

NON-PROPRIETARY CALCULATIONS

Book 6 of 8

**Attachments to PG&E Letter DIL-01-004
Dated December 21, 2001**

CF3.ID4
ATTACHMENT 7.2

TITLE: CALCULATION COVER SHEET

CALC No. 52.27.100.731, R0

RECORD OF REVISIONS

| Rev No. | Status | Reason for Revision | Prepared By: | LBIE Screen | LBIE | Check Method* | LBIE Approval | | Checked | Supervisor | Registered Engineer |
|---------|--------|--|------------------------------|---|---|---|---------------------|----------------------|------------------------------|------------------------------|-------------------------------|
| | | Remarks | Initials/ LAN ID/ Date | Yes/ No/ NA | Yes/ No/ NA | | PSRC Mtg. No. | PSRC Mtg. Date | Initials/ LAN ID/ Date | Initials/ LAN ID/ Date | Signature/ LAN ID/ Date |
| 0 | F | Acceptance of Geosciences Calc. No. GEO.DCPP.01.21, Rev. 2. Calc. supports current edition of 10CFR72 DCPD License Application to be reviewed by NRC prior to implementation. Prepared per CF3.ID17 requirements. | AFT2 12/15/01 | <input type="checkbox"/> Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> NA | <input type="checkbox"/> Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> NA | <input type="checkbox"/> A <input type="checkbox"/> B <input checked="" type="checkbox"/> C | N/A | N/A | N/A | LJS 2 12/17/01 | LJS 2 12/17/01 |
| | | | | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA | <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C | | | | | |
| | | | | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA | <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> NA | <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C | | | | | |

*Check Method: A: Detailed Check, B: Alternate Method (note added pages), C: Critical Point Check



SUBJECT Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPD ISFSI Site

MADE BY A. Tafoya DATE 12/15/01 CHECKED BY N/A DATE _____

Table of Contents:

| Item | Type | Title | Page Numbers |
|------|--------------|--|--------------|
| 1 | Index | Cross-Index (For Information Only) | 1 - 4 |
| 2 | Attachment A | Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPD ISFSI Site | 1 – 185 |



SUBJECT Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPD ISFSI Site

MADE BY A. Tafoya DATE 12/15/01 CHECKED BY N/A DATE _____

- 1- This table cross references between Geosciences calculation numbers and DCPD (Civil Group's) calculation numbers. This section is For Information Only.

**Cross-Index
(For Information Only)**

| Item No. | Geosciences Calc. No. | Title | PG&E Calc. No. | Comments |
|----------|-----------------------|---|----------------|--------------------------------------|
| 1 | GEO.DCPD.01.01 | Development of Young's Modulus and Poisson's Ratios for DCPD ISFSI Based on Field Data | 52.27.100.711 | |
| 2 | GEO.DCPD.01.02 | Determination of Probabilistically Reduced Peak Bedrock Accelerations for DCPD ISFSI Transporter Analyses | 52.27.100.712 | |
| 3 | GEO.DCPD.01.03 | Development of Allowable Bearing Capacity for DCPD ISFSI Pad and CTF Stability Analyses | 52.27.100.713 | |
| 4 | GEO.DCPD.01.04 | Methodology for Determining Sliding Resistance Along Base of DCPD ISFSI Pads | 52.27.100.714 | |
| 5 | GEO.DCPD.01.05 | Determination of Pseudostatic Acceleration Coefficient for Use in DCPD ISFSI Cutslope Stability Analyses | 52.27.100.715 | |
| 6 | GEO.DCPD.01.06 | Development of Lateral Bearing Capacity for DCPD CTF Stability Analyses | 52.27.100.716 | |
| 7 | GEO.DCPD.01.07 | Development of Coefficient of Subgrade Reaction for DCPD ISFSI Pad Stability Checks | 52.27.100.717 | |
| 8 | GEO.DCPD.01.08 | Determination of Rock Anchor Design Parameters for DCPD ISFSI Cutslope | 52.27.100.718 | |
| 9 | GEO.DCPD.01.09 | Determination of Applicability of Rock Elastic Stress-Strain Values to Calculated Strains Under | 52.27.100.719 | Calculation to be replaced by letter |



SUBJECT Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPD ISFSI Site

MADE BY A. Tafoya DATE 12/15/01 CHECKED BY N/A DATE _____

**Cross-Index
(For Information Only)**

| Item No. | Geosciences Calc. No. | Title | PG&E Calc. No. | Comments |
|----------|-----------------------|--|----------------|----------|
| | | DCPD ISFSI Pad | | |
| 10 | GEO.DCPD.01.10 | Determination of SSER 34 Long Period Spectral Values | 52.27.100.720 | |
| 11 | GEO.DCPD.01.11 | Development of ISFSI Spectra | 52.27.100.721 | |
| 12 | GEO.DCPD.01.12 | Development of Fling Model for Diablo Canyon ISFSI | 52.27.100.722 | |
| 13 | GEO.DCPD.01.13 | Development of Spectrum Compatible Time Histories | 52.27.100.723 | |
| 14 | GEO.DCPD.01.14 | Development of Time Histories with Fling | 52.27.100.724 | |
| 15 | GEO.DCPD.01.15 | Development of Young's Modulus and Poisson's Ratio Values for DCPD ISFSI Based on Laboratory Data | 52.27.100.725 | |
| 16 | GEO.DCPD.01.16 | Development of Strength Envelopes for Non-jointed Rock at DCPD ISFSI Based on Laboratory Data | 52.27.100.726 | |
| 17 | GEO.DCPD.01.17 | Determination of Mean and Standard Deviation of Unconfined Compression Strengths for Hard Rock at DCPD ISFSI Based on Laboratory Tests | 52.27.100.727 | |
| 18 | GEO.DCPD.01.18 | Determination of Basic Friction Angle Along Rock Discontinuities at DCPD ISFSI Based on Laboratory Tests | 52.27.100.728 | |
| 19 | GEO.DCPD.01.19 | Development of Strength Envelopes for Jointed Rock Mass at DCPD ISFSI Using | 52.27.100.729 | |



SUBJECT Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPD ISFSI Site

MADE BY A. Tafoya K1 DATE 12/15/01 CHECKED BY N/A DATE _____

**Cross-Index
(For Information Only)**

| Item No. | Geosciences Calc. No. | Title | PG&E Calc. No. | Comments |
|----------|-----------------------|---|----------------|----------|
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| 20 | GEO.DCPP.01.20 | Development of Strength Envelopes for Shallow Discontinuities at DCPD ISFSI Using Barton Equations | 52.27.100.730 | |
| 21 | GEO.DCPP.01.21 | Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPD ISFSI Site | 52.27.100.731 | |
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| 24 | GEO.DCPP.01.24 | Stability and Yield Acceleration Analysis of Cross-Section I-I' | 52.27.100.734 | |
| 25 | GEO.DCPP.01.25 | Determination of Seismic Coefficient Time Histories for Potential Sliding Masses Along Cut Slope Behind ISFSI Pad | 52.27.100.735 | |
| 26 | GEO.DCPP.01.26 | Determination of Earthquake-Induced Displacements of Potential Sliding Masses on ISFSI Slope | 52.27.100.736 | |
| 27 | GEO.DCPP.01.27 | Cold Machine Shop Retaining Wall Stability | 52.27.100.737 | |
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SUBJECT Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPD ISFSI Site

MADE BY A. Tafoya DATE 12/15/01 CHECKED BY N/A DATE _____

**Cross-Index
(For Information Only)**

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| 31 | GEO.DCPP.01.31 | Development of Strength Envelopes for Clay Beds at DCPD ISFSI | 52.27.100.741 | |
| 32 | GEO.DCPP.01.32 | Verification of Computer Program SPCTLR.EXE | 52.27.100.742 | |
| 33 | GEO.DCPP.01.33 | Verification of Program UTEXAS3 | 52.27.100.743 | |
| 34 | GEO.DCPP.01.34 | Verification of Computer Code - QUAD4M | 52.27.100.744 | |
| 35 | GEO.DCPP.01.35 | Verification of Computer Program DEFORMP | 52.27.100.745 | |
| 36 | GEO.DCPP.01.36 | Reserved | 52.27.100.746 | |
| 37 | GEO.DCPP.01.37 | Development of Freefield Ground Motion Storage Cask Spectra and Time Histories for the Used Fuel Storage Project | 52.27.100.747 | |

DEC 15 2001 4:01PM P 3

FROM : Cluff - San Francisco

DEC. 15, 2001 2:30PM

PG&E GEOSCIENCES DEPT

PHONE NO. : 415 564 6697

NO.089 P.1/5

AT
12/15/01

PG&E
Geosciences Department
Departmental Calculation Procedure

Page: 1 of 1

Title: Calculation Cover Sheet

PACIFIC GAS AND ELECTRIC COMPANY
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

Calc Number: GEO.DCFF. 01.21Revision: 2Date: December 14, 2001No. of Calc Pages: 181

Verification Method: _____

No. of Verification Pages: 2 } NOT ATTACHED
AT 12/15/01TITLE Analysis of Bedrock Stratigraphy and Geologic Structure at the DCFP ISFSI Site

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DATE 12/14/01

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PG&E Geosciences Dept.
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Exp. 12/31/02

PG&E
Geosciences Department
Departmental Calculation Procedure

Page: 1 of 1

Title: Calculation Cover Sheet

PACIFIC GAS AND ELECTRIC COMPANY
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

Calc Number: GEO.DCPP. 01.21

Revision: 2

Date: December 14, 2001

No. of Calc Pages: 181

Verification Method: _____

No. of Verification Pages: 2

TITLE Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPP ISFSI Site

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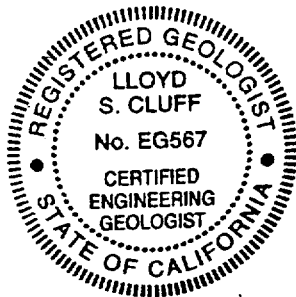
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DATE _____

PG&E Geosciences Dept.
Organization



Exp. 12/31/02

PG&E
Geosciences Department
Departmental Calculation Procedure

Page: 1 of 1

Title: Record of Revision

Calc Number: GEO.DCPP.01.21

Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPD ISFSI Site

| Rev. No. | Reason for Revision | Revision Date |
|----------|--|---------------|
| 0 | Initial Issue | 10/15/01 |
| Rev 1 | Remove letter designations from Record of Revisions (pg. 2); added references to the transmittals of maps and air photos from PG&E Geosciences to WLA; edited the section on Topographic maps (formerly 2.2 and now 2.1); added information on x-ray diffraction to the stratigraphic descriptions (5.2.1 to 5.2.3); revised the geologic maps (Figs. 21-1, 21-3, and 21-4) and cross sections (Figs. 21-14 to 21-25); added cross section L-L'; added sections on rockslide mass models (5.6.3) and estimate of potential slide mass displacement (5.6.4); changed section 5.6.3 Rock Block Dimensions to section 5.6.5; general minor edits to text and figures. | 11/6/01 |
| Rev 2 | Revised Introduction (Section 1); added description of geology along the transport route (5.5); added discussion of origin and non-capability of minor faults in the ISFSI study area (5.3.2.1); discussion of pre-existing landslides in Diablo Canyon near ISFSI site (5.7.1); general minor edits to text and figures in response to QA and ITR review | 12/12/01 |
| | | |
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DCPP ISFSI

CALCULATION PACKAGE GEO.DCPP.01.21
Analysis of Bedrock Stratigraphy and Geologic Structure
at the DCPD ISFSI Site

DCPP ISFSI
Calculation package GEO.DCPP.01.21
Analysis of Bedrock Stratigraphy and Geologic Structure
at the DCPD ISFSI Site

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Calculation Package GEO.DCPP.01.21

Title: Analysis of Bedrock Stratigraphy and Geologic Structure at the DCP
ISFSI Site

Calc Number: GEO.DCPP.01.21

Revision: Rev. 2

Author: William R. Lettis

Date: December 14, 2001

Verifier: Scott C. Lindvall

1.0 INTRODUCTION

The Diablo Canyon Power Plant (DCPP) Independent Spent Fuel Storage Facility (ISFSI) will be located on the plant site property in an area underlain by bedrock of the Tertiary Obispo Formation (Figure 21-1). The ISFSI will include the ISFSI pads, a Cask Transfer Facility (CTF), and a transport route leading from the power block to the CTF and onto the ISFSI pads. The ISFSI pads will be constructed on a bench cut into the Obispo Formation. For the purpose of discussion in this calculation package, the ISFSI pads, CTF, and cutslope and existing hillslope above the ISFSI pads are referred to as the ISFSI study area. The transport route includes the proposed route and the adjoining slopes above and below the route.

This calculation package describes the geology of the ISFSI study area and along the transport route. The stratigraphic and structural analysis was performed by William Lettis, Jeff Bachhuber, and Charles Brankman of WLA under the project direction and participation of William Page of PG&E Geosciences. The preparation of this calculation package was performed under the 2000 WLA Work Plan (Rev. 2) (William Lettis & Associates, Inc., Work Plan, 2000) using data collected under that Work Plan and a second WLA Work Plan (Rev. 1) (William Lettis & Associates, Inc., Work Plan, 2001) .

Security-Related Information – Withhold Under 10 CFR 2.390.

foundation properties for the ISFSI pads, the CTF facility, and the transport route; (2) to evaluate stability of the proposed cut slopes and existing hillslope above the ISFSI pads and transport route; (3) to identify and characterize bedrock faults in the study area; and (4) to compare bedrock conditions at the ISFSI site to bedrock conditions beneath the power block for ground motion characterization.

Information on the stratigraphy, structure and rock mass properties of the bedrock was used to analyze foundation properties, hillslope and cutslope stability, and ground motion site response in the ISFSI study area and along the transport route. These analyses are contained in the following calculation packages:

Calculation packages that characterize the ISFSI pads foundation properties:

GEO.DCPP.01.01 Development of Young's Modulus and Poisson's ratios for DCPD
ISFSI based on field data

GEO.DCPP.01.03 Development of allowable bearing capacity for DCPD ISFSI pad
and CTF stability analyses

GEO.DCPP.01.04 Methodology for determining sliding resistance along base of
DCPD ISFSI pads

GEO.DCPP.01.06 Development of lateral bearing capacity for DCPD CTF stability
analyses

GEO.DCPP.01.07 Development of coefficient of subgrade reaction for DCPD ISFSI
pad stability checks

GEO.DCPP.01.15 Development of Young's Modulus and Poisson's ratio values for
DCPD ISFSI based on laboratory data

Calculation packages that evaluate slope stability of the existing hillslope above the ISFSI site, the proposed ISFSI cutslopes, and the roadcuts above the transport route:

GEO.DCPP.01.08 Determination of rock anchor design parameters for DCPD ISFSI cutslope

GEO.DCPP.01.19 Development of strength envelopes for jointed rock mass at DCPD ISFSI using Hoek-Brown equations

GEO.DCPP.01.20 Development of strength envelopes for shallow discontinuities at DCPD ISFSI using Barton equations

GEO.DCPP.01.22 Kinematic stability analysis for cutslopes at DCPD ISFSI site

GEO.DCPP.01.23 Pseudostatic wedge analysis of DCPD ISFSI cutslope (SWEDGE analysis)

GEO.DCPP.01.24 Stability and yield acceleration analysis of cross section I-I'

GEO.DCPP.01.25 Determination of seismic coefficient time histories for potential sliding masses along cutslope behind ISFSI pad

GEO.DCPP.01.26 Determination of earthquake-induced displacements of potential sliding masses on DCPD ISFSI slope

GEO.DCPP.01.28 Stability and yield acceleration analysis of potential sliding masses along DCPD ISFSI transport route

GEO.DCPP.01.29 Determination of seismic coefficient time histories for potential sliding masses on DCPD ISFSI transport route

GEO.DCPP.01.30 Determination of earthquake-induced displacements of potential sliding masses along DCPD ISFSI transport route

Calculation packages that provide the rock conditions for evaluating ground motion site response:

GEO.DCPP.01.02 Determination of probabilistically reduced peak bedrock accelerations for DCPD ISFSI transporter analyses

GEO.DCPP.01.11 Development of ISFSI spectra

2.0 INPUTS

2.1 ISFSI Project Maps and Air Photos

Maps showing the topography of the plant site area and of the ISFSI project facility locations were received from PG&E Geosciences Department under letter of transmittal dated October 26, 2001 (PG&E Geosciences, 2001b). These maps were used to prepare the base maps for the geologic maps presented in this Calculation Package.

| <u>DRAWING</u> | <u>REVISION</u> | <u>TITLE</u> |
|----------------|-----------------|--|
| 471124 | 1 | Plot Plan |
| PGE-009-SK-001 | 0 | Site Plot Plan, ISFSI Cask Storage Pad, Cask Transfer Facility |
| UFSP-SK-004 | A | Cask Transfer Facility Structure (Schematic) |
| USFP-SK-005 | A | Four Topographic Profile Surveys (CYN-14r.dgn) |
| 354970 | I | Site Plan Liquid Storage Warehouse |
| 438042 | 18 | Finished Grading Plan, Plant Area |

| <u>DRAWING</u> | <u>REVISION</u> | <u>TITLE</u> |
|----------------|-----------------|--|
| 445669 | 2 | As Built Location of Overhead Power Lines and Property Access Road |
| 445670 | 7 | As Built Location of Compressor Building and Surrounding Buried & Overhead Utilities As Built Location of Buried Conduits, Overhead Power Line, Meteorological Facilities & Intake Structure |
| 445675 | 12 | As Built Location of Intake Structure Area & Breakwater Road |
| 445708 | 1 | Access Road to 150 ft. Meteorological Tower |
| 445719 | 0 | Access Road to 150 ft. Meteorological Tower |
| 445720 | 0 | Access Road to 150 ft. Meteorological Tower |
| 445724 | 0 | Access Road to 150 ft. Meteorological Tower |
| 445725 | 0 | Access Road to 150 ft. Meteorological Tower |
| 445726 | 0 | Access Road to 150 ft. Meteorological Tower |
| 445727 | 0 | Access Road to 150 ft. Meteorological Tower |
| 445731 | 0 | Access Road to 150 ft. Meteorological Tower |
| 445732 | 0 | Access Road to 150 ft. Meteorological Tower |
| 472116 | 4 | Finish Grading & Drainage Plan N.P.O. Permanent Warehouse |
| 472117 | 3 | Drainage Sections & Details N.P.O. Permanent Warehouse |
| 472118 | 4 | Vehicular Access Plan & Misc. Details N.P.O. Permanent Warehouse |
| 472119 | 3 | Foundation Plan and Details NPO Permanent Warehouse |
| 472679 | 7 | Fencing Plan and Detail for the Southern Portion of the Power Plant Yard |
| 512292 | 11 | Site Master Plan Master Plan Area A |
| 515971 | 4 | Finished Grading Plan Yard Area and Administration Building |
| 515973 | 3 | Concrete Outline Foundation Plan Administration Building |
| 516969 | 8 | Ground Floor Plan Cold Machine Shop |
| 516992 | 8 | Finished Grading Plan Cold Machine Shop |
| 516994 | 5 | Foundation, Plan and Details Cold Machine Shop |

| <u>DRAWING</u> | <u>REVISION</u> | <u>TITLE</u> |
|----------------|-----------------|---|
| 517998 | 4 | Plan, Sections & Details Stormwater/Transformer Deluge Retention Drainage System |
| Diablo-pns-x1x | - | The Points Lists submitted by Pacific Engineering for four topographic profile lines D-D', E-E', F-F' and I-I' |
| CYN-r14.dwg | - | A sketch prepared by Pacific Engineering showing in plan the routes of the four field survey lines and can serve as a guide to the relative locations of the tabulated data |
| 71498.asc | 7/14/98 | "Topo" of hillside |
| 61600.asc | 6/16/00 | Trenches |
| 122000.asc | 12/20/00 | Added trenches |
| 42301.asc | 4/23/01 | Bores |
| 9601.asc | 9/6/01 & 9/7/01 | Cross sections |
| 59451 | 7 | Plot Plan (Superseded) |
| 478104 | 1 | Surveys of sea floor terrain near Diablo Canyon and of breakwater configuration after wavestorm of January 28, 1981 |
| 57733 | 11 | Equipment location Section FF Auxiliary, Fuel Handling and Turbine Buildings |
| 438002 | 8 | Excavation Plan Plant Site |
| 438003 | 2 | Excavation sections Plant Site |
| 438023 | 2 | May, 1968, Topography Plant Site Area |
| 438034 | 7 | Foundations for water tanks |
| 438200 | 7 | Excavation for containment, turbine-generator & auxiliary buildings |
| 439514 | 9 | Concrete outline section J-J Auxiliary Building – Areas H & K |
| 443060 | 9 | Excavation of Turbine Building |
| 443061 | 2 | Excavation of Auxiliary Building |
| 455934 | 2 | Excavation, Grading Plan & Sections Solid Radwaste Storage Building |
| 455937 | 3 | Finish Grading Plan & Sections Solid Radwaste Storage Building |
| 500973 | 13 | Equipment Location Section "C-C" Turbine, Containment & Fuel Handling Buildings |

| <u>DRAWING</u> | <u>REVISION</u> | <u>TITLE</u> |
|----------------|-----------------|--|
| 517120 | 7 | Fencing and Grading Radwaste Storage and Laundry Facility Area |
| 517746 | 1 | Site Preparation Plan & Sections NPO Permanent Warehouse |
| 517780 | 10 | Finish Grading Plan and Sections Radwaste Storage Building |

In addition, stereo aerial photographs of the ISFSI study area and transport route were acquired and interpreted for the study. These photos include:

| <u>Date</u> | <u>Company</u> | <u>Frames</u> | <u>Scale</u> |
|-------------|-----------------------|---|---------------------------|
| 5/22/68 | Towill Corporation | Flight 2777 Frames 2808-1 to 2808-3 | 1:24,000 black & white |
| | | Flight 2773 Frames 2805-3 and 2805-4 | |
| 7/4/86 | PG&E | Flight PG&E 737 Frames 2-159, 2-160 and 2-114 to 2-116 | 1:24,000 color |
| 1/11/87 | PG&E | Flight PG&E 753 Frames 5-10 to 5-12 and 6-4 to 6-9 | 1:24,000 black & white |
| 7/13/00 | Golden Aerial Surveys | Flight GS4295 Frames 1-1 to 1-6 and 2-1 to 2-2 | 1:20,000 color |

2.2 Compilation of Topographic Base Maps

Four different topographic base maps were compiled to make a complete topographic map of the ISFSI study area and transport route. This topographic map was used as the base map for preparation of geologic maps and cross sections. As shown on Figure 21-6 and discussed below, these maps cover different parts of the plant site at different scales and topographic contour intervals:

- (1) Towill Corporation's topographic map of the power plant property based on 1966 aerial photography and prepared at a scale of 1:2,400. These maps were made prior to power plant construction and site grading, and have gone through numerous revisions that primarily consist of addition of site facilities and areas of major grading. Elevation contours are 5 to 10 feet. These maps are used to depict topography outside of graded areas and facilities. The pre-construction topography from these maps was also plotted on several cross sections to illustrate the geomorphology prior to construction.
- (2) PG&E's 1986 facility layout Plot Plan map, Sheet No. 471124, prepared at a scale of 1:2,400. This plan shows as-built footprints of site facilities and graded areas (such as parking lots and the switchyard fill pads), overprinted on a modified topographic base with 100-foot elevation contours taken from the Towill topographic map.
- (3) PG&E's topographic/civil maps prepared at a scale of 1:240 (referred to as the "20-scale civil drawings") and modified at various times since the early 1970s. The 20-scale topographic/civil maps include as-built topography and facility layouts. These maps have gone through numerous revisions to incorporate new facilities or changes in graded conditions, but do not include all newer facilities and changes. Contour intervals are typically 5 feet. The topography from the 20-scale drawings is used to show current as-built elevation contours in the areas of the power plant.
- (4) 2000-2001 ISFSI Site topographic map prepared at a scale of 1:600 (referred to as "ISFSI site map"). The ISFSI site map covers the ISFSI and CTF sites, and is based on both photogramatic and land surveys. Several phases of field surveys were performed to locate exploratory borings, trenches, geologic reference points, and cross section profiles. Topographic contours

are resolved to 5-foot vertical intervals. This map is used as the base for Figure 21-4 and for cross sections in this area.

The geologic maps shown on Figures 21-1, 21-3 and 21-4 cover different parts of the power plant site area and ISFSI study area and, thus, required the use of one or more of the different topographic maps. The different base maps were merged to create a uniform topographic base registered to the California State Coordinate System that is a common grid for cross-referencing. The contours were smoothed and adjusted at the map boundaries to eliminate mismatching at map edges. Some contour lines were removed to provide consistent map-to-map contour spacing. After the base topography was merged and edited, selected major plant facilities were added for reference. In the ISFSI site area, field surveys were also made to accurately locate the ISFSI borings and trenches. In order to provide accurate topography for the cross section profiles that extended into areas of the older Towill topographic map, the profiles were surveyed in the field as shown on Figure 21-6. These survey profiles, as well as the surveyed points in the ISFSI site area, were used to cross check between the various map sets and provide additional control for geologic data.

2.3 Geologic Inputs

Bedrock in the ISFSI study area has undergone a complex history of deposition, alteration and deformation. This complex history makes it difficult to recognize and correlate distinct lithologies and to identify bedding within the bedrock. Therefore, considerable effort was made to resolve this history and to understand the current stratigraphic and structural condition of the rock. This effort included:

- detailed surface mapping (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report A);
- continuous rock coring (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report B) supplemented by downhole velocity measurements (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report C) and caliper

NUCLEAR POWER GENERATION
CF3.ID4
ATTACHMENT 7.2

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| Index No. 402 _____ |
| Binder No. _____ |

TITLE: CALCULATION COVER SHEET

Unit(s): 1 & 2 File No.: 52.27
 Responsible Group: Civil Calculation No.: 52.27.100.731
 No. of Pages 3 pages + Index (4 pages) + 1 Design Calculation YES [x] NO []
Attachment (185 pages)
 System No. 42C Quality Classification Q (Safety-Related)
 Structure, System or Component: Independent Spent Fuel Storage Facility

Subject: Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPD ISFSI Site
 (GEO.DCPD.01.21, Rev. 2)

Electronic calculation YES [] NO [x]

| Computer Model | Computer ID | Program Location | Date of Last Change |
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| <p>A. Insert PE Stamp or Seal Below</p> <p>Expiration Date:</p> | <p>B. Insert stamp directing to the PE stamp or seal</p> <p style="text-align: center;">REGISTERED ENGINEERS' STAMPS AND EXPIRATION DATES ARE SHOWN ON DWG 063618</p> |
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NOTE 1: Update DCI promptly after approval.

NOTE 2: Forward electronic calculation file to CCTG for uploading to EDMS.

and optical televiewer data (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report E);

- seismic surface refraction surveys (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report C);
- trenching (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report D) and measuring of rock discontinuities (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report F), in situ strength properties (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report H), and structure (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report A);
- laboratory analysis of rock mass properties (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report I) and of clay bed properties (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report G); and
- petrographic and x-ray analyses of hand and core samples (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Reports J and K, respectively).

The details of each study, including methodology, personnel involved, and sequence and results of investigation are given in each respective William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report prepared by William Lettis & Associates, Inc. (2001).

Descriptions of the regional and site geology are provided in William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report A, which presents geologic maps and field data with minimal interpretation. This calculation package integrates the geologic map information included in William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report A with the subsurface and laboratory test data in William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Reports B through K to evaluate site-specific stratigraphy for the ISFSI study area. Interpretive geologic maps are shown on Figures 21-1, 21-3, and 21-4, and a site-specific stratigraphic column is shown on Figure 21-5. The stratigraphy was then used to define the structure and geometry of bedding and the distribution of bedrock lithology beneath the ISFSI and CTF sites, within the slope above the ISFSI site and along the transport route, and to help

identify and characterize the minor faults in the area. Topographic base maps used for Figures 21-1, 21-3 and 21-4 are shown on Figure 21-6.

This calculation package documents the iterative and interpretive procedures used to prepare: (1) a detailed stratigraphic column for bedrock in the study area (Figure 21-5); (2) a geologic model describing the evolution of bedrock in the study area (Figures 21-7 and 21-8); and (3) interpretive geologic maps (Figures 21-1, 21-3 and 21-4), summary boring logs (Figures 21-9 through 21-12), and cross sections (Figures 21-13 through 21-24) showing bedrock structure and distribution of lithologic units at the ISFSI and CTF sites and along the transport route. These data provide rock properties that were used to characterize slope stability, foundation response, and seismic ground motions. Particular emphasis was placed on correlating sedimentary facies, marker beds, and clay beds within the bedrock, and characterizing bedrock structure for use in evaluating the stability of cutslopes and hillslopes in the ISFSI study area and along the transport route.

3.0 ASSUMPTIONS

Several assumptions are used in the stratigraphic and structural analysis. These assumptions and supporting rationale are listed below. Evidence supporting these assumptions is provided in the Analysis section below. These assumptions are considered reasonable and are used to characterize the range of possible conditions of bedrock in the study area.

- (1) **Lateral Continuity.** Bedrock in the ISFSI study area was deposited in a moderate to deep marine environment (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report L). Under such conditions, it is reasonable to assume that individual beds and groups of beds were deposited with lateral continuity of equal to or greater extent than the ISFSI site dimensions (on the order of hundreds of feet). Thus, any interruptions to bedding across the site will be due to post-depositional erosion, chemical alteration, diagenesis (including

compaction), deformation (tectonic or non-tectonic), hydrocarbon or hydrothermal fluid migration, and/or igneous intrusion. Under this assumption, clay beds are conservatively assumed to be laterally continuous for distances of hundreds of feet unless demonstrated otherwise. This assumption is realistically conservative because field observations of facies changes, areas of rock-to-rock contact, localized cemented bedding planes (rock bridges), and faults commonly disrupt the continuity of bedding and clay beds.

(2) **Facies Variation.** Bedrock in the ISFSI study area includes both marine turbidite deposits and marine pelagic and biogenic deposits. These deposits are interfingered and undergo lateral facies transition from one to the other. This facies transition is an irregular, but mappable lithologic contact in the ISFSI study area. Given this depositional contact and general knowledge of depositional environments, the facies transition is assumed to be time-transgressive. Locally distinct beds of one facies interfinger with the other facies. In these instances, the facies contact is assumed to closely approximate an individual bed or group of beds that can be used to establish the general dip and lateral continuity of bedding within the bedrock. This is a reasonable assumption where stratigraphic sequences are constrained by closely spaced borings and surface exposures. The overall geometry of the facies transition, however, given its interfingering pattern, will appear to cross cut bedding.

(3) **Dolomitization.** Bedrock in the ISFSI study area has been partially, and in places, entirely recrystallized to dolomite. This process of dolomitization has affected all rock types and beds to varying degrees and, in places, the degree of dolomitization may vary laterally along the same bed(s). Thus, the degree of dolomitization cannot be used as a distinct lithologic unit that defines bedding or distinct marker horizons in the site area. However, the finer-grained dolomite beds of Unit Tof_{b-1} generally exhibit a greater degree of dolomitization than the coarser-grained sandstone beds of Unit Tof_{b-2}.

- (4) **Alteration.** Bedrock in the ISFSI study area has undergone several periods of alteration, including addition of petroliferous fluids, near-surface mechanical and chemical weathering and probable hydrothermal alteration. Based on detailed mapping, the petroliferous alteration is assumed to be relatively random throughout the bedrock and cannot be used to discriminate either original bedrock lithology or bedding. In contrast, the surface weathering and/or hydrothermal alteration appears to have differentially effected distinct lithologies and beds over short distances. These zones of alteration are assumed to correlate laterally over short distances and, therefore, can be used to help evaluate the stratigraphy and structure of bedrock in the ISFSI study area.

- (5) **Diabase Intrusion.** Rocks of a diabase intrusive complex are common in the Diablo Canyon plant site area and locally were present in the ISFSI site prior to excavation of the borrow site in 1971. Because of the proximity of known diabase intrusions, bedrock at the site may have been structurally deformed by the intrusive complex and/or hydrothermally altered from fluids emanating from the intrusion. This is a reasonable assumption considering the known occurrence and former proximity of the diabase.

- (6) **Bedding Attitudes.** Bedding attitudes obtained at the surface and in boreholes are assumed to reflect the geometry of adjacent bedrock, and that this bedding attitude can be projected along dip and strike for distances up to 100 feet. This is a reasonable assumption that is supported by the greater than 100 bedrock attitudes measured in the ISFSI study area. Changes in bedding attitudes between different locations are interpolated using geologic judgement and interpretation of fold and fault geometry.

- (7) **Faulting.** Several minor faults occur in the ISFSI study area. The faults are assumed to have lateral and vertical continuity at least equal to the dimensions of the site (on the order of hundreds of feet). In addition, the faults are assumed to project along trend to small bedrock faults observed on the north wall of Diablo

Canyon that have similar geometry and orientations. These assumptions are reasonable given the inferred amounts of displacement on the faults (several hundred feet or more). In addition, slickensides are preserved on several exposed fault planes. The orientation of the slickensides are assumed to reflect the sense of last displacement along the fault, a commonly accepted interpretation of fault displacement. Where the fault plane attitude is not well constrained, we assume that the fault is vertical. This assumption is reasonable since the sense of fault displacement is primarily strike slip and the majority of measured fault dips are greater than 70 degrees. Faults with a well-constrained geometry are shown with a solid line on the cross sections; faults with a poorly constrained geometry are shown with a dashed line.

4.0 METHODS

Stratigraphic and structural analyses of bedrock in the ISFSI study area and along the transport route were performed using fundamental principals of geology (e.g., uniformitarianism, stratigraphic superposition and lateral continuity, cross-cutting relative age relationships, etc.). Geologic data were collected in the field through surface geologic mapping, seismic surveys, trenching and borings (see Inputs section above). The data were compiled and analyzed using guidelines provided in "Geology in the Field" (Compton, 1985). Geologic field data were supplemented with laboratory petrographic and X-ray diffraction analyses (see Inputs Section above).

4.1 Bedding

Bedding attitudes were measured to evaluate stratigraphic continuity and geometry of bedrock in the study area and at the site. Particular care was used in measuring bedding in the ISFSI study area because of the importance to the analysis of slope stability. Attitudes were obtained on surface outcrops using a Brunton Compass (Figure 21-26) and in borings using optical televiewer data supplemented by visual examination of the rock

core (Figure 21-27). All of the bedding attitudes obtained from surface outcrops in the ISFSI study area and most of the attitudes from the borings were cross-checked by at least two geologists as described in William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Reports B, E, and L. Surface measurements of bedding attitudes were obtained from available exposures that exhibited moderate to well-defined bedding. These attitudes were used to help determine bedrock structure (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report L, Table L-1). All bedding attitudes from surface exposures were plotted on the geologic maps and those near the cross section lines were used in the construction of these cross sections across the ISFSI study area and along the transport route.

Bedding attitudes also were measured in borings by examination of televiwer data, rock core, and boring logs. Distinct beds and/or zones of "stratified" or laminated bedrock were initially noted on the geologic logs by the field geologist upon first examination of the recovered core (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report B). The dip of bedding was measured directly on the core with a protractor. Oriented coring techniques were not used; therefore, the strike and dip azimuth of bedding could not be determined in the field. Most of the dip measurements of bedding were checked by visual examination of the rock core by at least two other geologists (Figures 21-26 and 21-27). Borehole televiwer data were processed and interpreted by NORCAL (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report E). NORCAL identified bedding planes and defined the orientation and dip of selected bedding planes. The NORCAL data were independently checked by at least two geologists by comparing the televiwer data with the rock core. Additional bedding planes, or alternate measurements of NORCAL bedding measurements were made by the geologists using geometric and trigonometric solutions. Most of the bedding attitudes determined from the televiwer data were compared visually with the rock core to verify the existence of bedding as noted on the televiwer logs and the magnitude of dip as calculated from the televiwer logs. Cross-checking between the televiwer data, rock core, and boring logs provided a consistent, verifiable and documented set of bedding attitudes. Bedding attitudes in the borings are tabulated in Table 21-1. Only those beds

that were verified by visual examination of the core were used in the construction of cross sections across the ISFSI study area.

4.2 Clay Beds

The identification and characterization of clay beds in the ISFSI study area is important for two reasons: (1) The clay beds form local marker horizons that help define the structure and geometry of bedding in the study area; and (2) the clay beds could form a basal shear surface for potential shallow and deep slope failures that might affect the ISFSI. Thus, a significant effort was focused on identifying clay beds and evaluating their orientation and lateral continuity.

Distinct clay beds were observed in trench exposures, boreholes, and roadcut exposures (Figures 21-28, 21-29, 21-30). Clay beds were identified and logged in Trenches T-11, T-12, T-14, T-15 and T-18 (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report D). In each trench the thickness and attitude of the clay were recorded. Locations of clay beds observed in trenches and surface exposures are shown on Figure 21-4.

Clay beds also were identified in many of the borings (Table 21-2). The clay beds are more common and generally thicker in the dolomite bedrock (Unit To_{b-1}) and less common and thinner in the sandstone bedrock (Unit To_{b-2}) (Table 21-3). The identification of a clay bed (as opposed to a clay-filled fracture or joint) in the borings required careful analysis. The differentiation of clay beds from joint and fracture clay infills was initially noted by the geologist in the field during core logging (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report B). This information was reviewed and verified by at least two geologists through visual inspection of the rock core. Because confirmed bedding attitudes defined by clear stratigraphic laminations typically dip in the range of about 5 to 20 degrees, only clay occurrences with a dip of less than 30 degrees and judged to be a clay bed were identified as possible clay beds for incorporation in cross sections and highlighted by bold font in Table 21-2. Clay seams

dipping steeper than 30 degrees are interpreted to be clay coatings and infillings along faults and joints rather than stratigraphic clay beds and were not tabulated in Table 21-2.

Borehole televiewer data also provide documentation of the presence of in situ clay beds. Clay beds were identified in the televiewer images as zones of borehole erosion, "softer" and blocky to massive layers, and non-jointed zones between more brittle jointed rock. This information is particularly useful in portions of the borings where the recovery of rock core was less than 100 percent. NORCAL provided the initial interpretation of the optical televiewer data and identified possible clay beds (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report E). The NORCAL interpretation and the televiewer logs were then independently interpreted by at least two geologists to verify the existence of the clay beds. In most cases, clay beds identified on the televiewer logs were visually correlated and verified as clay beds in the rock core. Exceptions to the visual verification were some zones of possible clay that were not recovered in the core and appeared to have been "washed out" during drilling. Some other possible clay beds noted by examination of televiewer logs corresponded to clayey dolomite or sandstone zones in the core rather than clay beds. Confirmed clay beds identified on the televiewer logs were added to Table 21-2. All the interpreted clay beds were plotted and used to help evaluate bedding orientation and lateral continuity of the clay beds on the cross sections.

In addition, samples of the clay beds were collected for laboratory analysis of physical properties (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report G) and petrographic analysis of lithologic and chemical composition (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Reports J and K).

4.3 Cross Sections

The following methodology was used to prepare the geologic cross sections in the ISFSI study area and along the transport route.

1. A topographic profile showing cultural features was drawn based on topographic maps of the ISFSI and Plant Site areas as described in Section 2.2, and shown on Figure 21-6. Several cross sections that extend into areas covered only by the Towill topographic base map were constructed using field-surveyed profiles as described in Section 2.2.
2. All lithologic contacts, structural features, and exploratory boring and trench locations intersecting the cross section alignment were plotted. Boring, and trench locations within 100 feet of the cross section line were extrapolated at a right angle onto the section line using the following guidelines: no data were projected across faults or fold axes; borings were projected and placed on the cross section at their true elevation unless otherwise noted; trenches were not projected uphill or downhill onto the cross section.
3. Surface bedding attitudes within 100 feet of the section line were projected perpendicular to the line of section and plotted as apparent dips. Bedding attitudes from the borings were taken from the table on bedding in the ISFSI borings (Table 21-1) and plotted as apparent dips. The apparent dips were obtained using the apparent dip nomograph from Figure 2-22 of Suppe (1985) and checked using the equation:

$$\tan \alpha = \tan \delta \times \sin \beta,$$

where α = apparent dip, δ = true dip, and β = angle between the strike of bed and strike of section (Rowland, 1986).

Clay bed attitudes were used to constrain the geometry of bedding with an uncertainty of ± 5 degrees.

4. Contacts between the main stratigraphic units, sandstone (Unit Tof_{b-2}) and dolomite (Unit Tof_{b-1}), as shown in the borings logs were projected into the

cross section. The location, thickness, and dip of friable zones of dolomite and sandstone (Tof_{b-1a}, Tof_{b-2a}) in the borings were taken from the table summarizing the friable dolomite and sandstone (Table 21-4). Clay beds were plotted from the table of clay beds (Table 21-2).

5. Information from previous maps and studies were added to the sections after reviewing the data for consistency and quality. This information included pre-excavation topography from the Towill map, geologic stratigraphic and structural data, and subsurface exploration data. Primary sources for this geologic information included studies by Harding Miller Lawson Associates (HML, 1968) and Harding Lawson and Associates (HLA, 1970) and the Diablo Canyon Power Plant FSAR (PG&E, 2000). This information was plotted on the cross sections, as appropriate, in a similar fashion to items 1 to 4 above.
6. Cross section intersections were checked for consistent interpretation, and to provide additional stratigraphic and structural control between cross sections. In this manner, a single internally consistent interpretation of the three-dimensional geology of bedrock was developed for the ISFSI study area and along the transport route.

All interpreted clay beds from the borings (Table 21-2) and from the trenches (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report D) were plotted on the geologic cross sections. The variable thicknesses of the clay beds (Table 21-3) are indicated by different line weights: clay beds thinner than $\frac{1}{8}$ -inch have a thin line weight; $\frac{1}{8}$ - to $\frac{1}{4}$ -inch-thick beds have a medium line weight; beds thicker than $\frac{1}{4}$ -inch have a heavy line weight.

Similarly, the lateral continuity of clay beds is shown using the following criteria (see Section 5.2.2.4):

Clay beds $> \frac{1}{4}$ -inch thick – extended for 100 feet as a solid line and 100 feet as a dashed line from surface exposure, and to both sides of borings;

Clay beds $\frac{1}{8}$ - to $\frac{1}{4}$ -inch thick – extended for 50 feet as a solid line and 50 feet as a dashed line from surface exposures, and on both sides of borings; and,

Clay beds $< \frac{1}{8}$ -inch thick – extended for 25 feet as a solid line and 25 feet as a dashed line from surface exposures, and on both sides of borings.

Clay beds are shown with shorter lateral continuity where they are known to be absent in adjoining boreholes or are interpreted to be offset by faults.

Bedding attitudes measured in the boreholes are considered “local” or point attitudes because they are measured over only a 4-inch-wide core. As such, they may not record the true regional strike and dip, but may be a local attitude that is anomalous to the regional dip. For example, the attitude of the base of the clay bed at 55.4 feet depth in Boring 00BA-1 (Figure 21-30) is markedly different than the other attitudes in the boring or at the surface. Therefore, this measurement was not used on the cross section for controlling the dip of the strata of clay beds in that area.

Where possible, as between borings 01-F and 01-H, distinct lithologic beds were used to establish the dip of the strata. Elsewhere the dips measured in the boreholes and at the surface were compared and assessed for general continuity and the general attitude is used to project strata between borings.

Because the depositional environment for dolomite (Unit Tof_{b-1}) is interpreted to be pelagic deep marine (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report L), the clay beds were assumed to have been deposited as laterally continuous

beds. The thickness of the clay beds varies because clays were deposited on irregular erosional surfaces and because subsequent erosion and/or diagenetic differential compaction may have removed or thinned clay in some areas. For example, during deposition on a submarine fan, turbidite pulses of sand associated with sandstone of Unit Tof_{b-2} may have locally scoured and eroded the deep marine, pelagic clay beds. In the sandstone sequence (Unit Tof_{b-2}), the less frequent clay beds probably represent finer-grained tails at the distal ends of the turbidite flows, or the upper fine-grained pelagic "D" and "E" layers in the classic Bouma sequence (Reading, 1981).

In cross sections, clay beds were extrapolated between surface exposures and boring control points by projecting lines parallel to bedding strata and, in several constrained areas, parallel to the general facies contact between dolomite (Tof_{b-1}) and sandstone (Tof_{b-2}). The spacing between projected clay beds was kept constant to reflect uniform bedding thickness in the rock sequence. In some cases where clay beds encountered in individual borings and surface exposures are at the same stratigraphic level and have similar thickness and character, the clay beds were interpreted to be continuous and were connected between control points for distances up to several hundred feet. We believe that this is a conservative, but reasonable, interpretation. In other cases, clay beds were not encountered at the projected locations in other borings or surface exposures, and therefore were terminated at some distance away from control points.

Some cross sections, such as sections B-B'', C-C' and J-J' (Figures 21-15, 21-16 and 21-23), cross one or more faults that have displaced strata both horizontally and vertically. Trench and borehole data were not projected across faults onto the cross sections to eliminate problems associated with mismatching of stratigraphy and inaccurate plotting of fault displacement locations.

Other cross sections, such as I-I' and G-G' (Figures 21-22 and 21-20) were drawn within and roughly parallel to the fault blocks so that the continuity of clay beds and other strata such as friable zones, could be interpreted without the complications of significant faulting.

Friable zones in the dolomite and sandstone (Units Tof_{b-1a} and Tof_{b-2a}, respectively) appear to have limited lateral extent in trenches and surface outcrops. Therefore, in the cross sections, the friable zones were extended for 50 to 100 feet away from trench or borehole control points as irregular lenses. The distance of projection is related to the thickness of the friable zone, with thicker zones (over about 10-feet thick) having more distant projection than thinner zones.

5.0 ANALYSIS (BODY OF CALCULATION)

Geologic information obtained during this study is shown on a series of geologic maps covering the plant site area (Figure 21-1), the ISFSI study area including the transport route (Figure 21-3), and the ISFSI site (Figure 21-4). Information shown on Figure 21-1 was compiled largely from pre-existing information contained in the FSAR (PG&E 2000), LTSP (PG&E, 1988), and Hall et al. (1979) supplemented by more recent site reconnaissance mapping during the ISFSI site investigations. Information shown on Figures 21-3 and 21-4 was developed primarily during the ISFSI site investigation.

The geology in the ISFSI study area is complex. Understanding the complexity of the geology and the various geologic processes giving rise to the current geologic conditions is important for interpreting the stratigraphy and structural geology at the site. Below, the geologic processes giving rise to the bedrock complexity are described, followed by an analysis of the stratigraphic and structural relations at the site.

5.1 Bedrock Evolution

Bedrock in the ISFSI study area has undergone a complex history of deposition, alteration and deformation. Based on analysis of surface and subsurface data, supplemented by petrographic analyses of rock lithology, mineralogy, and depositional

history, the following events produced the current lithology and stratigraphic character of bedrock at the site (Figures 21-7 and 21-8):

1. Original deposition
2. Diagenesis and dolomitization
3. Localized addition of petroliferous fluids
4. Diabase intrusion, hydrothermal alteration, and associated deformation
5. Tectonic deformation (folding and faulting)
6. Surface erosion and weathering (both chemical and mechanical)
7. Borrow excavation and stress unloading

This sequence of events is illustrated in Figure 21-7 and described below. The approximate timing of these events is shown on Figure 21-8.

(1) Original Depositional Environment

Sediments comprising the lithified bedrock in the ISFSI study area were originally deposited in a moderate to deep marine environment, probably on the outer continental shelf or continental slope during the early to middle Miocene. Petrographic analyses show the presence of benthic foraminifera, sponge spicules, and other biogenic material indicative of a moderate to deep marine, pelagic environment.

Deposits consist of a sequence of tuffaceous arkosic and lithic arenitic sandstones and siltstones grading laterally into biogenic chemical limestones and pelagic siltstones. Thin pelagic clay beds, locally containing foraminifera, occur interbedded with the limestone/siltstone sequence and to a lesser extent within the sandstone sequence. Deposition of the clay in a moderate to deep marine environment suggests that the clay beds originally blanketed the sea floor and formed laterally continuous beds.

The sandstone sequence is interpreted to be a turbidite clastic fan prograding and interfingering with the deep marine quiet water biogenic and pelagic limestone and

siltstone sequence (Figure 21-7A). The ISFSI study area straddles the gradational facies contact between these two depositional environments. The turbidite sequence represents high-energy submarine debris flows that have reworked pyroclastic tuffaceous shallow marine deposits out onto the outer continental shelf or continental slope. Turbidite sediment was derived from continental erosion and volcanism, and consisted of mixtures of older terrigenous debris and volcanic airfall tuff and ash and alluvially-transported debris. The lesser amounts of clay in the turbidite sequence probably reflects localized erosion and scour of the clay deposits by the high-energy turbidite flows.

Borehole data at the ISFSI study area clearly show an upward textural facies change from a relatively coarse sequence of sandstone to relatively fine sequence of limestone and siltstone (now dolomite). This depositional facies change is illustrated on the upper part of Figure 21-7A.

Bedding ranges from thinly bedded (less than ¼-inch thick) to massively bedded (greater than 5 feet thick). Bedding generally is better developed and/or preserved in the limestone/siltstone sequence and less well developed and/or preserved in the sandstone sequence.

(2) Diagenesis and Dolomitization

Following deposition and burial, the entire depositional sequence was subjected to diagenesis and chemical replacement and recrystallization by a process called dolomitization (illustrated in Figure 21-7B). The degree of dolomitization varies markedly over short distances and was apparently influenced by grain size and permeability differences in the original sediments. In this process, the finer-grained limestone is completely or nearly completely recrystallized to crystalline dolomite, siltstone is strongly to moderately recrystallized, and sandstone is moderately to weakly recrystallized with localized beds of strongly recrystallized dolomite and localized beds of less-dolomitized friable sandstone. All the rock types, siltstone, sandstone and limestone, maintain their original relict textures to some extent as individual grains of

plagioclase and clastic material were replaced with dolomite. The process of dolomitization locally obscures bedding and in places makes lateral correlation of individual beds between boreholes very difficult. During diagenesis many clastic and plagioclase grains were altered to clay. In some cases, the clay was partially dolomitized; in other cases the clay is not dolomitized. Dolomite replacement increased the degree of cementation in the finer-grained rocks of the dolomite (Unit Tof_{b-1}), and as a result these rocks are somewhat stronger and more brittle than the sandstone (Unit Tof_{b-2}), which typically has less cementation.

The process of dolomitization may have been influenced by, or caused by, hydrothermal activity associated with the emplacement of shallow diabase intrusions in the site area. Diabase intrusion and hydrothermal activity is described in process 4 below.

(3) Localized Addition of Petroliferous Fluids

Zones of hydrocarbon accumulations are locally preserved throughout the rock sequence at the ISFSI study area, but preferentially within the dolomite. Black, sticky hydrocarbon films also were observed on fractures and within faults in some of the exploratory trenches (e.g., Trench T-20A, William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report D). The origin or source rock of the hydrocarbons is not known. It may be that during or after the process of dolomitization, diagenesis of the bioclastic fraction of the rock at the site caused the mobilization and localized deposition of hydrocarbons. The areas of hydrocarbon accumulation occur in patches or splotches within the rock mass as well as concentrated along some faults and joints, and are not confined to individual beds, showing that at least some migration of the hydrocarbons has occurred. The patches of hydrocarbons commonly crosscut bedding, and tend to stain and obscure the stratigraphic relationship. These patches of hydrocarbons are shown diagrammatically on Figure 21-7B.

(4) Diabase Intrusion, Hydrothermal Alteration, and Associated Deformation

Locally, hypabyssal shallow intrusions of diabase invaded the dolomitic sandstone, siltstone, and dolomite of the Obispo Formation as illustrated in Figure 21-7C.

Petrographic analyses show that the diabase is primarily an altered cataclastic gabbro and diorite. Radiometric dates on similar diabase elsewhere in the Irish Hills indicate that the intrusions are middle Miocene in age (Hall et al., 1979). The diabase occurs as sills, dikes, and larger, massive intrusive bodies. The diabase is locally exposed along Diablo Canyon Creek beneath the eastern part of the Raw Water Reservoir and along the northern margin of the canyon walls. Prior to the 1971 excavation of the borrow cut area, a large diabase sill in the Obispo sandstone and dolomite was present in the raw water reservoir area (Figure 21-14) (HLA, 1968). This body of diabase was entirely removed during the borrow excavation, and no diabase was observed in the ISFSI study area or along the transport route during surface mapping and subsurface exploration. However, the feeder vent for the now-removed diabase sill has not been identified and possibly it or other intrusions may underlie the ISFSI site.

Hydrothermal solutions associated with the diabase intrusion locally altered the diabase and probably altered the surrounding wall rock. Petrographic analyses of the diabase show clear evidence of hydrothermal alteration (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report J).

As mentioned above, the intrusion of diabase and associated hydrothermal activity also may have caused or influenced the process of dolomitization in the site area. Intrusion of the magnesium-rich diabase would have caused circulation of natural occurring magnesium-rich seawater or hydrothermal fluids rich in magnesium from the diabase in the surrounding wall rock. Partial replacement of the calcium by magnesium in the limestone, calcareous sandstone and siltstone may have produced the observed dolomite. Possible hydrothermal "dolomitization" of the bedrock is supported by the following observations:

- Hall et al. (1979) do not map or describe dolomite in the Obispo Formation in the plant site region (10 kilometer radius), thus, the dolomite appears to be localized in the vicinity of the diabase intrusion in Diablo Canyon.
- The diabase clearly was altered by late-phase hydrothermal solutions demonstrating the presence of hydrothermal activity.
- Petrographic analyses show the presence of zeolite and rare clays within the dolomitic sandstone and dolomite (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report J) suggesting hydrothermal activity may have produced low-grade metamorphic changes in the host rock.
- The diabase is magnesium-rich and is a possible source of magnesium to replace calcium in the dolomitization process. Alternatively, the intrusion may have driven magnesium-rich seawater, the most common source of magnesium for dolomitization, through the rocks by thermal convection.

Intrusion of the diabase also may have been accompanied by magmatic stoping and/or localized uplift, warping and faulting of the bedrock. This localized deformation is diagrammatically illustrated on Figure 21-7C. Local uplift (or doming) of the bedrock may be the cause of the change in bedding attitudes observed on the lower half of the slope above the ISFSI site (described in the Analysis section below), and possibly formed or modified joints in the bedrock.

(5) Tectonic Deformation (Folding and Faulting)

Subsequent to the diabase intrusions in the middle Miocene, bedrock in the ISFSI study area was tectonically folded and faulted (Figure 21-7D) as part of the regional deformation that formed the Pismo syncline (Hall et al., 1979). The tectonic faulting and folding deformed the bedding and facies contacts within the sandstone/dolomite sequence. Folding of the facies contact, as well as the bedding, complicates the interpretation and correlation of bedrock stratigraphy at the site.

This area-wide tectonic deformation is superimposed on the earlier localized intrusive deformation from the diabase described above. In addition, the tectonic deformation may have been locally influenced by the more ductile rheology of the diabase. The ISFSI study area is situated on a northwest-trending syncline/anticline couplet (Figures 21-3, 21-4). The syncline/anticline couplet forms tight folds with steep limbs of up to 50 to 70 degrees directly south of the ISFSI site but transitions into folds with broad crests and gentle limbs of 5 to 20 degrees across the ISFSI site as the fold axes approach the former area of the diabase intrusion. This change in structure may be the result of tectonic deformation superimposed on the earlier intrusive "doming", or it may reflect the more ductile behavior of the diabase intrusion, or it may be simply a change in tectonic deformation without any influence from the diabase intrusion.

In addition to folding, a zone of northwest-trending minor faults disrupts the bedrock stratigraphy in the ISFSI study area (e.g., cross section B-B'", Figures 21-15 and 21-32). The faults are high-angle and slickensides indicate strike-slip to oblique strike-slip displacement. As shown on Figure 21-15, northeast-side down, vertical separation of at least 50 feet, occurs across the fault zone over a width of about 200 feet. Given the northwest dip of bedding, this sense of vertical separation can be produced by pure right-lateral strike slip or by a component of oblique right slip. The strike slip displacement juxtaposes stratigraphic units of different thicknesses and lithologies. The strike slip displacement also complicates the interpretation and correlation of bedrock lithology, bedding, and facies changes in the lower part of the slope and offsets the axis of the small anticline across the site.

(6) Surface Erosion and Chemical Weathering

During the past 1 million years, the ISFSI study area and transport route has been exposed to marine, fluvial and hillslope erosion. Remnants of marine deposits and hillslope colluvium are preserved locally in the ISFSI study area where they were not removed during excavation of the borrow area in 1971.

Infiltration of surface water and groundwater migration has chemically weathered and altered the bedrock. The degree of surface weathering decreases with progressive depth beneath the site and occurs preferentially and penetrates more deeply along fractures, joints and faults as shown in Figure 21-7E. The 1971 borrow excavation at the ISFSI site area removed the surficial soil and a variable thickness of bedrock from the site, with up to 100 feet of rock removal above the ISFSI pads (cross sections A-A' and B-B''; Figures 21-14 and 21-15). The original ground surface was a resistant bedrock spur ridge that had been subjected to weathering for a substantial time period, and had developed a weathered zone penetrating an unknown depth into the rock mass. As a result, the rock now exposed in the central part of the borrow excavation that was considerably below the former ground surface is less weathered than the rock along the margins of the borrow excavation where excavation was shallower. Additional minor weathering has occurred within the rock exposed after the borrow excavation was completed, but this "secondary" zone of weathering is the result of only about 30 years of exposure, as opposed to the many tens to hundreds of thousands of years of exposure for the original bedrock surface.

The surface weathering is superimposed on the pre-existing hydrothermal alteration, petroliferous alteration and dolomitization as shown on Figure 21-7E. The combination of alteration products (to varying degrees of development) significantly masks the primary depositional lithology and bedding, and complicates the interpretation of depositional origin.

(7) Borrow Excavation and Stress Unloading

Rock removal associated with the borrow excavation decreased the lithostatic stress on the bedrock currently exposed at the site (Figure 21-7F). Since then, stress unloading has caused shallow localized dilation of the rock mass, and the opening of joints, fractures and other discontinuities. This shallow dilation of the rock mass tends to mask bedding, so differentiating bedding from joints and fractures in the bedrock is difficult in surface exposures and exploratory trenches.

5.2 Stratigraphic Analysis

Bedrock in the ISFSI study area and along the transport route is differentiated into distinct, mappable lithologic units taking into account the complex depositional history and alteration of the rock mass. The following sections describe this stratigraphy.

5.2.1 General Stratigraphy

Sandstone and dolomite bedrock in the ISFSI study area and along the transport route belongs to the fine-grained member of the early to middle Miocene Obispo Formation (Tof) as mapped by Hall et al. (1979). Mapping of the DCPD plant site area differentiated three subunits (Units Tof_a, Tof_b, Tof_c) of the fine-grained member of the Obispo Formation (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report A). As shown on Figure 21-1, Unit Tof_a occurs in the eastern part of the plant site area (entirely east of the ISFSI study area) and consists primarily of thick to massively bedded diatomaceous siltstone and tuffaceous sandstone. Unit Tof_b occurs in the central and west-central part of the DCPD plant site area, including the entire ISFSI study area, the upper part of the transport route and beneath the power block, and consists primarily of medium to thickly bedded dolomite, dolomitic siltstone, dolomitic sandstone, and sandstone. Unit Tof_c occurs in the western part of the plant site area beneath the lower part of the transport route and consists of thin to medium bedded, extensively sheared shale, claystone and siltstone. In addition, locally extensive areas of diabase intrusive rocks were mapped along the northern margin of Diablo Canyon Creek and locally below the raw water reservoir (Unit Tvr).

5.2.2 ISFSI Study Area Stratigraphy

In the ISFSI study area, Unit Tof_b is further divided into a dolomite subunit (Tof_{b-1}) and a sandstone subunit (Tof_{b-2}). For ease of discussion, these subunits are referred to as Units Tof_{b-1} and Tof_{b-2}. Figure 21-5 provides a generalized stratigraphic column illustrating the distribution of rock types within these two subunits. Unit Tof_{b-1} consists primarily of dolomite, dolomitic siltstone, fine-grained dolomitic sandstone, and limestone. Unit

Tof_{b-2} consists primarily of medium to coarse-grained dolomitic sandstone and sandstone. Figures 21-9 to 21-12 provide summary logs of all the borings drilled in the ISFSI study area during the ISFSI site investigation. These summary logs show the primary lithologic units and clay beds greater than ¼-inch thick. Additional thinner clay beds encountered in the borings are listed in Table 21-3. These data were used together with surface geologic data to construct 12 cross sections across the study area (Figures 21-13 to 21-25).

The contact between Units Tof_{b-1} and Tof_{b-2} marks a facies change from the deep marine dolomite sequence to the sandstone turbidite sequence. The contact varies from sharp to gradational and bedding from one unit locally interfingers with bedding of the other unit. For purposes of mapping, we arbitrarily place the contact at the first occurrence (proceeding down section) of medium to coarse-grained dolomitic sandstone. As shown on the cross sections, the interfingering nature of the dolomite/sandstone contact beneath the ISFSI study area can be interpreted. This relationship is shown on cross sections A-A', B-B'', C-C', and I-I' (Figures 21-14, 21-15, 21-16, and 21-22, respectively). Some of the thin interfingering beds provide direct evidence for the lateral continuity and geometry (i.e., attitude) of bedding within the hillslope (for example, between boring 01-F and 00BA-1 on section I-I').

Analysis of the cross sections shows that the facies contact between Units Tof_{b-1} and Tof_{b-2} generally extends from northwest to southeast across the ISFSI study area, with sandstone of Unit Tof_{b-2} primarily in the north and northeast part of the area and dolomite of Unit Tof_{b-1} primarily in the south and southwest part of the area. The three-dimensional distribution of the facies contact is well illustrated by comparing cross sections B-B'' and I-I' (Figures 21-15 and 21-22, respectively). This distribution of the two units indicates that the source area of sandstone turbidite sequence lay to the northeast and the moderate to deep marine basin lay to the southwest.

In addition, we recognize two different transgressions of the dolomite of Unit Tof_{b-1}, an upper transgression or tongue of dolomite and a lower transgression of dolomite. The

upper transgression of dolomite and its contact with the underlying sandstone, as described above, is well documented in the borings, trenches and surface outcrops as shown on Figures 21-4 and 21-22. The south-southwestern extent of the underlying sandstone facies is indicated by borehole 01-I (Figure 21-22), which penetrated a thick sequence of dolomite and documents the absence of sandstone above the elevation of the borehole bottom. The lower transgression or tongue of dolomite that underlies the sandstone is exposed in the roadcut along Reservoir Road in the vicinity of Parking Lot 8. Based on the occurrence of calcareous siltstone and locally abundant foraminifera in boreholes beneath the power block, the lower transgression of dolomite is inferred to extend beneath the power block as shown on cross sections B-B''' and C-C' (Figures 21-15 and 21-16, respectively).

During initial stratigraphic analysis, depositional facies within each of the two subunits were further differentiated: Unit Tof_{b-1} was divided into facies A (dolomite) and B (dolomitic siltstone); while Unit Tof_{b-2} was divided into facies C (dolomitic sandstone) and D (sandstone). These additional facies contacts were used to help evaluate the internal stratigraphy within each subunit and to understand the depositional environment of the bedrock. After thorough analysis of all the borings and surface outcrops, these additional facies (A, B, C, D) contacts could not be confidently mapped across the ISFSI study area; thus, we do not show these units on the summary boring logs or on the cross sections. However, boring logs in William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report B contain these facies designations for reference.

5.2.2.1 Dolomite (Unit Tof_{b-1})

The slope above the ISFSI site, including most of the 1971 borrow area excavation slope, is underlain by dolomite (Figure 21-4). The dolomite is exposed as scattered outcrops across the excavated slope, along the unpaved tower access road, in the upper part of most borings in the ISFSI study area (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report B), and in most exploratory trenches (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report D). The dolomite consists predominately of tan to yellowish-brown, competent, well-bedded dolomite, with

subordinate dolomitic siltstone to fine-grained dolomitic sandstone, and limestone (Figure 21-34). Petrographic analyses of hand and core samples from, and adjacent to, the ISFSI study area show that the rock is primarily carbonate (dolomite) with a variety of secondary components. The petrographic analyses show that the rock consists primarily of clayey dolomite, altered clayey carbonate and altered calcareous claystone, with lesser amounts of clayey fossiliferous, bioclastic and brecciated limestone, fossiliferous dolomite, and altered sandstone and siltstone (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report J, Tables J-1 and J-2). X-ray diffraction analyses show that the dolomite has about 25% quartz, 8% feldspar, 40 to 50% dolomite (including some calcite), a few percent clays, and 15 to 20% amorphous material (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report J, Table J-3). As described in the petrographic analysis, the carbonate component of these rocks is primarily dolomite; thus we use the general term dolomite and dolomitic sandstone to describe the rock.

The dolomite crops out on the excavated borrow area slope as flat to slightly undulating rock surfaces. The rock is moderately hard to hard and typically medium strong to brittle, with locally well-defined bedding that ranges between several inches to 10 feet thick in surface exposures and boreholes. Bedding planes are laterally continuous for several tens of feet as observed in outcrops, and may extend for hundreds of feet based on the interpreted marine depositional environment. The bedding planes are generally tight and bonded. Unbonded bedding parting surfaces are rare and generally limited to less than several tens of feet based on outcrop exposures.

5.2.2.2 Sandstone (Unit Tof_{b-2})

Strata of the sandstone Unit Tof_{b-2} generally underlies the ISFSI study area below about elevation 330 feet (Figure 21-4). Typically, the rocks in this subunit are well-cemented, hard sandstone and dolomitic sandstone and lesser dolomite beds, as encountered in the lower part of borings 98BA-1, 00BA-2 and 00BA -3, and in borings CTF-A, 01-A, 01-B, 01-C, 01-D, 01-E, 01-F, 01-G and 01-H (Figures 21-9 to 21-12).

The well-cemented sandstone encountered in the borings and trenches is tan to gray, moderately to thickly bedded, and competent (Figure 21-35). The rock is well sorted, fine to coarse-grained, and is typically moderately to well-cemented with dolomite. The rock is of low to medium hardness and medium strength. Petrographic analyses show that the sandstone is altered, and that its composition varies from arkosic to arenitic, with individual grains consisting of quartz, feldspar, and dolomite and volcanic rock fragments (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report J). The matrix of some samples contains a significant percentage of carbonate and calcareous silt to clay matrix (probably from alteration). X-ray diffraction analyses show that the sandstone is about 20% quartz, 15 to 20% feldspar, 15% dolomite (with some calcite), and about 40% clay (10% kaolin and 30% smectite); one sample (P-21) is dominantly clastic dolomite with only 7% quartz and about 15% clays (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report J, Table J-3). Petrographic and x-ray analyses show that the carbonate is primarily dolomite. Thus, these rocks are referred to as sandstone and dolomitic sandstone. Bedding in places is well defined, and bedding plane contacts are tight and well bonded. Similar to the dolomite beds, unbonded bedding surfaces within the sandstone are rare and generally limited to less than several tens of feet based on limited outcrop exposure.

5.2.2.3 Friable Bedrock

Distinct zones of friable bedrock are present within the generally more cemented sandstone and dolomite (Figures 21-4 and 21-32; Table 21-4). In some cases, the friable bedrock appears to reflect the original deposit without subsequent dolomitization. In other cases the friable bedrock appears to be related to subsequent chemical weathering, and/or hydrothermal alteration. All friable beds within Units Tof_{b-1} and Tof_{b-2} are designated with the subscript (a).

Unit Tof_{b-1a} consists primarily of altered-or-weathered dolomite or dolomitic siltstone that has block-in-matrix friable consistency or simply a silt and clay matrix with friable consistency. The friable rock is of low hardness and is very weak to weak. X-ray diffraction analyses show the friable dolomite to have about 20% quartz, 10% feldspar,

50% dolomite that is about half composed of a poorly crystalline phase, and 16% clay (mostly smectite) (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report J, Table J-3). The primary differences between the dolomite and friable dolomite is the poorly crystalline phase and a higher percentage of clay, both are probably caused by weathering or alteration of the dolomite.

Unit Tof_{b-2a} consists primarily of friable sandstone, is of low hardness, and is very weak to weak. X-ray diffraction analyses show the friable sandstone has about 15% quartz, 10% feldspar, 15 to 20% dolomite (including some calcite), and 50 to 60% clay (10% kaolin, 50% smectite); one sample (P-21) is dominantly a clastic dolomite with only 7% quartz and about 15% clay (Diablo Canyon ISFSI Date Report J, Table J-3). The friable sandstone exhibits a somewhat lower feldspar content and a higher percentage of clays than the non-friable sandstone. In many cases, the friable sandstone is the original sandstone that has been chemically weathered or altered to a clayey sand (i.e., plagioclase and lithics altered to clay). In other cases, the friable sandstone simply lacks dolomite cementation and retains its original friable nature.

The friable zones in the dolomite and sandstone are known from exposures in the trenches and in the borings to be limited vertically and laterally in their extent. The vertical thickness of the friable rock encountered in borings ranges from less than 1 foot to 32 feet; the thickest friable zones were encountered in Boring 00BA-2 (Figures 21-9 through 21-12). The friable zones extend laterally for tens of feet in trench exposures, and were correlated up to about 200 feet between borings. As illustrated on the cross sections (e.g., I-I', J-J') the zones of friable rock appear more common, and possibly more laterally continuous, in the sandstone than in the dolomite. Friable beds were observed between beds of competent cemented sandstone and/or dolomite in exploratory trenches in the ISFSI pads area. Based on trench exposures and borehole correlations, friable zones are more laterally continuous in a direction along bedding than across bedding. Some thin, irregular friable zones or zones of weak rock were observed along and parallel to joints and faults. These zones do not appear to be as laterally continuous or thick as the bedding-parallel friable zones, and are not shown on cross sections.

5.2.2.4 Clay Beds

Clay beds are present within both the sandstone and dolomite subunits in the ISFSI study area (Table 21-3). The clay beds were observed in several trenches (Figure 21-36) and in many of the borings (Table 21-2; Figures 21-29, 21-30, and 21-31). Because these clay beds are potential layers of weakness in the hill slope above the ISFSI site they were investigated in detail. The clay beds generally are bedding-parallel and commonly range in thickness from thin partings (<1/16-inch thick) to beds up to 2 to 4 inches thick; the maximum thickness encountered was approximately 8½ inches in Boring 00BA1. Two-thirds of the clay beds encountered in the borings are less than ¼-inch thick; in contrast, about two-thirds of the clay beds exposed in the trenches are greater than ¼-inch thick (Table 21-3). This difference in thickness between the borings and trenches, however, probably reflects our ability to better recognize and document very thin clay beds in the rock core than in the trenches, rather than a true stratigraphic change between surface and subsurface exposures. The clay beds are yellow-brown, orange-brown, and dark brown, sandy and silty, and stiff to hard. Petrographic analyses show that the clay contains marine microfossils and small rock inclusions; the rock inclusions are angular pieces of dolomite that are matrix-supported, and have no preferred orientation or shear fabric (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report K). In the trenches, the clay beds locally have slickensides and polished surfaces. The clay beds typically appear to be overconsolidated (because of original burial), and, where thick, have a blocky structure.

The clay beds encountered in the borings are recorded on the boring logs. In addition, in most of the borings, the clay beds were also documented in situ by a borehole televiwer. The televiwer logs show that the clay beds generally are in tight contact with the bounding rock and are bedding-parallel. The clay beds range from massive with no preferred shear fabric, to laminated with clear shear fabric. The shear fabric is interpreted to be the result of tectonic shearing during folding and flexural slip of the bedding surfaces; the shear fabric does not reflect gravitational sliding because features indicative of large-scale rock slides, such as disarticulation of the rock mass, lack of bedding

continuity or change in bedding orientation, tensional fissures and geomorphic expression of a landslide on pre-construction air photos, are not present.

Clay Beds in Dolomite. Clay beds are more frequent, thicker and more laterally continuous in the dolomite (Unit Tof_{b-1}). Examination of the continuity of clay beds within, and between, adjacent trenches, road cuts, and borings provided data on the lateral continuity (persistence) of the clay beds. Individual clay beds exposed in the trenches and road cuts appear to be persistent over distances of between tens of feet to over 160 feet, extending beyond the length of the exposures. The exposed clay beds are wavy and exhibit significant variations in thickness along the bed. Thinner clay beds (less than about ¼-inch thick) typically contain areas where asperities on the surfaces of the bounding adjacent hard rock project through or into the thin clay. The bedding surfaces also commonly are irregular and undulating with the height (amplitude) of the undulation greater than the thickness of the clay bed such that the clay beds likely have local rock-to-rock contact that increases shear strength along clay bed interfaces to a greater value than that of the clay itself. This would increase the average shear strength of the clay bed surface for analyses of potential sliding along these interfaces. For example, the clay bed exposed in Trenches T-14A and T-14B extends for about 160 feet, including the length of Trench T-14, the adjacent roadcut exposure, and correlation to the clay exposed Trench T-19. The thickness of this clay varies from about 4 inches in Trench T-14 and decreases to about ¼-inch in Trench T-19 where the clay splays into several thin clay beds. Many of the clay beds appear to correlate between outcrops and borings. For example, the clay bed in Trenches T-11 and T-12 appears to correlate over a distance of about 100 feet. Other correlations are shown on cross section I-I' (Figure 21-22). These correlations indicate that at least some clay beds extend over several hundred feet into the hillslope. However, some beds clearly do not correlate; for example, the clay beds exposed in Trenches T-14 and T-15 are not found in nearby Boring 01-I. The interpreted lateral continuity of clay beds is best illustrated on cross section I-I' (Figure 21-22).

Clay Beds in Sandstone. Clay beds are less frequent, generally thinner, and less laterally continuous in the sandstone (Unit Tof_{b-2}). As shown on Table 21-3, clay beds in the sandstone generally are less than ¼-inch thick. These thinner clay beds are difficult to correlate laterally between borings and, at least locally, are less than 50 to 100 feet in lateral extent. For example, as shown on cross sections B-B''' and I-I', (Figures 21-15 and 21-22, respectively), clay beds were not encountered in Boring 01-B but were encountered in adjacent borings 50 to 100 feet away (i.e., Borings 01-A and 01-H). Consequently, we interpret that the clay beds in the sandstone generally are thin (i.e., less than ¼-inch thick) and have lateral continuity of less than 100 feet in the ISFSI site area.

Clay Moisture Content. The clay beds encountered in the borings and trench excavations in both the dolomite and sandstone were moist. Clay beds uncovered in the trenches that dried out after exposure during the dry season, became hard and desiccated. When wetted during the rainy season, the clay in the trenches became soft and sticky; possible local perched water tables (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report B) also may soften the upper portions of the clay beds during the rainy season in the ISFSI site area.

Clay Composition. X-ray diffraction analyses (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report K) show that the clay-size fraction of the clay beds in Trenches T-11A, T-14A, T-14B, and T-15 consists of three primary minerals: kaolinite (a clay), ganophyllite (a zeolite), and sepiolite (a clay). The silt-size fraction of the sample consists primarily of rock and mineral fragments of quartz, dolomite/ankerite, and calcite. Petrographic examination of the clay (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report K) shows a clay matrix with matrix-supported angular rock fragments and no shear fabric. Included rock fragments have evidence of secondary dolomitization of original calcite (limestone), and localized post-depositional contact alteration. Some samples contain microfossils (benthic foraminifera). The ganophyllite minerals appear to be expansive, as evidenced by swelling of one sample (X-1 from Trench T-14A) after thin-section mounting. Sample X-2 also had a significant

percentage of ganophyllite, and a high plasticity index (PI) of 63 (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Reports K and G, respectively).

The presence of microfossils confirms that the clay is depositional in origin and was not formed by alteration or weathering of a lithified host rock. Therefore, the clay is interpreted to reflect pelagic deposition in a marine environment.

5.3 Structural Analysis

Bedrock in the ISFSI study area has been deformed by tectonic processes and possibly by intrusion of diabase. The detailed stratigraphic framework described above provides the basis for analyzing the geologic structure in the site area.

Geologic structures in the ISFSI study area include folds, faults, and joints and fractures. Understanding the distribution and geometry of these structures is important for evaluating rock mass conditions and slope stability for two reasons: (1) folds in the bedrock produce the inclination of bedding that is important for evaluating the potential for out-of-slope bedding-plane slope failures; and (2) faults and, to a lesser extent, joints in the bedrock produce laterally continuous rock discontinuities along which potential rock failures may detach in the proposed cutslopes.

The distribution and geometry of folds and faults in the bedrock were evaluated by detailed surface geologic mapping, trenches, and borings. Data from these studies were integrated to produce geologic maps (Figures 21-1, 21-3, and 21-4) and geologic cross sections (Figures 21-13 to 21-24). Cross sections were prepared oriented both down slope and parallel to slope to evaluate the three-dimensional distribution of structures. Bedding attitudes were obtained from surface mapping (including road cut and trench exposures) and from boreholes (based on visual inspection of rock core integrated with oriented televiewer data). Bedding attitudes from surface mapping are shown on the geologic maps. Bedding attitudes from boreholes are compiled in Table 21-1. All of

these bedding attitudes were used to constrain the distribution of bedrock lithologies and geometry of bedding shown on the cross sections as described earlier.

5.3.1 Folds

As shown on the geologic maps (Figures 21-1, 21-3 and 21-4) and cross sections (Figure 21-15, 21-16, 21-17 and 21-19), bedrock in the ISFSI study area is deformed into small northwest-trending synclines and anticlines along the western limb of the larger regional Pismo syncline (Figure 21-37). On the ridge southeast of the ISFSI study area, nearly continuous outcrops of resistant beds define an anticline and two en echelon synclines (Figures 21-1 and 21-3). These folds, which are relatively tight and sharp-crested with steep limbs, plunge to the northwest.

Within the ISFSI study area, a northwest-plunging anticline appears to represent the northwestward continuation of the anticline that is exposed in the ridgetop near the Skyview Road overlook (Figure 21-1). The anticline varies from a tight chevron fold southeast of the ISFSI study area to a very broad-crested open fold across the central part of the study area. The northwestward shallowing of dips along the anticlinal trend appears to reflect a flattening of fold limbs up section. In the ISFSI study area, the broad crest of the fold is offset and disrupted by series of fold-parallel, minor faults (Figure 21-15). The minor faults offset the fold axis as well as produce local drag-folding, which tends to disrupt and complicate the fold geometry. The axis of this broad-crested anticline is approximately located on the geologic map (Figure 21-4) where it best fits the data.

The en echelon syncline found at the ridge crest along Skyview Road projects to the northwest along the southwestern margin of the ISFSI study area. In this area, the syncline transitions into an en echelon northwest-trending monocline and syncline (Figures 21-1 and 21-3). In the ISFSI study area, the syncline opens into a broad, gently northwest-plunging (generally less than 15 degrees) fold with gently sloping limbs (generally less than 20 degrees). Bedding generally dips downslope to the northwest in the upper part of the slope above the ISFSI site and parallel to the slope to the southwest

and west in the lower part of the slope. Minor undulations in the bedding reflect the transition from a tight syncline to a relatively flat monocline, or "shoulder", and then back to a broad northwest-plunging syncline. These localized interruptions to the northwest plunge of the fold may be caused by the diabase intrusion and localized doming associated with the intrusion (compare Figures 21-7c and 7d).

Understanding the location, geometry and characteristics of the syncline at the site is important for evaluating bedrock beneath the power block and establishing a correlation of bedrock between the power block and the ISFSI site. As discussed above and shown on cross sections B-B'', C-C', D-D', E-E', and F-F' (Figures 21-15 to 21-19), the western limb of the small syncline varies from steeply dipping (approximately 70 degrees northwest) across the southern part of the plant site area to gently dipping (approximately 30 degrees northwest) beneath the power block. This change in dip of the syncline across the plant site mirrors the change in dip described above across the ISFSI site area.

Based on the geometry of the syncline, bedrock beneath the power block consists of sandstone of Unit Tof_{b-2} underlain by the lower body of dolomite of Unit Tof_{b-1} (cross sections B-B'' and C-C', Figures 21-15 and 21-16, respectively). The power block is located on the same stratigraphic sequence that is exposed at the ISFSI site, but is approximately 400 feet lower in the stratigraphic section. As shown on cross section B-B'', boreholes drilled during foundation exploration for the power block encountered calcareous siltstone with abundant foraminifera. This description of the rock is very similar to the dolomite of Unit Tof_{b-1}; thus, we interpret the lower contact between Units Tof_{b-1} and Tof_{b-2} to be present beneath the power block area.

Folding at the site occurred during growth of the northwest-trending regional Pismo syncline in the Pliocene to early Quaternary (PG&E, 1988). The smaller folds at and near the ISFSI site area are parasitic secondary folds along the southwest limb of the larger Pismo syncline. Because of their structural association to the Pismo syncline, we infer that the folding at the site also occurred during the Pliocene to early Quaternary

(Figure 21-8). Some deformation may have accompanied the earlier Miocene diabase intrusions.

5.3.2 Faults

Numerous minor, bedrock faults occur within the ISFSI study area (Figures 21-1, 21-4, 21-32, and 21-33). Based on offset lithologic and bedding contacts, most of the faults show vertical separations of a few inches to a few feet. At least five faults show vertical separation of several tens of feet. Slickensides and mullions on the fault surfaces generally show strike slip to oblique strike slip displacement (Table 21-5; Figure 21-38).

The primary faults trend northwest, subparallel to the local fold axes (Figure 21-38). They dip steeply to near-vertical, generally 70 to 90 degrees, both northeast and southwest (Table 21-5). They consist of interconnecting and anastomosing strands, in zones up to 5 feet wide. The primary faults have documented lengths of tens of feet to a few hundred feet, and are spaced from several tens of feet to hundreds of feet apart across the ISFSI site area based on trench exposures and surface geologic mapping.

Secondary faults have variable trends and inclinations. They have very small displacements, generally less than a few inches. Some secondary faults splay off of the primary faults, or form part of the primary fault zone, such as in trench T-1 and T-17. Others are far from primary faults, such as those in trenches T-11A, B, C and D, T-14B and T-15.

The fault surfaces within bedrock vary from tightly bonded or cemented rock/rock surfaces, to relatively soft slickensided clay/rock and clay film contacts. Individual faults are narrow, ranging in width from less than an inch to about 2 feet. Fault zones contain broken and slickensided rock, intermixed clay and rock, and locally soft, sheared, clayey gouge. The thickness of fault gouge and breccia is variable along the faults.

Cross section B-B''' (Figure 21-15) shows the subsurface stratigraphy and structure beneath the ISFSI pads. As shown on the map (Figure 21-4) and cross section, five

minor faults clearly juxtapose the dolomite (Tof_{b-1}) against the sandstone (Tof_{b-2}) and truncate individual friable beds. Vertical separation across individual faults ranges from about 10 feet to greater than 50 feet based on displacements of friable beds and the contact between Units Tof_{b-1} and Tof_{b-2} . Total vertical separation across the entire fault zone exceeds 50 feet. As described previously, the contact between Units Tof_{b-1} and Tof_{b-2} beneath the pads is based on the first occurrence of medium to coarse-grained sandstone, and there is no evidence of significant facies interfingering between the two units beneath the pads that would obscure the amount of offset. Therefore, the interpretation of vertical separation of bedrock along the faults is given a relatively high degree of confidence.

Subhorizontal slickensides indicate that the minor faults in the ISFSI site area have predominantly strike slip displacement (Table 21-5, Figure 21-39). Using a typical range of 10-20 degree rake on the slickensides and the vertical separation, total fault displacement is estimated to be several tens to several hundreds of feet. The faults trend subparallel to the axis of the Pismo syncline and trend approximately 35 to 55 degrees more westward than the offshore Hosgri fault zone (Figure 21-38).

The faults at the ISFSI site area may be continuous with several other minor faults exhibiting similar characteristics exposed along strike in dolomite in the Diablo Creek roadcut about 800 feet to the north (Figures 21-1, 21-3, and 21-38). Given this correlation and the presence of several hundred feet of strike slip displacement, we infer that the faults may be at least several thousand feet long. However, the correlation between faults exposed within the ISFSI site and the roadcut along Diablo Creek, assumes that the slopes northwest of Diablo Creek are in place and have not been translated or rotated down slope as the result of landsliding. Although not conclusive, some geomorphic evidence suggests the presence of an ancient landslide in this area north of Diablo Creek. If the roadcut exposure is part of a landslide mass then the faults would not correlate to the same minor faults found in the ISFSI site area. Interpretation of pre-borrow excavation aerial photography shows that the faults are not geomorphically

expressed (Figure 21-40) and there is no evidence of displaced Quaternary deposits along the fault trace.

5.3.2.1 Fault Origin and Capability

The faults most likely formed during a period of regional transtensional deformation during the Miocene. This most easily explains the observed normal oblique slip on the fault zone. A transition to transpressional deformation occurred during the late Miocene to Pliocene and is well expressed in the offshore Santa Maria Basin and along the Hosgri fault zone (PG&E, 1988). The minor bedrock faults at the ISFSI site were subsequently rotated during the growth of the Pismo Syncline, although the faults occur near the flat-lying crest of a small parasitic anticline and, thus, have not been rotated significantly. Given this origin, the faults formed during the Miocene contemporaneous with the transtensional formation of Miocene basins along the south-central coast of California prior to 5 million years ago.

Alternatively, the minor faults may be secondary faults related to growth of the regional Pismo syncline (Figure 21-37), as concluded for the small bedrock faults at the power block (PG&E, 2000, p. 2.5-49, -50). As shown on Figure 21-31, the faults trend subparallel to the axis of the Pismo syncline, and are located near the crest of a small anticline on the southwestern limb of the syncline. The apparent oblique displacements observed on the faults may be related to bending-moment normal faults and right shear along the axial plane of the small anticline that formed in the Pliocene to early Quaternary. The zone of minor faulting may have used the area of diabase intrusion as an area of crustal weakness to accommodate tensional stresses along the axial plane of the anticline. As described in the FSAR (PG&E, 2000, p. 2.5-14, -33, -34) and in the LTSP reports (PG&E, 1988, p. 2-34 to -38; PG&E, 1991, p. 2-10), growth of the Pismo syncline and related folds ceased prior to 500,000 to 1,000,000 years ago. Thus, the observed minor faults also would have ceased activity prior to 500,000 to 1,000,000 years ago.

A third alternative explanation for origin of the minor bedrock faults is that they are related to intrusion of the diabase into the Obispo Formation. Diabase is present locally in the ISFSI study area. Forceful intrusion, or magmatic stoping of the diabase may have produced faulting in response to stresses induced by the magma intrusion in the adjacent host rock. Hydrothermal alteration is extensive in the diabase. The altered sandstone and dolomite in the ISFSI site area are spatially associated with the zone of faulting (Figures 21-4, 21-14), indicating that the faults may have acted as a conduit for hydrothermal solutions. Assuming the hydrothermal fluids were associated with the diabase intrusion, the minor faults predate, or are contemporaneous with, intrusion of the diabase. Diabase intrusion into the Obispo Formation occurred in the middle Miocene (Hall, 1973; Hall and others, 1979), indicating that the faulting would have occurred prior to or contemporaneous with the diabase intrusion in the middle Miocene over 10 million years ago. The faulting may have originated by transtensional regional deformation as described above, and then subsequently modified by diabase intrusion.

In addition to their probable origin related to transtensional deformation in the Miocene, or to growth of the Pismo syncline in the Pliocene to early Quaternary, or to intrusion of the diabase in the middle Miocene, several additional lines of evidence indicate that the minor faults are not capable and do not present a surface faulting hazard at the site:

1. As described in the LTSP Final Report (PG&E, 1988, p. 37 to 39, Plates 10 and 12) the Quaternary marine terrace sequence in the plant site vicinity is not deformed, providing direct stratigraphic and geomorphic evidence demonstrating the absence of capable faulting. The minor faults observed at the ISFSI site project northwest across, but do not visibly displace the lower marine terrace platform, within a limit of resolution of ± 5 feet indicating the absence of deformation in the last 120 thousand years. Assuming that the displacement does not die out at the coast, this resolution is enough to recognize the greater than 50 of feet of vertical separation on the faults at the ISFSI site. However, no displacement of the terrace sequence is observed.

2. As described in the DCPD FSAR (PG&E, 2000, p. 2.5-35 to -50, Figures 2.5-13 to -16), similar northwest-trending minor faults were mapped in bedrock in the power block area. Detailed trenching investigations of these faults and mapping of the power block excavation provide direct stratigraphic evidence that they do not displace and, hence, are older than the late Pleistocene (120,000 years old) marine terrace deposits. By analogy, the minor faults at the ISFSI site also would be older than late Pleistocene.

3. Interpretation of aerial photographs taken before the 1971 excavation of the ISFSI site area (former borrow area) and construction of the raw water reservoir (Figure 21-32), shows that there are no geomorphic features in the ISFSI site area (tonal lineaments, drainage anomalies, scarps, etc.) indicative of displacement of the minor faults prior to grading. The landscape in the ISFSI site area is interpreted to have formed in the middle to late Quaternary (about 430,000 years ago), based on the preserved remnants of marine terraces in the surrounding site area.

Based on these lines of evidence, the minor faults observed in bedrock at the ISFSI site are not capable, hence, there is no potential for surface faulting at the ISFSI site.

5.3.3 Bedrock Discontinuities

Extensive data on bedrock discontinuities (joints and faults) were collected from the 12 borings and 15 of the trenches within the ISFSI site area to assess their orientation, intensity, and spatial variability across the ISFSI site area. These data are presented in William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report F and summarized in Table 21-6. Rose diagrams summarizing trends of faults and joints are presented in Figure 21-41. The discontinuity data were used in both the kinematic slope stability analyses (Calculation Package GEO.DCPD.01.22) and the pseudostatic wedge stability analyses (Calculation Package GEO.DCPD.01.23).

Bedrock discontinuities include joints, faults, bedding, and fractures of unknown origin. These discontinuities, in particular joints, are pervasive throughout bedrock in the ISFSI

study area and along the transport route (Figure 21-41). Steeply dipping faults and joint sets are the dominant discontinuities, giving the rock mass a subvertical fabric. Random and poorly developed low-angle joints also occur subparallel to bedding. The fault discontinuities are described in Section 5.3.2. Joint discontinuities are described below.

Joint contacts vary from tight to partially tight to slightly open; joint surfaces are slightly smooth to rough, and have thin iron oxide or manganese coatings (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report H). Joint lengths in trenches and outcrops typically range from a few feet to about 20 feet, and typical joint spacings range from about ½-foot to 4 feet with an observed maximum spacing of about 14 feet (as summarized on Table F-6, William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report F). The intersections of various joints, faults, and bedding divide the bedrock into blocks generally 2 to 3 feet in dimension, but up to a maximum of about 14 feet. Rock blocks formed by intersecting joints larger than those described above generally are keyed into the rock mass by intact rock bridges or asperity interlocking. The largest expected “free” block in the rock mass is, therefore, estimated to be on the order of about 14 feet in maximum dimension.

Both the well cemented sandstone and the dolomite contain numerous joints. The jointing typically is confined to individual beds or group of beds, giving the bedrock a blocky appearance in outcrop. Joints are less well-developed and less frequent in the friable sandstone and friable dolomite. Linear zones of discoloration in the friable sandstone may represent former joints and small faults, but these zones are partially recemented, and not as frequent or obvious as joints in the harder rock.

The character of joints also differs between the upper, dilated zone of bedrock (generally within the upper 4 feet in the ISFSI study area, but conservatively estimated to extend to a maximum of 20 feet deep, particularly toward the edges of the old borrow cut where the amount of rock removed in 1971 is minimal) and the underlying zone of “tight” bedrock. Joints are generally tight to open in the upper zone. In the lower zone, the joints are tight and, in places, bonded and healed. This is well demonstrated in borehole optical

televiewer logs included in William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report E that show the joints are typically tight and/or partly bonded throughout the borings. Discontinuities in recovered rock core appear to be more open than observed in the optical televiewer logs, and appear to have undergone stress-relief dilation and mechanical disruption during coring and core extraction. In both zones, the joints are locally clay-filled, and commonly contain thin fillings of clay, calcite, dolomite, and locally, gypsum. Joints and fractures in the borings are very closely to widely spaced (less than 0.1-foot to 3-foot spacing), with local crushed areas between joints.

Plots of fracture orientation and density are shown on Figure 21-41. In preparing these rose diagrams (Figure 21-41), discontinuity data from trenches (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report F) were filtered to exclude bedding and to include only joints and faults. Data for the boreholes were taken from the optical televiewer (OPTV) image logs and the discontinuities identified by NORCAL (see William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report E). Each feature identified on the logs by NORCAL was examined in detail by one or more geologists familiar with the core from the borings, to determine if the feature represents a true structural discontinuity. In many cases, the feature appeared to be alteration, discoloration of the bedrock, or a feature with a poorly constrained or undetermined orientation. Only those features that were interpreted as structural discontinuities (i.e., joints or faults), and for which accurate orientations could be determined, were included in the data set for the rose plots. The discontinuities used in the rose plots are tabulated in Table 21-6.

Examination of Figure 21-41 shows that the discontinuity data display a spatial variability across the site, even between trenches and borings located relatively close to each other. Jointing likely developed during several phases of folding, faulting, and diabase intrusion. As a result, joints exhibit variable orientations and cross-cutting, intersecting relationships. In general, the discontinuities group into two broad sets: a west- to west-northwest-striking set (e.g., Trenches T-1, T-3) and a north-northwest-striking set (e.g., Trenches T-5, T-15). In some trenches, fractures from both sets are

present (e.g., Trenches T-6, T-14, T-19, while some show a much greater scatter in orientation (e.g., Trenches T-17 and T-18). In these cases, a general northwest-southeast striking orientation is apparent. The variation in orientation of the discontinuities with strata and locality across the ISFSI site documents that the joints are limited in continuity.

The general northwest-southeast striking character of the fractures in the ISFSI site area is consistent with both the overall northwest striking regional structural grain associated with the Hosgri fault system, and with the axis of the Pismo syncline and the local fold axes in the ISFSI site area, described above (Figure 21-38). Local variations in discontinuity orientations and intensity are attributed to rheological differences between dolomite and sandstone, and their friable zones, as well as proximity to the minor faults that cut across the site area and/or former zones of diabase intrusion.

5.4 Stratigraphy and Structure of the ISFSI Pads Foundation

Figure 21-42 shows the expected bedrock conditions that will be encountered in the ISFSI pads foundation excavation at the assumed pads subgrade elevation of 302 feet. The pads will be founded primarily on dolomitic sandstone of Unit Tof_{b-2} and dolomite of Unit Tof_{b-1} . Dolomitic sandstone generally underlies most of the site, while dolomite underlies the eastern end of the site. The proposed cutslopes above the site are generally underlain by dolomitic sandstone in the western and central parts of the cut and by dolomite in the upper and eastern parts of the cut.

Locally, friable sandstone (Tof_{b-2a}) and friable dolomite (Tof_{b-1a}) underlies the ISFSI pads foundation and the proposed cutslopes as shown on Figure 21-43. Because the zones are highly variable in thickness and continuity, their actual distribution likely will vary from that shown on Figure 21-42. In particular, a large body of friable dolomite underlies the southeast portion of the proposed cut slope. Other smaller occurrences of friable sandstone and dolomite are expected to be encountered in the excavation. These friable rocks locally have “dense soil-like” properties; thus, specific analyses were performed to determine the foundation properties and slope stability of these friable rock zones

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plates A-1 to A-19), describe bedrock as tan and gray silty sandstone and tuffaceous sandstone (Figures 21-15 and 21-16). These rocks are moderately hard and moderately strong. The rock strata underlying this slope dip into the hillside and correlate with the sandstone and dolomite strata exposed on the west flank of the ridge (and west limb of the syncline) that are exposed in roadcuts along Reservoir Road south of the ISFSI site (Figures 21-1, 21-3 and 21-15) and in the deeper part of the borings at the ISFSI site.

3. **Shear Wave Velocity.** Shear wave velocity data from the various investigations at the power block are summarized on Table 21-7, and Figures 21-43 and 21-44. Velocity data in Figure 21-43 are from borehole surveys at the ISFSI site (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report C) and comparative velocities at the power block in Figure 21-44 are from the FSAR. Shear-wave velocities from surface refraction and borehole geophysical surveys at the ISFSI site are within the same range as those obtained at the power block (Figure 21-45). The velocity profiles at both sites are similar to one another and are consistent with the “rock” classification for purposes of ground motion estimation (Abrahamson and Shedlock, 1997).

5.7 Parameters Recommended for Stability Analysis

An analysis of slope stability is presented in Calculation packages GEO.DCPP.01.24 to GEO.DCPP.01.26. The following physical and stratigraphic descriptions and parameters provided the basis for these analyses.

5.7.1 Pre-Existing Landslides in Diablo Canyon Near the ISFSI site

Large, deep-seated landslide complexes exhibiting geomorphically well-expressed headscarps are present on the south slopes of Diablo Canyon near the ISFSI site, and south of the 230 kV and 500 kV switchyards (Figure 21-1). The complex lies entirely east of the ISFSI site, and does not encroach, undermine, or otherwise affect the ISFSI. These landslides consist of large (exceeding 100 acres), deep-seated, coalescing slides

that have failed within colluvium, and Tof_a and Tof_b bedrock on the north limb of an anticline (Section 5.3.1). The dip of the bedrock bedding in the vicinity of the slide complex is consistently to the north and downslope at moderately steep dip angles. This condition suggests that the failure planes for these slides probably are either at the contact between bedrock and overlying weathered bedrock, or within the bedrock along bedding planes, clay beds, or locally weaker diabase beds. In contrast, bedding dip directions at the ISFSI site are variable, and, where locally dipping out-of-slope, are at more-gentle dip inclinations than in the area of the old landslide complex to the east.

Although the overall shape of the landslide complex is well-expressed geomorphically, the landslide deposits have been modified and subdued by erosion. Thin stream-terrace deposits and remnants of a 430,000-year-old marine terrace at elevation 290 ±5 feet appear to have been cut into the toes of the some of the slides. These relations suggest that the landslides are old and likely formed in a wetter climate during the middle to late Pleistocene. The older landslide masses appear to have reached a stable configuration under the present climatic and topographic setting, and are partially buttressed by the large 500 kV switchyard fill that spans the canyon. There is no geomorphic evidence of large-scale Holocene movement, and the switchyard shows evidence of no post-construction slope movement. Localized, more-recent and shallower slides have formed within the old landslide complex, and appear to involve previously-disturbed slide materials.

The slide complex is separated from the ISFSI site by a low spur ridge that is along the trend of the anticlinal axis, and which is underlain by stable bedrock that shows no evidence of past slide activity on pre-and post-borrow excavation aerial photographs. Field mapping, subsurface exploration, and aerial photograph analyses during the ISFSI site investigations confirmed the absence of deep-seated bedrock slides at the site. Additionally, no stability problems were encountered during the 1971 borrow excavation using bulldozers and scrapers, and the slope has been stable since the 1971 excavation. The Raw Water Reservoir and Reservoir Road below the ISFSI site show no evidence of post-construction slope movements.

A former small, shallow landslide in colluvium existed at the ISFSI site prior to the 1971 borrow excavation, and is shown on Figure 21-40. This slide is apparent on the pre-excavation 1968 aerial photographs, and is expressed by a subtle, arcuate headscarp, hummocky landslide, and locally thicker vegetation probably reflecting high soil moisture within the slide debris (Figure 21-40). The slide was located in a slight swale in colluvial soils and possibly weathered bedrock that mantled the slope prior to excavation. The slide mass appears to have moved northeast along the axis of the swale, and oblique to the downdip direction of bedrock bedding. This suggests that the slide was not controlled by bedrock structure. This slide was investigated by Harding -Miller-Lawson Associates (HML, 1968), and was shown to be a shallow failure within colluvium, and possibly extending into the uppermost weathered bedrock (Cross Section A-A', Figure 21-14). This shallow slide was completely removed, along with colluvium and the surficial weathered rock zone, during the 1971 borrow excavation (Figure 21-14).

5.7.2 Clay Bed Strength

The strength of the clay in the clay beds was tested in the laboratory (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report G). However, the overall strength of the clay bed during sliding also is a function of the clay bed thickness, rock asperities along the clay surface, and the amplitude of irregularities or undulations on the clay surface relative to the clay thickness. Clay beds greater than ¼- to ½-inch thick potentially have limited or locally no rock to rock contact and the clay thickness may exceed the amplitude of bedding surface undulations. Thus, clay beds thicker than ¼-inch should be modeled in the stability analysis using the shear strength of the clay, and are differentiated on the cross sections. In addition, disruptions of the clay beds by joints and minor faults also will tend to resist sliding and increase the effective strength of the clay bed. The thinner beds likely exhibit shear strength greater than that of the clay due to partial rock-to-rock contacts and asperities projecting through the clay. The strength of clay beds less than <¼-inch can be approximated by a combination of rock-to-rock and rock-to-clay strength.

5.7.3 Geometry and Structure of Slide Mass Models

Cross section I-I' (Figure 21-22) parallels the most likely direction of potential slope failure and illustrates the geometry of bedding in the ISFSI study area for analysis of slope stability. The cross section shows apparent dips, and the facies variation and interfingering of beds between Units Tof_{b-1} and Tof_{b-2} beneath the slope. Lateral continuity of clay beds is approximated by the relative lengths and line weights as described above in Section 4.3. The clay beds are correlated based on stratigraphic position, projection of known bedding attitudes, and superposition of sandstone and dolomite beds (i.e., we do not allow clay beds to cross cut dolomite or sandstone beds, but allow them to cross the facies change). These clay beds, as drawn, are a reasonably conservative interpretation of their lateral continuity for the analysis of the global stability of the slope.

The geometry of the folds underlying the ISFSI study area influences the potential for rock slides in the slope. As illustrated on Figures 21-3 and 21-4, the small, tightly folded, en echelon syncline at the top of the ridge above the ISFSI site transitions into a monocline above Boring 01-I. This monocline transitions into a broad syncline farther down the slope near Boring 00BA-1. The approximate locations of these transitions are indicated on cross section I-I' (Figure 21-22), but the apparent dips shown in the cross sections at the transition locations do not change because the section azimuth is subparallel to the fold axes and the direction of strata flexure is into the section. The three-dimensional change in strata geometry across these transitions will tend to disrupt and limit potential rock slides because the dip directions of the clay beds change across the transitions.

In addition, the dip of the clay beds in the upper slope above Boring 00BA-1 dip out of the slope and are parallel to the downslope direction. Lower down on the slope (at the ISFSI pads and cutslope) the beds dip westerly. This change in geometry reduces the potential for large rock slides on clay beds on the lower part of the slope compared to the slope above 00BA-1.

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Model 3 is segmented into three sub-blocks: 3a, 3b, and 3c. The three blocks daylight in the proposed ISFSI pad cutslope, or at the junction between the ISFSI pad and base of the cutslope (Figure 21-48). All three modeled blocks have basal slide surfaces along clay beds encountered in borings 01-F, and /or 00BA-1 and 01-I. Models 3a and 3b have headscarp/tension break-up zones at the structural change in bedding strike (dip direction) described previously for model 2a (3a and 3b), or about 75 feet above the top of the borrow cut (3c) at an inferred maximum uphill extent of clay beds encountered in borings 01-I.

The toe daylight geometry reflects the propensity for failure planes to break out along bedding planes and along the projection of clay beds. The rock mass is inferred to exhibit anisotropic strength, with a lower shear strength along and parallel to bedding planes, than across bedding planes for toe shear failure. In contrast, the geometry of the headscarp-tension failure is inferred to be controlled by the dominant steep (greater than 70 degrees) joint/fault fabric in the rock mass that should control tensional failure/separation.

5.7.5 Estimate of Potential Slide Mass Displacement

Potential slide mass displacement can be constrained, in part, by past performance of the hillslope above the ISFSI site. As described below, the topographic ridge upon which the ISFSI site is located has been stable for the past 430,000 years or more. A back analysis of slope stability, therefore, provides constraints on the minimum shear strength and/or lateral continuity of the clay beds used in the analysis and a check on the conservatism of the assumptions used to analyze the stability of the proposed ISFSI site cutslopes and hillslope above the site.

Geomorphic and geologic data from mapping and trenching in the ISFSI Site Area provide evidence documenting the absence of past movements of large rock masses on the slope above the ISFSI. Analysis of pre-construction air photos shows no features indicative of such landslides: no arcuate scarps, no vegetation lineaments indicative of filled fissures, and no textural differences in the rock exposures or slopes indicative of a

broken rock mass in the ISFSI study area (Figure 21-41) (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report A). Similarly, the many trenches and exploratory borings on the slope, the tower access road cuts, and the extensive outcrops exposed by the 1971 borrow cut did not expose tension cracks or fissure fills on the hillslope (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Reports A, B and D). Open cracks or soil-filled fissures greater than 1 to 2 feet in width should be easily recognized across the slope given the extensive rock exposure provided by the borrow cut. Therefore, we conservatively assume that any cumulative displacement in the slope greater than 3 feet would have produced features that would be evident in rock slope. The absence of this evidence places a maximum threshold of 3 feet on the amount of cumulative slope displacement that may have occurred in the geologic past.

The hillslope at the ISFSI site is older than at least 430,000 years because remnants of the Q-5 (430,000 yrs) marine terrace are cut into the slope west of the ISFSI site (Figure 21-3). Preservation of the terrace documents that the slope has had minimal erosion since that time. Moreover, gradual reduction of the ridge by erosion at the ISFSI site would not destroy deep tension cracks or deep disruption of the rock mass; these features would be preserved as filled fractures and fissures even as the slope is lowered.

The topographic ridge upon which the ISFSI site is located is presumed to have experienced strong ground shaking from numerous earthquakes on the Hosgri fault zone during the past 430,000 years. PG&E (1988, p. 3-39) provides a recurrence interval of 11,350 years for an M_w 7.2 earthquake on the Hosgri fault. Therefore, approximately 35 to 40 large earthquakes have occurred during the past 430,000 years without causing ground motions large enough to produce significant (i.e., greater than 3 feet) cumulative slope displacement. Based on the absence of cumulative slope displacement within a limit of resolution of 3 feet, the amount of possible slope displacement during the Hosgri design earthquake is a maximum of 3 feet if produced by one earthquake with very large ground motions, or, more likely about 3 to 6 inches per event if produced by multiple earthquakes with large ground motions for a cumulative displacement of up to 3 feet. Slope displacement of 3 to 6 inches, therefore, can be used as a constraint in a "back

calculation" to assess overall rock mass strength and from that to estimate the strength of clay beds under natural slope conditions (i.e., conditions prior to the 1971 excavation of the borrow area). This back calculated strength can then be used to model potential displacements of rock slide masses in the current borrow-cut condition. This is described in Calculation Package GEO.DCPP.01.24.

5.7.6 Rock Block Dimensions

The size of potential wedge block failures in the ISFSI cutslope will be controlled, in part, by the spacing, continuity and shear strength of discontinuities in the rock mass. Both the dolomite (Unit Tof_{b-1}) and sandstone (Unit Tof_{b-2}) bedrock at the site are jointed and faulted. Joints and faults in friable dolomite and friable sandstone are less well-developed and do not control the mechanical behavior of the soil-like rock. Rather, the rock strength appears to be controlled primarily by the cementation properties of the rock.

Field data on the discontinuities (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data Report F) show that two primary joint sets are present as discussed above. The orientation of these joint sets varies somewhat across the site (Figure 21-41), but generally group into a west- to west-northwest-striking set and a north-northwest- to north-striking set. The joints are continuous for a few feet to about 20 feet, and commonly die out or terminate at subhorizontal bedding contacts. Field observations from surface exposures and trenches show that the joints commonly are slightly open or dilated in the upper 4 feet, probably due the stress unloading from the 1971 borrow excavation and/or surface weathering. Dilation of the joints reduces the shear strength of the discontinuity. To be conservative, we assume that the zone of near-surface dilation extends to a depth of 20 feet on the ISFSI cutslope. The Barton method is used to estimate the reduced shear strength on these discontinuities as described in Calculation Package GEO.DCPP.01.20.

Joints in the dolomite typically are spaced about ½-foot to 4 feet apart and divide the rock mass into blocks with average dimension of 2 to 3 feet with typical maximum dimensions of about 14 feet (William Lettis & Associates, Inc. (2001) Diablo Canyon ISFSI Data

Report F, Table F-6). We anticipate that the maximum block size will be less than 14 feet in dimension, and conservatively assume a maximum block size of 20 feet in the wedge block stability analysis (Calculation Package GEO.DCPP.01.23). This larger dimension conservatively allows for multiple-block wedges to form in the cutslope.

6.0 RESULTS

The results of the stratigraphic and structural analysis are presented on the geologic maps (Figures 21-1, 21-3, 21-4), a stratigraphic column (Figure 21-5), twelve cross sections (Figures 21-13 to 21-24), and a map of geologic conditions at the ISFSI and CTF foundation grade (Figure 21-42). This information was used to interpret the depositional and structural history of bedrock in the ISFSI study area and along the transport route (Figure 21-7). The results of this calculation package also provide important information used to evaluate the stability of cutslopes at the ISFSI site, the hillslope above the ISFSI site, and slopes above the transport route (Calculation packages GEO.DCPP.01.08, .22, .23, .24 and .28), and to characterize the foundation conditions at the ISFSI pads and cutslope (Calculation packages GEO.DCPP.01.03, .04 and .06).

7.0 SOFTWARE

The software program "DIPS" (Rocscience, 1999) was used to compile and analyze the structural continuity data presented on Figures 21-38 and 21-40. The DIPS program is documented and verified in Calculation package GEO.DCPP.01.22 "Kinematic stability analyses for cutslope at DCPD ISFSI site".

No other software programs were used in this calculation package.

8.0 CONCLUSIONS

This calculation package provides an analysis of the stratigraphic and structural geology of the plant site area (Figure 21-1), transport route (Figure 21-3), and the ISFSI study area (Figure 21-4). Interpreted cross sections and structural maps developed as a result of these analyses are used to characterize the ISFSI pads foundation properties, to evaluate slope stability of the existing hillside and proposed cutslopes above the ISFSI pads and along the transport route, and to understand subsurface bedrock conditions for use in evaluating ground motion site response.

Figure 21-42 shows the bedrock conditions expected at the ISFSI pads and CTF foundation grade levels. The ISFSI pads will be founded primarily on dolomitic sandstone of Unit Tof_{b-2} with dolomite of Unit Tof_{b-1} in the easternmost part of the site. Locally, friable sandstone and friable dolomite will be encountered beneath the ISFSI pads foundation. The proposed cutslopes above the site will be underlain by sandstone and dolomite, and by a large body of friable dolomite in the eastern part of the cutslope. At least two clay beds will daylight within the ISFSI pads foundation. Other clay beds may be encountered in the foundation excavation and in the cutslopes. The CTF will be founded on dolomitic sandstone of Unit Tof_{b-2} and friable sandstone of Unit Tof_{b-2a} .

Bedrock beneath the ISFSI and CTF sites is part of the same stratigraphic sequence that underlies the DCPD power block. Cross section B-B''' (Figure 21-15) illustrates the location of the ISFSI site and power block relative to the stratigraphic sequence. Bedrock encountered in boreholes at the ISFSI site and during site investigations for the power block (PG&E, 2000, Section 2.5.1.2.5.6) have similar lithology and shear wave velocities (Figure 21-45). The bedrock characteristics and velocity profiles at both sites are consistent with the "rock" classification of Abrahamson and Shedlock (1997).

Stratigraphic and structural information developed in this calculation package provide basic geologic information for the analysis of slope stability for the ISFSI pads cutslopes,

Security-Related Information – Withhold Under 10 CFR 2.390.

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Geosciences Calculation packages

GEO.DCPP.01.01 Development of Young's Modulus and Poisson's ratios for DCPD ISFSI based on field data

- GEO.DCPP.01.02 Determination of probabilistically reduced peak bedrock accelerations for DCPD ISFSI transporter stability analyses
- GEO.DCPP.01.03 Development of allowable bearing capacity for DCPD ISFSI pad and CTF stability analyses
- GEO.DCPP.01.04 Methodology for determining sliding resistance along base of DCPD ISFSI pad
- GEO.DCPP.01.06 Development of lateral bearing capacity for DCPD CTF stability analyses
- GEO.DCPP.01.07 Development of coefficient of subgrade reaction for DCPD ISFSI pad stability checks
- GEO.DCPP.01.08 Determination of rock anchor design parameters for DCPD ISFSI cutslope and CTF guy lines
- GEO.DCPP.01.11 Development of DCPD ISFSI horizontal and vertical spectra
- GEO.DCPP.01.15 Development of Young's Modulus and Poisson's ratio values for DCPD ISFSI based on laboratory data
- GEO.DCPP.01.19 Development of Strength Envelopes for jointed rock mass at DCPD ISFSI using Hoek-Brown equation
- GEO.DCPP.01.20 Development of strength envelopes for shallow discontinuities at DCPD ISFSI using Barton equations
- GEO.DCPP.01.22 Kinematic stability analysis for cut slopes at DCPD ISFSI site
- GEO.DCPP.01.23 Pseudostatic wedge analysis of DCPD ISFSI cutslope (SWEDGE analysis)
- GEO.DCPP.01.24 Stability and yield acceleration analysis of cross section I-I'
- GEO.DCPP.01.25 Determination of seismic coefficient time histories for potential sliding masses along cut slope behind ISFSI pad
- GEO.DCPP.01.26 Determination of earthquake-induced displacements of potential sliding masses on DCPD ISFSI slope
- GEO.DCPP.01.28 Stability and yield acceleration analysis of potential sliding masses along DCPD ISFSI transport route
- GEO.DCPP.01.29 Determination of seismic coefficient time histories for potential sliding masses on DCPD ISFSI transport route

**Table 21-1 Interpretation of Bedding in Boreholes,
ISFSI Study Area****Boring 00BA-1**

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televiwer Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|--|---|--|--|--|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 23.0- 23.2 | Four joints with thin clay coatings (altered zone) | 23.1 | Moderately steep joint and thin clay (?) bed, 295°, 9° (fair) | Not checked | N25°E 9°NW |
| 34.0- 38.0 | Dolomite to dolomitic sandstone, laminated bedding, dips 0° | 34.0- 38.0 | Massive rock with laminations, slightly etched surface at 36.9, 225°, 14° (good) | Clear bedding laminations, dips 11°, azimuth 224 measured from dip direction in televiwer | N45°W, 14°SW |
| 39.0 | Dolomite to dolomitic sandstone, laminated bedding, 0° dip | 38.1 | Slightly etched surface in massive rock with laminations 220°, 10° (good) | Excellent bedding, 10° | N50°W, 10°SW |
| 45.0- 48.5 | Dolomitic sandstone, laminated bedding, dips 0-7° | 45.2 | Color lamination in massive rock, 185°, 15° (fair) | Well defined parting surface at 48.8 feet along bedding, with fossils on bedding up to 0.2 inches, dips 10° | N85°W, 10°S |
| 55.6- 56.3 | Clay seam (0.7 foot) with planar rock contacts, bedding top dips 5°, bottom dips 5° | 54.9- 56.2 | Clay bed with sharp, tight rock contacts, etched, 188°, 20° (N) Remeasured dips: (good) top 11°, bottom 16° (good) | Core not available; removed for testing | N82°W, 11-16°S |
| 59.0- 61.0 | Dolomitic sandstone, bedding (?) at 59.7 dips 10° | 57.0- 60.5 | Hard rock with steep to moderately steep fractures, vague laminations | Good bedding at 59.7 feet, dips 16-18°, azimuth of 228° measured from fracture orientation (good) | N42°W, 16°SW |
| 79.5 | Stiff, silty clay seam (1/8-inch) on joint, dips 10° | 79.2 | Possible thin clay along bedding or joint, etched below 331°, 12° (N) Checked dip: 11° (fair) | 2-4 mm clay bed dips 16° | N61°E, 11-16°NW |
| 105.4 | Clay seam (1/4 inch) along fracture, dips 15° | 105.0- 105.3 | Clay seam, etched, sharp irregular top, smooth bottom contact, 257°, 12° (N) (good) | No clay found in core; appears that clay washed out during drilling | N13°W, 12°SW |
| 106.5 | Silty clay (1/8-1/4 inch), joint, dips 10° | 106.4 | Tight bedding with discoloration 248-253° (N), 17-18° (N) (fair) | Not checked | N20°W, 18°SW (?) |
| 140.0- 141.0 | Sandstone, changes to laminations @ 140.9 | 140.4 | Thin clay (?) bed, partly etched, 260°, 4° (fair) | Thin clay bed between runs, dips ~9°; not accurate | N10°W, 4°SW |

**Table 21-1. Interpretation of Bedding in Boreholes,
ISFSI Study Area (continued)****Boring 00BA-2**

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televue Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|---|--------------------------|--|--------------------------|-------------------------------|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 00.0 – 55.0 | No bedding recognized | | No bedding recognized | No bedding recognized | |

Boring 01CTF-A

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televue Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|---|---|--|--|--|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 8.0- 9.4 | Coarse to fine grained sandstone | 8.8-8.9 | Two subhorizontal, slightly open to etched partings on bedding (?), lower parting 217°, 6° (N) (poor to fair) | Core not available; removed for testing | N53°W, 6°SW (?) |
| 12.4 | Fine grained to coarse grained sandstone | 12.4- 12.6 | Two subhorizontal, slightly open to etched partings on bedding (?), upper parting 178°, 7° (N) (poor to fair) | Broken sandstone | N88°E, 7°S (?) |
| 32.4- 32.6 | Soft clayey sand, bedding (?), dips 30°? | 32.7- 33.5 | Soft clayey (?) zone, etched, irregular contacts, attitude not evident on image. | Core not available; removed for testing | ?? |

**Table 21-1. Interpretation of Bedding in Boreholes,
ISFSI Study Area (continued)**

Boring 01-A

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televiewer Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|---|--|---|--|---|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 37.7- 37.8 | Two clay (1 mm) coatings on joints, dips 20-30° | 36.7 | Low to moderate dipping joint or bedding (?), etched 224, 27, (N) remeasured orientation 230°, 20° (fair to good) | Not checked | N40°W, 20°SW |
| 42.1 | Sandstone, no recovery | 41.0- 41.1 | Textural change, etched, bedding (?) with clay (?) 251°, 23° (good) | Not checked | N19°W, 23°W |
| 54.9 | Silty clay with sand and gravel (1 inch), bedding (?) dips 20° | 54.1- 54.3 | Low-angle bedding with textural change, etched and eroded, 1/2- to 1-inch clay bed (?) 021°, 7° (N) | Could not confirm orientation, but modified pick appears reasonable | N69°E, 7°NE |
| 55.8 | Faults with thin clay coatings, slickensides, dips 8-20° | 55.3 | Bedding (?), etched, with thin clay (?) bed 226, 27°, (N) remeasured dip 20°, 27° (fair) | Not checked | N44W, 23°SW |
| 58.8 | 1 cm clay layer, dips 20° | 58.5 | Subhorizontal clay layer, eroded and etched, irregular, 1/4- 1/2 inch thick, bottom 259°, 22° (N) (fair) | Not checked | N11°W, 22°W |
| 63.0- 66.0 | Fine grained dolomitic sandstone | 64.7 | Slightly etched bedding (?) in massive rock with broad color laminations 256°, 12° (N) (good) | Bedding surface in core dips at 11° | N14°W, 11° W |

**Table 21-1. Interpretation of Bedding in Boreholes,
ISFSI Study Area (continued)****Boring 01-B**

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televue Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|---|---|--|---|--|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 25.0- 27.0 | Medium grained sandstone, joint at 26.2 dips 0° | 26.1 | Tight bedding plane (?), slightly etched, in zone of vague color laminations 325°, 9° (N) (fair) | Not checked | N55°E, 9°NW |
| 32.5 | Medium grained dolomitic sandstone | 32.0- 32.2 | Possible bedding, etched to partly open, 258°, 22° (N) remeasured 260°, 5° (N) (fair) | Two good laminations within coarser rock, azimuth, ~N50°W, dip 10-15° | N10°W, 10°SW |
| 37.7 | Gradational contact between medium to coarse grained sandstone, dip not indicated | 37.0 | Sharp textural change from hard fractured rock to massive etched rock, bedding, 276°, 7° (N) (good) | Not checked | N6E, 7°W |

Boring 01-C

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televue Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|---|--------------------------------------|--|--|---|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 13.0- 14.0 | Sandstone, medium to fine grained | 13.8 | Bedding, etched, 221°, 13° (N) (fair) | Not checked | N49°W, 13°SW |
| 16.3 | Clay film on joint, dips 15° | 15.9 (?) | Low-angle bedding, etched, with clay (?) (~1/8 inch) 197°, 15° (N) (good) | Surface in core not confirmed as bedding, dips 16-17° | N73°W, 15°S |
| 23.8 | Joint, dips 5° | 23.7- 23.8 | Bedding, etched, with clay (?) (~1/4 inch) 228°, 10° (N) Remeasured orientation: ~204°, 15° (fair to good) | Core not available; removed for testing | N66°W, 15° SW |

**Table 21-1. Interpretation of Bedding in Boreholes,
ISFSI Study Area (continued)**

Boring 01-D

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televiwer Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|---|---|--|--|--|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 36.0- 39.0 | Fine to medium grained sandstone with crushed zones, joints dip 0° and steeply | 36.9- 37.1 | Two subhorizontal fractures, open and in part tight, bedding (?), bottom 290°, 5° (N) (fair) | Not checked | N20°E 5°NW |
| 55.0- 55.5 | Crushed zone with clay, joint at 55.2 | 53.4- 54.9 | Eroded and etched zone (clayey?), rough bedding (?) at base 057°, 11° (N) (good) | Sandstone layers and contact with dolomite dip 10° | N33°W, 11°NE |

Boring 01-E

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televiwer Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|---|--|--|---|---|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 46.5- 48.0 | Sandy dolomite to dolomitic sandstone; horizontal to subhorizontal laminar banding | 46.5- 48.0 | Unfractured, hard rock, weak laminations | Irregular bedding laminations at 47.5 feet, 090°, dip 8° measured from fracture orientation on televiwer (good) | NS, 8°E |
| 48.0 | (same as above) | 48.0 | Top of thin (0.1 feet) dark bed (clay?), 332°, 17 (N) remeasured ~330°, 10° (fair) | Core not available; removed for testing | N60°E, 10°NW(?) |
| 48.8 | (same as above) | 48.8 | Bottom of moderately dark bed (0.7 feet), parallels the base of the dark bed at 48.1 feet 360°, 4° (fair to good) | Core not available; removed for testing. But @ 50.5 feet bedding laminations in core dip 3° | EW, 3°N |

**Table 21-1. Interpretation of Bedding in Boreholes,
ISFSI Study Area (continued)****Boring 01-F**

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televue Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|---|---|--|---|--|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 6.8 | Clay film (<1/16 inch), joint, dips 20° | 6.6 | Partly open joint with thin clay (?), shallow bedding (?) 200°, 9° (fair) | Not checked | N70°W, 9°SW |
| 94.3- 94.4 | Clayey, silty crushed rock with clay bed (0.5-1 cm thick (¼-½ in)) dips 0-10° | 93.2 | Subhorizontal joint along bedding with 1/4 inch clay (?), etched 180°, 15° (N) (good) | Thick clay (1/4- 1/2 inch) over 1/4-inch- thick, white, moderately- soft calcite vein at 94.8 feet, dips 14° | EW, 14°S |
| 117.0 | Clay layer (1 cm), bedding (?) dips 8-12° | 116.4 | Subhorizontal bedding, etched, possible thin clay (~1/8 inch) 200°, 5° (N) Remeasured dip: 6° (good) | Core not available; removed for testing | N70°W, 6-12°SW |

Boring 01-G

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televue Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|---|--|--|--|--|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 18.7 | Clay seam (1/2-3/4 inch) above broken rock zone on bedding (?), top horizontal, bottom dips 0-5° | 18.5 | Subhorizontal, tight bedding laminations possible thin (<1/4 inch) clay (?), 245-251°, 11-14° (N) average 248°, 13° (N) (fair to good) | Core not available; removed for testing | N22°W, 13°SW |
| 25.4 | Joint with clay coatings (<0.5 inch), dips 0-15° | 25.0 | subhorizontal bedding, tight with thin clay (?) (<1/8 inch), 192, 15 (N) (fair) | Not checked | N78°W, 15°S |
| 29.1 | Joint with very thin film, dips 0° | 28.8 | Bedding (?), partly broken out in zone of massive rock ~210, 12° (fair) | Not checked | N60°W, 12°SW |
| 56.3 | Clayey fracture zone parallel to laminations, laminations dip 0-10° | 55.8- 57.5 | Steep joints and broken rock, localized clay (up to ~1/2 inch) on joint | Red brown laminations dip 5-8° | Unknown strike, dips 5-8° |

**Table 21-1. Interpretation of Bedding in Boreholes,
ISFSI Study Area (continued)**

Boring 01-H

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televiewer Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|---|--|---|---|---|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 39.4 | Two very thin clay layers between fracture blocks dip 30° | 39.4- 41.2 | Subhorizontal bedding, slightly etched, with thin clay (?), 253-284, 2-4° (N) Remeasured orientation on clay bed at 41.2 feet: ~240°, 5° (fair) | Three thin clay beds, dip 15° | N30°W, 15°SW |
| 58.7 | Fine to medium grained dolomitic sandstone, @ 58.9 feet clay layer, 0.01 feet thick on 'joint' dips 10° | 58.7 | Thin bed 211, 13° (N) (fair) | Not evident in core. | N59°W, 13°SW |
| 82.3 | Clay seam (0.05 feet thick) on joint, dips 0° | 81.4 | Subhorizontal bedding laminations, tight, no clay evident, 225, 12° (N) (fair) | Not checked | N45°W, 12°SW |
| 89.6 | Sandstone | 88.8 | Bedding, textural change 203, 1-1° (N) (fair to good) | 2 mm clay bed twisted by drilling | N67°W, 11°SW |
| 94.5 | Dark gray clay layer (0.2 inch), dips 10-30° | 93.6 | Subhorizontal bedding, eroded with clay (?) 202, 2° (N) Remeasured: 232°, 21° (good) | Highly fractured, clay layer not found | N38°W, 21°SW |

**Table 21-1. Interpretation of Bedding in Boreholes,
ISFSI Study Area (continued)****Boring 01-I**

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televiwer Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|---|---|--|---|---|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 33.9 | Clay film (1/16 inch) on bedding, joint (?), dips 10° | 34.9 | Subhorizontal lamination, tight to partly eroded bedding, 309°, 6° (N) (good) | Not checked | N39°E, 6°NW |
| 43.1 | Clay on joint (1/4 inch), dips 20° | 43.4- 43.6 | Thin clay, eroded and etched along bedding(?), 325°, 18° (N) (good) | Not checked | N55°E, 18°NW |
| 45.6 | Clay bed (2 cm), dips 10-15° | 46.2 | Well imaged thin clay, etched, bedding parallel, 324°, 14° (N) (good) | Not checked | N54°E, 14°NW |
| 48.1 | Clay seam (1 cm) on joint associated with CaCO ₃ vein, dips 10- 20° | 48.8 | Subhorizontal joint/clay seam (1/4-1/2 inch), etched, 320°, 13° (N) (good) | Not checked | N50°E, 13°NW |
| 57.2 | Sandy crushed zone | 57.6- 57.9 | Subhorizontal, planar opening along eroded soft rock zone (1/2 to 1 inch); thin clay (?) along base, bedding, near bottom of clay bed 295°, 8° (N) (fair to good) | Crushed zone, remnant bedding dips 15° | N25°E, 8-15°NW |
| 86.0- 87.0 | Dolomitic sandstone, laminations dip 12-20° | 86.8- 88.5 | Clear laminations in hard rock, near vertical fracture | Bedding laminations dip 15°, azimuth of 285° measured using fracture orientation (good) | N15°E, 15°W |
| 89.5- 89.8 | Dolomitic sandstone | 89.2- 90.7 | Clear lithologic banding in unjointed, hard rock 276, 18° (N) 285, 20° (N) (fair) | Bedding laminations dip 13-14° | N15°E, 14°W |

**Table 21-1. Interpretation of Bedding in Boreholes,
ISFSI Study Area (continued)****Boring 01-I (continued)**

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televewer Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|---|--|--|--|---|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 102.0- 105.0 | Very fine grained to fine grained dolomitic sandstone, well defined laminations | 102.0- 105.0 | Hard rock with laminations and two near vertical fractures, at 103.7 315°, 11° | Laminations dip 13° (fair to good) | N45°E, 13°NW |
| 106.6 | Clayey/silty/sand seam (2 cm), bedding, dips 10-12° | 106.4 | Subhorizontal clayey seam (1 to 2 inches thick), eroded and etched along bedding top 266°, 16° (N) bottom 251°, 17° (N) (good) | Clay bed not found in core, but bedding laminations one foot above and below dip 12- 14° | N19°W, 12-14°W |
| 123.8- 124.0 | Clayey sandstone bed above coarse, 0.1-foot- thick sandstone bed, dips 10-20° | 124.1 | Irregular bedding contact between broken rock and soft, granular rock, eroded, 044°, 16° (N) (fair) | Not checked | N46°W, 16°NE |
| 130.3 | Stiff clay seam (1/2-1 cm) along bedding, dips 10° | 130.8 | Bedding with clay (?) slightly etched, 102°, 3° (N) (fair) | Not checked | N12°E, 3E |
| 131.0 | Joint with clay, dips 20° | 131.6 | Bedding with thin clay, subhorizontal, 171°, 8° (N) (good) | Not checked | N81°E, 8°S |
| 156.1 | Shaley seam (1/4 inch) with slickensides along bedding contact, dips 15-18 | 156.5- 156.8 | Softer rock zone, eroded and etched, subhorizontal, possible clay at base of zone, bedding, 335°, 12° (N) (good) | Bottom of clay bed washed out during drilling. | N65°E, 12-18°NW |
| 171.0- 171.2 | Crushed zone with silty clay in joint (1/8 inch), possible slough at bottom, dips 10° | 170.0- 173.0 | Clear laminations and steep, partly open joints with clay (?), 285°, 12° (N) (good) | Bedding dips 12°, at 170.5 feet azimuth of ~294° measured using fracture orientation | N20°E, 12°NW |
| 172.5- 173.1 | Dolomitic sandstone, laminations dip 10-12° | 171.0- 173.5 | Clear lithologic banding and near vertical joint 272-285° (N), 11-12°(N) | Bedding on two beds, dips 11°, 15° (azimuth measured using fracture orientation confirms strike in televewer) | N15°E, 11°W |

**Table 21-1. Interpretation of Bedding in Boreholes,
ISFSI Study Area (continued)**

Boring 01-I (continued)

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televiwer Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|---|---|--|--|--|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 173.8- 175.0 | Dolomitic sandstone, thick laminations dip ~10° | 173.5- 176.6 | Clear fine lithologic banding, typical: 296°, 15° (N) 285°, 14° (N) 292°, 13° (N) 309°, 10° (N) 316°, 13° (N) average 300°, 13° (good) | Core has good laminations, bedding dips 10-13° | N30°E, 10-13°NW |
| 185.0- 185.3 | Two clay beds (2 cm; 1 cm) with crushed zone between, dips 10- 20° | 185.7- 186.1 | Subhorizontal clay bed (0.4 feet thick), etched, Bottom 317°, 18° (N) (good) | Dip on bottom of clay bed is 12-14° | N47°E, 12-14°NW |
| 188.5 | Clay film (1/16 inch) on joint, dips 10° | 188.0- 189.0 | Solid rock with color laminations, slightly etched, 267°, 7° (N) (good) | Not checked | N3°W, 7°E |
| 198.4- 199.8 | Dolomitic sandstone, laminations dip 5-12° | 196.0- 201.0 | Massive rock with color laminations, slight etching at 197.1 Following are typical: 295°, 9° (N) 291°, 10° (N) 289°, 9° (N) average 290°, 9° (good) | Well defined laminations, dip 14°, 11° | N20°E, 12°NW |
| 215.8- 216.0 | Crushed zone with clay seam, slickensides | 215.9- 216.4 | Irregular, subhorizontal bedding with brown clay (1 inch), eroded and etched, bottom contact 274°, 29° (N) (good) | Not checked | N4°E, 29°W |
| 236.3 | Stiff clay seam (1 cm) on bedding, dips 15° | 236.8 | Subhorizontal clay (1/4-1/2 inch) along laminations, etched and squeezing into hole 253°, 13° (N) (good) | Bedding in core dips 12- 13°, azimuth measured using fracture orientation confirms strike from televiwer | N17°W, 13°SW |

**Table 21-1. Interpretation of Bedding in Boreholes,
ISFSI Study Area (continued)**

Boring 01-I (continued)

| Original Description from Log of Rock Boring including dip angle ⁽¹⁾ (DCPP ISFSI Data Report B) | | WLA Descriptions from NORCAL Televue Image including dip azimuth and dip angle ⁽²⁾ (DCPP ISFSI Data Report E) | | Review of Core ⁽³⁾ | Interpreted Bedding Attitude ⁽⁴⁾ (strike, dip) |
|---|---|--|--|--|--|
| Depth (feet) | Description | Depth (feet) | Description | | |
| 252.4- 252.7 | Bed of medium to coarse grained sandstone, contact dips 10-11°, bedding laminations dip 10° | 252.9- 253.2 | Washed out zone, friable sand (clay ?), bottom bedding 184°, 4° (N) remeasured 225°, 7° (fair to good) | Undulating laminations, dip 10-13° | N45°W, 10-13°W |
| 259.2- 259.6 | Very fine grained dolomitic sandstone, subhorizontal bedding laminations dip ~10° | 259.1- 259.5 | Lithologic banding; Following are typical: 254°, 12° (N) 262°, 13° (N) (good) | Irregular laminations at 259.0 dip ~18°, parting surfaces at 259.9 feet dip ~14-16° | N12°W, 12°W |
| 283.6- 286.3 | Very fine-grained sandstone, laminations, bedding dip 0° | 286.3- 286.7 | Laminations 299-315°, 13-17° (N) (fair) | Good laminations dip 11°; azimuth of 303° measured using fracture orientation | N33°E, 11°NW |
| 289.9- 290.0 | Clay seam/bed (1/2-1 cm), dips 10-15° | 290.4 | Subhorizontal clay bed (1/4-1/2 inch) along laminations, etched to partly open, irregular 322°, 18° (N) (fair) | Not checked | N62E, 18°NW |
| 316.0- 316.6 | Very fine grained sandstone, laminations | 316.0- 317.0 ° | Laminations 273°, 15 (N) 279°, 12° (N) (good) | Laminations dip 10-13°, with few irregular laminations up to 18° | N9°E, 12°W |

**Table 21-1. Interpretation of Bedding in Boreholes,
ISFSI Study Area (continued)**

Notes:

- (1) Description and depth (in feet) of feature described on log of rock boring by field geologist. Dip angle measured from core with protractor by field geologist. In some cases, no field measurement was taken. Note that some features such as joints have been reinterpreted as bedding from subsequent review of core and/or interpretation of televiewer image.
- (2) WLA description and depth (in feet) of feature observed in NORCAL Televiewer image of boring. Dip azimuth and dip angle measurements taken from NORCAL interpretation are designated with (N). NORCAL measurements are described in DCPD ISFSI SAR Section 2.6 Topical Report DCPD ISFSI Data Report E. All other dip azimuth and dip angle measurements were obtained by WLA from televiewer image and represent either bedding not picked by NORCAL or remeasured by WLA where noted. WLA physically measured dip and dip azimuth on televiewer image hard copy in the following manner: Bedding occurs as sinusoidal form on unfolded borehole image. The dip direction is taken as the lowest point on the sinusoidal curve. The dip angle is calculated using the parameters of (1) measured amplitude of the sinusoidal curve (h) and (2) the boring diameter (d) in the equation $\tan(\text{dip angle}) = h/d$. A good, fair, or poor rating was assigned to the bedding attitude to convey the quality of measurement and confidence that the feature in the televiewer image represents bedding.
- (3) Comments from reinspection of core samples including dip measurements where noted. Dip azimuths are measured and noted where core could be oriented using attitudes of prominent fractures or joints obtained from televiewer images. "Not checked" refers to bedding attitudes that were interpreted from televiewer images following the last reinspection of the core.
- (4) Strike and dip of interpreted bedding. The interpreted bedding represents the best information obtained from field logs, NORCAL televiewer images, and reinspection of core samples. For example, the interpreted strike of bedding may be obtained from the televiewer images, but the corresponding dip may be taken from original field measurements of core samples, televiewer images, or measurements of core during reinspection, whichever is considered highest quality/confidence.

**Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding,
ISFSI Study Area Borings**

Boring 98BA-1

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiewer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|--|---------------|--|---------------------|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 11.0- 11.4 | "Clay stringers" | -- | | No televiewer image | ✓ | | ? |
| 26.6 | Thin clay film (not clay bed) | 0-5 | | | | ✓? | ? |
| 65.0- 66.0 | Clayey joint coatings | 5-30 | | | | ✓ | |
| 66.6- 67.0 | Very soft clayey zone (not clay bed) | -- | | | ✓ | | |
| 69.4- 70.0 | Clayey rock, 1/8 inch seams; slickensides, disturbed | ? | | | | ✓? | ? |
| 87.0 | Silty clay in shoe | -- | | | | ✓ | ? |
| 90.4 | Clay with slickensides, joint | 25 | | | | ✓ | |
| 91.5 | Clay coatings with slickensides, joint | 30 | | | | ✓ | |
| 93.7 | Clay films, polished, joint | 0 | | | | ✓ | ✓? |
| 97.6 | Clay seam on joint with slickensides | 25 | | | | ✓ | |
| 99.1 | Clay on joint with slickensides | 25 | | | | ✓ | |
| 142.8 | Joint, 1/16 inch clay, polished | 10 | | | | ✓? | ✓? |
| 145.1- 145.4 | Clayey zone (not beds) | -- | | | ✓ | | |
| 162.0- 162.2 | Soft clayey rock zone | Low angle | | | ✓ | | |
| 165.3 | Joint with clay, polished | 5 | | | | ✓ | ✓? |
| 170.7 | Joint with clay films and slickensides | 0 | | | | ✓ | ✓? |
| 175.8 | 1.2 inches clay zone | 15 | | | | | ✓? |
| 192.4- 192.6 | Clay films with slickensides (shear zone) | 20 | | | | ✓ | |
| 194.2 | Joint with clay films, slickensides | 0 | | | | ✓ | ✓? |
| 203.3 | Bedding with clay seams (films) in 0.7 inch-wide breccia | 5-10 | | | | ✓? | ✓? |

**Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding,
ISFSI Study Area Borings (continued)****Boring 98BA-2**

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiewer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|---|---------------|--|---------------------|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 5.9 | Joint with clay seam | 10 | | No televiewer image | | ✓? | ✓? |
| 11.3 | Joint with clay seam | 30 | | | | ✓ | |
| 13.3 | Joint with clay film | 30 | | | | ✓ | |
| 36.5 | Joint with clay film | 15 | | | | ✓ | |
| 38.9 | Joint with clay film | 15 | | | | ✓ | |
| 53.4 | Joint with thin clay | 5 | | | | ✓ | ✓? |
| 58.2 | Joint with thin clay, slickensides | 30 | | | | ✓ | |
| 59.6 | Joint with thin clay | 5 | | | | ✓ | ✓? |
| 63.6 | Joint with thin clay, slickensides | 10 | | | | ✓ | ✓? |
| 67.3 | Joint with clay seams with shears | 10 | | | | ✓ | ✓? |
| 128.5 | Joint with clay films and slickensides | 0 | | | | ✓ | ✓? |

Boring 98BA-3

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiewer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|------------------------|---------------|--|---------------------|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| | No clay beds described | | | No televiewer image | | | |

**Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding,
ISFSI Study Area Borings (continued)**

Boring 00BA-1

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiewer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|---|---------------|--|---|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 23.0- 23.2 | Four joints with thin clay coatings (altered zone) | 0 | 23.1 | Thin clay (?) bed, N25°E, 9°NW and moderately steep joint | | | ✓? |
| 30.2 | Clay seam (1/8 inch), bedding? | 0? | 29.4- 30.2 | Moderately steep joint, etched, irregular with clay(?) | | ✓ | |
| 51.2 | Crushed clayey rock | - | 51.0- 51.6 | Irregular joint, tight | | ✓ | |
| 54.5 | Stiff clay (1/8 inch) | ~0 | 53.5- 54.5 | Steep filled joint, irregular tight with clay | | ✓ | |
| 55.6- 56.3 | Clay seam (8.4 inches) with planar rock contacts, bedding | ~5 | 54.9- 56.2 | Clay bed with sharp, tight rock contacts, etched, N82°W, 11°-16°S | | | ✓ |
| 69.2- 69.6 | Crushed zone with silt, some clay | -- | 69.2- 69.8 | Steep fracture, eroded, clay (?) | | ✓ | |
| 79.5 | Stiff, silty clay seam (1/8 inch) on joint | 10 | 79.2 | Possible thin clay along bedding or joint, etched below N61° E, 11°-16° NW | | | ✓ |
| 105.4 | Clay seam (1/4 inch) along fracture | 15 | 105.0- 105.3 | Clay seam, etched, irregular top, sharp, smooth bottom contact, N13°W, 12°SW | | | ✓ |
| 106.5 | Silty clay (1/8-1/4 inch), joint | 30 | 106.4 | Tight bedding with discoloration N20°W, 18°SW | | | ✓? |
| 109.5 | Clay lined joint | 10 | 108.9- 109.0 | Tight joint | | ✓ | |
| 140.0- 141.0 | Sandstone, changes to laminations @ 140.9 | -- | 140.4 | Thin clay (?) bed, partly etched N10°E, 4°SW | | | ✓ |
| 145.3- 145.7 | Crushed, broken zone with clay coatings (1/4 inch) | -- | 144.3- 145.7 | Steep joints, tight with clay (1/4-1/2 inch) | | ✓ | |

Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding, ISFSI Study Area Borings (continued)**Boring 00BA-2**

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televier Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|--|---------------|--|---|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 29.8- 30.0 | Crushed zone | -- | 29.8- 30.2 | Subhorizontal soft clay (?) zone, etched, irregular contact | ✓ | | ✓? |
| 40.4 | Crushed zone | -- | 40.4- 40.8 | Moderately steep, joint, partly open and etched, with thin clay (?) | | ✓ | |
| 52.4 | Clay (1/16 inch) on joint, minor striations | 0 | 52.4- 52.6 | Tight, moderately steep joint | | ✓ | |

Boring 00BA-3

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televier Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|--|---------------|--|-------------------|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 11.8- 12.8 | Clayey sandstone (not a clay bed) | -- | | No televier image | ✓ | | |
| 22 | Clay film on joint, polished | 30 | | | | ✓ | |
| 26.5 | Clay (1/16 inch) with slickensides, joint | 0 | | | | ✓ | ✓? |

Boring 01CTF-A

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televier Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|--|---------------|--|---|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 22.9 | Clay film on joint, polished | 30 | 22.6- 23.0 | Moderately dipping joint, tight, thin clay (?) | | ✓ | |
| 32.4- 32.6 | Soft clayey sand, bedding (?) | 30 | 32.7- 33.5 | Soft clayey (?) zone, etched, irregular contacts | ✓ | | |
| 37.7 | Clay (1/16 inch) on joint, polished, slickensides | 30 | 38.3- 40.7 | Tight, steep joints | | ✓ | |
| 38.2 | Clay film on joint, end of core run | ~5 | 38.3- 40.7 | Tight, steep joints | | ✓ | |
| 50.5- 50.6 | Clayey rock zone, not bedding clay | 10 | 51.1- 51.3 | Low-angle band (murky water) | ✓ | | |

**Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding,
ISFSI Study Area Borings (continued)**

Boring 01-A

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiwer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|---|---------------|---|---|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 15.2- 15.4 | Clay (0.4 inch) in fracture | 25-30 | 15.2- 15.4 | Moderately dipping joint, eroded, with clay (?) | | ✓ | |
| 29.9 | Clay layer (0.6 inch), joint | 30 | 29.6- 29.9 | Moderately dipping joint, etched to eroded, thin clay (?) (image distorted) | | ✓ | |
| 37.7- 37.8 | Two clay coatings (1/16 inch) on joints | 20-30 | 36.7 | Low to moderate dipping joint or bedding (?), etched N40°W, 20°SW | | ? | ✓? |
| 42.1 | Sandstone, no recovery | -- | 41.0- 41.1 42.2- 42.3 | Textural change, etched, bedding (?) with clay (?) Moderately dipping joint below broken, eroded zone with thin clay (?) N19°W, 23°W | | ✓? | ✓? |
| 46.0 | Faults with clay coatings, slickensides | 18-25 | 44.2- 49.2 | Eroded and etched zone irregular, near vertical joint | | ✓ | |
| 48.2 | Clay layer (1 inch) in broken zone | 0 | 44.2- 49.2 | Eroded and etched zone irregular, near vertical joint | ✓? | | ? |
| 52.0- 53.9 | Sandstone with joints | 0 | 53.3 | Low-angle joint, eroded with thin clay | | ✓ | |
| 54.9 | Silty clay with sand and gravel (1 inch), bedding? | 20 | 54.1- 54.3 | Low-angle bedding with textural difference, etched and eroded, 1/2-to 1 inch clay bed (?) N69°E, 7°NE | | | ✓ |
| 55.8 | Faults with thin clay coatings, slickensides | 8-20 | 55.3 | Bedding (?), etched, with thin clay (?) bed N11°W, 22°W | | | ✓? |
| 58.8 | 0.4 inch clay layer | 20 | 58.5 | Subhorizontal clay layer, eroded and etched, irregular, 1/4-1/2 inch thick, bottom N11°W, 22°W | | | ✓? |

**Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding,
ISFSI Study Area Borings (continued)****Boring 01-B**

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiewer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|--------------------------|---------------|--|------------------|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 43.3 | Trace clay on two joints | 0 | 43.3 | Broken rock zone | | ✓ | |
| 48.7 | Trace clay on joint | 30 | 48.7 | Broken rock zone | | ✓ | |

Boring 01-C

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiewer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|---|---------------|--|--|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 16.3 | Clay film on joint | 15 | 15.9(?) | Low-angle bedding, etched, with clay (?) (~1/8 inch) N73°W, 15°S | | | ✓? |
| 23.8 | Joint | 5 | 23.7- 23.8 | Bedding, eroded, with clay (?) (~1/4 inch) N66°W, 15°SW | | | ✓ |
| 41.1- 41.4 | Clay films on two joints, slickensides | 20-30 | 40.3- 40.5 | Moderately steep joint, etched, no visible clay | | ✓ | |
| 44.1 | Clay (0.2 inch) on bedding? | 0-5 | 43.6 | Subhorizontal bedding, etched to eroded, thin clay (?), irregular | | | ✓? |
| 55.8- 56.2 | Sandstone some clay | 5 | 54.9 | Subhorizontal, irregular bedding (?), etched to eroded, clay (?) | | ✓? | ? |
| 65.3 | Soft clay (1/4 inch) on joint, bedding (?) | 5 | 65.0 | Moderately steep joint, etched, slight clay (?) (water in hole, image fuzzy) | | ✓ | |

**Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding,
ISFSI Study Area Borings (continued)****Boring 01-D**

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiewer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|--|---------------|--|---|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 26.5- 27.0 | Joint, crumbly zone | 30 | 25.9- 26.9 | Eroded zone between two moderately steep joints, clayey (?), rock (6.25 inches wide) | | ✓ | |
| 55.0- 55.5 | Crushed zone with clay, joint at 55.2 | -- | 53.4- 54.9 | Eroded and etched zone (clayey?), rough bedding (?) at base N33°W, 11°N | ✓? | | |

Boring 01-E

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiewer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|--|---------------|--|---|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 12.85 | Clay layer (1/8 inch) | 10 | 12.1- 12.7 | Vein, joints, etched, clayey (?) | | ✓ | |
| 20.8 | Clay gouge (1/16 inch), joint | 30 | 20.4- 20.5 | Shallow joint, etched, irregular, with thin clay (?) | | ✓ | |
| 23.0- 25.0 | Zone of clay coated joints, polished, with rubble | 30 | 23.1- 24.3 | Moderately steep, tight to slightly etched, joints | | ✓ | |
| 71.7 | Clay film on joint | 30 | 71.4- 72.1 | Steep, tight joint (hole has water, image fuzzy) | | ✓ | |
| 77.4 | Clay filled joint | 0 | 77.0- 78.0 | No joints evident (hole has water, image fuzzy) | | ✓ | |

**Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding,
ISFSI Study Area Borings (continued)**

Boring 01-F

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiewer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|---|---------------|--|--|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 5.5 | Clay film (<1/16 inch), joint | 0 | 4.7- 6.6 | Fractured zone with clay (?) | | ✓ | |
| 6.8 | Clay film (<1/16 inch), joint | 20 | 6.6 | Partly open joint with thin clay (?), shallow bedding (?) N70°W, 9°SW | | ✓? | ✓? |
| 10.5- 10.8 | Sandy, clayey rock zone | -- | 10.2- 10.5 | Partly etched zone | ✓ | | |
| 16.1- 16.3 | Fractured clayey zone | -- | 15.2- 16.4 | Weak, etched and eroded rock | ✓ | | |
| 29.2 | Clayey crushed rock mixed with harder rock fragments | -- | 29.0- 30.2 | Weak, etched zone | ✓ | | ? |
| 35.5- 38.0 | Clayey fractured zone, altered | -- | 35.0- 38.0 | Soft, partly etched, locally fractured rock | ✓ | | |
| 43.8- 44.4 | Clayey fractured zone, altered | 0-10 80-90 | 43.7- 45.3 | Fractured rock with tight, subhorizontal joint and steep, partly open joints, some clay (?) | ✓ | ✓ | |
| 46.6- 46.8 | Clayey fracture zone, altered, bounded by joints | 0 | 46.0- 47.0 | Steep, eroded joints and fractured rock with clay | | ✓ | |
| 57.5- 57.7 | Clayey zone along possible bedding | 5-15 | 57.9 | Subhorizontal, tight lamination, slight clay (?) (<1/16 inch) | | ✓? | ✓? |
| 58.6 | Clay films on joint with slickensides, possible bedding | 20 | 57.0- 59.0 | Tight joints and subhorizontal laminations, possible clay (<1/16 inch) | | ✓ | ? |
| 58.6- 58.8 | Clayey lens in rock and clay films with slickensides, joint | 10 | 58.7- 58.9 | Moderately dipping joint, etched, with clay (?) (<1/16 inch) | ✓ | ✓ | |
| 94.3- 94.4 | Clayey, silty crushed rock with clay bed (1/4-1/2 inch thick) | 0-10 | 93.2 | Subhorizontal joint along bedding, etched, with 1/4 inch clay (?), etched EW, 14°S | | | ✓ |
| 98.0- 98.4 | Broken zone with clayey- silty matrix | 70 | 98.0- 99.0 | Fractured zone with apparent softer rock pockets, eroded (clay ?) | ✓ | | |

**Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding,
ISFSI Study Area Borings (continued)**

Boring 01-F (continued)

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiewer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|--|---------------|--|--|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 103.8 | Thin silt/clay coating on joint | 20 | 103.0-104.4 | Fractured zone with steep joints | | ✓ | |
| 104.4 | Clay on joint | 30 | 103.0-104.4 | Fractured zone with steep joints | | ✓ | |
| 105.5 | Clay seam (?) (<~1/2 inch) in broken zone (clay in crushed zone) | 65-80 | 105.0-106.0 | Tight rock with few steep fractures, laminations, no clay seam evident | ✓ | ✓? | |
| 107.3 | Trace clay on joint | 20 | 106.5-108.0 | Solid, unfractured rock, no clay or joints evident | | ? | |
| 111.3 | Trace clay on joint | 20 | 111.1-111.4 | Moderately steep joint, irregular, partial thin clay (?) | | ✓ | |
| 111.9 | Clay (<1/32 inch) on joint | 0 | 111.5-112.5 | Moderately steep, hairline fracture in otherwise solid unfractured rock | | ? | |
| 117.0 | Clay layer (0.4 inch) bedding (?) | 8-12 | 116.4 | Subhorizontal bedding, etched, possible thin clay (~1/8 inch) N70°W, 6°-12°SW | | | ✓? |
| 124.8 | Joint lined with 1/16 inch clay | 30 | 123.6-124.5 | Tight to open, steep joints, no clay evident | | ✓ | |
| 125.9 | Joint with trace clay, polished | 35 | 124.5-126.5 | Tight, sound rock with few tight to locally open, steep fractures | | ✓ | |

**Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding,
ISFSI Study Area Borings (continued)**

Boring 01-G

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiwer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|--|-----------------------------|---|--|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 8.6- 9.0 | Weak zone with clay, crushed | -- | 7.6- 8.6 | Moderately steep joints, partly broken out, with thin clay (?), massive rock below | | ✓ | |
| 14.3 | Clay lined joints | 30 | 14.0- 14.2 | Tight, moderately steep joint, no visible clay | | ✓ | |
| 18.7 | Clay seam (1/2-3/4 inch) above broken rock zone on bedding (?) | Top, ~0; Base, 0-5 | 18.5 | Subhorizontal, tight bedding laminations possible thin (<1/4 inch clay) (?), N22°W, 13°SW | | | ✓ |
| 25.4 | Joint with clay coatings (<0.5 inch) | 0- ~15 | 25.0 | Subhorizontal bedding, tight with thin clay (?) (<1/8 inch), N78°W, 15°S | | | ✓ |
| 29.1 | Joint with very thin film | 0 | 28.8 | Bedding (?), partly broken out in zone of massive rock N60°W, 12°SW | | | ✓? |
| 50.3 | Zone of silty clay | -- | 49.2- 50.6 | Steep, partly open joints and broken rock | ? | ✓ | |
| 56.3 | Clayey fracture zone parallel to laminations | 0-10 | 55.8- 57.5 | Steep joints and broken rock, localized clay (up to ~1/2 inch) on joint | | ✓ | |
| 67.2 | Minor clay/silt laminations | -- | 67.0- 68.0 | Laminated tight rock with steep joint, no visible clay | ✓ | | |
| 75.6 | Thin clay film on joints | 30-40 | | Below televiwer log | | ✓ | |

Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding, ISFSI Study Area Borings (continued)

Boring 01-H

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiwer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|---|---------------|---|--|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 10.0 | Clay films | 30 | 9.2- 9.4 | Moderately dipping joint partly broken out, with some clay (?) | | ✓ | |
| 39.4 | Two very thin clay layers between fracture blocks | 10 | 39.4 | Subhorizontal bedding, slightly etched, with thin clay (?), N30°W, 15°SW | | | ✓ |
| 40.3 | Joint with thin clay coating | 13 | 39.6- 41.0 | Massive, laminated rock | | ✓? | |
| 50.5 | Clay "clast" (1/4-3/4 inch), bedding parallel | 30 | 49.7- 51.6 | Massive rock, no clay evident, thin, slightly etched beds at 50.3 and 50.4 | ✓ | | |
| 59.9 | Clay layer (1/8 inch thick) | -- | 59.1- 59.8 | Subhorizontal softer rock zone, etched contact, vague | ✓ | | ✓? |
| 67.2 | Clay layer (1/8 inch thick) | 30 | 66.7- 66.9 | Moderately dipping joint, slightly etched, with thin clay (?) (<1/16 inch) | | ✓ | |
| 67.4 | Clay layer (1/8 inch thick) | 30 | 66.7- 66.9 | Moderately dipping joint with thin clay (?) (<1/16 inch) | | ✓ | |
| 72.8 | Clay on joint (1/16 inch thick) | 30 | 72.2 | Irregular, thin clay (?) layer in massive rock | | ✓? | ✓? |
| 82.3 | Clay seam (3/4 inch thick) | 0 | 81.4 | Subhorizontal bedding laminations, tight, no clay evident, N45°W, 12°SW | | | ? |
| 89.6 | Sandstone (1/16 inch clay bed twisted by drilling) | 0 | 88.8 | Bedding, textured change, N67°W, 11°SW | | | ✓ |
| 94.5 | Dark gray clay layer (1/4 inch thick) | 10-30 | 93.6 | Subhorizontal bedding, eroded with clay (?) (~1/4 inch), N38°W, 21°SW | | | ✓ |

Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding, ISFSI Study Area Borings (continued)**Boring 01-I**

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiewer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|--|---------------|--|---|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 15.6 | Clay on joint (0.2-0.4 inch) | 10 | 15.0- 16.0 | Broken zone, clay (?) along joints | | ✓ | |
| 18.9 | Clay on joint (1/16 inch) | 0 | 17.8- 20.0 | Broken out zone along steep joints, clay (?) | | ✓ | |
| 20.2 | Silty/clayey crushed rock zone (not clay bed) | 10-20 | 20.4- 21.0 | Broken, jointed zone | | ✓ | |
| 33.9 | Clay film (1/16 inch) on bedding, joint (?) | 10 | 34.9 | Subhorizontal lamination, tight to partly eroded bedding, N39°E, 6°NW | | | ✓ |
| 39.0- 40.0 | Crushed zone with silt, clay films | -- | 37.9- 40.1 | Fractured zone, steep joints, partly broken out | | ✓ | |
| 43.1 | Clay on joint (1/4 inch) | 20 | 43.4- 43.6 | Thin clay, eroded and etched along bedding (?), N55°E, 18°NW | | | ✓ |
| 45.6 | Clay bed (0.8 inch) | 10-15 | 46.2 | Well imaged thin clay, etched, bedding parallel, N54°E, 14°NW | | | ✓ |
| 48.1 | Clay seam (0.4 inch) on joint associated with CaCO ₃ vein | 10-20 | 48.8 | Subhorizontal joint/clay seam, etched, with clay (1/4-1/2 inch), N50°E, 13°NW | | | ✓ |
| 57.2 | Sandy crushed zone | -- | 57.6- 57.9 | Subhorizontal, planar opening along eroded soft rock zone (1/2 to 1 inch); thin clay (?) along base, bedding, N25°E, 8°-15°NW | | | ✓ |
| 61.0- 61.4 | Crushed rock zone with some clay, not bedding | -- | 60.0- 62.5 | Steep joints with clay (?) | | ✓ | |
| 62.7- 63.1 | Crushed rock zone with silt and clay, not bedding | -- | 63.3- 63.9 | Moderately steep, smooth joints with crushed and weak rock mixed with clay (?) in lower part (~2 inch thick) | | ✓ | |

**Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding,
ISFSI Study Area Borings (continued)**

Boring 01-I (continued)

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiwer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|---|---------------|---|--|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 68.6- 69.2 | Clay zone with crushed altered rock (not bedding) | -- | 68.3- 70.2 | Moderately steep to steep joints bounding 1 foot-thick, weak rock, deeply eroded with possible clay | | ✓ | |
| 70.8- 71.1 | Crushed zone with clay | -- | 70.5- 70.8 | Moderately steep fracture, partly open, with clay (?) | | ✓ | |
| 85.8 | Trace clay on joint | 20 | 85.4- 85.6 | Moderately steep, open joint, possible thin clay washed out? | | ✓ | |
| 90.1 | Clay (0.1-0.2 inch) on joint | 20 | 89.2- 90.7 | Massive unjointed rock with laminations | | ✓ | |
| 93.4- 93.9 | Three joints with trace clay | 30 | 93.4- 94.6 | Steep joints, with thin clay (?), partly eroded and bounded by massive unjointed rock with color laminations | | ✓ | |
| 100.2- 100.6 | Trace clay on two joints | 20 | 98.0- 100.8 | Fractured rock with steep open joints, discontinuous | | ✓ | |
| 106.6 | Clayey/silty/sand seam (~3/4 inch), bedding | 10-12 | 106.4 | Subhorizontal clayey seam (1 to 2 inches thick), eroded and etched along bedding N19°W, 12°-14°W | | | ✓ |
| 108.9 | Broken clay along joints | 18-20 | 108.0- 116.2 | Broken rock zone with steep joints, clay (?) | | ✓ | |
| 110.0 | Sandy clay (0.4 inch) at bottom of run, possible slough | -- | 108.0- 116.2 | Broken rock zone with steep joints, clay (?) | | ✓ | |
| 123.0 | Joint with 0.2 inch clay | 20 | 121.1- 124.1 | Broken rock zone, subhorizontal fabric, possible thin clay (?) laminations | | ✓ | |
| 123.8- 124.1 | Clayey sandstone bed above coarse, 1.2 inch-thick sandstone bed | 10-20 | 124.1 | Irregular bedding contact between broken rock and soft, granular rock, eroded, N46°W, 16°NE | ✓ | | |

Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding, ISFSI Study Area Borings (continued)

Boring 01-I (continued)

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televiwer Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|---|---------------|---|---|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 127.6- 127.8 | Crushed clayey zone (2.4 inches) | 20-35 | 126.5- 129.2 | Steep joints and broken rock, partly open, with clayey (?) zone at 127.8 | ✓ | ✓ | |
| 130.3 | Stiff clay seam (1/4-1/2 inch) along bedding | 10 | | Bedding with clay (?) slightly etched N12°E, 3°S | | | ✓ |
| 131.0 | Joint with clay | 20 | 131.6 | Bedding with thin clay, subhorizontal, N81°E, 8°S | | | ✓? |
| 146.3 | Clay (1/8 inch) on joint (or drilling clay?) | 20 | 145.2- 148.7 | Open, steep joint, eroded, possible washed-out soft rock or clay zone | | ✓? | |
| 151.4- 151.9 | Crushed silty/clayey zone, part slough? | -- | 149.5- 151.2 | Fractured rock, partly open and etched | ✓ | | |
| 156.1 | Shaley seam (1/4 inch) with slickensides along bedding contact | 15-18 | 156.5- 156.8 | Softer rock zone, eroded and etched, subhorizontal, possible clay at base of zone, bedding N65°E, 12°-18°NW | | | ✓? |
| 167.4- 167.8 | Zone with multiple clay seams (1/8-1/4 inch) along bedding | 10 | 167.0 | Thin clay (?), etched along bedding | | | ✓ |
| 171.0- 171.2 | Crushed zone with silty clay in joint (1/8 inch), possible slough at bottom | 10 | 170.0- 172.0 | Clear laminations and steep, partly open joints with clay N20°E, 12°NW | | ✓ | |
| 185.0- 185.3 | Two clay beds (0.8 inch; 0.4 inch) with crushed zone between | 10-20 | 185.7- 186.1 | Subhorizontal clay bed (4.8 inches-thick), etched N47°E, 12°-14°NW | | | ✓ |
| 188.5 | Clay film (1/16 inch) on joint | 10 | 188.0- 189.0 | Solid rock with color laminations, slightly etched, N3°W, 7°E | | | ✓? |

**Table 21-2 Evaluation of Clay 'Seams' on Low-Angle Fractures and Bedding,
ISFSI Study Area Borings (continued)**

Boring 01-I (continued)

| Log of Rock Boring (DCPP ISFSI Data Report B) | | | NORCAL Televue Image† (DCPP ISFSI Data Report E) | | Interpretation* | | |
|--|--|---------------|---|---|------------------------|-----------------|-------------|
| Depth (feet) | Description | Dip (deg.) | Depth (feet) | Description | Clayey rock zone | Joint/ Fault | Clay Bed |
| 197.0 | Clay films on joint | 0 | 196.0- 198.0 | Massive rock with color laminations, slight etching at 197.1, N20°E, 12°NW | | | ✓? |
| 210.2 | Crushed clayey, sandy zone at top of crushed zone | -- | 209.0- 211.0 | Broad color laminations and near-vertical joint with clay (?) | ✓ | ✓ | |
| 215.8- 216.0 | Crushed zone with clay seam, slickensides | -- | 215.9- 216.4 | Irregular, subhorizontal bedding with brown clay (1 inch), eroded and etched, bottom contact N4°E, 29°W | | | ✓ |
| 223.1 | Clay film on joint | 0 | 221.1- 223.8 | Massive rock with weak color laminations, moderately dipping, tight joint at 223.8 | | | ✓? |
| 230.7 | Irregular clay seam/bed (?) (0.4 inch) | 5-15 | 230.2- 231.0 230.9 | Steep joint with clay (?) Top of light color band, etched, clay (?) | | ✓ | ✓? |
| 236.3 | Stiff clay seam (0.4 inch) on bedding | 15 | 236.8 | Subhorizontal clay (1/4-1/2 inch) along laminations, etched and squeezing into hole N17°W, 13°SW | | | ✓ |
| 245.1 | Clay on joint (0.4 inch) | 0 | 244.8- 246.2 | Massive rock with a steep, tight to slightly open joint | | ✓ | |
| 289.9- 290.1 | Clay seam/bed (0.2-0.4 inch) | 10-15 | 290.4 | Subhorizontal clay bed (1/4-1/2 inch) along laminations, etched N62°E, 18°NW | | | ✓ |

Note: Clay on fractures steeper than 30 degrees are not included because bedding has dips less than 20 degrees in the site area.

† Bedding attitudes from Table 21-1

* Interpretation Categories

Bold type highlights clay bed or possible clay bed shown on cross sections

- ✓ Significant clay bed (> 1/4 inch thick, follows bedding; thickness in most cases taken from measurements on core)
- ✓ Clay along bedding, joint or fault
- ✓? Probable clay along bedding, joint or fault
- ? Possible clay along bedding, joint or fault

Table 21-3 Thickness Measurements of Clay Beds in Borings and Trenches

| Location | Boring Depth (feet) | Trench Station (meters) | Thickness (inches) ^a | | Notes on Thickness ^b | Subunit ^c |
|----------|------------------------|----------------------------|---------------------------------|---------|------------------------------------|--|
| | | | minimum | maximum | | |
| 98BA-1 | 93.7 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-2} |
| 98BA-1 | 142.8 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-2} |
| 98BA-1 | 165.3 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-2} |
| 98BA-1 | 170.7 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-2} |
| 98BA-1 | 175.8 | na | 0.25 | 1.20 | 1 | Tof _{b-2} |
| 98BA-1 | 194.2 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-2} |
| 98BA-1 | 203.3 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-2} |
| 98BA-2 | 5.9 | na | 0.06 | 0.12 | 3 | Tof _{b-2} |
| 98BA-2 | 53.4 | na | 0.06 | 0.12 | 3 | Tof _{b-2} |
| 98BA-2 | 59.6 | na | 0.06 | 0.12 | 3 | Tof _{b-2} |
| 98BA-2 | 63.6 | na | 0.06 | 0.12 | 3 | Tof _{b-2} |
| 98BA-2 | 67.3 | na | 0.06 | 0.12 | 3 | Tof _{b-2} |
| 98BA-2 | 128.5 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-2} |
| 00BA-1 | 23.0-23.2 | na | 0.06 | 0.12 | 3 | Tof _{b-1} |
| 00BA-1 | 55.6 to 56.3 | na | 8.40 | 8.40 | 1 | Tof _{b-1} |
| 00BA-1 | 79.5 | na | 0.12 | 0.12 | 1 | Tof _{b-1} |
| 00BA-1 | 105.4 | na | 0.25 | 0.25 | 1 | Tof _{b-1} |
| 00BA-1 | 106.5 | na | 0.12 | 0.25 | | Tof _{b-1} |
| 00BA-1 | 140.0 to 141.0 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-1} |
| 00BA-2 | 29.8-30.0 | na | 0.12 | 0.25 | 3 | Tof _{b-1} |
| 00BA-3 | 26.5 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-2} |
| 01-A | 37.7-37.8 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-2} |
| 01-A | 42.1 | na | 0.06 | 0.12 | 3 | Tof _{b-2} |
| 01-A | 54.9 | na | 0.50 | 1.00 | | Tof _{b-2} |
| 01-A | 55.8 | na | 0.06 | 0.12 | 3 | Tof _{b-2} |
| 01-A | 58.8 | na | 0.25 | 0.50 | | Tof _{b-2} |
| 01-C | 16.3 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-2} |
| 01-C | 23.8 | na | 0.25 | 0.25 | 1 | Tof _{b-2} |
| 01-C | 44.1 | na | 0.06 | 0.20 | 3 | Tof _{b-2} |
| 01-F | 6.8 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-1} |
| 01-F | 57.5-57.7 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-2} |
| 01-F | 94.3 to 94.4 | na | 0.25 | 0.50 | | Tof _{b-2} |
| 01-F | 117 | na | 0.12 | 0.40 | | Tof _{b-1} and Tof _{b-1a} |
| 01-G | 18.7 | na | 0.12 | 0.25 | 6 | Tof _{b-1} |
| 01-G | 25.4 | na | 0.12 | 0.12 | 6 | Tof _{b-1} |
| 01-G | 29.1 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-1} |

Table 21-3 Thickness Measurements of Clay Beds in Borings and Trenches

(continued)

| Location | Boring Depth (feet) | Trench Station (meters) | Thickness (inches) ^a | | Notes on Thickness ^b | Subunit ^c |
|----------|------------------------|----------------------------|---------------------------------|---------|------------------------------------|--|
| | | | minimum | maximum | | |
| 01-H | 39.4 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-2} |
| 01-H | 59.9 | na | 0.12 | 0.12 | 1 | Tof _{b-2} |
| 01-H | 72.8 | na | 0.06 | 0.06 | 1 | Tof _{b-2} |
| 01-H | 89.6 | na | 0.06 | 0.06 | 1 | Tof _{b-2} |
| 01-H | 94.5 | na | 0.25 | 0.25 | 1 | Tof _{b-2} |
| 01-I | 33.9 | na | 0.06 | 0.06 | 1 | Tof _{b-1} |
| 01-I | 43.1 | na | 0.25 | 0.25 | 1 | Tof _{b-1} |
| 01-I | 45.6 | na | 0.06 | 0.80 | 3 | Tof _{b-1} |
| 01-I | 48.1 | na | 0.25 | 0.50 | | Tof _{b-1} |
| 01-I | 57.2 | na | 0.06 | 0.12 | 3 | Tof _{b-1} |
| 01-I | 106.6 | na | 1.00 | 2.00 | 6 | Tof _{b-1} |
| 01-I | 130.3 | na | 0.25 | 0.50 | | Tof _{b-1} |
| 01-I | 131 | na | 0.06 | 0.12 | 3 | Tof _{b-1} |
| 01-I | 156.1 | na | 0.25 | 0.25 | 1 | Tof _{b-1} |
| 01-I | 167.4-167.8 | na | 0.12 | 0.25 | | Tof _{b-1} |
| 01-I | 185 | na | 0.40 | 0.40 | 1 | Tof _{b-1} |
| 01-I | 185.3 | na | 0.80 | 0.80 | 1 | Tof _{b-1} |
| 01-I | 188.5 | na | 0.06 | 0.06 | 1 | Tof _{b-1} |
| 01-I | 197.0 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-1} |
| 01-I | 215.8 to 216.0 | na | 1.00 | 1.00 | 1 | Tof _{b-1} |
| 01-I | 223.1 | na | 0.06 | 0.06 | 1, 2 | Tof _{b-1} |
| 01-I | 230.7 | na | 0.40 | 0.40 | 1 | Tof _{b-1} |
| 01-I | 236.3 | na | 0.25 | 0.50 | | Tof _{b-1} |
| 01-I | 289.9 to 290.1 | na | 0.25 | 0.50 | | Tof _{b-1} |
| T-11A | na | 3.0 to 7.5 | 0.06 | 0.12 | 5 | Tof _{b-1} and Tof _{b-1a} |
| T-11A | na | 7.5 to 11.0 | 0.20 | 0.80 | 4 | Tof _{b-1} and Tof _{b-1a} |
| T-11B | na | 0.5 to 5.4 | 0.20 | 0.60 | 5 | Tof _{b-1} and Tof _{b-1a} |
| T-11C | na | -1 to 2.3 | 0.20 | 0.60 | 4 | Tof _{b-1} and Tof _{b-1a} |
| T-11D | na | 0 to 8.5 | 0.20 | 0.80 | 4 | Tof _{b-1} and Tof _{b-1a} |
| T-12 | na | 4.5 to 11.0 | 0.06 | 0.25 | 5 | Tof _{b-1} and Tof _{b-1a} |
| T-14A | na | 0 to 8.5 | 1.00 | 4.00 | 5 | Tof _{b-1} |
| T-14A | na | 8.5 to 22.0 | 0.25 | 2.00 | 5 | Tof _{b-1} |
| T-14B | na | 0.00 to 4.00 | 2.00 | 4.00 | 7 | Tof _{b-1} |
| T-15 | na | 6.0 to 19.0 | 2.00 | 4.00 | 4 | Tof _{b-1} |
| T-18A | na | 1.0 to 4.5 | 0.06 | 0.25 | 4 | Tof _{b-1} |
| T-19 | na | 11.8 to 17 | 0.25 | 0.25 | 4 | Tof _{b-1} |

Table 21-3 Thickness Measurements of Clay Beds in Borings and Trenches
(continued)

STATISTICS ON CLAY BED THICKNESS

Measurements from boreholes and trenches

| | <u>minimum</u> | <u>maximum</u> |
|------------------------------------|----------------|-----------------|
| number of thickness measurements = | 72 | 72 measurements |
| minimum thickness = | 0.06 | 0.06 inches |
| maximum thickness = | 8.40 | 8.40 inches |
| median thickness = | 0.09 | 0.23 inches |
| mean thickness = | 0.35 | 0.59 inches |
| 1 standard deviation = | 1.03 | 1.25 inches |

Trench Data

| | | |
|--|---|--------------------|
| Cumulative length of clay beds exposed in trenches (feet) | | |
| (minimum because clay beds extend beyond end of trench) ≤ 1/4 inch thick | = | 64.64 feet (28%) |
| > 1/4 inch thick | = | 169.96 feet (72%) |
| Total | | 234.60 feet (100%) |

Boring Data

| | | | | |
|--|------------------|---|----|--------|
| Number of clay beds encountered in borings | ≤ 1/4 inch thick | = | 44 | (73%) |
| | > 1/4 inch thick | = | 16 | (27%) |
| | Total | | 60 | (100%) |

Footnotes: ^a measurements taken from trench exposures and borings; thicknesses may not represent the true ranges for individual beds

^b To_{f_{b-1}} = dolomite subunit, To_{f_{b-1a}} = friable dolomite subunit, To_{f_{b-2}} = sandstone subunit

^c Notes on thickness

1. Only a single measurement taken; this value used in both minimum and maximum columns
2. Field description of film as "very thin"; assumed thickness of 0.06 (1/16) inch
3. Field description of "thin" given range of 0.06 to 0.12 inches
4. Thickness range recorded in trenches reflects two discrete measurements made along clay bed.
5. Thickness range is estimated from notes on trench logs
6. Thickness estimates using televiewer information only (boring log not used).
7. Thickness measured from photographs.

Table 21-4. Friable Rock Zones in ISFSI Study Area Borings.

| Boring | Depth Interval of friable rock (feet) | Test Sample I.D. | Elevation Interval (feet) | Friable Zone Interval Thickness (ft) |
|---------------------------|---|---------------------|--|--|
| 98BA-1 | Elevation at ground surface | | 372.0 | |
| | 90.0-96.0 | | 282.0-276.0 | 6.0 |
| | 118-133.5 | | 254.0-238.5 | 15.5 |
| | 138.7-140.0 | | 233.3-232.0 | 1.3 |
| | 142.8-145.2 | | 229.2-226.8 | 2.4 |
| | 167.3-172.3 | | 204.7-199.7 | 5.0 |
| | 182.3-200.0 | | 189.7-172.0 | 17.7 |
| | 206.0-206.8 | | 166.0-165.2 | 0.8 |
| Total Borehole Depth = | 250.0 | | Total Friable Zone Interval Footage = | 48.7 % Friable = 19.5 |
| 98BA-2 | Elevation at ground surface | | 322.0 | |
| | 5.0-15.0 | | 317.0-307.0 | 10.0 |
| | 46.5-48.5 | | 275.5-273.5 | 2.0 |
| | 56.6-60.0 | | 265.4-262.0 | 3.4 |
| | 65.0-68.0 | | 257.0-254.0 | 3.0 |
| | 70.0-89.0 | | 252.0-233.0 | 19.0 |
| | 96.0-97.0 | | 226.0-225.0 | 1.0 |
| | 103.5-107.2 | | 218.5-214.8 | 3.7 |
| | 146.0-150.0 | | 176.0-172.0 | 4 |
| Total Borehole Depth = | 165.0 | | Total Friable Zone Interval Footage = | 46.1 % Friable = 27.9 |
| 98BA-3 | Elevation at ground surface | | 322.0 | |
| | 171.6-175.0 | | 150.4-147.0 | 3.4 |
| | 205.0-212.0 | | 117.0-110.0 | 7 |
| Total Borehole Depth = | 220.0 | | Total Friable Zone Interval Footage = | 10.4 % Friable = 4.7 |
| 00BA-1 | Elevation at ground surface | | 450.0 | |
| | 29.0-34.0 | | 421.0-416.0 | 5 |
| Total Borehole Depth = | 150.0 | | Total Friable Zone Interval Footage = | 5.0 % Friable = 3.3 |
| 00BA-2 | Elevation at ground surface | | 363.0 | |
| | 0.0-32.0 | | 363.0-331.0 | 32.0 |
| | 38.2-40.6 | | 324.8-322.4 | 2.4 |
| | 42.0-47.5 | | 321.0-315.5 | 5.5 |
| Total Borehole Depth = | 55.0 | | Total Friable Zone Interval Footage = | 39.9 % Friable = 72.5 |

Table 21-4 Friable rock zones in ISFSI Study Area borings. (continued)

| Boring | Depth Interval of friable rock (feet) | Test Sample I.D. | Elevation Interval (feet) | Friable Zone Interval Thickness (ft) | |
|---------------------------|---|---------------------|--|--|------------------|
| 00BA-3 | Elevation at ground surface | | 306.0 | | |
| | 4.0-5.6 | | 302.0-300.4 | 1.6 | |
| | 11.1-12.8 | | 294.9-293.2 | 1.7 | |
| | 21.6-24.0 | | 284.4-282.0 | 2.4 | |
| | | | | | |
| Total Borehole Depth = | 30.0 | | Total Friable Zone Interval Footage = | 5.7 | % Friable = 19.0 |
| 01CTF-A | Elevation at ground surface | | 306.1 | | |
| | 6.3-10.6 | | 299.8-295.5 | 4.3 | |
| | 18.0-24.7 | | 288.1-281.4 | 6.7 | |
| | | | | | |
| | | | | | |
| | 34.4-35.8 | | 271.7-270.3 | 1.4 | |
| | 37.7-39.5 | | 268.4-266.6 | 1.8 | |
| | 48.5-58.6 | | 257.6-247.5 | 10.1 | |
| | | | | | |
| | | | | | |
| Total Borehole Depth = | 58.6 | | Total Friable Zone Interval Footage = | 24.3 | % Friable = 41.5 |
| 01-A | Elevation at ground surface | | 305.7 | | |
| | 5.4-6.5 | | 300.3-299.2 | 1.1 | |
| | 26.2-28.4 | | 279.5-277.3 | 2.2 | |
| | 33.4-37.0 | | 272.3-268.7 | 3.6 | |
| | 46.2-48.8 | | 259.5-256.9 | 2.6 | |
| | 58.8 - 59.0 | | 364.5 - 364.7 | 0.2 | |
| | 70.0-71.6 | | 235.7-234.1 | 1.6 | |
| Total Borehole Depth = | 71.8 | | Total Friable Zone Interval Footage = | 11.3 | % Friable = 15.7 |
| 01-B | Elevation at ground surface | | 318.9 | | |
| | 38.0-39.8 | | 280.9-279.1 | 1.8 | |
| | 54.5-57.0 | | 264.4-261.9 | 2.5 | |
| Total Borehole Depth = | 72.0 | | Total Friable Zone Interval Footage = | 4.3 | % Friable = 6.0 |
| 01-C | Elevation at ground surface | | 323.0 | | |
| | 7.0-14.0 | | 316.0-309.0 | 7.0 | |
| | 40.4-42.0 | | 282.6-281.0 | 1.6 | |
| Total Borehole Depth = | 67.0 | | Total Friable Zone Interval Footage = | 8.6 | % Friable = 12.8 |

Table 21-4. Friable rock zones in ISFSI Study Area borings. (continued)

| Boring | Depth Interval of friable rock (feet) | Test Sample I.D. | Elevation Interval (feet) | Friable Zone Interval Thickness (ft) | |
|----------------|---|---------------------|------------------------------|--|------------------|
| 01-D | Elevation at ground surface | | 325.2 | | |
| | 22.0-37.6 | | 303.2-287.6 | 15.6 | |
| | 67.0-68.5 | | 258.2-256.7 | 1.5 | |
| | | | | | |
| Total Borehole | | | Total Friable Zone | | |
| Depth = | 68.5 | | Interval Footage = | 17.1 | % Friable = 25.0 |
| 01-E | Elevation at ground surface | | 337.6 | | |
| | 4.7-14.0 | | 331.3-323.6 | 9.3 | |
| | 39.2-43.0 | | 298.4-294.6 | 3.8 | |
| | 68.4-80.7 | | 269.2-256.9 | 12.3 | |
| Total Borehole | | | Total Friable Zone | | |
| Depth = | 81.0 | | Interval Footage = | 25.4 | % Friable = 31.4 |
| 01-F | Elevation at ground surface | | 390.6 | | |
| | 33.0-33.9 | | 357.6-356.7 | 0.9 | |
| | 37.0-38.0 | | 353.4-352.6 | 0.8 | |
| | 43.8-45.0 | | 346.8-345.6 | 1.2 | |
| | 46.6-47.4 | | 344.0-343.2 | 0.8 | |
| | 57.6-60.0 | | 333.0-330.6 | 2.4 | |
| | 103.0-106.0 | | 287.6-284.6 | 3.0 | |
| | 117.0-121.8 | | 273.6-268.8 | 4.8 | |
| | 123.0-124.2 | | 267.6-266.4 | 1.2 | |
| | 130.0-130.5 | | 260.6-260.1 | 0.5 | |
| Total Borehole | | | Total Friable Zone | | |
| Depth = | 130.5 | | Interval Footage = | 15.6 | % Friable = 12.0 |
| 01-G | Elevation at ground surface | | 316.8 | | |
| | 11.0-12.4 | | 305.8-304.4 | 1.4 | |
| | 19.2-20.4 | | 297.6-296.4 | 1.2 | |
| | 24.2-25.6 | | 292.6-291.2 | 1.4 | |
| | 66.0-76.0 | | 250.8-240.8 | 10 | |
| Total Borehole | | | Total Friable Zone | | |
| Depth = | 76.0 | | Interval Footage = | 14.0 | % Friable = 18.4 |

Table 21-4. Friable rock zones in ISFSI Study Area borings. (continued)

| Boring | Depth Interval of friable rock (feet) | Test Sample I.D. | Elevation Interval (feet) | Friable Zone Interval Thickness (ft) | | |
|----------------|---|---------------------|------------------------------|--|-------------|------|
| 01-H | Elevation at ground surface | | 346.6 | | | |
| | 12.0-12.6 | | 334.6-334.0 | 0.6 | | |
| | 23.7-24.0 | | 322.9-322.6 | 0.3 | | |
| | 29.4-32.0 | | 317.2-314.6 | 2.6 | | |
| | 55.5-58.6 | | 291.1-288.0 | 3.1 | | |
| | 61.0-61.2 | | 285.6-285.4 | 0.2 | | |
| | 81.0-83.0 | | 265.6-263.6 | 2.0 | | |
| | 89.2-98.2 | | 257.4-248.4 | 9.0 | | |
| Total Borehole | | | Total Friable Zone | | | |
| Depth = | 101.0 | | Interval Footage = | 17.8 | % Friable = | 17.6 |
| 01-I | Elevation at ground surface | | 566.9 | | | |
| | 33.6-39.8 | | 533.3-527.1 | 6.2 | | |
| | 61.0-61.4 | | 505.9-505.5 | 0.4 | | |
| | 62.7-63.0 | | 504.2-503.9 | 0.3 | | |
| | 68.5-69.1 | | 498.4-497.8 | 0.6 | | |
| | 109.0-115.8 | | 457.9-451.1 | 6.8 | | |
| | 155.6-156.6 | | 411.3-410.3 | 1.0 | | |
| | 252.4-252.8 | | 314.5-314.1 | 0.4 | | |
| Total Borehole | | | Total Friable Zone | | | |
| Depth = | 321.0 | | Interval Footage = | 15.7 | % Friable = | 4.9 |

Table 21-5 Discontinuity Data for Minor Faults¹

| Trench/Field Number | Trench Location | Fault Strike | Fault Dip | Fault Striation Rake | Slickensides (s) or mullions (m) | Person and Date |
|---------------------|---|--------------|-----------|----------------------|----------------------------------|----------------------------|
| T-1 | St. 23 | 170 | 85 S | 50 S | m | JLB 6/9/00 |
| T-1 | St. 24 | 297 | 72 S | 5-10 W | s | CMB 6/9/00 |
| T-2A | St 0.4 | 279 | 70 S | 8 E | m | JLB 6/11/00 |
| T-2A | St. 15 | 286 | 75 NE | 20 W | s | JLB 6/11/00 |
| T-2C | St. 3.6 | 281 | 70 N | 68 E | s | JNB/CMB 6/20/00 |
| T-2C | St. 1.2 | 264 | 84 S | 15 W | s | JNB/CMB 6/20/00 |
| T-2C | St. 0 | 280 | 70 S | 0 | s | JNB/CMB 6/20/00 |
| T-2C | St. 0 | 295 | 80 S | 0 | s | JNB/CMB 6/20/00 |
| T-3 | St. 7.5 | 295 | 55-75 S | 18 SE | m | WDP 7/10/00 |
| T-5 | St. 18 | 70 | 85 N | 2 E | s | WDP 8/2/00 |
| T-7 | St. 3.6 | 265 | 65 N | 15 E | s | JLB 6/12/00 |
| T-11A | St. 6 | 304 | 81 S | 43 E | s | RDK 8/8/00 |
| T-11A | St. 2.4 | 282 | 87 N | Subhor. | s | RDK 8/8/00 |
| T-11C | St. 3.5 | 85 | 73 S | Subhor. | s | JNB 6/19/00 |
| T-12 | St. 4 | 291 | 75 N | 10 E | s | JNB 6/20/00 |
| T-12 | St. 4 | 291 | 75 N | 8 E | m | JNB 6/20/00 |
| T-12 | St. 4.7 | 300 | 56 S | 10 E | s | JNB 6/20/00 |
| T-12 | St. 14 | 292 | 60 S | 10 W | s | JNB 6/20/00 |
| T-13 | St. 6.5 | 301 | 44 S | 10 W | s | JNB 6/20/00 |
| T-14B | St. 1.0 | 95 | 81 N | 0 | m | JLB 8/7/00 |
| T-14B | St. 1.5 | 101 | 86 S | Subhor. | m | JLB 8/7/00 |
| T-14B | St. 2.0 | 104 | 88 N | Subhor. | m | JLB 8/7/00 |
| T-15 | St. 18.5 | 297 | 83 N | Subhor. | s | JNB 6/20/00 |
| T-17A | St. 41 | 265 | 84 N | 65 W | s | JLB 8/2/00 |
| T-17A | St. 39 | 296 | 80 N | 47 W | s | JLB 8/2/00 |
| T-17A | St. 45.5 | 254 | 65 N | Subhor. | s | JLB 8/2/00 |
| T-17A | St. 11 | 90 | 85 S | Subhor. | s | JLB 8/2/00 |
| T-18B | St. 7.5 | 300 | 86-90 S | Subhor.-45 | m | JLB 8/23/00 |
| T-20A | St. 26 | 298 | 63 S | 16 SE | s | JLB 11/30/00 |
| T-20B | St. 3.2 | 273 | 61 S | 16 W | s | JLB 12/6/00 |
| T-21 | St. 20.5 | 286 | 80 N | Subhor. | s | JLB 4/16/01 WRL 4/28/01 |
| Field 1 | Diablo Canyon Rd. cut across from Raw Water Reservoirs and along projection of ISFSI site faults. | 305 | 75 N | Subhor. | m+s | WRL |

Table 21-5 Discontinuity Data for Minor Faults¹ (continued)

| Trench/Field Number | Trench Location | Fault Strike | Fault Dip | Fault Striation Rake | Slickensides (s) or mullions (m) | Person and Date |
|---------------------|---|--------------|-----------|----------------------|----------------------------------|------------------------|
| Field 2 | Diablo Canyon Rd. cut across from Raw Water Reservoirs and along projection of ISFSI site faults. Confirmed with JLB-17-1 station GPS 023 N 35° 51.264' W 120° 51.264'. | 305 | 75 N | 10 E | m+s | WRL/JLB/WDP 5/17/01 |
| JLB-17-2 | GPS 024 N35°12.927' W120°51.234'. North wall of Diablo Canyon. | 296 | 80 N | 10 E | m (?) | WRL/JLB/WDP |

¹ Fault is any discontinuity along which displacement of rock has occurred.

Table 21-6 Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches.

| Boring ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Depth ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|----------------------------------|
| 00BA-1 | 1 | 65.8 | 206 | 146.872 |
| | 2 | 56.2 | 219 | 146.613 |
| | 3 | 57.3 | 218 | 145.523 |
| | 4 | 63.5 | 68 | 137.049 |
| | 5 | 63.6 | 67 | 136.372 |
| | 6 | 72.4 | 62 | 136.243 |
| | 7 | 46.0 | 61 | 133.425 |
| | 8 | 73.0 | 229 | 132.268 |
| | 9 | 57.2 | 219 | 131.512 |
| | 10 | 69.2 | 54 | 130.582 |
| | 11 | 55.8 | 224 | 130.211 |
| | 12 | 67.5 | 229 | 129.655 |
| | 13 | 68.7 | 221 | 129.307 |
| | 14 | 63.5 | 303 | 128.736 |
| | 15 | 57.0 | 56 | 128.311 |
| | 16 | 60.4 | 73 | 126.856 |
| | 17 | 32.9 | 27 | 119.599 |
| | 18 | 69.6 | 265 | 117.687 |
| | 19 | 72.6 | 66 | 117.523 |
| | 20 | 63.7 | 84 | 110.720 |
| | 21 | 41.7 | 245 | 108.077 |
| | 22 | 17.9 | 253 | 106.846 |
| | 23 | 17.1 | 248 | 106.357 |
| | 24 | 12.2 | 257 | 105.331 |
| | 25 | 29.6 | 344 | 104.677 |
| | 26 | 41.8 | 90 | 104.074 |
| | 27 | 65.6 | 226 | 102.022 |
| | 28 | 78.1 | 203 | 95.511 |
| | 29 | 77.5 | 190 | 94.048 |
| | 30 | 72.1 | 214 | 92.707 |
| | 31 | 47.6 | 190 | 92.399 |
| | 32 | 62.2 | 230 | 91.544 |
| | 33 | 46.3 | 37 | 91.195 |
| | 34 | 68.0 | 67 | 90.227 |

| Boring ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Depth ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|----------------------------------|
| 00BA-1 continued | 35 | 36.5 | 86 | 86.763 |
| | 36 | 68.0 | 253 | 86.297 |
| | 37 | 36.2 | 235 | 83.310 |
| | 38 | 38.1 | 221 | 83.292 |
| | 39 | 63.7 | 229 | 80.387 |
| | 40 | 61.7 | 252 | 79.791 |
| | 41 | 72.0 | 201 | 78.688 |
| | 42 | 60.9 | 205 | 76.367 |
| | 43 | 52.9 | 201 | 75.547 |
| | 44 | 61.0 | 213 | 75.241 |
| | 45 | 33.9 | 221 | 73.429 |
| | 46 | 77.6 | 186 | 72.946 |
| | 47 | 38.2 | 40 | 72.034 |
| | 48 | 42.7 | 50 | 71.330 |
| | 49 | 68.5 | 233 | 71.055 |
| | 50 | 61.1 | 353 | 69.457 |
| | 51 | 68.6 | 261 | 62.156 |
| | 52 | 61.6 | 40 | 60.866 |
| | 53 | 44.7 | 202 | 59.012 |
| | 54 | 63.6 | 353 | 54.100 |
| | 55 | 64.6 | 218 | 52.725 |
| | 56 | 31.4 | 192 | 52.470 |
| | 57 | 65.7 | 360 | 51.869 |
| | 58 | 79.2 | 196 | 49.721 |
| | 59 | 70.9 | 4 | 48.368 |
| | 60 | 70.7 | 233 | 47.689 |
| | 61 | 59.0 | 238 | 47.077 |
| | 62 | 24.4 | 16 | 45.703 |
| | 63 | 73.7 | 215 | 25.729 |
| | 64 | 75.3 | 242 | 23.770 |
| | 65 | 49.6 | 232 | 23.152 |
| | 66 | 37.3 | 196 | 18.001 |
| | 67 | 65.5 | 214 | 13.289 |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Boring ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Depth ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|---------------------|-------------------------------------|
| 00BA-2 | 1 | 40.5 | 205 | 53.453 |
| | 2 | 18.6 | 267 | 50.147 |
| | 3 | 74.1 | 223 | 48.521 |
| | 4 | 48.9 | 237 | 40.597 |
| | 5 | 67.7 | 205 | 39.467 |
| | 6 | 66.8 | 214 | 39.208 |
| | 7 | 41.9 | 232 | 39.113 |
| | 8 | 40.5 | 240 | 38.731 |
| | 9 | 44.2 | 282 | 35.604 |
| | 10 | 48.1 | 272 | 34.321 |
| | 11 | 72.0 | 101 | 27.219 |
| | 12 | 71.0 | 120 | 26.263 |
| | 13 | 64.0 | 224 | 9.438 |

| Boring ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Depth ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|---------------------|-------------------------------------|
| 01CTF-A | 1 | 51.3 | 205 | 45.134 |
| | 2 | 55.1 | 250 | 44.431 |
| | 3 | 69.6 | 212 | 34.263 |
| | 4 | 55.1 | 216 | 31.310 |
| | 5 | 35.7 | 151 | 19.592 |

| Boring ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Depth ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|---------------------|-------------------------------------|
| 01-A | 1 | 70.5 | 264 | 69.083 |
| | 2 | 61.2 | 240 | 68.545 |
| | 3 | 76.6 | 235 | 68.240 |
| | 4 | 64.8 | 265 | 57.922 |
| | 5 | 49.8 | 199 | 57.577 |
| | 6 | 37.5 | 257 | 56.422 |
| | 7 | 35.7 | 358 | 53.227 |
| | 8 | 69.3 | 184 | 52.954 |
| | 9 | 67.6 | 249 | 51.988 |
| | 10 | 64.5 | 248 | 51.772 |
| | 11 | 29.4 | 182 | 51.682 |
| | 12 | 58.1 | 194 | 51.196 |
| | 13 | 34.4 | 55 | 50.081 |
| | 14 | 48.3 | 39 | 44.392 |
| | 15 | 35.1 | 225 | 42.265 |
| | 16 | 31.8 | 251 | 41.065 |
| | 17 | 24.3 | 243 | 40.711 |
| | 18 | 73.5 | 93 | 39.856 |
| | 19 | 35.8 | 229 | 37.372 |
| | 20 | 23.7 | 284 | 36.913 |
| | 21 | 26.6 | 224 | 36.724 |
| | 22 | 34.7 | 240 | 34.384 |
| | 23 | 78.8 | 192 | 33.245 |
| | 24 | 67.9 | 192 | 32.682 |
| | 25 | 76.3 | 150 | 31.869 |
| | 26 | 71.5 | 243 | 30.474 |
| | 27 | 56.5 | 223 | 23.229 |
| | 28 | 77.4 | 54 | 21.080 |
| | 29 | 67.2 | 231 | 19.973 |
| | 30 | 81.5 | 30 | 16.441 |
| | 31 | 31.3 | 171 | 15.275 |
| | 32 | 36.3 | 330 | 8.838 |
| | 33 | 77.2 | 50 | 7.758 |
| | 34 | 42.2 | 188 | 6.300 |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Boring ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Depth(5) of Fracture |
|-----------------------|-------------------|--------|------------------|----------------------|
| 01-B | 1 | 71.5 | 215 | |
| | 2 | 41.6 | 245 | 66.291 |
| | 3 | 69.0 | 250 | 65.902 |
| | 4 | 59.6 | 237 | 64.885 |
| | 5 | 36.5 | 194 | 47.241 |
| | 6 | 62.1 | 214 | 37.695 |
| | 7 | 60.8 | 266 | 33.099 |
| | 8 | 28.5 | 277 | 27.706 |
| | 9 | 83.0 | 257 | 26.796 |
| | 10 | 41.5 | 259 | 26.506 |
| | 11 | 39.4 | 163 | 22.992 |
| | 12 | 75.6 | 243 | 21.277 |
| | 13 | 27.8 | 180 | 20.117 |
| | 14 | 25.6 | 326 | 18.984 |
| | 15 | 28.7 | 273 | 16.330 |
| | 16 | 65.8 | 229 | 11.573 |

| Boring ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Depth ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|----------------------------------|
| 01-C | 1 | 28.6 | 229 | 65.059 |
| | 2 | 26.6 | 251 | 64.267 |
| | 3 | 63.1 | 246 | 62.051 |
| | 4 | 54.7 | 222 | 61.360 |
| | 5 | 42.8 | 195 | 57.847 |
| | 6 | 49.1 | 285 | 57.648 |
| | 7 | 64.4 | 76 | 57.448 |
| | 8 | 68.1 | 237 | 51.833 |
| | 9 | 67.2 | 39 | 50.875 |
| | 10 | 69.8 | 47 | 49.852 |
| | 11 | 30.7 | 194 | 49.044 |
| | 12 | 48.4 | 239 | 47.992 |
| | 13 | 32.6 | 167 | 45.804 |
| | 14 | 35.5 | 201 | 43.648 |
| | 15 | 37.7 | 203 | 40.429 |
| | 16 | 57.0 | 186 | 37.897 |
| | 17 | 15.5 | 206 | 37.393 |
| | 18 | 42.9 | 229 | 34.720 |
| | 19 | 41.2 | 176 | 31.155 |
| | 20 | 27.8 | 235 | 30.823 |
| | 21 | 52.9 | 345 | 30.601 |
| | 22 | 33.7 | 206 | 30.313 |
| | 23 | 72.9 | 236 | 29.238 |
| | 24 | 49.9 | 239 | 29.013 |
| | 25 | 40.9 | 250 | 28.693 |
| | 26 | 45.1 | 176 | 27.019 |
| | 27 | 64.8 | 232 | 26.428 |
| | 28 | 34.9 | 206 | 25.726 |
| | 29 | 58.6 | 226 | 24.910 |
| | 30 | 29.1 | 326 | 24.787 |
| | 31 | 40.2 | 224 | 22.735 |
| | 32 | 78.2 | 219 | 21.430 |
| | 33 | 59.7 | 249 | 19.690 |
| | 34 | 38.3 | 178 | 14.635 |
| | 35 | 50.0 | 184 | 13.636 |
| | 36 | 51.3 | 214 | 12.883 |
| | 37 | 60.2 | 187 | 12.247 |
| | 38 | 75.5 | 209 | 11.445 |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Boring ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Depth ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|----------------------------------|
| 01-D | 1 | 34.1 | 251 | 58.192 |
| | 2 | 44.3 | 192 | 50.247 |
| | 3 | 65.5 | 265 | 49.672 |
| | 4 | 33.6 | 191 | 47.825 |
| | 5 | 66.9 | 278 | 42.957 |
| | 6 | 61.8 | 275 | 42.454 |
| | 7 | 62.9 | 254 | 42.040 |
| | 8 | 51.6 | 108 | 40.118 |
| | 9 | 30.4 | 282 | 36.591 |
| | 10 | 26.2 | 303 | 36.454 |
| | 11 | 62.7 | 266 | 36.174 |
| | 12 | 42.8 | 204 | 34.882 |
| | 13 | 60.7 | 77 | 34.449 |
| | 14 | 30.9 | 328 | 33.706 |
| | 15 | 44.1 | 299 | 33.413 |
| | 16 | 19.1 | 346 | 32.307 |
| | 17 | 32.5 | 304 | 28.878 |
| | 18 | 42.4 | 332 | 26.744 |
| | 19 | 44.2 | 297 | 26.046 |
| | 20 | 34.5 | 200 | 24.130 |
| | 21 | 48.1 | 183 | 23.318 |
| | 22 | 37.7 | 229 | 17.242 |
| | 23 | 86.9 | 95 | 13.485 |
| | 24 | 77.6 | 241 | 8.355 |
| | 25 | 64.5 | 273 | 7.020 |

| Boring ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Depth ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|----------------------------------|
| 01-E | 1 | 51.8 | 210 | 79.228 |
| | 2 | 64.7 | 208 | 78.505 |
| | 3 | 72.1 | 210 | 75.400 |
| | 4 | 79.4 | 281 | 66.396 |
| | 5 | 75.2 | 253 | 59.959 |
| | 6 | 76.9 | 215 | 57.898 |
| | 7 | 67.6 | 229 | 54.626 |
| | 8 | 69.2 | 220 | 53.573 |
| | 9 | 85.4 | 232 | 51.698 |
| | 10 | 81.1 | 22 | 36.199 |
| | 11 | 63.8 | 267 | 35.461 |
| | 12 | 68.3 | 278 | 29.089 |
| | 13 | 45.0 | 236 | 25.673 |
| | 14 | 66.5 | 2 | 15.680 |
| | 15 | 72.7 | 342 | 13.177 |
| | 16 | 67.1 | 203 | 9.579 |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Boring ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Depth ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|----------------------------------|
| 01-F | 2 | 42.6 | 224 | 120.021 |
| | 3 | 79.2 | 45 | 87.824 |
| | 4 | 61.3 | 197 | 82.255 |
| | 5 | 57.9 | 213 | 82.036 |
| | 6 | 60.5 | 215 | 81.472 |
| | 7 | 62.7 | 228 | 81.159 |
| | 8 | 66.0 | 231 | 80.287 |
| | 9 | 48.0 | 238 | 71.965 |
| | 10 | 66.4 | 218 | 69.880 |
| | 11 | 66.8 | 190 | 69.665 |
| | 12 | 72.1 | 194 | 68.299 |
| | 13 | 65.5 | 223 | 64.732 |
| | 14 | 70.3 | 17 | 63.379 |
| | 15 | 53.9 | 178 | 61.017 |
| | 16 | 38.9 | 317 | 58.766 |
| | 17 | 29.0 | 200 | 53.569 |
| | 18 | 65.9 | 2 | 51.178 |
| | 19 | 40.0 | 182 | 50.897 |
| | 20 | 43.6 | 194 | 49.677 |
| | 21 | 71.8 | 230 | 46.728 |
| | 22 | 31.5 | 185 | 43.719 |
| | 23 | 32.2 | 188 | 41.198 |
| | 24 | 34.3 | 193 | 26.194 |
| | 25 | 53.6 | 211 | 4.924 |

| Boring ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Depth ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|----------------------------------|
| 01-G | 1 | 78.5 | 212 | 71.790 |
| | 2 | 61.6 | 272 | 70.765 |
| | 3 | 46.1 | 227 | 65.647 |
| | 4 | 68.2 | 210 | 63.781 |
| | 5 | 70.6 | 64 | 61.594 |
| | 6 | 69.4 | 237 | 50.116 |
| | 7 | 67.3 | 244 | 49.801 |
| | 8 | 67.4 | 249 | 49.303 |
| | 9 | 78.5 | 281 | 31.327 |
| | 10 | 58.5 | 297 | 26.302 |
| | 11 | 31.3 | 243 | 14.083 |
| | 12 | 72.1 | 286 | 11.392 |
| | 13 | 63.2 | 265 | 7.867 |

| Boring ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Depth ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|----------------------------------|
| 01-H | 1 | 42.3 | 289 | 91.717 |
| | 2 | 69.0 | 306 | 91.210 |
| | 3 | 75.9 | 259 | 82.788 |
| | 4 | 69.8 | 249 | 77.589 |
| | 5 | 69.6 | 242 | 75.574 |
| | 6 | 33.7 | 259 | 66.793 |
| | 7 | 34.5 | 253 | 66.625 |
| | 8 | 55.2 | 42 | 28.355 |
| | 9 | 51.0 | 275 | 24.063 |
| | 10 | 58.4 | 264 | 22.203 |
| | 11 | 35.1 | 230 | 16.238 |
| | 12 | 72.3 | 119 | 14.676 |
| | 13 | 79.4 | 256 | 11.530 |
| | 14 | 33.9 | 235 | 9.324 |
| | 15 | 25.5 | 231 | 7.332 |
| | 16 | 34.4 | 244 | 7.207 |
| | 17 | 56.2 | 253 | 6.520 |
| | 18 | 37.5 | 223 | 5.819 |
| | 19 | 52.8 | 6 | 4.867 |
| | 20 | 35.3 | 247 | 4.466 |
| | 21 | 41.4 | 227 | 4.297 |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches(continued).

| Boring ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Depth ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|----------------------------------|
| 01-I | 1 | 60.3 | 68 | 267.961 |
| | 2 | 76.1 | 20 | 245.512 |
| | 3 | 60.4 | 244 | 236.269 |
| | 4 | 81.0 | 73 | 234.018 |
| | 5 | 67.2 | 251 | 232.393 |
| | 6 | 65.7 | 308 | 230.599 |
| | 7 | 58.9 | 109 | 229.744 |
| | 8 | 68.6 | 198 | 205.711 |
| | 9 | 73.0 | 244 | 193.105 |
| | 10 | 61.5 | 259 | 187.690 |
| | 11 | 58.4 | 216 | 186.571 |
| | 12 | 77.9 | 240 | 170.377 |
| | 13 | 45.7 | 308 | 154.348 |
| | 14 | 70.8 | 243 | 146.380 |
| | 15 | 71.1 | 251 | 136.045 |
| | 16 | 60.8 | 228 | 134.206 |
| | 17 | 78.8 | 247 | 128.566 |
| | 18 | 69.7 | 225 | 127.132 |
| | 19 | 44.5 | 200 | 125.797 |
| | 20 | 36.6 | 131 | 125.125 |
| | 21 | 81.1 | 226 | 114.905 |
| | 22 | 81.6 | 234 | 103.383 |
| | 23 | 84.7 | 45 | 102.430 |
| | 24 | 70.2 | 44 | 99.427 |
| | 25 | 59.3 | 204 | 94.844 |
| | 26 | 69.2 | 71 | 94.040 |
| | 27 | 63.5 | 219 | 93.767 |
| | 28 | 63.9 | 277 | 91.139 |
| | 29 | 67.0 | 273 | 91.100 |
| | 30 | 32.2 | 248 | 85.493 |
| Boring ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Depth ⁽⁵⁾ of Fracture |
| 01-I | 31 | 67.5 | 51 | 78.887 |
| Continued | 32 | 31.3 | 212 | 75.704 |
| | 33 | 51.4 | 255 | 75.464 |
| | 34 | 70.5 | 235 | 74.900 |
| | 35 | 26.5 | 334 | 72.003 |
| | 36 | 41.9 | 55 | 70.583 |
| | 37 | 43.4 | 50 | 69.833 |
| | 38 | 75.5 | 30 | 68.897 |
| | 39 | 33.2 | 312 | 68.243 |
| | 40 | 32.0 | 353 | 67.022 |
| | 41 | 52.8 | 242 | 65.306 |
| | 42 | 34.7 | 253 | 63.965 |
| | 43 | 28.7 | 267 | 63.620 |
| | 44 | 62.8 | 232 | 63.491 |
| | 45 | 86.3 | 100 | 62.249 |
| | 46 | 70.3 | 224 | 59.336 |
| | 47 | 64.7 | 279 | 54.240 |
| | 48 | 81.7 | 246 | 52.161 |
| | 49 | 76.3 | 204 | 47.551 |
| | 50 | 72.4 | 44 | 44.221 |
| | 51 | 71.1 | 231 | 43.762 |
| | 52 | 70.2 | 213 | 36.817 |
| | 53 | 30.7 | 231 | 28.024 |
| | 54 | 73.2 | 52 | 19.099 |
| | 55 | 73.2 | 84 | 18.667 |
| | 56 | 57.2 | 238 | 16.602 |
| | 57 | 56.3 | 71 | 11.194 |
| | 58 | 31.1 | 262 | 9.688 |
| | 59 | 56.5 | 46 | 9.493 |
| | 60 | 63.3 | 97 | 7.176 |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-1 | 1 | 56 | 270 | Joint |
| | 2 | 88 | 347 | Joint |
| | 3 | 60 | 200 | Joint |
| | 4 | 84 | 200 | Joint |
| | 5 | 75 | 10 | Joint |
| | 6 | 74 | 5 | Joint |
| | 7 | 84 | 198 | Fault |
| | 8 | 76 | 78 | Joint |
| | 9 | 76 | 78 | Joint |
| | 10 | 78 | 215 | Joint |
| | 11 | 47 | 202 | Joint |
| | 12 | 47 | 202 | Joint |
| | 13 | 47 | 202 | Joint |
| | 14 | 72 | 355 | Fault |
| | 15 | 58 | 190 | Joint |
| | 16 | 82 | 182 | Joint |
| | 17 | 88 | 190 | Joint |
| | 18 | 72 | 175 | Fault |
| | 19 | 82 | 192 | Joint |
| | 20 | 65 | 185 | Joint |
| | 21 | 86 | 192 | Joint |
| | 22 | 86 | 192 | Joint |
| | 23 | 76 | 210 | Fault |
| | 24 | 85 | 195 | Fault |
| | 25 | 85 | 195 | Fault |
| | 26 | 48 | 175 | Joint |
| | 27 | 72 | 296 | Joint |
| | 28 | 83 | 235 | Joint |
| | 29 | 28 | 290 | Joint |
| | 30 | 80 | 205 | Joint |
| | 31 | 80 | 200 | Joint |
| | 32 | 88 | 260 | Joint |

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-1 Continued | 33 | 64 | 242 | Joint |
| | 34 | 87 | 285 | Joint |
| | 35 | 70 | 188 | Joint |
| | 36 | 74 | 71 | Joint |
| | 37 | 87 | 204 | Joint |
| | 38 | 54 | 75 | Joint |
| | 39 | 76 | 95 | Joint |
| | 40 | 64 | 255 | Joint |
| | 41 | 72 | 207 | Fault |
| | 42 | 72 | 195 | Fault |
| | 43 | 79 | 203 | Fault |
| | 44 | 70 | 210 | Fault |
| | 45 | 76 | 60 | Joint |
| | 46 | 85 | 220 | Joint |
| | 47 | 78 | 235 | Joint |
| | 48 | 70 | 40 | Joint |
| | 49 | 60 | 175 | Joint |
| | 50 | 65 | 25 | Joint |
| | 51 | 86 | 210 | Joint |
| | 52 | 80 | 8 | Joint |
| | 53 | 88 | 305 | Joint |
| | 54 | 80 | 200 | Joint |
| | 55 | 82 | 15 | Joint |
| | 56 | 86 | 194 | Joint |
| | 57 | 52 | 268 | Joint |
| | 58 | 80 | 252 | Joint |
| | 59 | 85 | 186 | Joint |
| | 60 | 70 | 250 | Joint |
| | 61 | 86 | 210 | Joint |
| | 62 | 74 | 260 | Joint |
| | 63 | 82 | 205 | Joint |
| | 64 | 55 | 265 | Joint |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-2 | 1 | 76 | 253 | Joint |
| | 2 | 85 | 187 | Joint |
| | 3 | 71 | 246 | Joint |
| | 4 | 73 | 1 | Joint |
| | 5 | 67 | 251 | Joint |
| | 6 | 86 | 199 | Joint |
| | 7 | 70 | 284 | Joint |
| | 8 | 75 | 24 | Joint |
| | 9 | 71 | 263 | Joint |
| | 10 | 84 | 229 | Joint |
| | 11 | 45 | 297 | Joint |
| | 12 | 86 | 223 | Joint |
| | 13 | 25 | 359 | Joint |
| | 14 | 56 | 277 | Joint |
| | 15 | 70 | 12 | Joint |
| | 16 | 65 | 251 | Joint |
| | 17 | 57 | 15 | Joint |
| | 18 | 64 | 246 | Joint |
| | 19 | 62 | 244 | Joint |
| | 20 | 76 | 290 | Joint |
| | 21 | 70 | 249 | Joint |
| | 22 | 40 | 311 | Joint |
| | 23 | 83 | 350 | Joint |
| | 24 | 89 | 211 | Joint |
| | 25 | 79 | 219 | Joint |
| | 26 | 78 | 65 | Joint |
| | 27 | 69 | 249 | Joint |
| | 28 | 71 | 236 | Joint |
| | 29 | 70 | 273 | Joint |
| | 30 | 84 | 26 | Joint |
| | 31 | 80 | 90 | Joint |
| | 32 | 84 | 215 | Joint |
| | 33 | 64 | 195 | Fault |
| | 34 | 65 | 266 | Joint |
| | 35 | 79 | 204 | Joint |
| | 36 | 75 | 286 | Fault |
| | 37 | 62 | 235 | Joint |
| | 38 | 53 | 323 | Joint |
| | 39 | 83 | 258 | Joint |
| | 40 | 88 | 220 | Joint |
| | 41 | 80 | 223 | Joint |
| | 42 | 86 | 106 | Joint |
| | 43 | 90 | 220 | Joint |
| T-2 Continued | 44 | 80 | 194 | Joint |
| | 45 | 89 | 114 | Joint |
| | 46 | 76 | 211 | Joint |
| | 47 | 85 | 196 | Joint |
| | 48 | 74 | 122 | Joint |
| | 49 | 86 | 289 | Joint |
| | 50 | 84 | 227 | Joint |
| | 51 | 80 | 100 | Joint |
| | 52 | 84 | 118 | Joint |
| | 53 | 51 | 301 | Joint |
| | 54 | 46 | 268 | Joint |
| | 55 | 81 | 119 | Joint |
| | 56 | 86 | 269 | Joint |
| | 57 | 85 | 200 | Joint |
| | 58 | 59 | 261 | Joint |
| | 59 | 86 | 95 | Joint |
| | 60 | 77 | 201 | Joint |
| | 61 | 84 | 278 | Joint |
| | 62 | 86 | 36 | Joint |
| | 63 | 44 | 198 | Joint |
| | 64 | 87 | 75 | Joint |
| | 65 | 65 | 212 | Joint |
| | 66 | 80 | 113 | Joint |
| | 67 | 74 | 222 | Joint |
| | 68 | 84 | 272 | Joint |
| | 69 | 86 | 216 | Joint |
| | 70 | 83 | 256 | Joint |
| | 71 | 70 | 190 | Fault |
| | 72 | 80 | 205 | Fault |
| | 73 | 89 | 3 | Joint |
| | 74 | 72 | 263 | Joint |
| | 75 | 84 | 174 | Fault |
| | 76 | 81 | 32 | Joint |
| | 77 | 90 | 181 | Joint |
| | 78 | 87 | 176 | Fault |
| | 79 | 60 | 2 | Joint |
| | 80 | 64 | 256 | Joint |
| | 81 | 80 | 11 | Fault |
| | 82 | 55 | 199 | Joint |
| | 83 | 61 | 191 | Joint |
| | 84 | 90 | 35 | Joint |
| | 85 | 61 | 286 | Joint |
| | 86 | 55 | 276 | Joint |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|---------------------|------------------------------------|
| T-3 | 1 | 71 | 208 | Joint |
| | 2 | 69 | 261 | Joint |
| | 3 | 74 | 226 | Fault |
| | 4 | 85 | 91 | Joint |
| | 5 | 76 | 261 | Joint |
| | 6 | 76 | 320 | Joint |
| | 7 | 73 | 234 | Joint |
| | 8 | 76 | 20 | Joint |
| | 9 | 90 | 190 | Joint |
| | 10 | 67 | 9 | Joint |
| | 11 | 30 | 206 | Joint |
| | 12 | 79 | 309 | Joint |
| | 13 | 65 | 187 | Joint |
| | 14 | 64 | 240 | Joint |
| | 15 | 74 | 208 | Fault |
| | 16 | 60 | 255 | Joint |
| | 17 | 85 | 180 | Joint |
| | 18 | 51 | 248 | Fault |
| | 19 | 66 | 21 | Joint |
| | 20 | 61 | 208 | Joint |
| | 21 | 79 | 218 | Joint |
| | 22 | 90 | 205 | Joint |
| | 23 | 62 | 291 | Joint |
| | 24 | 74 | 201 | Joint |
| | 25 | 90 | 269 | Joint |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|---------------------|------------------------------------|
| T-4 | 1 | 88 | 275 | Joint |
| | 2 | 85 | 5 | Joint |
| | 3 | 77 | 258 | Joint of crushed zone |
| | 4 | 75 | 248 | Joint |
| | 5 | 88 | 105 | Joint |
| | 6 | 60 | 11 | Joint |
| | 7 | 89 | 85 | Joint |
| | 8 | 58 | 186 | Joint |
| | 9 | 60 | 5 | Joint |
| | 10 | 86 | 94 | Joint |
| | 11 | 42 | 340 | Joint |
| | 12 | 65 | 100 | Joint |
| | 13 | 86 | 105 | Joint |
| | 14 | 88 | 106 | Joint |
| | 15 | 30 | 185 | Joint |
| | 16 | 56 | 158 | Joint |
| | 17 | 86 | 275 | Joint |
| | 18 | 74 | 220 | Joint |
| | 19 | 74 | 95 | Joint |
| | 20 | 50 | 352 | Joint |
| | 21 | 35 | 332 | Joint |
| | 22 | 66 | 240 | Joint |
| | 23 | 42 | 347 | Joint |
| | 24 | 62 | 250 | Joint |
| | 25 | 70 | 200 | Joint |
| | 26 | 82 | 355 | Fault |

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|---------------------|------------------------------------|
| T-4 | 27 | 82 | 125 | Joint |
| Continued | 28 | 88 | 330 | Joint |
| | 29 | 80 | 115 | Joint |
| | 30 | 12 | 275 | Joint |
| | 31 | 48 | 278 | Joint |
| | 32 | 68 | 335 | Joint |
| | 33 | 70 | 342 | Joint |
| | 34 | 82 | 5 | Joint |
| | 35 | 52 | 260 | Joint |
| | 36 | 80 | 164 | Joint |
| | 37 | 65 | 238 | Joint |
| | 38 | 75 | 215 | Joint |
| | 39 | 80 | 190 | Joint |
| | 40 | 45 | 220 | Joint |
| | 41 | 68 | 330 | Joint |
| | 42 | 68 | 272 | Joint |
| | 43 | 82 | 185 | Joint |
| | 44 | 80 | 60 | Joint |
| | 45 | 88 | 200 | Joint of crushed |
| | 46 | 58 | 280 | Joint |
| | 47 | 72 | 275 | Joint |
| | 48 | 8 | 250 | Joint |
| | 49 | 89 | 305 | Joint |
| | 50 | 70 | 275 | Joint |
| | 51 | 76 | 340 | Joint |
| | 52 | 62 | 260 | Joint |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-5 | 1 | 90 | 277 | Joint |
| | 2 | 90 | 307 | Joint |
| | 3 | 87 | 301 | Joint |
| | 4 | 90 | 283 | Joint |
| | 5 | 50 | 217 | Joint |
| | 6 | 83 | 198 | Joint |
| | 7 | 70 | 121 | Joint |
| | 8 | 90 | 201 | Joint |
| | 9 | 70 | 70 | Joint |
| | 10 | 85 | 330 | Fault |
| | 11 | 70 | 70 | bric of crushed zone |
| | 12 | 76 | 76 | Joint |
| | 13 | 77 | 105 | Joint |
| | 14 | 64 | 291 | Joint |
| | 15 | 90 | 42 | bric of crushed zone |
| | 16 | 87 | 294 | Joint |
| | 17 | 57 | 131 | Joint |
| | 18 | 55 | 265 | Joint |
| | 19 | 75 | 344 | Joint |
| | 20 | 50 | 254 | Joint |
| | 21 | 70 | 144 | Joint |
| | 22 | 65 | 249 | Joint |
| | 23 | 83 | 146 | Joint |
| | 24 | 84 | 55 | Joint |
| | 25 | 78 | 165 | Joint |

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-5 | 26 | 63 | 250 | Fault |
| Continued | 27 | 86 | 252 | Joint |
| | 28 | 74 | 345 | Joint |
| | 29 | 25 | 242 | Joint |
| | 30 | 75 | 264 | Joint |
| | 31 | 63 | 271 | Joint |
| | 32 | 78 | 249 | Joint |
| | 33 | 77 | 209 | Joint |
| | 34 | 70 | 270 | Joint |
| | 35 | 86 | 261 | Joint |
| | 36 | 76 | 204 | Joint |
| | 37 | 51 | 280 | Joint |
| | 38 | 70 | 252 | Joint |
| | 39 | 74 | 18 | Joint |
| | 40 | 75 | 258 | Joint |
| | 41 | 90 | 339 | Fault |
| | 42 | 85 | 340 | bric of crushed |
| | 43 | 79 | 206 | Joint |
| | 44 | 78 | 71 | Joint |
| | 45 | 83 | 185 | Joint |
| | 46 | 84 | 289 | Joint |
| | 47 | 57 | 226 | Joint |
| | 48 | 61 | 243 | Joint |
| | 49 | 75 | 241 | Joint |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches(continued).

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-6 | 1 | 70 | 0 | Joint |
| | 2 | 40 | 215 | Joint |
| | 3 | 48 | 10 | Joint |
| | 4 | 90 | 220 | Joint |
| | 5 | 78 | 70 | Joint |
| | 6 | 89 | 82 | Joint |
| | 7 | 71 | 92 | Joint |
| | 8 | 82 | 265 | Joint |
| | 9 | 68 | 25 | Fault |
| | 10 | 88 | 105 | Joint |
| | 11 | 82 | 52 | Joint |
| | 12 | 88 | 95 | Joint |
| | 13 | 90 | 310 | Joint |
| | 14 | 62 | 15 | Joint |
| | 15 | 15 | 240 | Joint |
| | 16 | 70 | 6 | Joint |
| | 17 | 88 | 85 | Joint |
| | 18 | 22 | 225 | Joint |
| | 19 | 80 | 255 | Joint |
| | 20 | 84 | 345 | Joint |
| | 21 | 18 | 230 | Joint |
| | 22 | 74 | 75 | Joint |
| | 23 | 72 | 238 | Joint |
| | 24 | 76 | 4 | Joint |

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-6 | 25 | 86 | 190 | Joint |
| Continued | 26 | 78 | 70 | Joint |
| | 27 | 82 | 200 | Fault |
| | 28 | 89 | 265 | Joint |
| | 29 | 78 | 255 | Joint |
| | 30 | 22 | 235 | Joint |
| | 31 | 89 | 180 | Joint |
| | 32 | 85 | 270 | Joint |
| | 33 | 85 | 145 | Joint |
| | 34 | 82 | 70 | Joint |
| | 35 | 80 | 255 | Joint |
| | 36 | 90 | 145 | Joint |
| | 37 | 86 | 46 | Joint |
| | 38 | 78 | 292 | Joint |
| | 39 | 76 | 333 | Joint |
| | 40 | 80 | 290 | Joint |
| | 41 | 78 | 185 | Joint |
| | 42 | 84 | 185 | Joint |
| | 43 | 74 | 245 | Joint |
| | 44 | 78 | 260 | Joint |
| | 45 | 86 | 215 | Joint |
| | 46 | 76 | 65 | Joint |
| | 47 | 75 | 250 | Joint |
| | 48 | 75 | 10 | Joint |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-11 | 1 | 79 | 122 | Joint |
| | 2 | 63 | 346 | Joint |
| | 3 | 80 | 317 | Joint |
| | 4 | 81 | 15 | Joint |
| | 5 | 65 | 349 | Joint |
| | 6 | 78 | 41 | Joint |
| | 7 | 65 | 314 | Joint |
| | 8 | 70 | 238 | Joint |
| | 9 | 70 | 1 | Joint |
| | 10 | 85 | 285 | Joint |
| | 11 | 84 | 295 | Joint |
| | 12 | 75 | 198 | Joint |
| | 13 | 50 | 355 | Joint |
| | 14 | 55 | 260 | Joint |
| | 15 | 86 | 180 | Joint |
| | 16 | 87 | 255 | Joint |
| | 17 | 85 | 10 | Joint |
| | 18 | 70 | 281 | Joint |
| | 19 | 35 | 314 | Joint |
| | 20 | 90 | 249 | Joint |
| | 21 | 82 | 264 | Joint |
| | 22 | 65 | 260 | Joint |
| | 23 | 85 | 171 | Joint |
| | 24 | 71 | 208 | Joint |
| | 25 | 89 | 242 | Joint |
| | 26 | 90 | 255 | Joint |
| | 27 | 64 | 0 | Joint |
| | 28 | 68 | 70 | Joint |
| | 29 | 72 | 221 | Joint |
| | 30 | 84 | 61 | Joint |
| | 31 | 80 | 164 | Joint |
| | 32 | 76 | 267 | Fault |
| | 33 | 81 | 66 | Joint |
| | 34 | 79 | 6 | Joint |
| | 35 | 79 | 229 | Joint |
| | 36 | 77 | 193 | Joint |

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-12 | 1 | 49 | 274 | Joint |
| | 2 | 83 | 236 | Joint |
| | 3 | 79 | 20 | Fault |
| | 4 | 77 | 180 | Joint |
| | 5 | 79 | 197 | Joint |
| | 6 | 85 | 1 | Joint |
| | 7 | 77 | 231 | Joint |
| | 8 | 55 | 258 | Joint |
| | 9 | 64 | 175 | Joint |
| | 10 | 73 | 226 | Joint |
| | 11 | 88 | 228 | Joint |
| | 12 | 45 | 213 | Joint |
| | 13 | 90 | 25 | Joint |
| | 14 | 67 | 221 | Joint |
| | 15 | 60 | 158 | Fault |
| | 16 | 80 | 350 | Fault |

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-13 | 1 | 81 | 208 | Joint |
| | 2 | 90 | 195 | Joint |
| | 3 | 66 | 248 | Joint |
| | 4 | 89 | 244 | Joint |
| | 5 | 87 | 202 | Joint |
| | 6 | 82 | 248 | Joint |
| | 7 | 55 | 210 | Fault |
| | 8 | 43 | 209 | Fault |
| | 9 | 81 | 340 | Fault |
| | 10 | 79 | 265 | Joint |
| | 11 | 23 | 205 | Joint |
| | 12 | 81 | 85 | Joint |
| | 13 | 47 | 46 | Joint |
| | 14 | 61 | 200 | Joint |
| | 15 | 14 | 200 | Joint |
| | 16 | 80 | 186 | Joint |
| | 17 | 69 | 9 | Joint |
| | 18 | 76 | 256 | Joint |
| | 19 | 51 | 254 | Joint |
| | 20 | 82 | 24 | Joint |
| | 21 | 83 | 195 | Joint |
| | 22 | 60 | 233 | Joint |
| | 23 | 86 | 15 | Joint |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-14 | 1 | 87 | 11 | Joint |
| | 2 | 49 | 266 | Joint |
| | 3 | 83 | 2 | Joint |
| | 4 | 74 | 195 | Joint |
| | 5 | 68 | 99 | Joint |
| | 6 | 48 | 154 | Joint |
| | 7 | 90 | 226 | Joint |
| | 8 | 30 | 1 | Joint |
| | 9 | 68 | 245 | Joint |
| | 10 | 86 | 183 | Joint |
| | 11 | 74 | 273 | Joint |
| | 12 | 59 | 4 | Joint |
| | 13 | 52 | 184 | Joint |
| | 14 | 50 | 185 | Joint |
| | 15 | 78 | 165 | Joint |
| | 16 | 71 | 264 | Joint |
| | 17 | 76 | 178 | Joint |
| | 18 | 85 | 279 | Joint |
| | 19 | 87 | 299 | Joint |
| | 20 | 83 | 250 | Joint |
| | 21 | 84 | 0 | Joint |
| | 22 | 86 | 279 | Joint |
| | 23 | 80 | 352 | Joint |
| | 24 | 85 | 322 | Joint |
| | 25 | 90 | 2 | Joint |
| | 26 | 79 | 6 | Joint |
| | 27 | 88 | 185 | Joint |
| | 28 | 90 | 270 | Joint |
| | 29 | 52 | 356 | Joint |
| | 30 | 75 | 162 | Joint |
| | 31 | 90 | 13 | Joint |
| | 32 | 84 | 330 | Joint |
| | 33 | 85 | 22 | Joint |
| | 34 | 80 | 266 | Joint |
| | 35 | 61 | 176 | Joint |
| | 36 | 90 | 279 | Joint |

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-14 | 37 | 84 | 333 | Joint |
| Continued | 38 | 85 | 81 | Joint |
| | 39 | 80 | 28 | Joint |
| | 40 | 86 | 196 | Joint |
| | 41 | 81 | 174 | Joint |
| | 42 | 85 | 115 | Joint |
| | 43 | 69 | 3 | Joint |
| | 44 | 81 | 96 | Joint |
| | 45 | 90 | 220 | Joint |

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-15 | 1 | 77 | 229 | Joint |
| | 2 | 66 | 209 | Joint |
| | 3 | 83 | 69 | Joint |
| | 4 | 85 | 72 | Joint |
| | 5 | 90 | 66 | Joint |
| | 6 | 86 | 70 | Joint |
| | 7 | 90 | 32 | Joint |
| | 8 | 90 | 64 | Joint |
| | 9 | 87 | 71 | Joint |
| | 10 | 85 | 246 | Joint |
| | 11 | 30 | 140 | Joint |
| | 12 | 83 | 44 | Joint |
| | 13 | 69 | 185 | Joint |
| | 14 | 83 | 248 | Joint |
| | 15 | 80 | 81 | Joint |
| | 16 | 62 | 39 | Joint |
| | 17 | 81 | 238 | Joint |
| | 18 | 65 | 312 | Joint |
| | 19 | 60 | 56 | Joint |
| | 20 | 76 | 255 | Joint |
| | 21 | 72 | 254 | Joint |
| | 22 | 78 | 222 | Joint |
| | 23 | 84 | 25 | Joint |
| | 24 | 87 | 21 | Joint |
| | 25 | 90 | 250 | Joint |
| | 26 | 87 | 240 | Joint |
| | 27 | 90 | 272 | Joint |
| | 28 | 87 | 285 | Fault |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|---------------------|------------------------------------|
| T-17 | 1 | 70 | 270 | joint |
| | 2 | 86 | 290 | joint |
| | 3 | 50 | 190 | joint |
| | 4 | 85 | 250 | joint |
| | 5 | 46 | 235 | joint |
| | 6 | 75 | 285 | joint |
| | 7 | 68 | 286 | joint |
| | 8 | 50 | 205 | joint |
| | 9 | 84 | 235 | shear zone |
| | 10 | 66 | 228 | joint |
| | 11 | 30 | 320 | joint |
| | 12 | 82 | 90 | joint |
| | 13 | 80 | 250 | joint |
| | 14 | 78 | 75 | joint |
| | 15 | 88 | 270 | joint |
| | 16 | 82 | 268 | joint |
| | 17 | 72 | 82 | joint |
| | 18 | 87 | 280 | joint |
| | 19 | 78 | 345 | joint |
| | 20 | 86 | 90 | joint |
| | 21 | 88 | 266 | joint |
| | 22 | 56 | 135 | joint |
| | 23 | 47 | 138 | joint |
| | 24 | 75 | 65 | fault |
| | 25 | 58 | 75 | joint |
| | 26 | 72 | 190 | joint |
| | 27 | 65 | 205 | joint |
| | 28 | 85 | 260 | joint |
| | 29 | 90 | 230 | joint |
| | 30 | 90 | 250 | joint |
| | 31 | 84 | 230 | joint |
| | 32 | 85 | 252 | joint |
| | 33 | 70 | 345 | joint |
| | 34 | 84 | 60 | joint |
| | 35 | 86 | 205 | joint |
| | 36 | 34 | 325 | joint |
| | 37 | 64 | 75 | joint/ shear |

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|---------------------|------------------------------------|
| T-17 | 38 | 81 | 80 | joint/ shear |
| Continued | 39 | 72 | 75 | joint |
| | 40 | 10 | 313 | joint/ shear |
| | 41 | 86 | 305 | joint |
| | 42 | 74 | 15 | joint |
| | 43 | 68 | 92 | joint |
| | 44 | 85 | 180 | fault |
| | 45 | 74 | 190 | fault |
| | 46 | 90 | 182 | fault |
| | 47 | 72 | 65 | joint |
| | 48 | 76 | 170 | joint |
| | 49 | 58 | 276 | joint |
| | 50 | 68 | 200 | joint |
| | 51 | 68 | 220 | fault |
| | 52 | 60 | 255 | joint |
| | 53 | 50 | 22 | joint |
| | 54 | 68 | 210 | joint |
| | 55 | 65 | 342 | fault |
| | 56 | 88 | 68 | joint |
| | 57 | 38 | 302 | joint |
| | 58 | 74 | 230 | fault |
| | 59 | 64 | 272 | joint |
| | 60 | 56 | 356 | joint |
| | 61 | 69 | 243 | joint |
| | 62 | 87 | 210 | joint |
| | 63 | 72 | 68 | joint |
| | 64 | 86 | 184 | joint |
| | 65 | 86 | 232 | joint |
| | 66 | 56 | 282 | joint |
| | 67 | 72 | 356 | joint |
| | 68 | 70 | 172 | fault |
| | 69 | 68 | 355 | joint/ fault |
| | 70 | 78 | 30 | fault |
| | 71 | 82 | 40 | joint |
| | 72 | 75 | 15 | joint |
| | 73 | 86 | 275 | joint |
| | 74 | 76 | 15 | joint |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|---------------------|------------------------------------|
| T-17 | 75 | 85 | 60 | joint |
| Continued | 76 | 88 | 85 | joint |
| | 77 | 45 | 345 | joint |
| | 78 | 41 | 315 | joint |
| | 79 | 90 | 235 | joint |
| | 80 | 56 | 245 | joint |
| | 81 | 65 | 205 | fault |
| | 82 | 65 | 185 | joint |
| | 83 | 60 | 236 | joint |
| | 84 | 69 | 350 | joint |
| | 85 | 38 | 182 | joint |
| | 86 | 74 | 204 | joint |
| | 87 | 64 | 335 | joint |
| | 88 | 64 | 232 | joint |
| | 89 | 66 | 245 | joint |
| | 90 | 77 | 200 | joint |
| | 91 | 82 | 15 | joint |
| | 92 | 63 | 320 | joint |
| | 93 | 82 | 182 | joint |
| | 94 | 64 | 191 | joint |
| | 95 | 87 | 270 | joint |
| | 96 | 88 | 244 | joint |
| | 97 | 27 | 272 | joint |
| | 98 | 12 | 217 | joint |
| | 99 | 74 | 78 | joint |
| | 100 | 74 | 49 | joint |
| | 101 | 90 | 271 | joint |
| | 102 | 4 | 221 | joint |
| | 103 | 88 | 269 | joint |
| | 104 | 21 | 220 | joint |
| | 105 | 74 | 196 | joint |
| | 106 | 89 | 70 | joint |
| | 107 | 88 | 120 | joint |
| | 108 | 88 | 254 | joint |
| | 109 | 88 | 207 | joint |
| | 110 | 68 | 33 | joint |
| | 111 | 82 | 120 | joint |
| | 112 | 11 | 195 | joint |
| | 113 | 81 | 185 | joint |
| | 114 | 84 | 250 | joint |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-18 | 1 | 76 | 165 | joint |
| | 2 | 47 | 245 | joint |
| | 3 | 80 | 240 | joint |
| | 4 | 88 | 148 | joint |
| | 5 | 70 | 237 | joint |
| | 6 | 26 | 235 | joint |
| | 7 | 87 | 300 | joint |
| | 8 | 73 | 228 | joint |
| | 9 | 25 | 230 | joint |
| | 10 | 71 | 232 | joint |
| | 11 | 30 | 218 | joint |
| | 12 | 21 | 225 | joint |
| | 13 | 89 | 231 | joint |
| | 14 | 39 | 247 | joint |
| | 15 | 38 | 230 | joint |
| | 16 | 32 | 227 | joint |
| | 17 | 84 | 215 | joint |
| | 18 | 87 | 210 | joint |
| | 19 | 78 | 105 | joint |
| | 20 | 80 | 192 | joint |
| | 21 | 72 | 98 | joint |
| | 22 | 84 | 270 | joint |
| | 23 | 84 | 325 | joint |
| | 24 | 80 | 268 | joint |
| | 25 | 25 | 234 | joint |
| | 26 | 87 | 210 | joint |
| | 27 | 82 | 275 | joint |
| | 28 | 72 | 320 | joint |
| | 29 | 76 | 40 | shear zone |
| | 30 | 78 | 245 | joint |
| | 31 | 88 | 88 | joint |
| | 32 | 79 | 257 | joint |
| | 33 | 87 | 100 | joint |
| | 34 | 88 | 95 | joint |
| | 35 | 82 | 280 | shear zone |
| | 36 | 80 | 250 | joint |
| | 37 | 62 | 265 | joint |
| | 38 | 82 | 250 | joint |
| | 39 | 72 | 273 | joint |
| | 40 | 80 | 5 | joint |
| | 41 | 88 | 262 | joint |

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-18 | 42 | 75 | 5 | joint |
| Continued | 43 | 76 | 298 | joint |
| | 44 | 88 | 46 | joint |
| | 45 | 57 | 250 | joint |
| | 46 | 79 | 250 | joint |
| | 47 | 86 | 215 | joint |
| | 48 | 28 | 250 | joint |
| | 49 | 88 | 279 | joint |
| | 50 | 84 | 240 | joint |
| | 51 | 69 | 292 | joint |
| | 52 | 70 | 205 | joint |
| | 53 | 68 | 285 | joint |
| | 54 | 87 | 210 | joint |
| | 55 | 72 | 287 | joint |
| | 56 | 67 | 257 | joint |
| | 57 | 80 | 205 | shear zone |
| | 58 | 38 | 325 | joint |
| | 59 | 78 | 80 | joint |
| | 60 | 76 | 10 | joint |
| | 61 | 80 | 110 | joint |
| | 62 | 83 | 5 | fault |
| | 63 | 88 | 16 | fault |
| | 64 | 60 | 282 | joint |

| Trench | ID | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|--------|----|--------|------------------|---------------------------------|
| T-19 | 1 | 38 | 319 | Fault |
| | 2 | 71 | 42 | Joint |
| | 3 | 85 | 32 | Joint |
| | 4 | 84 | 225 | Joint |
| | 5 | 74 | 224 | Joint |
| | 6 | 74 | 332 | Joint |
| | 7 | 76 | 22 | Joint |
| | 8 | 79 | 355 | Joint |
| | 9 | 90 | 344 | Joint |
| | 10 | 88 | 224 | Joint |
| | 11 | 85 | 169 | Joint |
| | 12 | 68 | 75 | Joint |
| | 13 | 88 | 162 | Joint |
| | 14 | 86 | 226 | Joint |
| | 15 | 86 | 160 | Joint |

Table 21-6. Selected Fractures (Joints, Faults and Shears) Observed in Borings and Trenches (continued).

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-20 | 1 | 63 | 208 | Fault |
| | 2 | 75 | 11 | Fault |
| | 3 | 68 | 242 | Joint |
| | 4 | 53 | 316 | Joint |
| | 5 | 72 | 189 | Joint |
| | 6 | 69 | 264 | Joint |
| | 7 | 83 | 47 | Joint |
| | 8 | 84 | 261 | Joint |
| | 9 | 82 | 29 | Joint |
| | 10 | 77 | 265 | Joint |
| | 12 | 59 | 215 | Fault |
| | 13 | 70 | 270 | Joint |
| | 14 | 70 | 48 | Joint |
| | 15 | 62 | 293 | Joint |
| | 16 | 61 | 220 | Joint |
| | 17 | 80 | 291 | Joint |
| | 18 | 56 | 286 | Joint |
| | 19 | 82 | 205 | Joint |
| | 20 | 74 | 231 | Joint |
| | 21 | 60 | 351 | Fault |
| | 22 | 76 | 176 | Fault |
| | 23 | 68 | 185 | Fault |
| | 24 | 80 | 10 | Joint |
| | 25 | 85 | 290 | Joint |

| Trench ⁽¹⁾ | ID ⁽²⁾ | Dip(3) | Dip Direction(4) | Type ⁽⁵⁾ of Fracture |
|-----------------------|-------------------|--------|------------------|---------------------------------|
| T-21 | 1 | 51 | 324 | Joint |
| | 2 | 85 | 353 | Joint |
| | 3 | 25 | 28 | Joint |
| | 4 | 44 | 42 | Joint |
| | 5 | 56 | 7 | Joint |
| | 6 | 77 | 68 | Joint |
| | 7 | 71 | 4 | Joint |
| | 8 | 40 | 331 | Joint |
| | 9 | 48 | 332 | Joint |
| | 10 | 20 | 344 | Joint |
| | 11 | 80 | 40 | Joint |
| | 12 | 53 | 320 | Joint |
| | 13 | 77 | 188 | Joint |
| | 14 | 83 | 314 | Joint |
| | 15 | 64 | 3 | Fault |

Notes: (1) Boring or trench where discontinuities, excluding known bedding, were made. In borings, NORCAL from the televiewer images and reviewed by WLA geologists (DCPP ISFSI SAR Section 2.6 Topical Report Appendix E). In trenches, discontinuities were directly observed and measured by field geologists (DCPP ISFSI SAR Section 2.6 Topical Report Appendix D).

- (2) Within each subsurface exploration (boring or trench), a unique number was assigned to each discontinuities were numbered sequentially beginning with the deepest (reverse stratigraphic order). In trenches, discontinuities were numbered sequentially from one end of excavation to the other.
- (3) In borings Dips shown to 0.1 of a degree originated from NORCAL interpretation of televiewer logs (Appendix E). In trenches, Dips were measured by field geologists (DCPP ISFSI SAR Section 2.6 Topical Report Appendix D).
- (4) Dip direction in azimuth degrees.
- (5) Depth (in feet) of discontinuity encountered in borings from NORCAL televiewer logs (ISFSI SAR type of discontinuity (fault, joint, or crushed zone) classified in trenches (DCPP ISFSI SAR Topical Report Appendix D).