Project Plan: Deep Borehole Field Test

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Used Fuel Disposition

Prepared by
Sandia National Laboratories

September 2014

FCRD-UFD-2014-000592, Rev. 0
SAND2014-18559R

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

FCT DOCUMENT COVER SHEET [1]

Name/Title of Deliverable/ Milestone/Revision No.	Project Execution Plan, M4FT-14SN0817031
Work Package Title and Number	Deep Borehole Experimental Test Support, FT-14SN081703
Work Package WBS Number	1.02.08.17
Responsible Work Package Manager	Geoff Freeze (Name/Signature)
Date Submitted	

Quality Rigor Level for Deliverable/Milestone[2]	☐ QRL-3	☐ QRL-2	☐ QRL-1 Nuclear Data	☒ Lab/Participant QA Program (no additional FCT QA requirements)

This deliverable was prepared in accordance with Sandia National Laboratories
(Participant/National Laboratory Name)

QA program which meets the requirements of

☒ DOE Order 414.1 ☐ NQA-1-2000 ☐ Other

This Deliverable was subjected to:

☐ Technical Review ☐ Peer Review

Technical Review (TR)
Review Documentation Provided

☐ Signed TR Report or,
☐ Signed TR Concurrence Sheet or,
☐ Signature of TR Reviewer(s) below

Peer Review (PR)
Review Documentation Provided

☐ Signed PR Report or,
☐ Signed PR Concurrence Sheet or,
☐ Signature of PR Reviewer(s) below

Name and Signature of Reviewers

NOTE 1: *FCT Document Cover Sheet should be filled out and submitted with the deliverable. Or, if the PICS:NE system permits, completely enter all applicable information in the PICS:NE Deliverable Form. The requirement is to ensure that all applicable information is entered either in the PICS:NE system or by using the FCT Document Cover Sheet.*

NOTE 2: *In some cases there may be a milestone where an item is being fabricated, maintenance is being performed on a facility, or a document is being issued through a formal document control process where it specifically calls out a formal review of the document. In these cases, documentation (e.g., inspection report, maintenance request, work planning package documentation or the documented review of the issued document through the document control process) of the completion of the activity, along with the Document Cover Sheet, is sufficient to demonstrate achieving the milestone. If QRL 1, 2, or 3 is not assigned, then the Lab / Participant QA Program (no additional FCT QA requirements) box must be checked, and the work is understood to be performed and any deliverable developed in conformance with the respective National Laboratory / Participant, DOE or NNSA-approved QA Program.*

REVISION HISTORY

Rev.	Date	Reason
0	07/31/14	Initial draft
0	09/30/14	Final

CONTENTS

FIGURES

TABLES

ACRONYMS

API	American Petroleum Institute
BCP	Baseline Change Proposal
BRC	Blue Ribbon Commission on America's Nuclear Future
CAA	Clean Air Act
CR	continuing resolution
CWA	Clean Water Act
DOE	U.S. Department of Energy
DOE-ID	DOE Idaho Operations Office
DOE-NE	DOE Office of Nuclear Energy
EA	Environmental Assessment
EIS	Environmental Impact Statement
ES&H	Environment, Safety, and Health
EVMS	earned value management system
FCT	DOE-NE Fuel Cycle Technologies Program
FY	fiscal year
HLW	high-level radioactive waste
NEPA	National Environmental Policy Act
NTD	National Technical Director
PA	performance assessment
PICS:NE	Project Information Collection System : Nuclear Energy
QA	quality assurance
R&D	research and development
RD&D	research, development, and demonstration
RFI	request for information
RFP	request for proposal
SFO	Sandia Field Office
SNF	spent nuclear fuel
SNL	Sandia National Laboratories
UFD	DOE-NE Office of Used Nuclear Fuel Disposition Research and Development
WBS	work breakdown structure
WIPP	Waste Isolation Pilot Plant

1. INTRODUCTION

1.1 Project Background

Deep borehole disposal of spent nuclear fuel (SNF) and high-level radioactive waste (HLW) has been given consideration for geological isolation for many years, including original evaluations of nuclear waste disposal options by the U.S. National Academy of Sciences in 1957 (NAS 1957). Efforts by the United States and the international community over the last half-century toward disposal of SNF and HLW (collectively referred to as high-activity waste) have primarily focused on mined geological repositories. Nonetheless, evaluations of deep borehole disposal have periodically continued in several countries (Arnold et al. 2013, Section 1.1). In recent years, an updated conceptual evaluation of deep borehole disposal of SNF and a preliminary performance assessment was completed (Brady et al. 2009), a reference design and operations were developed for deep borehole disposal of SNF using available drilling technology (Arnold et al. 2011), and site characterization methods were analyzed using basic performance assessment methodology (Vaughn et al. 2012). These studies identified no fundamental flaws regarding safety or implementation of the deep borehole disposal concept.

As a result, a research, development, and demonstration (RD&D) roadmap was developed for deep borehole disposal (Arnold et al. 2012) that emphasized a full-scale Deep Borehole Field Test around which research and development (R&D) activities would be organized. Further technical and logistical guidelines to advance the technical basis for the siting and implementation of the Deep Borehole Field Test were developed by Arnold et al. (2013) and Arnold et al. (2014).

The deep borehole disposal concept is straightforward and consists of drilling a borehole into crystalline basement rock to a depth of about 5,000 m, emplacing waste canisters in the lower part of the borehole, and sealing the upper part of the borehole with bentonite and concrete seals. A reference design of the disposal system (Arnold et al. 2011, Section 1.1; Arnold et al. 2012, Section 1.2) includes emplacement of 400 waste canisters in the lower 2,000 m of the borehole, seals and plugs in the uncased borehole for 1,500 m above the disposal zone, and standard borehole plugging in the cased upper 1,500 m of the borehole.

Factors suggesting that the deep borehole disposal concept is viable and safe have been summarized previously in Brady et al. (2009) and Arnold et al. (2011) and include: the great depth of burial (several times deeper than for typical mined repositories), the isolation provided by the deep natural geological environment, and the integrity of the borehole seals. In contrast, mined geological repositories, with the possible exception of those located in extensive salt or argillaceous formations, rely on engineered systems, such as waste canisters and/or buffer material, to a greater degree.

The U.S. Department of Energy (DOE), Office of Nuclear Energy (NE) is currently investigating deep borehole disposal as one alternative for the disposal of high-activity waste, along with R&D for mined repositories in salt, granite, and clay, as part of the Fuel Cycle Technologies (FCT) Program, Office of Used Nuclear Fuel Disposition (UFD) R&D. The deep borehole disposal R&D is consistent with a recent recommendation from the Blue Ribbon Commission on America's Nuclear Future (BRC 2012, p. 30) for "further RD&D to help resolve some of the current uncertainties about deep borehole disposal and to allow for a more comprehensive (and conclusive) evaluation of the potential practicality of licensing and deploying this approach, particularly as a disposal alternative for certain forms of waste that have essentially no potential for re-use."

1.2 Project Description

The full-scale Deep Borehole Field Test (DBFT) is designed to develop the logistics and advance the technical basis for the siting and implementation of a deep borehole disposal facility. The DBFT will be used to validate proof of concept, but will not involve the disposal of actual waste. The DBFT has three purposes: evaluation of the capability for drilling and construction of deep, large-diameter boreholes; downhole scientific analyses to assess hydrogeochemical conditions that control waste stability and containment; and engineering analysis to assess the viability and safety of deep borehole canister emplacement.

The DBFT consists of drilling two 4-5 km deep boreholes into crystalline basement rock in a geologically stable continental location. First, a Characterization Borehole with approximately an 8.5-in (0.216 m) bottom-hole diameter will be drilled and completed to facilitate downhole scientific testing (e.g., examination of hydrogeologic, geochemical, and geomechanical characteristics of the near-borehole host rock). The scientific testing and analysis activities will identify the critical downhole measurements that must be made to determine if conditions favorable to long-term isolation of high-activity waste exist at depth. Second, a Field Test Borehole with approximately a 17-in (0.432 m) bottom-hole diameter will be drilled and completed to facilitate proof-of-concept of engineering activities using surrogate waste canisters. The engineering analysis will evaluate the feasibility of canister emplacement operations by determining performance envelopes for drilling, canister handling, and canister retrieval during emplacement. In addition, borehole sealing materials and designs will be examined through above-ground testing.

Specific DBFT activities include:

- Field Test Siting (Site Solicitation, Selection, and Characterization)
- Procurements for Drilling and Engineering Services
- Legal and Regulatory Requirements
- Design, Drilling, and Construction for Characterization Borehole
- Scientific Testing and Analysis
- Design, Drilling, and Construction for Field Test Borehole
- Engineering and Demonstration Activities
- Field Test Assessment (Concept Evaluation, Engineering and Safety Analyses)

2. MANAGEMENT STRUCTURE

The organization for the DBFT project is shown in Figure 2-1.

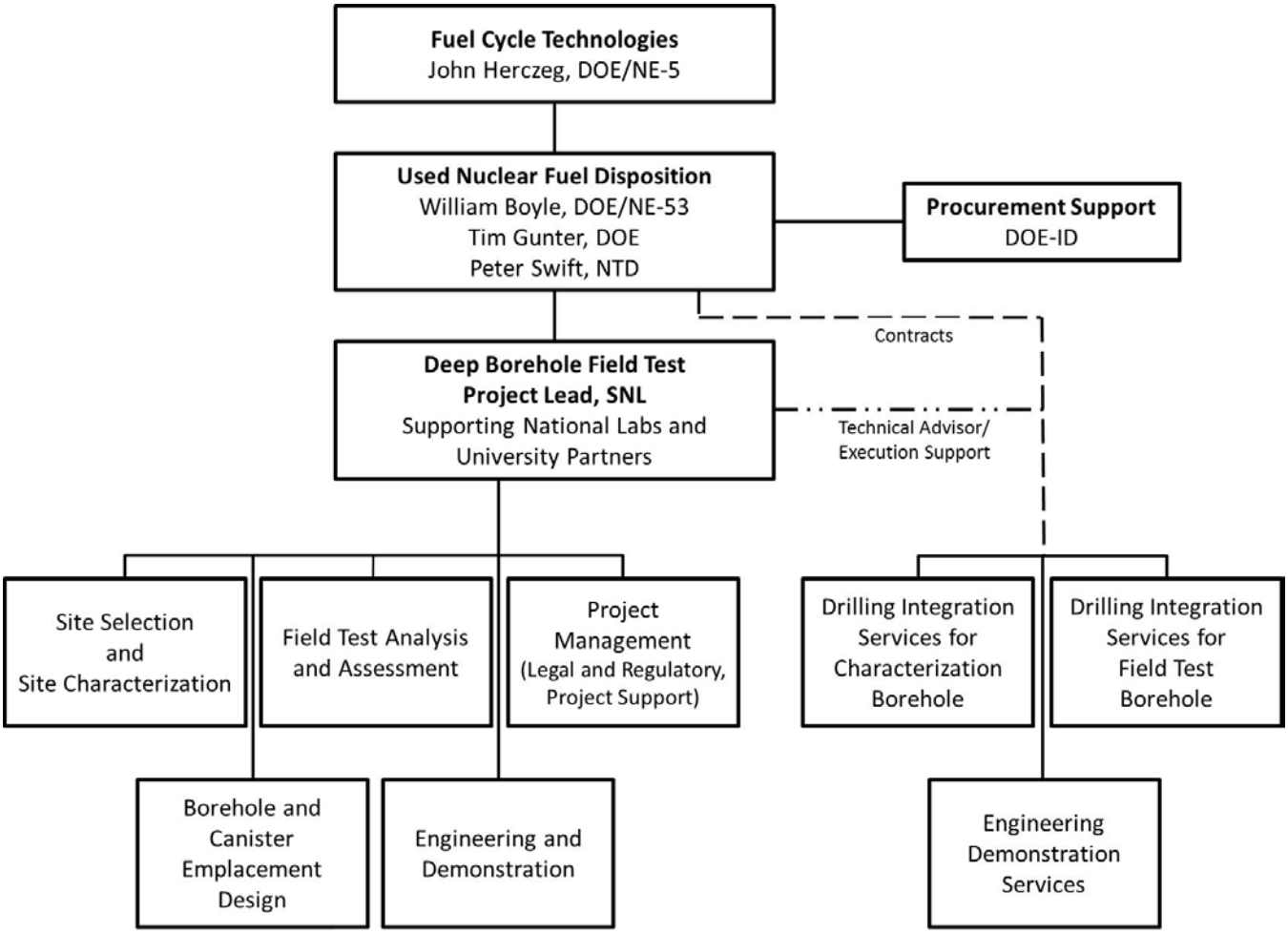


Figure 2-1. Deep Borehole Field Test Project Organization

2.1 Roles and Responsibilities

Deputy Assistant Secretary for Fuel Cycle Technologies (NE-5)

- Serves as the DBFT Project sponsor
- Responsible for ensuring adequate Project planning and execution
- Establishes broad policies and requirements for achieving Project goals
- Approves the Project Plan
- Coordinates with approval authority in National Environmental Policy Act (NEPA) determination
- Delegates approval authority for baseline changes in accordance with the Baseline Change Proposal (BCP) process (see Section 3.4)
- Provides funding for the Project

Director, Used Nuclear Fuel Disposition Research and Development (NE-53)

- Serves as the Federal Program Director for UFD
- Provides broad UFD Program guidance and delegates appropriate decision-making authority
- Approves UFD Program cost, schedule, performance, and scope baselines
- Approves baseline changes in accordance with thresholds identified in the BCP process

Program Manager, Used Nuclear Fuel Disposition Research and Development (NE-53)

- Serves as the Federal Program Manager for UFD and the Federal Project Manager for the DBFT
- Approves Project cost, schedule, performance, and scope baselines
- Ensures that Project design, construction, environmental, safety, security, health, and quality efforts performed comply with the contract, public law, regulations, and Executive Orders are integrated into the UFD Program
- Appointed as the Contracting Officer's Representative (COR), as determined by the Contracting Officer
- Approves (in coordination with the Contracting Officer) changes in compliance with the approved BCP process

National Technical Director (NTD), Used Nuclear Fuel Disposition Research and Development

- Responsible and accountable to DOE for executing the UFD Program within scope, cost, and schedule in a safe and responsible manner
- Provides technical UFD Program guidance to the SNL Project Manager, university partners, and other national laboratories
- Represents the UFD Program in interactions with the DOE, participates in management meetings with DOE, and communicates UFD Program status and issues
- Approves baseline changes in accordance with thresholds identified in the BCP process
- Identifies and manages UFD Program risks

Sandia National Laboratories (SNL) Project Manager

- Responsible and accountable to DOE for executing the Project within scope, cost, and schedule in a safe and responsible manner
- Provides technical Project guidance to subcontractors, university partners, and other national laboratories
- Provides access to laboratory/contractor resources, systems, and capabilities required to execute the Project
- Maintains Project progress and reports
- Ensures environmental, safety, security, health, and quality responsibilities and requirements are integrated into the Project
- Represents the Project in interactions with the DOE, participates in management meetings with DOE, and communicates Project status and issues
- Approves baseline changes in accordance with thresholds identified in the BCP process
- Identifies and manages Project risks

DOE Idaho (DOE-ID) Operations Office

- Responsible for DOE-led contract procurements for the Project, including assistance in developing the Acquisition Strategy Plan, requirements documents, and solicitation documents and the Review/Selection Plan
- Responsible for coordinating any required reviews of solicitations
- Repsonsible for issuing solicitations and obtaining proposals
- Responsible for negotiation, award, administration, and closeout of the contract
- Provides legal advice, counsel and support
- Monitor contract performance
- Approves NEPA documents and any permits in coordination with Project sponsors and other sites as required

Sandia Field Office (SFO) Manager

- Assists in determining the appropriate level of NEPA documentation and permitting required for the program

3. INTEGRATED PROJECT BASELINE

3.1 Scope

The DBFT is designed to evaluate the feasibility of the deep borehole disposal concept. The scope of activities to achieve this objective, listed in Section 1.2, include: siting, borehole drilling and construction, downhole scientific testing and analysis, engineering demonstration of downhole canister emplacement, field test analysis and feasibility assessment, and project management/support (e.g., procurement, legal and regulatory requirements). These activities are planned over a five-year project lifecycle.

A graphical depiction of the project work breakdown structure (WBS) to accomplish these activities is shown in Figure 3-1 down to project WBS Level 3. Details of project WBS elements over the five-year lifecycle down to project Level 4 are provided in Appendix A. The project WBS exists below, and is distinct from, the DOE-NE WBS. In the DOE-NE WBS, Fuel Cycle Technologies is 1.02 and UFD is 1.02.08. The DBFT project WBS starts at Level 4 of the DOE-NE WBS, under 1.2.08.17.

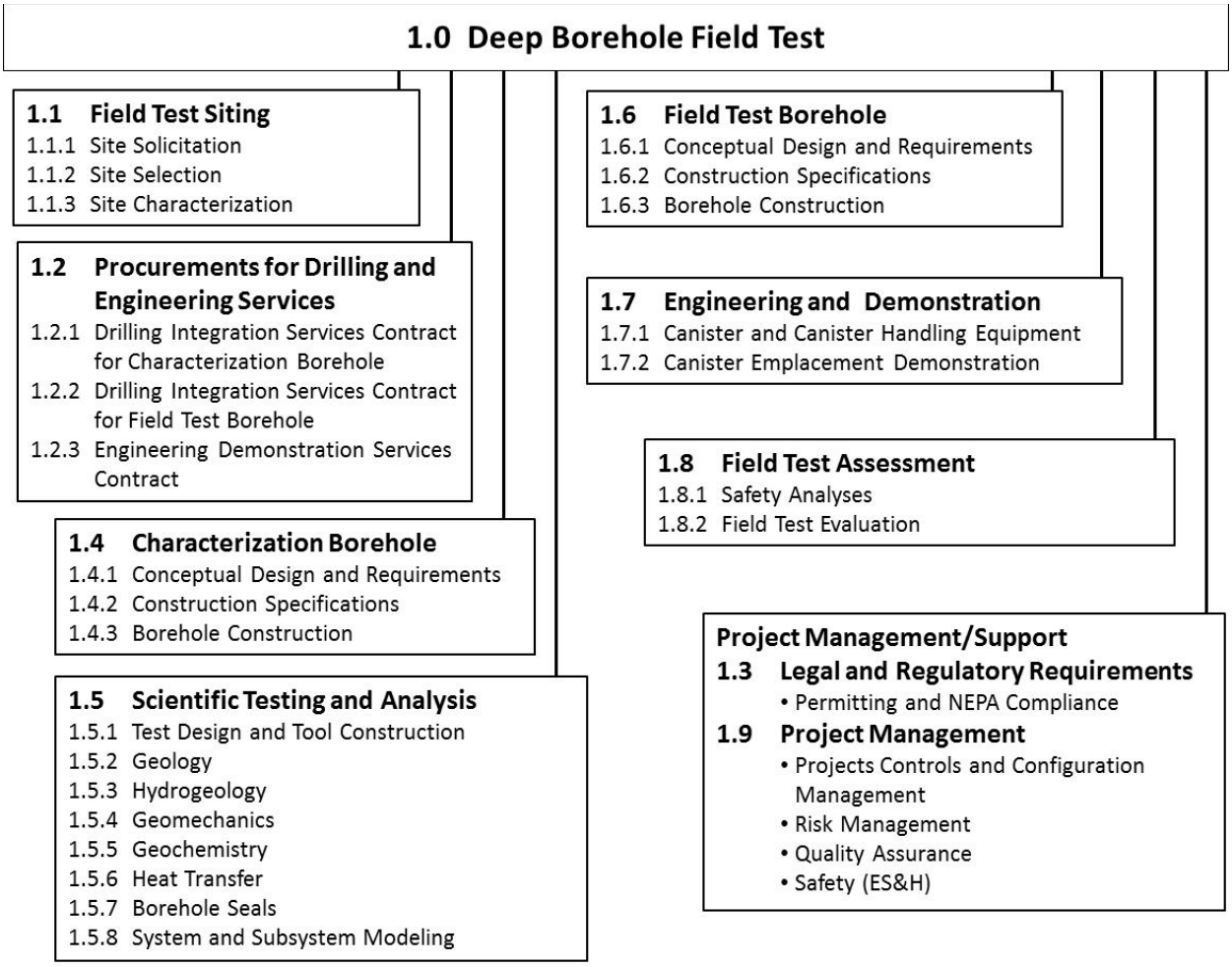


Figure 3-1. Deep Borehole Field Test Project WBS (to Project Level 3)

In addition to the high-level workscopes described in Appendix A, more detailed descriptions of the Fiscal Year (FY) 15 activities are provided in Appendix B.

3.2 Schedule

Major activities for the DBFT include: site selection and characterization, the design and drilling of two boreholes (a Characterization Borehole and a Field Test Borehole), the design of the field test (canisters, canister handling, and canister emplacement and retrieval), an engineering demonstration of canister emplacement, and related scientific R&D activities to validate the merits of the deep borehole disposal concept. Key milestones related to these major activities are shown in Table 3-1.

A detailed five-year schedule for all project WBS elements supporting these major activities and milestones is provided in Appendix C. This schedule will be refined as the project maturity progresses. Schedule contingency will be included, as appropriate, based on a risk assessment.

Table 3-1. Deep Borehole Field Test Key Milestones

	FY15	FY16	FY17	FY18	FY19
Field Test – Award Engineering Services Contract	◆ 04/01/15				
Site Selection – Decision	◆ 05/04/15				
Documentation – Borehole and Field Test Design	◆ 09/15/15				
Characterization Borehole - Award Drilling Integration Services Contract		◆ 11/30/15			
Characterization Borehole - Start Drilling		◆ 06/01/16			
Characterization Borehole - Complete Construction			◆ 11/16/16		
Field Test Borehole - Award Drilling Integration Services Contract			◆ 01/13/17		
Field Test Borehole - Start Drilling			◆ 07/07/17		
Field Test Borehole - Complete Construction				◆ 12/01/17	
Field Test – Start Emplacement Demonstration					◆ 10/18/18
Field Test – Complete Emplacement Demonstration					◆ 05/29/19
Documentation – Field Test Analyses and Evaluation					◆ 09/30/19

3.3 Costs

The estimated annual costs for each of the five years of the project are shown in Table 3-2 at project WBS Level 2. A refined resource loaded schedule will be developed and will serve as the baseline for monitoring project performance. Contingency has been added to the cost estimate based on a preliminary evaluation of risks.

Table 3-2. Deep Borehole Field Test Costs ($Million)

Project WBS	Activity	FY15	FY16	FY17	FY18	FY19	Total
1.1	Field Test Siting	2.5	2.0				**4.5**
1.2	Procurements for Drilling and Engineering Services[1]						
1.3	Legal and Regulatory Requirements	0.6	2.0				**2.6**
1.4	Characterization Borehole (Design, Drilling, and Construction)	0.6	16.0	3.0			**19.6**
1.5	Scientific Testing and Analysis	0.4	1.0	5.0	2.0		**8.4**
1.6	Field Test Borehole (Design, Drilling, and Construction)	0.3	0.4	11.0	17.5		**29.2**
1.7	Engineering and Demonstration	1.7	0.8	2.0	4.6	1.0	**10.1**
1.8	Field Test Assessment				1.5	2.0	**3.5**
1.9	Project Management	0.4	0.5	0.5	0.5	0.5	**2.4**
Total		**6.5**	**22.7**	**21.5**	**26.1**	**3.5**	**80.3**
	Contingency	1.5	4.0	4.0	5.0	1.0	**15.5**

[1] Procurement costs are included in other WBS elements.

3.4 Baseline Change Control

Baseline Change Control procedures are used to formally control and document any changes to the project performance measurement baseline after it has been formally approved. These baseline changes can occur as a result of various contractual changes and/or modifications, application of undistributed budget, new planning of programs and/or projects, and formal reprogramming.

This project will be managed using the Project Information Collection System: Nuclear Energy (PICS:NE). The Baseline Change Proposal (BCP) process is managed within PICS:NE.

4. PROJECT MANAGEMENT

The overall project management approach is described in the following subsections.

4.1 Project Reporting

The SNL Project Manager will report periodically to DOE/NE-53 to provide updates on project progress and to discuss and resolve issues.

Monthly status reports will be entered into the PICS:NE system as required. The SNL Oracle Financial system will provide required information related to project budget, cost, and commitments in WBS format.

4.1.1 Earned Value Management System (EVMS)

SNL corporate EVMS, consistent with the PICS:NE EVMS guide, will be used, as necessary, to manage, control, analyze and report on the project. EVMS is not required for acquisition of commercial products that are designed and built from commercial off-the-shelf technology.

4.2 Risk Management

Risk Management is an essential element of this project and must be analytical, forward looking, structured, and continuous. Risk assessments will be started as early as possible in the project life-cycle and will identify critical technical scope, cost, and schedule risks. Many risks can impact multiple aspects of the project. As risks are identified, they will be assessed, prioritized, and monitored. Where necessary, risk mitigation strategies and actions will be developed, documented, and implemented to mitigate and disposition risks. Some general areas of risk that will be considered are listed below:

- **Technical Scope Risk** – The project includes significant RD&D and thus has a high level of technical uncertainty. For example, deep borehole drilling has a large risk because of unknown conditions in the subsurface and limited industry experience with deep large-diameter holes. Independent technical reviews will be performed, as appropriate, to minimize technical risks.
- **Cost/Budget Risk** – The funding and budgeting of a federal activity are subject to changes (e.g., availability of funds, continuing resolutions (CRs), congressional action, changes in Administration, etc.).
- **Schedule Risk** – As the project proceeds, delays can occur (e.g., equipment failure, unexpected geology, technical development). There may also be schedule delays involved in the procurement process, such as delays in sending, receiving, reviewing or approving requests for information (RFIs) or requests for proposal (RFPs), delays in reaching agreement on contract terms, political impacts due to elections, etc.

The Risk Management Matrix in Appendix D provides a preliminary list of specific major risks currently identified, along with their risk mitigation approaches.

4.3 Engineering and Technology Readiness

The project will assess engineering and technology readiness through design reviews, reviews by university and industrial partners, and independent technical reviews. Specific engineering and technology related activities associated with the DBFT that will need to be reviewed include:

- Deep drilling of large-diameter boreholes
- Site characterization techniques/methods at depth
- Canister and handling equipment design
- Canister emplacement operations
- Seal system design

4.4 Environmental and Regulatory Compliance

National Environmental Policy Act (NEPA) Compliance

- As a Federally funded project, compliance with NEPA is a requirement. It is necessary to finalize a compliance strategy. Some uncertainty exists regarding the level of effort required to comply. It appears unlikely that a categorical exclusion would be granted. The project scope and duration is not of a magnitude that would generally require an Environmental Impact Statement (EIS), so for planning purposes the need for an Environmental Assessment (EA) is assumed. A NEPA Checklist for a non-site-specific deep drilling project is provided in Appendix E. In the near future, this checklist will be discussed with the Sandia Field Office, NEPA Compliance Officer.

Permitting

- The permits will vary by location. It is important to define who will be the responsible party holding the permit for the Characterization and Field Test boreholes. Permitting may require the posting of bonds.
  - **Drilling Permits** – The request for a drilling permit will generally require that a borehole plan be submitted. Regulators will require a casing program that isolates aquifers and assures effective control of down-hole pressure (e.g., a blow-out prevention system). They will also have regulations related to the mud system and containment and disposal of drill cuttings.
  - **Air Quality Permits** – Air quality permits may be required for the drilling operation since this represents a point source for emissions. Some states are much more restrictive than others and may require that Tier 3 engines on the drill rig and associated power units meet strict emission guidelines.
  - **Land/Water Use Permits** – Land use permits will be required on public lands; whereas land owner agreements and leases will be required on private lands. In many instances, the surface and subsurface rights may be separate. The drilling operation will consume large amounts of water. At a remote location it may be necessary to drill a water well to eliminate the use of long water hauls. This water well, if required, would be permitted through the appropriate state's division of water rights.

4.4.1 Integrated Safety Management

Integrated Safety Management is addressed through the SNL Corporate Process Requirements "Integrated Safety Management System" and applies to all activities at SNL. These activities will follow the guidelines and principles of integrated safety management.

Drilling operations will be covered under existing industrial standards and guidelines (skill of the trade) such as those identified by the American Petroleum Institute (API).

4.5 Configuration Management

A configuration management process will be established that controls changes to the physical configuration of project equipment, structures, and systems in compliance with DOE standards. This process ensures that the configuration is in agreement with the performance objectives identified in the technical baseline and the approved Quality Assurance (QA) Plan.

A configuration management system will identify and document the configuration of the end products (e.g., canisters, handling equipment, borehole components, etc.) and control configuration changes during the life cycle.

The configuration management system will use a tailored approach to the guidelines in the SNL Configuration Control.

4.6 Records Management/Document Control

Existing SNL corporate processes will be implemented to control preparation, review, comment resolution, approval, issuance, use, and revision of documents that establish policies, prescribe work, and specify requirements.

The principle project controlled documents include contract documents, the Project Plan, Milestone reports, work authorizations, design specifications, compliance documents, QA and Environment, Safety, and Health (ES&H) Plans, and the BCP log including disposition.

4.7 Quality Assurance

QA is an integral part of effective project management and will be employed throughout the design, procurement, and construction of the project. The Project QA Plan will be based on the SNL Corporate QA Plan and the UFD Program QA Plan (SNL 2014). QA requirements will apply to all subcontractors performing work on the project.

In addition, national codes and standards will be followed throughout as applicable. Quality control will be required for the purchase, construction, and/or fabrication of essential components.

4.8 Testing and Evaluation

The DBFT will be used to validate proof of concept. The field test will have two purposes: engineering analysis to assess the viability and safety of deep borehole waste emplacement; and downhole analysis to confirm geologic controls over waste stability and containment. Engineering analysis will evaluate the feasibility of downhole emplacement operations by determining performance envelopes for drilling, canister handling, and canister retrieval.

The ultimate evaluation will be to assess the viability of the concept of drilling a borehole to adequate depth and diameter, safely handle and lower nuclear waste to a disposal horizon, and thereby, confirm the preclosure and postclosure safety analyses.

4.9 Project Closeout

When the project nears completion, project closeout activities will be identified and implemented. The following activities will be considered for project close out:

- How all contract obligations, products, services, and deliverables have been completed
- How excess equipment and associated components will be properly dispositioned
- Determination for long-term use of site, facilities, and boreholes
- Project lessons learned
- Determination of the viability of deep borehole disposal of nuclear waste

5. REFERENCES

Arnold, B.W., P.V. Brady, S.J. Bauer, C. Herrick, S. Pye, and J. Finger 2011. *Reference Design and Operations for Deep Borehole Disposal of High-Level Radioactive Waste.* SAND2011-6749. Sandia National Laboratories, Albuquerque, NM.

Arnold, B.W., P. Brady, S. Altman, P. Vaughn, D. Nielson, J. Lee, F. Gibb, P. Mariner, K. Travis, W. Halsey, J. Beswick, and J. Tillman 2012. *Research, Development, and Demonstration Roadmap for Deep Borehole Disposal.* FCRD-USED-2012-000269, SAND2012-8527P. Sandia National Laboratories, Albuquerque, NM.

Arnold, B.W., P. Brady, S. Altman, P. Vaughn, D. Nielson, J. Lee, F. Gibb, P. Mariner, K. Travis, W. Halsey, J. Beswick, and J. Tillman 2013. *Deep Borehole Disposal Research: Demonstration Site Selection Guidelines, Borehole Seals Design, and RD&D Needs.* FCRD-USED-2013-000409, SAND2013-9490P. Sandia National Laboratories, Albuquerque, NM.

Arnold, B.W., P. Brady, M. Sutton, K. Travis, R. MacKinnon, F. Gibb, and H. Greenberg 2014. *Deep Borehole Disposal Research: Geological Data Evaluation, Alternative Waste Forms, and Borehole Seals.* FCRD-USED-2014-000332, SAND2014-17430R. Sandia National Laboratories, Albuquerque, NM.

Brady, P.V., B.W. Arnold, G.A. Freeze, P.N. Swift, S.J. Bauer, J.L. Kanney, R.P. Rechard, J.S. Stein, 2009. *Deep Borehole Disposal of High-Level Radioactive Waste.* SAND2009-4401. Sandia National Laboratories, Albuquerque, NM.

Beswick, J. 2008. *Status of Technology for Deep Borehole Disposal.* Report for the Nuclear Decommissioning Authority by EPS International Contract No. NP01185.

Blue Ribbon Commission on America's Nuclear Future (BRC) 2012. *Report to the Secretary of Energy.* U.S. Department of Energy.

National Academy of Sciences (NAS) 1957. *The Disposal of Radioactive Waste on Land.* http://www.nap.edu/openbook.php?record_id=10294

Sandia National Laboratories (SNL) 2014. *Sandia National Laboratories QA Program Interface Document for FCT Activities.* FCRD-TIO-2011-000032, Rev. 2 (Effective Date: 07/25/2014). Sandia National Laboratories, Albuquerque, NM.

Vaughn, P., B.W. Arnold, S.J. Altman, P.V. Brady, and W.P. Gardner 2012. *Site Characterization Methodology for Deep Borehole Disposal.* SAND2012-7981. Sandia National Laboratories, Albuquerque, NM.

APPENDIX A – DETAILED PROJECT WBS ELEMENT WORKSCOPE

DBFT WBS 1.1 – Field Test Siting	
WBS 1.1.1 – Site Solicitation	
1.1.1.1	Prepare RFI
1.1.1.2	Issue RFI
1.1.1.3	Responses to RFI
WBS 1.1.2 – Site Selection	
1.1.2.1	Verify responses meet guidelines
1.1.2.2	Evaluate and rank sites
1.1.2.3	Site selected
1.1.2.4	Site acquisition process
1.1.2.5	Site acquired
WBS 1.1.3 – Site Characterization	
1.1.3.1	Collect existing data
1.1.3.2	Site specific investigations

The Site Solicitation (WBS 1.1.1) process for the DBFT involves the preparation and issuance of an RFI from interested communities with potential test sites.

The Site Selection (WBS 1.1.2) process will review and verify the suitability of potential field test sites identified in RFI responses. Factual representations will be verified, evaluated on technical and other comparative criteria, and ranked if appropriate. The selection of a single site will be guided by program management and informed by technical, logistical, and sociopolitical factors. Technical factors include geological, hydrogeological, and geophysical characteristics of the site that could impact the drilling, borehole construction, and canister emplacement testing activities at the site. Specific technical indicators may include: depth to crystalline basement, crystalline basement lithology and structural complexity, horizontal stress, tectonic uplift, geothermal heat flux, topographic relief and hydraulic gradient, faults and volcanism, and mineral resources potential. Consideration of technical factors will also include relevance to demonstrating post-closure safety for a deep borehole disposal system. Logistical factors include the availability of deep drilling resources, downhole capabilities (e.g., equipment, engineering services, and materials), and research support for the field testing. Sociopolitical factors include the support or opposition of local and state entities to the DBFT. Site acquisition will require legal access (lease or purchase), environmental and other permits, and similar measures for additional support for site access (road improvements, utilities).

Site Characterization (WBS 1.1.3) for the DBFT will include the review of existing technical data and possible additional site-specific investigation. Prior to the site selection decision, existing data will be compiled for all potential sites. Site characterization data includes, but is not limited to, information describing the geological, hydrogeological, and geophysical factors identified in WBS 1.1.2.

Although the DBFT does not include waste disposal, it is desirable that the deep geological and hydrogeological conditions at the field test site be consistent with conditions important to post-closure waste isolation of a hypothetical disposal system. Therefore, the collection of site characterization data should focus on confirming that disposal zone depths are in crystalline basement rocks, deep fluids are highly saline, geochemical conditions are reducing, deep fluids exhibit evidence of long-term isolation from shallow groundwater resources, large-scale structural features are absent or not hydraulically transmissive, and economically attractive resources are absent in the deep subsurface.

DBFT WBS 1.2 – Procurement for Drilling and Engineering Services	
WBS 1.2.1 – Drilling Integration Services Contract for Characterization Borehole	
1.2.1.1	Acquisition activities
1.2.1.2	Issue RFP
1.2.1.3	Responses to RFP
1.2.1.4	Evaluate proposals and award contract
WBS 1.2.2 – Drilling Integration Services Contract for Field Test Borehole	
1.2.2.1	Acquisition activities
1.2.2.2	Issue RFP
1.2.2.3	Responses to RFP
1.2.2.4	Evaluate and award contract
WBS 1.2.3 – Engineering Demonstration Services Contract	
1.2.3.1	Acquisition activities
1.2.3.2	Issue RFP
1.2.3.3	Responses to RFP
1.2.3.4	Evaluate and award contract

Procurement (WBS 1.2) includes three separate procurements: drilling integration services for the Characterization Borehole; drilling integration services for the Field Test Borehole; and engineering demonstration services.

The first two procurements are related to the drilling and construction of the two deep boreholes. Deep drilling is now common within the petroleum industry, but there are few examples where large-diameter wells (greater than about 12 inches diameter) have been drilled in crystalline bedrock to depths of 4,000 to 5,000 meters (Beswick 2008). Seven drilling contractors have been identified in the U.S. that have the capability to drill the larger-diameter Field Test Borehole. These rigs are located in the western and southwestern U.S. A larger number of companies have the capability to drill the smaller-diameter Characterization Borehole.

The drilling integration services contractor for each borehole will procure and manage the drilling activities and drilling support services (e.g., completion and logging services), and procure equipment and materials.

The third procurement supports the engineering and deployment of one or more canister emplacement tests. The engineering demonstration services contractor will interface with the drilling integration services contractor for the Field Test Borehole to facilitate the canister emplacement test activities.

These procurements each include the preparation and issuance of a RFP to solicit competitive bids from qualified services contractors. The evaluation of RFP responses will include consideration of previous experience drilling and constructing boreholes in crystalline rock with depth and diameter comparable to the Characterization and Field Test Boreholes. These procurements will be conducted separately, but it may be possible for one company to be awarded more than one of the contracts.

DBFT WBS 1.3 – Legal and Regulatory Requirements

1.3.1	Local, State, and Federal permits
1.3.2	Drilling permits
1.3.3	Air quality permits
1.3.4	Land/water use permits
1.3.5	NEPA Compliance
1.3.6	EA and permits finalized
1.3.7	Update legal and regulatory requirements and permits as needed

The details of the Legal and Regulatory Requirements (WBS 1.3) for a DBFT will be initiated during the planning process for the site selection and continue through the planning and drilling of the two boreholes. Since the regulatory environment is different in different states and for Federal versus private land, it is important to initiate the process early to allow specific state and local requirements to be considered.

Compliance with NEPA is required, and the NEPA framework provides guidance to inform the decision on site selection. The project scope and duration are not of a magnitude that would generally require an EIS, so current planning assumes that an EA will be performed, which is considerably less rigorous than an EIS. An EA generally considers and evaluate the potential impacts related to air quality (in accordance with the Clean Air Act (CAA), water quality (in accordance with the Clean Water Act (CWA)), noise pollution, biological resources, cultural resources, and waste management.

Initial work will include the preparation of a NEPA Checklist and a meeting with the Sandia Site Office NEPA Compliance Officer. This will allow finalization of a NEPA compliance strategy. Because the DBFT will not include emplacement of radioactive materials, regulations pertaining to nuclear waste disposal do not apply. Nonetheless, RD&D activities will be conducted in a manner consistent with their potential future utilization in the regulatory processes associated with licensing a disposal facility.

Drilling permits and land and water use permits are generally subject to state regulation and are routinely granted for drilling operations in most states. A permit to drill the two test boreholes will be required from the state agency regulating wells. Land use permits will be required on public lands; whereas land owner agreements and leases will be required on private lands. In many instances, the surface and subsurface rights may be separate. The drilling operation will consume large amounts of water; therefore it is possible that a water well will be drilled on site to eliminate the use of water hauls. This water well, if required, will be permitted through the appropriate state agency of water rights.

DBFT WBS 1.4 – Characterization Borehole	
WBS 1.4.1 – Conceptual Design and Requirements	
1.4.1.1	Develop conceptual design
1.4.1.x	Borehole, casing, cementing, monitoring requirements
1.4.1.x	Site specific design requirements
1.4.1.9	Trade studies
WBS 1.4.2 – Construction Specifications	
1.4.2.1	Borehole specifications
1.4.2.2	Casing specifications
1.4.2.3	Cementing specifications
1.4.2.4	Monitoring specifications
WBS 1.4.3 – Borehole Construction	
1.4.3.1	Drill site preparation
1.4.3.2	Start drilling
1.4.3.3	Drilling and borehole construction
1.4.3.4	Logging and testing

The Characterization Borehole (WBS 1.4) activities include the conceptual design and requirements (WBS 1.4.1), borehole specifications (WBS 1.4.2), and borehole drilling and construction (WBS 1.4.3).

The Conceptual Design and Requirements (WBS 1.4.1) activity for the Characterization Borehole will develop a conceptual design that includes requirements for liners, casing, cementing, perforating, and monitoring. The final borehole Construction Specifications (WBS 1.4.2) will be developed based on the conceptual design and requirements and will include review input from the drilling contractor. Construction specifications will comprise a controlled configuration. Design of the Characterization Borehole will be consistent with a reference design for the Field Test Borehole (see WBS 1.6) in that similar drilling methods, construction methods, and materials will be used.

Borehole Construction (WBS 1.4.3) includes drill site preparation, drilling, borehole completion activities. Drill site preparation includes confirming permits, pad and access construction, and obtaining materials (casing, drilling fluid/mud, cement, etc.). Drilling is likely to require specialized technologies such as hard-rock drill bits, partial coring, and directional control. Borehole completion includes installing casing. Downhole logging will take place after each segment of the borehole is drilled and before casing is installed. Cased-hole logs will be used periodically to verify condition of the borehole. Downhole scientific testing activities will take place during and after borehole drilling and completion. Scientific testing and logging activities are described in WBS 1.5.

DBFT WBS 1.5 – Scientific Testing and Analysis	
WBS 1.5.1 – Test Design and Tool Construction	
WBS 1.5.2 – Geology	
1.5.2.1	Borehole-based characterization
WBS 1.5.3 – Hydrogeology	
1.5.3.x	Testing (drill stem, packer pump, and tracer)
WBS 1.5.4 – Geomechanics	
1.5.4.1	Logging (borehole televiewer, compressive and shear wave velocity, caliper)
1.5.4.2	Testing (mini frac, leak off)
WBS 1.5.5 – Geochemistry	
1.5.5.x	Sampling (cores, packer intervals)
WBS 1.5.6 – Heat Transfer	
1.5.6.1	Temperature logs
1.5.6.2	Downhole heater test
WBS 1.5.7 – Borehole Seals	
1.5.7.1	Seal design and testing
WBS 1.5.8 – System and Subsystem Modeling	
1.5.8.x	Modeling (to support design, data development, and postclosure safety analyses)

Scientific Testing and Analysis (WBS 1.5.1 through 1.5.6) will be performed in the Characterization Borehole to examine the hydrogeologic, geochemical, and geomechanical characteristics of the near-borehole host rock. These activities include planning, design, and procurement of testing equipment. Downhole testing activities, documented in Vaughn et al. (2012), will be conducted both during and subsequent to borehole drilling and construction. Scientific testing activities may involve circulating, swabbing, fluid injection, drill stem tests, and pumping tests.

Borehole Sealing (WBS 1.5.7) includes developing requirements, conceptual design, seal specifications and performing laboratory tests of candidate seal systems.

System and Subsystem Modeling (WBS 1.5.8) will support and help prioritize field testing related activities in the context of deep borehole Safety Analyses (WBS 1.8.1).

DBFT WBS 1.6 – Field Test Borehole	
WBS 1.6.1 – Conceptual Design and Requirements	
1.6.1.1	Develop conceptual design
1.6.1.x	Borehole, casing, cementing, monitoring requirements
1.6.1.7	Trade studies
WBS 1.6.2 – Construction Specifications	
1.6.2.1	Borehole specifications
1.6.2.2	Casing specifications
1.6.2.3	Cementing specifications
1.6.2.4	Monitoring specifications
WBS 1.6.3 – Borehole Construction	
1.6.3.1	Drill site preparation
1.6.3.2	Start drilling
1.6.3.3	Drilling and borehole construction
1.6.3.4	Logging and testing

The Field Test Borehole (WBS 1.6) activities include the conceptual design and requirements (WBS 1.6.1), borehole specifications (WBS 1.6.2), and borehole drilling and construction (WBS 1.6.3).

The Conceptual Design and Requirements (WBS 1.6.1) activities for the Field Test Borehole will develop a conceptual design that includes requirements for liners, casing, cementing, perforating, and monitoring. The final borehole Construction Specifications (WBS 1.6.2) will be developed based on the conceptual design and requirements and will include review input from the drilling contractor. Construction specifications will comprise a controlled configuration.

Borehole Construction (WBS 1.6.3) includes drill site preparation, drilling, borehole completion, well logging, and scientific testing. These activities will be similar to those described under WBS 1.4.3 for the Characterization Borehole, except that downhole scientific testing will be limited to those test activities that directly support the canister emplacement test.

DBFT WBS 1.7 – Engineering and Demonstration	
WBS 1.7.1 – Canister and Canister Handling Equipment	
1.7.1.1	Canisters (design, specifications, testing, and procurement)
1.7.1.2	Canister handling equipment (design, specifications, testing, and procurement)
WBS 1.7.2 – Canister Emplacement Demonstration	
1.7.2.1	Canister handling
1.7.2.2	Canister lowering and retrieval

Engineering and Demonstration (WBS 1.7) activities include Canister and Canister Handling Equipment Design (WBS 1.7.1) and a Canister Emplacement Demonstration (WBS 1.7.2).

The test canister will be designed to represent the dimensions and key characteristics of an actual disposal canister. Test canister requirements will consider system factors such as potential waste forms, waste packaging, and/or transportation. Test canister handling equipment is required to safely lower canisters to emplacement depth. For both the canisters and the handling equipment, this activity includes: design requirements, conceptual design, specifications, initial procurement and testing, revision to specifications based on initial testing as needed, and final procurement and construction.

The Canister Emplacement Demonstration (WBS 1.7.2) is a full-scale test of the downhole emplacement of one or more canisters to emplacement depth. This demonstration will evaluate the engineering feasibility by determining performance envelopes for surface equipment, canister handling, and canister emplacement and retrieval.

DBFT WBS 1.8 – Field Test Assessment
WBS 1.8.1 – Safety Analyses
1.8.1.1 Preclosure safety analysis 1.8.1.2 Postclosure safety analysis
WBS 1.8.2 – Field Test Evaluation
1.8.2.1 Safety case demonstration 1.8.2.2 Assessment of concept

Safety Analyses (WBS 1.8.1) include preclosure safety analyses (i.e., operational safety) and postclosure safety analyses (i.e., performance assessment for long-term safety). These safety analyses form the technical basis for the safety framework. Safety analyses are supported by System and Subsystem Modeling (WBS 1.5.8). These safety analyses will be updated, as necessary, based on information collected and analyses conducted prior to and during all stages of the DBFT.

The Field Test Evaluation (WBS 1.8.2) will be a compilation of the pertinent results from all DBFT engineering and testing activities into an updated safety case for deep borehole disposal. The safety case compilation will inform a future assessment as to the viability of the deep borehole disposal concept and it will help to identify and prioritize additional engineering and testing activities to confirm or strengthen the viability of the concept. A recommendation for the final disposition of the site will be included in the final evaluation.

DBFT WBS 1.9 – Project Management
Project Management (WBS 1.9) includes project controls, configuration management, risk management, QA, and safety, as described in Section 4.2.

APPENDIX B – FY15 WORK PACKAGE SCOPES

The following workscope descriptions are from PICS:NE planning for DOE-NE WBS 1.02.08.17 (Disposal Research Deep Borehole Disposal).

DOE-NE WBS 1.2.08.17 Objectives:

Deep Borehole Disposal is a five-year project, planned for FY15 through FY19, to design and implement a deep borehole field test. The deep borehole field test includes (1) drilling and downhole testing of a smaller-diameter Characterization Borehole, (2) drilling a larger-diameter Field Test Borehole, and (3) performing emplacement and retrieval tests with surrogate canisters (i.e., canisters that do not contain actual waste). Activities in FY15 will support the site selection, site characterization, and design of the deep borehole field test.

DOE-NE WBS 1.2.08.17 Scope:

In FY15, Deep Borehole Disposal includes four tasks associated with the siting and design of the deep borehole field test:

- **Site Selection** – Develop siting evaluation guidelines and support the comparison of candidate sites against siting guidelines.
- **Site Characterization** – Collect regional geological information and site-specific information for candidate sites. This activity will employ and update the UFD GIS database for site evaluation applications. Following site selection, perform site-specific investigations.
- **Field Test Design and Analysis** – Identify conceptual designs for drilling, borehole construction, downhole characterization, and field test implementation.
- **Project Management and Regulatory** – Integrate project scope, schedule, and cost planning and reporting. Also identify legal and regulatory requirements for site selection, characterization, and drilling.

Detailed Work Package scope descriptions for these four tasks are provided below.

Site Selection Scope (Work Package FT-15SN081706):

DBFT WBS 1.1.2

- Develop Siting Evaluation Guidelines - Identify siting guidelines/criteria to screen sites that are clearly unsuitable or inappropriate for the deep borehole field test – these may include technical, logistical/practical, and sociopolitical factors. Technical factors include geological, hydrogeochemical, and geophysical characteristics that (1) relate to the suitability of the site for drilling, borehole construction, and canister emplacement activities, and (2) would be indicative of the longer-term safety of a deep borehole disposal system (e.g., long-term stability and limited fluid flow at the bottom of the borehole). Logistical and practical factors to be considered during site selection include: the local or regional availability of drilling contractors (equipment, services, and materials) capable of drilling a deep, large-diameter hole; the legal and regulatory requirements associated with drilling, and site access. Social and political factors related to site selection include the support or opposition of local and state entities to the field test project and its operations.
- Support the Comparison of Candidate Sites – Examine regional technical, logistical, and sociopolitical information for the candidate sites. This information supports the evaluation of candidate sites against the siting guidelines.

Site Characterization Scope (Work Package FT-15SN081708):

DBFT WBS 1.1.3

- Collect Regional and Site-Specific Information for Candidate Sites – Research and acquire existing geological, geophysical, technical, logistical, and sociopolitical information for the candidate sites and engage with organizations and individuals (e.g., at state geological surveys, USGS, and universities) that possess relevant data and expertise. Of specific interest are regional- and local-scale geological, geotechnical, and hydrologic data (e.g., borehole and geophysical log data) that relate to the technical factors favorable for drilling and borehole construction, and bottom-hole stability.
- Utilize the UFD GIS Database – Employ and update the UFD GIS database for site evaluation applications.
- Perform Detailed Site Characterization at Selected Site – Following site selection, conduct detailed site characterization activities to further confirm the suitability of the selected site for the field test.

DBFT WBS 1.4.1 and 1.4.2

- Design Characterization Borehole – Develop a conceptual design and preliminary specifications for the Characterization Borehole to guide drilling and borehole construction activities.

DBFT WBS 1.5.1

- Identify Downhole Characterization Activities – Identify downhole logging and testing activities in the Characterization Borehole needed to characterize the borehole and site.

Field Test Design and Analysis Scope (Work Package FT-15SN081709):

DBFT WBS 1.7.1

- Design Field Test Borehole – Develop a preliminary design basis for the Field Test Borehole conceptual design (supplementing the conceptual design in deliverable M2FT-15SN0817081), to guide further design development, cost estimation, and scope of drilling and related construction activities.
- Design Canisters and Downhole Emplacement and Retrieval Activities – Develop a conceptual design and preliminary specifications for the test canisters and canister handling equipment to guide fabrication. Develop a conceptual design for the canister emplacement and retrieval activities.

DBFT WBS 1.5.7

- Examine Borehole Seal Designs – Develop a test plan for seal testing, which may include laboratory measurements, field testing, simulation, etc.

DBFT WBS 1.5.8

- Perform Modeling and Analyses – Modeling and analyses will be performed as necessary to (1) support the field test design, and (2) prioritize the science and engineering information needs to be addressed by the field test.

Project Management and Regulatory Scope (Work Package FT-15SN081710):

DBFT WBS 1.3

- Identify Legal and Regulatory Requirements – Collect preliminary information to support compliance with NEPA requirements and permitting for site selection, characterization, and drilling.

DBFT WBS 1.9

- Integrate Project Planning and Reporting – Maintain project documents that outline the scope, schedule, cost, and management structure required for site selection and implementation of the deep borehole field test.
- Support DOE Contracting – As needed, support the preparation and review of statements of work to be in contracts issued by DOE for deep borehole field test services.

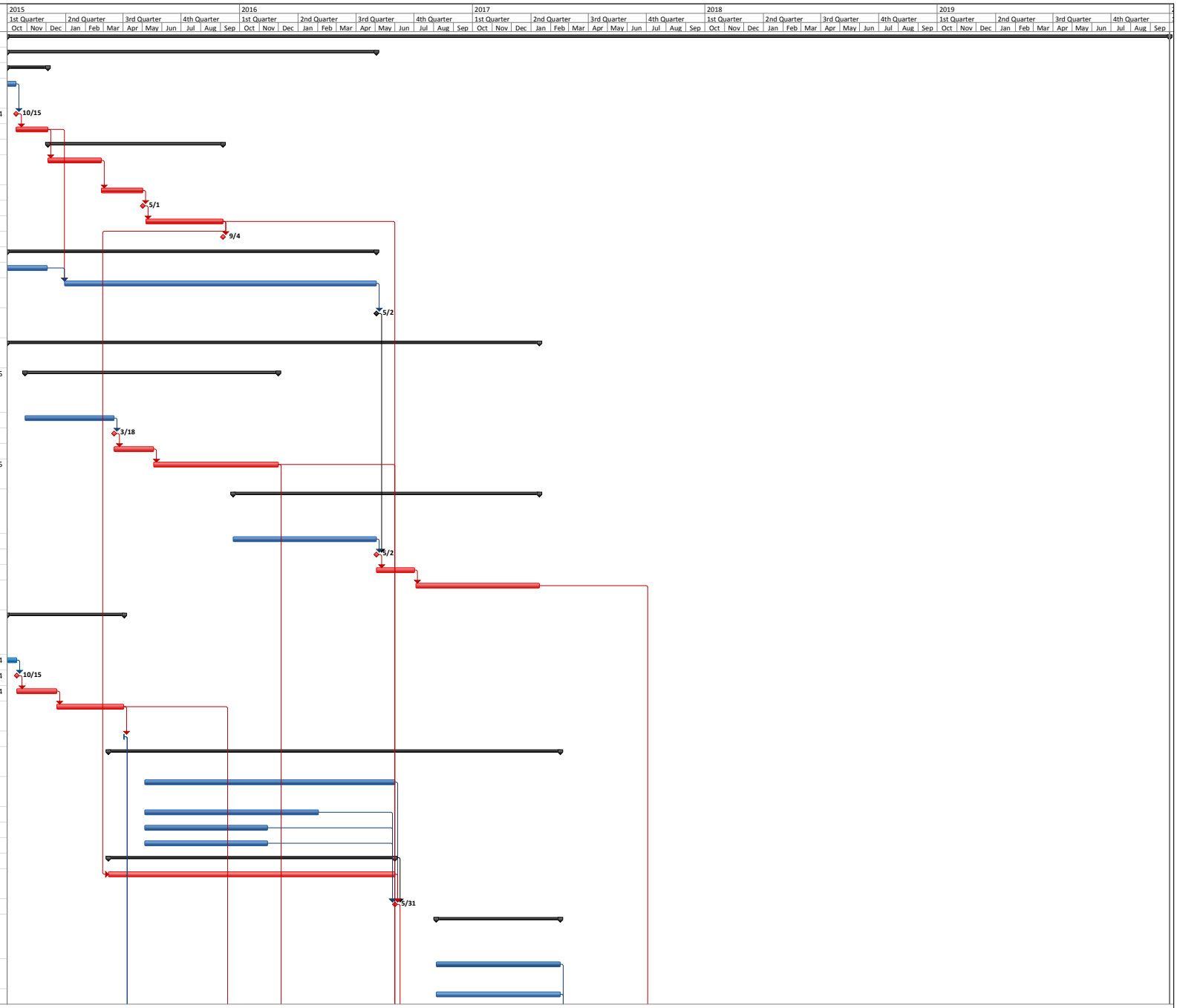
Additionally, there is one task associated with the procurement of contractor services:

Work Package FT-15HQ081707:

- **DBFT WBS 1.2** – For procurement of (1) engineering demonstration services contract, and (2) drilling integration services contract for the Characterization Borehole.

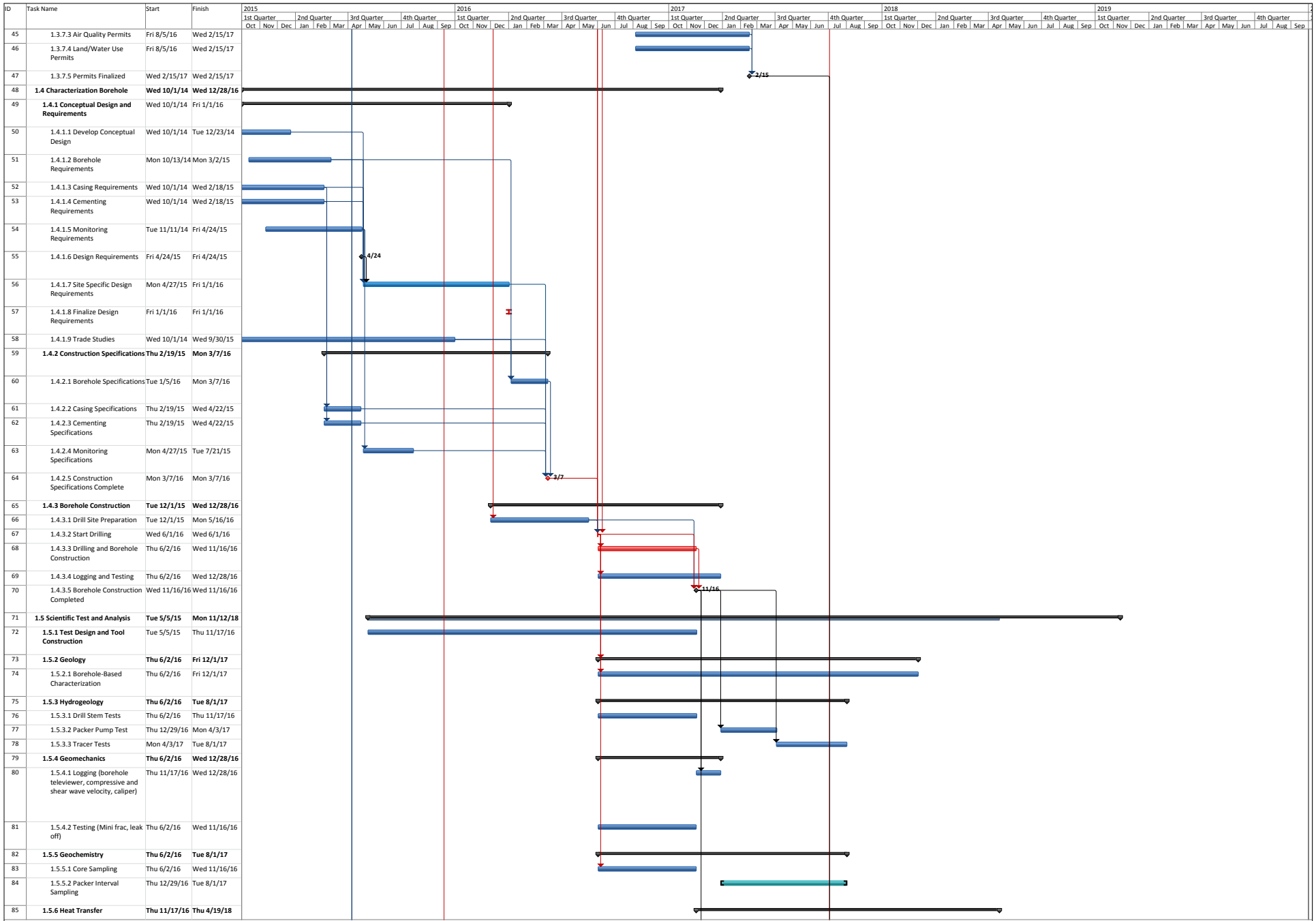
APPENDIX C – DETAILED PROJECT SCHEDULE

ID	Task Name	Start	Finish
1	**1 Deep Borehole Field Test**	**Wed 10/1/14**	**Mon 9/30/19**
2	**1.1 Field Test Siting**	**Wed 10/1/14**	Mon 5/2/16
3	**1.1.1 Site Solicitation**	**Wed 10/1/14**	**Wed 12/3/14**
4	1.1.1.1 Prepare Request for Information (RFI)	Wed 10/1/14	Tue 10/14/14
5	1.1.1.2 Issue RFI	Wed 10/15/14	Wed 10/15/14
6	1.1.1.3 Responses to RFI	Wed 10/15/14	Wed 12/3/14
7	**1.1.2 Site Selection**	**Thu 12/4/14**	**Fri 9/4/15**
8	1.1.2.1 Verify responses meet guidelines	Thu 12/4/14	Wed 2/25/15
9	1.1.2.2 Evaluate and Rank Sites	Thu 2/26/15	Fri 5/1/15
10	1.1.2.3 Site Selected	Fri 5/1/15	Fri 5/1/15
11	1.1.2.4 Site Acquiistion Process	Thu 5/7/15	Fri 9/4/15
12	1.1.2.5 Site Acquired	Fri 9/4/15	Fri 9/4/15
13	**1.1.3 Site Characterization**	**Wed 10/1/14**	**Mon 5/2/16**
14	1.1.3.1 Collect Existing Data	Wed 10/1/14	Tue 12/2/14
15	1.1.3.2 Site Specific Investigations	Tue 12/30/14	Mon 5/2/16
16	1.1.3.3 Characterization for Drilling and Construction	Mon 5/2/16	Mon 5/2/16
17	**1.2 Procurement for Drilling and Engineering Services**	Wed 10/1/14	Fri 1/13/17
18	**1.2.1 Drilling Intregration Services Contract for Characterization Borehole**	Wed 10/29/14	Mon 11/30/15
19	1.2.1.1 Acquisition Activities	Wed 10/29/14	Tue 3/17/15
20	1.2.1.2 Issue RFP	Wed 3/18/15	Wed 3/18/15
21	1.2.1.3 Responses to RFP	Wed 3/18/15	Mon 5/18/15
22	1.2.1.4 Evaluate and Award Contract	Tue 5/19/15	Mon 11/30/15
23	**1.2.2 Drilling Intregation Services Contract for Field Test Borehole**	Mon 9/21/15	Fri 1/13/17
24	1.2.2.1 Acquisition Activities	Mon 9/21/15	Mon 5/2/16
25	1.2.2.2 Issue RFP	Mon 5/2/16	Mon 5/2/16
26	1.2.2.3 Responses to RFP	Tue 5/3/16	Fri 7/1/16
27	1.2.2.4 Evaluate and Award Contract	Mon 7/4/16	Fri 1/13/17
28	**1.2.3 Engineering Demonstration Services Contract**	Wed 10/1/14	Thu 4/2/15
29	1.2.3.1 Acquisition Activities	Wed 10/1/14	Wed 10/15/14
30	1.2.3.2 Issue RFP	Wed 10/15/14	Wed 10/15/14
31	1.2.3.3 Responses to RFP	Thu 10/16/14	Wed 12/17/14
32	1.2.3.4 Evaluate and Award Contract	Thu 12/18/14	Wed 4/1/15
33	1.2.3.5 Performance Starts	Thu 4/2/15	Thu 4/2/15
34	**1.3 Legal and Regulatory Requirements**	**Mon 3/9/15**	**Wed 2/15/17**
35	1.3.1 Local, State, and Federal Permits	Tue 5/5/15	Tue 5/31/16
36	1.3.2 Drilling Permits	Tue 5/5/15	Mon 2/1/16
37	1.3.3 Air Quality Permits	Tue 5/5/15	Fri 11/13/15
38	1.3.4 Land/Water Use Permits	Tue 5/5/15	Fri 11/13/15
39	1.3.5 NEPA Compliance	**Mon 3/9/15**	**Tue 5/31/16**
40	1.3.5.1 Environmental Assessment	Mon 3/9/15	Tue 5/31/16
41	1.3.6 EA and Permits Finalized	Tue 5/31/16	Tue 5/31/16
42	1.3.7 Update Legal and Regulatory Requirements and Permits as Needed	**Fri 8/5/16**	**Wed 2/15/17**
43	1.3.7.1 Local, State, and Federal Permits	Fri 8/5/16	Wed 2/15/17
44	1.3.7.2 Drilling Permits	Fri 8/5/16	Wed 2/15/17



Project: DBH_Schedule_9_24_14_
Date: Tue 9/30/14

Task	Summary	External Milestone	Inactive Summary	Manual Summary Rollup	Finish-only	Critical Split
Split	Project Summary	Inactive Task	Manual Task	Manual Summary	Deadline	Progress
Milestone	External Tasks	Inactive Milestone	Duration-only	Start-only	Critical	

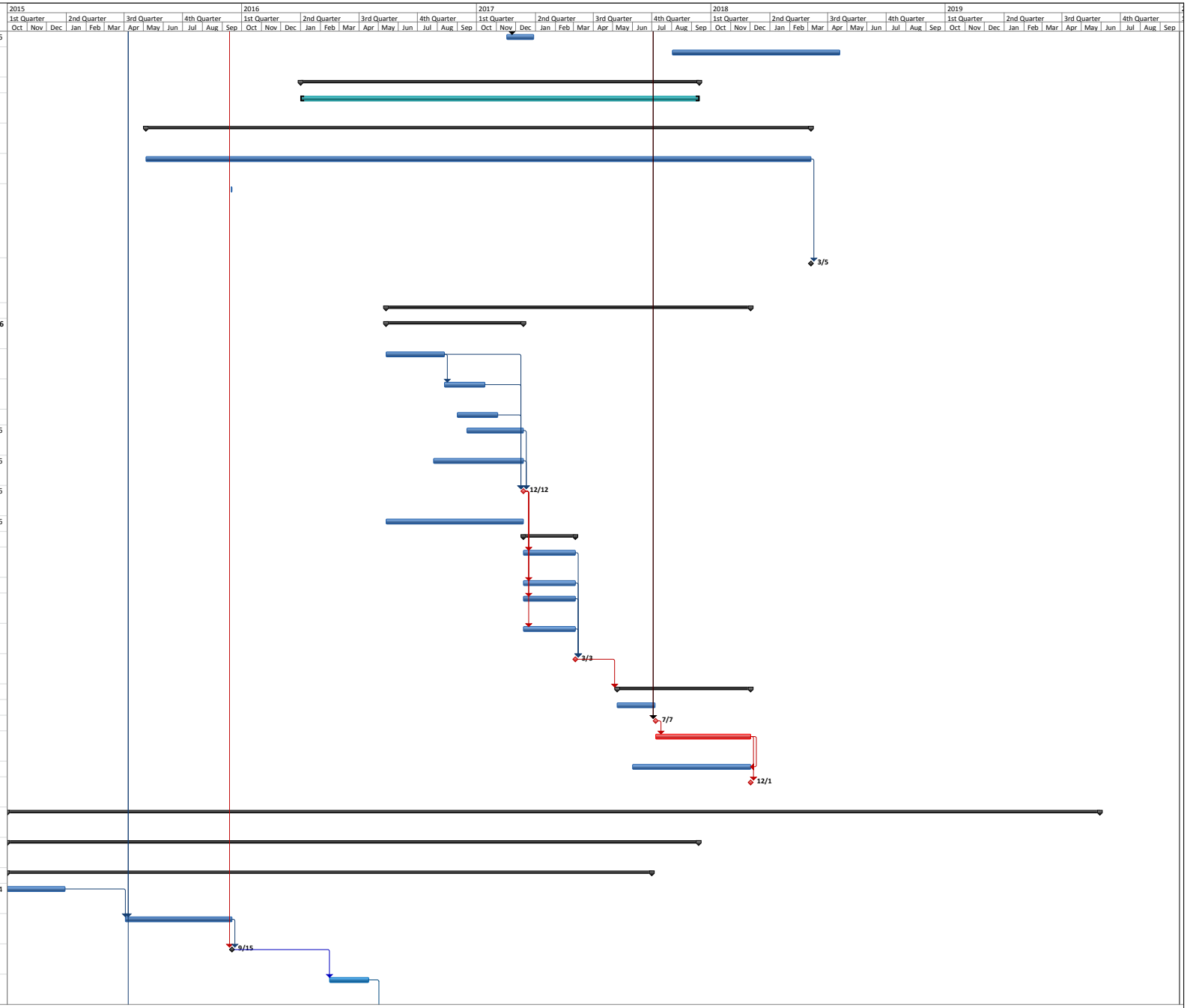


ID	Task Name	Start	Finish
45	1.3.7.3 Air Quality Permits	Fri 8/5/16	Wed 2/15/17
46	1.3.7.4 Land/Water Use Permits	Fri 8/5/16	Wed 2/15/17
47	1.3.7.5 Permits Finalized	Wed 2/15/17	Wed 2/15/17
48	**1.4 Characterization Borehole**	**Wed 10/1/14**	**Wed 12/28/16**
49	**1.4.1 Conceptual Design and Requirements**	Wed 10/1/14	Fri 1/1/16
50	1.4.1.1 Develop Conceptual Design	Wed 10/1/14	Tue 12/23/14
51	1.4.1.2 Borehole Requirements	Mon 10/13/14	Mon 3/2/15
52	1.4.1.3 Casing Requirements	Wed 10/1/14	Wed 2/18/15
53	1.4.1.4 Cementing Requirements	Wed 10/1/14	Wed 2/18/15
54	1.4.1.5 Monitoring Requirements	Tue 11/11/14	Fri 4/24/15
55	1.4.1.6 Design Requirements	Fri 4/24/15	Fri 4/24/15
56	1.4.1.7 Site Specific Design Requirements	Mon 4/27/15	Fri 1/1/16
57	1.4.1.8 Finalize Design Requirements	Fri 1/1/16	Fri 1/1/16
58	1.4.1.9 Trade Studies	Wed 10/1/14	Wed 9/30/15
59	**1.4.2 Construction Specifications**	**Thu 2/19/15**	**Mon 3/7/16**
60	1.4.2.1 Borehole Specifications	Tue 1/5/16	Mon 3/7/16
61	1.4.2.2 Casing Specifications	Thu 2/19/15	Wed 4/22/15
62	1.4.2.3 Cementing Specifications	Thu 2/19/15	Wed 4/22/15
63	1.4.2.4 Monitoring Specifications	Mon 4/27/15	Tue 7/21/15
64	1.4.2.5 Construction Specifications Complete	Mon 3/7/16	Mon 3/7/16
65	**1.4.3 Borehole Construction**	**Tue 12/1/15**	**Wed 12/28/16**
66	1.4.3.1 Drill Site Preparation	Tue 12/1/15	Mon 5/16/16
67	1.4.3.2 Start Drilling	Wed 6/1/16	Wed 6/1/16
68	1.4.3.3 Drilling and Borehole Construction	Thu 6/2/16	Wed 11/16/16
69	1.4.3.4 Logging and Testing	Thu 6/2/16	Wed 12/28/16
70	1.4.3.5 Borehole Construction Completed	Wed 11/16/16	Wed 11/16/16
71	**1.5 Scientific Test and Analysis**	**Tue 5/5/15**	**Mon 11/12/18**
72	**1.5.1 Test Design and Tool Construction**	Tue 5/5/15	Thu 11/17/16
73	**1.5.2 Geology**	**Thu 6/2/16**	**Fri 12/1/17**
74	1.5.2.1 Borehole-Based Characterization	Thu 6/2/16	Fri 12/1/17
75	**1.5.3 Hydrogeology**	**Thu 6/2/16**	**Tue 8/1/17**
76	1.5.3.1 Drill Stem Tests	Thu 6/2/16	Thu 11/17/16
77	1.5.3.2 Packer Pump Test	Thu 12/29/16	Mon 4/3/17
78	1.5.3.3 Tracer Tests	Mon 4/3/17	Tue 8/1/17
79	**1.5.4 Geomechanics**	**Thu 6/2/16**	**Wed 12/28/16**
80	1.5.4.1 Logging (borehole televiewer, compressive and shear wave velocity, caliper)	Thu 11/17/16	Wed 12/28/16
81	1.5.4.2 Testing (Mini frac, leak off)	Thu 6/2/16	Wed 11/16/16
82	**1.5.5 Geochemistry**	**Thu 6/2/16**	**Tue 8/1/17**
83	1.5.5.1 Core Sampling	Thu 6/2/16	Wed 11/16/16
84	1.5.5.2 Packer Interval Sampling	Thu 12/29/16	Tue 8/1/17
85	**1.5.6 Heat Transfer**	**Thu 11/17/16**	**Thu 4/19/18**

Project: DBH_Schedule_9_24_14_
Date: Tue 9/30/14

Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Critical
Critical Split
Progress

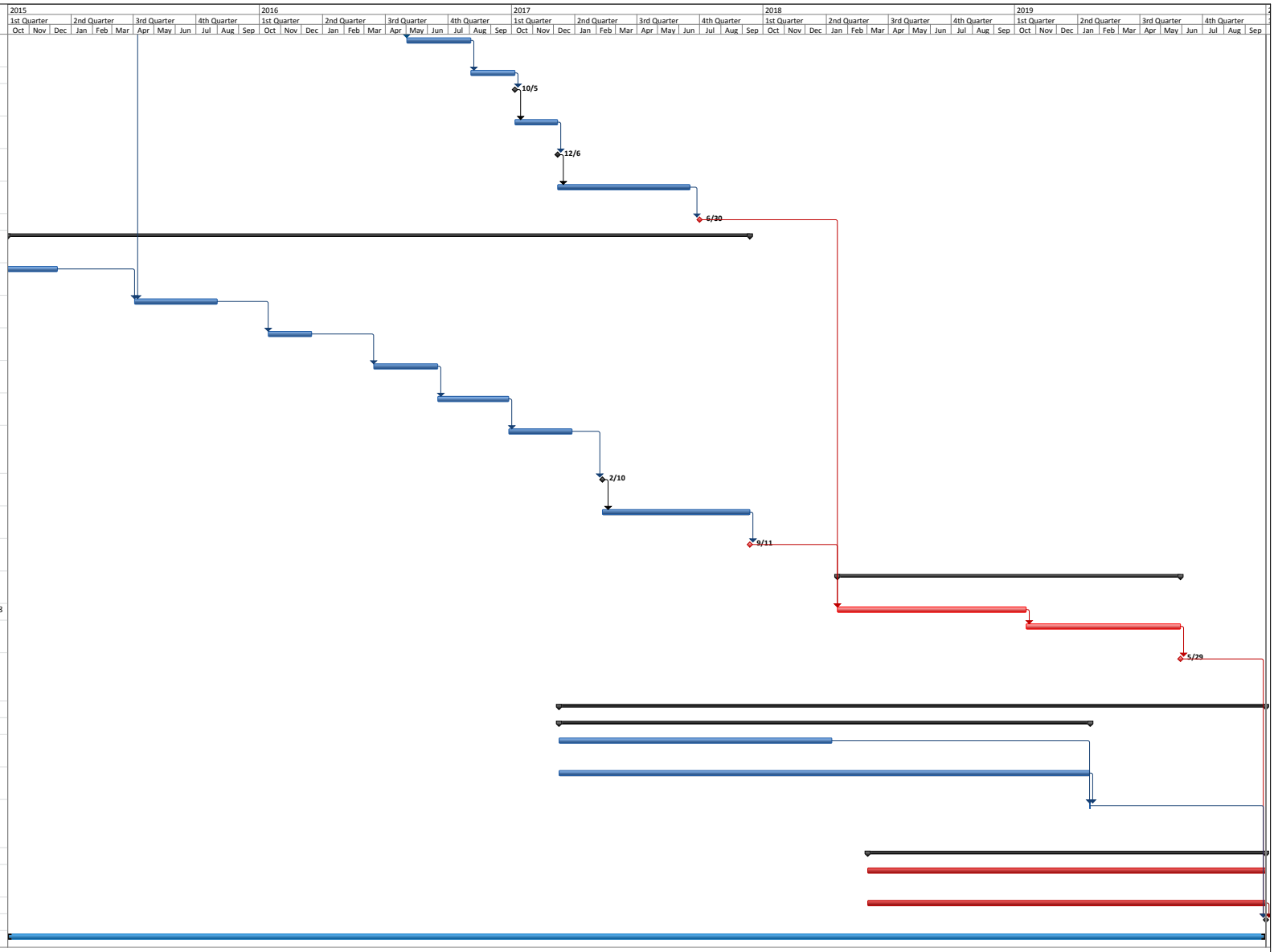
ID	Task Name	Start	Finish
86	1.5.6.1 Temperature Logs	Thu 11/17/16	Wed 12/28/16
87	1.5.6.2 Downhole Heater Test	Wed 8/2/17	Thu 4/19/18
88	**1.5.7 Borehole Seals**	**Fri 1/1/16**	**Tue 9/12/17**
89	1.5.7.1 Seal Design and Testing	Fri 1/1/16	Tue 9/12/17
90	**1.5.8 System and Subsystem Modeling**	Tue 5/5/15	**Mon 3/5/18**
91	1.5.8.1 Disposal System Modeling	Tue 5/5/15	**Mon 3/5/18**
92	1.5.8.2 Analysis and modeling completed to support design and development of post-closure safety analysis models and data	Tue 9/15/15	Tue 9/15/15
93	1.5.8.3 Modeling Completed Supporting Prioritization and Data Development	Mon 3/5/18	Mon 3/5/18
94	**1.6 Field Test Borehole**	Fri 5/13/16	Fri 12/1/17
95	**1.6.1 Conceptual Design and Requirements**	Fri 5/13/16	**Mon 12/12/16**
96	1.6.1.1 Develop Conceptual Design	Fri 5/13/16	Thu 8/11/16
97	1.6.1.2 Borehole Requirements	Fri 8/12/16	Thu 10/13/16
98	1.6.1.3 Casing Requirements	Thu 9/1/16	Wed 11/2/16
99	1.6.1.4 Cementing Requirements	Fri 9/16/16	Mon 12/12/16
100	1.6.1.5 Monitoring Requirements	Tue 7/26/16	Mon 12/12/16
101	1.6.1.6 Design Requirements Completed	Mon 12/12/16	Mon 12/12/16
102	1.6.1.7 Trade Studies	Fri 5/13/16	Mon 12/12/16
103	**1.6.2 Construction Specifications**	**Tue 12/13/16**	**Fri 3/3/17**
104	1.6.2.1 Borehole Specifications	Tue 12/13/16	Fri 3/3/17
105	1.6.2.2 Casing Specifications	Tue 12/13/16	Fri 3/3/17
106	1.6.2.3 Cementing Specifications	Tue 12/13/16	Fri 3/3/17
107	1.6.2.4 Monitoring Specifications	Tue 12/13/16	Fri 3/3/17
108	1.6.2.5 Construction Specifications Completed	Fri 3/3/17	Fri 3/3/17
109	**1.6.3 Borehole Construction**	**Mon 5/8/17**	**Fri 12/1/17**
110	1.6.3.1 Drill Site Preparation	Mon 5/8/17	Wed 7/5/17
111	1.6.3.2 Start Drilling	Fri 7/7/17	Fri 7/7/17
112	1.6.3.3 Drilling and Borehole Construction	Fri 7/7/17	Fri 12/1/17
113	1.6.3.4 Logging and Testing	Thu 6/1/17	Fri 12/1/17
114	1.6.3.5 Borehole Construction Completed	Fri 12/1/17	Fri 12/1/17
115	**1.7 Engineering and Demonstration**	Wed 10/1/14	Wed 5/29/19
116	**1.7.1 Canister and Canister Handling Equipment**	Wed 10/1/14	Mon 9/11/17
117	**1.7.1.1 Canisters**	Wed 10/1/14	Fri 6/30/17
118	1.7.1.1.1 Design Requirements	Wed 10/1/14	Mon 12/29/14
119	1.7.1.1.2 Conceptual Design	Fri 4/3/15	Tue 9/15/15
120	1.7.1.1.3 Deep Borehole Field Test Specification Report	Tue 9/15/15	Tue 9/15/15
121	1.7.1.1.4 Canister Specifications	Mon 2/15/16	Fri 4/15/16



Project: DBH_Schedule_9_24_14_
Date: Tue 9/30/14

Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Critical
Critical Split
Progress

ID	Task Name	Start	Finish
122	1.7.1.1.5 Procure Single Test Canister	Mon 5/2/16	Tue 8/2/16
123	1.7.1.1.6 Canister Testing	Wed 8/3/16	Wed 10/5/16
124	1.7.1.1.7 Canister Testing Complete	Wed 10/5/16	Wed 10/5/16
125	1.7.1.1.8 Revise Canister Specs if needed	Thu 10/6/16	Tue 12/6/16
126	1.7.1.1.9 Specification Finalized	Tue 12/6/16	Tue 12/6/16
127	1.7.1.1.10 Procure Canisters for String Testing	Wed 12/7/16	Fri 6/16/17
128	1.7.1.1.11 Test Canisters Pro	Fri 6/30/17	Fri 6/30/17
129	**1.7.1.2 Canister Handling Equipment**	Wed 10/1/14	Mon 9/11/17
130	1.7.1.2.1 Design Requirements	Wed 10/1/14	Thu 12/11/14
131	1.7.1.2.2 Conceptual Design	Fri 4/3/15	Fri 7/31/15
132	1.7.1.2.3 Handling Design Specifications	Wed 10/14/15	Tue 12/15/15
133	1.7.1.2.4 Procure Handling Equipment	Tue 3/15/16	Wed 6/15/16
134	1.7.1.2.5 Evaluaton and Testing Prototype	Thu 6/16/16	Mon 9/26/16
135	1.7.1.2.6 Revise Handling Equipment Specs if needed	Tue 9/27/16	Tue 12/27/16
136	1.7.1.2.7 Specifications Finalized	Fri 2/10/17	Fri 2/10/17
137	1.7.1.2.8 Procure Equipment	Fri 2/10/17	Mon 9/11/17
138	1.7.1.2.9 Handling Equipment Procured	Mon 9/11/17	Mon 9/11/17
139	**1.7.2 Canister Emplacement Demonstration**	**Wed 1/17/18**	**Wed 5/29/19**
140	1.7.2.1 Canister Handling	Wed 1/17/18	Wed 10/17/18
141	1.7.2.2 Canister Lowering and Retrieval	Thu 10/18/18	Wed 5/29/19
142	1.7.2.3 Engineering Demonstrations Activities Completed	Wed 5/29/19	Wed 5/29/19
143	**1.8 Field Test Assessment**	Fri 12/9/16	Mon 9/30/19
144	**1.8.1 Safety Analyses**	Fri 12/9/16	**Fri 1/18/19**
145	1.8.1.1 Preclosure Safety Analysis	Fri 12/9/16	Mon 1/8/18
146	1.8.1.2 Postclosure Safety Analysis	Fri 12/9/16	**Thu 1/17/19**
147	1.8.1.3 Safety Analyses for Field Experiment Concept Confirmation Completed	**Fri 1/18/19**	**Fri 1/18/19**
148	**1.8.2 Field Test Evaluation**	Fri 3/2/18	Mon 9/30/19
149	1.8.2.1 Safety Case Demonstration	Fri 3/2/18	Mon 9/30/19
150	1.8.2.2 Assessment of Concept	Fri 3/2/18	Mon 9/30/19
151	1.8.2.3 Assessment Completed	Mon 9/30/19	Mon 9/30/19
152	1.9 Project Managment	Wed 10/1/14	Sun 9/29/19



Project: DBH_Schedule_9_24_14_
Date: Tue 9/30/14

Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Critical
Critical Split
Progress

APPENDIX D – RISK MANAGEMENT MATRIX

Risk Statement (Title and Description)	Approach and Plan (Mitigation)	Status
1.1 Field Test Siting		
• No responses (or delayed response) to RFI. There may be schedule delays involved in the procurement process (i.e. delays in sending, receiving, reviewing or approving RFI or RFP, delays in reaching agreement on contract terms, political impacts due to election or changes in administrations, etc.).	• Plan for schedule contingency. Develop parallel paths to remove approval activities from the critical path. • Slip project schedule	
• RFI does not target responses	• Reissue RFI	
• Excessive NEPA Compliance Requirements	• Negotiate with regulators for reasonable, practical requirements	
• Site selection decision may face public/stakeholder opposition • Elections (state or local) change political and/or public opinion	• Hold public meetings	
• Economic conditions could impact the schedule through unavailability of equipment, services, or labor	• Contract in advance of start of drilling. Possibly lock in rates or fixed price on contract.	
• Inadequate Site Characterization Data Available	• Collect site specific data • Disqualify site that does not have data	

Risk Statement (Title and Description)	Approach and Plan (Mitigation)	Status
1.2 Procurements for Drilling and Engineering Services • Aggressive scheduling due to issuance of the RFP prior to site selection • Delays in obtaining DOE approval for the drilling procurement because of the large financial obligation • Limited response to drilling RFPs: o drilling contractors prefer "standard" oil drilling to "non-standard" deep borehole o "scientific" drilling (with several stops and starts for downhole experiments) has a more uncertain schedule than oil drilling o if there is only one procurement for both holes, only a few companies are capable of drilling larger Field Test Borehole • Decision on Field Test Borehole needs some feedback from the Characterization Borehole • Delays or limits on funding (e.g., continuing resolution, congressional shutdown) • A limited number of drilling contractors with the necessary skills for drilling large diameter boreholes to the required depths is available • Award Protests	• Phase the RFP with final site given before final submission of RFP • Drilling Integrated Services Contract • Offer financial incentives for non-standard activities (i.e., scientific drilling). • Break procurements into two RFPs and allowing bidding on either or both • Delay Field Test Borehole procurement until completion of Characterization Borehole • Plan to award contracts prior to start of Fiscal year • Develop a rigorous procurement processes including a competitive bid process, extremely detailed but flexible specifications and a request for information • Allow schedule contingency	• Contacting "large borehole" drilling contractors
1.3 Legal and Regulatory Requirements • Delays in permitting/approvals • NEPA (Environmental Assessment) process and DOE decision delays	• Allow schedule contingency • Schedule NEPA activities early in project • Find a site that has NEPA activities already in place in order to use site-wide EIS	• NEPA checklist under development

Risk Statement (Title and Description)	Approach and Plan (Mitigation)	Status
1.4 Characterization Borehole (Design, Drilling, and Construction)		
• Unexpected issues in drill site preparation – e.g., delays in building roads, fences, bad weather, uncover native artifacts)	• Employ experienced personnel and assure that the best expertise is present during critical activities in the borehole construction process. The project will use Standard Operating Practices developed by the drilling industry (i.e., API)	
• Lost time – accident	• Build in contingency, safety planning, contractor safety record and, training program, into RFP selection criteria	
• Scientific Hold Points	• Utilize a day rate contract	
• The risks involved in deep borehole drilling are the major risks to the project. Drilling has risk largely because of unknown conditions in the subsurface.		
• Uncertain lines of responsibilities about who can stop or delay work.	• Clarify roles and responsibilities in Project Plan (stop work authority, scientific delays. etc.). • Use an integrated contractor.	
• Downhole equipment failure (i.e. hung bit, blowout)	• Use experienced driller	
• Drilling through aquifers; how do we seal and assure the integrity?	• Clearly understand State regulations	
• Problems with availability of drilling services and personnel (e.g., oil boom monopolizes personnel)	• Contract for services early in project	
• Problems with availability of drilling materials (e.g., casing, mud)	• Contract for services early in project	
• Failure of bore hole to meet requirements	• Move site	

Risk Statement (Title and Description)	Approach and Plan (Mitigation)	Status
1.5 Scientific Testing and Analysis • Inability to conduct borehole testing because of borehole instability • Technical maturity • The project is performing R&D and thus has a high level of technical uncertainty • Technical questions to be answered could include the following: How do we characterize the borehole itself, the surrounding environment; closure with time; impacts of heat; what happens to the borehole over time; borehole closure (post emplacement)	• Stabilize borehole (casing, etc.) • Mature the technology on the Characterization Borehole prior to drilling the Field Test Borehole. • Perform independent technical reviews to minimize technical risks. The project has included cost and schedule contingency in case these risks are realized • Design a test and evaluation that responds to these technical issues	
1.6 Field Test Borehole (Design, Drilling, and Construction) • Unable to drill a large-diameter borehole	• See Characterization Borehole Risk • Conduct field test in smaller-diameter Characterization Borehole	
1.7 Engineering and Demonstration • Consider an unplanned accident scenario of the canister being stuck or other unexpected equipment failure	• Obtain good characterization of the borehole diameter using a Caliper log • Assure the canister is designed with sufficient tolerances to easily move through to borehole. • Design canister for ease of retrieval • Design canister to accommodate overdrilling (material type, configuration) • Conduct assessment of potential unplanned scenarios and develop mitigation plans	

Risk Statement (Title and Description)	Approach and Plan (Mitigation)	Status
1.8 Field Test Assessment • TBD		
1.9 Project Management • TBD		
Other Risks • Impact of prior DOE activities (e.g., WIPP incident) on project	• Study lessons learned from prior project with related technologies	

APPENDIX E – NEPA CHECKLIST

Sandia National Laboratories
NEPA Review Information

NEPA ID: NM14-0247

U.S. DEPARTMENT OF ENERGY
Sandia Site Office
NEPA CHECKLIST

Project/Activity Title: Deep Borehole Field Test	**NEPA ID Number:** NM14-0247	**Date:**
Program Office: DOE	**Project/Activity Number:**	
Contact Name(s)- Owner: Freeze,Geoffrey A., 06224, MS0747, 505-284-8594 **NEPA SME:** Miller,Amy Renee, 04143, MS0730, 505-845-8810	**Reviewed and Submitted By:** , MS,	

1.0 PROJECT/ACTIVITY DESCRIPTION: Include who, what, where, and why. (Attached)

2.0 ES&H CONCERNS: Identify ES&H issues in the following categories associated with the proposed project/activity.

		Yes	No
Use and Storage			
2.1	Chemicals	X	
2.2	Petroleum/fuel products	X	
2.3	High energy sources/explosives	X	
2.4	Pesticides/herbicides	X	
Waste			
2.5	Solid waste	X	
2.6	Hazardous waste	X	
2.7	Radioactive waste/materials *	X	
2.8	Mixed waste (rad + haz)		X
Emissions			
2.9	Air emissions	X	
2.10	Liquid effluents (other than those described in 2.5 - 2.8)	X	
Health & Safety Issues			
2.11	Radiation exposure		X
2.12	Chemical exposure	X	
2.13	Noise levels	X	
2.14	Transport of hazardous materials/waste	X	

		Yes	No
Land and Building Issues			
2.15	Clearing/excavation/land disturbance/landscaping	X	
2.16	Archaeological/cultural resources/building modifications	X	
2.17	Special status species/environment	X	
2.18	Real estate issues	X	
2.19	Related off-site activities	X	
Special Issues			
2.20	Asbestos		X
2.21	Utility system modifications/power use/water use	X	
2.22	Environmental Restoration/Long Term Environmental Stewardship	X	
2.23	Microorganisms/biological toxins		X
2.24	Fire danger/Other environmental concerns	X	
2.25	Nanomaterials		X
2.26	Comments on ES&H Concerns		X

* While not anticipated, trace amounts of naturally occurring radioactive material might be encountered during drilling and/or in soil and water samples.