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Groundwater Treatment at SRS: An Innovative Approach

by

M. A. Jorque

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

G. H. Golshir

B. Davis

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GROUNDWATER TREATMENT AT SRS:

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Brad Davis
G. Hossein Golshir
Monica A. Jorque, Ph.D.

ABSTRACT

Treatment and control systems for contaminated groundwater were designed, built and are in operational testing at the Department of Energy Savannah River Site (SRS). These facilities were required to achieve compliance with the F & H Area Resource Conservation and Recovery Act (RCRA) Permit issued by the South Carolina Department of Health and Environmental Control.

From 1955 until 1988, process waste water containing RCRA contaminants of concern including arsenic, barium, cadmium, chromium, lead and mercury, in addition to nitrates, radionuclides and tritium, were generated in the chemical separations facilities and discharged to three unlined earthen basins in F-Area and four similar basins in H-Area. The affected aquifers and extent of contamination include: F-Area water table (63 hectares nitrates-metals/94 hectares tritium), F-Area upper semi-confined (31 hectares nitrates-metals/77 hectares tritium), F-Area lower semi-confined (10 hectares nitrates-metals), H-Area water table (62 hectares nitrates-metals/78 hectares tritium) and H-Area upper semi confined (34 hectares nitrates-metals/67 hectares tritium). In 1986, it was determined that the basins should be regulated under RCRA as mixed waste disposal facilities. Closure activities were initiated in June 1989, immediately after SCDHEC approval of the closure plans, and the basins were certified closed in 1991.

Controlled pumping of contaminated groundwater from 25 extraction wells supplies the treatment facilities with a combined design capacity of 1500 liters per minute. Each facility incorporates prefiltration ahead of a reverse osmosis unit. The reverse osmosis concentrate is sent to a secondary treatment train consisting of coagulation and precipitation to achieve TCLP levels in the secondary waste. The solids are thickened and sent to a pressure filter followed by electric drying to achieve a filter cake with good handling characteristics. The plant effluent is piped to 20 injection wells whose volumes are individually controllable.

As no commercially viable treatment option is available to remove tritium from the groundwater, it was decided to manage the tritium plumes by establishing hydraulic control. Reinjecting and recycling the treated water provides additional time for tritium to naturally decay and thereby prevents its discharge to a seepline associated with a stream, Four Mile Branch, a tributary of the Savannah River.

INTRODUCTION

The SRS is located in southwestern South Carolina, occupying an almost circular area of approximately 800 km^2 within Aiken, Barnwell and Allendale counties. The site lies approximately 36 km southeast of Augusta, Georgia, and is bounded by the Savannah River along its southwestern border. Prior to the establishment of the SRS in 1952, the area was largely a rural agricultural community. As part of the defense complex, the SRS produced special nuclear materials for the national defense.

From 1955 until 1988, unlined earthen basins were used to dispose of wastewater from the SRS separations facilities located in the F and H areas. Approximately 300 million liters of wastewater was transported annually from the process areas through underground piping to the basins. The wastewater was allowed to evaporate and to seep into the underlying formations. There were three basins in the F-Area covering a total of about 3 hectares; while the H-Area was served by four basins covering about 6 hectares. The seepage basins closure was started in 1989 and SCDHEC certified the closures as completed in 1991.

Groundwater monitoring conducted in accordance with the provisions of the RCRA Permit determined that the underlying hydrogeologic units were contaminated by tritium, radioactive metals (primarily $Cesium^{137}$, $Strontium^{90}$ and $Uranium^{238}$), nitrate and heavy metals, some of which are defined as hazardous by RCRA. Under the terms and conditions of the RCRA Post-Closure Permit, it was necessary to remediate the contaminated groundwater plumes.

PROCESS SELECTION

Selection of the treatment process for the contaminated groundwater posed a number of design challenges due to the type of contamination in the groundwater. The ultimate design of choice required balancing a number of factors including: a wide variation of contaminant concentrations in the feed, the need for innovative design, low capital and operating costs, high reliability, simplicity of operation, waste minimization, and protection of human health and the environment. In addition to these factors, there were four stakeholders: the Department of Energy, the Operation and Maintenance Contractor, SCDHEC and the public, whose involvement was necessary to facilitate the selection of a treatment system to address the problem.

The first step in the process design was to decide between in-situ treatment and extraction treatment. An intense literature search did not reveal any applicable in-situ technology and the extraction option of pump and treat was selected. (See Figure 1.) ***Place Figure 1 here.***

Potential treatment technologies were initially identified and further assessed to determine if each was a potentially viable option. The short list of candidate technologies were assessed against four criteria.

The first criterion was the technological and mechanical maturity of the technology. This meant that basic principle of operation must have been successfully employed in a commercial operation. The technology must be sufficiently developed to allow design, procurement, construction and startup on schedule with a high degree of confidence that milestones would be met. The same criteria were applied to individual pieces of mechanical equipment.

The second criterion was the ability to comply with effluent quality requirements and establish hydrologic control over the movement of the tritium contaminated groundwater plume to prevent discharge to the seepline and associated streams. The effluent water quality must be in accordance with SCDHEC requirements and meet Underground Injection Control standards, except for tritium (for which no commercial treatment process exists) and nitrates (which would have resulted in a large increase in costs without commensurate benefits). The primary technologies under evaluation had to provide reasonable assurance that discharge effluent limitations would be met while simultaneously allowing large volumes of wastewater to be treated to achieve hydraulic control. Also of crucial importance is the formation of secondary waste; achieving compliance with one regulation while creating a difficulty with another would be grounds for rejecting a technology.

Third on the selection criteria list was process availability. A lower limit of 90% availability was chosen. This criterion required the selection of equipment with high reliability and ease of maintenance. These factors are of particular importance in a facility which processes radioactive materials because of the high additional costs of protective equipment, detailed procedures, health physics monitoring and disposal costs of failed components.

Finally, the acceptance criteria of the ultimate disposal sites required consideration. The dewatered sludge must meet the TCLP criteria, as well as SRS criteria for disposal.

PROCESS FLOWSHEET

A number of unit operations were identified as technically suitable for contaminant removal including: reverse osmosis, electrochemical treatment, ultraviolet oxidation, biological process, adsorption, ion exchange and thermal processes. Because no single process could achieve the required effluent limitations, several unit operations were combined to form the process facility. (See Figure 2.) ***Place Figure 2 here.***

Groundwater from extraction wells in the upper two aquifers is pumped through a sand filter to remove coarse solids. The sand filters are equipped with a manual backwash system to allow for cleaning when the pressure differential across the filters exceeds pre-set limits. From the sand filters, the pre-treated water enters a booster pump that injects the water into reverse osmosis units that concentrate the dissolved solids. The treated effluent from these units is directed to the treated water storage tank prior to reinjection into the water table and upper confined aquifers. The reverse osmosis concentrate is treated with a variety of coagulants and flocculants prior to a liquid/solid separation in the clarifier. The clarifier underflow, consisting of densified solids, is sent to a plate and frame pressure filter for final dewatering. The clarifier overflow is directed to ion exchange units for final polishing before joining the reverse osmosis effluent in the treated water storage tank.

Because of the inherent variability of the feed to the treatment plants, a process control system is utilized to assist in maintaining the facility operating efficiency. The PC based system allows one operator to adjust the flow from each extraction well and the reinjection rates of each individual well. The PC also provides a comprehensive history of operating parameters and maintenance activities. In addition to the computer control of the plant, process samples are required to confirm efficient operation. A methodology was developed that allows for rapid turnaround of data on selective radioactive analytes. The analytical method, which uses solid phase extraction disks and gas flow alpha/beta proportional counting, will reduce normal sample turnaround time from 45 days to 1 day. The injection criteria were defined by an Underground Injection Control Permit issued by SCDHEC.

HYDRAULIC CONTROL AND MODELING

While the facility meets performance expectations with respect to metals and radionuclides, it does not have any capability to remove tritium from the groundwater. Early in the design process, it was recognized that there was no suitable technology available for tritium removal and an innovative strategy of hydraulic control was developed. The strategy involves locating the extraction wells upgradient of the seepline. The effluent from the plant, which still contains tritium, is reinjected upgradient of the extraction wells. Movement of the plume is controlled by recirculating water from down gradient extraction wells to upgradient injection wells. Approximately 70 percent of the tritium is captured, thereby minimizing the amount reaching the seeplines. With the relatively short half-life of 12 years, the tritium not contained by hydraulic control is expected to naturally attenuate to a level protective of human health and the environment before reaching surface waters.

A commercially available model was used to represent the groundwater flow regime. The model output was used to size the treatment units with respect to hydraulic control, resulting in a combined capacity of 1500 liters per minute. This model was used to select the optimum locations for the extraction and injection wells and the initial flowrate for each individual well. The model is presently in the validation and calibration stage using input data from a network of 234 groundwater monitoring wells located at strategic points in and at the boundaries of the plume. These wells are monitored on a quarterly basis. In an iterative process, the model will be adjusted during the life of the project to reflect current conditions and model output will be used for extraction/injection control.

The treated water from the facility is reinjected upgradient into the upper two aquifers, in approximately the same ratio as it was withdrawn. Because the feed capacity of the plants is ultimately dependent on the ability to inject the treated water back into the aquifers, the reinjection parameters were carefully studied to determine the control variables. Initial column and laboratory batch studies confirmed that the formations underlying the basins were sensitive to minor changes in groundwater composition resulting from the treated water chemistry. These findings led to the implementation of field testing programs to determine the requirements for successful reinjection. One of the contributing variables was determined to be pH. The pH of the treated water must be kept low to minimize clay dispersion within the aquifers which would result in injection well failure. Efforts are on-going to determine the optimal pH for reinjection.

OPERATIONS

Prior to beginning startup, plant personnel were given extensive training in the operation and maintenance of the facilities. In addition, site-specific safety training was provided, with emphasis on the radiological nature of the facility. Detailed procedures insure safe and environmentally sound operation. State regulations require that the facilities be managed by a Class A Operator (the highest classification).

The facility is currently in the startup and testing phase. The volume of solid waste generated is significantly greater than was anticipated and efforts are being directed towards reducing this volume. It is interesting to note that although the two facilities are within 2 km of each other, water characteristics are different. Data which validates design criteria and performance are currently being collected and evaluated.

PERIPHERAL ISSUES

A continuing mission at SRS is the cleanup of the legacy of contamination left from the production of nuclear materials during the cold war. In an effort to continuously improve upon methods of doing business, several new approaches were employed during the execution of this project which have resulted in cost savings. First, a new procurement approach was used in which the bidders were asked to provide design, construction, startup and operation of the facilities. While it was ultimately decided to operate the facility with on-site personnel, the design and construction time was significantly reduced by using a company whose core business was wastewater treatment. This approach resulted in lower capital costs. In addition, although the facility was located at a nuclear processing site, the units were classified as general service, the lowest classification at SRS. Additionally, necessary and sufficient standards were developed and applied to the F and H project. This resulted in exemption from key DOE orders and allowed a more commercial approach to the project. These actions allowed lower operating costs, while still providing a high level of protection of human health and the environment.

CONCLUSION

SRS has taken a conventional groundwater corrective action technology (for the treatment of "hot spots") and is applying it innovatively to hydraulically control the movement of tritium contaminated groundwater. This is accomplished by extraction of contaminated groundwater, treatment and reinjection. The resultant sizing of the treatment system and the ability of the injection system to accept such large volumes continues to present a technological challenge to the staff at SRS. Much progress is being made in this regard.

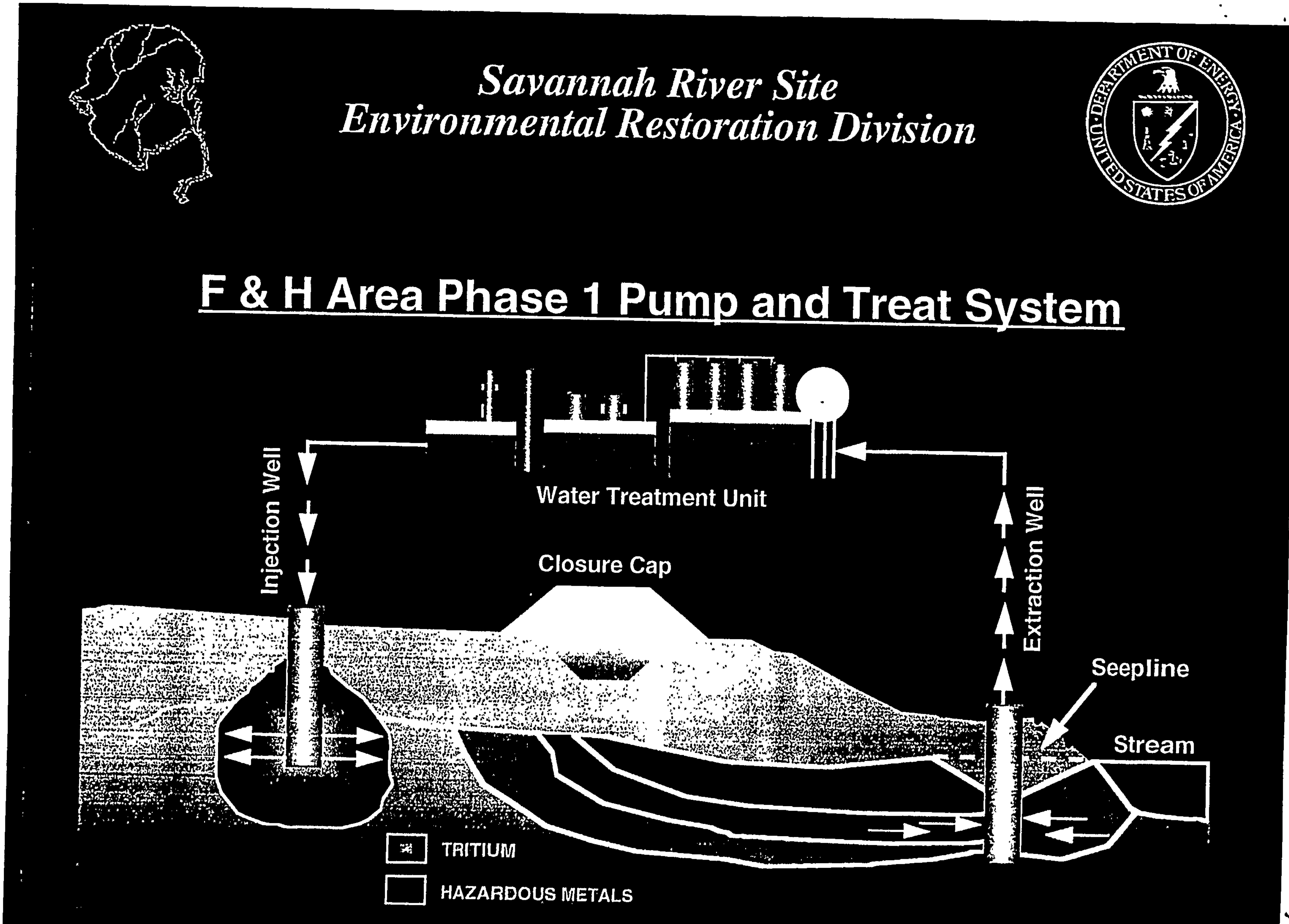
Savannah River Site
Environmental Restoration Division
F & H Area Phase 1 Pump and Treat System
Water Treatment Unit
Injection Well
Closure Cap
Extraction Well
Seepline
Stream
TRITIUM
HAZARDOUS METALS

Figure 1

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Savannah River Site
Environmental Restoration Division

F & H Groundwater Treatment Process

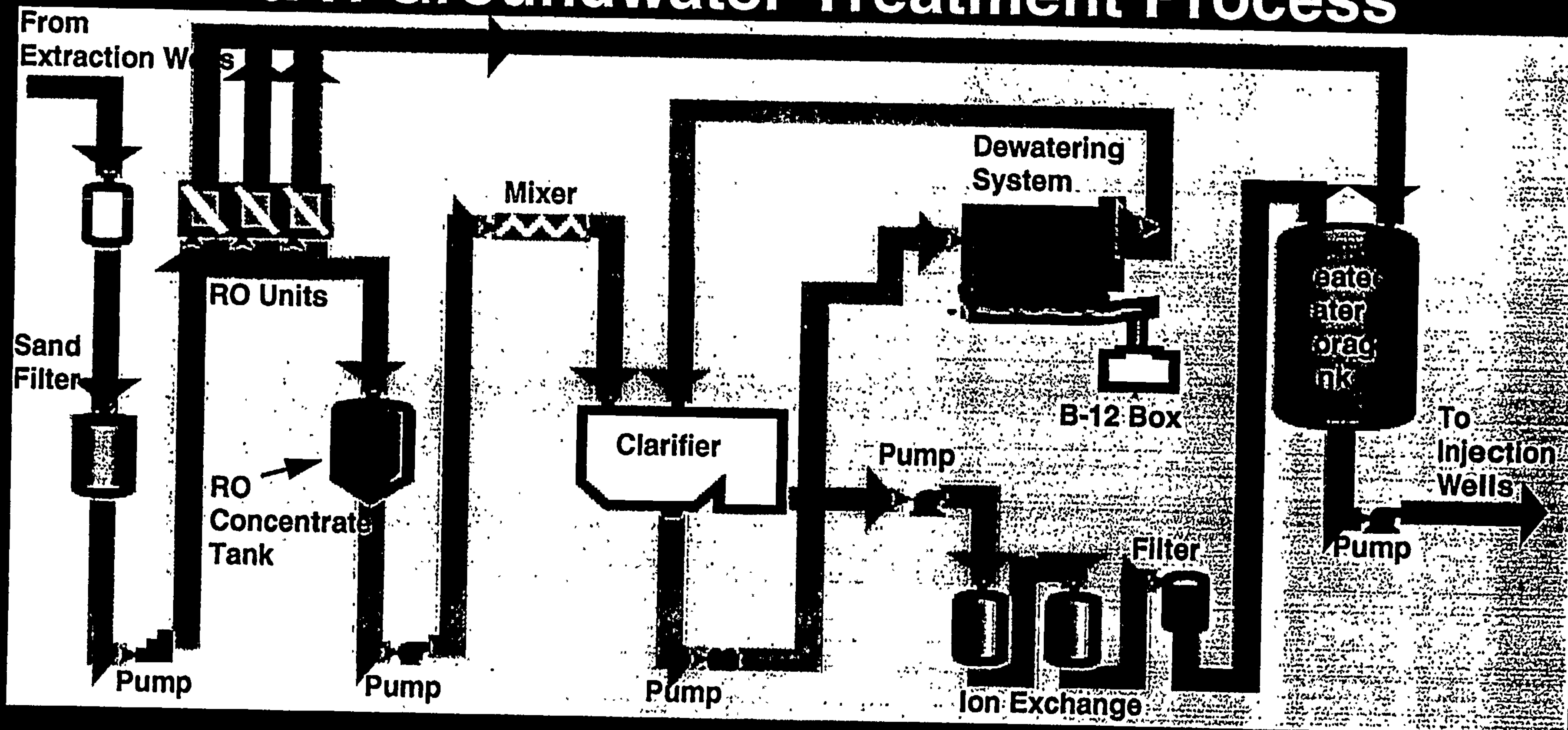

Diagram shows movement of untreated water (red lines) and treated water (green lines) through the water treatment unit.

Figure 2