[Form 2 (to be reported to Committee on Countermeasures for Contaminated Water Treatment and to be disclosed to public)

Technology Information	
Area	6 (Select the number from “Areas of Technologies Requested”)
Title	Understanding Groundwater Flow
Submitted by	Shaw Global Services, LLC

1. Overview of Technologies (features, specification, functions, owners, etc.)

Shaw Global Services is responding to the request for the information on understanding groundwater flow as follows.

- ***Collect data necessary to investigate groundwater flow (geological condition/ groundwater data measurement system, etc.) Investigating area geological structure, water permeability, groundwater level, groundwater pressure, groundwater velocity.***

  Shaw Global Services has extensive experience and expertise in assessing and solving groundwater problems, from water supply to environmental assessment and cleanup, including sites with radionuclide contamination of soils and groundwater. A powerful approach to evaluating and designing groundwater projects that Shaw Global Services provides our clients is to evaluate existing data, recommend areas for acquisition of additional data to improve understanding of the hydrogeology, and integrate the data to using 3-dimensional numerical modeling to evaluate alternatives to manage groundwater flow. Shaw Global Services has significant capabilities that may assist in understanding groundwater flow at the Fukushima Daiichi plant and design systems to divert or block groundwater from flowing into and under the buildings and carrying radionuclides to the ocean.

  Shaw Global Services proposes using a combination of visualization tools such as GIS and groundwater flow and transport models to provide a framework for decision making and adaptive management. Numerical models efficiently integrate local geologic and hydrogeological complexities in a framework that can be used to test the efficiency of remedial or mitigation measures. The models will be “living” tools that can be used during the design phase, and construction and operation phases as well. Post-construction, these tools will be useful to assess the short-term and long-term impacts of the mitigation measures, and may be used to direct reductions/enhancements/adjustments of the mitigation measures.

Our proposed approach is as follows:

1. Shaw Global Services can support the design and management of groundwater monitoring programs and data collection activities. Shaw Global Services will review data from the existing 100 boreholes at the site in order to generate a conceptual site model that will represent the subsurface materials and groundwater flow in a 3-dimensional perspective using advanced 3-dimensional hydrogeologic modeling and GIS tools.

2. Data gaps in the understanding of the groundwater flow will be identified using the 3-dimensional visualization of existing site information. These data gaps will be ranked in order of importance and criticality to meeting the end goal of understanding the groundwater flow system sufficiently in order to design and model the outcome of potential groundwater control and mitigation systems.

3. Critical data gaps will be removed by collection of additional data. These may include identifying geological contacts, groundwater elevations, hydraulic conductivities, adsorption capacities of subsurface media that may affect the rate of migration of radionuclides, and data on fracture density and orientations in the sandstone formation. Although it may not be feasible to collect these data remotely or in an unmanned fashion, Shaw Global Services will minimize worker exposure and ground penetration through following means:

    i. Use of sub-surface Geophysical techniques to minimize intrusive activities that require penetration of ground with a drilling rig and generate contaminated soil waste. The following technologies will be considered for application:

        a. Seismic reflection or seismic refraction tomography to determine depth to bedrock and configuration of the bedrock surface and other layers, depth to groundwater and saturated thickness, and locating fractures.

        b. Electrical Resistivity Imaging (ERI) to delineate subsurface structures including bedrock and soil layers and variations, lenses, voids, fractures, faults, paleo channels, and determine saturated thickness.

        c. Very Low Frequency (VLF) method can be used to map water-filled fractures in bedrock.

d. Geophysical Borehole Logging. Existing wells, if uncased or PVC-cased, can be logged using electromagnetic (EM) induction technology to determine relative hydraulic conductivities of individual lithological units.

ii. Aquifer testing using automated data loggers and telemetric data collection systems. The data collection devices such as groundwater pressure transducers used during the performance of aquifer tests to determine hydraulic conductivities may either be wire-lined to a centralized download center, connected by long data transmission cables, or alternatively the data loggers may be connected to telemetry systems that provide either direct connection or web access to monitoring instruments.

4. Using existing and newly acquired data, generate updated 3-D subsurface aquifer and groundwater flow visuals and models. The flow model will be calibrated to measured groundwater elevations and will be used to determine groundwater flow paths, preferential flow paths, flow barriers and boundaries.

5. Connect the flow model to a 3-D radionuclide transport model to be used in assessing the transport of radionuclides in the subsurface.

6. Using the 3-D model, evaluate the effect of currently proposed groundwater mitigation measures (hydraulic containment using by-pass wells, effect of cutting runoff by impermeable cap between barrier wall at O.P. +35m and the buildings, freeze wall at O.P. +10, sheet pile and other permeable/impermeable flow control barriers).

7. Optimize planned mitigation measures by running a series of model scenarios with various configurations and combinations of individual technologies.

8. Assess short-term and long-term impact of mitigation measures.

- ***Simple measuring techniques besides the boring system, or an unmanned-controllable boring apparatus***

Shaw Global Services proposes to employ vibratory sonic drilling, where high frequency mechanical oscillations are transmitted to the subsurface media to be drilled as resonant vibrations down the drill string to the drill bit, while the operator controls these frequencies to suit the specific conditions of the soil/rock geology. Vibrations may also be generated within the drill head. The frequency is generally between 50 and 120 hertz (cycles per second) and can be varied by the operator. The vibratory action fluidizes the soil particles, destroying the shear strength and pushing the particles away from the drill bit and along the sides of the drill string. The sonic rig drives an outer drill casing and an inner string consisting of drill rods and core barrel. This method allows for fast and easy penetration through most geological formations. An internal spring system isolates these vibrational forces from the rest of the drill rig.

This method has several advantages, including the following:

1. Faster than rotary and other traditional drilling methods. One estimate provided by a vendor indicates that vibratory sonic drilling can be least twice as fast as traditional drilling methods in overburden materials, and slightly faster in the consolidated rock units.
2. Ability to continuously core unconsolidated and some consolidated formations with a minimal amount of disturbance and compaction. If massive or highly consolidated sediments are encountered, the vibratory drilling can be supplemented with a rotary action through an add-on diamond bit.
3. Collection of undisturbed core samples to provide a detailed stratigraphic profile.
4. Ability to install observation as well as extraction wells
5. Ability to install wells up to a diameter of 12-inches (0.3 m)
6. Ability to drill up to depths of 240 m
7. Significant reduction in waste soil generated during drilling (IDW) as compared to traditional drilling technologies because the drilling can proceed with or without the use of drilling fluids. One estimate provided by a vendor indicates that the method on an average reduces IDW by 80%.

   While the method as currently applied by most vendors required a manned rig, Shaw Global Services has a relationship with a vendor who has the capacity to modify the drilling system so that a reduction in worker time at the rig itself can be achieved, thereby reducing worker exposure duration. Shaw Global Service's vendor will be able to provide large track mounted rig(s) which can be modified so that the rig(s) can be operated with the operator located at a certain distance from the drill site. Shaw Global Services proposes to achieve this by moving the rig's operational console from to a certain distance away where exposure to radiation is diminished. Shaw Global Services will work with its vendor to engineer a system using extended wire lines from the console to the rig. Therefore the rig operations can proceed remotely in an unmanned fashion, although the core retrieval from the core barrel has to be done in a manned fashion, along with containerization of IDW.

- ***Digging observation holes with minimum numbers of workers and working hours (less than 10 workers *day/ 30-meter-deep hole)***

  The vibratory sonic observation hole technology that Shaw Global Services proposes to utilize is more efficient and progresses at a faster rate than rotary. At a routine site where radiation related health and safety (H&S) is not involved, this method is capable of installing an observation well to depth of 30 m along with core collection in approximately 6 hours with a 2-man crew, which is less than rotary or other traditional drilling methods. Shaw Global Services will be able to use this technology to performing the well installation in less than 10 worker days (2-man crew operation 5 days) depending upon the additional H&S aspects; at a minimum it will be faster than rotary with less volume of IDW generation, which shall also speed the process.

- ***Preventing the sampling water taken from the observation holes from being mixed with the contaminated materials interfused from the surrounding soil.***

  Shaw Global Services proposes to prevent cross-contamination of the sampled water using the following approaches:

  1. Shaw Global Services will use sonic drilling method which employs 3 meter long core barrels (CB) that are strung on a central rod to collect core samples. The CBs work inside a casing string, which stays in place while the core barrel is advanced or retrieved, preventing formation material collapsing in the borehole during drilling. This should alleviate concerns about contaminated soil sloughing off to the bottom of the borehole prior to retrieval.

  2. Where necessary, Shaw Global Services will use double cased wells, with impermeable seals (e.g., bentonite) above and below the well screen, to prevent groundwater sample cross-contamination. The contaminated soil zone will be cased off so that drilling may continue below the casing with reduced potential of cross contamination. A pilot borehole will be drilled through the terrace deposits and/or the

contaminated zone, through the sandstone, into the muddy confining layer. The borehole and outer casing will extend into the confining layer a minimum of two feet. Shaw Global Services will then place an outer casing (surface/pilot casing) into the borehole and seal it with grout from the bottom to the ground surface. After the grout plug (seal) has cured, Shaw Global Services will then install an inner casing and well screen with the filter pack, bentonite seal, and annular grout. Shaw Global Services will the complete the well by constructing a surface protective casing and concrete pad. The double cased well installation will result in isolating the monitoring zone(s) and minimizing cross-contamination of the sampled water. The method provides additional structural integrity to the well, especially in unstable areas (steeply dipping rock formation) where the bedrock has a tendency to shift or move when disturbed.

2. Notes (Please provide following information if possible.)

- Technology readiness level (including cases of application, not limited to nuclear industry, time line for application)

The proposed technologies are all commercially available and have been demonstrated. The exhibit below shows examples of Shaw Global Services Understanding Groundwater Flow Experience:

Project	Work Scope
U.S. Army Corps of Engineers, Former Guterl Specialty Steel Corporation, Lockport, New York	Between 1948 and 1952, up to 35 million pounds of natural uranium metal were processed at the site. The resulting dust, thermal scale, mill shavings and associated land disposal contaminated the facility and on-site soils as well as groundwater. Shaw Global Services analyzed the available environmental data to determine adequacy of delineation of the horizontal and vertical extent of contamination so that remediation alternatives could be identified, developed, screened, and analyzed reliably. The data review covered chemical analyses of soil, groundwater, surface water, sediments and buildings; geochemical modeling; the site-specific adsorption coefficients (Kd) values; and RESRAD and RESRAD-Build modeling to determine whether additional data are needed to support development of remediation alternatives. Shaw Global Services prepared a Data Gap Analysis Report (DGAR) to identify gaps in existing data and recommend collection of additional data to be used in the preparation of the numerical groundwater

	model and the Feasibility Study. Shaw Global Services performed groundwater fate and transport modeling to assess the transfer of dissolved uranium from the contaminated soils and buildings to groundwater and subsequently to the nearby surface water body, the Erie Canal. Remedial technologies evaluated to serve as design basis include groundwater extraction and treatment
U.S. Army Corps of Engineers, FUSRAP Maywood Superfund Site, Maywood, New Jersey	Shaw Global Services conducted soil, groundwater, sediment, and surface water characterization studies for both radiological (thorium, uranium, radium, and isotopes) and non-radiological contamination at the FUSRAP Maywood Superfund Site. Borehole geophysical logging surveys were performed to further define the bedrock lithology and fracture density and orientation. Shaw Global Services performed groundwater flow and solute transport computer modeling to project the future extent of contaminant plumes and to evaluate potential remedial approaches. The 3-dimensional groundwater flow and solute transport model was developed for bedrock and overburden materials using the computer codes MODFLOW and MT3D within the Groundwater Modeling System (GMS) graphical user interface. Modeling scenarios conducted for the detailed evaluations of alternatives included: no action, groundwater extraction and treatment, enhanced bioremediation for solvents, in situ redox adjustment to bind metals, and monitored natural attenuation.
Naval Facilities Engineering Command, Atlantic Division, Marine Corps Air Station, Operable Unit 1, Cherry Point, North Carolina	Shaw Global Services combined hydrogeological visualization, evaluation of contaminant distribution, and groundwater flow modeling to evaluate and optimize a groundwater containment and recovery system. We performed ground water flow and capture zone modeling to: 1) Assess the efficiency of the on-going groundwater extraction remedial system, and 2) Develop an optimization approach in order to better align system performance with the long term accomplishment of remedial goals, and eliminate redundant extraction points. To evaluate the completeness of groundwater plume capture, capture zones were calculated and groundwater flow paths / contaminant extraction trajectories were superimposed on the plume maps. Results of the model were used to make system adjustments and operational changes in order to optimize the performance of the remedial system. Net system capacity reduction of 17% was recommended, resulting in estimated cost savings of nearly $450,000 per year in treatment cost. The cost savings recognized from the reduction of extraction requirement offset the investment in the model based evaluation by several hundred thousand dollars.

Vance Air Force Base, Vance, Oklahoma	Shaw Global Services constructed a 3-dimensional groundwater flow model for North Site SS-07 to evaluate and design a barrier wall along with an interceptor collection trench (ICT). We determined reduction in groundwater discharges with and without the barrier wall, designed and placed the ICT and barrier wall, and produced plume and capture zone maps for the shallow and intermediate transmissive zones.

- Challenges

The major challenges are access to locations on steep slopes or covered with debris or structure, and minimizing worker exposure. We believe that the technologies proposed provide solutions to both of these problems.

- Others (referential information on patent if any)

【Areas of Technologies Requested】

(1) Accumulation of contaminated water (Storage Tanks, etc.)
(2) Treatment of contaminated water (Tritium, etc.)
(3) Removal of radioactive materials from the seawater in the harbor
(4) Management of contaminated water inside the buildings
(5) Management measures to block groundwater from flowing into the site
(6) Understanding the groundwater flow