Savannah River Technology Center
Westinghouse Savannah River Company
Aiken, SC 29808

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Summary of Testing of SuperLig® 639 at the TFL Ion Exchange Facility

J. L. Steimke
M. A. Norato
T. J. Steeper
D. J. McCabe

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SUMMARY

A pilot scale facility was designed and built in the Thermal Fluids Laboratory at the Savannah River Technology Center to test ion exchange resins for removing technetium and cesium from simulated Hanford Low Activity Waste (LAW). The facility supports the design of the Hanford River Protection Project for BNFL, Inc. The pilot scale system mimics the full-length of the columns and the operational scenario of the planned ion exchange system. Purposes of the testing include confirmation of the design, evaluation of methods for process optimization and developing methods for waste volume minimization. This report documents the performance of the technetium removal resin.

The BNFL Inc. design for the plant-scale technetium ion exchange system assumes 100 bed volumes of LAW solution can be processed before the concentration of pertechnetate reaches 50% of the influent pertechnetate concentration (the so called 50% breakthrough point). Additionally, the BNFL Inc. design assumes that, on average, 80% of the total technetium can be removed from LAW solution. The ion exchange resin selected by BNFL Inc. for separating technetium from LAW solutions will only separate the pertechnetate (TcO_4^-) form of technetium.

The Hanford LAW solutions are classified by and grouped into three envelopes, A, B, and C. The pertechnetate is about 99% of the total technetium in LAW Envelope A and B solutions. However, LAW Envelope C solutions contain relatively high concentrations of chelating organic compounds (e.g., EDTA, HEDTA) and the pertechnetate is only 25 to 30% of the total technetium. Therefore in practice, the ion exchange columns will separate ~98% of the total technetium from LAW Envelope A and B solutions and only about 25 to 30% of the total technetium from LAW Envelope C solutions.

To date, SuperLig® 639 resin from IBC Advanced Technologies, Inc. has been used to remove rhenium (as perrhenate ReO_4^-), a non-radioactive surrogate for technetium (as pertechnetate), from simulated LAW. Eleven test runs with durations ranging from five to seven days were performed. Test run #2 was repeated because of hardware failures during the first attempt. A valve leaked during Test Run 1, leaving nine usable test runs. The testing has been highly successful at demonstrating the removal efficiency of perrhenate and confirming the overall design parameters. However, numerous technical problems that are unique to the pilot-scale system were encountered and addressed during the first test runs. These problems were mechanical equipment issues, such as valve failures, sampler failures, computer software conflicts, ion selective electrode calibrations, and flow rate meter drift. No significant mechanical or chemical degradation of the resin was observed during these runs.

Each test run consisted of the following steps; a LAW simulant (Simulant A designed to simulate Envelope A waste) containing sodium perrhenate was pumped through the two ion exchange columns in series, partially loading the columns with perrhenate, a 0.1 M caustic (sodium hydroxide) solution was used to displace the simulant from the lead column while the lag column was allowed to remain full of simulant, eluent (usually water) was pumped through the lead column to remove perrhenate from the resin and a 1.0 molar caustic solution was used to regenerate the lead column. For the next test the

lead and lag columns were interchanged. Note that the new lead column usually started the next test run partially loaded from the previous test run unless an additional elution was performed. Liquid samples were collected throughout each test run and subsequently analyzed.

During the loading step the first column typically removed 72% of the rhenium, the second removed 24% and the remaining 4% passed through both columns to the simulant collection tank. Loading was always conducted in downflow. The rhenium concentration in the simulant exiting the lead column was initially low and increased with time. For the loading steps, breakthough was defined as the point at which the exit rhenium concentration from the lead column was equal to 50% of the simulant rhenium concentration. The number of column volumes to reach breakthrough was correlated with the following equation, valid for rhenium loading with Simulant A at 18ºC.

$$V_{bt} = 199 - 1.56\ L - 14.5\ Q \qquad (1)$$

In Equation 1, V_{bt} is the number of bed volumes of simulant that result in breakthrough, L is the pre-loading of the column expressed as the number of bed volumes of simulant that contain as many grams of rhenium as was initially on the lead column and Q is the simulant flowrate expressed in BV/hr. Each resin bed occupies a volume of 1.2 liters. For one test the nominal feed concentration of rhenium was changed from 12.8 mg/L to 6.0 mg/L. This change made no difference in the normalized loading curves for the two columns indicating that adsorption occurred over a linear portion of the adsorption isotherm.

The loading step was followed by displacement of simulant and then elution. Most of the runs were eluted in downflow, however test runs 7 through 10 were conducted in upflow. For approximately the first five bed volumes of eluate exiting the lead column, the concentration of rhenium increased with time. Thereafter, the concentration of rhenium in the eluate decreased in a semi-logarithmic fashion. Also, the mass of rhenium remaining on the column during elution decreased in a semi-logarithmic fashion. For eluent at a temperature of 18ºC, typically 12 BV of eluent were required to decrease the remaining rhenium on the resin by a factor of ten. For eluent at a temperature of 55ºC, 4.7 BV of eluent were required to decrease the remaining rhenium on the resin by a factor of ten. Also, warming the eluent from 18ºC to 55ºC reduced the required amount of eluent to extract 99% of the rhenium by a factor of two. The direction of flow, upflow or downflow, made no noticeable difference in the elution profiles.

During each run different fluids were pumped sequentially through the columns. Assuming plug flow through the columns, it should have required a time equal to the column liquid volume (CLV = 2.0 liters) divided by the liquid flowrate for the boundary between the different process fluids to reach the outlet of the columns. Observation of the output of conductivity probes showed that the conductivity began to change at the time predicted assuming plug flow. However, the conductivity continued to change for additional time. The difference is attributed to mixing effects in the column; axial mixing or dispersion, interstitial mixing and resin pore mixing. For downflow, and the transitions from simulant to 0.1 M NaOH and from 0.1 M NaOH to water, the total amount of liquid necessary to complete the transition was 2.3 CLV instead of the plug flow assumption of 1.0 CLV. For the upflow transition from water to 1.0 M NaOH, the total amount of liquid necessary was 1.35 CLV instead of 1.0 CLV.

INTRODUCTION

As part of the Hanford River Protection Program, BNFL Inc. has contracted to treat LAW and High Level Waste from underground storage tanks at the Hanford Site in Washington[1]. After solids are removed from the LAW, the LAW will be passed through ion exchange columns to remove cesium and technetium (in the form of pertechnetate). The LAW will be vitrified and stored at the Hanford Site. The cesium and technetium eluted from the ion exchange columns will be mixed with tank sludge, vitrified as High Level Waste, and eventually stored at a federal repository. Once loaded, the ion exchange resins will be eluted to remove the ions and then the resin will be regenerated. BNFL, Inc. subcontracted with SRTC to perform pilot scale tests of the two ion exchange processes using a simulated LAW having a high concentration of sodium. The primary activities of this task are to: (1) design and construct a pilot scale ion exchange test facility; (2) perform ion absorption, elution, and regeneration with two different ion exchange resins; (3) measure pressure drop across the resin bed; (4) measure swelling or contraction of the bed; and (5) optimize the process by minimizing chemical additions. The major objectives of the task are to collect data that could allow improvements to the BNFL flow sheet and establishment of plant operating conditions. [2][3][4]

EXPERIMENTAL

Description of Hardware

The test facility is shown in Figure 1 and is documented in Drawing EES-22696-M6-001. The ion exchange resin is contained in two columns hydraulically connected in series. Each column has an inside diameter of 1.01” (25.7 mm), a total length of 15’ 1.6” (4.61 m), and an approximate swelled resin height of 7’ 6” (2.30 m). Therefore, the top half of the column contained only liquid. The total length and the swelled resin height were chosen to duplicate the design of the full-scale facility. The presence of the large liquid filled space affects the transition between different process fluids. For downflow, a transition from a more dense fluid such as simulant to a less dense fluid such as water is expected to produce a sharp transition zone that moves down the top half of the column. The transition from less dense fluid to more dense fluid is expected to produce a wide transition zone as fingers on the dense fluid fall through the less dense fluid.

The inside diameter of the columns was chosen to satisfy the criterion given by Helfferich [5] that the diameter of an ion exchange column be at least 30 times as large as the average resin particle diameter (0.03” or 0.75 mm for SuperLig® 639) to eliminate any significant bypass flow at the wall. The transparent columns are double walled for safety. The inner tube is transparent PVC, which has good chemical resistance to the simulant and other liquids involved in the tests. The outer wall is glass, which has excellent transparency, is only used to contain the resin and simulant in the event of leakage of the PVC tube.

The liquid pump for the facility is an FMI Labpump model QV piston pump for which the stroke length is manually adjustable and the frequency may be controlled an by external current signal. It had been anticipated that the pump would act as a positive displacement pump. However, prior to testing it was observed that its flowrate depended on pressure. Therefore, the pumping rate was controlled by the system computer using feedback from the flow meter. The control computer compared the flow set point that it had been provided with the measured flow and calculated the required magnitude of the control signal. The computer generated this control signal, which was sent to the pump controller.

Simulant was stored in a 55 gallon fiberglass tank that had a tight, but not sealed, lid. An in-line cartridge filter was used to remove insoluble solids. Simulant was collected in a plastic 55 gallon drum that rested on a 1000 lb. scale. Other liquids were contained in 15 and 50 liter polyethylene carboys. Liquids entered and left tanks or carboys via polyethylene tubes that passed through slightly oversize holes in the lids that allowed gas venting. All other connections in the facility were made with ¼" o.d. stainless steel tubing. Pressure relief valves set at 50 psig were connected to the tops of both columns.

The piping for the facility included thirty five diaphragm type solenoid valves that were controlled by the computer and fourteen manual valves. By opening and closing the appropriate valves, either the left hand column (#1) or the right hand column (#2) could be the lead column and flow could be either upward or downward in the columns. Liquid flowing out of the lead column can be directed through the lag column or directly to the collection tanks. For most of the steps in the process, flow was downward in both columns. However, for the resin post-elution rinsing and regeneration steps, the direction of flow was upward. It was discovered that the solenoid valves occasionally leak. Therefore, after Run #2, every solenoid valve was checked for leaks before every run. After Run #2R the seat on solenoid valve 11 was found to be badly corroded. A metallurgical evaluation determined that the solenoid valves were made of 304 stainless steel, although the vendor had advertised them as 316 stainless steel. Corrosion was attributed to the fact that the position of the valve in the piping allowed it to repeatedly wet with caustic solution and then dry, forming very concentrated solutions. Drying is possible even though the facility piping is not open to the atmosphere because some sections have air pockets. Air pockets result from the fact there is insufficient liquid flow to purge the air. No other valves were affected.

Liquid samples having a volume of 5 mL were collected using a Sampling Systems automatic sampler. As many as forty empty sample vials were placed in a carousel. The sampler collected a sample each time that it received a signal from the control computer. An intermittent failure to advance the sampler carousel during Run 2R caused two samples to mix together on four occasions. The problem was finally determined to be a software error in the controller that was supplied as an integral part of the sampler. The sampler worked well after the vendor corrected the error.

System instrumentation is listed in the following table. Note that everything except one rotameter (item #3) had an electronic output that was connected to the data acquisition system (DAS).

Instruments

1. Krohne type DK 37E rotameter flowmeter
2. two McMillan model 111 paddle wheel type flowmeters
3. rotameter flowmeter with no electronic readout, manual readout only
4. thermocouples located near the liquid sampler and in effluent line from lag column
5. Rosemount model 1144 pressure transducer P1 at top of left column (column #1)
6. Rosemount model 1144 pressure transducer P2 at top of right column (column #2)
7. Rosemount model 1144 pressure transducer P3 downstream of pump and upstream of inlet filter
8. Rosemount model 1144 pressure transducer P4 at bottom of left column (column #1)
9. Rosemount model 1144 pressure transducer P5 at bottom of right column (column #2)
10. 1000 lb. capacity scale
11. conductivity probes located near the liquid sampler and in effluent line from lag column
12. pH probe
13. nitrate ion-selective electrode probe

The nitrate, pH and conductivity probes were calibrated before every run using standard solutions. The pressure transducers were calibrated at the start and end of the testing. In addition, zero-flow readings were recorded for the pressure transducers at the start of each run to determine if any of the transducer readings was drifting. The two thermocouples were calibrated at the start and end of testing. The McMillan flowmeters and the manual rotameter were calibrated at the start of testing, but were not used for long and were not calibrated at the end of testing. The 1000 lb. scale is calibrated with an annual frequency. The calibration of the Krohne flowmeter was checked during each run by calculating the rate of change of mass of the simulant collection tank, as measured using the 1000 lb. scale, and dividing by the measured simulant density. Fluid densities were measured once per run by weighing a 100 mL volumetric flask both empty and filled to the mark.

The simulant seems to have an adhesive quality based on the following observations.
1. With water or caustic solution all three types of flowmeter operated well with no noticeable drift or hysteresis.
2. With simulant, the floats in both rotameters (instruments 1 and 3 in above list) had a tendency to stick to the inside of the rotameter tube. Tapping readily freed the float, so a mechanical vibrator was attached to the flowmeter.
3. With simulant, the calibration of the paddle wheel type flowmeters tended to shift.
Because of concerns about the flowmeters when used with simulant, the output of the scale under the simulant collection drum was monitored. Also, all supply jugs and collection jugs were weighed both before and after each run.

The McMillan flowmeters were connected in parallel because the individual flowmeters did not have sufficient range. Because of the observed drift with the McMillan flowmeters, a Krohne rotameter type flowmeter was installed in series with the McMillan flowmeters after the end of Run #2R (repeat). The Krohne flowmeter has significantly different calibrations for different fluids, primarily because of viscosity differences. Calibrations were performed with different fluids and the control spreadsheet was instructed which calibration equation to use for each step of the process.

Control Computer

A Dell Optiplex GXIP computer using LabView Version 5.1 software was used to control the tests and to display and record experimental data. The inputs to the computer were the outputs from the thirteen instruments listed above. The outputs from the computer were 110 volt signals to the thirty five solenoid valves and a current signal (4-20 mA) to the pump controller. The LabView program read a test file, which contained instructions for the duration of each step in the run, which valves were to be open for that step, the flowrate for that step, which flow calibration curve was to used and the initial delay and time interval between collection of samples.

Probes

Nitrate, pH and conductivity probes were installed in the facility. The commercially obtained conductivity probe was not adequate so conductivity probes were fabricated in the laboratory. The in-house conductivity probe worked well and data from them appear as Figures 29 through 32 later in this report. The pH probe did not function correctly with the original pH controller, so the controller was replaced. The nitrate probe demonstrated significant drift for all runs. Unfortunately, the data collected from the pH probe and the nitrate probe do not appear to be usable because of instrument drift.

Safety

Testing follows a written procedure [6]. The primary safety hazards were the high and low pH solutions, which could cause serious tissue damage. There are spill detectors located on the floor of the catch basin and in the jug that catches overflow from the pressure relief valves. The spill detector shuts down the pump when a spill is detected. Also, the computer shuts down the pump when any of the pressure gages exceeds 45 psig. During testing there were shutdowns for both spills and high pressure. A spill occurred when a receiving jug was inadvertently overfilled. High pressure occurred when a solenoid valve became plugged or failed to open on demand. The computer alarms but takes no other action when any pressure exceeds 35 psig. Personnel wear safety glasses, face shield, plastic apron, safety shoes and rubber gloves whenever handling simulant, caustic solutions or acid solutions. The resin columns are double walled. Nearly all of the tubing containing liquids under pressure is stainless steel.

Facility Shakedown

To perform facility shakedown, different colored water was put into each of the supply jugs. The control computer was programmed to configure the actual flows of the process, but with abbreviated durations for the steps. Visual confirmation was made that the correct color liquid was flowing in the appropriate column in the appropriate direction, upflow or downflow. During the facility shakedown a valve inadvertently closed because of a bad electrical connection at the valve. This closure deadheaded the pump and the resulting pressure increase caused the pressure relief valves to open. Flow was diverted to a collection jug located outside the laboratory building, as designed. This verified that the pressure relief system was operating correctly.

Properties of Solutions
Hanford Envelope A waste from Tank 241-AN-105 was simulated using the formulation listed in Table 1. Ionic constituents for that formulation are also listed in Table 1. The concentrations were 5.0 M [Na^+] and a nominal 12.8 mg/L of rhenium for all tests with the exception of Test Run 10, for which the rhenium concentration was a nominal 6.0 mg/L. Nominal means calculated based on the simulant formulation as opposed to measured analytically after the fact. The measured density and viscosity for the simulant at 20º C and 5.0 M [Na^+] are 1.225 g/mL and 2.94 cp, respectively. The measured densities for 0.1 molar NaOH solution, 1.0 molar NaOH solution and 0.5 molar nitric acid solution were 0.997, 1.023 and 1.017 g/mL, respectively. The CRC Handbook lists the viscosity for 0.1 molar NaOH at 20º C as 1.02 cp as compared with 1.0 cp for water. Densities were measured by weighing a 100 mL volumetric flask, both empty and full. Simulant viscosity was measured using Cannon Fenske viscometers.

Pretreatment and Loading of SL-639 Resin into IX Columns:
SuperLig® 639 resin came from two batches, 640.57 g (1.3 L dry) from batch 981015DHC720011 and 624.0 g (1.3 L dry) from batch 990420DHC720067. King [7] discusses the physical properties, batch contact, and smaller scale simulant column tests that were conducted with this mixture of SuperLig® 639 resin. These batches of resin were mixed dry and as-received. The dry resin exhibited a tendency to cling to the walls of the polypropylene bottle, presumably due to electrostatic forces. The resin was soaked in deionized water for one hour. The deionized water was decanted from the resin and replaced with 1 M NaOH, and the resin-caustic mixture was intermittently mixed over a 2-hour period.

The top retaining screen and valve assemblies were removed from each of the two ion exchange columns and replaced with 8” diameter funnels. A bottle containing resin-caustic mixture was manually agitated while the slurry was poured into the columns, dividing the resin approximately evenly between the two columns. This was done by visually observing the amount of resin in each column during loading. Significant bridging occurred during loading which dissipated as more slurry was introduced. Once loaded into the columns, the resin was allowed to settle under gravity overnight. The following morning, the height of the resin bed in each column was measured. The heights were found to be 90.75” (230.5 cm) in Column #1 and 90.5” (229.9 cm) in Column #2.

Retaining screens and valve assemblies were installed on both columns. Then, the resin bed in Column #1 was backflushed with 1 M NaOH at a flow rate of 2 L/hr. The resin was quasi-fluidized as large air bubbles worked their way through the resin bed. Bubbles were caused by air trapped in the feed lines, and their size was comparable to the 1” column diameter. As the large bubbles moved up the column, they tended to pack the resin above them into plugs. The resin below the plugs tended to settle into definable beds, but were not tightly packed as motion of individual particles in the bed was observed.

The large bubbles carried the resin plugs to the top of the column and packed the uppermost plug against the screen. Liquid channeled around the air bubbles, through the resin, and out of the screen. At this time, the flow of caustic was switched to downflow at 2 L/hr, which caused some of the uppermost resin plug to flow downward. All resin plugs showed some signs of breaking up as the air bubbles worked their way out of the resin and up the column. Alternating upflow and downflow allowed for removal of all air bubbles in the column. The same alternating flow procedure was then used to remove trapped air from Column #2.

Experience showed that the resin was repacked most easily by beginning with upflow at a moderate flow rate (approximately 2 L/hr), and then increasing the flow to about 6 L/hr. When the resin plug begins to pack against the top screen, the flow should immediately be switched to downflow at approximately the same flow rate until the resin packs at the bottom of the column. This procedure should be repeated until all air is removed. The final step is downflow to pack the resin bed in the lower section of the column.

RESULTS AND DISCUSSION

Pressure Drop Measurements

Pressure drop was measured for both columns for a range of flows and for both 0.1 molar caustic solution and simulant. Note that 0.1 molar caustic solution has a density and viscosity close to that of water. Results for downflow pressure drop measurements with dilute caustic and 5.0 M Na simulant are shown in Figure 2. As was expected, pressure drops are nearly the same for the two columns and are linear functions of liquid superficial velocity consistent with Darcy Flow through a packed bed. Superficial velocity is defined as the volumetric flow divided by the cross sectional area of the tube that holds the resin. The measured pressure drop for the simulant is higher than for the 0.1 molar caustic solution because simulant is more viscous. The permeability, K, of a packed bed is defined by equation 2.

$$K = \frac{U\,\mu\,\Delta z}{\Delta P} \qquad (2)$$

U = liquid superficial velocity, volumetric flowrate divided by cross sectional area of the column
μ = liquid viscosity
Δz = resin height
ΔP = pressure drop

For all flowrates and both fluids the permeability was 5.2×10^{-6} cm^2 ±10%.

Tests were run with the columns in upflow to characterize fluidization. Results for runs with 0.1 molar caustic are shown in Figure 3. The resin bed expands with increasing flow and the height of the resin bed is proportional to liquid superficial velocity. When the upflow test was run with 1.0 molar caustic the bed was fluidized at a flow of 19 cm/min but the resin was not uniformly dispersed so that the resin concentration was visibly greater near the bottom of the column. The upflow test was also run with simulant. At the lowest measurable superficial velocity of 1.6 cm/min, all of the resin was pressed against the upper screen. Therefore, it appears to be relatively easy to fluidize resin with simulant due to the similarity of densities of the liquid and resin. In some runs resin floated when there was downflow or no flow. Details are given in the section "Observations on Individual Rhenium Runs".

Sequence of Individual Test Runs

Prior to a test run, the used simulant from the previous test was analyzed for rhenium concentration. This analytical result was used to reconstitute the rhenium concentration to the desired amount, usually 12.8 mg/L. Solutions of caustic and nitric acid (for Runs 1 and 2 only) were prepared, placed in jugs and weighed. Control instructions for the DAS were prepared and input to the DAS. These instructions specified what valves would be open for every step in the process, the duration of the step, what flowrate would be used and what flowmeter calibration curve would be used. Paper filters were weighed and placed in the lines leading from the column outlet to the various collection jugs. The filter papers were used to collect any resin fragments that passed through the column screens or precipitates that formed in the test solutions.

Listed below are the steps in a typical test run.

a. Pump simulant through the lead and lag columns in series.

b. Pump 0.1 M NaOH through the lead column to displace the simulant from the resin without causing solids to precipitate.

c. Pump deionized water through the lead column to displace the 0.1 M NaOH and then to elute the resin.

d. For the first two runs the previous step was divided into three steps; displacement with deionized water, elution with 0.5 M nitric acid solution and displacement with deionized water.

d. Pump 1.0 M NaOH through the lead column in upflow to regenerate the resin.

e. At the conclusion of the run the lead column contained 1.0 M NaOH and the lag column contained simulant.

Table 2 below summarizes the test variables.

Table 2 Test Matrix

Run #	Lead column #	Simulant displace. (BV)	Water displace. (BV)	Eluent and regen. rate (BV/hr)	Eluent volume (BV)	Sim. and displace-ment rate (BV/hr)
3	1	3.3	3.3	1.0	32	3.0
2R	2	3.3	1.7	1.1	45	1.8
4	1	3.3	3.3	1.3	26	1.8
5	2	3.3	3.3	1.1	38	2.6

5 IE	1	0	0	1.1	47	0.
6	1	3.3	0	1.1	38	1.8
7	2	3.3	3.3	1.1	42	2.7
8	1	3.3	1.7	1.1	43	1.7
8 IE	2	0	0	1.1	25	0
9	1	3.3	0	1.1	47	3.3
9 IE	1	0	0	1.1	49	0
10	1	3.3	0	1.1	39	3.3

Bed Volume (BV) (1.2 liters) is defined as the height of the packed resin column multiplied by its cross sectional area. The Column Liquid Volume (CLV) (2.0 liters) is the total liquid volume consisting of the volume of liquid over the top of the resin plus the volume of liquid between resin particles plus the volume of liquid in the pores of the resin particles. In Runs 1 and 2 the elution step was conducted with 0.5 molar nitric acid. However, bench scale test results indicated that water (pH = 7) was the preferred eluent. Therefore, water was used for all subsequent elutions, the eluent flowrate was adjusted to 1.0 BV/hr, and the duration of elution was increased beyond the volume specified in the test plan to remove more rhenium from the resin. The "Lead Column #" refers to which column was in the lead position for the test, as the design plan is to only elute the lead column and place it in the lag position when the pair of columns return to service.

Solids Collected on Filters

Each of the collection tank inlet tubing was equipped with a filter to remove particulates. Particulates could be broken pieces of resin or precipitation products. Table 3 lists the amount of dried solids collected on each filter for Runs 1 through 6. Filters were not used for Runs 7 through 10. At the end of a run the filters were removed from their holders, air-dried and then placed in an oven at 80°C for one hour. Note that the greatest mass of solids collected for any run was 0.26 grams. The masses of solids on the filters were small compared with the more than 1 kg of resin held by the columns. The solids were light tan in color and the filter paper had the appearance of fine sandpaper.

Chemical Analyses

The carousel sampler was used to collect liquid samples. In addition, samples were manually collected from the effluent of the lag resin column, from the simulant tank prior to each run and from each collection tank after the run. Tanks were stirred prior to collecting samples. Samples were analyzed by the Analytical Development Section (ADS) of SRTC. Results will be discussed in sections that follow. Tables 4 through 12 are Excel spreadsheets containing the results of the chemical analyses for each test run. Analyses listing concentrations for more than a dozen elements were Inductively Coupled Plasma Emission Spectroscopy (ICP-ES). Analyses listing only rhenium concentrations were Inductively Coupled Plasma Mass Spectroscopy (ICP-MS). Detection limits may be inferred whenever a result is listed as less than some number, e.g. <0.7. ADS typically claims an accuracy of ±5% although some analyses appear to be less accurate, based on the following table. The first eleven lines of the table are a comparison of rhenium feed concentration based on the measured mass of sodium perrhenate added to the known volume of simulant and ADS analyses by ICP-ES. The units are mg/L and the number of significant digits is as reported by ADS. Discrepancies are as large as 24%. The last two lines are a comparison of the analysis of the same samples of spent simulant by ICP-ES and ICP-MS. The largest discrepancy between the two methods was also 24%.

Run	formula	ICP-ES 1	ICP-ES 2	ICP-MS 1	ICP-MS 2
1	13.6	13.2	13.3		
2	12.8	10	10		
3	12.8	11	11		
2R	12.8	9.8	10.1		
4	12.8	11.4	11.7		
5	12.8	12	12		
6	12.8	11.5	11.4		
7	12.8	11.4	11.7		
8	12.8	12.7	12.8		
9	12.8	11.2	11.0		
10	6.0	5.0	5.2		
1		3.54	4.46	3.99	3.87
2		2.5	2.6	3.06	3.42

Samples collected with the sampler have sample numbers of the form Re-4-12, meaning this was the twelfth sample collected downstream of the lead column with the sampler during Rhenium Run 4. Here are some abbreviations used in Tables 4 through 12.

lag	sample of simulant collected after the lag column
efcmp	sample of the mixed (composite) simulant that was run through both columns
fdcmp	sample of the mixed simulant before the run was started
elucmp	sample of the mixed eluate
reg	sample of the mixed regeneration solution
fddsp	sample of the mixed 0.1 M NaOH displacement solution
wtrdsp	sample of the mixed water displacement solution

Mass Balances

Data from the chemical analyses and flows were used to prepare Table 13, which contains mass balances as well as other information. The columns of data are described below.

1	Run	the run number
2	simulant pumped	pounds of simulant pumped
3	simulant density	measured density
4	Re conc in feed	rhenium concentration in feed based on analysis
5	mass Re in feed	calculated from columns 2, 3 and 4
6	Re conc spent	rhenium concentration in simulant that flowed through both columns
7	mass Re spent	calculated from columns 2, 3, and 6
8	eluate vol 1	the volume of eluate in the first eluate collection jug

9	eluate vol 2	the volume of eluate in the second eluate collection jug
10	elucmp1	mixed rhenium concentration in the first eluate jug
11	elucmp2	mixed rhenium concentration in second eluate jug
12	vol reg	volume of regeneration solution collected
13	Re reg	concentration of rhenium in regeneration solution
14	vol fddsp	volume of 0.1 M NaOH solution
15	Re fddsp	concentration of previous solution
16	lead column	
17	mass Re in feed	same as column 5
18	mass Re spent sim.	same as column 6
19	integral mass exiting lead	graphical integration of plot of Re concentration exiting lead column during loading vs. BV
20	integral mass exiting lag	graphical integration of plot of Re concentration exiting lag column during loading vs. BV
21	lead col. elution, Simpson	numerical integration using Simpson's Rule of Re concentration exiting lead column during elution vs. BV
22	lead col. elution, Trapezoid	numerical integration using Trapezoidal Rule of Re concentration exiting lead column during elution vs. BV
23	mass elucmp	mass of Re in the mixed eluate calculated from columns 8 through 11
24	mass added to lead	column 17 minus column 19
25	mass added to lag	column 19 minus column 20
26	breakthrough	number of BV to simulant Re concentration exiting lead column to equal 50% of feed concentration
27	simulant flowrate	
28	eluent flowrate	
29	mass fraction on lead	column 24 divided by column 17
30	mass fraction on lag	column 25 divided by column 17
31	mass fraction	column 20 divided by column 17
32	final lead concentration normal	final Re concentration in simulant during loading of lead column divided by feed Re concentration
33	final lag concentration normal	final Re concentration in simulant during loading of lag column divided by feed Re concentration
34	parameter x axis	x axis of Figure 13
35	preloading of lead	column 25 for previous run, zero when lag column was eluted prior to run
36	preloading of lead	column 36 expressed as equivalent BV of feed
37	decontamination factor	reciprocal of column 31

Column Loading Results

Breakthrough data for rhenium loading are plotted in Figures 4 through 12. The rhenium concentrations in the column effluent samples were measured and normalized by dividing by the rhenium concentration of the simulant pumped to the lead column. For consistency both the numerator and denominator were measured by ADS using ICP-ES. The abscissa is cumulative bed volumes of simulant. The rhenium concentration exiting the columns starts low and increases with time. Naturally, rhenium concentrations exiting the lag column are much lower than for the lead column. Simpson's Rule was used to numerically integrate the mass of rhenium exiting both the lead and lag columns for each test run. Simpson's Rule for numerical integration for pairs of x and y values and a fixed value of delta x is expressed as the following equation.

$$\int y \ dx = \frac{\Delta x}{3} \sum y_1 + 4y_2 + 2y_3 + 4y_4 + 2y_5 + ... + y_n \qquad (3)$$

The results are listed in Table 13, which contains mass balance information. The simulant feed concentrations of rhenium listed in the table were those measured by ADS rather than based on the formulation of the simulant. For each loading plot, breakthough was defined as the point at which the exit rhenium concentration from the lead column was equal to 50% of the simulant rhenium concentration. The number of bed volumes of simulant to reach breakthrough was determined graphically. The number of bed volumes for breakthrough was expected to decrease with both increased rhenium pre-loading of the lead column and increased simulant flowrate. Pre-loading occurred because the lead column was previously the lag column and for most of the test runs the lag column was not eluted. As a method of evaluating the consistency of the experimental results, the number of bed volumes for breakthrough was correlated with pre-loading and simulant flowrate using the following equation, valid for rhenium loading from Simulant A at 18ºC.

$$V_{bt} = 199 - 1.56 \text{ L} - 14.5 \text{ Q} \qquad (4)$$

In equation 4, V_{bt} is the number of bed volumes of simulant that result in 50 % breakthrough, L is the pre-loading of the column expressed as the number of bed volumes of simulant that contain as much rhenium as was initially on the lead column and Q is the simulant flowrate expressed in BV/hr. The data and the correlation are plotted in Figure 13. The data for Test Run 3 were not used in the correlation because the pre-loading for Run 3 was not well known. Equation 4 is not appropriate for predicting the absorption of technetium from actual radioactive waste.

Column Elution Results

Data from eluate samples are plotted in Figures 14 through 25. The rhenium concentration in the column effluent samples was measured and normalized by dividing by the rhenium concentration of the simulant pumped to the lead column. The concentration of rhenium in the eluate initially increases for roughly 5 BV, then decreases in a semi-logarithmic fashion. After Runs 5, 8 and 9 special elutions were performed so that both columns would be nearly free of rhenium for the start of Runs 6, 9 and 10. These special elutions were called Runs 5 IE, 8 IE and 9 IE. Elution profiles for the special elutions are also included. For Run 9, Figure 23, the concentration of aluminum is also plotted for comparison. Unlike rhenium, aluminum is not chemically bound to the SL-639 and so it washed quickly off the resin.

For one of the test runs, Run 8, the eluent was at an average temperature of 55ºC rather than the usual 18ºC. Figure 26 shows that estimated temperature profile in the lead column for Run 8. The computed profile took into account temperature measurements at the bottom and top of the column. The temperature decreases because of heat losses. Figure 27 is a comparison of the rhenium concentrations during elution for Run 8 at an average 55ºC and Run 5 at 18ºC. At the higher temperature the initial rhenium concentrations are larger but then decrease faster. Figure 28 shows the mass of rhenium left on the lead column during elution for Runs 5 and 8. The masses were calculated by using Simpson's Rule to integrate the mass of rhenium removed during elution. (The calculations are based on the composition of the eluent, and not on direct analysis of resin. If rhenium remains on the resin, this technique would not identify it. Other work with technetium on SuperLig® 639 shows that this is valid [8]). To achieve a factor of ten reduction in the mass of rhenium remaining on the resin at 18ºC required about 12 BV of eluent. Increasing the average eluent temperature to 55º C decreased the required amount of eluent to about 5 BV. Therefore, warming the eluent appears to be desirable.

Elutions were performed in both upflow and downflow. Inspection of the elution profiles did not show a significant difference between the downflow profiles (Runs 3 – 6) and the upflow profiles (Runs 7 – 10).

Feed Displacement and Regeneration Steps

Composite samples were collected for the feed displacement with 0.1 molar caustic and regeneration with 1.0 molar caustic. Table 13, the Mass Balances, shows the mass of rhenium in these samples. The maximum amounts of rhenium in the displacement solution and in the regeneration solution were 30 mg and 4 mg, respectively. These are small masses compared to the 1.8 to 2.5 grams of rhenium in the feed for these test runs. The 3.3 BV of 0.1 M NaOH solution appears to adequately displace the feed solution, as evident by the 100 to 1000-fold reduction of feed components (e.g., Al) in the displacement solution and the first eluate samples. The flow rate at which the 0.1 M NaOH solution was transferred through the column does not seem to affect the displacement of feed, at the two superficial velocities studied. The 1.0 M NaOH regeneration solution also appears to be adequate for conditioning the column before introduction of feed to prevent aluminum precipitation.

Conductivity Probe Results

Conductivity probes were placed in the piping downstream of the two ion exchange columns. These were useful in showing the progress of the different fluids through the columns and piping. For example, simulant, 0.1 molar caustic and deionized water have conductivities of roughly 100, 50 and 1 mS/cm (millisiemens per centimeter), respectively. The conductivity probes have a limitation for tracking different solutions because conductivity is a function of temperature as well as concentration.

Figures 29 through 32 show the output of the conductivity probe at the outlet of the lead column during Runs 9 and 10. The response of the conductivity probe was nearly the same in those two runs as will be discussed. The figures also plot a square wave to identify the fluids being pumped to the inlet of the lead column at different times. For Figures 29 and 30 there is a transition from simulant to 0.1 M NaOH and a subsequent transition to deionized water. For both transitions the flow is in downflow and a less dense liquid is being pumped on top of a more dense liquid. Therefore, the interface between liquids is expected to remain stratified. The caustic solution was being pumped at about 4.5 L/hr and the liquid volume of the lead column was 2 liters so using an assumption of plug flow the caustic solution was expected to penetrate the column 0.44 hours after first being pumped in. Those plug flow penetration times are marked on the figures. At those times in Figures 29 and 30 the conductivity actually initially increased. This was the result of a temperature (TC1) increase at that time as shown in the graph. The temperature increase most likely represents the heat of mixing of simulant and dilute caustic. According to the International Critical Tables conductivity typically increases 3% for every °C. The temperature increased by 2° C and the conductivity increased by 6% so the observations are consistent. The conductivity then decreased, but a total of about 2.2 CLV dilute caustic flow were required to reduce the conductivity to about 55 millisiemens per cm (mS/cm) instead of the plug flow requirement of 1.0 CLV.

Figures 29 and 30 also show the transition to water flow. The plug flow time for deionized water to reach the conductivity probe was also marked. There was a decrease in conductivity at that time but a total of 2.4 CLV of water flow was required to reduce the conductivity to less than 5 mS/cm rather than the plug flow prediction of 1.0 CLV. The additional flow required is attributed to mixing effects in the column; axial mixing (dispersion), interstitial mixing and pore mixing.

Figures 31 and 32 show the transition from water to 1.0 M NaOH for Runs 9 and 10. Upflow was used for the caustic solution so that more dense liquid was being pumped under less dense liquid. Therefore, the interface between liquids is expected to remain stratified. The transition was completed when 1.35 CLV of caustic solution was pumped instead of the plug flow prediction of 1.0 CLV. It is not known why this transition required less liquid than the two previous transitions.

Observations on Individual Rhenium Runs

The runs are listed in the order in which they were performed. Unique events, features or observations are highlighted.

Rhenium Run #1

A layer of resin 8.5” thick was observed to be floating in Column 1 during the loading phase. During Run #1, solenoid valve #12 leaked, allowing some of the simulant to bypass both resin columns and flow directly into the simulant recovery tank. The exact flow rate profile through the column could not be re-created, so the Run 1 data were not included.

Observations on Rhenium Run #2

A layer of resin 0.4” thick was observed to be floating in column 1 during the loading phase. A solenoid valve leaked allowing simulant from the feed tank to bypass the lead column (#2). Therefore, many samples contained a mixture of feed simulant and ion exchange column effluent. Since there is no way to recreate accurate flow rate information, the test results were invalid. Both columns were backflushed, resettled, and eluted at the conclusion of the cycle. The elution step may not have used sufficient eluent to remove all of the rhenium.

Observations on Rhenium Run #3
The simulant recovery tank was placed on a scale to permit flow rate determination. On the second day, the loading cycle was briefly stopped for less than 30 minutes to perform software changes. Each column initially had 7” of floating resin at the top.

Observations on Rhenium Run #2R
Floating resin was mentioned in the lab book but the amount was not listed. Additional simulant, 35 liters was prepared and added to the simulant feed tank. A diffuse quantity of suspended resin was observed at mid-height of column #1 (lag). A quantity of resin 3” thick was floating at the top of column #2 (lead).

Observations on Rhenium Run 4
A layer of resin 14” thick was observed to be floating in column 1 during the loading phase. When water displacement was to begin a valve did not open and the run had to be restarted. Run 4 had an intentionally short elution.

The lead column for Run 4 was the lead column during Run 3 and the lag column during Run 2R. During Run 3, the lead column was only partially eluted with the Re concentration in the eluate ~6% of the feed concentration. This column subsequently served as the lag column during run 2R, where additional Re was loaded onto this column. For Run 4, the effect of using this partially loaded column as the lead column was seen almost immediately. The Re concentration in the first sample of effluent from the lead column was ~11.6% of the feed concentration, due to the column being partially loaded. The 50% Re breakthrough occurred after processing only ~110 BV, which is less simulant solution than processed in all other runs, except Run 5.

Observations on Rhenium Run 5
A layer of resin 1” thick was observed to be floating in column 1 during the loading phase. No floating resin was observed in subsequent tests. Run 5 also experienced similar early rhenium breakthrough due to using the partially loaded lag column from Run 4 as the lead column during Run 5. The Re concentration in the effluent from the lag column during Run 4 reached ~17% of the feed concentration at the end of the loading cycle. When this column was used as the lead column during Run 5, the Re concentration in the column effluent is approximately the same concentration as that at the ending concentration during Run 4.

Observations on Rhenium Run 6
A special elution was conducted after Run 5 to ensure the lead and columns were fairly free of rhenium before starting Run 6. Solids accumulated in the filter downstream of the pump during the loading phase causing a high pressure trip at night. Ten hours later the filter was cleaned and the run was resumed. During the run the decision was made to

increase the volume of eluent from 10 BV to 40 BV. At the conclusion of Run 6 corrosion of the feed tank was noted. Apparently, some of the epoxy coating flaked off allowing the caustic simulant to attack the fiberglass. These solids probably caused fouling of the filter.

Observations on Rhenium Run 7

A valve leaked causing 30 liters of simulant to flow from the lag column into another test loop rather than the simulant recovery tank. The flow of simulant was stopped for 30 minutes to correct the problem.

Observations on Rhenium Run 8

Run 8 experienced early 50% rhenium breakthrough due to using the partially loaded lag column from Run 7 as the lead column during Run 8. The Re concentration in the effluent from the lag column during Run 7 reached ~10% of the feed concentration at the end of the loading cycle. When this column was used as the lead column during Run 8, the Re concentration in the column effluent was approximately the same concentration as that at the ending concentration during Run 7.

The elution was conducted with 55ºC water. Thermal expansion of the PVC column caused it to warp permanently. As a result, no further warm elutions were run.

Observations on Rhenium Run 9

A special elution was conducted after Run 8 to ensure the lead and lag columns were fairly free of rhenium before starting Run 9.

Observations on Rhenium Run 10

Feed rhenium concentration was intentionally decreased to 6 mg/L. For the loading phase the first lead column rhenium concentration seems to be anomalously high. The reason for this is not known. A water leak into the catch pan shut down the test during elution, after 8.5 bed volumes of eluent had passed. The inline filter still contained about 50 mL of simulant with eluent, which was released into the eluent line by the pressure surges caused by shutdown and restart. This release caused a spike in aluminum and sodium in the eluent after that time. The increased ionic strength and rise or drop in pH caused a decrease in rhenium concentration at that time. Because of this event, the elution was incomplete and the eluate composite samples do not contain all of the rhenium.

DISCUSSION

Numerous technical problems were encountered and overcome with the pilot scale ion exchange facility. Almost all parts of the facility are currently operating well. Two exceptions are the online probes for the measurement of nitrate and pH, which continued to exhibit significant drift. The problems identified are not expected to cause operational issues in the BNFL Inc. designed facility, as they were largely equipment or computer software related. However, some issues inadvertently identified should be considered. The flow interruption during elution of the lag column in run #10 caused pressure surges, which caused simulant to be mixed with eluent. This caused a high ionic strength in the incoming eluent, stopping elution. If the BNFL Inc. designed facility has dead-legs containing feed, or if valve sequencing cause a mixing of high ionic strength solution with in-flowing eluent, then the eluate could be contaminated with the high ionic strength solutions. Also, heating of the column during elution caused warping of the column, probably due to expansion. Allowance for expansion during hot water elution is needed. No attempt was made in this test program to evaluate if the resin will survive multiple thermal cycles.

Eleven test runs were completed. Runs 1 and 2 had enough hardware problems that the results are invalid. The test conditions designated for these runs were used for subsequent runs (2R and 10). All runs exceeded the design criteria of 100 BV to 50% breakthrough. Decontamination factors, DF, were as high as 300. The DF was as low as 12 in Run #5, but this was due to intentionally incompletely eluting the column in the prior test to examine its effect on performance.

The procedure of interchanging the lead and lag columns after each test run worked well. However, it is important to recognize that incomplete elution will diminish the overall DF on the subsequent run. Examples of this are shown in Runs 4 and 5. The Re that remains on the resin will cause early breakthrough. Similarly, running the lead column to high breakthrough (70%) will cause early breakthrough in the lead column on the subsequent run. In this case, the lag column is partially loaded with rhenium (~10%), and the subsequent run begins at about the same level. A correlation was developed to relate the pre-loading of a full height ion exchange column containing SL-639 and the flow rate of waste simulant through the column to the volume simulant that may be processed with the column before breakthrough is reached. This correlation may be used to optimize the process.

Normalized rhenium concentrations were presented in the report for all of the process fluids exiting the columns. This allowed the determination of breakthrough for the loading phase and fraction of the rhenium removed during the elution phase. The material balance for most experiments is reasonably good.

Different process fluids are pumped through the ion exchange columns in sequence. Data from conductivity probes indicate that the transition from one fluid to another is not sharp. If the flow regime were plug flow, a sharp transition in conductivity at the outlet of the column would be observed after one column liquid volume of the new fluid was pumped into the column. Instead it requires about two column liquid volumes to complete the transition. This effect is probably due to the liquid mixing zone above the resin bed in each column. The BNFL Inc. designed full-scale columns are of a similar design and will probably experience non-plug flow of solutions. No fouling of the ion exchange beds or the post-column in-line filters was observed. The in-line pre-filter on the columns indicated a high pressure drop during testing, but this was attributable to the high viscosity of the simulant. The pressure drop across the filter decreased when dilute caustic and water were pumped in.

The fiberglass tank, which had been purported to withstand the simulant chemistry, was observed to have deteriorated and was taken out of service after several tests. Other polymeric components withstood the harsh chemical environment.

The only other element removed by the process was silicon. The initial simulant composition contained ~250 mg/L silicon, which had dropped to ~100 mg/L by Run #4. The silicon does not appear in the eluate or caustic displacement solutions. Apparently, it was precipitating in the feed tank between runs and was removed by the cartridge filter.

CONCLUSIONS

The data contained in this report will be used to assess the VERSE ion exchange computer model used to aid in design and optimization of the BNFL Inc. facility. Tests conducted to date using Envelope A simulant support the BNFL Inc. design assumptions for performance of the full-scale SL-639 technetium ion exchange system. Further research is needed with other envelopes (B and C) and with a larger diameter column to further reduce wall effects. Design modifications are needed to fully demonstrate the benefit of heating the eluent.

APPROVALS

J. L. Steimke, Author	Date
M. A. Norato, Author	Date
T. J. Steeper, Author	Date
D. J. McCabe, Author	Date
L. L. Hamm, Design Check	Date
M. A Kyle, Manager of ETF	Date
M. A Ebra, Manager of EDS	Date

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Table 1 Simulant Formulation

Simple Envelope A Formulation

Total Volume of Simulant Feed = 159.9 L

To a 50 L Nalgene Carboy add

	Mass, grams	
Water	30000	(i.e. 30 L)

Transition Metals and Complexing agents

Compounds	Formula	Mass, grams	mole wt.	molarity
Boric Acid	H3BO3	21.9	43.82	0.003126
Calcium Nitrate	Ca(NO3)2.4H2O	17.7	164.09	0.000675
Cesium Nitrate	CsNO3	1.8	194.91	5.78E-05
Magnesium Nitrate	Mg(NO3)2.6H2O	4.3	256.41	0.000105
Potassium Nitrate	KNO3	1442	101.11	0.089191
Zinc Nitrate	Zn(NO3)2.6H2O	3.5	297.47	7.36E-05
Glycolic Acid	HOCH2COOH, 70 wt%	124.9	76.05	0.00719
Sodium Chloride	NaCl	1124	58.44	0.120284
Sodium Fluoride	NaF	31.5	41.99	0.004692
Sodium Perrhenate	NaReO4	3	273.19	6.87E-05
Sodium Sulfate	Na2SO4	85.5	142.09	0.003763
Potassium Molybdate	K2MoO4	15.3	238.14	0.000402
Ammonium Acetate	CH3COONH4	38.5	77.08	0.003124

Place solution in the Simulant Supply Tank

In a separate 50 L carboy mix the following

Add	grams	
Water	45000	(i.e 45 L)

Compounds	Formula	Mass, grams		
Sodium Hydroxide	NaOH	10340	40	1.616635

*********CAUTION!!!!!!!!!! NaOH MUST BE ADDED SLOWLY TO AVOID EXCESSIVE HEATING OF SOLUTION!!!!!!!!!!!!!!!

When ALL NaOH is dissolved and solution temperature is below about 60 deg. C add the following

Compounds	Formula	Mass, grams		
Sodium Aluminate	2NaAlO2.3H2O	12030	217.94	0.345207
Sodium meta-silicate	NaSiO3.9H2O	160.1	284.2	0.003523
Sodium Acetate	NaCH3COO.3H2O	289.9	136.08	0.013323
Sodium Formate	HCOONa	326.3	68.01	0.030005
Sodium Oxalate	Na2C2O4	69.7	134	0.003253
Sodium Phosphate	Na3PO4.12H2O	171.1	380.12	0.002815

Mix thoroughly. Then add this solution to the Simulant Supply Tank.

Add	Formula	Mass, grams		
Sodium Carbonate	Na2CO3	1661	105.99	0.098007

Mix thoroughly.

Add	Formula	Mass, grams		
Sodium Nitrate	NaNO3	15730	84.99	1.157477
Sodium Nitrite	NaNO2	12490	69	1.132048

Mix thoroughly and bring to a final solution volume of 159.9 L.

total molarity of sodium	4.99
total molarity of nitrate	1.248

Table 3 Mass of Solids Collected on Whatman Filters

masses in grams

Destination of filtrate	Run 1	Run 2	Run 3	Run 2R	Run 4	Run 5	Run 6
simulant collection tank	0.17	0.02	0.14	0.04	0.21	0.02	0.26
regeneration caustic coll.	0.1	0	0.03	0.05	0.05	0.02	0.01
acid water collection	0	0.01	na	na	na	na	na
dilute caustic collection	0.05	0.01	0.01	0	0.03	0.01	0.01
caustic water collection	na	na	na	na	0.05	0.01	0
eluate collection	0.05	0.01	0	0.01	0.06	0.01	0.01

Table 4 Analytical Results for Rhenium Run 3

Concentrations in mg/L

ADS #	130899	130900	130946	130947	130948	131059	131060	131061	131062	131063	131064	131065
TFL #	fdcomp-1	fdcomp-2	Re-3-1	Re-3-2	Re-3-3	Re-3-7	Re-3-8	Re-3-9	Re-3-10	Re-3-11	Re-3-12	Re-3-13
liquid	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant
hours	0	0	4.48	7.78	11.1	21.08	24.77	28.08	31.4	34.7	38.02	41.33
BV	0.0	0.0	10.8	20.0	29.1	56.7	66.9	76.0	85.2	94.3	103.4	112.6
Al	18850	18950	19000	19050	19300	19650	18450	19900	19300	19630	19540	20000
B	25	23	23	24	24	28	24	26	24	25	25	25
Ba	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ca	1.3	1.3	1.1	1.1	1.2	1.3	1.1	1.1	1.1	1.3	1.1	1.1
Cd	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Co	0.5	0.5	0.5	0.5	0.4	0.5	0.4	0.4	0.4	0.5	0.5	0.5
Cr	0.6	0.7	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.7	0.7
Cu	0.4	0.3	0.3	0.4	0.4	0.3	0.2	0.2	0.2	0.3	0.3	0.2
Fe	4.7	4.7	4.7	4.9	5	5.2	7.5	5.3	5.0	5.6	5.5	5.2
La	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Li	<0.07	<0.07	<0.07	<0.07	<0.07	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Mg	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mn	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mo	33	33	33	34	34	36	34	37	34	37	36	36
Na												
Ni	0.2	0.2	0.2	0.2	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
P	75	75	76	78	78	86	81	88	81	85	82	85
Pb	<5	<5	<5	<5	<5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Si	208	212	214	216	228	247	233	249	237	243	245	237
Sn	0.5	0.5	0.4	0.5	0.5	0.6	0.5	0.6	0.5	0.5	0.5	0.6
Sr	<0.5	<0.5	<0.5	<0.5	<0.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ti	<0.05	<0.05	<0.05	<0.05	<0.05	0.2	0.2	0.2	0.2	0.2	0.2	0.1
V	<0.12	<0.12	<0.12	<0.12	<0.12	0.1	0.1	0.2	0.1	0.5	0.6	0.1
Zn	3.2	3.3	4.2	4.6	5	3.3	4.9	3.8	3.3	3.5	3.5	3.5
Zr	<0.15	<0.15	<0.15	<0.15	<0.15	0.2	0.3	0.4	0.2	0.1	0.2	0.2
Re	11	11	0.2	0.2	0.7	0.9	1.5	2.3	2.7	3.8	4.4	4.9
Re/Re0			0.0182	0.0182	0.0636	0.0812	0.1379	0.2112	0.2473	0.3424	0.4036	0.4461

Table 4 Analytical Results for Rhenium Run 3

			ICP-MS	ICP-MS							
131066	131067	131068	131069	131070	ADS sample #	131111	131113	131114	131115	131116	131117
Re-3-14	Re-3-15	Re-3-16	Re-3-lagef-1	Re-3-lagef-2	TFL sample #	Re-3-17	Re-3-22	Re-3-23	Re-3-24	Re-3-25	Re-3-26
simulant	dil. caust.	dil. caust.	simulant	simulant		eluate H2O	eluate H2O	eluate H2O	eluate H2O	eluate H2O	eluate H2O
42.17	42.72	43.27	21.98	30.31	elapsed hours	44.9	47.9	50.9	53.9	56.9	59.9
114.9			59.2	82.1	col. resin vol of eluat	0	3.835	7.813	11.713	15.613	19.513
19250	16900	16800			Al	50	11	3.9	3.2	3.7	3.2
24	21	21			B	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
<0.05	<0.05	<0.05			Ba	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1.1	3.1	3.1			Ca	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
<0.05	<0.05	<0.05			Cd	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.4	0.8	0.8			Co	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.6	0.6	0.6			Cr	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
0.2	0.2	0.2			Cu	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
5.0	4.7	4.7			Fe	0.3	0.2	0.6	0.1	0.07	<0.06
<0.15	<0.15	<0.15			La	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
<0.7	<0.7	<0.7			Li	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
<0.05	0.67	0.65			Mg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.05	<0.05	<0.05			Mn	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
34	30	30			Mo	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
					Na	402	131	61	42	126	50
<0.1	<0.1	<0.1			Ni	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
81	69	67			P	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9
<0.5	<0.5	<0.5			Pb	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
229	195	193			Si	1.2	<0.6	<0.6	<0.6	<0.6	<0.6
0.6	0.6	0.5			Sn	<0.4	0.51	<0.4	<0.4	<0.4	<0.4
<0.2	<0.2	<0.2			Sr	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.1	0.2	0.2			Ti	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.2	0.1	0.1			V	<0.12	<0.12	<0.12	0.2	0.125	<0.12
3.5	2.9	2.8			Zn	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
0.3	0.1	0.2			Zr	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
5.0	4.9	4.8	0.0497	0.229	Re	23	212	67	18	7.0	3.0
0.4518	0.4479	0.4394	0.0045	0.0208	Re/Re0	2.0818	19.2424	6.0879	1.6212	0.6382	0.2733
					avg Re	36.97					

Table 4 Analytical Results for Rhenium Run 3

131118	131119	131120	131121	131122	131123	131124	131178	131125	131179
Re-3-27	Re-3-28	Re-3-29	elucomp-1	elucomp-2	reg-1	reg-2	fddsp	efcmp1	efcmp2
eluate H2O	eluate H2O	eluate H2O							
62.9	65.9	68.3							
23.413	27.313	30.355							
0.9	0.7	1.1	3.4	3.5	355	354	1550		
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	1.7		
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
<0.2	<0.2	<0.2	<0.2	<0.2	0.4	0.4	0.7		
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
<0.05	<0.05	<0.05	<0.05	<0.05	0.055	<0.05	0.1		
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
0.075	<0.06	0.075	<0.06	<0.06	0.2	0.5	0.6		
<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15		
<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7		
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
<0.04	<0.04	<0.04	<0.04	<0.04	0.4	0.5	2.7		
19	15	29	39	39	21000	21000	11500		
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06		
<0.9	<0.9	<0.9	<0.9	<0.9	1.5	1.7	5.3		
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		
<0.6	<0.6	<0.6	<0.6	<0.6	5.5	5.5	20		
<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4		
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12		
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		
<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15		
1.6	1.0	0.8	12	13	<0.1	<0.1	3.9	0.0491	0.0365
0.1433	0.0867	0.0694							

Table 5 Analytical Results for Rhenium Run 2R
Concentration with dilution correction (mg/L)

ADS #	131666	131667	131660	131661	131662	131791	133127	133127	133147	133147	131792	131793
TFL #	Re-2R-fdcomp1	Re-2R-fdcomp2	Re-2R-1	Re-2R-2	Re-2R-3	Re-2R-4	Re-2R-5	Re-2R-5	Re-2R-6	Re-2R-6	Re-2R-7	Re-2R-8
liquid	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant
Al	1.8E+04	1.8E+04	2.1E+04	1.8E+04	1.9E+04	18150	20250		21300		19050	16850
B	23	23	26	23	24	23	28.1		28.3		25	24
Ba	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02					<0.02	<0.02
Ca	4.0	4.1	0.96	0.76	0.73	<0.2					<0.2	<0.2
Cd	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05					<0.05	<0.05
Co	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					<0.05	<0.05
Cr	0.38	0.40	1.8	0.55	0.53	0.7	0.6		0.6		0.8	0.7
Cu	0.17	0.16	0.25	0.17	0.15	<0.05					<0.05	<0.05
Fe	4.5	4.7	5.1	4.6	4.7	<0.06	0.3		1.7		<0.06	<0.06
Li	<0.07	<0.07	<0.07	<0.07	<0.07	<0.7					<0.7	<0.7
Mg	<0.03	<0.03	<0.03	<0.03	<0.03	<0.05					<0.05	<0.05
Mn	<0.02	<0.02	<0.02	<0.02	<0.02	<0.04					<0.04	<0.04
Mo	33	34	39	33	35	34	40		40		36	34
						*					*	*
Ni	<0.06	<0.06	<0.06	<0.06	<0.06	0.3					0.3	0.3
P	97	99	113	97	102	95	120		120		103	98
Pb	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5					<0.5	<0.5
Si	181	185	214	183	191	190	220		216		205	195
Sn	<0.38	<0.38	<0.38	<0.38	<0.38	<0.4					<0.4	<0.4
Sr	<0.2	<0.2	<0.2	<0.2	<0.2	<0.05					<0.05	<0.05
Ti	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					<0.05	<0.05
V	0	0	0	0	0	<0.1					<0.1	<0.1
Zn	4.4	4.5	4.9	4.3	4.6	4.7	2.2		3.6		4.8	2.2
Zr	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15					<0.15	<0.15
Re	9.8	10.1	0.70	0.71	0.92	1.0	2.5	2.5	3	3	4.1	4.5
Re/Re0			0.070	0.071	0.092	0.103	0.251	0.251	0.302	0.302	0.407	0.450
elapsed hours			5.66	11.35	17.03	22.71	28.40	39.75	34.06	45.43	51.11	56.80
BV			10.47	21.00	31.51	42.01	52.54	73.54	63.01	84.05	94.55	105.08

Table 5 Analytical Results for Rhenium Run 2R

131794	131795	131796	131797	131798	131799	131800	131801	131802	131803	131804	131805	131806
Re-2R-9	Re-2R-10	Re-2R-11	Re-2R-12	Re-2R-13	Re-2R-15	Re-2R-16	Re-2R-19	Re-2R-20	Re-2R-21	Re-2R-22	Re-2R-23	Re-2R-24
simulant	simulant	simulant	simulant	simulant	dilute cau	eluant	eluant	eluant	eluant	eluant	eluant	eluant
18300	18700	16450	14000	15550	578	193	24	22	13	7.8	5.4	3.1
23	24	23	23	25	1.7	0.3	<0.1	<0.1	0	0	0	0
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.2	<0.2	<0.2	<0.2	<0.2	2.1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	0.08	0.08	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.7	0.8	0.7	0.7	0.7	0.3	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.06	<0.06	<0.06	<0.06	<0.06	0.3	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
34	35	33	33	36	1.3	0.6	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
*	*	*	*	*	8570	1255	264	260	183	145	102	92
0.3	0.4	0.3	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
96	98	96	96	103	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
192	196	192	190	201	11.5	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
4.5	4.8	1.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
4.9	5.6	6.0	6.7	7.4	3.7	19	62	94	164	188	211	184
0.494	0.558	0.606	0.677	0.740	0.373	1.891	6.233	9.454	16.459	18.871	21.183	18.469
62.46	68.15	73.83	79.51	85.20	91.60	93.25	98.98	99.98	100.98	101.98	102.98	103.98
115.55	126.08	136.59	147.09	157.62		0.20	4.97	6.11	7.24	8.37	9.51	10.64

Table 5 Analytical Results for Rhenium Run 2R

131807	131808	131809	131810	131811	131812	131813	131814	131815	131816	131817		131818
Re-2R-25	Re-2R-26	Re-2R-27	Re-2R-28	Re-2R-29	Re-2R-30	Re-2R-31	Re-2R-32	Re-2R-33	Re-2R-34	Re-2R-35		Re-2R-36
eluant	eluant	eluant	eluant	eluant	eluant	eluant	eluant	eluant	eluant	eluant		con.caust
2.6	3.4	2.7	5.0	0.3	4.4	1.7	2.1	1.9	2.1	0.1	Al	0.1
0	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	B	<0.1
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	Ba	<0.02
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	Ca	<0.2
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	Cd	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	Co	<0.05
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	Cr	<0.06
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	Cu	<0.05
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	Fe	<0.06
<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	Li	<0.7
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	Mg	<0.05
<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	Mn	<0.04
<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	Mo	<0.04
70	74	62.55	115	<2	50	64	141	194	93	<2		<2
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	Ni	<0.06
<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	P	<0.9
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	Pb	<0.5
<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	Si	<0.6
<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	Sn	<0.4
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	Sr	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	Ti	<0.05
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	V	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	Zn	<0.1
<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	Zr	<0.15
135	101	73	20	10	5.6	3.7	2.6	1.9	1.2	0.8	Re	0.9
13.595	10.178	7.344	1.972	1.007	0.566	0.367	0.262	0.189	0.121	0.079	Re/Re0	0.090
104.98	105.98	106.98	110.93	113.93	116.93	119.93	122.93	125.93	128.93	131.93	hours	133.18
11.77	12.91	14.04	18.52	21.92	25.32	28.72	32.12	35.52	38.92	42.32	BV	

Table 5 Analytical Results for Rhenium Run 2R

131819 Re-2R-elucomp1	131820 Re-2R-elucomp2	131821 Re-2R-dispcomp	131822 Re-2R-reg1	131823 Re-2R-reg2	131663 Re-2R-lag1	131364 Re-2R-lag2	131665 Re-2R-lag3	131668 Re-2R-efcomp1	131669 Re-2R-efcomp2
68	23	692	251	247					
<0.1	<0.1	0.7	0.2	0.1					
<0.02	<0.02	<0.02	<0.02	<0.02					
<0.2	<0.2	1.8	<0.2	<0.2					
<0.05	<0.05	<0.05	<0.05	<0.05					
<0.05	<0.05	0.11	<0.05	<0.05					
<0.06	<0.06	<0.06	<0.06	<0.06					
<0.05	<0.05	<0.05	<0.05	<0.05					
<0.06	<0.06	0.07	<0.06	<0.06					
<0.7	<0.7	<0.7	<0.7	<0.7					
<0.05	<0.05	0.78	<0.05	<0.05					
<0.04	<0.04	<0.04	<0.04	<0.04					
0.4	0.3	1.5	0.7	0.7					
28	10	413	204	199					
<0.06	<0.06	<0.06	<0.06	<0.06					
<0.9	<0.9	<0.9	<0.9	<0.9					
<0.5	<0.5	<0.5	<0.5	<0.5					
<0.6	<0.6	9.3	1.4	1.4					
<0.4	<0.4	<0.4	<0.4	<0.4					
<0.05	<0.05	<0.05	<0.05	<0.05					
<0.05	<0.05	<0.05	<0.05	<0.05					
<0.1	<0.1	<0.1	<0.1	<0.1					
<0.1	<0.1	<0.1	<0.1	<0.1					
<0.15	<0.15	<0.15	<0.15	<0.15					
1.2	47	4.8	<0.1	<0.1	0.065	0.080	0.366	0.152	0.219
0.117	4.680	0.482			0.006	0.008	0.037		
					21.98	30.31	70.65		
					39.93	55.06	128.35		

Table 6 Analytical Results for Rhenium Run 4

Concentration with dilution correction (mg/L)

ADS #	134277	134278	134247	134248	134249	134250	134251	134252	134253	134254	134255	
TFL #	Re-4-fdcp1	Re-4-fdcp2	Re-4-4	Re-4-5	Re-4-6	Re-4-7	Re-4-8	Re-4-9	Re-4-10	Re-4-11	Re-4-12	
liquid	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	
hours			1.89	7.58	13.26	18.94	24.61	30.29	35.98	41.66	47.34	
BV			3.5	14.0	24.4	34.9	45.3	55.8	66.3	76.7	87.2	
Al	16500	16800	17050	17050	17000	16850	16650	15900	16050	17050	17100	Al
B	22	23	24	24	24	23	23	24	24	24	24	B
Ba	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	Ba
Ca	1.6	1.3	1.2	0.6	0.6	0.7	0.8	0.3	0.5	0.4	0.8	Ca
Cd	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	Cd
Co	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	Co
Cr	0.7	0.8	0.8	1.0	0.8	1.0	0.9	1.2	0.9	0.9	0.9	Cr
Cu	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	Cu
Fe	4.2	4.2	4.0	4.2	4.1	4.0	4.1	3.5	3.5	3.9	4.3	Fe
La	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	La
Li	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	Li
Mg	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	Mg
Mn	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	Mn
Mo	32	33	34	34	33	32	32	35	35	34	33	Mo
Ni	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.6	0.6	0.8	0.8	Ni
P	90	92	95	94	92	88	89	89	88	93	93	P
Pb	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	Pb
Si	103	106	113	112	110	105	104	80	82	110	111	Si
Sn	1.3	1.4	1.6	1.5	1.3	1.3	1.3	1.2	1.2	1.5	1.5	Sn
Sr	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	Sr
Ti	0.18	0.21	0.21	0.24	0.23	0.18	0.17	0.27	0.27	0.21	0.23	Ti
V	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	V
Zn	4.5	4.5	4.6	4.4	4.3	4.2	4.3	4.5	4.4	4.3	4.4	Zn
Zr	<0.15	<0.15	0.1	<0.15	<0.15	0.2	<0.15	0.2	<0.15	0.2	<0.15	Zr
S	116	117	120	118	116	111	113	92	95	118	117	S
Re	11.4	11.7	1.5	1.9	1.9	1.9	2.3	2.9	3.1	3.6	4.5	Re
Re/Re0	0.990	1.016	0.129	0.161	0.166	0.165	0.199	0.253	0.270	0.312	0.390	Re/Re0

Table 6 Analytical Results for Rhenium Run 4

134256	134257	134258	134259	134260	134261	134262	134263	134264	134265	134266	134267	134268
Re-4-13	Re-4-14	Re-4-15	Re-4-16	Re-4-17	Re-4-18	Re-4-19	Re-4-20	Re-4-21	Re-4-22	Re-4-23	Re-4-24	Re-4-25
simulant	simulant	simulant	simulant	simulant	simulant	simulant	sim./dil.	dil.caust.	dil.caust.	water	water	water
53.01	58.69	64.38	70.06	75.74	81.43	84.73	85.66	86.61	86.78	88.66	90.31	91.81
97.6	108.1	118.6	129.0	139.5	150.0	156.0		-1.6	-1.3	1.5	3.6	5.6
16950	17150	16500	16600	16850	16650	16350	15850	1003	865	23	11.6	8.0
24	25	24	23	23	23	23	22	1.7	1.2	<0.2	<0.2	<0.2
<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
0.4	0.4	0.3	0.6	0.6	0.7	0.8	0.7	<0.2	<0.2	<0.2	<0.2	<0.2
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.9	0.8	0.8	0.7	0.8	0.7	0.7	0.6	0.05	<0.05	<0.05	<0.05	<0.05
0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.02	0.01	0.02	0.015	0.03
3.9	4.3	4.0	4.1	4.0	4.1	4.1	3.8	2.6	0.35	<0.06	<0.06	<0.06
<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
33	34	33	33	33	32	32	31	2.0	1.7	<0.05	<0.05	<0.05
0.8	0.8	0.8	0.7	0.8	0.8	0.8	0.7	0.08	<0.06	<0.06	<0.06	<0.06
93	95	91	91	91	90	90	84	5.4	4.8	<0.9	<0.9	<0.9
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
108	112	105	103	105	103	102	92	10	9.9	1.3	3.1	2.7
1.3	1.5	1.4	1.4	1.3	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.20	0.24	0.17	0.15	0.18	0.17	0.16	0.14	<0.05	<0.05	<0.05	<0.05	<0.05
<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
4.2	4.4	4.3	4.2	4.3	4.3	4.5	4.2	0.2	0.2	<0.05	<0.05	<0.05
<0.15	<0.15	0.2	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
117	120	117	116	115	115	115	111	7.6	6.6	2.4	6.0	6.6
5.5	6.3	6.9	7.6	8.4	8.6	8.9	8.9	5.7	6.0	93	182	193
0.474	0.543	0.597	0.660	0.725	0.743	0.766	0.773	0.497	0.519	8.043	15.737	16.747

Table 6 Analytical Results for Rhenium Run 4

134269	134270	134271	134272	134273	134274	134275	134276	134279	134280	134281		134282
Re-4-27	Re-4-28	Re-4-29	Re-4-30	Re-4-31	Re-4-32	Re-4-33	Re-4-34	Re-4-lag1	Re-4-lag2	Re-4-lag3		Re-4-lag4
water	water	water	water	water	water	water	water	simulant	simulant	simulant		simulant
94.24	95.74	97.24	98.74	100.24	101.74	103.24	104.64	18.86	26.23	49.84		84.13
8.8	10.7	12.7	14.7	16.6	18.6	20.5	22.4	34.6	48.1	91.4		154.2
5.8	4.8	4.2	4.0	2.0	2.2	2.4	1.5				Al	
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2				B	
<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03				Ba	
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2				Ca	
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02				Cd	
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05				Co	
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05				Cr	
0	0.015	-0.01	0.005	0.01	1.45	0.015	0.015				Cu	
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06				Fe	
<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14				La	
<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7				Li	
<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03				Mg	
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05				Mo	
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05				Na	
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06				Ni	
<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9				P	
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5				Pb	
1.7	1.4	1.1	1.0	<0.6	<0.6	<0.6	<0.6				Si	
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5				Sn	
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05				Sr	
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05				Ti	
<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12				V	
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05				Zn	
<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15				Zr	
3.7	2.4	1.4	0.9	0.6	<0.5	<0.5	<0.5				S	
137	90	58	39	26	17	13	8.8	0.42	0.5	0.8	Re	2.2
11.841	7.807	5.001	3.397	2.251	1.481	1.085	0.764	0.036	0.043	0.069	Re/Re0	0.190

Table 6 Analytical Results for Rhenium Run 4

143505 Re-4-efcomp1 simulant	143506 Re-4-efcomp2 simulant	134507 Re-4-elucomp1 water	134508 Re-4-elucomp2 water	134509 Re-4-reg1 con.caust.	134510 Re-4-reg2 con.caust.	134511 Re-4-fddsp dil.caust.	134512 Re-4-wtrdsp1 water	134513 Re-4-wtrdsp2 water
				589	579	3240	595	600
				0.8	0.7	4.2	0.8	0.9
				<0.05	<0.05	<0.05	<0.05	<0.05
				2.8	2.8	0.9	<0.2	<0.2
				<0.02	<0.02	<0.02	<0.02	<0.02
				2.0	0.2	0.1	<0.05	<0.05
				0.3	<0.1	<0.1	<0.1	<0.1
				0.1	0.1	<0.05	<0.05	<0.05
				0.3	0.3	0.9	0.2	0.2
				<0.14	<0.14	<0.14	<0.14	<0.14
				<0.7	<0.7	<0.7	<0.7	<0.7
				<0.05	<0.05	0.415	<0.05	<0.05
				1.3	1.2	6.0	1.1	1.2
				23000	22300	27100	5580	5750
				0.1	0.1	0.2	0.1	0.1
				3.4	2.8	16.2	2.8	2.8
				<0.5	<0.5	<0.5	<0.5	<0.5
				9.5	9.2	26	7.4	7.9
				<0.4	<0.4	<0.4	<0.4	<0.4
				<0.05	<0.05	<0.05	<0.05	<0.05
				<0.05	<0.05	<0.05	<0.05	<0.05
				<0.12	<0.12	<0.12	<0.12	<0.12
				0.38	0.29	0.84	0.20	0.20
				<0.15	<0.15	<0.15	<0.15	<0.15
				5.6	3.8	21	4.5	4.2
0.93	0.96	7	7.2	<0.05	<0.05	6.8	17.4	17.7
0.081	0.083	0.606	0.623					

Table 7 Analytical Results for Rhenium Run 5

				Concentration (mg/L)								
ADS #	134793	134794		134836	134837	134838	134839	134840	134841	134842	134843	134844
TFL #	Re-5-fdcmp1 simulant	Re-5-fdcmp2 simulant		Re-5-1 simulant	Re-5-2 simulant	Re-5-3 simulant	Re-5-4 simulant	Re-5-5 simulant	Re-5-6 simulant	Re-5-7 simulant	Re-5-8 simulant	Re-5-9 simulant
hours			hours	3.85	7.16	10.48	13.78	17.1	20.4	23.71	27.03	30.33
BV			BV	10.1	18.8	27.5	36.2	44.9	53.6	62.2	71.0	79.6
Al	18400	18350	Al	16950	17550	17200	16950	17000	16900	16900	17550	17000
B	27	26	B	24	25	24	24	24	24	24	25	24
Ba	<0.02	<0.02	Ba	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ca	1.2	1.1	Ca	0.9	0.9	1.0	0.9	0.9	1.0	0.9	0.9	0.9
Cd	<0.05	<0.05	Cd	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Co	<0.05	<0.05	Co	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cr	0.4	0.5	Cr	0.7	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5
Cu	0.3	0.3	Cu	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Fe	4.8	4.6	Fe	4.2	4.2	4.1	4.0	4.1	4.0	4.0	4.2	4.0
La	<0.14	<0.14	La	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
Li	<0.7	<0.7	Li	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Mg	<0.03	<0.03	Mg	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Mn	<0.04	<0.04	Mn	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Mo	36	34	Mo	33	34	33	32	33	33	32	34	33
Ni	0.8	0.7	Ni	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
P	102	99	P	95	98	95	93	95	93	92	98	95
Pb	<0.5	<0.5	Pb	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Si	111	105	Si	103	101	102	99	99	100	98	104	100
Sn	<0.5	<0.5	Sn	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sr	<0.05	<0.05	Sr	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ti	0.29	0.20	Ti	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.2
V	<0.12	<0.12	V	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
Zn	4.7	4.5	Zn	4.4	4.4	4.3	4.2	4.3	4.3	4.2	4.4	4.3
Zr	0.2	1.0	Zr	0.2	0.5	0.2	0.4	0.2	0.2	0.4	0.4	0.2
			S	117	124	120	115	120	118	115	125	118
Re	12	12	Re	2.8	3.1	3.4	3.7	4.3	4.9	5.5	6.6	6.6
			Re/Re0	0.236	0.259	0.281	0.311	0.356	0.404	0.462	0.552	0.549

Table 7 Analytical Results for Rhenium Run 5

134845	134846	134847	134848	134849	134850	134851	134852	134853	134854	134855	134856	134857
Re-5-10	Re-5-11	Re-5-12	Re-5-13	Re-5-14	Re-5-15	Re-5-16	Re-5-17	Re-5-18	Re-5-19	Re-5-20	Re-5-21	Re-5-22
simulant	simulant	simulant	simulant	simulant	simulant	sim/dil	dil. caustic	dil./water	water	water	water	water
33.65	36.95	40.26	43.58	46.88	49.58	50.13	50.68	52.35	54	55.66	57.16	58.66
88.3	97.0	105.7	114.4	123.1	130.1	131.6		0	1.86	3.74	5.43	7.13
16900	17550	17050	16850	17400	17000	17250	960	82	16	11	7.5	4.4
24	24	24	25	25	24	24	1.52	0.3	0.2	0.2	0.3	0.2
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.3	<0.1	<0.1	<0.1	<0.1	<0.1
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.4	0.4	0.4	0.4	0.5	0.4	0.4	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.3	0.3	0.3	0.3	0.3	0.3	0.3	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
4.0	4.1	4.1	4.1	4.2	4.1	4.1	0.3	0.1	<0.06	<0.06	<0.06	<0.06
<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
32	33	33	34	35	33	33	1.9	0.15	<0.05	<0.05	<0.05	<0.05
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.2	0.2	0.1	0.1
92	96	95	97	98	96	95	5.1	<0.9	<0.9	<0.9	<0.9	<0.9
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
97	100	99	102	103	100	100	11	2.4	3.9	1.9	1.1	0.9
<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
0.1	0.1	0.1	0.2	0.2	0.1	0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
4.2	4.3	4.3	4.4	4.6	4.3	4.3	0.2	<0.05	<0.05	<0.05	<0.05	<0.05
0.3	0.2	0.2	0.2	0.2	0.2	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
119	124	122	121	123	119	122	7.3	<0.5	<0.5	<0.5	<0.5	<0.5
6.8	7.3	7.6	8.3	9.2	9.4	9.4	6.4	12	193	238	173	116
0.568	0.610	0.633	0.694	0.769	0.784	0.784	0.532	1.008	16.105	19.855	14.416	9.662
						Cl	273	121	108	106	108	
						NO3	6592	2227	191	167	167	
						NO2	2814	228	36	24	26	

Table 7 Analytical Results for Rhenium Run 5

134858	134859	134860	134861	134862	134863	134864	134865	134866	134867	134868	134869	134870
Re-5-23	Re-5-24	Re-5-25	Re-5-26	Re-5-27	Re-5-28	Re-5-29	Re-5-30	Re-5-31	Re-5-32	Re-5-33	Re-5-34	Re-5-35
water	water	water	water	water	water	water	water	water	water	water	water	water
60.16	61.66	63.16	64.66	66.16	67.66	69.16	70.66	72.16	73.66	75.16	76.66	78.16
8.82	10.51	12.21	13.90	15.59	17.29	18.98	20.68	22.37	24.06	25.76	27.45	29.14
3.5	3.6	1.6	1.6	1.0	1.6	3.2	<0.5	1.1	2.6	<0.5	<0.5	<0.5
0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
0.9	0.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
66	43	29	20	15	11	9.1	7.2	5.4	4.1	3.4	2.1	1.4
5.509	3.570	2.409	1.703	1.234	0.956	0.761	0.600	0.454	0.343	0.282	0.173	0.118

Table 7 Analytical Results for Rhenium Run 5

				Concentration in mg/L						
134871	134872	134873	134874		135121	135122	135123	135124	135125	135126
Re-5-36	Re-5-37	Re-5-38	Re-5-39		Re-5-reg1	Re-5-reg2	Re-5-elucmp1	Re-5-elucmp2	Re-5-fddsp1	Re-5-fddsp2
water	water	water	water		1.0 M NaOH	1.0 M NaOH	water	water	0.1 M NaOH	0.1 M NaOH
79.66	81.16	82.66	84							
30.84	32.53	34.23	35.74							
<0.5	<0.5	1.9	2.2	Al	602	611	12	12	3795	3785
<0.1	<0.1	<0.1	<0.1	B	1.1	1.0	<0.1	<0.1	5.2	5.4
<0.05	<0.05	<0.05	<0.05	Ba	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
<0.1	<0.1	<0.1	<0.1	Ca	0.5	0.5	<0.1	<0.1	0.4	0.4
<0.02	<0.02	<0.02	<0.02	Cd	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.05	<0.05	<0.05	<0.05	Co	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	Cr	<0.05	<0.05	<0.05	<0.05	0.11	0.10
<0.04	<0.04	<0.04	<0.04	Cu	<0.05	<0.05	<0.05	<0.05	0.07	0.08
<0.06	<0.06	<0.06	<0.06	Fe	<0.06	<0.06	<0.06	<0.06	0.76	0.79
<0.14	<0.14	<0.14	<0.14	La	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
<0.7	<0.7	<0.7	<0.7	Li	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
<0.03	<0.03	<0.03	<0.03	Mg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.04	<0.04	<0.04	<0.04	Mn	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
<0.05	<0.05	<0.05	<0.05	Mo	1.5	1.4	<0.05	<0.05	7.4	7.6
<0.05	<0.05	<0.05	<0.05	Ni	<0.06	<0.06	<0.06	<0.06	0.2	0.2
<0.9	<0.9	<0.9	<0.9	P	2.9	2.7	<0.9	<0.9	19	20
<0.5	<0.5	<0.5	<0.5	Pb	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
<0.5	<0.5	<0.5	<0.5	Si	10	11	<2	<2	27	27
<1	<1	<1	<1	Sn	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
<0.1	<0.1	<0.1	<0.1	Sr	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	Ti	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.12	<0.12	<0.12	<0.12	V	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
<0.05	<0.05	<0.05	<0.05	Zn	0.09	0.1	<0.05	<0.05	0.9	0.9
<0.1	<0.1	<0.1	<0.1	Zr	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
<0.5	<0.5	<0.5	<0.5	S	4.4	4.5	<0.5	<0.5	24	25
1.0	0.7	0.5	0.4	Re	0.09	0.09	30	31	7.3	7.6
0.084	0.059	0.042	0.034		0.007	0.008	2.536	2.547	0.611	0.629

Table 7 Analytical Results for Rhenium Run 5

135127	135128	134795	134796	134797	134798
Re-5-wtrdsp1	Re-5-wtrdsp2	Re-5-efcomp1	Re-5-efcomp2	Re-5-lag1	Re-5-lag2
water	water	simulant	simulant	simulant	simulant
				44.5	49.61
				116.81	130.23
30	30				
0.2	0.2				
<0.06	<0.06				
<0.1	<0.1				
<0.02	<0.02				
<0.05	<0.05				
<0.05	<0.05				
<0.05	<0.05				
<0.06	<0.06				
<0.14	<0.14				
<0.7	<0.7				
<0.1	<0.1				
<0.03	<0.03				
<0.05	<0.05				
<0.06	<0.06				
<0.9	<0.9				
<0.5	<0.5				
<2	<2				
<0.4	<0.4				
<0.05	<0.05				
<0.05	<0.05				
<0.12	<0.12				
<0.05	<0.05				
<0.15	<0.15				
<0.5	<0.5				
143	142	1.1	1.1	2	2.6
11.897	11.842	0.092	0.092	0.167	0.217

Table 8 Analytical Results for Rhenium Run 6

Concentration with dilution correction (mg/L)

ADS #	135419	135420	135421	135422	135423	135424	135425	135426	135427	135428	135429	135430
TFL #	Re-6-1	Re-6-2	Re-6-3	Re-6-4	Re-6-5	Re-6-6	Re-6-7	Re-6-8	Re-6-9	Re-6-10	Re-6-11	Re-6-12
liquid	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant
hours	1.93	7.62	19.15	24.83	30.52	36.18	41.87	47.55	53.23	58.92	64.58	70.27
BV	2.78	10.97	12.72	21.52	34.1	46.51	58.95	71.66	84.18	96.73	109.27	120.73
Al	16650	20300	19950	18900	20350	20800	21700	19650	20100	20700	20300	20500
B	22	24	25	24	25	26	25	24	24	25	24	26
Ba	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.075	<0.05
Ca	0.69	0.71	0.81	0.70	0.48	0.48	0.51	0.48	0.63	0.66	0.68	0.62
Cd	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Co	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cr	0.48	0.47	0.48	0.46	0.48	0.50	0.49	0.49	0.48	0.45	0.49	0.57
Cu	0.22	0.29	0.11	0.28	0.25	0.28	0.29	0.26	0.31	0.27	0.30	0.29
Fe	3.7	4.2	4.2	4.1	4.2	4.3	4.2	4.0	4.3	4.3	4.3	4.3
La	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
Li	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Mg	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Mn	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mo	32	36	37	36	38	39	38	36	37	36	37	38
Ni	0.46	0.53	0.51	0.52	0.52	0.57	0.54	0.52	0.53	0.52	0.54	0.55
P	88	108	104	100	112	114	115	105	110	108	107	111
Pb	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Si	92	110	104	102	115	110	116	105	111	111	107	108
Sn	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Sr	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ti	0.16	0.18	0.19	0.17	0.19	0.20	0.17	0.12	0.18	0.19	0.18	0.16
V	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
Zn	4.0	4.4	4.5	4.4	4.6	4.7	4.6	4.4	4.6	4.5	4.6	4.8
Zr	0.15	0.20	0.23	0.17	0.20	0.22	0.22	0.21	0.20	0.19	0.19	0.28
S												
Re	0.23	0.24	0.26	0.21	0.27	0.41	0.72	1.3	2.0	2.7	3.5	4.4
Re/Re(feed)	0.020	0.021	0.023	0.018	0.023	0.036	0.063	0.114	0.178	0.238	0.305	0.381

Table 8 Analytical Results for Rhenium Run 6

135431	135432	135433	135434	135587	135440	135441		135587	135589	135590	135591	135592
Re-6-13	Re-6-14	Re-6-15	Re-6-16	Re-6-17	Re-6-fdcmp1	Re-6-fdcmp2		Re-6-17	Re-6-18	Re-6-19	Re-6-20	Re-6-21
simulant	simulant	simulant	simulant	simulant	simulant	simulant		simulant		water	water	water
75.95	81.63	87.32	91.67	92.43				92.43	93.38	94.92	96.42	97.92
129.15	137.37	145.55	151.63	152.69				152.69		0.00	1.63	3.25
18950	18850	19950	21250	18650	18600	21400	Al	18650	967.1	374.1	23.65	15.5
24	25	25	25	26.13333	24	25	B	26.13333	1.75	0.713333	<0.2	<0.2
<0.05	0.085	<0.05	<0.05	0.076667	<0.05	<0.05	Ba	0.076667	<0.05	<0.05	<0.05	<0.05
0.68	0.62	0.68	0.74	0.793333	2.5	2.6	Ca	0.793333	<0.2	<0.2	<0.2	<0.2
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	Cd	<0.02	<0.02	<0.02	<0.02	<0.02
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	Co	<0.05	<0.05	<0.05	<0.05	<0.05
0.48	0.57	0.47	0.48	0.53	0.43	0.47	Cr	0.53	0.036667	<0.03	<0.03	<0.03
0.27	0.29	0.29	0.31	0.325	0.28	0.31	Cu	0.325	<0.05	<0.05	<0.05	<0.05
4.2	4.1	4.3	4.4	4.08	4.1	4.7	Fe	4.08	0.126667	<0.06	<0.06	<0.06
<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	La	<0.14	<0.14	<0.14	<0.14	<0.14
<0.7	<0.7	<0.7	<0.7	<0.9	<0.7	<0.7	Li	<0.9	<0.9	<0.9	<0.9	<0.9
<0.03	<0.03	<0.03	<0.03	<0.05	0.06	0.11	Mg	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	Mn	<0.05	<0.05	<0.05	<0.05	<0.05
37	36	37	36	35.55333	35	36	Mo	35.55333	1.946667	0.71	<0.05	<0.05
0.53	0.5	0.54	0.55	0.836667	0.53	0.61	Ni	0.836667	0.093333	<0.06	<0.06	<0.06
105	102	110	113	100.9	98	117	P	100.9	5.973333	2.426667	<0.9	<0.9
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	Pb	<0.5	<0.5	<0.5	<0.5	<0.5
103	99	106	110	101.3367	131	151	Si	101.3367	10.67	4.99	1.58	3.456667
<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	Sn	<0.4	<0.4	<0.4	<0.4	<0.4
<0.1	<0.1	<0.1	<0.1	0.073333	<0.1	<0.1	Sr	0.073333	<0.05	<0.05	<0.05	<0.05
0.16	0.18	0.20	0.20	0.166667	0.19	0.22	Ti	0.166667	<0.05	<0.05	<0.05	<0.05
<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	V	<0.12	<0.12	<0.12	<0.12	<0.12
4.5	4.6	4.7	4.8	4.753333	4.4	4.8	Zn	4.753333	0.226667	<0.05	<0.05	<0.05
0.17	0.17	0.19	0.19	0.89	0.19	0.22	Zr	0.89	<0.15	<0.15	<0.15	<0.15
				81.5			S	81.5	10.3	3.96	<0.5	<0.5
4.5	4.9	5.2	5.3	5.325	11.5	11.4	Re	5.325	2.84	4.63	38.46	123.46
0.393	0.430	0.454	0.459	0.465	1.008	0.993		0.465	0.248	0.404	3.359	10.783

Table 8 Analytical Results for Rhenium Run 6

135593	135594	135595	135596	135597	135598	135599	135600	135601	135602	135603	135604	135605
Re-6-22	Re-6-23	Re-6-24	Re-6-25	Re-6-26	Re-6-27	Re-6-28	Re-6-29	Re-6-30	Re-6-31	Re-6-32	Re-6-33	Re-6-34
water	water	water	water	water	water	water	water	water	water	water	water	water
99.42	100.92	102.42	103.92	105.42	106.92	108.42	109.92	111.42	112.92	114.42	115.92	117.42
4.88	6.50	8.13	9.75	11.38	13.00	14.63	16.25	17.88	19.50	21.13	22.75	24.38
11.3	7.035	7.34	4.505	3.315	4.49	2.345	2.205	2.035	1.525	6.17	2.02	1.01
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.076667	<0.03	<0.03
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.06	<0.06	<0.06	<0.06	4.853333	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
3.14	1.426667	0.946667	0.806667	1.256667	1.306667	0.596667	<0.6	1.21	<0.6	2.826667	0.656667	0.566667
<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
<0.05	<0.05	0.37	<0.05	<0.05	0.4	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
<0.5	<0.5	<0.5	<0.5	<0.5	2.23	<0.5	<0.5	<0.5	<0.5	1.29	<0.5	<0.5
172.96	159.96	114.96	82.96	57.61	43.16	32.06	23.86	18.56	14.01	10.36	9.015	7.41
15.106	13.970	10.040	7.245	5.031	3.769	2.800	2.084	1.621	1.224	0.905	0.787	0.647

Table 8 Analytical Results for Rhenium Run 6

135606	135607	135608	135609	135610	135611	135614	135616	135617	135618	135619	135620
Re-6-35	Re-6-36	Re-6-37	Re-6-38	Re-6-39	Re-6-40	Re-6-41	Re-6-42	Re-6-43	Re-6-44	Re-6-45	Re-6-elucmp1
water	water	water	water	water	water	water	water	water	water	water	water
117.9	117.92	119.42	120.92	122.42	123.92	125.42	126.92	128.42	129.92	130.32	
24.90	24.92	26.54	28.17	29.79	31.42	33.04	34.67	36.29	37.92		
1.055	2.46	1.395	1.265	1.06	1.51	0.42	0.265	0.33	0.3	1.165	33.4
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
<0.6	<0.6	0.883333	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	0.72	1.106666667
<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
<0.05	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
<0.5	0.59	0.84	<0.5	0.58	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
6.855	6.7	6.52	6.045	4.575	3.35	2.665	2.085	1.535	1.29	1.275	38.21
0.599	0.585	0.569	0.528	0.400	0.293	0.233	0.182	0.134	0.113	0.111	3.337

Table 8 Analytical Results for Rhenium Run 6

135621	135622	135623	135435	135436	135437	135438	135439	135472	135473
Re-6-elucmp2	Re-6-reg	Re-6-fddsp	Re-6-lag1	Re-6-lag2	Re-6-lag3	Re-6-lag4	Re-6-lag5	Re-6-efcmp1	Re-6-efcmp2
water	con.caust.	dil.caust.	sim	sim	sim	sim	sim	sim	sim
			2.57	19.4	25.78	68.32	90.32		
			4	13	24	115	148		
32.25	249.5	4035							
<0.2	0.3566667	5.75							
<0.05	<0.05	<0.05							
<0.2	0.4966667	0.196667							
<0.02	<0.02	<0.02							
<0.05	<0.05	<0.05							
0.043333333	0.0566667	0.153333							
<0.05	0.085	0.11							
<0.06	<0.06	0.77							
<0.14	<0.14	<0.14							
<0.9	<0.9	<0.9							
<0.05	<0.05	<0.05							
<0.05	<0.05	<0.05							
<0.05	0.47	7.966667							
<0.06	<0.06	0.21							
<0.9	1.8066667	22.4							
<0.5	<0.5	<0.5							
0.976666667	3.9233333	25.60333							
<0.4	<0.4	<0.4							
<0.05	<0.05	<0.05							
<0.05	<0.05	<0.05							
<0.12	<0.12	<0.12							
<0.05	0.08	1.05							
<0.15	<0.15	<0.15							
<0.5	1.8	27.6							
37.31	0.1	3.68	0.037	<.012	<.012	0.088	0.26	0.12	0.12
3.259	0.009	0.321	0.003			0.008	0.023	0.010	0.010

Table 9 Analytical Results for Rhenium Run 7

Concentration (mg/L)

ADS#	135977	135978	135979	135980	135981	135982	135983	135984	135985	135986	135987	135988
TFL#	Re-7-1	Re-7-2	Re-7-3	Re-7-4	Re-7-5	Re-7-6	Re-7-7	Re-7-8	Re-7-9	Re-7-10	Re-7-11	Re-7-12
hours	3.84	7.16	10.47	13.77	17.09	20.39	23.71	29.12	32.44	35.74	39.06	42.36
BV	10.00	19.50	28.00	37.00	47.00	55.00	67.00	81.00	90.00	97.00	107.00	115.00
liquid	simulant	sim	sim	sim	sim	sim	sim	sim	sim	sim	sim	sim
Al	16350	17750	16950	16900	17300	16800	17950	17400	17250	16650	17000	16950
B	24	26	24	24	25	24	27	25	25	25	24	24
Ba	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ca	0.9	0.8	0.7	0.8	0.8	0.8	0.6	0.5	0.6	0.9	0.7	0.7
Cd	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Co	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cr	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Cu	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Fe	3.6	4.0	3.6	3.7	3.7	3.6	3.7	3.6	3.6	3.7	3.6	3.6
La	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
Li	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Mg	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mn	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mo	33	36	33	33	33	32	36	33	33	34	33	33
Ni	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
P	90	99	88	90	91	88	99	91	90	92	90	90
Pb	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Si	89	96	87	89	90	88	97	88	88	91	87	88
Sn	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Sr	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ti	0.11	0.19	0.09	0.13	0.39	0.11	0.18	0.08	0.09	0.15	0.09	0.12
V	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
Zn	9.3	6.2	6.3	4.6	5.1	4.9	6.8	5.8	5.1	5.7	4.8	5.5
Zr	0.14	0.20	1.02	0.22	0.54	0.16	0.54	1.1	0.56	0.16	1.4	0.22
S	111	122	110	112	113	109	123	114	112	115	113	112
Re	0.70	0.79	1.01	1.4	1.8	2.5	3.9	4.3	4.7	5.2	5.6	6.0
Re/Re(fd)	0.061	0.068	0.087	0.122	0.159	0.215	0.335	0.368	0.410	0.452	0.482	0.519
Cl												
NO3												
NO2												

Table 9 Analytical Results for Rhenium Run 7

135989	135990	135991	135992	135993	135994	135995	135996	135997	135998	135999	136000	136001
Re-7-13	Re-7-14	Re-7-15	Re-7-16	Re-7-17	Re-7-18	Re-7-19	Re-7-20	Re-7-21	Re-7-22	Re-7-23	Re-7-24	Re-7-25
45.67	48.99	49.99	50.54	51.09	52.61	54.14	55.67	57.17	58.67	60.17	61.67	63.17
124.00	131.00	135.00			0.00	1.73	3.47	5.17	6.87	8.57	10.27	11.97
sim	sim	sim	dil.caustic	dil.caustic	water	water	water	water	water	water	water	water
19600	17150	17450	17100	323	257	115	737	102	76	100	63	98
28	24	26	24	1.1	1.0	0.7	1.5	0.2	0.3	0.3	0.1	0.2
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
0.9	0.5	0.7	0.5	<0.2	<0.2	<0.2	0.4	<0.2	<0.2	<0.2	<0.2	<0.2
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.5	0.5	0.5	0.4	<0.05	<0.05	<0.05	<0.05	0.06	0.05	<0.05	<0.05	<0.05
0.3	0.3	0.3	0.3	0.06	<0.05	0.07	<0.05	<0.05	0.05	<0.05	<0.05	<0.05
4.1	3.6	3.8	3.6	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
37	33	35	33	0.8	0.7	0.4	1.7	0.3	0.1	0.2	0.1	0.2
0.4	0.4	0.4	0.4	<0.06	<0.06	0.2	<0.06	<0.06	0.1	0.10	0.06	<0.06
103	92	96	90	1.8	1.3	<0.9	3.9	<0.9	<0.9	<0.9	<0.9	0.9
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
100	90	93	89	8.4	6.0	2.5	5.3	2.8	2.8	2.3	1.6	1.5
<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	0.58	<0.4	<0.4	0.88	0.69	<0.4	<0.4
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
0.11	0.11	0.18	0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
5.4	5.1	5.6	5.5	1.0	1.0	0.9	0.5	0.6	0.8	1.1	0.66	2.4
0.38	0.24	0.37	0.19	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
128	113	119	112	4.1	2.6	0.7	5.0	1.3	0.9	0.9	0.9	1.0
8.1	7.4	7.9	7.4	2.3	8.6	186	1.9	90	287	212	116	61
0.698	0.642	0.684	0.639	0.200	0.748	16.068	0.161	7.752	24.855	18.319	10.050	5.241
		Cl	4150	204	177	135	244					
		NO3	72593	2784	803	514	3345					
		NO2	48730	817	718	293	2236					

Table 9 Analytical Results for Rhenium Run 7

136002	136003	136004	136005	136006	136007	136008	136009	136010	136011	136018	136019
Re-7-26	Re-7-27	Re-7-28	Re-7-29	Re-7-30	Re-7-31	Re-7-32	Re-7-33	Re-7-34	Re-7-35	Re-7-elucmp	Re-7-fddsp
66.67	69.67	72.67	75.67	78.67	81.67	84.67	87.67	90.67	91.06		
15.93	19.33	22.73	26.13	29.53	32.93	36.33	39.73	43.13	43.58		
water	water	water	water	water	water	water	water	water	water	water	dil.caustic
72	117	113	16	5.3	3.4	3.6	7.2	2.5	1.5	16	2835
0.1	0.2	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	4.2
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.1
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	0.6
<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.2	0.3	0.3	0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	5.8
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	0.2
0.9	1.1	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	16
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1.4	1.3	1.3	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	0.79	21
<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
0.6	0.8	1.1	0.1	0.22	0.06	<0.05	0.09	0.11	<0.05	0.05	0.8
<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
0.7	1.1	0.7	1.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	22
14.2	3.6	1.5	0.67	0.32	0.2	1.2	0.16	0.08	0.10	33	4.4
1.232	0.308	0.130	0.058	0.028	0.017	0.101	0.013	0.006	0.009	2.834	0.378
									Cl	122	725
									NO3	204	18019
									NO2	45	8690

Table 9 Analytical Results for Rhenium Run 7

136020	136021	135012	135013	135975	135976	136014	136015	136016	136017
Re-7-wtrdsp	Re-7-reg	Re-7-fdcmp1	Re-7-fdcmp2	Re-7-efcmp1	Re-7-efcmp2	Re-7-lag1	Re-7-lag2	Re-7-lag3	Re-7-lag4
						18.09	25.99	41.09	48.57
						48.00	72.00	112.00	128.00
water	con.caustic	sim	sim	sim	sim	sim	sim	sim	sim
472	659	16800	16650						
0.6	0.9	23	24						
<0.02	<0.02	<0.02	<0.02						
<0.2	1.1	2.2	2.2						
<0.02	<0.02	<0.02	<0.02						
<0.05	<0.05	<0.05	<0.05						
<0.05	0.06	0.4	0.5						
<0.05	<0.05	0.3	0.3						
0.1	0.2	3.7	3.8						
<0.14	<0.14	<0.14	<0.14						
<0.7	<0.7	<0.7	<0.7						
<0.05	<0.05	0.17	0.175						
<0.05	<0.05	<0.05	<0.05						
1.0	1.3	32	33						
0.06	0.06	0.4	0.4						
3.0	4.2	88	91						
<0.5	<0.5	<0.5	<0.5						
4.5	6.9	92	94						
<0.4	<0.4	<0.4	<0.4						
<0.1	<0.1	<0.1	<0.1						
<0.05	<0.05	0.2	0.2						
<0.12	<0.12	<0.12	<0.12						
0.2	0.3	4.2	4.3						
<0.15	<0.15	<0.15	<0.15						
3.4	8.8	109	113						
40	0.35	11.4	11.7	0.52	0.46	0.13	0.24	0.71	1.3
3.483	0.030	0.985	1.016	0.045	0.040	0.011	0.021	0.061	0.113
194									
1726									
1221									

Table 10 Analytical Results for Rhenium Run 8
Concentrations in mg/L

ADS #	136819	136820	136821	136822	136823	136824	136825	136826	136827	136828	136829	136830
TFL #	Re-8-1	Re-8-2	Re-8-3	Re-8-4	Re-8-5	Re-8-6	Re-8-7	Re-8-8	Re-8-9	Re-8-10	Re-8-11	Re-8-12
liquid	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant
time, hrs.	14.74	17.96	23.64	29.32	35.01	40.69	46.37	52.04	57.72	63.41	69.09	74.77
BV	20.70	25.90	36.10	46.30	56.60	67.00	77.30	87.70	98.10	108.40	118.90	129.40
Al	16800	17000	16700	16800	16600	16350	16900	16700	16450	16300	16450	16650
B	24	24	24	24	24	23	24	24	23	23	23	23
Ba	0.02	0.03	0.03	0.07	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.04
Ca	1.0	0.8	0.8	0.7	0.7	0.8	0.5	0.6	0.7	0.8	0.5	1.2
Cd	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Co	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cr	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Cu	0.3	0.3	0.3	0.2	0.3	0.3	1.7	0.3	0.3	0.3	0.2	0.3
Fe	3.5	3.7	3.8	3.8	3.7	3.7	3.7	3.6	3.6	3.6	3.4	3.7
La	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Li	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.1	<0.1	0.2	0.15	0.13
Mg	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09
Mn	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
Mo	33	33	33	34	33	32	33	33	32	32	33	33
Ni	0.42	0.36	0.38	0.37	0.37	0.36	0.35	0.35	0.33	0.34	0.34	0.35
P	95	92	90	92	90	87	91	89	87	88	89	89
Pb	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Si	93	90	102	103	102	99	103	101	100	99	100	103
Sr	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ti	0.20	0.18	0.20	0.19	0.19	0.17	0.19	0.20	0.17	0.17	0.17	0.19
V	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13
Zn	6.5	4.3	4.3	4.3	4.3	4.1	4.2	4.2	4.1	4.1	4.1	4.2
Zr	0.18	0.20	0.22	0.21	0.17	0.16	0.19	0.18	0.17	0.19	0.19	0.21
Re	1.30	1.41	1.75	2.15	2.63	3.05	3.89	4.44	4.96	5.50	7.28	6.88
Re/Re(fd)	0.102	0.110	0.137	0.169	0.206	0.239	0.305	0.348	0.389	0.431	0.571	0.540

Table 10 Analytical Results for Rhenium Run 8

136831	136832	136833	136834	136835	136836	136837	136838	136839	136840	136841	136842	136843
Re-8-13	Re-8-14	Re-8-15	Re-8-16	Re-8-17	Re-8-18	Re-8-19	Re-8-20	Re-8-21	Re-8-22	Re-8-23	Re-8-24	Re-8-25
simulant	simulant	sim/dil	dil./water	water	water	water	water	water	water	water	water	water
80.4	84.99	85.82	86.76	88.29	89.79	91.29	92.79	94.29	95.79	99.29	102.29	105.29
139.80	148.00	149.70	0.00	1.81	3.59	5.36	7.14	8.91	10.69	14.83	18.38	21.93
16300	16350	11150	1325	33	12	8.3	5.5	3.4	4.4	3.1	0.6	0.9
23	23	16	2.2	0.7	0.5	0.2	<0.21	<0.23	<0.23	<0.23	<0.23	<0.23
0.04	0.03	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.011	<0.011	<0.011	<0.011	<0.011
0.8	0.7	0.5	0.7	0.05	0.06	0.04	<0.04	<0.05	<0.05	<0.05	<0.05	<0.05
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.03	<0.03	<0.03	<0.03	<0.03
<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.4	0.4	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.11	<0.11	<0.11	<0.11	<0.11
0.2	0.2	0.2	<0.05	0.07	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
3.8	3.6	2.4	0.4	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.07	<0.07	<0.07	<0.07	<0.07
0.12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.11	<0.11	<0.11	<0.11	<0.11
<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.10	<0.10	<0.10	<0.10	<0.10
<0.009	<0.009	<0.009	0.02	0.03	0.02	<0.009	<0.009	<0.01	<0.01	<0.01	<0.01	<0.01
33	32	22	2.7	<0.1	<0.1	<0.1	<0.1	<0.11	<0.11	<0.11	<0.11	<0.11
0.35	0.33	0.25	0.06	0.6	0.43	0.21	0.09	<0.07	<0.07	<0.07	<0.07	<0.07
88	87	55	7.0	<0.68	<0.68	<0.68	<0.68	<0.75	<0.75	<0.75	<0.75	<0.75
<0.6	<0.6	<0.6	<0.6	2.5	1.8	0.9	<0.6	<0.65	<0.65	<0.65	<0.65	<0.65
99	98	66	16	3.8	3.2	2.9	2.7	2.6	2.7	2.1	1.4	1.5
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02
0.19	0.17	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.15	<0.15	<0.15	<0.15	<0.15
<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.15	<0.15	<0.15	<0.15	<0.15
4.2	4.1	3.2	<0.37	<0.37	<0.37	<0.37	<0.37	<0.4	<0.4	<0.4	<0.4	<0.4
0.22	0.18	0.11	<0.05	<0.05	<0.05	<0.05	<0.05	<0.06	<0.06	<0.06	<0.06	<0.06
7.27	7.47	8.03	17	398	290	139	54	24	8.3	0.80	0.23	0.104
0.570	0.586	0.630	1.344	31.180	22.748	10.866	4.238	1.875	0.651	0.062	0.018	0.008

Table 10 Analytical Results for Rhenium Run 8

136844	136845	136846	136847	136848	136849	136850	136851	136852	136858	136859	136860
Re-8-26	Re-8-27	Re-8-28	Re-8-29	Re-8-30	Re-8-31	Re-8-32	Re-8-fdcmp1	Re-8-fdcmp2	Re-8-fddsp	Re-8-elucmp1	Re-8-elucmp2
water	water	water	water	water	water	water					
108.29	111.29	114.29	117.29	120.29	123.29	123.69					
25.48	29.03	32.58	36.13	39.68	43.23	43.70					
0.6	0.8	0.5	0.8	0.6	0.4	0.7	17822	17931	2327	3.3	3.3
<0.23	<0.23	<0.23	<0.23	<0.23	<0.23	<0.23	26	26	3.7	<0.23	<0.23
<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	0.03	0.04	<0.011	<0.011	<0.011
<0.05	<0.05	<0.05	<0.05	<0.05	0.0763	<0.05	1.0	1.1	3.1	0.04	0.08
<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	0.43	0.46	<0.11	<0.11	<0.11
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.31	0.31	<0.05	<0.05	<0.05
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	3.9	4.0	0.5	<0.06	<0.06
<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	0.27	0.21	<0.11	<0.11	<0.11
<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	34	35	4.6	<0.109	<0.109
<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	0.40	0.40	0.08	<0.07	<0.07
<0.75	<0.75	<0.75	<0.75	<0.75	<0.75	<0.75	99	99	12.9	<0.75	<0.75
<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65	<0.65
1.5	1.7	1.4	1.5	1.6	1.5	1.7	98	98	32	1.9	2.0
<0.02	<0.02	<0.02	<0.02	<0.02	0.07	0.12	0.06	<0.02	<0.02	<0.02	0.03
<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	0.20	0.20	<0.15	<0.15	<0.15
<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	4.4	4.4	<0.4	<0.4	<0.4
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	0.17	0.18	<0.06	<0.06	<0.06
0.07	<0.05	0.05	0.05	<0.05	<0.05	<0.05	12.7	12.8	5.7	34	33
0.005		0.004	0.004				0.994	1.003	0.449	2.700	2.572

Table 10 Analytical Results for Rhenium Run 8

136861	136881		136853	136854	136855	136856	136857	136817	136818
Re-8-reg1	Re-8-reg2		Re-8-lag1	Re-8-lag	Re-8-lag3	Re-8-lag4	Re-8-lag5	Re-8-efcmp1	Re-8-efcmp2
			simulant	simulant	simulant	simulant	simulant		
			14.24	23.39	38.89	62.79	83.97		
			20.00	35.70	63.75	107.40	146.30		
455	466								
0.6	0.7								
<0.011	<0.011								
1.8	1.7								
<0.03	<0.03								
0.09	0.08								
<0.11	<0.11								
<0.05	<0.05								
<0.06	<0.06								
<0.07	<0.07								
<0.11	<0.11								
<0.10	<0.10								
<0.01	<0.01								
0.77	0.80								
<0.07	<0.07								
2.5	2.7								
<0.65	<0.65								
8.7	9.0								
<0.02	<0.02								
<0.15	<0.15								
<0.15	<0.15								
<0.4	<0.4								
<0.06	<0.06								
1.22	1.26		0.035	0.037	0.069	0.37	1.1	0.27	0.28
0.095	0.099	0.000	0.003	0.003	0.005	0.029	0.086	0.021	0.022

Table 11 Analytical Results for Rhenium Run 9

Concentration in mg/L

ADS #	138031	138032	138033	138034	138035	138036	138037	138038	138039	138040	138041	138042
TFL #	Re-9-1	Re-9-2	Re-9-3	Re-9-4	Re-9-5	Re-9-6	Re-9-7	Re-9-8	Re-9-9	Re-9-10	Re-9-11	Re-9-12
liquid	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant	simulant
hours	4.14	7.15	10.19	13.22	16.25	19.29	22.3	25.34	28.37	31.4	34.44	37.47
BV	11.76	21.67	31.88	42.05	52.23	62.44	72.55	82.75	92.93	103.11	113.32	123.49
Al	16263	16200	16267	16721	16583	16440	16264	16346	16110	16584	16501	16517
B	23.9	23.2	23.5	24.2	23.9	23.6	23.0	23.3	22.9	23.4	23.3	23.4
Ba	0.04	0.05	0.04	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Ca	0.69	0.67	0.63	0.76	0.84	0.85	0.78	0.81	0.80	0.80	0.72	0.70
Cd	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Co	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cr	0.46	0.44	0.43	0.44	0.43	0.43	0.42	0.43	0.42	0.41	0.43	0.42
Cu	0.25	0.26	0.25	0.27	0.26	0.30	0.26	0.26	0.25	0.26	0.26	0.26
Fe	3.6	3.5	3.6	3.8	3.8	3.8	3.7	3.7	3.6	3.7	3.7	3.7
La	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Li	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Mg	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09
Mn	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
Mo	33.2	32.9	32.5	33.6	33.0	32.7	32.2	32.5	32.0	32.7	32.3	32.6
Ni	0.49	0.49	0.47	0.49	0.47	0.45	0.48	0.47	0.46	0.48	0.47	0.49
P	93	92	90	93	91	91	89	90	88	91	90	90
Pb	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Si	104	104	103	105	104	103	101	101	100	104	103	103
Sn	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26
Sr	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Ti	0.16	0.27	<0.14	0.16	0.16	0.17	<0.14	0.15	<0.14	0.15	0.15	0.15
V	0.26	0.26	0.23	0.31	0.31	0.28	0.28	0.25	0.24	0.28	0.27	0.27
Zn	4.3	4.3	4.3	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Zr	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Re	0.28	0.38	0.43	0.77	1.16	1.67	2.22	2.83	3.47	4.06	4.55	5.02
Re/Re(fd)	0.0253	0.0342	0.0388	0.0693	0.1043	0.1504	0.1997	0.2552	0.3124	0.3654	0.4098	0.4525
Al/Al(fd)	1.004	1.000	1.004	1.032	1.024	1.015	1.004	1.009	0.994	1.024	1.019	1.020

Table 11 Analytical Results for Rhenium Run 9

138043	138044	138045	138046	138047	138048	138049	138050	138051	138052	138053	138054	138055
Re-9-13	Re-9-14	Re-9-15	Re-9-16	Re-9-17	Re-9-18	Re-9-19	Re-9-20	Re-9-21	Re-9-22	Re-9-23	Re-9-24	Re-9-25
simulant	simulant	simulant	sim/dil	dil. caust.	dil. caust.	dil. caust.	dil. caust.	dil. caust.	dil. caust.	dil/water	water	water
40.49	43.52	45.55	46.05	46.55	46.79	47	47.24	47.47	47.7	47.94	48.07	48.99
133.63	143.81	150.63	152.31	-1.51	-1.25	-1.02	-0.76	-0.51	-0.26	0.00	0.14	1.14
16409	16324	16380	14852	296	71	78	115	177	179	900	838	123
23	23	23	21	0.6	<0.21	<0.21	<0.21	0.24	0.24	1.29	1.21	0.26
0.04	0.04	0.04	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	0.011167	<0.01	<0.01	<0.01
0.76	0.76	0.80	0.62	0.53	0.16	0.15	0.11	1.04	1.54	0.78	0.51	0.08
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.13	0.17	0.07	<0.05	<0.05
0.42	0.41	0.43	0.38	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
0.26	0.25	0.26	0.24	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
3.6	3.6	3.7	3.2	0.18	<0.06	<0.06	<0.06	0.30	0.43	0.33	0.16	<0.06
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	0.33	0.53	0.17	<0.09	<0.09
<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	0.04	0.07	0.03	<0.009	0.01
32	32	33	30	0.65	0.14	0.15	0.24	0.31	0.30	1.91	1.73	0.23
0.48	0.46	0.46	0.44	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	0.09
89	88	90	78	1.7	<0.68	<0.68	<0.68	0.80	0.83	4.7	4.4	<0.68
<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
102	100	101	87	4.48	1.73	1.67	1.88	19.8	21.2	9.55	6.60	1.76
0.37	0.45	0.27	0.37	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26
0.05	0.05	0.05	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
0.15	<0.14	0.15	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	0.18	<0.14	<0.14	<0.14
0.31	0.27	0.29	0.24	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13
4.3	4.2	4.3	3.9	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37
0.2	0.2	0.2	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.19	<0.05	0.05
5.39	5.77	6.10	6.05	1.89	0.06	0.07	0.09	8.1	9.5	11.3	13.9	75.2
0.4855	0.5196	0.5493	0.5448	0.1704	0.0053	0.0060	0.0084	0.7324	0.8516	1.0196	1.2480	6.7751
1.013	1.008	1.011	0.917	0.018	0.004	0.005	0.007	0.011	0.011	0.056	0.052	0.008

Table 11 Analytical Results for Rhenium Run 9

138056	138057	138058	138059	138060	138061	138062	138075	138076	138077	138078	138079	138080
Re-9-26	Re-9-27	Re-9-28	Re-9-29	Re-9-30	Re-9-31	Re-9-32	Re-9-33	Re-9-39	Re-9-35	Re-9-36	Re-9-37	Re-9-38
water	water	water	water	water	water	water	water	water	water	water	water	water
49.9	50.84	51.75	52.67	56.07	59.07	62.07	65.07	83.07	71.07	74.07	77.07	80.07
2.12	3.14	4.13	5.13	8.81	12.06	15.31	18.56	38.07	25.06	28.31	31.56	34.81
27	12.7	8.1	5.0	4.5	4.7	1.8	4.88	0.70	0.68	<0.32	2.5	1.4
<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21
<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.10	<0.01	<0.01
<0.04	<0.04	0.06	<0.04	<0.04	0.13	<0.04	<0.04	<0.04	<0.04	<0.04	0.06	0.05
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
0.07	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	0.18	<0.06	<0.06	0.12	<0.06	<0.06
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09
0.01	0.01	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	0.08	<0.009	<0.009
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
0.16	0.15	0.15	0.13	0.10	0.06	<0.06	<0.06	<0.06	<0.06	0.16	<0.06	<0.06
<0.68	<0.68	<0.68	<0.68	<0.68	<0.68	<0.68	<0.68	<0.68	<0.68	<0.68	<0.68	<0.68
0.85	0.82	0.81	0.74	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
0.98	0.83	0.76	0.55	0.66	0.34	0.53	0.51	0.33	0.48	0.86	0.43	0.43
<0.26	0.29	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26
<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.27	<0.01	<0.01
<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13
<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37
0.05	0.06	<0.05	<0.05	0.05	<0.05	0.05	0.06	<0.05	<0.05	<0.05	<0.05	<0.05
122	128	127	115	74	48	33	18.9	0.52	4.68	2.43	1.45	0.88
11.0249	11.5463	11.4341	10.3325	6.6231	4.3076	3.0030	1.7065	0.0469	0.4218	0.2189	0.1305	0.0789
0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000

Table 11 Analytical Results for Rhenium Run 9

138081	138082	138083	138084	138085	138063	138064	138065	138066	138067	138068	138069	138070
Re-9-34	Re-9-40	Re-9-41	Re-9-42	Re-9-43	Re-9-fdcmp1	Re-9-fdcmp2	Re-9-lag1	Re-9-lag2	Re-9-lag3	Re-9-reg	Re-9-pack	Re-9-fddsp
water	water	water	water	water	simulant	simulant	simulant	simulant	simulant	con.caust.	dil.caus.	dil.caust.
68.07	86.07	89.07	92.07	92.7			23.02	29.09	45.1			
21.81	41.32	44.57	47.82	48.50			74.96	95.35	149.12			
2.8	5.8	<0.32	<0.32	<0.32	16354	16079	16150	16142	16188	183	419	2226
<0.21	<0.21	<0.21	<0.21	<0.21	23	23	23	23	23	0.4	0.6	3.2
<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.04	0.04	0.04	0.04	<0.01	<0.01	<0.01
<0.04	<0.04	<0.04	<0.04	0.18	0.81	0.86	0.76	0.81	0.82	2.15	1.13	0.41
<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	0.07	<0.05
<0.1	<0.1	<0.1	<0.1	<0.1	0.40	0.40	0.41	0.41	0.42	<0.1	<0.1	<0.1
<0.05	<0.05	<0.05	<0.05	<0.05	0.26	0.26	0.26	0.26	0.26	<0.05	<0.05	<0.05
<0.06	<0.06	0.10	<0.06	<0.06	3.64	3.58	3.57	3.53	3.6	0.09	0.54	0.46
<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	0.2	<0.09
<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	0.02	<0.009
<0.1	<0.1	<0.1	<0.1	<0.1	33	32	32	32	32	0.40	0.80	4.6
<0.06	<0.06	<0.06	<0.06	<0.06	0.47	0.47	0.45	0.45	0.46	<0.06	<0.06	<0.06
<0.68	<0.68	<0.68	<0.68	<0.68	88.9	88.2	88.4	88.9	89	1.2	2.4	12
<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
0.42	0.29	0.39	0.35	0.41	100	101	99	99	99	4.4	11	15
<0.26	<0.26	<0.26	<0.26	<0.26	0.36	0.29	0.43	0.45	0.27	<0.26	<0.26	<0.26
<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.05	0.05	0.05	0.05	0.02	<0.01	<0.01
<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
<0.13	<0.13	<0.13	<0.13	<0.13	0.34	0.31	0.26	0.31	0.32	<0.13	<0.13	<0.13
<0.37	<0.37	<0.37	<0.37	<0.37	4.3	4.2	4.2	4.2	4.37	<0.37	<0.37	0.63
<0.05	<0.05	<0.05	<0.05	<0.05	0.2	0.2	0.2	0.2	0.17	<0.05	<0.05	<0.05
9.02	0.37	0.24	0.20	0.18	11.2	11.0	0.26	0.40	1.09	<0.05	0.58	3.75
0.8127	0.0333	0.0216	0.0183	0.0159	1.0125	0.9885	0.0237	0.0357	0.0981	#VALUE!	0.0521	0.3381
0.000	0.000				1.009	0.993	0.997	0.996	0.999	0.011	0.026	0.137

Table 11 Analytical Results for Rhenium Run 9

138071 Re-9-elucmp1 water	138072 Re-9-elucmp2 water	138073 Re-9-elucmp3 water	138074 Re-9-elucmp4 water
22.2	22.3	0.40	0.52
<0.21	<0.21	<0.21	<0.21
<0.01	<0.01	<0.01	<0.01
<0.04	<0.04	<0.04	<0.04
<0.02	<0.02	<0.02	<0.02
<0.05	<0.05	<0.05	<0.05
<0.1	<0.1	<0.1	<0.1
<0.05	<0.05	<0.05	<0.05
<0.06	<0.06	<0.06	<0.06
<0.06	<0.06	<0.06	<0.06
<0.1	<0.1	<0.1	<0.1
<0.09	<0.09	<0.09	<0.09
<0.009	<0.009	<0.009	<0.009
<0.1	<0.1	<0.1	<0.1
<0.06	<0.06	<0.06	<0.06
<0.68	<0.68	<0.68	<0.68
<0.6	<0.6	<0.6	<0.6
0.64	0.66	0.35	0.35
<0.26	<0.26	<0.26	<0.26
<0.01	<0.01	<0.01	<0.01
<0.14	<0.14	<0.14	<0.14
<0.13	<0.13	<0.13	<0.13
<0.37	<0.37	<0.37	<0.37
0.05	0.06	0.05	<0.05
44.7	45.3	0.59	0.62
4.0255	4.0806	0.0531	0.0555
0.001	0.001	0.000	0.000

Table 12 Analytical Results for Rhenium Run 10

Concentrations in mg/L

ADS #	138696	138697	138698	138699	138700	138701	138702	138703	138704	138705	138706	138707
TFL #	Re-10-1	Re-10-2	Re-10-3	Re-10-4	Re-10-5	Re-10-6	Re-10-7	Re-10-8	Re-10-9	Re-10-10	Re-10-11	Re-10-12
liquid	simulant	sim	sim	sim	sim	sim	sim	sim	sim	sim	sim	sim
hours	4.03	7.05	10.08	13.11	16.15	19.18	22.2	25.23	28.26	31.3	34.33	37.36
BV	13.3	23.3	33.3	43.3	53.3	63.3	73.3	83.3	93.3	103.3	113.3	123.3
Al	16963	16823	16792	17406	16520	16676	16402	16670	16615	16661	16160	16628
B	23.6	24.0	24.7	25.4	24.0	24.0	23.2	24.9	23.9	23.3	23.2	23.3
Ba	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ca	0.8	0.7	0.9	0.9	0.9	0.9	0.9	0.7	0.8	0.8	0.8	0.8
Cr	0.42	0.38	0.39	0.42	0.40	0.38	0.36	0.38	0.37	0.37	0.36	0.35
Cu	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Fe	3.7	3.8	3.9	4.1	3.9	3.8	3.7	3.9	3.8	3.7	3.7	3.7
La	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061
Mg	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084
Mn	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
Mo	33	33	34	36	33	33	32	35	33	32	32	32
Na												
Ni	0.3	0.2	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3
P	93	93	95	99	93	93	90	97	93	91	90	89
Si	99	99.3	104	103	98	100	97	102	99	97	96	97
Sr	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03
Ti	<0.14	<0.14	0.2	0.2	<0.14	0.2	0.2	0.2	<0.14	<0.14	<0.14	<0.14
Zn	4.4	4.4	4.5	4.7	4.5	4.4	4.4	4.5	4.4	4.3	4.3	4.3
Zr	0.2	0.3	0.4	0.2	0.3	0.3	0.2	0.3	0.3	0.2	0.2	0.2
Re	0.41	0.25	0.36	0.45	0.60	0.81	1.0	1.4	1.6	1.7	1.9	2.1
Re/Re(fd)	0.0808	0.0489	0.0709	0.0891	0.1186	0.1594	0.1951	0.2675	0.3061	0.3367	0.3781	0.4170
Al/Al(feed)	1.009712	1.001395	0.999532	1.036065	0.983312	0.992627	0.976286	0.992287	0.988976	0.991755	0.961928	0.989777

Table 12 Analytical Results for Rhenium Run 10

138708	138709	138710	138711	138712	138713	138714	138715	138716	138717	138718	138719	138720
Re-10-13	Re-10-14	Re-10-15	Re-10-16	Re-10-17	Re-10-18	Re-10-19	Re-10-20	Re-10-21	Re-10-22	Re-10-23	Re-10-24	Re-10-25
sim	sim	sim	sim/dil	dil.caus.	dil.caus.	dil.caus.	dil.caus.	dil.caus.	dil.caus.	dil.caus.	dil/water	water
40.38	43.41	45.45	45.95	46.45	46.68	46.9	47.13	47.36	47.6	47.83	47.96	48.88
133.3	143.3	150.0	151.6	-1.6	-1.4	-1.1	-0.9	-0.7	-0.4	-0.1	0.0	1.0
16957	16337	16977	13228	261	65	76	80	124	188	928	761	101
24.0	22.9	24.6	19.0	0.7	<0.21	<0.21	<0.21	<0.21	<0.21	1.3	1.1	<0.21
0.1	0.1	0.1	0.05	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012
0.9	0.8	0.9	0.7	0.1	0.1	0.2	0.1	0.5	0.3	0.2	0.1	<0.04
0.38	0.35	0.38	0.30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
0.1	0.1	0.1	0.1	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049
3.9	3.6	4.0	3.0	0.1	<0.044	0.1	0.05	0.2	0.1	0.2	0.2	<0.044
<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061
<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	0.11	0.08	<0.084	<0.084	<0.084
<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	0.02	0.01	<0.009	<0.009	<0.009
34	32	34	26	0.6	0.1	0.1	0.1	0.19	0.33	1.9	1.6	0.2
				7217.0	5934.0	6425.0	6167.0	6302.00	6470.00	8307.0	7078.0	1129.0
0.2	0.2	0.3	0.2	<0.062	<0.062	<0.062	<0.062	<0.062	<0.062	<0.062	<0.062	<0.062
94	88	95	68	1.4	<0.68	<0.68	<0.68	0.7	1.1	4.8	4.1	<0.68
99	96	102	72	3.0	1.4	1.7	1.5	8.6	6.0	6.3	5.3	0.9
0.04	0.03	0.04	0.02	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
0	<0.14	0	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
4.5	4.2	4.5	3.5	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37
0.2	0.2	0.2	0.1	<0.048	<0.048	<0.048	<0.048	<0.048	<0.048	<0.048	<0.048	0.06
2.5	2.5	2.9	2.7	1.0	<0.05	<0.05	<0.05	3.7	5.6	6.2	7.7	40.5
0.4806	0.4949	0.5644	0.5389	0.1879				0.7351	1.0899	1.2176	1.5022	7.9504
1.009374	0.972462	1.010538	0.787397	0.015565	0.003853	0.004494	0.004779	0.007356	0.011169	0.055235	0.045309	0.006
			Na/Na(fd)	0.059156	0.048639	0.052664	0.050549	0.051656	0.053033	0.06809	0.058016	0.009254

Table 12 Analytical Results for Rhenium Run 10

138721	138722	138723	138724	138725	138726	138727	138728	138729	138730	138731	138732	138733
Re-10-26	Re-10-27	Re-10-28	Re-10-29	Re-10-30	Re-10-31	Re-10-32	Re-10-33	Re-10-34	Re-10-35	Re-10-36	Re-10-37	Re-10-38
water	water	water	water	water	water	water	water	water	water	water	water	water
49.8	50.73	51.65	52.56	55.83	66.65	69.65	72.65	75.65	78.65	81.65	84.65	87.65
2.0	3.0	4.0	5.0	8.5	8.5	11.8	15.0	18.3	21.5	24.8	28.0	31.3
21	12	7.2	6.0	2.6	29	183	41	2.8	1.9	2.1	3.9	0.7
<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21
<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012
<0.04	0.1	<0.04	<0.04	<0.04	0.05	0.12	<0.04	<0.04	<0.04	0	<0.04	<0.04
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049
<0.044	<0.044	<0.044	<0.044	<0.044	<0.044	<0.044	<0.044	<0.044	<0.044	0	<0.044	<0.044
<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061
<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084
<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	0.01	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
295	173	135	97	67	166	1300.0	305	70	41	35	63	25
<0.062	0	<0.062	<0.062	<0.062	<0.062	<0.062	<0.062	<0.062	<0.062	<0.062	<0.062	<0.062
<0.68	<0.68	<0.68	<0.68	<0.68	<0.68	1.2	<0.68	<0.68	<0.68	<0.68	<0.68	<0.68
0.4	0.4	0.2	0.4	<0.13	0.4	1.3	0.4	0.2	0.2	0.3	0.2	0.2
<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37
0.05	<0.048	<0.048	0.1	<0.048	0.06	0.06	0.06	0.06	0.06	0.05	<0.048	0.06
71.4	76.6	66.7	61.6	34.0	1.3	1.5	4.2	15.4	5.8	1.3	0.2	0.09
13.9930	15.0240	13.0724	12.0850	6.6738	0.2454	0.3023	0.8189	3.0254	1.1304	0.2570	0.0478	0.0184
0.001256	0.000716	0.000428	0.000355	0.000155	0.001699	0.010904	0.002455	0.000167	0.000114	0.000126	0.000233	4.01E-05
0.002418	0.001418	0.001107	0.000795	0.000549	0.001361	0.010656	0.0025	0.000574	0.000336	0.000287	0.000516	0.000205

Table 12 Analytical Results for Rhenium Run 10

138734	138735	138736	138737	138738	138739	138740	138741	138742	138743	138744	138745
Re-10-39	Re-10-40	Re-10-41	Re-10-42	Re-10-43	Re-10-44	Re-10-lag1	Re-10-lag2	Re-10-lag3	Re-10-lag4	Re-10-fdcmp1	Re-10-fdcmp2
water	water	water	water	water	water	sim	sim	sim	sim	sim	sim
90.65	93.65	96.65	99.65	102.65	103.4	17.83	26.13	41.56	45.06		
34.5	37.8	41.0	44.3	47.5	48.4	58.8	86.2	137.1	148.7		
1.3	0.5	0.5	<0.24	0.5	1.3	16336	16402	16505	16461	16363	16701
<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	23	23	24	24	23	24
<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	0.08	0.08	0.08	0.08	0.07	0.07
<0.04	<0.04	0.1	<0.04	0.1	0.2	0.8	0.8	0.9	1.0	0.9	1.0
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.35	0.36	0.38	0.38	0.35	0.39
<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	0.06	0.07	0.06	0.06	0.07	0.12
<0.044	<0.044	<0.044	<0.044	<0.044	<0.044	3.6	3.7	3.8	3.7	3.7	3.8
<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061	<0.061
<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084	<0.084
<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	31	32	33	32	32	33
24	16	15	12	16	44						
<0.062	<0.062	<0.062	<0.062	<0.062	<0.062	0.3	0.3	0.3	0.3	0.3	0.3
<0.68	<0.68	0.8	<0.68	<0.68	<0.68	89	92	93	92	90	94
0.2	0.5	0.4	0.4	0.5	0.3	98	101	102	101	100	104
<0.002	0.004	<0.002	<0.002	<0.002	<0.002	0.05	0.05	0.05	0.05	0.05	0.05
<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	0.14	0.16	0.15	<0.14	0.18
<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	4.1	4.2	4.3	4.3	4.2	4.3
0.05	0.06	0.06	0.05	0	<0.048	0.2	0.2	0.2	0.3	0.2	0.2
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.24	0.33	0.55	0.59	5.0	5.2
						0.0465	0.0641	0.1077	0.1150	0.9898	1.0170
7.54E-05	2.87E-05	3.01E-05		2.84E-05	7.48E-05	0.972386	0.9763052	0.982424	0.9798398	0.973998716	0.994116058
									free OH, M	1.52	1.51
0.000197	0.000131	0.000123	9.84E-05	0.000131	0.000361				Cl	4559	4631
									NO3	70573	7086
									NO2	46095	47343

Table 12 Analytical Results for Rhenium Run 10

138746 Re-10-efcmp1 sim	138747 Re-10-efcmp2 sim	138748 Re-10-elucmp1 water	138749 Re-10-elucmp2 water	138750 Re-10-reg con caus	138751 Re-10-fddsp dil caustic
16793	16626	86	78	1084	1766
24	24	0.22	<0.21	1.5	2.4
0.08	0.08	<0.012	<0.012	<0.012	<0.012
0.9	0.8	<0.04	<0.04	0.9	0.3
0.40	0.38	<0.1	<0.1	<0.1	<0.1
0.07	0.07	<0.049	<0.049	<0.049	<0.049
3.9	3.7	<0.044	<0.044	0.26	0.43
<0.061	<0.061	<0.061	<0.061	<0.061	<0.061
<0.084	<0.084	<0.084	<0.084	<0.084	<0.084
<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
33	32	0.2	0.2	2.2	3.6
0	0	<0.062	<0.062	<0.062	<0.062
95	93	1.0	1.1	6.7	10
103	102	0.7	0.6	9.6	12
0.05	0.05	<0.002	<0.002	0.01	0.005
0.18	0.17	<0.14	<0.14	<0.14	<0.14
4.4	4.3	<0.37	<0.37	<0.37	0.49
0.23	0.23	0.08	0.07	0.05	0.06
0.35	0.40	3.4	3.3	0.73	1.8
0.0682	0.0781	0.6595	0.6496	0.1434	0.3574
0.999612674	0.989668076	0.005147	0.004619672	0.064509	0.1050987
				0.88	
			170	478	525
		390	385	614	12889
		197	192	1844	5445

Table 13 Mass Balances

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Run	mass simulant pumped lb	simulant density g/mL	Re conc feed mg/L	mass Re in feed, g	Re conc spent mg/L	mass Re spent, g	eluant vol 1, liters	eluant vol 2, liters	elucmp1 mg/L	elucmp2 mg/L	vol reg liters	Re reg mg/L	vol fddsp liters	Re fddsp mg/L
3	376	1.225	11	1.53	0.042	0.01	39	0	12.5	0	4.3	0	4.8	3.9
2R	527	1.223	9.95	1.95	0.186	0.04	41	13.2	47	1.2	2.4	0	1.12	4.8
4	506	1.223	11.55	2.17	0.94	0.18	26.5	4.11	7.1	17.55	0.22	0	2.1	6.8
5	427	1.225	12	1.90	1.1	0.17	40.65	4.55	30.5	142.5	2.4	0.09	4.5	7.45
5IE	0	1	0	0.00	0	0.00	56	0	14.65	0	0	0	0	0
6	495	1.22	11.45	2.11	0.12	0.02	46	0	38	0	2.4	0.1	4	3.68
7	437	1.222	11.55	1.88	0.49	0.08	29.8	20.3	33	33	2.15	0.35	3.45	4.4
8	480.1	1.223	12.75	2.27	0.275	0.05	43.25	9.17	33.5	33.5	1.9	1.24	2.3	5.7
8IE	0	1	0	0.00	0	0.00	30	0	21.8	0.7	0	0	0	0
9	486.2	1.226	11.1	2.00	0.3	0.05	37.08	19.73	44.9	0.6	2.3	0	3.9	3.75
9IE	0	1	0	0.00	0	0.00	46.08	12.28	5.74	0.023	2.95	0.16	0	0
10	484.1	1.223	5.1	0.92	0.375	0.07	47.3	0	3.35	0	4.8	0.73	4	1.8

Table 13 Mass Balances

	16	17	18	19	20	21	22	23	24	25	26	27
Run	lead column	mass Re in feed, g	mass Re spent sim. g	integral mass exiting lead, g	integral mass exiting lag, g	lead col. elution Simpson, g	lead col. elution trapezoid, g	mass elucmp, g	mass added to lead, g	mass added to lag, g	break through BV	simulant flowrate BV/hr
3	1	1.53	0.006	0.23	0.013	1.81		0.49	1.30	0.217	133	2.79
2R	2	1.95	0.036	0.67	0.037	1.87		1.94	1.28	0.633	140	1.85
4	1	2.17	0.177	0.85	0.18	1.99		0.26	1.32	0.67	110	1.84
5	2	1.90	0.174	0.91	0.16	1.95		1.89	0.99	0.75	80	2.6
5IE	1	0.00	0.000	0	0			0.82	0.00	0		
6	1	2.11	0.022	0.379	0.017	1.85		1.75	1.73	0.362	170	1.85
7	2	1.88	0.080	0.586	0.063	1.86	1.79	1.65	1.29	0.523	120	2.7
8	1	2.27	0.049	0.69	0.049	2.1	1.96	1.76	1.58	0.641	120	1.74
8IE	2	0.00	0.000	0	0			0.65	0.00	0		
9	1	2.00	0.054	0.49	0.068	1.58		1.68	1.51	0.422	155	3.3
9IE	1	0.00	0.000	0	0	0.01		0.26	0.00	0		
10	1	0.92	0.067	0.22	0.056	0.655		0.16	0.70	0.164	150	3.3

Table 13 Mass Balances

Run	28 eluent flowrate BV/hr	29 mass fraction on lead	30 mass fraction on lag	31 mass fraction leaking	32 final lead concen-tration normal	33 final lag concen-tration normal	34 parameter x axis	35 preloading of lead column, g	36 preloading of lead, BV	37 deconta-mination factor
3	1.3	0.850	0.142	0.004	0.45	0.03				261.9
2R	1.13	0.656	0.325	0.019	0.77	0.04	35.38	0.217	18.17	53.5
4	1.3	0.608	0.309	0.081	0.76	0.2	62.78	0.633	45.67	12.3
5	1.13	0.521	0.395	0.092	0.79	0.21	70.71	0.67	46.53	10.9
5IE	1.1						0.00			
6	1.1	0.820	0.172	0.010	0.47	0.025	17.21	0	0.00	95.4
7	1.14	0.688	0.279	0.042	0.69	0.12	51.23	0.362	26.12	23.6
8	1.1	0.696	0.282	0.022	0.62	0.09	50.37	0.523	34.18	46.4
8IE	1.1						0.00			
9	1.1	0.755	0.211	0.027	0.58	0.1	30.69	0	0.00	37.0
9IE	1.1						0.00			
10	1.1	0.760	0.179	0.074	0.59	0.12	30.69	0	0.00	13.6
							constant			
							9.30			

Figure 1 Schematic of TFL Pilot Scale Ion Exchange Facility

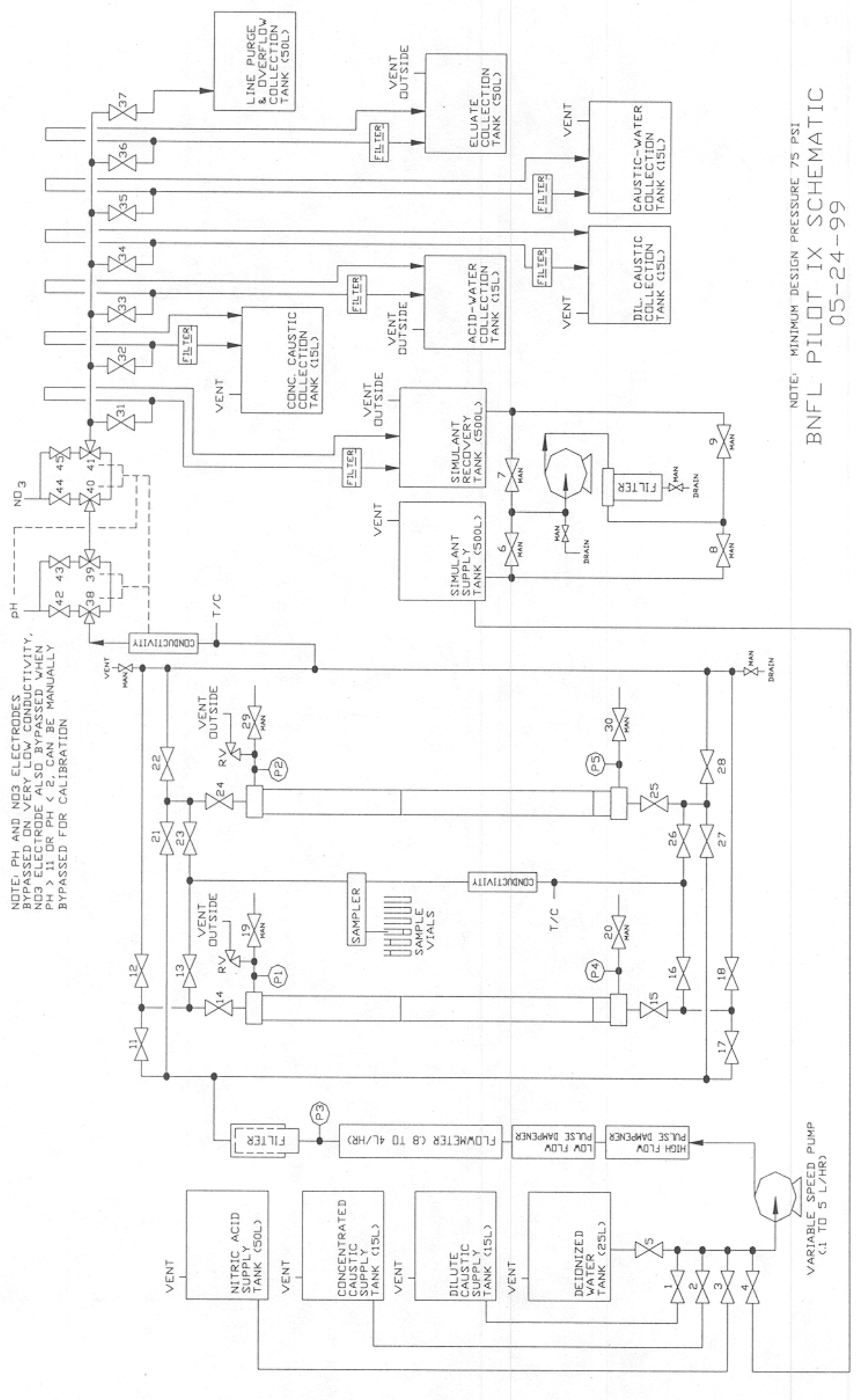

Figure 2

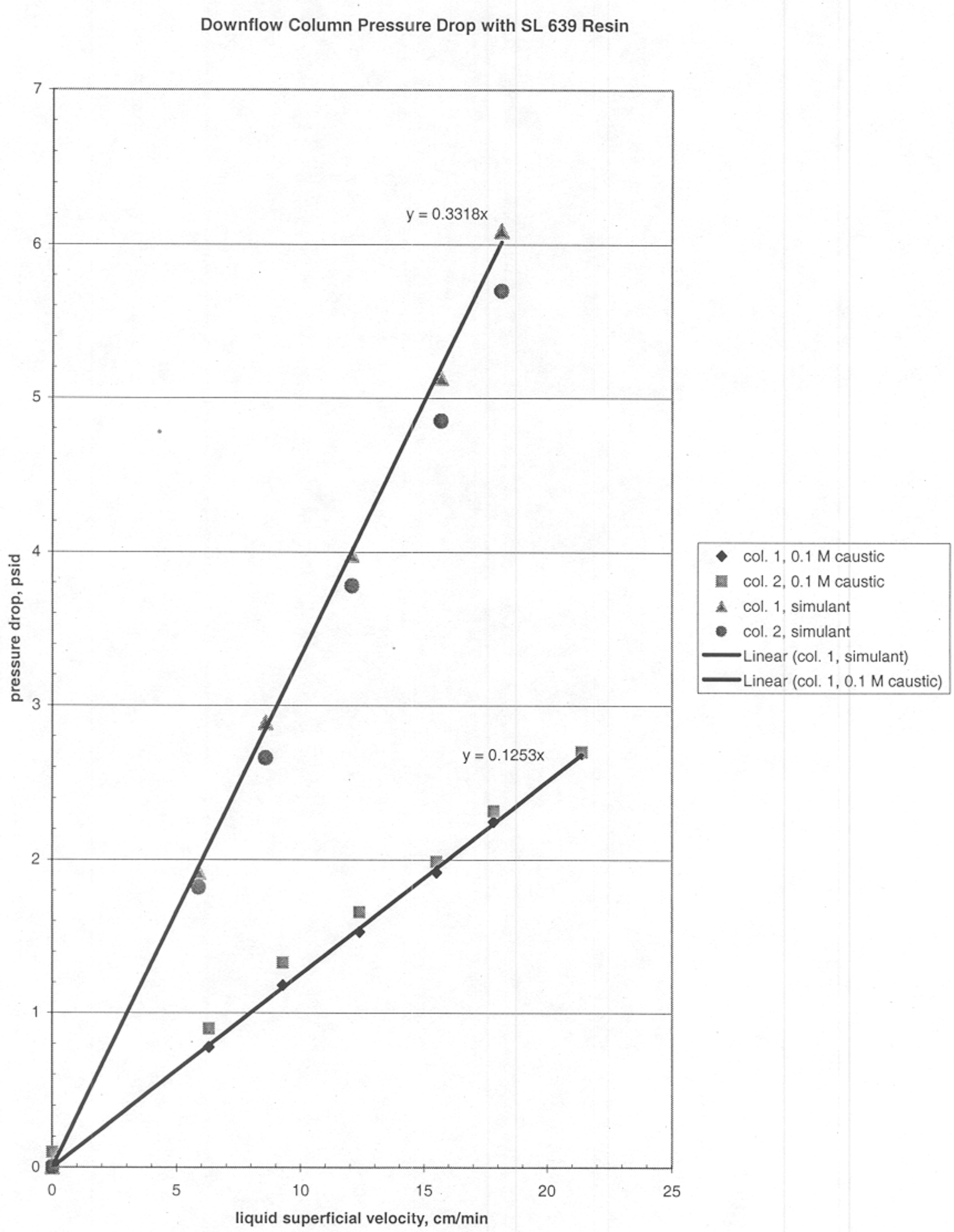
Downflow Column Pressure Drop with SL 639 Resin
y = 0.3318x
y = 0.1253x
pressure drop, psid
liquid superficial velocity, cm/min
0
1
2
3
4
5
6
7
0
5
10
15
20
25
col. 1, 0.1 M caustic
col. 2, 0.1 M caustic
col. 1, simulant
col. 2, simulant
Linear (col. 1, simulant)
Linear (col. 1, 0.1 M caustic)

Figure 3

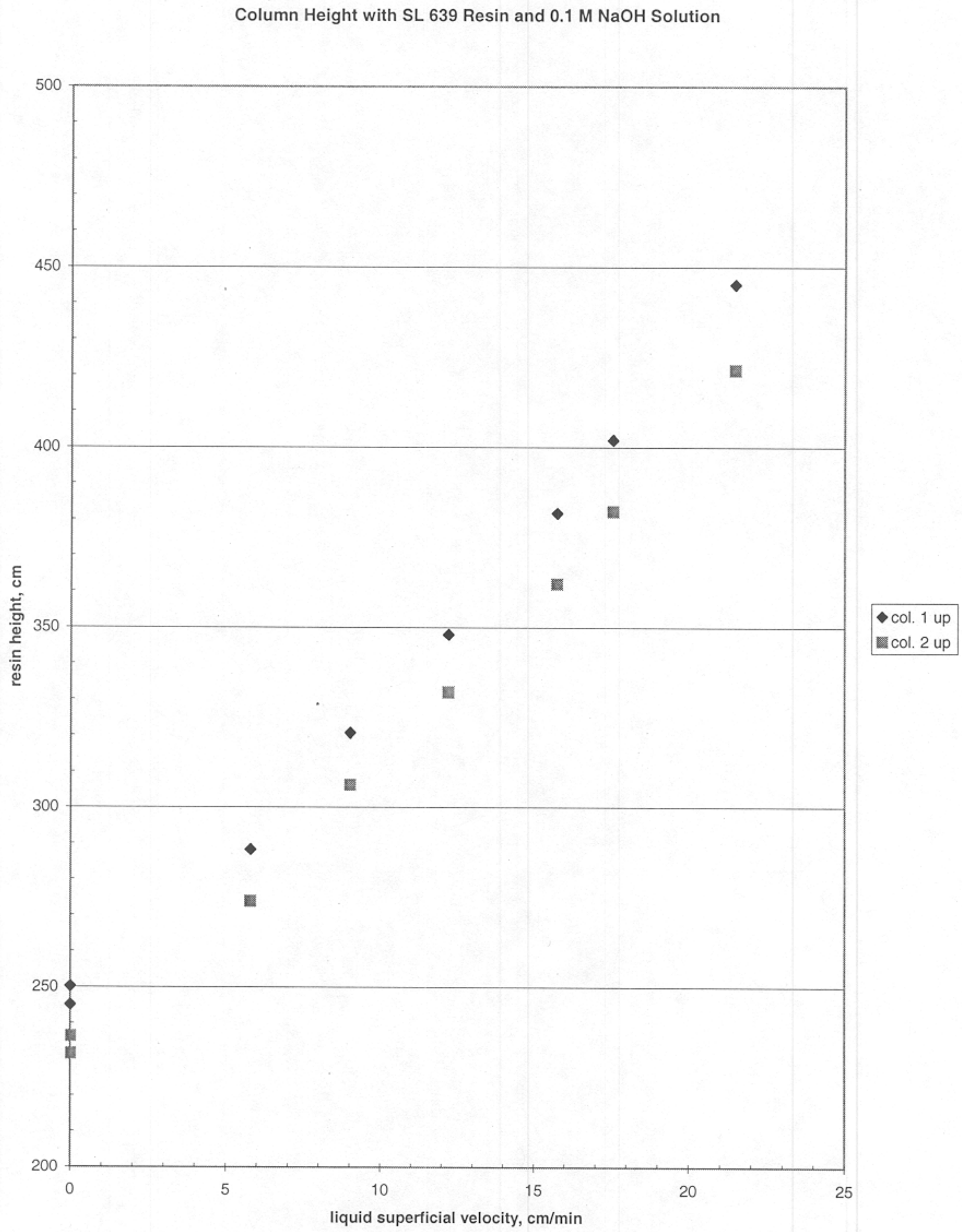
Column Height with SL 639 Resin and 0.1 M NaOH Solution
500
450
400
350
300
250
200
resin height, cm
0
5
10
15
20
25
liquid superficial velocity, cm/min
col. 1 up
col. 2 up

Figure 4   Re Run 3 Loading Profiles

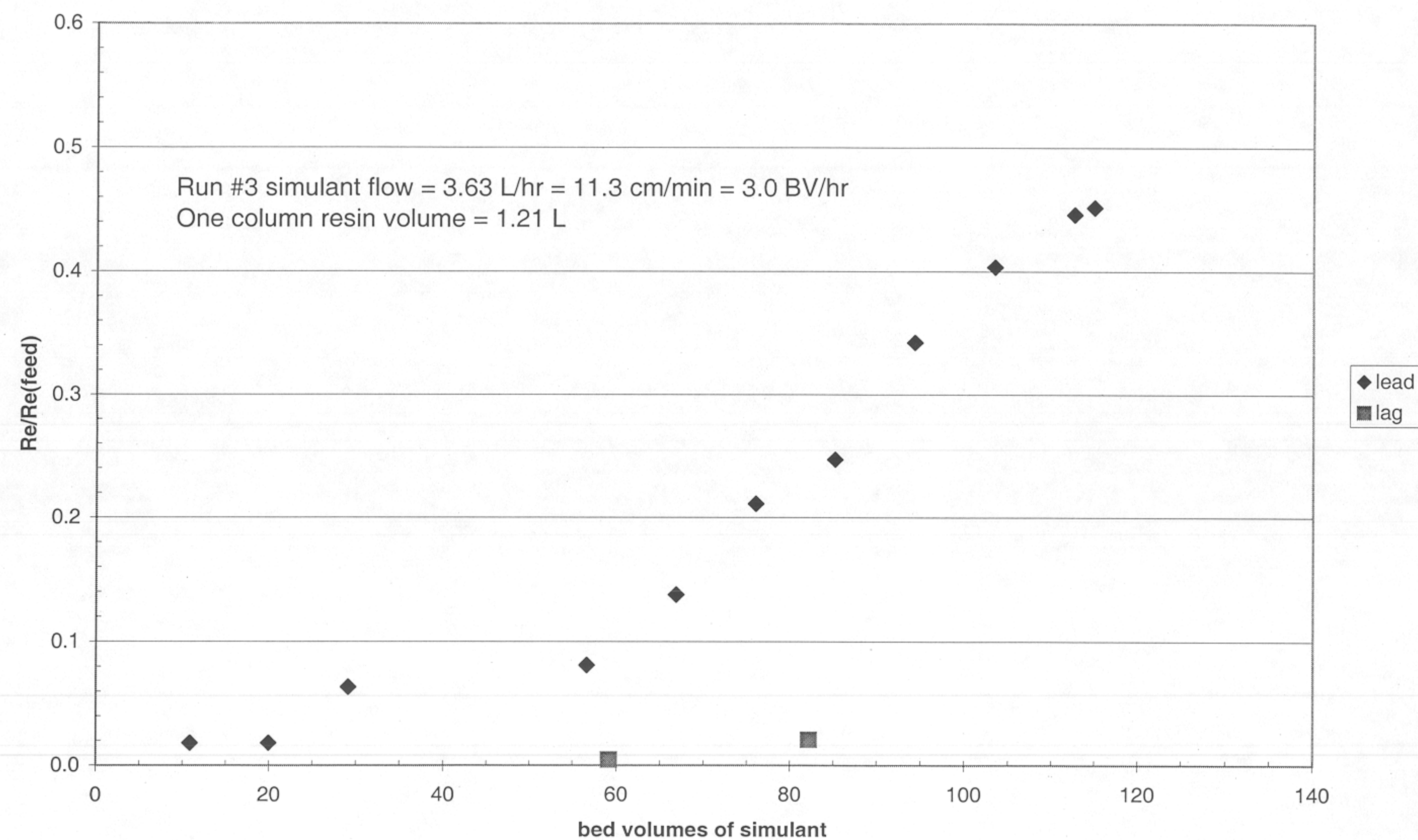

Figure 5 Re Run 2R Loading Profiles

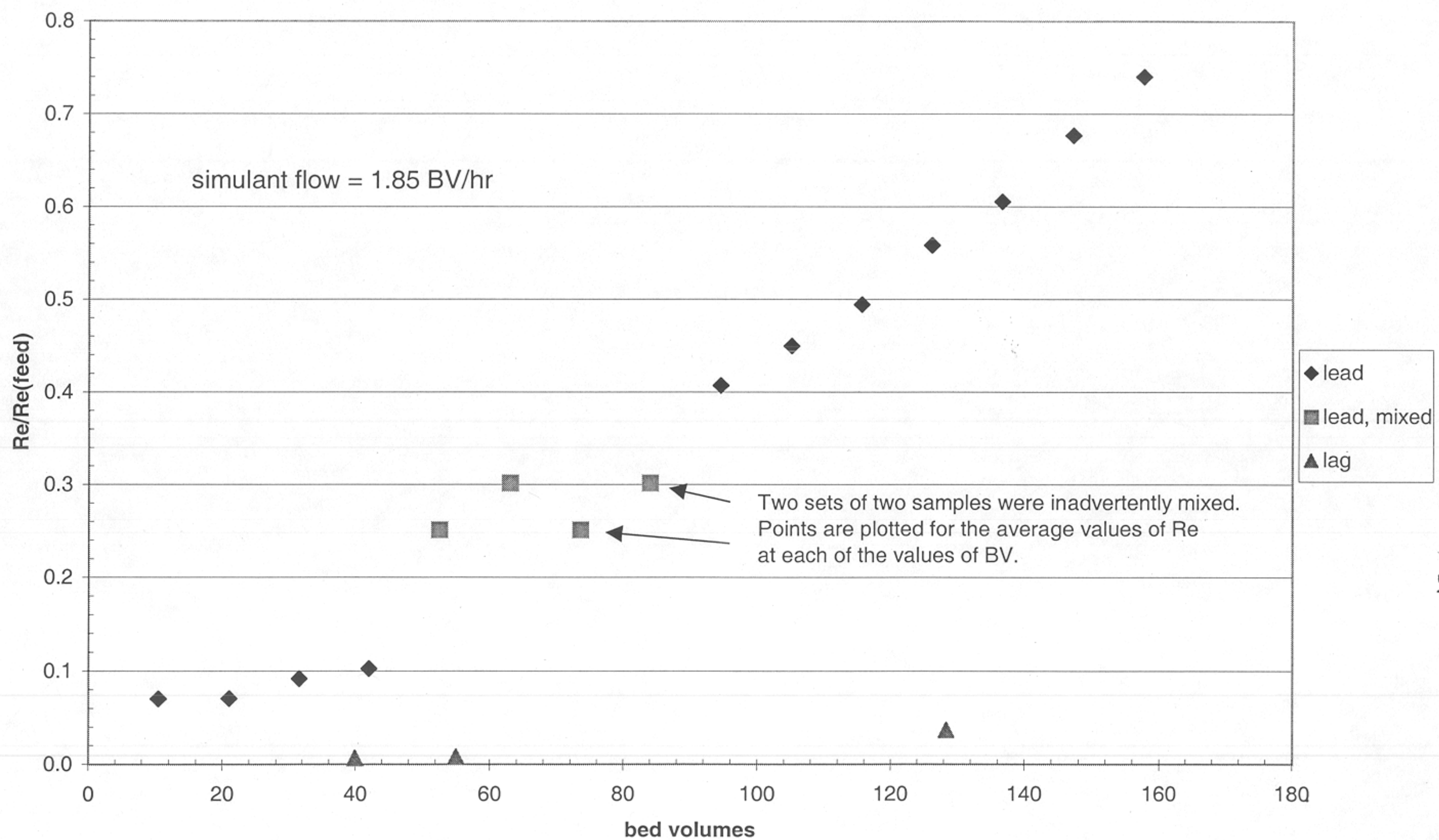

Figure 6   Re Run 4 Loading Profiles

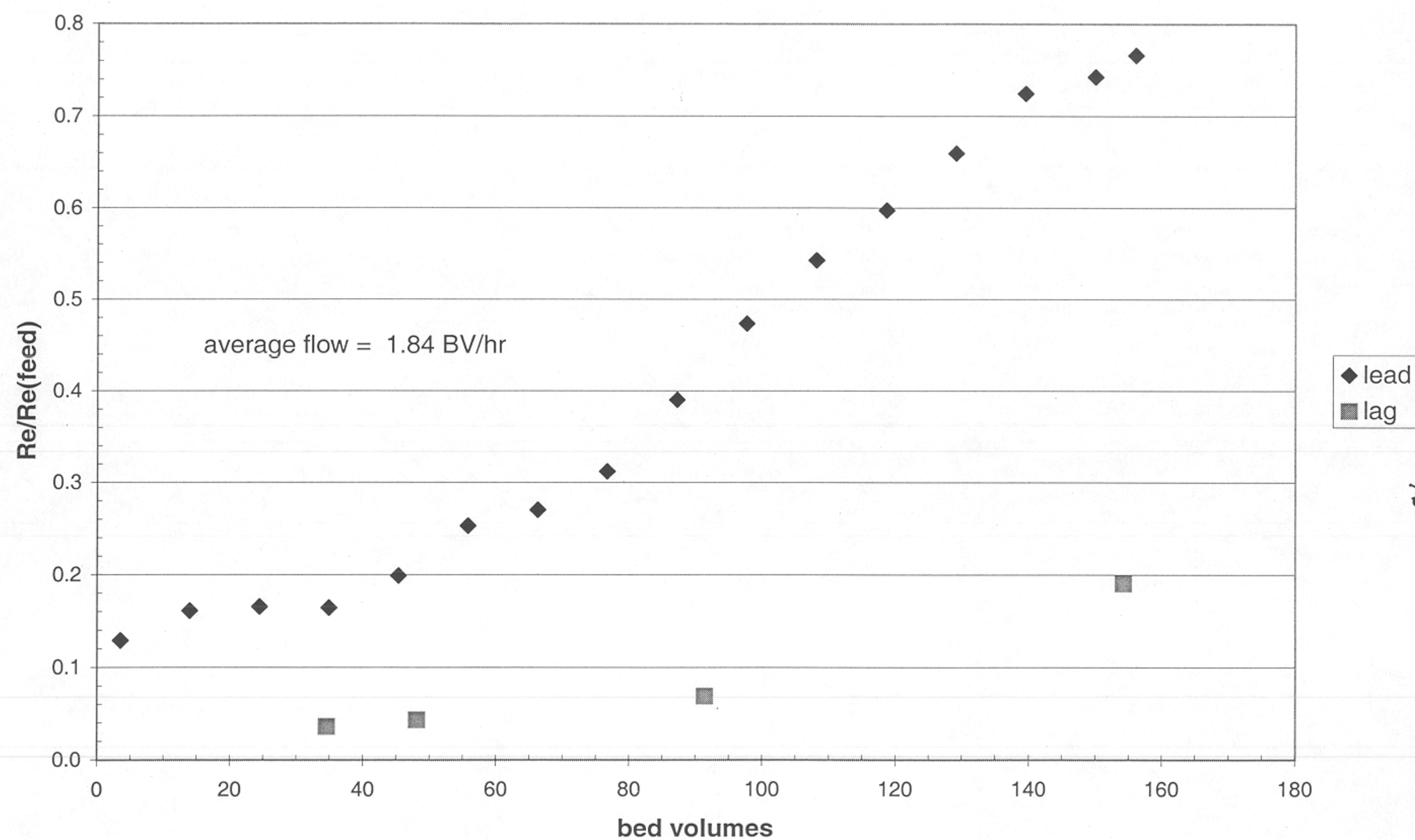

Figure 7   Re Run 5 Loading Profiles

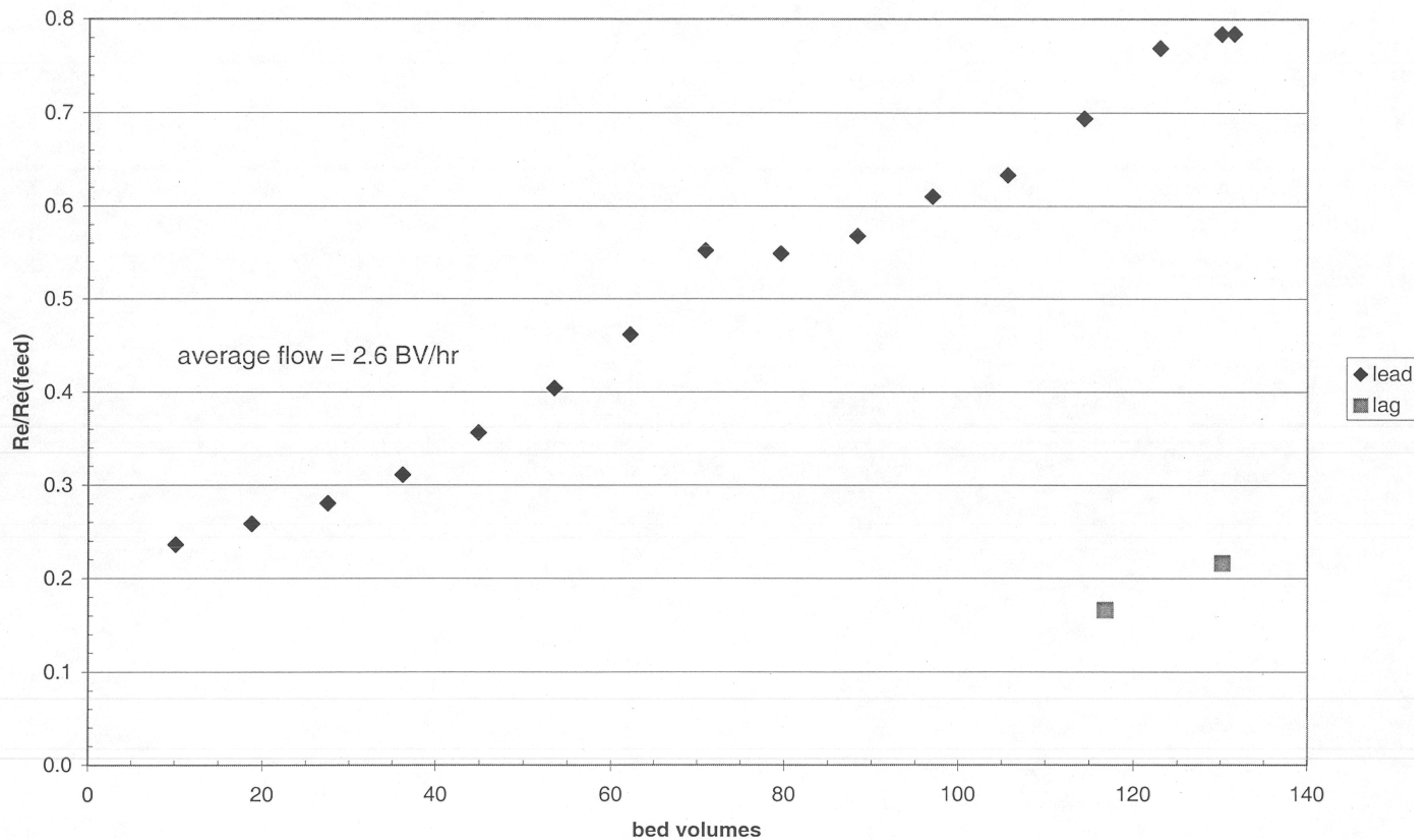

Figure 8 Re Run 6 Loading Profiles

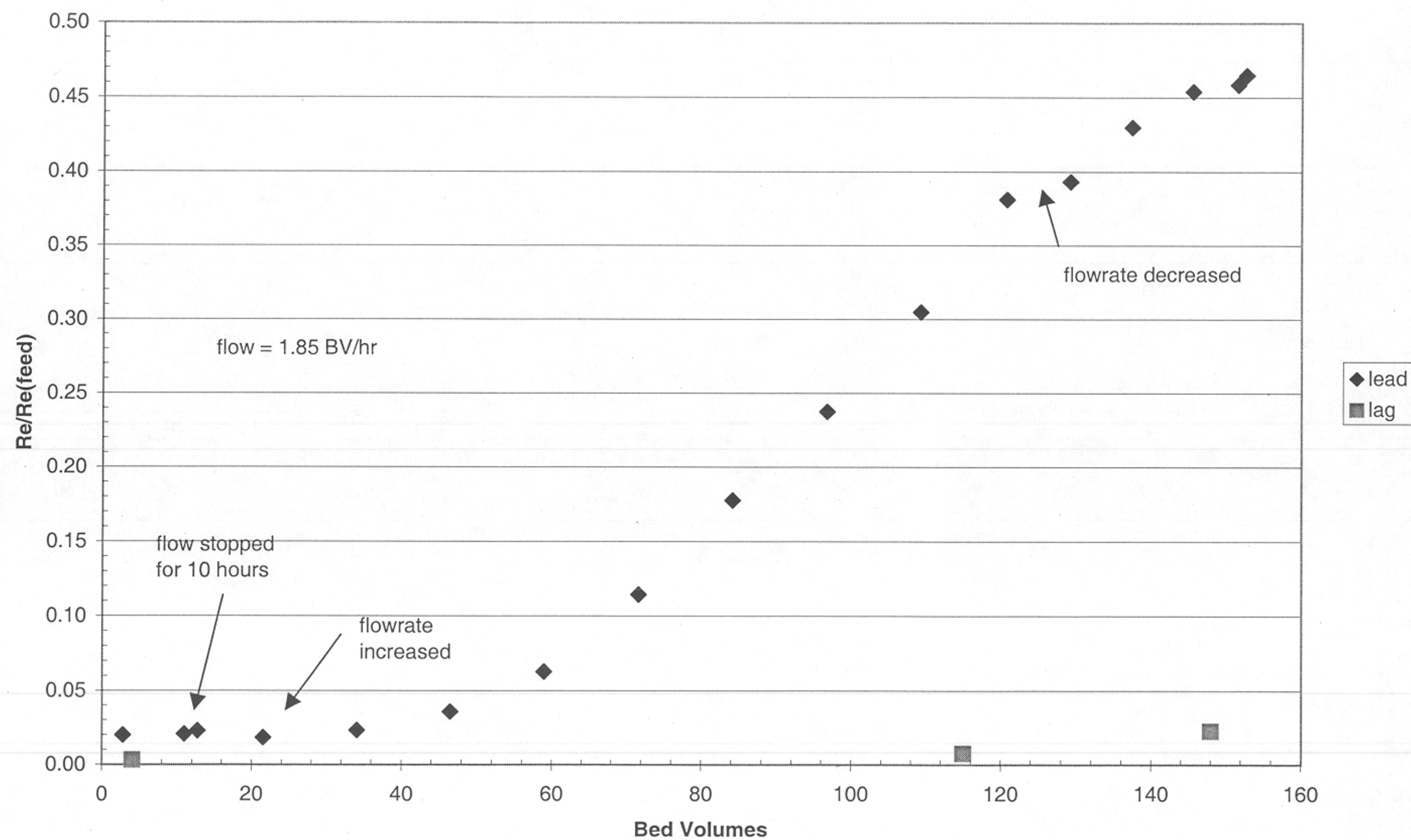

Figure 9   Re Run 7 Loading Profiles

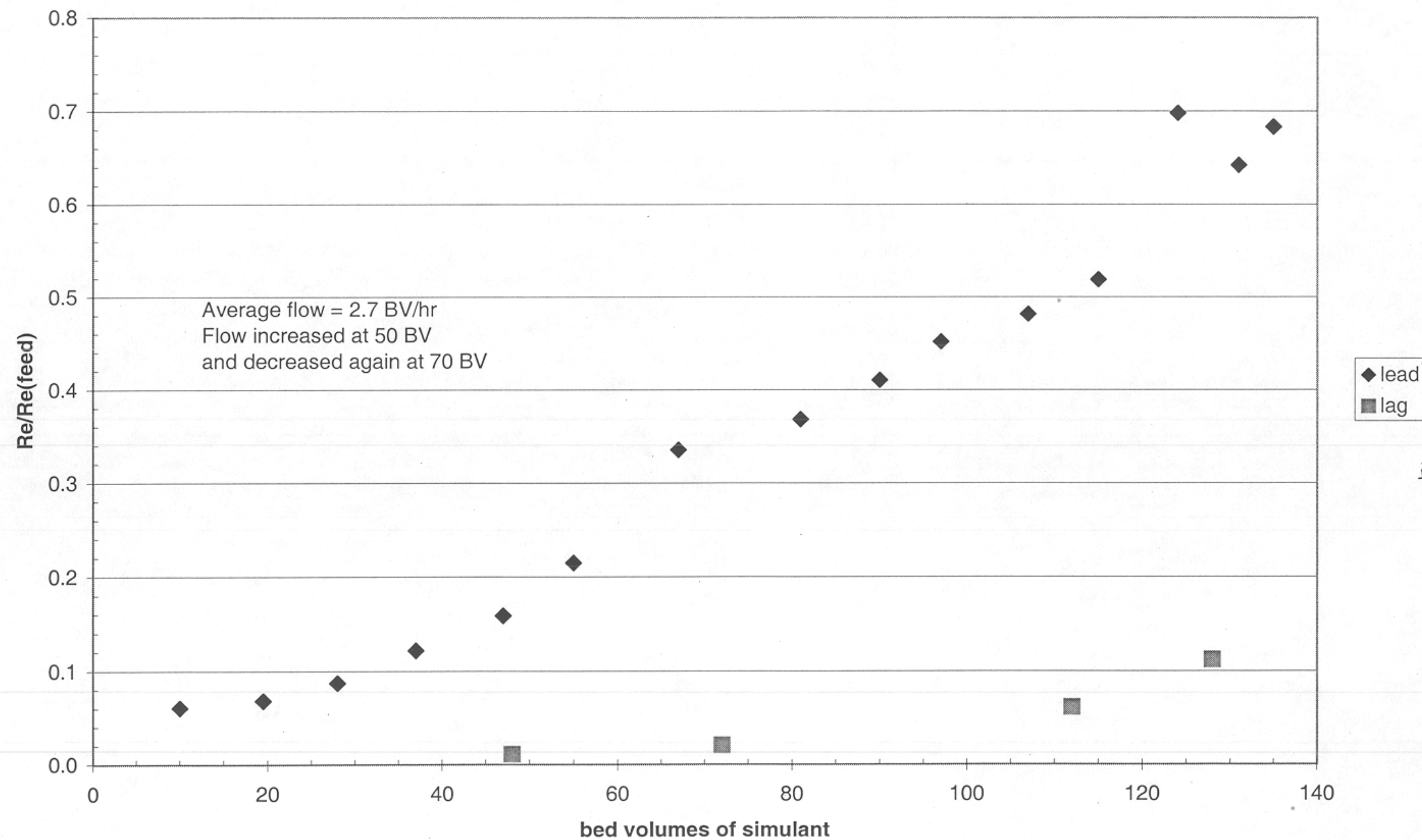

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Figure 10   Re Run 8 Loading Profile

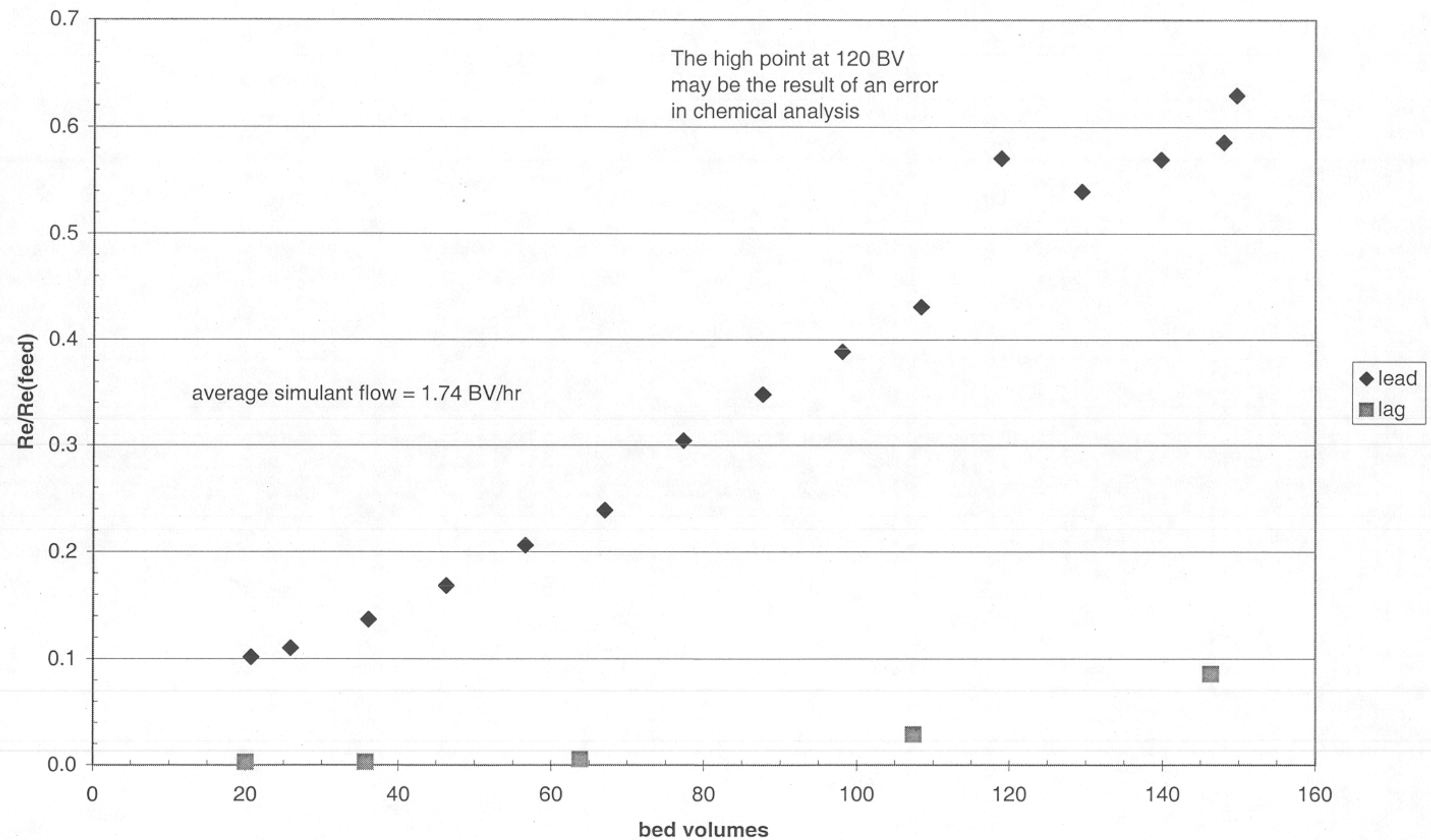

Figure 11 Run 9 Rhenium Loading Profiles

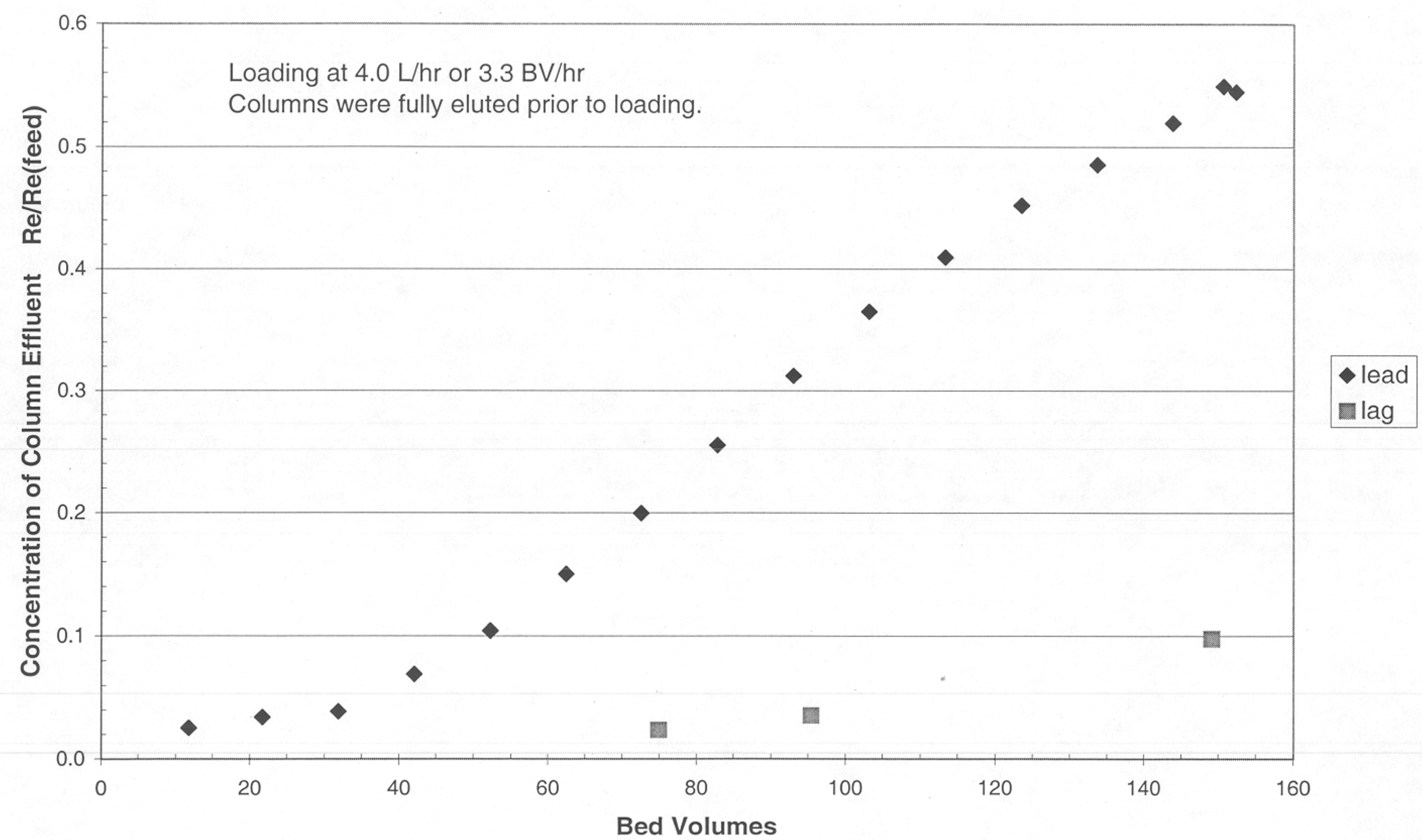

Figure 12 Re Run 10 Loading Profile

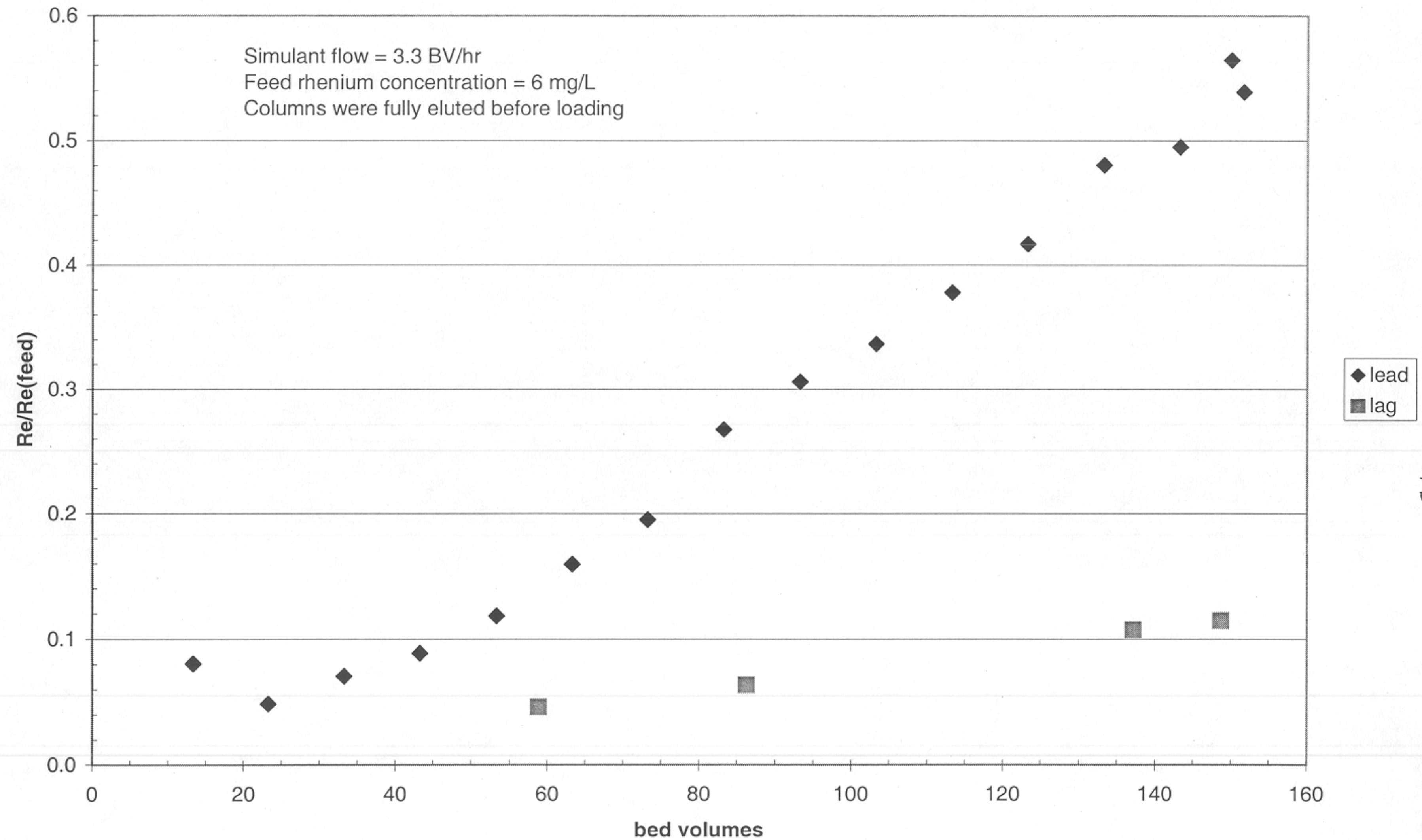

Figure 13 Number of Bed Volumes for Breakthrough

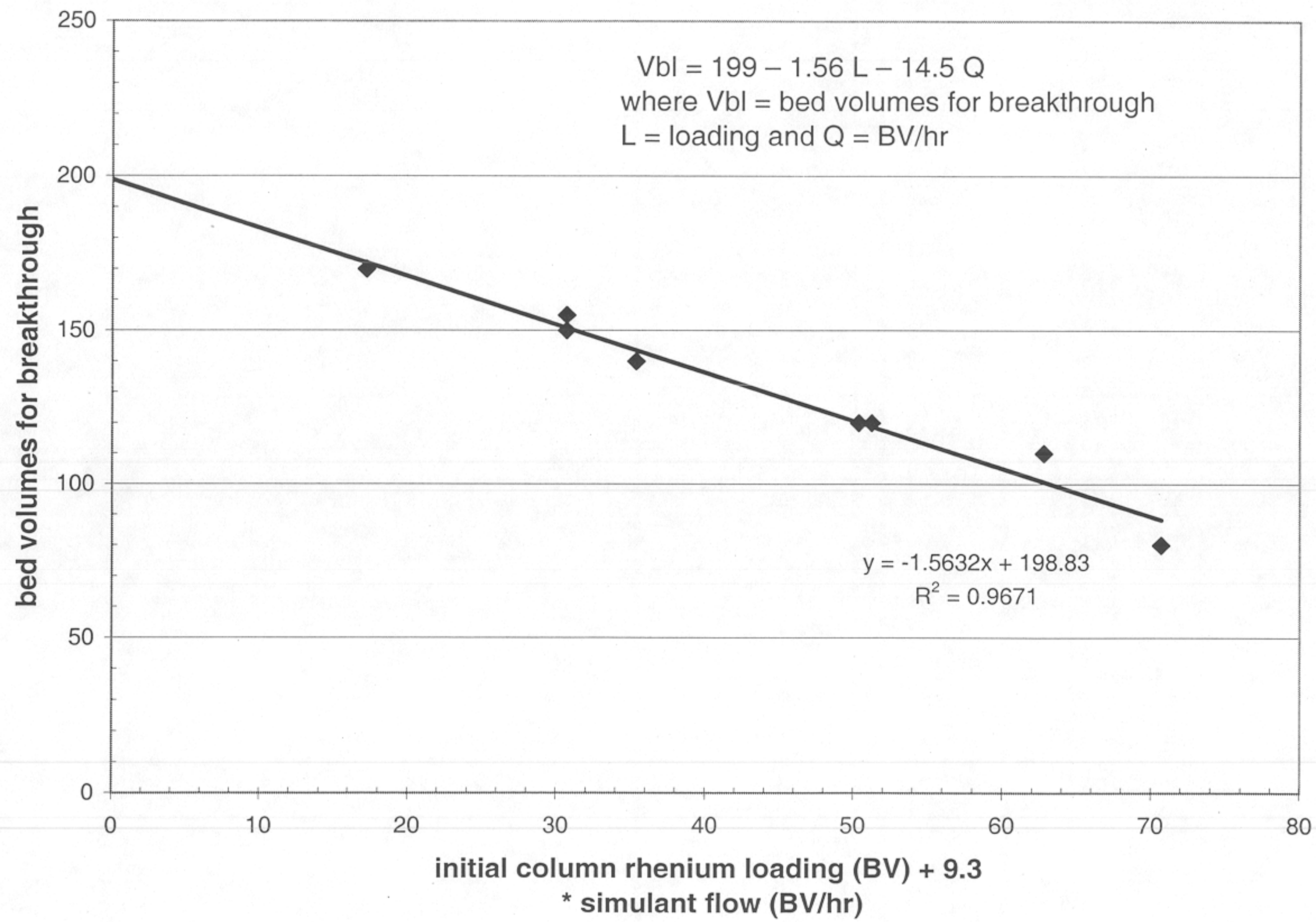

Figure 14 Re Run 3 Elution Profile

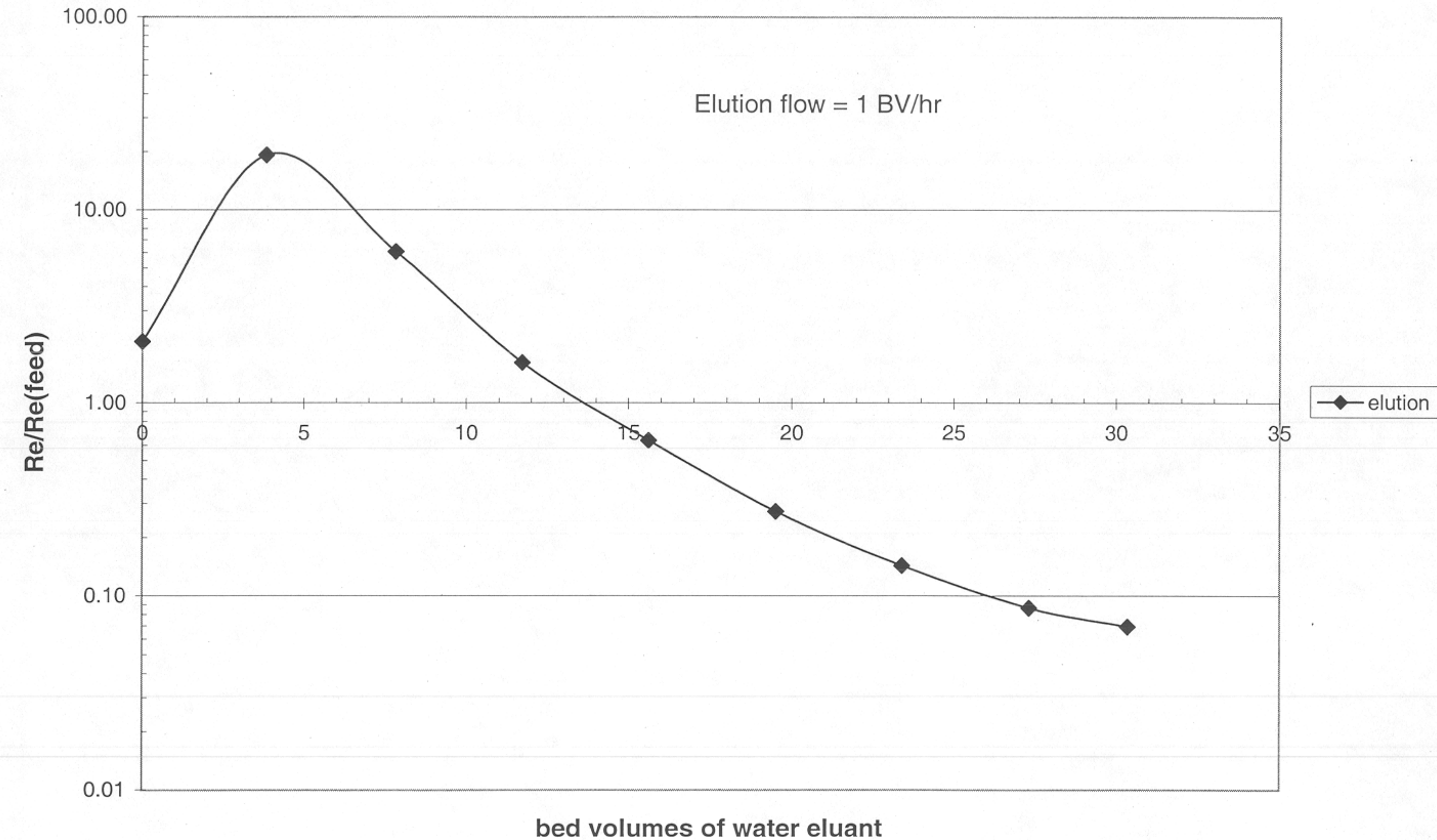

Figure 15 Re Run 2R Elution Profile

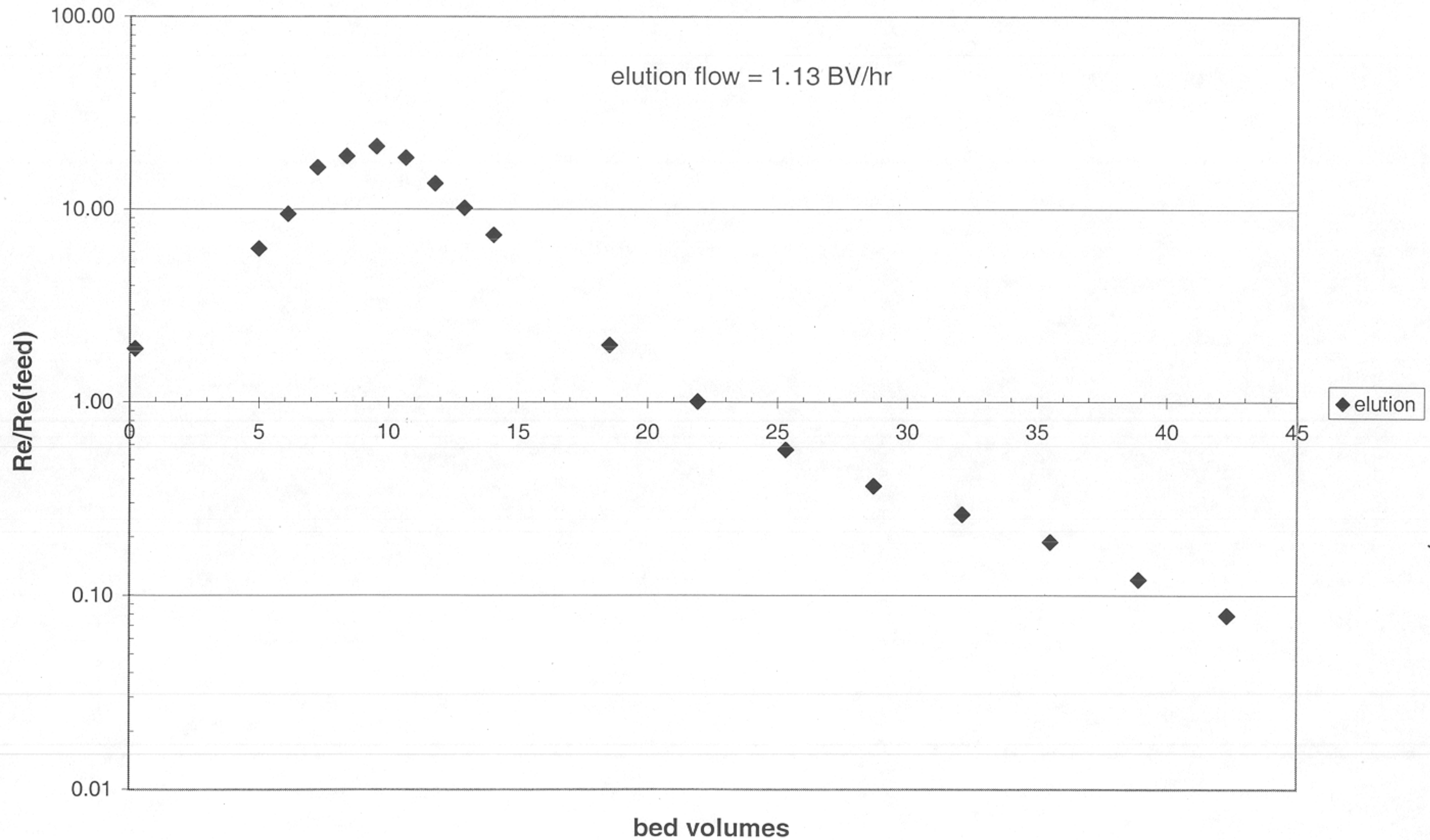

Figure 16   Re Run 4 Elution Profile

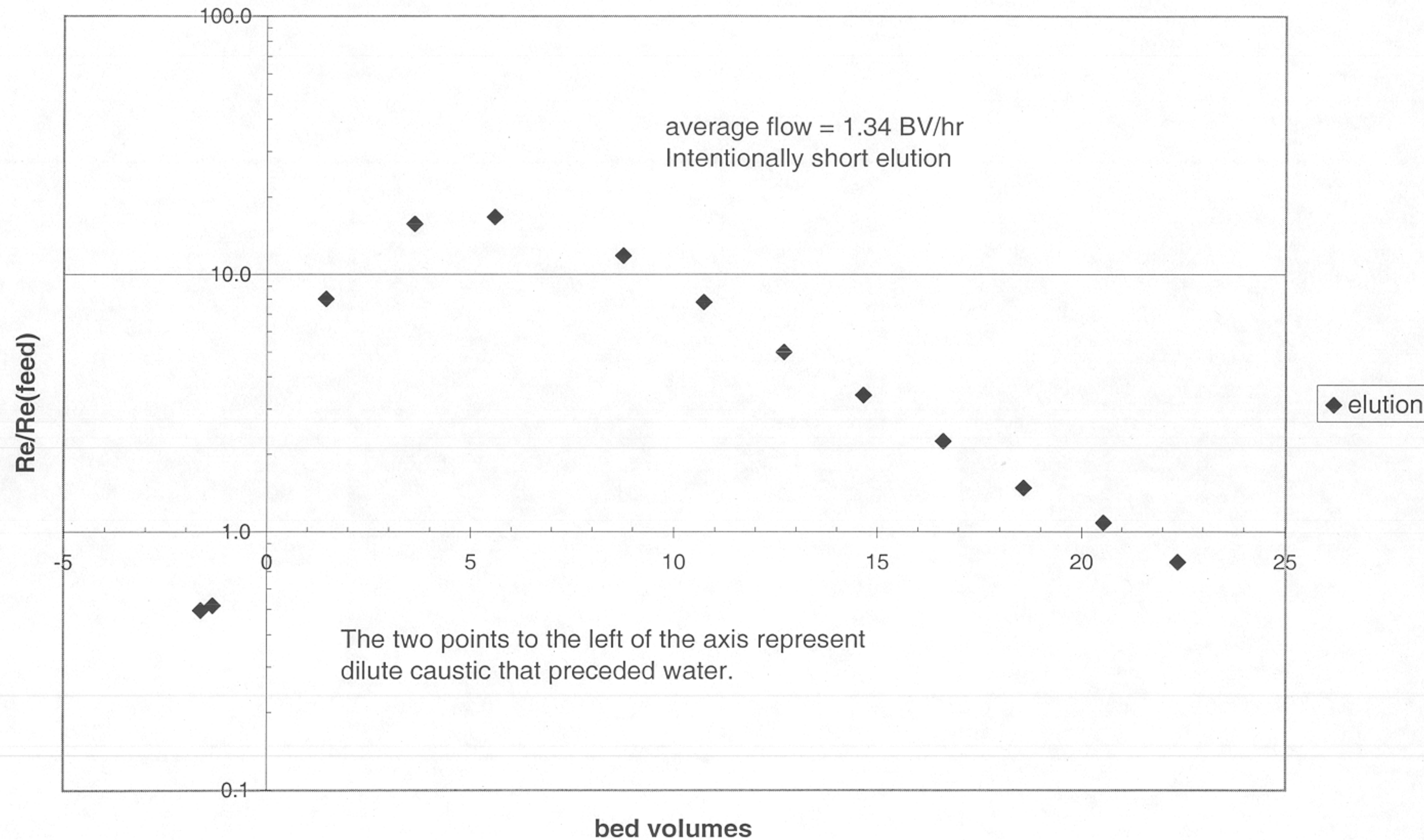

Figure 17   Re Run 5 Elution Profile

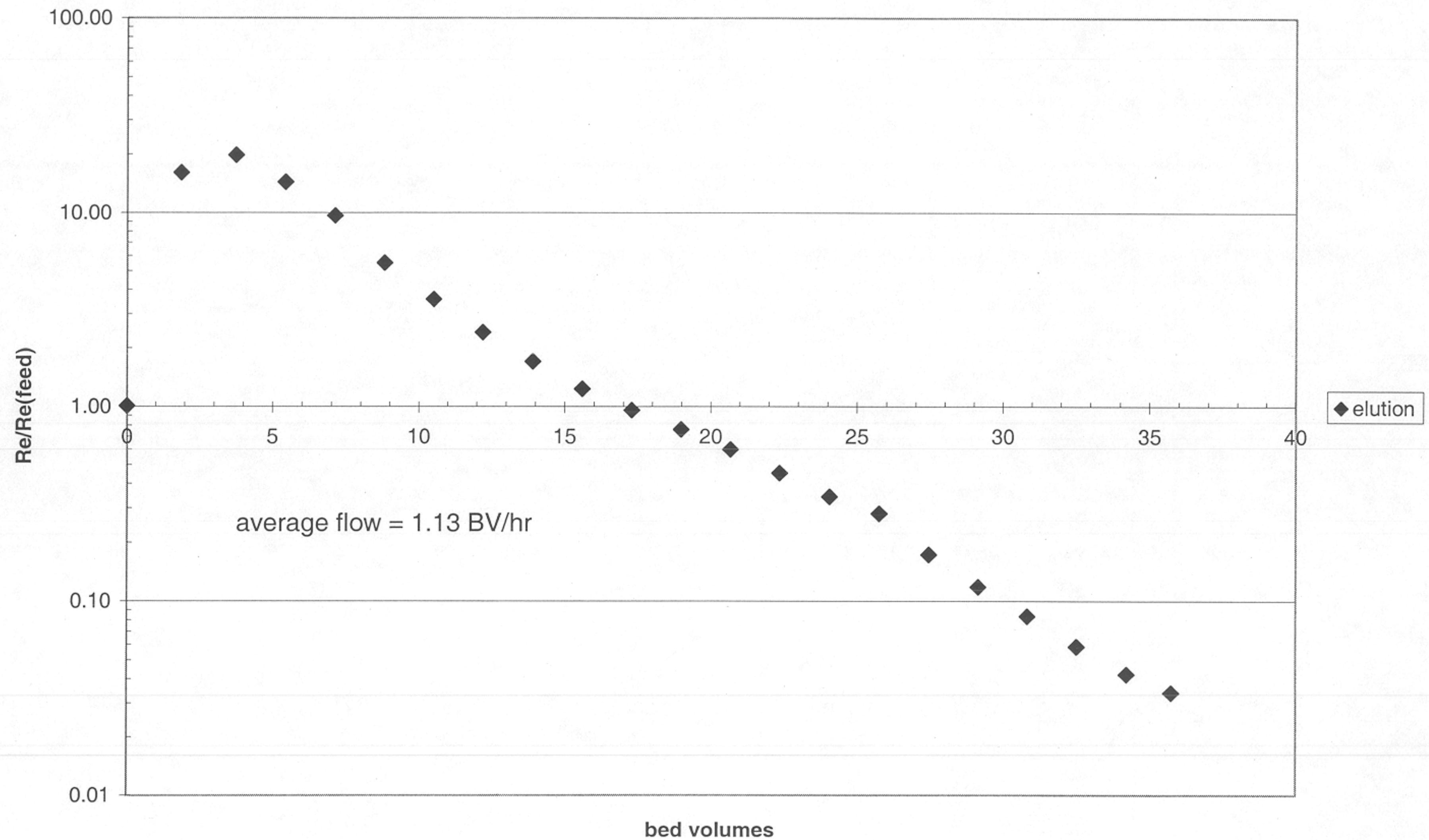

Figure 18   Re Run 5 IE Elution Profiles

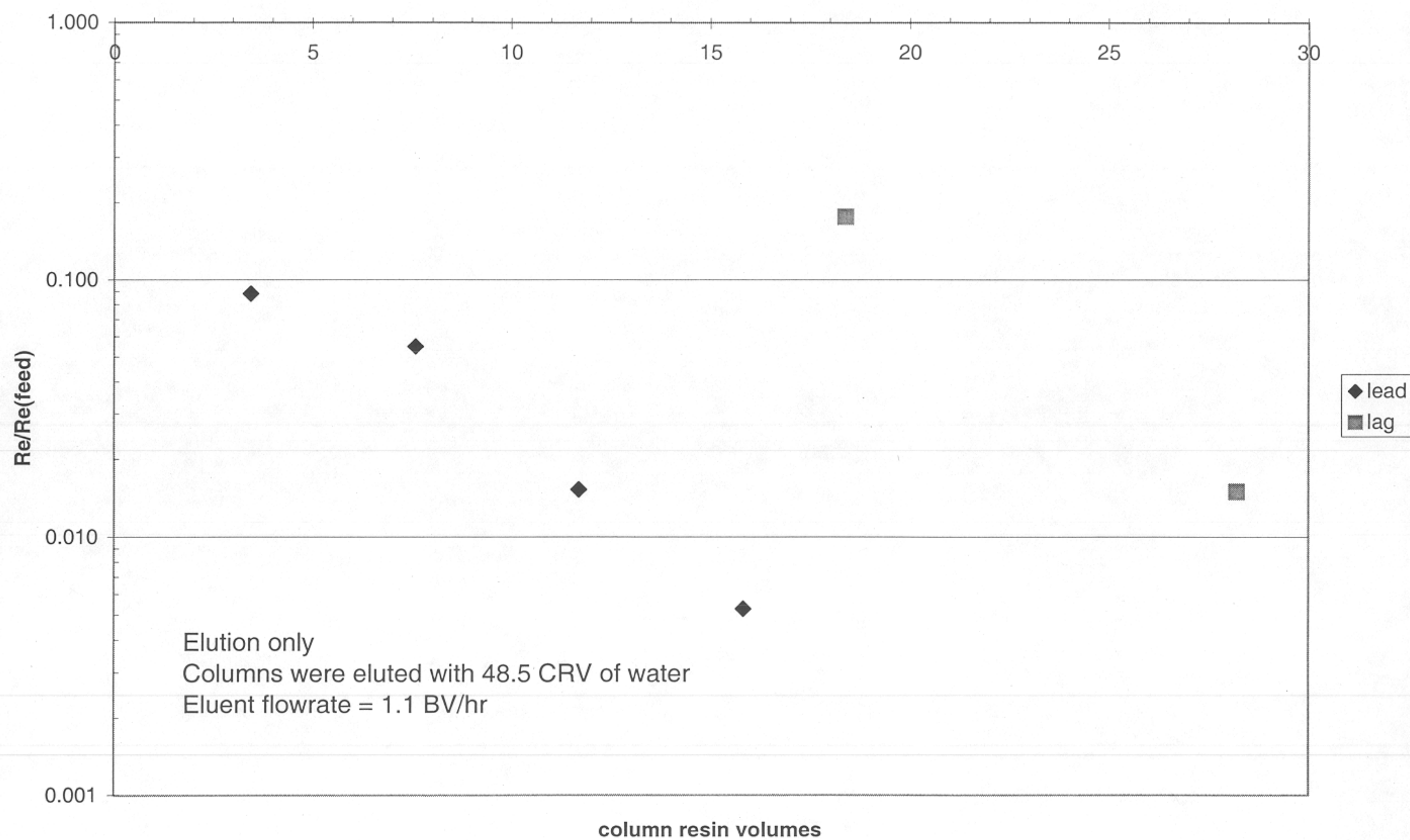

Figure 19 Re Run 6 Elution Profile

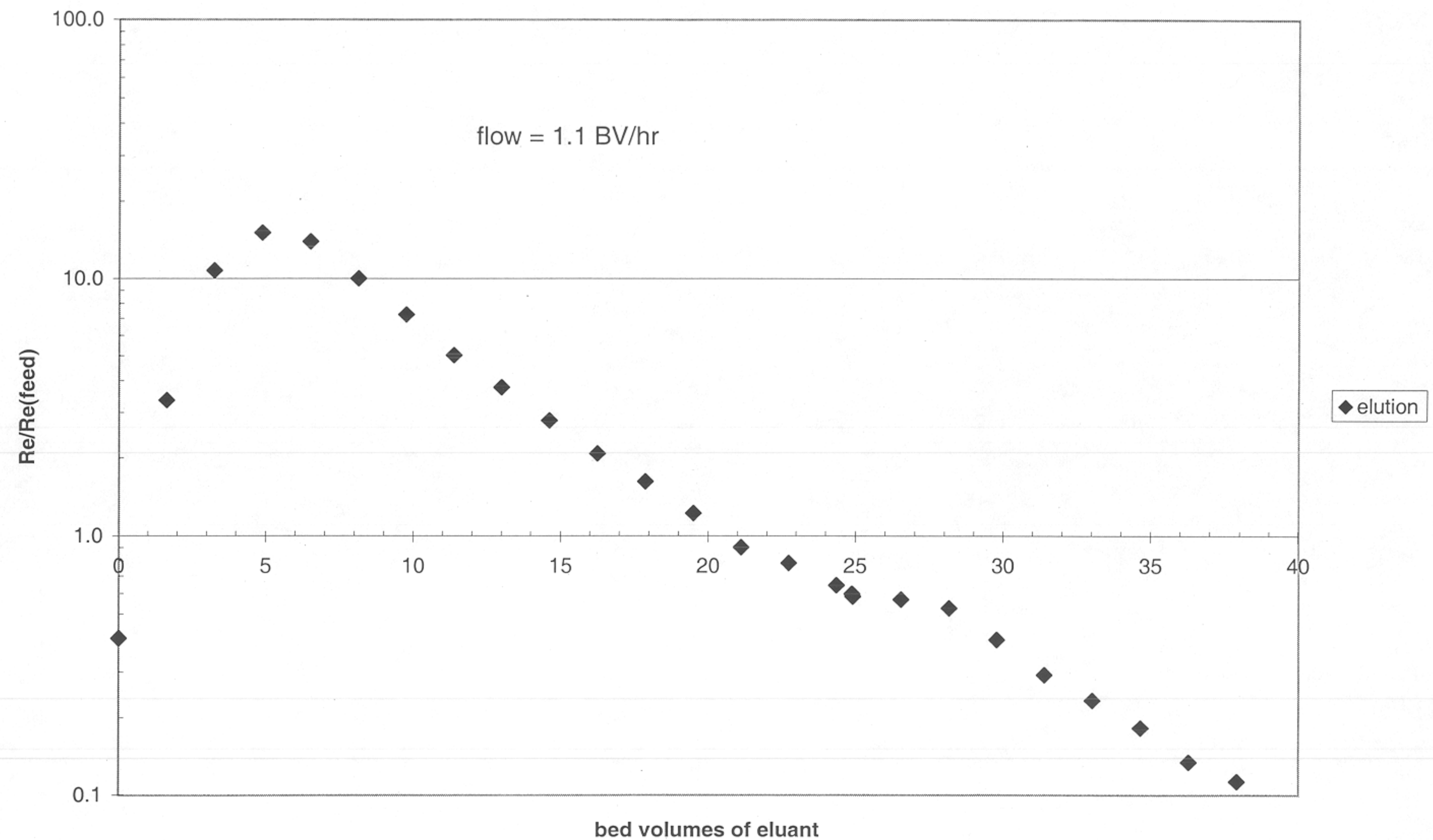

Figure 20 Re Run 7 Elution Profile

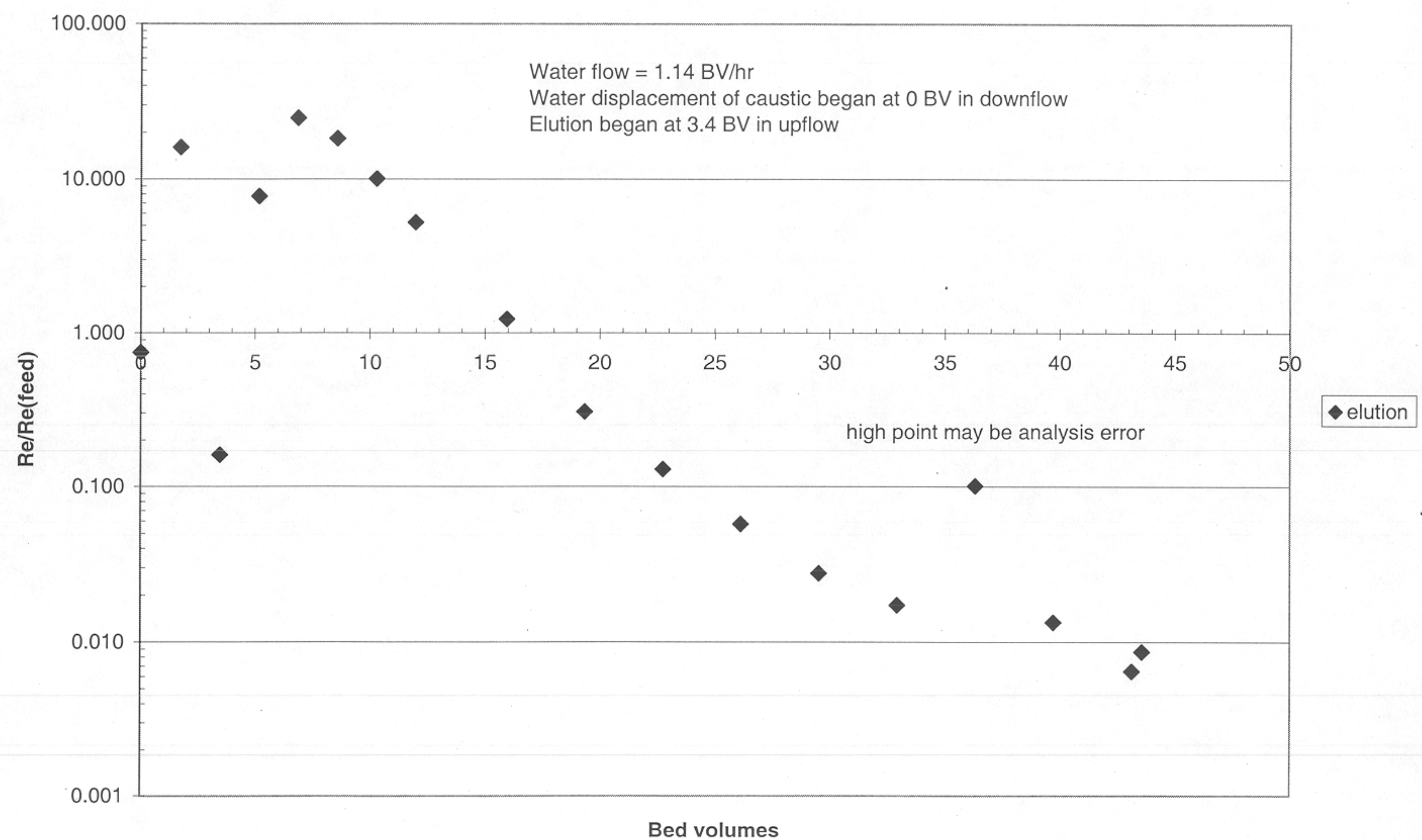

Figure 21 Re Run 8 Elution Profile

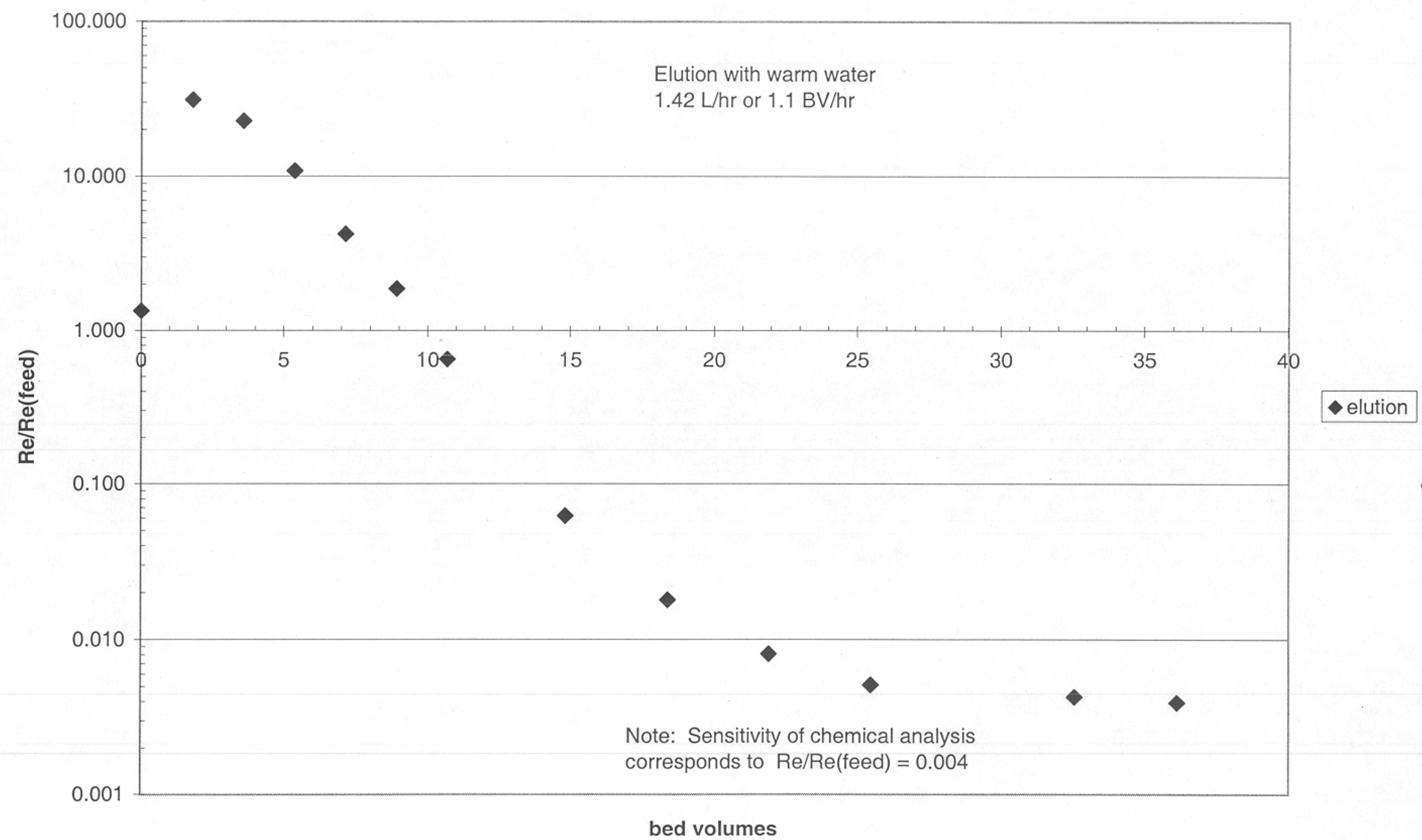

Figure 22 Re Run 8 IE Elution Profile

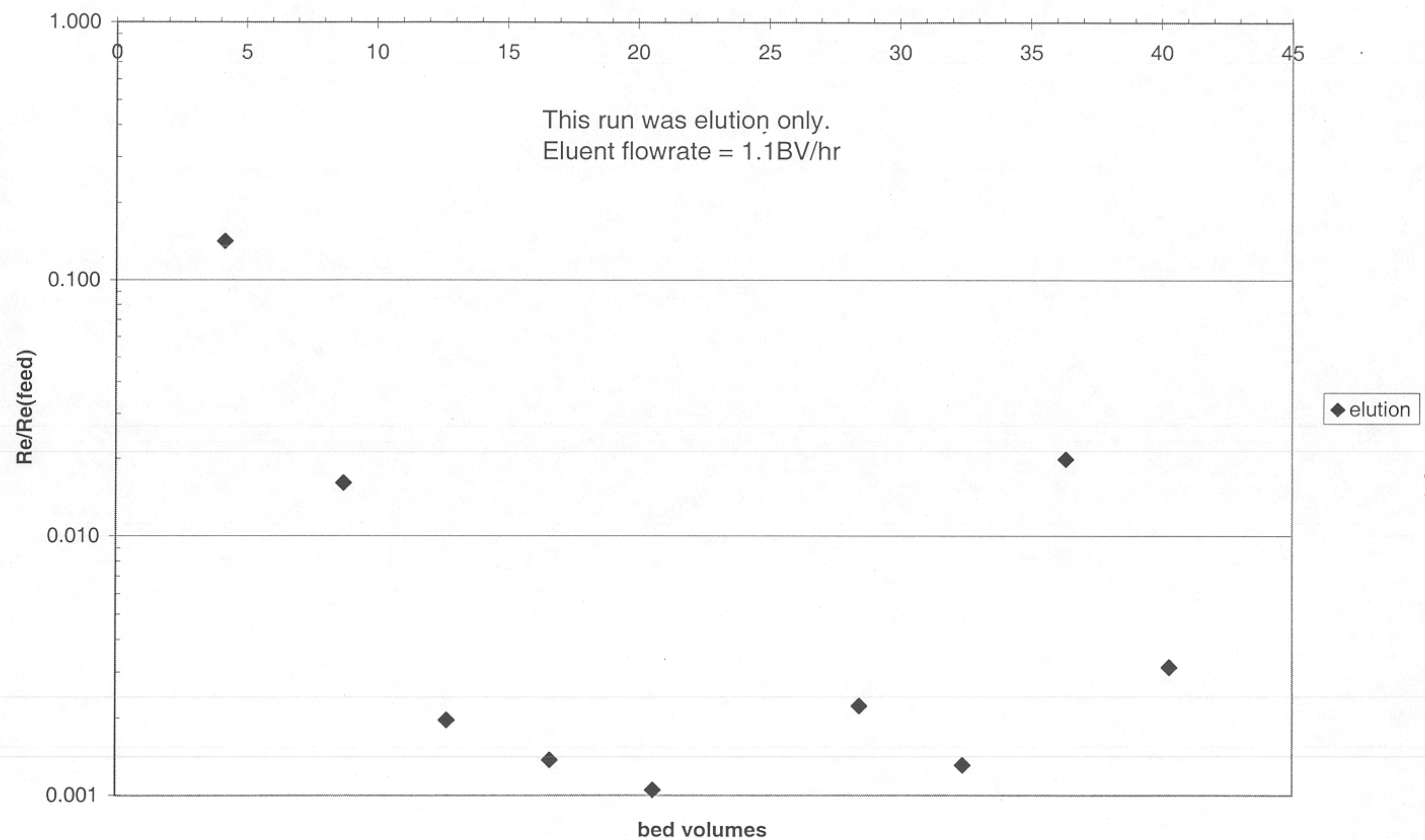

Figure 23 Re Run 9 Elution

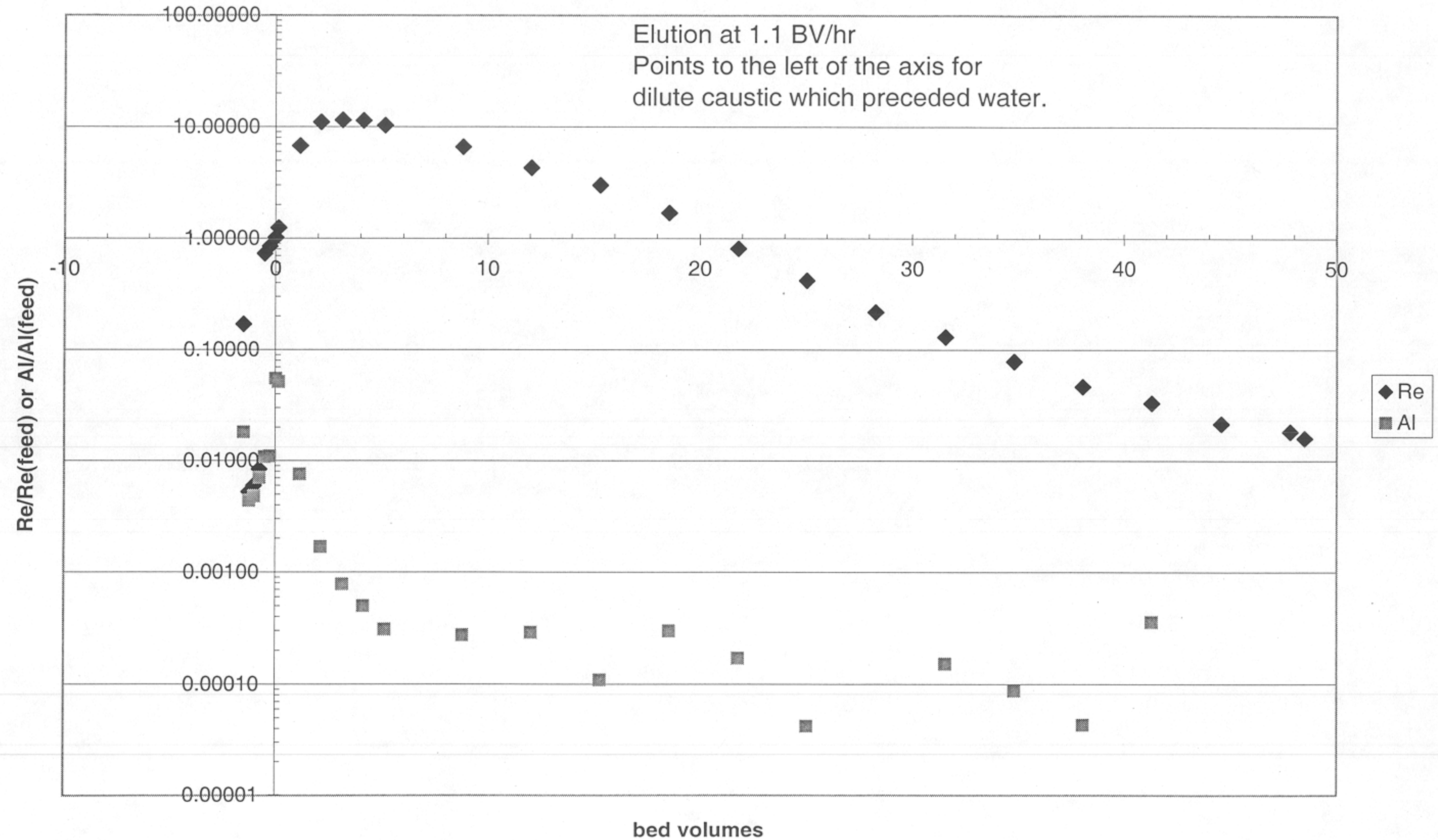

Figure 24   Re Run 9 IE Elution Profile

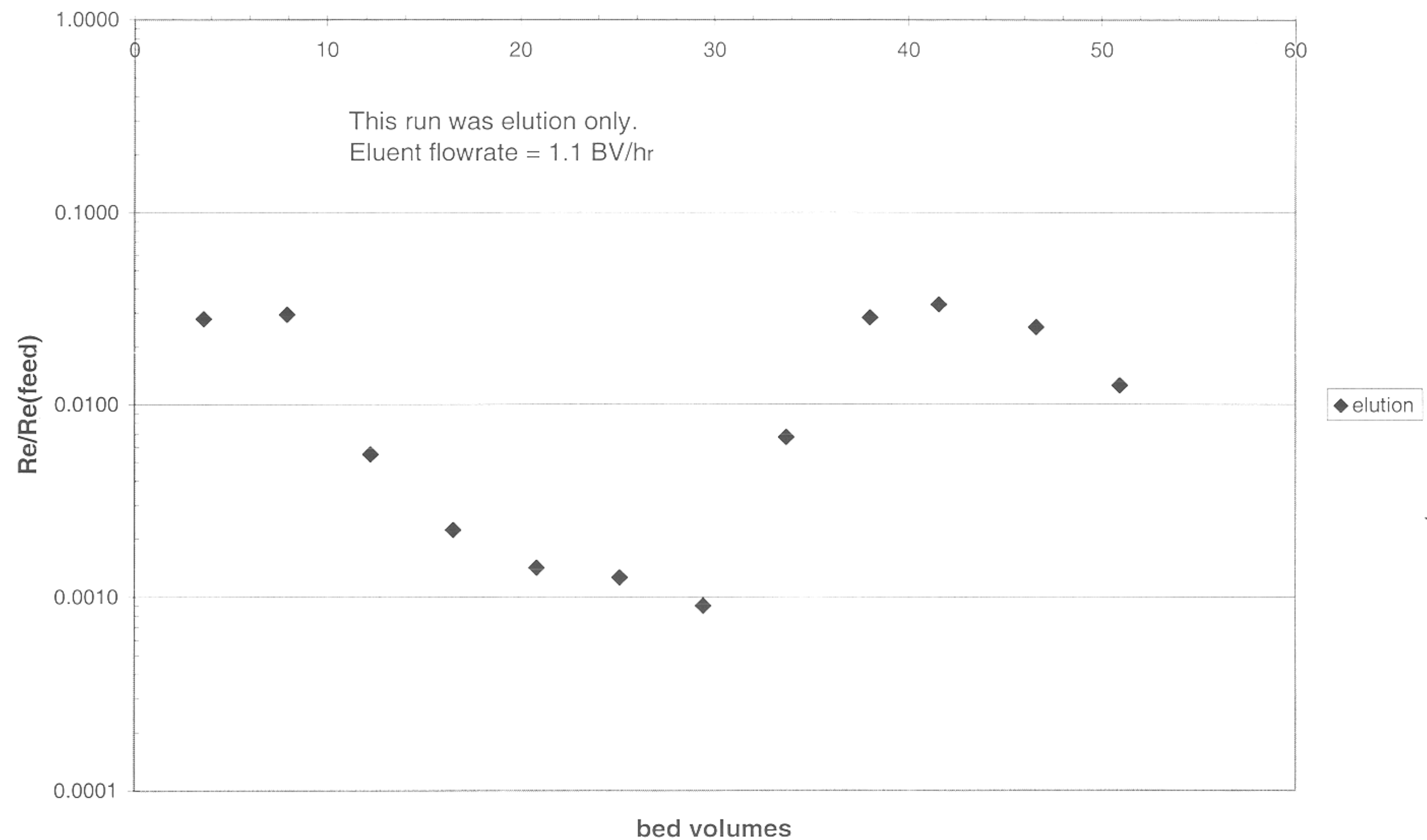

Figure 25 Re Run 10 Elution Profile

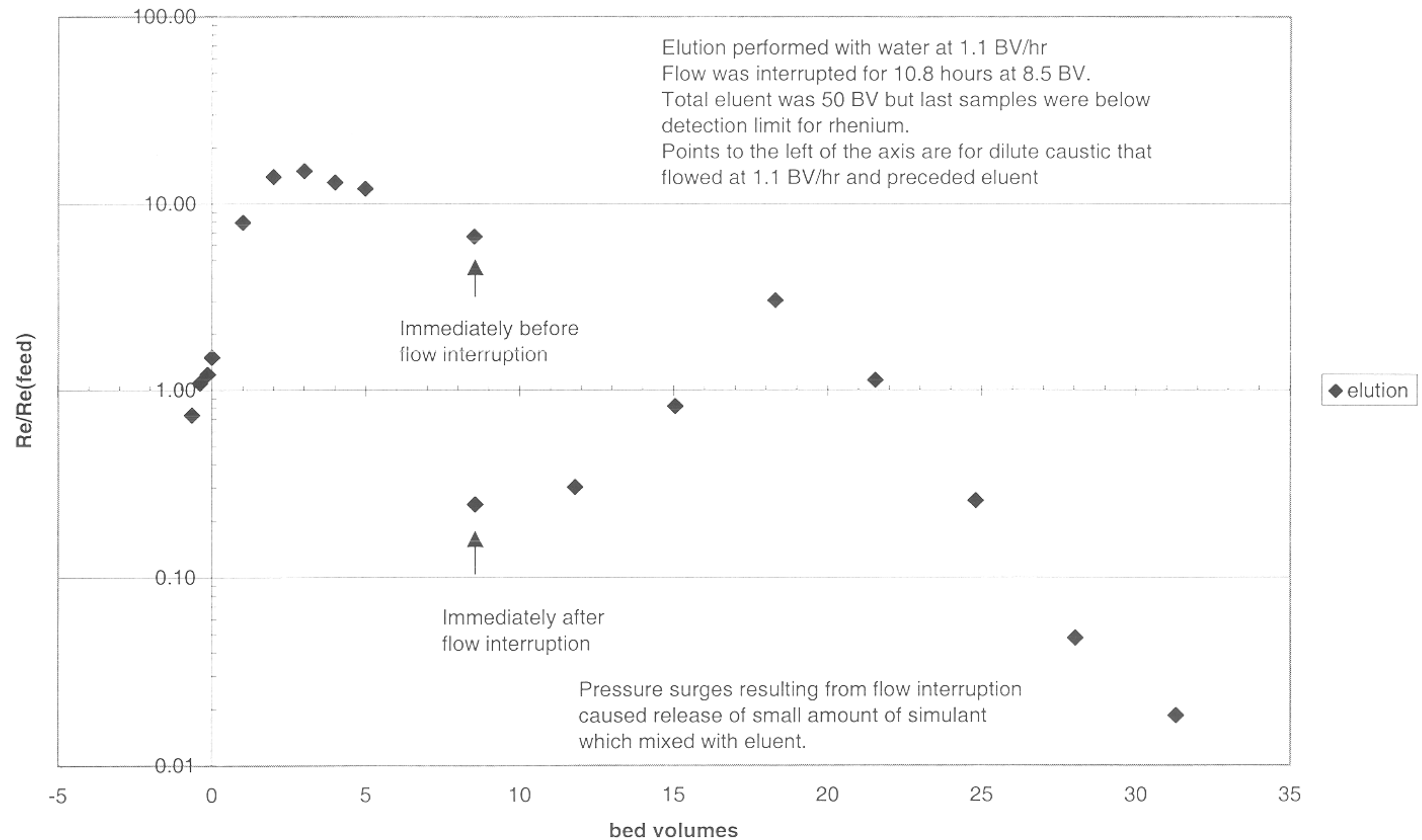

Figure 26 Re Run 8 Estimated Temperature Profile in Column During Heated Elution

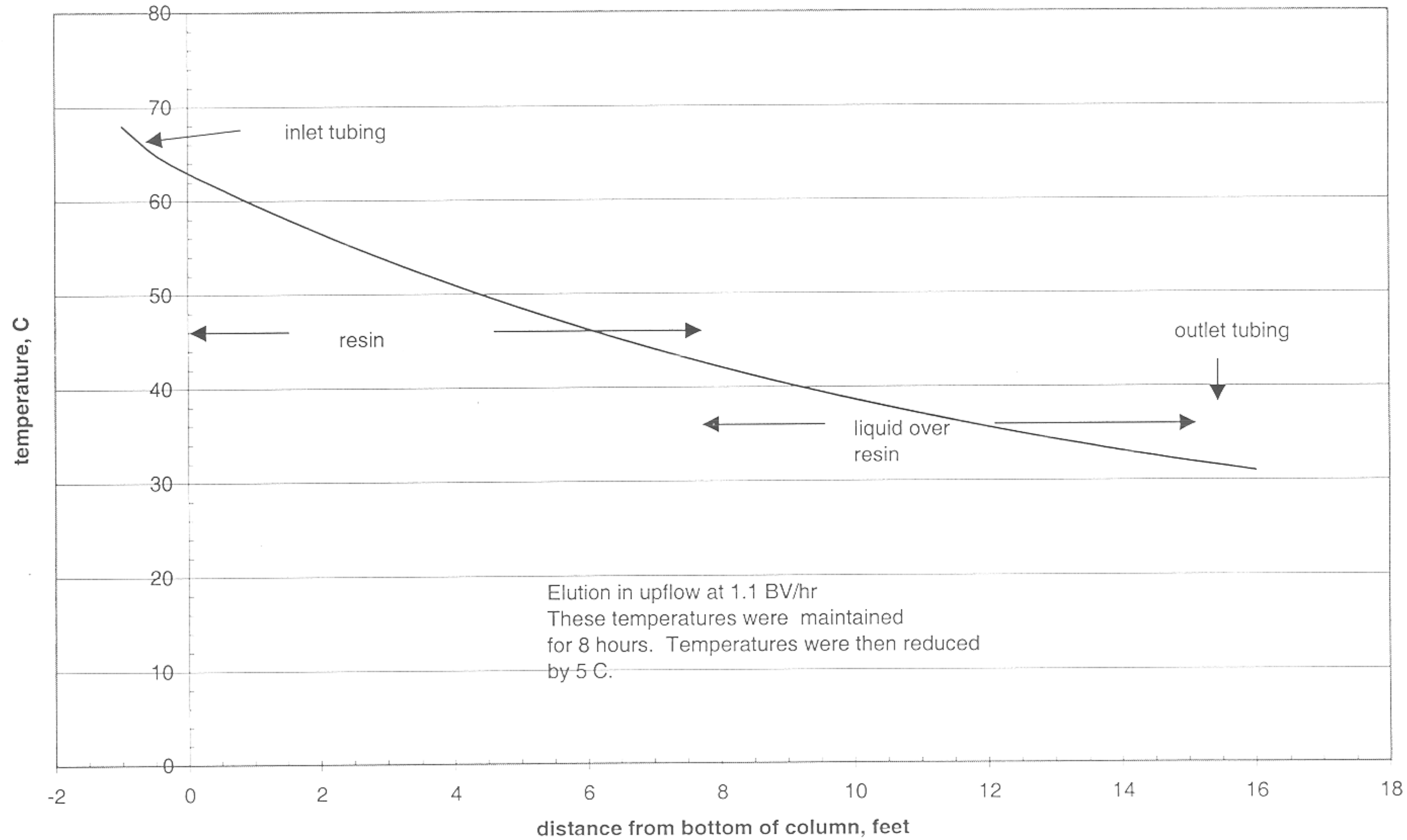

Figure 27 Column Elution at Different Temperatures

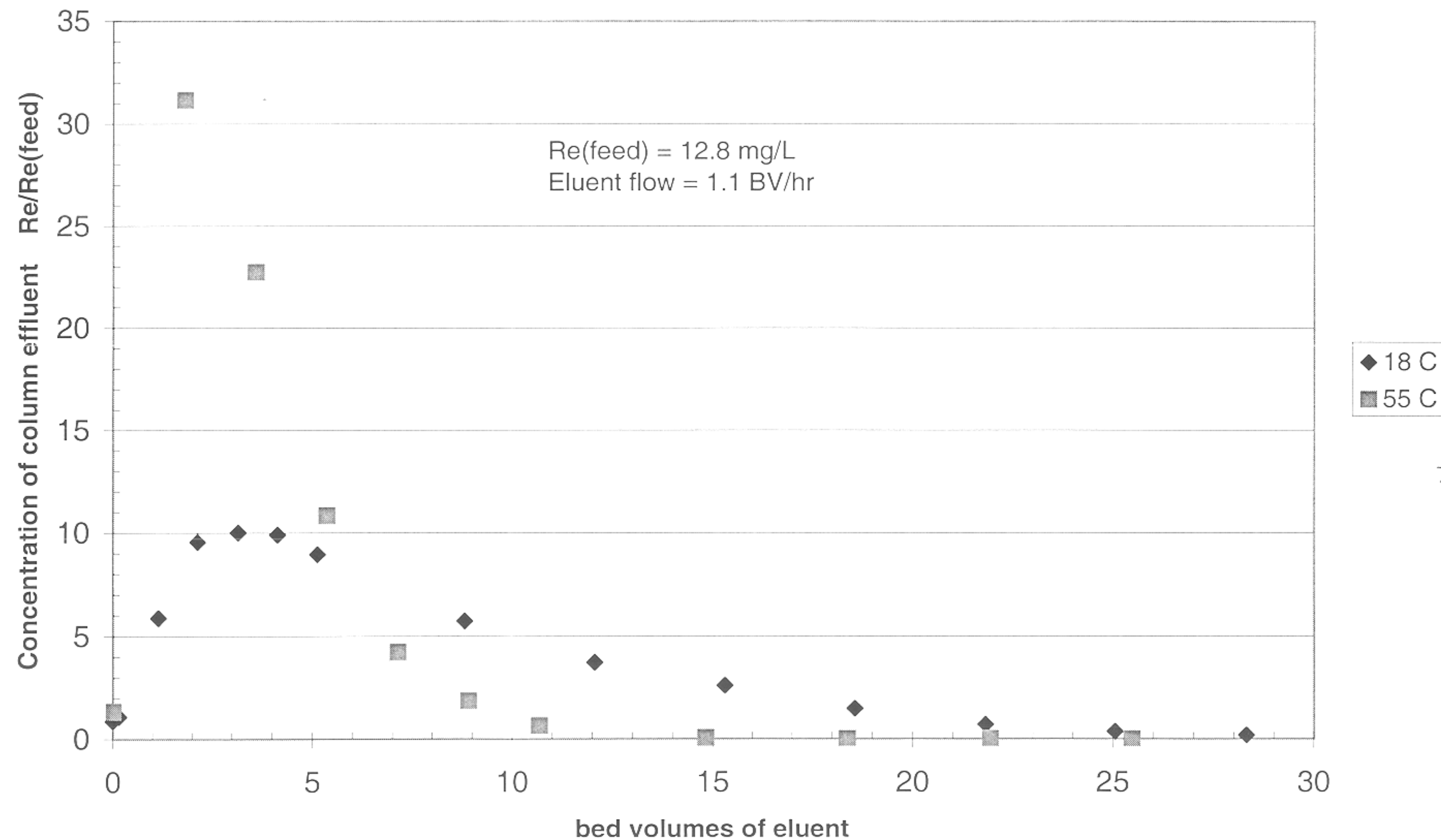

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Figure 28 Rhenium Remaining on Lead Column During Elution at Two Different Temperatures

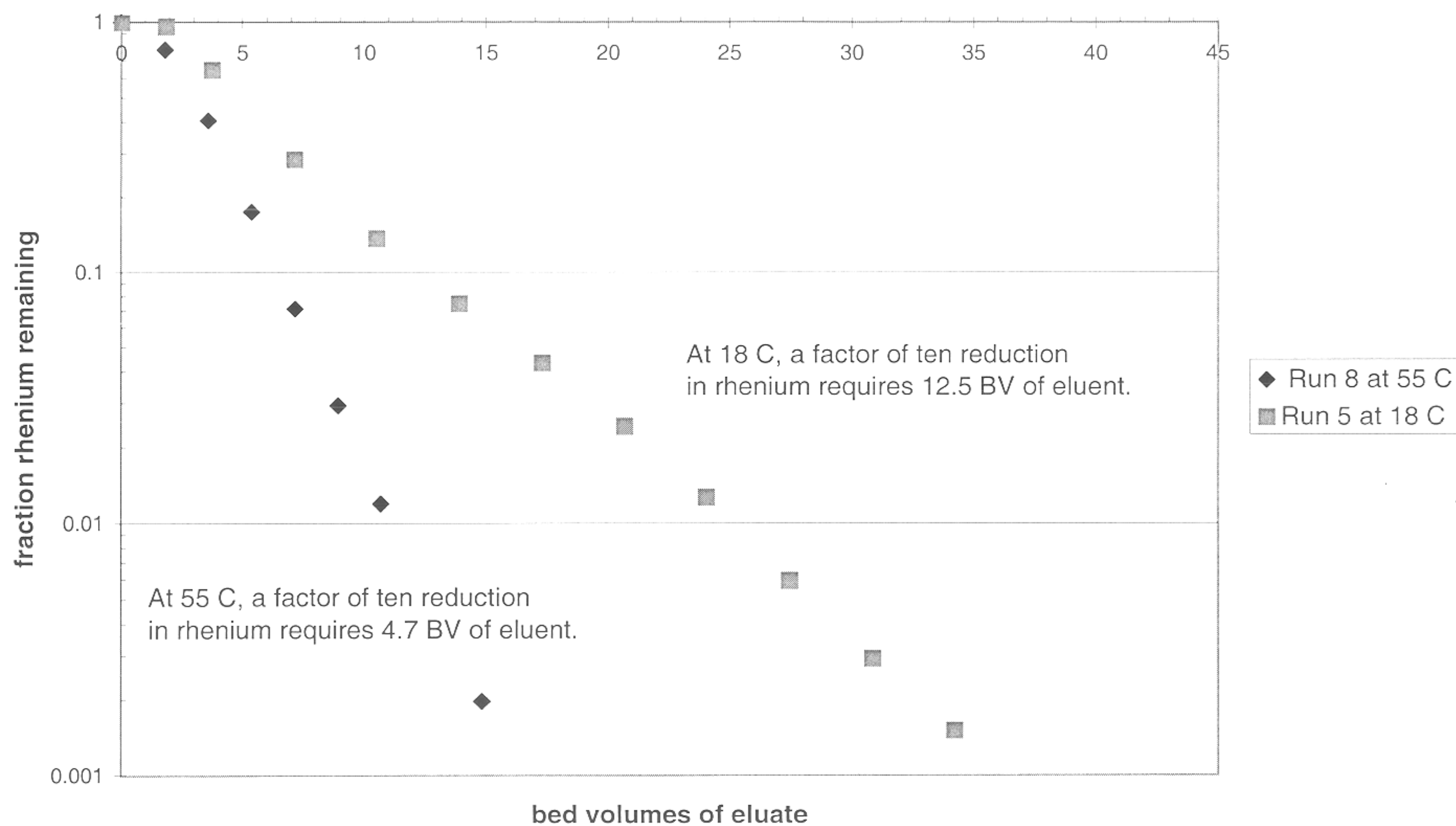

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Figure 29 Re Run 9 Conductivity at Lead Column Outlet

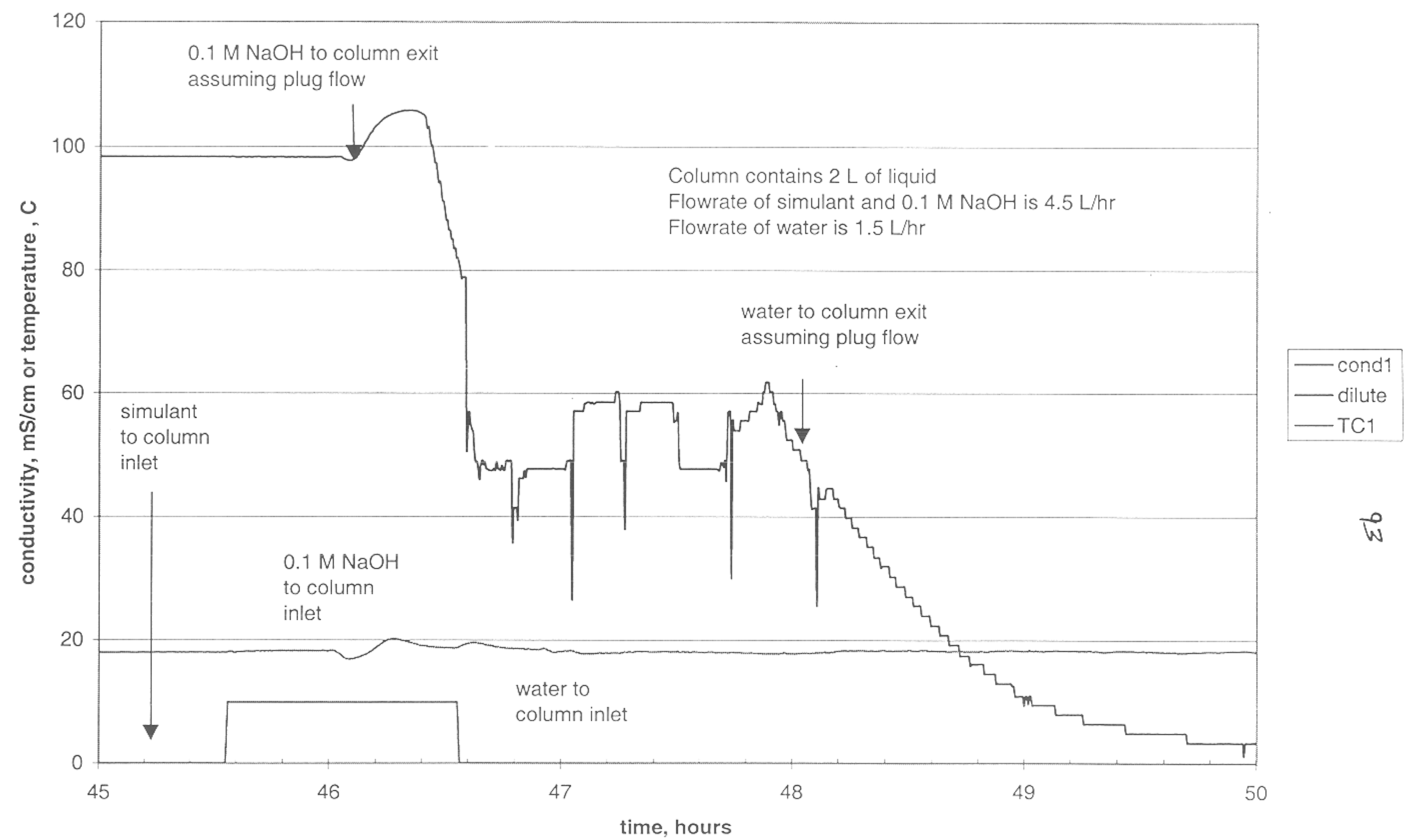

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Figure 30   Re Run 10 Liquid Conductivity at Lead Column Outlet

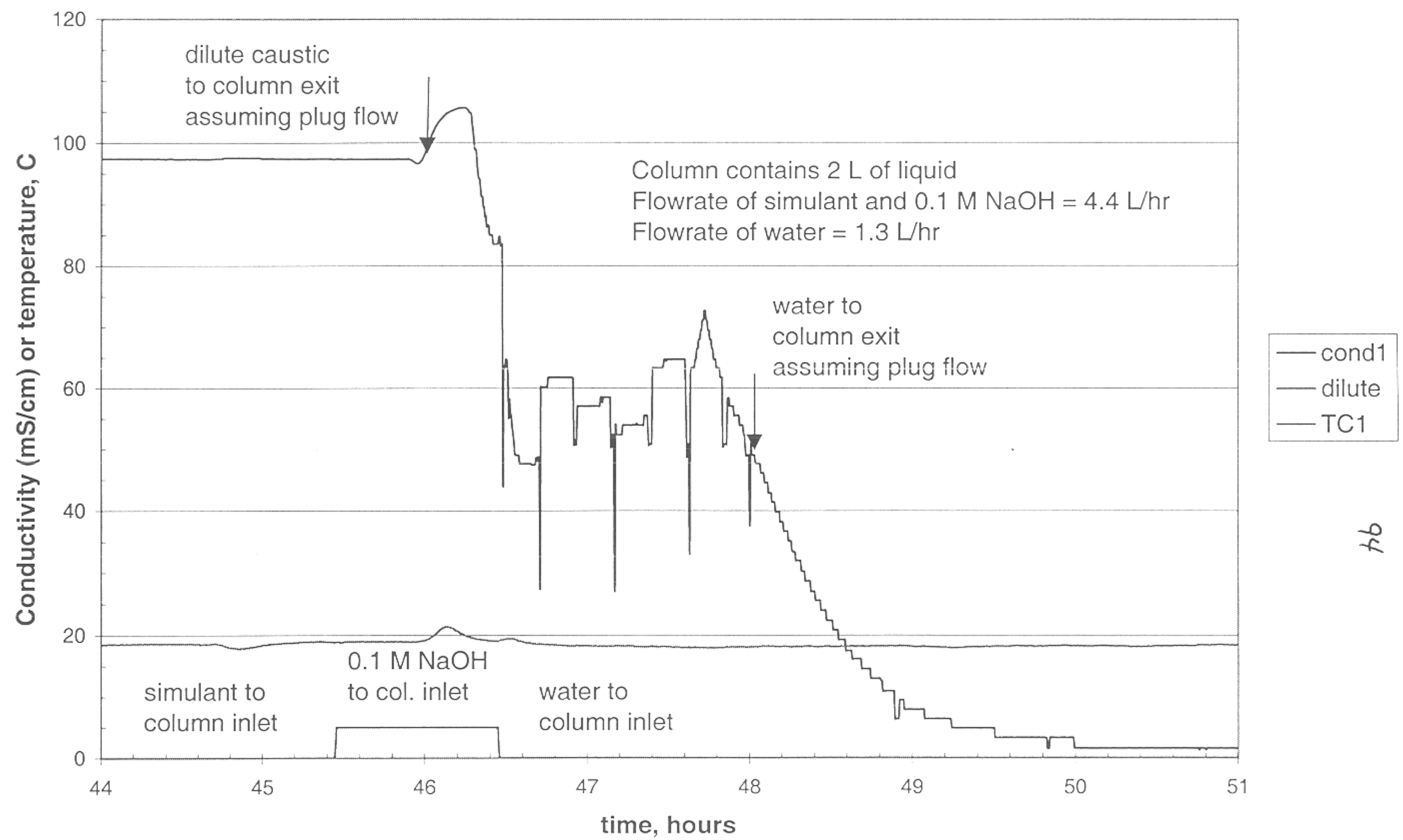

Figure 31 Rhenium Run 9 Conductivity at Exit of Lead Column

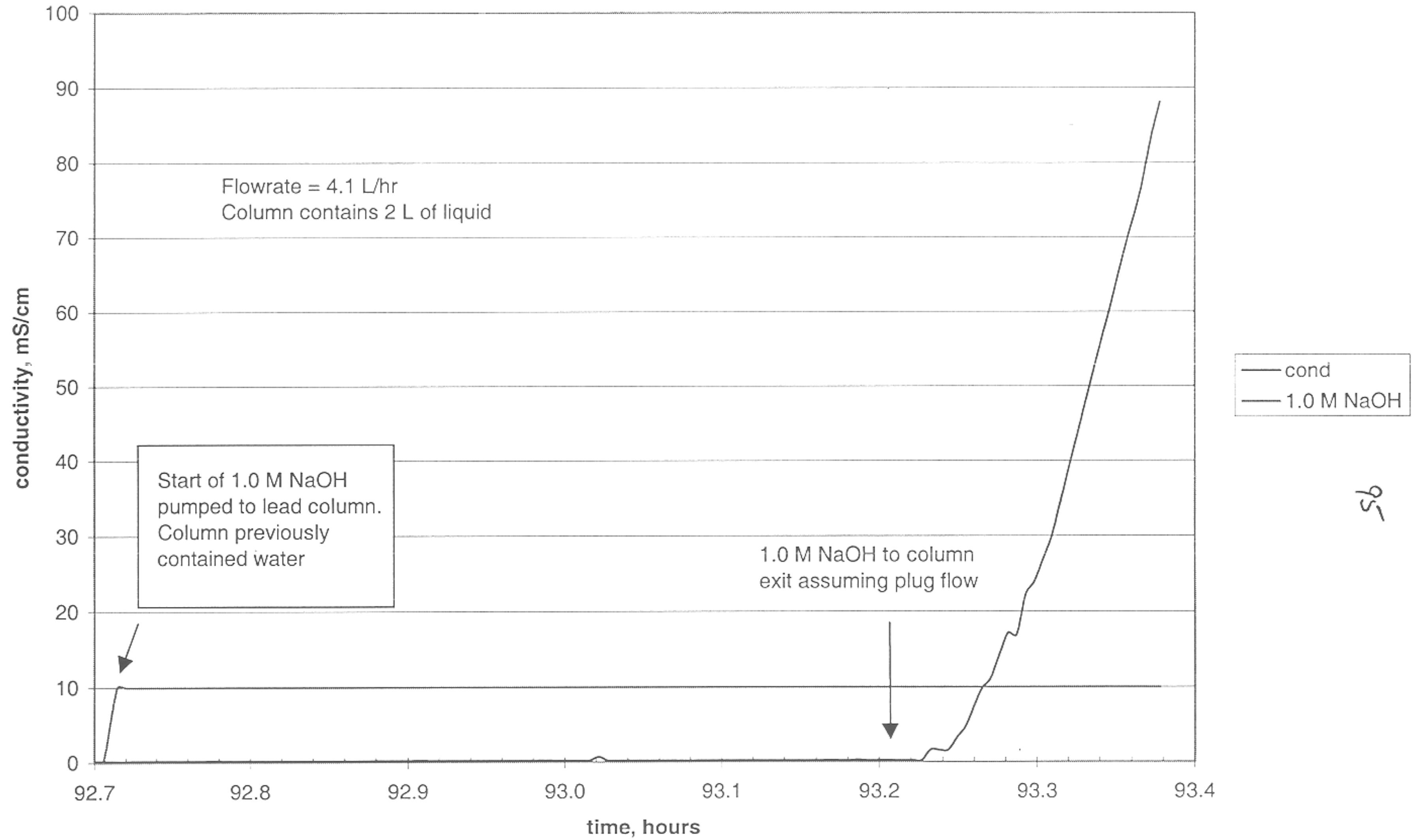

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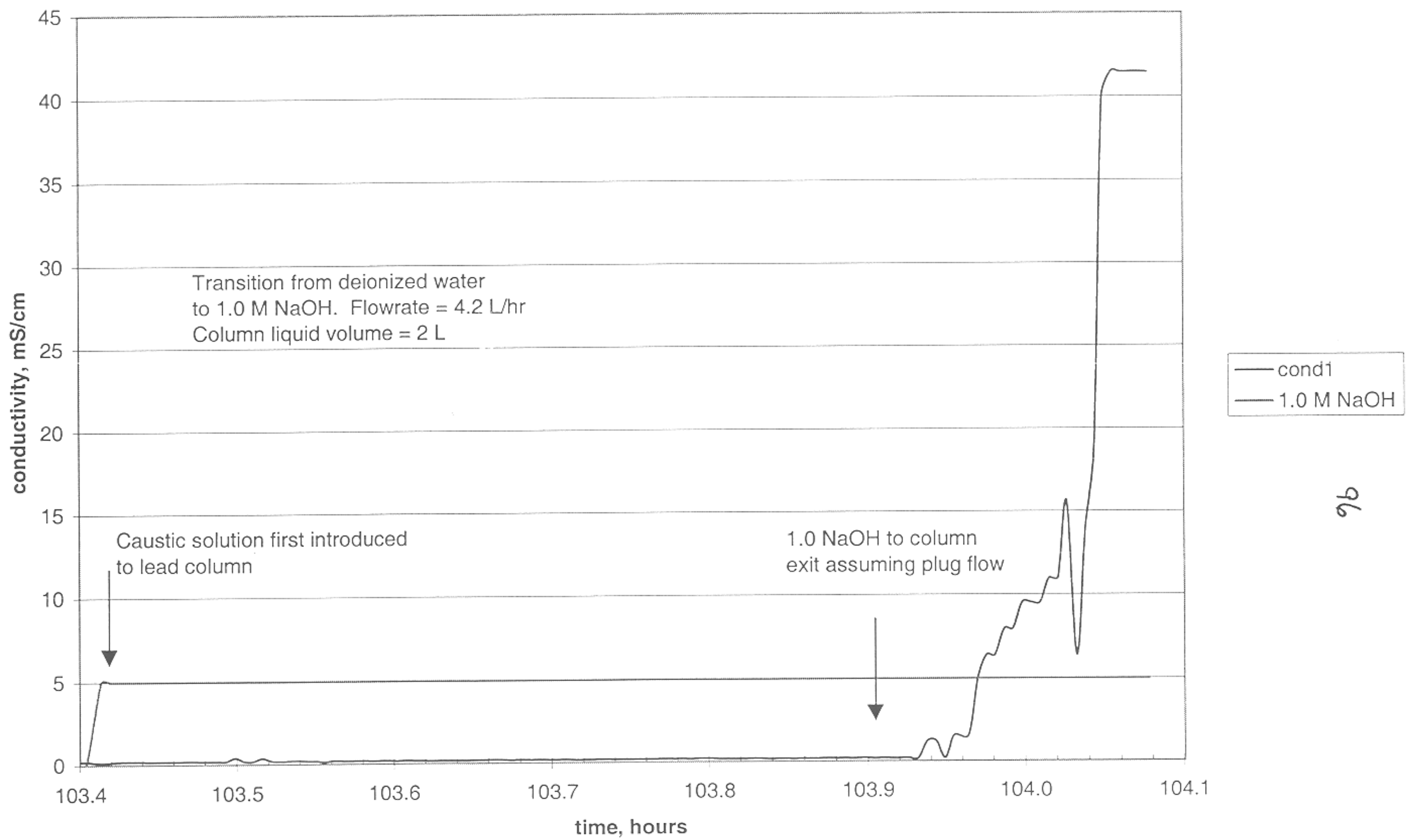
Figure 32 Rhenium Run 10 Conductivity at Lead Column Outlet



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