FACTSHEET FOR PARTNERSHIP FIELD VALIDATION TEST

Partnership Name	Big Sky Regional Carbon Partnership		
Contacts:	Name	Organization	E-Mail
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Principal Investigator	Lee Spangler		
Field Test Information:	Basalt Sequestration Pilot Test		
Test Location	Near Wallula township in Eastern Washington State		
Amount and Source of CO_2	Tons	Source	
	3000	Refinery	
Field Test Partners (Primary Sponsors)	Pacific Northwest National Lab – Pacific Northwest Division, Idaho State University, Idaho National Lab, Boise White Paper L.L.C., Shell Oil Company, Port of Walla Walla, Portland General Electric		

Summary of Field Test Site and Operations:

The goal of the Basalt Sequestration Pilot Test is to prepare for and conduct a small scale CO_2 sequestration project in deep basalts of the Columbia River Basalt Group. The effort under Phase II consists of site characterization activities to be followed by injection of 3000 tons maximum of CO_2, provided site characterization data demonstrate the feasibility and safety of doing so and a permit for the injection phase is approved by the Washington State Department of Ecology.

The field test location is situated approximately 11 miles south of Pasco, Washington in a general area that is lightly inhabited and on private property owned by Boise White Paper L.L.C. in western Walla Walla County, within eastern Washington State. Figure 1 shows the general features of the field test pilot study area, which is located within an active paper mill industrial facility.

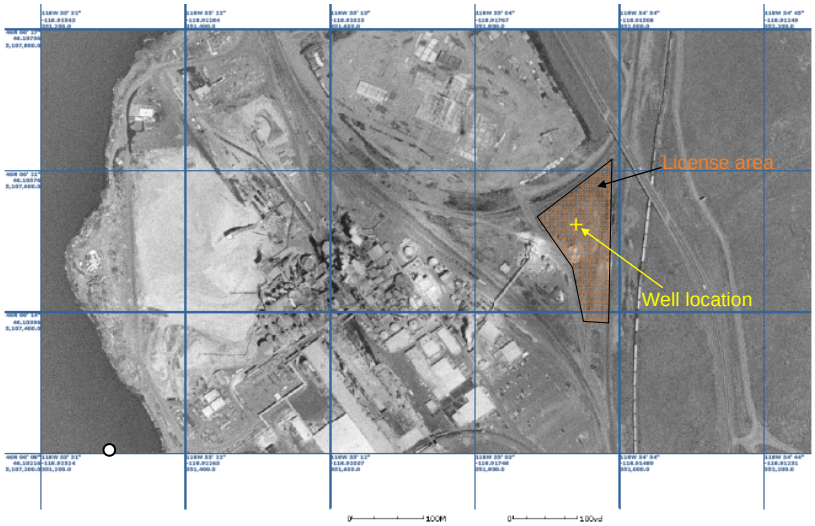

Figure 1. Satellite View of Field Test Study Area. Candidate injection well location is indicated.

The location of the proposed field test site lies within the Columbia River Basalt province. Anticipated subsurface geologic conditions at the field test site include: 100 ft of surficial alluvial deposits; 1,200 ft of combined Saddle Mountains Basalt Formation (5 basalt flows) and

sedimentary interbeds of the Ellensburg Formation (4 to 5 sedimentary interbeds); 1,200 ft of Wanapum Basalt (11 basalt flows); 5 to 40 ft of Vantage interbed/paleosol horizon; >6,000 ft of Grande Ronde Basalt/undifferentiated CRB (>20 basalt flows); >1,000 ft undifferentiated sub-basalt, sedimentary formation deposits; and the underlying crystalline/metamorphic basement complex. Groundwater within the Grande Ronde Basalt and below is expected to be non-potable containing high concentrations of fluoride and sulfides.

Research Objectives:

The overall objectives of the Basalt Sequestration Pilot Test include:

1. Address the critical technical issues associated with the injection, and fate and transport of supercritical CO_2 in one or more interflow zones in a deep basalt formation
2. Participate in public outreach activities as required or as requested by industry partners
3. Work with state regulators to ensure timely support of necessary permitting.

Site characterization activities will be undertaken to support drilling, injection, and monitoring. These activities will include: 1) installation of shallow soil gas monitoring probes and collection and analyses of gas samples from these probes to begin development of a database on variability in CO_2 and other trace gas concentrations at the site, and 2) conducting a quasi-3D seismic survey near the site to identify any faults or fracture zones that must be avoided in locating an injection well at the site.

Summary of Modeling and MMV Efforts: (Use the table provided for MMV)

Preliminary simulations of CO_2 injection into the flow tops of two individual basalt flows in the Grande Ronde (GR) basalt formation were executed using the STOMP-H_2O-CO_2-NaCl simulator (White and Oostrom 2006). The two flows considered were the GR-5 flow and the Umtanum flow. Both flow tops have high permeabilities and are good candidates for injection. The objective of the simulations was to determine the radius of a CO_2 plume injected during a proposed pilot scale test needed for submission of permit documents. Two basalt flow tops in the Grande Ronde Basalt formation were considered, the RRL-2/GR-5 (unnamed flow), 26 ft thick, and the RRL-2/GR-9 (Umtanum Flow).

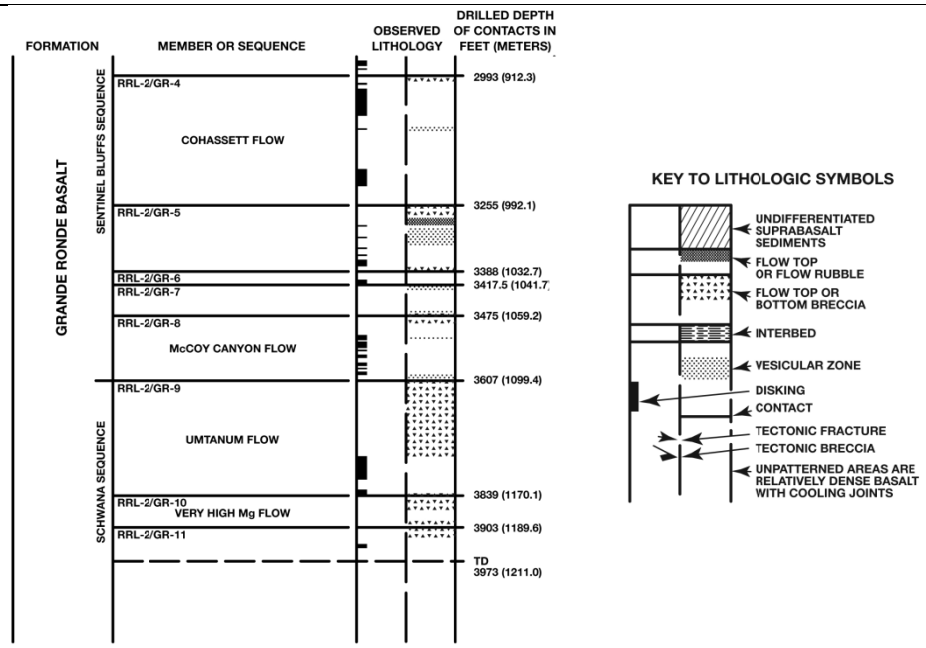

Figure 2. Lithologic Unts in the RRL-2 Corehole based on (Wintczak 1984) used to estimate properties at the Wallula test site.

The transmissivity of GR-5 flow top in the RRL-2 well was determined to be 9.87 ft^2/day ($1.06x10^{-5}$ m^2/s) using hydraulic tests (Strait and Spane 1983). The transmissivity of the Umtanum flow top was determined to be 480 ft^2/day ($5.16x10^{-4}$ m^2/s) using hydraulic tests (Strait and Spane 1982). The permeabilities assumed for the basalt flow materials were $1x10^{-11}$ m/s for the dense flow interiors, $1x10^{-4}$ m/s for the GR-5 flow top breccia, $1x10^{-5}$ m/s for the Umtanum flow top breccia, $2x10^{-7}$ for rubble, and $1x10^{-7}$ for vesicular basalt. Two-dimensional simulations with a cylindrical coordinate grid were developed. Vertical grid spacing was 1 ft, while radial grid spacing was variable, ranging from 0.08 m to 5.9 m. Homogeneous layers were assumed based on the observed lithology surrounding the GR-5 flow top and the Umtanum flow top. The contacts between the layers were given a random amount of roughness to simulate the heterogeneity of those contacts.

In the Umtanum flow top simulations, 3000 MT of CO_2 is injected over an interval between 3607-3761 ft below ground surface (bgs) and the injected CO_2 quickly rises to the top of the formation where it is trapped by the low-permeability overlying McCoy Canyon flow. The resulting plume has a radius of 550 ft. After 2 years, 26% of the injected CO_2 has dissolved into the aqueous phase.

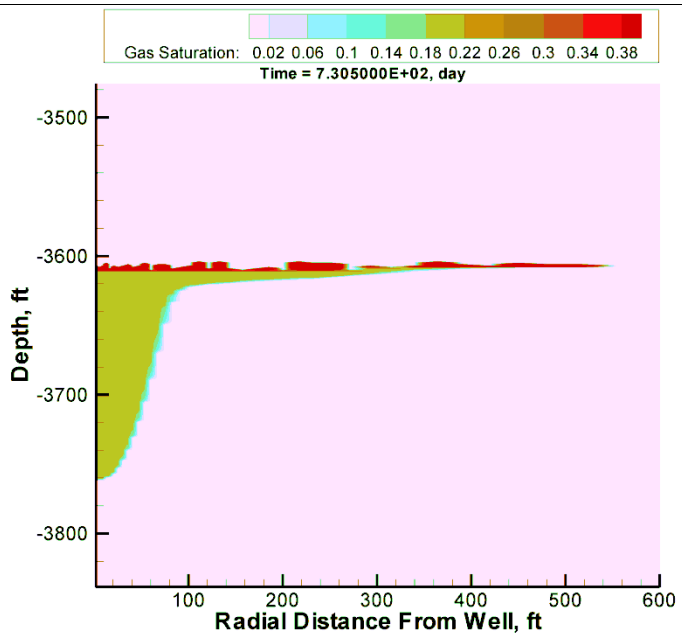

Figure 3. CO_2 Gas Saturation in the Umtanum Flow Top 2 Years Post-Injection at the Rate of 100 tonnes/day for 30 days

The results of the numerical modeling indicate that both the Umtanum flow top and the GR-5 flow top are good candidates for CO_2 injection due to their high permeability. There is uncertainty in the results of these simulations because the unsaturated flow properties (e.g., air entry pressure) of the basalt flow tops were estimates and the data are taken from wellbore data approximately 30 miles from the pilot injection site. Additional simulations were conducted to assess risk of vertical CO_2 migration through undetected faults or fractures. Regardless of the number and extent of high permeability features in the flow interior sections added in the model, the results all show very limited vertical migration of the CO2. The high permeability interflow zones act as CO_2 sinks. Complete dissolution of the CO_2 occurs into the formation water in the immediately overlying interflow zones so that all the CO_2 remained thousands of feet below the Wanapum basalt aquifer.

MMV Summary

To date, the MMV activities undertaken are shallow soil gas monitoring and a seismic survey. Both compositional analysis and isotope fraction mass spectrometry have been conducted on the gas samples and show no anomalous chemical or isotopic properties.

An innovative 2D surface seismic swath profile was acquired near Wallula, Washington in December, 2007 and provides the framework for fault detection and first order characterization of subsurface stratigraphy and structure at the field site. Modern seismic vibrators address the challenge of producing consistent station-to-station wavelets with multiple vibrating sources is through the use of ground-force phase locking (GFPL) technology.

The results from the seismic acquisition (Figure 4) show that there are no deep seated surface or subsurface faults along the seismic line, and that a thick succession of basalt layers are present and undisturbed by large scale faulting. This information indicates that it is safe to proceed with the next stage of site characterization through drilling a well into the basalts and analyzing subsurface geologic and hydrogeologic data. This seismic survey represents the first known success of surface-based seismic imaging of subsurface basalt geology and represents a critical milestone for future subsurface characterization and monitoring of sequestration of CO_2 in basalts. In addition, subsets of the data gathered by this survey form a valuable resource for

government, academia, and industry researchers in the development of new seismic technologies for improved imaging of basalts and other fast velocity rocks.

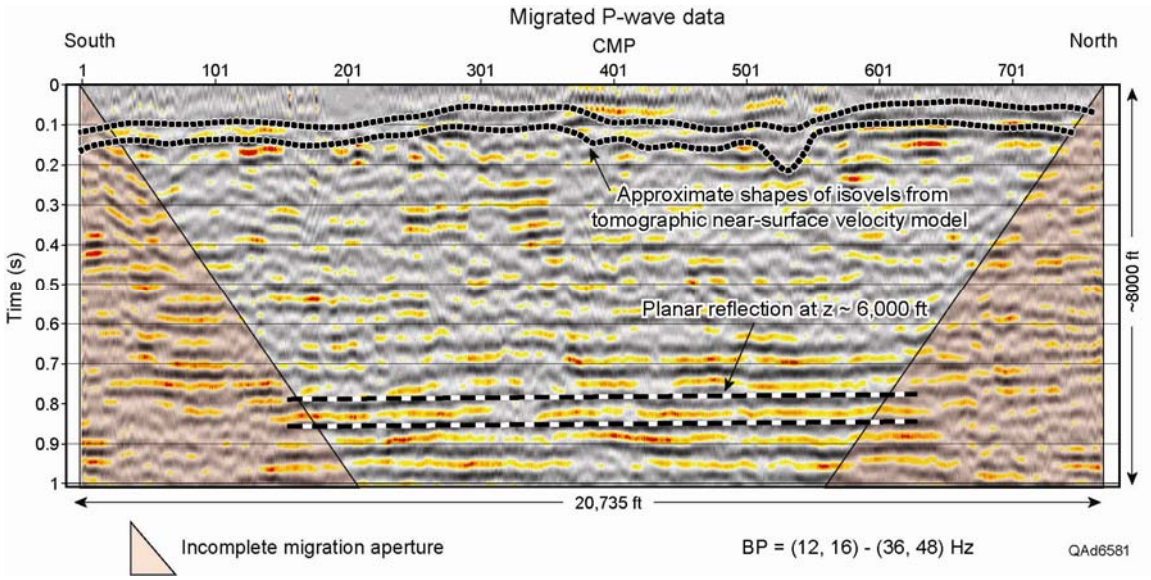

Figure 4. P-P image produced in early-stage processing of the Wallula data. The triangular areas at the ends of the profile show end of line affects on the data redundancy. The flat lying reflectors at about 0.8 seconds (two way time) are evidence for lack of deep seated faulting.

In the course of processing the Wallula seismic data, two important discoveries also were made:

- The P-wave data are heavily overprinted by shear waves on the vertical P-wave geophone. The identification and 3C separation of this type of noise allowed its removal. This would have not been possible with standard acquisition and processing methods.
- Down-going P-waves generated shear waves that both continued down and returned to the surface as shear waves. This most likely occurred when down-going P waves hit the top of the uppermost basalt flows. This production of down-going shear waves is similar to using an expensive shear wave seismic source to generate yet another type of valuable seismic data. These data, when separated to form images as an additional research experiment, may reveal considerable new information on the subsurface geology.

Accomplishments to Date:

- An innovative seismic survey was completed in December 2007 that resulted in successful imaging of the deep basalt strata at the field site.
- A revised Field Activity Plan for the field pilot study was issued in September 2008:

  Spane, F. A., B. P. McGrail, E. C. Sullivan, D. S. Goldberg, T. L. McLing, R. S. Weeks, and R. W. Smith. 2007. *Field Activity Plan: Characterization Test for CO_2 Sequestration in the Columbia River Basalt Group*. PNWD-3844, Revision 3 Pacific Northwest National Laboratory, Richland, Washington.
- Two shallow soil gas probes were installed in the vicinity of the field site. Gas samples have been collected on a monthly basis to look for any anomalous gas composition readings and to establish background concentrations for CO_2 and other gases well ahead of injection.

- A Class V Well Registration package was prepared and submitted to the WADOE
- Site preparation and contracts for drilling and drilling services are either complete or nearing completion
- Extensive stakeholder and public involvement activities have been conducted.

Summarize Target Sink Storage Opportunities and Benefits to the Region:
Within the BSCSP region, there are several major geological provinces with high potential for geologic sequestration. One of these is the Columbia Plateau Volcanic Province, which represents the dominant regional geologic feature occupying much of Idaho, Oregon, and Washington states. The CO_2 storage potential of the Columbia River Basalt Group (CRBG) within this volcanic province has been estimated at between 50 to 100 $GtCO_2$, making it one of the most significant potential deep geological storage formations in the region. The ultimate goal of the Basalt Sequestration Pilot Test is to demonstrate and validate the safe, permanent storage of CO_2 in reactive mafic formations that underlie this site and surrounding region.

Cost:

Total Field Project Cost: $6,248,768

DOE Share:	**$4,748,768**	**76%**
Non-Doe Share:	**$1,500,000**	**24%**

Field Project Key Dates:

Baseline Completed: 06/30/2009

Drilling Operations Begin: November 2008

Injection Operations Begin: June 2008

MMV Events: Soil gas monitoring in progress, seismic survey completed

Field Test Schedule and Milestones (Gantt Chart):

Task 16.0	Q1-06	Q2	Q3	Q4	Q1-07	Q2	Q3	Q4	Q1-08	Q2	Q3	Q4	Q1-09	Q2	Q3	Q4	Q1-10	Q2
Task 16.1 Planning and Permitting																		
Public Outreach and Regulatory Briefings								Gm31										
Submit NEPA EQ									Gm32									
Submit Class V UIC Application															Gm33			
Submit SEPA Application										Gm34								
Task 16.2 Characterization Options and Reservoir Simulations																		
Transport and Reactive Process Modeling Simulations								Gm35										
Task 16.3 Site Characterization Activities																		
Install Soil Gas Monitoring Probes								Gm36										
Obtain land access permission from adjoining landowners								Gm37										
Complete Seismic Survey								Gm38										
Task 16.4 - Pre-Injection Characterization and Drilling																		
Drill and Complete Well														Gm39				
Complete Pre-Injection Sampling and Testing															Gm40			
Task 16.5 - CO2 Procurement																		
Complete CO2 Injection Facilities															Gm41			
Task 16.6 - Injection																		
Complete Injection and Evaluate Pressure Responses															Gm42			
Task 16.7 - Site Monitoring and Verification																		
Conduct Atmospheric & Soil, Geochemical, and Microbiological Monitoring																		Gm43
Task 16.8 - Pre-Closure Characterization																		
Assess in-situ geochemical reactions																		Gm44
Task 16.9 Site Closure and Restoration																		
Continued Use Determination or Plug and Abandon Well																		Gm45