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JUL 05 2002

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TRANSMITTAL OF REPORT ADDRESSING KEY TECHNICAL ISSUE (KTI) AGREEMENT ITEM UNSATURATED AND SATURATED ZONE FLOW UNDER ISOTHERMAL CONDITIONS (USFIC) 5.11

This letter transmits the report entitled *Solitario Canyon Fault Alternative Conceptual Model* which provides information to support resolution and closure of the subject KTI agreement. The agreement is as follows:

> USFIC 5.11 - "In order to test an alternative conceptual flow model for Yucca Mountain, run the SZ flow and transport code assuming a north south barrier along the Solitario Canyon fault whose effect diminishes with depth or provide justification not to."
> "DOE will run the saturated zone flow and transport model assuming the specified barrier and will provide the results in an update to the Calibration of the Site Scale Saturated Zone Flow Model AMR expected to be available during FY 2002."

The enclosure comprises a detailed discussion of the results of an alternative conceptual flow model for Yucca Mountain, Nevada, and briefly discusses the results in terms of overall impact to the saturated zone model results. While the agreement for USFIC 5.11 indicated that this information would be provided in an Analysis and Model Report, the information has been included in this report as discussed at the April 15-16, 2002, U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on KTIs. Agreement Item General (GEN).1.01 (103) is also related to an alternate treatment of the Solitario Canyon Fault. GEN.1.01 (103) is addressed in its entirety by the enclosure.

NMSS07
WM-11

This letter contains no new regulatory commitments. Please direct any questions concerning this letter and its enclosure to Drew H. Coleman at (702) 794-5537 or Timothy C. Gunter at (702) 794-1343.

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OL&RC:TCG-1357

Enclosure:
Solitario Canyon Fault Alternative Conceptual Model

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SOLITARIO CANYAN FAULT ALTERNATIVE CONCEPTUAL MODEL

June 2002

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ENCLOSURE

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ACRONYMS AND ABBREVIATIONS

DOE	U.S. Department of Energy
KTI	Key Technical Issue
NRC	Nuclear Regulatory Commission
SZ	saturated zone
TSPA-SR	Total System Performance Assessment–Site Recommendation
USFIC	Unsaturated and Saturated Flow under Isothermal Conditions

1. BACKGROUND

The subject of this report, *Saturated Zone Flow and Transport with Alternative Conceptualizations of the Solitario Canyon Fault*, presents the technical basis for closure of the key technical issue (KTI) agreement presented in the Unsaturated and Saturated Flow under Isothermal Conditions (USFIC 5), Subissue 5, agreement 11 (USFIC 5.11).

The interest in the alternative conceptualization described in this report originated with requests for information by the Nuclear Regulatory Commission (NRC) under USFIC Subissue 5 pertaining to the representation of anisotropy in the saturated zone model, in particular with regard to discrete features, such as faults. Additional discussion by the NRC focused on the issue of anisotropy as it would affect the model calibration. The Solitario Canyon fault is a major north-south feature that may contribute to anisotropy and, according to Luckey et al. (1996, p. 25), may represent a barrier to west-to-east flow. In an October 31 through November 2, 2000, technical exchange, the request addressed in this report was formalized in an NRC/U.S. Department of Energy (DOE) agreement that the DOE would test an alternative conceptual flow model for Yucca Mountain by running the saturated zone flow model with a different representation of the Solitario Canyon fault flow barrier (Reamer and Williams 2000).

2. APPLICABLE NUCLEAR SAFETY STANDARDS/REQUIREMENTS/GUIDANCE

2.1 APPLICABLE REQUIREMENTS

The Yucca Mountain disposal regulations include requirements for evaluating postclosure performance of the repository, including multiple barriers (10CFR63.113(a)) and a description of the capabilities of the natural barriers (10CFR63.115(b)). The regulations also include requirements that the DOE demonstrate that the performance of the natural barrier will limit radiological exposure to the reasonably maximally exposed individual (10CFR63.113). The sensitivity analyses presented in this report provide further demonstration of the characterization of the saturated zone barrier, part of the multiple barrier system.

2.2 KTI AGREEMENTS

This report addresses the following KTI agreement:

USFIC 5.11: In order to test an alternative conceptual flow model for Yucca Mountain, run the SZ flow and transport code assuming a north-south barrier along the Solitario Canyon fault whose effect diminishes with depth or provide justification not to. DOE will run the saturated zone flow and transport model assuming the specified barrier and will provide the results in an update to the Calibration of the Site-Scale Saturated Zone Flow Model AMR expected to be available during FY 2002.

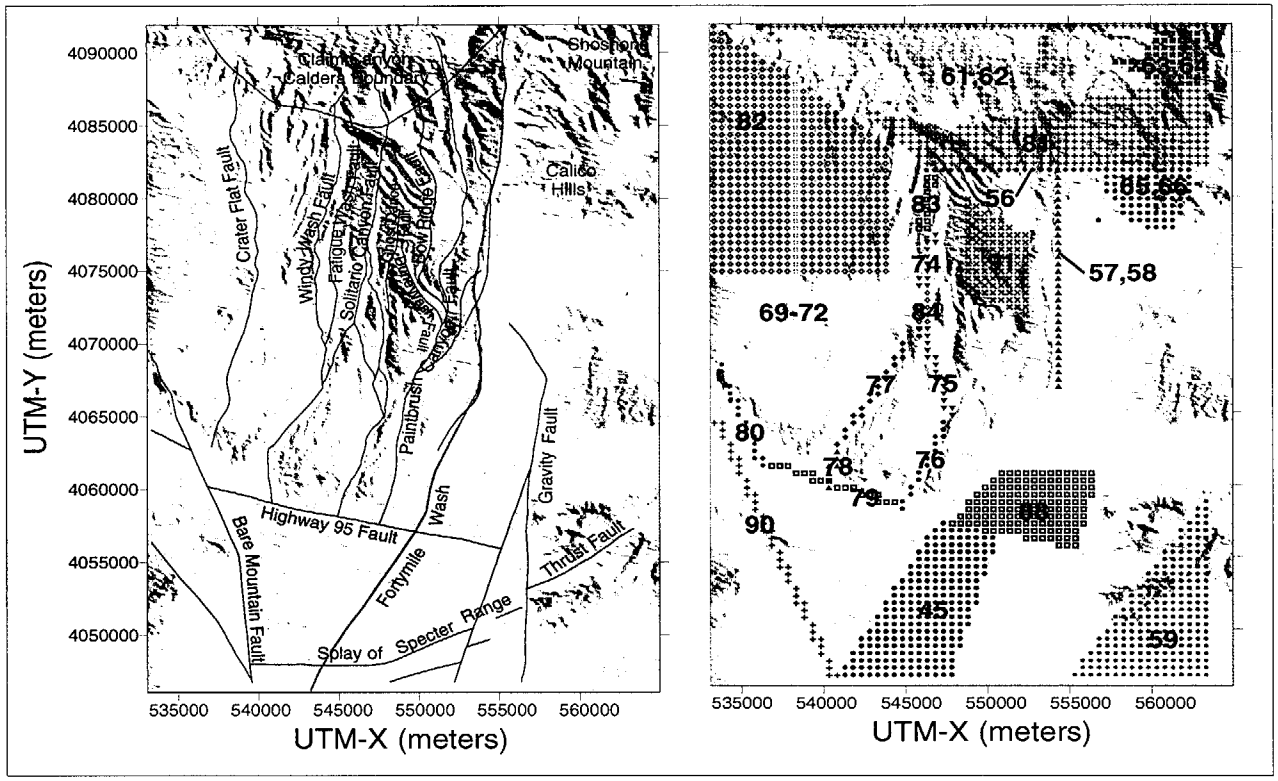
The requested information pertains to the results of the alternative conceptualization of Solitario Canyon Fault as a hydraulic barrier. While the original agreement indicated that this information would be provided in an analysis model report, the Doe believes that this report contains the information necessary to satisfy the agreement.

3. SATURATED ZONE FLOW AND TRANSPORT WITH ALTERNATIVE CONCEPUTALIZATIONS OF THE SOLITARIO CANYON FAULT

3.1 INTRODUCTION

The Solitario Canyon fault and its east and west branches make up three of the 17 discrete geologic features and regions represented with distinct hydrological properties in the site-scale saturated-zone (SZ) flow and transport model. The location of the Solitario Canyon fault in the SZ model domain is shown in the left panel of Figure 1, and the SZ model representation is shown in the right panel of the same figure. The Solitario Canyon fault consists of generally north-south trending features just to the west of Yucca Mountain. Both east and west branches consist of generally north-northeast trending linear features, also just to the west of Yucca Mountain. The hydrological characteristics of these features in the model provide both zones of permeability enhancement in the vertical and fault-parallel directions and permeability reduction normal to the fault.

The parameterization of the Solitario Canyon fault is an important part of the SZ flow and transport model because it can potentially control flow from Crater Flat to Fortymile Wash. The impact on the model of these features is to generate a higher head gradient to the west of Yucca Mountain and to impede flow from Crater Flat to Yucca Mountain. This effect on flow is important in determining the amount of alluvial material that groundwater flowing from beneath the potential repository region passes through en route to the accessible environment. This fault is included as a discrete feature in the site-scale SZ flow and transport model. Simulations performed for the Total System Performance Assessment–Site Recommendation (TSPA-SR) (CRWMS M&O 2000) included this fault as a feature that extended from the bottom of the model to the top of the water table. While the Solitario Canyon fault has been identified as a major fault in the site-scale model region, conceptual uncertainty remains in the hydrogeologic framework model as to the depth of this fault. This uncertainty translates into uncertainty regarding the likely hydraulic behavior of this feature at depth. The following sections describe an investigation of an alternative treatment of the Solitario Canyon fault to test the impact of the Solitario Canyon fault depth on the flow system.



DTN: GS000508312332.002; LA0105GZ12213S.001.

NOTE: Field data are on the left panel; the SZ model representation is the right panel (vertical scales are identical for both panels). Numbers designate the following regions: 45 - Lower FortyMile Wash Zone; 56 - East-West Barrier Zone; 57 and 58 - Fortymile Wash Zones; 59 - Spotted Range-Mine Mountain Zone; 61 and 62 - Claim Canyon Caldera Zones; 63 and 64 - Shoshone Mountain Zones; 65 and 66 - Calico Hills Zones; 69, 70, 71, and 72 - Crater Flat Fault Zones; 74, 83, and 84 - Solitario Canyon Fault Zones; 75 and 76 - Solitario Canyon Fault Zones (East Branch); 77 and 78 - Solitario Canyon Fault Zones (West Branch); 79 - Highway 95 Fault Zone; 80 and 90 - Bare Mountain Fault Zones; 81 - Northern Zone; 82 - Northern Crater Flat Zone; 88 - Alluvial Uncertainty Zone (expected case); 91 - Imbricate Fault Zone

Figure 1. Geologic Features in the Area of the Site-Scale Flow and Transport Model

3.2 EFFECT OF SOLITARIO CANYON FAULT DEPTH

To investigate the importance of Solitario Canyon fault depth, an alternative conceptualization was simulated in which the fault extends from the water table only to the top of the carbonate aquifer. This alternative is referred to as the Shallow Fault Alternative model. This alternative was identical to the TSPA-SR (CRWMS M&O, 2000) model in all respects except for the Solitario Canyon fault properties. Table 1 compares the modeled head values from the Shallow Fault Alternative model for the 32 wells in the low-gradient region to the south and east of Yucca Mountain with measured values and values from the original TSPA-SR model. Locations of the wells in Table 1 are shown in Figure 2. This area was chosen for comparison because of its influence on the specific discharge to the 5-km boundary, an important performance assessment (PA) performance measure. Contour plots of simulated water-level data for the two cases are shown in Figure 3. To provide a quantitative measure of the calibration of the Shallow Fault Alternative model versus the TSPA-SR model, modeled heads at selected wells and water level contours over the model domain can be compared. As seen from the comparison of modeled heads in Table 1 and the water-level contours in Figure 3, this simulation produced essentially the same result as the original TSPA-SR model with the deeper fault zone. For the shallow fault case, however, the calibrated permeability for the fault was approximately 25 percent lower than the original deeper fault.

One hundred transport pathways are shown in Figure 3. The particles were distributed uniformly over the area of the proposed repository. Path lines for the two cases were nearly identical. These results indicate that simulated water levels, hydraulic gradients, and transport pathways are not significantly affected by decreasing the depth of the Solitario Canyon fault to the top of the carbonate aquifer. While travel times are calculated and discussed in detail in the TSPA-SR, the small differences between the permeabilities and flow paths of the two models indicates that travel times will not be affected by Solitario Canyon fault depth. Since the flow paths for the two cases were nearly identical and the models were identical except for the Solitario Canyon fault properties, the influence of reducing the depth of the Solitario Canyon fault on Total System Performance is expected to be minor.

Table 1. Observation Wells with Computed Head Data

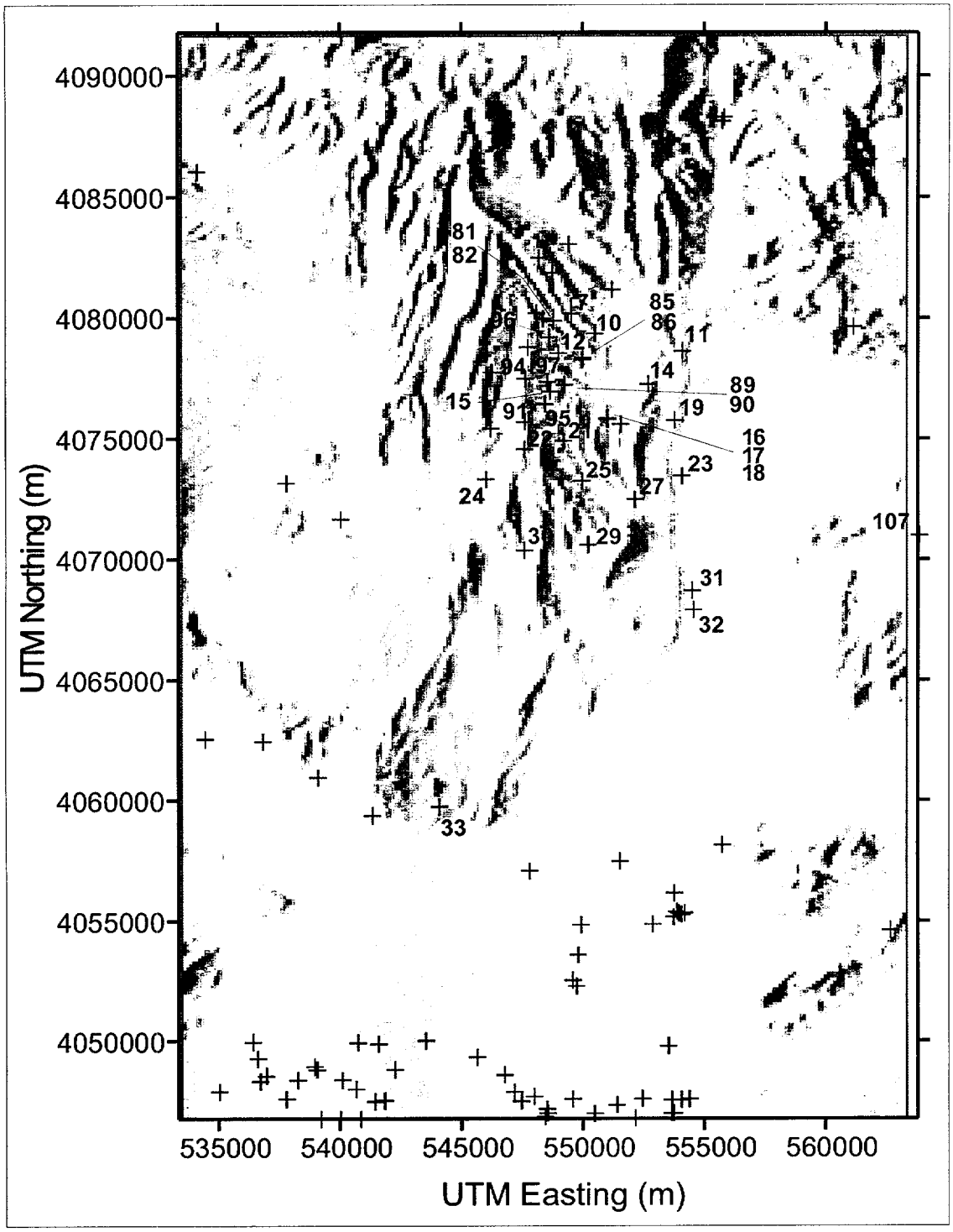
Site Name	Fig. 2 Label	*x* (UTM) (m)	*y* (UTM) (m)	*z* (elevation) (m)	Measured Head Data (m)	TSPA-SR Model Head Data (m)	Shallow Fault Alternative Model Head Data (m)	Weight
UE-25 WT 18	7	549468	4080240	722.1	730.8	734.67	734.93	20
UE-25 WT 4	10	550439	4079410	709	730.8	734.46	734.70	20
UE-25 WT 15	11	554034	4078690	698.7	729.2	733.87	734.02	20
USW G-4	12	548933	4078600	542.2	730.1	734.5	734.77	20
UE-25 WT 14	14	552630	4077330	703.6	729.7	733.79	733.95	20
USW WT-2	15	548595	4077030	702	730.7	734.18	734.46	20
UE-25c 1 HTH	16	550955	4075930	473.2	730.3	733.92	734.11	20
UE-25c 3	17	550930	4075900	474.3	730.3	733.92	734.11	20
UE-25c 2	18	550955	4075870	553.2	730.2	733.9	734.10	20
UE-25 WT 13	19	553730	4075830	703.8	729.1	733.35	733.47	20
USW WT-1	21	549152	4074970	708.4	730.4	733.86	734.05	20
USW G-3	22	547543	4074620	318.1	730.5	734.96	738.02	20
J-13 WW	23	554017	4073520	354.8	728.4	732.74	732.83	20
UE-25 WT 17	25	549905	4073310	705.4	729.7	733.58	733.70	20
UE-25 WT 3	27	552090	4072550	705.8	729.6	733.08	733.18	20
UE-25 WT 12	29	550168	4070660	702.6	729.5	732.92	732.89	20
USW WT-11	30	547542	4070430	691.9	730.7	733.71	733.43	20
J-12 WW	31	554444	4068770	659.6	727.9	731.44	731.48	20

Table 1 (Continued). Observation Wells with Computed Head Data

Site Name	Fig. 2 Label	*x* (UTM) (m)	*y* (UTM) (m)	*z* (elevation) (m)	Measured Head Data (m)	TSPA-SR Model Head Data (m)	Shallow Fault Alternative Model Head Data (m)	Weight
JF-3 Well	32	554498	4067970	662.7	727.8	731.15	731.19	20
Cind-R-Lite Well	33	544027	4059810	710.2	729.8	737.49	735.75	20
USW H-1 HTH tube 3	81	548727	4079930	562.5	730.6	734.63	734.89	20
USW H-1 HTH tube 4	82	548727	4079930	680.5	730.9	734.65	734.92	20
UE-25b 1 HTH lower	85	549949	4078420	–8.8	729.7	735.53	735.84	20
UE-25b 1 HTH upper	86	549949	4078420	366.2	730.7	734.34	734.58	20
USW H-4 HTH upper	89	549188	4077310	395.5	730.4	734.25	734.51	20
USW H-4 HTH lower	90	549188	4077310	45	730.5	735.1	735.48	20
USW H-3 HTH upper	91	547562	4075760	576.9	731.5	734.48	736.23	20
USW SD-6	94	547578	4077550	725.9	731.2	734.84	735.21	20
USW SD-7	95	548384	4076500	637.7	727.6	734.13	734.43	20
USW SD-9	96	548550	4079260	678.3	731.1	734.64	734.91	20
USW SD-12	97	548492	4077420	696.7	730	734.31	734.61	20
J-11 WW	107	563799	4071060	687.2	732.2	731.57	731.57	20

DTN: GS000508312332.001, LA01015GZ12213S.001, LA0105GZ12213S.004.

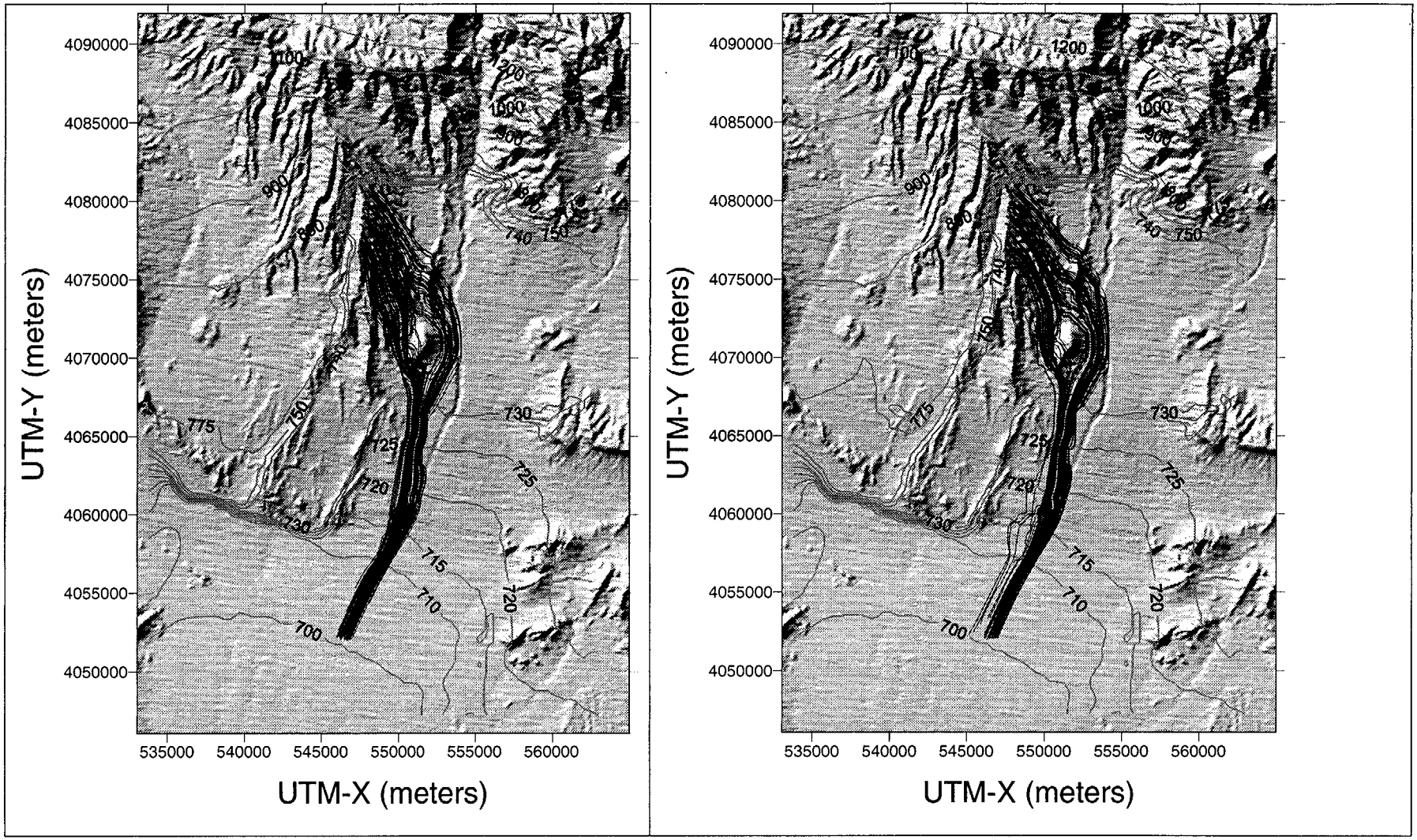
NOTE: The *x* and *y* units refer to Easting and Northing directions of the Nevada State Planar Universal Transverse Mercator coordinate system. The *z* unit refers to elevation at the observation point, which typically is at ground surface but may be down in the borehole. Head is the pressure head of the groundwater in units of meters of water. Weight is a statistical factor used in the model calibration process.



DTN: GS000508312332.001.

NOTE: The plus symbols are locations of wells in the Yucca Mountain area. The numbers in the figure indicate the wells used in this report and refer to the label listed in the second column of Table 1.

Figure 2. Location of Observation Wells



DTN: LA0105GZ12213S.001 (left panel); LA0105GZ12213S.004 (right panel).

Figure 3. Flow Paths from the Proposed Repository with Simulated Hydraulic Head Contours for the Calibrated Site-Scale SZ Model (Left Panel) and the Shallow Solitario Canyon Fault Conceptualization (Right Panel)

3.3. CONCLUSION

The Solitario Canyon fault separates Crater Flat from Yucca Mountain, and its parameterization is an important part of the SZ flow and transport model. Simulations performed for the TSPA-SR (CRWMS M&O 2000) included this fault as a feature that extended from the bottom of the model to the top of the water table. The KTI agreement USFIC 5.11 (Reamer and Williams 2000) requires testing of an alternative conceptual flow model that includes a north-south barrier along the Solitario Canyon fault, the effect of which diminishes with depth. In response to this KTI agreement, an investigation of alternative treatments of the Solitario Canyon fault was initiated in which a simulation was performed, treating the fault as extending from the water table only to the top of the carbonate aquifer. This simulation produced essentially the same result as the original TSPA-SR model with the deeper fault zone. For the shallow fault case, however, the calibrated permeability for the fault was approximately 25 percent lower than the original deeper fault. Thus, travel times for the shallow fault case will not be shorter. The results of this investigation indicate that simulated water levels, hydraulic gradients, and transport pathways are not significantly affected by this alternative conceptualization of the Solitario Canyon fault. The small differences between the permeabilities and flow paths of the two models indicates that travel times will not be affected by Solitario Canyon fault depth. The influence of reducing the depth of the Solitario Canyon fault on Total System Performance is expected to be minor. An alternative conceptualization of the Solitario Canyon fault extending only from the water table to the top of the carbonate aquifer resulted in no significant changes to the flow system and thus will have no consequences for transport.

4. INPUTS AND REFERENCES

4.1 DOCUMENTS CITED

CRWMS M&O (Civilian Radioactive Waste Management System Management and Operations) 2000. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O.

Luckey, R.R.; Tucci, P.; Faunt, C.C.; Ervin, E.M.; Steinkampf, W.C.; D'Agnese, F.A.; and Patterson, G.L. 1996. *Status of Understanding of the Saturated-Zone Ground-Water Flow System at Yucca Mountain, Nevada, as of 1995.* Water-Resources Investigation Report 96-4077. Denver, Colorado: U.S. Geological Survey.

Reamer, C.W. and Williams, D.R. 2000. Summary Highlights of NRC/DOE Technical Exchange and Management Meeting on Unsaturated and Saturated Flow Under Isothermal Conditions. Washington, D.C.: U.S. Nuclear Regulatory Commission.

4.2 SOURCE DATA, LISTED BY DATA TRACKING NUMBER

GS000508312332.001. Water Level and Data Analysis for the Saturated Zone Site-Scale Flow and Transport Model. Submittal date: 06/01/2000. (Qualified)

GS000508312332.002. Hydrogeologic Framework Model for the Saturated-Zone Site-Scale Flow and Transport Model. Submittal date: 06/01/2000. (Qualified)

4.3 OUTPUT DATA, LISTED BY DATA TRACKING NUMBER

LA0105GZ12213S.001. SZ Flow Model with no East-West Barrier with NW Trending Fault Zone. Submittal date: 05/11/2001. (Requires verification and/or qualification)

LA0105GZ12213S.004. SZ Flow Model with Shallow Solitario Canyon Fault. Submittal date: 05/24/2001. (Requires verification and/or qualification)