



## **Pilot Study Report**

for

### **Z-88® Radium Treatment Process**



conducted for

### **City of Farmington, Missouri Well No. 17**

**September 14, 2006**

## Executive Summary

This radium removal pilot study was conducted for the City of Farmington, Missouri Well No. 17 treatment facility. The Farmington water system contains concentrations of radium and gross alpha in excess of the Maximum Contaminant Levels (MCL).

The City of Farmington selected Water Remediation Technology's (WRT) Z-88® Radium Treatment Process as a possible cost effective solution for their radium problem. WRT provided a 1.0 GPM (gallons per minute) treatment system, which was delivered and installed on January 30, 2006.

The purpose of this pilot study is to document the effectiveness of the WRT system on high radium and gross alpha water and to provide information necessary to meet regulatory compliance.

The treatment system successfully met radium compliance at all times during the pilot study. The system was in operation for 84 days prior to writing this report and effectively reduced the level of radium (Figure 1) and gross alpha (Figure 2) to less than the MCL .

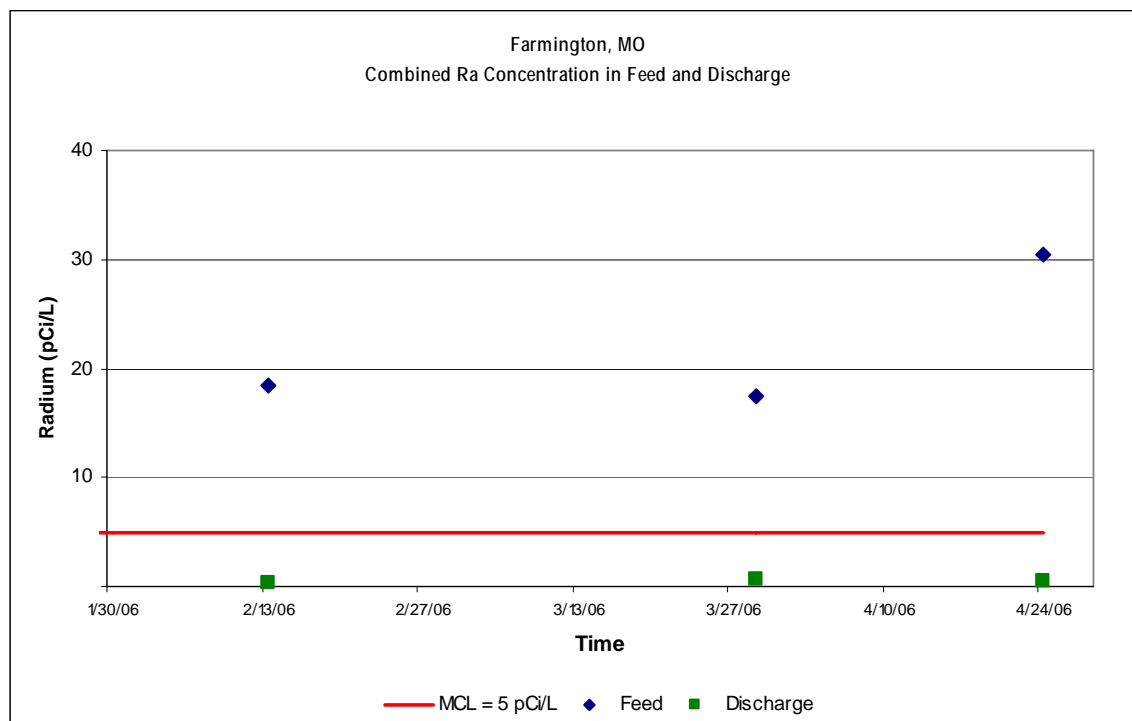


Figure 1

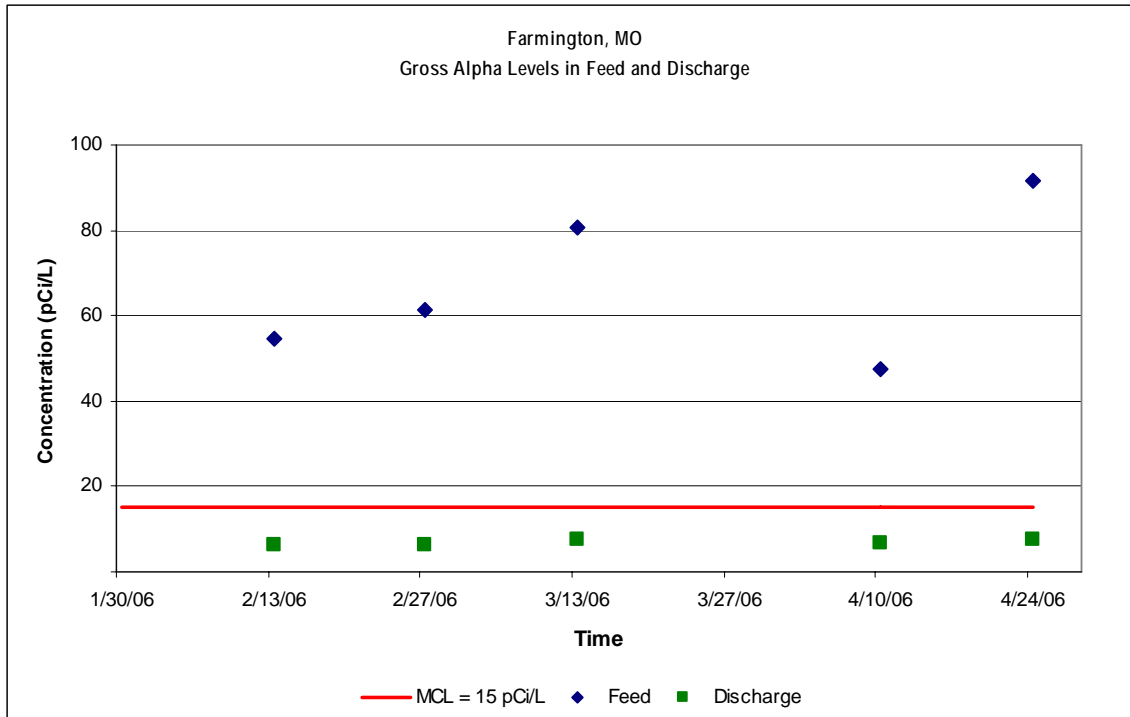


Figure 2

The results are also shown in Table 1. The average feed concentration of combined radium, 22.1 pCi/L, was reduced to an average of 0.5 pCi/L; well below the MCL of 5 pCi/L. The average feed concentration of gross alpha, 67.0 pCi/L, was reduced to 6.9 pCi/L; also below the MCL of 15 pCi/L.

**Table 1. Radium and Gross Alpha levels in feed and discharge water.**

Combined Radium	Feed (pCi/L)	Discharge @ Column 4 (pCi/L)
<b>Radium MCL</b>	—	<b>5.0</b>
Average	22.1	0.5
Highest value	30.4	0.7
Lowest Value	17.4	0.5
Gross Alpha	Feed (pCi/L)	Discharge @ Column 4 (pCi/L)
<b>Gross Alpha MCL</b>	—	<b>15.0</b>
Average	67.0	6.9
Highest value	91.5	7.7
Lowest Value	47.3	6.2



### Application Information

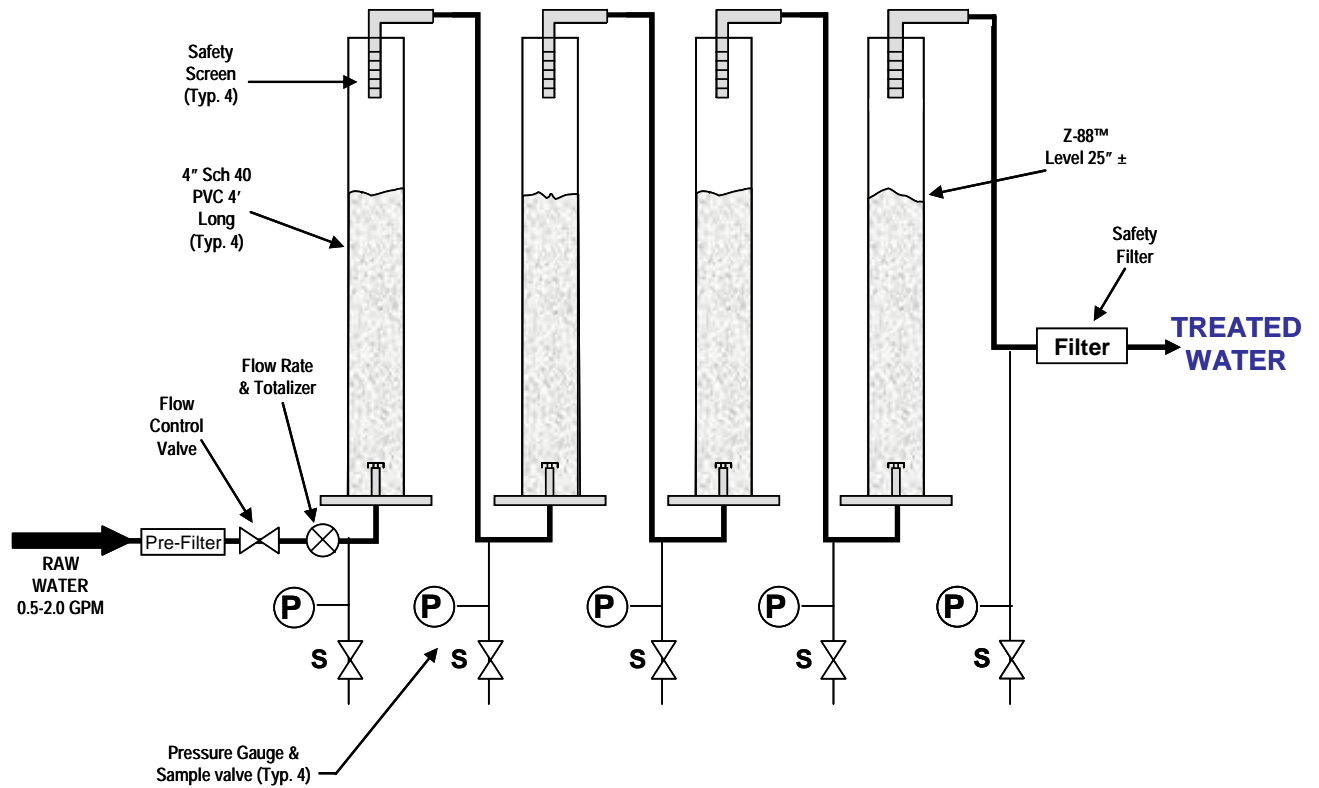
The City of Farmington is located in St. Francois County, Missouri. Farmington is a historic location known as the “City of Tradition and Progress” due to its preservation of traditional family values and continual and consistent population, area and economic growth. Farmington, located approximately 70 miles southwest of St. Louis, has a current population of over 14,000. Well No. 17 treatment facility is one of thirteen wells that currently serves the community. This well is approximately 900 feet deep.

### Technology Overview

Water Remediation Technology’s (WRT) Z-88® Radium Treatment Process utilizes proprietary adsorptive media in a series of up flow treatment vessels to remove radium from drinking water. The water is moved through the treatment system using the water pressure generated from the well source. No chemicals are added to the water for the treatment process. After the media is loaded with radium, it is removed from the circuit and permanently disposed of in a licensed facility. WRT designs, manufactures and provides the equipment and media used in the facility. The handling and exchange of new media to replace spent media, as well as the shipping and disposal into licensed disposal sites, is handled by WRT. The treatment media are ANSI/NSF Standard 61 certified for use in drinking water.

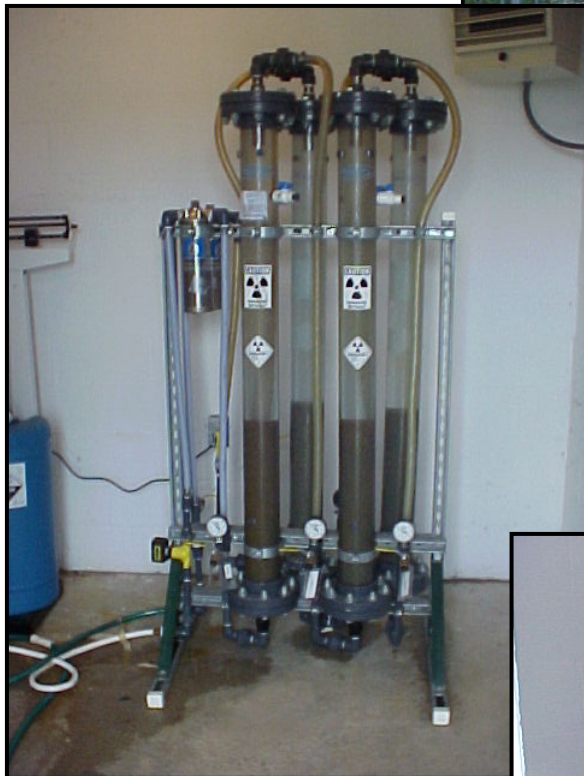
### Equipment Overview

The pilot equipment was installed in the City of Farmington’s Well No. 17 treatment facility. The treatment train used for this pilot study consists of four 4-inch diameter by 5-foot vertical height columns each containing approximately 25 inches of Z-88® media. The columns in the pilot unit are clear for visual observation of the media and process. The source water enters the unit through a ¾-inch diameter hose, passes through a control valve and flow meter, and enters the bottom of the first column. All columns operate in an up-flow configuration, with the flow exiting the top of the first column, then following the same flow path through columns 2 through 4 in series (see Figure 3). The last component in the system is a safety filter. Sample ports are located prior to the first column, and after each of the columns in the series.



**Figure 3. Simplified Process Flow Diagram.**

City of Farmington's Z-88®  
Radium treatment system  
located at Well No. 17.







### Statement of Purpose

The combined radium levels in the raw water during the pilot study were as high as 30.4 pCi/L, exceeding the Environmental Protection Agency (EPA) mandated combined radium MCL of 5 pCi/L. Similarly, the gross alpha was as high as 91.5 pCi/L, also exceeding the required MCL of 15 pCi/L for adjusted gross alpha.

The purposes of this pilot study are to:

- Demonstrate the ability of the WRT Z-88® Treatment Process to consistently and effectively reduce the radium to below the MCL on this specific water.
- Demonstrate the reliability and ease of operation of the WRT Process.
- Comply with regulatory requirements.
- Develop design criteria for the full-scale facility.

### Delivery and Installation of the Treatment System

The treatment system was delivered and installed on January 30, 2006. Set up consists of mounting the columns to a frame and connecting the water source and discharge line. The pilot study began the same day. Data was collected for 84 days prior to writing this report.

Operator training for system operation, monitoring and sampling was conducted on the day of installation, and a schedule for sampling was established. Samples were collected by the City of Farmington personnel from sample valves located in the feed line and after discharge from each respective treatment vessel, at pre-determined sample intervals.

### Analytical

The samples were delivered to the Saint Louis County Department of Health, Environment Laboratories, a branch of the Missouri Department of Natural Resources – Division of Environmental Quality, Public Drinking Water Program, for radium, gross alpha, uranium and inorganic analysis. This laboratory is a National Environmental Laboratory Accreditation Program certified laboratory. Methods for analysis were:

Gross Alpha	EPA 900.0
Radium 226	EPA 903.1
Radium 228	EPA 904.0
Uranium	EPA 908.0

Results

The sampling results are shown in Tables 2 and 3. Feed samples were collected immediately prior to the first treatment vessel. Samples were taken immediately after column no. 2 (C2), and at the discharge point. Analytical laboratory certificates are attached as Appendix A. Figures 4, and 5 show combined radium 226 and 228 and gross alpha levels in the feed water entering the pilot unit, and treated water exiting the pilot unit. The graphs show that the pilot unit successfully reduced combined radium in the treated water to significantly below the required MCL.

**Table 2. Radium Test Results**

<b>Radium 226</b>	<b>Column Concentrations (pCi/L)</b>			
<b>Date</b>	<b>Feed</b>	<b>C2</b>	<b>C4</b>	<b>MCL</b>
1/30/06				—
2/13/06	10.4	1.0	0.3	—
3/29/06	8.9	0.9	0.6	—
4/24/06	16.8	0.5	0.4	—
<b>Radium 228</b>	<b>Column Concentrations (pCi/L)</b>			
<b>Date</b>	<b>Feed</b>	<b>C2</b>	<b>C4</b>	<b>MCL</b>
1/30/06				—
2/13/06	8.1	<1.0	<1.0	—
3/29/06	8.5	<1.0	<1.0	—
4/24/06	13.6	<1.0	<1.0	—
<b>Combined Radium</b>	<b>Column Concentrations (pCi/L)</b>			
<b>Date</b>	<b>Feed</b>	<b>C2</b>	<b>C4</b>	<b>MCL</b>
1/30/06				5.0
2/13/06	18.5	1.1	0.4	5.0
3/29/06	17.4	1.0	0.7	5.0
4/24/06	30.4	0.6	0.5	5.0



Figure 4 below, presents in graph format, the data in Table 2.

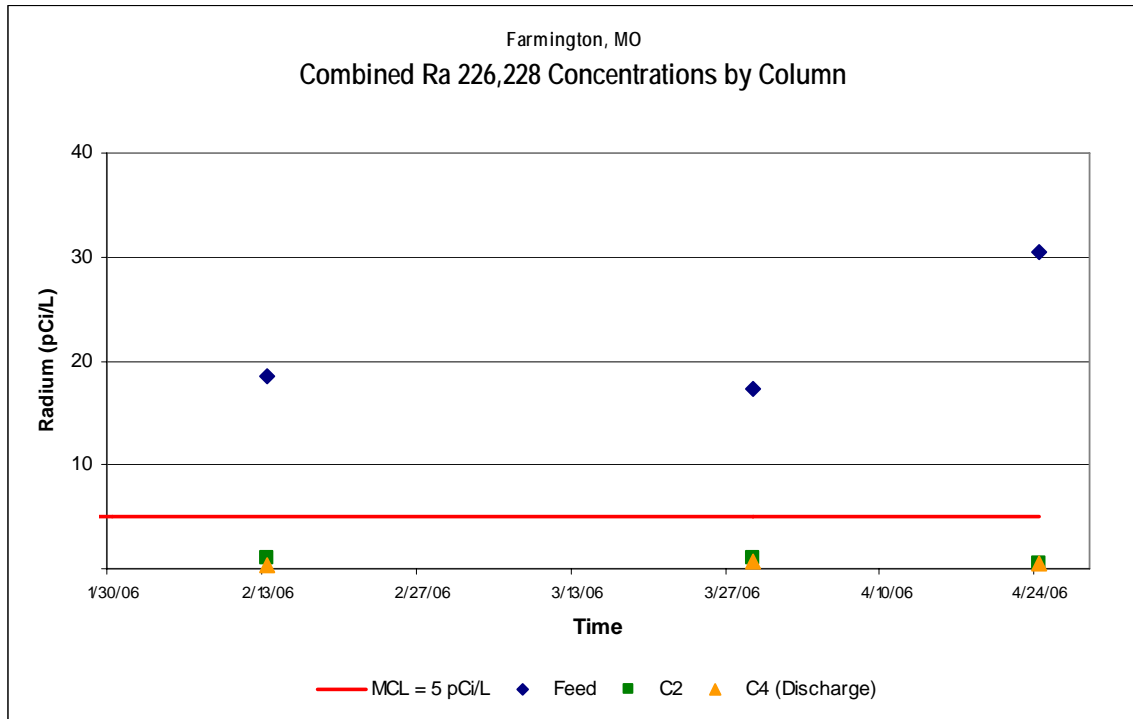


Figure 4

**Table 3. Gross Alpha Test Results**

Gross Alpha Date	Column Concentrations (pCi/L)			
	Feed	C2	C4	MCL
1/30/06				15.0
2/13/06	54.6	10.9	6.2	15.0
2/27/06	61.2	9.9	6.3	15.0
3/13/06	80.6	10.8	7.7	15.0
4/10/06	47.3	5.9	6.7	15.0
4/24/06	91.5	8.6	7.7	15.0

Figure 5 below, presents in graph format, the data in Table 3.

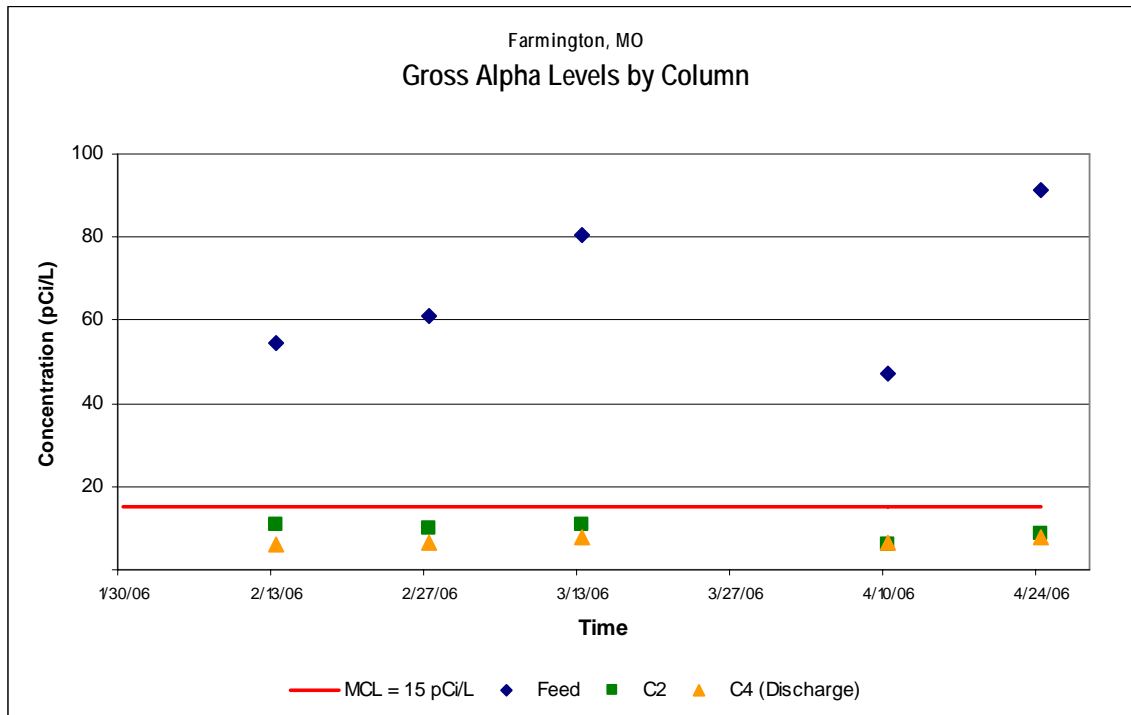


Figure 5

## Water Quality

A water quality analysis was performed on feed water to the pilot unit and on treated water exiting the WRT pilot unit to document any changes in water quality through the Z-88® treatment process. The results of those tests are shown in Table 4. Other than the reduction of radium and gross alpha, there is no statistically significant change to the water quality. Support documentation for Table 4 is attached as Appendix B.

**Table 4. Water Quality Data entering the WRT treatment process**

Farmington, MO – Water Quality Data			
Item	Pre WRT Process	units	Post WRT Process
Alkalinity	292	mg/L	260
Aluminum	<10	µg/L	44.6
Antimony	<1	µg/L	<1
Arsenic	3.54	µg/L	4.61
Barium	11.8	µg/L	2.34
Beryllium	<1	µg/L	<1
Cadmium	<1	µg/L	<1
Calcium	80.8	mg/L	69.9
Chloride	22.8	mg/L	15.1
Chromium	<1	µg/L	1.25
Copper	3.11	µg/L	13.5
Cyanide	<0.01	mg/L	<0.01
Fluoride	0.21	mg/L	0.49
Hardness	467	mg/L	387
Iron	100	µg/L	10.0
Lead	1.16	µg/L	3.11
Magnesium	64.3	mg/L	51.7
Manganese	19.8	µg/L	12.0
Mercury	<0.2	µg/L	<0.2
Nickel	11.7	µg/L	116
pH	7.6	unit	7.62
Potassium	1.33	mg/L	1.37
Selenium	<5	µg/L	<5
Silver	<1	µg/L	<1
Sodium	38.2	mg/L	25.2
Sulfate	220	mg/L	147
Thallium	<1	µg/L	<1
Total Dissolved Solids	609	mg/L	489
Turbidity	<1	NTU	<1
Zinc	23.0	µg/L	26.3

The initial water quality test performed showed an elevated nickel level exiting the pilot unit. Of the many similarly installed pilot tests conducted to date, none showed this elevated nickel level on pilot unit discharge. Following shutdown and prior to pilot unit decommissioning, the pilot was restarted, run for 1 hour and duplicate samples were taken for a retest of nickel concentration before and after the pilot unit to determine the validity of the initial test results. The retest for nickel showed a slight increase in nickel content from 4.2 to 27.8 µg/L, as shown in Table 5. This resulting value, although higher than that experienced at all previous WRT pilot locations is nevertheless well below the most recent EPA contaminant MCL of 100 µg/L. Because this is the first occurrence of any elevated metal contaminant through the Z-88® process, WRT is currently unable to explain the result. We are however investigating variations in this installation from others to study the matter further. In any event, the relatively low elevated nickel concentration shown on retest is inconsequential to expected final water quality meeting current drinking water standards. Support documentation for Table 5 is attached as Appendix B.

**Table 5: Nickel Retest Data Entering the WRT Z-88® treatment process.**

Nickel	Column Concentrations (µg/L)		
	Date	Feed	C4
	8/9/06	4.2	27.8

Hydraulic Loading Rate (HLR) and Empty-bed Contact Time (EBCT)

The pilot unit operated nominally at 1.1 gallons per minute, for a HLR of 12.6 gallons per minute per square foot. The pilot unit ran continuously during this test. The total gallons treated during the pilot study are summarized in Table 6 and Appendix C.

The EBCT at this HLR through four columns, each containing 25 inches of media, is 4.9 minutes.

**Table 6. Cumulative treated flow in gallons**

Sample Data	Treated Flow in Gallons
1/30/06	0
2/13/06	24,634
2/27/06	35,142
3/13/06	43,308
3/29/06	51,166
4/10/06	53,775
4/24/06	60,124

## Uranium

Samples were collected during this study to evaluate the general level of uranium in the product water. Table 7 contains the uranium test results taken during the pilot study. The WRT Z-88® process is not designed to remove uranium. Supporting documentation for Table 6 is attached as Appendix A.

Because the uranium levels in the initial water analysis were well below the MCL, uranium removal was precluded as a target contaminant in reducing gross alpha. Uranium levels remained below detection limits in the feed water and discharge throughout the pilot testing.

**Table 7. Uranium Test Results**

<b>Uranium</b>	<b>Column Concentrations (pCi/L)</b>			
<b>Date</b>	<b>Feed</b>	<b>C2</b>	<b>C4</b>	<b>MCL</b>
2/13/06	4.3	3.8	4.7	20.1
4/24/06	5.4	3.9	4.3	20.1

## Radiation Safety

The pilot unit is designed to collect naturally occurring radioactive material while in operation. Because of this action, it gradually becomes radioactive during normal operation. WRT both predicts and monitors the level of radiation present in the treatment system.

The total amount of radiation that members of the public can be exposed to is 2 mrem per hour and 100 mrem over the course of a year. WRT's maximum measured activity is less than half of the hourly exposure limit. Due to the limited amount of operator attention necessary for the pilot test, the annual exposure limit is also readily met.

WRT has prepared a safety plan for its tests that includes radiation level monitoring, logging time spent in proximity to a test unit, emergency procedures to be followed and an introduction to radiation safety for operators. Operators are instructed in radiation safety before the pilot test is started.

Any full scale system will include appropriate equipment, radiation level monitoring, and a corresponding safety plan approved by regulatory authorities.



### Operational Results

An operation log was maintained during the pilot study, and is attached as Appendix C. The treatment system operated easily and reliably during the study.

### Conclusion

The WRT Z-88® Radium Treatment Process consistently reduced the combined radium 226 and 228 and gross alpha discharge to levels well below the required MCLs.

WRT would like to thank the personnel and staff of the City of Farmington for their cooperation and participation in this study.





Appendices available upon request