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CULEBRA TRANSPORT PROGRAM

**TEST PLAN:
TRACER TESTING OF THE CULEBRA DOLOMITE MEMBER
OF THE RUSTLER FORMATION AT THE H-19 AND H-11
HYDROPADS ON THE WIPP SITE**

**Richard L. Beauheim
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and

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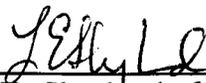
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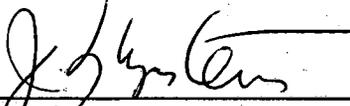
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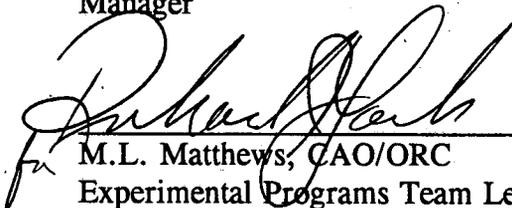
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DEFINITIONS OF ACRONYMS

BASys	Baker Acquisition System
bgs	below ground surface
BTC	breakthrough curve
CAO	Carlsbad Area Office (of DOE)
CCDF	cumulative complementary distribution function
CMR	Central Monitoring Room
DAS	data-acquisition system
DOE	(United States) Department of Energy
DQO	data quality objective
EC&S	Environmental Compliance and Support
EPA	Environmental Protection Agency
ES&H	Environmental Safety and Health
FOP	Field Operations Plan
GET	General Employee Training
gpm	gallons per minute
hp	horsepower
HRC	Harry Reid Center for Environmental Studies (at University of Nevada-Las Vegas)
ID	inside diameter
MSDS	Material Safety Data Sheet
NEPA	National Environmental Policy Act
NIST	National Institute of Standards and Technology
OD	outside diameter
PA	Performance Assessment
PHA	Preliminary Hazard Assessment
PI	Principal Investigator
PIT	Passive-Injection Tool
psia	pounds per square inch absolute
psig	pounds per square inch gauge
PVC	polyvinyl chloride
QA	Quality Assurance
QAP	Quality Assurance Procedure
QAPD	Quality Assurance Program Description
SNL	Sandia National Laboratories
SOP	Safe Operating Procedure
SR	Sandia Representative
SWCF	Sandia WIPP Central Files
SWIW	single-well injection-withdrawal
TOP	Technical Operating Procedure
TTC	Tracer-Test Coordinator
WIPP	Waste Isolation Pilot Plant
WID	Waste Isolation Division (of Westinghouse)

1. SUMMARY

The Culebra Dolomite Member of the Rustler Formation is considered to be the most likely pathway for radionuclide transport to the accessible environment in the event of a breach of the Waste Isolation Pilot Plant (WIPP) repository by inadvertent human intrusion. Evaluation of WIPP's compliance with 40 CFR 191 Subpart B by the WIPP Performance Assessment Computational Support Department of Sandia National Laboratories (SNL) relies in part on a model of radionuclide transport through the Culebra. Modeling of transport through the Culebra requires, first, a conceptual model of the mechanisms and processes governing that transport and, second, quantitative estimates of the parameters required for numerical simulation of those processes. The Culebra Transport Program represents the combined efforts of the SNL Geohydrology (6115) and WIPP Chemical and Disposal Room Processes (6748) Departments to provide the conceptual understanding and data necessary to construct a model for Culebra transport.

Field tracer tests are a major component of the Culebra Transport Program. Tracer tests provide data with which to evaluate different processes affecting transport and to estimate transport parameters. Interpretations of previous tracer tests conducted at the WIPP site (Jones et al., 1992) suggest that the Culebra behaves locally as a double-porosity medium in which advective flow occurs through fractures while diffusion of solutes from the fractures to the surrounding rock matrix acts to retard solute transport. Using a double-porosity transport model based on these tracer-test interpretations, the WIPP PA Department (1993b) showed that physical retardation arising from matrix diffusion makes the Culebra an effective barrier to release of radionuclides to the accessible environment.

Independent reviewers of the interpretations of the previous tracer tests have questioned the assumption that matrix diffusion was the only mechanism causing physical retardation during those tracer tests, and suggested other processes, such as channeling caused by variations in fracture apertures (causing heterogeneity in permeability) and delayed tracer release from the injection wells, that might have contributed to the observed physical retardation. These other processes might be less effective at retarding transport on the regional scale than matrix diffusion. The data from the previous tests are inadequate to determine the relative contributions of different potential retardation mechanisms, primarily because too few flow paths were tested, only one tracer-injection technique was employed, tracers having different free-water diffusion coefficients were not used, and tests were not repeated at different pumping rates. The previous tests also did not: 1) examine the importance of vertical heterogeneity in the Culebra; 2) address

scaling issues (changing transport parameters as a function of transport distance); and 3) provide sufficient data to determine whether variations in transport behavior along different flow paths were due solely to anisotropic permeability in the Culebra or were caused by heterogeneity.

The tracer tests of the Culebra described in this Test Plan are being designed to provide data with which to: 1) demonstrate the importance of matrix diffusion as a physical-retardation mechanism; 2) evaluate the relative importances of different processes causing physical retardation during transport; 3) investigate transport processes at different scales; 4) evaluate the effects of heterogeneity, anisotropy, and layering on transport; 5) quantify important transport parameters; and 6) as an end result, develop a model of transport in the Culebra that can be used by PA and defended with a high level of confidence. An added benefit of the tracer testing is that the long-term pumping associated with the tests will produce transient pressure responses that can be interpreted to define the distribution of transmissivity in the Culebra in the area within which transport is expected to occur in the event of a breach of the WIPP repository by inadvertent human intrusion.

New tracer tests are being planned at two locations, the H-19 and H-11 hydropads. The testing planned at the H-19 hydropad is much more extensive than that to be performed at the H-11 hydropad. The H-19 testing will include a single-well injection-withdrawal (SWIW) test over the lower portion of the Culebra and a convergent-flow multiwell tracer test involving multiple tracer injections, tracer injections over different intervals of the Culebra, tracer injections using different injection techniques, tracers with different free-water diffusion coefficients, and different pumping rates. These tests should provide tracer-breakthrough and recovery curves that can be used to quantify the amount of matrix diffusion occurring, determine how the different layers within the Culebra interact, and evaluate the effects of anisotropy and heterogeneity on transport on the hydropad scale.

Tracer testing at the H-11 hydropad is focused on a few key issues. This testing will consist of a single-well tracer test in H-11b1 and a two-well convergent-flow tracer test between H-11b3 and H-11b1. Both H-11 tests will be performed over the entire thickness of Culebra. The single-well test should provide additional evidence for the occurrence of matrix diffusion and, in combination with the H-19 single-well test, provide information on the heterogeneity of the Culebra. The two-well test at H-11 will serve to corroborate and quantify the effects of matrix diffusion interpreted from the 1988 tracer test at that location by providing a repeated test at a different pumping rate. Tracers with different free-water diffusion coefficients, if available, will also be used in this test to provide additional evidence for matrix diffusion. An improved tracer-

injection tool, which will prevent tracer-laden water from sinking to the bottom of the hole and providing a potential long-term diffusional source of tracer in the wellbore, will help to resolve source-term questions associated with the earlier test.

This Test Plan describes the overall goals and objectives of the tracer testing program and the methods that will be employed to achieve them. The plan describes the types of tests to be performed, equipment configurations, testing requirements and procedures, data-acquisition systems, data-quality objectives, quality assurance requirements, regulatory requirements, and health and safety concerns.

2. INTRODUCTION

The tracer-testing activities described in this Test Plan constitute one component of a SNL program to understand groundwater flow and solute transport through the Culebra Dolomite Member of the Rustler Formation at the WIPP site. The background and justification for the Culebra Transport Program are discussed below, followed by a summary of the specific activities described in this Test Plan and their objectives.

2.1 Background

The WIPP is a U.S. Department of Energy (DOE) research and development facility designed to demonstrate the safe disposal of transuranic wastes resulting from the United States' defense programs. The WIPP repository is excavated in the bedded halite of the Salado Formation, approximately 2150 ft below land surface. At the WIPP site, the Salado Formation is approximately 2000 ft thick and is overlain by the approximately 300-ft-thick Rustler Formation, the 500-ft-thick Dewey Lake Redbeds, and approximately 50 ft of surficial deposits ranging from weathered sedimentary bedrock to Quaternary eolian deposits (Figure 2-1). The approximately 24-ft-thick Culebra Dolomite Member of the Rustler Formation is the most transmissive saturated bedrock unit above the WIPP repository and is considered to be the most likely pathway for radionuclide transport to the accessible environment in the event of a breach of the repository.

The Culebra is a laminated to thinly bedded argillaceous dolomite with abundant open and gypsum-filled fractures and vugs. Holt and Powers (1990) identified six distinct sedimentological "map units" from examination of the Culebra in the WIPP Air-Intake Shaft. They found vugs and fractures, as well as the majority of the visible water flow, to be concentrated in the middle two units occupying approximately 10 ft of the Culebra thickness. While fracturing of the Culebra appears to be ubiquitous over the WIPP site, the hydraulic and transport significance of fractures at any given location depends on whether the fractures are open or filled, their frequency, and the degree to which they are interconnected over significant distances. Offsite transport of contaminants from the WIPP would most likely occur through high-permeability, open, interconnected fractures.

Pumping tests conducted at various locations where the Culebra has been observed to be fractured, such as DOE-1 and H-11, have shown apparent double-porosity hydraulic responses (Beauheim, 1987, 1989). The observed responses have been interpreted to indicate initial

System	Series	Group	Formation	Member	Approximate Thickness* (m ft)		
Recent	Recent		Surficial Deposits		3	10	
Quaternary	Pleistocene		Mescalero Caliche		10	30	
			Gatuña				
Triassic		Dockum	Undivided		3	10	
Permian	Ochoan		Dewey Lake Redbeds		150	500	
			Rustler	Forty-niner		18	60
				Magenta Dolomite		7	24
				Tamarisk		26	85
				Culebra Dolomite		7	24
				unnamed		37	120
	Salado		600	2000			
	Castile		400	1300			
	Guadalupian	Delaware Mountain	Bell Canyon		310	1000	
			Cherry Canyon		335	1100	
			Brushy Canyon		550	1800	

* At center of WIPP site.

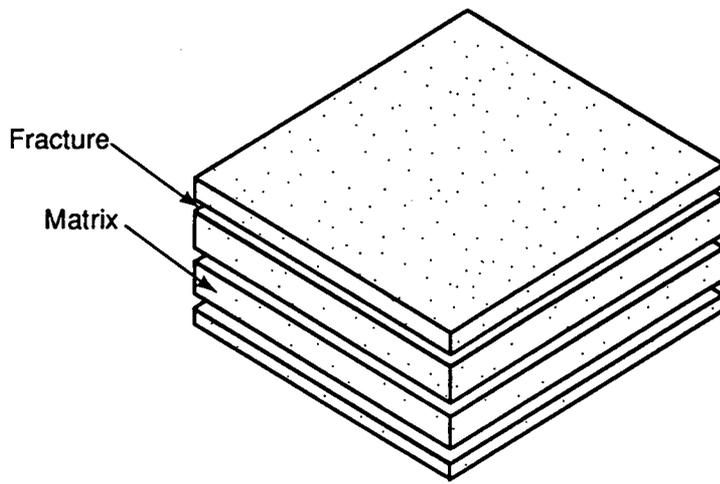
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Figure 2-1. Stratigraphic units at the WIPP site.

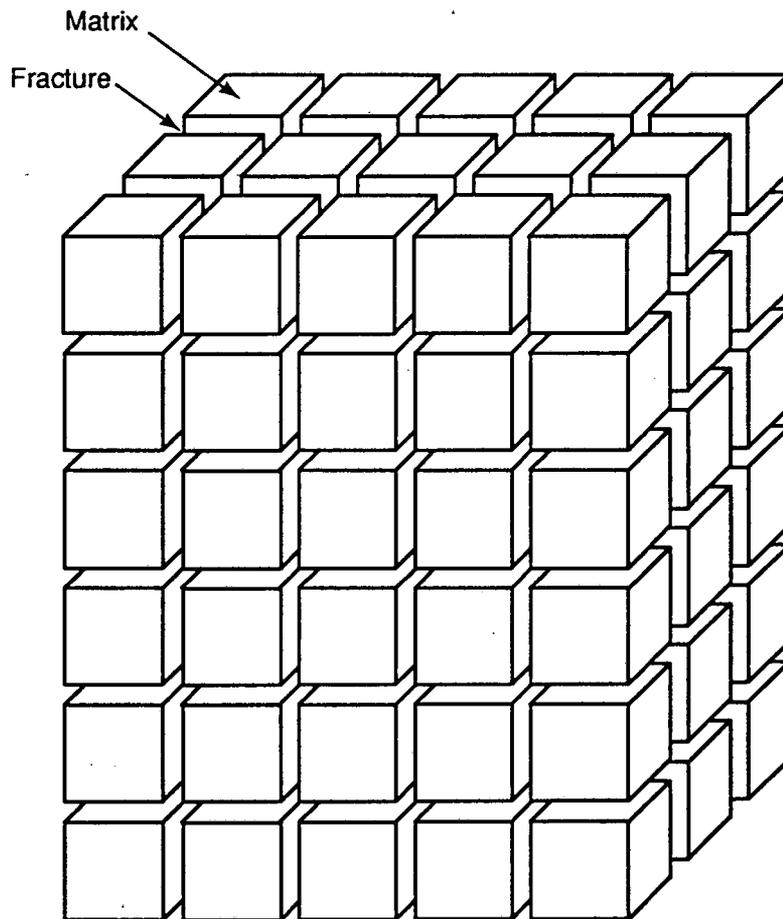
production and associated drawdown from a high-transmissivity fracture system connecting the wells, a slowing of drawdown as the fractures become depressurized and the rock matrix begins to contribute water to the fractures, followed by continuing drawdown in both the fractures and matrix. The classical conceptualization of double-porosity systems (e.g., Warren and Root, 1963; Kazemi, 1969) envisions extensive and highly interconnected fractures such that the fracture system can be adequately represented as a continuum. Continuum double-porosity models may represent the fracture system in idealized geometry as either a single set of parallel fractures separated by uniform, tabular matrix blocks, or as three orthogonal sets of fractures separated by cubical matrix blocks (Figure 2-2). Typically, in double-porosity media, most of the permeability is associated with the secondary (fracture) porosity while most of the storage capacity is associated with the primary (matrix) porosity. The Culebra pumping-test responses have been successfully simulated using double-porosity continuum models with idealized fracture geometries.

With respect to solute transport, classical double-porosity models assume that advective transport of solutes occurs only through fractures and diffusive transport occurs between the fractures and the matrix in response to concentration gradients (Grisak and Pickens, 1980; Feenstra et al., 1984). For a solute introduced into a double-porosity formation by advective flow, diffusion from the fractures into the rock matrix (matrix diffusion) is controlled by the surface area of the fractures and the volume of matrix. In an idealized, geometrically uniform double-porosity model, the ratio of fracture surface area to matrix volume, known as specific surface, can be represented by the fracture spacing and/or matrix-block length. Matrix diffusion can result in significant physical retardation of solutes relative to water velocity in fractures.

In recent years, numerous authors (e.g., Neretnieks, 1987; Neuman, 1987; Tsang et al., 1988; Dverstorp and Andersson, 1989; Shapiro and Nicholas, 1989; Moreno et al., 1990; Long et al., 1990; Cacas et al., 1990a,b; Abelin et al., 1991; Johns and Roberts, 1991; Dershowitz et al., 1991) have proposed different ways of conceptualizing flow and transport through fractured media with spatially varying properties. In general, their ideas all include the concept of flow occurring through discontinuous networks of high-conductivity channels within discrete fractures or fracture zones (Figure 2-3). Typically, these channels represent areas where fracture apertures and fracture connectivity are greatest. Areas where fracture apertures are smaller, or where potential flow paths run into dead ends, represent relatively stagnant areas accessible primarily by diffusion that may provide temporary storage of solutes/contaminants. A key feature of these channel models is the concept that what constitutes a significant channel depends on the orientation of the hydraulic stress applied to the system (Tsang and Tsang, 1989). That



One Fracture Set



Three Intersecting Fracture Sets

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Figure 2-2. Alternative double-porosity continuum conceptualizations.

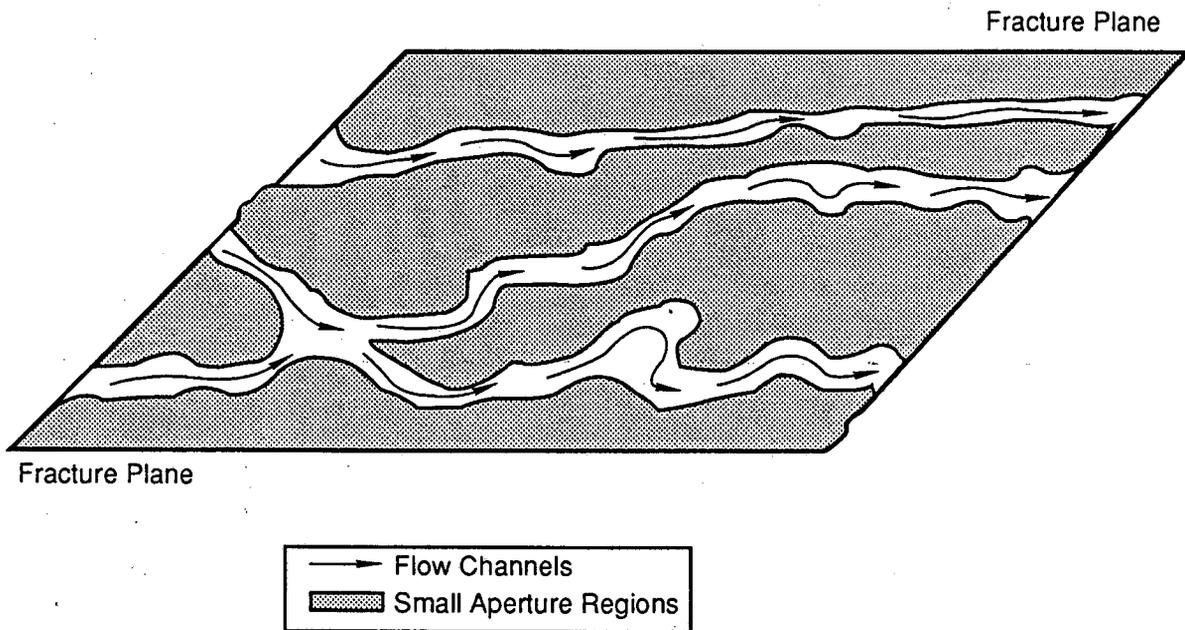


Figure 2-3. Schematic illustration of flow channels in a fracture plane.

is, highly conductive paths may be (well-)connected only in certain directions. Thus, a tracer test that creates gradients different from those existing under undisturbed conditions might reveal the existence of highly conductive pathways that are not significant under undisturbed conditions, or might fail to reveal the existence of pathways that are significant under natural gradients.

Two principal approaches have been adopted to study and/or simulate channel systems: the discrete-fracture approach and the stochastic-continuum approach. In the discrete-fracture approach (e.g., Long et al., 1990; Cacas et al., 1990a,b; Dershowitz et al., 1991), a model network of individual fractures is constructed in an attempt to define the simplest network that is consistent with the observed responses (hydraulic and/or tracer) of the real system. Because of the lack of global interconnection of all points in discrete-fracture systems, they are sometimes referred to as discontinuum systems (Long et al., 1990). The discrete-fracture approach was developed to simulate transport through sparsely fractured crystalline rock; its applicability to the Culebra will be determined through evaluation of the hydraulic and tracer data from H-19. In the stochastic-continuum approach (e.g., Neuman, 1987; Tsang and Tsang, 1989), permeability is distributed stochastically over a continuum. Channels are created/formed by interconnected high-permeability regions.

If significant matrix porosity is present, channel systems can still be considered to be double-porosity systems because fracture-matrix interaction by matrix diffusion will still occur. However, less matrix diffusion would be expected in a channel system than in a double-porosity continuum system for two reasons. First, the conductive surface area available for diffusion could be significantly lower in a channel system than in a double-porosity continuum system. Second, for a given flux, the mean pore-water velocity increases as the percentage of the fracture volume in which the flow is channeled decreases. Both of these processes would contribute to lower matrix diffusion and increased transport.

In 1983, 1984, and 1988, convergent-flow tracer tests using conservative tracers were performed at three locations where the Culebra is significantly fractured: the H-3, H-6, and H-11 hydropads (Figure 2-4). Jones et al. (1992) interpreted these tests using a homogeneous continuum double-porosity model with three orthogonal fracture sets. The tracer-test interpretations, however, relied on an idealized model of the hydraulics of the Culebra. Specifically, the interpretations assumed that fractures were evenly spaced over the entire thickness of Culebra and that all fractures had the same aperture and were equally conductive. This uniform fracture system was assumed to be anisotropic with respect to horizontal permeability, and the magnitude of the anisotropy and the orientations of the principal directions

of permeability were determined from fitting the observed tracer-breakthrough data to calculated tracer-breakthrough curves. Using these geometric assumptions and assuming that all of the physical retardation observed during the tracer tests was caused by matrix diffusion, Jones et al. (1992) were able to estimate the specific surface at the test locations. These results were expressed in terms of the parameter called "matrix-block length", which is dependent on the assumed fracture geometry, rather than in terms of specific surface, which is independent of geometry.

The WIPP PA Department (1993a) has used a double-porosity continuum model with a single set of horizontal fractures and parameter estimates provided by Jones et al. (1992) to calculate the potential for release of radionuclides to the accessible environment through the Culebra. From these calculations, the WIPP PA Department (1993b) concluded that Culebra fracture spacing (which is the PA model parameter representing specific surface) is a "Very Important Parameter", sixth in overall importance, with respect to demonstrating compliance with 40 CFR 191 Subpart B.

Independent reviewers of the interpretations of the previous tracer tests have questioned the assumption that matrix diffusion was the only mechanism causing physical retardation during those tracer tests (Hautojärvi and Vuori, 1992). They have suggested that other processes in addition to matrix diffusion, such as channeling caused by variations in fracture apertures or delayed release of tracer from the injection wells to the formation, may have contributed to the observed physical retardation and that discontinuum models or heterogeneous continuum models might provide a more realistic representation of the Culebra than homogeneous continuum models. The data from the previous tests are inadequate to resolve these questions because too few flow paths were tested, no direct measurements of tracer concentrations in the injection wells were made during the tests, tracers having different free-water diffusion coefficients were not used, and tests were not repeated at different pumping rates. The previous tests also did not: 1) examine the importance of vertical heterogeneity in the Culebra; 2) address scaling issues (changing transport parameters as a function of transport distance); and 3) provide sufficient data to determine whether variations in transport behavior along different flowpaths were due solely to anisotropic permeability in the Culebra or were caused by heterogeneity. As a result, the conceptual model and parameter values underlying the WIPP PA calculations of transport through the Culebra are considered by some reviewers to have insufficient experimental support to be defensible with a high level of confidence. In particular, the specific surfaces for diffusion interpreted from the previous tracer tests and used by the current PA model are considered by these reviewers to represent upper-bound estimates only because they attribute all of the observed

physical retardation to matrix diffusion. Lower-bound estimates of specific surface, which would produce the least amounts of matrix diffusion in PA models, cannot be defined with the available data.

In the absence of defensible lower-bound estimates of specific surface, WIPP PA (1993b) has used a model of transport through fractures with no matrix diffusion to place a maximum limit on potential radionuclide transport through the Culebra. The cumulative complementary distribution function (CCDF) of radionuclide releases to the accessible environment using this model is shifted nearly two orders of magnitude toward noncompliance with 40 CFR 191 Subpart B relative to CCDFs that include matrix diffusion. If experimental evidence were available with which to define the minimum amount of matrix diffusion that might be expected, WIPP PA would no longer have to consider the unrealistic, but bounding, scenario of no matrix diffusion.

To provide the information needed by WIPP PA and, in the process, address the questions raised by reviewers, a number of experimental activities are being undertaken as part of the Culebra Transport Program. The overall purpose of the Culebra Transport Program is to provide the experimental justification for mechanisms affecting transport, such as matrix diffusion, and defensible ranges of parameter to be used in PA calculations. As part of this program, a new seven-well testing location, the H-19 hydropad, was established, single-well and preliminary multiwell tracer tests were conducted at H-19, and hydrogeologic characterization of the Culebra at H-19 is underway using a variety of logging and testing techniques. This Test Plan describes plans, procedures, and specifications for an extensive series of tracer tests to be conducted at both the H-19 hydropad and the previously tested H-11 hydropad (Figure 2-4) to demonstrate and quantify matrix diffusion and provide other conceptual and quantitative information needed to model transport through the Culebra.

2.2 Purpose of Tracer Tests of the Culebra at the H-19 Hydropad

The H-19 hydropad consists of seven wells arranged as shown on Figure 2-5. The wells are completed through the Culebra as shown in Figures 2-6 and 2-7. Hydraulic characterization of the Culebra is currently being performed at the H-19 hydropad to provide a realistic description of the hydraulics of the Culebra. It will indicate whether or not the Culebra can be treated as a vertically homogeneous unit or if there are layers of different hydraulic conductivity that must be treated individually. The testing will provide direct information on the anisotropy of the Culebra as a whole, and potentially of individual layers. The results of the hydraulic testing will be used as direct input into the design and interpretation of the tracer tests.

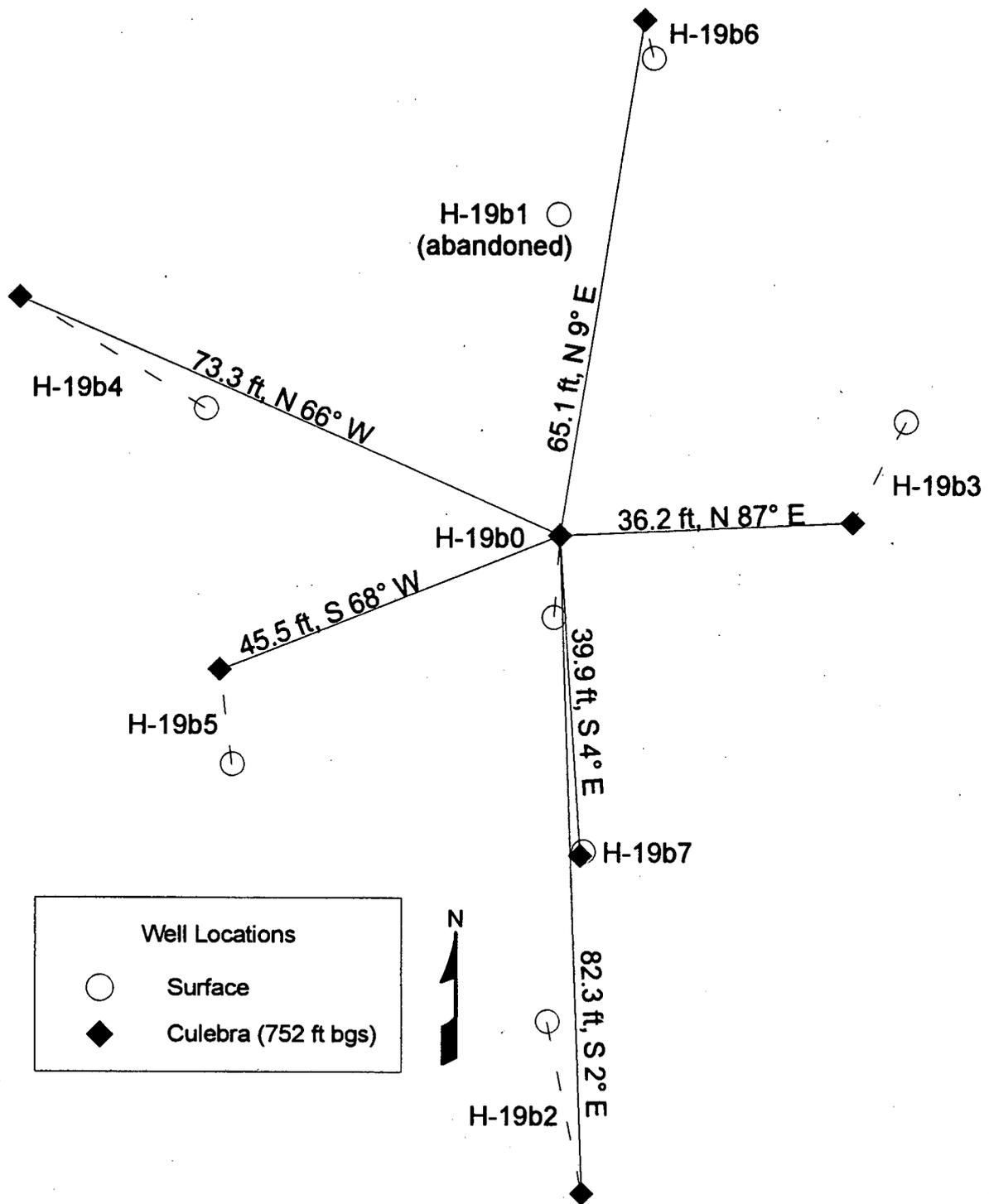
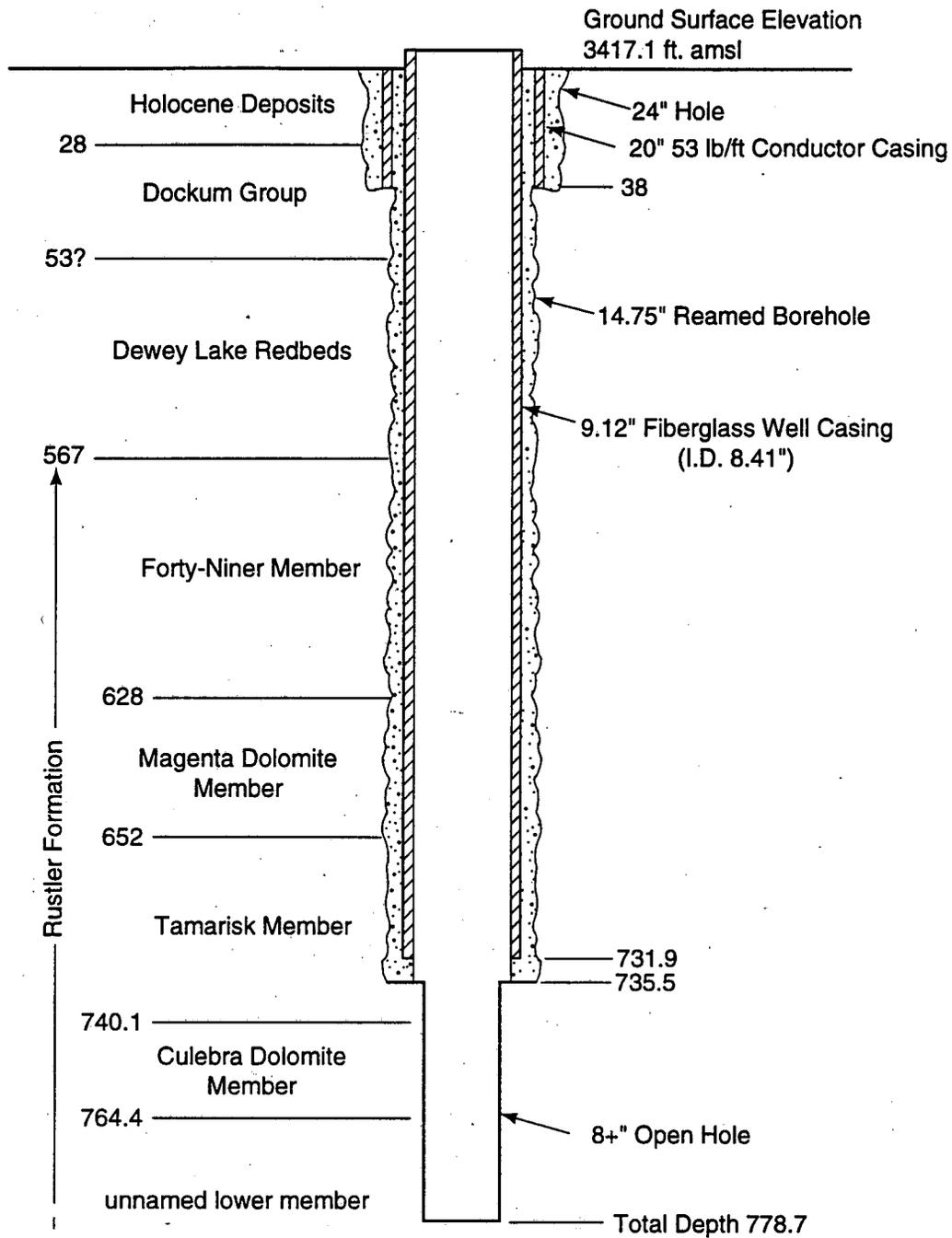


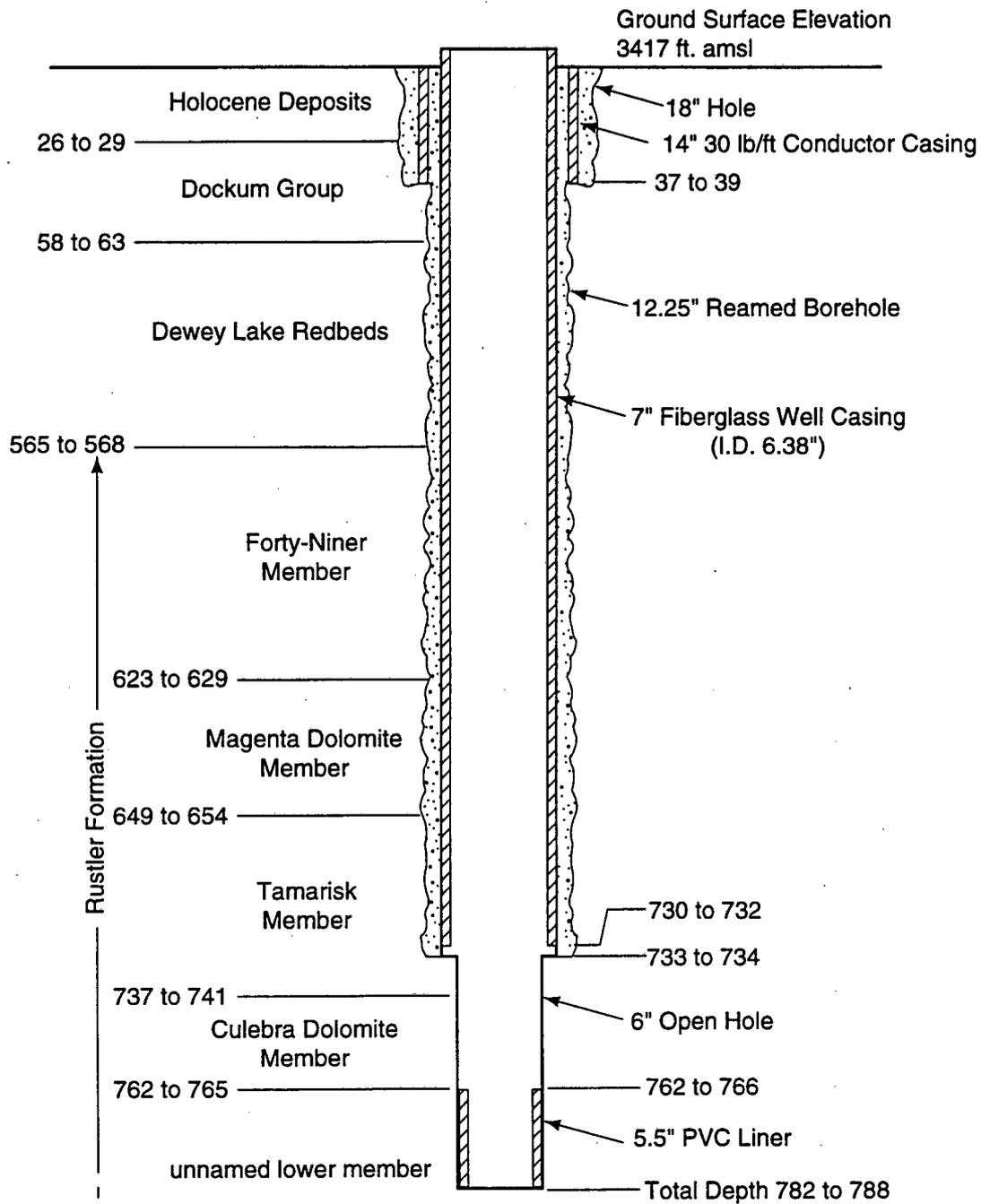
Figure 2-5. Configuration of the wells drilled at the H-19 hydropad.



Note: Depths in feet approximate
Not to Scale

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Figure 2-6. As-built completion of well H-19b0.



TRI-6115-138-2

Figure 2-7. Generalized completion of wells H-19b2 through H-19b7.

The H-19 tracer-testing program is intended to provide data with which to estimate the solute transport characteristics of the Culebra. Tracer testing will include a single-well injection-withdrawal (SWIW) test over the lower portion of the Culebra and a convergent-flow multiwell tracer test involving multiple tracer injections, tracer injections over different intervals of the Culebra, tracer injections using different injection techniques, tracers with different free-water diffusion coefficients, different pumping rates, and injection tools that prevent tracer-laden water from sinking to the bottom of the hole and providing a potential long-term diffusional source of tracer in the wellbore. These tests should provide tracer-breakthrough and recovery curves that can be used to quantify the amount of matrix diffusion occurring, determine how the different layers within the Culebra interact, and evaluate the effects of anisotropy and heterogeneity on transport on the hydropad scale. In addition, the expected length of the principal convergent-flow tracer test means that the test will also serve as a large-scale pumping test, providing more data with which to define the distribution of transmissivity within the Culebra across the WIPP site.

2.3 Purpose of Tracer Tests of the Culebra at the H-11 Hydropad

The H-11 hydropad consists of four wells arranged as shown on Figure 2-8. The two wells that will be involved in tracer testing, H-11b1 and H-11b3, are completed as shown in Figure 2-9. The tracer testing at H-11 will consist of a single-well test in H-11b1 and a two-well convergent-flow test between H-11b3 and H-11b1. Both H-11 tests will be performed over the entire thickness of Culebra. The tracer testing to be performed at the H-11 hydropad is intended to: 1. provide evidence for matrix diffusion; 2. resolve uncertainties and/or ambiguities associated with the interpretation of the H-11 tracer tests conducted in 1988; and 3. provide information to be used in spatial extrapolation of transport properties.

The SWIW tracer test to be performed in H-11b1 should provide additional evidence for the occurrence of matrix diffusion as well as information on the heterogeneity of the Culebra. The two-well convergent-flow tracer test to be conducted between H-11b3 and H-11b1 will serve to corroborate and quantify the effects of matrix diffusion interpreted from the 1988 tracer test at that location by providing a repeated test at a different pumping rate. Tracers with different free-water diffusion coefficients, if available, will also be used in this test to provide additional evidence for matrix diffusion. An improved tracer-injection tool, which will prevent tracer-laden water from sinking to the bottom of the hole and providing a potential long-term diffusional source of tracer in the wellbore, will help to resolve source-term questions associated with the earlier test. The new data provided by the H-11 tracer tests will be combined with that from the H-19 tracer tests and earlier tracer tests to define the conceptual model for transport within the

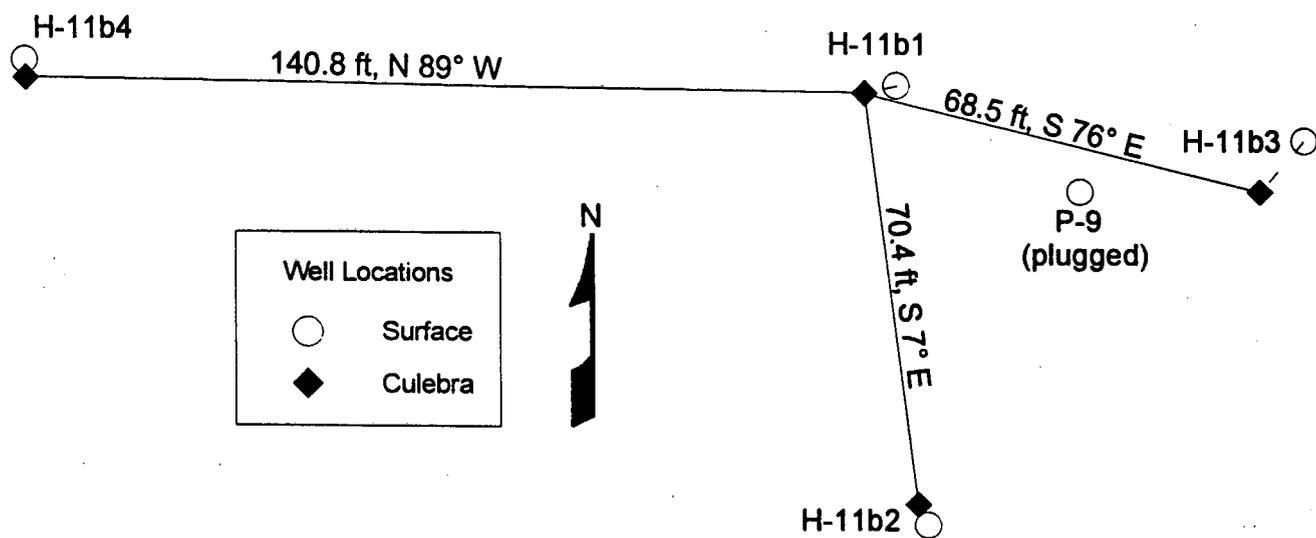
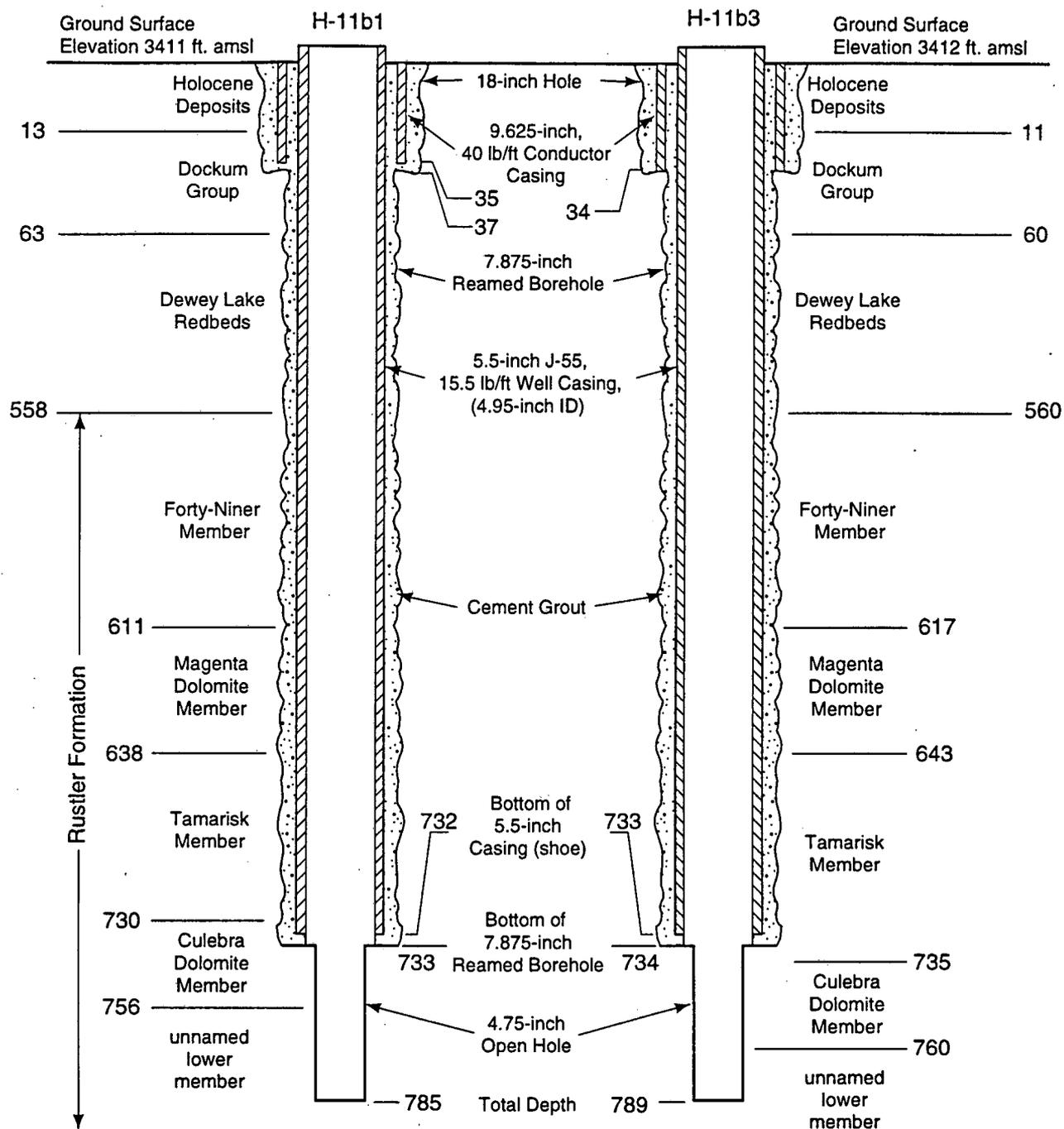


Figure 2-8. Configuration of the wells drilled at the H-11 hydrograd.



Notes: All formation depths (in feet approximate) from geophysical logs.
Not to scale

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Figure 2-9. As-built completions of wells H-11b1 and H-11b3.

Culebra over the WIPP site and ranges of parameter values to be used in Performance Assessment modeling.

3. REGULATORY AND PERMIT REQUIREMENTS

The Westinghouse Waste Isolation Division (WID) is responsible for ensuring that WIPP-site activities are conducted in accordance with applicable federal, state, and local regulatory requirements. The WID is responsible for assessing regulatory impacts and compliance, and for obtaining necessary permits. Appropriate National Environmental Policy Act (NEPA) checklists governing the proposed testing at the H-19 and H-11 hydropads have been generated and approved. SNL is responsible for ensuring that all contracted experimental work performed by SNL contractors at the WIPP site meets all applicable federal, state, and local regulatory requirements. Permits for the wells at the H-19 and H-11 hydropads have been obtained from the New Mexico State Engineer by the WID and SNL, respectively. These permits govern the drilling, completion, and pumping of those wells. Pumping restrictions applicable to this Test Plan are discussed below along with plans for the disposal of the pumped water.

3.1 Limitations on Pumping

The permits issued by the New Mexico State Engineer for the H-19 wells contain limitations on the allowable volumes of water that can be pumped from each well on an annual basis. The maximum allowable volume that can be withdrawn from well H-19b0 during any year is 10.0 acre-feet (3,258,288 gallons). No more than 20.0 acre-ft (6,516,576 gallons) can be withdrawn from H-19b0 through January 31, 1998, when the permit terminates. For wells H-19b2 through H-19b7, no more than 1.0 acre-ft per year (325,829 gallons) can be withdrawn from each well, and no more than 2.0 acre-ft (651,658 gallons) can be withdrawn from an individual well through January 31, 1998, when the permits terminate. Therefore, totalizing flow meters must be used on the discharge tubing from any H-19 well pumped under this test plan to monitor cumulative discharge during all pumping activities. The initial meter readings must be reported to the State Engineer when the meters are installed and the meter readings on the first day of January, April, July, and October of each year must be submitted to the State Engineer by the tenth day of those months. This information will be provided by the Tracer-Test Coordinator (TTC) or his designee to the WID Environmental Compliance and Support (EC&S) Manager on the first working day of each applicable month. The WID EC&S Manager is responsible for transmitting the information to the State Engineer. The State Engineer must also be notified at least 48 hr in advance of any pumping test at H-19. The TTC or his designee will notify the WID EC&S Manager of the intent to pump at least 72 hr in advance so that the WID EC&S Manager can provide the required notification to the State Engineer. The New Mexico State Engineer has placed no volumetric or notification restrictions on pumping at the H-11 hydropad.

3.2 Water Disposal

All formation water produced during testing at the H-19 and H-11 hydropads will be disposed of in an evaporation pond on the H-19 hydropad. No disposal of water off the WIPP site will be required.

4. COMPLIANCE JUSTIFICATION

The preliminary performance assessments of the WIPP (e.g., WIPP PA Dept., 1993b) have shown that physical and/or chemical retardation occurring as radionuclides are transported through the Culebra can make a significant contribution to WIPP's compliance with 40 CFR 191 Subpart B. Modeling of transport through the Culebra requires, first, a conceptual model of the mechanisms and processes governing that transport and, second, quantitative estimates of the parameters required for numerical simulation of those processes. The Culebra Transport Program represents the combined efforts of the SNL Geohydrology (6115) and WIPP Chemical and Disposal Room Processes (6748) Departments to provide the conceptual understanding and data necessary to construct a defensible numerical model for Culebra transport. Section 2.1 presents additional information pertinent to the compliance justification of the activities to be performed under this Test Plan.

5. TEST OBJECTIVES

The H-19 tracer-testing program will consist of a single-well injection-withdrawal test followed by a multiwell convergent-flow tracer test involving multiple injections and tracers. The H-11 tracer tests will involve a single-well injection-withdrawal test followed by a two-well convergent-flow test. The tests will provide data which will serve as input toward the continued development of conceptual models of both the groundwater flow and mechanisms for solute transport in the Culebra. Information on hydraulic conductivity, anisotropy, layering, interconnection between layers, and heterogeneity will be used as input to the interpretation of these tracer tests.

The tracer tests have the following objectives:

- to identify fracture and/or high-permeability connections among the wells at the H-19 hydropad and the extent to which heterogeneity, anisotropy, layering, and the scale of testing affect flow and transport;
- to provide data to assist in discriminating between the different models proposed for solute transport in the Culebra;
- to provide data to demonstrate and quantify the effects of matrix diffusion in the Culebra;
- to identify the relative importances of hydrologic processes affecting transport;
- to evaluate possible source-term uncertainty resulting from tracer-injection techniques used in earlier tracer tests of the Culebra;
- to evaluate the degree of flow stratification within the Culebra; and
- to evaluate the extent to which long-term pumping of the Culebra at the H-19 hydropad affects water levels in other observation wells on the WIPP site.

6. EXPERIMENTAL PROCESS DESCRIPTION

The tracer tests to be performed in the Culebra at the H-19 hydropad will involve multiple tracers and several tracer-injection techniques. The specific approach to be taken is being developed through evaluation of the data provided by activities performed under a Field Operations Plan for drilling and preliminary hydraulic and tracer testing (Saulnier and Beauheim, 1995) and a Test Plan for hydraulic characterization of the Culebra at H-19 (Kloska et al., 1995). Core samples, water-production and pressure responses observed during drilling, geophysical logs, borehole imagery, and hydrophysical logs have been used to develop a two-layer conceptual model of the Culebra. The upper layer is approximately 10 ft thick, is composed largely of massive, intact dolomite with few vugs or fractures, and produces only about one gallon per minute (gpm) of water. The lower layer is approximately 14 ft thick, is composed of less-competent dolomite containing abundant vugs, many of which are interconnected by fractures, and produces several gpm of water. Cross-hole hydraulic tests of isolated layers will provide quantitative information on the properties of these two layers, as well as indications of their degree of hydraulic connection. The results of these tests will be used to select and design equipment configurations in wells and operational parameters for tracer testing.

Two types of tracer tests will be performed at H-19: a single-well injection-withdrawal (SWIW) test and a multiwell convergent-flow test. In general, the experimental process will proceed as follows. The pumping well for the tracer tests, H-19b0, will be equipped with a pump, a tracer-injection assembly, and three packers (one just above the Culebra to remove wellbore storage in the well casing, one in the Culebra to separate the two layers, and one at the base of the Culebra). The tracer-injection assembly will be configured so as to allow tracer injection into the lower layer of the Culebra when the packer in the Culebra is inflated, and pumping from the entire Culebra when the packer is deflated. The six tracer-injection wells will be equipped with either two-packer or three-packer tracer-injection assemblies. Two-packer tools will be installed in the three wells farthest from H-19b0: H-19b2, H-19b4, and H-19b6. One packer will be set just above the Culebra and the other packer will be set across the contact between the Culebra and the unnamed lower member of the Rustler. Tracers will be injected over the entire thickness of Culebra in these wells. The upper and lower packers of the three-packer tools will be set in the same positions as those in the two-packer tools, while the third packer will be used to separate the two layers of the Culebra. The tracer-injection assemblies will be configured to allow separate injections into the two layers when the middle packer is inflated, or injection over the entire thickness of Culebra when the middle packer is deflated.

Three-packer tools will be installed only in the three wells closest to H-19b0 (H-19b3, H-19b5, and H-19b7) because the time required to obtain interpretable breakthrough curves from tracer injections in the upper layers of the more distant wells is likely longer than is available.

The SWIW test will provide data with which to help establish whether single- or double-porosity transport behavior is evident in the Culebra at the H-19 hydropad. During the preliminary tracer testing performed at H-19, a SWIW test was performed over the entire Culebra interval in H-19b0. Preliminary interpretation of that test has suggested that the tracer-recovery curve observed may reflect the superimposed effects of transport in multiple layers. To provide additional information to evaluate the effects of layering, another SWIW test will be performed as part of the current testing program that will involve injecting one or two tracers in only the lower layer of the Culebra in H-19b0. After a waiting period of at least overnight, the packer separating the upper and lower layers will be deflated and a pump will be turned on at the maximum rate that is sustainable for a two-month period, probably about five gpm. (Pumping from the entire Culebra is necessary for the multiwell convergent-flow tracer test.) Sampling and analysis of the discharge from the pumping well will begin immediately and continue throughout the pumping period. The tracer-recovery data will be analyzed for evidence of matrix diffusion in the Culebra at the H-19 hydropad. The pumping for the SWIW test will continue directly into the convergent-flow test.

The convergent-flow tracer test will involve all seven wells at the H-19 hydropad with H-19b0 being the pumping well and H-19b2 through H-19b7 serving as tracer-injection wells. Tracer injections in the six wells will begin using slug-injection techniques after the flow field toward the pumping well has been established and the rate of drawdown in all wells has stabilized, probably within one week of the start of pumping for the SWIW test. The initial injections in those wells containing three-packer assemblies may be over either the entire thickness of Culebra or over individual layers. One of the initial tracer injections will involve a pair of tracers having different free-water diffusion coefficients. Pumping will be maintained at a constant rate until all tracers have been detected at the pumping well, their concentrations have passed their peaks, and the concentration of the tracer from the slowest path has declined to approximately one-half of its peak value. Based on the tracer-breakthrough data obtained from the preliminary H-19 tracer test, this criterion should ensure that concentrations of tracers from the faster paths have decreased to less than one-third of their peak values. The pumping rate will then be decreased by 35 to 50% and, after drawdown rates have again stabilized, additional tracers will be injected in the six wells. If possible, one of these injections will also involve two tracers having different free-water diffusion coefficients.

Because of the different distances of the tracer-injection wells from the pumping well and directional differences in transport properties, some breakthrough curves will be adequately defined for interpretation before others. Based on interpretation of the preliminary tracer test performed on the H-19 hydropad, tracer from H-19b7 is expected to reach H-19b0 faster than the tracers from the other wells. After the first tracer-breakthrough curve is adequately defined at the initial pumping rate, the injection assembly from that tracer's source well (presumably H-19b7) will be removed and replaced with a passive-injection tool (PIT; see Section 7.2.1.4). The purpose of the PIT is to introduce tracer into the Culebra without the overpressurization relative to ambient formation pore pressures caused by slug-injection techniques. After installing the PIT, tracer that is conveyed downhole within the tool will be released and circulated within the test interval. The tracer concentration in the test interval should decrease with time as the tracer-laced water is drawn towards the pumping well. Samples of the fluid in the well at different times will be collected using a modified Kuster® sampler. These samples will be analyzed to define the source term to be used in modeling the tracer breakthrough at the pumping well. These data will help resolve uncertainties about possible influences of slug-injection techniques on observed breakthrough curves. Time permitting, the PIT may also be used in additional wells during either the first or second pumping period.

If the breakthrough curves from the other wells containing three-packer assemblies are adequately defined before sufficient data have been collected from the longer flow paths, the inflation status of the middle packers will be changed (e.g., inflated if previously deflated) in those wells and additional tracers will be injected over the new isolated interval(s) of the Culebra. Evaluation and comparison of the breakthrough curves from the (potentially) three different injections in those wells will allow determination of the amount of interchange of solutes occurring between the two layers of the Culebra.

The convergent-flow tracer test at H-19 is expected to have a duration of four to five months. Previous tests of similar durations at the WIPP site have affected water levels over several square miles. Therefore, the water-level/fluid-pressure responses to the convergent-flow tracer test will be monitored in WIPP observation wells in the region around the H-19 hydropad. The duration of pumping at H-19 will determine the length of the recovery-monitoring period. During other WIPP regional-scale pumping tests, recoveries have been monitored for periods of up to twice as long as the pumping period to document the effects of testing.

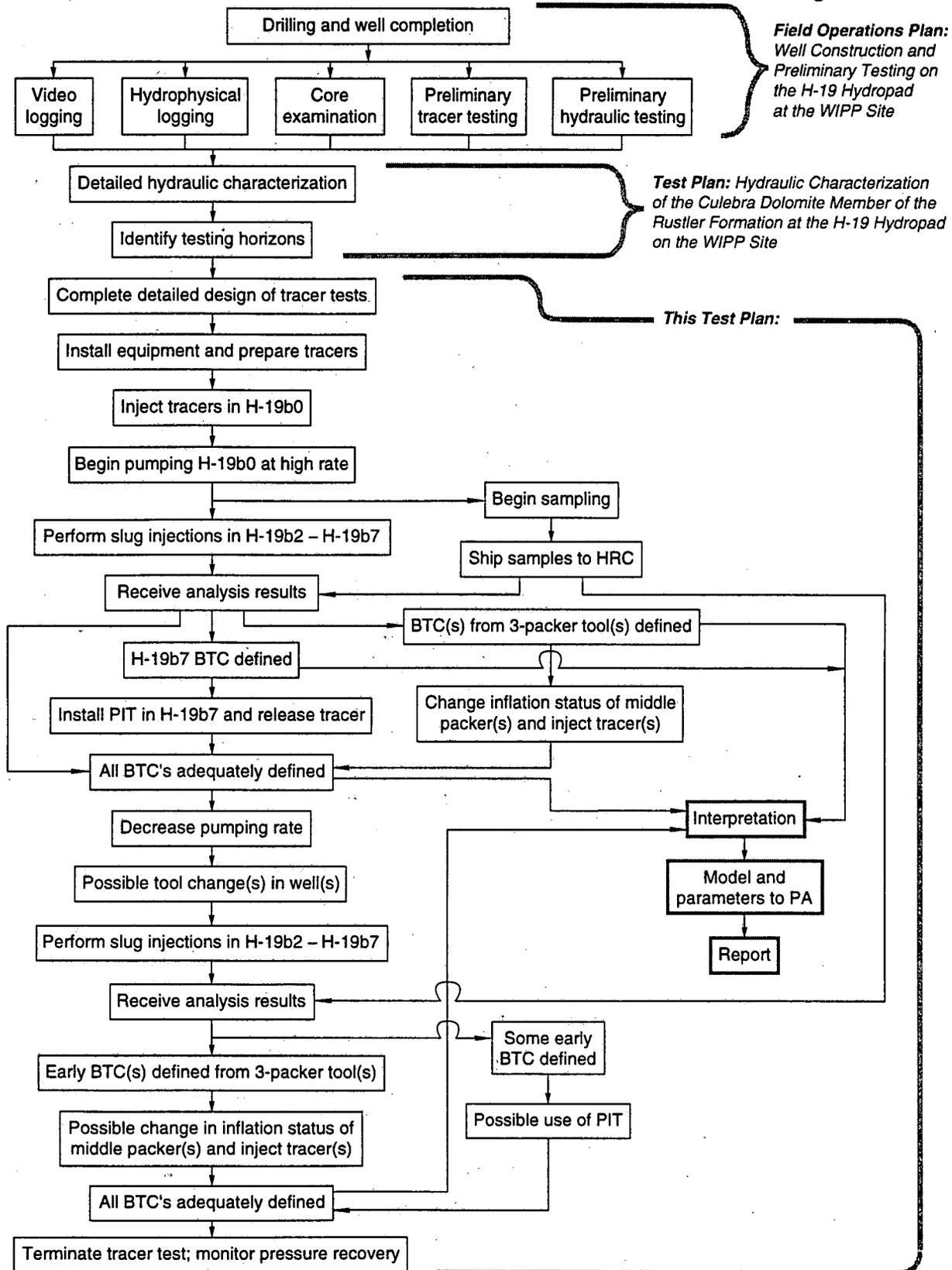
The tracer tests to be performed at the H-11 hydropad include a SWIW test in H-11b1 followed immediately by a two-well convergent-flow test to be conducted between H-11b3 and

H-11b1. H-11b1 will be equipped with a pump, a tracer-injection assembly, and packers at the top and bottom of the Culebra. The SWIW test will be conducted over the full thickness of Culebra in H-11b1 so that its results are comparable to those from the preliminary SWIW test conducted in H-19b0. One of the same tracer-injection assemblies used for the 1988 H-11 tracer test will be installed in H-11b3. The assembly will span the entire thickness of Culebra and will be modified to accommodate a packer at the base of the Culebra. The tests will commence by injecting one to three tracers into H-11b1 and allowing them to rest in the formation overnight. The next day, the pump in H-11b1 will be turned on at a rate of three to four gpm (50 to 65 % of the rate used in the 1988 test) and sampling and analysis of the discharge will begin. After a stable gradient has developed between H-11b3 and H-11b1, two tracers having different free-water diffusion coefficients (if available) will be injected into H-11b3, followed by a chaser volume of untraced Culebra water. Pumping and sampling from H-11b1 will continue for three to four weeks to define the tracer-breakthrough curve from H-11b3.

The flow path between H-11b3 and H-11b1 showed the most rapid tracer breakthrough and least retardation of the paths tested during the 1988 H-11 tracer test (Jones et al., 1992). The new test is being conducted along that flow path to develop a better understanding of "fast" transport paths. The tracer injection in H-11b3 will be designed to mimic the 1988 injection in that well as closely as possible. By duplicating the earlier injection conditions, pumping H-11b1 at a rate of three to four gpm compared to the six gpm used for the 1988 test, and by possibly using two tracers with different free-water diffusion coefficients, the new test will allow a clear demonstration and quantification of the effects of matrix diffusion on the H-11b3 to H-11b1 flow path.

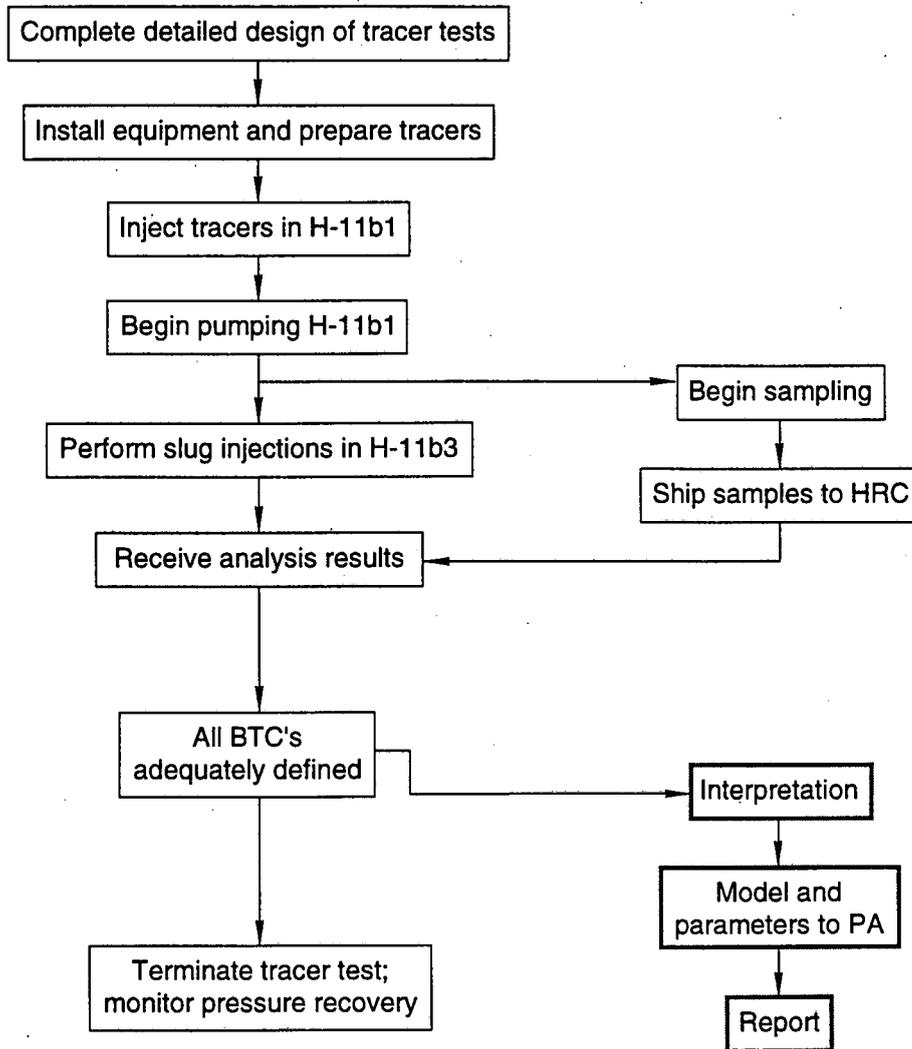
All elements of the H-19 and H-11 tracer test designs will be subject to modification as testing proceeds. The modifications will affect the operational aspects of the testing but not the underlying principles upon which the testing concepts depend. The TTC will, in consultation with the PI, modify ongoing tests to allow the operating procedures to be consistent with the information developed during and immediately preceding different elements of the convergent-flow tracer tests. The TTC will document all modifications to test designs and procedures in the scientific notebooks as they occur. Figures 6-1 and 6-2 show flow charts of the experimental processes for the H-19 and H-11 tracer tests, respectively.

Controlling Document



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Figure 6-1. Flow chart of the elements of the H-19 tracer tests.



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Figure 6-2. Flow chart of the elements of the H-11 tracer tests.

7. INSTRUMENTATION/TEST EQUIPMENT/FACILITIES

Equipment needed for the performance of tracer testing at the H-19 and H-11 hydropads under this Test Plan will consist of equipment at land surface and downhole equipment to be installed in the wells. All equipment used for the test will be documented as part of the QA data package for the tracer-testing program.

7.1 Surface Equipment

The H-19 and H-11 tracer-testing program will be conducted utilizing some equipment at land surface and some equipment installed in the wells (i.e., downhole equipment). All equipment will be operated observing all relevant SNL and WID ES&H procedures and protocols. The surface equipment will consist of data-acquisition systems (DASs) to monitor the tests, a packer-inflation system, a flow-control system, a barometer, water-level sounders, water-quality measurement instruments, diesel-powered generators, storage tanks, and tracer-mixing tanks.

7.1.1 Data-Acquisition Systems

Computer-controlled DASs will be used to control and monitor the pumps used for the H-19 and H-11 tracer tests, as well as to monitor fluid pressures in the wells on the H-19 and H-11 hydropads. The DASs will send and receive signals to and from a flow meter, flow-control valve, and downhole pressure transmitters, and record the signals on the computer's hard disk and on floppy diskettes. The DASs used for the tracer testing will most likely be the SNL PERM DAS, although BASys (Baker Acquisition System), provided by Baker Oil Tools, is also being considered. Data acquired from the flow-control system and downhole pressure sensors will be operationally verified using Technical Operating Procedure (TOP) 508: Installation of Pressure Transducers, Flow Meters, and Thermocouple Gauge Checkout.

7.1.1.1 PERM DATA-ACQUISITION SYSTEM

The PERM DAS will be operated in accordance with TOP 509: Operation of PERM DAS Program. A schematic illustration of the PERM DAS is shown on Figure 7-1. The basic system consists of a power-excitation input to access downhole pressure transmitters, a barometer, and electronic flow meter(s), a digital voltmeter to observe the gauges' output signals, a data-control unit to access each gauge's signal, a programmable voltage standard to verify the signal output from gauge and excitation devices, and a microcomputer to store and process the data. The

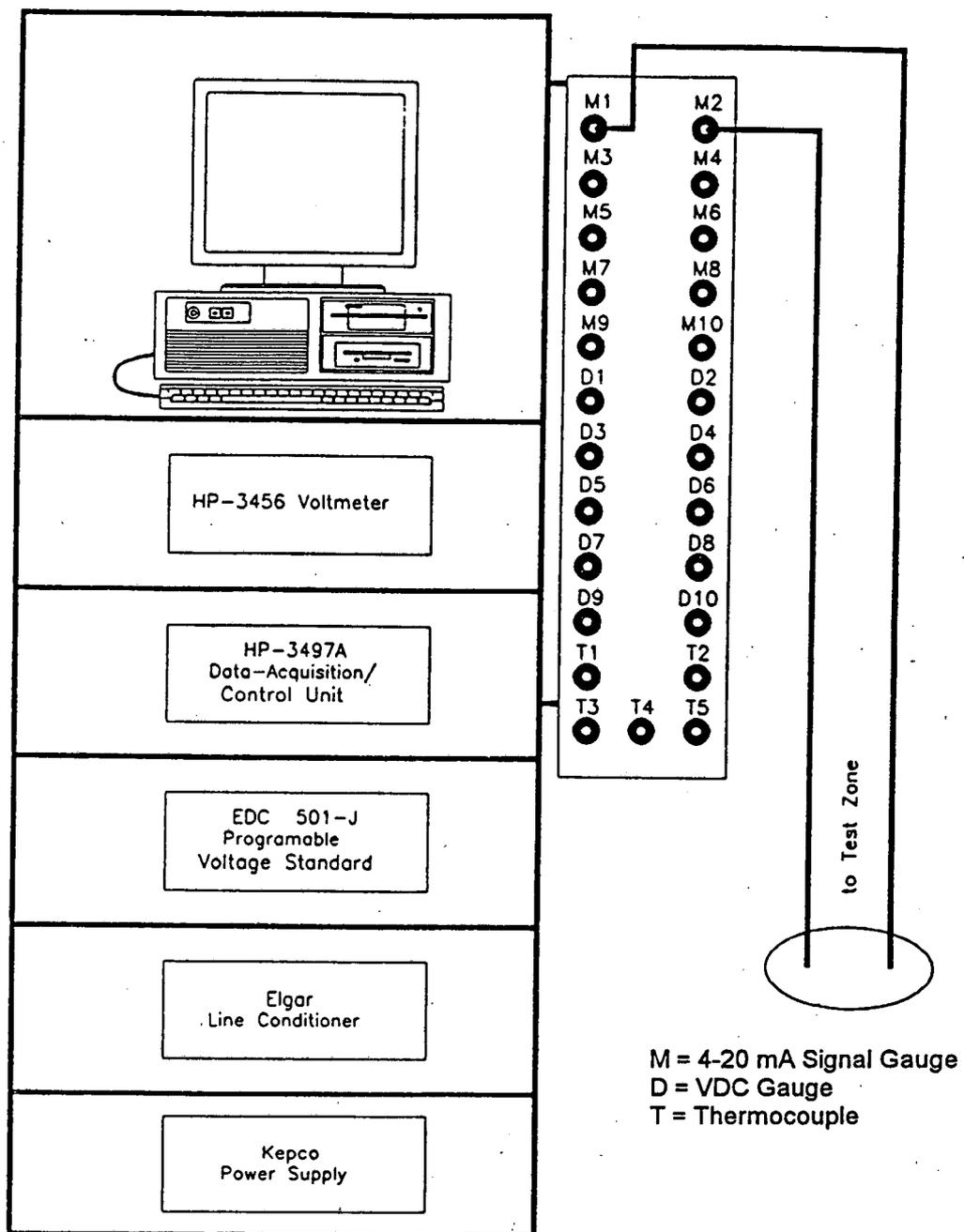


Figure 7-1. Schematic illustration of the SNL PERM data-acquisition system.

PERM DAS will collect and process the gauges' output signals and store the data on hard disk and on floppy disks using SNL's PERM5 data-acquisition software (Version 1.01), which has been submitted for qualification in accordance with Quality Assurance Procedure (QAP) 19-1, Rev. 1.

7.1.1.2 BASys DATA-ACQUISITION SYSTEM

BASys is a computer-controlled DAS which can monitor up to 48 input channels/gauges with real-time plotting, printing, and graphical interactive video display. The system includes a 12-bit analog-to-digital (A to D) converter card that observes the signal input from the various gauges and in turn inputs those signals into an IBM-type desk-top computer. The computer is used to control the rate of data collection, monitor and record data on magnetic media, and output the signal input in engineering units through an IEEE bus and graphical interface to printer, plotter, and video-display peripherals. The BASys DAS can monitor each channel/gauge at 24-msec intervals. The BASys DAS is leased from the supplier and is controlled by proprietary software. The hardware and software (Version 1.A0) for the BASys DAS have undergone verification testing. Documentation of this verification has been submitted in accordance with QAP 19-1, Rev. 1. Figure 7-2 is a schematic illustration of the BASys DAS.

7.1.2 Packer-Inflation System

The downhole packers used in the tracer-injection assemblies will be inflated with compressed nitrogen or compressed air. The inflation process will be performed in accordance with TOP 505: Pumping Tests. If, in special cases, the packers will be inflated with fluid, an intensifier pump will be used in accordance with TOP 472: Intensifier Pump: Operation and Use.

7.1.3 Flow-Control System

Pumping rates for the tracer-testing program at the H-19 and H-11 hydropads will be controlled using a computer-controlled flow-control system consisting of an in-line inductive flowmeter, a programmable electronic flow controller, and an electro-pneumatic valve. The flow-control system will be operated with the DAS and all flow rates will be recorded by the DAS. The components of the system are combined in a simple feedback loop. Thus, the flow-rate output from the flow meter will be used as input to the electro-pneumatic valve allowing stable flow-rate changes to be introduced with electronic instructions from the DAS in real time.

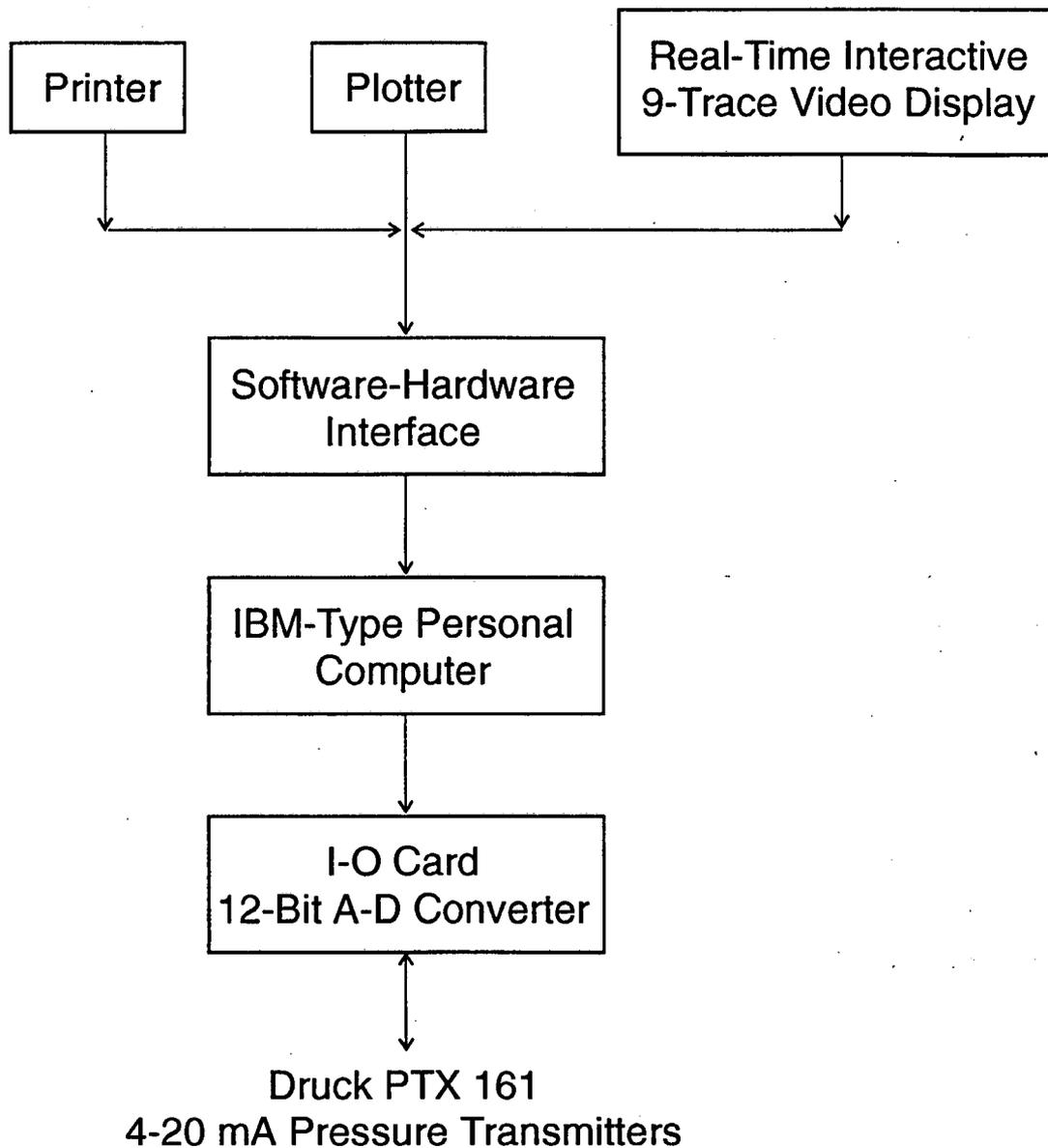


Figure 7-2. Schematic illustration of the BASys data-acquisition system.

The setpoint can be set manually at the controller or remotely through the DAS. The design control range for flow rate is expected to be approximately two to five gpm.

Fluid-discharge data will be collected during all production periods during the tracer-testing program. The pumping-rate/discharge data will be obtained using both a totalizing flow meter and an electronic flow meter. An additional check on the discharge rate may be provided using a calibrated standpipe according to TOP 514: Verification of Totalizing Flow Meter Measurements Using a Verified Standpipe.

The New Mexico State Engineer requires that the cumulative volume of water produced from each well be determined and reported during testing activities at the H-19 hydropad (Section 3.1). Therefore, the flow-control/discharge-measurement system at H-19 will also include a totalizing flow meter. The total discharge will be measured with a Carlon (or equivalent) in-line totalizing flow meter. The Carlon flow meter has a $\frac{5}{8}$ -inch orifice, and is a brass-housed synthetic (non-corrosive) turbine flow meter designed for discharge rates of 1 to 20 gpm, with scale divisions of 0.10 gallons. The Carlon flow meter is a totalizing flow meter and monitors only the total volume of fluid pumped. If necessary, the average pumping rate for any period can be calculated from the meter readings made at the beginning and end of the period. Totalizing-flow-meter data will be documented as part of the QA data package.

In addition to the Carlon flow meter, an Endress-Hauser FTI 1943 Variomax Electromagnetic flow meter, or equivalent, will be used to measure the discharge rate during pumping periods. The Variomax is a $\frac{1}{2}$ -inch orifice magnetic flow meter requiring 115 VAC with a 4-20 mA signal output providing both discrete and totalizing flow measurements for pumping rates ranging from 0 to 15 gpm. The operation of the magnetic flow meter is based on Faraday's Law which states that the voltage induced across any conductor as it moves at right angles through a magnetic field is proportional to the velocity of that conductor. In this case, the conductor is the formation fluid flowing through a discharge pipe.

The pumping rates will be regulated using an electronically actuated flow-control valve to apply back pressure to the pump, and a Dole in-line flow-regulation valve located upstream of the flow meter. These two valves, in combination with the check-valve at the pump, will prevent unregulated flow from damaging the flow meter and will prevent spurious early-time data during the pumping tests.

7.1.4 Barometer

Barometric-pressure measurements will be collected during the H-19 and H-11 tracer-testing program using a Druck PTX 260 series 0 to 17-psia pressure transmitter mounted at the H-19 hydropad. Druck PTX transmitters require a 9 to 30 VDC input voltage and produce a 4 to 20-ma output signal which is converted to a voltage output and monitored by the DAS. The barometer output monitored by the DAS and converted pressure data will be recorded at the same frequency as the downhole fluid-pressure data.

7.1.5 Water-Level Sounders

Water levels will be measured before installing testing equipment in the H-19 and H-11 wells. Water levels will also be measured manually in some observation wells during the tracer tests. The water levels will be measured using Solinst electric water-level sounders according to TOP 512: Depth-to-Water Measurement Using Solinst Brand Electric Sounder. All measurements will be documented as part of the QA data package. The Solinst meter consists of a graduated plastic tape with two wire leads, a water-level probe at the downhole end of the tape, batteries, and a signal light and buzzer mounted on a surface reel. When the water-level probe enters the water, the electrical conductivity of the water closes the electric circuit on the tape, activating the surface light and buzzer. The water level is read directly, in feet or meters, on the graduated plastic tape, at the observation-well measuring point, which will be clearly marked on the surface casing. See Section 7.2.4 regarding downhole fluid-pressure measurements.

7.1.6 Water-Quality Measurement Instruments

Throughout the pumping phases of the tracer-testing program, the electrolytic conductivity, temperature, pH, and specific gravity of the produced water will be measured on a routine basis following TOP 513: Water Quality Data: Measurements of Specific Gravity, Conductance, pH, and Temperature. These data will be considered qualitative in nature and will not be used for interpretation, but only to indicate relative changes in the quality of the fluid produced from the wells. The electrolytic conductivity will be measured with a Yellow Springs Instruments S-C-T meter or equivalent; the temperature with a laboratory-grade mercury thermometer; pH with an Orion pH meter or equivalent; and the specific gravity with a certified, laboratory-grade hydrometer. Measurements will be carried out in conjunction with discharge-control measurements. Measurements showing unusual or rapid changes in the conductivity data will

be documented as part of the QA data package and the measurement frequency will be modified to accommodate documenting these changes.

7.1.7 Diesel-Powered Generators

Diesel-powered generators are needed to generate electricity for the tracer-testing program. They will be operated in accordance with all relevant WID and SNL safety regulations.

7.1.8 Storage Tanks

All groundwater produced from the pumping well H-19b0 (or any other designated pumping well) during the tracer-testing program will be pumped either directly into the H-19 evaporation pond or into storage tanks provided by a service company under a SNL contract. The tanks will be drained into the evaporation pond when the need for temporary storage of the water passes. Groundwater produced from pumping at the H-11 hydropad will be stored in tanks on the hydropad before being transported to the H-19 evaporation pond. The tanks will likely be 130-barrel-capacity standard oil-field-type frac tanks. The tanks will be steam cleaned and/or sand blasted (if required) before use.

The fluid to be used for tracer mixing and injection in the H-19 and H-11 wells will be produced from wells on the respective hydropads (or possibly WQSP-4 for the H-19 tests) prior to the tests and stored on each site in portable, clean, polyethylene tanks. Holding tanks for injection fluids will be covered to avoid evaporation and/or dilution.

7.1.9 Tracer Mixing and Injection Systems

Tracers are received from manufacturers in powdered form and will be mixed with Culebra water at the H-19 and H-11 hydropads in 300-gallon polyethylene tanks. High-capacity magnetic drive pumps will be used to circulate the tracer solutions within the tanks and to pump the solutions downhole.

7.2 Downhole Equipment

Downhole equipment in the production and tracer-injection wells will consist of some or all of the following items or classes of equipment: tracer-injection tools; submersible pumps; pressure transmitters; downhole memory gauges; bridge plugs; and ion-specific electrodes.

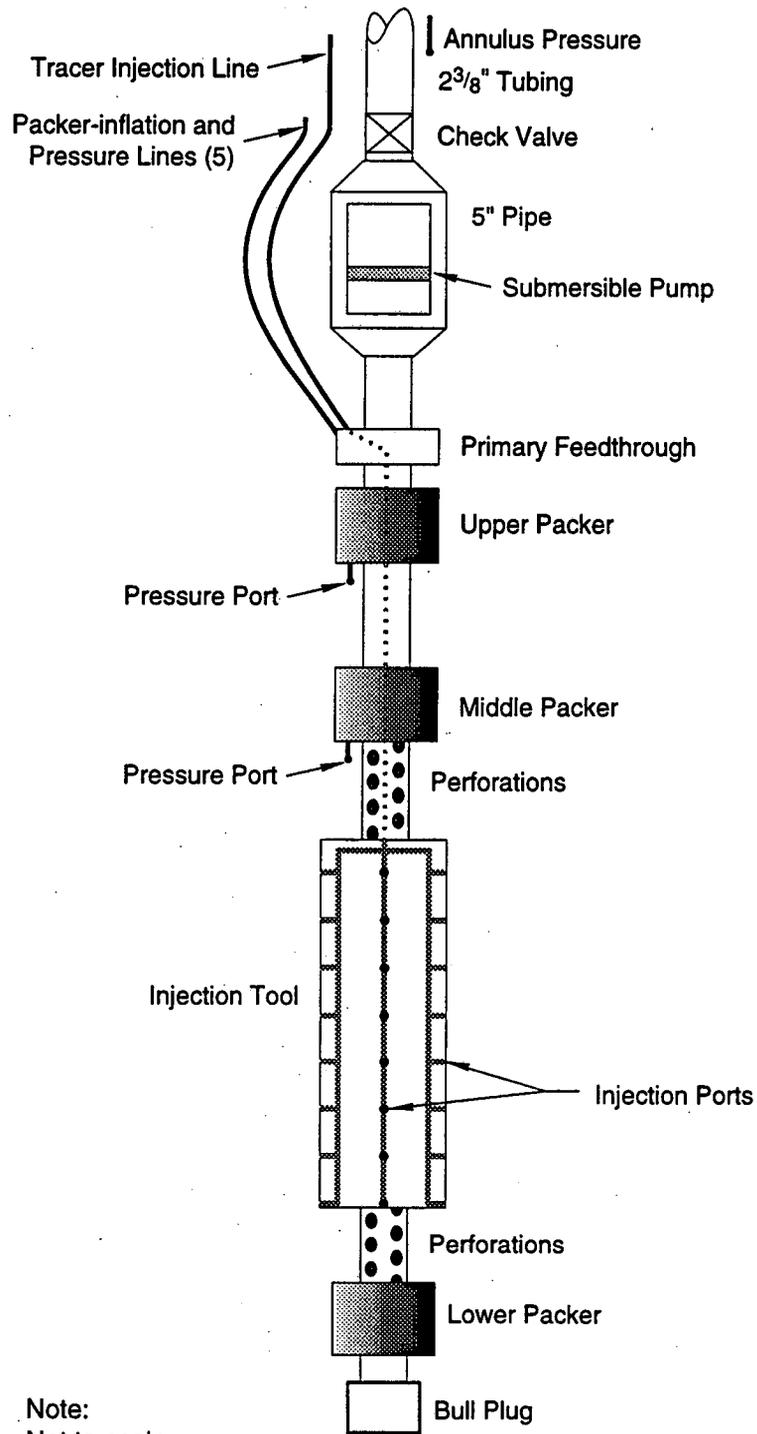
7.2.1 Tracer-Injection Tools

Six different tracer-injection tools may be used during the H-19 and H-11 tracer tests: an injection assembly to be used for the SWIW test in H-19b0; two-packer assemblies to be used in H-19b2, H-19b4, and H-19b6; three-packer assemblies to be used in H-19b3, H-19b5, and H-19b7; a passive-injection tool that may be used in one or more of the H-19 tracer-injection wells; an injection assembly to be used for the SWIW test in H-11b1; and a two-packer assembly to be used in H-11b3. These tools are described below.

7.2.1.1 SWIW Assembly for H-19b0

The injection assembly to be used for the SWIW test in H-19b0 is shown schematically in Figure 7-3. The assembly consists of a pump shroud, a check valve, three packers, a number of feedthrough assemblies, and a combined volume-displacement/injection tool. The pump shroud is a length of 5-inch outside diameter (OD) pipe or casing connected by swedges to 2 $\frac{3}{8}$ -inch tubing above and below. The submersible pump (Section 7.2.2) will be set inside the shroud and produce water from below the packers through the 2 $\frac{3}{8}$ -inch tubing. The check valve is positioned below the pump shroud and prevents water in the 2 $\frac{3}{8}$ -inch tubing from draining into the Culebra when the pump is turned off. The upper packer will be set with its lower seal at the upper contact of the Culebra, the lower seal of the middle packer will be set near the base of the upper, low-transmissivity section of the Culebra, and the lower packer will be set across the contact between the Culebra and unnamed lower member. The feedthrough assemblies pass tracer-injection, packer-inflation, and pressure transmitter lines into and out of the mandrils of the packers as required.

The tracer solution flows down from the ground surface through a single $\frac{1}{2}$ -inch stainless steel tube that gets reduced to a $\frac{3}{8}$ -inch tube when it enters the test tool, and is then distributed into four $\frac{1}{4}$ -inch stainless steel tubes that pass into the volume-displacement/injection tool. The volume-displacement/injection tool will be positioned between the middle and lower packers and



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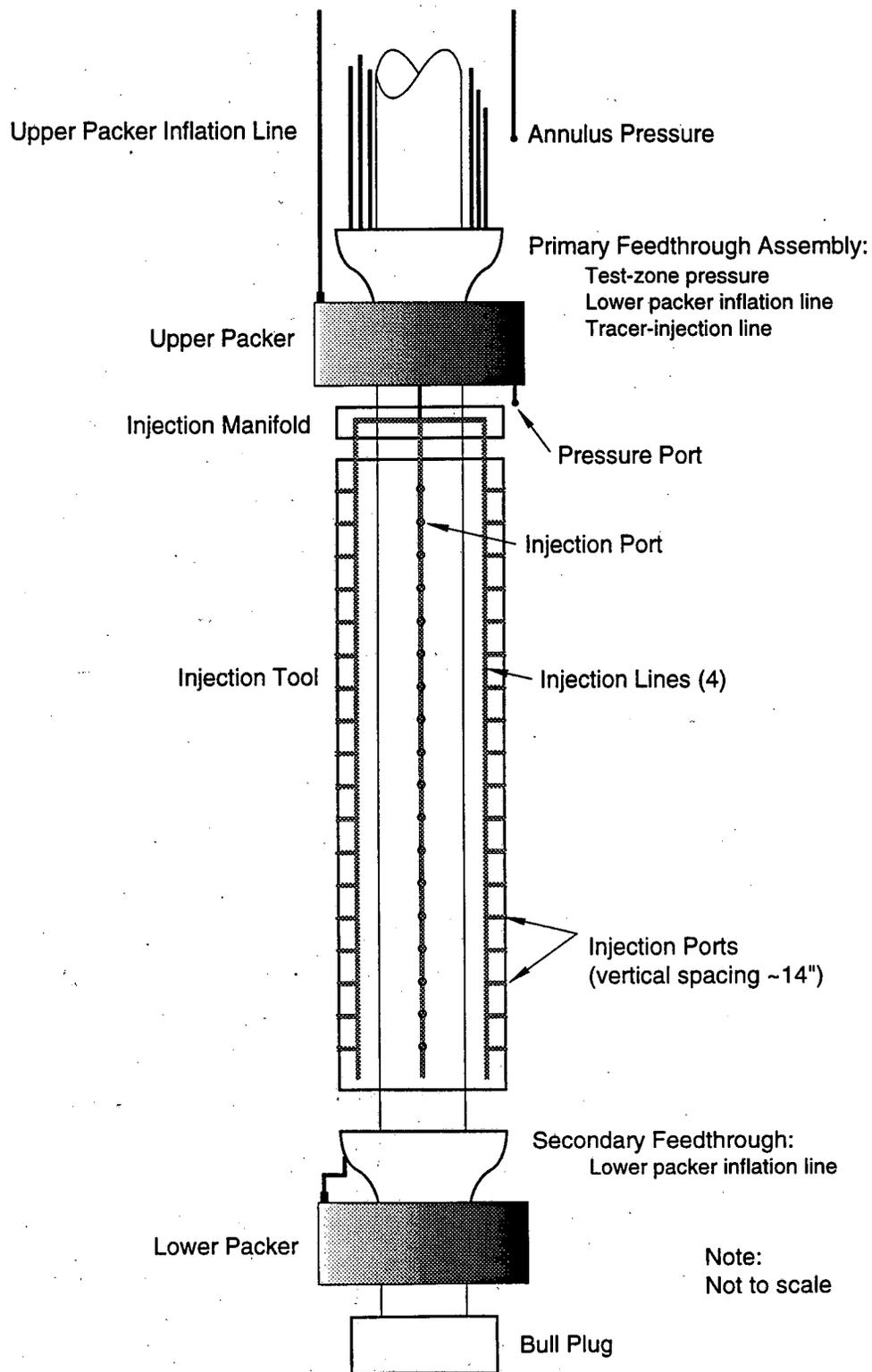
Figure 7-3. Tracer-injection and pumping equipment to be installed in H-19b0.

extend to near the bottom of the Culebra. The body of the volume-displacement/injection tool consists of 7-inch OD pipe sealed at both ends to displace test-interval fluid. By minimizing the test-interval fluid volume, the volume of tracer-laced fluid injected during testing will be minimally diluted in the well and will resemble a uniform-concentration plug-flow injection into the formation. The four ¼-inch stainless steel injection tubes are ported through the 7-inch pipe approximately every 14 inches. The ports have orifices that increase in size with depth to provide for uniform tracer distribution over the lower portion of the Culebra. The 2⅝-inch tubing will be perforated above and below the injection tool so that the pump can draw water from the Culebra. When the middle packer is inflated, tracer will be injected only into the lower portion of the Culebra. When the middle packer is deflated, pumping will produce water from the entire thickness of Culebra.

7.2.1.2 Two-Packer Slug-Injection Assemblies for H-19b2, H-19b4, and H-19b6

Figure 7-4 illustrates the components of the two-packer slug-injection assemblies that will be used to inject tracers into the entire Culebra intervals in H-19b2, H-19b4, and H-19b6. Each assembly will contain two inflatable packers, a number of feedthrough assemblies, an injection manifold, and a volume-displacement/injection tool. The upper packers will have 5-inch (uninflated) diameters and 27-inch sealing elements, and will be set in the lower Tamarisk Member where the reamed hole diameters are approximately six inches. The lower packers will have 3½-inch (uninflated) diameters and 30-inch sealing elements, and will be set partially in the 4⅞-inch inside diameter (ID) PVC liners in the bottoms of the wells and partially in the open holes above the liners. The packers will be inflated using compressed nitrogen. The packers will serve to keep the water in the wellbore above and below the Culebra from mixing with the injected tracer. The lower packer will also prevent tracer-laden water, which will be slightly more dense than natural Culebra water, from sinking to the bottom of the hole and providing a potential long-term diffusional source of tracer in the wellbore. The feedthrough assemblies pass tracer-injection, packer-inflation, and pressure transmitter lines into and out of the mandrils of the packers as required.

The injection manifold will distribute the tracer solution, which will flow from the ground surface through a single ⅝-inch stainless steel tube, into four ¼-inch stainless steel tubes that pass into the volume-displacement/injection tool. The body of the volume-displacement/injection tool consists of 5-inch OD pipe sealed at both ends to displace test-interval fluid. The tubes are ported through the 5-inch pipe approximately every 14 inches. The ports have orifices that increase in size with depth to provide for uniform tracer distribution over the entire Culebra.



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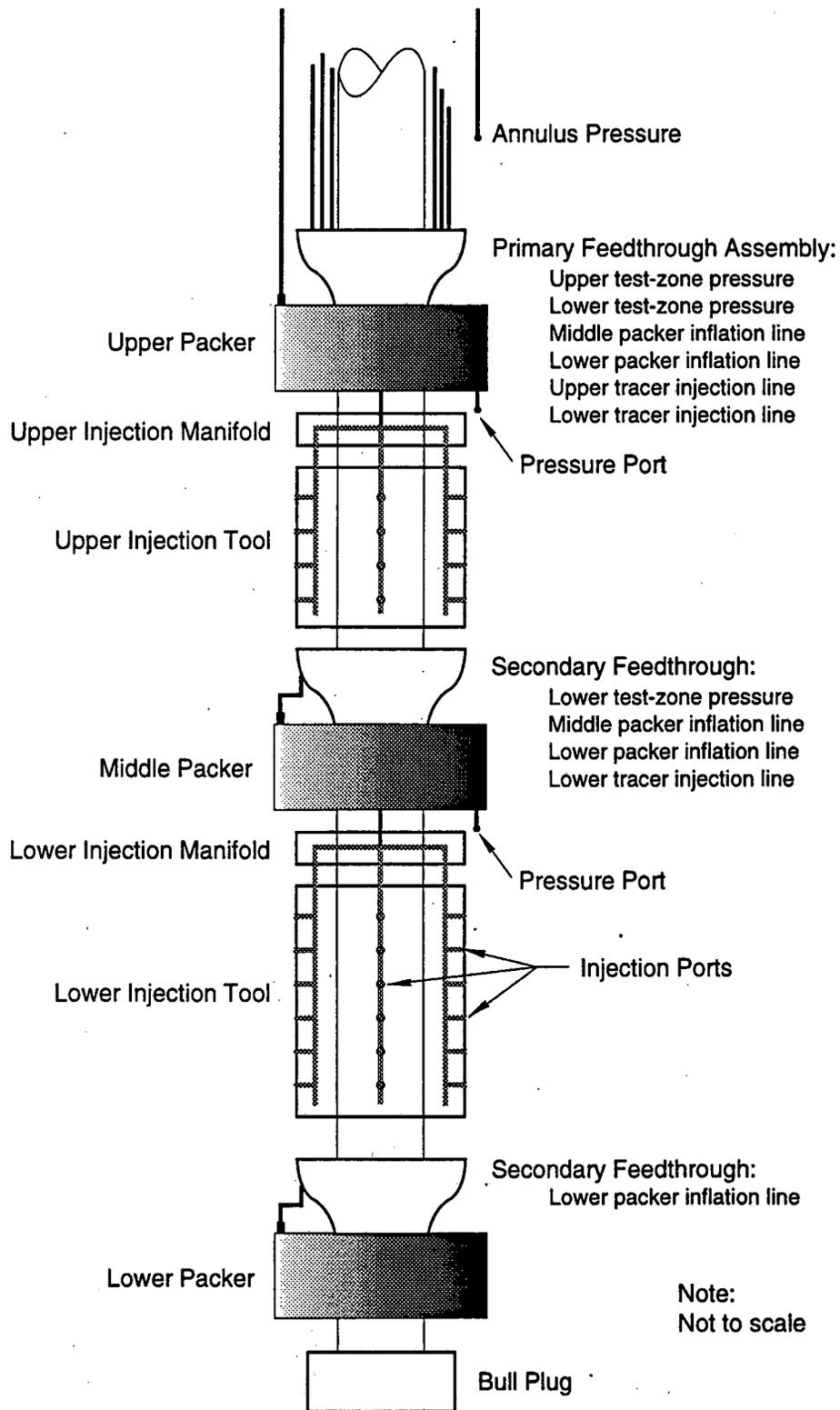
Figure 7-4. Illustration of H-19 two-packer slug-injection assembly.

7.2.1.3 Three-Packer Slug-Injection Assemblies for H-19b3, H-19b5, and H-19b7

The three-packer slug-injection assemblies to be used in H-19b3, H-19b5, and H-19b7 will be similar to the two-packer assemblies, except that they will allow injection of tracers into subsections of the Culebra. Figure 7-5 illustrates the components of a three-packer slug-injection assembly. The middle (5-inch-diameter) packer will be set near the base of the upper, low-transmissivity section of the Culebra, while the upper and lower packers will be set at the same positions as are used for the two-packer tools. Two volume-displacement/injection tools will be positioned between the packers, with separate injection tubes and manifolds for each section. With the middle packer inflated, different tracers can be injected either simultaneously or sequentially into the upper and lower sections of the Culebra. With the middle packer deflated, a single tracer can be injected through both injection tools simultaneously, providing an injection over the entire Culebra similar to that provided by the two-packer assembly. The other elements of the three-packer assemblies will be the same as those used in the two-packer assemblies.

7.2.1.4 Passive-Injection Tool

The passive-injection tool (PIT) consists of a tool string with two packers, a tracer carrier, a circulation pump, two shut-in tools, ion-specific electrodes, a sampling sub, and circulation paths through the tool. The PIT provides a means of introducing tracer(s) into the Culebra without the overpressurization (relative to ambient formation pore pressures) that results from slug injection. Instead of being injected from the surface and forced radially away from the injection well, tracer is conveyed downhole in a carrier built into the PIT itself. After the tool has been installed at the test depth and the packers have been inflated, the shut-in tool near the lower packer is opened and the circulation pump is started. The pump draws water from within the wellbore near the bottom of the tool and circulates it upward through the tool, displacing the tracer solution in the tracer carrier out into the wellbore near the top of the tool. Continued circulation serves to mix the tracer with the wellbore fluid, creating a uniform concentration in the well. Most of the circulated fluid is passed by ion-specific electrodes (Section 7.2.6) that measure the concentrations of iodide and/or fluoride that have been mixed in the tracer solution. Approximately one-sixth of the circulated fluid passes through a sampling sub at the top of the tool containing a port for a Kuster® sampler, which can be used to collect a sample of the circulating fluid at any time. Instead of being spread radially around the injection well, tracer from the PIT moves into the formation only by flow through the wellbore caused by pumping at the production well.



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Figure 7-5. Illustration of H-19 three-packer slug-injection assembly.

A second shut-in tool near the top of the PIT isolates the circulation system from the 2 $\frac{3}{8}$ -inch tubing that is used to lower the PIT to the test depth. By opening this shut-in tool, additional tracer can be injected through the 2 $\frac{3}{8}$ -inch tubing for a slug injection. The upper shut-in tool can then be closed and the circulation pump can be used to mix any tracer remaining in the system with the other wellbore fluid and pass it by the ion-specific electrodes. A schematic drawing of the PIT is shown in Figure 7-6.

7.2.1.5 SWIW Assembly for H-11b1

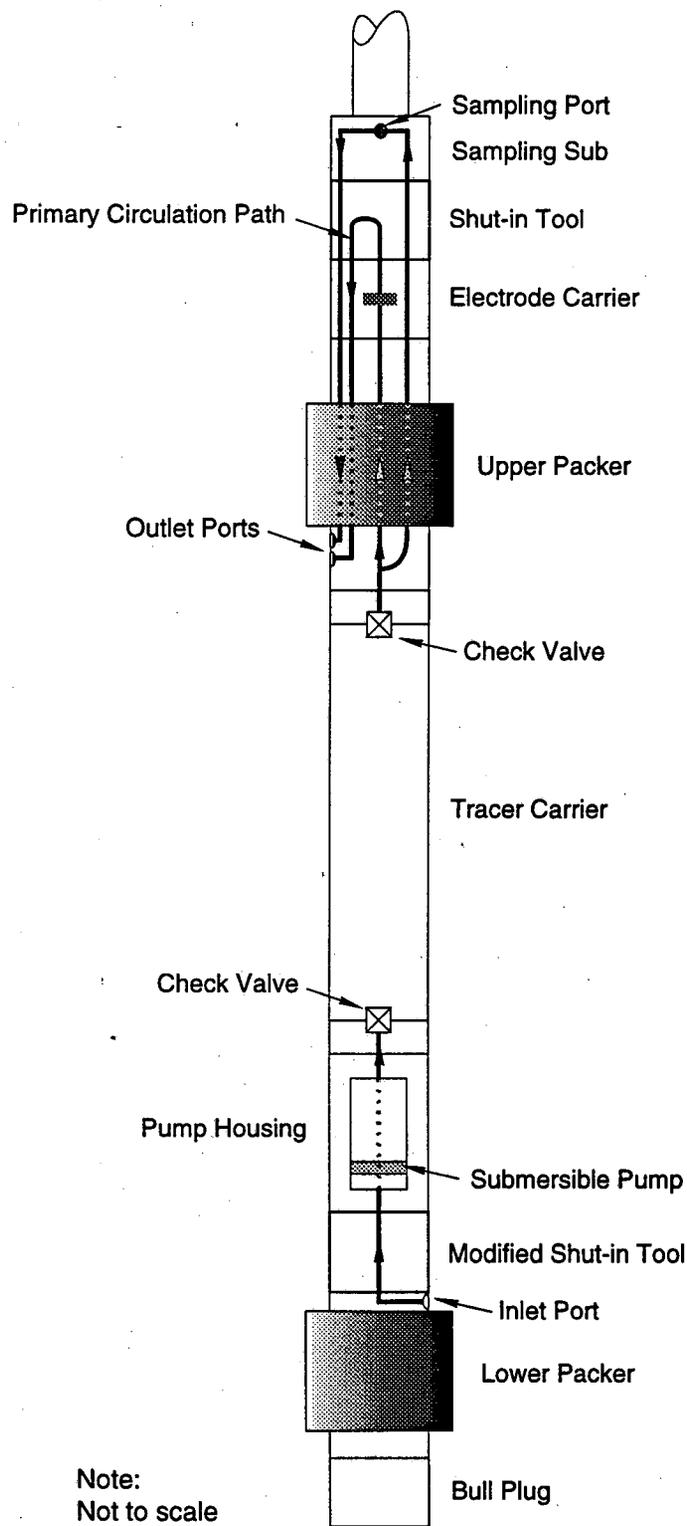
The SWIW assembly to be used in H-11b1 is similar in concept to the one designed for H-19b0 (Section 7.2.1.1), except that it will include only a single packer and will inject tracers over the entire thickness of Culebra. The diameters of the pump shroud, packer, and injection tool will be smaller than for the H-19b0 assembly so that they can pass through the 4.95-inch ID casing in H-11b1. A bridge plug will be set across the contact between the Culebra and unnamed lower member of the Rustler to isolate the Culebra from the lower portion of the well. A schematic illustration of the SWIW assembly for H-11b1 is shown in Figure 7-7.

7.2.1.6 Two-Packer Slug-Injection Assembly for H-11b3

The two-packer slug-injection assembly to be used in H-11b3 will be the same assembly used in the 1988 H-11 tracer test, with a few modifications. The assembly includes an upper packer and an injection column consisting of 3 $\frac{3}{4}$ -inch OD, 1-inch ID tubing approximately 24 ft long with four $\frac{3}{4}$ -inch perforations (injection ports) every two ft. Different sizes of orifices may be attached to the injection ports to improve the vertical distribution of tracer in the well. The shale basket originally at the bottom of the tool will be replaced with a packer to provide better isolation between the Culebra and the lower portion of the well. A schematic illustration of the assembly to be used in H-11b3 is shown in Figure 7-8.

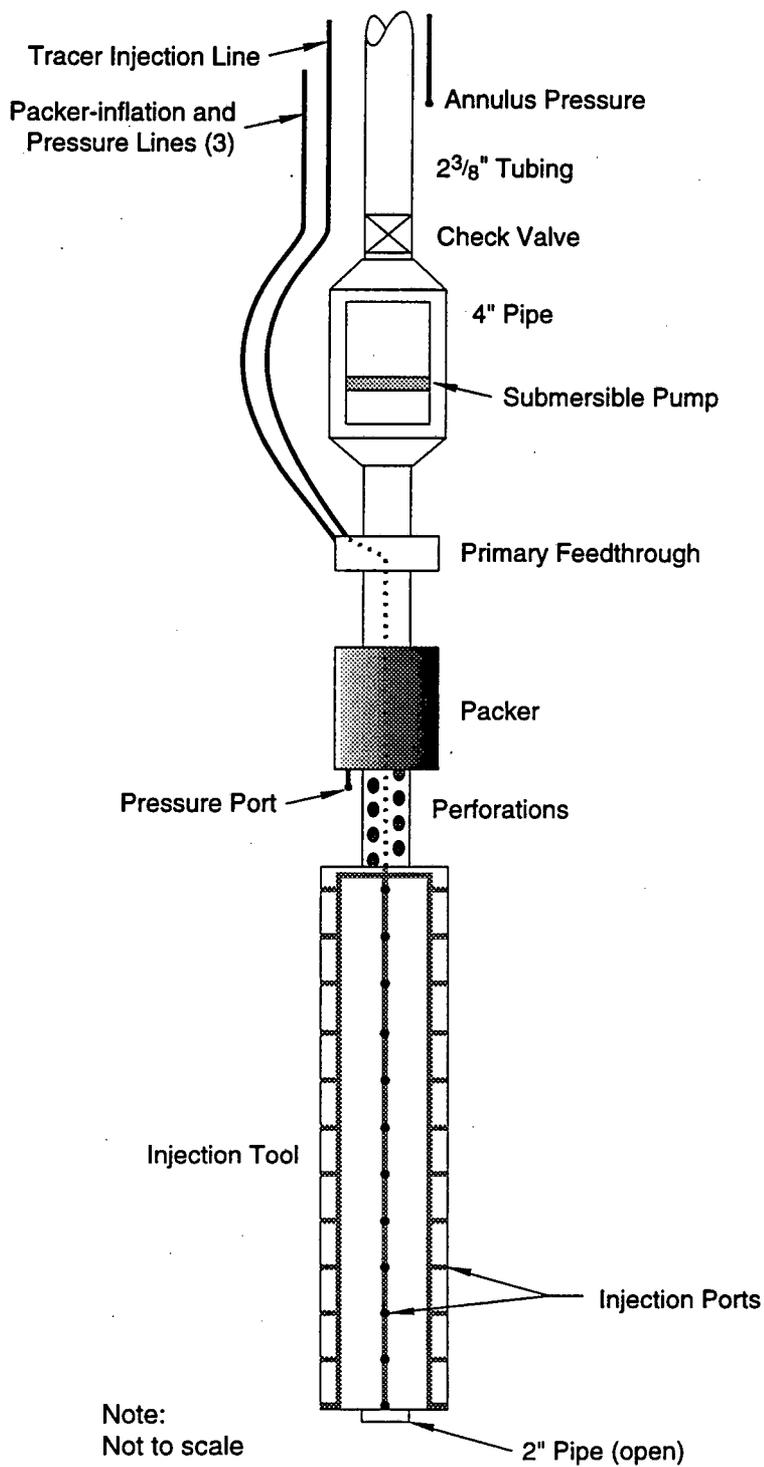
7.2.2 Submersible Pumps

Submersible pumps will be installed in the pumping wells on the H-19 and H-11 hydropads to produce convergent-flow fields between the production and injection wells at the hydropad. A 3-horsepower (hp) Gould pump will likely be used in H-19b0, and a 1 $\frac{1}{2}$ -hp Grundfos pump will likely be used in H-11b1. Both pumps have production capacities of approximately 1 to 10 gpm. Each pump will be installed with an in-line check valve to assure that the discharge tubing column above the pump will be filled with fluid at the start of pumping, thus ensuring immediate



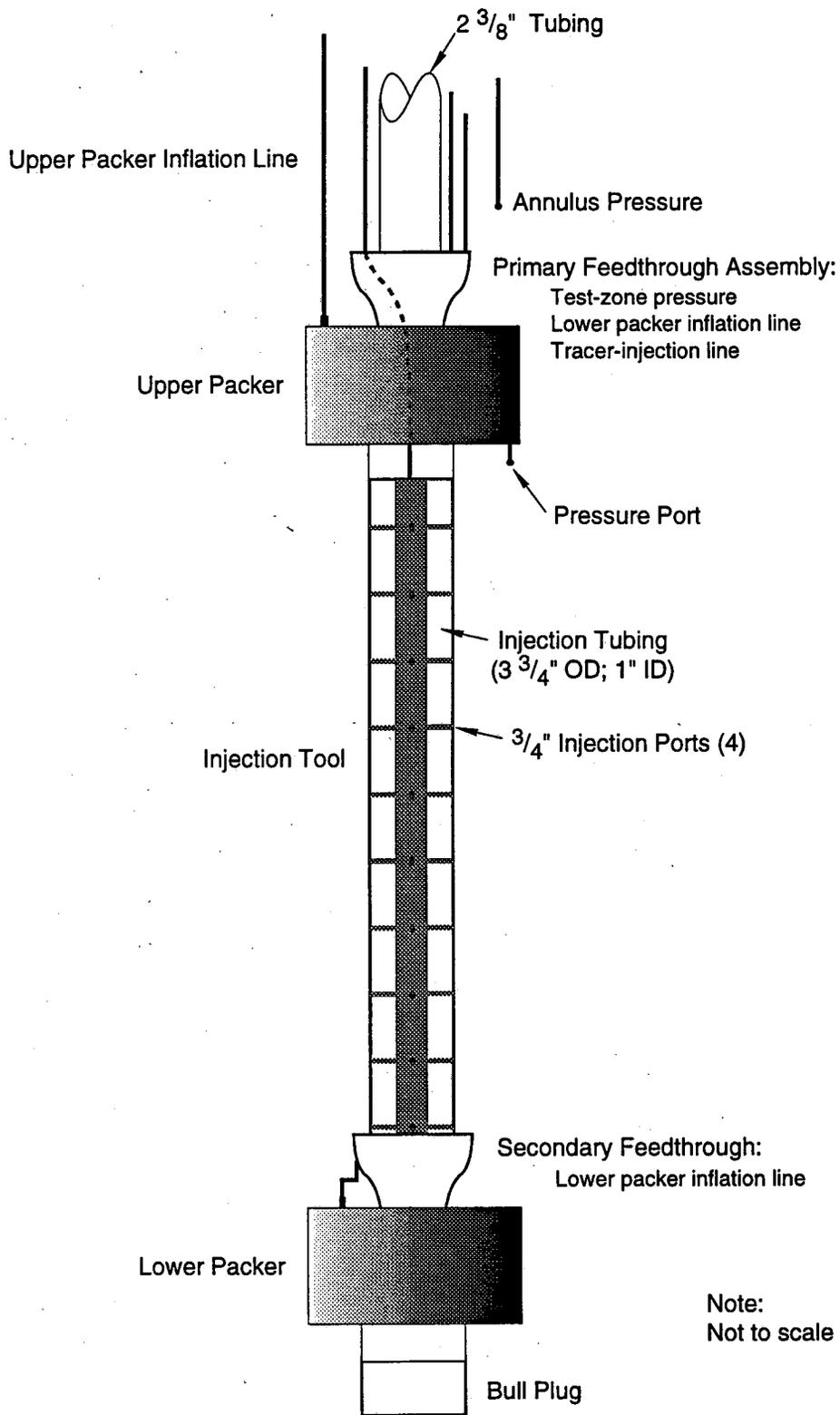
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Figure 7-6. Schematic illustration of passive-injection tool.



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Figure 7-7. Tracer-injection and pumping equipment to be installed in H-11b1.



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Figure 7-8. Illustration of H-11b3 two-packer slug-injection assembly.

flow control and regulation. The configuration of the pump with respect to the tracer-injection assembly for the SWIW test in H-19b0 is shown in Figure 7-3, and that for the test in H-11b1 is shown in Figure 7-7.

7.2.3 Pressure Transmitters

During tracer tests, Druck PTX 161 pressure transmitters will be used in the pumping and tracer-injection wells to monitor changes in pressure in the Culebra test zone(s), in the bottom of each hole below the lowermost packer, and in the annulus between the tracer-injection or production tubing and the well casing above the uppermost packer. The transmitters will be positioned above the top packer in each well, with ¼-inch stainless steel tubing connecting the transmitters to the zones to be monitored. The Druck PTX 161 pressure transmitters have a 0 to 300-psig range of operation. These pressure transmitters will be monitored with the DAS, which will record both the 4- to 20-milliamp output from the gages and the converted data in the desired pressure units.

7.2.4 Downhole Memory Gauges

For certain observation wells in the vicinity of the H-19 and H-11 hydropads, the PI and/or the TTC may choose to utilize In Situ Troll downhole memory gauges to observe the fluid-pressure responses to the pumping for the tracer tests. The gauges consist of a downhole pressure transducer and data-storage device installed at a selected depth in an observation well. The pressure transducer and data-storage device are accessed from land surface by RS-485 or RS-232 cables allowing the accumulated data to be downloaded to a compatible receiver. These battery-operated devices can operate for long periods of time and provide data at any desired frequency consistent with the storage capacity of the unit.

7.2.5 Bridge Plugs

A bridge plug is an inflatable packer that, after inflation, can be disengaged from the 2⅝-inch tubing used to set it at the desired depth. The tubing can be re-engaged when the bridge plug is to be deflated and removed. A bridge plug may be used in H-11b1 to isolate the Culebra from the portion of the unnamed lower member of the Rustler Formation exposed in the borehole.

7.2.6 Ion-Specific Electrodes

Ion-specific electrodes are used in conjunction with the PIT to determine downhole concentrations of iodide and/or fluoride mixed with the tracers. The electrodes provide millivolt output signals that are read by the DAS and can be converted to concentrations of the particular ions. The electrodes used are manufactured by Innovative Sensors, Inc., of Anaheim, CA. The data provided by the ion-specific electrodes will be used only as qualitative indicators of downhole tracer concentrations during use of the PIT. Quantitative tracer-concentration data to be used in test interpretation will be provided by the analysis of samples collected using the Kuster® sampler.

7.3 Tracer Selection/Laboratory Interface

Past tracer tests at the WIPP site have used benzoic acids, fluorinated benzoic acids, thiocyanate, and halomethanes (Hydro Geo Chem, 1985; Stensrud et al., 1990). Fluorinated benzoic acids were also used to trace drilling fluid during the drilling of H-14, H-15, H-17, and H-18 (Stensrud et al., 1987, 1988). The experience gained during these tests and work by Benson and Bowman (1994) suggest that certain fluorinated benzoic acids are well suited for tracer tests because they are conservative, not subject to a high degree of biodegradation, can be analyzed in very low concentrations, and are not found in the natural environment.

Pretest laboratory evaluation of fluorinated and chlorinated benzoic acids, and other fluorinated organic acids, is being performed by the Harry Reid Center (HRC) for Environmental Studies at the University of Nevada, Las Vegas. The HRC has performed or is performing batch tests on 32 compounds using Culebra water from H-3 and H-19 and Culebra core samples from H-3, H-11, H-15, H-16, and H-19 to identify those compounds that will neither degrade nor sorb in the Culebra environment. Laboratory analyses are performed using high-performance liquid chromatography techniques. Table 7-1 lists the compounds found to be suitable as tracers by the HRC that are likely to be used during the H-19 and H-11 tracer tests. If needed, additional tracers will be evaluated and qualified by the HRC. Samples collected during the tracer tests will be shipped to the HRC for analysis of tracer concentrations.

Table 7-1. Potential Tracers for Use in Tracer Testing.

Compound	Abbreviation
Fluorobenzoates	
2,3-Difluorobenzoic acid	2,3-DFBA
2,4-Difluorobenzoic acid	2,4-DFBA
2,5-Difluorobenzoic acid	2,5-DFBA
2,6-Difluorobenzoic acid	2,6-DFBA
3,4-Difluorobenzoic acid	3,4-DFBA
3,5-Difluorobenzoic acid	3,5-DFBA
2,3,4-Trifluorobenzoic acid	2,3,4-TFBA
2,3,6-Trifluorobenzoic acid	2,3,6-TFBA
2,4,5-Trifluorobenzoic acid	2,4,5-TFBA
2,4,6-Trifluorobenzoic acid	2,4,6-TFBA
3,4,5-Trifluorobenzoic acid	3,4,5-TFBA
2,3,4,5-Tetrafluorobenzoic acid	2,3,4,5-TEFBA
2,3,5,6-Tetrafluorobenzoic acid	2,3,5,6-TEFBA
Pentafluorobenzoic acid	PFBA
Chlorobenzoates	
2,3-Dichlorobenzoic acid	2,3-DCBA
2,4-Dichlorobenzoic acid	2,4-DCBA
2,5-Dichlorobenzoic acid	2,5-DCBA
2,6-Dichlorobenzoic acid	2,6-DCBA
3,5-Dichlorobenzoic acid	3,5-DCBA
2,3,5-Trichlorobenzoic acid	2,3,5-TCBA
2,4,6-Trichlorobenzoic acid	2,4,6-TCBA
Fluoromethylbenzoates (Toluates)	
ortho-Trifluoromethylbenzoic acid	o-TFMBA
meta-Trifluoromethylbenzoic acid	m-TFMBA
para-Trifluoromethylbenzoic acid	p-TFMBA
Perfluoroaliphatic acids	
pentafluoropropionic acid	PFPA
heptafluorobutyric acid	HFBA
Other	
tetrafluorophthalic acid	TEFPA

8. TEST REQUIREMENTS/PROCEDURES

8.1 Test Requirements

The tracer-testing program, testing methods, and test equipment are designed to meet the following requirements:

The applied testing procedures should:

1. minimize source-term ambiguity;
2. provide data adequate for differentiation among alternative conceptual models; and
3. provide data adequate for quantification of all important parameters of the conceptual model found to be appropriate.

The test equipment used for the tracer-testing program should:

1. provide data consistent with the objectives of the test(s);
2. perform according to design specifications; and
3. be calibrated, as appropriate, according to the requirements of the SNL QAPD.

8.2 H-19 Test Procedures

The H-19 tracer tests will involve the following activities: a single-well injection-withdrawal tracer test in H-19b0, the pumping for which will produce a converging-flow field on the H-19 hydropad; multiple tracer injections in H-19b2, H-19b3, H-19b4, H-19b5, H-19b6, and H-19b7 using multipacker slug-injection assemblies and/or the passive-injection tool; sampling the discharge from H-19b0 for laboratory analysis of tracer concentrations; and monitoring fluid-pressure and water-level responses during and after pumping at the H-19 hydropad and at other affected observation wells (Figure 6-1). Field operations will be under the direction of the PI. Day-to-day direction of field activities will be provided by the TTC. The TTC, in conjunction with the PI or other Sandia Representative (SR), will direct the field crews and schedule any required subcontractor activity. The field team will perform and record all field measurements and be responsible for permanent records on floppy disks and in scientific notebooks.

The specific procedures and tool configurations used for the H-19 tracer-testing program may vary depending on the conditions encountered and the results of the hydraulic characterization of the Culebra. The tracer testing will be performed in accordance with procedures specified in this Test Plan and with approved TOPs, which are referenced in Section 13.5. Details about the actual implementation of all procedures will be documented in the field scientific notebooks. A step-by-step description of the currently planned testing procedures at the H-19 hydropad is as follows:

1. Monitor water levels at the H-19 hydropad and at nearby observation wells that responded to the preliminary tracer-test pumping. The wells will be monitored either manually using Solinst meters (Section 7.1.5) or remotely using Troll downhole memory gauges (Section 7.2.4). The monitoring schedule will be established in consultation with the PI.
2. Install the SWIW test assembly (Section 7.2.1.1) in H-19b0. Inflate upper and lower packers. Briefly operate the pump to check proper operation of the DAS, flow meters, flow controller, and the discharge tubing. Collect a water sample to establish background concentrations of tracers. Inflate middle packer. Begin monitoring fluid pressures above, below, and between all packers and continue for the duration of testing.
3. Install multipacker slug-injection assemblies in H-19b2, H-19b3, H-19b4, H-19b5, H-19b6, and H-19b7. Inflate packers. Begin monitoring fluid pressures above, below, and between the packers and continue for the duration of testing. (Note: steps 2 and 3 can be performed in either order or concurrently.)
4. Prepare tracer solutions according to recipes provided by the HRC, documenting the exact procedure followed in the field scientific notebook. In general, tracer preparation will involve pH conditioning of an appropriate volume of Culebra water from the H-19 hydropad, dissolving a quantity of tracer chosen to provide the desired injection concentration, and reconditioning the pH of the injectate to near-formation conditions consistent with the solubility requirements of the chosen tracer. Some or all of the following steps will be used to mix tracers:
 - a. Weigh out the desired amount of the tracer to be utilized.
 - b. Prepare a tracer concentrate by mixing the tracer with an equal amount of potassium hydroxide (KOH), or equivalent base, and Culebra water from the H-19 hydropad and/or deionized water or methanol.
 - c. Combine the concentrate with enough H-19 Culebra water to produce the intended tracer-injection solution and store in a clean polyethylene tank at the H-19 hydropad.

- d. Add HCl (or equivalent acid) to modify the tracer-solution pH to be as close to formation pH as is practical.
 - e. Collect and preserve three samples of the tracer injectate and chaser fluid (if any). The samples will be kept in 60-cm³ amberglass bottles with teflon seals in their caps, and kept refrigerated until prepared for shipment to the laboratory. All bottles will be marked with indelible markers and stickers with the well name, date, time, and a sequence number.
5. Inject the tracer(s) and chaser (if any) in the lower isolated interval of the Culebra in H-19b0. The tracer(s) to be injected, the concentrations and volumes of those tracers, and the volume of chaser fluid will be determined and documented in a Memorandum of Record by the PI. Wait overnight or for some other interval specified by the PI.
 6. Deflate the middle packer in H-19b0 and begin pumping at the highest rate sustainable for a two-month period, as determined from evaluation of the well's performance during earlier pumping exercises. The design pumping rate will be selected by the TTC in consultation with the PI.
 7. Begin collecting samples in duplicate of the discharge from H-19b0 in 60-cm³ amberglass bottles. The sampling schedule will be defined and documented in a Memorandum of Record by the PI. Keep samples refrigerated until ready for shipment to the HRC. All bottles will be marked with indelible markers and stickers with the well name, date and time of sample collection, and a sequence number. A log will be kept of all samples collected and copies of the sampling log will be provided to the HRC. Chain-of-custody forms will accompany all samples sent from the field location. Copies of all sample logs and chain-of-custody forms will be made after the completion of the sampling. For approximately the first two weeks after tracer injection, pack samples in ice in a cooler and ship approximately every other day by commercial air-express service to the HRC. After the first two weeks, samples will be shipped to the HRC approximately weekly.
 8. Measure the specific conductance, pH, temperature, and specific gravity of water produced from H-19b0 on a frequency to be determined by the TTC in consultation with the PI.
 9. After the rates of pressure decline in the H-19 wells have stabilized and quasi-steady-state gradients have been created on the hydro pad, probably after approximately seven days of pumping, begin injecting tracers in H-19b2, H-19b3, H-19b4, H-19b5, H-19b6, and H-19b7, followed by chaser fluid. The tracers to be injected in each injection well, the concentrations and volumes of those tracers, the volumes of chaser fluid, and the sequence of injections will be determined and documented in a Memorandum of Record by the PI.
 10. The HRC will provide the PI with analytical results within a day of completing the analysis of each sample, which will allow the PI to determine when the tracer-

breakthrough data from each of the injection wells are adequate for interpretation. After the PI determines that sufficient data have been collected from the fastest of the six transport pathways tested (probably the path from H-19b7 to H-19b0), remove the multipacker slug-injection assembly from the corresponding tracer-injection well. Fill the tracer reservoir in the PIT and install the tool in the vacant well. Inflate packers. Wait overnight or for some other interval specified by the PI.

11. Open the lower shut-in tool on the PIT and turn on the circulation pump in the tool. Monitor downhole tracer concentration with ion-specific electrodes. Collect downhole samples using the Kuster® sampler as directed by the PI.
12. After determining that sufficient data have been collected from other transport pathways involving three-packer slug-injection assemblies, the PI may direct that the inflation status of the middle packer be changed and that one or more additional slug injections of tracer be performed.
13. After the PI determines that sufficient data have been collected from all six of the tested pathways, the pumping rate from H-19b0 will be reduced by 35 to 50 percent. Tool configurations may be altered in the tracer-injection wells at the discretion of the PI. After the rates of pressure decline in the H-19 wells have again stabilized, begin injecting tracers in H-19b2, H-19b3, H-19b4, H-19b5, H-19b6, and H-19b7. The tracers to be injected in each injection well, the concentrations of those tracers, and the sequence of injections will be determined and documented in a Memorandum of Record by the PI.
14. After determining that sufficient data have been collected from any of the transport pathways, the PI may direct that the tool configuration be changed and an additional tracer injection be performed in the corresponding tracer-injection well(s).
15. After determining that sufficient data have been collected from all of the transport pathways, the PI will direct that sampling be terminated and the pump shut off. Continue to monitor fluid pressures in the pumping, injection, and observation wells. The monitoring period will continue until recovery provides sufficient data for analysis as determined by the TTC in consultation with the PI. No packers will be deflated or equipment removed from the wells until directed by the PI.

8.3 H-11 Test Procedures

The H-11 tracer tests will involve the following activities: a single-well injection-withdrawal tracer test in H-11b1, the pumping for which will produce a converging-flow field on the H-11 hydropad; tracer injections in H-11b3 using a multipacker slug-injection assembly and/or the passive-injection tool; sampling the discharge from H-11b1 for laboratory analysis of tracer concentrations; and monitoring fluid-pressure and water-level responses during and after pumping at the H-11 hydropad and at other affected observation wells (Figure 6-2). Field operations will

be under the direction of the PI. Day-to-day direction of field activities will be provided by the TTC. The TTC, in conjunction with the PI or other Sandia Representative (SR), will direct the field crews and schedule any required subcontractor activity. The field team will perform and record all field measurements and be responsible for permanent records on floppy disks and in scientific notebooks. The tracer testing will be performed in accordance with procedures specified in this Test Plan and with approved TOPs, which are referenced in Section 13.5. Details about the actual implementation of all procedures will be documented in the field scientific notebooks. A step-by-step description of the currently planned testing procedures at the H-11 hydropad is as follows:

1. Monitor water levels at the H-11 hydropad and at nearby observation wells that responded to pumping at H-11 during the 1988 tracer test. The wells will be monitored either manually using Solinst meters (Section 7.1.5) or remotely using Troll downhole memory gauges (Section 7.2.4). The monitoring schedule will be established in consultation with the PI.
2. Install the SWIW test assembly (Section 7.2.1.5) in H-11b1. Inflate upper and lower packers. Briefly operate the pump to check proper operation of the DAS, flow meters, flow controller, and the discharge tubing. Collect a water sample to establish background concentrations of tracers. Begin monitoring fluid pressures above, below, and between packers and continue for the duration of testing.
3. Install two-packer slug-injection assembly (Section 7.2.1.6) in H-11b3. Inflate packers. Begin monitoring fluid pressures above, below, and between the packers and continue for the duration of testing. (Note: steps 2 and 3 can be performed in either order or concurrently.)
4. Prepare tracer solutions according to recipes provided by the HRC, documenting the exact procedure followed in the field scientific notebook. In general, tracer preparation will involve pH conditioning of an appropriate volume of Culebra water from the H-11 hydropad, dissolving a quantity of tracer chosen to provide the desired injection concentration, and reconditioning the pH of the injectate to near-formation conditions consistent with the solubility requirements of the chosen tracer. Some or all of the following steps will be used to mix tracers:
 - a. Weigh out the desired amount of the tracer to be utilized.
 - b. Prepare a tracer concentrate by mixing the tracer with an equal amount of potassium hydroxide (KOH), or equivalent base, and Culebra water from the H-11 hydropad and/or deionized water or methanol.

- c. Combine the concentrate with enough H-11 Culebra water to produce the intended tracer-injection solution and store in a clean polyethylene tank at the H-11 hydropad.
 - d. Add HCl (or equivalent acid) to modify the tracer-solution pH to be as close to formation pH as is practical.
 - e. Collect and preserve three samples of the tracer injectate and chaser fluid (if any). The samples will be kept in 60-cm³ amberglass bottles with teflon seals in their caps, and kept refrigerated until prepared for shipment to the laboratory. All bottles will be marked with indelible markers and stickers with the well name, date, time, and a sequence number.
5. Inject the tracers and chaser in the isolated Culebra in H-11b1. The tracers to be injected, the concentrations and volumes of those tracers, and the volume of chaser fluid will be determined and documented in a Memorandum of Record by the PI. Wait overnight or for some other interval specified by the PI.
 6. Begin pumping at three to four gpm, or some other rate selected by the PI.
 7. Begin collecting samples in duplicate of the discharge from H-11b1 in 60-cm³ amberglass bottles. The sampling schedule will be defined and documented in a Memorandum of Record by the PI. Keep samples refrigerated until ready for shipment to the HRC. All bottles will be marked with indelible markers and stickers with the well name, date and time of sample collection, and a sequence number. A log will be kept of all samples collected and copies of the sampling log will be provided to the HRC. Chain-of-custody forms will accompany all samples sent from the field location. Copies of all sample logs and chain-of-custody forms will be made after the completion of the sampling. For approximately the first two weeks after tracer injection, pack samples in ice in a cooler and ship approximately every other day by commercial air-express service to the HRC. After the first two weeks, samples will be shipped to the HRC approximately weekly.
 8. Measure the specific conductance, pH, temperature, and specific gravity of water produced from H-11b1 on a frequency to be determined by the TTC in consultation with the PI.
 9. After the rates of pressure decline in the H-11 wells have stabilized and quasi-steady-state gradients have been created on the hydropad, probably after approximately seven days of pumping, begin injecting tracers in H-11b3 followed by chaser fluid. The tracers to be injected, the concentrations and volumes of those tracers, and the volume of chaser fluid will be determined and documented in a Memorandum of Record by the PI.
 10. The HRC will provide the PI with analytical results within a day of completing the analysis of each sample, which will allow the PI to determine when the tracer-

breakthrough data are adequate for interpretation. After the PI determines that sufficient data have been collected for interpretation, the PI may direct that the tool configuration and/or pumping rate be changed and an additional tracer injection be performed in H-11b3.

11. After determining that sufficient data have been collected, the PI will direct that sampling be terminated and the pump shut off. Continue to monitor fluid pressures in the pumping, injection, and observation wells. The monitoring period will continue until recovery provides sufficient data for analysis as determined by the TTC in consultation with the PI. No packers will be deflated or equipment removed from the wells until directed by the PI.

8.4 Modifications of Test Procedures

Test procedures may be modified at any time as directed by the PI or TTC. Modifications and the rationales for the modifications will be documented by the PI or TTC in the scientific notebook as they occur as part of the QA data package.

9. DATA-ACQUISITION PLAN

Both manually and electronically collected data will be acquired during the tracer-testing program at the H-19 and H-11 hydropads. The following types of data will be recorded:

- electronically collected downhole pressure data from isolated and/or tested intervals;
- electronically and/or manually collected pumping rate and volume data from wells being pumped;
- electronically collected barometric-pressure data;
- manually collected water-level data;
- manually collected water-quality data concerning the temperature, pH, specific gravity, and electrolytic conductivity of fluid produced during pumping; and
- manually collected data on equipment and instrument configurations in the wells and at the surface.

9.1 Data-Acquisition System

Electronic data acquisition will be performed using the SNL PERM DAS described in Section 7.1.1.1 and shown schematically in Figure 7-1. The PERM DAS will be operated according to TOP 509. During the early time of any test event (test sequence, rate change, etc.), the test operator will run the DAS at the fastest possible data-acquisition rate to control the test. The data will be displayed in text form and graphically to allow real-time estimates of the performance of the test equipment and the formation response. File management systems will be noted in the field scientific notebook and documented in the QA data package for these tests.

9.2 Manual Data Acquisition

Manual data collection will be carried out either using forms designed specifically for each activity or data type or by recording relevant information in the TTC's field scientific notebook (see Section 13.8). The forms to be used are contained in WIPP procedures that have been prepared for different data-collection activities, including those TOPs referenced in Section 13.5. Copies of all relevant procedures will be kept on file in the field trailer.

Some of the information required on forms specified in WIPP procedures will be documented in data files during operation of the DAS or in the field scientific notebooks. Therefore, to minimize transcription errors, use of the forms specified in the TOPs is not mandatory. The TTC will ensure that all information recorded on forms will be documented as part of the QA data package.

When data forms are utilized, specific QA approval of each form is not required. Note that generator data recorded on Form 146, as specified in TOP 510, do not affect the quality of the test data. Therefore, documentation of this information is recommended but not mandatory.

9.3 Data Backup

Data will be copied no less frequently than weekly and the copies will be stored at a WIPP-site location off the H-19 and H-11 hydropads. In the case of data files collected by the DAS, multiple final backup copies will be made when the data files are closed. Interim backup copies will be destroyed at that time. Similarly, final backup copies of data forms will be made when the forms are completely filled (or the data-collection activity is completed), and interim copies will then be destroyed. The carbon sheets in the field scientific notebooks will be removed following resolution of a notebook-completeness review that will be performed by the TTC or his designee no less frequently than twice a month. Final copies of the affected pages of the notebooks will be made at that time, and interim copies will be destroyed.

9.4 On-Site Data Evaluation

During the H-19 and H-11 tracer-testing program, the TTC will monitor the hydraulic-response data as they are acquired. The data will be diagnosed for any tool failure and/or test-procedure-induced effect that may affect the quality of either the tracer-breakthrough or hydraulic-response data. The TTC will take immediate action (if so required) to make any necessary changes to the test-equipment configuration or the test procedures to assure the data quality is consistent with the test objectives.

The TTC will use real-time evaluation of the acquired data during any given test to assure that all systems are operating in accordance with their specifications and that the fluid-pressure data are usable for hydraulic interpretation. For example:

- The TTC may use specialized plots to interpret the formation response and ensure that the formation is responding in a manner consistent with the responses observed during the hydraulic-testing program.
- The TTC may use real-time analysis of the acquired data to evaluate the hydraulic responses at the hydropad.
- The TTC may use real-time analysis to determine whether or not a test or test sequence must be terminated earlier than planned, and to develop a revised testing schedule as appropriate. For example, a specific pumping rate that was intended to be held constant for a particular duration might have to be decreased if analysis showed that the well could not sustain that rate for the desired duration.

10. DATA-QUALITY OBJECTIVES

Most of the test objectives outlined in Section 5 will be met by interpreting the tracer-recovery and breakthrough curves, which will be generated with the analysis results provided by the HRC. The HRC performs all analyses under a Sandia QA-approved Quality Assurance Plan. The requirements of that QA Plan are not discussed herein because the HRC analyses provide only qualitative guidance to the field activities that are the subject of this Test Plan. Flow-rate and perhaps pressure data also play a role in tracer-test interpretation, however, and both are critical in interpreting the hydraulic responses that will be observed during the tracer testing. Accordingly, data-quality objectives (DQOs) have been established for the instruments that will be used in the field to provide quantitative information that will be used in test interpretation. Those DQOs are listed in Table 10-1.

Table 10-1. Data-quality objectives for instrumentation used in tracer and/or hydraulic tests.

Objective	Flow Meter	Barometer	Water-Level Sonder	Pressure Transmitter/ Transducer
Range	0.2-20 gpm	10-15 psia	0-500 ft	0-200 psig
Accuracy	±0.1 gpm	±0.5 psi	±1 ft	±2 psi
Precision	±0.05 gpm	±0.1 psi	±0.1 ft	±0.5 psi

11. DESIGN ANALYSIS

The design of the H-19 and H-11 tracer-testing program is reviewed as this Test Plan is reviewed. There is no need for additional review. The equipment and materials to be used in the H-19 and H-11 tracer-testing program, with the exception of the tracer-injection assemblies, have all been used previously either as part of the WIPP site hydrogeologic-characterization program or during the preliminary hydraulic and tracer testing at the H-19 hydropad. The tracer-injection assemblies to be used are modified versions of assemblies used either in the preliminary H-19 tracer testing or the 1988 H-11 tracer testing.

12. PROVISIONS FOR SIGNIFICANT EVENTS

Any event occurring during the operations and activities performed under this Test Plan that may affect the quality and interpretation of the test data is deemed significant and must be documented in the field scientific notebook. This includes both unanticipated events, such as power failures, and events that are anticipated but for which the appropriate action cannot be predetermined, such as the magnitude of a change in pumping rate. The TTC will inform the PI of any significant events that occur. Significant events include, but are not limited to:

- interruptions in the power supplied by electric generators;
- failure of testing or support/ancillary equipment;
- discovery of *in situ* conditions that preclude the conduct of tests as designed;
- changes in the planned sequence of testing events;
- changes in testing parameters, such as pumping rates, that were previously programmed or specified;
- changes to the original program of technical tasks, such as added or deleted tracer injections, tool replacements, or water-quality sampling;
- unanticipated or unusual test results; and
- actions taken by the TTC to deal with any of the above.

13. QUALITY ASSURANCE

13.1 Hierarchy of Documents

Several types of documents are used to control work performed under this Test Plan. If inconsistencies or conflicts exist among the requirements specified in these documents, the following hierarchy shall apply:

1. Memoranda or other written instructions used to modify or clarify the requirements of the Test Plan (most recent instructions having precedence over previous instructions);
2. Test Plan: Tracer Testing of the Culebra Dolomite Member of the Rustler Formation at the H-19 and H-11 Hydropads on the WIPP Site;
3. SNL WIPP Quality Assurance Procedures (see Section 13.4); and
4. Technical Operating Procedures (see Section 13.5).

SNL QA written concurrence will be obtained for deviations from Quality Assurance Procedures applicable to work conducted under this Test Plan.

13.2 Quality-Affecting Activities

Activities performed under this Test Plan are quality-affecting activities with the following exceptions:

- water-quality measurements as specified in TOP 513 (see Section 7.1.6);
- operation of diesel-powered generators (see Section 7.1.7);
- assistance provided by the manufacturer/contractor for the installation of tools and testing equipment;
- support services for tasks which do not involve data collections, such as roustabouts, pulling rigs, machining, welding, fishing services, fuel, earth moving, etc.; and
- water collection and disposal (see Section 3.2).

Activities that are not quality-affecting are not subject to the requirements of the SNL QA program.

13.3 Quality Assurance Program Description

The SNL WIPP Quality Assurance Program Description (QAPD), Rev. R, is currently in effect and has been approved by the DOE Carlsbad Area Office (CAO) for all WIPP activities assigned to SNL. The requirements and guidance specified in the QAPD are based on criteria contained in 10 CFR 830, American Society of Mechanical Engineers (ASME) NQA-1-1989 Edition (ASME, 1989a), ASME NQA-2a-1990 addenda (Part 2.7) to ASME NQA-2-1989 Edition (ASME, 1989b), ASME NQA-3-1989 Edition (excluding Basic Requirements Section 2.1 (b) and (c)) (ASME, 1989c), DOE Order 5700.6C, and 40 CFR 191. The requirements of the SNL WIPP QAPD, and any revisions thereto, are passed down and implemented through the SNL WIPP Quality Assurance Procedures.

13.4 Quality Assurance Procedures

Quality Assurance Procedures (QAPs) will be implemented in a graded manner as appropriate for the work performed under this Test Plan. The PI will be responsible for identifying and documenting the specific QA requirements that apply to this Test Plan. The SNL QA Chief (or designee) will approve the graded implementation of QA requirements prior to the beginning of data-collection activities.

13.5 WIPP Technical Operating Procedures

The WIPP Technical Operating Procedures (TOPs) that may apply to work performed under this Test Plan include:

TOP 263: Sample Tracking System

TOP 277: Engineering Sketch Control

TOP 472: Intensifier Pump: Operation and Use

TOP 505: Pumping Tests

TOP 507: Installation System Verification During Gage Connection to HP-3497A Stand-Alone Data-Acquisition Systems

TOP 508: Installation of Pressure Transducers, Flow Meters, and Thermocouple Gauge Checkout

TOP 509: Operation of PERM DAS Program

TOP 510: Manual Start of Remote Diesel Generators

TOP 512: Depth-to-Water Measurement Using Solinst Brand Electric Sounder

TOP 513: Water Quality Data: Measurements of Specific Gravity, Conductance, pH, and Temperature

TOP 514: Verification of Totalizing Flow Meter Measurements Using a Verified Standpipe

Modification to these procedures may be required during testing. Such modifications are not deviations and will not be reported as nonconformances that require corrective action. However, modifications will be documented by the TTC in the scientific notebook as they occur as part of the QA records.

13.6 Data Integrity

Care will be taken throughout the performance of the operations for this Test Plan to ensure the integrity of all data collected including documentation on hard copy and data collected on magnetic media. Duplicate copies of all data will be produced no less frequently than weekly (Section 9.3) and the duplicate copies will be maintained at separate locations to ensure that data are not lost. Data collected during testing activities shall not be released unless and until the data are reviewed and approved by the PI.

13.7 Instrument Calibration

All quality-affecting work performed by or for SNL as part of this Test Plan will be done with calibrated instruments and equipment. Measurements of specific gravity, electrical conductance, pH, and temperature as specified in TOP 513 are qualitative in nature and are used only to indicate relative changes in the quality of the fluid produced from the wells. Instruments used for electrical conductance and pH measurements should meet the data-quality objectives defined by the manufacturers specifications, but do not require calibrations traceable to NIST or other nationally recognized standards. Hydrometers and thermometers used to perform specific-gravity and temperature measurements must be certified by the manufacturer as meeting the manufacturer's specifications.

Flow meters must be certified by the manufacturer as meeting the manufacturer's specifications. The operation of flow meters will be checked in the field prior to use as directed by the TTC. Such operational checks will be documented in the scientific notebook by the TTC as part of the QA records.

Memory gauges used in measuring fluid-pressure changes in observation wells must be certified by the manufacturer as meeting the manufacturer's specifications. The operation of memory gauges will be checked in the field prior to use as directed by the TTC. Such operational checks will be documented by the TTC in the scientific notebook as part of the QA records.

If the accuracy and/or precision of data obtained from hydrometers, thermometers, flow meters, or memory gauges becomes questionable, post-test calibrations or other appropriate methods of verifying the manufacturer's certifications will be performed and documented in the scientific notebook.

13.8 Records

Records shall be maintained as described in this Test Plan and applicable QA implementing procedures. QA records may consist of bound scientific notebooks, loose-leaf pages, forms, printouts, or information stored on electronic media. The TTC will ensure that the required records are maintained. Other records that are not quality affecting may also be maintained.

13.8.1 Required QA Records

As a minimum, the documentation of QA records will include:

- times, dates, and intervals of all tests;
- persons performing tests;
- test procedures used;
- lists, including model and serial numbers where appropriate, of all equipment used in the tests;
- equipment-specification sheets or information;

- calibration records for all controlled equipment;
- tubing tallies and other information used to establish test depths;
- sketches of equipment configurations, showing measured dimensions;
- photographs taken of the equipment and activities;
- a log of photographs taken of the equipment and activities;
- descriptions of activities performed;
- rationales for decisions concerning test intervals, durations, modifications to procedures, or other factors;
- manually collected data;
- data files collected by the DAS;
- a log of data files collected by the DAS;
- documentation of tracer-concentrate and tracer-injectate preparation;
- a log of samples collected;
- chain-of-custody forms for sample shipments; and
- other information pertinent to the testing.

13.8.2 Miscellaneous Non-QA Records

Additional records that are useful in documenting the history of the testing activities but are considered non-QA records may be maintained and submitted to the SWCF. These records include:

- as-built diagrams of equipment supplied by contractors;
- pulling-rig and other equipment certifications;
- water-quality measurements;
- ion-specific electrode measurements;
- information related to operation of diesel generators;

- equipment manifests; and
- cost and billing information regarding contracted services.

These records do not support Performance Assessment or regulatory compliance and, therefore, are not quality-affecting information.

13.8.3 Submittal of Records

Records resulting from work conducted under this Test Plan, including forms and data stored on electronic media, will not be submitted to the SNL Quality Assurance Department for review and approval as specified in the WIPP procedures. Instead, the records will be assembled into a records package(s) which will be reviewed by the PI and submitted to the SWCF.

14. HEALTH AND SAFETY

SNL field operations will be conducted on land controlled by the WID and the field operations team assembled for this Test Plan will follow all WID safety practices and policies. Operational safety for individual field operations will be addressed through ES&H Preliminary Hazard Assessments (PHAs) and Safe Operating Procedures (SOPs) developed by SNL. Project-specific WIPP-site safety procedures will be approved through the PI, WID safety personnel, and the SNL WIPP-site Safety Advisor. ES&H SOPs applicable to the testing program include those relating to identification of potential hazards, emergency-shutdown procedures, and personnel to be contacted in case of emergencies.

14.1 Safety Requirements

All equipment will be operated in accordance with the appropriate allowable operating pressures and in accordance with the SNL ES&H pressure-safety manual. Pressure ratings for individual parts such as valves and pressure tubing will be either marked by the manufacturer with the maximum allowable operating pressure or such information will be made available in written documentation according to guidelines of the SNL Center 6700 Safety Representative for WIPP-Site Operations.

Additional safety requirements to be observed by field personnel are:

1. appropriate use of safety shoes, safety glasses, hard hats, and protective gloves;
2. ensuring adequate fuel is available for all field vehicles, especially those traveling to remote locations;
3. proper installation and safety procedures when handling electrical submersible pumps and other electrical equipment;
4. proper procedures for operation of diesel-powered generators for on-site electric power;
5. observation of scheduled working hours and driving time;
6. familiarity with on- and off-site road conditions and driving regulations;
7. familiarity with the locations of First Aid supplies, medical support facilities, and fire extinguishers and other safety equipment;

8. familiarity with the location of lists of emergency telephone numbers and persons and offices to notify in the event of emergencies;
9. familiarity with the location of posted crew schedules;
10. safe handling of tracers and pH conditioning agents;
11. use of respirators in tracer preparation; and
12. familiarity with the location of all MSDS information.

All field personnel assigned to the field operations described in this Test Plan will receive a safety briefing before the beginning of field operations. In addition, the field-site or shift supervisor will conduct daily safety meetings at the beginning of daily operations or at the beginning of each shift. All personnel receiving safety briefings are required to sign and date the safety-briefing form as part of safety-documentation procedures. All work locations will maintain a mobile communication system. In case of accident, injury, or sudden illness, the WIPP Central Monitoring Room (CMR) will be notified immediately. The CMR will coordinate emergency response activities.

14.2 Special Training

All SNL and WIPP-site contractor personnel must receive WIPP-site General Employee Training (GET) followed by annual refreshers as part of employment requirements at WIPP. No other special training requirements are anticipated in addition to the GET and the safety briefings described in Section 14.1.

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