

MAY 04 1995

ENGINEERING CHANGE NOTICE

ECN - 616123

~~1. ECN No. 616123~~

5/4/95
~~Proj. ECN ER 5480-1~~

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31 Sta. 36

2. ECN Category (mark one) <input type="checkbox"/> Supplemental <input checked="" type="checkbox"/> Direct Revision <input type="checkbox"/> Change ECN <input type="checkbox"/> Temporary <input type="checkbox"/> Standby <input type="checkbox"/> Supersedure <input type="checkbox"/> Cancel/Void	3. Originator's Name, Organization, MSIN, and Telephone No. T. Ambalam, ICF-KH, E6-46, 376-6049	3a. USQ Required? No	4. Date 5/3/95	
	5. Project Title/No./Work Order No. Hanford Facilities Tracer Study Report (315 Water Treatment Facility)	6. Bldg./Sys./Fac. No. 315 Water Treatment Facility	7. Approval Designator NA	
	8. Document Numbers Changed by this ECN (includes sheet no. and rev.) WHC-SD-ER5480-ER-001 REV 0	9. Related ECN No(s). NA	10. Related PO No. NA	

11a. Modification Work <input type="checkbox"/> Yes (fill out Blk. 11b) <input checked="" type="checkbox"/> No (NA Blks. 11b, 11c, 11d)	11b. Work Package No. N/A	11c. Modification Work Complete N/A _____ Cog. Engineer Signature & Date	11d. Restored to Original Condition (Temp. or Standby ECN only) N/A _____ Cog. Engineer Signature & Date
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12. Description of Change
 Changes in units of measurements and references were added.

13a. Justification (mark one)

Criteria Change <input type="checkbox"/>	Design Improvement <input checked="" type="checkbox"/>	Environmental <input type="checkbox"/>	Facility Deactivation <input type="checkbox"/>
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Document Number: WHC-SD-ER5480-ER-001, Rev. 1

Document Title: Hanford Facilities Tracer Study Report (315 Water Treatment Facility)

Release Date: May 3, 1995

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May 3, 1995

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SUPPORTING DOCUMENT

1. Total Pages 2195
9M 51495

<p>2. Title HANFORD FACILITIES TRACER STUDY REPORT (315 WATER TREATMENT FACILITY)</p>	<p>3. Number WHC-SD-ER5480-ER-001</p>	<p>4. Rev No. 1</p>
<p>5. Key Words WATER TREATMENT-SURFACE WATER TREATMENT RULE- CONTACT TIME- TRACER STUDY- 300 AREA</p>	<p>6. Author Name: THIRUCHITR(TOM) AMBALAM <i>Thiruchitr Ambalam</i> Signature Organization/Charge Code 57200</p>	
<p>7. Abstract Reported are the results and findings of a tracer study to determine contact time for the disinfection process of 315 Water Treatment Facility at 300 Area. The study utilized fluoride as the tracer and contact times were determined for two flow rates. Interpolation of data and short circuiting effects are also discussed.</p>		
<p>8. RELEASE STAMP <div style="border: 1px solid black; padding: 10px; width: fit-content; margin: auto;"><p>OFFICIAL RELEASE BY W/C DATE MAY 04 1995</p></div></p>		

ENGINEERING REPORT
HANFORD FACILITIES TRACER STUDY REPORT,
315 WATER TREATMENT FACILITY
(ID# 418408)
WORK ORDER ER5480

Prepared for
WASHINGTON STATE DEPARTMENT OF HEALTH
May 1995

For the U.S. Department of Energy
Contract DE-AC06-93RL12359

Prepared by
ICF Kaiser Hanford Company
Richland, Washington

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ENGINEERING REPORT

FOR

HANFORD FACILITIES TRACER STUDY REPORT,

315 WATER TREATMENT FACILITY

(ID# 418408)

WORK ORDER ER5480

Prepared by

ICF Kaiser Hanford Company

Richland, Washington

Thornhill 5/2/95 Imad Bayless 5/3/95

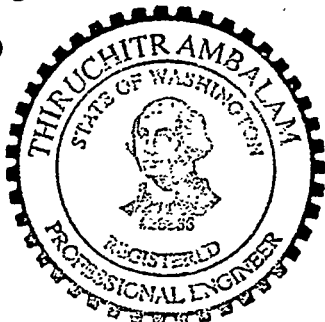
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APPENDICES:

- Appendix A. Calculation No. ER5480-G-007, "Contact Time in the 300 Area Filter Plant Determined From A Two Flow Tracer Test," Rev. 0, prepared by ICF Kaiser Hanford Company, March 1995.
- Appendix B. Calculation No. ER5480-G-005, "Theoretical Detention Time and Fluoride Injection Rate," Rev. 2, prepared by ICF Kaiser Hanford Company, March 1995.
- Appendix C. Calculation No. ER5480-G-004, "Fluoride Loss Due to Addition of Alum," Rev. 0, prepared by ICF Kaiser Hanford Company, November 1994
- Appendix D. 315 Water Treatment Facility Layout
- Appendix E. Washington State DOH Tracer Evaluation Work Sheet

ENGINEERING REPORT

HANFORD FACILITIES TRACER REPORT,
315 WATER TREATMENT FACILITY (ID# 418408)

WORK ORDER ER5480

I. INTRODUCTION

Historically, water from the Columbia River has been pumped from several locations to be used on the Hanford Nuclear Reservation for nuclear reactors, processing facilities, steam generation, fire protection, and drinking water.

Five surface water treatment facilities currently supply drinking water to various areas on the reservation which include the 183-N Water Treatment Facility (ID# 418532); the 183-K Water Treatment Facility (ID# 0177J); the 283-E Water Treatment Facility (ID# 41866V); the 283-W Water Treatment Facility (ID# 001004); and the 315 Water Treatment Facility (ID# 418408) that supplies sanitary water for the 300 Area.

The Surface Water Treatment Rule (SWTR), outlined in the 1986 Safe Drinking Water Act Amendments enacted by the EPA in 1989 and regulated by the Washington State Department of Health (DOH) in Section 246-290-600 of the Washington Administrative Code (WAC), stipulates filtration and disinfection requirements for public water systems under the direct influence of surface water. The SWTR disinfection guidelines require that each treatment system achieves

predetermined inactivation ratios. The inactivation by disinfection is approximated with a measure called CxT, where C is the disinfectant residual concentration and T is the effective contact time of the water with the disinfectant.

According to WAC 246-290-636, "Determination of Disinfectant Contact Time," the water purveyor shall use tracer studies or empirical methods to determine T. Empirical methods to calculate T may not be used unless the system components are demonstrated to have configurations analogous to components on which tracer studies have been conducted and results have been documented. The CxT calculations for the Hanford water treatment facilities were derived from the total volume of the contact basin(s). In the absence of empirical data to support CxT calculations, the DOH determined that the CxT values used in the monthly reports for the water treatment facilities on the Hanford Site were invalid and required the performance of a tracer study at each facility. In response to that determination, a tracer study will be performed to determine the actual contact times of the facilities for the CxT calculations. The facility located at 300 Area was selected for study now and studies for other facilities will follow.

II. SUMMARY

A tracer study at two flow rates (Q peak and $0.90 * Q$ peak) was performed at the 315 Water Treatment Facility in accordance with the Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems using Surface Water Sources (Guidance Manual), and the Disinfection

Contact Time Study Plan (CTS Plan), (ref 1 and 2). The CTS Plan was submitted and approved by the DOH (ref 3).

The actual detention times at each flow were determined. Table 1 shows the results of the two tracer tests.

Target Flow	Average Test Flow	Theoretical Residence Time (T)	Actual Residence Time (T_{10})	% Tracer Recovered
2,400 gpm	2,380 gpm	178 min	102 min	85%
2,160 gpm	2,127 gpm	199 min	167 min	45%

The study results were evaluated to provide a means for determining the actual residence time (T_{10}) at any flow experienced at the 315 Water Treatment Facility when it is operating under a configuration similar to the configuration during the tracer tests. Figure 1 is a graph that was developed from the 315 Water Treatment Facility tracer study results.

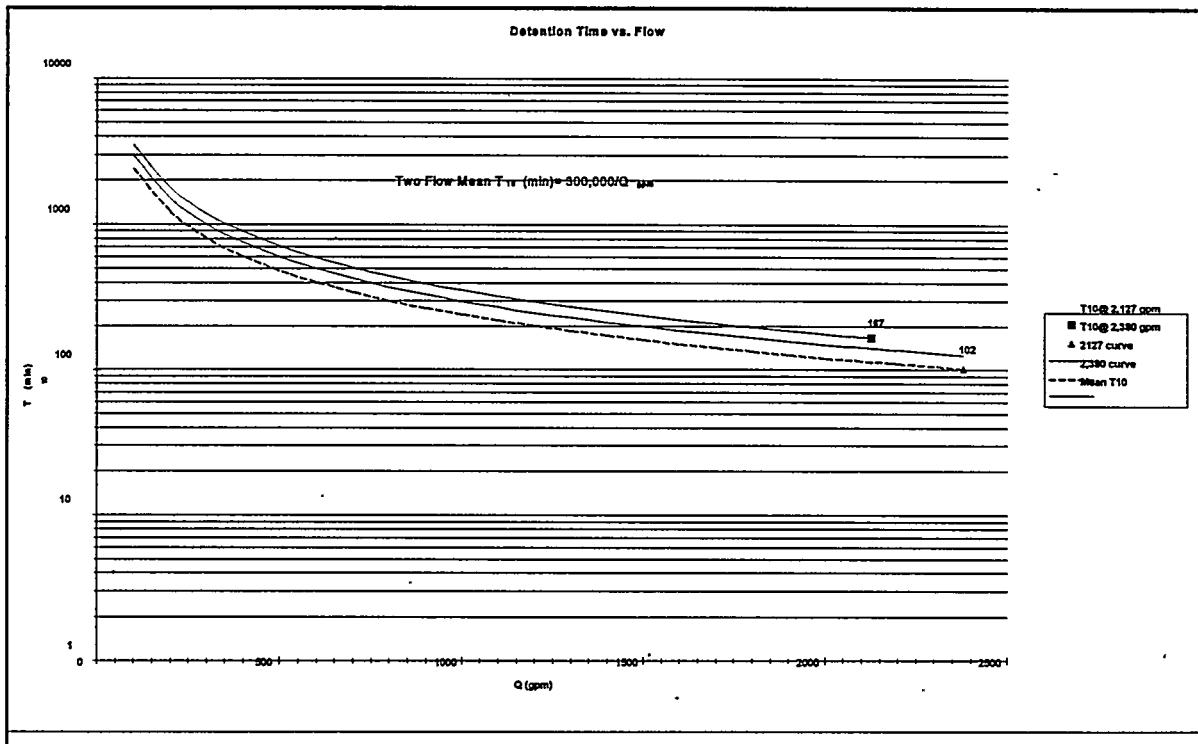


Figure 1: 315 Filter Facility T_{10} determination for any flow (Appendix A, p. A-C-13)

III. PURPOSE

The objective of this report is to outline the results of tracer studies at the 315 Water Treatment Facility, answer potential questions, give the facility operators a tool for determining the actual detention time experienced at the facility under various flow conditions, and fulfill the DOH requirement for a Tracer Study Evaluation Work Sheet. The worksheet is contained in Appendix E.

In order to provide the tool, a tracer is tracked in the treatment train and the results are analyzed in accordance with the Guidance Manual. The Guidance

Manual requires at least one tracer test at a flowrate of no less than 91% of the highest flow experienced at that section (ref 1, p. C-2). By conducting tracer studies, the detention time for corresponding peak hourly flow conditions can be determined. When tracer tests are performed at peak flows, they provide a conservative estimate in CxT calculations for flowrates less than or equal to the tracer test flowrate (ref 1, p. C-2).

If the tracer tests are not performed, the facilities will not be in compliance with the SWTR and there is an inability to ensure that sufficient contact time has occurred for disinfection prior to delivery of the water to the customers.

IV. DESCRIPTION

A. PLAN OF STUDY

The tracer studies are proposed to meet the requirements of WAC 246-290-636, "Determination of Disinfection Contact Time." The 315 Water Treatment Facility tracer study was performed in accordance with the Guidance Manual and the CTS Plan.

The tracer study flowrates are based on the peak hourly flows recorded on the SWTR CxT Determination Logsheets that are submitted to the DOH. System demand in the future will vary due to source reduction and other water conservation measures scheduled for implementation on the Hanford Reservation. The future peak flows are expected to be less than the current flowrates at the treatment facility.

A tracer study using sodium fluoride was performed on the treatment train typically used at the facility for final disinfection. Of the two most common methods of tracer addition employed in water treatment evaluations, the step-dose method was selected because the resulting normalized concentration versus time profile can be used directly to determine the detention time (T_{10}) required for calculating $C \times T$. The step-dose method entails introduction of a tracer chemical at a constant dosage and monitoring for that tracer at the desired end point. Fluoride was chosen as the tracer chemical because it is approved for potable water use and is not normally added for water treatment on the Hanford Reservation.

Immediately prior to the test, the background fluoride concentration was determined and recorded. Appropriate fluoride injection flowrates were calculated after the predetermined flowrates had been established in the facility. The sodium fluoride was injected with a Liquid Metronics Injector® (LMI) Fluoride saturator and an electronic metering pump. The sodium fluoride was injected as close to the point of chlorination as possible. The tracer was monitored prior to the first service connection with a HACH DR/700 Colorimeter at a point downstream of the export pump.

Based on fluoride loss due to alum precipitation and raw water residual concentration, fluoride was added at a calculated dosage that would result in a residual concentration of approximately 1.5 mg/L in the

facility effluent (ref 1 and Appendix C, p. C-3). Recommended fluoride concentrations as low as 1.0 to 1.5 mg/L are practical when the raw water fluoride level is not significant. The duration for fluoride addition was selected to be twice the theoretical detention times as suggested by Hudson (ref 4).

Sampling occurred at 10 minute intervals until the tracer concentration in the effluent exceeded the background levels. Once a concentration change was observed, sampling was performed at 2 - 5 minute sampling intervals until a steady-state concentration was reached, or twice the theoretical detention time had elapsed which provided data for a well-defined plot of tracer concentration versus time. At this point, the tracer addition was discontinued. The receding tracer concentration was monitored at reasonable sampling intervals based on overall detention. Tracking the receding curve allowed for calculation of tracer recovery. Monitoring of the tracer was discontinued when 90% of the tracer was accounted for or the fluoride levels reached background. The water level, flow, and temperature were recorded during the test.

B. 300 AREA FILTER FACILITY

The 300 Area Water Treatment Facility (ID# 418408) pumps raw water from the Columbia River. The raw water is treated and supplied to various process and domestic users throughout the 300 Area. The water system distribution piping in the 300 Area provides potable and process water to less than 214 buildings. The water system consists of a river

water pumphouse, the water treatment facility, the water distribution system, and two above-ground water storage tanks. The tanks are used as storage vessels to supply potable water to the distribution system for a short period of time during an emergency. During emergencies and maintenance outages, the City of Richland can supply potable water to the 300 Area.

The river water pumps supply raw water to the water treatment facility and fish study facilities in the Pacific Northwest Laboratory Life Sciences Building 331. The river water pumphouse (312 Building) contains two motor-driven vertical turbine pumps and a smaller emergency (biology) pump. The two primary pumps are operated alternately at one-week intervals. Each of the two river water pumps is rated at 10,000 gal/min.

The 315 Water Treatment Facility is supplied water at approximately 70 psi through a 10-inch line branched from the 24-inch raw water line downstream of the river pumps. Water treatment consisting of coagulation, chlorination, sedimentation, and filtration is accomplished at the 315 Water Treatment Facility. A layout of the facility is contained in Appendix D. Coagulation occurs at the flash mix chamber which contains two upright mixing baffles where the water mixes with alum. At the exit of the chamber, chlorine is injected to deter algae formations, disinfect the water, and provide residual chlorine in the distribution system. The flash mixer overflows a weir into a

distribution flume. The flume has four 14-inch openings in the bottom, spaced to supply water to the center of the entrance of four sedimentation basins. The water strikes stilling baffles and continues out into the sedimentation basins.

At the discharge of the sedimentation basins, the clarified water overflows a weir into the filter influent flume. Water from this flume is fed to the four filter entrance gullets. Prestol 2515, an anionic acrylamide copolymer, is sometimes added at the gullets to aid in filtration when high turbidity conditions exist in the Columbia River. The four filters are designed for a flow of 6 gpm per square foot. Water flows from the filter influent gullet into two troughs over each filter. The water overflows the troughs onto the top of the filter bed. From the bottom of the filter, the water flows into the clearwell. The clearwell has a capacity of approximately 70,000 gallons. Though rarely practiced, chlorine can be fed directly to the clearwell from each of the filter inlets. Two clearwell pumps supply filtered water to the 300 Area distribution grid.

The 315 Water Treatment Facility typically experiences flows less than those maintained during the tracer tests, as shown in Table 2. Frequently, when lower flows are experienced in the facility, one or two filters will be removed from service.

	Winter	Spring	Summer	Fall
Maximum Temp (C°)	10	15.3	24.0	20.2
Average Temp (C°)	6.2	10.6	19.8	13.2
Average Flow (gpm)	763	802	1,112	913

1. TEST SETUP

The layout of the 315 Water Treatment Facility in Appendix D shows the four basins and filters that were utilized during the tests. In accordance with the CTS Plan, the background fluoride concentration was determined by monitoring prior to beginning the tests at the sampling point where the disinfectant residual is measured for CxT calculations. An onsite analysis was performed using a HACH Colorimeter and fluoride reagent packs (SPADNS). Background monitoring was performed for 30 minutes at 5 minute intervals. The background was determined to be 0.4 mg/l during all tracer tests in the 315 Water Treatment Facility.

When the desired flowrate (2,400 gpm or 2,160 gpm) was established, the fluoride feed supplied from a LMI Model

28850 Fluoride Saturator was energized and left at a constant rate for the duration of the test. Fluoride was added at the exit of the mixing chamber leading to the sedimentation basins and was monitored from a sample tap off of the discharge line from the clearwell. The tracer study was performed on the treatment train starting at the exit of the flash mix chamber, and included four sedimentation basins, four filters, and the clearwell. The combined volume of these components is approximately 424,000 gallons (Appendix B, p. B-3).

During the 2,400 gpm test on March 6, 1995 (Test 1), tracer was added at a rate of 620.8 ml/min for 6 hrs. The fluoride injector was then de-energized and the receding curve was tracked for an additional 4 hrs and 55 min until the tank storage space was exhausted and the artificially elevated flowrate could no longer be maintained.

A 2,160 gpm tracer test (Test 2) was attempted at the 315 Water Treatment Facility on March 10, 1995. The results of the test were not consistent with estimates of fluoride residual. Therefore, a retest was scheduled.

During the 2,160 gpm test on March 23, 1995 (Test 3), tracer was added at a rate of 580 ml/min for 6 hrs and 35 min. The

fluoride injector was de-energized and the receding curve was tracked for an additional 5 hrs and 5 min until background fluoride concentrations were detected again.

C. DISCUSSION OF RESULTS

A two-flow tracer study (Q peak and 0.90* Q peak) was performed at the 315 Water Treatment Facility in the 300 Area, and the actual detention time at those flows was determined. Table 3 shows a summary of the data taken during the two reliable tracer tests and the corresponding results.

TABLE 3. 315 Water Treatment Facility Step-Dose Method Sodium Fluoride Tracer Study		
Test Date	March 6, 1995 (Test 1)	March 23, 1995 (Test 3)
Target Flow	2,400 gpm	2,160 gpm
Average Test Flow	2,380 gpm	2,127 gpm
Average Clearwell Depth	10.8 ft	10.8 ft
Normal Clearwell Depth	10.8 ft	10.8 ft
Average Water Temp	5.8 °C	7.9 °C
Normal Seasonal Temp	6.2 °C	6.2 °C

Background Tracer Levels	0.4 mg/l	0.4 mg/l
Tracer Dose	1.21 mg/l	1.27 mg/l
Alum Dose	20 mg/l	25 mg/l
Expected Tracer Loss Due to Alum	0.1 mg/l	0.15-0.2 mg/l
Expected Maximum Detected Tracer Residuals	1.51 mg/l	1.47 mg/l
Actual Maximum Detected Tracer Residuals	1.5 mg/l	1.2 mg/l
Injection Period	6 hrs	6.6 hrs
Sampling Period	10.9 hrs	11.7 hrs
Theoretical Residence Time (T)	178 min	199 min
Actual Residence Time (T_{10})	102 min	167 min
% Tracer Recovered	85%	45%

Source: Appendix A.

The March 6, 1995 tracer test (Test 1) appears to be a textbook example of the step-dose method tracer test. The flowrate during the peak flow test averaged 2,380 gpm (-0.8% of the target flow). There was apparently some short circuiting with the actual residence time being approximately 60% of theoretical. However, some channeling effect (short circuiting) can be expected in the long sedimentation basins that have no baffling. The clearwell is a large single basin that may experience some effects similar to the sedimentation basins. These slight short circuiting problems do not appear to be extensive. The tracer mass recovery was calculated at 85% and an additional 10% can be attributed to alum loss (see Appendices A and C). The calculated maximum tracer residual of 1.5 mg/l was obtained during effluent testing. Figure 2, a graph of relative concentration versus time, shows that the tracer approached a steady state level before the end of the tracer addition (twice the theoretical detention time).

The data was evaluated numerically and the correlation coefficient indicated a good statistical fit (0.95). Therefore, T_{10} was determined as the solution to an equation based on the straight-line parameters to a linear regression analysis of the tracer test data instead of an "eyeball" estimate from a data plot (ref 1, p. C-19; Appendix A, p. A-C-4 and A-C-5).

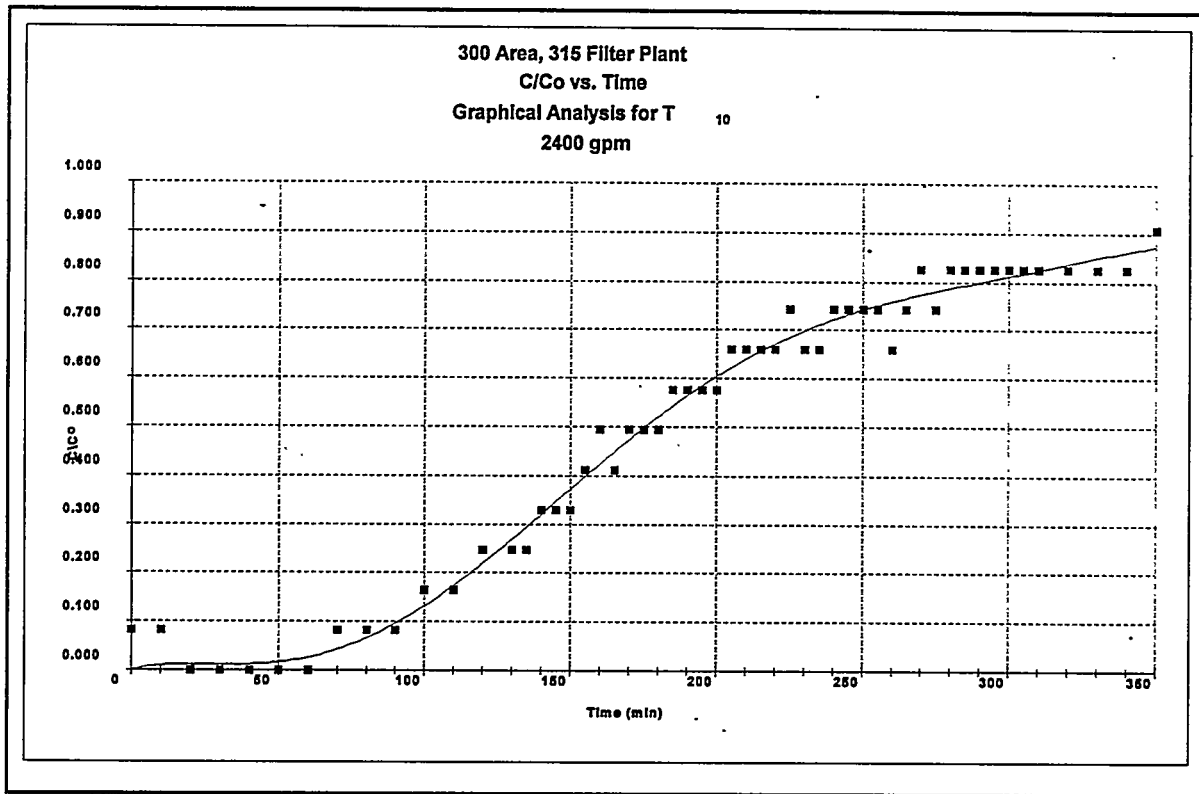


Figure 2: 315 Filter Facility 2,400 gpm tracer test (Source: Appendix A, p. A-C-4)

The March 23, 1995 tracer test (Test 3) appears to provide an actual detention time that is in agreement with Test 1. The flowrate during Test 3 averaged 2,127 gpm (-1.5% of the target flow). Compared to the results of Test 1, less short circuiting was seen with the actual residence time being approximately 84% of theoretical. However, the mass of tracer recovered appears to be a lower than the first test. The tracer mass recovery was calculated at 45% with an additional 16% attributed to alum loss. The calculated maximum tracer residual was never reached in the effluent. The maximum detected tracer concentration was 1.2 mg/l when a concentration of 1.47 mg/l was

expected.

The data was evaluated numerically and the correlation coefficient was not high enough to indicate a good statistical fit (0.87). As a result, T_{10} was required to be determined graphically as an estimate from a data plot (Appendix A, p. A-C-11).

The disparities between the two tests have been examined as follows: the alum dosage during Test 3 was slightly higher than during Test 1; and the increased alum dosage doubles the fluoride loss that can be attributed to alum (see Appendix C).

The second potential cause of these disparities is the potential interference of Prestol 2515. Prestol 2515 is a polymer that is sometimes added to the filter beds to enhance filtration. The polymer attracts colloidal material through its affinity for charged particles. The negatively charged fluoride ions could become adsorbed in the filter beds in the presence of this material and never reach the effluent stream. The polymer was not in use during the first test and it hadn't been used during the previous week. Prior to March 10, 1995, Prestol 2515 was introduced to the filter media again. A 2,160 gpm tracer test (Test 2) was attempted at the 315 Water Treatment Facility on March 10 while the polymer was being used. Due to polymer interference, the results of Test 2 were not consistent with estimates of fluoride residual; therefore, Test 3 was scheduled. When the manufacturer of the polymer

(Stockhauser) was contacted, the individual knew of no test to determine residual concentrations in a media and did not know the half-life of the material. In preparation for Test 3, the filters were backwashed every day to flush out as much polymer as possible. Nevertheless, the degree of polymer removal is unknown. The lower recovery rate for the tracer may be attributed to residual polymer in the media.

Finally, a review of the graph of relative concentration versus time (Figure 3) shows that the tracer had not quite reached a steady state level before the end of the tracer addition (twice the theoretical detention time) during Test 3. However, according to the Guidance Manual, "it is not necessary to reach a steady state concentration in the exiting water to determine T_{10} ; however, it is necessary to determine tracer recovery. It is recommended that the tracer recovery be determined to identify hydraulic characteristics or density problems" (ref 1, p. C-10). Therefore, the T_{10} determination is still valid for this test.

The T_{10} values determined from these two tests provide conservative T_{10} estimates for any flow less than the tests flows. Averaging the T_{10} analyses will provide conservative estimates of T_{10} for all flows less than or equal to 2,318 gpm.

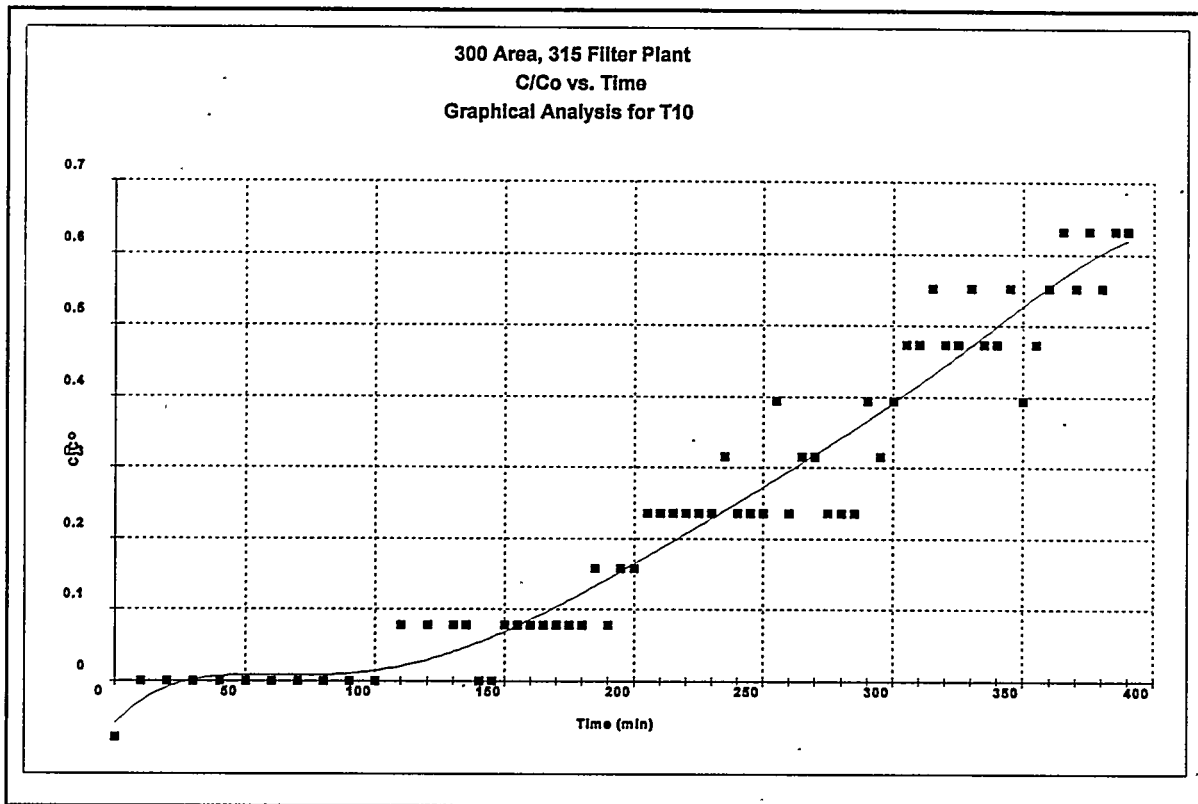


Figure 3: 315 Filter Facility 2,160 gpm tracer test (Source: Appendix A, p. A-C-10)

V. CONCLUSIONS AND RECOMMENDATIONS

The results of the two flow tracer studies (Q peak and 0.90* Q peak) performed at the 315 Water Treatment Facility are shown in Table 4.

TABLE 4 Results of Two Tracer Tests at The 315 Water Treatment Facility				
Target Flow	Average Test Flow	Theoretical Residence Time (T)	Actual Residence Time (T ₁₀)	% Tracer Recovered
2,400 gpm (Test 1)	2,380 gpm	178 min	102 min	85%
2,160 gpm (Test 3)	2,127 gpm	199 min	167 min	45%

T₁₀ for any flow can be determined by the following equation:

$$T_{10} = T_{10T} \times Q_T / Q$$

Where: (ref 1, p. C-3)

T₁₀ = Detention time at system flow rate

Q = System flow rate

T_{10T} = Detention time from tracer test

Q_T = Flow during tracer test

This equation, when used in conjunction with the results of the 315 Water Treatment Facility tracer tests, simplifies to the following:

$$T_{10} = 300,000 / Q$$

Where: (Appendix A, p. A-8)

T₁₀ = Detention time at any flow (minutes)

Q = Flow (gallons per minute)

Because of the change in mission at Hanford from weapons production to environmental restoration, the water treatment facilities are expected to continue having decreased demands. The high flow tracer study performed at the 315 Water Treatment Facility (ID# 418408) would continue to provide conservative T_{10} estimates if future flows do not exceed test flows.

The March 6 tracer test verified that there were no unfavorable hydraulic characteristics or density problems with 95% of the tracer recovered or accounted for when the test was stopped. The March 6 test appeared to provide a reliable determination of T_{10} . The results from the March 23 test were analogous to the first test, but such a high recovery was not indicated. However, conditions that may have affected tracer recovery should not have impacted the T_{10} determination. The data was not far from a good statistical fit (0.85) and the calculated retention time fell in line with the results of the first test. A steady state concentration in the exiting water is not necessary to determine T_{10} which would indicate that the T_{10} determinations from these tests provide a reliable means to determine T_{10} at any flow through the same configuration using the average of the two tests.

VI. REFERENCES

1. Guidance Manual for Compliance With The Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources; U.S. Environmental Protection Agency, March 1991.

2. Disinfection Contact Time Study Plan, "300 Area Tracer Study," Rev. 2, prepared by ICF Kaiser Hanford Company, December 1994.
3. Letter, C.L Riley (Washington State Department of Health) to D.J. Ortiz (U.S. Dept. of Energy), "Hanford Nuclear Reservation, Surface Water Treatment Plants Tracer Study Requirements," October 19, 1994.
- 4) Hudson, H.E., Jr; "Water Clarification Processes: Practical Design and Evaluation," Van Nostrand Reinhold Company, New York, 1981.

APPENDIX A

**Calculation No. ER5480-G-007
Contact Time in the 300 Area Filter Facility
Determined From A Two Flow Tracer Test, Rev. 0**

**KAISER ENGINEERS
HANFORD**

CALCULATION IDENTIFICATION AND INDEX

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Date 3/28/95

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline ENVIRONMENTAL ENG WO/Job No. EA5480 Calculation No. EA5480-6-007
 Project No. & Name TRACER/CONTACT STUDY OF HANFORD WATER PLANTS
 Calculation Item CONTACT TIME IN 300 AREA FILTER PLANT DETERMINED FROM TWO FLOW TRACER TEST

These calculations apply to:

Dwg. No. _____ Rev. No. _____
 Dwg. No. _____ Rev. No. _____
 Other (Study, CDR) _____ Rev. No. _____

The status of these calculations is:

- Preliminary Calculations
- Final Calculations
- Check Calculations (On Calculation Dated _____)
- Void Calculation (Reason Voided _____)

Incorporated in Final Drawings? Yes No
 This calculation verified by independent "check" calculations? Yes No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	<u>William R. Kelly</u> <u>3/27/95</u>		
Checked by	<u>J.W. Fink</u> <u>3/31/95</u>		
Approved by			
Checked Against Approved Vendor Data			

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<u>3-9</u>	<u>CALCULATIONS CONT'</u>
<u>10</u>	<u>CONCLUSIONS</u>
<u>A1-A17</u>	<u>APPENDIX A FIELD NOTES AND DATA</u>
<u>B1-B5</u>	<u>APPENDIX B SPREAD SHEET FORMULAS</u>
<u>C1-C14</u>	<u>APPENDIX C SPREAD SHEET CALCULATIONS</u>

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Calc. No. ER5480-6-067

Revision 0

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DESIGN ANALYSIS

Client	ICF-KH	WO/Job No.	ER5480 / F00684
Subject	315 Filter Plant	Date	3/27/95 By William W. Pickett
Retention Time		Checked	3/31/95 By J. W. Fink
Location	300 AREA	Revised	By

OBJECTIVE: THE PURPOSE OF THIS CALCULATION IS TO DETERMINE THE ACTUAL DETENTION TIME (T_{10}) IN THE 300 AREA FILTER PLANT BASED ON RESULTS OF A SODIUM FLUORIDE TRACER STUDY

Given Data: 315 Filter Plant Volume with Four Basins and Four Filters on Line is 1.605×10^6 L (REF 3 P. 3)

The Fluoride ion concentration in the Feed Solution is 17.6 g/c (REF 3 P. 4)

The Background Fluoride Concentration was 0.4 mg/L and the Fluoride Feed Rate was 620.8 mg/min during the 2,400 gpm Test. (Appendix A P. A-1)

The Background Fluoride Concentration was 0.4 mg/L and the Fluoride Feed Rate was 580.0 mg/min during the 2,160 gpm Test. (Appendix A P. A-12)

Fluoride Ion Loss Due to 20 ppm alum Dosage is 0.1 mg/L (REF 4 P. 3)

Fluoride Ion Loss Due to 25 ppm alum Dosage is 0.2 mg/L (REF 4 P. 3)

METHODS: THE CALCULATIONS ARE PERFORMED USING METHODS OUTLINED IN REFERENCE 2 AND STANDARD ENGINEERING EQUATIONS. EXCEL 5.0 WAS USED AS A SPREADSHEET FOR REPEATING CALCULATIONS AND GRAPHING.

REFERENCES:

- 1) Disinfection Contact Time Study Plan, 300 AREA TRACER STUDY, Rev. 2, December 1994.
- 2) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources; March 1991.
- 3) Calculation ER5480-6-005 Rev. 3 "Theoretical Detention Time and Fluoride Injection Rate (300 AREA)"
- 4) Calculation ER5480-6-004 Rev. 0 "Fluoride Loss From Addition of Alum"

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DESIGN ANALYSIS

Calc. No. ER5480-6-007
Revision 0
Page No. 2 of 10

Client ICF-KH
Subject 315 Filter Plant
Retention Time
Location 300 AREA

WO/Job No. ER5480-6-007
Date 3/27/95 By William W. Pickett
Checked 3/31/95 By J. W. Paul
Revised By

Findings:

The Residence Time of the 315 Filter Plant in the 300 AREA were determined to be:

Target Flow	Average Flow	Residence Time (T ₁₀)	% Fluoride Recover.
2,400 gpm	2,380	102 min	85%
2,160 gpm	2,127 gpm	167 min	45%

(Appendix A, P. C-3, C-9, C-10)

The Residence Time (T₁₀) in the 315 Filter Plant can be calculated using the following equation if 4 filters and 4 basins are being used:

$$T_{10}(\text{min}) = \frac{300,000}{\text{Flow (gpm)}}$$

Appendix A contains the field notes and data that were taken during the test that supplied the data for this residence time calculation.

Appendix B contains the spreadsheet cell formulas that were used to calculate % Fluoride Recovery and Residence Time.

Appendix C contains the spreadsheet calculations and graphs used to calculate % Fluoride Recovery and Residence Time.

Calculations:

The majority of these calculations will be performed on the data gathered at 13:40 during the March 6, 1995 2,400 gpm test. These calculations were performed over and over with an Excel spreadsheet (See Appendix C).

Data from a step dose tracer study can be evaluated two ways.

- 1) graphical method (Ref. 2, P. C-14)
- 2) numerical method

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Calc. No. ER5480-6-007

Revision 0

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DESIGN ANALYSIS

Client	ICF-KH	WO/Job No.	ER5480 / F00114
Subject	315 Bldg Retention Time	Date	3/27/85 BY William W. Peckert
Location	300 AREA	Checked	3/31/85 BY J. W. Fink
		Revised	BY

Determination of Detention Time T_{10} :

In the graphical method, T_{10} is read directly from a graph of dimensionless concentration versus time.

In the numerical method, the data is evaluated numerically and a straight line is developed through a semi-logarithmic plot of the data. The resulting equation of the line is used to calculate the T_{10} value, assuming the correlation coefficient indicates a good statistical fit (0.9 or above).

(Ref. 2, P. C-14)

With the numerical method, T_{10} is determined as the solution to an equation instead of an "eyeball" estimate from a data plot.

(Ref. 2, P. C-18, C-19)

The tracer fluoride concentration is obtained as follows

$$\text{Tracer conc}(C) = \text{Fluoride measured} - \text{Baseline}$$

$$C = 1.1 - 0.4$$

(Ref. 2, P. C-16)

$$C = 0.7 \text{ mole}$$

Dimensionless concentrations are developed by dividing tracer concentrations by the applied fluoride dose (C_0).

(Ref. 2, P. C-16)

C_0 is determined from the sodium fluoride injection rate and the average flow as follows:

$$C_0 = 620.8 \text{ mg/min} \quad (\text{Appendix A, P. A-1})$$

$$\text{Fluoride Ion Concentration} = \frac{17.6 \text{ g F}}{\text{L injected sol}} \quad (\text{Ref. 3, P. 4})$$

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Calc. No. ER5480-6-007

Revision 0

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DESIGN ANALYSIS

Client ICF-KH

WO/Job No. ER5480/FOURB4

Subject 315 Facility Retention

Date 3/27/95 By William W. Pickett

Location TIME

Checked 3/31/95 By J. W. Fush

Location 300

Revised By

T₁₀ cont.

Average Test Flow = 9009 ⁴/min (Appendix C, P. (-1))

$$C_o = \frac{\text{Injection Feed Rate} \times \text{F. Conc. in Feed}}{\text{Average Flow}}$$

Average Flow

$$C_o = \frac{620.8 \frac{\text{ml Feed}}{\text{min}} \left(\frac{17.6 \text{ g F}}{1 \text{ Feed}} \right) \left(\frac{1 \text{ L}}{1000 \text{ mL}} \right) \left(\frac{1000 \text{ mg}}{1 \text{ g}} \right)}{9009 \frac{\text{L}}{\text{min}}}$$

$$C_o = 1.213 \text{ mg/L}$$

The Dimensionless Concentration is now determined:

$$\%C_o = \frac{0.7}{1.213} = 0.577$$

For the Graphical method a plot of %C_o versus Time is developed. T₁₀ is read directly from the graph when %C_o = 0.10 (Ref. 2, P. (-17))

Graphical analysis of T₁₀ for 2,920 gpm is approximately:

90 min (See Appendix C, P. (-4))

The Numerical analysis for T₁₀ requires the additional steps:

determination of $\log_{10}(1 - \%C_o)$

determination of $\frac{1}{T}$

(Ref. 2, P. (-17))

Where: t = elapsed time

and T = Theoretical Residence Time

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Calc. No. ER5480-6-007

Revision 0

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DESIGN ANALYSIS

Client ICF-KH

WO/Job No. ER5480/F00B84

Subject 315 FACILITY Retention
Time

Date 3/6 7/95 By William W. Pickett

Location 300 AREA

Checked 3/31/95 By J.W. Fuchs

Revised By

[To Cont.]

In the example used earlier Time = 13:40

$$t = 13:40 - 10:20$$

$$t = 200 \text{ min}$$

$$T = \frac{\text{Plant Volume}}{\text{Average Test Flow}}$$

$$T = \frac{1.605 \times 10^6 \text{ L}}{9.009 \text{ L/min}}$$

$$T = 178 \text{ min}$$

Therefore the two missing pieces can be solved for and the graphical analysis completed

$$\log_{10}(1 - \%_0) = \log_{10}(1 - 0.577)$$

$$= -0.374$$

$$\frac{t}{T} = \frac{200}{178}$$

$$= 1.12$$

These calculations are repeated at each time interval. These data are linearly regressed as $\log_{10}(1 - \%_0)$ versus t/T to obtain the fitted straight-line parameters to the following equation:

$$\log_{10}(1 - \%_0) = m\left(\frac{t}{T}\right) + b \quad (\text{Ref. 2, p. 18})$$

Where: Slope = $m = -0.6059$

Intercept = $b = 0.3004$

Correlation coefficient = 0.95 (Appendix C, p. 65-66)

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Calc. No. ER5480-6-007

Revision 0

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DESIGN ANALYSIS

Client	ICF-KH	WO/Job No.	ER5480 / F00884
Subject	315 Facility Retention Time	Date	3/27/95 By William W. Pickel
Location	300 AREA	Checked	3/31/95 By J.W. Fink
		Revised	BY

T₁₀ CONT'

The numerical analysis, as with the graphical analysis, is evaluated at $\%C_0 = 0.10$. Rearranging the previous equation:

$$T = \frac{(\log_{10}(1 - \%C_0) - b)}{m} (T)$$

When $t = T_{10}$

$$T_{10} = \frac{(\log_{10}(1 - 0.1) - 0.3004)}{-0.6059} (178)$$

$$@ 2,380 \text{ gm } T_{10} = 102 \text{ min}$$

Because the regression is a good statistical fit (0.95) and the numerical method eliminates the need to "eyeball" a T₁₀ value, the numerical results will be used.

The data from the 3/23/95 tracer test were not a good statistical fit (0.87). Therefore the graphical method had to be used.

$$@ 2,127 \text{ gm } T_{10} = 167 \text{ min (Appendix C, P. C-9, C-10)}$$

Determination of % Mass Recovery:

The first part of determining % mass recovered is calculating mass injected.

$$\text{mass injected} = (\text{injection Feed Rate}) (\text{Time injected})$$

$$= 620.8 \frac{\text{mL}}{\text{min}} \left(\frac{17.69 \text{ F}}{\text{L}} \right) \left(\frac{1 \text{ L}}{1000 \text{ mL}} \right) (360 \text{ min})$$

$$@ 2,380 \text{ gm mass injected} = 3,933.9$$

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Calc. No. ERS480-6-007

Revision 0

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DESIGN ANALYSIS

Client <u>ICF-KH</u>	WO/Job No. <u>ERS480/F003B4</u>
Subject <u>315 Facility Retention Time</u>	Date <u>3/27/95</u> BY <u>William W. Pickett</u>
Location <u>300 AREA</u>	Checked <u>3/31/95</u> BY <u>J. W. Fink</u>
	Revised _____ BY _____

Mass Recovery Cont'

Determination of Mass Recovered:

The mass recovered is obtained by determining the total area under the rising and falling step dose curve.

The area is found with a numerical integration technique called the rectangle rule.

The fluoride concentration at the end of a time interval is multiplied times the time interval to obtain an incremental area.

Our March 6, 1995 13:40 Example

$$\begin{aligned} \text{Incremental area} &= \text{Sampling Time Interval} \times \text{Fluoride Conc.} \\ &= (200 - 195 \text{ min}) (0.7) \\ &= 3.5 \frac{\text{mg} \cdot \text{min}}{\text{L}} \quad (\text{Ref. 2, P. C-21}) \end{aligned}$$

The incremental areas are summed and the total area determined

$$\text{Total AREA} = 3.70 \frac{\text{mg} \cdot \text{min}}{\text{L}} \quad (\text{Appendix B, P. B-3})$$

The mass recovered can now be determined

$$\begin{aligned} \text{Total Mass Recovered} &= (\text{Total AREA}) (\text{average Flow}) \\ &= \left(3.70 \frac{\text{mg} \cdot \text{min}}{\text{L}} \right) \left(\frac{1.9}{1000 \text{ mg}} \right) \left(\frac{900 \text{ gL}}{\text{min}} \right) \\ &= 3,333 \text{ g.} \quad (\text{Ref. 2, P. C-23}) \end{aligned}$$

$$\% \text{ Recover} = \frac{\text{Mass Recovered}}{\text{Mass Injected}} \times 100$$

@ 2,380 g/m Recovery = 85%

@ 2,127 g/m % Recovery = 45%

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DESIGN ANALYSIS

Calc. No. ER5480-6-007
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Client	FCF-KH	WO/Job No.	ER5480 / F001B4
Subject	315 Facility Retention Time	Date	3/27/95
		Checked	3/31/95
Location	300 AREA	Revised	

Determination of T_{10} at any Flow in the 315 Filter Plant using 4 Filters and 4 Basins.

T_{10} is inversely proportional to Flow Rate, therefore, the T_{10} at a Flow rate other than that with which the tracer study was conducted can be determined with the following:

$$T_{10 @ Q} = \frac{(T_{10T})(Q_T)}{Q}$$

(Ref 2, P. C-3.) Where T_{10T} = T_{10} at Tracer Study Flow Rate
 Q_T = Tracer Study Flow Rate
 Q = ANY SYSTEM Flow Rate
 $T_{10 @ Q}$ = T_{10} at any system Flow Rate

From previously: $T_{10 @ 2,380 \text{ gpm}} = 107 \text{ min}$
 $T_{10 @ 2,127 \text{ gpm}} = 167 \text{ min}$

Using the above equation and the T_{10} at 2,380 gpm a calculated T_{10} can be determined for the 2,127 Flow Rate

$$@ 2,127 \text{ gpm } T_{10} \text{ calculate} = \frac{(107)(2380)}{2,127}$$

$$T_{10} \text{ calc} = 114.13 \text{ min}$$

Using $T_{10} \text{ calc}$ and $T_{10} \text{ actual}$ an average T_{10} can be determined and used to calculate T_{10} for any Flow.

@ 2,127 gpm $T_{10} \text{ actual} = 167 \text{ min}$
 $T_{10} \text{ calculated from } 2,380 \text{ gpm} = 114.13 \text{ min}$

$$\bar{T}_{10} = 141 \text{ min when Flow} = 2,127 \text{ gpm}$$

AN Equation is developed for all Flows:

$$T_{10 @ Q} = \frac{(141)(2,127)}{Q}$$

$$T_{10 @ Q} = \frac{300,000}{Q}$$

Following is a plot of this calculation.

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DESIGN ANALYSIS

Calc. No. ER5480-6-00

Revision 0

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Client ICF-KH

WO/Job No. ER5480/F000154

Subject 315 Facility Retention Time

Date 3/27/95 By William W. Pickett

Checked 3/31/95 By J. W. Fink

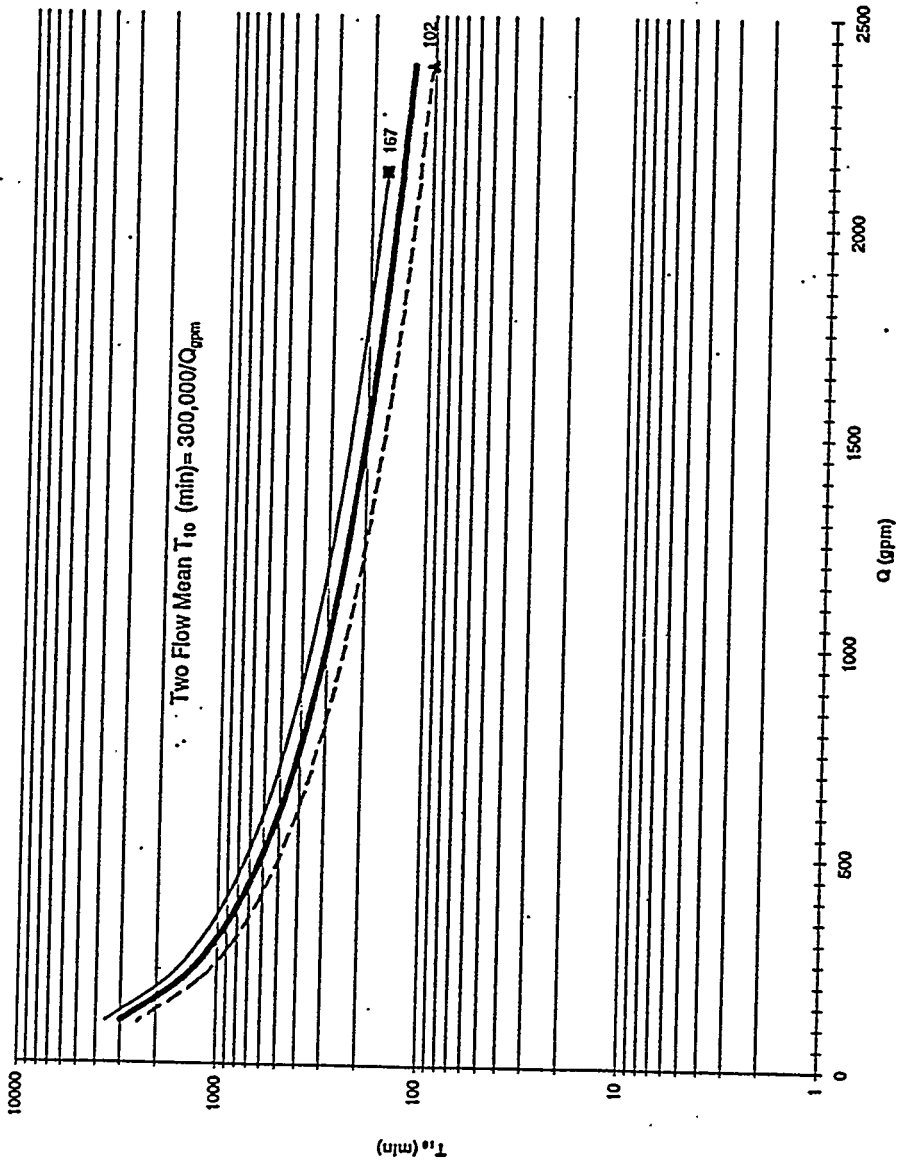
Location 300 AREA

Revised By

The Data For This Plot and This Plot are in Appendix C, PC-13 and C-14.

T₁₀ 315 Filter Plant, 300 Area

Detention Time vs. Flow



Prepared by ICF Kaiser

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Calc. No. ER5480-6-007Revision 0Page No. 10 of 10

DESIGN ANALYSIS

Client ICF-KHWO/Job No. ER5480/F000654Subject 315 Facility Retention TimeDate 3/27/95By William W. PickertChecked 3/31/95By J.W. FishLocation 300 AREA

Revised

By

CONCLUSIONS:

THE 315 FILTER PLANT THEORETICAL
RETENTION TIMES ARE AS FOLLOWS:

$$T @ 9009 \frac{1}{2} \text{min} (2380 \text{gpm}) = 178 \text{min}$$

$$T @ 8050 \frac{1}{2} \text{min} (2127 \text{gpm}) = 199 \text{min}$$

THE 315 FILTER PLANT ACTUAL RETENTION
TIME (T_{10}) ARE AS FOLLOWS:

$$T_{10} @ 9009 \frac{1}{2} \text{min} = 102 \text{min} \quad (\text{Determined Numerically})$$

$$T_{10} @ 8050 \frac{1}{2} \text{min} = 167 \text{min} \quad (\text{Determined Graphically})$$

THE MASS RECOVERY OF THE INJECTED
TRACER AT THE 315 FILTER PLANT ARE
AS FOLLOWS:

$$\text{Mass Fluoride Recovered @ } 9009 \frac{1}{2} \text{min} = 85\%$$

$$\text{Mass Fluoride Recovered @ } 8050 \frac{1}{2} \text{min} = 45\%$$

RETENTION TIME AT ANY FLOW CAN BE
DETERMINED FROM THE FOLLOWING EQUATION

$$T_{10}(\text{min}) = \frac{300,000}{Q(\text{gpm})}$$

APPENDIX A

Field Notes and Data

2400 gpm 3/6 Tracer Test

Engineers : Will Pickett
Toby Bratcher
Dennis Cuchala

Operators : Roy Hammond - lead
Lynn Adams - valve
Berry Rowe
Luanne Brewster

Others :
Safety + Health Steve Stevenson
Utilities Sam Campbell, Jim Day, Dan Gleason
Lynn Kelly

Basins on-line - 1, 2, 3, 4
Filters on-line - 1, 2, 3, 4
Alum Dosage (ppm) - 20 ppm
Average Background F (ppm) 0.30 ~~0.40~~ 1.20-1.25
Required Injection Concentration (ppm) - ~~1.25~~ 1.25 ppm
Injection Flow Rate (m³/min) - 620.8
Required Pump Speed Setting (%) 62.5

$90\% \times 1.2 = 1.08$

$1.4 - 1.08 = 0.32$

Pre Job 8:00 - 9:00

Load sampler, 9:10 - 9:30

Background established 10:00

FL 0.35 ppm - 0.40 ppm

$$C_i = 1.5 + 0.1 - 0.35$$

$$C_i = 1.25 \text{ ppm}$$

$$Q_{injection} = 1.25 \cdot Flow \cdot 0.2174 = 645.3$$

Pump speed %
 $= \frac{Q_{injection}}{1.5 \cdot 9535} + 1.311783$
 $= 66.14\%$

Q Flow = 2,280
 P speed = 62.8%

10:10 A.M. flow established
 2404

P5set 62.5 %
 Flow = 620.8 m/min

Start pump 10:20:45

Pump OFF

Test over 9:20 10:20:45 4:20:00

Time	Flowable Background	Flowable Inerted	Travel Distance	Recovery After injected
0	0	1	0	
80	0	1	3	
90	0	1	4	
100	0	1	5	
110	0.1	1	6	
120	0.1	1	7	
130	0.1	1	8.5	
135	0.3	1.5	10.0	
140	0.3	1.5	11.5	
145	0.4	2.0	13.5	
150	0.4	2.0	15.5	
155	0.4	2.0	17.5	
160	0.5	2.5	20.0	
165	0.5	3.0	23.0	
170	0.5	2.5	25.5	
175	0.6	3.0	28.5	
180	0.6	3.0	31.5	
185	0.7	3.5	35.0	
190	0.7	3.5	38.5	
195	0.7	3.5	42.0	
			45.5	

Dose (mg-min) =

inj. conc x Time injected

= 620.8 $\frac{ml}{min}$ @ 4.8 set

$(620.8 \frac{ml}{min}) (7.69 \frac{F}{L set soln})$
 $(620.8 \frac{ml}{min}) (7.69 \frac{F}{L set soln})$

= 10.939 F

42.27

Pump off @ 4.20
 6.115 = 3,935 gOFF

Flow	Area	Time	Temp	Pressure	Flow	Area	Time	Temp	Pressure
200	1.7	3.5	41.5	104.0	3,935	1.7	3.5	41.5	104.0
205	1.7	3.5	41.0	109.0		1.7	3.5	41.0	109.0
210	1.8	4.0	57.0	111.5		1.8	4.0	57.0	111.5
215	1.8	4.0	61.0	118.5		1.8	4.0	61.0	118.5
220	1.8	4.0	65.0	123.5		1.8	4.0	65.0	123.5
225	1.8	4.0	69.5	128.5		1.8	4.0	69.5	128.5
230	1.8	4.0	73.5	133.5		1.8	4.0	73.5	133.5
235	1.8	4.0	77.5	138.5		1.8	4.0	77.5	138.5
240	1.9	4.5	81.0	143.5		1.9	4.5	81.0	143.5
245	1.9	4.5	86.5	148.5		1.9	4.5	86.5	148.5
250	1.9	4.5	91.0	153.5		1.9	4.5	91.0	153.5
255	1.9	4.5	95.5	158.5		1.9	4.5	95.5	158.5
260	1.9	4.5	99.5	163.5		1.9	4.5	99.5	163.5
265	1.9	4.5	104.0	168.5		1.9	4.5	104.0	168.5
270	1.9	4.5	109.0	173.5		1.9	4.5	109.0	173.5
275	1.9	4.5	111.5	178.5		1.9	4.5	111.5	178.5
280	1.9	4.5	118.5	183.5		1.9	4.5	118.5	183.5
285	1.9	4.5	123.5	188.5		1.9	4.5	123.5	188.5
290	1.9	4.5	128.5	193.5		1.9	4.5	128.5	193.5
295	1.9	4.5	133.5	198.5		1.9	4.5	133.5	198.5
300	1.9	4.5	138.5	203.5		1.9	4.5	138.5	203.5
305	1.9	4.5	143.5	208.5		1.9	4.5	143.5	208.5
310	1.9	4.5	148.5	213.5		1.9	4.5	148.5	213.5
315	1.9	4.5	153.5	218.5		1.9	4.5	153.5	218.5
320	1.9	4.5	163.5	223.5		1.9	4.5	163.5	223.5
325	1.9	4.5	173.5	228.5		1.9	4.5	173.5	228.5
330	1.9	4.5	183.5	233.5		1.9	4.5	183.5	233.5
335	1.9	4.5	193.5	238.5		1.9	4.5	193.5	238.5
340	1.9	4.5	203.5	243.5		1.9	4.5	203.5	243.5
345	1.9	4.5	213.5	248.5		1.9	4.5	213.5	248.5
350	1.9	4.5	223.5	253.5		1.9	4.5	223.5	253.5

Flow = 9,084 $\frac{m^3}{hr}$
 $3,935 - (1000 \times 0.9) = 2,035$
 $2,035 \times 0.9 = 1,831.5$
 $1,831.5 + 1,203 = 3,034.5$



-14:10
-4:15

1.1 - .41 = 1.0 90% = 90% = .90 1.4 - .90 = 0.5
 1.5 - .41 = 1.1 0.99 1.5 - 0.99 = 0.5

Time	F-P.G.	Area	Sum Area
360	1.1	7.1	194.5
370	1.0	10	204.5
385	1.1	16.5	221.0
400	1.0	15	236.0
415	1.0	15	251
430	1.0	15	266
445	0.9	13.5	279.5
500	0.9	13.5	293.0
515	0.8	12.0	305.0
530	0.7	10.5	315.5
545	0.6	9.0	324.5
600	0.5	7.5	332.0
615	0.5	7.5	339.5
630	0.4	6.0	345.5
645	0.3	4.5	350
700	0.3	4.5	354.5
715	0.3	4.5	359.0
730	0.2	3.0	362.0
745	0.2	3.0	365.0

(310) (3)

ASG ✓

3-935 gulf

Recovered =

(1.1 Reg / 1000) x (1908.1)

~~2.1800~~

Time	F-156	AREA	Count Rate	(4)
745	0.7	3.0	365.0	ASSET = 3935
800	0.1	1.5	366.5	area / 1000 + 2089
815	0.1	1.5	368.0	2380
			371	

ICF KAISER HANFORD COMPANY				FLUORIDE TRACER TEST			
DATE: 3/6/95		FACILITY: 315 Filter Plant 300 A Red					
SAMPLES TAKEN BY: Dennis Leubala, Neil Kibbett				SIGNATURE: <i>Dennis Leubala</i> <i>Neil Kibbett</i>			
PUMP SPEED: 62.5%		PUMP STROKE: 50%					
TIME OF INJECTION OF FLUORIDE TRACER: 10:20 - 16:20							
SAMPLE NUMBER # - T	TIME OF SAMPLE (H:MM)	WATER LEVEL IN CLEARWELL (FT)	SYSTEM FLOWRATE (GPM)	TIME OF ANALYSIS (H:MM)	TEMP BEFORE TESTING (F)	RESIDUAL FLUORIDE (MG/L)	COMMENTS
1-T	10:30	10.80	2359	10:32	45	0.5	
2-T	10:40	10.80	2354	10:42	45	0.5	
3-T	10:50	10.80	2341	10:52	44	0.4	
4-T	11:00	10.80	2392	11:02	44	0.4	
5-T	11:10	10.80	2408	11:12	44	0.4	
6-T	11:20	10.80	2411	11:22	44	0.4	
7-T	11:30	10.80	2440	11:32	44	0.4	
8-T	11:40	10.79	2447	11:41	44	0.5	
9-T	11:50	10.79	2411	11:52	44	0.5	
10-T	12:00	10.80	2433	12:02	44	0.5	
11-T	12:10	10.80	2424	12:11	43	0.6	
12-T	12:20	10.80	2424	12:22	43	0.6	
13-T	12:30	10.80	2408	12:32	43	0.7	
14-T	12:35	10.80	2413	12:37	43	0.7	
15-T	12:40	10.80	2439	12:42	43	0.7	
16-T	12:45	10.79	2456	12:47	43	0.8	
17-T	12:50	10.79	2431	12:53	42	0.8	
18-T	12:55	10.80	2410	12:57	42	0.8	
19-T	13:00	10.80	2447	13:02	42	0.9	
20-T	13:05	10.80	2459	13:07	42	1.0	
21-T	13:10	10.80	2432	13:13	42	0.9	
22	13:15	10.79	2416	13:17	42	1.0	
23	13:20	10.80	2398	13:22	43	1.0	
24	13:25	10.79	2403	13:27	43	1.0	
25	13:30	10.79	2408	13:32	43	1.1	
26	13:35	10.80	2386	13:37	43	1.1	
27	13:40	10.80	2389	13:42	43	1.1	
28	13:45	10.80	2375	13:47	42	1.1	
29	13:50	10.80	2380	13:52	42	1.2	
30	13:55	10.80	2367	13:57	43	1.2	
31-T	14:00	10.80	2382	14:02	42	1.2	
32-T	14:05	10.80	2384	14:07	42	1.2	
33-T	14:10	10.79	2383	14:12	42	1.3	

ICF KAISER HANFORD COMPANY				FLUORIDE TRACER TEST			
DATE: 3/6/95		FACILITY: 315 Filter Plant 300 AREA					
SAMPLES TAKEN BY: Dennis Laubala/Will Pickett SIGNATURE: Dennis Laubala Will Pickett							
PUMP SPEED: 62.5%		PUMP STROKE: 50%					
TIME OF INJECTION OF FLUORIDE TRACER: 10:20 - 16:20							
SAMPLE NUMBER # - T	TIME OF SAMPLE (H:MM)	WATER LEVEL IN CLEARWELL (FT)	SYSTEM FLOWRATE (GPM)	TIME OF ANALYSIS (H:MM)	TEMP BEFORE TESTING (F°)	RESIDUAL FLUORIDE (MGL)	COMMENTS
34	14:15	10.8	2363	14:16	43	1.2	
35	14:20	10.8	2386	14:22	42	1.2	
36	14:25	10.8	2385	14:27	42	1.3	
37	14:30	10.8	2372	14:32	42	1.3	
38	14:37	10.79	2385	14:38	42	1.3	
39	14:40	10.8	2375	14:42	42	1.3	
40	14:45	10.8	2360	14:47	42	1.2	
41	14:50	10.8	2374	14:52	42	1.3	
42	14:55	10.79	2367	14:57	42	1.4	
43	15:01	10.80	2356	15:02	42	1.3	
44	15:05	10.79	2370	15:07	42	1.4	
45	15:10	10.79	2389	15:12	42	1.4	
46	15:15	10.80	2378	15:17	42	1.4	
47	15:20	10.79	2395	15:22	42	1.4	
48	15:25	10.80	2384	15:27	42	1.4	
49	15:30	10.80	2398	15:32	42	1.4	
50	15:40	10.8	2389	15:42	42	1.4	
51	15:50	10.8	2368	15:52	42	1.4	
52	16:00	10.8	2353	16:02	42	1.4	
53	16:10	10.8	2342	16:12	42	1.4	
54	16:20	10.8	2341	16:22	42	1.5	Saturated turned off
55	16:30	10.8	2374	16:32	42	1.4	
56	16:45	10.8	2383	16:47	42	1.5	
57	17:00	10.8	2373	17:02	42	1.4	
58	17:15	10.8	2352	17:17	42	1.4	
59	17:30	10.8	2366	17:33	42	1.4	
60	17:45	10.79	2346	17:47	42	1.3	
61	18:00	10.80	2351	18:02	42	1.3	
62	18:15	10.79	2332	18:17	42	1.2	
63	18:30	10.79	2393	18:32	42	1.1	
64	18:45	10.79	2342	18:47	42	1.0	
65	19:00	10.80	2341	19:02	42	0.9	
66	19:15	10.80	2337	19:17	42	0.9	

500

3/23/95 2:60 6pm Tracer Test

Engineers: Will Pickett
Dennis Lakhula

Operators: Roy Hammond
Luanna Brewster
Lynn Adams
Berry Bovee

Others: Sam Camp
Lynn Kelly
Jim Ray
Dan Gleason

Basins on Line: 1, 2, 3, 4

Filters on Line: 1, 2, 3, 4

Alum Dosage: 2.5 ppm

F Loss Due To Alum: 0.15 - 0.20 ppm

TEST START TIME 8:54 (C Tank Valve Opened)

F Background Established : 9:12

F Background Conc : 0.4 mg/l

2160 gpm established : 9:25

In Section Concentration:

$$C_i = \text{Desired Effluent Conc} + \text{Alum Loss} - \text{Background}$$

$$C_i = 1.5 + 0.25 - 0.4$$

$$C_i = 1.25 \text{ mg/l}$$

Calculated In Section Flow Rate:

$$Q_i = C_i \cdot \text{Flow} \cdot 0.21474$$

$$Q_i = 1.25 \cdot 2160 \cdot 0.21474$$

$$Q_i = 580 \text{ mL/min}$$

Actual In Section Flow Rate: Pump Speed = 55-56

V ₁	V ₂	ΔV	Time	mL/min
1000	485	575	60.05	575
1000	410	590	60.20	588
1000	470	580	60.20	578

In Section Flow Rate = 580 mL/min

Injection Start Time: 9:50:00

Pump OFF Time: 16:25:00

Test Over: 21:30:00

ICF KAISER HANFORD COMPANY				FLUORIDE TRACER TEST			
DATE: 3/23/95		FACILITY: 315 Filter Plant					
SAMPLES TAKEN BY: Dennis Lusk / Will Pickert				SIGNATURE: Dennis Lusk / Will Pickert			
PUMP SPEED: 5690		PUMP STROKE: 50%					
TIME OF INJECTION OF FLUORIDE TRACER: 9:50-16:25							
SAMPLE NUMBER # - T	TIME OF SAMPLE (H:MM)	WATER LEVEL IN CLEARWELL (FT)	SYSTEM FLOWRATE (GPM)	TIME OF ANALYSIS (H:MM)	TEMP BEFORE TESTING (F°)	RESIDUAL FLUORIDE (MG/L)	COMMENTS
1	10:00	10.79	2161	10:02	47	0.3	
2	10:10	10.81	2106	10:12	47	0.4	
3	10:20	10.79	2108	10:22	47	0.4	
4	10:30	10.80	2098	10:32	46	0.4	
5	10:40	10.80	2105	10:42	46	0.4	
6	10:50	10.82	2159	10:52	46	0.4	
7	11:00	10.82	2118	11:02	46	0.4	
8	11:10	10.82	2124	11:12	45	0.4	
9	11:20	10.82	2133	11:22	46	0.4	
10	11:30	10.82	2123	11:32	46	0.4	
11	11:40	10.82	2098	11:42	46	0.4	
12	11:50	10.82	2172	11:52	45	0.5	
13	12:00	10.82	2152	12:02	45	0.5	
14	12:05	10.82	2128	12:07	45	0.5	
15	12:10	10.82	2122	12:12	45	0.5	
16	12:15	10.79	2118	12:17	45	0.4	
17	12:20	10.81	2160	12:22	45	0.4	
18	12:25	10.80	2132	12:27	45	0.5	
19	12:30	10.80	2135	12:32	45	0.5	
20	12:35	10.8	2196	12:37	45	0.5	
21	12:40	10.8	2148	12:42	45	0.5	
22	12:45	10.8	2176	12:47	45	0.5	
23	12:50	10.8	2184	12:52	45	0.5	
24	12:55	10.8	2142	12:57	44	0.5	
25	13:00	10.8	2138	13:02	44	0.6	
26	13:05	10.8	2165	13:07	45	0.5	
27	13:10	10.8	2170	13:12	45	0.6	
28	13:15	10.79	2239	13:17	45	0.6	
29	13:20	10.80	2182	13:22	45	0.7	
30	13:25	10.81	2063	13:27	45	0.7	
31	13:30	10.80	2071	13:32	45	0.7	
32	13:35	10.80	2071	13:37	45	0.7	
33	13:40	10.80	2110	13:43	45	0.7	

Start Satmeter 09:50

ICF KAISER HANFORD COMPANY				FLUORIDE TRACER TEST			
DATE: 3/23/95		FACILITY: 315 Filter Plant					
SAMPLES TAKEN BY: Dennis Leubke / Will Lichte??				SIGNATURE: Dennis L. Leubke / Will Lichte??			
PUMP SPEED: 56%		PUMP STROKE: 50%					
TIME OF INJECTION OF FLUORIDE TRACER: 9:50-16:25							
SAMPLE NUMBER # - T	TIME OF SAMPLE (H:MM)	WATER LEVEL IN CLEARWELL (FT)	SYSTEM FLOWRATE (GPM)	TIME OF ANALYSIS (H:MM)	TEMP BEFORE TESTING (F°)	RESIDUAL FLUORIDE (MGL)	COMMENTS
34	13:45	10.79	2200	13:47	46	0.7	
35	13:50	10.81	2150	13:53	44	0.8	
36	13:55	10.78	2059	13:58	44	0.7	
37	14:00	10.78	2072	14:02	45	0.7	
38	14:05	10.80	2136	14:07	45	0.7	
39	14:10	10.82	2117	14:12	45	0.9	
40	14:15	10.80	2187	14:17	45	0.7	
41	14:20	10.79	2242	14:22	45	0.8	
42	14:25	10.80	2105	14:27	46	0.8	
43	14:30	10.80	2100	14:32	45	0.7	
44	14:35	10.80	2086	14:37	45	0.7	
45	14:40	10.80	2101	14:42	45	0.7	
46	14:45	10.80	2116	14:47	45	0.9	
47	14:50	10.80	2109	14:52	45	0.8	
48	14:55	10.80	2111	14:57	45	0.9	
49	15:00	10.80	2100	15:02	45	1.0	
50	15:05	10.80	2112	15:07	45	1.0	
51	15:10	10.81	2141	15:12	45	1.1	
52	15:15	10.80	2163	15:17	45	1.0	
53	15:20	10.90	2136	15:22	45	1.0	
54	15:25	10.80	2093	15:27	45	1.1	
55	15:30	10.80	2136	15:32	45	1.0	
56	15:35	10.80	2132	15:37	45	1.0	
57	15:40	10.80	2111	15:42	46	1.1	
58	15:45	10.80	2114	15:48	45	0.9	
59	15:50	10.80	2106	15:52	46	1.0	
60	15:55	10.79	2128	15:57	45	1.1	
61	16:00	10.80	2114	16:02	46	1.2	
62	16:05	10.80	2087	16:07	45	1.1	
63	16:10	10.80	2111	16:12	45	1.2	
64	16:15	10.80	2112	16:17	46	1.1	
65	16:20	10.80	2107	16:22	45	1.2	
66	16:25	10.82	2143	16:27	45	1.2	Saturator off

ICF KAISER HANFORD COMPANY				FLUORIDE TRACER TEST			
DATE: 3/23/95		FACILITY: 35 Filter Plant					
SAMPLES TAKEN BY: Dennis Lusk / Will Pickett				SIGNATURE: <i>Dennis Lusk</i> / <i>Will Pickett</i>			
PUMP SPEED: 56%		PUMP STROKE: 50%					
TIME OF INJECTION OF FLUORIDE TRACER: 9:50 - 16:25							
SAMPLE NUMBER # - T	TIME OF SAMPLE (H:MM)	WATER LEVEL IN CLEARWELL (FT)	SYSTEM FLOWRATE (GPM)	TIME OF ANALYSIS (H:MM)	TEMP BEFORE TESTING (F)	RESIDUAL FLUORIDE (MGL)	COMMENTS
67	16:30	10.80	2115	16:30	45	1.0	
68	16:45	10.80	2131	16:47	45	1.0	
69	17:00	10.80	2153	17:02	45	1.0	
70	17:15	10.80	2108	17:17	45	1.0	
71	17:30	10.80	2112	17:32	45	1.0	
72	17:45	10.80	2108	17:48	45	1.0	
73	18:00	10.80	2088	18:05	45	1.0	
74	18:15	10.80	2127	18:19	45	1.0	
75	18:30	10.80	2137	18:33	45	0.8	
76	18:45	10.80	2134	18:47	45	1.0	
77	19:00	10.80	2140	19:03	45	0.9	
78	19:15	10.80	2140	19:18	45	0.8	
79	19:30	10.80	2129	19:33	46	0.9	
80	19:45	10.80	2134	19:47	46	0.8	
81	20:00	10.80	2142	20:02	45	0.6	
82	20:15	10.80	2126	20:17	45	0.8	
83	20:30	10.80	2137	20:33	45	0.2	?? Next Reagent St.
84	20:40	10.80	2131	20:43	45	0.6	Changed Reagent
85	20:45	10.80	2126	20:47	45	0.6	20:40
86	21:00	10.80	2120	21:02	45	0.4	(0.6)
87	21:15	10.80	2126	21:17	45	0.4	
88	21:30	10.80	2119	21:32	45	0.4	
89	21:45						
90	22:00						
	10.12	10.57			46	726	
	10.5	79.05			45	2970	
	10.9	799.4			401	220	
	10.7	797.07					

APPENDIX B

Spread Sheet Formulas

1700 c/pet

A	B	C	D	E	F	G	H	I	J	K	L	M
1	ICF KAI											
2	Date: 34764											
3	ge test flow = AVERAGE(E18:E91)											
4	Theoretical Residence Time (T _r) = 1665000/5E53											
5												
6												
7												
8												
9	Background											
10	0.395833333											
11	0.399305555											
12	0.402777777											
13	0.40625											
14	0.409722222											
15	0.413194444											
16	0.423811111											
17	Start Injection											
18	0.430555555											
19	0.4375											
20	0.444444444											
21	0.451388888											
22	0.458333333											
23	0.465277777											
24	0.472222222											
25	0.479166666											
26	0.486111111											
27	0.493055555											
28	0.500000000											
29	0.506944444											
30	0.513888888											
31	0.520833333											
32	0.527777777											
33	0.534722222											
34	0.541666666											
35	0.548611111											
36	0.555555555											
37	0.562500000											
38	0.569444444											
39	0.576388888											
40	0.583333333											
41	0.590277777											
42	0.597222222											
43	0.604166666											
44	0.611111111											
45	0.618055555											
46	0.625000000											
47	0.631944444											
48	0.638888888											
49	0.645833333											
50	0.652777777											
51	0.659722222											
52	0.666666666											
53	0.673611111											
54	0.680555555											
55	0.687500000											
56	0.694444444											
57	0.701388888											
58	0.708333333											
59	0.715277777											
60	0.722222222											
61	0.729166666											
62	0.736111111											
63	0.743055555											
64	0.750000000											
65	0.756944444											
66	0.763888888											
67	0.770833333											
68	0.777777777											
69	0.784722222											
70	0.791666666											
71	0.798611111											
72	0.805555555											
73	0.812500000											
74	0.819444444											
75	0.826388888											

2160ppm

A	B	C	D	E	F	G	H	I	J	K	L	M
ICF KAISER HANF												
Date: 3/7/81												
3gs test flow = AVERAGE(E18:E104) =D33.785306												
Theoretical Residence Time (T) = 1605000/ES3												
de Dossage (Co) = 560												
centration (Baseline) = 0.4												
ide loss due to alum = 0.2												
=S14*17.6/ES3												
1	2	3	4	5	6	7	8	9	10	11	12	13
Time	Time t (hr:min)	Time t (min)	Flowrate (gpm)	Flowrate (gpm)	Fluoride Measured (mg/L)	Tracer concentration (mg/L)	Incremental Area (mg·min/L)	Cumulative Area (mg·min/L)	C/Co	1-C/Co	Log10(1-C/Co)	VT
Background	0.3645833	495	0.4	0	N/A	N/A	N/A	N/A				
0.3680555	0.3715277	493	0.4	0	N/A	N/A	N/A	N/A				
0.375	0.3784722	498	0.4	0	N/A	N/A	N/A	N/A				
0.3819444	1318	1567	0.3	0	N/A	N/A	N/A	N/A				
0.4097222	=B17-SB\$17 0											
0.4166666	=B16-SB\$17 10	2161	0.3	=F18-0.4	0	=G18\$J\$4	=H17-H18			=1-J18	=LOG10(K18)	=D18\$E\$4
0.4238111	=B19-SB\$17 20	2106	0.4	=F19-0.4	=G18*(D18-D18)	=G19\$J\$4	=H18+H19			=1-J19	=LOG10(K19)	=D19\$E\$4
0.4305555	=B20-SB\$17 30	2108	0.4	=F20-0.4	=G20*(D20-D19)	=G20\$J\$4	=H19+H20			=1-J20	=LOG10(K20)	=D20\$E\$4
0.4375	=B21-SB\$17 40	2092	0.4	=F21-0.4	=G21*(D21-D20)	=G21\$J\$4	=H20+H21			=1-J21	=LOG10(K21)	=D21\$E\$4
0.4444444	=B22-SB\$17 50	2105	0.4	=F22-0.4	=G22*(D22-D21)	=G22\$J\$4	=H21+H22			=1-J22	=LOG10(K22)	=D22\$E\$4
0.4513888	=B23-SB\$17 60	2159	0.4	=F23-0.4	=G23*(D23-D22)	=G23\$J\$4	=H22+H23			=1-J23	=LOG10(K23)	=D23\$E\$4
0.4583333	=B24-SB\$17 70	2118	0.4	=F24-0.4	=G24*(D24-D23)	=G24\$J\$4	=H23+H24			=1-J24	=LOG10(K24)	=D24\$E\$4
0.4652777	=B25-SB\$17 80	2124	0.4	=F25-0.4	=G25*(D25-D24)	=G25\$J\$4	=H24+H25			=1-J25	=LOG10(K25)	=D25\$E\$4
0.4722222	=B26-SB\$17 90	2133	0.4	=F26-0.4	=G26*(D26-D25)	=G26\$J\$4	=H25+H26			=1-J26	=LOG10(K26)	=D26\$E\$4
0.4791666	=B27-SB\$17 100	2123	0.4	=F27-0.4	=G27*(D27-D26)	=G27\$J\$4	=H26+H27			=1-J27	=LOG10(K27)	=D27\$E\$4
0.4861111	=B28-SB\$17 110	2098	0.4	=F28-0.4	=G28*(D28-D27)	=G28\$J\$4	=H27+H28			=1-J28	=LOG10(K28)	=D28\$E\$4
0.4930555	=B29-SB\$17 120	2172	0.5	=F29-0.4	=G29*(D29-D28)	=G29\$J\$4	=H28+H29			=1-J29	=LOG10(K29)	=D29\$E\$4
0.5000000	=B30-SB\$17 130	2150	0.5	=F30-0.4	=G30*(D30-D29)	=G30\$J\$4	=H29+H30			=1-J30	=LOG10(K30)	=D30\$E\$4
0.5034722	=B31-SB\$17 135	2128	0.5	=F31-0.4	=G31*(D31-D30)	=G31\$J\$4	=H30+H31			=1-J31	=LOG10(K31)	=D31\$E\$4
0.5069444	=B32-SB\$17 140	2128	0.5	=F32-0.4	=G32*(D32-D31)	=G32\$J\$4	=H31+H32			=1-J32	=LOG10(K32)	=D32\$E\$4
0.5138888	=B33-SB\$17 145	2116	0.4	=F33-0.4	=G33*(D33-D32)	=G33\$J\$4	=H32+H33			=1-J33	=LOG10(K33)	=D33\$E\$4
0.5173811	=B34-SB\$17 150	2160	0.4	=F34-0.4	=G34*(D34-D33)	=G34\$J\$4	=H33+H34			=1-J34	=LOG10(K34)	=D34\$E\$4
0.5208333	=B35-SB\$17 155	2130	0.5	=F35-0.4	=G35*(D35-D34)	=G35\$J\$4	=H34+H35			=1-J35	=LOG10(K35)	=D35\$E\$4
0.5243055	=B36-SB\$17 160	2135	0.5	=F36-0.4	=G36*(D36-D35)	=G36\$J\$4	=H35+H36			=1-J36	=LOG10(K36)	=D36\$E\$4
0.5277777	=B37-SB\$17 165	2146	0.5	=F37-0.4	=G37*(D37-D36)	=G37\$J\$4	=H36+H37			=1-J37	=LOG10(K37)	=D37\$E\$4
0.53125	=B38-SB\$17 170	2176	0.5	=F38-0.4	=G38*(D38-D37)	=G38\$J\$4	=H37+H38			=1-J38	=LOG10(K38)	=D38\$E\$4
0.5347222	=B39-SB\$17 175	2184	0.5	=F39-0.4	=G39*(D39-D38)	=G39\$J\$4	=H38+H39			=1-J39	=LOG10(K39)	=D39\$E\$4
0.5381944	=B40-SB\$17 180	2142	0.5	=F40-0.4	=G40*(D40-D39)	=G40\$J\$4	=H39+H40			=1-J40	=LOG10(K40)	=D40\$E\$4
0.5416666	=B41-SB\$17 185	2138	0.6	=F41-0.4	=G41*(D41-D40)	=G41\$J\$4	=H40+H41			=1-J41	=LOG10(K41)	=D41\$E\$4
0.5451388	=B42-SB\$17 190	2165	0.5	=F42-0.4	=G42*(D42-D41)	=G42\$J\$4	=H41+H42			=1-J42	=LOG10(K42)	=D42\$E\$4
0.5486111	=B43-SB\$17 195	2170	0.6	=F43-0.4	=G43*(D43-D42)	=G43\$J\$4	=H42+H43			=1-J43	=LOG10(K43)	=D43\$E\$4
0.5520833	=B44-SB\$17 200	2239	0.6	=F44-0.4	=G44*(D44-D43)	=G44\$J\$4	=H43+H44			=1-J44	=LOG10(K44)	=D44\$E\$4
0.5555555	=B45-SB\$17 205	2182	0.7	=F45-0.4	=G45*(D45-D44)	=G45\$J\$4	=H44+H45			=1-J45	=LOG10(K45)	=D45\$E\$4
0.5590277	=B46-SB\$17 210	2063	0.7	=F46-0.4	=G46*(D46-D45)	=G46\$J\$4	=H45+H46			=1-J46	=LOG10(K46)	=D46\$E\$4
0.5625	=B47-SB\$17 215	2071	0.7	=F47-0.4	=G47*(D47-D46)	=G47\$J\$4	=H46+H47			=1-J47	=LOG10(K47)	=D47\$E\$4
0.5659722	=B48-SB\$17 220	2071	0.7	=F48-0.4	=G48*(D48-D47)	=G48\$J\$4	=H47+H48			=1-J48	=LOG10(K48)	=D48\$E\$4
0.5694444	=B49-SB\$17 225	2110	0.7	=F49-0.4	=G49*(D49-D48)	=G49\$J\$4	=H48+H49			=1-J49	=LOG10(K49)	=D49\$E\$4
0.5729166	=B50-SB\$17 230	2200	0.7	=F50-0.4	=G50*(D50-D49)	=G50\$J\$4	=H49+H50			=1-J50	=LOG10(K50)	=D50\$E\$4
0.5763888	=B51-SB\$17 235	2150	0.8	=F51-0.4	=G51*(D51-D50)	=G51\$J\$4	=H50+H51			=1-J51	=LOG10(K51)	=D51\$E\$4
0.5798611	=B52-SB\$17 240	2059	0.7	=F52-0.4	=G52*(D52-D51)	=G52\$J\$4	=H51+H52			=1-J52	=LOG10(K52)	=D52\$E\$4
0.5833333	=B53-SB\$17 245	2072	0.7	=F53-0.4	=G53*(D53-D52)	=G53\$J\$4	=H52+H53			=1-J53	=LOG10(K53)	=D53\$E\$4
0.5868055	=B54-SB\$17 250	2136	0.7	=F54-0.4	=G54*(D54-D53)	=G54\$J\$4	=H53+H54			=1-J54	=LOG10(K54)	=D54\$E\$4
0.5902777	=B55-SB\$17 255	2136	0.7	=F55-0.4	=G55*(D55-D54)	=G55\$J\$4	=H54+H55			=1-J55	=LOG10(K55)	=D55\$E\$4

2160ppm

A	B	C	D	E	F	G	H	I	J	K	L	M
56	0.590277	=B56-\$B\$17	260	2117	0.9	=F56-0.4	=G56*(D56-D55)	=I55+H56	=G56/\$J\$4	=1-J56	=LOG10(K56)	=D56/\$E\$4
57	0.59375	=B57-\$B\$17	265	2107	0.7	=F57-0.4	=G57*(D57-D56)	=I56+H57	=G57/\$J\$4	=1-J57	=LOG10(K57)	=D57/\$E\$4
58	0.597222	=B58-\$B\$17	270	2202	0.8	=F58-0.4	=G58*(D58-D57)	=I57+H58	=G58/\$J\$4	=1-J58	=LOG10(K58)	=D58/\$E\$4
59	0.600694	=B59-\$B\$17	275	2105	0.8	=F59-0.4	=G59*(D59-D58)	=I58+H59	=G59/\$J\$4	=1-J59	=LOG10(K59)	=D59/\$E\$4
60	0.604166	=B60-\$B\$17	280	2100	0.7	=F60-0.4	=G60*(D60-D59)	=I59+H60	=G60/\$J\$4	=1-J60	=LOG10(K60)	=D60/\$E\$4
61	0.607638	=B61-\$B\$17	285	2086	0.7	=F61-0.4	=G61*(D61-D60)	=I60+H61	=G61/\$J\$4	=1-J61	=LOG10(K61)	=D61/\$E\$4
62	0.611111	=B62-\$B\$17	290	2101	0.7	=F62-0.4	=G62*(D62-D61)	=I61+H62	=G62/\$J\$4	=1-J62	=LOG10(K62)	=D62/\$E\$4
63	0.614583	=B63-\$B\$17	295	2116	0.9	=F63-0.4	=G63*(D63-D62)	=I62+H63	=G63/\$J\$4	=1-J63	=LOG10(K63)	=D63/\$E\$4
64	0.618055	=B64-\$B\$17	300	2109	0.8	=F64-0.4	=G64*(D64-D63)	=I63+H64	=G64/\$J\$4	=1-J64	=LOG10(K64)	=D64/\$E\$4
65	0.621527	=B65-\$B\$17	305	2111	0.9	=F65-0.4	=G65*(D65-D64)	=I64+H65	=G65/\$J\$4	=1-J65	=LOG10(K65)	=D65/\$E\$4
66	0.625	=B66-\$B\$17	310	2100	1	=F66-0.4	=G66*(D66-D65)	=I65+H66	=G66/\$J\$4	=1-J66	=LOG10(K66)	=D66/\$E\$4
67	0.628472	=B67-\$B\$17	315	2112	1	=F67-0.4	=G67*(D67-D66)	=I66+H67	=G67/\$J\$4	=1-J67	=LOG10(K67)	=D67/\$E\$4
68	0.631944	=B68-\$B\$17	320	2141	1.1	=F68-0.4	=G68*(D68-D67)	=I67+H68	=G68/\$J\$4	=1-J68	=LOG10(K68)	=D68/\$E\$4
69	0.635416	=B69-\$B\$17	325	2163	1	=F69-0.4	=G69*(D69-D68)	=I68+H69	=G69/\$J\$4	=1-J69	=LOG10(K69)	=D69/\$E\$4
70	0.638888	=B70-\$B\$17	330	2136	1	=F70-0.4	=G70*(D70-D69)	=I69+H70	=G70/\$J\$4	=1-J70	=LOG10(K70)	=D70/\$E\$4
71	0.642361	=B71-\$B\$17	335	2093	1.1	=F71-0.4	=G71*(D71-D70)	=I70+H71	=G71/\$J\$4	=1-J71	=LOG10(K71)	=D71/\$E\$4
72	0.645833	=B72-\$B\$17	340	2136	1	=F72-0.4	=G72*(D72-D71)	=I71+H72	=G72/\$J\$4	=1-J72	=LOG10(K72)	=D72/\$E\$4
73	0.649305	=B73-\$B\$17	345	2132	1	=F73-0.4	=G73*(D73-D72)	=I72+H73	=G73/\$J\$4	=1-J73	=LOG10(K73)	=D73/\$E\$4
74	0.652777	=B74-\$B\$17	350	2111	1.1	=F74-0.4	=G74*(D74-D73)	=I73+H74	=G74/\$J\$4	=1-J74	=LOG10(K74)	=D74/\$E\$4
75	0.656249	=B75-\$B\$17	355	2114	0.9	=F75-0.4	=G75*(D75-D74)	=I74+H75	=G75/\$J\$4	=1-J75	=LOG10(K75)	=D75/\$E\$4
76	0.659722	=B76-\$B\$17	360	2106	1	=F76-0.4	=G76*(D76-D75)	=I75+H76	=G76/\$J\$4	=1-J76	=LOG10(K76)	=D76/\$E\$4
77	0.663194	=B77-\$B\$17	365	2128	1.1	=F77-0.4	=G77*(D77-D76)	=I76+H77	=G77/\$J\$4	=1-J77	=LOG10(K77)	=D77/\$E\$4
78	0.666666	=B78-\$B\$17	370	2114	1.2	=F78-0.4	=G78*(D78-D77)	=I77+H78	=G78/\$J\$4	=1-J78	=LOG10(K78)	=D78/\$E\$4
79	0.670138	=B79-\$B\$17	375	2087	1.1	=F79-0.4	=G79*(D79-D78)	=I78+H79	=G79/\$J\$4	=1-J79	=LOG10(K79)	=D79/\$E\$4
80	0.673611	=B80-\$B\$17	380	2111	1.2	=F80-0.4	=G80*(D80-D79)	=I79+H80	=G80/\$J\$4	=1-J80	=LOG10(K80)	=D80/\$E\$4
81	0.677083	=B81-\$B\$17	385	2112	1.1	=F81-0.4	=G81*(D81-D80)	=I80+H81	=G81/\$J\$4	=1-J81	=LOG10(K81)	=D81/\$E\$4
82	0.680555	=B82-\$B\$17	390	2107	1.2	=F82-0.4	=G82*(D82-D81)	=I81+H82	=G82/\$J\$4	=1-J82	=LOG10(K82)	=D82/\$E\$4
83	0.684027	=B83-\$B\$17	395	2143	1.2	=F83-0.4	=G83*(D83-D82)	=I82+H83	=G83/\$J\$4	=1-J83	=LOG10(K83)	=D83/\$E\$4
84	0.687499	=B84-\$B\$17	400	2115	1	=F84-0.4	=G84*(D84-D83)	=I83+H84	=G84/\$J\$4	=1-J84	=LOG10(K84)	=D84/\$E\$4
85	0.690971	=B85-\$B\$17	415	2131	1	=F85-0.4	=G85*(D85-D84)	=I84+H85				
86	0.694443	=B86-\$B\$17	430	2153	1	=F86-0.4	=G86*(D86-D85)	=I85+H86				
87	0.697915	=B87-\$B\$17	445	2108	1	=F87-0.4	=G87*(D87-D86)	=I86+H87				
88	0.701387	=B88-\$B\$17	460	2112	1	=F88-0.4	=G88*(D88-D87)	=I87+H88				
89	0.704859	=B89-\$B\$17	475	2108	1	=F89-0.4	=G89*(D89-D88)	=I88+H89				
90	0.708331	=B90-\$B\$17	490	2088	1	=F90-0.4	=G90*(D90-D89)	=I89+H90				
91	0.711803	=B91-\$B\$17	505	2127	1	=F91-0.4	=G91*(D91-D90)	=I90+H91				
92	0.715275	=B92-\$B\$17	520	2131	0.8	=F92-0.4	=G92*(D92-D91)	=I91+H92				
93	0.718747	=B93-\$B\$17	535	2134	1	=F93-0.4	=G93*(D93-D92)	=I92+H93				
94	0.722219	=B94-\$B\$17	550	2140	0.8	=F94-0.4	=G94*(D94-D93)	=I93+H94				
95	0.725691	=B95-\$B\$17	565	2140	0.8	=F95-0.4	=G95*(D95-D94)	=I94+H95				
96	0.729163	=B96-\$B\$17	580	2129	0.9	=F96-0.4	=G96*(D96-D95)	=I95+H96				
97	0.732635	=B97-\$B\$17	595	2134	0.8	=F97-0.4	=G97*(D97-D96)	=I96+H97				
98	0.736107	=B98-\$B\$17	610	2142	0.6	=F98-0.4	=G98*(D98-D97)	=I97+H98				
99	0.739579	=B99-\$B\$17	625	2126	0.8	=F99-0.4	=G99*(D99-D98)	=I98+H99				
100	0.743051	=B100-\$B\$17	650	2131	0.6	=F100-0.4	=G100*(D100-D99)	=I99+H100				
101	0.746523	=B101-\$B\$17	655	2128	0.6	=F101-0.4	=G101*(D101-D100)	=I100+H101				
102	0.75	=B102-\$B\$17	670	2120	0.4	=F102-0.4	=G102*(D102-D101)	=I101+H102				
103	0.753475	=B103-\$B\$17	685	2126	0.4	=F103-0.4	=G103*(D103-D102)	=I102+H103				
104	0.756947	=B104-\$B\$17	700	2119	0.4	=F104-0.4	=G104*(D104-D103)	=I103+H104				
105												
106												
107												
108												
109												
110												
111												

Fluoride Injected = = \$34,395*17.6/1000
oxide Recovered = = \$3,104*\$E\$3/1000
oxide Recovered = = \$3,106*\$I\$105

Time (T10) = = ((LOG10(0.9)-3C\$143)/6C\$144)*\$E\$4
n Coefficient = = \$C\$131

2160ppm

	A	B	C	D	E	F	G	H	I	J	K	L	M
112													
113													
114													
115													
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SUMMARY

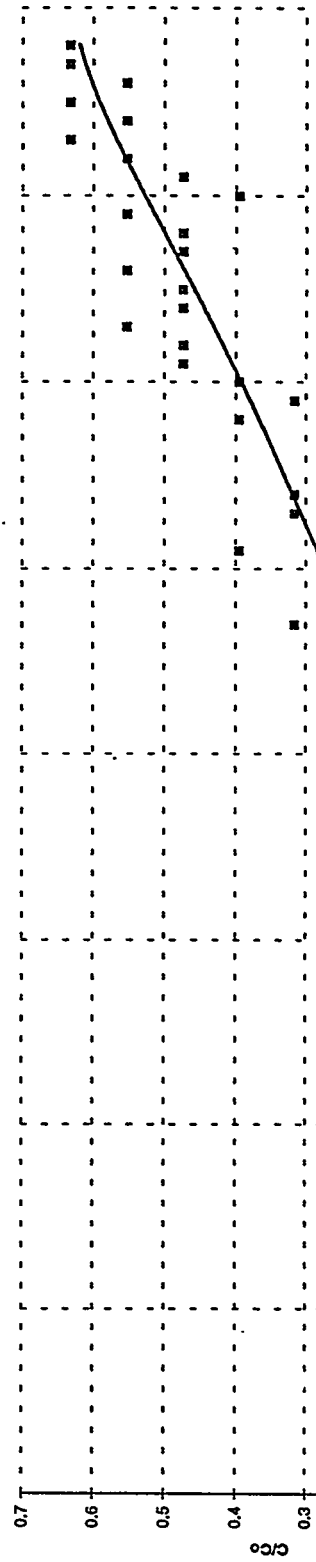
Regress
 Multiple R 0.835176610
 R Square 0.8745540782
 Adjusted R 0.8718850160
 Standard 10.0446383462
 Observations 49

ANOVA

	df	SS	MS	F	Significance
Regression 1		0.652896248989584	0.652896248989584	327.86344803811421	
Residual 47		0.0936513518568435	0.001992581856		
Total 48		0.746547660946407			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.000%	Upper 95.000%
Intercept	0.2584365460	0.025607071748724	10.0923896565552	3.78136E-10	0.206921810309951281	0.309951281100911	0.206921810944925	0.309951281100911
X Variable 1	-0.3254698151	0.0179813853186062	-18.101476053078	0.038114E-03	-0.3816634	-0.2893157885519	-0.381663462874199	-0.289315788551895

300 Area, 315 Filter Plant
 C/Co vs. Time
 Graphical Analysis for T10



APPENDIX C

Spread Sheet Calculations

2400gpm

ICF KAISER HANFORD COMPANY										315 Filter Plant, 300 Area				2400 GPM Tracer Test			
Date: 3/6/95										Background Fluoride Concentration (Baseline)= 0.40 mg/L							
Average test flow = 2380 gpm (9009 L/min)										Fluoride loss due to alum ~ 0.10 mg/L (8%)							
Theoretical Residence Time (T) = 178 min										Applied Fluoride Dosage (Co) = 620.8 ml/min (1.21 mg/L)							
Time	Time t (h:mm)	Time t (min)	Flowrate (gpm)	Fluoride Measured (mg/L)	Tracer concentration (mg/L)	Incremental Area (mg-min/L)	Cumulative Area (mg-min/L)	C/Co	1-C/Co	Log ₁₀ (1-C/Co)	t/T						
Background	9:30		720	0.3	0	N/A	N/A										
	9:35		1163	0.4	0	N/A	N/A										
	9:40		1451	0.3	0	N/A	N/A										
	9:45		1733	0.4	0	N/A	N/A										
	9:50		2026	0.3	0	N/A	N/A										
	9:55		2240	0.4	0	N/A	N/A										
	10:10		2404														
Start injection	10:20	0:00					0										
	10:30	0:10	2359	0.5	0.1	0	0	0.082	0.918	-0.037	0.06						
	10:40	0:20	2354	0.5	0.1	1	1	0.082	0.918	-0.037	0.11						
	10:50	0:30	2344	0.4	0	0	1	0.000	1.000	0.000	0.17						
	11:00	0:40	2398	0.4	0	0	1	0.000	1.000	0.000	0.22						
	11:10	0:50	2408	0.4	0	0	1	0.000	1.000	0.000	0.28						
	11:20	1:00	2411	0.4	0	0	1	0.000	1.000	0.000	0.34						
	11:30	1:10	2440	0.4	0	0	1	0.000	1.000	0.000	0.39						
	11:40	1:20	2441	0.5	0.1	1	2	0.082	0.918	-0.037	0.45						
	11:50	1:30	2411	0.5	0.1	1	3	0.082	0.918	-0.037	0.51						
	12:00	1:40	2433	0.5	0.1	1	4	0.082	0.918	-0.037	0.56						
	12:10	1:50	2424	0.6	0.2	2	6	0.165	0.835	-0.078	0.62						
	12:20	2:00	2424	0.6	0.2	2	8	0.165	0.835	-0.078	0.67						
	12:30	2:10	2408	0.7	0.3	3	11	0.247	0.753	-0.123	0.73						
	12:35	2:15	2413	0.7	0.3	1.5	12.5	0.247	0.753	-0.123	0.76						
	12:40	2:20	2434	0.7	0.3	1.5	14	0.247	0.753	-0.123	0.79						
	12:45	2:25	2456	0.8	0.4	2	16	0.330	0.670	-0.174	0.81						
	12:50	2:30	2431	0.8	0.4	2	18	0.330	0.670	-0.174	0.84						
	12:55	2:35	2410	0.8	0.4	2	20	0.330	0.670	-0.174	0.87						
	13:00	2:40	2447	0.9	0.5	2.5	22.5	0.412	0.588	-0.231	0.90						
	13:05	2:45	2459	1	0.6	3	25.5	0.495	0.505	-0.296	0.93						
	13:10	2:50	2432	0.9	0.5	2.5	28	0.412	0.588	-0.231	0.95						
	13:15	2:55	2416	1	0.6	3	31	0.495	0.505	-0.296	0.98						
	13:20	3:00	2398	1	0.6	3	34	0.495	0.505	-0.296	1.01						
	13:25	3:05	2403	1	0.6	3	37	0.495	0.505	-0.296	1.04						
	13:30	3:10	2408	1.1	0.7	3.5	40.5	0.577	0.423	-0.374	1.07						
	13:35	3:15	2386	1.1	0.7	3.5	44	0.577	0.423	-0.374	1.09						
	13:40	3:20	2388	1.1	0.7	3.5	47.5	0.577	0.423	-0.374	1.12						
	13:45	3:25	2375	1.1	0.7	3.5	51	0.577	0.423	-0.374	1.15						

2400gpm

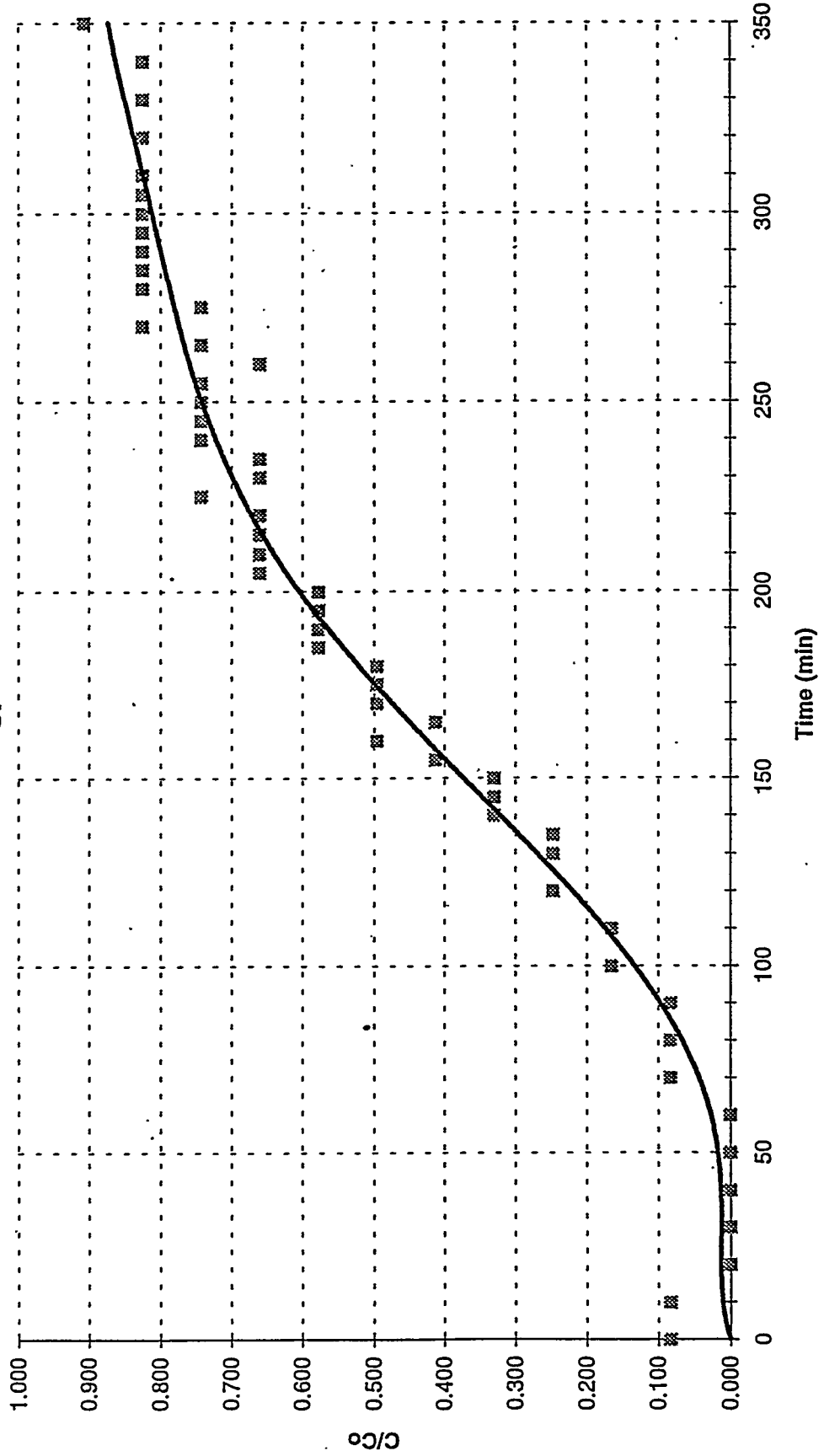
ICF KAISER HANFORD COMPANY										315 Filter Plant, 300 Area					2400 GPM Tracer Test				
Date: 3/6/95										Background Fluoride Concentration (Baseline)= 0.40 mg/L									
Average test flow = 2380 gpm (9009 L/min)										Fluoride loss due to alum ~ 0.10 mg/L (8%)									
Theoretical Residence Time (T)= 178 min										Applied Fluoride Dosage (Co) = 620.8 ml/min (1.21 mg/L)									
Time	Time t (h:mm)	Time t (min)	Flowrate (gpm)	Fluoride Measured (mg/L)	Tracer concentration (mg/L)	Incremental Area (mg-min/L)	Cumulative Area (mg-min/L)	C/Co	1-C/Co	Log ₁₀ (1-C/Co)	VT								
13:50	3:30	210	2380	1.2	0.8	4	55	0.660	0.340	-0.468	1.18								
13:55	3:35	215	2367	1.2	0.8	4	59	0.660	0.340	-0.468	1.21								
14:00	3:40	220	2382	1.2	0.8	4	63	0.660	0.340	-0.468	1.23								
14:05	3:45	225	2384	1.2	0.8	4	67	0.660	0.340	-0.468	1.26								
14:10	3:50	230	2383	1.3	0.9	4.5	71.5	0.742	0.258	-0.589	1.29								
14:15	3:55	235	2363	1.2	0.8	4	75.5	0.660	0.340	-0.468	1.32								
14:20	4:00	240	2386	1.2	0.8	4	79.5	0.660	0.340	-0.468	1.35								
14:25	4:05	245	2385	1.3	0.9	4.5	84	0.742	0.258	-0.589	1.38								
14:30	4:10	250	2372	1.3	0.9	4.5	88.5	0.742	0.258	-0.589	1.40								
14:35	4:15	255	2385	1.3	0.9	4.5	93	0.742	0.258	-0.589	1.43								
14:40	4:20	260	2375	1.3	0.9	4.5	97.5	0.742	0.258	-0.589	1.46								
14:45	4:25	265	2360	1.2	0.8	4	101.5	0.660	0.340	-0.468	1.49								
14:50	4:30	270	2374	1.3	0.9	4.5	106	0.742	0.258	-0.589	1.52								
14:55	4:35	275	2367	1.4	1	5	111	0.825	0.175	-0.756	1.54								
15:00	4:40	280	2356	1.3	0.9	4.5	115.5	0.742	0.258	-0.589	1.57								
15:05	4:45	285	2370	1.4	1	5	120.5	0.825	0.175	-0.756	1.60								
15:10	4:50	290	2389	1.4	1	5	125.5	0.825	0.175	-0.756	1.63								
15:15	4:55	295	2378	1.4	1	5	130.5	0.825	0.175	-0.756	1.66								
15:20	5:00	300	2345	1.4	1	5	135.5	0.825	0.175	-0.756	1.68								
15:25	5:05	305	2384	1.4	1	5	140.5	0.825	0.175	-0.756	1.71								
15:30	5:10	310	2398	1.4	1	5	145.5	0.825	0.175	-0.756	1.74								
15:40	5:20	320	2389	1.4	1	10	155.5	0.825	0.175	-0.756	1.80								
15:50	5:30	330	2368	1.4	1	10	165.5	0.825	0.175	-0.756	1.85								
16:00	5:40	340	2353	1.4	1	10	175.5	0.825	0.175	-0.756	1.91								
16:10	5:50	350	2342	1.4	1	10	185.5	0.825	0.175	-0.756	1.96								
16:20	6:00	360	2341	1.5	1.1	11	196.5	0.907	0.093	-1.032	2.02								
16:30	6:10	370	2374	1.4	1	10	206.5												
16:45	6:25	385	2383	1.5	1.1	16.5	223												
17:00	6:40	400	2373	1.4	1	15	238												
17:15	6:55	415	2352	1.4	1	15	253												
17:30	7:10	430	2366	1.4	1	15	268												
17:45	7:25	445	2346	1.3	0.9	13.5	281.5												
18:00	7:40	460	2351	1.3	0.9	13.5	295												
18:15	7:55	475	2332	1.2	0.8	12	307												
18:30	8:10	490	2343	1.1	0.7	10.5	317.5												
18:45	8:25	505	2342	1	0.6	9	326.5												
19:00	8:40	520	2341	0.9	0.5	7.5	334												

2400gpm

ICF KAISER HANFORD COMPANY				315 Filter Plant, 300 Area				2400 GPM Tracer Test			
Date: 3/6/95		Average test flow = 2380 gpm (9009 L/min)		Background Fluoride Concentration (Baseline) = 0.40 mg/L		Fluoride loss due to alum ~ 0.10 mg/L (8%)		Applied Fluoride Dosage (Co) = 620.8 ml/min (1.21 mg/L)			
Theoretical Residence Time (T) = 178 min											
Time	Time t (h:mm)	Time t (min)	Flowrate (gpm)	Fluoride Measured (mg/L)	Tracer concentration (mg/L)	Incremental Area (mg-min/L)	Cumulative Area (mg-min/L)	C/Co	1-C/Co	Log ₁₀ (1-C/Co)	t/T
19:15	8:55	535	2337	0.9	0.5	7.5	341.5				
19:30	9:10	550	2345	0.8	0.4	6	347.5				
19:45	9:25	565	2339	0.7	0.3	4.5	352				
20:00	9:40	580	2341	0.7	0.3	4.5	356.5				
20:15	9:55	595	2329	0.7	0.3	4.5	361				
20:30	10:10	610	2337	0.6	0.2	3	364				
20:45	10:25	625	2336	0.6	0.2	3	367				
21:00	10:40	640	2328	0.5	0.1	1.5	368.5				
21:15	10:55	655	2340	0.5	0.1	1.5	370				
Calculated Residence Time (T ₁₀) = 102 min				Mass Fluoride injected = 3933 g							
Correlation Coefficient = 0.95				Mass Fluoride Recovered = 3333 g							
				% Fluoride Recovered = 85%							

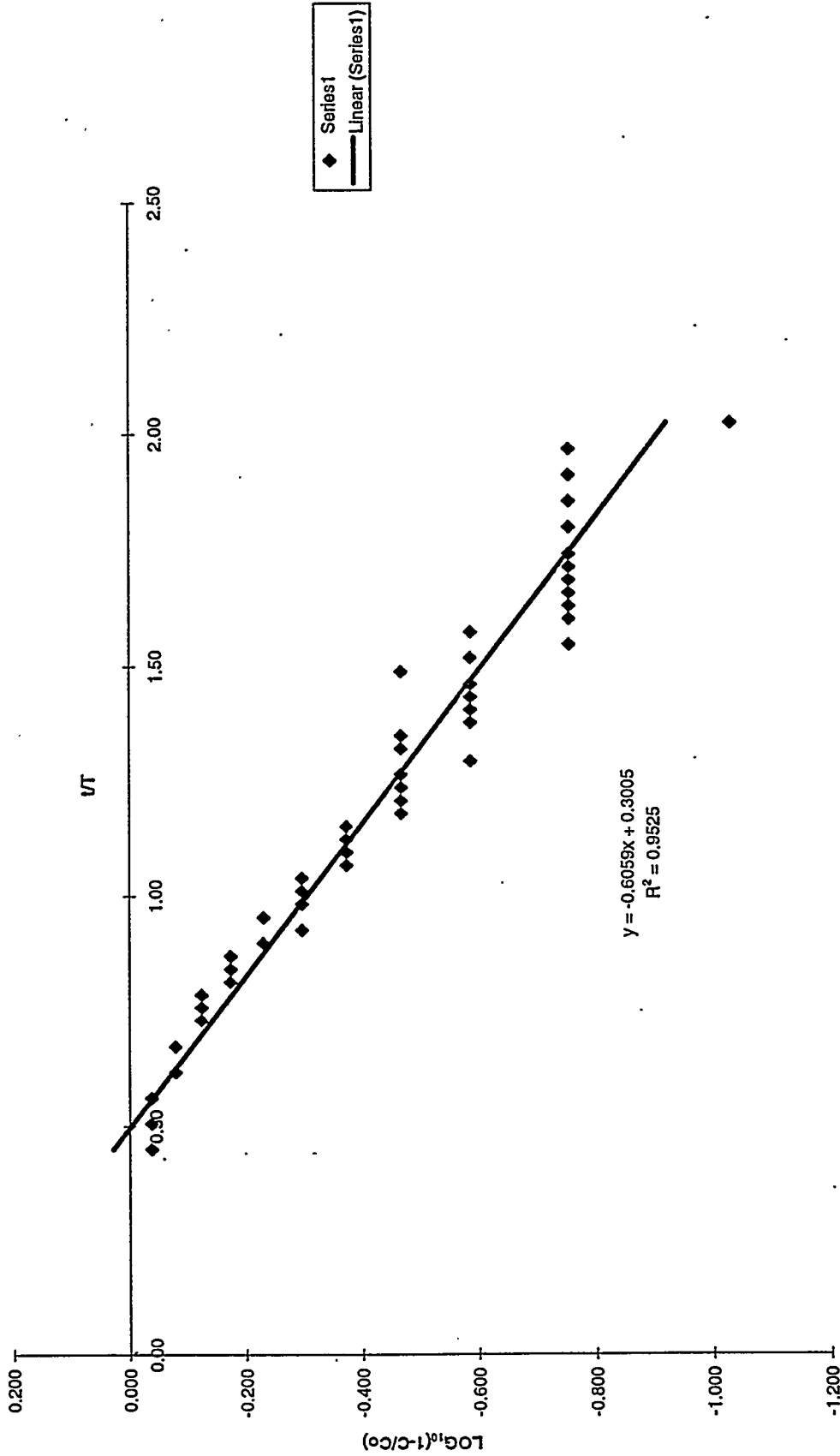
Chart 1
2400 GPM

300 Area, 315 Filter Plant
C/Co vs. Time
Graphical Analysis for T₁₀
2400 gpm



2400 gpm Chart 2

300 Area, 315 Filter Plant
LOG₁₀(1-C/Co) vs. t/T
Numerical Analysis for T₁₀
2400 gpm



Prepared by ICF Kaiser

2400gpm

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9759846
R Square	0.952546
Adjusted	0.9514915
Standard	0.0567451
Observati	47

ANOVA

	df	SS	MS	F	Significance F
Regression	1	2.908591	2.90859095	903.2869	1.9914E-31
Residual	45	0.1449004	0.00322001		
Total	46	3.0534913			

	Coefficients	Standard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.000	pper 95.000%
Intercept	0.3004406	0.0262357	11.4516157	6.3E-15	0.2475993	0.353281936	0.247599304	0.35328194
X Variable	-0.6059094	0.0201602	-30.054732	1.99E-31	-0.64651408	-0.56530463	-0.64651408	-0.5653046

2160gpm

ICF KAISER HANFORD COMPANY										315 Filter Plant, 300 Area				2160 GPM Tracer Test			
Date: 3/23/95										Background Fluoride Concentration (Baseline)= 0.40 mg/L							
Average test flow = 2127 gpm (8050 L/min)										Fluoride loss due to alum = 0.20 mg/L (16%)							
Theoretical Residence Time (T)= 199 min										Applied Fluoride Dosage (Co) = 580.0 ml/min (1.27 mg/L)							
Time	Time t (h:mm)	Time t (min)	Flowrate (gpm)	Fluoride Measured (mg/L)	Tracer concentration (mg/L)	Incremental Area (mg-min/L)	Cumulative Area (mg-min/L)	C/Co	1-C/Co	Log10(1-C/Co)	t/T						
Background	8:45			0.3	0	N/A	N/A										
	8:50		495	0.4	0	N/A	N/A										
	8:55		493	0.4	0	N/A	N/A										
	9:00		438	0.4	0	N/A	N/A										
	9:05		775	0.4	0	N/A	N/A										
	9:10		1318	0.4	0	N/A	N/A										
			1567	0.3	0	N/A	N/A										
Start injection	9:50	0:00	0														
	10:00	0:10	2161	0.3	-0.1	0	0	-0.079	1.079	0.033	0.05						
	10:10	0:20	2106	0.4	0	0	0	0.000	1.000	0.000	0.10						
	10:20	0:30	2108	0.4	0	0	0	0.000	1.000	0.000	0.15						
	10:30	0:40	2092	0.4	0	0	0	0.000	1.000	0.000	0.20						
	10:40	0:50	2105	0.4	0	0	0	0.000	1.000	0.000	0.25						
	10:50	1:00	2159	0.4	0	0	0	0.000	1.000	0.000	0.30						
	11:00	1:10	2118	0.4	0	0	0	0.000	1.000	0.000	0.35						
	11:10	1:20	2124	0.4	0	0	0	0.000	1.000	0.000	0.40						
	11:20	1:30	2133	0.4	0	0	0	0.000	1.000	0.000	0.45						
	11:30	1:40	2123	0.4	0	0	0	0.000	1.000	0.000	0.50						
	11:40	1:50	2098	0.4	0	0	0	0.000	1.000	0.000	0.55						
	11:50	2:00	2172	0.5	0.1	1	1	0.079	0.921	-0.036	0.60						
	12:00	2:10	2150	0.5	0.1	1	2	0.079	0.921	-0.036	0.65						
	12:05	2:15	2128	0.5	0.1	0.5	2.5	0.079	0.921	-0.036	0.68						
	12:10	2:20	2128	0.5	0.1	0.5	3	0.079	0.921	-0.036	0.70						
	12:15	2:25	2118	0.4	0	0	3	0.000	1.000	0.000	0.73						
	12:20	2:30	2160	0.4	0	0	3	0.000	1.000	0.000	0.75						
	12:25	2:35	2130	0.5	0.1	0.5	3.5	0.079	0.921	-0.036	0.78						
	12:30	2:40	2135	0.5	0.1	0.5	4	0.079	0.921	-0.036	0.80						
	12:35	2:45	2146	0.5	0.1	0.5	4.5	0.079	0.921	-0.036	0.83						
	12:40	2:50	2148	0.5	0.1	0.5	5	0.079	0.921	-0.036	0.85						
	12:45	2:55	2176	0.5	0.1	0.5	5.5	0.079	0.921	-0.036	0.88						
	12:50	3:00	2184	0.5	0.1	0.5	6	0.079	0.921	-0.036	0.90						
	12:55	3:05	2142	0.5	0.1	0.5	6.5	0.079	0.921	-0.036	0.93						
	13:00	3:10	2138	0.6	0.2	1	7.5	0.158	0.842	-0.075	0.95						

2160gpm

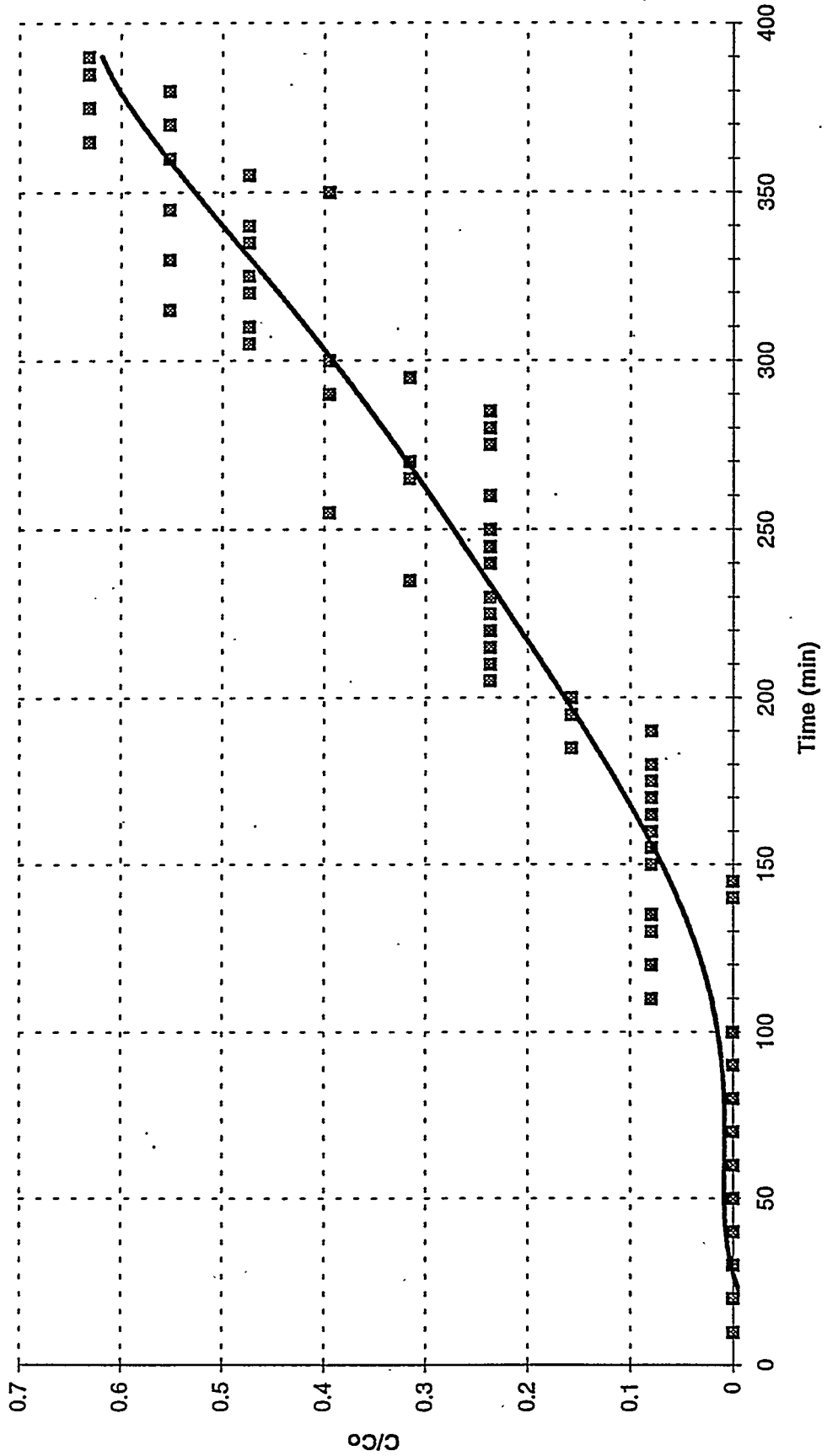
ICF KAISER HANFORD COMPANY				315 Filter Plant, 300 Area				2160 GPM Tracer Test			
Date: 3/23/95				Background Fluoride Concentration (Baseline)= 0.40 mg/L							
Average test flow = 2127 gpm (8050 L/min)				Fluoride loss due to alum ~ 0.20 mg/L (16%)							
Theoretical Residence Time (T)= 199 min				Applied Fluoride Dosage (Co) = 580.0 ml/min (1.27 mg/L)							
Time	Time t (h:mm)	Time t (min)	Flowrate (gpm)	Fluoride Measured (mg/L)	Tracer concentration (mg/L)	Incremental Area (mg-min/L)	Cumulative Area (mg-min/L)	C/Co	1-C/Co	Log10(1-C/Co)	VT
13:05	3:15	195	2165	0.5	0.1	0.5	8	0.079	0.921	-0.036	0.98
13:10	3:20	200	2170	0.6	0.2	1	9	0.158	0.842	-0.075	1.00
13:15	3:25	205	2239	0.6	0.2	1	10	0.158	0.842	-0.075	1.03
13:20	3:30	210	2182	0.7	0.3	1.5	11.5	0.237	0.763	-0.117	1.05
13:25	3:35	215	2063	0.7	0.3	1.5	13	0.237	0.763	-0.117	1.08
13:30	3:40	220	2071	0.7	0.3	1.5	14.5	0.237	0.763	-0.117	1.10
13:35	3:45	225	2071	0.7	0.3	1.5	16	0.237	0.763	-0.117	1.13
13:40	3:50	230	2110	0.7	0.3	1.5	17.5	0.237	0.763	-0.117	1.15
13:45	3:55	235	2200	0.7	0.3	1.5	19	0.237	0.763	-0.117	1.18
13:50	4:00	240	2150	0.8	0.4	2	21	0.315	0.685	-0.165	1.20
13:55	4:05	245	2059	0.7	0.3	1.5	22.5	0.237	0.763	-0.117	1.23
14:00	4:10	250	2072	0.7	0.3	1.5	24	0.237	0.763	-0.117	1.25
14:05	4:15	255	2136	0.7	0.3	1.5	25.5	0.237	0.763	-0.117	1.28
14:10	4:20	260	2117	0.9	0.5	2.5	28	0.394	0.606	-0.218	1.30
14:15	4:25	265	2107	0.7	0.3	1.5	29.5	0.237	0.763	-0.117	1.33
14:20	4:30	270	2202	0.8	0.4	2	31.5	0.315	0.685	-0.165	1.35
14:25	4:35	275	2105	0.8	0.4	2	33.5	0.315	0.685	-0.165	1.38
14:30	4:40	280	2100	0.7	0.3	1.5	35	0.237	0.763	-0.117	1.40
14:35	4:45	285	2086	0.7	0.3	1.5	36.5	0.237	0.763	-0.117	1.43
14:40	4:50	290	2101	0.7	0.3	1.5	38	0.237	0.763	-0.117	1.45
14:45	4:55	295	2116	0.9	0.5	2.5	40.5	0.394	0.606	-0.218	1.48
14:50	5:00	300	2109	0.8	0.4	2	42.5	0.315	0.685	-0.165	1.50
14:55	5:05	305	2111	0.9	0.5	2.5	45	0.394	0.606	-0.218	1.53
15:00	5:10	310	2100	1	0.6	3	48	0.473	0.527	-0.278	1.55
15:05	5:15	315	2112	1	0.6	3	51	0.473	0.527	-0.278	1.58
15:10	5:20	320	2141	1.1	0.7	3.5	54.5	0.552	0.448	-0.349	1.60
15:15	5:25	325	2163	1	0.6	3	57.5	0.473	0.527	-0.278	1.63
15:20	5:30	330	2136	1	0.6	3	60.5	0.473	0.527	-0.278	1.66
15:25	5:35	335	2093	1.1	0.7	3.5	64	0.552	0.448	-0.349	1.68
15:30	5:40	340	2136	1	0.6	3	67	0.473	0.527	-0.278	1.71
15:35	5:45	345	2132	1	0.6	3	70	0.473	0.527	-0.278	1.73
15:40	5:50	350	2111	1.1	0.7	3.5	73.5	0.552	0.448	-0.349	1.76
15:45	5:55	355	2114	0.9	0.5	2.5	76	0.394	0.606	-0.218	1.78
15:50	6:00	360	2106	1	0.6	3	79	0.473	0.527	-0.278	1.81

2160gpm

ICF KAISER HANFORD COMPANY				315 Filter Plant, 300 Area				2160 GPM Tracer Test			
Date: 3/23/95				Background Fluoride Concentration (Baseline)= 0.40 mg/L							
Average test flow = 2127 gpm (8050 L/min)				Fluoride loss due to alum = 0.20 mg/L (16%)							
Theoretical Residence Time (T)= 199 min				Applied Fluoride Dosage (Co) = 580.0 ml/min (1.27 mg/L)							
Time	Time t (h:mm)	Time t (min)	Flowrate (gpm)	Fluoride Measured (mg/L)	Tracer concentration (mg/L)	Incremental Area (mg-min/L)	Cumulative Area (mg-min/L)	C/Co	1-C/Co	Log10(1-C/Co)	VT
15:55	6:05	365	2128	1.1	0.7	3.5	82.5	0.552	0.448	-0.349	1.83
16:00	6:10	370	2114	1.2	0.8	4	86.5	0.631	0.369	-0.433	1.86
16:05	6:15	375	2087	1.1	0.7	3.5	90	0.552	0.448	-0.349	1.88
16:10	6:20	380	2111	1.2	0.8	4	94	0.631	0.369	-0.433	1.91
16:15	6:25	385	2112	1.1	0.7	3.5	97.5	0.552	0.448	-0.349	1.93
16:20	6:30	390	2107	1.2	0.8	4	101.5	0.631	0.369	-0.433	1.96
16:25	6:35	395	2143	1.2	0.8	4	105.5	0.631	0.369	-0.433	1.98
16:30	6:40	400	2115	1	0.6	3	108.5	0.473	0.527	-0.278	2.01
16:45	6:55	415	2131	1	0.6	9	117.5				
17:00	7:10	430	2153	1	0.6	9	126.5				
17:15	7:25	445	2108	1	0.6	9	135.5				
17:30	7:40	460	2112	1	0.6	9	144.5				
17:45	7:55	475	2108	1	0.6	9	153.5				
18:00	8:10	490	2088	1	0.6	9	162.5				
18:15	8:25	505	2127	1	0.6	9	171.5				
18:30	8:40	520	2131	0.8	0.4	6	177.5				
18:45	8:55	535	2134	1	0.6	9	186.5				
19:00	9:10	550	2140	0.8	0.4	6	192.5				
19:15	9:25	565	2140	0.8	0.4	6	198.5				
19:30	9:40	580	2129	0.9	0.5	7.5	206				
19:45	9:55	595	2134	0.8	0.4	6	212				
20:00	10:10	610	2142	0.6	0.2	3	215				
20:15	10:25	625	2126	0.8	0.4	6	221				
20:40	10:50	650	2131	0.6	0.2	5	226				
20:45	10:55	655	2126	0.6	0.2	1	227				
21:00	11:10	670	2120	0.4	0	0	227				
21:15	11:25	685	2126	0.4	0	0	227				
21:30	11:40	700	2119	0.4	0	0	227				
Calculated Residence Time (T10) = 186 min				Mass Fluoride injected = 4032 g							
				Mass Fluoride Recovered = 1827 g							
				% Fluoride Recovered = 45%							
				Correlation Coefficient = 0.87							

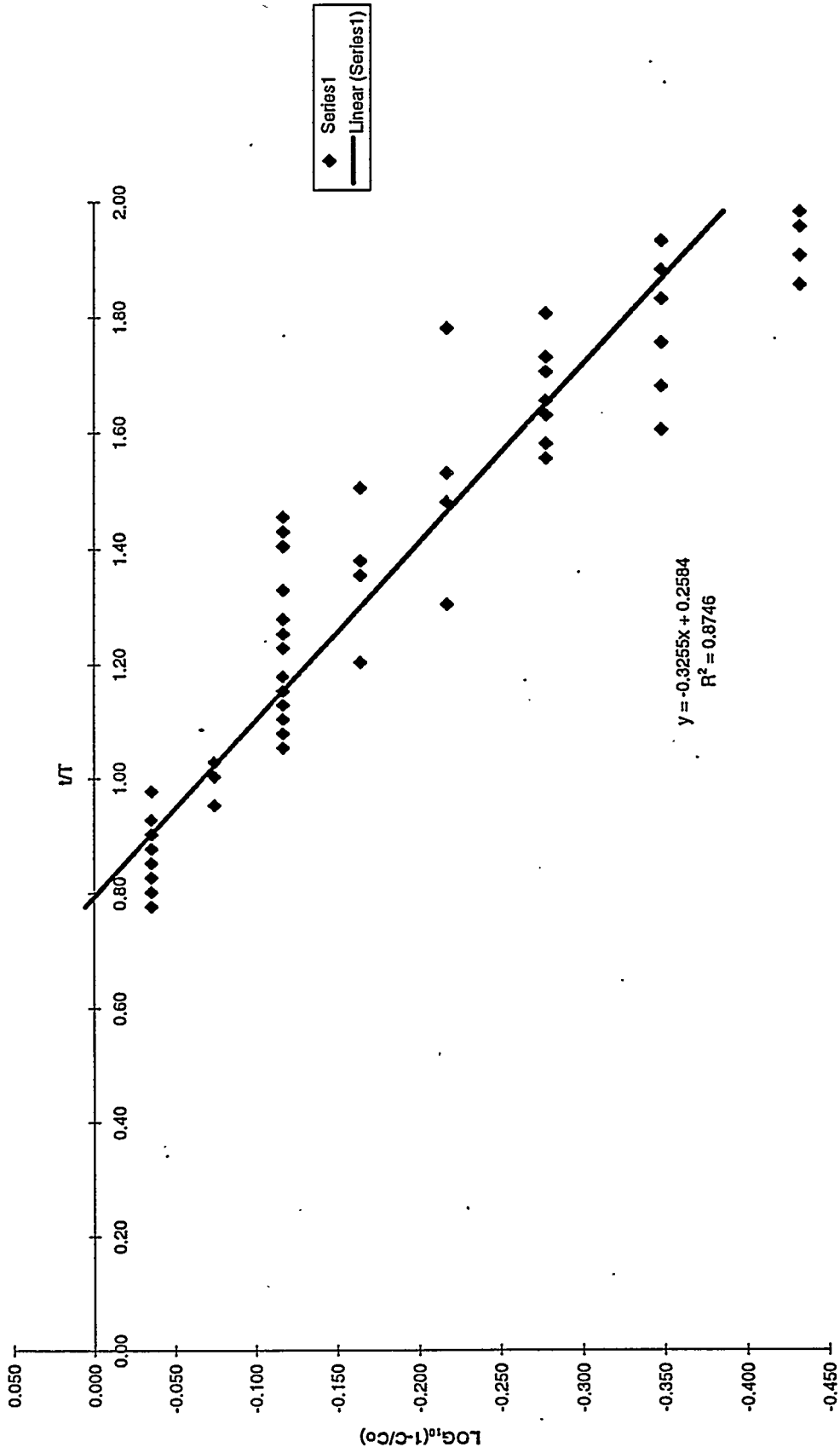
Chart 1
2160 GPM

300 Area, 315 Filter Plant C/Co vs. Time Graphical Analysis for T10



2160 GPM Chart 2

300 Area, 315 Filter Plant
LOG₁₀(1-C/Co) vs. t/T
Numerical Analysis for T₁₀
2160 gpm



Prepared by ICF Kaiser

2160gpm

SUMMARY OUTPUT

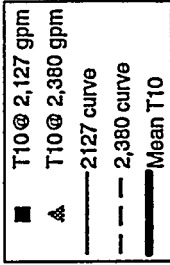
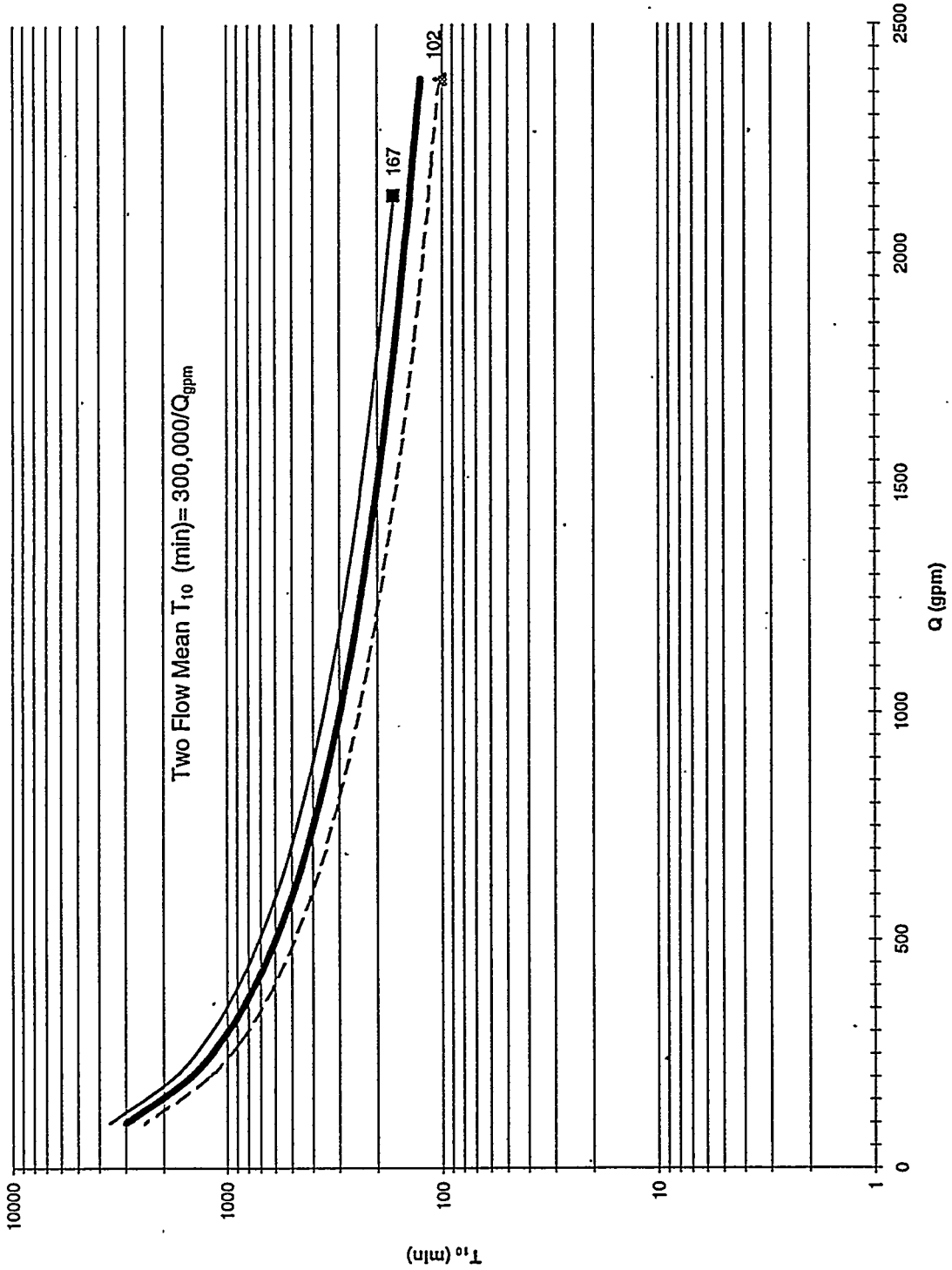
<u>Regression Statistics</u>	
Multiple R	0.935176
R Square	0.874554
Adjusted F	0.871885
Standard E	0.044638
Observatic	49

ANOVA					
	df	SS	MS	F	Significance F
Regression	1	0.652896	0.652896249	327.6634	8.03811E-23
Residual	47	0.093651	0.001992582		
Total	48	0.746548			

	Coefficient	Standard Err	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.000%	Upper 95.000%
Intercept	0.258437	0.025607	10.09238966	2.38E-13	0.206921811	0.30995128	0.206921811	0.30995128
X Variable	-0.32549	0.017981	-18.1014761	8.04E-23	-0.361663463	-0.2893158	-0.361663463	-0.28931577

T₁₀ 315 Filter Plant, 300 Area

Detention Time vs. Flow



T₁₀ 315 Filter Plant, 300 Area

FLOW	T10						
2127 gpm	167						
2380	102						
2380 GPM RESULTS		2127 GPM RESULTS				AVERAGED RESULTS	
						FLOW	Average
FLOW	T10			FLOW	T10		T10
2380	102			2380	149	2380	126
2200	110			2127	167	2164	139
2100	116			2100	169	2100	142
2000	121			2000	178	2000	149
1900	128			1900	187	1900	157
1800	135			1800	197	1800	166
1700	143			1700	209	1700	176
1600	152			1600	222	1600	187
1500	162			1500	237	1500	199
1400	173			1400	254	1400	214
1300	187			1300	273	1300	230
1200	202			1200	296	1200	249
1100	221			1100	323	1100	272
1000	243			1000	355	1000	299
900	270			900	395	900	332
800	303			800	444	800	374
700	347			700	507	700	427
600	405			600	592	600	498
500	486			500	710	500	598
400	607			400	888	400	747
300	809			300	1184	300	997
200	1214			200	1776	200	1495
100	2428			100	3552	100	2990
0				0		0	0

APPENDIX B

**Calculation No. ER5480-G-005
Theoretical Detention Time and Fluoride Injection
Rate, Rev. 2**

**KAISER ENGINEERS
HANFORD**

CALCULATION IDENTIFICATION AND INDEX

Page 1 of 4
Date 11/5/94

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline ENVIRONMENTAL (ZZ) WO/Job No. ER5480 Calculation No. ER5480-G-005
 Project No. & Name TRACER STUDIES OF 300 FILTER TREATMENT PLANT
 Calculation Item THEORETICAL DETENTION TIME AND FLUORIDE INJECTION RATE

These calculations apply to:

Dwg. No. _____ Rev. No. _____
 Dwg. No. _____ Rev. No. _____
 Other (Study; CDR) _____ Rev. No. _____

The status of these calculations is:

- Preliminary Calculations
- Final Calculations
- Check Calculations (On Calculation Dated _____)
- Void Calculation (Reason Voided _____)

Incorporated in Final Drawings? Yes No
 This calculation verified by independent "check" calculations? Yes No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	<i>W. D. Boucher 11/5/94</i>	<i>W. D. Boucher 12/21/94</i>	<i>William W. Smith 3/28/95</i>
Checked by	<i>William W. Smith 11/15/94</i>	<i>William W. Smith 12/21/94</i>	<i>Thomas C. Smith 3/28/95</i>
Approved by			
Checked Against Approved Vendor Data			

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Design Analysis
Page No.

Description

<u>2</u>	<u>OBJECTIVE</u>
<u>2-4</u>	<u>DESIGN INPUTS, ASSUMPTIONS, METHOD, REFERENCES CALCULATION</u>

KAISER ENGINEERS
HANFORD

Calc. No. ER5480-G-001

Revision 2

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DESIGN ANALYSIS

Client	ICF-KH	WO/Job No.	ER 5480
Subject	THEORETICAL DETENTION TIME	Date	11/5/94
	BY INJECTION QUANTITY	Checked	By
Location	300 AREA FILTER PLANT	Revised	12-22-94
		By	JOHN BOUCHER

OBJECTIVE: THE PURPOSE OF THIS CALCULATION IS TO DETERMINE THE THEORETICAL DETENTION TIME AND THE FLUORIDE INJECTION CONCENTRATION FOR A TRACER STUDY.

DESIGN INPUTS: A TRACER STUDY WILL BE PERFORMED ON THE FLASH MIXER, THREE SEDIMENTATION BASINS, THREE FILTERS AND THE CLEARWELL. THE HACH COLORIMETER DETECTS FLUORIDE BETWEEN 0.0 mg/l to 2.0 mg/l; THEREFORE, FLUORIDE WILL BE INJECTED AT 1.0 mg/l to 1.5 mg/l.

ASSUMPTIONS: THE PLANT WILL BE MAINTAINED AT THE TWO FLOW RATES OF 2,400 GPM AND 2,160 GPM. BACKGROUND FLUORIDE CONCENTRATIONS WILL NOT VARY SIGNIFICANTLY. AVERAGE FILTER POROSITY IS TO 40%.

METHOD: HAND CALCULATION WILL BE PERFORMED.

- REFERENCES:
- ① DRAWING NUMBERS: H-3-14193, 6 SHEETS
H-3-14192, 6 SHEETS
 - ② MONTHLY FLOW RATES FOR PLANT 1994
 - ③ CALCULATION ER5480-G-004
 - ④ HANFORD ENVIRONMENTAL HEALTH FOUNDATION REPORT FOR CY 1992.
 - ⑤ GUIDANCE FOR COMPLIANCE WITH FILTRATION AND DISINFECTION REQUIREMENTS, EPA, MARCH 199
 - ⑥ LMI catalog See 31 pg. 1900

FINDINGS: THE THEORETICAL DETENTION TIME AND CORRESPONDING FLUORIDE INJECTION RATE IS AS FOLLOWS:

$$T_{300,1} = 2.3 \text{ HRS} \quad Q_{FIN,1} = 46.4 \text{ l/min}$$

$$T_{300,2} = 2.6 \text{ HRS} \quad Q_{FIN,2} = 41.8 \text{ l/min}$$

CALCULATION: THE PLANT VOLUME WAS DETERMINED USING ORIGINAL DRAWINGS. ONCE THE VOLUME OF EACH UNIT IS KNOWN, THE VOLUME OF THE SYSTEM CAN BE DETERMINED. THE THEORETICAL DETENTION TIME CAN BE DETERMINED GIVEN THE VOLUME OF WATER IN THE PLANT AND THE PEAK HOURLY FLOW RATE.

**KAISER ENGINEERS
HANFORD**

Calc. No. ER5480-G-00

Revision 2

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DESIGN ANALYSIS

Client ICF-KM WO/Job No. ER5480
 Subject THEORETICAL DETENTION TIME Date 11-5-94 By TOOD BOUCHER
+ INJECTION QUANTITY Checked _____ By _____
 Location 300 AREA FILTER PLANT Revised 12-22-94 By TOOD BOUCHER

THEORETICAL DETENTION TIME OF 300 AREA FILTER PLANT.

THE VOLUME OF THE 300 AREA PLANT: ①

$$V_{300} = \text{FLASH MIXER} + 3 (\text{FLOCCULATORS} + \text{SEDIMENTATION BASINS}) + \text{CLEARWELL} + 3 (\text{FILTERS})$$

$$V_{300} = 7.78 \times 10^9 \text{ mm}^3 + 3 (5.42 \times 10^{10} \text{ mm}^3 + 2.59 \times 10^{11} \text{ mm}^3)$$

3F. 170L
3Basins $(4' * 5.5' * 12.5')$ $(17' * 15' * 7.5')$ $(53' * 15' * 11.5')$

$$+ 2.76 \times 10^{11} \text{ mm}^3 + 3 [(40\% \text{ POROSITY}) 4.28 \times 10^{10} \text{ mm}^3]$$

3F. 170L
3Basins $(18' * 47' * 11.5')$ $(12' * 12' * 10.5')$

$$V_{300} = \frac{1.28 \times 10^{12} \text{ mm}^3}{(45,012 \text{ ft}^3)} \left(\frac{1 \text{ LITER}}{1.0 \times 10^6 \text{ mm}^3} \right) = 1.28 \times 10^6 \text{ L}$$

3F. 170L
3Basins

$$V_{300} \text{ (4F. 170L + 4Basins)} = 1.605 \times 10^6 \text{ L}$$

$$Q_{300,1} = 9,084 \text{ L/MIN} (2,400 \text{ gal/MIN}) \text{ @ } 90\% \text{ OF } Q_{\text{PEAK}}$$

$$Q_{300,2} = 8,175 \text{ L/MIN} (2,160 \text{ gal/MIN})$$

$$Q = \frac{V}{T} \text{ OR } T = \frac{V}{Q}$$

$$T_{300,1} = \frac{1.605 \times 10^6 \text{ L}}{9,084 \text{ L}} = 177 \text{ MINUTES} \left(\frac{\text{HR}}{60 \text{ MINUTES}} \right) =$$

$$T_{300,1} = 2.95 \text{ HRS @ } 9,084 \text{ L/min}$$

$$T_{300,2} = \frac{1.605 \times 10^6 \text{ L}}{8,175 \text{ L/min}} = 196 \text{ MIN} \left(\frac{\text{HR}}{60 \text{ MINUTES}} \right) =$$

$$T_{300,2} = 3.3 \text{ HRS @ } 8,175 \text{ L/min}$$

DESIGN ANALYSIS

Client ICF-KM WO/Job No. ER5480
 Subject THEORETICAL DETENTION TIME Date 11-5-94 By TODD BOUCHER
INJECTION QUANTITY Checked By
 Location 300 AREA FILTER PLANT Revised 12-22-94 By TODD BOUCHER

THE TRACER INJECTION CONCENTRATION IS DEPENDENT ON TWO FACTORS: THE EFFECTS OF ALUM ON THE FLUORIDE AND THE BACKGROUND FLUORIDE CONCENTRATIONS

FLUORIDE LOSS DUE TO ALUM = $F_A \cong 0.1 \text{ mg/l}$ (3)

FLUORIDE BACKGROUND CONCENTRATION = $F_B = 0.1 \text{ mg/l}$ (4)
(300 AREA)

FLUORIDE INJECTION CONCENTRATION = $F_C = ?$

MAXIMUM FLUORIDE CONCENTRATION = $F_M = 1.5 \text{ mg/l}$ (5)

$F_M = F_B + F_C - F_A$ OR $F_M + F_A - F_B = F_C$

$F_C = 1.5 \text{ mg/l} + 0.1 \text{ mg/l} - 0.1 \text{ mg/l}$

$F_C = 1.5 \text{ mg/l}$

THE FLOWRATE OF SODIUM FLUORIDE NEEDED TO DO THE TEST CAN BE DETERMINED.

$1.5 \text{ ppm} = \frac{1.5 \text{ grams}}{1.0 \times 10^6 \text{ grams of H}_2\text{O}}$

$\frac{1.5 \text{ g of F}}{1.0 \times 10^6 \text{ g of WATER}} = \frac{X}{9,084 \text{ l/min} \left(\frac{1,000 \text{ g of WATER}}{\text{l}} \right)}$

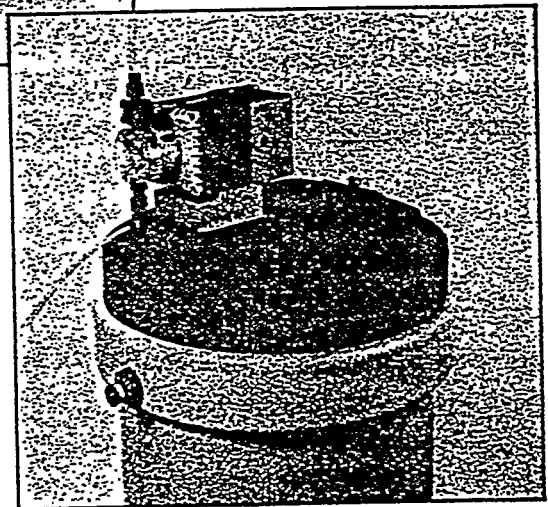
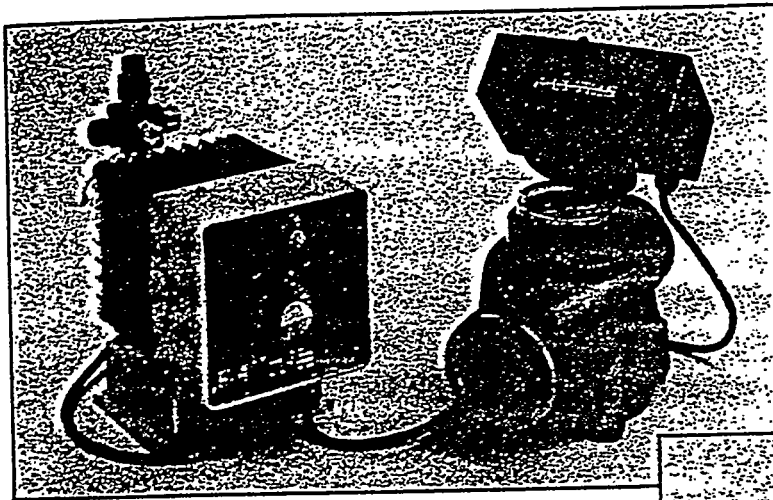
$X = \frac{13.6 \text{ g of F}}{\text{MIN}}$

(Ref. 6) 4% SATURATION SOLUTION AND 144% FLUORIDE ION CONCENTRATION
 $\frac{0.04 \text{ g of NaF}}{\text{g of H}_2\text{O}} \left(\frac{1,000 \text{ g of H}_2\text{O}}{\text{l}} \right) (144\% \text{ F}) = 17.6 \text{ g of F/l SAT Sol}$

$Q_{MIN,1} = \frac{13.6 \text{ g of F}}{\text{MIN}} \left(\frac{\text{l}}{17.6 \text{ g}} \right) \left(\frac{60 \text{ MIN}}{\text{HR}} \right) = 46.4 \text{ l/hr or } 12.25 \text{ g/hr}$
 @ 9,084 l/min

$Q_{MIN,2} = \frac{12.3 \text{ g of F}}{\text{MIN}} \left(\frac{\text{l}}{17.6 \text{ g}} \right) \left(\frac{60 \text{ MIN}}{\text{HR}} \right) = 41.8 \text{ l/hr or } 11.04 \text{ g/hr}$
 @ 8,175 l/min

FLUORIDATION



CHEMICAL CHOICE

The three most common fluoridation chemicals are sodium silicofluoride, sodium fluoride and hydrofluosilicic acid. This brochure deals with solution feed systems, utilizing the latter two of these chemicals.

Chemical	Properties	Typical Comm. Strength	Fluoride Ion Content
Sodium Fluoride NaF	white, odorless powder/crystals	90-98%	44%
Hydrofluosilicic Acid H ₂ SiF ₆	clear to yellow	30%	23.7%
	liquid, pungent	25%	19.8%
	odor, skin irritant	22%	17.4%

The optimum concentration of fluoride in a public water supply has been set at approximately one part per million (1 ppm) according to the U.S. Department of Health and Human Services, Center for Disease Control 1982 Fluoridation Handbook. Levels may vary. Be sure to check with local health authorities when designing your fluoridation system.



LMI
LIQUID METRONICS DIVISION
MILTON ROY

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FAX (508) 264-9172

Catalog Sec. 3.1, pg. 1900
Replaces same of 5/85
1242.B 3/87

APPENDIX C

**Calculation No. ER5480-G-004
Fluoride Loss Due to Addition of Alum, Rev. 0**

**KAISER ENGINEERS
HANFORD**

CALCULATION IDENTIFICATION AND INDEX

Page 1 of 3
Date Nov 11, 1994

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline General WO/Job No. ER5480 Calculation No. ER5480-G-004
 Project No. & Name EGSBR4 - Tracer Study
 Calculation Item Fluoride Loss from addition of alum.

These calculations apply to:

Dwg. No. _____ Rev. No. _____
 Dwg. No. _____ Rev. No. _____
 Other (Study, CDR) _____ Rev. No. _____

The status of these calculations is:

- Preliminary Calculations
- Final Calculations
- Check Calculations (On Calculation Dated _____)
- Void Calculation (Reason Voided _____)

Incorporated in Final Drawings? Yes No
 This calculation verified by independent "check" calculations? Yes No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	<u>Dennis G. Lenth</u> 11/11/94		
Checked by	<u>Todd D. Boucher</u> 11/11/94		
Approved by			
Checked Against Approved Vendor Data			

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<u>2</u>	<u>Objectives, Design Inputs, Criteria</u>
<u>3</u>	<u>Figure, Results</u>

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Calc. No. ER5480-G-004

Revision 0

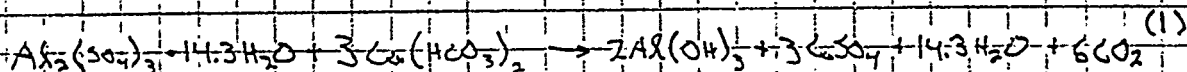
Page No. 2 of 3

DESIGN ANALYSIS

Client	ICF KH	WO/Job No.	FOXBB4
Subject	Fluoride Loss due to addition of Alum	Date	Nov 11, 1994
		By	Dani A. Jankle
		Checked	11/11/94
		By	Wald N. Boucher
Location		Revised	
		By	

OBJECTIVE:

Alum is used in water treatment plants to reduce the turbidity of the water by flocculation. During this process, residual fluoride is adsorbed onto the $Al(OH)_3$ molecules created by the following reaction of alum in water:



Since Fluoride is being added for a tracer study test, we must determine the amount of the tracer that will be lost.

DESIGN INPUTS:

CRITERIA:

The maximum allowable fluoride concentration in the exit stream may not exceed 2 ppm because the equipment used to test for residual fluoride has a maximum detection range of 2.0 ppm. We will assume that the maximum amount of alum will be added throughout the study. Sam Culp, 300 Area Treatment Plant, stated that alum addition in the 300 area water treatment plant to be from 5 to 20 ppm. We will use 20 ppm for determining fluoride loss.

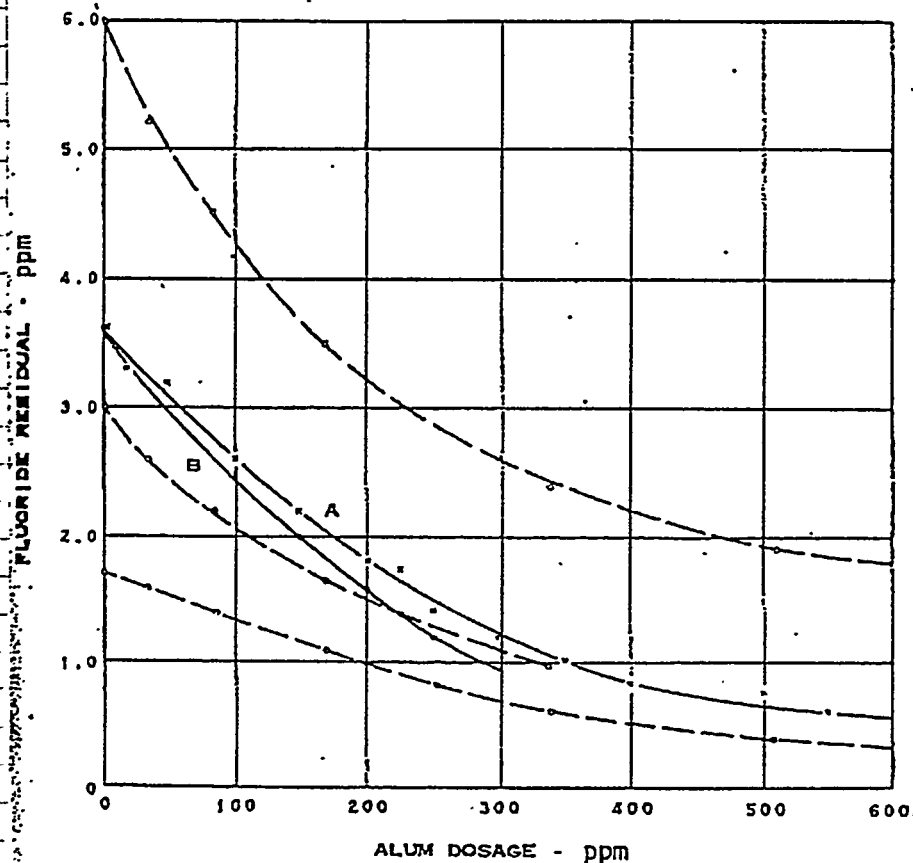
(1) Culp, Handbook of Public Water Systems, 1986, p656.

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Calc. No. ER5480-G-001
Revision 0
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DESIGN ANALYSIS

Client ICF KH WO/Job No. F00884
Subject Fluoride loss due to addition of Alum Date Nov 11, 1994 By Dennis A. Lankford
Alum Checked 11/11/94 By Wald N. Bouchier
Location _____ Revised _____ By _____



The above figure is the plotted data results from tests conducted by Culp and Stallenberg on fluoride removal at various alum dosages. (1)

RESULTS:

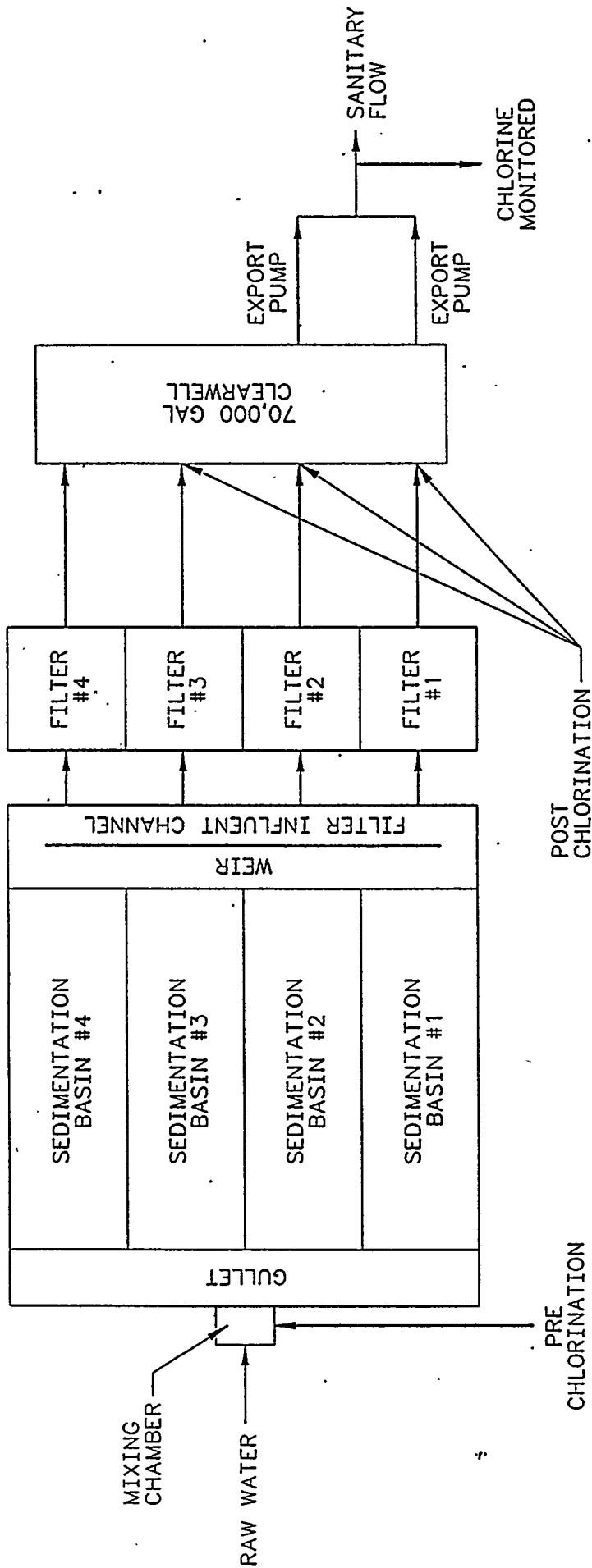
From the above plot, we can see that a 1.8 ppm initial concentration of fluoride is reduced to 1.7 ppm (5.9% loss) with a 20 ppm alum dosage.

Thus, the alum will not greatly effect the fluoride added to the system or the tracer study. The study will inject at a maximum of 1.5 ppm, so a loss of 0.1 ppm can be assumed.

(1) Culp, Handbook of Public Water Systems, 1986, p. 656.

APPENDIX D

315 Water Treatment Facility Layout



(1 - BASIN IN WINTER, 2 OR 3 DURING SUMMER)

ICF KAISER HANFORD

ENGINEERING SKETCH

Attachment to Or Description:

300 AREA WATER TREATMENT PLANT

Prepared By: BA LOREZIO	Sh 1 of 1	Rev
Checked By:	CAEING ESS480E1	0

APPENDIX E

**Washington State DOH
Tracer Evaluation Work Sheet**

Tracer Study Evaluation Work Sheet

Evaluation by: T. Ambalam Date: April 3, 1995
 Utility Name: Dept of Energy Richland Operations
 Treatment Plant/ Facility Name: 315 Water Treatment Facility
 Basin/Treatment Train Designation: 418408 Flashmixers Sedimentation basins, filter clearwell
 Sample Point Designation: Sample Tap off clearwell discharge line.
 Plant Flow Rates: 2,400 gpm (Q_p) Peak/Design Flow [MGD/GPD/gpm]
898 gpm (Q_{av}) Average Flow [MGD/GPD/gpm]
 Basin Volume: 424,000 gal (V) [cubic feet/gallons]
 Theoretical detention time: 1.77 min (T) [days/hours/minutes]
 $T = V/Q_p$

Study flow rate:

Multiple Flow Rate Study: (Equal increments required)

- Q₁ = 2,400 gpm [MGD/GPD/gpm] (= Q_p)
- Q₂ = 2,160 gpm [MGD/GPD/gpm] (0.90 Q_p)
- Q₃ = _____ [MGD/GPD/gpm] (= Q_{av})
- Q₄ = _____ [MGD/GPD/gpm] (> 0.91 Q_p)

Single Flow Rate Study:

Q₁ = _____ [MGD/GPD/gpm] (> 0.91 Q_p)

Basin Water Level = 10.8 feet (depth)

Normal Basin Water Level = 10.8 feet (depth)

Water Temperature: Test Period 42.5-46.2 °F

Normal Temperature for Season 43-51 °F

Seasonal Variation:	Winter	Spring	Summer	Fall
Maximum (°F)	<u>50</u>	<u>59.5</u>	<u>75.2</u>	<u>68.4</u>
Average (°F)	<u>43.2</u>	<u>51.1</u>	<u>67.6</u>	<u>55.8</u>
Fall (°F)	_____	_____	_____	_____

Tracer Selection

Chemical Tracer: Sodium Fluoride Dose: 1.21-1.27 ppm

Note: Recommended dosage for chloride is 20 ppm if background chloride levels are < 10 ppm

Recommended dosage for fluoride is C₁ < 2 ppm

Rhodamine WT is acceptable if maximum concentration is .10 ppm, drinking water concentration < 0.1 ppb, exposure is brief and infrequent, and tracer concentrations should be 2 ppb

Common tracer chemicals not recommended for use are Rhodamine B; potassium permanganate; alum; chlorine; and sodium carbonate.

Compatibility with potable water usage : Yes

Background levels of tracer in raw water: 0.4 ppm

Feeding equipment & methods: LMI Model 28850 Fluoride saturator as an electronic metering pump

Consumer acceptance of tracer chemical: Yes

Test Procedure

Step-dose method

Slug-dose method

Tracer Addition & Sampling:

Sampling Period: 10.9-11.7H [days/hours/minutes] (t_s)

$t_s < 2 T$ Yes No

Sampling Frequency: 2-5 min Acceptable Unacceptable

Note: Sampling required every 10 minutes for first 10 minutes or until background concentration is exceeded; sampling over 2 to 5 minutes during required for remaining sampling period; sampling continued until steady-state effluent concentration is reached beyond t_s .

Health concerns:

Is effluent tracer concentration limited? Yes No

Maximum level: 1.5 ppm;

How is concentration maintained: Flow rates maintained to ensure concentrations do not exceed 2.0 ppm

Step-dose method:

Tracer addition = sampling period? Yes No

slug-dose method:

Instantaneous injection period: _____ t_i ($t_i < 2 T$)

Is injected mass based on basin volume equal to step-dose level? Yes No

Density current effects (Mitigation efforts): _____

Tracer recovery:

Is alum used in plant treatment? Yes No

90% tracer recovery? Yes No

Data Evaluation:

Evaluation technique: graphical numerical

$T_s = \frac{300,000}{Q}$ minutes
Q=Flow (gpm)

END DATE

7-25-95