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Docket No. 40-8714
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MEMORANDUM FOR: Docket File No. 40-8714

FROM: Sandra L. Wastler, Project Manager
Licensing Branch 1
Uranium Recovery Field Office

SUBJECT: RESTORATION OF CLEVELAND CLIFFS IRON COMPANY A-1 AND B WELL FIELDS AT THE COLLINS DRAW ISL PROJECT

Background

Research and Development testing at the Collins Draw site began in the A-1 well field in March 1980, and was expanded to the B well field in November 1980. Ammonium carbonate lixiviant was used in both well fields. Restoration of the A-1 wellfield was initiated on November 4, 1980. Restoration methodology utilized in the A-1 well field included transfer of lixiviant to the B well field, recirculation with treatment by ion exchange, reverse osmosis, air stripping and finally, injection of the well field with fresh ground water. Restoration of the B well field began on July 14, 1981. Restoration methodology utilized in the B well field included air stripping, ground-water sweep, and injection of fresh ground water. Restoration of the A-1 and B well fields was terminated by Cleveland Cliffs Iron Company (CCIC) in December 1982.

Following the termination of restoration efforts at the A-1 well field, ground water was sampled over a 6-month period to ascertain the adequacy of restoration and stability of the water quality in the mined aquifer. At the conclusion of restoration in the B well field, samples were collected for all A-1 and B wells to determine ammonium, selenium and arsenic concentrations. The most recent water quality data was for 10



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wells in the B well field, sampled 10 months (September 1983) after restoration efforts ended.

By letter dated March 8, 1984, the NRC staff presented the results of their review of all data pertaining to ground-water restoration of the A-1 and B well fields at CCIC's Collins Draw ISL Project submitted since November 13, 1981. In this letter, the NRC staff concluded that aquifer restoration at the Collins Draw site had not been achieved, but that any decision by the NRC regarding additional restoration must consider the effectiveness of the restoration technologies employed. Additional information regarding the restoration technologies employed by CCIC was requested in order to allow the NRC to accurately assess the existing conditions of the aquifer and to provide insight as to methods which could be employed if additional restoration is necessary. CCIC responded by letter dated May 2, 1984.

Computer Simulation

The NRC staff utilized the requested data submitted by CCIC and the existing aquifer parameters to simulate the production and restoration operations in the A-1 well field using a modified version of the "Random Walk" solute transport computer model (microcomputer version) written by Prickett and Voorhees. The purpose of modeling the mining and restoration activities was to evaluate whether all lixiviant and dissolved ions introduced into the 1-Sand aquifer during mining could have been removed during restoration operations.

The results of the simulations show that the complex pumping and injection scheme utilized by CCIC during the restoration period tended to push the contaminants away from the well field rather than remove them and to reduce total dissolved solids (TDS) and ammonium ($NH_4^+$) by dilution. The simulations indicate that the pumping-injection scheme displaced the lixiviant to the outside of the well field with some mixing occurring at the lixiviant front, due to dispersion. A substantial fraction of the lixiviant remains in the aquifer outside the well field.

Evaluation of CCIC's Restoration Program for the A-1 Wellfield

Restoration of aquifers such as the 1-Sand at Collins Draw is a difficult task because injection-withdrawal procedures produce complex velocity fields within the aquifer during mining and restoration. In addition, lixiviant and dissolved ions may in reality migrate in preferred

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directions along high hydraulic conductivity zones during mining. These zones also may impose nonuniform gradients during restoration. These complexities may result in inefficient and nonuniform removal of lixiviant and dissolved ions from the aquifer.

Restoration of aquifers is complicated also by the effects of advection, dispersion and chemical reactions such as adsorption, desorption, dissolution, precipitation, oxidation, reduction and complexation. In the case of Collins Draw, the most readily apparent of these complications is the adsorption of ammonium ions onto clay particles of the aquifer matrix. This physiochemical reaction undoubtedly has disrupted the chemical equilibrium of the aquifer system to some extent. Restoration efforts are required to reverse the destabilizing reactions caused by mining. However, the rate at which the system proceeds toward a new equilibrium often lags behind the physical removal of the contaminated ground water. The NRC staff's evaluation of the adequacy of restoration at the Collins Draw mine reflects the above uncertainties.

The omission of the construction of an evaporation pond at the Collins Draw mine site required CCIC to operate with balanced production and injection rates. The absence of an evaporation pond prevented CCIC from over-producing for an extended period of time. In theory, in situ uranium leaching can be accomplished with completely balanced production and injection rates. However, in reality, fluctuations in production and/or injection rates occur often due to a number of potential causes. Continuous overproduction provides a measure of operating safety that was unavailable to CCIC.

Had an evaporation pond been available, other restoration methods such as directional ground-water sweeping with reinjection of treated water could have been a more feasible technique. The existence of an evaporation pond would have benefited reverse osmosis also by providing more flexibility in the disposal of the waste stream.

CCIC (1984) reported that difficulty in reducing radium concentrations to acceptable levels in reverse osmosis (RO) waste water inhibited discharge of the waste stream to the surface and thus detracted from the success of reverse osmosis restoration. Four additional complicating factors hindered the successful completion of restoration by reverse osmosis. These are:

1. The Wyoming Department of Environmental Quality (WDEQ) permit limited the amount of radium, uranium, and total gallons of waste

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water that CCIC could discharge to their drain field to pervent overtaxing the field. CCIC was not able to operate the RO unit for a sufficient period of time under these limitations to successfully restore the 1-Sand aquifer.

2. CCIC did not have adequate storage facilities to contain the waste stream from the RO unit. Without the ability to discharge the waste stream to the drain field, CCIC was unable to use RO effectively to restore the 1-Sand aquifer.

3. Problems with calcium precipitation caused plugging of resins and membranes in the RO unit. A 20% bleed stream was necessary to avoid plugging problems. Disposal of this unusually large bleed stream was hindered by the absence of adequate waste water storage facilities.

4. Reverse osmosis was not effective at reducing $NH_4^+$ concentrations to baseline concentrations. Reverse osmosis reduced the bulk of the $NH_4^+$ in the withdrawn ground water (from 630 to 140 mg/l); however, RO probably was ineffective at reducing relatively low concentrations of $NH_4^+$ in the withdrawn ground water.

The piecemeal manner in which CCIC approached restoration of the A-1 and B well fields did not promote success in reducing both the $NH_4^+$ and TDS concentrations to premining quality. Air stripping to remove $NH_4^+$ from the ground water was probably considered to be the best practicable technology at the time restoration operations were conducted at the Collins Draw site. CCIC's attempts to remove $NH_4^+$ from clays in the aquifer by maintaining a high TDS concentration in the ground water could be considered an enhanced method of $NH_4^+$ removal. However, CCIC did not make any attempt to control the pH of the injected solutions. CCIC did not make a sufficient effort to reduce the high TDS concentration in the ground water to premining levels after the completion of the procedures for $NH_4^+$ removal.

Although CCIC reported that RO was ineffective at reducing $NH_4^+$ concentrations, available data suggest that it was in fact effective to some extent. In restoring the A-1 well field, cessation of RO due to failure of the ion exchange process resulted in an increase in the $NH_4^+$ concentration of the ground water from 420 to 630 mg/l, suggesting that ion exchange was fairly efficient at removing $NH_4^+$ from clays. Calcium produced from calcite dissolution probably exchanged with $NH_4^+$ on the clays. However, calcium also exchanged with $NH_4^+$ on the resins. Reverse

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osmosis technology was utilized after the ion exchange restoration effort; $NH_4^+$ concentrations were reduced to 140 mg/l after 33 days of reverse osmosis treatment (CCIC, 1982). Reverse osmosis treatment therefore, would seem to have been an attractive method for reducing the "bulk" of $NH_4^+$ in the ground water at the Collins Draw mine.

Restoration of the A-1 well field cannot be considered complete because the TDS concentration in the ground water is still elevated. Ion exchange, RO and air stripping were fairly effective at reducing $NH_4^+$ concentrations in the withdrawn ground water, but they were ineffective in reducing TDS to baseline ranges. Extended restoration efforts employing enhanced methods of permanent $NH_4^+$ removal from clays would be necessary to maintain low $NH_4^+$ concentrations in the ground water due to continual desorption of $NH_4^+$ into the ground water. The reinjection of withdrawn ground water treated by RO, ion exchange or air stripping will not reduce the $NH_4^+$ concentrations on the clays significantly. These methods are capable of reducing the $NH_4^+$ concentrations in the withdrawn ground water only.

The methods used by CCIC to reduce TDS in the ground water cannot be considered to be the best practicable technology. Attempts by CCIC to reduce TDS by dilution were ineffective. By injecting "outside" water into the 1-Sand, CCIC was able to reduce the total TDS concentration in the immediate vicinity of the injection wells; however, ground water with elevated levels of dissolved solids was pushed out of the well field. This water remains in the aquifer at the present time.

Data are lacking to indicate the water quality at the end of each of the various stages of restoration. For this reason, it is difficult to evaluate adequately the relative success of each method. The data that are available constitute the concentrations of numerous parameters at the end of the air stripping (January 25, 1982) and at the end of the initial ground-water sweep (March 24, 1982) at the B well field. This information shows that the concentrations of the majority of constituents were reduced by the ground-water sweep. Total dissolved solids were reduced from 1,198 mg/l to 782 mg/l; chloride from 188 mg/l to 112 mg/l; sulfate from 504 mg/l to 342 mg/l and ammonia from 154 mg/l to 119 mg/l (CCIC, 1982).

Evaluation of CCIC's Restoration Program for the B Wellfield

Water quality data for the B well field indicate that ground-water sweep was effective in reducing total dissolved solids and ammonia. However,

ground-water sweep was not conducted for a long enough period of time to reduce these constituents to baseline ranges. Estimates of pore volumes removed during sweeping, based on the approximate dimensions of the B well field (Figure 1), suggest that less than 1.4 pore volumes of contaminated ground water were removed. This estimate assumes the following factors:

1. Approximate B well field dimensions 62.5 by 64.0 m (205 by 210 ft).

2. Average 1-Sand thickness of 15.9 m (52 ft).

3. Porosity of 0.28.

Based on these values, the approximate volume of ground water contained within the B well field is 17,800 $m^3$ (4,700,000 gallons). This estimate is conservative, and the actual affected area probably is much larger based on the results of the simulation of the A-1 well field, and excursions that were detected in monitor wells MW238 and MW298, located about 33.5 m (110 ft) and 61 m (200 ft) southeast of the B well field, respectively. According to CCIC (1984), a total of 24,186 $m^3$ (6,383,891 gallons) of ground water from the 1-Sand were discharged to the land surface during the ground-water sweep. Even from a conservative viewpoint, the withdrawal of this volume of ground water was clearly inadequate to restore the affected portion of the 1-Sand aquifer.

The volume of ground water removed from the aquifer during the ground-water sweep was several times less than that required to achieve adequate restoration at other in situ uranium mine sites (Williams et al., 1984). As an example, it was necessary for Teton Exploration Drilling Company to remove more than 24 pore volumes by ground-water sweeping to achieve adequate restoration of the N well field at their Leuenberger Mine in Converse County, Wyoming. To reduce TDS concentrations in the B well field to baseline ranges, it probably would be necessary for CCIC to remove several additional pore volumes of ground water.

The final method of restoration used in the B well field involved injection of "outside" water obtained from an overlying aquifer into the mined aquifer to dilute the concentrations of trace elements in the ground water. While this technique reduced $NH_4^+$ and arsenic concentrations at the wells monitored, it displaced residual lixiviant and dissolved ions away from the injection wells into other portions of the aquifer.

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Air stripping for removal of $NH_4^+$ from the ground water withdrawn from the B well field could be considered to be the best practicable technology at the time of restoration operations. Extended restoration efforts employing enhanced methods of $NH_4^+$ removal from clays would be necessary to reduce the $NH_4^+$ concentrations in the ground water permanently. The methods (ground-water sweeping and dilution) used to reduce TDS, although they could be considered to be the best practicable technology, were not adequate since they were not utilized for sufficient periods of time.

Conclusions and Recommendations

Based on the above discussion, the NRC staff concludes that:

1. Although the methods of restoration used by CCIC may be considered to be the best practicable technology available at the time, they were not properly utilized.

2. Modeling of the Collins Draw site strongly suggests that injection of "outside" water into the 1-Sand pushed the contaminated water to the periphery of the A-1 and B well fields.

Therefore, the NRC staff should require CCIC to perform additional restoration of the 1-Sand at the A-1 and B well fields. CCIC should provide for NRC review and approval, a detailed plan for additional restoration. CCIC's plan for additional restoration should include consideration of the following:

1. Installation of additional high volume pumping/injection wells around the A-1 and B well fields sufficient to define the extent of the contaminated area. These wells should be fully penetrating.

2. Sampling of all wells (including the additional wells noted above) for at least $NH_4^+$, TDS, sulfate, chloride and total carbonate in order to delineate the contaminated area.

4. An evaluation of the spatial distribution and total mass of contaminants should be used in combination with modeling of the contaminant plume to design an effective pumping scheme. The model should also estimate the time required to achieve restoration.

5. Some method to monitor the recovery stream should be developed to evaluate the progress of restoration. Such things as a graph of

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accumulated mass and/or concentration of constituents could be used to evaluate the efficiency of constituent removal and to predict when additional restoration would produce little improvement.

6. Reduction in TDS to baseline ranges should be one measure of restoration adequacy. Determination of the point in the restoration program where continued restoration would yield diminishing returns in terms of contaminant mass removed/volume of ground water recovered should be made jointly between CCIC and the NRC, if concentrations are not at or below baseline.

7. Since CCIC does not have evaporation ponds, any viable restoration plan will require either construction of evaporation ponds or a surface discharge permit from the State of Wyoming and an amendment to their license from the NRC.

/s/

Sandra L. Wastler, Project Manager
Licensing Branch 1
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Original Signed By
Edward F. Hawkins

Approved by: ______________________
Edward F. Hawkins, Chief
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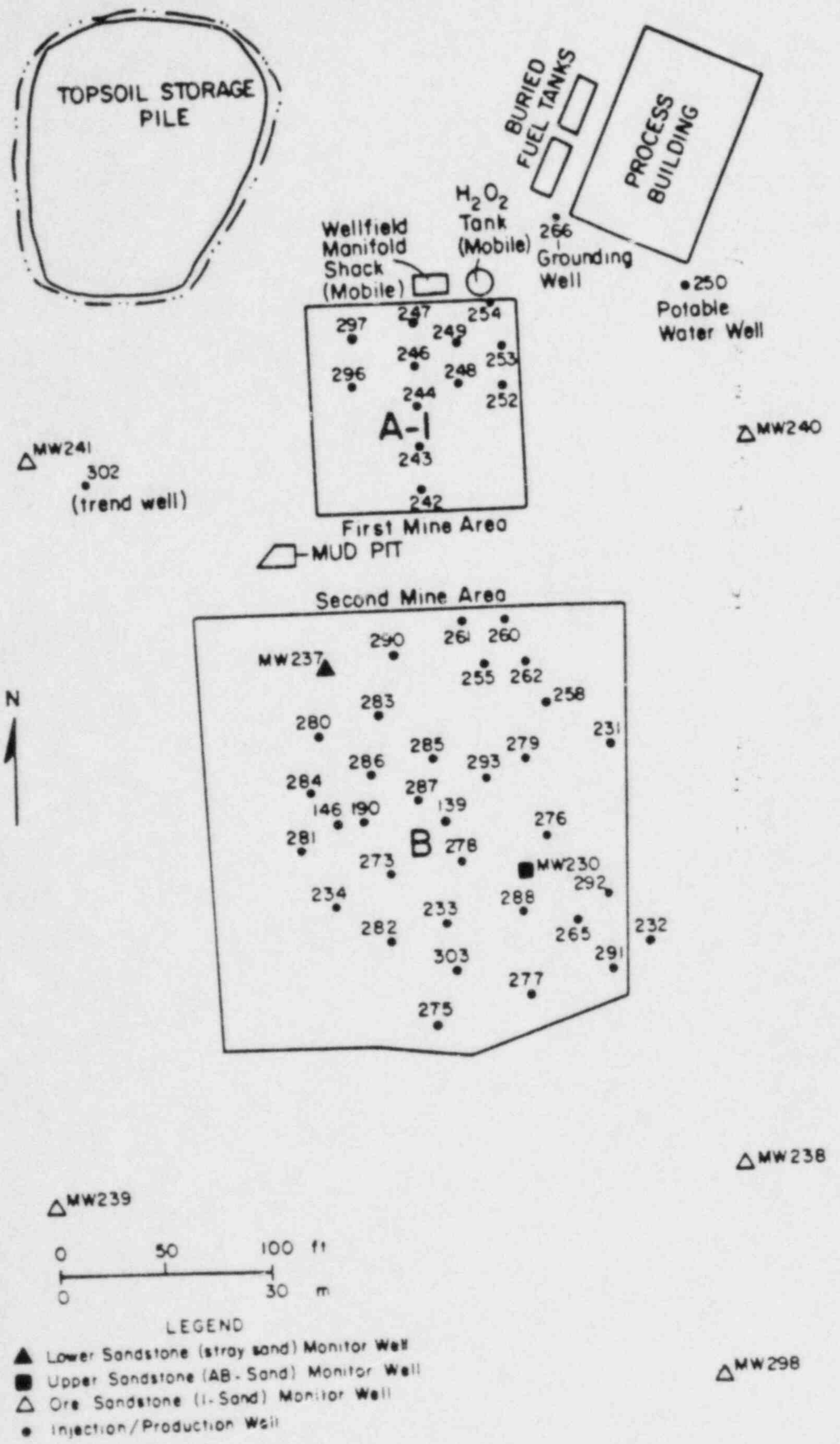


Fig. 1 Location map of the facilities at the Collins Draw mine (after Cleveland Cliffs Iron Company, 1981a).