast of the cone in a thick, flat portion of the deposit; lacks well-defined drainage
25	Sample location appears to be mislocated by at least 6 m [19.7 ft]; collected along the margin of a large patch of tephra. The proximity to a hill within the alluvial basin (i.e., inselberg) may have protected it from burial or overland flow across the basin. The slope at this site is just over 10 degrees.
26	Tephra deposited on lava; northeast flow field
27	South of the cone near the southernmost extent of the lava flow field; tephra found on margin of lava flow
28	South-southeast of the cone in the lava flow field; tephra deposited on lava
29	Sample location appears to be mislocated by at least 5 m [16.4 ft]; proximal deposit west-northwest of cone
30	Proximal deposit southwest of the cone; near mining operations
31	Proximal deposit southwest of the cone; near mining operations and possibly disturbed
32	Proximal deposit south of the cone; near mining operations and between two roads
33	Proximal deposit south of the cone; near mining operations and most likely disturbed deposit
34	Sampled far to the north of the cone, approximately at the base of the western side of Busted Butte
35	Sampled far to the north of the cone in lightly dissected terrain just west of Yucca Mountain; near a road/jeep trail