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Environment & Remediation Support Services

Standard Operating Procedure

for **SLUG TESTS**

APPROVAL SIGNATURES:

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1.0 PURPOSE AND SCOPE

The purpose of this procedure is to describe the process for determining saturated hydraulic conductivity under in situ conditions by the slug test withdrawal method of analysis for the Environment & Remediation Support Services (ERSS) Division of the Los Alamos National Laboratory (LANL or the Laboratory).

2.0 BACKGROUND AND PRECAUTIONS

This procedure is used in conjunction with an approved Integrated Work Document (IWD). Also, consult the IWD for information on and use of all personal protective equipment (PPE).

The slug test measures the rate of water level recovery in a well over time in response to the injection or withdrawal of a mass (slug) beneath the groundwater surface. The slug can be a quantity of water or a solid of known volume. Hydraulic conductivity in the immediate vicinity of the well can be determined by measuring water level versus time data after the slug is added or removed. Refer to the site-specific work plan for more information on the scope of work, a description of slug testing activities, and the locations of the wells that are to be tested.

First, a solid slug is inserted to a level beneath the groundwater surface and the water level is allowed to reach equilibrium. Then the slug is removed and the rise in water level is measured with time. Alternatively, a slug of water is injected or withdrawn and water level response monitored.

The primary advantages of using slug tests to estimate conductivities are:

- estimates can be made in situ and the errors incurred in the laboratory testing of disturbed samples can be avoided;
- tests can be performed quickly at relatively low costs because a pumping well and observation wells are not required;
- the hydraulic conductivity of small, discrete portions of a saturated medium can be estimated (e.g., sand layers in a clay);
- certain assumptions are made in the analysis process (i.e., if the assumptions are inappropriate for the geologic conditions at the site, the slug test data are invalid);
- the storage coefficient, S , usually cannot be determined; and
- data sufficient for analysis may not be collected if the hydraulic conductivity is relatively high.

The time required for a slug test is a function of the volume of the slug, the hydraulic conductivity of the formation, and the type of well completion. The slug volume should be large enough that a sufficient number of water level measurements can be made before the water level returns to equilibrium conditions. The length of the test may range from less than a minute to several hours.

If the well is to be used for monitoring, take precautions so contamination is not introduced by equipment placed in the well. If water is added to the monitoring well, it must be obtained from an uncontaminated source and transported in a clean container. Clean bailers or measuring devices before the test.

Conduct slug tests on relatively undisturbed wells. If a test is conducted on a well that has recently been pumped for water sampling purposes, the measured water level must be within 0.1 ft of the static water level at the wells. [NOTE: The exact dimensions of the borehole, casing, and filter must be recorded for accurate analysis of the slug test data.]

Site workers preparing for field operations should read and understand the procedures outlined in the SSHAP for the particular health and safety equipment to be used.

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3.0 EQUIPMENT AND TOOLS

- water pressure transducers;
- electronic data logger;
- electric water level indicator (if transducer method is not used);
- manufacturer's operating manuals for equipment selected above;
- weighted tapes with plover (plumb bob);
- steel tape (graduated in hundredths of a foot);
- blue surveyor's chalk;
- teflon or stainless steel bailer of a known volume;
- stopwatch or watch with a second hand;
- tape measure (graduated in tenths of a foot);
- semi log graph paper;
- straight edge;
- calculator;
- appropriate reference material;
- slug test data forms;
- indelible dark ink pens;
- five gallon bucket;
- groundwater elevation forms;
- daily activity logs;
- any PPE listed or required in the site-specific health and safety plan (SSHASP); and
- any additional supplies listed in associated procedures, as needed.

4.0 STEP-BY-STEP PROCESS DESCRIPTION

4.1 Slug Test With Pressure Transducer and Data Logger

Field Team	1.	Enter the required information into the electronic data logger in accordance with the manufacturer's instructions. [NOTE: It is important to consult the Operations Manual for the proper data entry sequence as different models require different data entry procedures.]
	2.	Store all data internally, and also on computer diskettes or on tape.
	3.	Transfer the information directly to the appropriate computer for analysis as soon as practical after the test is completed.
	4.	Maintain a computer printout of the data in the project files as documentation.
	5.	Determine the static water level in the well; measure the depth to water periodically for several minutes to several hours, and take the average of the readings.
	6.	Record information on the water level elevation data sheet form, with additional information recorded on the daily activity log.
	7.	Install the transducer and cable in the well below the estimated target drawdown depth.
	8.	Ensure the depth of submergence is within the design range stamped on the transducer.
	9.	Tape the transducer cable to the well to hold the transducer at a constant depth.
	10.	Connect the transducer cable to the electronic data logger.
	11.	Enter the initial water level and transducer design range into the recording device according to the manufacturer's operating instructions.
	12.	Record the initial water level on the recording device.
	13.	Smoothly lower the slug or bailer into the well.
	14.	Observe the transducer readout to detect where the slug contacts the water.
	15.	Allow the water level to stabilize (within 0.1 ft) and remove the cylinder or bailer.
	16.	Remove the slug or volume as quickly and smoothly as possible because the analysis assumes that an instantaneous change in volume is created in the well.

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| Field Team
(Continued) | 17. | Continue measuring and recording depth/time measurements until the water level returns to equilibrium conditions or a sufficient number of readings have been made to clearly show a trend on a plot of water level recovery versus the logarithm of time. |
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4.2 Slug Test with Electric Water Level Meter

[NOTE: This method should only be used if an electronic data recorder cannot be obtained. This method cannot be used for saturated zones with high hydraulic conductivities because stabilization of groundwater will occur rapidly. If the slug test data are collected and recorded manually, record observations on the slug test data form (see Attachments 1 and 2).]

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| Field Team | 1. | Determine the static water level in the well. |
| | 2. | Measure the depth to water periodically for several minutes and take the average of the readings.
[NOTE: In order to accurately measure water level changes, it is important to take the measurements rapidly.] |
| | 3. | Record the results on the water level elevation data sheet form. |
| | 4. | Smoothly lower the slug or bailer into the well. |
| | 5. | Mark the depth to water onto the slug line to estimate the depth where the top of the slug contacts the water. |
| | 6. | Measure and record the depth to water and time of each reading.
[NOTE: The moment when the volume is removed is time zero. Depths should be measured to the nearest one hundredth of a foot. The number of depth/time measurements necessary to complete the test varies.] |
| | 7. | Continue measuring and recording depth/time measurements until the water level returns to equilibrium conditions or a sufficient number of readings have been made to clearly show a trend on a plot of water level recovery versus the logarithm of time. |

4.3 Straddle-Packer/Injection Test with Transducer and Data Logger

[NOTE: This method is used when the well is completed with multiple screens that must be isolated for testing. The straddle-packer/injection assembly is available from the field support facility.]

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| Field Team | 1. | Insert straddle-packer/injection assembly opposite screen of interest. |
| | 2. | Determine the static water level in the well; measure the depth to water periodically for several minutes to several hours, and taking the average of the readings. |
| | 3. | Record information on the water level elevation data sheet form; and additional information should be recorded on the daily activity log. |
| | 4. | Install the transducer and cable in the well below the estimated target drawdown depth.
[NOTE: Ensure the depth of submergence is within the design range stamped on the transducer.] |
| | 5. | Tape the transducer cable to the well to hold the transducer at a constant depth. |
| | 6. | Connect the transducer cable to the electronic data logger. |
| | 7. | Enter the initial water level and transducer design range into the recording device according to the manufacturer's operating instructions. |
| | 8. | Record the initial water level on the recording device. |

Field Team
(Continued)

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| 9. | Enter the required information into the electronic data logger in accordance with the manufacturer's instructions.
[NOTE: It is important to consult the operations manual for the proper data entry sequence as different models require different data entry procedures.] |
| 10. | Fill large open stock tank with potable water. |
| 11. | Connect flow meter on inflow side of pump on drill rig. |
| 12. | Connect hose to open end of flow meter and submerge other end in stock tank. |
| 13. | Connect another hose to the outflow end of pump on drill rig. |
| 14. | With pump on, adjust the flow to reasonable rate before starting the test (direct discharge back into stock tank). |
| 15. | Read and record totalizer on flow meter (gal.). |
| 16. | Direct discharge down rod connected to straddle-packer assembly and record the time injection started. |
| 17. | After a short time interval, halt injection by removing hose and placing it in stock tank. |
| 18. | Record time and totalizer on flow meter (gal.). |
| 19. | Continue measuring and recording depth/time measurements until the water level returns to equilibrium conditions or a sufficient number of readings have been made to clearly show a trend on a plot of water level versus the logarithm of time. |
| 20. | Complete straddle-packer/injection test data sheet form (see Attachments 3 and 4). |

4.4 Post-Operation Activities

Field Team

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| 1. | Decontaminate the downhole equipment. |
| 2. | Cut off contaminated portions of rope and dispose of them. |
| 3. | Proceed as follows if electronic data logger is used: <ul style="list-style-type: none"> • stop the logging sequence; • download the data to a computer, print the data, file them on a floppy disk, and • save the memory and disconnect the battery at the end of the day's activities. |

Field Team
Leader

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| 4. | Check all data collection forms for completeness. |
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4.5 RecordsField Team
Leader

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| 1. | Submit the following records generated by this procedure to the Records Processing Facility: <ul style="list-style-type: none"> • completed slug test data form; • completed water level elevation data sheet form; • completed saddle-packer/injection test data sheet form; and • daily activity log. |
|----|---|

5.0 PROCESS FLOW CHART

Flow chart is to be included at a later date.

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6.0 ATTACHMENTS

- Attachment 1: 5038-1 Slug Test Data Sheet (1 page)
- Attachment 2: 5038-2 Slug Test Data Sheet Completion Guidelines (1 page)
- Attachment 3: 5038-3 Straddle-Packer/Injection Test Data Sheet (1 page)
- Attachment 4: 5038-4 Straddle-Packer/Injection Test Data Sheet Completion Guidelines (2 pages)

7.0 REVISION HISTORY

Author: Rick Haacker

Revision No. Enter current revision number, beginning with Rev..0	Effective Date DCC inserts effective date for revision	Description of Changes List specific changes made since the previous revision	Type of Change Technical (T) or Editorial (E)
0.0	02/09/07	Reformatted and renumbered, supersedes SOP-07.03	E

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ATTACHMENT 1: SLUG TEST DATA SHEET

5038-1

Records Use only

Slug Test Data Sheet



Slug Test Data Sheet

Location _____ Geologic Unit _____ Well Number _____ Sheet _____ of _____

Field Team Member Signature _____
(Print name and title, then sign)

Test Method: ___ Slug Injection or ___ Slug Withdrawal Slug Dimensions or volume

Well Construction Details (attach diagram): _____

Test Started _____ Test Stopped _____ Test ID _____

Method of Water-Level Measurement: _____

Comments: _____

Time of Measurement	Elapsed Time (min)	Depth to Water (ft)	Time of Measurement	Elapsed Time (min)	Depth to Water (ft)

Check here if continued on the back of this sheet.

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ATTACHMENT 2: SLUG TEST DATA SHEET COMPLETION GUIDELINES**5038-2**

Records Use only

Slug Test Data Sheet Completion Guidelines

Use an indelible dark ink pen. Make an entry in each blank. Where there is no data entry, enter UNK for Unknown, NA for Not Applicable, or ND for Not Done. To change an entry, draw a single line through it, add the correct information above it, and date and initial the change. For all Water Level Elevation Data Sheet forms, complete the information listed below.

Item	Instruction(s)
Header Information	
1.	Location – record Technical Area, Canyon, well field, as appropriate.
2.	Geologic unit – note stratigraphic unit behind screen tested.
3.	Well Number – record the well designation number.
4.	Sheet Number – number all the sheets that are used for this activity, by day or by some practical unit.
5.	Field Team Member Identification – print your name and position title, then sign.
Slug Test Parameters	
1.	Test Method – record whether the slug device is injected or withdrawn (pulled out) from the monitor well.
2.	Slug Dimensions – the slug and/or bailer dimensions or water volume must be known in order to perform calculations properly.
3.	Well Construction Details – the well screen length (especially of openings), filter pack length, casing diameter and borehole diameter must be known, at a minimum, to perform these calculations. Attach diagram of well design.
4.	Test Started – record clock time slug inserted or withdrawn.
5.	Test Stopped – record clock time monitoring halted.
6.	Test Identification – for data logger file if transducer used.
7.	Method of Water Level Measurement – record the type of instrument used to measure water level.
8.	Comments – record any relevant weather and all other conditions pertinent to the sample collection in this section.
Slug Test Data	
1.	Time of Measurement – record clock time that reading was made in the following formats: DD-MMM-YY (e.g., 01-JAN-06) and the 24-hour clock time (e.g., 0837 for 8:37 a.m. and 1912 for 7:12 p.m.)
2.	Elapsed time (min.) – record, in minutes, the cumulative time readings from the beginning of the test (time zero) to the end of the test.
3.	Depth to Water (ft) – record the depth to water measured in hundredths of feet.

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ATTACHMENT 3: STRADDLE-PACKER/INJECTION TEST DATA SHEET

5038-3

Records Use only

Straddle-Packer/Injection Test Data Sheet



7.1 STRADDLE-PACKER/INJECTION TEST DATA SHEET

Well _____ Screen no. _____ Open interval _____ ft Geologic unit _____

Test ID _____ Test Date _____ Conducted by _____

Borehole diameter _____ in. Screen type _____ Screen ID _____ in.

Packer Assembly

Upper packer length _____ ft Bottom set at depth of _____ ft

Flow pipe length _____ ft Packer pressure _____ psi

Lower packer length _____ ft Top set at depth of _____ ft

Water Level (WL)

Measuring point (MP) _____ Stick-up _____ ft

WL method _____ Measured by _____

WL Depth (ft) _____ Time _____ WL Depth (ft) _____ Time _____ WL Depth (ft) _____ Time _____

Static WL depth below MP _____ ft Date _____ Time _____

Ground-surface elevation _____ ft MP elevation _____ ft

MP "stickup" + _____ ft Static WL depth - _____ ft

MP elevation = _____ ft **Level reference** = _____ ft

Transducer rating _____ psi Safe transducer depth _____ ft T. Placement _____ ft

Flow Rate (continue on back if needed)

Volume (gal.) Time (min) Flow Rate (gpm) Volume (gal.) Time (min) Flow Rate (gpm)

Flow-rate method _____ **Average flow rate** _____ gpm

Test

Test started _____ Injection Stopped _____ Test stopped _____ Length of test _____

Flow meter at start _____ gal. Flow meter at stop _____ gal. Volume injected _____ gal.

Comments:

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ATTACHMENT 4: STRADDLE-PACKER/INJECTION TEST DATA SHEET COMPLETION GUIDELINES

5038-4

Straddle-Packer/Injection Test Data Sheet Completion Guidelines

Records Use only



Use an indelible dark ink pen. Make an entry in each blank. Where there is no data entry, enter UNK for Unknown, NA for Not Applicable, or ND for Not Done. To change an entry, draw a single line through it, add the correct information above it, and date and initial the change. For all water level elevation data sheet forms, complete the information listed below.

Item	Instruction(s)
Header Information	
1.	Well – record the number of the well tested.
2.	Screen – record number of the screen tested, counting from the top down.
3.	Open Interval – record the length of openings on the screen (ft).
4.	Geologic Unit – record the stratigraphic unit the screen is open to.
5.	Test Identification – label for data logger file: "From Well and Screen Number R-22-2".
6.	Test Date – record month, day, and year of test.
7.	Conducted By – Print name of main person performing the test.
8.	Borehole Diameter – enter size (inches).
9.	Screen Type – tell kind of screen (e.g., wire wrapped, louvered, etc.)
10.	Screen Identification – enter inside diameter of screen (in.).
Packer Assembly	
1.	Upper Packer Length – enter length (ft).
2.	Bottom Set At – enter depth of base of upper packer (ft).
3.	Flow Pipe Length – enter length of perforated pipe between packers (ft). <i>NOTE: Do not include length of any blank rod between perforated pipe and packers.</i>
4.	Packer Pressure – record pressure from gauge on tank (psi).
5.	Lower Packer Length – enter length (ft).
6.	Top Set At – enter depth of top of lower package (ft).
Water Level	
1.	Measuring Point – describe what was used.
2.	Stick-Up – give height of measuring point above ground surface (ft).
3.	WL Method – tell how water level was measured (i.e., device used).
4.	Measured By – identify who was taking water level readings.
5.	WL Depth/Time – record all water level readings and times made.
6.	Static WL Depth Below MP – give final water level reading, date, and time.

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ATTACHMENT 4: STRADDLE-PACKER/INJECTION TEST DATA SHEET COMPLETION GUIDELINES

5038-4

Straddle-Packer/Injection Test Data Sheet Completion Guidelines

Records Use only



7.	Ground Surface Elevation – record site elevation. <i>NOTE: Indicate if estimated.</i>
8.	MP Stick-Up – same as Item 2 within this section.
9.	MP Elevation – sum of Items 7 and 8 within this section.
10.	MP Elevation – same as Item 9 within this section.
11.	Static WL Depth – same as Item 6 within this section.
12.	Level Reference – For data logger software (i.e., 10 minus 11).
13.	Transducer Rating – record that specified on instrument (psi).
14.	Safe Transducer Depth – value that would not exceed rating (ft).
15.	Placement – record depth at which transducer was placed.
Flow Rate	
1.	Volume/Time/Flow Rate – volume of water pumped (gal.) during specified time interval (min.) and the flow rate indicated (gpm); calculate frequently so variability of flow rate can be determined.
2.	Flow Rate Method – tell how rate was determined (volume per discrete time interval or time per discrete flow volume).
3.	Average Flow Rate – give mean of the various determinations.
Test	
1.	Test Started – record clock time when water first injected.
2.	Injection Stopped – record time when injection halted.
3.	Test Stopped – record clock time when monitoring WL halted.
4.	Length of Test – record difference between Items 1 and 3 within this section.
5.	Flow Meter at Start – record totalizer value on meter when injection begins.
6.	Flow Meter at Stop – record totalizer value on meter when injection halted.
7.	Volume Injected – record difference between Items 6 and 5 within this section.

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