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Title:

Heap Leach Studies on the Removal of Uranium from Soil

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Submitted to:

Office of Technology Development Uranium in Soils Integrated Demonstration

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LA-UR-94-1361

HEAP LEACH STUDIES ON THE REMOVAL OF URANIUM FROM SOIL

**REPORT OF LABORATORY-SCALE
TEST RESULTS**

Technical Task Plan AL121121

Soil Decontamination Task Group

**Uranium in Soils
Integrated Demonstration**

May 1994

**Prepared for the
Office of Technology Development
(EW 4010)**

**Prepared by the
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U.S. Department of Energy
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ABSTRACT

This report details the initial results of laboratory-scale testing of heap leach that is being developed as a method for removing uranium from uranium-contaminated soil. The soil used was obtained from the site of the Feed Materials Production Center (FMPC) near the village of Fernald in Ohio, which produced uranium metal and compounds from 1951 to 1989. After cessation of production, this site was renamed Fernald Environmental Management Project (FEMP). The testing is being conducted by the Los Alamos National Laboratory and is sponsored by the U. S. Department of Energy (DOE), Office of Technology Development through the *Uranium in Soils Integrated Demonstration* (USID) program. The USID was established to develop new technologies that will enable DOE to remediate large quantities of uranium-contaminated soils in a safe and economical manner.

The testing is being conducted on a laboratory scale, but it is intended that this methodology will eventually be enlarged to field scale where millions of cubic meters of uranium-contaminated soil can be remediated. The laboratory scale experiments show that, using carbonate/bicarbonate solutions, uranium can be effectively removed from the soil from initial values of around 600 ppm down to 100 ppm or less. The remaining uranium approximates to the uranium (IV) component with the uranium (VI) being completely removed. The maximum quantity of soil so far tested in a single batch is 10 kg.

The goal of this research is to selectively remove uranium from the contaminated soil, without causing serious changes in the characteristics of the soil. It is also hoped that the new technologies developed for soil remediation at FEMP will be transferred to other sites (DOE, commercial, and private) that also have uranium-contaminated soil.

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Glossary

AEC	Atomic Energy Commission
AEM	Analytical Electron Microscope
CFSTR	Continuous-Flow Stirred-Tank Reactor
DOE	Department of Energy
EPA	Environmental Protection Agency
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Company
FMPC	Feed Materials Production Center
ICP	Inductively Coupled Plasma
LANL	Los Alamos National Laboratory
NRC	Nuclear Regulatory Commission
PFR	Plug-Flow Reactor
SAED	Selected-Area Electron Diffraction
USID	Uranium in Soils Integrated Demonstration

Acknowledgments

We would like to acknowledge the following persons for their contributions to this project (in order of involvement):

Zohrab A. Samani, New Mexico State University
Adrain T. Hanson, New Mexico State University
Robert R. Ryan, LANL, CST-3, retired
James R. Brainard, LANL, CST-3
Bruce Thomson, University of New Mexico
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Heap Leach Studies on the Removal of Uranium from Soil.

1. INTRODUCTION

A. Background

The post World War II growth of the nuclear industry in the United States was rapid and resulted in the founding of several new production facilities. The facility for producing uranium metal and uranium tetrafluoride was built at the U.S. Atomic Energy Commission's (AEC) Feed Materials Production Center (FMPC) near the village of Fernald, OH. It began operation in 1951. Subsequently, the FMPC was renamed the Fernald Environmental Management Project (FEMP) after uranium production was ceased in 1989.

The activities at FMPC, for which details are available elsewhere (USID August 1992) resulted in significant uranium contamination of the soils near Fernald. Estimates suggest that 2,000,000 to 4,000,000 m³ of soil may have unacceptable levels of uranium contamination (Francis, 1992).

Current technologies for remediation of uranium-contaminated soil include (1) excavation and transportation of the uranium-contaminated soil to a repository, (2) immobilization of the uranium in place, (3) physical separation and removal of the more highly contaminated soil fractions from the balance of the soil, and (4) soil washing.

Heap leach is one method of soil washing currently being studied for remediation of uranium-contaminated soil. In a heap leach process, the contaminated soil is piled (heaped) on top of an impermeable pad built on the surface of the ground. An overhead sprinkler system sprays the heap with a solution which solubilizes (leaches) the uranium as the solution passes downward through the heap, as shown diagrammatically in Fig. 1. This method has been successfully implemented by the mining industry to recover precious metals from low grade ores (1 ppm, or less).

The benefits of this soil washing technique include (1) on-site cleanup, (2) conservation of repository space, and (3) elimination/reduction of long-term costs for monitoring, isolation, and habitat protection. In this way a *permanent solution* to the soil contamination problem is obtained rather than a relocation of the soil with a resultant increase in volume and expense for future care.

As of this writing, no approved regulatory cleanup level has been established for the Fernald soil. However, the maximum permissible level for contamination from uranium mill tailings established by the Nuclear Regulatory Commission (NRC) is 35 pCi/g. The same screening level was adopted by the Soil Decontamination Task Group of the USID. This is equivalent to a uranium concentration of 52 mg/kg of soil, based on the distribution of uranium isotopes in naturally occurring uranium.

Figure 1 Field-Scale Heap Leach System.

B. Objectives

The objective of this research is to develop heap leach technology for uranium removal from soil so that it can be used on a large scale at the FEMP site. Secondary objectives include having sufficient data to allow comparison with other soil washing techniques. The parameters affecting the process include (a) efficiency of removal, (b) soil degradation, (c) unwanted removal of other constituents, (d) cost, (e) recycling characteristics, (f) simplicity, and (g) size of secondary waste streams. This study, to date, mainly deals with the efficiency of removal, although the other parameters are briefly mentioned.

C. Theory of Heap Leach

Leaching of uranium ore is accomplished by crushing the host rock and leaching it with either a strongly acidic or strongly alkaline solution, see Fig. 1. Uranium can then be recovered from the leachate using either solvent extraction or ion exchange processes. Merritt (Merritt, 1971) prepared a comprehensive discussion of the technology that included flow diagrams of most of the major uranium mills in the U.S.

In a geologic setting, under reducing conditions, uranium is present as insoluble U(IV) with typical minerals being uraninite (UO_2), coffinite (USiO_4), and others (Brookins, 1977). Under oxidizing conditions, U(VI) is stable and usually is present as the uranyl moiety (UO_2^{2+}) in both solids and solution. Uranyl forms strong aqueous complexes with carbonate, sulfate, chloride, and other anions. The objective of the milling process is to change the solution chemistry in the crushed ore from reducing conditions near neutral pH where uranium is insoluble, to oxidizing conditions at either low pH where aqueous UO_2^{2+} is stable, or at high pH where the anionic uranyl tri-carbonate complex ($\text{UO}_2(\text{CO}_3)_3^{4-}$) is dominant.

At many uranium-contaminated sites, the major form of uranium as a soil contaminant is in the U(VI) oxidation state, specifically often in the form of schoepite, $\text{UO}_2(\text{OH})_2 \cdot \text{H}_2\text{O}$ (or $\text{UO}_3 \cdot 2\text{H}_2\text{O}$). (Ebinger, 1994) This is in contrast to the uranium being an integral part of the geology. This is consistent with the knowledge that much of the contamination at FEMP originated as small uranium particles from exhaust stacks in the form of UF_4 and U_3O_8 , which oxidize in the atmosphere. (Radiological Assessments Corporation, 1993)

D. Approach

For a simulated heap leach approach, the soils, which were received from the FEMP center, were placed in laboratory-scale leach columns. A solution of the reagent that was expected to solubilize the uranium (in this case, an equimolar mixture of carbonate/bicarbonate) was dripped into the top of the column. Uranium analyses were performed on the soil both before and after leaching. Uranium analyses were also performed on the leachate (the solution emerging from the bottom of the column). A diagram of the system is shown in Fig. 2.

Figure 2. Flow Diagram of Column Study.

2. EXPERIMENTAL METHODS AND MATERIALS

A. Soil (i) Introduction

Our initial column experiments were conducted on homogenized soil samples that were prepared in large batches at FEMP for the Treatability Subtask Group of the USID. All investigators in this Subtask Group (i.e., at Oak Ridge, Los Alamos, Savannah River, and Argonne National Laboratories) used soil samples from the same batch insuring test results that would be comparable. Later experiments at Los Alamos were conducted on heterogeneous soil samples.

We have received three different batches of soil from the FEMP site (with initial uranium concentrations of ~540 to ~640 mg/kg of soil) with which to conduct heap leach experiments:

1. The first batch of soil, was taken from an area near the Plant 1 Storage Pad Area, designated SP4, see Fig. 3. The storage pad area is thought to be contaminated with uranium product spills (S.Y. Lee, January 1992). Activities that were conducted at Plant 1 and the Storage Pad Area include shipping, receiving, milling and classifying isotopic composition of uranium materials, sampling and analysis of incoming materials, and storage of materials awaiting off-site shipment. Throughout this document this soil is referred to as **SP4**.
2. The second batch of soil was taken from an area adjacent to the Incinerator Area, designated SP9, see Fig. 4. It was received from FEMP in 1993. SP9 is located a few hundred yards east of the main Fernald production area. The Incinerator Area of FEMP (Lee, January 1992) was chosen in order to investigate airborne dust contamination. In this case, the airborne contamination came from both the incineration process and the nearby milling and machining operations. Throughout this report this soil is referred to as **SP9(93)**.
3. The third batch of soil was taken from the same area as the second batch and was received in January 1994. This is being used for scale up experiments since the previous batches of soil had been exhausted. Throughout this report this soil is referred to as **SP9(94)**.

Figure 3. Sample Sites in Production Area

Figure 4. Sample Sites near Incinerator Area

A. (ii) Characterization

The single most significant finding from the speciation characterization work thus far is the prevalence of the hexavalent oxidation state in the uranium-contaminated soils. Based on x-ray absorption spectroscopy, the uranium in all samples examined thus far exists principally (80-90%) in the hexavalent oxidation states (USID August, 1992).

Based on the mineralogical analyses and scanning electron microscopy of ten different samples from five sites at FEMP, the uranium phases are found to be similar throughout the site, although the distribution and size of the particulates vary. Uranium-bearing phases identified by various methods [e.g., analytical electron microscopy (AEM), selected-area electron diffraction (SAED)] include: uranium silicates, uranium phosphates, uranium oxides and hydroxides, calcium uranium oxide, and uranium contained within a calcium fluorite phase. Results suggest that the majority of these phases contain uranium in the (VI) oxidation state, however small ($< 10\mu\text{m}$) particles of uranium (IV) phases have also been identified, including uranium silicide (USi_{2-x}) and uranium oxide (UO_2). Even though these phases have all been identified, these results give no information as to the relative abundance of the different phases.

SP4 Soil

This soil is thought to be contaminated mostly by uranium spill products. More than 80% of the uranium is associated with the sand and silt fractions. These fractions make up about 74% of the soil. Three major phases were found; a calcium phase, an iron oxide phase and uranium oxide particles. In addition, a uranium phosphate phase was identified.

SP9 Soil

Since this site was chosen in order to study airborne emissions, the major primary contaminants are U_3O_8 , UF_4 , (the forms of uranium released from the stacks), and weathered products of these primary contaminants. Uranium oxide (UO_2) particles were detected in the soil samples. A major phase found was a uranium phosphate phase, identified by SAED as an autunite [$\text{Ca}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot x\text{H}_2\text{O}$]. The majority of the autunite was present as distinct particles. In cases, however, autunite appeared to be connected to uranium oxide, suggesting that it was an alteration product of primary UO_2 . Autunites, as well as gummite ($\text{UO}_3 \cdot \text{H}_2\text{O}$) and uranyl silicates, are well-known alteration products of uraninite $\text{UO}_2(\text{cr})$ (R.J. Finch, 1992). Thus, by inference, UO_2 in the Fernald soils near the incinerator may have undergone weathering, accounting in part for the above described phases being observed in the vicinity of the incinerator.

In general, the surface soil in the SP9 area consists of 13% gravel, 21% sand, 53% silt, and 13% clay. Although in the past the soil was mixed with limestone gravel, the texture of the SP9 soil was similar to other less disturbed soils inside the plant. (Lee, January 1992)

A (iii). Soil Preparation

The first two batches of soil [i.e., SP4 and SP9(93)] were not "as excavated". Before the samples were shipped, the soils were tumbled in a mixer with just sufficient water to control dust emissions. During the tumbling process, the clays and silts were unintentionally rolled up around the coarser soil particles to form small agglomerates (one to two cm in diameter). This soil is referred to as **Homogenized** soil (although this description is not strictly true).

The third batch of soil is referred to as **Heterogeneous** soil. This soil was "as excavated" that is, not treated before shipment to Los Alamos. It contains small amounts of organic matter including sticks, grass, etc.

In none of the three soils [(i.e., SP4, SP9(93), and SP9(94))] can the uranium contamination, or the soil structure itself, be considered homogeneous. It was agreed early in the testing that representative samples would be difficult to obtain without crushing and blending all of the soil inventory first. This was not desirable because it would change the physical characteristics of the soil.

The soil was not separated into its size fractions (i.e., gravel, sand, silt, and clay) before it was placed into the columns, although some pretreatment was carried out. See Table 1. (Results Section)

After arrival at LANL, some of the SP4 and SP9(93) soil was further agglomerated with a cement additive of $\approx 0.6\%$ CaO by weight. This soil is termed **Agglomerated with Cement** soil. Column experiments carried out in 1993 included both homogenized soil and agglomerated with cement soil. Agglomeration is discussed later.

The last batch of soil [i.e., SP9(94)] received, was tumbled with water to form agglomerates prior to being placed into the leach columns. This soil is referred to as **Agglomerated with Water** soil. Initially, this was done by rolling the soil in polyethylene bottles but later this process was carried out in a laboratory-scale agglomerator.

B. Laboratory Column Leach System

A laboratory-scale column testing system was designed and built to simulate a field-scale heap leach operation, see Fig. 1. The Plexiglas columns were approximately 9 cm I.D. and varied in height from 15 cm (~6 in) to 150 cm (~60 in). Initially, the columns were intentionally small but, after the early successes, scale up columns are now being used. These are discussed later. Leaching solutions were prepared by dissolving appropriate amounts of (ACS reagent-grade) Na_2CO_3 and NaHCO_3 in double-deionized ("Milli-Q") water in large polyethylene dewars. All column experiments were conducted at room temperature and pressure under non saturated, aerobic conditions.

Between 1 and 10 kg of soil were used in each experiment. The soil was not separated into its size fractions or otherwise treated (except for use of agglomerated soils in certain experiments) before being introduced into the leach columns. The soil was placed into the columns from the open top and held in the column at the bottom with a cellulite filter over a wire-mesh screen. The filter was covered with a layer of filtering (Ottawa) sand approximately 3 cm thick (Fig. 5). No attempt was made to compact the soil.

The carbonate/bicarbonate leaching reagent was introduced at the top of the column. Continuous uniform flow was achieved by use of a peristaltic pump to transfer leaching reagent from the reagent dewars through Tygon tubing to the top of the column. The reagent flowed downward by force of gravity. The loading rate of the reagent was typically of the order of $0.01 \text{ ml/cm}^2/\text{min}$ (or, ~ 1 liter/24 hr period over an area 8.5 cm in diameter). For convenience purposes, this flow rate was named 1X. This flow rate was selected (1) to mimic flow rates typically used in heap leach of precious metals, and (2) to keep the ratio of liquid-to-solid as low as practical. This would minimize the volume of the waste stream. Other tests were conducted at 0.3X and 2X.

The conditions in the column can be described as unsaturated. Following initial breakthrough of the leachate, which occurred within several hours, the leachate output flow rate approximated to input flow rate. Flowing liquid was not visible through the walls of the column; however, the soil became noticeably wetter during the course of the experiment. Often the soil compacted slightly during the first six hours of the experiments. This was shown by a decrease in the height of the soil column by as much as 20% in the columns.

⚠ RADIOACTIVE ⚠

Figure 5. 15 Cm Column Experiment

The leachate was collected from the bottom of the column for subsequent analysis. No attempt has been made yet to regenerate the reagent and recirculate the carbonate/bicarbonate leach solution back to the inlet of the column (this is done in the mining industry as a normal course of action). During the first 72 hours of leaching, leachate samples were taken at regular intervals (~ 1/2 to 1 hr) using a fraction collector. After about three 24-hr days, the samples were collected in larger bottles that were manually changed every 1 to 2 days. Leaching was continued 7 days/week. The high frequency of sampling in early experiments enabled us to determine the uranium release as a function of time. In later experiments sample collection times were longer.

The volume, pH, and uranium concentration were measured for the leachate fractions. Uranium analyses were performed on a Varian Liberty 200 Inductively Coupled Plasma (ICP) spectrophotometer. Triplicate measurements at two different uranium absorbance lines were taken for each sample. Uranium concentration of the leachate was determined by comparison with concentration-intensity curves for calibration standards at regular intervals. Calibration standards were prepared by diluting 10 000 ppm stock uranium in a bicarbonate/carbonate solution of an appropriate concentration to minimize matrix effects. The total quantity of uranium in each sample was then calculated using the concentration of uranium and volume of the collected leachate sample. The total quantities of uranium (in each successive sample) were then integrated to calculate the total amount of uranium removed from the soil, as a function of time.

At the conclusion of leaching, the column setup was dismantled and samples of the leached soil were recovered for uranium and other elements. The samples were taken at different radial and vertical locations (1) to establish the distribution of the residual (remaining) uranium and (2) to determine if any column-wall effects existed. The uranium content of the leached and starting soils was determined by delayed neutron counting and/or by neutron activation analysis. One set of analyses was performed for elements (other than uranium) that may have been simultaneously leached from the soil. Selected samples of the leached soil have been given to the members of the Characterization Subtask Group of the USID for complete characterization of the soils.

Slight differences in procedure were used for the SP4 soil, as noted below:

- (i) K_2CO_3 and $KHCO_3$ were used in place of Na_2CO_3 and $NaHCO_3$.
- (ii) All samples were collected manually.
- (iii) Uranium analyses for the leachate were determined using a Direct Current Plasma Spectrometer. Fifteen measurements at a single uranium absorbance line were taken for each sample.

Because of the success with leaching the 15 cm tall columns, we have extended this study to include 30 cm, 75 cm, and 150 cm tall columns thus far using the SP9(94) soil. The 30 cm column was constructed by placing 15 cm units on top of each other, whereas the 75 cm column is as shown in Fig. 6. Apart from being taller, these columns were treated in the same way as has been previously described.

Figure 6. 150 Cm Column Experiment

3. RESULTS

A. Carbonate/Bicarbonate Leach Tests

Table 1 lists the all the column experiments performed. Selected results of the uranium concentration in the leachate are shown in Fig. 7-10 while Fig. 11 shows the variation in pH as a function of time. Complete lists of all the results are presented in Appendix A. Breakthrough times for the initial leachate were approximately proportional to the height of the columns. Leach time was not proportional to the height of the columns.

Table 2 lists the ions and concentrations that were found in the leachate. These have been used in modeling calculations, which are fully reported in Appendix B(i).

The results of the characterization of the soils after uranium removal and some of the neutron activation analysis measurements on the soil have not yet been received. The neutron activation analyses that have been received show that uranium results are 5-7 % higher than analysis by wet digestion and ICP mass spectrometry.

Electrical energy consumption during lab scale testing was negligible. As an example the only electrical energy used to leach 1 kg of soil was enough to lift 1 to 2 L of leached solution 1' vertically every 24 hours.

TABLE 1
SUMMARY OF COLUMN EXPERIMENTS
PERFORMED IN FY 93 & FY 94

	Column Number	M	Carbonate Salt	Flow Rate	Mass (kg)	Soil	Preparation
FY93							
1	C021193	0.1	Potassium	1X	1	SP4	Homogenized
2	C052593	0.1	Sodium	1X	1	SP9(93)	Homogenized
3	C100193	0.1	Sodium	1X	1	SP9(93)	Homogenized, Agglomerated w/ cement
4	C100293	0.1	Sodium	1X	1	SP9(93)	Homogenized
5	C092893	0.1	Sodium	2X	1	SP9(93)	Homogenized
6	C060493	0.20	Sodium	1X	1	SP9(93)	Homogenized
7	C082693	0.25	Sodium	1X	1	SP9(93)	Homogenized
8	C082793	0.25	Sodium	1X	1	SP9(93)	Homogenized
9	C060393	0.5	Sodium	1X	1	SP9(93)	Homogenized
10	C081693	0.5	Sodium	1X	1	SP9(93)	Homogenized
11	C081793	0.5	Sodium	1X	1	SP9(93)	Homogenized, Agglomerated w/ cement
12	C091393	0.5	Sodium	2X	1	SP9(93)	Homogenized
13	C091493	0.5	Sodium	2X	1	SP9(93)	Homogenized
FY94							
1	C012694	0.5	Sodium	1X	1	SP9(94)	Heterogeneous, Agglomerated with water
2	C012794	0.5	Sodium	1X	1	SP9(94)	Heterogeneous, Agglomerated with water
3	C020494	0.5	Sodium	0.3X	1	SP9(94)	Heterogeneous, Agglomerated with water
4	C020594	0.5	Sodium	0.3X	1	SP9(94)	Heterogeneous, Agglomerated with water
5	C012894	0.5	Sodium	1X	3	SP9(94)	Heterogeneous, Agglomerated with water
6	C030894	0.5	Sodium	1X	3	SP9(94)	Heterogeneous, Agglomerated with water
7	C022394	0.5	Sodium	1X	10	SP9(94)	Heterogeneous, Agglomerated with water
8	C032594	0.5	Sodium	1X	10	SP9(94)	Heterogeneous, Agglomerated with water

Figure 7. Uranium Removal as a Function of Time.
 Results Using SP9(93) Soil,
 $X = \text{Loading Rate } (X) = 0.01 \text{ ml/Cm}^2/\text{min.}$

Figure 8.

Effect of Variation of Concentration of Sodium Carbonate/Sodium Bicarbonate Solution.

Results Using SP9(93) Soil,

X = Loading Rate (X) = 0.01 ml/Cm²/min.

Figure 9.

ppm of Uranium in Leachate, Using SP9(93) Soil,
 $X = \text{Loading Rate (X)} = 0.01 \text{ ml/Cm}^2/\text{min.}$
 $(0.5\text{M Na}_2\text{CO}_3/\text{NaHCO}_3)$

Figure 10.

Uranium Removal as a Function of Time Using SP9(94) Spoil and Different Quantities of Soil

Figure 11. pH as a Function of Time Using Sp9(94) Soil During Uranium Removal

Table 2. Solution Chemistry of Column Effluents Using SP9(93) Soil, Fernald, Ohio.

(All values in ppm except where noted, pH values in standard units)

Cumulative Effluent Vol (L)	pe ¹	pH	Ca	Al	U	Fe	Mg	K	H ₄ SiO ₄	Alkalinity (mg/L CaCO ₃)
0.027	1.76	9.58	20.27	0.50	289	3.11	20.37	7.20	40.60	25,300
0.225	1.47	9.64	22.59	0.83	292	8.63	18.06	6.10	37.80	26,900
0.545	1.41	9.68	33.80	0.70	176	8.66	17.90	6.30	29.60	32,600
1.105	1.41	9.70	31.63	0.90	112	7.80	13.21	2.40	26.30	36,600
2.665	1.51	9.73	19.97	0.59	21.77	4.37	9.48	2.50	25.30	37,300
3.630	1.61	9.73	12.77	0.59	10.00	2.71	6.34	0.30	24.90	38,500
4.720	1.64	9.73	9.90	0.51	7.00	2.33	6.13	0.80	22.80	36,200
5.065	1.64	9.73	10.50	0.49	5.00	2.37	6.53	6.00	24.30	38,100

1. pe = negative log of the electron activity. pe is calculated from summing and taking the average of H₂O/O₂ and Fe²⁺/Fe(OH)₃ redox couples.

B . Soil Characteristics after Leach.

Soils in the columns were used without removing the larger particles or plant fragments. The homogenized material consists primarily of granular soil aggregates. Kneff (Kneff, 1992) reports that 83 (range 72 to 89)% and 70 (range 50 to 82)% of the particles of the SP4 and SP9 soils, respectively, were greater than 2 mm in size. However, these large particles are primarily aggregates of smaller particles, as suggested by the markedly different size distribution measured after wet sieving these homogenized soils. Specifically Francis (Francis, 1992) reports that >93% of the wet sieved soils were less than 2 mm. However, the wet-sieved SP9 soil still contained a fraction of aggregates within the < 2mm fraction which are thought to form during the incineration process. The homogenized soils also have a high organic content; some organic matter was removed during the column studies resulting in a light to medium dark brown leachate after several hours of experiment. In general the leachate was darker for higher carbonate concentrations. During the course of the experiments, the soil in the columns also became noticeably more yellow which is consistent with the removal of organic matter. The homogenized soil was carefully loaded into the column, retaining the original aggregate structure. However, the texture of the soils changed during the course of the experiment. Within the first six hours, the columns compacted slightly, as shown by a 10 to 20% decrease in height. After this initial compaction, very further compaction was seen. The aggregates also appeared to become deformed and there was a slight increase in fines. The soil had to be forced from the column on completion of the experiment and separated as a single slug. After removal from the column, the soil noticeably slumped but remained intact as a block. These properties indicate that the soil lost some of its structural rigidity and became more plastic during the experiments. Furthermore, the soil became visibly wet during the course of the experiments and the final moisture content was 1 1/2 to 2 times greater than the starting material.

Agglomerating the homogenized soil in our laboratory with cement resulted in soil aggregates which, on average, were slightly larger than the initial material. The textural changes were slightly different and the agglomerated soil compacted much less. In addition, the agglomerated soil retained more of its structural rigidity. This is supported by the time of breakthrough (first appearance) of the leachate in the agglomerated columns which was earlier than for the untreated soils indicating less retention and possibly a more direct path for fluid flow. Concerns about swelling of the clays in the soil were found not to be valid.

Because the whole purpose of this study is to be able to return the soil to its original use, i.e., supporting vegetative growth, we planted both radish and corn seeds in some of the leached soil, without further treatment of the soil. All the seeds germinated. When the soil was mixed one-to-one with potting soil the seeds produced seedling plants. This shows that the soil can be usefully returned to the environment. A full description of these experiments will be reported later.

4. DISCUSSION

A. Leach Tests

(i) Chemical removal

In all the column experiments so far completed, over 80% of the uranium was removed. This is true for all the parameters measured; column heights, flow rates, change in associated cation (i.e., potassium in place of sodium) and change in molarity of lixiviant. Irrespective of the column height, most of the uranium removal was accomplished in the first ten days, (See Fig. 11). It is apparent from Fig. 10 that, when the columns become larger, (3 kg or greater), a large increase in removal is first seen prior to the regular decreases which were found in the small one kg column.

From the chemistry of uranium, we know that the uranium (VI) will be easily solubilized to a carbonate complex whereas the uranium (IV) will be unaffected by the presence of carbonate. The stages of solubilization have been documented by (Grenthe 1992):

It is possible that we are successfully removing all the (VI) while leaving the (IV) attached to the soil. The initial forms of contaminant are airborne UF_4 and U_3O_8 forms (Radiological Assessments Corporation, 1993). These will become oxidized and weathered in the atmosphere. The oxide emitted is already 66% in the oxidized state. However we lack data as the relative amounts of UF_4 and U_3O_8 was emitted. Suffice to say that some oxidation will take place, although, demonstrably, this is incomplete.

Data collected during the course of experiments included concentrations of U, Ca, Al, Fe, Mg, K, Is, pH and alkalinity in the column effluents (e.g. Table 2), along with U, Fe and pH analysis of the soils before and after leach experiments. From these data several relationships can be observed, giving rise to possible explanation of the chemical processes taking place during leach experiments.

Initially, the pH of the unleached soil is 6.9. The starting pH of the approximately 0.5 M sodium-carbonate-bicarbonate ($\text{Na}_2\text{CO}_3\text{-NaHCO}_3$) leach solutions (25 g NaHCO_3/L + 25 g $\text{Na}_2\text{CO}_3/\text{L}$) was 9.6. In virtually all of the FY94 experiments, the pH of the soil at completion of the leach tests was 9.6 as well. This suggests that the natural buffering capacity of the soil was surpassed at some point during the leach process, and the carbonate-bicarbonate controlled the pH by the completion of each experiment.

Maximum U concentration in the leachate occurs in the 10 kg column experiments at $\text{pH} \approx 7.5$, $\text{U} \approx 1720$ ppm. Uranium concentration of the 3 kg experiment leachate is greatest at $\text{pH} \approx 8$ with $\text{U} \approx 1100$ ppm. U concentration of the 10 kg column effluent is also about 1100 ppm at $\text{pH} \approx 8$. Maximum U concentration in the 1 kg column occurred at $\text{pH} 9.4$, $\text{U} = 500$ ppm. Concentration of the 3 kg and 10 kg columns were also about 500 ppm at $\text{pH} \approx 9.4$.

pH analysis of leachates from all of the FY94 columns show that U concentration of the leachate is greatest between pH=7.5 and pH=9. Above pH=9, uranium concentrations decrease sharply by as much as two orders of magnitudes to its lowest concentrations at pH=9.6.

Analysis of various FY94 leachate samples for Fe and Mg show moderate concentrations at pH 9 (10^{-2} M and $10^{-3.5}$ M, respectively). Fe concentrations almost double between pH=9 and pH=9.5 to about $10^{-3.3}$ M. Mg concentrations remain steady up to pH 9.6 where it dramatically drops two orders of magnitudes to 10^{-4} M.

This suggests that pH is controlling the U dissolution process.

Brookins (1987) shows the stability fields of U (Fig. 12), with UO_2CO_3 (Eq. 1) between pH=5 and pH=6.25, $\text{UO}_2(\text{CO}_3)_2^{2-}$ (Eq. 2) between pHs 6.25 and 8.5 and $\text{UO}_2(\text{CO}_3)_3^{4-}$ at pH greater than 8.5. Greatest U removal in SP9(94) would therefore have U in the $\text{UO}_2(\text{CO}_3)_2^{2-}$ phase.

$\text{Mg}(\text{OH})_2$ occupies the stability field above pH=9 (Fig. 13). Brookins (1987) explains that at concentrations of Mg less than 10^{-3} M, MgCO_3 will likely substitute for $\text{Mg}(\text{OH})_2$. This could well be the case in our leach solutions, and could further explain the reason that the carbonate is complexing with Mg and not necessarily with the U at those pHs.

Longmire (1994) reports that the dissolved Fe concentration may be controlled by the precipitation of FeCO_3 (siderite). Precipitation of siderite is possible through reductive dissolution of $\text{Fe}(\text{OH})_3$. Fig. 14 shows FeCO_3 occupying a small field between pHs 6.8 and 9.4, separating Fe^{2+} from $\text{Fe}(\text{OH})_2$, and encroaching slightly on the $\text{Fe}(\text{OH})_3$ field. This could explain the increase in Fe concentration between the pHs of 9 and 9.5. Uraninite (UO_2) becomes oxidized, forming schoepite ($\text{UO}_3 \cdot 2\text{H}_2\text{O}$), as $\text{Fe}(\text{OH})_3$ becomes reduced. Schoepite undergoes rapid dissolution within the alkaline pH, carbonate rich leach solutions.

Further reduction of the collected data should provide a means by which to mathematically model the desorption and dissolution process that takes place during the heap leach process. This should further enable us to more accurately predict what the effects of scaling the process up to pilot and full size heap leach are on the carbonate-bicarbonate-uranium chemistry.

Figure 12. Eh-pH diagram for part of the system U-C-O-H.
Assumed activities for dissolved species are: $U = 10^{-4}$, $C = 10^{-3}$.
Brookins 1987

Figure 13 Eh-pH diagram for part of the system Mg-O-H.
Assumed activity of dissolved Mg = 10^{-2} – 10^{-3} . See text for discussion
Brookins 1987

Figure 14. Eh-pH diagram for part of the system Fe-C-O-H.
Assumed activities of dissolved species are: Fe = 10^{-6} , C = 10^{-3} .

Brookins 1987

(ii) Physical Soil Characteristics

Thus far, in our laboratory column experiments, we have been able to maintain adequate hydraulic conductivity through the soil. The two exceptions were columns FY94, 7. and 8., see Table 1. In these columns the solution pooled above the mid-height filter, but this is thought to be a filter problem and not a soil conductivity problem. Most of the Fernald tests were conducted with agglomerated soil. Some soils were agglomerated with water only. Other soils were agglomerated with water and a binding agent, i.e., Type I Portland cement.

It was demonstrated in our tests that there is a penalty associated with using Portland cement as a binding agent. The uranium removal efficiency was slightly lower when Portland cement was used than when it was not used.

The agglomerates made with the Portland cement in the laboratory had a water content of approximately 20%. Once the agglomerates were formed, they were cured before leaching was started, that is the cement was allowed to hydrate. The agglomerates must not be allowed to dry out. If allowed to dry, they will lose their structure when rewetted with the leaching solution. Therefore, agglomerates were either kept in a humidior or were loaded directly from the agglomerator into the leaching column.

B. Agglomeration

Agglomeration (i.e., the process of rolling ore into pellets) has been demonstrated by the mining industry to (1) increase hydraulic conductivity within a heap and (2) eliminate preferential flow paths within a heap. This is particularly true when leaching ores, and presumably soils, that are high in clay content. Fernald soil is known to be high in silt and clay. (Lee, January 1992)

As stated earlier, there is a penalty associated with using Portland cement as a binding agent for our tests. The uranium removal efficiency was slightly lower when Portland cement was used than when it was not used.

While Portland cement is an acceptable agglomerating agent for gold leaching, it is probably not the ideal agglomerating agent for removing uranium from soil. Most gold leaching solutions have a pH of approximately 11. Our solutions had a pH of 9.3 to 9.5. The Portland cement was added to the Fernald soil at the rate of 12 lb cement/ton of soil (i.e. 0.6 % by weight). Recent information indicates that uranium leaches best at a pH of 7.5 to 9.0. (Carpenter, 1994) This may explain the penalty experienced with using Portland cement. Therefore, a binding agent with a lower pH than Portland cement will be sought.

Agglomeration with a binding agent has not been necessary thus far in our testing effort. However, as the columns get taller there is a possibility of loss, or impairment, of hydraulic conductivity. As the column height is increased to 150 cm (5 ft), and then to 3.5 m (12 ft), the agglomerates at the bottom of the column may be crushed by the overburden weight. If and when this occurs, it may be necessary to agglomerate the soil with a binding agent to give the agglomerates added strength. If agglomeration is not required in 3.5 m tall columns, it still may be required for pilot-scale and/or field-scale leaching. Here, for the first time, the operation will not be conducted in laboratory conditions. The uncertainties introduced by large equipment, equipment operators, and weather may make agglomeration with a binding agent necessary.

Agglomerates made with water only maintain their structural integrity in natural water containing electrolytes, at least at the column heights and pH tested. However, if a non-ionic solution, such as distilled and hydraulic conductivity is lost or severely impaired. From this experience, we concluded that:

- (1) If field-scale leaching of water-agglomerated soil is performed in the outdoors, water from rain storms and/or snow could stop or severely degrade the process effectiveness.
- (3) If field-scale leaching of water-agglomerated soil is performed indoors, there is a chance that the soil might not have to be agglomerated with a binding agent.
- (3) The optimization process, regardless of column height, should be performed on the correct soil type, i.e., water-agglomerated vs. agglomerated with a binding agent. Otherwise, the optimization is not being performed under the correct physical and chemical conditions.

Although our experience with agglomeration is limited, we can draw upon the experience of the precious metals mining industry. In that industry, the ore is crushed down to typically 3/8". This produces a lot of fines that can stop up the heap. So, they agglomerate the fines to the 3/8" course material. The agglomerating mixture is formed by mixing 10-20 lb of Portland cement with one ton of ore. This represents a 0.5% to 1% addition, by weight, to the ore. The mixture is then tumbled in a rotating vessel while liquid, normally water, is added in coarse drops (sometimes the leaching solution itself is used instead of water). As the agglomerating machine turns, the material inside tries to climb the rotating side of the agglomerator but eventually slides and rolls down an inclined surface by gravity. The water drops sprayed on the material, serve as a nuclei and causes the fine materials to stick together and roll up around the course material into pellets or balls, i.e., agglomerates. The agglomerates are normally placed on the heap with a retreating stacker and are allowed to cure for approximately 24 hours before leaching is started. The agglomerates are a very poor grade of concrete and are intended to maintain their shape and consistency only long enough to permit the leaching. Most of the physical structure is destroyed when the agglomerates are removed from the leaching pad and returned to the ground. From this knowledge of precious-metals-ore agglomeration, we hope to build a knowledge base for agglomerating uranium-contaminated soil.

As reported by McClelland, (McClelland, 9034) the optimal values of the parameters governing agglomeration are:

1. Using a drum agglomerator, or disc pelletizer, for the mechanical tumbling of agglomeration.
2. Using equal proportions of agglomerating agent (lime and cement). In the study reported, 25: 25 lb per ton of tailings gave the best results (strength, permeability, minimum additions). Percolation rate was approximately unaffected by binder additions of 15:15 lb.
3. The quantity of water added was best between 20 - 25%.
4. The time between agglomeration and the leach process increased the percolation rate up to about 24 hr, beyond which there was little change.

Our collaborators at New Mexico State University have determined that most information of agglomeration is empirical in nature. Little experimental data have been found on

compressive and sheer strengths of agglomerates. Agglomeration seems to be more of an art than a science.

Within a properly agglomerated heap, there should be no "preferred pathways", because all "pathways are preferred".

C. Mathematical Models of Leaching Systems

The objective of the laboratory column studies is to determine the behavior of the heap leach system in response to external and internal inputs. It is important to be able to predict the chemical and hydraulic performance of the system. In predicting hydraulic performance, it has become common practice to use models that have been developed to describe the hydraulic characteristics of reactors to carry out chemical and biological reactions.

The leaching reactor models that are of interest are (1) the batch reactor, (2) the complete-mix reactor, (3) the plug-flow reactor, and (4) the cascade of complete-mix reactors.

Batch Reactors

A reactor in which flow is neither entering nor leaving is defined as a batch reactor. Batch reactors can be used to model vat leaching.

Complete-Mix Reactors

In the complete-mix reactor, fluid particles that enter the reactor are instantaneously dispersed throughout the reactor volume. The fluid particles leave the reactor in proportion to their statistical population. In the field of chemical engineering, the complete-mix reactor is known as the *continuous-flow stirred-tank reactor* (CFSTR). The complete-mix model is used to study reservoirs, such as those used in vat leaching, with continuous inputs and outputs.

Plug-Flow Reactors

In a plug-flow reactor (PFR), fluid particles pass through the reactor and are discharged in the same sequence in which they entered the reactor. Each fluid particle remains in the reactor for a time period equal to the theoretical detention time. Plug-flow models can be used to study heap leach systems.

Cascade of Complete-Mix Reactors

The cascade of complete-mix reactors is used to model the flow regime that exists between the hydraulic flow patterns corresponding to the complete-mix and plug-flow reactors. If the cascade is composed of one reactor, the complete-mix flow regime prevails. If the cascade consists of an infinite number of reactors in series, the plug-flow regime results.

Plug-flow reactors (PFRs) are ideally mixed in the lateral direction and unmixed longitudinally. Although this is an unrealistic assumption for most real-world systems, the PFR is used to define a limit and, as will be shown, can be approximated closely. Because longitudinal mixing does not occur in a PFR, the mean hydraulic residence time, qH , is the true hydraulic residence time. An effluent tracer signal is exactly the same as the input, except that it is transposed in time qH .

A materials balance on a reactive material must be made on an incremental volume, $DV=ADx$ because a longitudinal concentration gradient exists. For the Reaction A $\rightarrow$ E, the mass balance over the increment is given by (Tchobanoglous, 1987):

$$\begin{aligned} \frac{\partial C_A}{\partial t} \Delta V &= (Q C_A)|_x - (Q C_A)|_{x+\Delta x} + r_A \Delta V \\ &= \text{Accumulation} = \text{Inflow} - \text{Outflow} + \text{Generation} \end{aligned} \quad (1)$$

where C_A = concentration of material A in volume element

V = volume

Q = volumetric flow rate

r_A = rate of reaction reactant A

Because $DV = ADx$, the above equation can be written as follows by taking the limit as Dx approaches zero:

$$\frac{\partial C_A}{\partial t} = -\frac{Q}{A} \frac{\partial C_A}{\partial x} + r_A \quad (2)$$

Generally, the flow rate Q is nearly constant, and the following transformation can be made:

$$\frac{1}{A} \frac{\partial C_A}{\partial t} = -\frac{Q}{A} \frac{\partial C_A}{\partial x} = \frac{\partial C_A}{\partial \theta_H} \quad (3)$$

where

$$\frac{A \partial x}{Q} = \partial \theta_H \quad (4)$$

After substitution of the above transformation into Eq(4), the steady-state

$$\frac{\partial C_A}{\partial \theta_H} = r_A \quad (5)$$

PFRs are more efficient than CFSTRs for most reaction systems because the average reaction rate is higher. If the reaction rate was calculated at various points along the length of a PFR, or in this case the depth of the heap, the values would gradually decrease. The lowest value would be at the outlet, or at the bottom of the heap, where the reactant concentration was the lowest. Comparing this situation with the CFSTR, where the reaction rate must be the same everywhere, and therefore must be the lowest value, explains why PFRs are more efficient than CFSTRs.

5. Future Directions

A. Summary Plans

1. Investigate oxidation of U(IV) to U(VI) to improve overall uranium leachability.
2. Determine the need for agglomeration at field-scale using a binding agent.
3. Search for a better agglomerating (binding) agent than Portland cement, if necessary.
4. Complete optimization of the leaching process using the correct soil, i.e., agglomerated with water only vs. agglomerated with a binding agent (determined in 2 above).
5. Scale up process in columns ~38 cm (15-in) diam. x ~150 cm (5-ft) tall.
6. Pilot-Scale Testing
 - a. Scale up process at Los Alamos in columns ~38 cm (15-in) diam. x ~366 cm (12-ft) tall
 - b. Conduct pilot-scale tests at FEMP (Fernald, OH) with 1 cubic meter and 800 to 1000 cubic meters on impermeable pad.
7. Conduct a 5 kg column (~5 ft) in order to analyze the mechanisms of uranium removal, for comparison with the data displayed on Fig. 10.

Until now, the volume of the columns has been kept small deliberately, until the primary chemistry of the process can be understood. As soon as that is accomplished, the engineering for the large scaleup of the process will be added to the chemistry and the two reconciled with each other.

B. Optimization of Process

Investigations into optimizing the process will be continued. The first investigation will involve the possible use of an oxidizer to convert U(IV) to U(VI) before leaching with carbonate. It is hypothesized that the current process is removing most, or all, of the U(VI), but not substantially affecting the U(IV). Several oxidizers will be considered, e.g., hydrogen peroxide, hypochlorite.

As stated in the section on agglomeration, it must be determined if agglomeration is needed at field scale. The need depends upon (1) the strength of agglomerates made with water only and their ability to withstand column heights of 366 cm (12 ft), or greater and (2) the possible requirement by regulators to conduct field-scale leaching indoors for reasons of safety and esthetics. If agglomeration is needed, a search for a better agglomerating agent will be conducted. It is possible that a neutral pH agglomerating agent might be found that does not penalize leaching efficiency. This is discussed more fully in the Agglomeration section.

C. Pilot Scale Tests

The first phase of pilot scale testing will be conducted in Los Alamos, NM. At least two columns ~38 cm (15-in) diam. x ~366 cm (12-ft) tall will be leached.

The second phase of pilot-scale testing will be conducted at FEMP. This test will involve a one-cubic meter test. A test will be conducted to cleanup about 800 to 1000 cubic meters of soil on a tennis court-size leach pad. This second phase of the testing will be conducted by FERMCO and its subcontractors under the technical direction of Los Alamos.

The pilot-scale test design will be performed in Los Alamos. The design of the pilot-scale test will include a leaching pad (50 by 50 ft) with a leachate collection sump at the bottom of the heap, a reagent distribution system for the top of the heap, a leachate regeneration system, and instrumentation. The need for containment of airborne pollutants will be evaluated and, if necessary, suitable measures will be designed.

All *scientific* equipment and materials for the 1 cubic meter and pilot-scale tests will be procured by Los Alamos or its collaborators. All *non-scientific* equipment and materials for the tests will be procured by FERMCO, based upon design information supplied by Los Alamos. FERMCO will obtain the necessary federal, state, and local permits to conduct the tests at Fernald, OH.

The scientific equipment will be assembled and bench-tested in Los Alamos while the leach pad and containment structure (if necessary) are being constructed by FERMCO. The scientific equipment will be shipped to FERMCO and installed, in modular fashion, by FERMCO under Los Alamos direction.

The pilot-scale tests will be conducted on an impermeable and properly sloped pad. The leachate will be collected at the low point on the pad (in a sump) and will be regenerated for reuse. The exact method for regeneration will be determined until the successful leaching reagent is selected. This method will be simple and economical, such as adjusting the pH and causing precipitation of the uranium. The pad and all leachate collection and regeneration equipment will be constructed and tested before any soil is excavated.

Before the large pilot-scale test is performed, a small heap will be constructed on the pad and test-leached. This test will involve about 1 cubic meter of contaminated soil. This test will serve as an intermediate step to check out the newly activated equipment, the agglomeration process, the proposed heap geometry, the reagent application method, and test instrumentation.

When all is ready, soil for the large pilot-scale test will be excavated under controlled conditions, agglomerated, and the heap will be constructed, using a retreating stacker. The pilot-scale heap will be 12 to 16 ft in height, depending upon several things such as the strength of the agglomerates, the kinetics of the chemical reaction, and the economics of operation. Numerous samples of the soil will be collected as the heap is being constructed.

The reagent dispensing system (i.e., a modified sprinkler, or drip-irrigation system) will be added to the top. The progress of the tests will be evaluated by measuring the integrated volume of leachate and the concentration of the waste within the leachate. A mass balance will be established (that is, how much uranium was in the original heap less the amount that was removed) to determine the amount of uranium remaining in the heap. Additionally, core samples will be taken from the heap at planned intervals to measure progress of the test and to confirm the mass balance. The leaching phase of each test will probably take 2 to 4 months to meet EPA criteria for uranium in soil. Currently, the

maximum limit for uranium in soil has not been officially established. For testing purposes it is assumed to be 35 pCi/gm or 52 ppm. This estimate of leaching time is based on experience of the precious metals mining industry. The leaching time is related to many parameters, e.g., height of heap, hydraulic conductivity, rate of application of reagent, speed of chemical reaction, outdoor temperature. At the conclusion of the test, the heap will be dismantled, visually inspected, and chemically tested, to further verify that the soil has met the criteria for clean soil.

Technical direction of all the testing, i.e., laboratory-scale and pilot-scale, will be the responsibility of Los Alamos. This would involve active participation (and approval authority) in the test planning, test execution, data analysis, and reporting. Actual day-to-day testing effort would be conducted by FERMCO personnel. Los Alamos will issue the scientific report of results.

At the end of the pilot-scale tests, FERMCO personnel should be able to continue the process or supervise the site cleanup by a subcontractor.

6. CONCLUSIONS

We have shown that uranium can be removed from the specific uranium contaminated soil from the FEMP site using a simulated heap leach process in the laboratory. These results suggest that the process may be applicable on a larger column scale and also in a real time heap leach scenario.

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8. APPENDICES

Appendix A.

Complete Data on Column Experiments

Table A1.1. lists all the column experiments completed in FY 1993. This is followed by the complete set of data which are linked to Table A1.1 by the column number. The same linkage is true for Table A1.2 for the FY 1994 results.

TABLE A 1.1
SUMMARY OF COLUMN EXPERIMENTS
PERFORMED IN FY 93

	Column Number	M	Carbonate Salt	Flow Rate	Mass (kg)	Soil	Preparation
1	C021193	0.1	Potassium	1X	1	SP4	Homogenized
2	C052593	0.1	Sodium	1X	1	SP9(93)	Homogenized
3	C100193	0.1	Sodium	1X	1	SP9(93)	Homogenized, Agglomerated w/ cement
4	C100293	0.1	Sodium	1X	1	SP9(93)	Homogenized
5	C092893	0.1	Sodium	2X	1	SP9(93)	Homogenized
6	C060493	0.20	Sodium	1X	1	SP9(93)	Homogenized
7	C082693	0.25	Sodium	1X	1	SP9(93)	Homogenized
8	C082793	0.25	Sodium	1X	1	SP9(93)	Homogenized
9	C060393	0.5	Sodium	1X	1	SP9(93)	Homogenized
10	C081693	0.5	Sodium	1X	1	SP9(93)	Homogenized
11	C081793	0.5	Sodium	1X	1	SP9(93)	Homogenized, Agglomerated w/ cement
12	C091393	0.5	Sodium	2X	1	SP9(93)	Homogenized
13	C091493	0.5	Sodium	2X	1	SP9(93)	Homogenized

C021193 - 0.5 M Potassium-Carbonate-Bicarbonate, 1X, 1 kg SP4, Homogenized

Sample	u(367) (mg/L)	U(385) (mg/L)	U(AVE) (mg/L)	SAMPLE VOL (L)	U REMOVED (mg)	TOTAL U REMOVED (mg/kg)	EXPERIMENT TIME (day)	U(AVE) (mg/L)	EXPERIMENT TIME (hr)	U REMAINING IN COLUMN	EPA ACTION LIMIT
S02119301	46.910	46.960	47	0.072273	4.06	4.06	0	47	5.0	416	52
S02119302	0.914	0.948	186	0.607147	135.14	139.19	1	186	20.9	281	52
S02119303	1.069	1.055	212	0.137730	34.97	174.16	1	212	24.7	246	52
S02119304	0.983	1.014	200	0.109860	26.22	200.38	1	200	27.5	220	52
S02119305	1.000	0.960	196	0.104773	24.55	224.94	1	196	30.3	195	52
S02119306	0.559	0.602	116	0.752290	104.48	329.42	2	116	49.8	91	52
S02119307	23.040	22.430	23	0.098293	2.67	332.09	2	23	52.4	88	52
S02119308	9.363	8.376	9	0.781350	8.28	340.37	3	9	73.4	80	52
S02119309	5.601	5.776	6	0.092874	0.63	341.00	3	6	75.9	79	52
S02119310	6.645	6.481	7	0.074390	0.58	341.59	3	7	77.9	78	52
S02119311	4.314	4.092	4	1.411020	7.09	348.68	5	4	117.3	71	52
S02119312	3.690	3.669	4	0.095855	0.42	349.10	5	4	120.0	71	52
S02119313	3.225	3.202	3	0.117342	0.45	349.55	5	3	129.1	70	52
S02119314	3.023	3.108	3	0.086334	0.32	349.87	5	3	125.4	70	52
S02119315	2.900	2.929	3	0.634188	2.21	352.08	6	3	142.5	68	52
S02119316	2.848	2.818	3	0.108574	0.37	352.44	6	3	145.4	68	52
S02119317	2.739	2.754	3	0.130624	0.43	352.87	6	3	148.9	67	52
S02119318	2.431	2.508	2	0.705800	2.08	354.96	7	2	168.7	65	52
S02119319	2.206	2.232	2	0.084880	0.23	355.18	7	2	171.0	65	52
S02119320	2.148	2.171	2	0.096790	0.25	355.43	7	2	175.5	65	52
S02119321	1.986	2.067	2	0.703041	1.70	357.13	8	2	192.2	63	52
S02119322	2.070	2.085	2	0.141977	0.35	357.49	8	2	196.2	63	52
S02119323	2.180	2.225	2	0.865116	2.28	359.76	9	2	220.3	60	52
S02119324	2.127	2.088	2	0.839700	2.12	361.88	10	2	244.7	58	52
S02119325	1.595	1.692	2	0.647526	1.27	363.15	11	2	264.0	57	52
S02119326	1.508	1.440	1	0.854603	1.51	364.66	12	1	288.0	55	52
S02119327	1.291	1.277	1	0.819714	1.26	365.92	13	1	311.6	54	52
S02119328	1.153	1.171	1	0.839779	1.17	367.08	14	1	336.3	53	52

CAS2593 - 0.1M Sodium-Carbonate-Bicarbonate, 1X, 1 kg SPQ(93), Homogenized

Sample No.	Test Tube No.	Time (hrs.)	U (mg/L)	U (mg/L)	Ave. (mg/L)	Std. Dev. (mg/L)	Sample Vol (mL)	Total Vol (mL)	Dilution	U (mg/L)	Volume (mL)	U (mg/L)	UTOT (mg/L)	EPA Target KCP	EPA Target NAA	EPA Target SE
S0052593 1	16	3	4.53	4.53	4.57	0.21	1.0000	1.0000	1.0	4.57	3.7	0	0	448	538	52
S0052593 2	17	3	8.77	7.26	7.93	0.28	1.0000	1.0000	1.0	7.94	5.5	0	0	448	538	52
S0052593 3	18	3	8.74	8.11	8.43	0.26	1.0000	1.0000	1.0	8.68	5.5	0	0	448	538	52
S0052593 4	24	4	1.76	2.34	2.00	0.34	0.9998	10.0132	10.1	20.21	33.0	1	1	447	537	52
S0052593 5	30	5	8.44	8.79	8.62	0.25	0.9951	10.2871	10.3	86.49	34.0	3	4	444	534	52
S0052593 6	36	6	12.48	13.59	13.29	0.13	0.9958	10.1175	10.2	134.39	34.0	5	8	444	530	52
S0052593 7	42	7	17.79	18.79	18.25	0.77	0.9958	10.0552	10.2	185.72	32.0	7	18	432	522	52
S0052593 8	48	8	18.72	19.59	19.01	0.40	0.9817	10.0024	10.2	193.84	31.0	8	22	425	515	52
S0052593 9	54	9	28.49	28.83	28.62	0.30	0.9851	10.0035	10.1	279.85	30.0	9	32	418	508	52
S0052593 10	60	10	24.47	25.97	25.22	1.05	0.9958	10.0094	10.1	254.75	30.0	9	41	407	497	52
S0052593 11	66	11	21.64	23.63	22.64	1.41	0.9721	10.0789	10.4	234.64	28.0	10	58	400	490	52
S0052593 12	72	12	27.68	27.68	27.40	0.57	0.9852	10.0817	10.2	279.55	31.0	10	58	390	480	52
S0052593 13	78	13	29.57	29.58	30.45	0.21	0.9854	10.0477	10.2	299.68	31.0	11	69	379	469	52
S0052593 14	84	14	29.72	31.16	29.95	1.72	0.9754	10.1179	10.4	319.85	31.0	11	80	368	458	52
S0052593 15	90	15	31.21	33.71	32.72	1.40	0.9476	10.0554	10.2	332.15	30.0	11	92	354	448	52
S0052593 16	96	16	33.51	35.96	34.53	1.87	0.9539	10.0742	10.2	364.57	31.0	11	104	344	434	52
S0052593 17	102	17	31.63	34.96	33.25	1.86	0.9767	10.2905	10.5	348.26	31.0	12	117	331	421	52
S0052593 18	108	18	28.85	32.71	30.78	2.73	0.9798	10.0785	10.2	314.73	31.0	11	128	320	410	52
S0052593 19	114	19	31.31	32.79	32.04	1.03	0.9628	10.0568	10.2	332.14	30.0	11	151	297	387	52
S0052593 20	120	20	31.89	32.89	32.44	0.77	0.9521	10.0568	10.2	332.14	30.0	11	151	297	387	52
S0052593 21	126	21	29.68	30.89	29.69	1.41	0.9628	10.1402	10.3	289.27	32.0	11	162	286	376	52
S0052593 22	132	22	29.87	29.31	27.54	0.95	0.9854	10.0212	10.2	299.87	32.0	10	173	275	365	52
S0052593 23	138	23	25.58	27.81	26.15	1.22	0.9890	10.0639	10.2	269.86	30.0	9	182	266	356	52
S0052593 24	144	24	15.98	16.95	16.37	0.69	0.9744	14.0214	14.1	249.47	27.0	7	197	251	341	52
S0052593 25	150	25	21.48	24.31	22.89	2.02	0.9520	10.3186	10.5	239.85	30.0	8	205	243	333	52
S0052593 26	156	26	21.54	22.31	21.86	0.47	0.9416	10.0507	10.2	223.88	30.0	8	205	243	333	52
S0052593 27	161	27	21.89	22.72	21.57	0.81	0.9425	10.1242	10.2	224.58	31.0	8	213	236	325	52
S0052593 28	167	28	19.49	20.73	20.11	0.89	0.9472	10.0915	10.2	184.17	34.0	8	221	227	317	52
S0052593 29	173	29	18.12	19.54	18.83	1.00	0.9914	10.1177	10.2	182.14	33.0	8	228	220	310	52
S0052593 30	181	30	15.98	16.95	16.21	0.89	0.9911	10.7965	10.9	149.76	46.0	9	237	211	301	52
S0052593 31	186	31	19.26	20.52	19.79	0.75	0.9907	10.0212	10.1	189.76	33.0	8	245	203	293	52
S0052593 32	192	32	17.63	18.69	18.11	0.69	0.9908	10.0509	10.1	183.72	34.0	7	252	196	286	52
S0052593 33	198	33	15.12	15.98	15.37	0.35	1.0028	10.0568	10.0	154.17	34.0	6	259	189	279	52
S0052593 34	204	34	14.68	15.16	14.83	0.48	1.0068	10.0551	9.9	147.21	34.0	6	265	183	273	52
S0052593 35	210	35	14.68	15.16	14.83	0.48	1.0068	10.0551	10.1	139.29	34.0	5	270	178	268	52
S0052593 36	216	36	13.57	13.35	13.04	0.47	1.0001	10.2251	10.2	124.39	38.0	5	276	172	262	52
S0052593 37	222	37	12.75	12.49	12.15	0.47	1.0001	10.0431	10.1	119.84	35.0	4	281	167	257	52
S0052593 38	228	38	11.85	12.49	12.15	0.49	0.9944	10.0431	10.1	119.84	35.0	4	284	162	252	52
S0052593 39	234	39	11.16	11.96	11.51	0.49	0.9944	10.0431	10.1	119.84	35.0	4	289	149	239	52
S0052593 40	240	40	18.79	11.98	10.89	0.32	1.0000	10.0689	10.1	89.33	34.0	3	303	145	235	52
S0052593 41	246	41	8.66	9.53	9.31	0.42	0.9958	10.0778	10.1	89.33	34.0	3	306	142	232	52
S0052593 42	252	42	8.53	9.65	8.84	0.30	0.9998	10.0778	10.1	86.89	35.0	3	309	139	229	52
S0052593 43	258	43	8.66	8.98	8.19	0.29	1.0021	10.4709	10.5	76.21	34.0	3	312	136	226	52
S0052593 44	264	44	7.45	7.89	7.61	0.34	1.0021	10.4624	10.4	73.21	34.0	3	315	133	223	52
S0052593 45	270	45	6.79	7.27	7.03	0.34	1.0021	10.4624	10.4	73.21	34.0	3	318	130	220	52
S0052593 46	276	46	7.78	7.34	7.13	0.15	0.9998	10.1352	10.2	71.85	35.0	3	321	127	217	52
S0052593 47	282	47	6.84	7.39	7.13	0.23	0.9972	10.0945	10.1	64.95	34.0	3	324	124	214	52
S0052593 48	288	48	6.65	6.93	6.64	0.27	1.0028	10.0639	10.0	64.95	35.0	2	329	125	215	52
S0052593 49	294	49	5.79	6.69	5.90	0.15	0.9981	10.0910	10.1	64.95	38.0	3	335	122	212	52
S0052593 50	300	50	5.79	5.99	5.81	0.12	0.9998	10.0949	10.0	59.34	38.0	3	338	120	210	52
S0052593 51	306	51	5.72	5.99	5.95	0.19	0.9970	10.1082	10.1	59.34	38.0	3	339	118	208	52
S0052593 52	312	52	5.33	5.53	5.45	0.21	0.9943	10.0371	10.1	55.34	30.0	2	339	116	206	52
S0052593 53	318	53	4.98	4.91	4.82	0.15	0.9953	10.0118	10.0	48.55	30.0	2	332	114	204	52
S0052593 54	324	54	4.79	4.84	4.82	0.13	0.9953	10.0099	10.1	48.55	30.0	2	334	111	201	52
S0052593 55	330	55	4.79	4.84	4.81	0.12	0.9944	10.0647	10.2	48.55	30.0	2	337	109	199	52
S0052593 56	336	56	4.89	4.89	4.89	0.07	0.9954	10.0702	10.1	48.55	30.0	2	339	109	199	52
S0052593 A	163	163	2.19	2.15	2.17	0.03	1.0005	10.0378	10.0	21.79	104.1	27	346	82	172	52
S0052593 B	134	134	11.85	12.49	12.15	0.47	1.0000	1.0000	1.0	12.15	87.9	12	373	76	160	52
S0052593 C	144	144	7.72	8.13	7.93	0.29	1.0000	1.0000	1.0	7.93	113.1	10	398	64	150	52
S0052593 D	189	189	5.94	6.45	5.99	0.09	1.0000	1.0000	1.0	5.99	1032.7	7	395	53	143	52
S0052593 E	192	192	4.68	4.93	4.81	0.19	1.0000	1.0000	1.0	4.81	89.3	5	400	48	138	52
S0052593 F	216	216	15.14	17.26	16.75	0.85	0.9858	10.1277	10.3	172.47	0	0	0			52
S0.5M.06			42.91	48.55	47.19	1.94	1.0000	9.9953	9.9	48.55	0	0	0			52
S0.5M.07			42.91	48.55	47.19	1.94	1.0172	10.0278	9.9	48.55	0	0	0			52
S0.5M.08			42.91	48.55	47.19	1.94	1.0172	10.0278	9.9	48.55	0	0	0			52
S0.5M.09			33.83	38.71	36.05	0.94	1.0162	10.2127	10.0	36.05	0	0	0			52
S0.5M.10			33.83	38.71	36.05	1.02	1.0174	10.1894	10.0	36.05	0	0	0			52
S0052593 A			2.19	2.15	2.17	0.03	1.0005	10.0378	10.0	21.79	0	0	0			52
S0052593 B			11.85	12.49	12.15	0.47	1.0000	1.0000	1.0	12.15	0	0	0			52
S0052593 C			7.18	7.98	7.34	0.22	1.0000	1.0000	1.0	7.34	0	0	0			52

C060393 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X, 1 kg SP9(93), Homogenized

Sample No.	Test Tube No.	Time (hrs.)	Time (days)	U (28S) (mg/L)	U (28S) (mg/L)	Ave. (mg/L)	Std. Dev. (mg/L)	Sample Vol (mL)	Total Vol. (mL)	Dilution	U (mg/L)	Volume (mL)	U (mg/kg)	UTOT (mg/kg)	NAA	EPA Target
		0												0	537	52
S060393 4	24	4	0	31.34	32.56	31.95	0.66	0.9946	10.1490	10.2	328	30	11.2	11	528	52
S060393 5	30	5	0	30.55	36.99	36.27	1.81	0.9946	10.1490	10.2	391	30	13.4	25	512	52
S060393 6	36	6	0	34.56	36.80	35.68	1.58	0.9836	10.1277	10.3	387	30	12.6	37	500	52
S060393 7	42	7	0	32.61	35.00	33.81	1.69	1.0202	9.9953	9.9	331	30	11.4	49	488	52
S060393 8	48	8	0	33.04	35.25	34.15	1.56	1.0172	10.0279	9.9	337	30	11.6	60	477	52
S060393 9	54	9	0	33.53	35.40	34.47	1.32	1.0182	10.2127	10.0	346	30	11.9	72	465	52
S060393 10	60	10	0	33.48	35.48	34.48	1.41	1.0174	10.1884	10.0	348	30	11.9	84	453	52
S060393 11	66	11	0	34.57	35.53	35.55	1.39	1.0228	10.1248	9.9	362	30	12.1	96	441	52
S060393 12	72	12	1	33.49	35.84	34.67	1.68	0.5049	10.0038	19.8	697	30	23.8	120	417	52
S060393 13	78	13	1	33.47	35.56	34.51	1.47	0.5149	10.0838	19.8	677	30	23.2	143	394	52
S060393 14	84	14	1	33.26	34.62	33.94	0.98	0.5042	10.0614	20.0	677	30	23.2	166	371	52
S060393 15	90	15	1	34.20	36.50	35.35	1.63	0.5043	10.1725	20.2	713	30	24.5	190	347	52
S060393 16	96	16	1	29.79	31.73	30.72	1.44	0.5018	10.2038	20.3	623	30	21.4	212	325	52
S060393 17	102	17	1	32.00	33.30	32.65	0.92	0.4993	10.0171	20.1	656	30	22.5	234	303	52
S060393 18	108	18	1	32.18	34.34	33.26	1.53	0.5015	10.1194	20.2	671	35	26.9	281	276	52
S060393 19	114	19	1	31.59	33.37	32.48	1.28	1.0081	10.1028	10.0	328	35	13.0	274	263	52
S060393 20	120	20	1	31.38	33.59	32.49	1.58	1.0066	10.1105	10.0	325	35	13.0	287	250	52
S060393 10	60	21	1	31.02	28.42	29.72	1.84	1.0174	10.1884	10.0	298	35	11.9	299	238	52
S060393 11	66	22	1	27.06	25.82	26.49	0.81	1.0228	10.1248	9.9	282	35	10.5	310	227	52
S060393 12	72	23	1	12.86	12.48	12.67	0.28	0.5049	10.0038	19.8	251	35	10.0	320	217	52
S060393 13	78	24	1	11.31	10.67	10.99	0.45	0.5149	10.0838	19.8	218	35	8.6	328	209	52
S060393 14	84	25	1	10.12	9.51	9.82	0.43	0.5042	10.0614	20.0	196	35	7.8	336	201	52
S060393 15	90	26	1	8.71	8.31	8.51	0.28	0.5043	10.1725	20.2	172	35	6.9	343	194	52
S060393 16	96	27	1	8.02	7.80	7.91	0.18	0.5018	10.2038	20.3	161	35	6.4	350	187	52
S060393 17	102	28	1	7.21	6.98	7.10	0.17	0.4993	10.0171	20.1	142	35	5.7	355	182	52
S060393 18	108	29	1	5.73	5.48	5.60	0.18	0.5015	10.1194	20.2	113	35	4.5	360	177	52
S060393 19	114	30	1	10.38	10.12	10.25	0.18	1.0081	10.1028	10.0	188	35	4.1	364	173	52
S060393 20	120	31	1	10.38	10.02	10.20	0.25	1.0096	10.1105	10.0	182	35	4.1	368	169	52
S060393 21	126	32	1	9.88	9.64	9.76	0.17	1.0093	10.1313	10.0	98	35	3.9	372	165	52
S060393 22	132	33	1	9.36	9.07	9.21	0.21	1.0274	10.0146	9.7	90	35	3.6	376	161	52
S060393 23	138	34	1	8.82	8.30	8.56	0.37	1.0221	10.0821	9.9	84	35	3.4	379	158	52
S060393 24	144	35	1	8.89	7.84	7.93	0.13	1.0025	10.0418	10.0	79	35	3.2	382	155	52
S060393 25	150	36	2	7.46	7.15	7.30	0.22	1.0007	10.0233	10.0	73	35	2.9	385	152	52
S060393 26	156	37	2	7.06	6.76	6.91	0.21	0.9950	10.2883	10.3	71	35	2.9	388	149	52
S060393 27	162	38	2	6.73	6.61	6.67	0.08	1.0012	10.0171	10.0	67	35	2.7	391	146	52
S060393 28	168	39	2	6.34	5.96	6.15	0.27	1.0004	10.0285	10.0	62	35	2.5	393	144	52
S060393 29	174	40	2	5.86	5.51	5.69	0.24	1.0008	10.0385	10.0	57	35	2.3	395	142	52
S060393 30	180	41	2	5.73	5.58	5.65	0.11	1.0053	10.2443	10.2	58	35	2.3	398	139	52
S060393 31	186	42	2	5.07	4.91	4.99	0.11	1.0040	10.3251	10.3	51	35	2.1	400	137	52
S060393 32	192	43	2	5.00	4.86	4.99	0.01	1.0085	10.0304	9.9	80	35	2.0	402	135	52
S060393 33	198	44	2	4.74	4.57	4.66	0.12	1.0289	10.0520	9.8	46	35	1.8	403	134	52
S060393 34	204	45	2	4.51	4.38	4.44	0.09	1.0033	10.0327	10.0	44	35	1.8	405	132	52
S060393 35	210	46	2	4.25	4.17	4.21	0.08	1.0006	10.0057	10.0	42	35	1.7	407	130	52
S060393 36	216	47	2	3.82	3.33	3.42	0.13	1.0085	10.1543	10.1	34	35	1.4	408	129	52
S060393 37	222	48	2	3.87	3.89	3.88	0.02	1.0079	10.0891	10.0	38	35	1.6	410	127	52
S060393 38	228	49	2	3.67	3.76	3.71	0.07	0.9987	10.0934	10.1	38	35	1.5	411	126	52
S060393 39	234	50	2	3.64	3.74	3.64	0.14	1.0059	10.1383	10.1	37	35	1.5	413	124	52
S060393 40	240	51	2	3.42	3.43	3.42	0.01	1.0025	10.0234	10.0	34	35	1.4	414	123	52
S060393 41	246	52	2	3.34	3.20	3.27	0.10	1.0052	10.0891	10.0	33	35	1.3	416	121	52
S060393 42	252	53	2	3.10	3.17	3.14	0.05	1.0022	10.0130	10.0	31	35	1.3	417	120	52
S060393 43	258	54	2	3.31	3.19	3.25	0.08	1.0157	10.0389	9.9	32	35	1.3	418	119	52
S060393 44	264	55	2	3.18	3.41	3.29	0.16	1.0128	10.1104	10.0	33	35	1.3	419	118	52
S060393 45	270	56	2	3.26	3.11	3.18	0.11	1.0168	10.0339	9.9	31	35	1.3	421	116	52
S060393 46	276	57	2	2.88	2.84	2.86	0.03	1.0171	10.2089	10.0	29	35	1.1	422	115	52
S060393 47	282	58	2	2.78	2.79	2.78	0.02	1.0131	10.1727	10.0	28	35	1.1	423	114	52
S060393 48	288	59	2	2.74	2.81	2.77	0.05	1.0230	10.1455	9.9	27	35	1.1	424	113	52
S060393 49	294	60	3	2.70	2.85	2.68	0.04	1.0136	10.4066	10.3	27	35	1.1	425	112	52
S060393 50	300	61	3	2.35	2.30	2.33	0.03	1.0124	10.1055	10.0	23	35	0.9	426	111	52
S060393 51	306	62	3	2.10	2.06	2.08	0.02	1.0252	10.0432	9.8	20	35	0.8	427	110	52
S060393 52	312	63	3	1.94	1.86	1.90	0.06	1.0036	10.0557	10.0	19	35	0.8	428	109	52
S060393 53	318	64	3	0.94	1.00	0.97	0.05	2.0526	20.1921	9.8	10	35	0.4	428	109	52
S060393 A	324	66	4	2.40	2.78	2.57	0.25	2.0203	10.0895	5.0	13	767	11.3	439	98	52
S060393 B	330	117	5	1.41	1.77	1.59	0.25	1.9879	10.2198	5.1	8	1005	9.4	449	88	52
S060393 C	330	147	6	0.92	1.00	0.96	0.08	2.0075	10.0494	5.0	5	1025	5.7	454	83	52

C060493 - 0.2 M Sodium-Carbonate-Bicarbonate, 1X, 1 kg SP9(93), Homogenized

Sample No.	Test Tube No.	Time (hrs.)	Time (days)	U (385) (mg/L)	U (283) (mg/L)	Ave. (mg/L)	Std. Dev. (mg/L)	Sample Vol (mL)	Total Vol. (mL)	Dilution	U (mg/L)	Volume (mL)	U (mg/kg)	UTOT (mg/kg)	U (mg/kg/hr)	EPA Target
C060493 4		4	0	11.18	18.91	10.94	0.15	1.0020	10.0079	10.0	188	0	0.9	537	7.6	52
C060493 5	30	5	0	24.00	21.33	22.31	0.35	1.0124	10.0045	9.9	221	30	7.8	529	9.9	52
C060493 6	36	6	0	31.80	28.64	29.41	0.48	1.0249	10.0465	9.8	268	30	8.9	519	11.8	52
C060493 7	42	7	0	37.97	33.86	34.56	1.08	1.0009	10.0055	10.0	345	30	11.9	508	12.2	52
C060493 8	48	8	0	35.63	34.54	35.51	1.08	1.0030	10.0145	10.0	323	33	12.5	485	12.5	52
C060493 9	54	9	0	37.93	38.47	37.17	0.58	0.9985	10.0384	10.4	362	30	12.5	483	12.7	52
C060493 10	60	10	0	39.14	37.93	38.28	0.62	0.9888	10.0558	10.2	388	30	12.7	470	12.7	52
C060493 11	66	11	0	33.08	32.86	32.95	0.51	0.8948	10.1561	11.4	388	30	12.9	458	12.6	52
C060493 12	72	12	1	34.63	33.57	35.40	0.92	0.9458	10.0341	10.2	333	30	11.5	447	11.5	52
C060493 13	78	13	1	34.12	33.08	32.65	0.64	0.9878	10.0080	10.1	318	30	18.9	436	10.9	52
C060493 14	84	14	1	30.55	28.63	30.26	0.47	0.9432	10.0296	10.2	288	30	18.9	426	10.9	52
C060493 15	90	15	1	29.29	28.41	29.44	0.56	0.9457	10.0482	10.2	288	31	18.9	416	10.9	52
C060493 16	96	16	1	26.55	25.76	26.02	0.40	0.9429	10.0182	10.4	256	33	9.7	408	9.7	52
C060493 17	102	17	1	28.78	25.97	26.17	0.80	0.9580	10.0587	10.5	265	33	9.7	386	9.7	52
C060493 18	108	18	1	28.14	25.37	24.79	0.88	0.9921	9.9840	10.1	249	35	9.6	367	9.6	52
C060493 19	114	19	1	25.67	24.91	24.33	0.67	0.9930	9.9942	10.1	235	35	8.5	377	8.5	52
C060493 20	120	20	1	23.21	22.54	22.47	0.41	1.0030	10.1015	10.1	215	35	8.5	360	8.5	52
C060493 21	126	21	1	23.42	22.74	22.07	0.34	0.9978	10.0025	10.0	218	34	8.5	360	8.5	52
C060493 22	132	22	1	20.53	18.95	19.24	0.35	0.9719	10.0230	10.3	188	35	8.8	352	8.0	52
C060493 23	138	23	1	19.58	18.03	17.87	0.33	0.9965	10.0060	10.0	184	35	7.4	345	7.4	52
C060493 24	144	24	1	18.94	18.41	17.95	0.31	0.9952	9.9894	10.0	178	35	7.1	338	7.1	52
C060493 25	150	25	1	17.89	17.28	17.72	0.25	0.9978	10.0149	10.0	167	35	6.7	331	6.7	52
C060493 26	156	26	1	15.28	14.87	15.15	0.21	0.9880	10.3191	10.4	149	35	6.0	325	6.0	52
C060493 27	162	27	1	14.46	14.05	13.17	0.29	0.9904	10.1873	10.3	148	35	6.0	319	5.6	52
C060493 28	168	28	1	13.55	13.28	13.93	0.37	0.9880	10.0891	10.2	131	35	5.3	314	5.3	52
C060493 29	174	29	1	12.39	12.08	12.80	0.36	0.9928	9.9735	10.0	118	35	4.8	309	4.8	52
C060493 30	180	30	1	11.28	11.91	11.72	0.36	0.9928	9.9843	10.1	108	35	4.3	305	4.3	52
C060493 31	186	31	1	9.57	9.44	9.52	0.24	0.9944	11.0548	11.1	108	35	4.9	301	3.7	52
C060493 32	192	32	1	9.57	8.36	9.04	0.81	0.9944	10.0899	10.2	93	35	3.7	297	3.7	52
C060493 33	198	33	1	9.03	8.55	8.28	0.24	0.9944	9.9815	10.0	86	35	3.4	284	3.4	52
C060493 34	204	34	1	7.98	7.82	7.82	0.36	0.9958	10.0850	10.1	78	35	3.1	281	3.1	52
C060493 35	210	35	1	7.58	7.41	7.41	0.17	0.9937	10.1707	10.2	73	35	2.9	288	2.9	52
C060493 36	216	36	2	7.01	6.88	7.69	0.44	0.9941	9.9906	10.0	69	35	2.8	285	2.8	52
C060493 37	222	37	2	6.97	6.57	7.03	0.24	0.9933	10.1124	10.2	65	35	2.6	282	2.6	52
C060493 38	228	38	2	6.97	6.36	6.75	0.25	0.9923	10.1882	10.3	63	35	2.5	280	2.5	52
C060493 39	234	39	2	5.65	5.65	5.97	0.22	0.9956	10.3952	10.4	57	35	2.3	278	2.3	52
C060493 40	240	40	2	5.68	5.57	5.93	0.18	0.9914	10.2257	10.3	56	35	2.2	275	2.2	52
C060493 41	246	41	2	5.60	5.51	5.82	0.05	0.9858	10.1807	10.3	54	35	2.1	273	2.1	52
C060493 42	252	42	2	5.45	5.37	5.62	0.24	0.9933	10.0824	10.1	53	35	2.1	271	2.1	52
C060493 43	258	43	2	5.37	5.39	5.12	0.05	0.9990	10.1290	10.1	58	35	2.0	269	2.0	52
C060493 44	264	44	2	4.53	4.48	4.58	0.04	0.9952	11.5434	11.8	49	35	1.9	265	1.9	52
C060493 45	270	45	2	4.56	4.48	4.68	0.05	0.9941	10.1182	10.2	46	35	1.8	263	1.8	52
C060493 46	276	46	2	4.56	4.48	4.68	0.05	0.9941	10.0868	10.1	47	35	1.9	263	1.9	52
C060493 47	282	47	2	4.53	4.77	4.58	0.10	0.9909	10.0709	10.2	47	35	1.9	261	1.9	52
C060493 48	288	48	2	4.18	4.12	4.44	0.08	0.9921	10.1058	10.2	43	35	1.7	258	1.7	52
C060493 49	294	49	2	4.54	4.48	4.68	0.11	0.9921	10.1058	10.2	43	35	1.7	258	1.7	52
C060493 50	300	50	2	4.47	4.42	4.64	0.20	0.9916	10.0008	10.1	43	35	1.7	258	1.7	52
C060493 51	306	51	2	4.37	4.32	4.61	0.10	0.9916	10.0132	10.1	37	38	1.5	244	1.5	52
C060493 52	312	52	2	4.25	4.21	4.58	0.08	0.9941	10.0248	10.1	37	38	1.5	242	1.5	52
C060493 53	318	53	2	4.31	4.27	4.68	0.23	0.9912	10.0248	10.1	42	38	1.8	249	1.8	52
C060493 54	324	54	2	4.42	4.36	4.43	0.03	0.9924	10.0288	10.1	42	38	1.8	247	1.8	52
C060493 55	330	55	2	4.25	4.21	4.58	0.10	0.9916	10.0206	10.1	42	38	1.5	246	1.5	52
C060493 56	336	56	2	4.02	3.98	4.17	0.08	0.9903	10.0008	10.1	39	38	1.7	248	1.7	52
C060493 57	342	57	2	3.97	3.94	4.00	0.08	0.9903	10.0132	10.1	37	38	1.5	244	1.5	52
C060493 58	348	58	2	3.78	3.75	3.90	0.06	0.9748	10.1188	10.4	37	38	1.8	241	1.8	52
C060493 59	354	59	3	3.74	3.71	4.00	0.16	0.9874	10.0489	10.1	37	38	1.8	241	1.8	52
C060493 60	360	60	3	3.54	3.53	3.86	0.19	0.9845	10.1637	10.3	36	38	1.8	239	1.8	52
C060493 61	366	61	3	3.50	3.48	3.60	0.18	0.9800	10.0109	10.1	35	38	1.5	238	1.5	52
C060493 62	372	62	3	3.41	3.36	3.62	0.24	0.9850	10.3411	10.4	33	38	1.4	235	1.4	52
C060493 63	378	63	3	3.30	3.29	3.58	0.16	0.9800	10.0782	10.1	30	38	1.3	233	1.3	52
C060493 64	384	64	3	3.13	3.13	3.31	0.10	0.9800	10.1577	10.2	31	38	1.4	232	1.4	52
C060493 65	390	65	3	3.19	3.19	3.36	0.07	0.9800	10.1577	10.2	31	38	1.4	231	1.4	52
C060493 66	396	66	3	3.15	3.15	3.23	0.35	0.9878	10.0184	10.0	32	38	1.4	229	1.4	52
C060493 67	402	67	3	3.14	3.14	3.21	0.33	0.9878	10.0789	10.1	32	38	1.4	229	1.4	52
C060493 A		117	5	4.08	4.08	4.68	0.27	2.0142	10.0020	5.0	29	767	25.8	203	1.2	52
C060493 B		117	5	4.87	4.81	4.74	0.29	1.9828	10.0139	5.0	24	1005	27.7	178	1.0	52
C060493 C		147	6	4.68	4.62	4.75	0.08	1.9860	10.1186	5.1	25	1025	28.5	149	0.9	52

C081693 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X, 1 kg SP2(93), Homogenized

Sample No.	Time (hrs.)	Time (days)	U (367) Intensity	U (367) (mg/L)	U (409) Intensity	U (409) (mg/L)	Ave. (mg/L)	Std. Dev. (mg/L)	% Diff.	Sample Vol (mL)	Water Vol (mL)	Total Vol (mL)	Dilution	U (mg/L)	Volume (mL)	U (mg/kg)	U TOT (mg/kg)	U mg/kg/hr	NAA Analysis	EPA Target
0	0	0																	538	52
S081693 3	3	0	24819.8	40.02	43698.8	38.98	38.49	2.18	7.8	1.00	15.18	16.2	16.2	623	20	14.3	14.3	4.8	524	52
S081693 4	4	0	19700.0	32.82	34070.0	28.89	30.86	2.77	12.0	1.00	15.21	16.2	16.2	500	36	20.8	34.9	20.6	503	52
S081693 6	6	0	17920.0	29.84	33210.0	28.18	29.00	1.19	5.6	1.01	16.00	17.0	16.8	438	80	44.7	79.8	22.4	458	52
S081693 8	8	0	16350.0	27.22	30020.0	25.45	26.34	1.25	6.5	1.00	16.34	17.3	17.3	457	82	42.8	122.4	21.4	416	52
S081693 10	10	0	13980.0	23.28	27040.0	22.92	23.09	0.24	1.5	1.00	15.32	16.3	16.3	377	84	38.2	158.6	18.1	378	52
S081693 12	12	1	18650.0	31.08	32280.0	27.35	29.21	2.82	11.9	1.00	15.99	17.0	17.0	486	88	50.0	208.6	25.0	329	52
S081693 14	14	1	15730.0	26.19	28150.0	23.88	25.02	1.84	8.9	1.00	16.09	17.1	17.1	428	90	44.0	252.8	22.0	285	52
S081693 16	16	1	15620.0	26.00	29080.0	24.83	25.32	0.97	5.3	1.00	16.09	17.1	17.1	433	92	45.5	298.2	22.8	240	52
S081693 18	18	1	12890.0	21.44	22240.0	18.84	20.14	1.84	12.1	1.00	15.21	16.2	16.2	328	94	35.1	333.3	17.8	205	52
S081693 20	20	1	10910.0	18.13	19730.0	16.70	17.42	1.01	7.9	1.00	15.68	16.7	16.7	291	96	31.9	365.2	16.0	173	52
S081693 22	22	1	6443.0	10.67	12200.0	10.30	10.49	0.26	3.5	1.01	15.98	17.0	16.8	176	98	19.8	384.9	9.9	153	52
S081693 24	24	1	4834.0	7.98	8852.0	7.45	7.72	0.37	6.6	1.01	16.03	17.0	16.9	130	100	14.9	388.8	7.4	138	52
S081693 26	26	1	4203.0	6.83	7189.0	6.04	6.48	0.63	12.8	1.00	15.63	16.6	16.6	108	100	12.3	412.2	6.2	126	52
S081693 28	28	1	3007.0	4.93	5344.0	4.47	4.70	0.33	9.3	1.00	15.37	16.4	16.4	77	100	8.8	421.0	4.4	117	52
S081693 30	30	1	2463.0	4.02	4461.0	3.72	3.87	0.21	7.5	1.01	15.48	16.5	16.5	63	100	7.2	428.2	3.6	110	52
S081693 32	32	1	2120.0	3.45	4017.0	3.34	3.40	0.07	3.1	1.00	16.31	17.3	17.3	58	100	6.7	434.8	3.4	103	52
S081693 34	34	1	1881.0	3.05	3378.0	2.80	2.92	0.18	8.2	1.00	16.02	17.0	17.0	50	100	5.7	440.6	2.8	97	52
S081693 36	36	2	1450.0	2.33	2854.0	2.18	2.28	0.10	6.2	1.00	16.45	17.5	17.5	39	100	4.5	445.1	2.3	93	52
S081693 38	38	2	1480.0	2.35	2584.0	2.12	2.24	0.16	8.5	1.01	16.33	17.3	17.2	38	100	4.4	448.5	2.2	88	52
S081693 40	40	2	1155.0	1.84	2028.0	1.85	1.74	0.13	10.0	1.01	15.44	16.5	16.5	28	100	3.3	452.8	1.8	85	52
S081693 42	42	2	918.0	1.44	1722.0	1.38	1.41	0.03	3.2	1.01	16.48	17.5	17.5	24	100	2.8	455.6	1.4	82	52
S081693 44	44	2	889.8	1.38	1803.0	1.29	1.34	0.07	7.4	1.01	16.28	17.3	17.1	23	100	2.6	458.2	1.3	80	52
S081693 46	46	2	751.0	1.16	1289.0	1.02	1.09	0.10	11.9	1.03	16.07	17.1	16.8	18	100	2.1	460.3	1.0	78	52
S081693 48	48	2	767.7	1.19	1337.0	1.08	1.13	0.08	10.5	1.02	16.49	17.5	17.2	19	100	2.2	462.5	1.1	75	52
S081693 50	50	2	654.7	1.00	1199.0	0.95	0.97	0.04	5.4	1.02	16.48	17.5	17.2	17	100	1.9	464.4	1.0	74	52
S081693 52	52	2	744.8	1.15	1305.0	1.04	1.08	0.08	9.9	1.02	16.53	17.6	17.2	19	100	2.2	466.6	1.1	71	52
S081693 54	54	2	636.8	0.97	1173.0	0.92	0.95	0.03	4.8	1.03	16.34	17.4	16.9	16	100	1.8	468.4	0.9	70	52
S081693 56	56	2	606.1	0.92	1083.0	0.85	0.88	0.05	7.8	1.02	16.89	17.7	17.4	15	100	1.8	470.2	0.9	68	52
S081693 58	58	2	789.5	1.23	1411.0	1.13	1.18	0.07	8.1	1.02	13.80	14.8	14.5	17	100	2.0	472.1	1.0	66	52
S081693 60	60	3	704.9	1.08	1340.0	1.07	1.08	0.01	1.7	1.03	10.20	11.2	10.9	12	100	1.3	473.5	0.7	65	52
S081693 62	62	3	1304.0	2.08	2300.0	1.88	1.98	0.14	9.7	2.04	10.50	12.5	6.1	12	100	1.4	474.9	0.7	63	52
S081693 64	64	3	1147.0	1.82	2083.0	1.71	1.77	0.08	6.4	2.06	10.20	12.3	6.0	11	100	1.2	476.1	0.6	62	52
S081693 66	66	3	982.5	1.55	1929.0	1.57	1.58	0.01	1.2	2.05	10.40	12.5	6.1	9	100	1.1	477.1	0.5	61	52
S081693 68	68	3	945.3	1.48	1761.0	1.42	1.48	0.04	4.1	2.04	10.22	12.3	6.0	9	100	1.0	478.1	0.5	60	52
S081693 70	70	3	775.9	1.20	1532.0	1.23	1.22	0.02	2.2	2.01	10.28	12.3	6.1	7	100	0.9	479.0	0.4	59	52
S081693 72	72	3	725.1	1.12	1482.0	1.20	1.16	0.05	6.9	2.03	10.49	12.5	6.2	7	100	0.8	479.8	0.4	58	52
S081693 73	73	4	844.8	1.32	1684.0	1.34	1.33	0.02	1.8	2.02	10.12	12.1	6.0	8	1000	8.1	489.0	-0.1	48	52
S081693 74	74	5	780.8	1.18	1481.0	1.17	1.17	0.01	0.7	2.03	10.24	12.3	6.0	7	1000	8.1	487.1	#DIV/0!	41	52
S081693 75	75	6	707.5	1.08	1391.0	1.11	1.10	0.01	1.9	2.02	10.47	12.5	6.2	7	1000	7.8	504.9	#DIV/0!	33	52
S081693 76	76	7	622.4	0.95	1119.0	0.88	0.91	0.05	7.2	2.03	10.86	12.7	6.3	6	1000	6.5	511.4	#DIV/0!	27	52
S081693 77	77	8	483.1	0.71	983.0	0.75	0.73	0.02	4.5	2.05	10.17	12.2	6.0	4	1000	5.0	516.4	#DIV/0!	22	52
S081693 78	78	9	398.8	0.57	798.1	0.61	0.58	0.03	6.3	2.00	10.38	12.4	6.2	4	1000	4.2	520.5	#DIV/0!	17	52
S081693 79	79	10	325.9	0.45	705.9	0.53	0.48	0.05	18.8	2.02	10.50	12.5	6.2	3	1000	3.5	524.0	#DIV/0!	14	52
S081693 80	80	11	406.1	0.59	810.0	0.62	0.60	0.02	5.2	2.00	10.86	12.9	6.4	4	1000	4.4	528.4	#DIV/0!	10	52
S081693 81	81	12	312.4	0.43	636.3	0.47	0.45	0.03	9.2	2.05	10.21	12.3	6.0	3	1000	3.1	531.5	#DIV/0!	7	52
S081693 82	82	13	423.1	0.61	713.6	0.53	0.57	0.08	13.0	2.07	10.40	12.5	6.0	3	1000	4.0	535.5	#DIV/0!	3	52
S081693 83	83	14	248.6	0.32	473.5	0.33	0.33	0.01	2.3	2.05	10.35	12.4	6.1	2	1000	2.2	537.7	#DIV/0!	0	52
S081693 84	84	15	202.0	0.24	418.7	0.28	0.28	0.03	15.9	2.03	10.35	12.4	6.1	2	1000	1.8	538.5	#DIV/0!	-2	52
S081693 85	85	16	-43.4	0.00	411.9	0.28	0.14	0.20	0.0	2.03	10.54	12.6	6.2	1	1000	1.0	540.5	#DIV/0!	-3	52
S081693 86	86	17	243.4	0.31	480.1	0.32	0.32	0.00	1.8	2.05	10.55	12.6	6.1	2	1000	2.2	542.8	#DIV/0!	-5	52
S081693 87	87	18	248.8	0.32	435.0	0.30	0.31	0.02	8.4	2.02	10.53	12.6	6.2	2	1000	2.2	545.0	#DIV/0!	-7	52
S081693 88	88	19	272.0	0.38	521.7	0.37	0.37	0.01	2.8	2.08	10.23	12.3	5.9	2	1000	2.5	547.4	#DIV/0!	-8	52
S081693 89	89	20	180.7	0.18	342.0	0.22	0.20	0.03	24.3	2.05	10.27	12.3	6.0	1	1000	1.4	548.8	#DIV/0!	-11	52
S081693 91	91	21	201.7	0.24	358.6	0.23	0.24	0.01	5.5	2.03	10.34	12.4	6.1	1	1000	1.7	550.4	#DIV/0!	-12	52
S081693 93	93	22	0.0	0.00	337.1	0.21	0.11	0.15	0.0	2.04	10.38	12.4	6.1	1	1000	0.7	551.2	#DIV/0!	-13	52
S081693 95	95	23	180.1	0.17	275.4	0.18	0.17	0.01	7.4	2.06	10.28	12.3	6.0	1	1000	1.2	552.3	#DIV/0!	-14	52
S081693 97	97	24	0.0	0.00	0.0	0.00	0.00	0.00	0.0	2.04	10.86	12.7	6.2	0	1000	0.0	552.3	#DIV/0!	-14	52
S081693 98	98	25	158.1	0.17	285.3	0.17	0.17	0.00	1.2	2.05	10.40	12.5	6.1	1	1000	1.2	553.5	#DIV/0!	-16	52
S081693 99	99	26	0.0	0.00	0.0	0.00	0.00	0.00	0.0	2.03	10.32	12.4	6.1	0	1000	0.0	553.5	#DIV/0!	-16	52
S081693 101	101	26	0.0	0.00	0.0	0.00	0.00	0.00	0.0	2.03	10.32	12.4	6.1	0	1000	0.0	553.5	#DIV/0!	-16	52
S081693 103	103	27	0.0	0.00	0.0	0.00	0.00	0.00	0.0	2.01	10.16	12.2	6.1	0	1000	0.0	553.5	#DIV/0!	-16	52

C061793 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X, 1 kg SP3(93), Homogenized, Agglomerated with cement

Sample No.	Time (hrs.)	Time (days)	U (367) Intensity	U (367) (mg/L)	U (405) Intensity	U (405) (mg/L)	Avg. (mg/L)	Std. Dev. (mg/L)	% Diff.	Sample Vol (mL)	Total Vol. (mL)	Dilution	U (mg/L)	Volume (mL)	U (mg/kg)	U TOT (mg/kg)	U mg/kg/hr	Order of Sample	NAA Analysis	EPA Target
0	0	0														0		1	538	52
S061793 3	3	0	5076	16.82	12380	16.44	16.63	0.3	2.2	0.99	16.98	17.3	288	36	6.6	6.6	2.2	1	531	52
S061793 4	4	0	5702	16.06	11870	15.78	15.92	0.2	1.7	0.99	16.28	16.4	281	36	10.8	10.8	2.2	2	521	52
S061793 6	6	0	6828	19.25	13030	17.33	18.29	1.4	18.8	0.99	16.88	17.0	311	36	28.5	45.9	14.2	3	492	52
S061793 8	8	0	6281	17.72	12680	16.88	17.30	0.6	4.8	0.99	16.53	16.8	282	36	27.4	73.2	13.7	4	486	52
S061793 10	10	0	5121	14.44	10050	13.38	13.91	0.8	7.3	0.99	16.51	17.2	238	36	22.9	98.2	11.5	5	442	52
S061793 12	12	1	5184	14.63	9808	13.07	13.85	1.1	16.7	0.99	17.08	17.2	238	36	24.0	120.2	12.0	6	418	52
S061793 14	14	1	3885	10.96	7905	10.54	10.75	0.3	3.8	0.99	17.09	17.3	186	36	19.1	139.3	8.8	7	389	52
S061793 16	16	1	3620	10.78	7746	10.33	10.58	0.3	4.1	0.99	16.50	16.7	178	36	18.1	157.4	9.1	8	381	52
S061793 18	18	1	3220	9.08	6375	8.51	8.80	0.4	6.9	0.97	16.94	17.5	154	36	15.8	173.2	7.9	9	385	52
S061793 20	20	1	3680	11.28	8158	10.90	11.09	0.3	3.4	0.99	16.37	16.7	185	36	19.1	192.3	9.5	10	346	52
S061793 22	22	1	3300	9.32	6885	9.18	9.25	0.1	1.8	0.99	16.23	16.4	182	36	15.6	207.9	7.8	11	330	52
S061793 24	24	1	3217	9.09	6481	8.89	8.89	0.3	4.5	1.05	16.97	16.2	144	36	14.8	222.7	7.4	12	315	52
S061793 26	26	1	2975	8.41	5820	7.79	8.10	0.4	7.4	1.01	16.84	16.7	135	36	13.9	238.8	7.0	13	301	52
S061793 28	28	1	6218	17.88	12510	16.78	17.22	0.8	5.2	1.02	16.17	15.8	273	36	28.1	284.7	14.1	14	273	52
S061793 30	30	1	2488	6.97	4859	6.30	6.63	0.5	9.7	0.99	16.84	16.8	112	36	11.5	276.2	5.7	15	282	52
S061793 32	32	1	1824	5.14	3701	4.98	5.05	0.1	3.5	0.99	16.57	16.7	85	36	8.7	284.9	4.4	16	283	52
S061793 34	34	1	2205	6.23	3880	5.22	5.73	0.7	18.3	0.99	16.94	17.3	80	36	10.2	285.1	5.1	17	263	52
S061793 36	36	2	1919	5.42	3787	5.08	5.25	0.2	6.2	0.99	16.25	16.6	87	36	8.0	304.1	4.5	18	234	52
S061793 38	38	2	1884	5.32	3621	5.27	5.28	0.0	1.1	1.10	14.09	12.8	68	36	7.0	311.1	3.5	19	227	52
S061793 40	40	2	1858	5.54	3577	4.81	5.17	0.5	13.3	0.99	16.28	16.8	88	36	8.9	318.8	4.4	20	218	52
S061793 42	42	2	1274	3.58	2577	3.48	3.62	0.1	3.2	1.00	16.18	16.2	57	36	5.9	325.8	2.8	21	212	52
S061793 44	44	2	1514	4.27	2888	4.03	4.15	0.2	5.7	0.99	15.82	16.1	67	36	6.3	332.7	3.5	22	205	52
S061793 46	46	2	1154	3.24	2332	3.14	3.18	0.1	3.2	0.99	15.92	16.1	51	36	5.9	338.0	2.8	23	200	52
S061793 48	48	2	1117	3.14	2328	3.13	3.13	0.0	0.1	0.99	15.78	16.1	50	36	5.2	343.2	2.8	24	186	52
S061793 50	50	2	986	2.78	1970	2.85	2.72	0.1	4.8	0.99	15.41	15.8	42	36	4.4	347.5	2.2	25	180	52
S061793 52	52	2	1017	2.85	2178	2.94	2.89	0.1	2.9	1.00	12.22	12.3	35	36	3.8	351.2	1.8	26	187	52
S061793 54	54	2	927	2.80	1839	2.48	2.54	0.1	4.7	1.01	15.62	15.5	38	36	4.0	355.2	2.0	27	183	52
S061793 56	56	2	804	2.24	1685	2.25	2.24	0.0	0.1	0.99	12.17	12.4	28	36	2.9	358.1	1.4	28	177	52
S061793 58	58	2	770	2.15	1600	2.16	2.15	0.0	0.0	0.95	11.98	12.6	27	36	2.8	360.9	1.4	29	177	52
S061793 60	60	3	870	2.73	2080	2.81	2.77	0.1	3.1	0.99	11.97	12.2	34	36	3.5	364.3	1.7	30	174	52
S061793 62	62	3	2324	6.85	4818	6.52	6.58	0.1	1.9	2.05	10.32	5.0	33	36	3.4	367.7	1.7	31	170	52
S061793 64	64	3	2282	6.30	4801	6.23	6.27	0.0	1.0	1.99	10.34	5.1	32	36	3.3	371.1	1.7	32	167	52
S061793 66	66	3	1988	5.82	3790	5.14	5.38	0.3	8.7	2.01	10.23	5.1	27	36	2.8	373.8	1.4	33	164	52
S061793 68	68	3	1582	4.45	3377	4.58	4.62	0.1	2.9	2.02	10.34	5.1	23	36	2.4	378.3	1.2	34	162	52
S061793 70	70	3	1470	4.18	3214	4.38	4.27	0.1	4.1	2.04	10.30	5.0	22	36	2.2	378.5	1.1	35	160	52
S061793 71	71	3	935.1	2.84	1978	2.88	2.88	0.0	1.8	1.47	8.85	6.0	18	36	1.7	380.1	1.7	36	158	52
S061793 73		4	1167.0	3.31	2582	3.52	3.42	0.1	6.3	2.01	10.67	5.4	18	36	18.0	388.2		37	138	52
S061793 74		5	883.7	2.48	1950	2.85	2.57	0.1	6.9	2.00	10.21	5.1	13	36	13.5	412.7		38	125	52
S061793 75		6	935.8	2.86	2085	2.81	2.73	0.1	6.1	1.99	10.68	5.3	14	36	14.9	427.8		39	110	52
S061793 76		7	957.8	1.98	1273	1.73	1.86	0.1	8.7	2.01	10.08	5.0	8	36	8.5	438.2		40	102	52
S061793 77		8	633.1	1.77	1388	1.88	1.82	0.1	6.3	2.02	11.00	5.4	10	36	10.2	448.3		41	82	52
S061793 78		9	445.9	1.22	988.1	1.34	1.28	0.1	8.8	2.01	11.38	5.7	7	36	7.5	453.8		42	84	52
S061793 79		10	350.5	0.96	788.9	1.03	0.99	0.1	8.7	2.04	10.80	5.3	5	36	5.4	458.2		43	75	52
S061793 80		11	373.2	1.01	823.3	1.12	1.07	0.1	18.8	2.01	10.11	5.0	5	36	5.5	464.7		44	75	52
S061793 81		12	283.3	0.75	611.7	0.83	0.79	0.1	18.8	2.00	10.25	5.1	4	36	4.2	468.9		45	68	52
S061793 82		13	300.4	0.80	517.8	0.70	0.75	0.1	12.8	2.02	10.88	5.3	4	36	4.1	473.0		46	66	52
S061793 83		14	201.2	0.51	413.3	0.58	0.54	0.0	8.5	2.03	10.07	5.0	3	36	2.7	478.7		47	62	52
S061793 84		15	188.4	0.48	383.1	0.53	0.51	0.0	11.8	2.03	10.67	5.3	3	36	2.7	478.5		48	60	52
S061793 85		16	204.4	0.52	458.7	0.62	0.57	0.1	18.8	2.01	10.27	5.1	3	36	3.0	481.5		49	57	52
S061793 86		17	214.8	0.55	482.4	0.67	0.61	0.1	21.1	1.98	9.78	5.0	3	36	3.1	484.6		50	53	52
S061793 87		18	242.7	0.64	505.2	0.68	0.66	0.0	8.3	2.03	10.48	5.2	3	36	3.5	488.1		51	50	52
S061793 88		19	177.1	0.44	424.2	0.58	0.51	0.1	38.3	2.03	10.35	5.1	3	36	2.7	488.8		52	47	52
S061793 89		20	185.7	0.41	413.5	0.58	0.48	0.1	37.3	2.01	10.33	5.1	3	36	2.8	488.4		53	45	52
S061793 91		21	171.8	0.43	354.1	0.48	0.48	0.0	12.4	2.01	10.54	5.2	2	36	2.5	485.8		54	42	52
S061793 93		22	100.2	0.22	272.3	0.37	0.29	0.1	68.5	1.98	10.38	5.2	2	36	1.8	487.4		55	41	52
S061793 95		23	143.4	0.35	287.4	0.38	0.37	0.0	12.8	2.05	10.18	5.0	2	36	1.9	488.3		56	38	52
S061793 97		24	120.8	0.28	258.4	0.35	0.31	0.1	38.8	2.02	10.38	5.1	2	36	1.7	500.9		57	37	52
S061793 99		25	110.0	0.25	283.2	0.38	0.30	0.1	44.4	2.02	10.48	5.2	2	36	1.8	502.6		58	35	52
S061793 101		26	128.4	0.30	277.4	0.38	0.34	0.1	34.8	1.98	10.08	5.1	2	36	1.8	504.3		59	34	52
S061793 103		27	101.4	0.22	251.3	0.34	0.28	0.1	88.4	2.02	10.53	5.2	1	36	1.5	505.8		60	32	52

Co22003 - 0.25 M Sodium-Carbonate-Bicarbonate, 1X, 1 kg SPQ(03), Homogenized

Sample No.	Time (hrs.)	Time (days)	U (207) Intensity	U (207) (mg/L)	U (409) Intensity	U (409) (mg/L)	Ave. (mg/L)	Std. Dev. (mg/L)	% Diff.	Sample Vol (mL)	Total Vol. (mL)	U (mg/L)	Volume (mL)	U (mg/L)	U (mg/L)	U (mg/L)	Sample Outer
SO22003 2	2	0	654.7	1.72	1533	1.36	1.82	0.16	13.1	0.06	18.21	18.5	27	0.0	0.0	0.0	1
SO22003 4	4	0	1481.0	31.66	2015.0	20.81	30.33	1.03	4.7	0.06	15.70	15.6	481	11.0	11.0	5.5	2
SO22003 6	6	0	1522.0	32.86	3072.0	31.28	31.68	0.55	2.4	0.06	15.25	15.4	488	20.1	20.1	10.0	3
SO22003 8	8	0	1702.0	36.62	3250.0	33.19	34.61	2.00	7.9	0.05	15.87	18.7	578	28.5	28.5	13.2	4
SO22003 10	10	0	1737.0	38.83	3391.0	34.73	35.83	1.56	6.0	1.00	16.18	18.0	580	28.5	28.5	13.5	5
SO22003 12	12	0	1409.0	38.88	2881.0	28.37	28.73	0.50	2.4	0.07	15.80	16.3	484	22.2	22.2	10.3	6
SO22003 14	14	1	1417.0	38.39	2727.0	28.07	28.23	0.64	7.6	0.06	15.65	18.5	488	22.6	22.6	11.3	7
SO22003 16	16	1	1443.0	31.87	2632.0	27.17	28.12	2.76	12.6	0.07	16.15	16.6	485	23.3	23.3	11.6	8
SO22003 18	18	1	1178.0	25.48	2294.0	23.74	24.61	1.24	6.6	0.06	15.65	16.5	465	20.2	20.2	10.1	9
SO22003 20	20	1	1017.0	22.16	1850.0	20.23	21.16	1.32	8.5	0.06	15.84	18.5	348	17.6	17.6	8.8	10
SO22003 22	22	1	888.0	14.88	1353.0	14.88	14.81	0.65	6.1	0.06	15.00	15.6	227	11.4	11.4	5.7	11
SO22003 24	24	1	710.1	13.98	1380.0	14.88	14.81	1.08	8.6	0.06	13.89	14.2	210	8.3	8.3	4.2	12
SO22003 26	26	1	571.1	12.96	1100.0	11.48	12.02	0.78	8.6	0.06	13.33	13.5	182	5.0	5.0	2.5	13
SO22003 28	28	1	733.1	16.31	1417.0	14.88	15.53	0.97	7.0	1.00	13.30	13.3	210	8.3	8.3	4.2	14
SO22003 30	30	1	638.5	14.38	1258.0	13.71	13.71	0.48	6.2	1.00	12.42	12.4	182	5.0	5.0	2.5	15
SO22003 32	32	1	470.1	18.48	934.3	9.88	10.15	0.48	6.2	1.00	12.42	12.4	182	5.0	5.0	2.5	16
SO22003 34	34	1	301.3	6.73	834.3	6.27	6.50	0.32	6.7	1.00	12.42	12.4	182	5.0	5.0	2.5	17
SO22003 36	36	2	2281.1	5.16	450.8	4.74	4.82	0.28	7.1	1.00	12.13	12.1	60	2.4	2.4	1.2	18
SO22003 38	38	2	1821.1	4.31	367.5	3.75	4.09	0.31	10.2	1.00	11.78	11.8	48	1.9	1.9	1.0	19
SO22003 40	40	2	1488.1	3.34	298.5	3.12	3.23	0.16	6.6	1.00	11.58	11.6	37	1.5	1.5	0.7	20
SO22003 42	42	2	1324.1	2.86	254.8	2.63	2.83	0.07	4.9	1.01	10.85	10.9	23	0.9	0.9	0.5	21
SO22003 44	44	2	974.5	2.18	188.5	2.08	2.14	0.07	4.9	1.01	10.85	10.9	23	0.9	0.9	0.5	22
SO22003 46	46	2	882.1	2.22	188.0	1.88	2.10	0.16	10.4	1.01	10.88	10.9	18	0.7	0.7	0.4	23
SO22003 48	48	2	784.2	1.77	153.3	1.81	1.88	0.11	8.2	1.00	11.21	11.2	17	0.7	0.7	0.4	24
SO22003 50	50	2	708.0	1.88	138.1	1.45	1.52	0.11	8.6	1.00	11.21	11.2	17	0.7	0.7	0.4	25
SO22003 52	52	2	708.9	1.82	147.2	1.58	1.68	0.19	14.9	1.00	11.18	11.2	18	0.7	0.7	0.4	26
SO22003 54	54	2	730.7	1.88	146.1	1.35	1.61	0.11	9.4	1.00	11.40	11.3	17	0.7	0.7	0.4	27
SO22003 56	56	2	673.8	1.88	134.1	1.42	1.48	0.10	8.1	1.01	11.40	11.3	17	0.7	0.7	0.4	28
SO22003 58	58	2	580.3	1.36	118.8	1.38	1.31	0.07	7.1	1.00	11.55	11.6	15	0.6	0.6	0.3	29
SO22003 60	60	3	582.8	1.27	117.8	1.24	1.28	0.02	2.1	1.01	11.17	11.1	14	0.6	0.6	0.3	30
SO22003 62	62	3	1022.1	2.41	188.1	2.08	2.22	0.27	13.8	2.02	10.53	10.5	12	0.5	0.5	0.2	31
SO22003 64	64	3	875.7	2.67	178.3	1.88	1.98	0.12	8.0	1.98	10.30	10.3	11	0.4	0.4	0.2	32
SO22003 66	66	3	800.2	2.21	181.2	1.88	2.08	0.18	11.3	1.98	10.30	10.3	11	0.4	0.4	0.2	33
SO22003 68	68	3	770.5	1.83	152.5	1.88	1.74	0.13	10.1	1.98	10.48	10.5	8	0.4	0.4	0.2	34
SO22003 70	70	3	772.1	1.88	157.3	1.71	1.78	0.10	7.5	2.04	10.34	10.4	8	0.4	0.4	0.2	35
SO22003 72	72	3	718.1	1.72	140.8	1.38	1.62	0.14	11.6	2.01	10.68	10.6	8	0.3	0.3	0.2	36
SO22003 74	74	3	728.1	1.76	145.3	1.38	1.67	0.12	9.8	2.01	10.21	10.2	8	0.3	0.3	0.2	37
SO22003 76	76	3	720.2	1.75	144.0	1.37	1.66	0.12	9.8	2.01	10.48	10.4	7	0.3	0.3	0.2	38
SO22003 78	78	3	580.2	1.42	118.8	1.38	1.38	0.08	8.8	2.01	10.05	10.0	7	0.3	0.3	0.2	39
SO22003 80	80	3	481.6	1.18	887.3	1.88	1.10	0.08	9.9	2.01	10.30	10.3	5	0.2	0.2	0.1	40
SO22003 82	82	3	403.8	0.88	820.0	0.88	0.94	0.07	9.5	2.00	10.19	10.1	5	0.2	0.2	0.1	41
SO22003 84	84	4	428.2	1.88	878.2	0.88	0.88	0.06	8.4	2.00	10.30	10.3	5	0.2	0.2	0.1	42
SO22003 86	86	4	412.7	1.88	840.4	0.81	0.88	0.07	8.5	1.98	10.30	10.3	5	0.2	0.2	0.1	43
SO22003 88	88	4	328.8	0.78	688.1	0.78	0.75	0.05	9.0	2.01	10.27	10.2	4	0.1	0.1	0.1	44
SO22003 90	90	4	305.0	0.74	681.0	0.74	0.74	0.01	1.2	2.00	10.07	10.0	4	0.1	0.1	0.1	45
SO22003 92	92	4	484.2	1.21	612.6	0.88	1.05	0.23	28.5	2.01	10.28	10.2	5	0.1	0.1	0.1	46
SO22003 94	94	4	304.5	0.74	594.4	0.84	0.69	0.07	14.2	2.01	10.04	10.0	4	0.1	0.1	0.1	47
SO22003 96	96	4	278.6	0.67	517.5	0.88	0.61	0.08	18.3	1.98	10.04	10.0	3	0.1	0.1	0.1	48
SO22003 98	98	4	222.3	0.53	388.0	0.88	0.47	0.08	24.6	2.01	10.07	10.0	3	0.1	0.1	0.1	49
SO22003 100	100	4	243.3	0.88	418.8	0.88	0.52	0.11	28.0	2.00	10.08	10.0	3	0.1	0.1	0.1	50
SO22003 102	102	4	243.3	0.88	396.1	0.88	0.45	0.05	13.4	2.00	10.23	10.2	2	0.1	0.1	0.1	51
SO22003 104	104	4	188.8	0.48	372.0	0.88	0.32	0.05	8.7	2.01	10.37	10.3	2	0.1	0.1	0.1	52
SO22003 106	106	4	188.8	0.48	372.0	0.88	0.32	0.05	8.7	2.01	10.37	10.3	2	0.1	0.1	0.1	53
SO22003 108	108	5	207.7	0.51	438.8	0.88	0.48	0.05	15.1	2.01	10.27	10.2	2	0.1	0.1	0.1	54
SO22003 110	110	5	207.8	0.51	410.6	0.88	0.48	0.05	15.1	2.01	10.27	10.2	2	0.1	0.1	0.1	55
SO22003 112	112	5	208.4	0.52	388.9	0.88	0.47	0.07	20.4	2.01	10.37	10.3	2	0.1	0.1	0.1	56
SO22003 114	114	5	145.6	0.35	278.0	0.88	0.31	0.05	19.2	2.00	10.10	10.1	1	0.9	0.9	0.5	57
SO22003 116	116	6	88.47	0.19	187.2	0.88	0.18	0.01	8.2	2.00	10.10	10.1	2	1.8	1.8	0.9	58
SO22003 118	118	7	133.7	0.32	273.0	0.88	0.30	0.03	13.1	2.00	10.43	10.4	2	1.1	1.1	0.6	59
SO22003 120	120	8	93.37	0.21	173.0	0.88	0.18	0.04	29.8	2.00	10.07	10.0	1	1.1	1.1	0.6	60

C001303 - 0.5 M Sodium-Carbonate-Bicarbonate, 2X, 1 kg SP9(93), Homogenized

Sample No.	Time (days)	U (367) Intensity	U (367) (mg/L)	U (409) Intensity	U (409) (mg/L)	Ave. (mg/L)	Std. Dev. (mg/L)	% Diff	Sample Vol (mL)	Total Vol. (mL)	Dilution	U (mg/L)	Volume (mL)	U (mg/kg)	UTOT (mg/kg)	U (mg/kg)	Sample Order
	0																
S001303 3A	1	9798	24.54	20900	22.10	23.32	1.72	9.93	1.00	15.74	15.7	367		0.0	0.0	0.0	1
S001303 4A	2	13070	32.79	25900	28.54	30.86	3.00	12.95	1.00	15.74	15.7	483		0.0	0.0	0.0	2
S001303 2	3	10540	26.66	21800	23.92	25.29	1.94	10.28	1.97	28.61	14.5	367	20	8.4	8.4	8.4	3
S001303 3	4	1518	3.68	2708	3.01	3.35	0.48	18.30	1.03	15.84	15.4	51	36	2.1	10.5	2.1	4
S001303 4	5	1130	2.70	2220	2.37	2.54	0.23	12.21	1.01	15.89	15.5	39	40	1.8	12.3	1.8	5
S001303 5	6	1177	2.82	2247	2.40	2.61	0.30	14.97	1.03	15.97	15.5	40	40	1.9	14.2	1.9	6
S001303 6A	7	1441	3.49	2684	3.07	3.28	0.29	11.93	1.01	16.40	16.2	53	40	2.4	16.8	2.4	7
S001303 6B	8	975.7	2.31	1821	2.04	2.17	0.20	12.02	1.08	15.99	14.8	32	41	1.5	18.1	1.5	8
S001303 7	9	1242	2.98	2384	2.54	2.76	0.32	14.97	1.03	15.47	15.0	41	42	2.0	20.1	2.0	9
S001303 8	10	1039	2.47	2091	2.22	2.34	0.18	10.45	1.00	17.75	17.8	42	42	2.0	22.1	2.0	10
S001303 9	11	870.8	2.05	1938	1.64	1.85	0.29	19.85	1.02	12.08	11.8	22	42	1.1	23.2	1.1	11
S001303 10	12	379.0	0.81	723.5	0.72	0.77	0.06	10.79	1.00	11.16	11.2	9	42	0.4	23.6	0.4	12
S001303 11	13	489.4	1.01	877.2	0.88	0.95	0.09	12.29	1.03	11.00	10.7	10	42	0.5	24.1	0.5	13
S001303 12	14	348.3	0.73	732.2	0.73	0.73	0.00	0.41	1.00	11.00	11.0	8	48	0.4	24.5	0.4	14
S001303 13	15	223.8	0.42	435.5	0.41	0.41	0.01	2.70	1.01	11.53	11.4	5	36	0.2	24.7	0.2	15
S001303 14	16	279.5	0.58	585.0	0.57	0.56	0.01	1.82	2.03	12.43	6.1	3	36	0.1	24.8	0.1	16
S001303 16	17	216.3	0.40	344.3	0.31	0.35	0.07	23.02	2.07	12.87	6.1	2	36	0.1	24.9	0.1	17
S001303 17	18	367.0	0.78	239.2	0.19	0.49	0.41	75.06	2.04	12.71	6.2	3	36	0.1	25.0	0.1	18
S001303 20	19	147.7	0.23	322.2	0.28	0.26	0.04	24.90	2.04	11.88	5.8	1	36	0.1	25.1	0.1	19
S001303 23	20	88.10	0.07	148.5	0.10	0.08	0.02	32.91	1.97	12.86	6.4	1	36	0.0	25.1	0.0	20
S001303 26	21	66.02	0.02	142.7	0.09	0.06	0.05	309.86	2.02	12.25	6.1	0	36	0.0	#REF!	#REF!	21
S001303 32	22	88.32	0.07	182.7	0.10	0.09	0.02	37.48	1.98	12.24	6.2	1	36	0.0	#REF!	0.0	22

C-91493 - 0.5 M Sodium-Carbonate-Bicarbonate, 2X, 1 kg SP9(93), Homogenized

[illegible]

C002003 - 0.1 M Sodium-Carbonate-Bicarbonate, 2X, SPQ(03), Homogenized

Sample No.	Time (hrs.)	Time (days)	U (357) Intensity	U (357) (mg/L)	Ave. (mg/L)	Std. Dev. (mg/L)	% DIL.	Sample Vol. (mL)	Total Vol. (mL)	Dilution	U (mg/L)	Volume (mL)	U (mg/kg)	UTOT (mg/kg)	U (mg/kg)	NAA Analysis	EPA Target
	0	0															
S002003 3	2	0	3202	7.78	7.87	0.12	2.1	1.03	15.86	15.5	122	378	0.0	0.0	0.0	538	52
S002003 12	6	0	9717	23.19	22.47	1.02	8.2	0.97	16.17	16.7	376	378	167.3	167.3	167.3	381	52
S002003 20	10	0	8879	21.18	20.01	1.06	11.1	0.96	15.88	16.0	321	336	119.8	277.2	30.0	281	52
S002003 28	14	1	5612	13.11	12.84	0.88	7.1	0.98	13.48	13.6	172	336	64.3	341.4	16.1	197	52
S002003 36	18	1	3639	8.09	8.31	0.55	8.6	1.00	13.07	13.1	114	438	53.1	384.5	10.6	143	52
S002003 44	22	1	2808	6.83	6.58	0.36	7.4	1.09	13.21	13.2	87	282	24.3	418.9	8.1	119	52
S002003 46	24	1	3102	7.33	6.97	0.51	8.8	0.95	12.85	13.1	91	198	17.1	435.9	6.5	102	52
S002003 58	28	1	2405	5.66	5.12	0.39	8.4	1.00	12.83	12.9	70	336	28.0	481.9	8.5	76	52
S002003 64	32	1	1942	4.55	4.42	0.17	5.4	0.97	11.48	11.8	52	336	19.5	481.5	4.9	57	52
S002003 72	36	2	1289	2.91	2.77	0.25	8.6	0.95	11.37	11.8	32	336	12.0	480.4	3.0	45	52
S002003 80	40	2	954.3	2.18	1.97	0.15	9.8	0.97	11.24	11.2	24	336	9.0	502.4	2.2	38	52
S002003 96	48	2	784.3	1.82	2.07	0.15	4.8	1.00	11.12	11.1	18	672	13.2	515.6	1.8	22	52
S002003 112	56	2	431	0.92	0.92	0.01	1.3	1.00	11.39	11.3	10	672	7.7	523.3	1.0	15	52
S002003 128	64	3	311.5	0.83	0.81	0.02	4.1	1.00	12.15	11.2	7	672	6.2	532.9	0.7	8	52
S002003 144	72	3	448.8	0.99	0.99	0.03	4.6	2.01	12.15	8.0	6	672	4.4	532.9	0.6	5	52
S002003 146	96	4	583.1	1.21	1.18	0.06	8.9	1.98	12.13	8.1	7	1974	15.5	548.4	9.7	-10	52
S002003 148	120	5	342.1	0.83	0.76	0.06	10.3	1.94	12.13	8.3	6	2916	11.0	558.4	0.5	-21	52
S002003 147	144	6	341.2	0.71	0.70	0.03	0.9	2.00	12.18	8.1	4	2916	9.6	560.0	0.4	-31	52
S002003 148	167	7	284.8	0.60	0.51	0.01	3.7	2.00	12.18	8.1	3	2916	8.7	576.7	0.3	-38	52
S002003 148	215	8	188.7	0.28	0.31	0.03	14.6	2.02	12.07	8.0	2	4874	8.3	583.9	0.2	-48	52
S002003 151	247	10	180.7	0.25	0.25	0.03	1.6	2.02	12.28	8.1	1	2788	4.5	588.4	0.1	-80	52
S002003 154			171.2	0.30	0.30	0.03	1.6	2.00	12.91	8.0	2		0.0	588.4	0.0		52

C100193 - 0.1 M Sodium-Carbonate-Bicarbonate, 1X, 1 kg SP9(93), Homogenized, Agglomerated with cement

Sample No.	Time (hrs.)	Time (days)	U (367) Intensity	U (367) (mg/L)	U (409) Intensity	U (409) (mg/L)	Ave. (mg/L)	Std. Dev. (mg/L)	% Diff	Sample Vol (mL)	Total Vol. (mL)	Dilution	U (mg/L)	Volume (mL)	U (mg/kg)	UTOT (mg/kg)	U mg/kg/hr	NAA Analysis	EPA Target
	0															0		538	52
S100193_3	3	0	9825	23.69	20010	23.19	23.44	0.36	2.1	0.98	15.98	16.3	382	0	0.0	0.0	0.0	538	52
S100193_6	6	0	8120	19.38	18090	18.64	19.00	0.51	3.8	0.98	15.26	15.8	296	126	42.7	42.7	14.2	495	52
S100193_10	10	0	5812	13.83	12450	14.41	14.12	0.41	4.2	0.95	15.90	16.7	236	168	45.4	88.1	11.4	450	52
S100193_14	14	1	6599	15.72	12650	14.87	15.29	0.60	5.4	0.98	15.39	16.0	245	168	47.1	135.2	11.8	403	52
S100193_18	18	1	5124	12.18	10420	12.06	12.11	0.09	1.1	0.97	15.87	16.4	198	168	38.1	173.3	9.5	385	52
S100193_22	22	1	6194	14.74	10810	12.59	13.62	1.59	15.2	0.97	15.88	16.4	223	168	42.9	216.2	10.7	322	52
S100193_24	24	1	6078	14.47	10890	12.58	13.53	1.32	12.9	0.97	13.24	13.6	185	84	17.7	253.9	8.9	304	52
S100193_28	28	1	4894	11.63	9818	11.35	11.49	0.20	2.4	0.97	13.31	13.7	158	168	30.3	284.2	7.6	274	52
S100193_32	32	1	4267	10.12	8028	9.27	9.89	0.61	8.5	0.97	13.23	13.6	132	168	25.4	289.6	6.4	248	52
S100193_36	36	2	3373	7.98	6280	7.21	7.60	0.54	9.6	0.98	12.98	13.2	101	168	19.3	308.0	2.4	229	52
S100193_40	40	2	2969	7.08	5328	6.13	6.61	0.67	13.4	0.98	12.92	13.2	87	168	16.7	325.7	4.2	212	52
S100193_48	48	2	2549	6.00	4636	5.33	5.88	0.48	11.3	0.98	13.17	13.4	78	336	29.3	355.0	3.7	183	52
S100193_56	56	2	2228	5.23	4285	4.92	5.07	0.22	6.0	0.97	13.07	13.5	68	336	26.3	381.3	3.3	157	52
S100193_64	64	3	1772	4.14	3240	3.70	3.92	0.31	10.5	0.98	13.90	13.9	54	336	20.9	402.2	2.6	136	52
S100193_72	72	3	1428	3.31	2660	3.03	3.17	0.20	8.6	0.98	13.05	13.3	42	336	18.2	418.4	2.0	120	52
S100193_73	116	5	1914.0	4.48	3867.0	4.20	4.34	0.20	6.2	1.99	11.75	5.9	26	1848	54.2	472.6	1.2	65	52
S100193_74	164	7	941	2.14	1807.00	2.04	2.09	0.07	4.9	2.00	12.10	6.1	13	2016	29.2	501.7	0.6	38	52
S100193_75	209	9	673	1.50	1268.00	1.41	1.48	0.08	6.0	2.00	12.16	6.1	9	1890	19.1	520.9	0.4	17	52

C100293 - 0.1 M Sodium-Carbonate-Bicarbonate, 1X, 1 kg SP9(93), Homogenized

Sample No.	Time (hrs.)	Time (days)	U (357) Intensity	U (357) (mg/L)	U (488) Intensity	U (488) (mg/L)	Ave. (mg/L)	Std. Dev. (mg/L)	% Diff.	Sample Vol (mL)	Total Vol. (mL)	Dilution	U (mg/L)	Volume (mL)	U (mg/kg)	UTOT (mg/kg)	U (mg/kg/yr)	NAA Analysis	EPA Target
	0														0	0		538	52
S100293 3	3	0	128.1	0.19	287.2	0.25	0.22	0.04	27.5	0.99	15.98	15.8	3		0	0	0	538	52
S100293 6	6	0	7127	16.98	13170	15.24	16.11	1.23	10.2	0.99	15.89	15.8	255	128	33	33	11	506	52
S100293 10	10	0	11180	26.86	23620	27.27	26.96	0.44	2.3	1.00	15.49	15.5	418	168	72	104	18	434	52
S100293 14	14	1	10800	25.79	22880	26.31	26.06	0.36	2.0	0.99	16.12	16.3	424	168	73	177	18	361	52
S100293 18	18	1	9594	22.90	19310	22.38	22.84	0.37	2.3	0.98	16.00	16.3	370	168	63	241	16	297	52
S100293 22	22	1	10700	25.55	21970	25.47	25.51	0.08	0.3	0.99	13.26	13.4	342	168	59	299	15	239	52
S100293 24	24	1	10590	25.29	21010	24.36	24.82	0.68	3.7	0.95	12.39	13.0	324	84	28	327	14	211	52
S100293 28	28	1	8404	20.05	18500	19.11	19.58	0.68	4.6	0.98	13.02	13.3	280	168	45	371	11	167	52
S100293 32	32	1	7772	18.53	14530	16.82	17.68	1.21	9.2	0.95	13.45	13.7	243	168	42	413	10	125	52
S100293 36	36	2	7330	17.47	12880	14.55	16.08	1.99	18.1	0.98	13.32	13.6	218	168	37	450	9	88	52
S100293 40	40	2	5721	13.61	10770	12.45	13.03	0.82	8.5	0.98	13.12	13.4	174	168	30	480	7	58	52
S100293 48A	48	2	2141	5.02	3961	4.54	4.78	0.34	8.8	0.99	13.08	13.2	63	336	22	502	3	36	52
S100293 56A	56	2	1419	3.29	2634	3.00	3.14	0.21	8.9	0.98	13.21	13.5	42	336	15	617	2	21	52
S100293 64A	64	3	798.5	1.80	1481	1.68	1.73	0.10	6.1	0.99	13.45	13.6	24	336	8	525	1	13	52
S100293 72A	72	3	611.4	1.35	1074	1.19	1.27	0.12	12.4	0.95	13.22	13.9	18	336	6	531	1	7	52
S100293 73		4	797.7	1.80	1509	1.69	1.75	0.08	6.1	2.03	12.49	6.2	11		0	531	0		
S100293 74		5	430.3	0.92	810.5	0.88	0.90	0.03	4.3	2.01	12.20	6.1	5		0	531	#DIV/0!		
S100293 75		6	381.3	0.75	679.1	0.73	0.74	0.02	3.6	2.01	12.78	6.4	5		0	531	#DIV/0!		
S100293 76		7	307.1	0.62	604.0	0.64	0.63	0.01	2.5	2.02	12.40	6.1	4		0	531	#DIV/0!		

**C021193 - 0.1 M Potassium-Carbonate-Bicarbonate,
1X, 1 kg SP4, Homogenized**

**0.1 M Sodium-Carbonate-Bicarbonate, 1X, 1 kg
SP9(93), Homogenized**

**0.5 M Sodium-Carbonate-Bicarbonate, 1X, 1 kg
SP9(93), Homogenized**

**C060493 - 0.2 M Sodium-Carbonate-Bicarbonate, 1X,
1 kg SP9(93), Homogenized**

**C081693 - 0.5 M Sodium0Carbonate-Bicarbonate, 1X,
1 kg (SP9(93), Homogenized**

**C081793 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X,
1 kg (SP9(93), Homogenized, Agglomerated with
cement**

**C082693 - 0.25 M Sodium-Carbonate-Bicarbonate, 1X,
1 kg SP9(93), Homogenized**

**C091393 - 0.5 M Sodium-Carbonate-Bicarbonate, 2X,
1 kg SP9(93), Homogenized**

**C091493 - 0.5 M Sodium-Bicarbonate-Carbonate, 2X,
1 kg SP9(93), Homogenized**

**C092893 - 0.1 M Sodium-Carbonate-Bicarbonate, 2X,
SP9(93), Homogenized**

**C100193 - 0.1 M Sodium-Carbonate-Bicarbonate, 1X,
1 kg SP9(93), Homogenized, Agglomerated with
cement**

**C100293 - 0.1 M Sodium-Carbonate-Carbonate, 1X, 1
kg SP9(93), Homogenized**

TABLE A 1.2
SUMMARY OF COLUMN EXPERIMENTS
PERFORMED IN FY 94

	Column Number	M	Carbonate Salt	Flow Rate	Mass (kg)	Soil	Preparation
1	C012694	0.5	Sodium	1X	1	SP9(94)	Heterogeneous, Agglomerated with water
2	C012794	0.5	Sodium	1X	1	SP9(94)	Heterogeneous, Agglomerated with water
3	C020494	0.5	Sodium	0.3X	1	SP9(94)	Heterogeneous, Agglomerated with water
4	C020594	0.5	Sodium	0.3X	1	SP9(94)	Heterogeneous, Agglomerated with water
5	C012894	0.5	Sodium	1X	3	SP9(94)	Heterogeneous, Agglomerated with water
6	C030894	0.5	Sodium	1X	3	SP9(94)	Heterogeneous, Agglomerated with water
7	C022394	0.5	Sodium	1X	10	SP9(94)	Heterogeneous, Agglomerated with water
8	C032594	0.5	Sodium	1X	10	SP9(94)	Heterogeneous, Agglomerated with water

C012694 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X, 1 kg SP9(94), Heterogeneous, Agglomerated with water

Sample	Time sample pulled	Sample mass	Total mass	Dilution	ppm U (ICP 367)	ppm U (ICP 409)	Ave ICP ppm U	Std. Dev.	Experiment Time	mg U/L	pH	Empty container mass (g)	Full container mass (g)	Flow Rate (L/day)	mg U/kg soil	Cumulative mg U/kg soil
	1/26/94 11:00 AM															
S012694 2	1/26/94 1:00 PM	1.1038	19.8468	18.0	28.58	28.48	28.5	0.0	0	513	9.485	10.4159	15.51	0.96	3	3
S012694 3	1/26/94 2:00 PM	1.0129	19.9532	19.7	24.37	24.44	24.4	0.0	0	481	9.346	10.3435	47.26	0.89	22	25
S012694 4	1/26/94 3:00 PM	0.9653	20.1102	20.8	19.91	19.84	19.9	0.0	0	414	9.434	10.4288	49.98	0.95	20	45
S012694 5	1/26/94 4:00 PM	0.9955	20.1218	20.2	17.93	17.98	18.0	0.0	0	363	9.481	10.4183	51.71	0.99	19	64
S012694 6	1/26/94 5:00 PM	1.0128	20.0392	19.8	16.46	16.42	16.4	0.0	0	325	9.529	10.4113	52.07	1.00	17	81
S012694 7	1/26/94 6:00 PM	1.0178	20.2046	19.9	15.4	15.43	15.4	0.0	0	306	9.544	10.4406	52.48	1.01	16	96
S012694 26A	1/26/94 11:00 PM	1.0375	20.0086	19.3	13.4	13.44	13.4	0.0	1	259	9.567	51.7162	266.69	1.03	69	165
S012694 26B	1/27/94 11:00 AM	1.0204	19.9442	19.5	10.15	10.11	10.1	0.0	1	198	9.598	124.2384	657.11	1.07	130	295
S012694 26C	1/27/94 11:00 PM	1.0177	20.1311	19.8	8.884	8.834	8.9	0.0	2	175	9.607	124.3913	662.48	1.08	116	412
S012694 26D	1/28/94 11:00 AM	4.1576	20.4337	4.9	24.23	23.79	24.0	0.2	2	118	9.61	124.3251	668.04	1.09	79	491
S012694 26E	1/28/94 7:00 PM	3.9308	19.9773	5.1	16.81	16.44	16.6	0.2	2	84	9.627	82.9029	451.43	1.11	38	529
S012694 57	1/29/94 11:00 AM	3.9892	20.0524	5.0	12.24	12.04	12.1	0.1	3	61	9.662	100.57	848.25	1.12	56	586
S012694 58	1/30/94 9:35 AM	4.1809	20.1222	4.8	8.843	8.698	8.8	0.1	4	42	9.65	99.73	1162.27	1.13	55	641
S012694 59	1/31/94 8:12 AM	4.0283	20.0649	5.0	6.476	6.352	6.4	0.1	5	32	9.634	99.84	1160.86	1.13	42	683
S012694 60	2/1/94 7:00 AM	4.1448	20.2221	4.9	5.26	5.167	5.2	0.0	6	25	9.638	100.134	1185.65	1.14	34	717
S012694 61	2/1/94 5:25 PM	4.2112	20.0835	4.8	5.424	5.314	5.4	0.1	6	26	9.636	100.58	585.36	1.12	15	732
S012694 62	2/2/94 4:30 PM	3.9295	19.9502	5.1	5.478	5.396	5.4	0.0	7	28	9.627	100.306	1194.23	1.14	37	770
S012694 63	2/3/94 3:15 PM	4.1742	20.0773	4.8	4.759	4.623	4.7	0.1	8	23	9.627	100.564	1171.44	1.13	30	800
S012694 64	2/4/94 3:30 PM	3.7606	20.0134	5.3	3.649	3.531	3.6	0.1	9	19	9.618	100.979	1223.64	1.11	26	826
S012694 65	2/4/94 4:00 PM	4.0665	19.9768	4.9	3.904	3.842	3.9	0.0	9	19	9.612	10.3493	32.12	1.04	1	827
S012694 66	2/5/94 8:15 AM	3.8287	20.6103	5.4	2.967	2.891	2.9	0.0	10	16	9.62	100.648	879.5	1.15	15	842
S012694 67	2/6/94 7:00 AM	4.0442	20.0666	5.0	2.522	2.489	2.5	0.0	11	12	9.621	100.597	1165.18	1.12	16	858
S012694 68	2/6/94 5:00 PM	4.1473	20.0137	4.8	2.126	2.075	2.1	0.0	11	10	9.612	100.543	577.36	1.14	6	864
S012694 69	2/7/94 3:25 PM	4.1900	19.9800	4.8	1.927	1.891	1.9	0.0	12	9	9.608	99.85	1156.94	1.13	12	876
S012694 70	2/8/94 3:15 PM	4.0281	20.0296	5.0	1.623	1.576	1.6	0.0	13	8	9.626	100.69	1221.27	1.13	11	887
S012694 71	2/9/94 10:15 AM	4.1784	20.1715	4.8	1.742	1.659	1.7	0.0	14	8	9.619	100.03	999.05	1.14	9	896
S012694 72	2/10/94 9:05 AM	4.1730	20.0522	4.8	1.823	1.742	1.8	0.0	15	9	9.616	100.38	1173.3	1.13	11	907
S012694 73	2/11/94 8:15 AM	4.1041	19.9998	4.9	1.345	1.243	1.3	0.1	16	6	9.616	100.01	1193.57	1.13	9	916
S012694 74	2/11/94 5:20 PM	4.1604	20.0157	4.8	1.118	1.079	1.1	0.0	16	5	9.608	100.18	534.41	1.15	3	919
S012694 75	2/12/94 12:18 PM	4.1708	20.2847	4.9	1.016	0.9733	1.0	0.0	17	5	9.607	100.4	996.44	1.13	5	924
S012694 76	2/13/94 9:50 AM	4.1486	19.9699	4.8	0.8521	0.816	0.8	0.0	18	4	9.613	99.71	1120.8	1.14	5	929
S012694 77	2/14/94 8:21 AM	4.1741	19.9433	4.8	0.8239	0.7957	0.8	0.0	19	4	9.614	100.72	1164.26	1.13	5	934
S012694 78	2/15/94 6:23 AM	4.1776	20.0403	4.8	0.753	0.7519	0.8	0.0	20	4	9.612	101.83	1140.91	1.13	5	939
S012694 79	2/16/94 12:03 AM	4.1145	20.0723	4.9	0.7712	0.7233	0.7	0.0	21	4	9.618	102.89	933.71	1.13	4	943
S012694 80	2/16/94 10:38 PM	4.1516	20.2529	4.9	0.7784	0.7473	0.8	0.0	21	4	9.629	102.63	1167.29	1.13	5	947
S012694 81	2/17/94 3:40 PM	4.1503	20.2378	4.9	0.8074	0.7978	0.8	0.0	22	4	9.633	101.85	888.16	1.11	4	951
S012694 82	2/18/94 1:32 PM	4.1023	19.8993	4.9	0.824	0.7886	0.8	0.0	23	4	9.636	101.94	1115.35	1.11	5	956
S012694 83	2/19/94 11:37 AM	4.1645	20.2350	4.9	0.6545	0.6476	0.7	0.0	24	3	9.628	102	1131.22	1.12	4	960
S012694 84	2/20/94 2:40 PM	4.1955	20.0543	4.8	0.5701	0.5529	0.6	0.0	25	3	9.638	101.98	1187.87	0.96	4	964
S012694 85	2/21/94 9:40 AM	4.1838	19.9029	4.8	0.5227	0.4856	0.5	0.0	26	2	9.631	101.98	980.4	1.11	3	966
S012694 86	2/22/94 8:30 AM	4.1618	20.4453	4.9	0.5171	0.4885	0.5	0.0	27	2	9.633	101.893	1157.5	1.11	3	970
S012694 87	2/22/94 12:25 PM	4.1243	19.9503	4.8	0.5277	0.4921	0.5	0.0	27	2	9.617	101.9	284.66	1.12	1	970
S012694 88	2/22/94 12:26 PM	4.1536	20.0599	4.8	0.595	0.5568	0.6	0.0	27	3	9.631	54.73	69.18	0.00	0	970

C012794 - 0.5M Sodium-Carbonate-Bicarbonate, 1X, 1 kg SP9(94), Heterogeneous, Agglomerated with water

Sample	Time sample pulled	Sample mass	Total mass	Dilution	ppm U (ICP 367)	ppm U (ICP 409)	Ave ICP ppm U	Std. Dev.	Experiment Time	ppm U	pH	Empty container mass (g)	Full container mass (g)	Flow Rate (L/day)	mg U/kg soil	Cumulative mg U / kg soil
	1/26/94 11:00 AM															
S012794 3	1/26/94 2:00 PM	0.9967	19.9350	20	33.36	33.59	33.5	0.1	0	670	8.685	10.3988	29.67	0.2	16	16
S012794 4	1/26/94 3:00 PM	1.0065	19.8036	20	28.43	28.53	28.5	0.1	0	560	9.164	10.3924	47.53	0.9	26	42
S012794 5	1/26/94 4:00 PM	1.0083	19.8338	20	23.33	23.47	23.4	0.1	0	460	9.328	10.3857	50.12	1.0	23	64
S012794 6	1/26/94 5:00 PM	1.0106	20.0559	20	20.51	20.42	20.5	0.0	0	406	9.454	10.2942	51.07	1.0	20	85
S012794 7	1/26/94 6:00 PM	1.0198	20.1161	20	18.56	18.45	18.5	0.1	0	365	9.449	10.3607	51.9	1.0	19	103
S012794 8	1/26/94 7:00 PM	0.9968	20.1873	20	16.68	16.61	16.6	0.0	0	337	9.531	10.2495	52.19	1.0	17	121
S012794 9	1/26/94 8:00 PM	1.0172	20.7226	20	15.31	15.38	15.3	0.0	0	313	9.498	10.3685	52.7	1.0	16	137
S012794 10	1/26/94 9:00 PM	1.0054	20.0200	20	14.96	14.9	14.9	0.0	0	297	9.521	10.362	52.83	1.0	16	153
S012794 11	1/26/94 10:00 PM	0.9706	19.8898	20	14.09	14.01	14.1	0.0	0	288	9.517	10.363	53.14	1.0	15	168
S012794 12	1/26/94 11:00 PM	1.0261	20.2064	20	14.35	14.29	14.3	0.0	0	282	9.531	10.36	53.41	1.0	15	183
S012794 A	1/27/94 11:00 AM	0.9979	20.3689	20	12.67	12.56	12.6	0.1	1	257	9.552	123.9807	657.09	1.1	160	352
S012794 B	1/27/94 11:00 PM	1.0306	20.5760	20	10.83	10.76	10.8	0.0	1	216	9.586	124.2115	668.05	1.1	145	497
S012794 C	1/28/94 11:00 AM	1.0338	19.9894	19	7.729	7.646	7.7	0.0	2	149	9.608	124.4409	679.63	1.1	102	599
S012794 D	1/28/94 11:00 PM	4.1829	19.9766	5	16.79	16.79	16.8	0.0	2	80	9.629	124.4663	685.16	1.1	56	655
S012794 E	1/29/94 11:00 AM	4.1211	20.1752	5	10.83	10.71	10.8	0.1	3	53	9.651	123.9436	687.57	1.1	37	691
S012794 F	1/30/94 9:35 AM	3.9238	20.0722	5	7.204	7.079	7.1	0.1	3	37	9.637	100.33	1179.8	1.1	49	740
S012794 73	1/31/94 8:10 AM	4.1882	20.1886	5	4.967	4.934	5.0	0.0	4	24	9.629	100.39	1177.29	1.1	32	772
S012794 75	2/1/94 7:00 AM	4.1856	20.3921	5	3.411	3.356	3.4	0.0	5	16	9.634	100.4	1197.1	1.2	22	794
S012794 76	2/1/94 5:25 PM	3.8417	20.3490	5	2.653	2.605	2.6	0.0	6	14	9.633	100.11	594.98	1.1	9	802
S012794 77	2/2/94 4:30 PM	4.1402	20.0177	5	2.507	2.442	2.5	0.0	6	12	9.627	100.327	1210.87	1.2	16	819
S012794 78	2/3/94 3:15 PM	4.0218	20.1674	5	2.127	2.055	2.1	0.0	7	10	9.629	100.899	1190.96	1.1	14	833
S012794 79	2/4/94 3:30 PM	4.1286	20.3015	5	1.842	1.815	1.8	0.0	8	9	9.627	100.295	1211.56	1.1	12	845
S012794 80	2/4/94 3:55 PM	4.1164	20.4688	5	2.083	2.012	2.0	0.0	9	10	9.742	10.3483	29.18	1.1	0	846
S012794 81	2/5/94 8:15 AM	4.1468	20.7957	5	1.671	1.615	1.6	0.0	9	8	9.629	100.724	895.29	1.2	8	854
S012794 82	2/6/94 7:00 AM	4.1541	19.9341	5	1.548	1.519	1.5	0.0	10	7	9.629	101.049	1186.67	1.1	10	863
S012794 83	2/6/94 5:00 PM	4.1204	20.4431	5	1.316	1.272	1.3	0.0	11	6	9.628	100.727	587.34	1.2	4	867
S012794 84	2/7/94 3:25 PM	4.1820	19.8997	5	1.183	1.165	1.2	0.0	11	6	9.630	100	1176.34	1.2	7	875
S012794 85	2/8/94 3:15 PM	4.1482	20.3387	5	1.032	0.9898	1.0	0.0	12	5	9.631	100.72	1219.27	1.1	7	882
S012794 86	2/9/94 10:15 AM	4.1874	20.1905	5	1.121	1.086	1.1	0.0	13	5	9.629	100.69	1041.14	1.2	6	888
S012794 87	2/10/94 9:05 AM	4.1589	20.1317	5	1.255	1.239	1.2	0.0	14	6	9.622	100.95	1212.64	1.2	8	896
S012794 88	2/11/94 8:10 AM	4.0197	20.5083	5	0.7856	0.7695	0.8	0.0	15	4	9.618	100.61	1220.86	1.2	5	902
S012794 89	2/11/94 5:20 PM	4.0538	20.2824	5	0.6771	0.6454	0.7	0.0	16	3	9.611	100.26	551.48	1.2	2	903
S012794 90	2/12/94 12:18 PM	4.1166	20.0685	5	0.642	0.5979	0.6	0.0	16	3	9.613	99.6	1024.41	1.2	3	907
S012794 91	2/13/94 9:50 AM	4.0711	20.1361	5	0.5032	0.4651	0.5	0.0	17	2	9.616	100.44	1153.81	1.2	3	919
S012794 92	2/14/94 8:20 AM	4.0774	20.0608	5	0.4854	0.4507	0.5	0.0	18	2	9.614	100.78	1197.13	1.2	3	913
S012794 93	2/15/94 6:22 AM	4.1262	20.5163	5	0.4694	0.4606	0.5	0.0	19	2	9.620	102.07	1174.98	1.2	3	916
S012794 94	2/16/94 12:03 AM	4.1828	19.9188	5	0.4895	0.4641	0.5	0.0	20	2	9.619	101.73	957.26	1.2	2	918
S012794 95	2/16/94 10:35 PM	4.1232	20.2285	5	0.5082	0.5015	0.5	0.0	21	2	9.629	101.85	1189.12	1.2	3	922
S012794 96	2/17/94 3:39 PM	4.1544	20.1919	5	0.5737	0.5571	0.6	0.0	21	3	9.638	101.9	917.58	1.1	3	925
S012794 97	2/18/94 1:31 PM	4.0745	20.1563	5	0.5482	0.5575	0.6	0.0	22	3	9.643	101.87	1147.4	1.1	4	928
S012794 98	2/19/94 11:36 AM	4.1468	20.4438	5	0.4413	0.4111	0.4	0.0	23	2	9.638	102.36	1163.01	1.2	3	931
S012794 99	2/20/94 2:40 PM	4.1181	20.0473	5	0.333	0.3258	0.3	0.0	24	2	9.644	101.79	1190.48	1.0	2	933
S012794 100	2/21/94 9:40 AM	4.0680	20.2020	5	0.3125	0.3161	0.3	0.0	25	2	9.638	101.87	1006.3	1.1	2	935
S012794 101	2/22/94 8:24 AM	4.1613	20.0378	5	0.35	0.3161	0.3	0.0	26	2	9.640	101.838	1185.31	1.1	2	937
S012794 102	2/22/94 12:25 PM	3.9948	20.2486	5	0.3155	0.2908	0.3	0.0	27	2	9.624	101.61	293	1.1	0	937
S012794 103	2/22/94 12:26 PM	4.0479	20.2653	5	0.3154	0.3039	0.3	0.0	27	2	9.644	54.37	71.29	0.0	0	937

C012894 - 0.5M Sodium-Carbonate-Bicarbonate, 1X, 3 kg SP9(94), Heterogeneous, Agglomerated with water

Sample	Time sample pulled	Sample mass	Total mass	Dilution	ppm U (ICP 367)	ppm U (ICP 409)	Ave ICP ppm U	Std. Dev.	Experiment Time	mg U/L	pH	Empty container mass (g)	Full container mass (g)	Flow Rate (L/day)	mg U/kg soil	Cumulative mg U/kg soil	-log [U]
	1/28/94 11:00 AM																
S012894 7	1/28/94 6:30 PM	0.7787	20.2144	26.0	1.916	1.999	2.0	0.0	0	51	8	10.33	28.14	0.1	0	0	4
S012894 8	1/28/94 7:00 PM	0.7888	20.0989	25.5	11.88	11.88	11.9	0.0	0	303	8	10.36	40.22	0.7	4	4	3
S012894 9	1/28/94 8:00 PM	0.7910	20.3590	25.7	27.04	26.77	26.9	0.1	0	882	8	10.33	42.40	0.8	9	13	3
S012894 10	1/28/94 9:00 PM	0.7900	20.1892	25.5	37.10	36.38	36.7	0.4	0	839	7	10.42	43.62	0.8	12	25	2
S012894 11	1/28/94 10:00 PM	0.7902	20.0306	25.3	41.12	40.94	41.0	0.1	0	1040	8	10.38	44.46	0.8	14	40	2
S012894 12	1/28/94 11:00 PM	0.7901	20.2095	25.6	41.53	41.03	41.3	0.2	1	1056	8	10.38	44.62	0.8	15	54	2
S012894 23A	1/27/94 11:00 AM	0.7480	20.1888	27.0	38.58	37.72	38.2	0.4	1	1029	9	123.90	554.83	0.9	178	232	2
S012894 28B	1/27/94 11:00 PM	0.7948	20.0278	25.2	36.32	36.03	36.2	0.1	2	912	9	124.38	574.16	0.9	186	397	2
S012894 28C	1/28/94 11:00 AM	0.8152	20.0232	24.8	30.79	30.78	30.8	0.0	2	756	9	124.58	618.50	1.0	150	547	2
S012894 28D	1/28/94 11:00 PM	0.8228	20.5885	25.0	23.63	23.17	23.4	0.2	3	588	9	124.32	634.14	1.0	120	667	3
S012894 28E	1/29/94 11:00 AM	0.8228	20.4778	24.9	18.52	18.29	18.4	0.2	3	457	9	124.54	648.11	1.0	96	763	3
S012894 73	1/30/94 9:35 AM	0.8343	20.1275	24.1	13.78	13.62	13.8	0.1	4	329	10	101.21	1110.36	1.1	133	898	3
S012894 74	1/31/94 8:12 AM	2.0177	20.1064	10.6	20.82	20.49	20.7	0.2	5	208	10	100.02	1122.31	1.1	85	981	3
S012894 75	2/1/94 7:00 AM	1.9517	20.4379	10.5	13.99	13.67	13.8	0.2	6	145	10	100.81	1147.45	1.1	81	1041	3
S012894 76	2/1/94 5:25 PM	1.9478	20.1831	10.4	11.47	11.25	11.4	0.1	6	118	10	100.42	573.25	1.1	22	1064	3
S012894 77	2/2/94 4:30 PM	2.0877	20.0020	9.7	10.16	9.979	10.1	0.1	7	97	10	100.17	1163.81	1.1	42	1105	3
S012894 78	2/3/94 3:15 PM	2.0544	20.4395	9.9	8.255	8.200	8.2	0.0	8	82	10	100.25	1143.08	1.1	34	1140	3
S012894 79	2/4/94 3:30 PM	2.0655	20.0990	8.7	7.303	7.189	7.2	0.1	9	78	10	100.22	1207.74	1.1	31	1171	4
S012894 80	2/4/94 3:53 PM	2.0429	20.3726	10.0	8.782	8.714	8.8	0.0	9	67	10	100.28	27.88	1.1	0	1172	4
S012894 81	2/5/94 8:15 AM	2.0707	20.3993	9.9	8.485	8.334	8.4	0.1	10	63	10	100.88	982.78	1.1	19	1191	4
S012894 82	2/6/94 7:00 AM	4.2011	20.2902	4.8	11.08	10.880	11.0	0.1	11	53	10	100.54	1146.39	1.1	22	1213	4
S012894 83	2/6/94 5:00 PM	4.0840	20.1342	5.0	9.411	9.255	9.3	0.1	11	46	10	100.88	571.05	1.1	9	1222	4
S012894 84	2/7/94 3:25 PM	4.1781	20.3378	4.9	8.888	8.881	8.9	0.2	12	41	10	100.89	1138.09	1.1	17	1239	4
S012894 85	2/8/94 3:15 PM	3.9678	20.1857	5.1	7.114	6.905	7.0	0.1	13	38	10	100.20	1202.77	1.1	16	1255	4
S012894 86	2/9/94 10:15 AM	3.7712	20.3870	5.4	6.532	6.225	6.5	0.2	14	35	10	100.57	982.22	1.1	13	1267	4
S012894 87	2/10/94 9:05 AM	4.0328	20.3319	5.0	7.482	7.316	7.4	0.1	15	37	10	100.25	1148.44	1.1	18	1283	4
S012894 88	2/11/94 8:15 AM	3.9057	20.4200	5.2	5.488	5.430	5.5	0.0	16	29	10	101.13	1176.19	1.1	12	1295	4
S012894 89	2/11/94 5:20 PM	4.1892	20.0930	4.8	4.778	4.631	4.7	0.1	16	23	10	101.20	528.77	1.1	4	1298	4
S012894 90	2/12/94 12:18 PM	4.1688	20.5819	4.9	4.157	4.085	4.1	0.0	17	20	10	99.85	978.39	1.1	7	1307	4
S012894 91	2/13/94 9:50 AM	4.1184	20.1205	4.9	3.562	3.361	3.4	0.1	18	17	10	99.54	1101.57	1.1	7	1313	4
S012894 92	2/14/94 8:21 AM	3.9047	20.5206	5.3	2.890	2.823	2.9	0.0	19	15	10	99.95	1145.95	1.1	6	1320	4
S012894 93	2/15/94 6:23 AM	3.9894	20.1744	5.1	2.832	2.833	2.8	0.0	20	15	10	101.88	1123.73	1.1	6	1326	4
S012894 94	2/16/94 12:03 AM	4.1316	20.3308	4.9	3.170	3.110	3.1	0.0	21	15	10	102.07	918.82	1.1	5	1331	4
S012894 95	2/16/94 10:38 PM	4.0514	20.6889	5.1	2.858	2.787	2.8	0.0	21	14	10	102.53	1150.61	1.1	6	1337	4
S012894 96	2/17/94 3:40 PM	4.1750	20.1036	4.8	3.065	2.950	3.0	0.1	22	14	10	101.84	882.87	1.1	5	1341	4
S012894 97	2/18/94 1:32 PM	4.0899	20.0202	4.9	3.023	2.950	3.0	0.0	23	15	10	102.00	1103.75	1.1	6	1347	4
S012894 98	2/19/94 11:37 AM	4.1305	20.0335	4.9	2.325	2.570	2.4	0.1	24	12	10	102.51	1117.49	1.1	5	1352	4
S012894 99	2/20/94 2:40 PM	4.1248	20.5317	5.0	1.895	1.819	2.0	0.0	25	10	10	101.73	1186.41	1.0	4	1356	4
S012894 100	2/21/94 9:40 AM	4.1807	20.3292	4.9	1.725	1.804	1.7	0.0	26	8	10	102.15	972.92	1.1	3	1359	4
S012894 101	2/22/94 9:30 AM	3.9443	20.0809	5.1	1.585	1.549	1.6	0.0	27	8	10	102.90	1151.71	1.1	3	1362	4
S012894 102	2/22/94 12:25 PM	4.1224	20.1387	4.9	1.615	1.583	1.6	0.0	27	8	10	102.04	282.73	1.1	1	1363	4
S012894 103	2/22/94 12:28 PM	4.0872	20.3117	5.0	1.611	1.584	1.6	0.0	27	8	10	95.07	118.91	0.0	0	1363	4

C020494 - 0.5 M Sodium-Carbonate-Bicarbonate, 0.3X, 1 kg SP9(94), Heterogeneous, Agglomerated with water

Sample	Time sample pulled	Sample mass	Total mass	Dilution	ppm U (ICP 367)	ppm U (ICP 409)	Ave ICP ppm U	Std. Dev.	Experiment Time	mg U/L	pH	Empty container mass (g)	Full container mass (g)	Flow Rate (L/day)	mg U/kg soil	Cumulative mg U/kg soil
	2/4/94 12:06 PM															
S020494 9	2/4/94 9:05 PM	1.0062	20.1262	20	30.87	30.68	30.8	0.1	0	616	9.30	10.3567	15.8386	0.01	4	4
S020494 10	2/4/94 10:05 PM	0.9985	20.2298	20	30.93	30.82	30.9	0.1	0	626	9.36	10.2543	19.8629	0.23	7	11
S020494 11	2/4/94 11:05 PM	0.9185	20.3567	22	28.32	30.68	29.5	1.2	0	654	9.32	10.3353	20.1618	0.24	8	19
S020494 12	2/5/94 12:05 AM	0.9990	20.0256	20	30.68	30.59	30.6	0.0	1	614	9.47	10.3662	20.2431	0.24	7	27
S020494 A	2/5/94 12:05 PM	0.9301	20.0236	22	24.58	24.50	24.5	0.0	1	528	9.39	124.27	248.92	0.25	80	107
S020494 B	2/6/94 12:05 AM	0.9974	20.0643	20	19.20	19.08	19.1	0.1	2	385	9.54	124.37	252.04	0.26	60	167
S020494 C	2/6/94 12:05 PM	0.9922	20.1256	20	15.84	15.77	15.8	0.0	2	321	9.51	124.49	255.00	0.26	51	218
S020494 D	2/6/94 10:25 PM	0.9466	20.0053	21	12.42	12.23	12.3	0.1	2	260	9.55	124.17	242.00	0.27	37	255
S020494 E	2/7/94 10:25 AM	0.9585	20.0080	21	11.61	11.47	11.5	0.1	3	241	9.54	124.10	259.65	0.27	40	295
S020494 73	2/6/94 3:15 PM	1.9344	20.1124	10	16.79	16.61	16.7	0.1	4	174	9.57	100.70	432.90	0.28	70	366
S020494 74	2/9/94 10:15 AM	1.9780	20.2780	10	13.34	13.26	13.3	0.0	5	138	9.59	100.51	314.71	0.27	36	401
S020494 75	2/10/94 9:05 AM	2.0413	20.3909	10	14.48	14.28	14.4	0.1	6	144	9.56	100.46	382.40	0.28	46	447
S020494 76	2/11/94 8:15 AM	1.9908	20.1964	10	11.50	11.33	11.4	0.1	7	116	9.59	100.04	376.22	0.29	39	486
S020494 77	2/11/94 5:20 PM	2.0388	20.0487	10	9.783	9.628	9.7	0.1	7	95	9.61	100.46	206.18	0.28	13	499
S020494 78	2/12/94 12:15 PM	1.9870	20.1534	10	8.283	8.196	8.2	0.0	8	84	9.61	54.43	290.69	0.29	23	522
S020494 79	2/13/94 9:50 AM	2.0636	20.3368	10	7.115	7.045	7.1	0.0	8	70	9.60	55.05	313.61	0.29	22	544
S020494 80	2/14/94 8:20 AM	1.9598	20.2841	10	5.907	5.888	5.9	0.0	10	61	9.61	55.14	325.64	0.29	20	564
S020494 81	2/15/94 6:20 AM	1.9613	20.7450	11	5.595	5.494	5.5	0.1	11	59	9.62	54.75	317.82	0.29	19	583
S020494 82	2/16/94 12:03 AM	2.0458	20.1171	10	5.481	5.416	5.4	0.0	11	54	9.62	54.85	266.38	0.29	14	596
S020494 83	2/16/94 1:15 PM	2.0256	20.1354	10	5.341	5.282	5.3	0.0	12	53	9.65	54.48	80.89	0.05	2	598
S020494 84	2/16/94 10:39 PM	1.9814	20.1793	10	7.021	6.928	7.0	0.0	12	71	9.62	54.78	158.80	0.26	9	607
S020494 85	2/17/94 3:37 PM	1.9218	20.1582	10	6.239	6.142	6.2	0.0	13	65	9.62	54.78	255.91	0.28	16	623
S020494 86	2/18/94 1:30 PM	2.0295	20.0145	10	5.180	5.058	5.1	0.1	14	50	9.64	54.77	314.39	0.28	16	639
S020494 87	2/19/94 11:34 PM	2.0358	20.0473	10	4.067	4.003	4.0	0.0	15	40	9.65	54.43	319.18	0.19	13	652
S020494 88	2/20/94 2:40 PM	2.0421	20.2050	10	3.705	3.650	3.7	0.0	16	36	9.65	55.10	383.30	0.52	15	666
S020494 89	2/21/94 9:40 AM	2.0564	20.0100	10	3.549	3.499	3.5	0.0	17	34	9.65	54.77	281.69	0.29	9	676
S020494 90	2/22/94 8:28 AM	1.9570	20.5488	11	3.149	3.111	3.1	0.0	18	33	9.62	54.53	327.91	0.29	11	687
S020494 91	2/23/94 8:43 PM	2.0032	20.6050	10	2.951	2.891	2.9	0.0	19	30	9.63	55.09	346.73	0.19	11	697
S020494 92	2/24/94 8:16 AM	1.9526	20.1861	10	2.759	2.696	2.7	0.0	20	28	9.63	55.08	336.43	0.58	10	707
S020494 93	2/25/94 9:05 AM	1.9425	20.1770	10	2.580	2.481	2.5	0.0	21	26	9.64	54.31	351.87	0.29	10	717
S020494 94	2/26/94 11:24 AM	2.0260	20.4620	10	2.612	2.552	2.6	0.0	22	26	9.64	55.17	370.57	0.29	10	727
S020494 95	2/27/94 10:06 AM	2.0390	20.2807	10	2.509	2.483	2.5	0.0	23	25	9.63	55.18	328.12	0.29	8	735
S020494 96	2/28/94 9:11 AM	1.9492	20.4097	10	2.310	2.241	2.3	0.0	24	24	9.63	54.81	331.74	0.29	8	743
S020494 97	3/1/94 8:59 AM	2.0211	20.9790	10	2.207	2.191	2.2	0.0	25	23	9.66	54.26	340.21	0.29	8	751
S020494 98	3/2/94 8:35 AM	1.9745	20.2073	10	2.056	2.008	2.0	0.0	26	21	9.65	67.08	348.22	0.29	7	758
S020494 99	3/3/94 8:49 AM	1.9563	20.3545	10	1.968	1.938	2.0	0.0	27	20	9.65	67.34	355.15	0.29	7	765
S020494 100	3/4/94 8:28 AM	2.0609	20.9584	10	2.006	1.950	2.0	0.0	28	20	9.66	102.20	385.39	0.29	7	772
S020494 101	3/5/94 12:15 PM	2.0670	20.2511	10	2.045	1.998	2.0	0.0	29	20	9.67	69.64	400.46	0.29	8	780
S020494 102	3/6/94 11:03 AM	2.0629	20.4778	10	1.947	1.896	1.9	0.0	30	19	9.67	71.59	343.59	0.29	6	786
S020494 103	3/7/94 11:45 AM	2.0388	20.3250	10	1.910	1.860	1.9	0.0	31	19	9.67	69.61	364.67	0.29	7	793
S020494 104	3/7/94 11:46 AM	2.0642	20.1809	10	2.137	2.091	2.1	0.0	31	21	9.66	14.46	30.42	0.00	0	794

C020594 - 0.5 M Sodium-Carbonate-Bicarbonate, 0.3X, 1 kg SP9(94), Heterogeneous, Agglomerated with water

Sample	Time sample pulled	Sample mass	Total mass	Dilution	ppm U (ICP 367)	ppm U (ICP 409)	Ave ICP ppm U	Std. Dev.	Experiment Time	mg U/L	pH	Empty container mass (g)	Full container mass (g)	Flow Rate (L/day)	mg U/kg soil	Cumulative mg U/kg soil
	2/4/94 12:05 PM															
S020594 8	2/4/94 8:05 PM	0.9915	20.5028	21	26.07	26.02	26.0	0.0	0	539	9.288	10.3999	14.29	0.01	3	3
S020594 9	2/4/94 9:05 PM	0.9977	20.2925	20	29.52	29.41	29.5	0.1	0	599	9.068	10.3247	18.78	0.20	6	9
S020594 10	2/4/94 10:05 PM	0.9298	20.4115	22	29.16	29.06	29.1	0.0	0	639	9.076	10.4165	19.03	0.21	7	15
S020594 11	2/4/94 11:05 PM	0.9999	20.4957	20	35.36	34.83	35.1	0.3	0	719	9.367	10.3424	19.27	0.21	8	23
S020594 12	2/5/94 12:05 AM	1.0032	20.3870	20	33.25	33.20	33.2	0.0	1	675	9.090	10.3300	19.41	0.22	7	31
S020594 A	2/5/94 12:05 PM	1.0067	20.1074	20	29.34	29.27	29.3	0.0	1	585	9.133	124.0164	232.88	0.22	78	109
S020594 B	2/6/94 12:05 AM	1.0163	20.4690	20	23.63	23.54	23.6	0.0	2	475	9.505	124.2846	247.60	0.25	71	180
S020594 C	2/6/94 12:05 PM	1.0176	20.4509	20	18.50	18.28	18.4	0.1	2	370	9.476	124.2256	252.43	0.26	58	238
S020594 D	2/7/94 12:05 AM	1.0195	20.1657	20	14.47	14.31	14.4	0.1	3	285	9.533	124.1582	254.34	0.26	45	283
S020594 E	2/7/94 10:15 AM	1.0197	20.6972	20	11.51	11.34	11.4	0.1	3	232	9.570	123.7858	256.55	0.31	38	320
S020594 73	2/8/94 3:15 PM	2.0714	20.9126	10	17.68	17.55	17.6	0.1	4	178	9.563	100.902	427.71	0.27	71	391
S020594 74	2/9/94 10:15 AM	2.0685	20.1094	10	15.86	15.54	15.6	0.1	5	152	9.565	100.68	311.00	0.27	39	430
S020594 75	2/10/94 9:05 AM	2.0680	20.7452	10	12.01	11.88	11.9	0.1	6	120	9.570	100.69	355.37	0.27	37	467
S020594 76	2/11/94 8:10 AM	2.0364	20.2023	10	9.720	9.54	9.6	0.1	7	96	9.587	101.48	368.76	0.28	31	498
S020594 77	2/11/94 5:20 PM	1.9977	20.2512	10	7.969	7.923	8.0	0.0	7	81	9.605	100.87	204.94	0.27	10	509
S020594 78	2/12/94 12:15 PM	2.0812	20.1264	10	7.456	7.365	7.4	0.0	8	72	9.601	55.06	276.91	0.28	19	528
S020594 79	2/13/94 9:50 AM	2.1262	20.3080	10	6.559	6.438	6.5	0.1	9	62	9.617	54.81	308.87	0.28	19	547
S020594 80	2/14/94 8:20 AM	2.1208	20.2881	10	5.637	5.556	5.6	0.0	10	54	9.613	55.00	320.62	0.28	17	565
S020594 81	2/15/94 6:20 AM	2.0764	20.1439	10	4.894	4.799	4.8	0.0	11	47	9.615	55.16	313.76	0.28	15	580
S020594 82	2/16/94 12:03 AM	2.0919	20.2017	10	4.613	4.523	4.6	0.0	11	44	9.619	55.15	262.89	0.28	11	591
S020594 83	2/16/94 10:38 PM	2.0674	20.6499	10	4.241	4.136	4.2	0.1	12	41	9.626	55.02	321.77	0.28	13	604
S020594 84	2/17/94 3:38 PM	1.9580	20.2705	10	4.145	4.099	4.1	0.0	13	43	9.640	54.44	251.76	0.28	10	615
S020594 85	2/18/94 1:30 PM	1.9619	20.7680	11	3.677	3.653	3.7	0.0	14	39	9.631	54.84	308.46	0.28	12	627
S020594 86	2/19/94 11:34 PM	2.0376	20.2093	10	3.474	3.440	3.5	0.0	15	34	9.633	54.68	313.09	0.18	11	637
S020594 87	2/20/94 2:40 PM	2.0398	20.2686	10	3.201	3.145	3.2	0.0	16	32	9.632	55.06	374.74	0.51	12	650
S020594 88	2/21/94 9:40 AM	2.0246	20.1530	10	3.191	3.139	3.2	0.0	17	32	9.635	55.01	278.1	0.28	8	658
S020594 89	2/22/94 6:28 AM	1.9608	20.4341	10	2.916	2.883	2.9	0.0	18	30	9.644	55.2846	321.99	0.28	10	668
S020594 90	2/23/94 6:43 PM	2.1112	20.2039	10	3.008	2.936	3.0	0.0	19	28	9.620	54.33	338.93	0.19	10	678
S020594 91	2/24/94 8:17 AM	2.1061	20.1011	10	2.867	2.818	2.8	0.0	20	27	9.620	55.09	330.85	0.57	9	687
S020594 92	2/25/94 9:06 AM	1.9650	20.4757	10	2.568	2.551	2.6	0.0	21	27	9.633	54.45	345.81	0.28	9	697
S020594 93	2/26/94 11:24 AM	2.0416	20.1292	10	2.712	2.714	2.7	0.0	22	27	9.631	54.7	363.87	0.28	10	707
S020594 94	2/27/94 10:05 AM	2.0504	20.1687	10	2.848	2.786	2.8	0.0	23	28	9.630	54.77	321.5	0.28	9	716
S020594 95	2/28/94 9:11 AM	2.0713	20.2078	10	2.896	2.906	2.9	0.0	24	28	9.628	55.18	326.21	0.28	9	725
S020594 96	3/1/94 8:58 AM	2.0357	20.5495	10	2.789	2.710	2.7	0.0	25	28	9.633	54.78	334.34	0.28	9	734
S020594 97	3/2/94 8:35 AM	2.0501	20.1285	10	2.689	2.647	2.7	0.0	26	26	9.633	67.57	342.21	0.28	9	743
S020594 98	3/3/94 8:48 AM	1.9835	20.6895	10	2.443	2.425	2.4	0.0	27	25	9.635	67.19	348.91	0.28	9	752
S020594 99	3/4/94 8:27 AM	1.9561	20.2229	10	2.400	2.351	2.4	0.0	28	25	9.680	61.71	379.75	0.32	10	761
S020594 100	3/5/94 12:15 PM	1.9887	20.1987	10	2.345	2.301	2.3	0.0	29	24	9.653	71.56	385.18	0.28	9	771
S020594 101	3/6/94 11:02 AM	2.0508	20.2845	10	2.306	2.279	2.3	0.0	30	23	9.646	71.37	338.8	0.28	7	778
S020594 102	3/7/94 11:45 AM	2.0401	20.1743	10	2.126	2.131	2.1	0.0	31	21	9.642	71.48	360.29	0.28	7	785
S020594 103	3/7/94 11:46 AM	1.9556	20.1521	10	2.255	2.231	2.2	0.0	31	23	9.644	14.37	27.4	0.00	0	789

C022394 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X, 10 kg SP9(94), Heterogeneous, Agglomerated with water

Sample	Time sample pulled	Sample mass	Total mass	Dilution	ppm U (ICP 367)	ppm U (ICP 409)	Ave ICP ppm U	Std. Dev.	Experiment Time	mg U/L	pH	Empty container mass (g)	Full container mass (g)	Flow Rate (L/day)	mg U/kg soil	Cumulative mg U/kg soil	-log [U]
	2/25/94 6:05 PM																
S022394 19	2/26/94 1:05 PM	0.4936	20.2164	41.0	0	0	0.0 0.0	1	0	0	8	10.35	39.19	0.04	0	0	
S022394 20	2/26/94 2:05 PM	0.4893	20.0887	41.1	0	0	0.0 0.0	1	0	0	7	10.31	37.36	0.65	0	0	
S022394 21	2/26/94 3:05 PM	0.5295	20.1821	38.1	0	0	0.0 0.0	1	0	0	7	10.33	38.78	0.68	0	0	
S022394 22	2/26/94 4:05 PM	0.5258	20.1882	38.4	0	0	0.0 0.0	1	0	0	7	10.32	36.29	0.62	0	0	
S022394 23	2/26/94 5:05 PM	0.5363	10.0913	18.8	0	0	0.0 0.0	1	0	0	7	10.22	49.07	0.93	0	0	
S022394 24	2/26/94 6:05 PM	0.5235	10.0668	19.2	0.01799	0.02883	0.0 0.0	1	0	0	8	10.31	38.13	0.67	0	0	6
S022394 A	2/27/94 6:05 AM	0.5169	20.7348	40.1	0.1827	0.1813	0.2 0.0	1	7	8	123.74	496.28	0.75	0	0	5	
S020394 B	2/27/94 6:05 PM	0.5121	20.0763	39.2	4.941	4.958	4.9 0.0	2	194	8	123.44	548.46	0.85	10	11	3	
S022393 C	2/28/94 6:05 AM	0.5170	20.6484	39.9	35.88	35.88	35.9 0.0	2	1433	7	123.67	542.19	0.84	74	85	2	
S022394 D	2/28/94 5:05 PM	0.5334	20.6336	38.7	44.57	44.38	44.5 0.1	2	1720	7	123.67	542.2	0.91	89	173	2	
S022394 E	3/1/94 5:05 AM	0.5311	20.1474	37.9	43.73	43.76	43.7 0.0	3	1659	8	195.578	629.23	0.87	89	262	2	
S022394 F	3/1/94 6:05 PM	0.8104	20.3609	25.1	58.47	58.61	59.0 0.8	3	1483	8	260.19	737.07	0.88	87	350	2	
S022394 117	3/2/94 8:05 PM	0.8260	20.5405	24.9	52.75	52.86	52.8 0.1	4	1313	8	103.82	1140.99	0.98	168	518	2	
S022394 118	3/3/94 3:30 PM	0.8099	20.7599	25.6	43.09	43.01	43.1 0.0	5	1103	8	101.39	891.41	0.98	108	625	2	
S022394 119	3/4/94 2:45 PM	0.8479	20.6721	24.4	33.76	34.09	33.9 0.2	6	827	9	104.84	1078.48	1.01	99	725	2	
S022394 120	3/5/94 12:15 PM	0.8333	20.5511	24.7	23.80	23.06	23.4 0.4	7	578	9	104.8	1039.31	1.04	67	792	3	
S022394 121	3/6/94 11:01 AM	0.8161	20.6070	25.3	14.91	14.48	14.7 0.2	8	371	9	104.23	1130.52	1.08	47	839	3	
S022394 122	3/7/94 12:30 PM	0.8363	20.1070	24.0	10.15	10.02	10.1 0.1	9	242	9	100.78	1263.86	1.10	35	873	3	
S022394 123	3/8/94 12:48 PM	0.8398	20.1720	24.0	6.235	6.065	6.2 0.1	10	148	10	100.81	1218.94	1.10	20	894	3	
S022394 124	3/9/94 8:27 AM	0.8213	20.4692	24.9	3.996	4.000	4.0 0.0	11	100	7	100.83	1038	1.14	12	905	3	
S022394 125	3/10/94 9:35 AM	0.8359	20.0655	24.0	3.101	3.057	3.1 0.0	12	74	10	101.31	1308.26	1.15	11	916	4	
S022394 126	3/11/94 8:45 AM	0.8150	20.2725	24.9	2.526	2.458	2.5 0.0	13	62	10	101.84	1198.35	1.14	8	925	4	
S022394 127	3/12/94 8:40 AM	0.8408	20.1397	24.0	2.311	2.262	2.3 0.0	14	55	10	100.85	1284.54	1.17	8	933	4	
S022394 128	3/13/94 1:56 PM	0.8150	20.6285	25.3	2.095	1.996	2.0 0.0	15	52	10	99.9	1516.75	1.16	9	942	4	
S022394 129	3/15/94 8:03 AM	0.8487	20.2138	23.8	1.856	1.873	1.9 0.0	16	44	10	104.55	2146.73	1.18	11	953	4	
S022394 130	3/16/94 8:08 AM	0.8107	20.3053	25.0	1.837	1.800	1.8 0.0	18	46	10	100.78	1257.22	1.15	7	959	4	
S022394 131	3/17/94 8:08 AM	0.8089	20.1316	24.9	1.779	1.748	1.8 0.0	19	44	10	104.22	1257.62	1.15	6	966	4	
S022394 132	3/18/94 8:05 AM	0.8116	20.1490	24.8	1.948	1.916	1.9 0.0	20	48	10	101.4	1155.13	1.06	6	972	4	
S022394 133	3/19/94 10:17 AM	0.8126	20.1128	24.8	1.738	1.712	1.7 0.0	21	43	10	101.99	1182.2	0.99	6	977	4	
S022394 134	3/20/94 8:37 AM	0.8221	20.5436	25.0	1.580	1.547	1.6 0.0	22	39	10	101.87	1169.47	1.15	5	983	4	
S022394 135	3/21/94 8:37 AM	0.8182	20.2825	24.8	1.386	1.359	1.4 0.0	23	34	10	102.35	1182.55	1.08	5	987	4	
S022394 136	3/21/94 4:45 PM	0.8188	20.3309	24.8	1.292	1.267	1.3 0.0	24	32	10	101.76	454.8	1.04	1	989	4	
S022394 137	3/22/94 11:14 AM	0.8168	20.2679	24.6	1.277	1.230	1.3 0.0	24	31	10	101.92	890.52	1.02	3	992	4	
S022394 138	3/22/94 5:15 PM	0.8339	20.2104	24.2	1.344	1.342	1.3 0.0	25	33	10	101.71	294.19	0.77	1	992	4	
S022394 139	3/24/94 8:09 AM	0.8219	20.5301	25.0	1.623	1.589	1.6 0.0	25	40	10	206.09	1586.08	0.85	7	999	4	
S022394 140	3/24/94 4:49 PM	0.8180	20.2525	24.8	1.584	1.524	1.6 0.0	27	38	10	102.08	445.59	0.95	2	1001	4	
S022394 141	3/25/94 3:30 PM	0.8390	20.2166	24.1	1.441	1.417	1.4 0.0	27	34	10	102.08	991.73	0.94	4	1005	4	
S022394 142	3/26/94 9:07 PM	0.8500	20.4898	24.1	1.278	1.256	1.3 0.0	28	31	10	102.38	1127.33	0.83	4	1008	4	
S022394 143	3/27/94 4:34 PM	0.8472	20.0410	23.7	1.053	1.021	1.0 0.0	29	26	10	102.3	946.15	1.04	3	1011	4	
S022394 144	3/28/94 12:10 PM	0.8241	20.5090	24.9	0.9062	0.9115	0.9 0.0	30	23	10	100.25	1003.5	1.11	3	1014	4	
S022394 145	3/29/94 11:55 AM	0.7992	20.5011	25.7	0.7808	0.7705	0.8 0.0	31	20	10	100.37	966.62	0.88	2	1016	4	
S022394 146	3/29/94 8:10 PM	0.8311	20.5238	24.7	0.8498	0.8215	0.8 0.0	32	21	10	101.91	362.84	0.78	1	1016	4	
S022394 147	3/30/94 11:15 AM	0.8398	20.5960	24.5	0.7641	0.7529	0.8 0.0	32	19	10	102.48	636.92	0.85	1	1017	4	
S022394 148	4/1/94 4:30 AM	0.8208	20.2536	24.7	0.9714	0.9680	1.0 0.0	33	24	10	102.03	871.35	0.45	2	1020	4	
S022394 149	4/1/94 4:31 AM	0.8159	20.1141	24.7	1.629	1.623	1.6 0.0	34	40	10	101.98	487.58	0.00	2	1022	4	

C03084 - 0.5M Sodium-Carbonate-Bicarbonate, 1X, 1 kg SP9(94), Heterogeneous, Agglomerated with water

Sample	Time sample pulled	Sample mass	Total mass	Dilution	ppm U (ICP 367)	ppm U (ICP 469)	Ave ICP ppm U	Std. Dev.	Experiment Time	Center Time Step	ppm U	pH	Empty container mass (g)	Full container mass (g)	Flow Rate (L/day)	mg U/kg soil	Cumulative mg U / kg soil	Temp
	3/9/94 2:15 PM																	
S030894 1	3/9/94 8:25 AM	0.8018	20.1747	25	27.11	27.29	27.2	0.1	1	1	684		101.04	758.97	0.9	185	185	
S030894 2	3/11/94 9:47 AM	0.8399	20.4840	24	25.48	25.38	25.4	0.1	1	2	620		101.34	2084.66	1.0	506	691	
S030894 3	3/12/94 8:40 AM	0.8452	20.1823	24	10.45	10.34	10.4	0.1	3	2	248		100.89	1138.89	1.1	106	797	
S030894 4	3/13/94 1:55 PM	0.8560	20.4200	24	5.674	5.557	5.6	0.1	4	4	134		100.38	1390.12	1.1	71	868	
S030894 5	3/15/94 8:05 AM	0.8463	20.2058	24	3.346	3.262	3.3	0.0	5	5	79		102.26	1982.28	1.1	60	929	19.6
S030894 6	3/16/94 8:10 AM	0.8561	20.1314	24	2.595	2.548	2.6	0.0	7	6	60		100.95	1164.31	1.1	26	955	19.6
S030894 7	3/17/94 8:10 AM	0.8442	20.2643	24	2.12	2.037	2.1	0.0	8	8	50		101.39	1171.15	1.1	22	977	19.6
S030894 8	3/18/94 8:07 AM	0.8564	20.4980	24	1.817	1.797	1.8	0.0	9	9	43		103.74	1172.41	1.1	19	996	
S030894 9	3/19/94 10:19 AM	1.0159	19.9805	20	1.736	1.701	1.7	0.0	10	10	34		102.04	1193.88	1.0	15	1011	
S030894 10	3/20/94 8:38 AM	0.9966	20.0010	20	1.431	1.359	1.4	0.0	11	11	28		101.90	1102.98	1.1	12	1023	21.5
S030894 11	3/21/94 8:38 AM	0.9965	20.0747	20	1.246	1.158	1.2	0.0	12	12	24		102.15	1172.42	1.1	11	1034	
S030894 12	3/21/94 5:45 PM	1.0010	20.0401	20	1.149	1.13	1.1	0.0	13	12	23		102.06	465.42	1.0	3	1037	
S030894 13	3/22/94 11:12 AM	4.0803	20.0840	5	3.999	3.938	4.0	0.0	13	13	20		102.10	919.41	1.1	7	1044	
S030894 14	3/22/94 5:18 PM	4.0301	20.1965	5	3.878	3.772	3.8	0.1	14	14	19		102.18	374.00	1.1	2	1046	
S030894 15	3/24/94 8:10 AM	4.0365	20.0530	5	3.744	3.655	3.7	0.0	14	15	18		206.46	1931.60	1.1	13	1059	
S030894 16	3/24/94 4:50 PM	4.0141	19.9932	5	3.547	3.488	3.5	0.0	16	15	18		101.71	487.99	1.1	3	1062	
S030894 17	3/25/94 3:35 PM	4.0203	19.9769	5	3.521	3.406	3.5	0.1	16	16	17		101.80	1106.88	1.1	7	1069	
S030894 18	3/26/94 8:22 PM	3.9888	19.9933	5	3.166	3.01	3.1	0.1	17	17	15		102.19	1160.25	0.9	7	1075	
S030894 19	3/27/94 4:35 PM	4.0338	20.0630	5	2.636	2.566	2.6	0.0	18	18	13		102.31	976.47	1.0	5	1080	
S030894 20	3/28/94 12:10 PM	3.9075	19.9611	5	2.252	2.16	2.2	0.0	19	19	11		102.09	968.89	1.1	4	1084	
S030894 21	3/29/94 11:55 AM	4.0261	20.5515	5	1.858	1.79	1.8	0.0	20	20	9		103.54	1151.69	1.1	4	1088	
S030894 22	3/30/94 2:05 PM	3.9888	20.1220	5	1.81	1.723	1.8	0.0	21	21	9		102.30	1138.22	1.0	4	1092	
S030894 22A	3/30/94 4:00 PM			5	1.769	1.7095	1.7	0.0	22	21	9		71.40	166.36	1.1	0	1092	
S030894 23	3/31/94 2:03 PM	4.0114	19.9633	5	1.728	1.696	1.7	0.0	22	22	9		102.47	1184.48	1.2	4	1096	18
S030894 23A	4/1/94 8:40 AM			5	1.6925	1.657	1.7	0.0	23	23	8		71.46	629.46	0.7	2	1098	21.3
S030894 24	4/1/94 4:32 PM	4.0005	20.9230	5	1.657	1.618	1.6	0.0	24	24	9		69.34	421.49	1.1	1	1099	
S030894 25	4/2/94 3:13 PM	3.9739	20.0833	5	1.786	1.714	1.8	0.0	24	24	9		101.88	1136.57	1.1	4	1103	
S030894 26	4/3/94 3:30 PM	3.9167	20.1800	5	1.717	1.67	1.7	0.0	25	25	9		102.08	1194.38	1.1	4	1107	
S030894 27	4/4/94 10:40 AM	4.0042	19.6481	5	1.665	1.607	1.6	0.0	26	26	8		101.98	927.59	1.0	3	1110	
S030894 28	4/5/94 10:45 AM	4.0691	20.5799	5	1.675	1.624	1.6	0.0	27	27	8		102.21	1186.31	1.1	4	1113	
S030894 29	4/6/94 8:30 AM	4.0319	19.8303	5	1.56	1.495	1.5	0.0	28	28	7		102.34	1082.64	1.1	3	1116	
S030894 30	4/7/94 9:40 AM	4.0444	20.3170	5	1.278	1.288	1.3	0.0	29	29	6		102.17	1184.47	1.0	3	1119	17.3
S030894 31	4/8/94 8:30 AM	4.0511	19.9784	5	1.369	1.296	1.3	0.0	30	30	7		100.46	1130.42	1.1	3	1122	20.1
S030894 32	4/9/94 9:18 AM	3.9952	20.4327	5	1.264	1.221	1.2	0.0	31	31	6		99.85	1204.17	1.1	3	1125	18.9
S030894 33	4/10/94 12:10 PM	4.0526	20.7205	5	1.222	1.174	1.2	0.0	32	32	6		102.07	1205.18	1.0	3	1128	18.9
S030894 34	4/11/94 10:55 AM	3.9676	20.3781	5	1.016	0.9954	1.0	0.0	33	33	5		102.74	1113.84	1.1	2	1130	18.4
S030894 35	4/12/94 11:07 AM	3.9434	20.2787	5	0.9415	0.8798	0.9	0.0	34	34	5		101.97	1181.80	1.1	2	1132	18.6
S030894 36	4/12/94 5:55 PM	4.0098	20.6151	5	0.9036	0.8625	0.9	0.0	35	35	5		41.42	346.70	1.1	1	1132	18.4
S030894 37	4/14/94 11:30 AM	4.0617	20.4670	5	1.037	0.9563	1.0	0.0	35	36	5		202.64	2033.80	1.1	4	1136	21.8
S030894 38	4/16/94 12:55 PM			#DIV/0!			#DIV/0!	#NUM!	37	37	###		199.44	2370.16	1.1	#DIV/0!	#DIV/0!	22.5
S030894 39	4/18/94 8:55 AM			#DIV/0!			#DIV/0!	#NUM!	39	39	###		204.06		-0.1	#DIV/0!	#DIV/0!	23.5
S030894 40	4/19/94 5:10 PM			#DIV/0!			#DIV/0!	#NUM!	41	41	###		203.17	1637.48	1.1	#DIV/0!	#DIV/0!	23.3
S030894 41				#DIV/0!			#DIV/0!	#NUM!	42	41	###		206.21		0.0	#DIV/0!	#DIV/0!	25

C012694 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X,
1 kg SP9(94), Heterogeneous, Agglomerated with
water

C012694 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X,
1 kg SP9(94), Heterogeneous, Agglomerated with
water

C012793 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X,
1 kg SP9(94), Heterogeneous, Agglomerated with
water

C012793 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X,
1 kg SP9(94), Heterogeneous, Agglomerated with
water

C012894 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X,
3 kg SP9(94), Heterogeneous, Agglomerated with
water

C012894 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X,
3 kg SP9(94), Heterogeneous, Agglomerated with
water

C020494 - 0.5 M Sodium-Carbonate-Bicarbonate,
0.3X, 1 kg SP9(94), Heterogeneous, Agglomerated
with water

C020494 - 0.5 M Sodium-Carbonate-Bicarbonate,
0.3X, 1 kg SP9(94), Heterogeneous, Agglomerated
with water

**C020594 - 0.5 M Sodium-Carbonate-Bicarbonate, 0.3X,
1 kg SP9(94), Heterogeneous, Agglomerated with
water**

**C020594 - 0.5 M Sodium-Carbonate-Bicarbonate, 0.3X,
1 kg SP9(94), Heterogeneous, Agglomerated with
water**

C022394 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X,
10 kg SP9(94), Heterogeneous, Agglomerated with
water

C022394 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X,
10 kg SP9(94), Heterogeneous, Agglomerated with
water

C030894 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X,
3 kg SP9(94), Heterogeneous, Agglomerated with
water

C030894 - 0.5 M Sodium-Carbonate-Bicarbonate, 1X,
3 kg SP9(94), Heterogeneous, Agglomerated with
water

Appendix B.

Papers presented at Waste Management '94

(i) Predictive Geochemical Modeling of Uranium and other Contaminants in Laboratory Columns in Relatively Oxidizing, Carbonate-Rich Conditions.

Patrick Longmire, William R.J. R. Turney, Caroline F. V. Mason, David C. Dander, and Don A. York

(ii) Carbonate Heap Leach of Uranium-Contaminated Soils.

William R.J. R. Turney, Catherine J. Chisholm-Brause, Caroline F. V. Mason, Patrick Longmire, David C. Dander, Don A. York and Bruce M. Thomson

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Appendix C.

COST STUDY OF HEAP LEACHING AND BATCH-REACTOR LEACHING (using data available for gold)

SUMMARY CONCLUSIONS:

The study was conducted on gold because heap leach data on gold are readily available whereas heap leach data on uranium are not.

The following summary conclusions were reached during this study.

- Heap leaching of gold can be performed for one-third to one-half of the cost of batch-reactor leaching of gold.
- On large-scale, gold heap-leaching operations, ore can be processed for less than \$150/cu yd and, in many cases, for less than \$100/cu yd. These costs can be expected to be one-third to one-half of the costs for gold batch-reactor leaching.
- Up to 50 tons of ore can be processed to obtain 1 oz of gold; this work must be done for less than the current price of gold (~\$370/oz), otherwise, the mining company loses money.
- When gold leaching is completed, the gold left in the depleted ore is measured in *parts per billion*. EPA regulations for allowable contamination in soil are expressed in *parts per million*. Therefore, leaching of soil for contamination removal can be terminated sooner than for leaching of gold from gold ore. Shorter leaching times should result in lower costs.

Except for exact dollar costs, these conclusions can be extrapolated to heap leach of contamination from soil.

WHAT ARE THE COSTS OF LEACHING:

The costs of heap leaching are readily available in the current-day mining literature. The following table is partially taken from the *Homestake Mining Company 1991 Annual Report* and partially calculated.

7-Mar-83

1991 COST OF HOMESTAKE MINING

MINE	TYPE OF MINE	MILLFEED	GOLD PROD	TONS ORE PROCESSED /OZ GOLD	CU YDS ORE PROCESSED PER OZ GOLD	TOTAL PROD COST	TOTAL PROD COST	RECOVERED GOLD	UNRECOVERD GOLD	ORE GRADE	UNRECOVERED GOLD IN DEPLETED ORE	
		(million tons ore)	(oz)	(tonnes/oz)	(,000 cu yds/oz)	(\$/oz Gold)	(\$/cu yd)	(%)	(%)	(oz Gold /ton Ore)	(oz gold per oz depleted ore)	Percentage
		Col. A (from HM Rpt.)	Col. B (from HM Rpt.)	C = A/B	D = C * .005	Col. E (from HM Rpt.)	F = ED	Col. G (from HM Rpt.)	H = 100-G	Col. I (from HM Rpt.)	K = $\frac{D * F * 100}{2 * \text{Depleted Ore}}$	L = K * 1000
Homestake	Underground Mine & Open Pit	2.5	319080	7.84	5.22	400	76.88	92.70	7.3	0.14	3.40E-07	346
McLaughlin	Open Pit	2.3	262719	8.75	5.83	343	88.83	91.33	8.67	0.125	3.71E-07	371
Round Mountain	Open Pit	3.9	84755	46.01	30.65	314	10.25	65.90	34.1	0.031	5.01E-07	501
Mineral Hill	Open Pit	0.1	21344	4.80	3.12	381	122.18	90.50	9.5	0.279	9.18E-07	918
Wood Gulch	Open Pit	-	-	-	-	-	-	-	-	-	-	-
H3AL-Kalgoorlie Operations	Open Pit	3.3	233160	14.15	9.43	350	37.13	88.30	11.7	0.082	3.40E-07	340
H3AL-Fortnum	Open Pit	0.5	30435	16.43	10.94	494	46.15	96.60	3.4	0.002	6.82E-08	68
El Hueso	Open Pit	3.5	65356	53.55	35.67	422	11.83	74.00	26	0.036	3.96E-07	396
Golden Bear	Open Pit	0.1	28350	3.53	2.35	389	157.87	89.00	11	0.400	1.93E-06	1927

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NOTES ON MATRIX

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1991 COST OF HOMESTAKE MINING

1. Columns A, B, E, G, and I on the matrix are taken from the *Homestake Mining Company 1991 Annual Report*.
2. Columns C, D, F, H, K, and L are calculated based upon Columns A, B, E, G, and I.
3. The TOTAL PROD COSTS (i.e., Columns E & F) are achievable only with scaleup of the leaching process to the amounts shown in MILLFEED (Column A). Smaller scale leaching can be expected to produce higher costs.
4. In all cases, the leaching process (on any heap) was halted because it was no longer profitable to continue. Further leaching was technically possible. As an example, recovery of gold at Wood Gulch was terminated in 1990 because it was no longer profitable.
5. In Column D, the ore was assumed to weigh 1.5 tons/cu yd (or .666 cu yd/ton).
6. Note that the UNRECOVERED GOLD IN DEPLETED ORE (Columns K & L) are considerably lower than the EPA limits on uranium in soil (i.e., 52 ppm or 52,000 ppb).
7. In the *Homestake Mining Company 1991 Annual Report* it is not clear if the units of *tons* are long tons (2240 lb.) or short tons (2000 lb.). Likewise, the units of *ounces* are not specifically called out as troy ounces (14.58 oz/lb) or avoirdupois (16 oz/lb) ounces. The matrix assumes short tones and avoirdupois ounces. The difference, however, is not important.

Following are two comparisons of the costs of heap leaching to the costs of batch-reactor leaching. The first comparison is a *relative cost comparison* and the second is a *quantitative cost comparison*.

RELATIVE COST COMPARISON:

TOTAL PROD COSTS (i.e., Columns E & F) on the preceding table, entitled *1991 COST OF HOMESTAKE MINING* include:

- a. exploration
- b. mine development (property purchase, roads, mill construction, overburden removal, leach pad, leachate recovery system, etc.)
- c. excavation of ore
- d. transportation of ore to mill
- e. crushing
- f. agglomeration
- g. heap stacking and sprinkler installation
- h. leaching
- i. rinsing of depleted ore
- j. recovery of gold from leachate
- k. heap and sprinkler system dismantling
- l. transportation of depleted ore back to pit
- m. restoration of site

When comparing the costs of heap leaching to the costs of batch-reactor leaching, many of the items above are common to both processes and, therefore, can be ignored in a *relative cost comparison*. That is, their costs cancel each other out. The only exceptions are the items discussed below.

leach pad -

Heap leaching requires an impermeable pad that can cover acres and be constructed of standard road building materials.

Batch-reactor leaching requires no leach pad. Instead, a reactor (large vessel for agitation) is required. To maintain high throughput, multiple reactors are required.

agglomeration -

Some ores require agglomeration before leaching. If required, the cost of agglomeration includes (1) agglomerator, (2) power, (3) water, and (4) ~6 pounds of Portland cement per ton of ore.

Batch-reactor leaching does not require agglomeration of the ore.

heap stacking and sprinkler installation -

In heap leaching, the heap is built with a retreating stacker, i.e., an inclined belt conveyor that rotates left and right and moves backward when the heap reaches the proper height.

Distribution of the leaching reagent on the top of the heap is accomplished either with sprinklers or drip irrigation equipment. The reagent distribution system has

connecting hoses and pumps. The costs here include (1) the stacker, (2) operational costs of the stacker, (3) sprinklers or drip emitters, hoses, & pumps, and (4) labor for laying and connecting the distribution system on top of the heap.

In this phase of batch-reactor leaching, the reactor loading machinery and operator are required as often as the reactor is to be loaded (approximately full time, i.e., 3 shifts/day, if throughput is to be maintained).

leaching -

In this phase of heap leaching, the only moving equipment consists of pumps and sprinklers. The cost of actual leaching includes (1) supply and sump pumps, (2) leaching reagents, (3) rinse water, and (4) power to operate the pumps. A full-time operator is not required, only someone to checkup the pumps and sprinklers (or emitters) on a daily basis. Chemical analysis of the leachate does not have to be done in real time. The end of the leaching process can be predicted days in advance, allowing for sampling and analysis at a remote laboratory.

In this phase of batch-reactor leaching, the costs consist of (1) a large agitating (rotating) vessel(s), (2) labor to operate the batch reactor(s), (3) leaching reagents, (4) rinse water, and (5) a full-time, on-site, chemical analysis system with chemist. The full-time chemical analysis system is needed to determine when the batch reactor should be emptied and recharged with new ore. Power costs for the batch-reactor system can be quite large. At least one full-time operator is required to (1) frequently sample the batch and (2) operate the equipment to maximize throughput.

The cost of leaching reagents and rinse water should be the same for both heap and batch-reactor leaching.

heap and sprinkler dismantling -

In this phase of heap leaching, the costs would include (1) labor to remove the hoses and sprinklers or emitters from the heap for future use, (2) a front-end loader, and (3) a dump truck.

In this phase of batch-reactor leaching, the reactor unloading machinery and operator are needed on approximately a full-time basis, i.e., three shifts/day. Removal of the liquid fraction from the solid fraction requires (1) a filtering system, (2) a settling pond, (3) a centrifuge, or (4) some other dewatering device. Each method of dewatering requires power.

The following is a relative comparison table of heap leaching costs vs. batch-reactor leaching costs.

COST COMPARISON

<u>ITEM DESCRIPTION</u>	<u>HEAP LEACHING</u>	<u>BATCH REACTOR LEACHING</u>
Equipment:		
leach pad	Moderate	None
agglomerator (if required)	Low	None
retreating stacker	Low	None
sprinklers/emitters and hoses	Low	None
pumps for reagent distribution	Low	None
batch reactor vessels	None	High
reactor load/unload machinery	None	Low
dewatering filter, pond, etc.	None	High
pumps for dewatering	None	Moderate
Agglomeration (if required):		
Portland cement	Low	None
labor for agglomeration	Low	None
Heap/Batch Preparation:		
heap stacking/sprinkler installation	Low	None
labor for heap/batch prep	Low	High
Leaching:		
leaching reagents	Same	Same
chemical analysis	Low	High
rinse water	Same	Same
labor for leaching	None	High
Dewatering:		
labor for dewatering	None	High
Heap/Batch Dismantling:		
labor for heap/batch dismantling	Low	High
Power:		
power for agglomerator	Low	None
power for pumps/sprinklers	Low	None
power for agitation	None	High
power for reactor pumps	None	Moderate
power for dewatering	None	High
All Other Operations:	Same	Same

QUANTITATIVE COST COMPARISON:

According to Wentz, C. A., (*Hazardous Waste Management*, McGraw-Hill, New York, 461 pages, 1989) the *capital* costs of heap leaching are 20% to 36% of the same costs for batch-reactor leaching. Also, Wentz states that the *operating* costs for heap leaching are 40% to 55 % of the same costs for batch-reactor leaching.

Low Side Comparison: for every \$1 of *capital* spent on batch-reactor leaching, only \$.20 of *capital* is spent on heap leaching. And, for every \$1 of *operating* spent on batch reactor leaching, only \$.40 of *operating* is spent on heap leaching. That is,

	<u>Capital</u>	<u>Operating</u>	<u>Total</u>	<u>Gold</u>
Batch Reactor (i.e., BRL)	1.00	1.00	2.00	X _{BRL}
Heap (i.e., HL)	\$.20	\$.40	\$.60	\$276.00*

$$\begin{array}{rcl} \frac{\$2.00_{\text{BRL}}}{\$.60_{\text{HL}}} & = & \frac{X_{\text{BRL}}}{\$276.00_{\text{HL}}} \\ X_{\text{BRL}} & = & \$920/\text{oz} \end{array}$$

* \$276 is the average total cost of heap-leach gold production per ounce by US companies in 1991.

High Side Comparison: for every \$1 of *capital* spent on batch-reactor leaching, only \$.36 of *capital* is spent on heap leaching. And, for every \$1 of *operating* spent on batch reactor leaching, only \$.55 of *operating* is spent on heap leaching. That is,

	<u>Capital</u>	<u>Operating</u>	<u>Total</u>	<u>Gold</u>
Batch Reactor (i.e., BRL)	1.00	1.00	2.00	X _{BRL}
Heap (i.e., HL)	\$.36	\$.55	\$.91	\$276.00

$$\begin{array}{rcl} \frac{\$2.00_{\text{BRL}}}{\$.91_{\text{HL}}} & = & \frac{X_{\text{BRL}}}{\$276.00_{\text{HL}}} \\ X_{\text{BRL}} & = & \$606/\text{oz} \end{array}$$

It is therefore concluded from Wentz and Homestake Mining (Ref.) that the cost of batch-reactor leaching ranges from approximately \$600 to \$900/oz of gold. This is two to three times that of heap leaching of gold (i.e., \$276/oz).

OTHER COST COMPARISON DATA:

According to *Hazmat World*, September 1991, Geochem Inc. of Lakewood, CO, evaluated a process to recover lead from contaminated soil at a former battery manufacturing plant near Melbourne, Australia. According to *Hazmat World*, the "lead concentrations were reduced in three days from more than 8000 parts per million (ppm) to 300 ppm using a modified heap leach mining method. The method will cost about \$30 per ton, one-tenth as much as transporting the contaminated soil to a secure landfill."

REFERENCES FOR COST STUDY:

1. *1991 Annual Report*, Homestake Mining Company, 650 California Street, San Francisco, CA 94108.
2. Wentz, C. A., *Hazardous Waste Management*, McGraw-Hill, New York, 461 pages, 1989.
3. *Hazmat World*, September 1991.

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