UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

June 18, 2014

4WD-FFB

Rachel Blumenfeld
United States Department of Energy
Portsmouth/Paducah Project Site Office
P.O. Box 1410
Paducah, Kentucky 42002

RE: **EPA Conditional Concurrence of the Treatability Study Design, Design Drawings and Technical Specifications Package for the C-400 Interim Remedial Action Phase IIb Steam Injection Treatability Study at Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/LX-07-1295&D2)**

Dear Ms. Blumenfeld,

EPA has reviewed the *Treatability Study Design, Design Drawings and Technical Specifications Package for the C-400 Interim Remedial Action Phase IIb Steam Injection Treatability Study at Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/LX-07-1295&D2)* (TS Design). As described in the October 31, 2014 Memorandum of Agreement for resolution of dispute for the C-400 project, the FFA parties agreed to have 'on board' real-time reviews of the TS Design in order to accelerate the review cycle and approve the D2 document to reduce the overall TS schedule. The FFA parties have had several real-time review meetings to resolve issues related to the D1 document, and much progress has been made toward finalizing the TS Design.

During the last meeting on May 8, 2014, the FFA parties agreed on an approach for resolving the remaining issues specifically the model calibration criteria. However, the D2 TS Design submitted by Department of Energy (DOE) on May 24, 2014 did not include calibration criteria and uncertainty language that EPA requested and discussed in great length during the meeting. EPA is disappointed that DOE did not include language agreed to, that no explanation was provided before the document was submitted, and that DOE refused to have a conference call to quickly resolve the issue once EPA and KDEP realized the language was not included in the D2 document. However, DOE inadvertently posted a D2 TS Design document on their Secure FTP site on June 2, 2014 that *did* include language EPA requested. EPA would like this calibration criteria language added with some modification to the D2 document along with uncertainty language specified below.

In accordance with the Federal Facility Agreement (FFA) Section X.X.I. Finalization of Documents, EPA is issuing a conditional concurrence on this Primary

Document. The condition which must be satisfied for EPA concurrence is for the DOE to revise this Primary Document as specified in EPA's comments [Enclosed]. The revised Treatability Study Design (styled as a D2/R1), satisfying the condition set forth above, shall be submitted by the DOE on or before July 18, 2014 for EPA approval.

If you have any questions or require additional information, please contact me at (404) 562-8513.

Sincerely,

Jennifer Tufts

Digitally signed by Jennifer Tufts
DN: cn=Jennifer Tufts, o=US EPA Region 4, ou=Federal Facilities Branch, email=tufts.jennifer@epa.gov, c=US
Date: 2014.06.18 07:50:40 -04'00'

Jennifer Tufts
Remedial Project Manager
Federal Facilities Branch

EPA Conditional Concurrence of the Treatability Study Design, Design Drawings and Technical Specifications Package for the C-400 Interim Remedial Action Phase IIb Steam Injection Treatability Study at Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/LX-07-1295&D2)

EPA Region 4 Conditional Concurrence is contingent on the following comments being addressed in the C-400 Treatability Design Document:

1. Section 3.4 Temperature Monitoring Point, page 15. The text states that the temperature sensors in the bottom of the UCRS and top of the McNairy will be 'within 18 inches' of the interface with the RGA. However, the Drawing (page A-5) shows two sensors in both the UCRS and McNairy, one foot and two feet away from the interface. The drawing or text should be corrected.

2. Appendix C. Section F of 02181-3 (page C-18) contains functionality testing language discussed during the review meetings. Section G of 02180-4 (page C-14) should also include the functionality testing language included in Section F of 02181-3.

3. As discussed in the review meetings, a description of the model uncertainty should be added to the document but was not included. The following language should be added to Section 6.5.1 2-D Radially Symmetric Model of Phase I Steam Injection: "The model uncertainty will be evaluated based on the NRMSE, the error in the validation run(s), and the results of the sensitivity analysis. This uncertainty will be used to put bounds on the results of the predictive model results, so that a range of engineering parameters for the conceptual design for a full scale steam injection will be determined from the modeling. The range in engineering parameters will be incorporated into the cost estimates developed for the full scale remediation."

4. The FFA parties agreed on an approach for resolving model calibration criteria (5/8/14). However, the D2 document DOE submitted 5/24/14 did not include calibration criteria. DOE posted a different version of the D2 TS Design document on the Secure FTP site on June 2, 2014 that did include calibration criteria language EPA requested. The redlined calibration criteria language on the pages numbered 36 and 37 should be added to the D2 document (attached) with the exception that the first two sentences of the 5th paragraph on page 37 should be rewritten as:

   "The model will be considered to be calibrated when the RSS is minimized and the NRMSE is 10% with an approximately random spatial distribution of model error. This criterion of 10% NRMSE is considered a goal because it is based on groundwater modeling studies where the simulation variable is the hydraulic head."

5. Model validation should be conducted during the calibration process. A subset of 20 to 30% of the data should be separated from the calibration process and be used for model validation purpose. The NRMSE value should be used for validation analysis. The NRMSE value for validation should be as close as possible to the same value for calibration (preferably, within 5% of the calibration NRMSE). Iterative approach should be used to improve the calibration and validation NRMSE values. Model validation should be described in Section 6.5.1 2-D Radially Symmetric Model of Phase I Steam Injection.

Redline pages 36 and 37 from the Treatability Study Design, Design Drawings and Technical Specifications Package for the C-400 Interim Remedial Action Phase IIb Steam Injection Treatability Study at PGDP, Paducah, Kentucky (DOE/LX-07-1295&D2).

should be atmospheric pressure and temperature. Estimates of the porous media thermal properties (rock grain density, porosity, rock grain specific heat capacity, and dry and wet thermal conductivity) consistent with the known properties of the RGA and geologic formations of similar composition (Lake 1989) should be used. The multiphase relative permeability and capillary pressure curves also should be consistent with the known properties of the RGA (McConnell and Numbere 1995).

Deleted: and geologic formations of similar composition ([illegible] 2003)

The model input will consist of the measured steam injection rates and specific enthalpies into the Middle and Lower RGA well screens. The model output will consist of the time-dependent, 2-D distribution of temperature; gas phase saturation; and pressure. The model will be calibrated by adjusting the RGA formation intrinsic permeability in the horizontal and vertical directions to produce a best match of the observed temperatures from the multiple temperature sensor locations. Matching the field data may require the use of layering within the RGA.

The primary calibration target is the steam arrival time at each temperature sensor, as determined by the time from the start of steam injection until steam temperatures of approximately 100°C are observed at the sensor. While there are no benchmarks for model calibration as there are with groundwater models, this approach was used successfully as part of the 321M Area pilot testing at the Savannah River Site.

Deleted: to calibrate modeling conducted

Deleted: site. The model will be considered to be calibrated when it can predict the steam front arrival time to an accuracy of +/- 15% in at least 75% of the temperature sensors. Note that there will be approximately 140 individual temperature sensor locations in this test.

The model calibration will be performed by minimizing the relative error between the observed and predicted steam arrival times at the temperature sensors. At each sensor location "I," the relative error is defined as follows:

$$relative\ error_i = \frac{(observed_i - predicted_i)}{observed_i}$$

The overall error from a model simulation is calculated by summing the square of the errors. In optimization theory, this is known as the "residual sum of squares," or RSS. The RSS is as follows:

$$RSS = \sum_{i=1}^{n} (relative\ error_i)^2$$

where n is the number of temperature monitoring points.

A special treatment is required for temperature monitoring locations that do not reach steam conditions (either in the field or in the model). At these locations, there would be no numerical value associated with the steam arrival time. The standard way of incorporating these types of data in the RSS is to assign a numerical penalty function for the error at a location if the model fails to match the field observation. For this problem, the value of the penalty could be in the range of 0.5 to 1 (50% to 100% relative error). Therefore, if the model predicts steam arrival at a location where it was not seen, or if the model fails to predict steam arrival at a location where it was seen, then the error at that location could be assigned a value of 0.5 to 1.

The minimization of the RSS will be performed by adjusting calibration parameters (primarily the vertical and horizontal permeability and the thermal properties). This minimization may be done manually, or the process may be automated. The error in the calibration is minimized when further adjustments of the calibration parameters fail to yield any further reduction of the RSS.

36

The average relative error of the predicted versus observed steam front arrival times can be calculated by summing the absolute value of relative errors from the monitoring points, and dividing by the number of points:

$$\text{average relative error} = \frac{\sum_{i=1}^{n} |\text{relative error}_i|}{n}$$

In the field of groundwater modeling, model calibration usually is performed by minimizing the root mean square of the absolute error (RMSE). The absolute error is the difference between the observed and predicticted values:

$$\text{error}_i = (\text{observed}_i - \text{predicted}_i)$$

The RMSE is calculated by

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (\text{error}_i)^2}{n}}$$

Groundwater model calibration error is quantified by calculating the normalized root mean square error (NRMSE), which is the RMSE divided by the range of observed values:

$$NRMSE = \frac{RMSE}{\text{observed}_{max} - \text{observed}_{min}}$$

The model will be considered to be calibrated when the RSS is minimized and the NRMSE is less than 10%, with an approximately random spatial distribution of model error. This criterion of 10% NRMSE is based on groundwater modeling studies where the simulation variable is the hydraulic head. It should be recognized, however, that the model calibration being performed here is fundamentally different from groundwater modeling, because it involves multiphase flow and heat transfer, and the simulation variable is the steam front arrival time. Note that there will be approximately 160 individual temperature sensor locations in this test. Following calibration, a parameter sensitivity study will be performed by varying the main calibration parameters (horizontal and vertical permeabilities, and thermal properties).

It is possible that the observed steam temperature front during Phase I injection may not be radially symmetric due to the influence of local heterogeneities. In this event, it may be necessary to use a 3-D configuration to model the Phase I steam injection. If a 3-D model is used, it will be subject to the same calibration criteria described above.

The key output from this calibration effort will be the values of horizontal and vertical permeability in the RGA in the vicinity of the Middle and Lower RGA well screens. It also is possible that information on the structure of layering or heterogeneity in the RGA may be determined from this test.