U.S. Department of Energy
Grand Junction Office
2597 B¾ Road
Grand Junction, CO 81503

JUL 02 2001

Mr. Melvin Leach, Chief
U.S. Nuclear Regulatory Commission
Fuel Cycle Licensing Branch
Division of Fuel Cycle Safety & Standards
Mail Stop T8A33
Washington, D.C. 20555-0001

Subject: Revised *Ground Water Compliance Action Plan for the Old Rifle, Colorado, UMTRA Project*

Dear Mr. Leach:

Enclosed are two copies of the revised Old Rifle Ground Water Compliance Action Plan for your approval. We have addressed all of your staff's technical concerns.

If you have any questions, please call me at 970/248-7612.

Sincerely,

Donald R. Metzler
Technical/Project Manager

Enclosures

cc w/o enclosure:
W. Naugle, CDPHE
S. Marutzky, MACTEC-ERS
Project File GWRFL 1.9 (P. Taylor)

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U.S. Department of Energy
Grand Junction Office
2597 B¾ Road
Grand Junction, CO 81503

JUL 02 2001

Ms. Wendy Naugle
Colorado Department of Public Health and Environment
Remedial Programs Section
Hazardous Materials & Waste Management Division
4300 Cherry Creek Drive South
Denver, CO 80246-1530

Subject: Revised *Ground Water Compliance Action Plan for the Old Rifle, Colorado, UMTRA Project*

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MAC-GWRFL 1.9

UMTRA
Ground Water Project

Ground Water Compliance Action Plan for the Old Rifle, Colorado, UMTRA Project Site

June 2001

Prepared by the
U.S. Department of Energy
Grand Junction Office

Work Performed Under DOE Contract No. DE-AC13-96GJ87335 for the U.S. Department of Energy
Approved for public release; distribution is unlimited.

GJO-2000-177-TAR
MAC–GWRFL 1.9

Ground Water Compliance Action Plan for the Old Rifle, Colorado, UMTRA Project Site

June 2001

Prepared by
U.S. Department of Energy
Grand Junction Office
Grand Junction, Colorado

Project Number UGW–511–0017–12–000
Document Number U0066302

Work Performed under DOE Contract No. DE–AC13–96GJ87335

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1.0 Introduction

This Ground Water Compliance Action Plan (GCAP) will serve as a stand-alone modification to Section E.3.6 of the *Final Remedial Action Plan and Site Design for Stabilization of the Inactive Uranium Mill Tailings Sites at Rifle, Colorado* (DOE 1992) and is the concurrence document for compliance with Subpart B of 40 CFR 192 for the Old Rifle site.

The proposed compliance strategies for the Old Rifle site are based on the "compliance strategy selection framework" following the steps prescribed in Section 2.1 of the *Final Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project* (PEIS) (DOE 1996b) (Figure 1). The proposed action is based on information presented in the *Final Site Observational Work Plan for the UMTRA Project Old Rifle Site* (SOWP) (DOE 1999).

2.0 Ground Water Compliance

The U.S. Department of Energy (DOE) is required by the PEIS to follow the ground water compliance strategy selection framework summarized in Figures 1 and 2 in selecting the appropriate compliance strategies to clean up ground water in the surficial aquifer (uppermost aquifer) affected by former processing activities at the Old Rifle site. The surficial aquifer is defined as the alluvial aquifer and the upper weathered Wasatch Formation that is hydraulically connected with the alluvium. The deeper Wasatch Formation is not contaminated at the Old Rifle site and is therefore not considered in the development of a compliance strategy.

DOE has determined that natural flushing of the surficial aquifer, in conjunction with the establishment of alternate concentration limits (ACL) and institutional controls, are the appropriate compliance strategies for the Old Rifle site. The compliance strategies focus on contaminants of concern (COC) retained after completion of the updated human health and ecological risk assessment screening processes (DOE 1999). This proposed action has been determined by applying the compliance strategy selection framework from the PEIS, consisting of several evaluative steps discussed below. An explanation of how the targeted strategies were selected is summarized in Tables 1 and 2.

2.1 Assessment of Environmental Data

The first step in the decision process was an assessment of both historical and new environmental data collected to characterize hydrogeological conditions and the extent of ground water contamination related to uranium processing activities at the site. The Old Rifle site is located along a low-lying erosional meander of the Colorado River. The alluvial floodplain consists of a complex interfingering of fine and coarse-grain materials, which contain sand, silt, gravel, and cobbles, with a uniform thickness of approximately 20 to 25 feet. Depth to ground water ranges from 5 to 15 feet below land surface. The alluvium directly overlies an 8- to 13-foot section of weathered Wasatch Formation claystone that appears to be hydraulically connected to, and of similar hydraulic characteristics as, the unconsolidated sediments of the alluvium. The resistant cliff-forming beds of the Wasatch Formation control the western, northern, and eastern extent of the alluvium at the site. Ground water beneath the site generally flows in a southwest

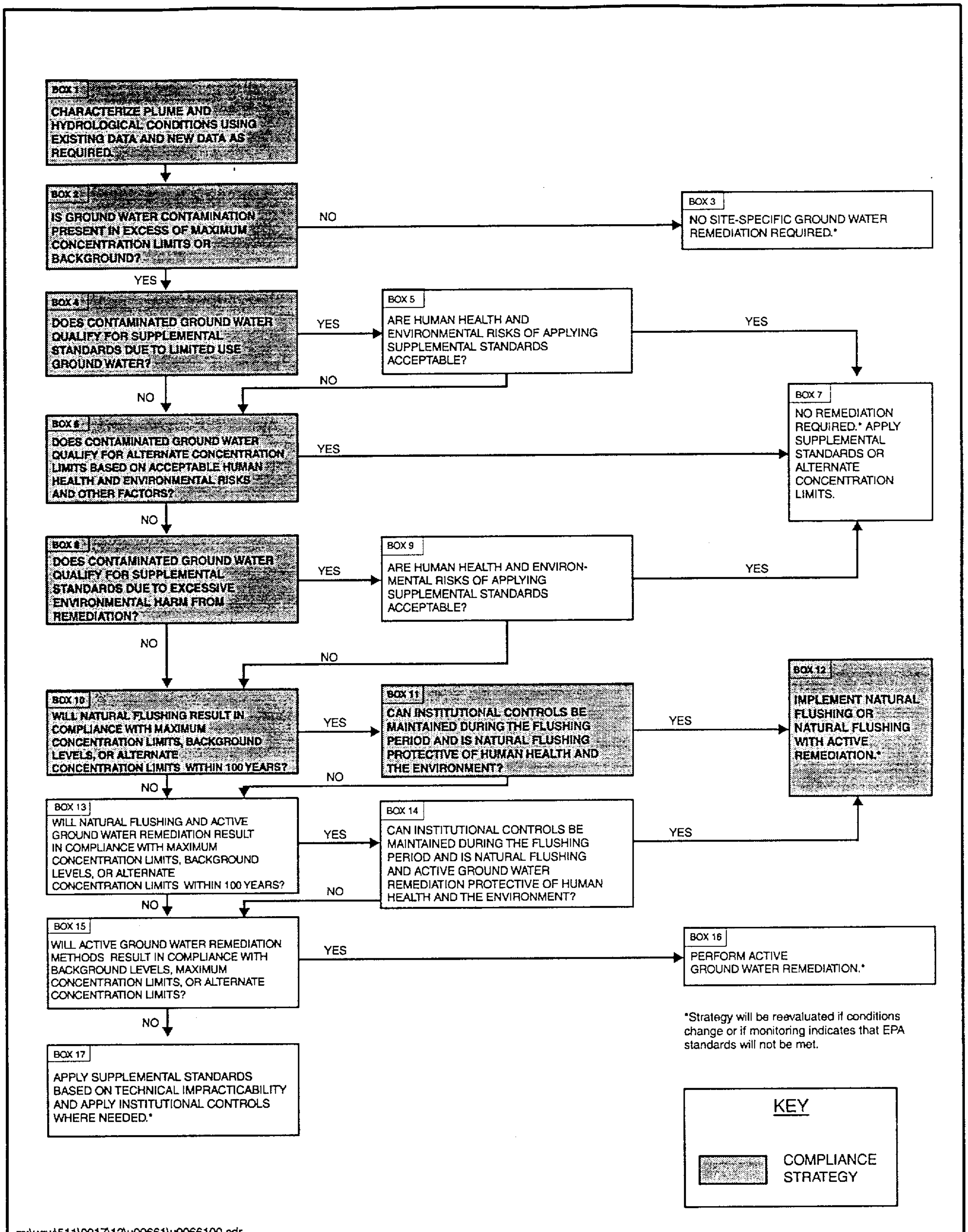

Figure 1. Compliance Selection Framework for Selenium and Uranium at the Old Rifle Site

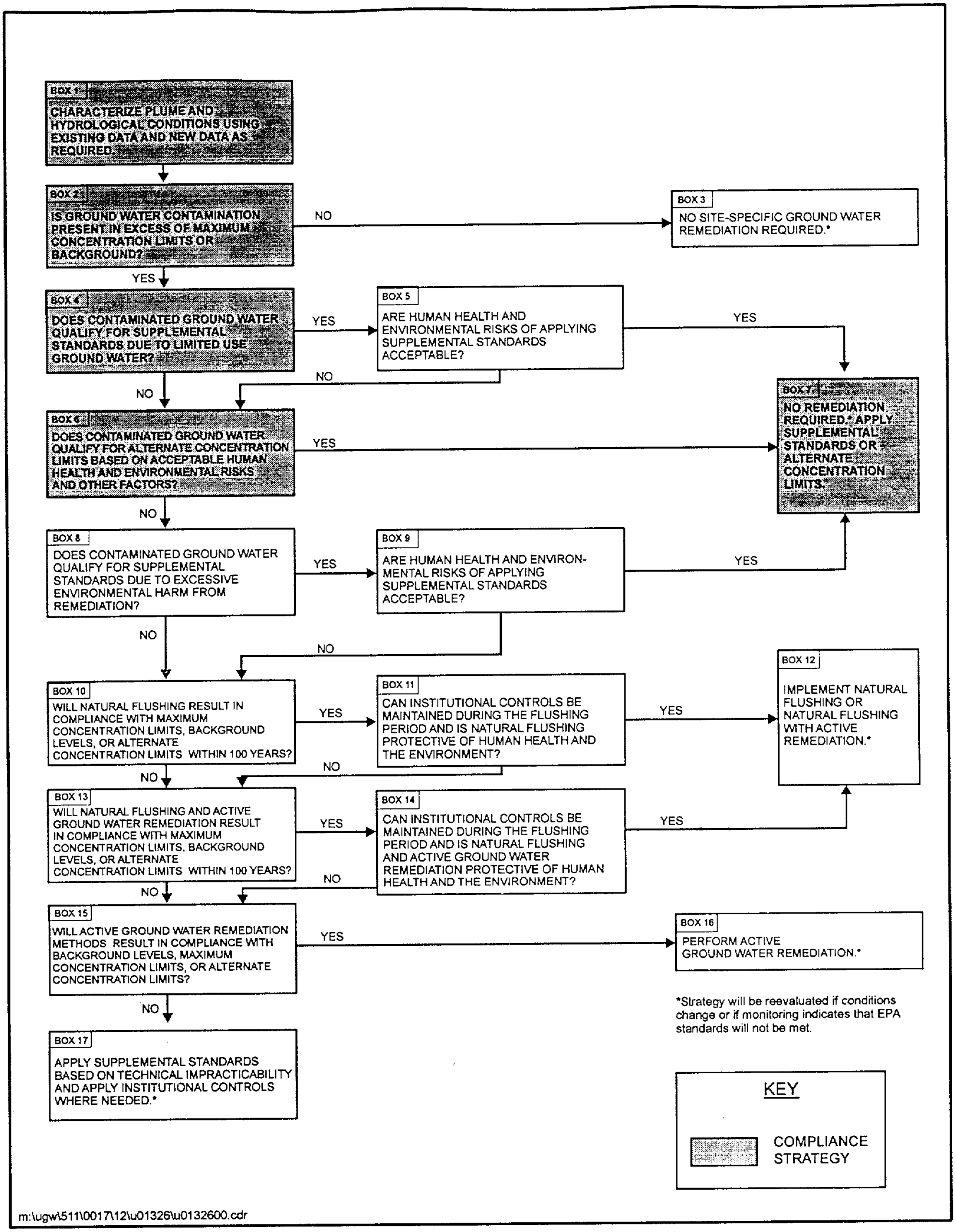

Figure 2. Compliance Selection Framework for Vanadium at the Old Rifle Site

Table 1. Explanation of Compliance Strategy Selection Process for Uranium and Selenium

Box (Figure 1)	Action or Question	Result or Decision
1	Characterize plume and hydrological conditions.	See conceptual site model in Section 5.0 of the SOWP (DOE 1999). Move to Box 2.
2	Is ground water contamination present in excess of UMTRA MCLs or background?	Selenium and uranium exceed the UMTRA MCL. Arsenic is below the UMTRA Project MCL. Move to Box 4.
4	Does contaminated ground water qualify for supplemental standards due to limited use ground water?	Alluvial ground water does not meet the criteria for limited use ground water and therefore does not qualify for supplemental standards. Move to Box 6.
6	Does contaminated ground water qualify for ACLs based on acceptable human health and environmental risk and other factors?	Ground water does not currently qualify for ACLs on the basis of acceptable human health and environmental risk. MCLs exist for these constituents. Move to Box 8.
8	Does contaminated ground water qualify for supplemental standards due to excessive environmental harm from remediation?	Although the applicability has not been formally assessed, it is unlikely that remedial action would cause excessive harm to the environment. Move to Box 10.
10	Will natural flushing result in compliance with UMTRA MCLs, background, or ACLs within 100 years?	Ground water modeling shows that natural flushing will reduce uranium to background or below MCLs well within the 100-year time frame. Selenium will achieve its proposed ACL within 100 years. Move to Box 11.
11	Can institutional controls be maintained during the flushing period and is the compliance strategy protective of human health and the environment?	The final compliance strategy is protective of human health and the environment. Institutional controls are in place and will prevent use of water. Move to Box 12 – implement natural flushing.

Table 2. Explanation of Compliance Strategy Selection Process for Vanadium

Box (Figure 2)	Action or Question	Result or Decision
1	Characterize plume and hydrological conditions.	See conceptual site model in Section 5.0 of the SOWP (DOE 1999). Move to Box 2.
2	Is ground water contamination present in excess of UMTRA MCLs or background?	Vanadium is elevated compared to background and exceeds risk-based concentrations. Move to Box 4.
4	Does contaminated ground water qualify for supplemental standards due to limited use ground water?	Alluvial ground water does not meet the criteria for limited use ground water and therefore does not qualify for supplemental standards. Move to Box 6.
6	Does contaminated ground water qualify for ACLs based on acceptable human health and environmental risk and other factors?	Ground water qualifies for ACLs on the basis of acceptable human health and environmental risk because of institutional controls. Move to Box 7. No remediation required. Apply supplemental standards or alternate concentration limits.

direction with a hydraulic gradient of approximately 0.004 ft/ft. Recharge to the alluvial aquifer occurs mostly as infiltration of precipitation, leakage from the drainage ditches north of U.S. Highway 6, and leakage from the open ditch that extends north to south across the site. The Colorado River bounds the site on the south and the alluvial aquifer discharges ground water to the river along most of the site extent. The conceptual site model is presented in Section 5.0 of the SOWP (DOE 1999).

2.2 Ground Water Contaminants

After collection of site characterization data, COCs in ground water are compared with maximum concentration limits (MCLs) or background levels. The discussion here focuses on monitoring data collected during 2000. Ground water beneath the Old Rifle site was contaminated by former vanadium and uranium ore-processing operations that were ongoing from 1924 through 1958. Site-specific field investigations reveal the alluvial ground water is the only aquifer affected by the former milling operations. COCs in the alluvial aquifer are identified as arsenic, selenium, uranium, and vanadium.

Uranium is the most prevalent site-related contaminant occurring in the alluvial ground water. Concentrations up to 0.17 milligrams per liter (mg/L) present beneath the site exceed the Uranium Mill Tailings Remedial Action (UMTRA) MCL of 0.044 mg/L, but steadily decrease to background levels near the downgradient edge of the site. Similarly, selenium concentrations exceeding the 0.01 mg/L UMTRA MCL are present up to 0.06 mg/L near the center of the former tailings pile footprint and also decrease to background levels near the downgradient edge of the site. No ground water standards have been established for vanadium. However, concentrations up to 0.87 mg/L are present near the former tailings pile footprint which exceed the 0.33 mg/L human health risk-based concentration for a residential setting (EPA 2000). Arsenic concentrations in ground water are less than the UMTRA MCL of 0.05 mg/L, but exceed maximum acceptable levels for human health risk at a single location near the center of the former tailings pile footprint.

Because uranium and selenium are elevated above MCLs, a "no remediation" decision is not appropriate for these constituents. As outlined in Table 1, site data were evaluated to determine if supplemental standards could be applied or if current contaminant concentrations qualify for ACLs. The determination was made that supplemental standards were not applicable based on limited use or excessive environmental harm; current contaminant concentrations are unacceptable for ACLs without restricted use. Therefore, the applicability of natural flushing was evaluated.

2.3 Compliance Strategy Rationale

Site data were evaluated to see if natural flushing could achieve compliance with MCLs, background levels, or ACLs within 100 years. Results of ground water contaminant transport modeling are presented in Section 5.0 and Appendix D of the SOWP (DOE 1999). Predicted concentrations for selenium, uranium, and vanadium after 100 years of natural flushing are summarized here. Concentrations of arsenic are already below the UMTRA MCL and concentrations are only elevated above background at a single location. Because compliance is already met, this constituent was not modeled.

2.3.1 Ground Water Modeling Predictions

Computer ground water flow and contaminant transport modeling was done to assist in forecasting whether natural flushing of the major COCs (uranium, selenium, and vanadium) is a viable remediation alternative. Modeling was done using the MODFLOW code for ground water flow and the MT3D code for contaminant transport. These codes are described and referenced in the SOWP (DOE 1999) and have been verified, benchmarked, and approved for use by most government and regulatory agencies. The results of this modeling are summarized below. Comparative modeling was done using the probabilistic code GANDT, developed by Sandia National Laboratories, and produced similar results.

Uranium is predicted to decrease to levels below the UMTRA standard after a period of just 10 years. However, it should be noted that a background concentration of 0.038 mg/L uranium was used for purposes of ground water modeling. This is the average calculated background uranium concentration. Levels of uranium in excess of 0.06 mg/L have been observed in one background well. Therefore, the compliance standard for uranium in site ground water may be either background or the UMTRA MCL. The monitoring strategy is designed to account for variations in background uranium that may exceed the UMTRA standard.

Maximum selenium concentrations after 50 years are predicted to be at the Safe Drinking Water Act (SDWA) standard of 0.05 mg/L in the most contaminated portion of the plume. Background wells had concentrations of selenium up to nearly 3 times the UMTRA standard based on results from the most recent sampling round. However, these concentrations have been determined to be protective of human health and the environment (DOE 1999).

No drinking water standard exists for vanadium; plume concentrations currently exceed the risk-based concentration for human health as well as the phytotoxicity value for plants (0.33 mg/L and 0.2 mg/L, respectively; U.S. Environmental Protection Agency (EPA) 2000 and Efroymson, et al. 1997). However, concentrations at the point of exposure (POE), the Colorado River, are below both the human health risk-based concentration and EPA's Ecotox Threshold for aquatic life of 0.019 mg/L (EPA 1996) and are not expected to increase. Contaminated ground water discharging to the Colorado River is diluted by a factor of more than 30,000. Unrealistically high contaminant concentrations would need to be present at the site to have any impact on river water quality. Therefore, there are no unacceptable risks associated with currently complete exposure pathways.

2.3.2 Alternate Concentration Limits

Because selenium may exceed the UMTRA standard after 100 years of natural flushing due to natural background concentrations and because vanadium exceeds background and has no drinking water standard, ACLs are required for these contaminants. An ACL application is found in Attachment 1. The SDWA MCL of 0.05 mg/L is proposed as the ACL for selenium. This value is below the risk-based value of 0.18 mg/L for protection of human health (EPA 2000) and is also below all ecological benchmarks. Therefore, the proposed ACL is protective of human health and the environment. Contaminant transport modeling indicates that selenium in the most contaminated portion of the plume will be reduced to levels at or below 0.05 mg/L within the 100-year natural flushing time frame and will thus achieve regulatory compliance.

A concentration of 0.33 mg/L is proposed as the ACL for vanadium at the point of exposure (POE), which is the Colorado River for the duration of institutional controls. This concentration is the human-health risk based value for residential exposure. The action level proposed for the point of compliance (POC; any on-site well) is 1.0 mg/L. If the action level is exceeded, this could trigger some form of corrective action. Because of the large amount of dilution as ground water discharges to the Colorado River, the on site action level should be protective of all receptors at the POE. Concentrations are not predicted to increase at the POE. Before the site itself is released for unrestricted use, the ACL for vanadium will be attained at all on-site wells;

institutional controls will be maintained until the ACL is met. Ground water modeling indicates that the proposed ACL of 0.33 mg/L should be met on site in slightly over 100 years. Unrestricted use of ground water could occur after that time and would be protective of human health and the environment.

2.4 Human Health and Environmental Risks

2.4.1 Institutional Controls

After demonstrating that 100 years of natural flushing can achieve remediation goals, it is necessary to determine if natural flushing is protective of human health and the environment during the 100-year flushing period. Part of this includes an evaluation of institutional controls.

To prevent use of potentially harmful contaminated ground water at the Old Rifle site during the 100-year natural flushing period, an institutional control in the form of a deed restriction is being placed on the site. This restriction may be extended beyond 100 years if vanadium has not yet attained its ACL. A copy of the deed restriction is included in Appendix B. The land is currently State-owned and will be transferred to the City of Rifle at some future date. A deed restriction will be initiated at the time the land is transferred, thus making the deed restriction legal and enforceable. The deed restriction will apply to the land within the boundaries of the Old Rifle site and will cover all areas in which contaminants in ground water are expected to exceed applicable standards. The restrictions will prohibit the installation of wells into the shallow alluvial aquifer for any purpose and will prohibit the use of ground water for ponds and fountains. The deed restriction is considered to be a reliable mechanism to prohibit ground water use for the 100-year natural flushing period.

An additional consideration at the Old Rifle site may be future modification of use and configuration of surface water features. Modeling predictions are based on ground water flow patterns resulting from recharge and discharge conditions currently existing. Any change in these conditions should be subject to approval by the State and DOE to ascertain that any modifications will not adversely impact the projected cleanup of contaminated ground water as determined in this document.

2.4.2 Summary of Site Risks

An evaluation of present-day conditions at the Old Rifle site indicates that no risks currently exist for human or ecological receptors. All exposure pathways are incomplete at this time; the only potential risks from site ground water are associated with future changes in ground water use or with changes in site vegetation. However, development of a compliance strategy for the site must account for potential risks that could exist until cleanup goals are met. Table 3 summarizes the contaminants that could not be eliminated through application of human health or ecological screening criteria during the risk assessment updates described in the SOWP (DOE 1999). However, these hypothetical risks are mitigated through the institutional controls established at the site.

Table 3. Summary of Current and Potential Future Risks

Contaminant	Current Risks		Future Risks		Comments
	Human	Ecological	Human	Ecological	
Arsenic	N	N	Y	Y	MCL not exceeded, but risks exceed maximum acceptable for humans; plant phytoxicity levels exceeded in ground water
Selenium	N	N	Y	N	Exceeds UMTRA MCL; no ecological benchmarks exceeded
Uranium	N	N	Y	N	Exceeds MCL in near term; no ecological benchmarks exceeded
Vanadium	N	N	Y	Y	Exceeds risk-based values for human health; plant phytoxicity levels exceeded in ground water

Additional information on potential risk to human health and the environment is provided in Section 3.0.

2.5 Compliance Strategy Selection

The final step in the decision framework is the selection of an appropriate compliance strategy to meet the EPA ground water protection standards. DOE has determined that natural flushing of the uppermost (surficial) aquifer, in conjunction with the establishment of ACLs and institutional controls, are the appropriate compliance strategies for the Old Rifle site. This approach will be protective of human health and the environment.

2.6 Ground Water and Surface Water Monitoring

2.6.1 Monitoring Strategy

The monitoring strategy for the alluvial aquifer is designed to determine progress in meeting compliance standards for site COCs. Standards for selenium and vanadium are their proposed ACLs of 0.05 mg/L and 0.33 mg/L, respectively. For uranium the cleanup goal is the UMTRA standard of 0.044 mg/L or background, whichever is higher. Monitoring will focus on these three contaminants. Arsenic, while exceeding human health and ecological risk benchmarks, has decreased to below the UMTRA standard of 0.05 mg/L and is at or below the detection limit for most on-site wells. Because of the limited extent of arsenic contamination and the fact that it meets UMTRA ground water standards, monitoring of arsenic at the Old Rifle site is not proposed. By the time the other contaminants have decreased to target goals, arsenic should be at background concentrations based on its limited extent and historic trends.

Monitor wells 305, 656, 655, 309, 310, 304, and 292 have been established as appropriate for monitoring the progress of natural flushing in the alluvial aquifer (Figure 3 and Table 4). Well 656 is located in the center of the plume on the east side of the ditch which flows through the site and well 655 is at the center of the plume on the west side of the ditch. The highest concentrations of selenium and vanadium were detected in these wells during the most recent sampling events. Elevated concentrations of uranium were also detected in samples from these wells. Wells 304, 309, and 310 are located on the farthest downgradient edge of the plume. Well 310 had the highest concentrations of uranium detected in samples collected in 1998, suggesting that the center of this plume has already migrated downgradient in this direction.

Therefore, the wells included in this monitoring network should be adequate for tracking the progress of natural flushing. Well 292 is an upgradient background well.

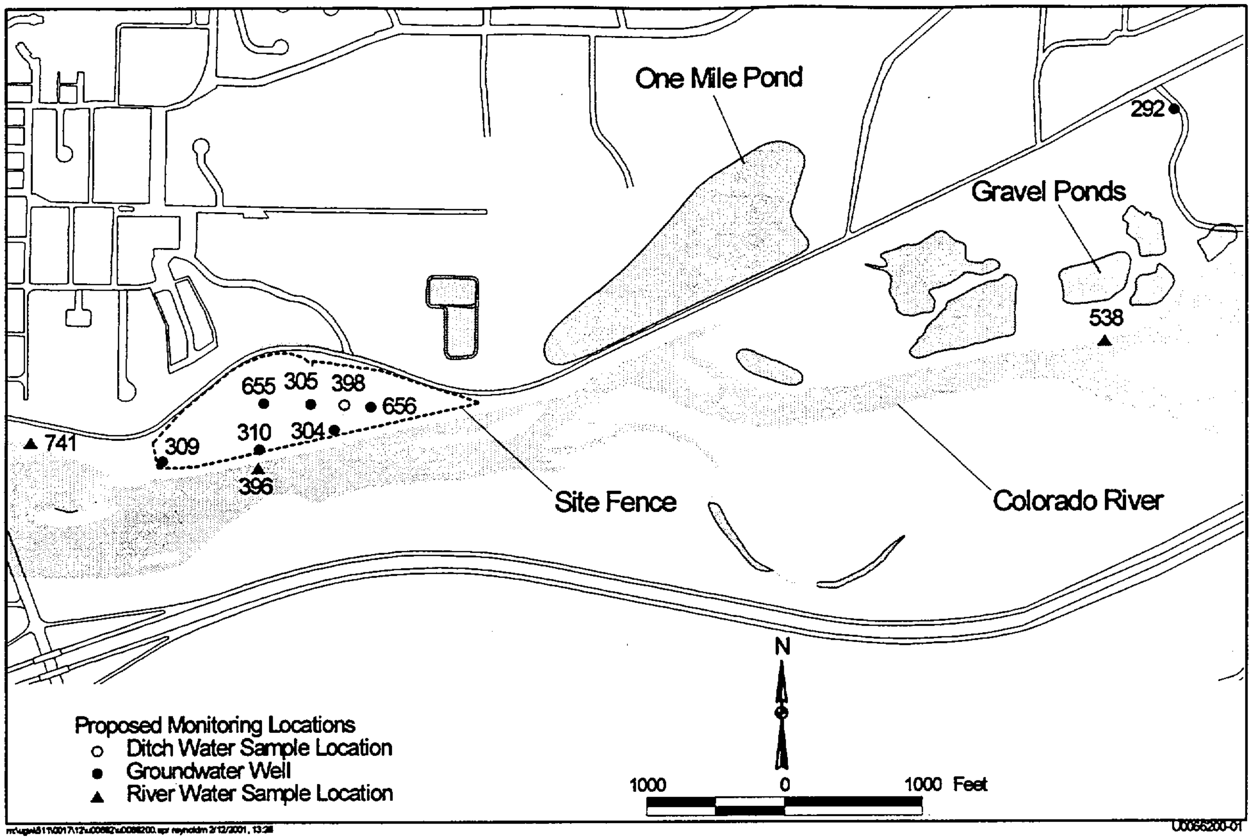

Figure 3. Proposed Monitoring Locations for the Old Rifle Site

Table 4. Summary of Monitoring Requirements

Location	Monitoring Purpose	Analytes	Frequency[a]
RFO–305, –655	Center of plume west side of ditch	Se, U, V	Twice yearly for 5 years; at least every 5 years thereafter until 2030
RFO–656	Center of plume east side of ditch	Se, U, V	Twice yearly for 5 years; at least every 5 years thereafter until 2030
RFO–304, –309, –310	Most downgradient location; leading edge of plume	Se, U, V	Twice yearly for 5 years; at least every 5 years thereafter until 2030
RFO–292	Background ground water quality; upgradient monitor well	Se, U, V	Twice yearly for 5 years; at least every 5 years thereafter until 2030
RFO–398	Monitor background U recharging aquifer; on-site ditch	U	Twice yearly for 5 years; at least every 5 years thereafter until 2030
RFO–538, –396, –741	Upgradient, adjacent to site, and downgradient locations on Colorado River; monitor effect of site on river	Se, U, V	Twice yearly for 5 years; at least every 5 years thereafter until 2030

[a]Annual monitoring will be initiated when contaminant decreases at or below respective compliance standard. Monitoring will be discontinued after demonstrating the contaminant has remained below compliance levels for 3 consecutive years.

All of the on-site wells are considered to be POC wells for purposes of monitoring. The POE is considered to be the Colorado River adjacent to the site. Surface water locations RFO–538, –396, and –741 are located upgradient, adjacent to the site, and downgradient, respectively. These locations will be used to monitor the effect of the site on the river.

Monitoring of wells 305, 655, and 656 will take place until contaminants have decreased to their respective compliance standards for 3 consecutive years. At that time, monitoring for that contaminant will be discontinued. This is consistent with the approach established for monitoring Resource Conservation and Recovery Act (RCRA) corrective actions. Samples will also be collected from the onsite ditch at location 398 to monitor background uranium concentrations recharging the aquifer. If onsite wells appear to have leveled off in uranium concentration, but still exceed the UMTRA standard, results of the ditch samples and background well 292 will be used to determine if onsite samples are statistically similar to background and have met the compliance standard. Surface water samples will be analyzed for the COCs until each COC has peaked in wells 309 and 310 at the downgradient edge of the site and then decreased to acceptable levels for 3 consecutive years. At that time, the COC can be dropped from surface water locations.

Contaminant concentrations in most samples collected from downgradient wells 304, 309, and 310 are below target cleanup goals with the exception of uranium. Ground water modeling results show that concentrations of selenium and vanadium are expected to increase slightly before steadily declining. However, concentrations of these constituents are not predicted to increase to levels considered unacceptable. Samples from these wells will be analyzed for selenium and vanadium for the first 5 years to ensure concentrations remain at acceptable levels. The need to continue monitoring for those constituents in the downgradient wells will be reassessed at that time.

Monitoring will take place twice yearly for the first 5 years—at high river stage and at low river stage. After that 5-year period, data will be evaluated to determine whether monitoring frequency should be adjusted. Monitoring will take place at least every 5 years until the year 2030. At that time the monitoring strategy will be reevaluated and adjusted as appropriate based on previous results. To accommodate the specification of observing concentrations of COCs at or below the compliance standards for 3 consecutive years before discontinuing monitoring for that constituent, an annual monitoring frequency will be imposed as necessary to make this determination. If uranium concentrations decrease as predicted by the modeling, this should occur within the initial 10-year time frame. In the case of selenium, the predicted period for reaching the compliance standards is 50 years. Monitoring requirements are summarized in Table 3. The site monitoring plan is found in Attachment 2 to this document.

Abandonment of all other monitor wells at the Old Rifle site no longer needed for compliance monitoring will be undertaken in the near future in accordance with applicable Colorado State regulations. This will be accomplished under the Long-Term Surveillance and Maintenance (LTSM) program.

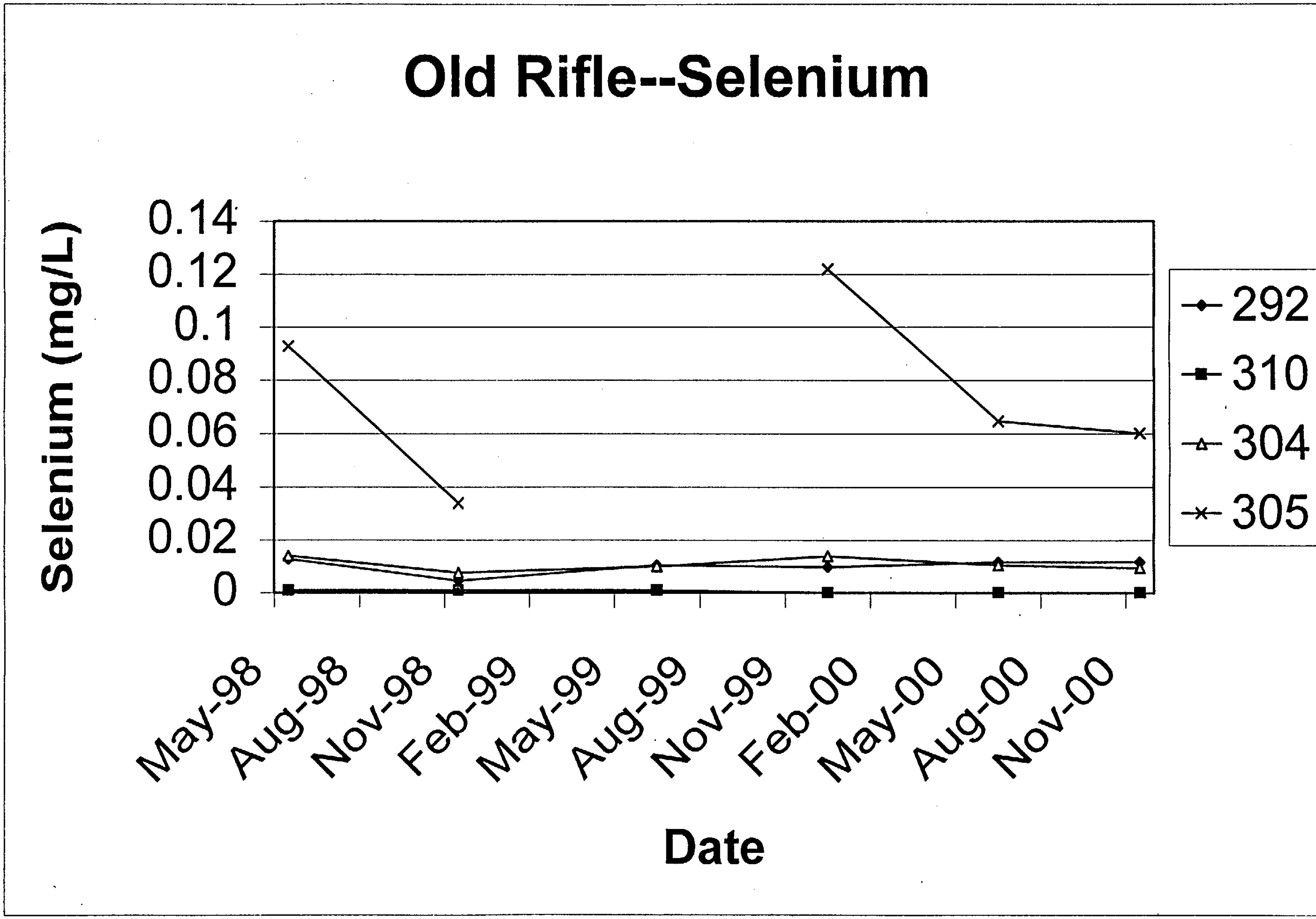

Figure 4. Time-Concentration Plot for Selenium for Old Rifle Wells 292, 304, 305, and 310

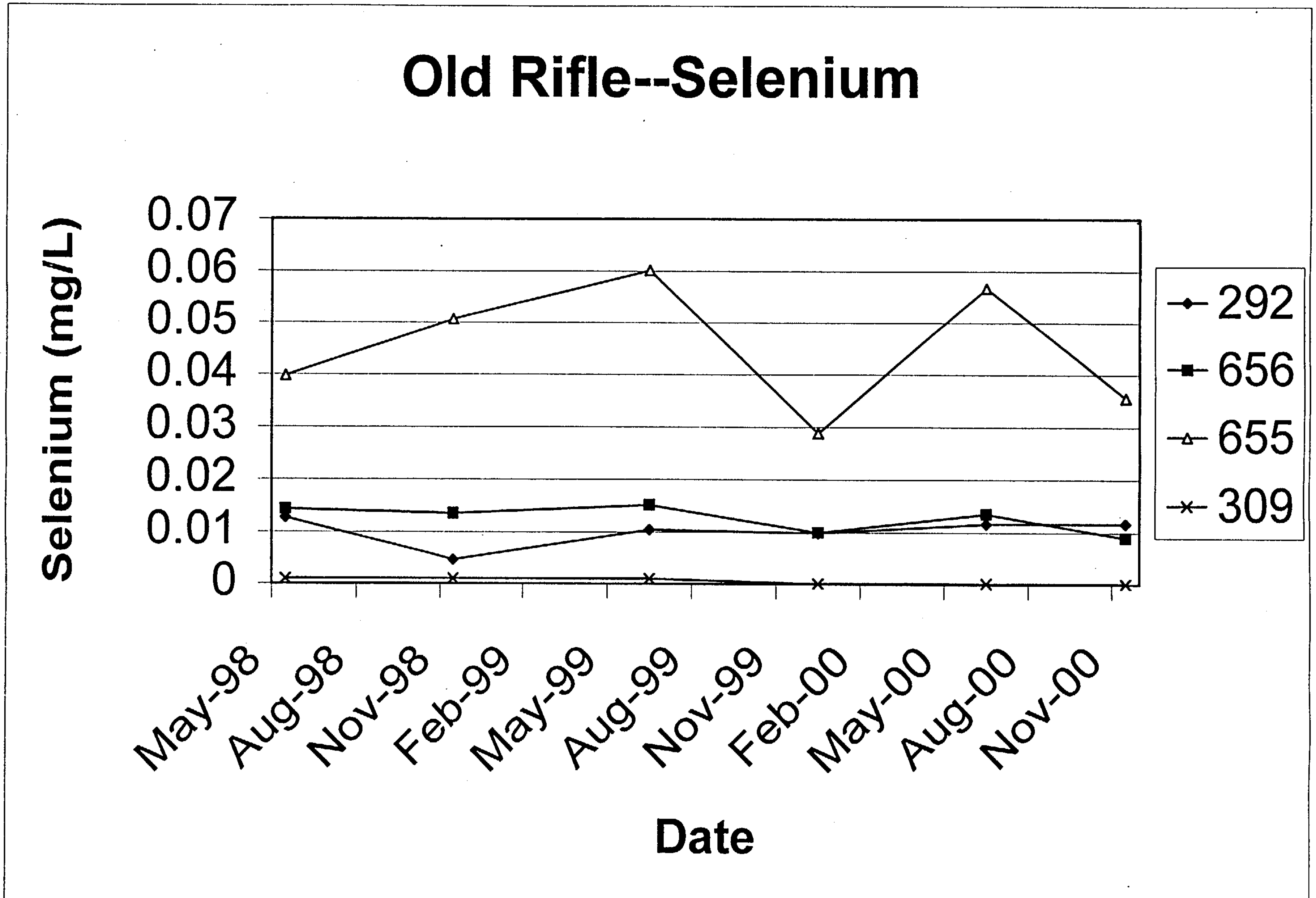

Figure 5. Time-Concentration Plot for Selenium for Old Rifle Wells 292, 309, 655, and 656

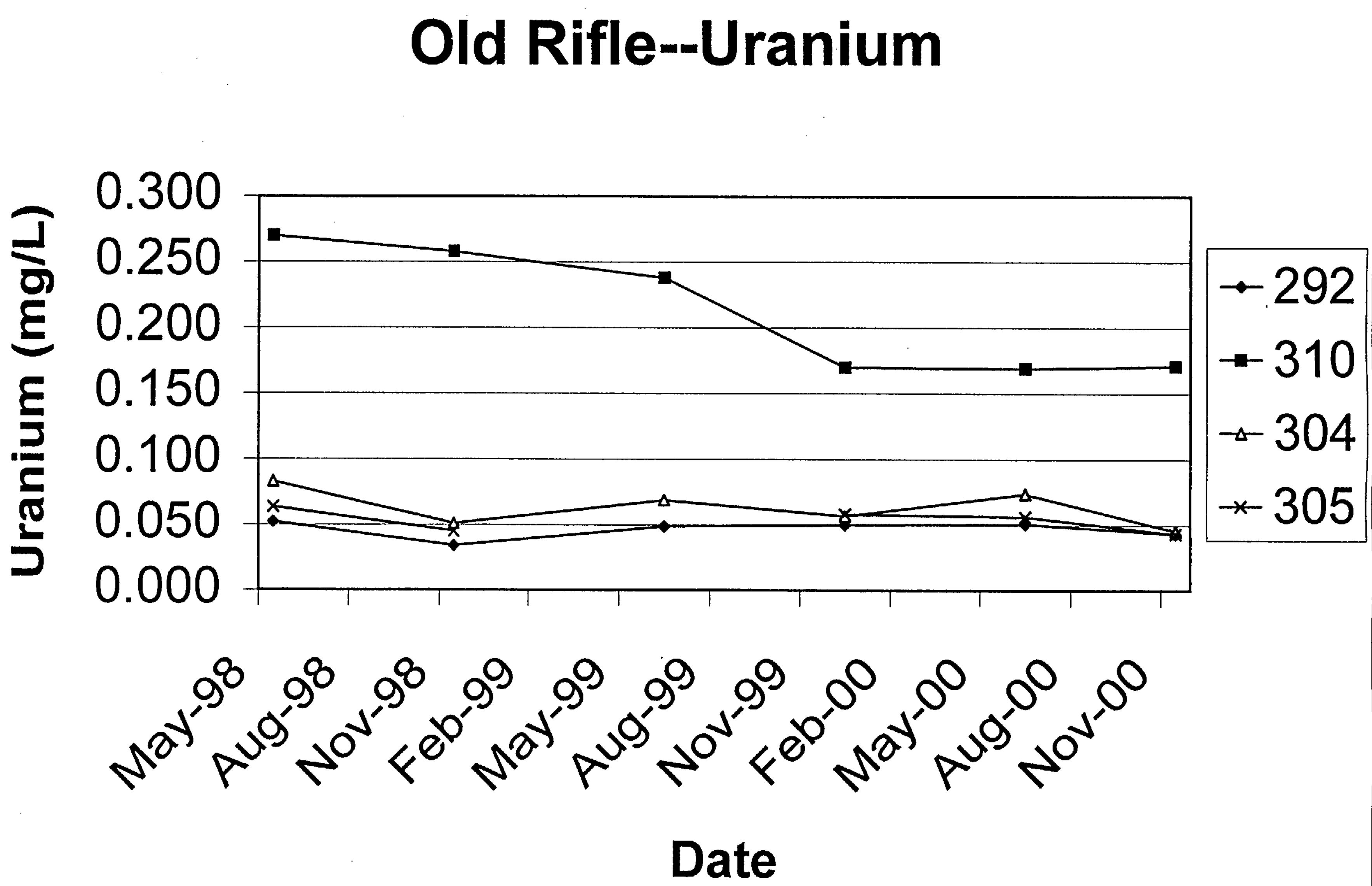

Figure 6. Time-Concentration Plot for Uranium for Old Rifle Wells 292, 304, 305, and 310

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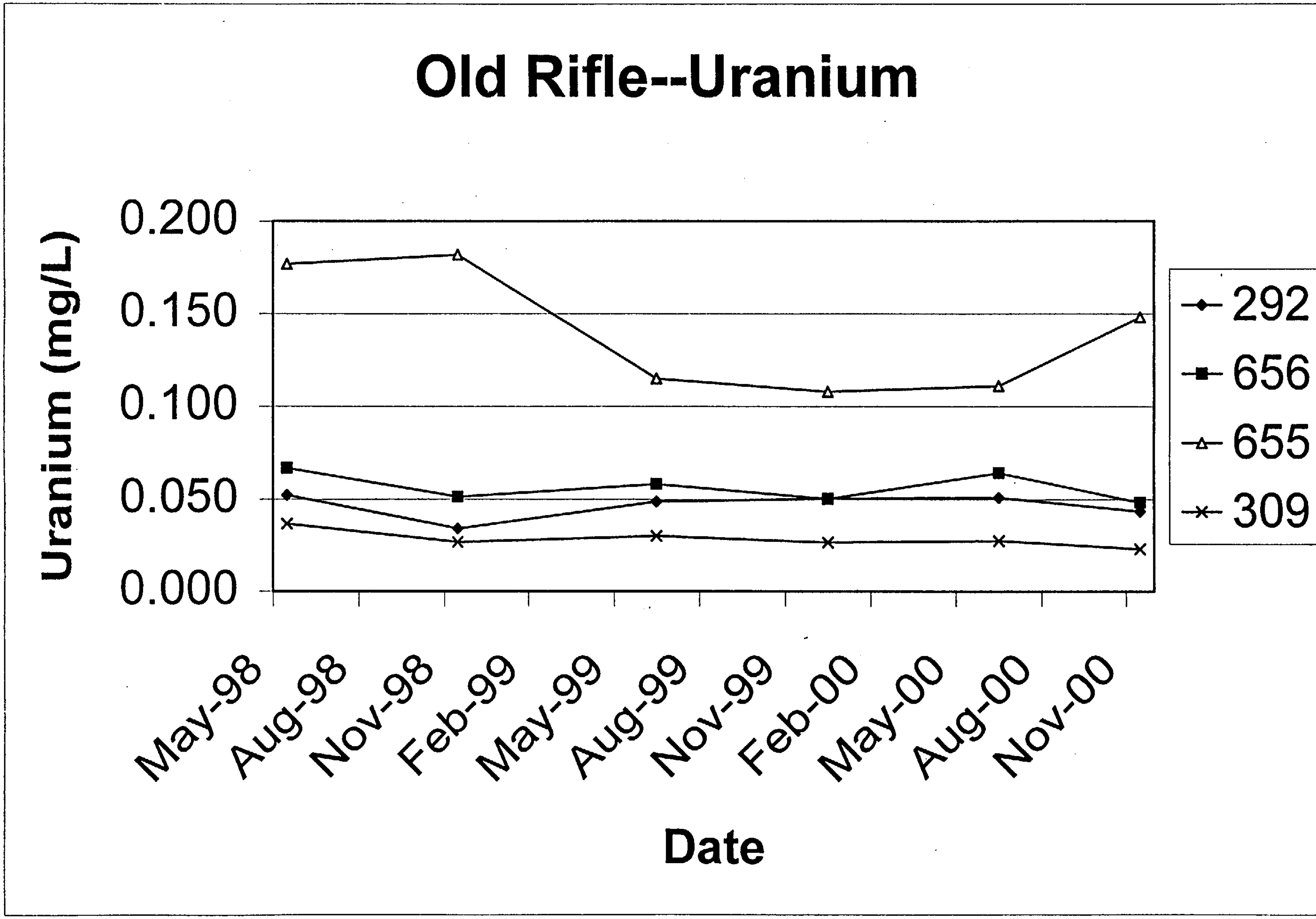

Figure 7. Time-Concentration Plot for Uranium for Old Rifle Wells 292, 309, 655, and 656

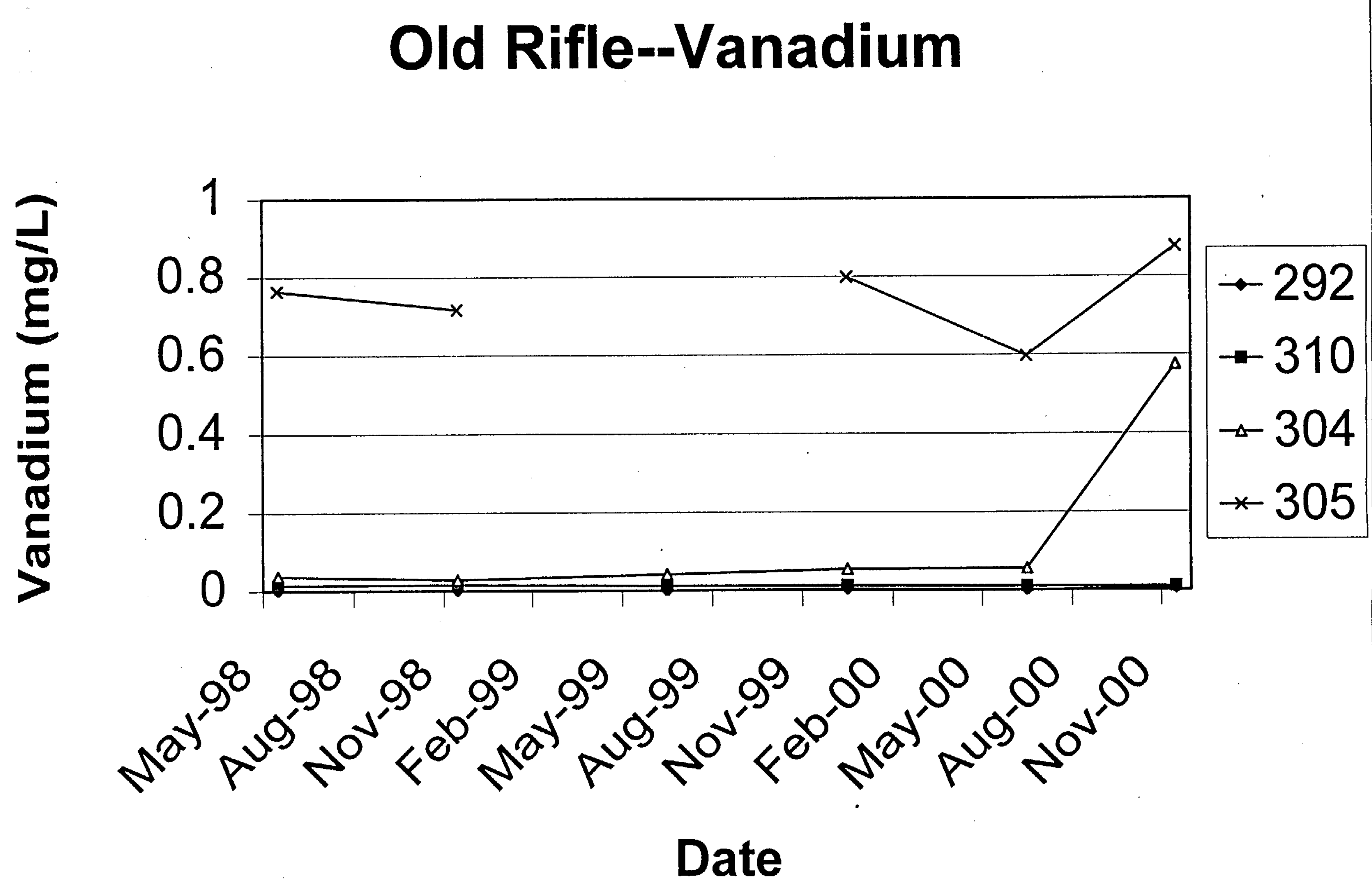

Figure 8. Time-Concentration Plot for Vanadium for Old Rifle Wells 292, 304, 305, and 310

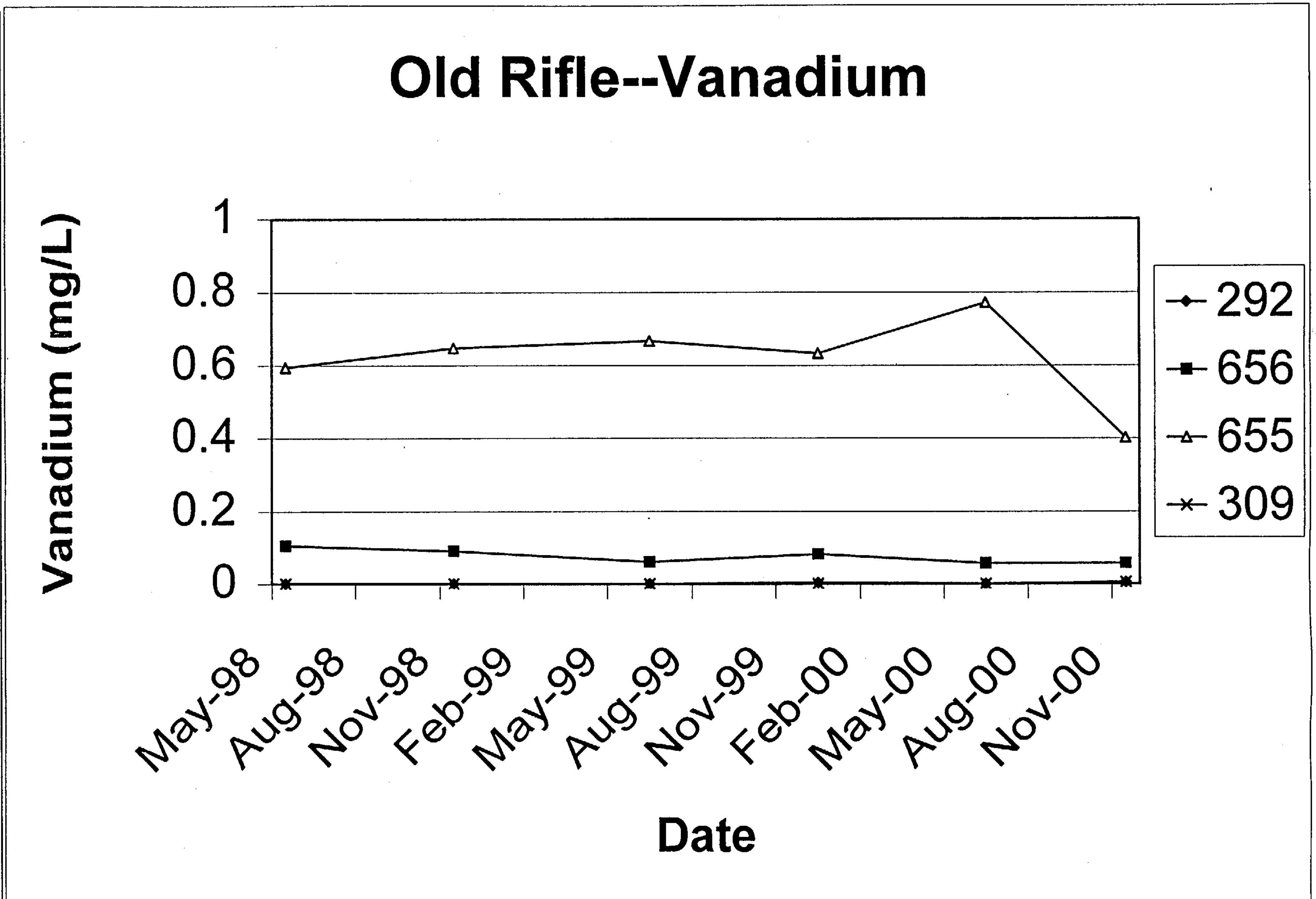

Figure 9. Time-Concentration Plot for Vanadium for Old Rifle Wells 292, 309, 655, and 656

2.6.2 Preliminary Monitoring Results

Six rounds of monitoring data are available at this time. Time-concentration plots for on-site and background monitoring wells are shown in Figures 4 through 9 for selenium, uranium, and vanadium. Well RFO–292 represents background. Appendix A contains similar plots for each plume well along with predicted concentrations as determined by ground water modeling conducted as part of the SOWP. (Well RFO–305 was inadvertently omitted during one round of sampling so only five rounds of data are available for this location.) With the exception of uranium for well RFO–310, which displays a nearly consistently decreasing trend, minor to large fluctuations in concentration occur. Part of this may be attributable to a seasonal effect, particularly for wells at the low end of the concentration range. Background well RFO–292 fluctuations are probably typical seasonal variations; wells with contaminant concentrations close to background also display similar patterns.

Figures 10, 11, and 12 indicate the estimated distribution of contaminants at the start of the monitoring period (May 1998) that were used in the ground water modeling. If the actual distribution did not closely match this, it would account for some of the discrepancy between modeled and observed concentrations and the seeming lack of well defined trends.

For a quantitative analysis of trends displayed by the data, the Mann-Kendall test statistic is recommended. See the site monitoring plan in Attachment 2 for a discussion of this statistic and preliminary results.

3.0 Environmental Considerations

To comply with National Environmental Policy Act (NEPA) requirements DOE prepared the PEIS, which was issued in October 1996 (DOE 1996b). The PEIS assesses the potential programmatic effects of conducting the ground water project, provides a method for determining site-specific ground water compliance strategies, and provides data and information that can be used to prepare site-specific environmental impact analyses more efficiently. In the proposed action (preferred alternative), ground water compliance strategies are tailored to each site to achieve conditions that are protective of human health and the environment. The selection framework for determining an appropriate compliance strategy at each site is presented in Section 2.1 of the PEIS and is discussed in Section 2.0 of this GCAP. Relevant areas of environmental concern are discussed below.

Environmental issues and resources potentially affected by the proposed action may include the following:

- Risk to human health and the environment.
- Ground water use.
- Surface water use.
- Land use.
- Exposure to potentially contaminated ground water.
- Environmental site restoration.

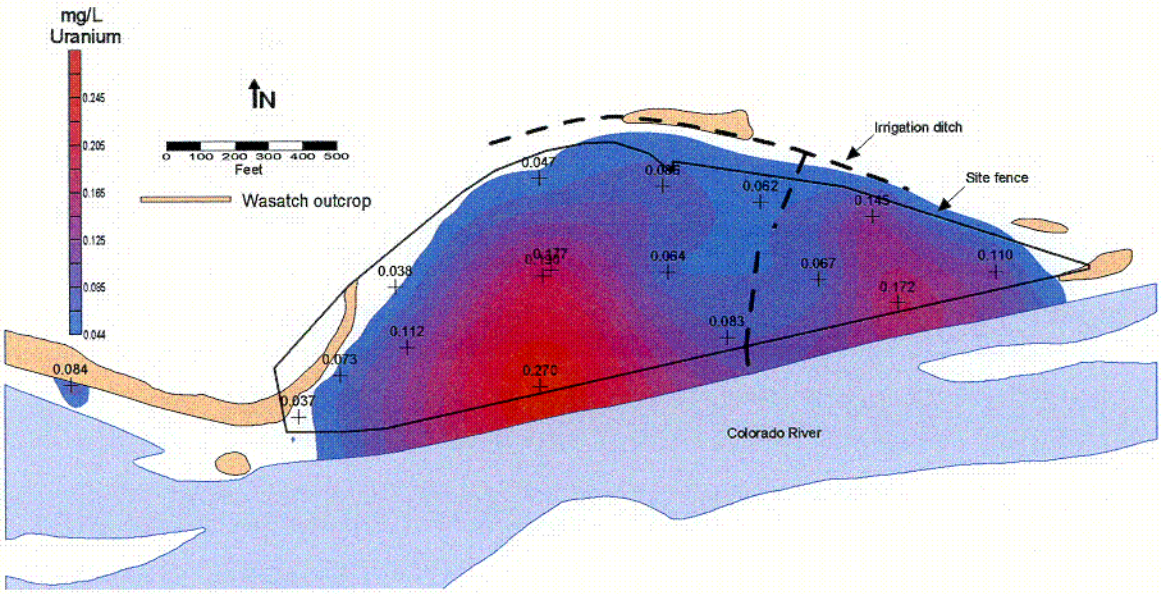

Figure 10. Uranium Distribution in Alluvial Aquifer—Old Rifle, May 1998

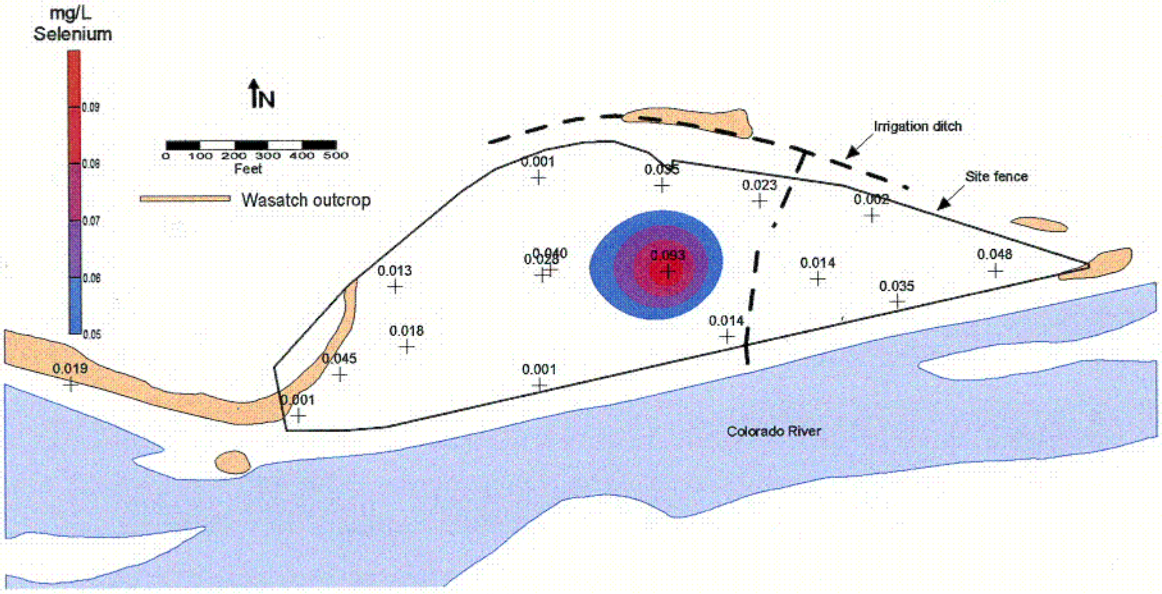

Figure 11. Selenium Distribution in Alluvial Aquifer—Old Rifle, May 1998

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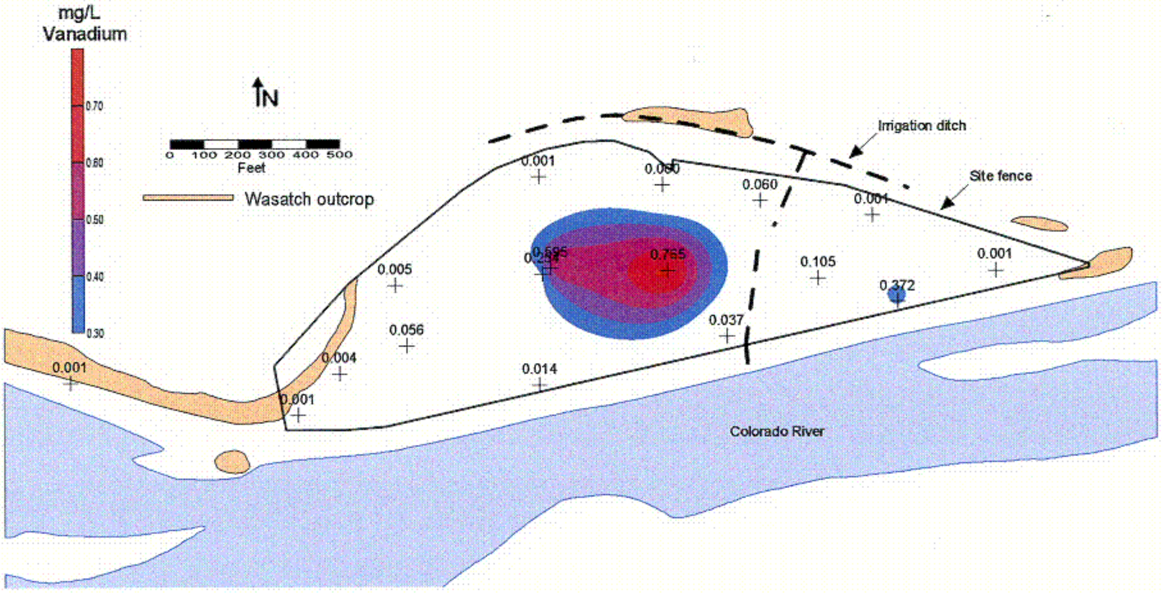


Figure 12. Vanadium Distribution in Alluvial Aquifer—Old Rifle, May 1998

Environmental impacts from the proposed action on these issues and resources have been assessed in several referenced documents (DOE 1990, 1992, 1996a, 1996b, and 1999). Results are summarized below.

The proposed compliance strategy will not involve any surface-disturbing activities. The only field activities required following implementation of the GCAP will be continued monitoring of the wells shown in Figure 2, along with limited well-abandonment activities. Therefore, potential adverse effects typically associated with surface-disturbing activities will not occur.

The proposed action will produce no adverse effects to air quality, surface water quality, cultural resources, sensitive plant or wildlife species (including threatened or endangered species), or designated or sensitive natural resource areas (e.g., wetlands, wilderness, parks, and scenic rivers). Although contaminants will flush to the Colorado River, calculations in Section 5.2.2 of the SOWP indicate that the dilution factor of the Colorado River is so great (3.0×10^{-5}) that the COCs will be essentially undetectable. General comments received in the PEIS suggest that the public may consider monitoring wells a scenic impact. The majority of the wells at the Old Rifle site are hidden by distance and visual barriers, but any potential impacts could be resolved with flush mounts of the well at the surface.

On the basis of data in the SOWP, only four constituents present in the alluvial aquifer—arsenic, selenium, uranium, and vanadium—were determined to pose a potential risk to human health. The data also indicated that contamination was restricted to the shallow aquifer; the deeper Wasatch Formation has not been contaminated as a result of residual radioactive material. Therefore, risk assessment in the final SOWP (Section 6.0) focuses on the uppermost aquifer.

The SOWP determined that ingestion of alluvial ground water as a regular source of drinking water would result in the only unacceptable risks to human health. Currently this pathway is incomplete; hence, no current human health risk exists. Under the proposed action, institutional

C02

controls would prohibit ground water use for any purpose. It is assumed that institutional controls will exist at the site for the 100-year natural flushing period due to the nature of the deed restrictions (see Appendix B); this timeframe could be extended in the vanadium ACL is not met during this period. Because of the institutional control restrictions, no human health risks will exist for the duration of those controls. Arsenic concentrations are currently well below the established UMTRA standard and will be expected to decrease even further through 100 years of natural flushing. Uranium concentrations are expected to decrease to the UMTRA standard or background levels within 10 years of natural flushing. Selenium will flush through the aquifer more slowly, but concentrations are anticipated to meet the proposed ACL within 50 years. Vanadium will probably meet its proposed ACL within 100 years or shortly thereafter.

Site ground water currently presents no ecological risks because no exposure pathways are complete. If ground water were used for irrigation, the water could be harmful to terrestrial plants because of current concentrations of arsenic and vanadium. Proposed institutional controls would prohibit use of alluvial ground water for irrigation or in ponds or fountains for 100 years (or more if required); no ecological risks from alluvial ground water will exist during that time.

Existing documents, including the SOWP and the PEIS (Sections 4.4.2 and 4.4.3), describe the human health and ecological risks associated with implementing the proposed compliance strategy. Implementation of institutional controls will be protective of human health and the environment. Both the SOWP and the Environmental Impact Statement for surface remediation identify background ground water quality as generally poor and not projected for use as a public water supply system. The major portion of the contaminant plume is located on site; the site is fenced and is relatively inaccessible because of topography and physical features. The potential for inadvertent intrusion and access to ground water is remote. Existing documents and public participation efforts comply with DOE's NEPA regulations, orders, and guidance, and therefore an environmental assessment is not necessary. The conditions for evaluating a risk scenario and selecting a compliance strategy at the Old Rifle site closely parallel the conditions at the Canonsburg, Pennsylvania, UMTRA site, for which an environmental assessment was not required.

To accommodate the NEPA obligation to make relevant environmental information available to public officials and citizens before decisions are made and before actions are implemented, DOE has distributed relevant environmental documents (including this document) to the stakeholders.

4.0 References

Efroymson, R.A., M.E. Will, G.W. Suter II, A.C. Wooten, 1997. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision*, ES/ER/TM–85/R3, prepared for the U.S. Department of Energy, East Tennessee Technology Park, Tennessee, November.

U.S. Department of Energy, 1990. *Final Environmental Impact Statement for Remedial Actions at the Former Union Carbide Corporation Uranium Mill Sites, Rifle, Garfield County, Colorado*, DOE/EIS–0132–F, prepared by the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico, March.

U.S. Department of Energy, 1992. *Final Remedial Action Plan and Site Design for Stabilization of the Inactive Uranium Mill Tailings Sits at Rifle, Colorado*, prepared by the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico, February.

———, 1996a. *Baseline Risk Assessment of Ground Water Contamination at the Uranium Mill Tailings Sites Near Rifle, Colorado,* DOE/AL/62350–179, Rev. 2, February.

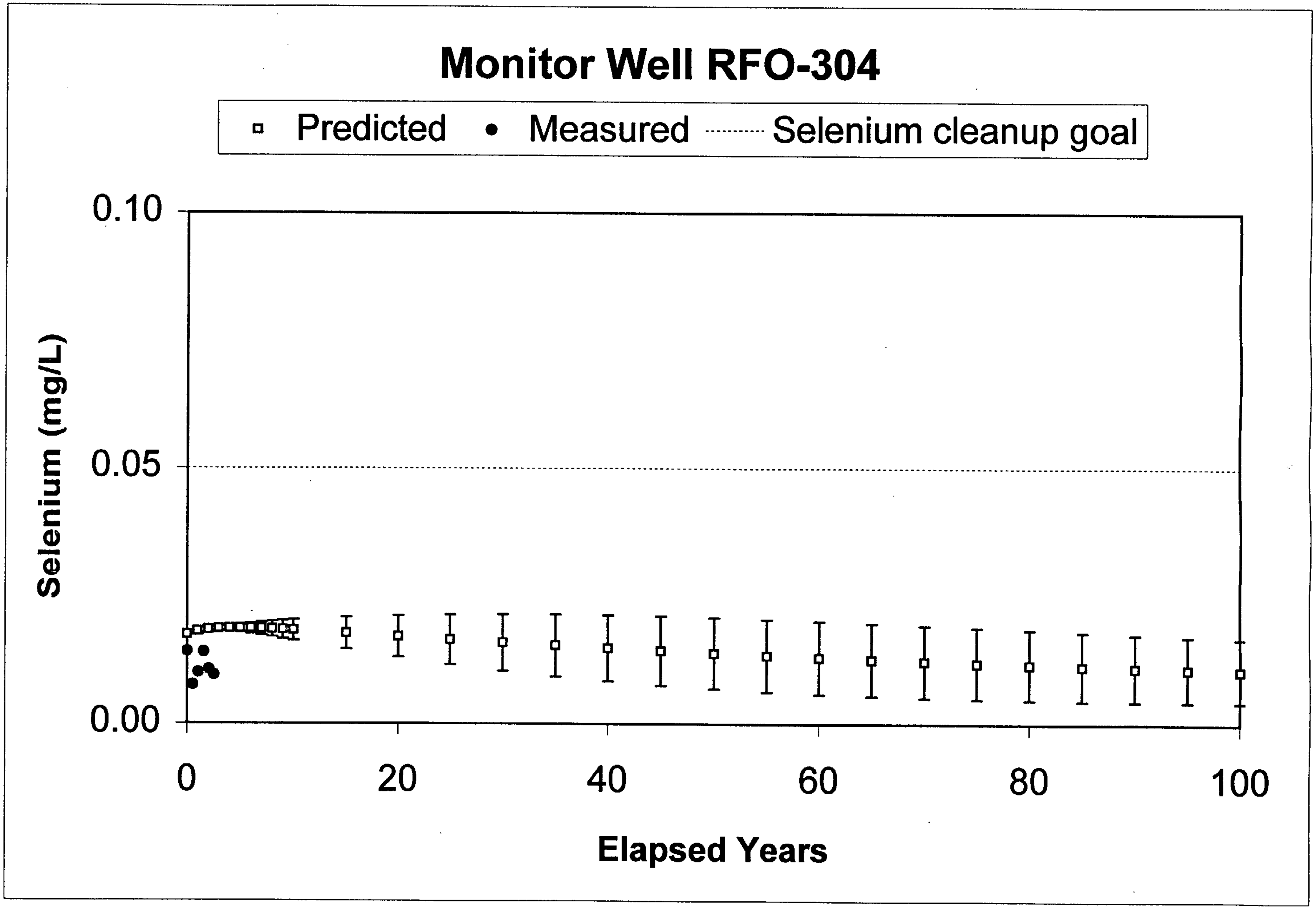
———, 1996b. *Final Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project,* DOE/EIS–0198, prepared by the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico, October.

———, 1999. *Final Site Observational Work Plan for the UMTRA Project Old Rifle Site,* GJO–99–88–TAR, Rev. 1, prepared by the U.S. Department of Energy, UMTRA Project Office, Grand Junction Office, Grand Junction, Colorado, April.

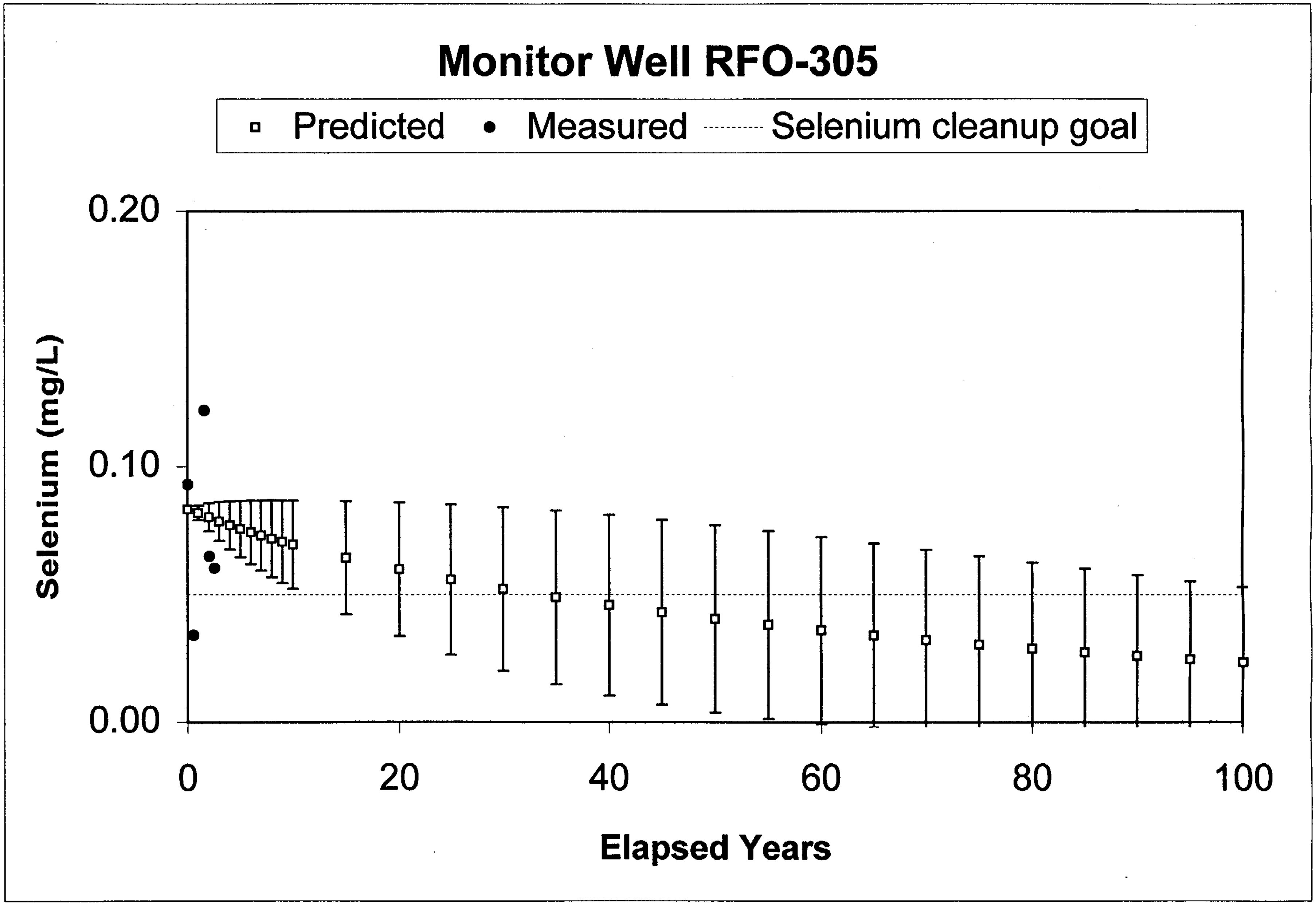
———, 2000. "Updated Risk-Based Concentration Table," from Jennifer Hubbard, available on the EPA Region III Internet Website at http://www.epa.gov/reg3hwmd/risk/riskmenu.htm.

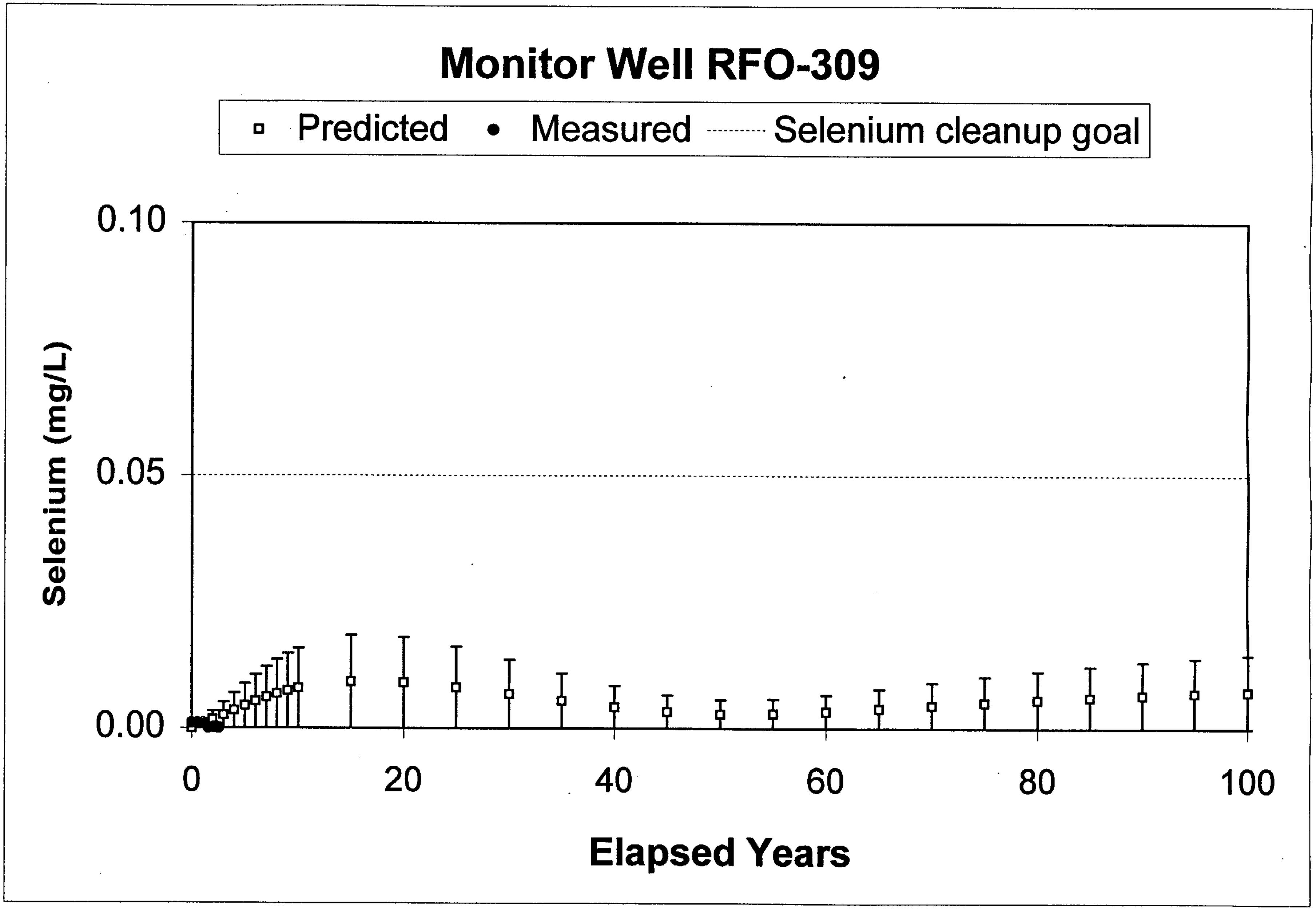
Appendix A

Predicted and Observed Time-Concentration Plots for the Old Rifle Site

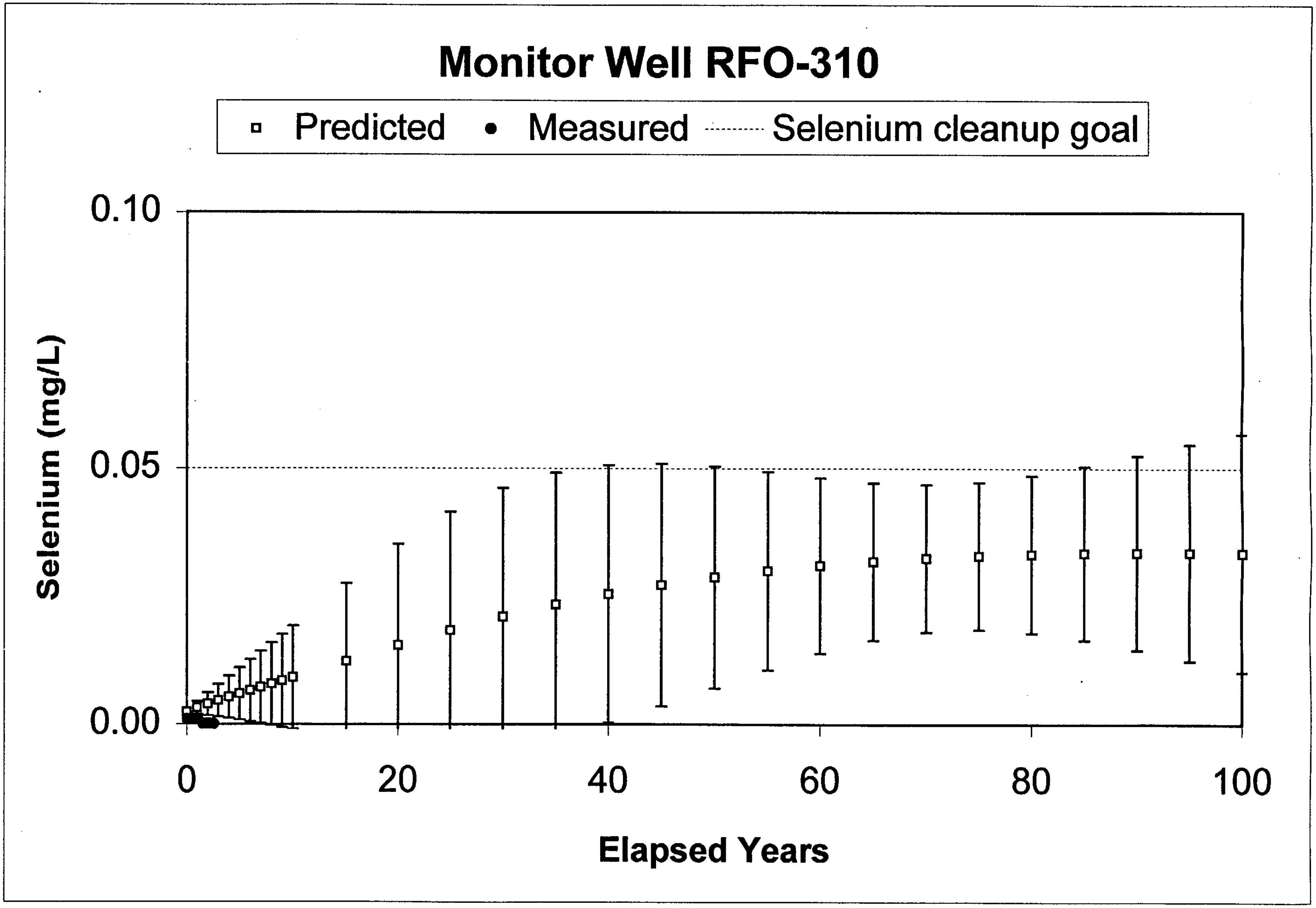


Monitor Well RFO-304
Predicted
Measured
Selenium cleanup goal
0.10
0.05
0.00
Selenium (mg/L)
0
20
40
60
80
100
Elapsed Years

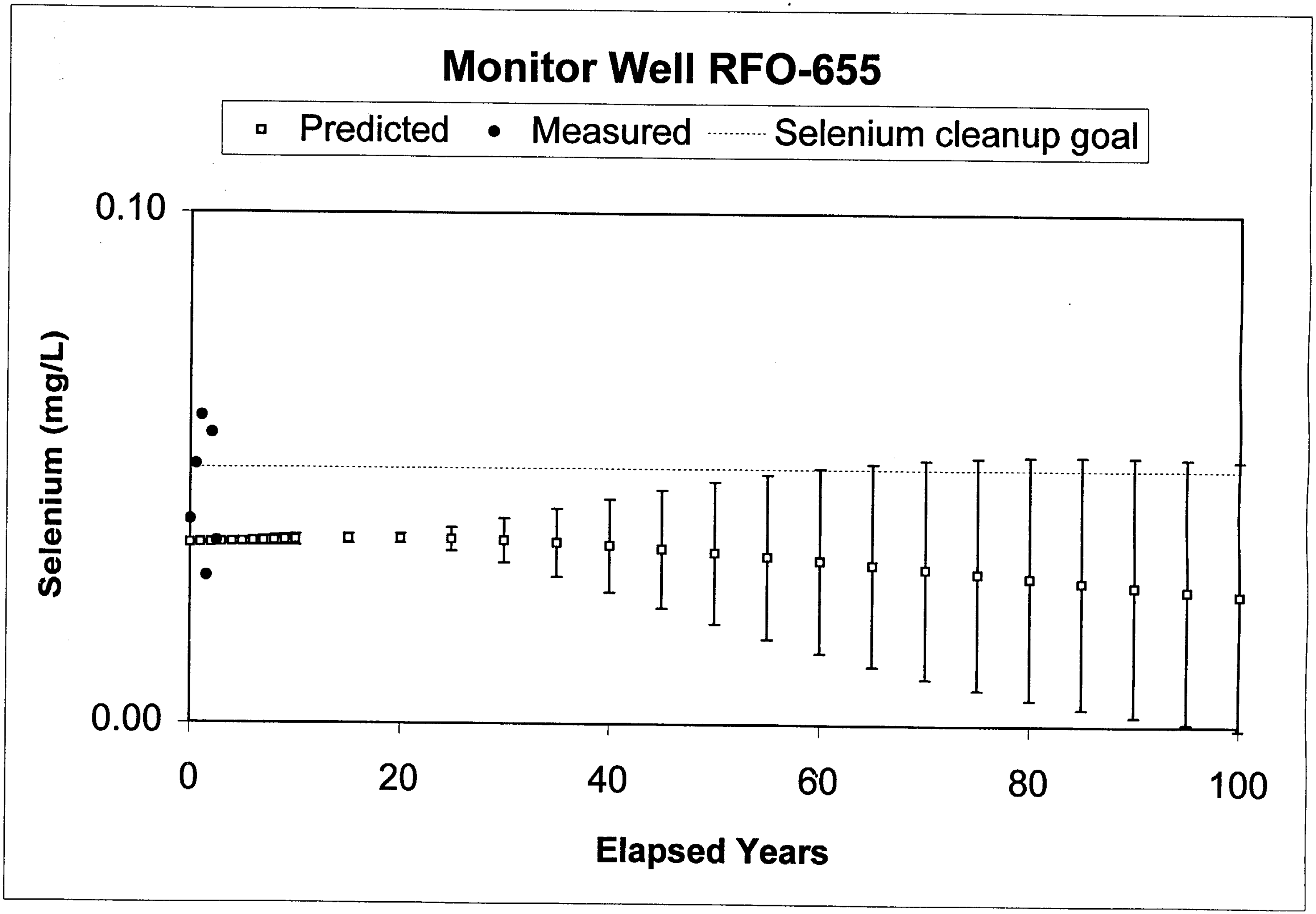

Monitor Well RFO-305
Predicted
Measured
Selenium cleanup goal
0.20
0.10
0.00
Selenium (mg/L)
0
20
40
60
80
100
Elapsed Years



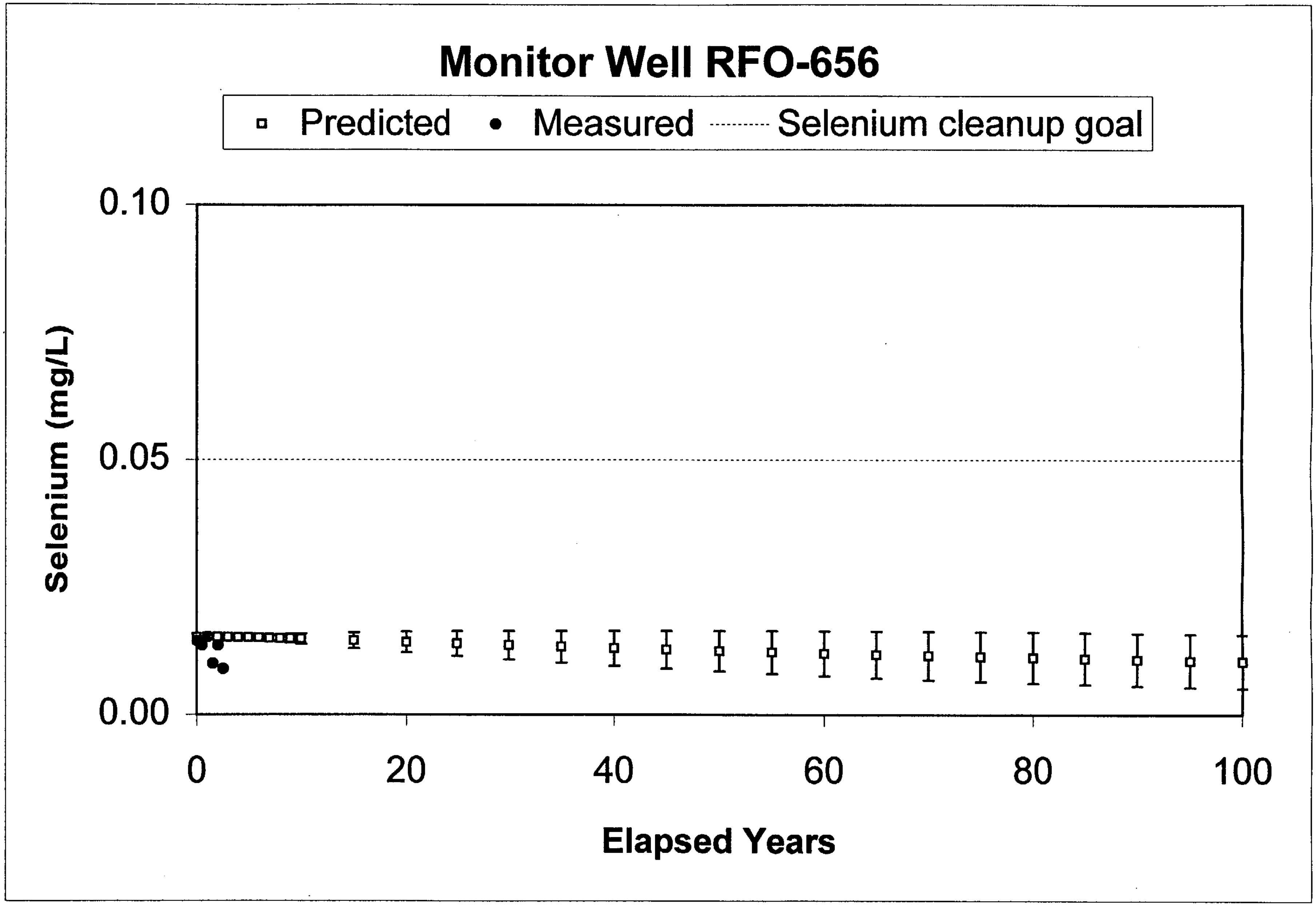
Monitor Well RFO-309
Predicted
Measured
Selenium cleanup goal
0.10
0.05
0.00
Selenium (mg/L)
0
20
40
60
80
100
Elapsed Years



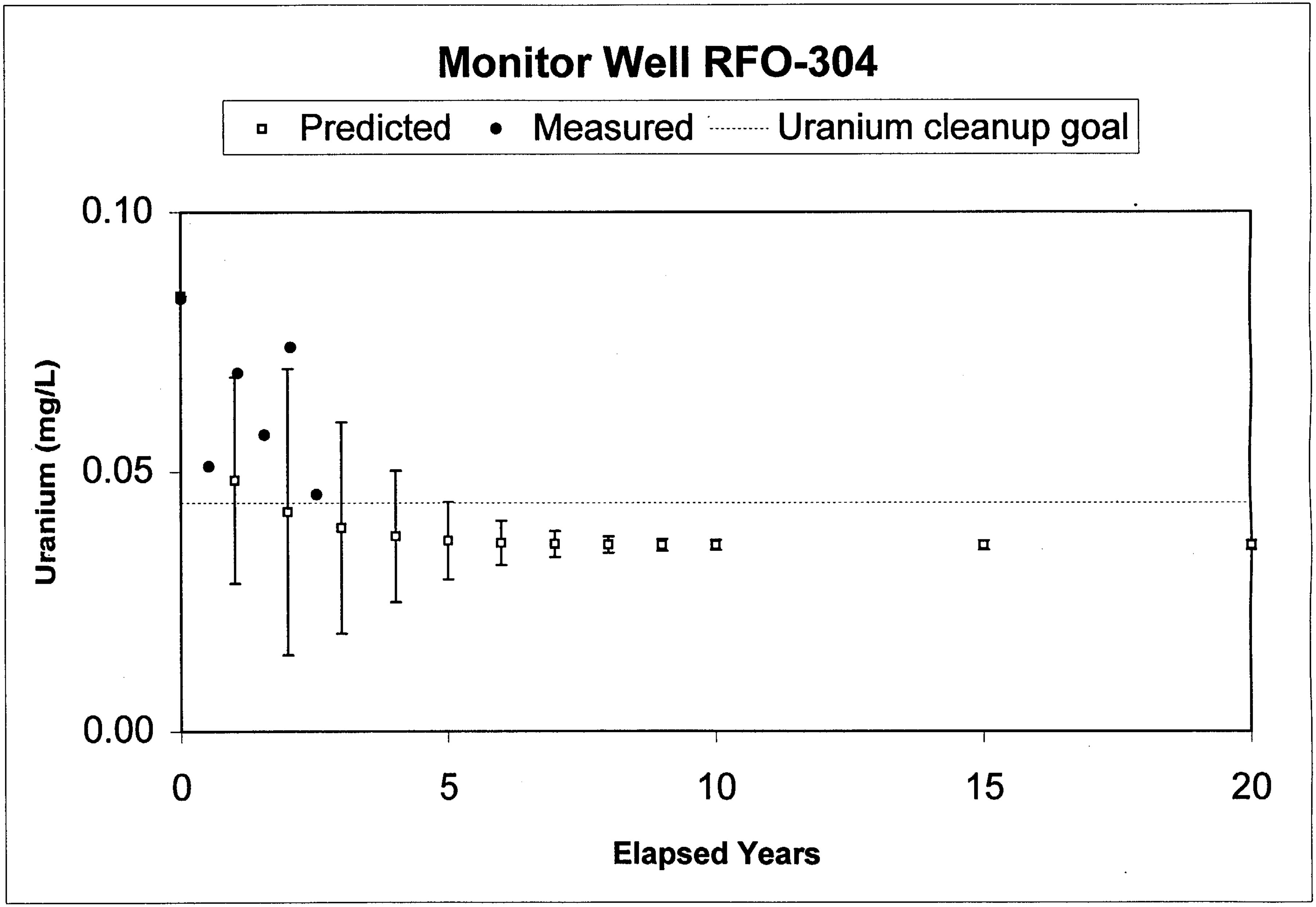
Monitor Well RFO-310
Predicted
Measured
Selenium cleanup goal
0.10
0.05
0.00
Selenium (mg/L)
0
20
40
60
80
100
Elapsed Years



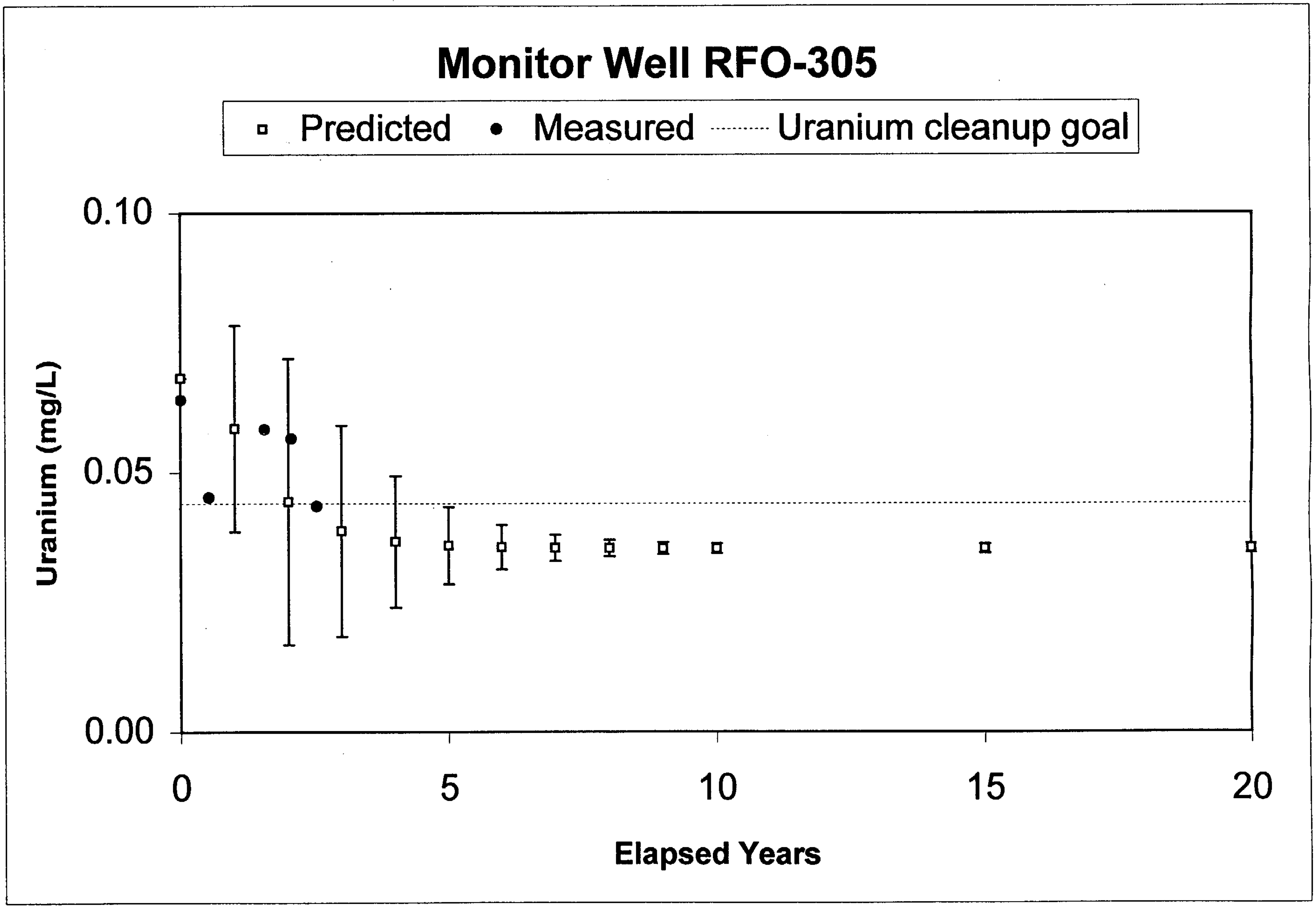
Monitor Well RFO-655
Predicted
Measured
Selenium cleanup goal
Selenium (mg/L)
0.10
0.00
0
20
40
60
80
100
Elapsed Years

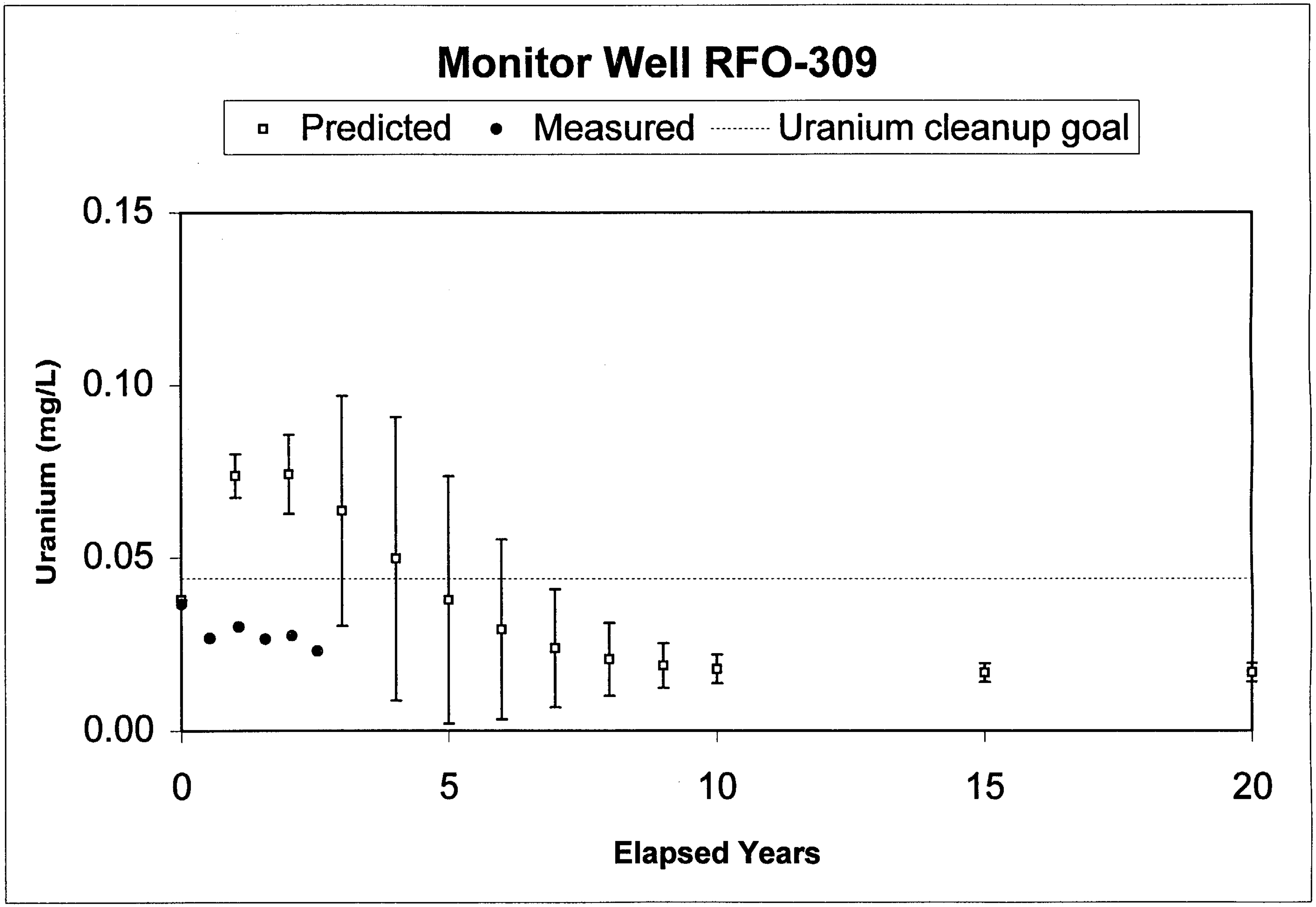


Monitor Well RFO-656
Predicted
Measured
Selenium cleanup goal
0.10
0.05
0.00
Selenium (mg/L)
0
20
40
60
80
100
Elapsed Years

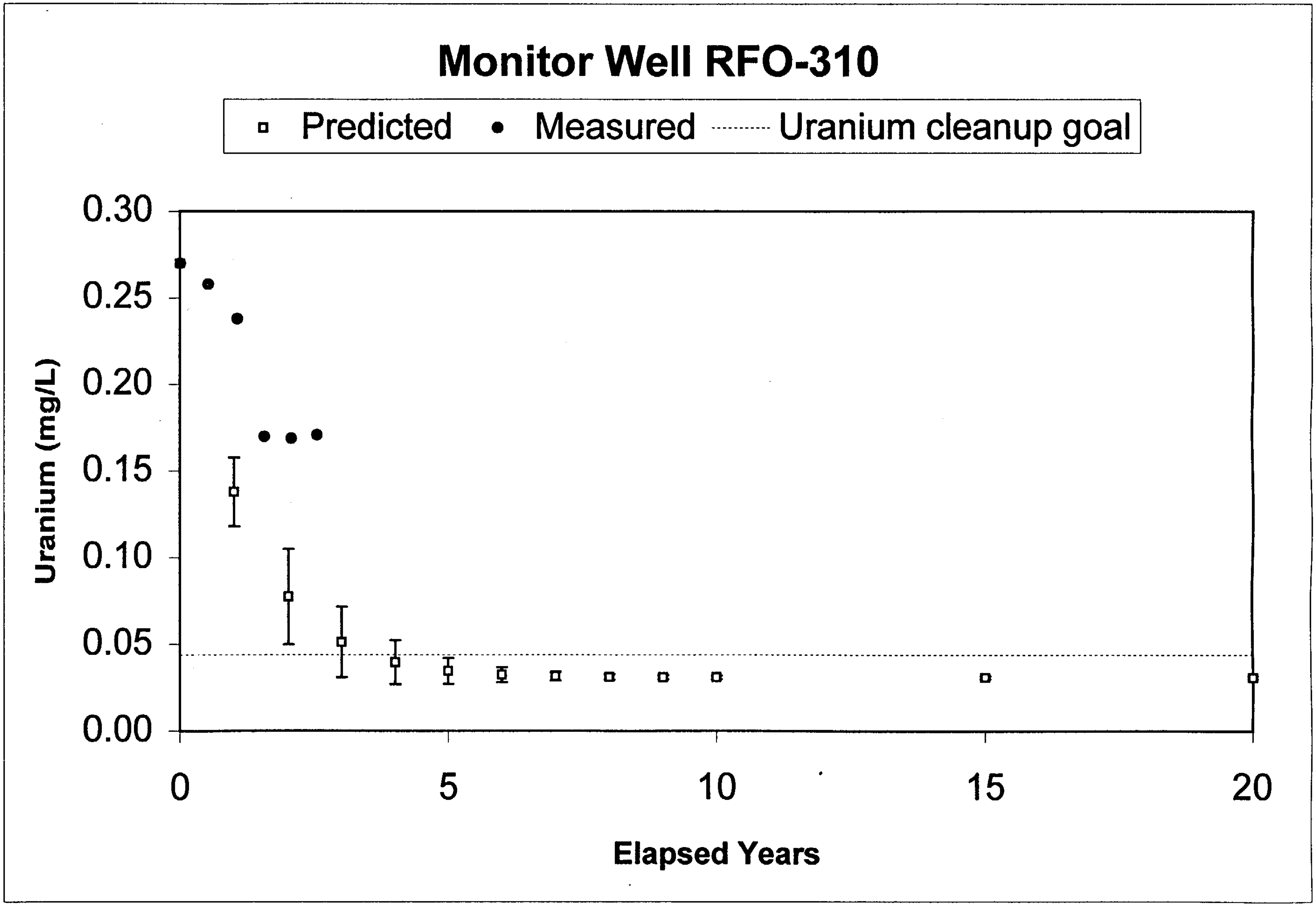


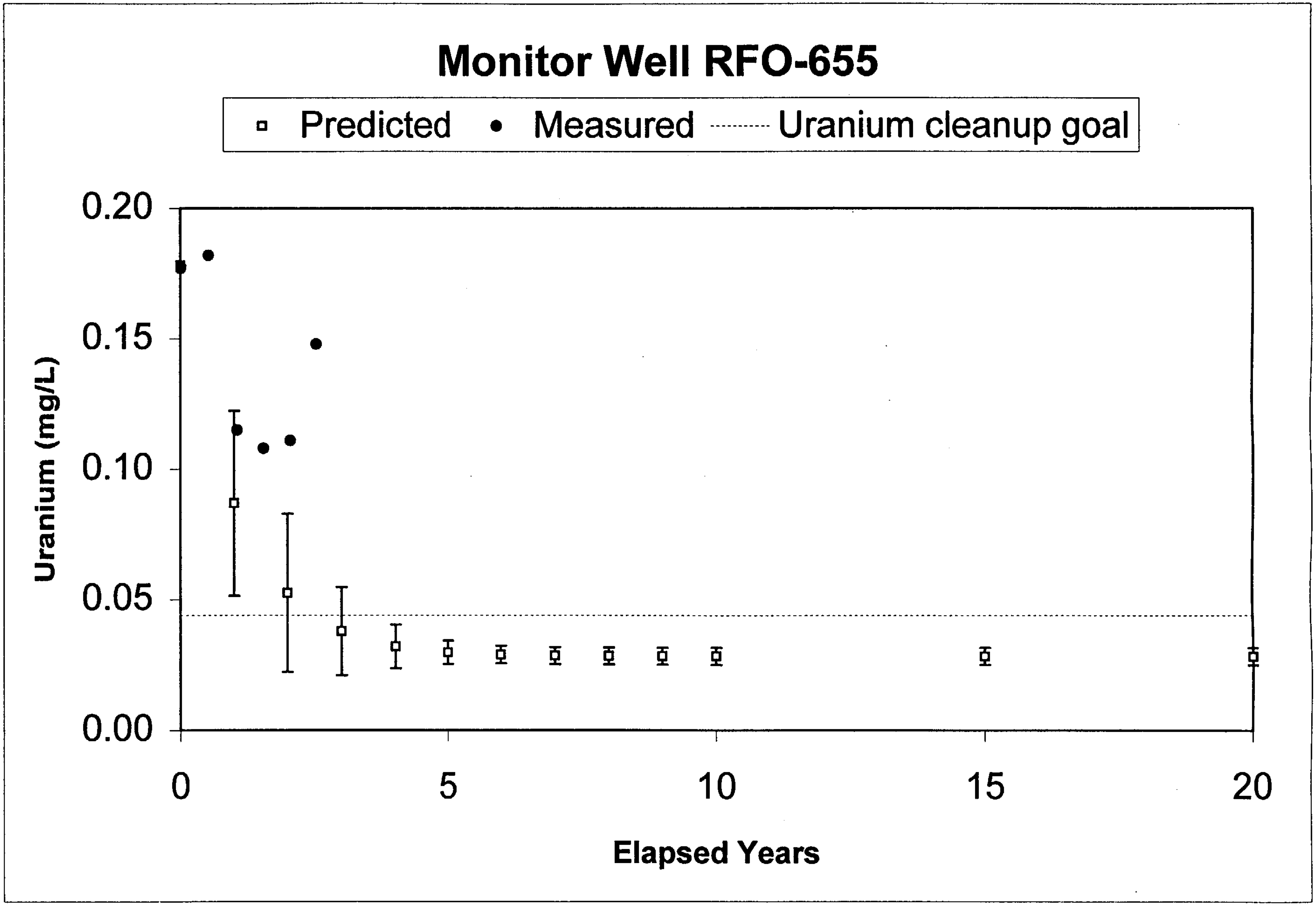
Monitor Well RFO-304
Predicted
Measured
Uranium cleanup goal
0.10
0.05
0.00
Uranium (mg/L)
0
5
10
15
20
Elapsed Years

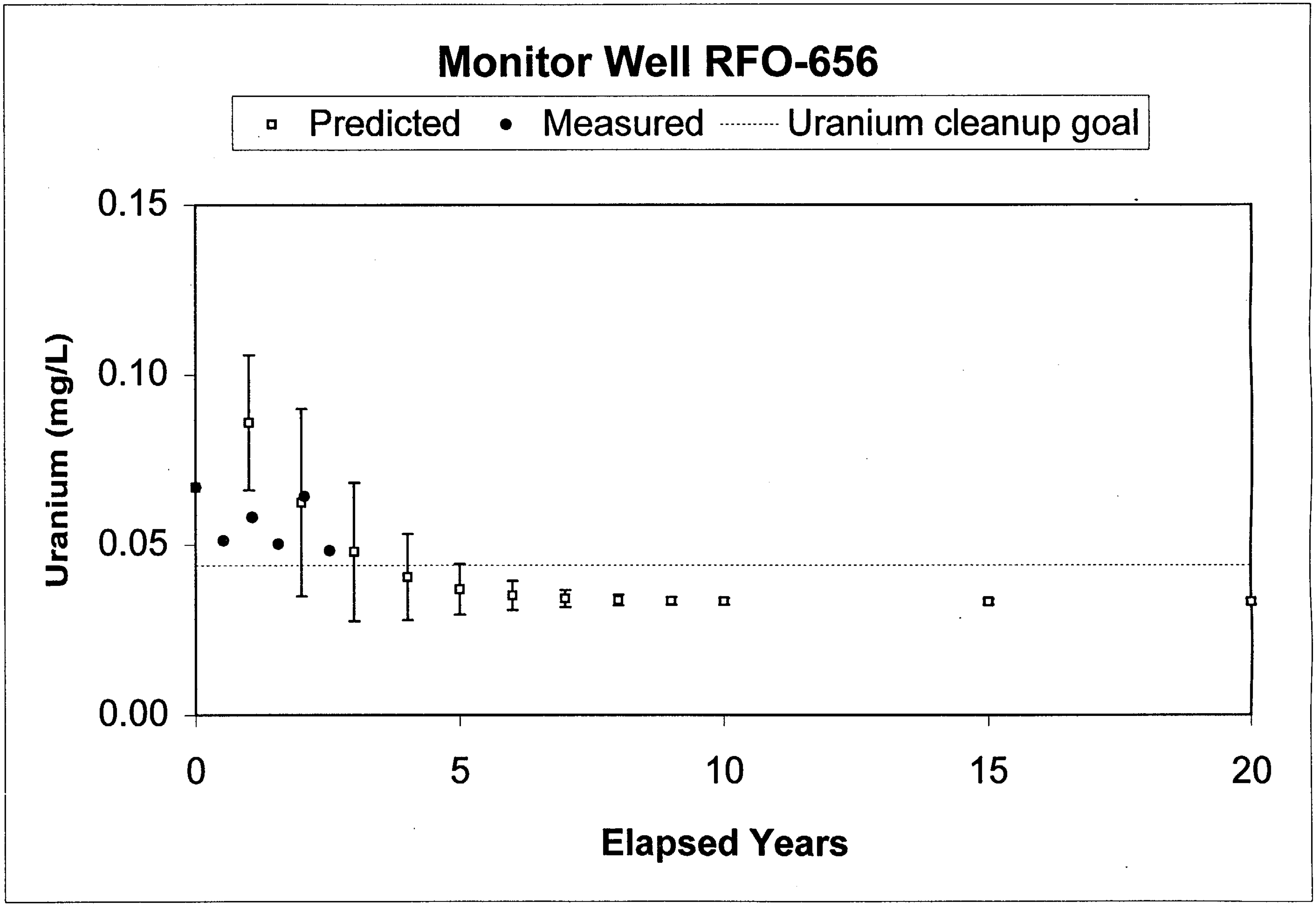

Monitor Well RFO-305
Predicted
Measured
Uranium cleanup goal
0.10
0.05
0.00
Uranium (mg/L)
0
5
10
15
20
Elapsed Years



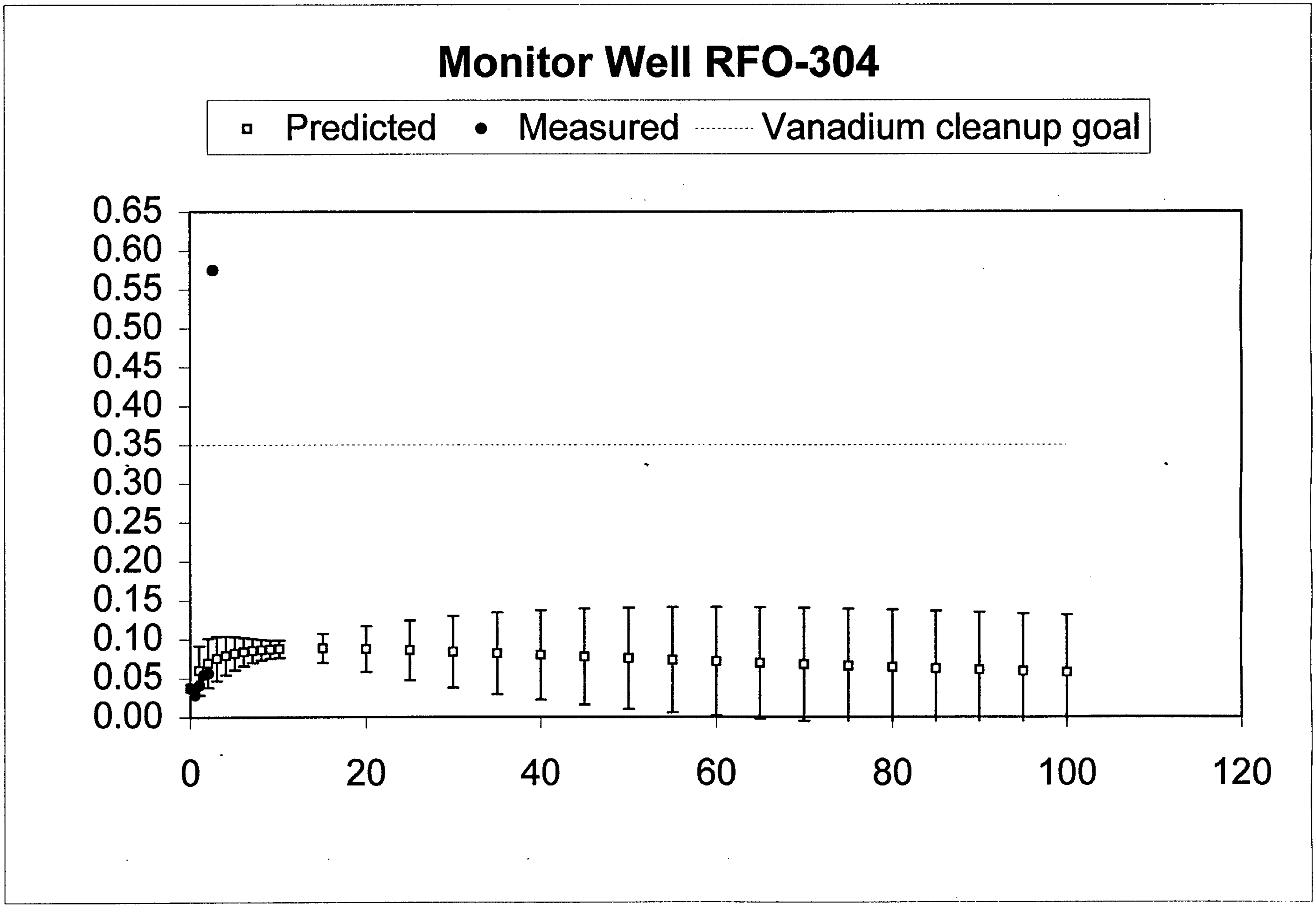
Monitor Well RFO-309
Predicted
Measured
Uranium cleanup goal
Uranium (mg/L)
0.15
0.10
0.05
0.00
0
5
10
15
20
Elapsed Years

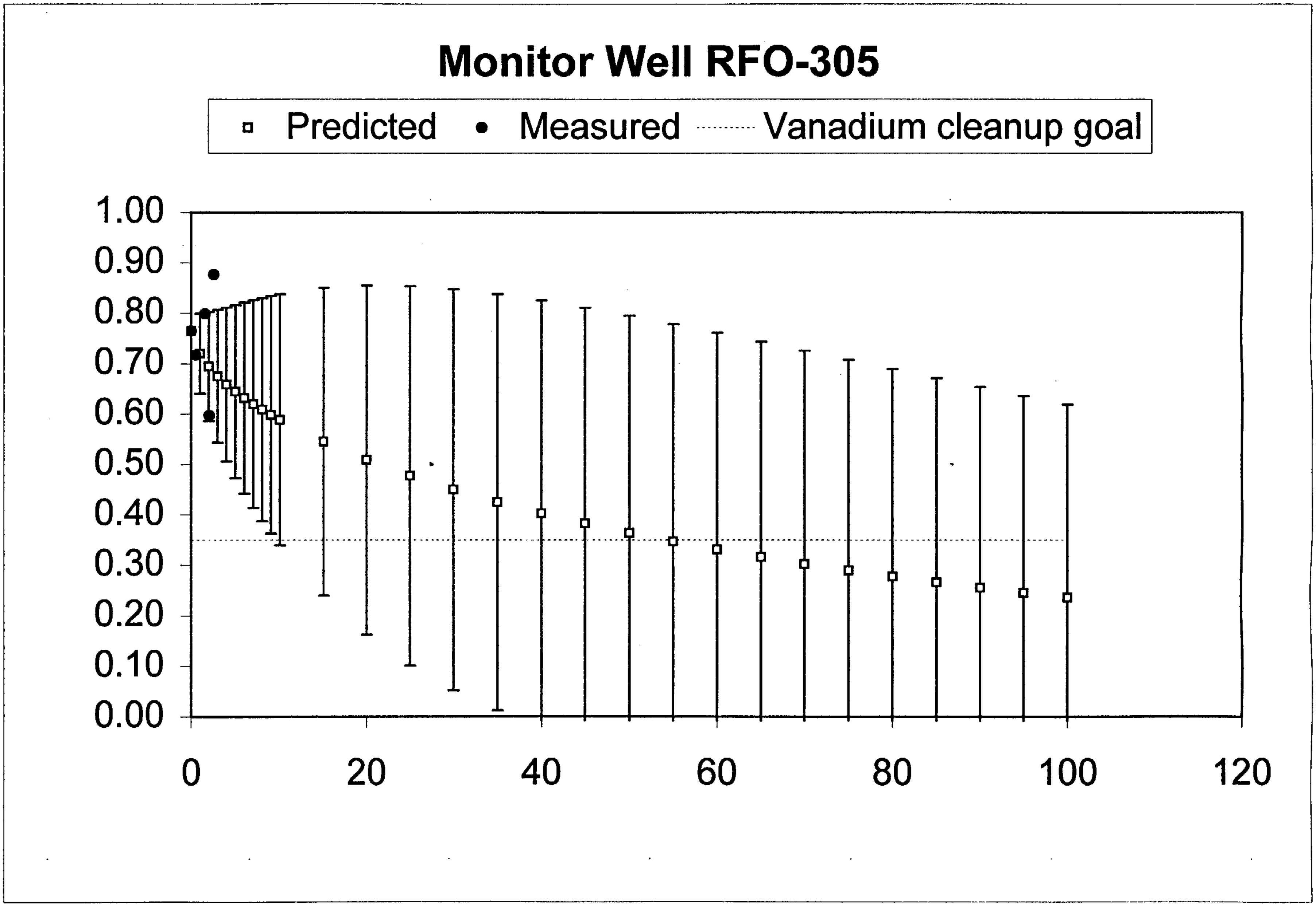

Monitor Well RFO-310
Predicted
Measured
Uranium cleanup goal
Uranium (mg/L)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
Elapsed Years


Monitor Well RFO-655
Predicted
Measured
Uranium cleanup goal
0.20
0.15
0.10
0.05
0.00
Uranium (mg/L)
0
5
10
15
20
Elapsed Years

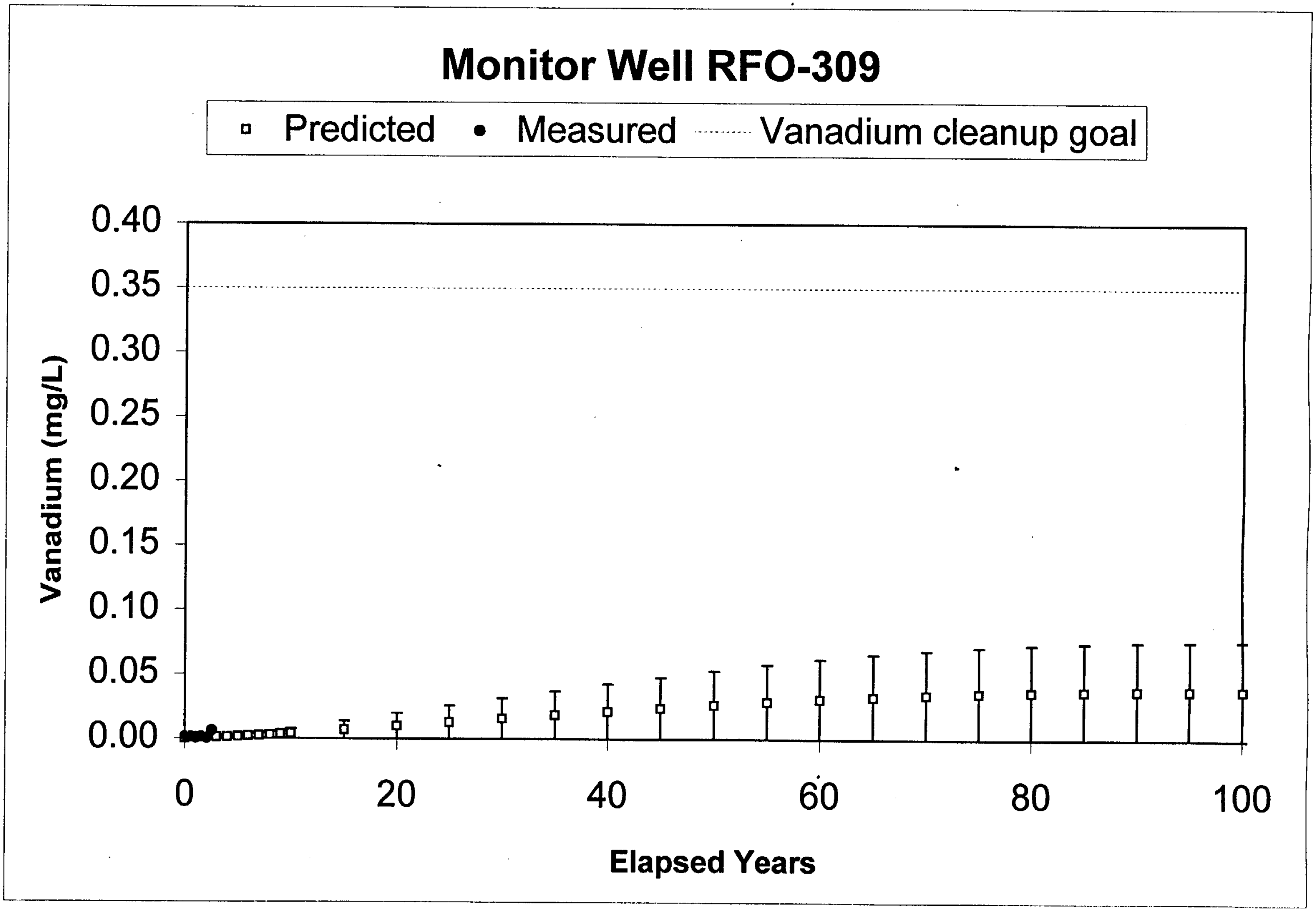


Monitor Well RFO-656
Predicted
Measured
Uranium cleanup goal
0.15
0.10
0.05
0.00
Uranium (mg/L)
0
5
10
15
20
Elapsed Years

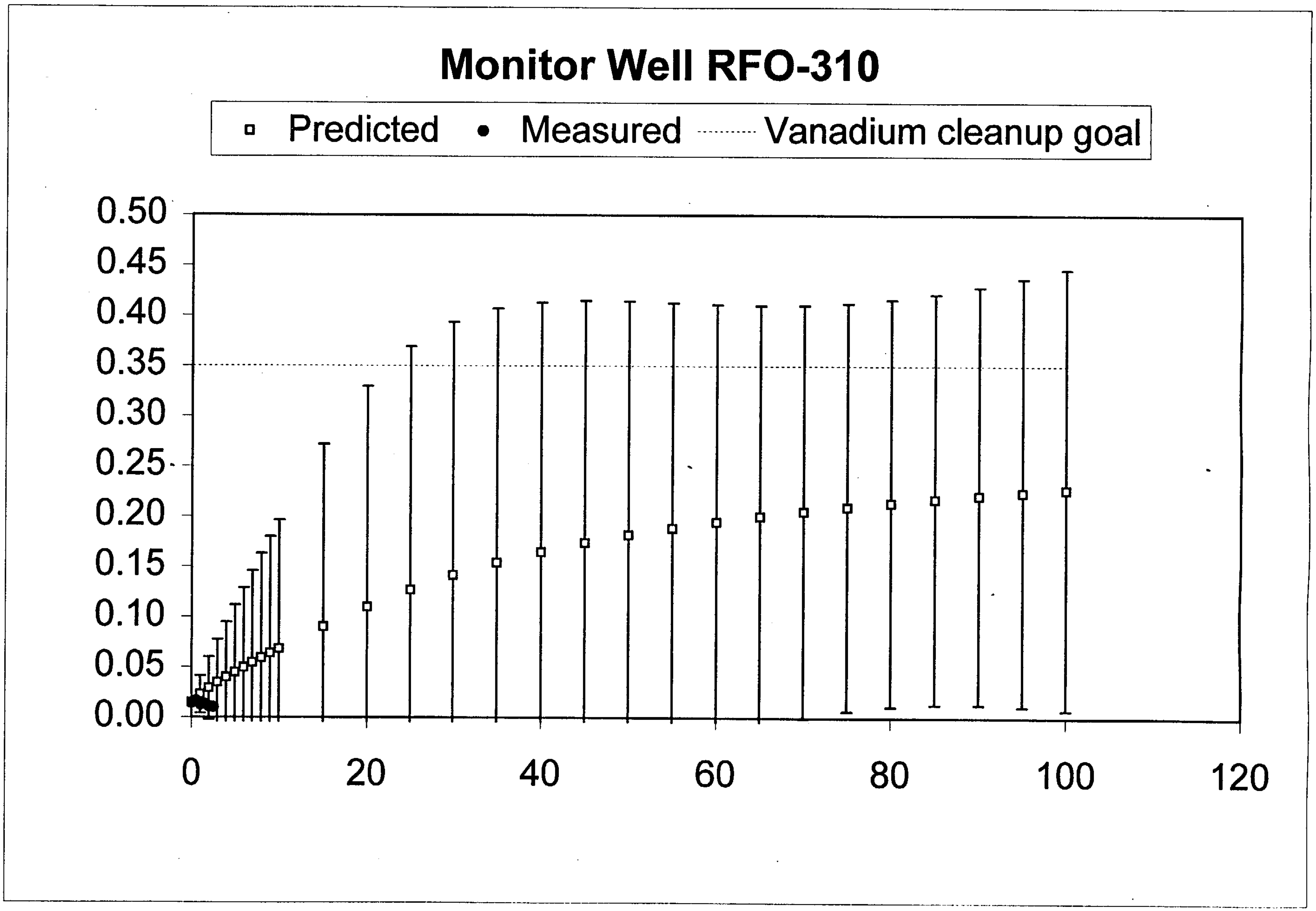

Monitor Well RFO-304
Predicted
Measured
Vanadium cleanup goal
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
20
40
60
80
100
120

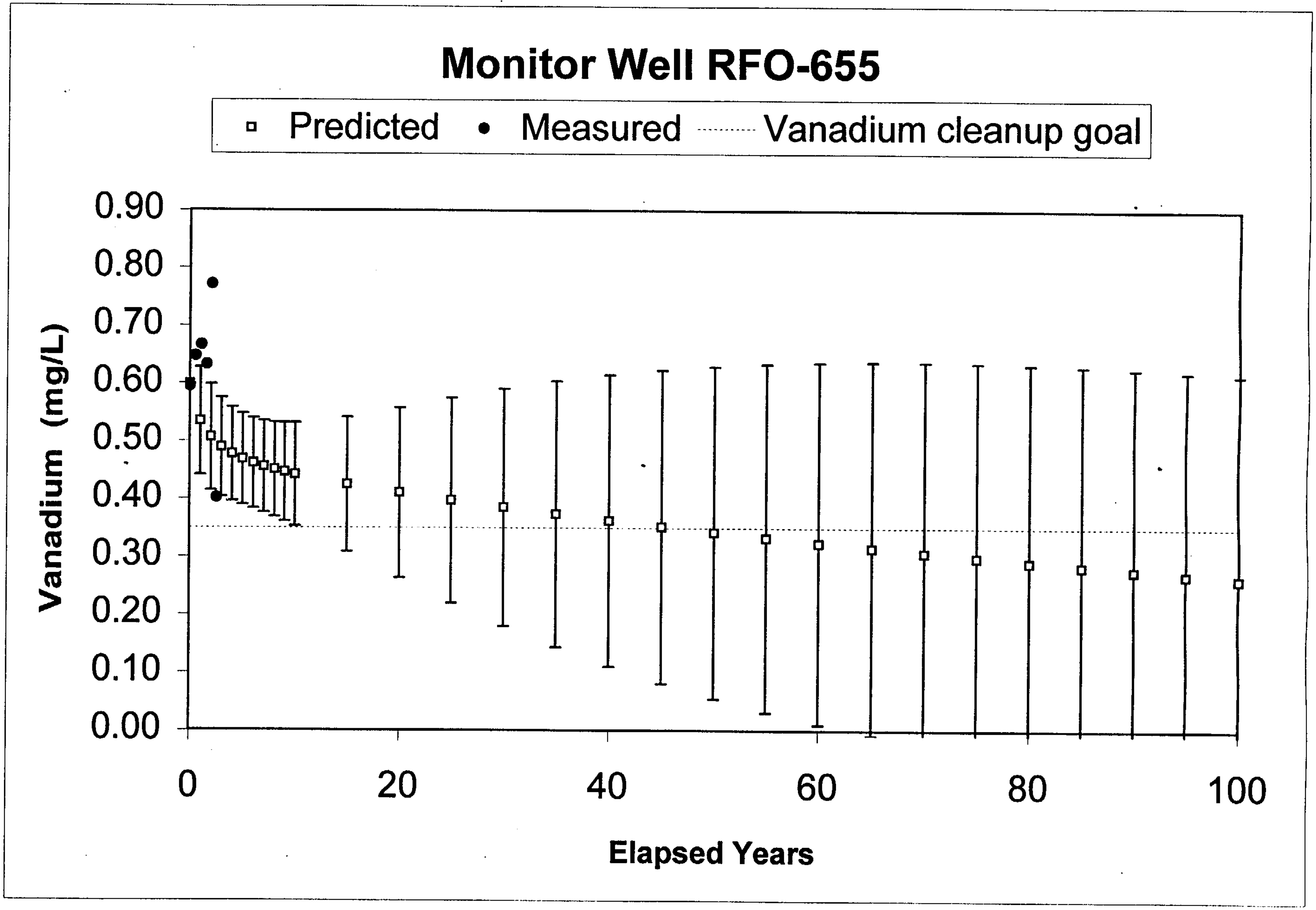


Monitor Well RFO-305
Predicted
Measured
Vanadium cleanup goal
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
20
40
60
80
100
120

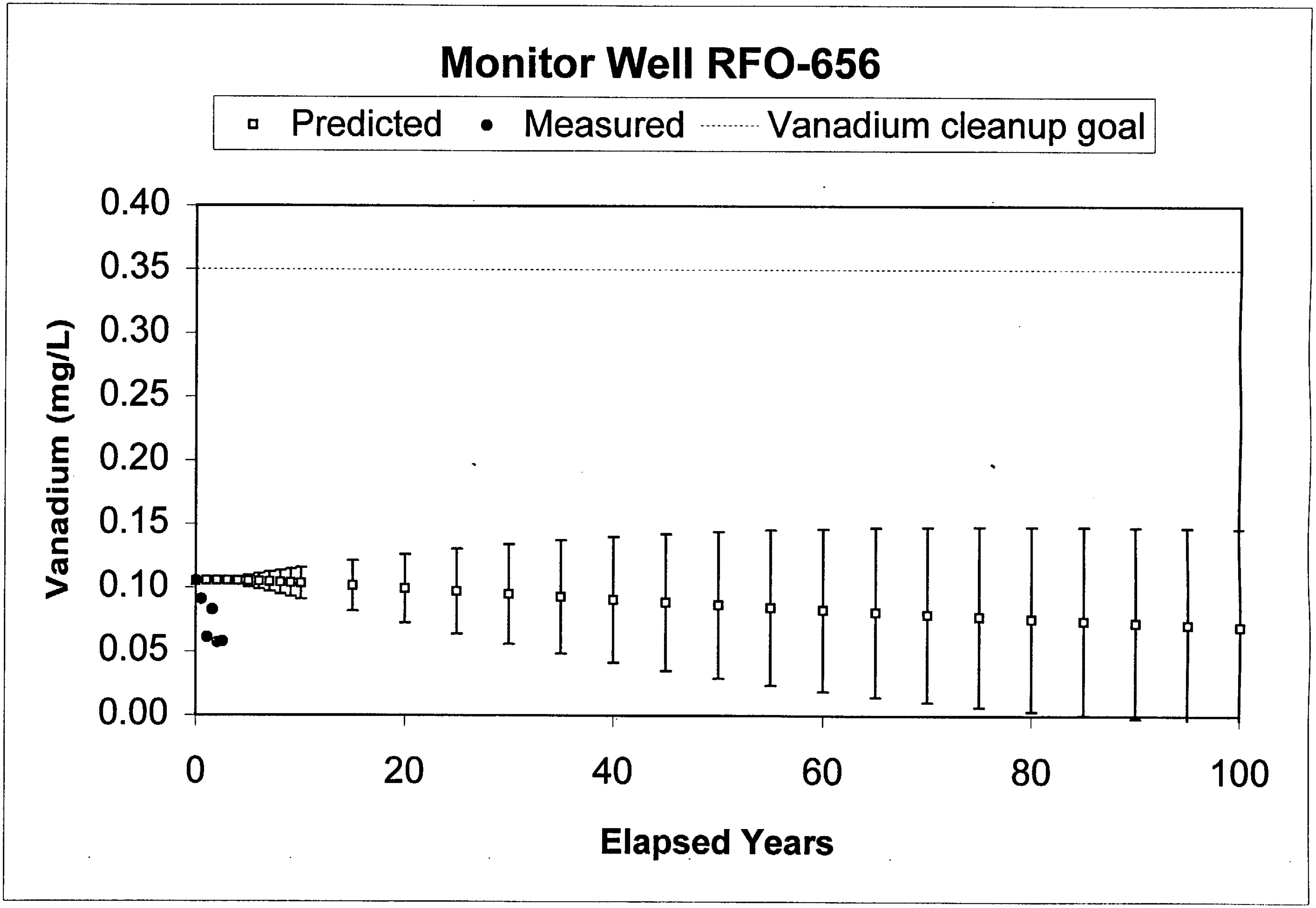


Monitor Well RFO-309
Predicted
Measured
Vanadium cleanup goal
Vanadium (mg/L)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
20
40
60
80
100
Elapsed Years


Monitor Well RFO-310
Predicted
Measured
Vanadium cleanup goal
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
20
40
60
80
100
120



Monitor Well RFO-655
Predicted
Measured
Vanadium cleanup goal
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Vanadium (mg/L)
0
20
40
60
80
100
Elapsed Years


Monitor Well RFO-656
Predicted
Measured
Vanadium cleanup goal
Vanadium (mg/L)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
20
40
60
80
100
Elapsed Years

Appendix B

Deed Restriction for the Old Rifle Site

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

January 12, 2000

JAN 18 2000

Ms. Donna Bergman-Tabbert, Manager
U.S. Department of Energy
Grand Junction Office
2597 B 3/4 Road
Grand Junction, CO 81503

SUBJECT: TRANSFER OF FORMER URANIUM PROCESSING SITE AT OLD RIFLE, COLORADO

Dear Ms. Bergman-Tabbert:

By letter dated December 20, 1999, the U.S. Department of Energy (DOE) provided information related to the request from the Colorado Department of Public Health and Environment (CDPHE) for DOE and U.S. Nuclear Regulatory Commission (NRC) concurrence to transfer the Old Rifle former uranium processing site to the City of Rifle for perpetual public use. In this regard, Section 104(e)(1) of the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) requires DOE and NRC concurrence in the final disposition of processing sites acquired by the cooperating state, and DOE has indicated it concurs with the CDPHE request to transfer the Old Rifle site to the City of Rifle, Colorado.

The NRC staff has reviewed the Old Rifle land transfer information provided by DOE, including the "Quit Claim Deed" and attached "Land Annotation" which will be used to effect the transfer of the property. The staff finds that the "Quit Claim Deed" and attached "Land Annotation" appropriately reflect the requirements of UMTRCA Section 104. Accordingly, NRC concurs with the CDPHE request to transfer the Old Rifle site to the City of Rifle, Colorado.

If you have any questions regarding this letter, please contact the NRC Project Manager, Rick Weller, at (301) 415-7287.

Sincerely,

Thomas H. Essig, Chief
Uranium Recovery and
Low-Level Waste Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

cc: R. Edge, DOE-GJO
J. Deckler, CO

ATTACHMENT A

LAND ANNOTATION

OLD RIFLE, COLORADO PROCESSING SITE

The Uranium Mill Tailings Radiation Control Act (Public Law 95-604), Section 104, requires that the State notify any person who acquires a designated processing site of the nature and extent of residual radioactive materials removed from the site, including notice of the date when such action took place, and the condition of the site after such action. The following information is provided to fulfill this requirement.

The Old Rifle Colorado processing site consists of one land parcel which contained a large tailings pile. The site was operated by Standard Chemical company and later the U.S. Vanadium Corporation, over the period from 1924 to 1946 as a uranium processing facility. Approximately 597,000 cubic yards of contaminated materials which included 1) tailings; 2) subpile soils; 3) surficial materials in the mill yard; and 4) windblown materials; were removed from the mill site from 1992-1996. The remediation was conducted in accordance with regulations promulgated by the U.S. Environmental Protection Agency, in 40 CFR 192. These regulations require that the concentration of radium-226 in land averaged over any area of 100 square meters shall not exceed the background level by more than: 5 pCi/g (picocuries per gram), averaged over the first 15 cm (centimeters) of soil below the surface, and 15 pCi/g averaged over 15 cm thick layers of soil more than 15 cm below the surface. Verification measurements were conducted at the site by dividing the site into approximately 30-foot by 30-foot grids. A soil sample was collected and analyzed for contaminants from each grid to verify that the standards had been met. All verification grids on the site met the EPA standards for radium and thorium.

After remediation was complete the site was backfilled with clean fill material, graded for drainage and revegetated. Backfill materials were routinely analyzed for radium-226 and were determined to have concentrations near background (1.5 pCi/g).

Excavation of residual radioactive material was also conducted for thorium-230 beneath the tailings pile in the subpile soils. For thorium-230, the cleanup standard was determined as a projected 1,000 year radium-226 concentration based on the eventual decay of the thorium to radium. The average thorium in-growth at depth was calculated to be 3.8 pCi/g.

The EPA standards also allow for contamination to be left in place where removal would present a risk of injury to workers, would result in environmental harm, or where the cost of removal clearly outweighs the benefit in terms of risk reduction. At the Old Rifle site, these areas where contamination was left (called "supplemental standards") are the following:

1) an area 1,600 feet long, along the steep slopes at the northern edge of the property. This deposit extends under U.S. Highway 6 & 24;

2) under the railroad right of way extending the length of the site off the southern boundary; and

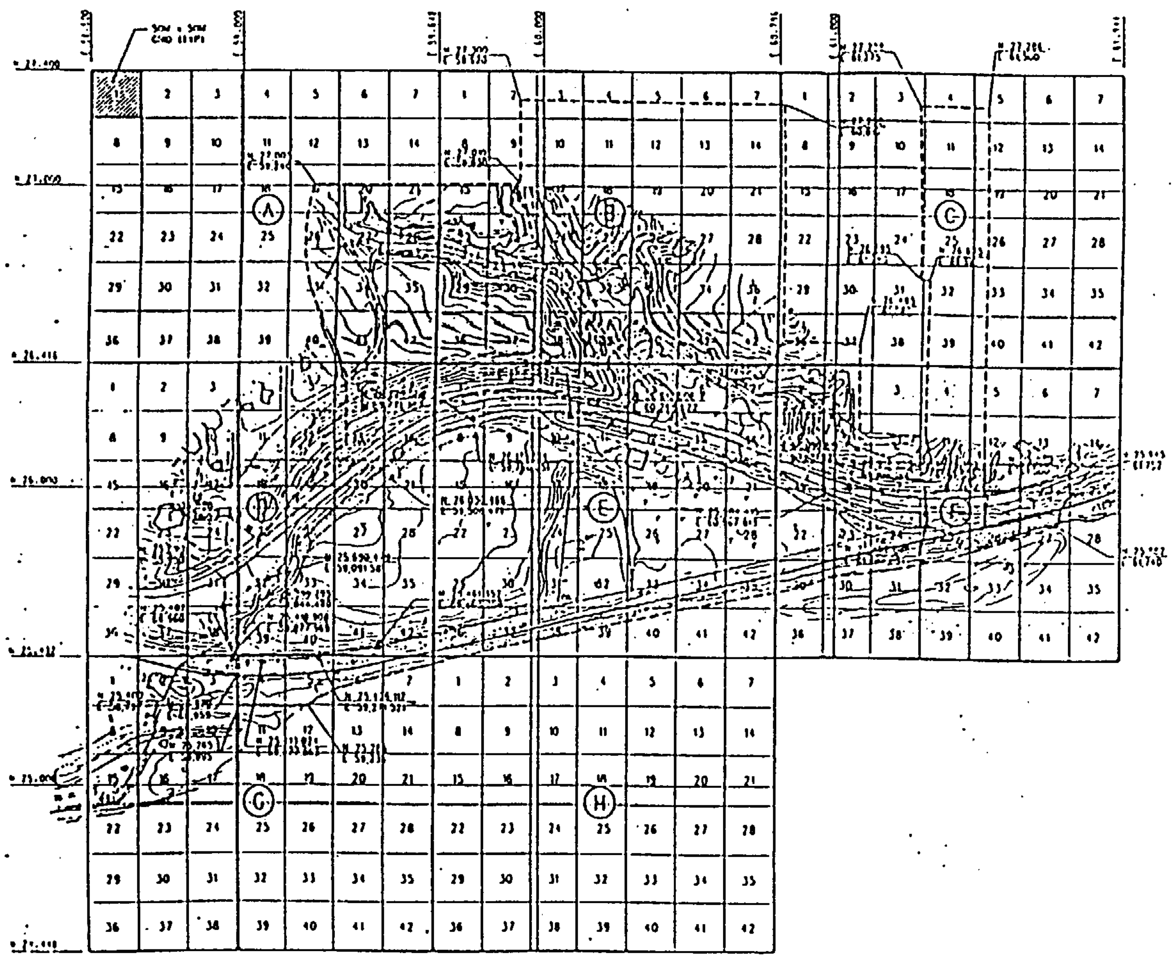
3) along the riverbank to the south of the site.

The supplemental standards areas are shown on the attached map. These deposits have been covered with clean fill and pose no risk unless disturbed. The average gamma exposure is 11 microroentgen per hour at waist height, which is equivalent to background.

The groundwater beneath the Old Rifle mill site remains contaminated and will be addressed during Phase II of the Uranium Mill Tailings Remedial Action Project. Several groundwater monitor wells are present on and downgradient of the site and will remain in place until the U.S. Department of Energy determines that they can be removed.

Any person who acquires a designated processing site shall apply for any permits, including U.S. Army Corps of Engineers Section 404 permits regarding construction in or near wetlands, as required by law.

Additional information concerning the remedial action, and groundwater conditions is available from the Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division.



NOTES:

1. SOILS IN GRIDS A,B,C AND D HAVE ALREADY BEEN VERIFIED USING THE ENGLISH DISTANCE MEASUREMENT SYSTEM. SOILS IN GRIDS E,F,G AND H ARE TO BE VERIFIED USING THE METRIC DISTANCE MEASUREMENT SYSTEM, AS SHOWN.
2. CONTROL POINTS AND GRID SYSTEM COORDINATES AS SHOWN ARE IN FEET.

REFERENCE DRAWINGS:

RFL-SVOR-0002 THRU 0009 SOIL VERIFICATION GRID SYSTEM

LEGEND

– – – – –	APPROXIMATE LIMIT OF CONTAMINATED MATERIAL EXCAVATION
═══	ROAD AND HIGHWAY
┼┼┼┼	RAILROAD
— —	WATER LINE (POND/RIVER)
—A—	SURVEY POINTS AND PROPERTY LINE BOUNDARY

50 0 50 100
SCALE METERS

200 0 200 400
SCALE FEET

U.S. DEPARTMENT OF ENERGY
ALBUQUERQUE, NEW MEXICO

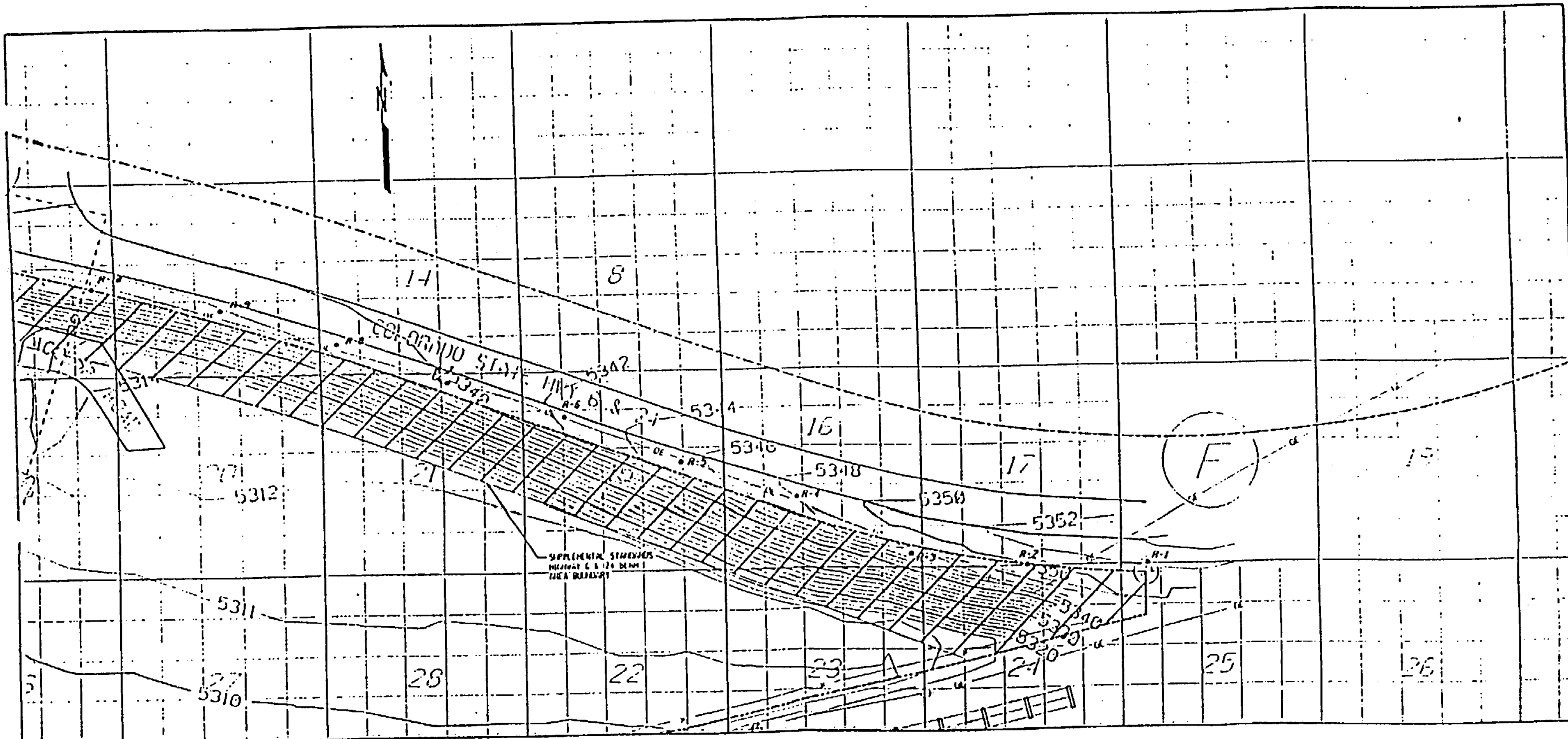
OLD RIFLE PROCESSING SITE
RIFLE, COLORADO

PLAN OF SOIL VERIFICATION GRID SYSTEM

MORRISON KNUDSEN CORPORATION
UMTRA PROJECT

DE-AC04-83AL18796

RFL-SVOR-00001. 0



LEGEND

PROPERTY BOUNDARY LINE
FINISHED GRADE CONTOURS
FENCE LINE
OVERHEAD ELECTRIC LINES
POWER POLE
D & RGW RAILROAD
• R-11 RIG TEST STARTING LOCATION

50M

10M	10M	10M	10M	10M
1	2	3	4	5
6	7	8	9	10
11	12	(42)	14	15
16	17	18	19	20
21	22	23	24	25

SAMPLE GRID NO.

E-42-19

E - SHEET NO. (SEE KEY MAP ABOVE)

42 - 50M x 50M GRID
19 - 10M x 10M SUBGRID

NOTES:

1. OLD RIFLE BOUNDARY LINES SHOWN ARE FROM HORIZONTAL AND VERTICAL CONTROL SHEET BY JACOBS ENGINEERING GROUP INC. DATED AUGUST 13, 1984.

2. HIGHWAY R.O.W. SHOWN WAS TAKEN FROM CONSTRUCTION SURVEYS DRAWING. NO RESEARCH WAS DONE TO DETERMINE LOCATION OF R.O.W..

REFERENCE DRAWINGS:

RFL-550R-0002 SITE PLAN

SCALE 10 0 10 20 30 METERS

SCALE 0 20 40 80 120 160 FEET

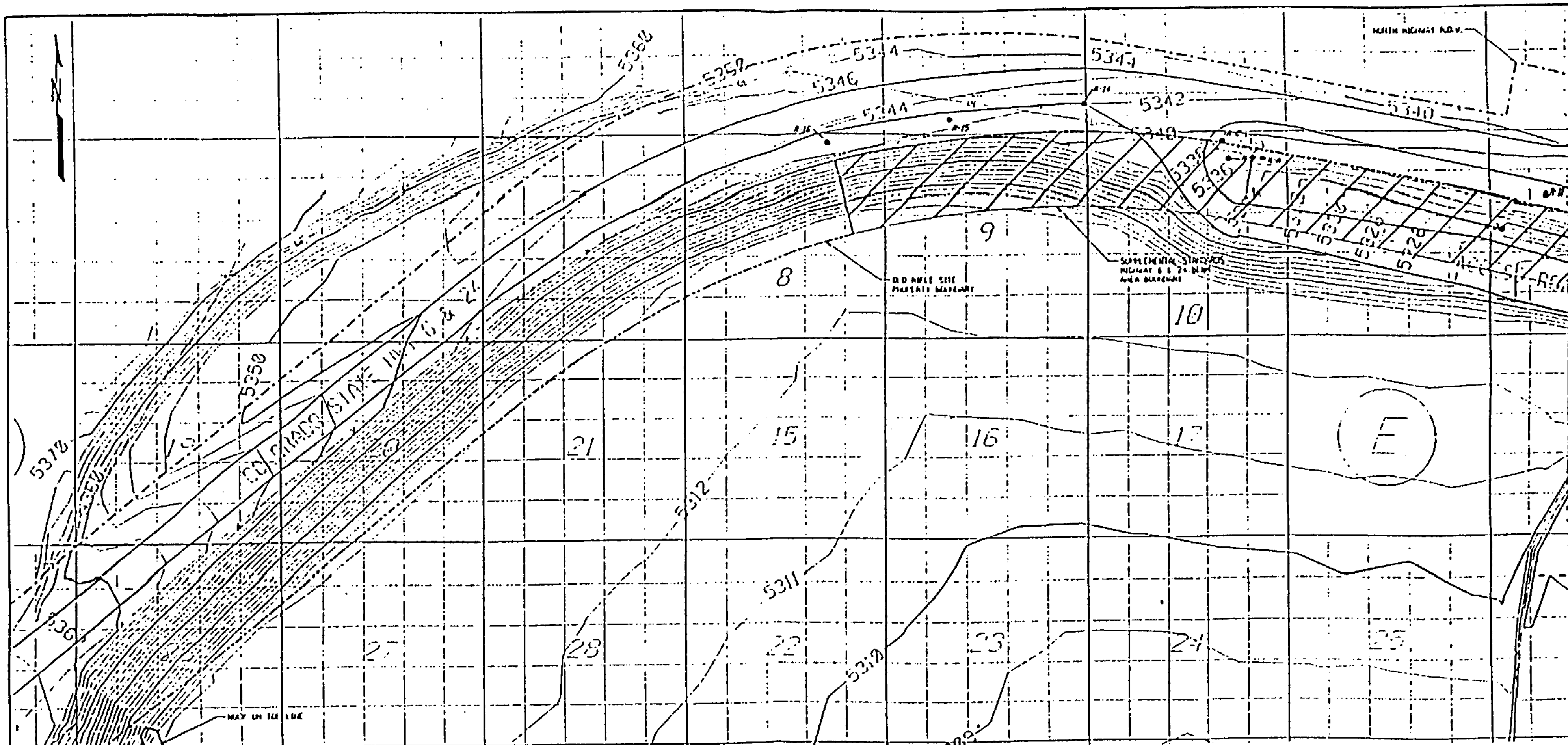
U.S. DEPARTMENT OF ENERGY
ALBUQUERQUE, NEW MEXICO

OLD RIFLE PROCESSING SITE
RIFLE, COLORADO
SUPPLEMENTAL STANDARDS FOR HIGHWAY 6 & 24 BERM

HIGHWAY 6 & 24 BERM
LOCATIONS OF SUBSURFACE SAMPLES
(SHEET 2 OF 2)

MORRISON KNUDSEN CORPORATION

DE-AC04-83AL18796



LEGEND

— · — · —	PROPERTY BOUNDARY LINE
—5310—	FINISHED GRADE CONTOURS
— · —	FENCE LINE
— · —	OVERHEAD ELECTRIC LINES
•	POWER POLE
	D & RGW RAILROAD
• R-11	AUGER TEST STARTING LOCATION

50M

	10M	10M	10M	10M	10M
10M	1	2	3	4	5
10M	6	7	8	9	10
10M	11	12	(42)	14	15
10M	16	17	18	19	20
10M	21	22	23	24	25

SAMPLE GRID NO.

E-42-19

E - SHEET NO. (SEE KEY MAP ABOVE)

42 - 50M x 50M GRID

19 - 10M x 10M SUBGRID

NOTES:

1. OLD RIFLE BOUNDARY LINES SHOWN ARE FROM HORIZONTAL AND VERTICAL CONTROL SHEET BY JACOBS ENGINEERING GROUP INC. DATED AUGUST 13, 1984.
2. HIGHWAY R.O.W. SHOWN WAS TAKEN FROM CONSTRUCTION SURVEYS GRADING. NO RESEARCH WAS DONE TO DETERMINE LOCATION OF R.O.W.

REFERENCE DRAWINGS:

RFL-SSOR-0002 SITE PLAN

SCALE 10 0 10 20 30 METERS

U.S. DEPARTMENT OF ENERGY

ALBUQUERQUE, NEW MEXICO

OLD RIFLE PROCESSING SITE

RIFLE, COLORADO

SUPPLEMENTAL STANDARDS FOR HIGHWAY 6 & 24 BERM

HIGHWAY 6 & 24 BERM

LOCATIONS OF SUBSURFACE SAMPLES

(SHEET 1 OF 2)

Recorded at ____________ o'clock ________M., ____________
Reception No. ____ Recorder

QUIT CLAIM DEED

The Colorado Department of Public Health and the Environment ("Grantor"), whose address is 4300 Cherry Creek Drive South, Denver, Colorado, 80222-1530, City and County of Denver, State of Colorado, pursuant to 42 U.S.C.§ 7914 (c) (1) (B) and C.R.S. § 25-11-303, hereby donates and quit claim(s) to the City of Rifle ("Grantee"), whose address is 202 Railroad Avenue, Rifle, Colorado, 81650, City of Rifle, County of Garfield, State of Colorado, the following real property in the County of Garfield, State of Colorado, to wit: A parcel of land described as follows:

Beginning at a point on the South right-of-way line of the U.S. Highway 6 & 24, said point more particularly described as being South 0°18' West 1415 feet more or less, from the northeast corner of the NW-1/4 of the NW-1/4 of Section 15, Township 6 South, Range 93 West, 6th P.M. and running then South 0°18' West 36.5 feet to the North right-of-way line of the D&RGW Railroad, thence South 76°36' West 1891.8 feet along said right-of-way, thence continuing along said right-of-way line the following courses and distances. South 79°2' West, 194.9 feet; South 85°35' West 194.1 feet; North 87°20' West 193.9 feet; North 80°23' West 194.0 feet; North 79°32' West 26.7 feet; thence North 74.5 feet to the said South right-of-way line of the U.S. Highway 6 & 24, and a point on a 673 foot radius curve to the left, thence Northeasterly along said curve an arc distance of 453.5 feet (chord bears north 69°26'30" East 445 feet); thence North 50°07' East 655.7 feet to a point on a 472.98 foot radius curve to the right, thence Northeasterly along said curve an arc distance of 223.16 feet (chord bears North 63°38' East 221.1 feet); thence North 80°51'30" East 293.9 feet; thence South 79°33' East 157.7 feet to a point on a 2825 foot radius curve to the right, thence Southeasterly along said curve an arc distance of 460.21 feet (chord bears South 74°53' East 459.7 feet); thence South 70°13' East 306.5 feet to a point on a 1081.8 foot radius curve to the left, thence Easterly along said curve an arc distance of 348.81 feet (chord bears South 79°24' East 347.2 feet) to the point of beginning.

EXCEPTING therefrom those portions of the above described property conveyed to the Denver and Rio Grande Western Railroad Company in deed recorded May 8, 1978 in Book 509 at Page 551 and that part conveyed to the City of Rifle in deed recorded January 18, 1971 in Book 416 at Page 257.

Subject to: (i) any coal, oil, gas, or other mineral rights in any person; (ii) existing rights-of-way for roads, railroads, telephone lines, transmission lines, utilities, ditches, conduits, or pipelines on, over, or across said lands; (iii) court liens, judgments, or financial encumbrances such as deeds of trust for which a formal consent or order has been obtained from a court for the lien holder; (iv) other rights, interests, easements, reservation or exceptions of record; and the following terms, conditions, rights, reservations and covenants:

Grantor reserves to (i) itself, the U. S. Department of Energy, their employees, agents and contractors the right of access to the property as may be necessary to complete activities under the Uranium Mill Tailings Radiation Control Act of 1978, 42 U.S.C. § 7901 et seq. ("UMTRCA") and for other lawful purposes, until such time as Grantor and the U.S. Department of Energy determine that all remedial activities are complete; and (ii) to itself any non-tributary groundwater underlying this parcel, the right to develop tributary groundwater, and the right to surface access for groundwater development.

Grantee covenants to hold harmless the Grantor and the Department of Energy for any liability associated with disruption of any public purpose ventures on the property conveyed by this deed, the disruption of any improvement on said property made by the Grantee, its successors and assigns, and any temporary or permanent limitations to the use of the property, should the Grantor and the Department of Energy be required to perform additional surface remedial activities on the property conveyed by this deed.

Grantee covenants (i) to comply with the applicable provisions of UMTRCA, 42 U.S.C. #7901 et. seq., as amended; (ii) not to use ground water from the site for any purpose, and not to construct wells or any means of exposing ground water to the surface unless prior written approval for such use is given by the Grantor and the U.S. Department of Energy; (iii) not to sell or transfer the land to anyone other than a governmental entity within the state; (iv) that any sale or transfer of the property described in this deed shall have prior written approval from the Grantor and the U.S. Department of Energy; and that any deed or other document created for such sale or transfer and any subsequent sale or transfer will include information stating that the property was once used as a uranium milling site and all other information regarding the extent of residual radioactive materials removed from the property as required by Section 104(d) of the Uranium Mill Tailings, 42 U.S.C. sec. 7014(d), and as set forth in the Annotation attached hereto; (v) not to perform construction and/or excavation or soil removal of any kind on the property without permission from the Grantor and the U.S. Department of Energy unless prior written approval of construction plans (e.g., facilities type and location), is given by the Grantor and the U.S. Department of Energy; (vi) that any habitable structures constructed on the property shall employ a radon ventilation system or other radon mitigation measures; and (vii) that its use of the property shall not adversely impact groundwater quality, nor interfere in any way, with groundwater remediation under UMTRCA activities; and (viii) to use the property and any profits or benefits derived therefrom only for public purposes as required by UMTRCA sec. 104(c)(1)(C), 42 U.S.C. 7914 (c)(1)(C).

These covenants are made in favor and to the benefit of Grantor, shall run with the land and be binding upon Grantee and its successors and assigns, and shall be enforceable by Grantor;

Grantee acknowledges that the property was once used as a uranium milling site, and that the Grantor makes no representations or warranties that the property is suitable for Grantee's purposes;

IN WITNESS WHEREOF:

APPROVED AS TO FORM:

David Kreutzer, Assistant Attorney General

GRANTOR:

STATE OF COLORADO
Bill Owens, Governor
Acting by and through
The Department of Public Health and Environment

By:______________________
Executive Director

By:______________________
Program Approval

ACCEPTANCE OF DEED
AND COVENANTS

GRANTEE:

____
(Full Legal Name of Agency)

By:______________________
Name

Title:______________________

Signed this day of , 19

STATE OF COLORADO,
County of } ss.

The foregoing instrument was acknowledged before me this day of , 19 , by

My commission expires.

Witness my hand and official seal ______________________

Notary Public.

Attachment 1

Alternate Concentration Limits Application

GWRFL11.14–1

Application for Alternate Concentration Limits for the Old Rifle, Colorado, UMTRA Project Site

June 2001

Prepared by
U.S. Department of Energy
Grand Junction Office
Grand Junction, Colorado

Project Number UGW–511–0017–20–000
Document Number U0086802

Work Performed under DOE Contract No. DE–AC13–96GJ87335

Contents

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1.0 Introduction

1.1 Purpose

The purpose of this document is to fulfill the Nuclear Regulatory Commission (NRC) requirements for an application for Alternate Concentration Limits (ACLs) for two constituents at the Uranium Mill Tailings Remedial Action (UMTRA) Project Old Rifle Site ("Old Rifle"), Colorado. Much of the information required by the NRC for an ACL application (10 CFR Part 40, Appendix A and NRC 1996) has been compiled in the Site Observational Work Plan (SOWP; DOE 1999) for Old Rifle as well as the Ground Water Compliance Action Plan (GCAP). This document is an addendum to the GCAP. The intent of this addendum is not to duplicate information found elsewhere, but to provide a link between NRC evaluation criteria and relevant detailed discussion pertaining to those criteria in previously prepared documents. NRC guidance for preparing ACL applications for Title II sites (NRC 1996) was used as a model for this application. This document summarizes pertinent information from the SOWP regarding "Factors Considered in Making Present and Potential Hazard Findings" (Table 1 in NRC 1996; also specified in 40 CFR Part 192 with slight modifications). It also identifies sections of the SOWP that contain information corresponding to sections listed in the "Standard ACL Application Format" (Table 2 in NRC 1996). This ensures that all factors and information related to the proposed ACLs have been considered, while minimizing duplication of effort.

NRC's ACL guidance was prepared for Title II UMTRA sites. It is also noted that the guidance can be applied to Title I sites, with modifications made to accommodate the differences between Title II and Title I sites. One of the major differences between these sites is that the regulations for Title I sites (40 CFR Part 192) permit natural flushing as the selected ground water compliance strategy, providing that ground water will reach acceptable levels (UMTRA standards, background, or ACLs) within a period of 100 years. Active remediation alternatives may not be evaluated for sites meeting this criterion, as indicated in the flow chart in Figure 1 of the GCAP. Therefore, data corresponding to the corrective action assessment portion of the standard ACL application may be quite limited, as is the case for the Old Rifle site.

Section 2.0 of this document briefly discusses the constituents for which ACLs are proposed and the rationale for the numerical values. Section 3.0 summarizes the factors considered in making hazard findings. Section 4.0 presents the "roadmap" to the SOWP following the standard ACL application format. References are included in Section 5.0.

1.2 Brief Site Background

The U.S. Vanadium Company constructed the original Old Rifle processing plant in 1924 for the production of vanadium (Merritt 1971) (Figure 1). In 1926 the assets of the U.S. Vanadium Company were purchased by Union Carbide and Carbon Corporation (Union Carbide), and the U.S. Vanadium Corporation was established as a subsidiary (Chenoweth 1982). The plant closed in 1932 as a result of a shortage of vanadium ore. In 1942 Union Carbide reactivated the plant for vanadium production as a result of an increase in demand due to World War II. The plant continued to operate until 1946 when it was modified to include the recovery of uranium as well as vanadium. Uranium and vanadium production continued until 1958 when the plant was replaced with a new mill located approximately 3 miles west of the Old Rifle site. Millfeed consisted of raw ore mined from deposits located primarily in Garfield (Garfield and Rifle

Mines), Mesa, Montrose, Moffat (Meeker Mine), and San Miguel Counties in Colorado (Chenoweth 1982). Atomic Energy Commission (AEC) records from 1947 to 1958 indicate that 761,000 tons of ore were processed at the site. Over 2,000 tons of uranium concentrate (U_3O_8) were sold to the AEC (Chenoweth 1982).

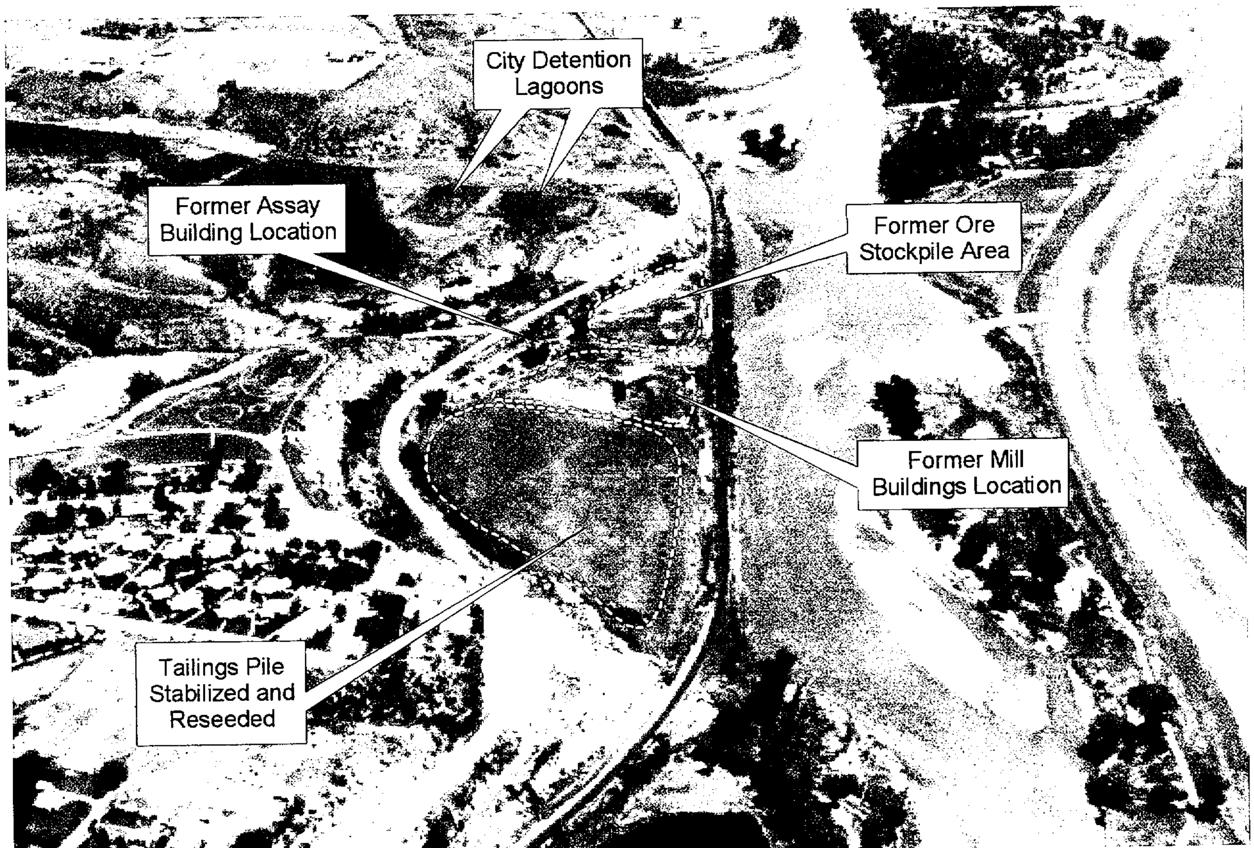

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Figure 1. Former Tailings Pile, Ore Storage Area, and Associated Buildings at the Old Rifle Site June 1987

Approximately 13 acres of tailings remained at the Old Rifle site before the surface remedial action. No structures remained at the millsite. The relatively flat tailings pile was stabilized by Union Carbide in 1967 in accordance with the State of Colorado regulations. The edge of the pile was moved away from the railroad tracks and the entire pile was covered with 6 inches of soil, fertilized, and seeded with native grasses. Water from the Colorado River was used for irrigation. Surface water draining from an upgradient seep across U.S. Highway 6 flowed through the site. The seep water collected in a lined pond after it passed the tailings pile. Overflow from the pond was released into the Colorado River. The pond and tailings were removed during surface remedial action completed in 1996.

2.0 Proposed ACLs

ACLs are proposed for two constituents at the Old Rifle site—selenium and vanadium. An ACL for selenium is required because background concentrations in the surficial aquifer system exceed the UMTRA standard of 0.01 milligrams per liter (mg/L). An ACL is required for vanadium because vanadium at the site is elevated above background concentrations and no standard has been established for vanadium in ground water.

A selenium concentration of 0.05 mg/L is proposed as the ACL. This value corresponds to the national primary drinking water standard as well as the Colorado state drinking water standard. It is also well below the risk-based concentration of 0.18 mg/L, which corresponds to a maximum acceptable risk when used as drinking water on a regular basis (EPA 2000; EPA Region III risk-based concentration table).

The ACL proposed for vanadium is 0.33 mg/L at the point of exposure (POE), which is the Colorado River for as long as institutional controls are in place. The proposed ACL corresponds to the human health risk-based concentration for drinking water in a residential setting (EPA 2000). The proposed ACL should be met in on-site wells in slightly more than 100 years of natural flushing. Institutional controls will be maintained until the ACL is met in all on-site wells. An action level of 1.0 mg/L is proposed for the point of compliance (POC; any on-site well) until the ACL is met. If the action level is exceeded, some form of corrective action may be triggered. As long as on-site concentrations remain below the action level, all potential receptors at the POE will be protected. Vanadium concentrations in the Colorado River are not expected to increase. Once the ACL is met on site, unrestricted ground water use will be permitted and will be protective of human health and the environment.

Ground water modeling predicts that selenium will reach its proposed ACL within the 100-year period for which natural flushing of ground water is permitted. Vanadium concentrations may be reduced to its proposed ACL in this time frame or slightly longer; institutional controls will prevent ground water use until both ACLs are achieved.

3.0 Factors Considered In Making Present And Potential Hazard Findings

The list of factors below is from the Title I regulations [40 CFR 192.02(c)(3)(ii)(B)(1) and (2), which differ slightly from those in the NRC Title II guidance, and add another factor to the ground water quality list.

3.1 Potential Adverse Effects on Ground Water Quality

3.1.1 **The physical and chemical characteristics of constituents in the residual radioactive material at the site, including their potential for migration.** No disposal cell is present at the site. Surface remediation was completed in 1996. Subpile soil analysis indicates that no significant contamination remains in place that would contribute to ground water contamination (see SOWP, Section 5.3.1.3).

3.1.2 **The hydrogeological characteristics of the site and surrounding land.** The hydrogeology of the site was characterized for input to the flow and transport model (see SOWP, Sections 5.1 "Geology," and 5.2 "Hydrologic System"). Impermeable rock outcrops at the downgradient site boundary prevent downgradient migration of ground water. All ground water within the site discharges to the Colorado River. There are no surface expressions of contaminated ground water on site.

3.1.3 **The quantity of ground water and the direction of ground water flow.** Ground water flow is generally west-southwest at a rate of 1.4 to 2.0 ft/day. The volume of contaminated ground water is estimated at approximately 30 million gallons.

3.1.4 **The proximity and withdrawal rates of ground water users.** There are no ground water users located in the vicinity of the site. Contamination is prevented from migrating to downgradient users by the impermeable rock outcrops at the downgradient site boundary.

3.1.5 **The current and future uses of ground water in the region surrounding the site.** There are some private ground water wells in the site vicinity. Wells used for drinking water have some sort of treatment system, as the quality of ground water in the area is generally poor. Other uses for well water at residences include bathing, showering, and watering plants and livestock. There are some wells that obtain ground water for industrial purposes. The zoning for the land encompassing the site is agricultural/industrial. Potential future uses could be open space/agricultural, wildlife habitat enhancement, environmental education, passive recreation, and mine reclamation. Institutional controls prevent the use of ground water for any purpose at the site itself; water use at nearby properties is most likely to be agricultural or industrial.

3.1.6 **The existing quality of ground water, including other sources of contamination and their cumulative impact on ground water quality.** Ground water quality at the site is generally poor, as is most of the ground water in the Rifle vicinity. Historically, background concentrations of molybdenum, selenium, and uranium have exceeded EPA standards. Fluoride, iron, manganese, and sulfate in background water all exceed EPA's secondary drinking water standards. Water at the site also has elevated concentrations of arsenic, selenium, uranium, and vanadium as a result of milling activities.

3.1.7 **The potential for health risks caused by human exposure to constituents.** The only potentially unacceptable risks to humans would occur through regular use of ground water as drinking water in a residential scenario, which currently does not exist. Incidental use would not result in any unacceptable risks. After 100 years of natural flushing or slightly longer, use of ground water as drinking water would not pose risks any greater than using background ground water. Institutional controls and the designation of the site as agricultural/industrial will ensure that ground water will not be used in any manner resulting in human health risks.

3.1.8 **The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to constituents.** There are currently no exposures of wildlife, crops, or vegetation to contaminated ground water. There are no physical structures on site; exposure of physical structures to ground water would result in no physical damage. Water from the site discharges into the Colorado River and is rapidly diluted to undetectable levels, leaving aquatic life unaffected. Institutional controls will prevent exposure of wildlife, crops, and vegetation to contamination. Eventually, contaminant levels will be low enough that exposure to ground water would result in no potential damage.

3.1.9 **The persistence and permanence of the potential adverse effects.** It is possible that ground water contamination could remain at levels determined to be unacceptable for drinking water for the entire 100-year natural flushing time period. However, during that period of time institutional controls will ensure that no improper use of water occurs that could produce adverse effects. Ground water would be acceptable for unrestricted use after the 100-year natural flushing period (or slightly longer if the vanadium ACL is not achieved).

3.1.10 **The presence of underground sources of drinking water and exempted aquifers identified under §144.7 of this chapter.** There are no sources of drinking water or exempted aquifers that can be affected by contamination at the site, as all ground water at the site discharges into the Colorado River.

3.2 Potential Adverse Effects on Hydraulically Connected Surface Water Quality

3.2.1 **The volume and physical and chemical characteristics of the residual radioactive material at the site.** No disposal cell is present at the site. Surface remediation was completed in 1996. Subpile soil analysis indicates that no significant contamination remains in place that would contribute to ground water contamination (see SOWP, Section 5.3.1.3).

3.2.2 **The hydrogeological characteristics of the site and surrounding land.** Only the surficial aquifer at the site is contaminated. It is composed of unconsolidated alluvial material deposited by the Colorado River; the material ranges in size from clay to cobbles. The alluvial material is approximately 20 to 25 feet thick over most of the site. The saturated thickness of the aquifer ranges from 5 to 20 feet. Ground water movement is generally west-southwest. All ground water from the site discharges into the Colorado River. Movement downgradient of the site is prevented by outcrops of impermeable bedrock at the western site boundary. Seeps are located north of the site and an irrigation ditch runs north-south across the site and discharges to the Colorado River. The seeps and ditch provide recharge to the surficial aquifer and are unaffected by site contamination. (Sections 5.1 and 5.2 of the SOWP describe the geology and hydrology of the site, respectively.)

3.2.3 **The quantity and quality of ground water and the direction and of ground water flow.** Ground water flow is generally west-southwest at a rate of 1.4 to 2.0 ft/day. Water quality is poor, with several constituents exceeding ground water standards. For a detailed discussion of ground water quality, see Section 5.3.3 of the SOWP. The quantity of contaminated ground water is estimated at approximately 30 million gallons.

3.2.4 **The patterns of rainfall in the region.** The site receives on average approximately 11.0 inches of total precipitation per year. Rainfall occurs during the summer in high-intensity, short-duration, late afternoon thunderstorms that are conducive to runoff. Precipitation occurs in the winter as snowfall. Precipitation events have no measurable effect on quality of water in the Colorado River as a result of site contamination.

3.2.5 **The proximity of the site to surface waters.** The Colorado River forms the southern boundary of the site.

3.2.6 **The current and future uses of surface waters in the region surrounding the site and any water-quality standards established for those surface waters.** The Colorado River in the site vicinity is classified for use as recreation, water supply (i.e., source of drinking water for a community), and agriculture. Water quality standards for the river are established in Regulation No. 37 of the Colorado Department of Public Health and the Environment's Water Quality Control Commission. The river water in the site vicinity does not exceed any of these standards or any of the Colorado state standards established for agricultural water use. No drinking water standards for human health or water quality criteria for aquatic life are exceeded. For details about surface water quality, see Section 5.3.2 of the SOWP.

3.2.7 **The existing quality of surface water, including other sources of contamination and the cumulative impact on surface water quality.** Water in the Colorado River is the vicinity of the site is designated high quality by the State of Colorado. The site has no measurable impact on the river water quality. Water in the vicinity of the site is indistinguishable from background Colorado River water samples.

3.2.8 **The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to constituents.** There is no potential damage as site contamination has no impact on the Colorado River quality.

3.2.9 **The persistence and permanence of potential adverse effects.** No adverse affects are currently present in the Colorado River and none are expected in the future.

4.0 "Roadmap" to the Old Rifle SOWP

4.1 General Information

4.1.1 Introduction—Section 1.0 of SOWP
4.1.2 Facility Description—Sections 3.2 and 5.3.1 of SOWP
4.1.3 Extent of Ground Water Contamination—Section 5.3.3.2 of SOWP
4.1.4 Current Ground Water Protection Standards—Table 2–1 of SOWP
4.1.5 Proposed Alternate Concentration Limits—Section 2.3.2 of GCAP

4.2 Hazard Assessment—Generally corresponds to Section 6 of SOWP, which contains human health and ecological risk assessments

4.2.1 Source and Contamination Characterization—Sections 5.3.1 and Table 6–1 of SOWP

4.2.2 Transport Assessment—Section 5.3.5 and Appendix D of SOWP
4.2.3 Exposure Assessment—Sections 6.1.2.2 and 6.1.2.3 of SOWP for human health; Sections 6.2.2.2, 6.2.2.3, and 6.2.2.4 of SOWP for ecological risk

4.3 Corrective Action Assessment

4.3.1 Results of Corrective Action Program

Two phases of remedial action were performed to reduce the potential for exposure to contaminated soils at the Old Rifle site. Approximately 13 acres of tailings remained at the Old Rifle site before the surface remedial action. The relatively flat tailings pile was stabilized by Union Carbide in 1967 in accordance with the State of Colorado regulations. The edge of the pile was moved away from the railroad tracks and the entire pile was covered with 6 inches of soil, fertilized, and seeded with native grasses. Water from the Colorado River was used for irrigation. Surface water draining from an upgradient seep across U.S. Highway 6 flowed through the site. The seep water collected in a lined pond after it passed the tailings pile. Overflow from the pond was released into the Colorado River. The pond and tailings were removed during the second phase of surface remedial action completed in 1996. They were disposed in an off-site disposal cell.

The Colorado Department of Public Health and Environment (CDPHE) currently owns the site, with plans to eventually transfer it to the City of Rifle. A deed restriction will be placed on the property at the time of transfer that prohibits use of ground water for any purpose without permission of both U.S. Department of Energy (DOE) and CDPHE.

4.3.2 Feasibility of Alternative Corrective Actions

DOE has performed remedial action at the Old Rifle site to mitigate exposures to contaminated soils. The cleanup effectively removed the source of the contaminants that were potentially affecting ground water. However, residual contamination does exist in ground water. All contaminants at the Old Rifle site that have cleanup standards will flush to those standards in the 100 years allotted for natural flushing to occur. The State of Colorado and national primary drinking water standards of 0.05 mg/L is proposed as an ACL for selenium, as background concentrations of selenium exceed the UMTRA standard of 0.01 mg/L. Vanadium does not have a cleanup standard so an ACL also is being proposed. The NRC requires a reasonable analysis of alternate corrective actions in order to assess the benefits of the ACL application. Because the ACL being proposed for selenium is an accepted standard, the focus of this analysis is on corrective actions for vanadium.

"Hot Spot" Pump-and-Treat

The most common approach to mitigating ground water contamination is an active ground water withdrawal and ex situ treatment process (commonly referred to as a pump-and-treat method). One or more pumping wells are typically installed to hydraulically capture the contaminant plume, and the discharge water undergoes some form of ex situ treatment. Pump-and-treat methods are typically time-consuming and costly because of the complex nature of contaminant transport processes in heterogeneous media. Depending on the cleanup criteria, some pump-and-treat operations have not been able to meet their technical objectives because of heterogeneities and sorption characteristics of the aquifer matrix. Despite the potential shortcomings, it is still considered the baseline technology for a comparison of alternatives.

An alternatives analysis for the New Rifle site (located 2.3 miles west of the City of Rifle) indicated the most promising treatment technology for vanadium was zero valent iron (ZVI) (DOE 1999b). A pilot study is currently underway at that site to evaluate the feasibility of using ZVI. Much higher concentrations of vanadium occur in New Rifle ground water than Old Rifle ground water. Preliminary results for using ZVI are promising. Therefore, for this evaluation, ZVI is assumed as the optimum treatment technology with vertical wells used for extraction of water.

Pump-and-treat is feasible for the Old Rifle site only if vanadium can be easily extracted from the aquifer. Laboratory studies for aquifer material from the Old Rifle site indicate that vanadium is likely to be strongly sorbed to the solid phase in the aquifer (DOE 1999a). Therefore, it is likely to require numerous pore volumes of water to be extracted from the plume area before a significant reduction in ground water concentration can be achieved. However, because modeling results indicate that natural flushing alone will come close to achieving the human-health risk-based value of 0.33 mg/L for vanadium, it is assumed that marginal improvements that could be made by a limited duration pump-and-treat would enhance the natural flushing process.

For purposes of this analysis, an 18-month duration for hot-spot pump-and-treat is assumed. This should be a long enough duration to make some improvements in ground water quality. After that time, the ground water model for the site would be re-run and natural flushing re-evaluated. The vanadium plume covers and area roughly 240,000 square feet (ft^2) with an average saturated thickness of 15 feet (ft). Assuming a porosity of 0.25, one pore volume of water would consist of 6.7 million gallons. A reasonable and sustainable pumping rate for the Old Rifle site over the size of the plume would be approximately 40 gallons per minute (gpm). If water were extracted at this rate over 18 months at a 90 percent efficiency rate, just over 4 pore volumes of water could be extracted. This might not reduce concentrations of vanadium to levels required for unrestricted use, but should be sufficient to allow natural flushing to do so within a 100-year time frame.

In-Situ Stabilization

An alternative to removal of vanadium from the ground water followed by ex situ treatment might be in-situ stabilization of vanadium. The vanadium could be stabilized in place by increasing the amount partitioned into the immobile sold fraction. If the sorbent concentration in the aquifer is increased, partitioning of vanadium to the immobile solids will be enhanced and the concentration in ground water will be reduced.

One means of increasing the sorptive portion of the aquifer is to introduce ferric oxyhydroxide. This can be accomplished by injecting dissolved ferric chloride into the aquifer. The acidic ferric chloride solution reacts with alkaline aquifer materials and precipitates ferric oxyhydroxide which immobilizes vanadium by incorporating it in a semicrystalline structure. Treatability tests and a pilot demonstration would be required to determine the acid-neutralizing capacity of the aquifer and the ability of the ferric oxyhydroxide to incorporate vanadium, as well as the feasibility of the injection process.

4.3.3 Corrective Action Costs

Detailed cost estimates were not conducted for Old Rifle remedial alternatives, as a comparative analysis of alternatives was not completed for the Old Rifle SOWP. Costs reported here can be considered as order-of-magnitude estimates and are provided for a relative comparison only. Costs are based on estimates developed for the New Rifle site (DOE 1999b), which is similar in geology and chemistry to the Old Rifle site.

Pump-and-Treat

A pump-and-treat system would require installation of extraction wells, construction and installation of a treatment system, and injection or disposal of system effluent. Costs would also be incurred for operation and maintenance of the system. Capital costs for a pumping system capable of extracting 30 gpm are estimated at $52,500. Annual operation and maintenance costs are estimated at $1,550 for the pumping system. Capital costs for the ZVI system is estimated at $76,000 with annual operating costs of about $57,000, including costs for disposal of spent ZVI. Costs for effluent discharge are not included, as these would depend on the quality of the effluent and could only be determined after completion of a site-specific pilot study. The 18-month present worth cost of this treatment alternative, excluding effluent disposal, is estimated at $0.22 million.

In-Situ Stabilization

The process for stabilizing vanadium in situ has not been developed or demonstrated, so no meaningful cost estimate can be prepared at this time. Costs will be required for chemicals used and development of a process for injecting chemicals into the ground in such a way that subterranean mixing is optimized. Monitoring of the subsurface in some fashion would also be required. However, in-situ stabilization will not require extraction, treatment or effluent disposal systems and is therefore expected to cost less than a pump-and-treat system.

4.3.4 Corrective Action Benefits

After 100 years, the maximum concentration of vanadium at the Old Rifle site is estimated to be close to the proposed ACL of 0.33 mg/L; active remediation would probably have a marginal effect on the length required to achieve compliance. Residential use of the land is improbable; the risk-based concentration is calculated based on highly conservative assumptions and relies on toxicity data with a 100-fold uncertainty factor applied. The plume is predicted to be approximately 150 ft by 150 ft in area, and would contain approximately 4 million gallons of ground water. Under the pump-and-treat situation evaluated, 28 million gallons of water would be pumped and treated. The benefits of taking this action to reduce the remediation timeframe only marginally are negligible.

In situ stabilization would immobilize vanadium and tie it up in the solid phase. If successful, this would allow for the unlikely use of ground water in a residential setting. The main potential benefit for immobilization would be to reduce ecological risks as the plume migrates and discharges to the Colorado River. However, dilution of contaminants by the river is very high (5 orders of magnitude) and plume immobilization therefore provides no benefit.

4.3.5 ALARA Demonstration

The As Low As Reasonable Achievable (ALARA) concept does not directly apply to the ACL proposed for vanadium because its intent is to limit exposure to radioactivity. However, the general goal of achieving a cleanup goal that is as low as can reasonably be met is satisfied by applying an ACL for vanadium at the site. As described above, it would not be reasonable to pursue active remediation for the very small amount of potential risk reduction that could be realized by doing so, particularly with the large degree of uncertainty that active remediation would by successful.

4.4 Proposed Alternate Concentration Limits

- 4.4.1 Proposed Alternate Concentration Limits—Section 2.3.2 of GCAP
- 4.4.2 Proposed Implementation Measures—Section 7.3 of SOWP; Sections 2.5 and 2.6 of the GCAP)

4.5 References—Section 8 of SOWP

4.6 Appendices and Supporting Information—Appendices A through E of SOWP

5.0 References

10 CFR Part 40. "Domestic Licensing of Source Material," *U.S. Code of Federal Regulations*, June 1, 1994.

40 CFR Part 192. "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings," *U.S. Code of Federal Regulations*, July 1, 1996.

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Attachment 2

Old Rifle Site Ground Water Monitoring Plan

U.S. Department of Energy

UMTRA Ground Water Project

Ground Water Monitoring Plan

Old Rifle Site, Colorado

June 2001

Prepared by
U.S. Department of Energy
Grand Junction Office
Grand Junction, Colorado

Project Number UGW–511–0017–26–000
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1.0 Introduction

Natural flushing with institutional controls, the application of alternate concentration limits (ACLs), and monitoring was selected as the compliance strategy for the Old Rifle Uranium Mill Tailings Remedial Action (UMTRA) ground water site near Rifle, Colorado. Ground water modeling has predicted that levels of the three contaminants of concern (COCs)—uranium, vanadium, and selenium—will be reduced to their target remediation levels by natural flushing in a timeframe of 100 years or less. Monitoring of the ground water quality is necessary to determine if contaminant levels are changing as predicted and ensure that the flushing process is working satisfactorily. This plan describes the monitoring and sampling approach.

2.0 Purpose and Scope

This plan first provides a very brief site background. More detailed descriptions of the site can be found in numerous documents including the *Final Site Observational Work Plan for the UMTRA Project Old Rifle Site* (SOWP; DOE 1999). The monitoring plan is then described and includes a discussion of the monitoring network, analytes, sampling methods and procedures, and quality assurance/quality control (QA/QC) measures. A discussion is provided regarding data interpretation and evaluation of the progress of natural flushing. Lastly, environmental compliance issues are addressed.

3.0 Site Background

The Old Rifle UMTRA Project site is a former ore-processing facility located approximately 0.3 mile east of the city of Rifle in Garfield County, Colorado.

The Old Rifle site is located along a low-lying erosional meander of the Colorado River. The alluvial floodplain consists of a complex interfingering of fine and coarse-grain materials, which contain sand, silt, gravel, and cobbles, with a uniform thickness of approximately 20 to 25 feet. Depth to ground water ranges from 5 to 15 feet below land surface. The alluvium directly overlies an 8- to 13-foot section of weathered Wasatch Formation claystone that appears to be hydraulically connected to, and of similar hydraulic characteristics as, the unconsolidated sediments of the alluvium.

The resistant cliff-forming beds of the Wasatch Formation control the western, northern, and eastern extent of the alluvium at the site. Ground water beneath the site generally flows in a southwestern direction with a hydraulic gradient of approximately 0.004 ft/ft. Recharge to the alluvial aquifer occurs mostly as infiltration of precipitation, leakage from the drainage ditches north of U.S. Highway 6, and leakage from the open ditch that extends north to south across the site. The Colorado River bounds the site on the south and the alluvial aquifer discharges ground water to the river along most of the site extent. The conceptual site model is presented in Section 5.0 of the SOWP (DOE 1999).

Site-specific field investigations reveal the alluvial ground water is the only aquifer affected by the former milling operations. COCs in the alluvial aquifer are identified as selenium, uranium, and vanadium. Uranium is the most prevalent site-related contaminant occurring in the alluvial ground water. Figures 1, 2, and 3 show the distribution of uranium, selenium, and vanadium, respectively, in May of 1998 at the start of current monitoring activities.

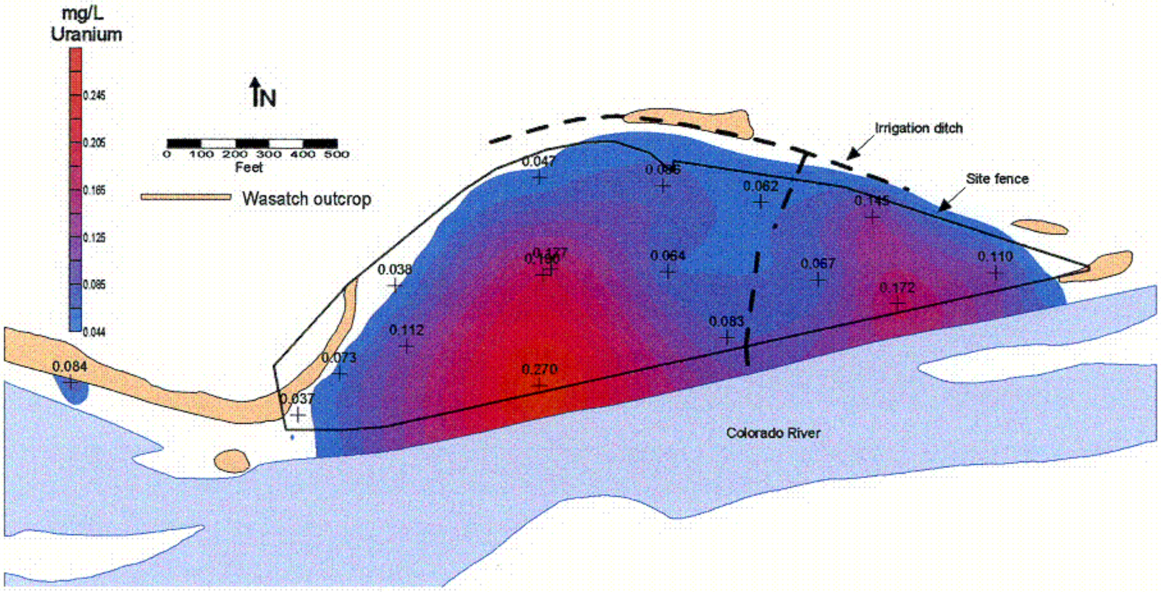

Figure 1. Uranium Distribution in Alluvial Aquifer—Old Rifle, May 1998

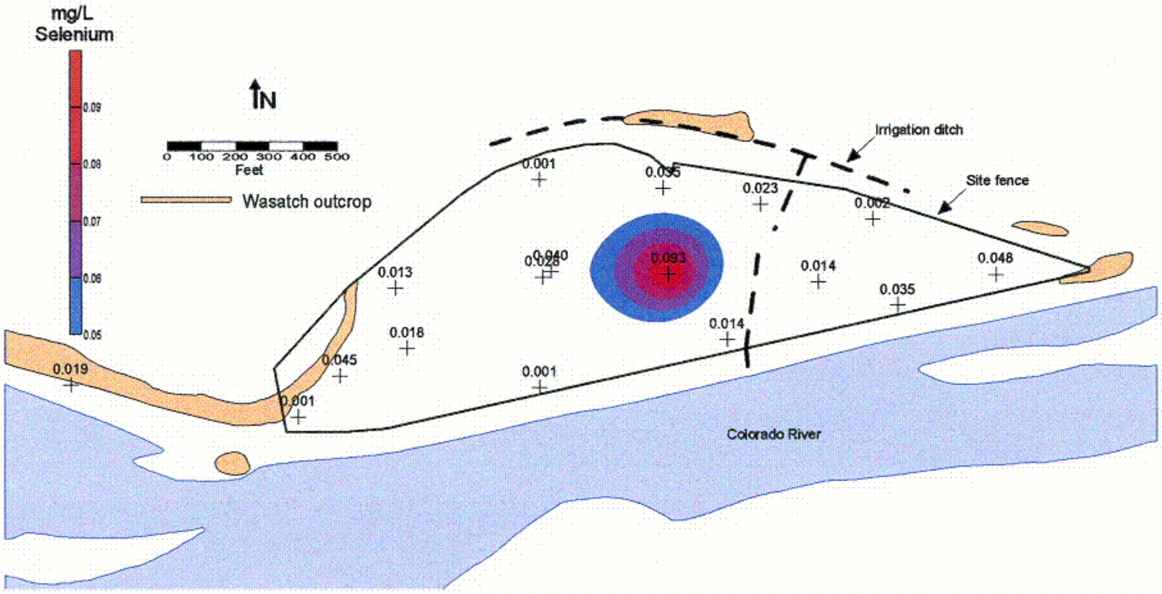

Figure 2. Selenium Distribution in Alluvial Aquifer—Old Rifle, May 1998

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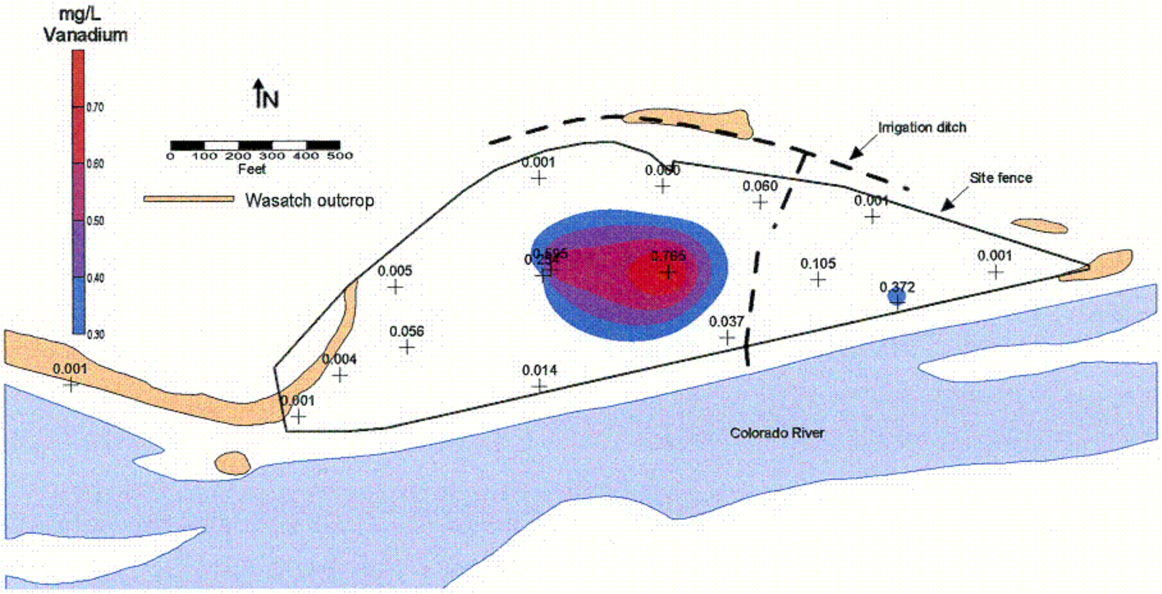

Figure 3. Vanadium Distribution in Alluvial Aquifer—Old Rifle, May 1998

Computer ground water flow and contaminant transport modeling was done to assist in forecasting whether natural flushing of the major COCs (uranium, selenium, and vanadium) is a viable remediation alternative. Modeling was done using the MODFLOW code for ground water flow and the MT3D code for contaminant transport. These codes are described and referenced in the SOWP (DOE 1999) and have been verified, benchmarked, and approved for use by most government and regulatory agencies. The results of this modeling are summarized below. Comparative modeling was done using the probabilistic code GANDT, developed by Sandia National Laboratories and produced similar results.

Uranium is predicted to decrease to levels below the UMTRA standard after a period of just 10 years. However, it should be noted that a background concentration of 0.038 milligrams per liter (mg/L) uranium was used for purposes of ground water modeling. This is the average calculated background uranium concentration. Levels of uranium in excess of 0.06 mg/L have been observed in one background well. Therefore, the compliance standard for uranium in site ground water may be either background or the UMTRA maximum concentration limit (MCL). The monitoring strategy is designed to account for variations in background uranium that may exceed the UMTRA standard.

For selenium, an ACL was proposed as the cleanup standard because of naturally high occurrences of selenium in the alluvial aquifer near Rifle. Maximum selenium concentrations after 50 years are predicted to be at the proposed ACL—the Safe Drinking Water Act (SDWA) standard of 0.05 mg/L—in the most contaminated portion of the plume. Background wells had concentrations of selenium up to nearly 3 times the UMTRA standard based on results from the most recent sampling round. However, these concentrations have been determined to be protective of human health and the environment (DOE 1999).

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No drinking water standard exists for vanadium; however, plume concentrations currently exceed the risk-based concentration for human health as well as the phytotoxicity value for plants (0.33 mg/L and 0.2 mg/L, respectively; EPA 2000 and Efroymson, et al. 1997). The maximum predicted concentration for vanadium after 100 years of natural flushing is approximately 0.35 mg/L, a value slightly above the risk-based concentration of 0.33 mg/L for human health and almost double the phytotoxicity value for plants. However, because institutional controls at the site prohibit the use of ground water for any purpose, the only potential exposure to ground water occurs where ground water discharges to the Colorado River along the southern boundary of the site.

The highest concentration of vanadium at the site during the last few years of monitoring has been approximately 0.9 mg/L. This concentration on-site is protective of aquatic life at the point of exposure (POE) because of the large amount of dilution that occurs as ground water discharges to the Colorado River. An ACL of 0.33 mg/L is proposed for vanadium at the POE. An action level at the point of compliance (POC; any on-site well) of 1.0 mg/L vanadium is proposed. If the action level is exceeded, corrective action may be triggered. If the action level is maintained at the POC, vanadium concentrations at the POE will be protective of all potential receptors. Modeling indicates that vanadium could be reduced to the ACL after 100 years of natural flushing, though it could take a slightly longer period of time. Institutional controls would be maintained until the ACL is achieved at all on-site wells.

4.0 Ground Water and Surface Water Sampling and Analysis

4.1 Monitoring Strategy

The monitoring strategy for the alluvial aquifer is designed to determine progress of the natural flushing process in meeting compliance standards for site COCs. Standards for selenium and vanadium are their proposed ACLs of 0.05 mg/L and 0.33 mg/L, respectively. For uranium the cleanup goal is the UMTRA standard of 0.044 mg/L or background, whichever is higher. Monitoring will focus on these three contaminants. Arsenic, while exceeding human health and ecological risk benchmarks, has decreased to below the UMTRA standard of 0.05 mg/L and is at or below the detection limit for most on-site wells. Because of the limited extent of arsenic contamination and the fact that it meets UMTRA ground water standards, monitoring of arsenic at the Old Rifle site is not proposed. By the time the other contaminants have decreased to target goals, arsenic should be at background concentrations based on its limited extent and historic trends.

Monitor wells 305, 656, 655, 309, 310, 304, and 292 have been established as appropriate for monitoring the progress of natural flushing in the alluvial aquifer (Figure 4 and Table 1). Well 656 is located in the center of the plume on the east side of the ditch which flows through the site and well 655 is at the center of the plume on the west side of the ditch. The highest concentrations of selenium and vanadium were detected in these wells during recent sampling events. Elevated concentrations of uranium were also detected in samples from these wells. Wells 304, 309, and 310 are located on the farthest downgradient edge of the plume. Well 310 had the highest concentrations of uranium detected in samples collected in 1998, suggesting that the center of this plume has already migrated downgradient in this direction. Therefore, the wells included in this monitoring network should be adequate for tracking the progress of natural flushing. Well 292 is an upgradient background well.

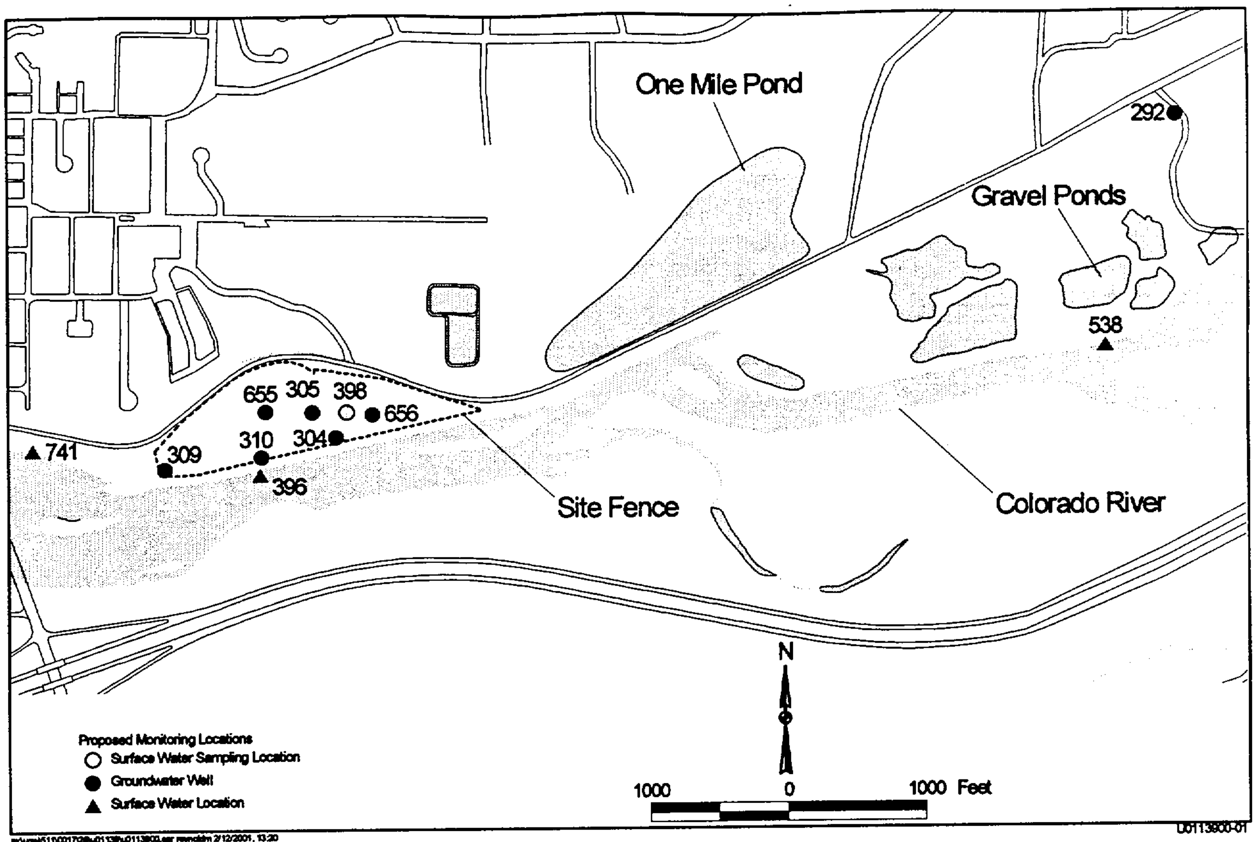

Figure 4. Proposed Monitoring Locations for the Old Rifle Site

Table 1. Summary of Monitoring Requirements

Location	Monitoring Purpose	Analytes	Frequency[a]
RFO–305, –655	Center of plume west side of ditch	Se, U, V	Twice yearly for 5 years; at least every 5 years thereafter until 2030
RFO–656	Center of plume east side of ditch	Se, U, V	Twice yearly for 5 years; at least every 5 years thereafter until 2030
RFO–304, –309, –310	Most downgradient location; leading edge of plume	Se, U, V	Twice yearly for 5 years; at least every 5 years thereafter until 2030
RFO–292	Background ground water quality; upgradient monitor well	Se, U, V	Twice yearly for 5 years; at least every 5 years thereafter until 2030
RFO–398	Monitor background U recharging aquifer; on-site ditch	U	Twice yearly for 5 years; at least every 5 years thereafter until 2030
RFO–538, –396, –741	Upgradient, adjacent to site, and downgradient locations on Colorado River; monitor effect of site on river	Se, U, V	Twice yearly for 5 years; at least every 5 years thereafter until 2030

[a] Annual monitoring will be initiated when contaminant decreases at or below respective compliance standard. Monitoring will be discontinued after demonstrating the contaminant has remained below compliance levels for 3 consecutive years.

Monitoring of wells 305, 655, and 656 will take place until contaminants have decreased to their respective compliance standards for 3 consecutive years. At that time, monitoring for that contaminant will be discontinued. This is consistent with the approach established for monitoring Resource Conservation and Recovery Act (RCRA) corrective actions. Samples will also be collected from the onsite ditch at location 398 to monitor background uranium concentrations recharging the aquifer. If onsite wells appear to have leveled off in uranium concentration, but still exceed the UMTRA standard, results of the ditch samples and background well 292 will be used to determine if onsite samples are statistically similar to background and have met the compliance standard. RFO–538, –396, and –731 are upgradient, adjacent to the site, and downgradient locations, respectively, along the Colorado River. These surface water locations will be monitored to ensure contamination from the site does not affect the river water quality. Surface water samples will be analyzed for the COCs until each COC has peaked on wells 309 and 310 at the downgradient edge of the site and then decreased to acceptable levels for 3 consecutive years. At that time the COC can be dropped from surface water locations.

Contaminant concentrations in most samples collected from downgradient wells 304, 309, and 310 are below target cleanup goals with the exception of uranium. Ground water modeling results show that concentrations of selenium and vanadium are expected to increase slightly before reaching steadily declining levels. However, neither is expected to increase above its respective ACL. Monitoring of these constituents will take place for 5 years to better understand their behavior. At that time the need to continue to analyze for them in downgradient wells will be reassessed.

Monitoring will take place twice yearly for the first 5 years—at high river stage and at low river stage. Data will be evaluated at that time to determine whether monitoring frequency should be adjusted. Monitoring will take place at least every 5 years until the year 2030. At that time the monitoring strategy will be reevaluated and adjusted as appropriate based on previous results. To accommodate the specification of observing concentrations of COCs at or below the compliance standards for 3 consecutive years before discontinuing monitoring for that constituent, an annual monitoring frequency will be imposed as necessary to make this determination. If uranium concentrations decrease as predicted by the modeling, this should occur within the initial 10-year time frame. In the case of selenium and vanadium, the predicted periods for reaching the compliance standards are 50 and 100 years, respectively. Monitoring requirements are summarized in Table 1.

Abandonment of all other monitor wells at the Old Rifle site no longer needed for compliance monitoring will be undertaken in the near future in accordance with applicable Colorado State regulations. This will be accomplished under the Long-Term Surveillance and Maintenance (LTSM) program.

4.2 Ground Water and Surface Water Sampling

Ground water and surface water sampling will be performed in accordance with the *Addendum to the Sampling and Analysis Plan for the UMTRA Ground Water Project* (DOE 1996) and the *Environmental Procedures Catalog* (GJO 1997). Ground water samples will be collected from each of the wells and the surface water location specified in Table 1 and submitted to the Grand Junction Office (GJO) Analytical Laboratory for analysis. Samples will be collected twice a year—once during high river flow (May—June) and once during low flow (October—February) for the first 5 years of monitoring.

The following procedures from the *Environmental Procedures Catalog* (GJO 1997) will be used for ground-water sampling:

- GN-8(P), "Standard Practice for Sample Labeling."

- GN-9(P), "Standard Practice for Chain-of-Sample-Custody and Physical Security of Samples."
- GN-13(JP), "Standard Practice for Equipment Decontamination."
- LQ-2(T), "Standard Test Method for the Measurement of Water Levels in Ground Water Monitor Wells."
- LQ-3(P), "Standard Practice for Purging Monitor Wells."
- LQ-4(T), "Standard Test Method for the Field Measurement of pH."
- LQ-5(T), "Standard Test Method for the Field Measurement of Specific Conductance."
- LQ-6(T), "Standard Test Method for the Field Measurement of the Oxidation-Reduction Potential (Eh)."
- LQ-7(T), "Standard Test Method for the Field Measurement of Alkalinity."
- LQ-8(T), "Standard Test Method for the Field Measurement of Temperature."
- LQ-9(T), "Standard Test Method for the Field Measurement of Dissolved Oxygen."
- LQ-10(T), "Standard Test Method for Turbidity in Water."
- LQ-11(P), "Standard Practice for Sampling Liquids."
- LQ-12(P), "Standard Practice for the Collection, Filtration, and Preservation of Liquid Samples."

4.3 GJO Laboratory Analysis

Ground water and surface water samples will be submitted to the GJO Analytical Laboratory. All procedures will be checked for accuracy through internal laboratory QC checks (e.g., analysis of blind duplicates, splits, and known standards). Sample preservation will consist of storing the samples in an ice chest with Blue Ice (or equivalent) to cool samples during field sampling, packaging, and shipping. Ground water samples will be analyzed for total dissolved solids (TDS) and the three COCs—uranium, vanadium, and selenium.

4.4 Quality Assurance and Quality Control

The objective of QA and QC measures is to provide systematic control of all tasks so as to maximize accuracy, precision, comparability, and completeness. Basic sampling procedures are presented in the *Environmental Procedures Catalog* (GJO 1997). Deviations from these procedures will be noted in a Field Variance Log with an explanation and a description of its possible effect on data quality.

4.4.1 Sample Control

To maintain evidence of authenticity, the samples collected must be properly identified and easily distinguished from other samples. Samples collected at the Old Rifle site will be identified by a label attached to the sample container specifying the sample identification number, location, date collected, time collected, and the sampler's name or initials.

Ground water and surface water samples for laboratory analysis will be kept under custody from the time of collection to the time of analysis. Chain-of-custody forms will be used to list all sample transfers to show that the sample was in constant custody between collection and analysis.

While the samples are in shipment to the GJO Analytical Laboratory, custody seals will be placed over the cooler opening to ensure that the integrity of the samples has not been compromised. The receiving laboratory must examine the seals on arrival and document that the seals are intact. Upon opening the container, the receiving laboratory will note the condition of the sample containers (e.g., broken or leaking bottles).

4.4.2 Laboratory Quality Control

Laboratory QC will follow the specifications in relevant EPA (SW-846) or the *Handbook of Analytical and Sample-Preparation Procedures,* Volumes I, II, III, and IV (*WASTREN-GJ,* undated). Quality control will include analysis of blanks, duplicates, spikes, and check samples.

5.0 Data Evaluation and Interpretation

5.1 Preliminary Monitoring Results

Six rounds of monitoring data are available at this time. Time-concentration plots for on-site and background monitoring wells are shown in Figures 5 through 10 for selenium, uranium, and vanadium. Well RFO–292 represents background. Appendix A contains similar plots for each plume well along with predicted concentrations as determined by ground water modeling conducted as part of the SOWP. (Well RFO–305 was inadvertently omitted during one round of sampling so only five rounds of data are available for this location.) With the exception of uranium for wells RFO–310, which displays a nearly consistently decreasing trend, minor to large fluctuations in concentration occur. Part of this may be attributable to a seasonal effect, particularly for wells at the low end of the concentration range. Background well RFO–292 fluctuations are probably typical seasonal variations; wells with contaminant concentrations similar to background display also display similar patterns (Figures 7 and 8).

Figures 1, 2, and 3 indicate the estimated distribution of contaminants at the start of the monitoring period (May 1998) used in the ground water model. If the actual distribution did not closely match this, it would account for some of the discrepancy between modeled and observed concentrations and the seeming lack of well-defined trends.

The figures included in Appendix A show both observed and predicted contaminant concentrations for each well in the monitoring network. Each predicted measurement shows an error bar representing ±3 standard deviations. These are based on uncertainty in model parameters such as hydraulic conductivity, distribution coefficients, and hydraulic gradients, among others. As can be seen, depending on the well, these error bars can span quite a wide concentration range. Though not shown, a similar uncertainty range could be calculated for each observed measurement to take into account analytical uncertainty, sampling uncertainty, and seasonal variation. Because of the uncertainty associated with both sets of data, it is unlikely that any rigorous statistical comparison of the data sets would be meaningful. Current work being done by Oak Ridge National Laboratory (Alan Lasse, personal communication) has shown that in many cases, monitoring periods of less than 30 or 40 years yield inconclusive results regarding the effectiveness of natural flushing.

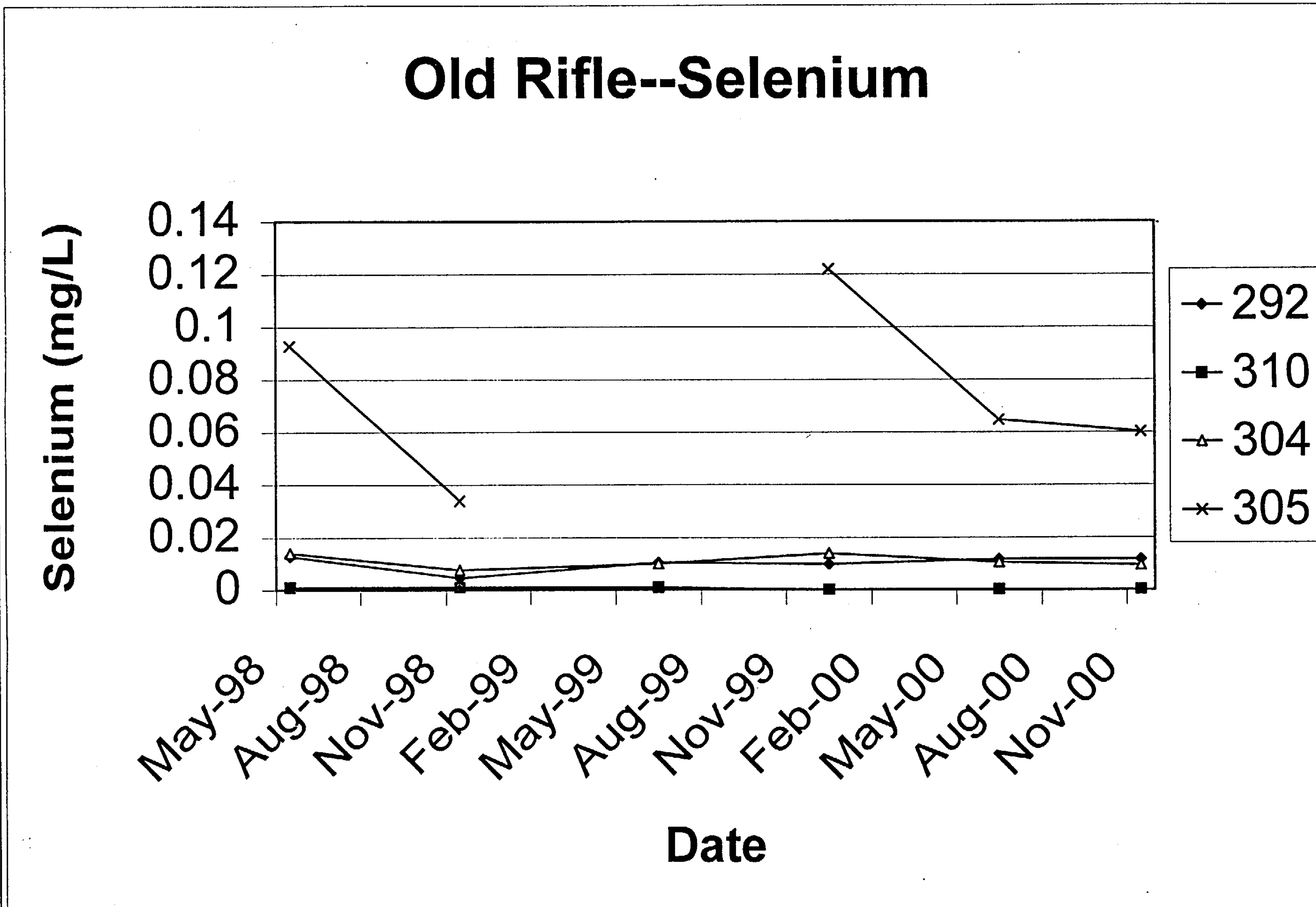

Figure 5. Time-Concentration Plot for Selenium for Old Rifle Wells 292, 304, 305, and 310

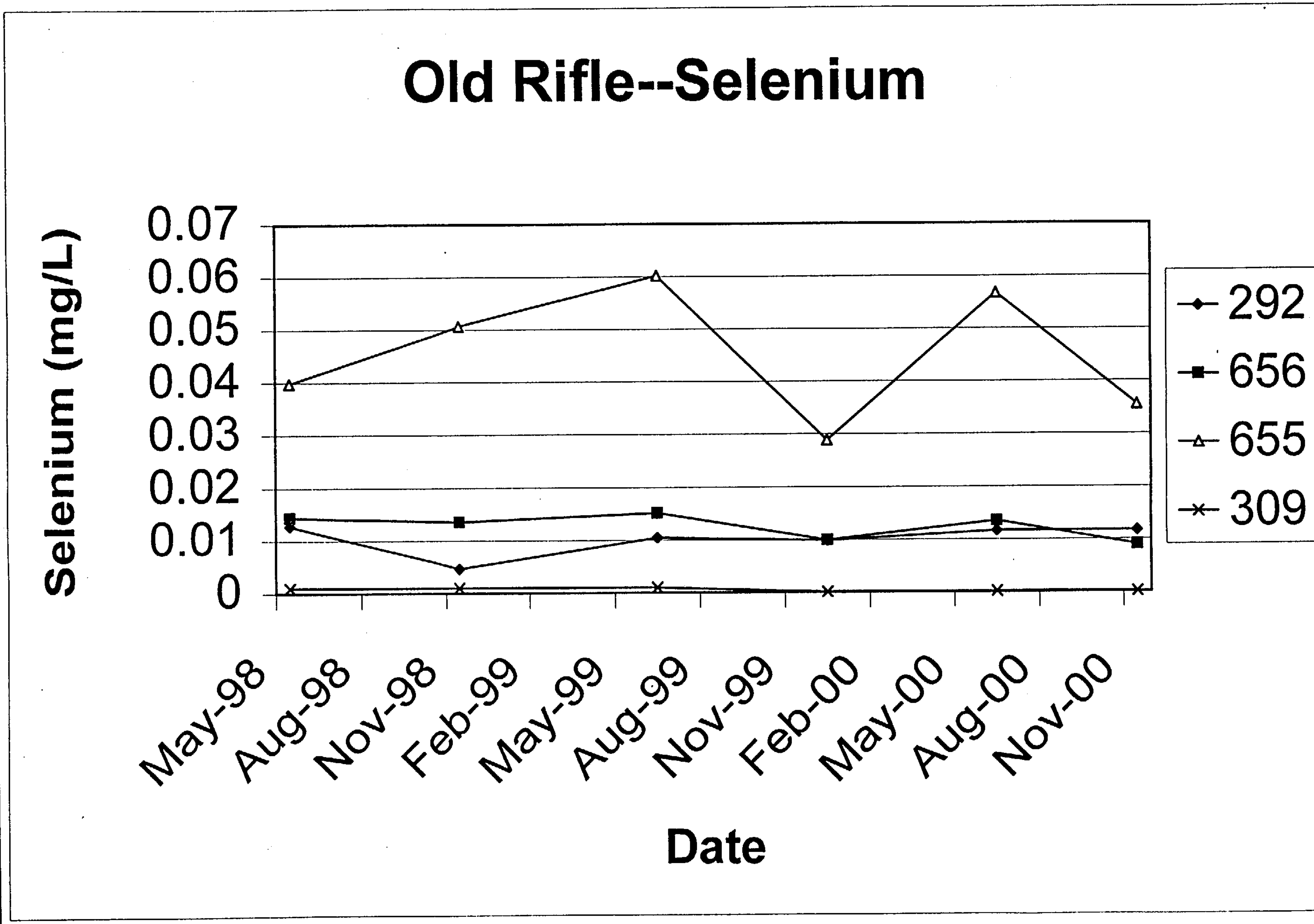

Figure 6. Time-Concentration Plot for Selenium for Old Rifle Wells 292, 309, 655, and 656

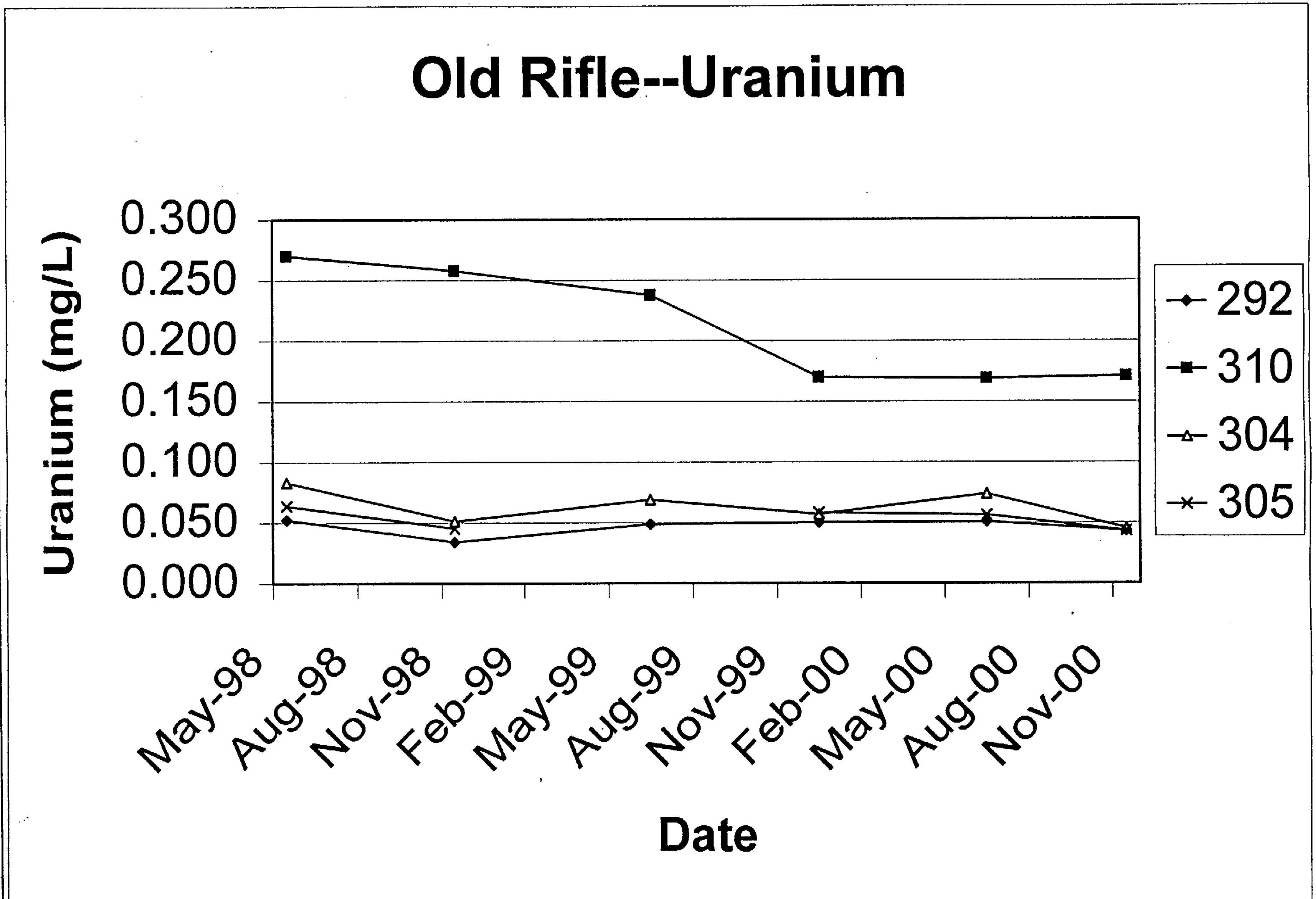

Figure 7. Time-Concentration Plot for Uranium for Old Rifle Wells 292, 304, 305, and 310

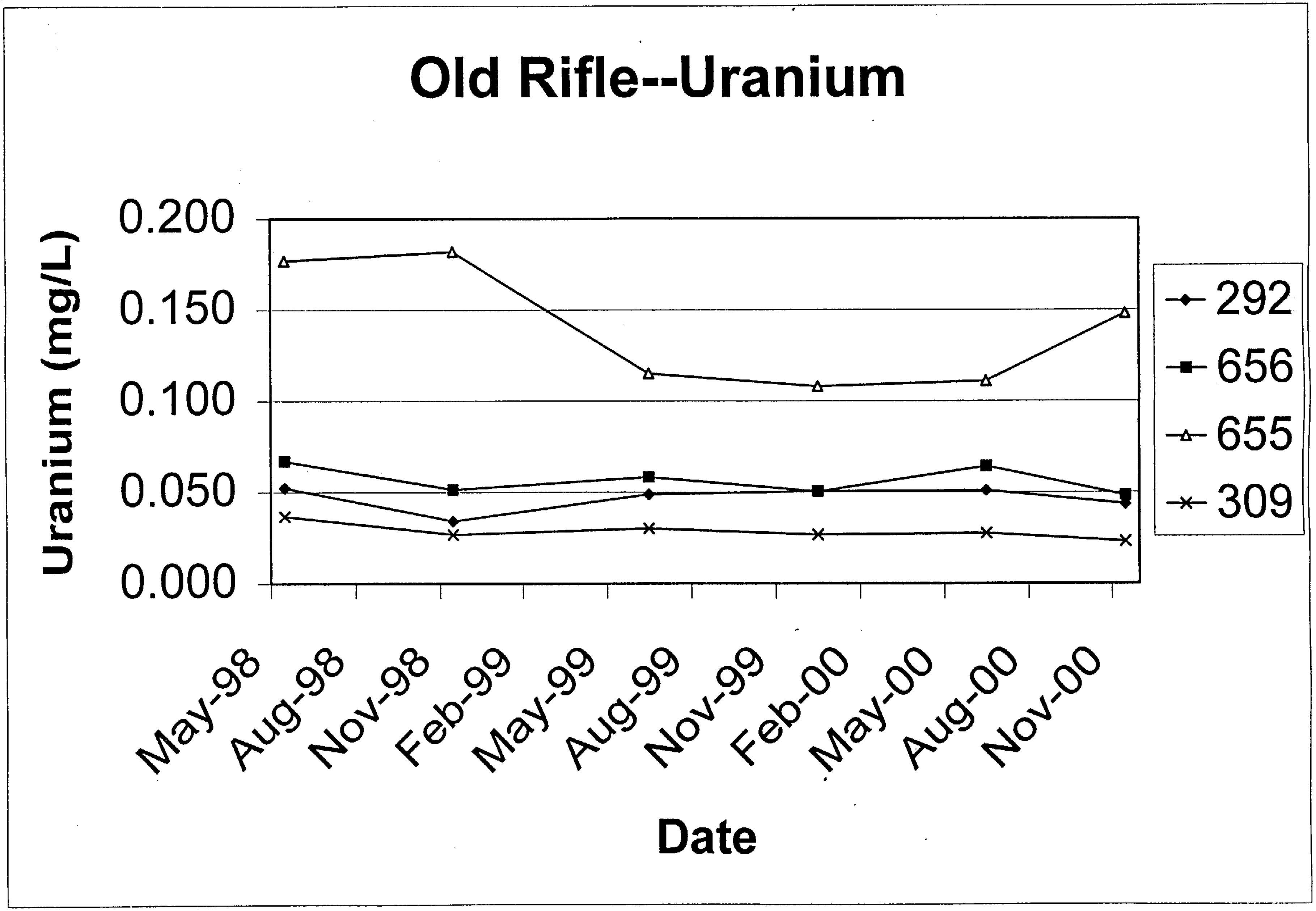

Figure 8. Time-Concentration Plot for Uranium for Old Rifle Wells 292, 309, 655, and 656

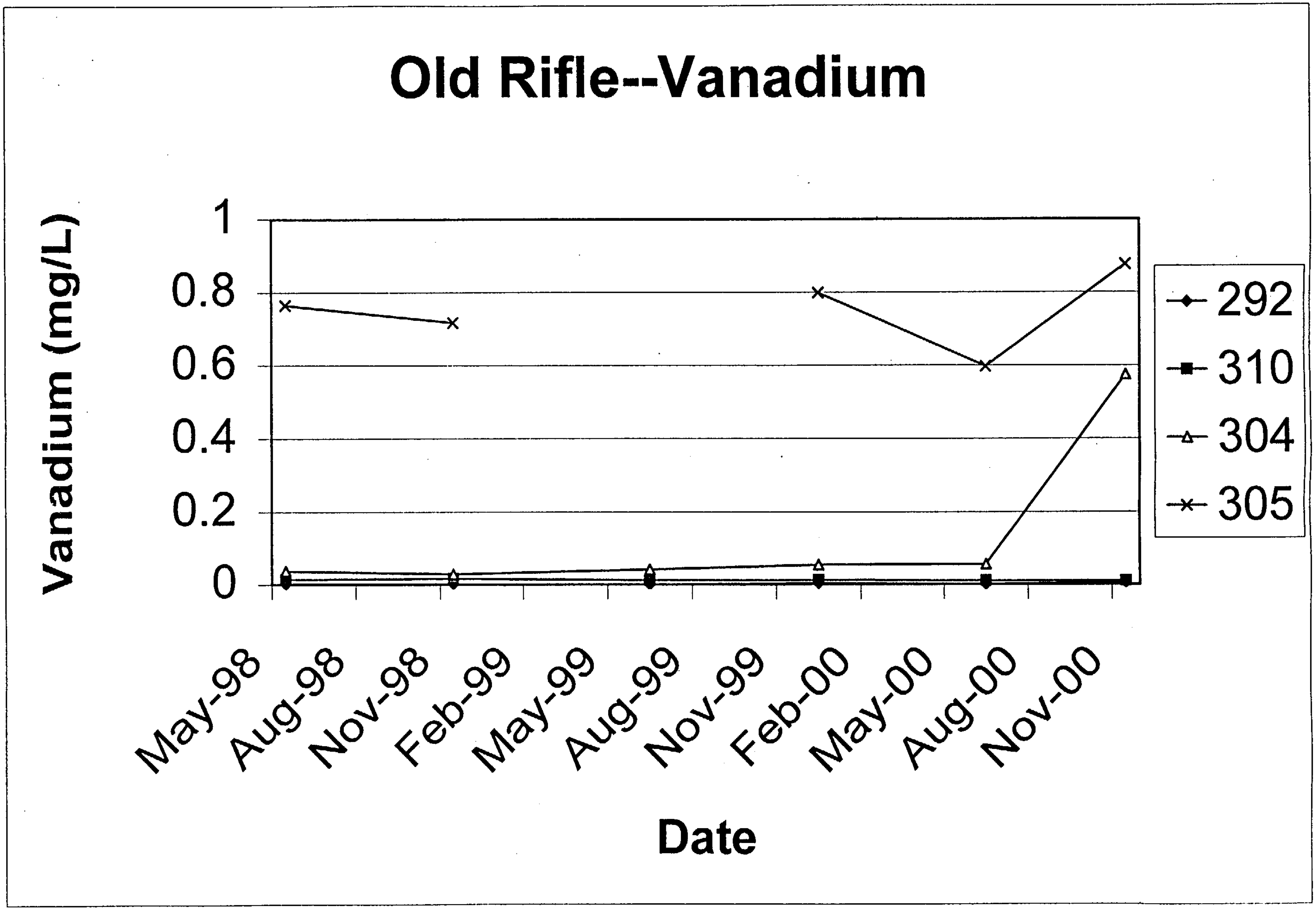

Figure 9. Time-Concentration Plot for Vanadium for Old Rifle Wells 292, 304, 305, and 310

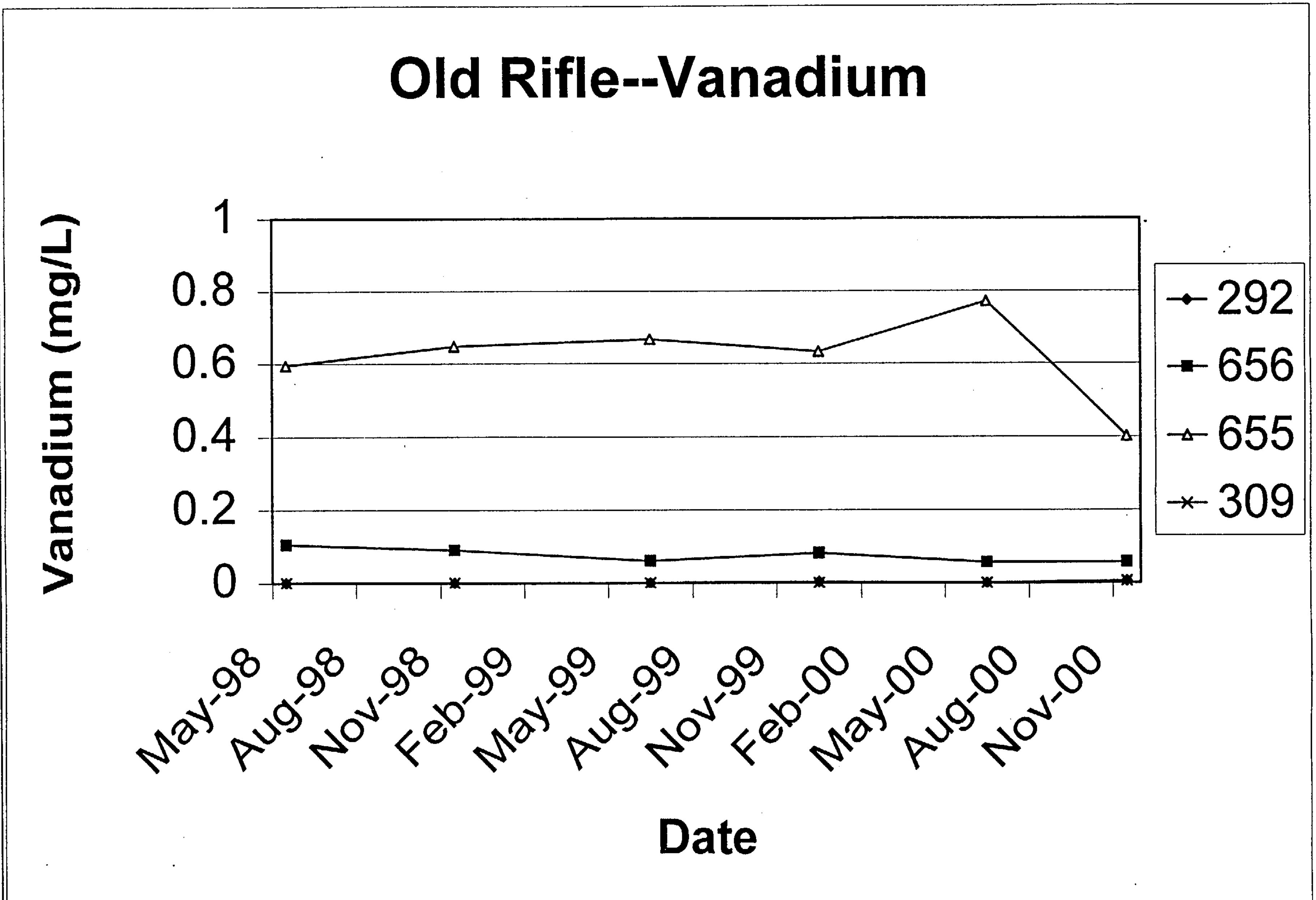

Figure 10. Time-Concentration Plot for Vanadium for Old Rifle Wells 292, 309, 655, and 656

One method of trend analysis that may be applicable to the Old Rifle data is the nonparametric Mann-Kendall test for trend. A discussion of this test methodology is provided in Appendix B. The test does not require any particular data distribution and will accommodate missing values and data reported as less than the detection limit. Essentially it analyzes a series of data by subtracting the values of earlier collected data from later collected data. The number of resulting positive values are summed and resulting negative values are summed. The difference of these sums is determined by subtracting the number of negative values from the number of positive values. The result is the S statistic. This is compared to a probability table (also in Appendix B) to determine the probability that the series of values does not represent an increasing or decreasing trend. Therefore, the smaller the probability, the greater the confidence that a real trend exists.

The Mann-Kendall statistic was calculated for uranium in wells RFO–655 and RFO–310 (highest concentration wells) and vanadium in wells RFO–655 and RFO–305 (also highest concentration wells) to determine if any significant trends could be defined. The statistic was also calculated for uranium in the background well RFO–292. Calculations (done using an Excel spreadsheet) and results are presented in Table 2. Results indicate that uranium in well RFO–310 is very probably decreasing and that uranium in well RFO–655 is also likely decreasing. The other results are ambiguous and do not show any strongly increasing or decreasing trends.

Use of the Mann-Kendall statistic does not assist in comparing predicted versus observed contaminant concentrations, but it does give a measure of how much significance should be attached to otherwise qualitative conclusions. If wells in critical locations at the site (e.g., plume centers) began to exhibit data that showed no clear trends, and if concentrations at those wells were unacceptably high, this could be an indication that natural flushing is not working and that the compliance strategy should be reassessed. If, on the other hand, data from critical wells continued to display decreasing trends, it could mean that natural flushing should continue to operate. While not providing a clear "go—no-go" answer, results from application of the Mann-Kendall test may help in the decision-making process. As each round of sampling data become available, the statistical calculations should be updated and results reported.

6.0 Environmental Compliance and Waste Management

6.1 Compliance Requirements

National Environmental Policy Act (NEPA): The entire area has had surveys and investigations completed. No additional cultural resources or threatened and endangered (T&E) surveys are required. U.S. Department of Energy (DOE) has categorically excluded the activities in this monitoring plan from further NEPA review.

Transportation Requirements: Transportation of hazardous materials and regulated waste will be performed in compliance with the regulatory requirements of the U.S. Department of Transportation at 49 CFR Parts 106-180 and applicable local and state transportation requirements.

Table 2. Mann-Kendall Trend Statistic—Ground Water at Old Rifle Site

Well 655-Uranium

Time	May-98	Dec-98	Jun-99	Dec-99	Jun-00	Nov-00	No. of +	No. of –
Concentration	0.177	0.182	0.115	0.108	0.111	0.148		
		0.005	-0.062	-0.069	-0.066	-0.029	1	4
			-0.067	-0.074	-0.071	-0.034	0	4
				-0.007	-0.004	0.033	1	2
					0.003	0.04	2	0
						0.037	1	0
							5	10

S= -5
probability = .235 of no trend
(approx. 78% probability that a decreasing trend exists)

Well 310-Uranium

Time								
Concentration	May-98	Dec-98	Jun-99	Dec-99	Jun-00	Nov-00	No. of +	No. of –
	0.27	0.258	0.238	0.17	0.169	0.171		
		-0.012	-0.032	-0.1	-0.101	-0.099	0	5
			-0.02	-0.088	-0.089	-0.087	0	4
				-0.068	-0.069	-0.067	0	3
					-0.001	0.001	1	1
						0.002	1	0
							2	13

S= -11
probability = .028 of no trend
(>98% probability of decreasing trend)

Well 655-Vanadium

Time								
Concentration	May-98	Dec-98	Jun-99	Dec-99	Jun-00	Nov-00	No. of +	No. of –
	0.595	0.648	0.667	0.633	0.772	0.402		
		0.053	0.072	0.038	0.177	-0.193	4	1
			0.019	-0.015	0.124	-0.265	2	2
				-0.034	0.105	-0.231	1	2
					0.139	-0.231	1	1
						-0.37	0	1
							8	7

S= 1
probability = .5 of no trend
(chance of a trend is as good as no trend)

Table 2 (continued). Mann-Kendall Trend Statistic—Ground Water at Old Rifle Site

Well 305-Vanadium

Time Concentration	May-98	Dec-98	Dec-99	Jun-00	Nov-00	No. of +	No. of –
	0.765	0.717	0.799	0.597	0.877		
		-0.048	0.034	-0.168	0.112	2	2
			0.082	-0.12	0.16	2	1
				-0.202	0.078	1	1
					0.28	1	0
						6	4

S= 2
probability = .408 of no trend
(60 % probability that an increasing trend exists)

Well 292-Uranium

Time Concentration	May-98	Dec-98	Jun-99	Dec-99	Jun-00	Nov-00	No. of +	No. of –
	0.0524	0.034	0.0488	0.0504	0.0509	0.0435		
		-0.0184	-0.0036	-0.002	-0.0015	-0.0089	0	5
			0.0148	0.0164	0.0169	0.0095	4	0
				0.0016	0.0021	-0.0053	2	1
					0.0005	-0.0069	1	1
						-0.0074	0	1
							7	8

S= -1
probability = .500 of no trend
(chance of a trend as good as no trend)

6.2 Waste Management

Investigation Derived Waste (IDW): Although few regulatory requirements exist that are directly applicable to field-generated IDW management, DOE remains committed to managing IDW in a manner that is protective of human health and the environment through the use of best management practices.

All *liquid IDW,* consisting of well purge water, will be dispersed on the ground at the well from which the water was extracted.

Solid IDW includes disposable sampling equipment, personal protective equipment (PPE), used field test kits, and trash. All solid IDW must be containerized in plastic bags and managed as solid waste at a permitted, licensed, or registered solid or industrial waste disposal or treatment facility. A radiological field evaluation is not required because the sampling is not being conducted in a supplemental standards area and because solid IDW that has come in incidental contact with contaminated ground water is not considered residual radioactive material (RRM).

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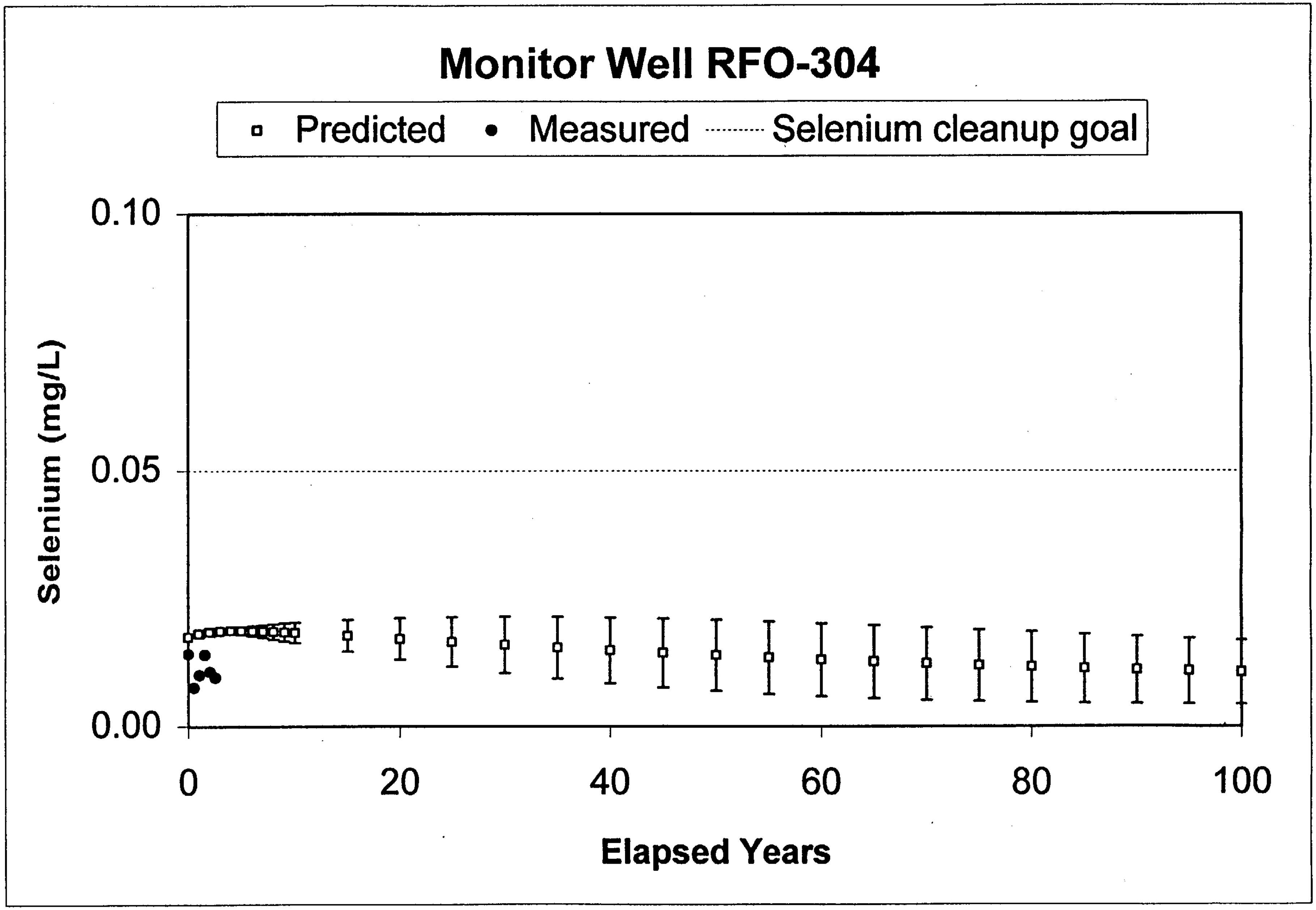
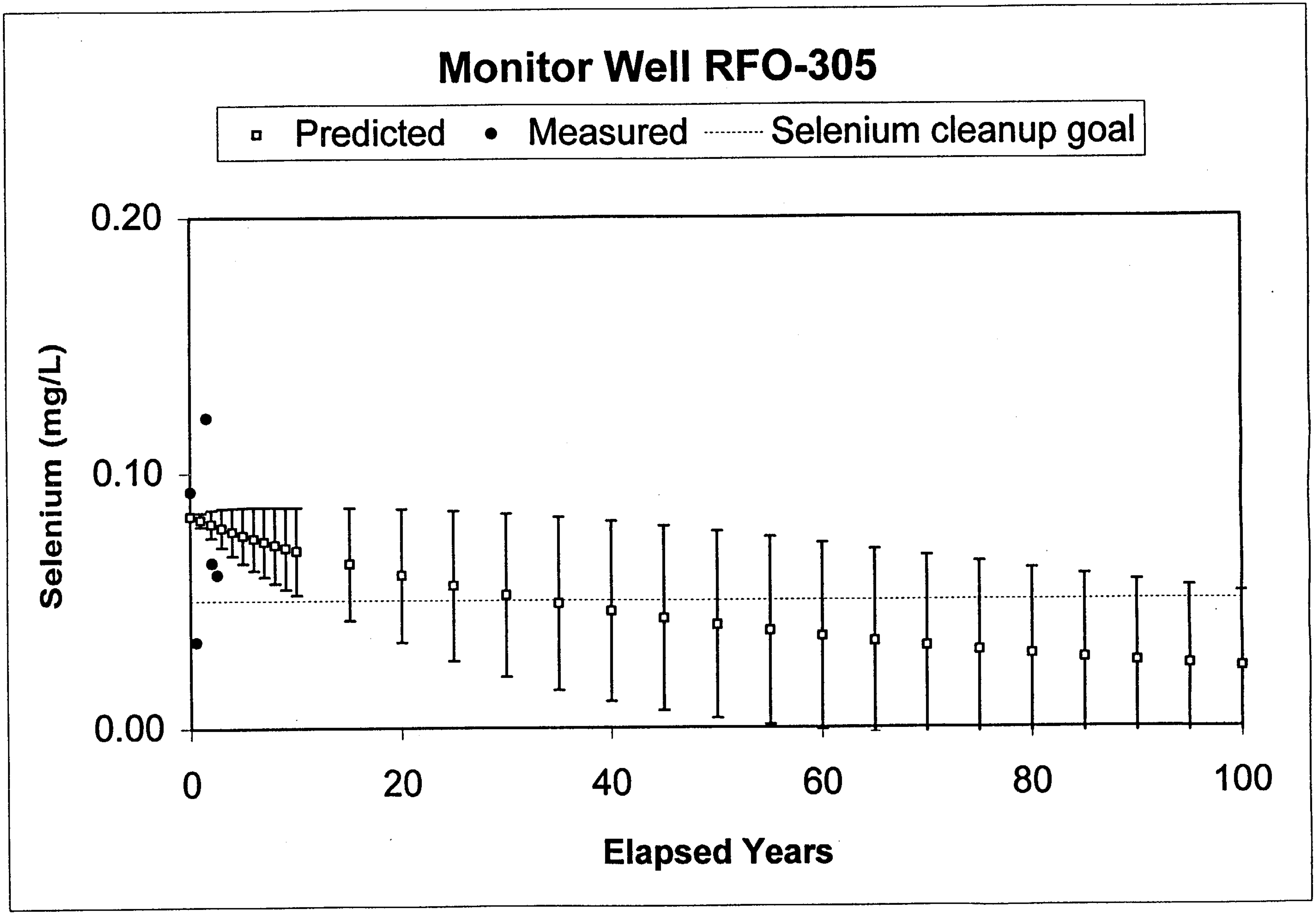
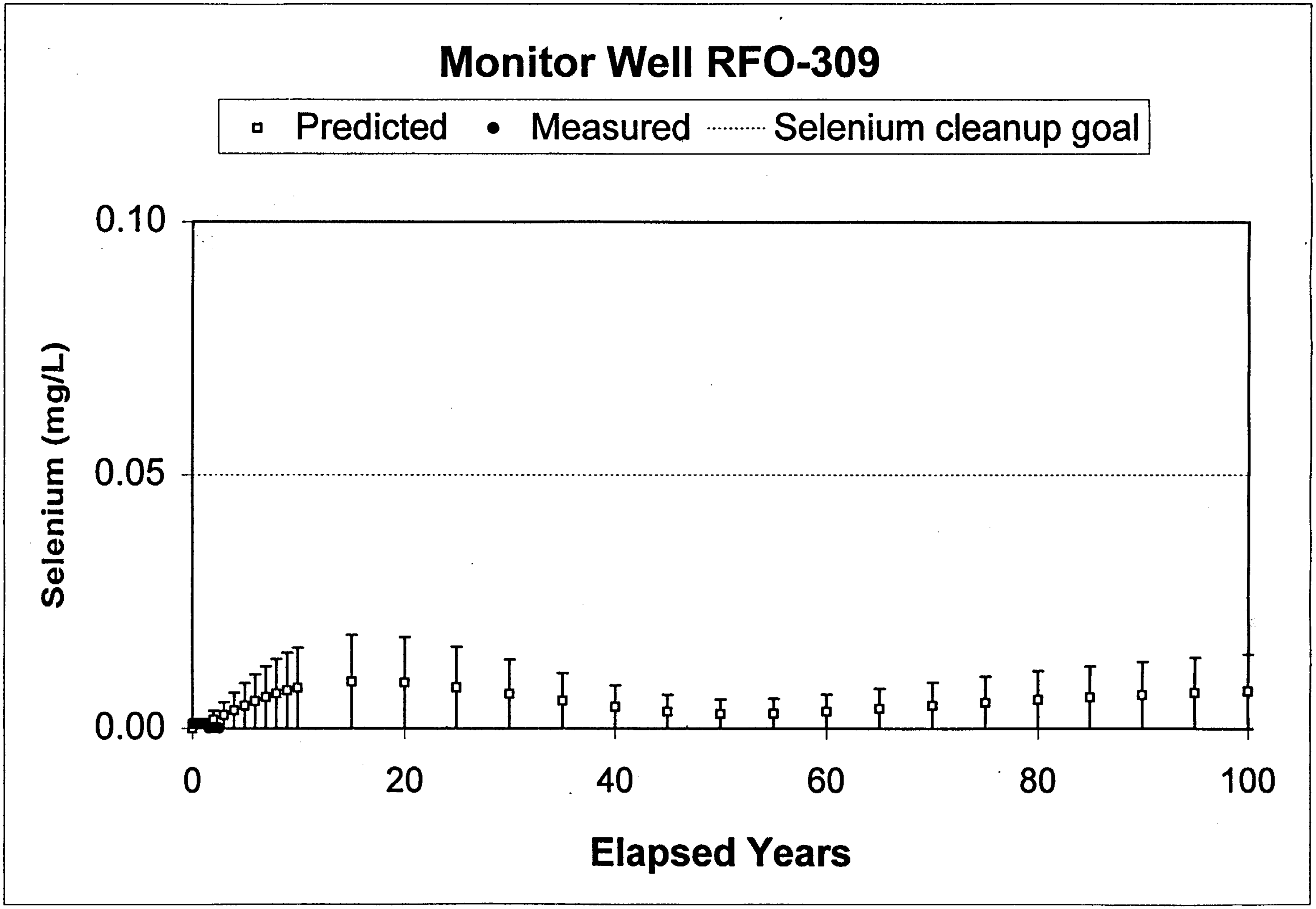
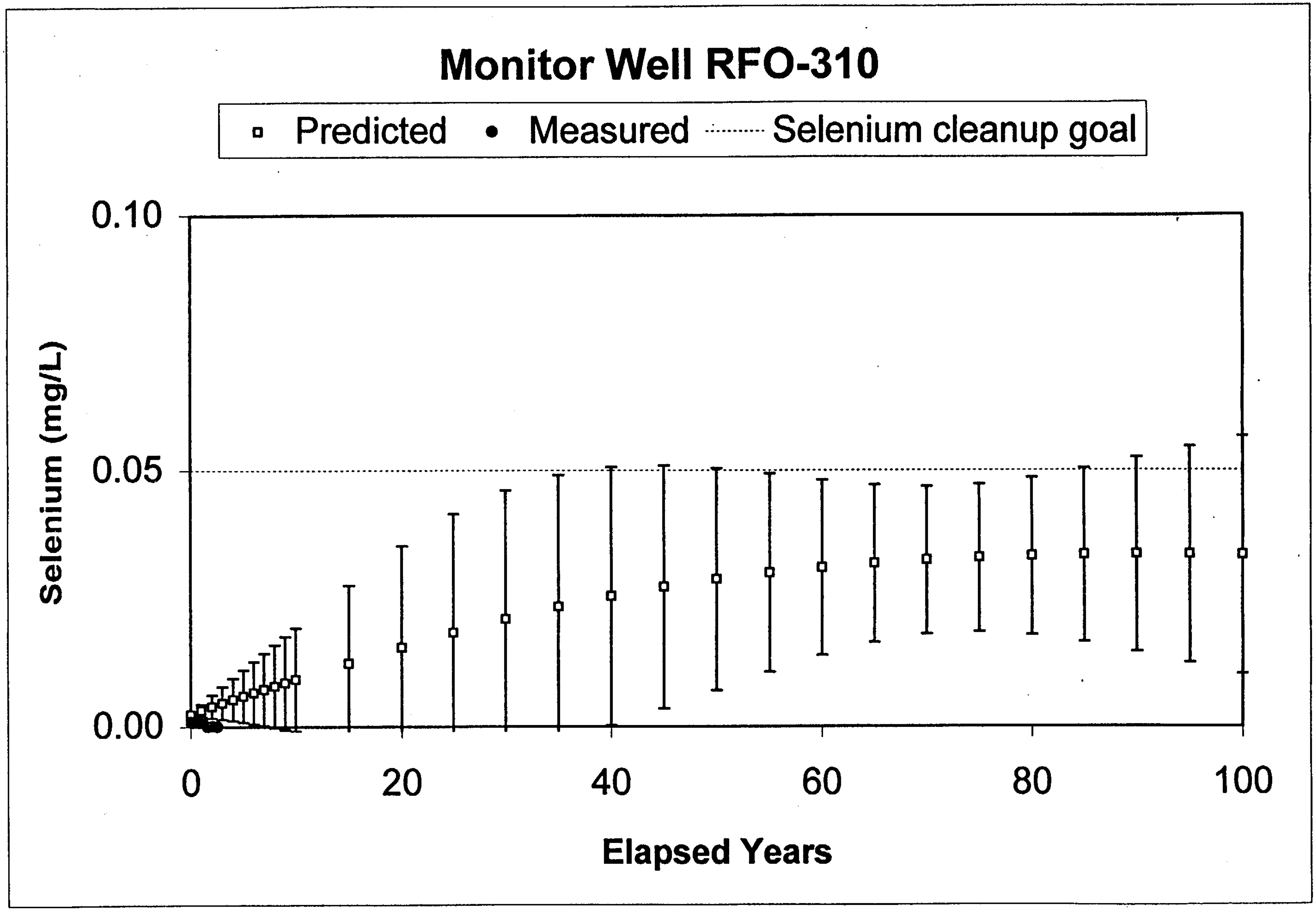
Appendix A

Time-Concentration Plots for Measured and Predicted Contaminant Values

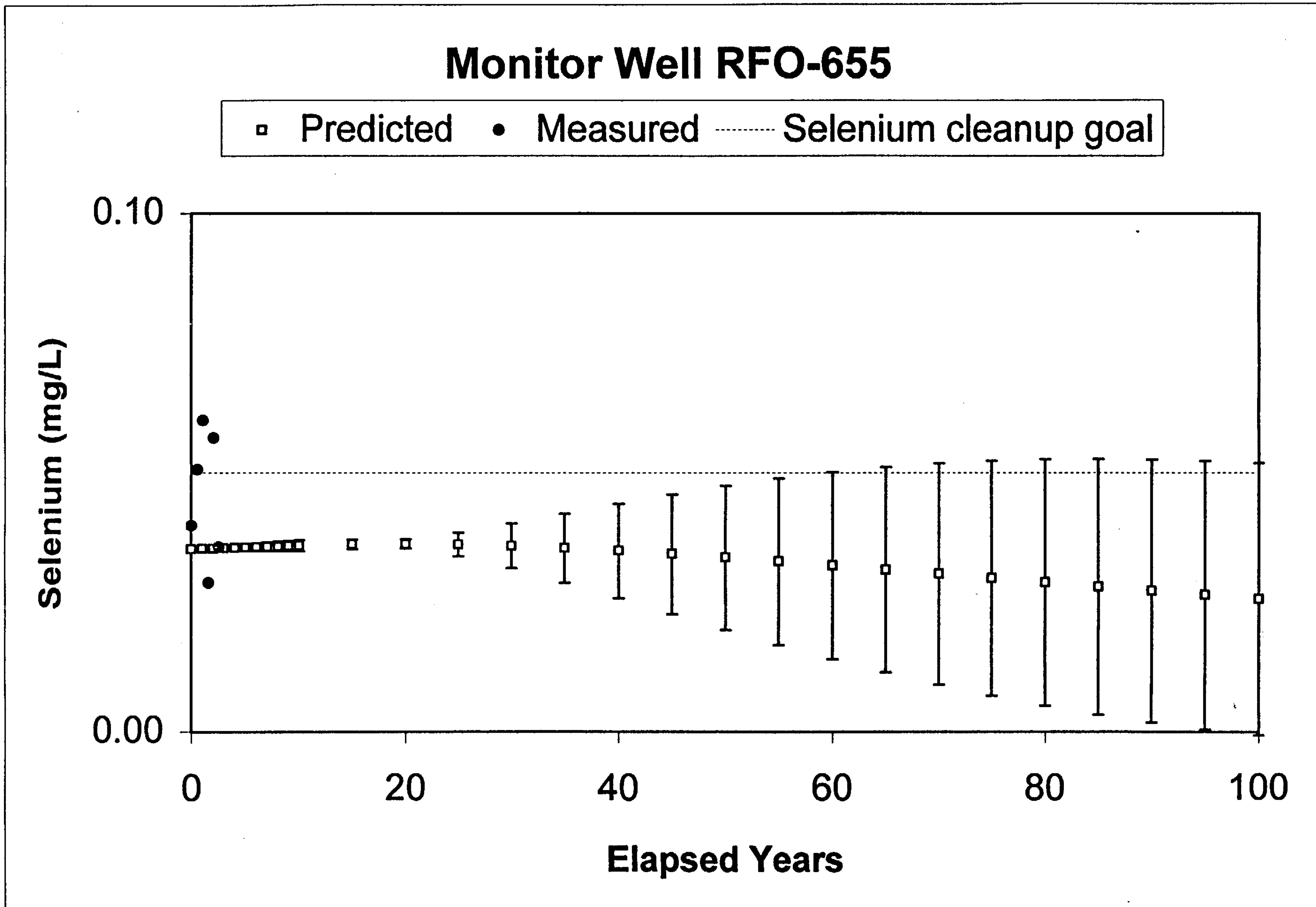

Monitor Well RFO-304
Predicted
Measured
Selenium cleanup goal
Selenium (mg/L)
0.10
0.05
0.00
0
20
40
60
80
100
Elapsed Years

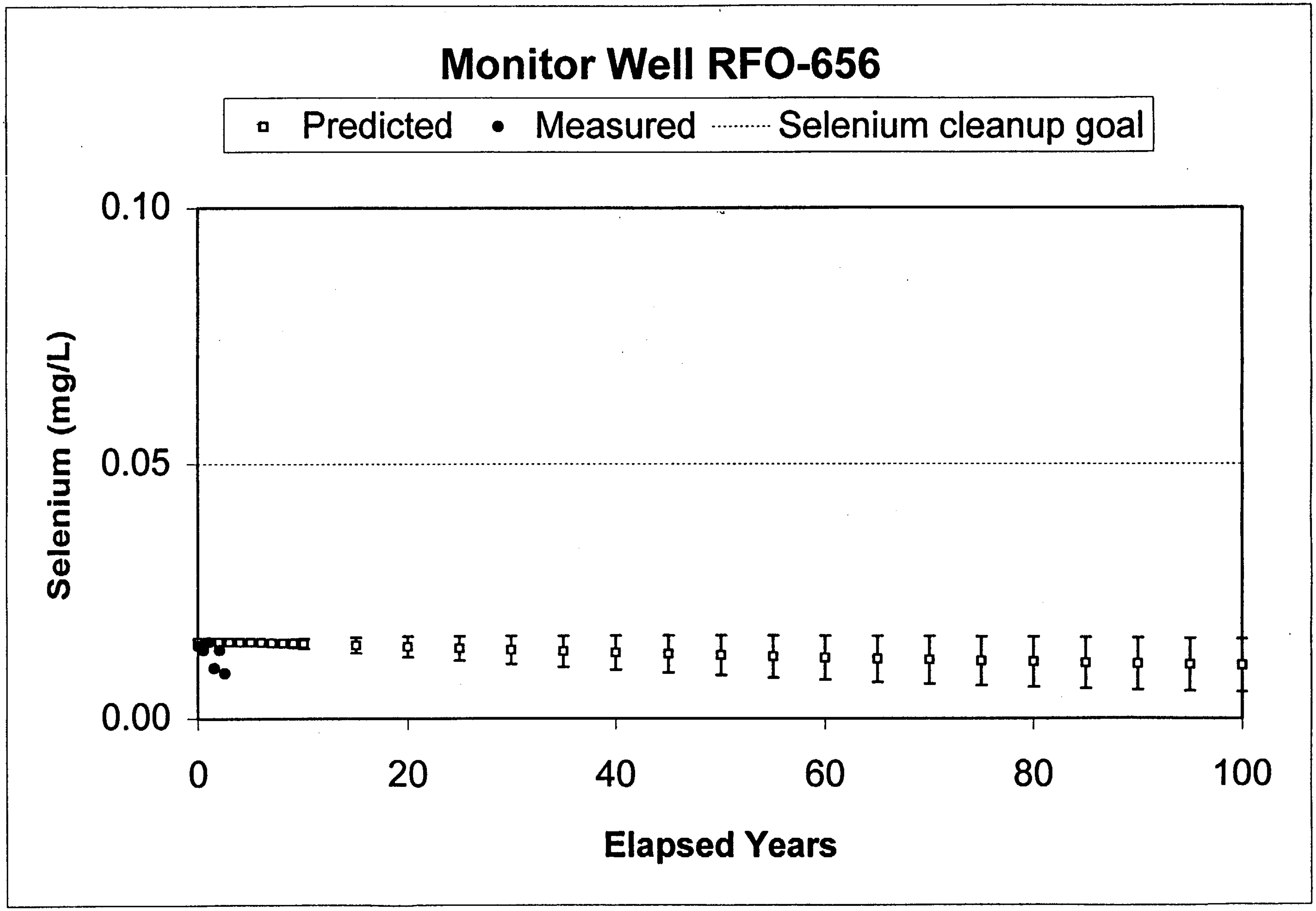

Monitor Well RFO-305
Predicted
Measured
Selenium cleanup goal
0.20
0.10
0.00
Selenium (mg/L)
0
20
40
60
80
100
Elapsed Years


Monitor Well RFO-309
Predicted
Measured
Selenium cleanup goal
0.10
0.05
0.00
Selenium (mg/L)
0
20
40
60
80
100
Elapsed Years

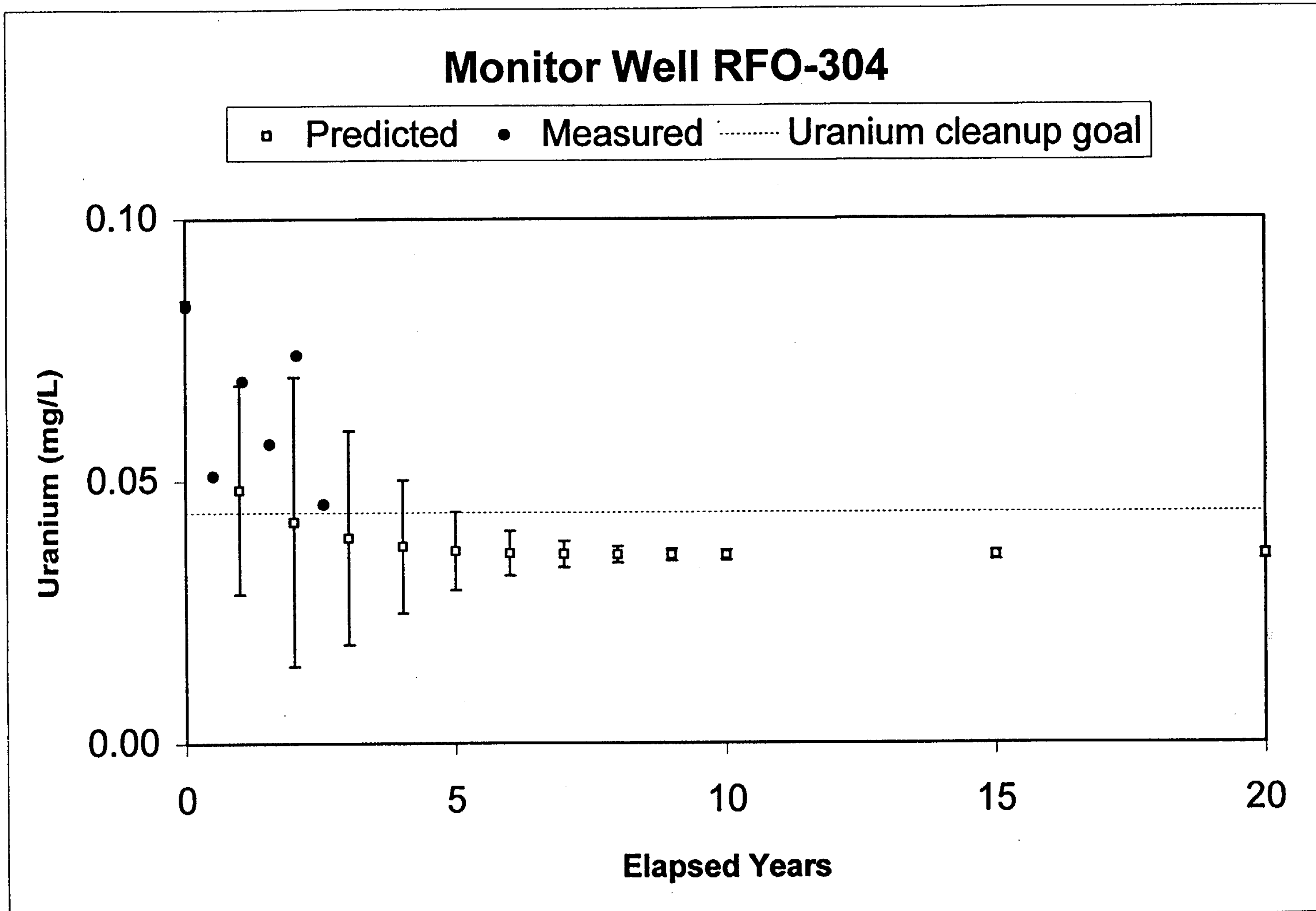


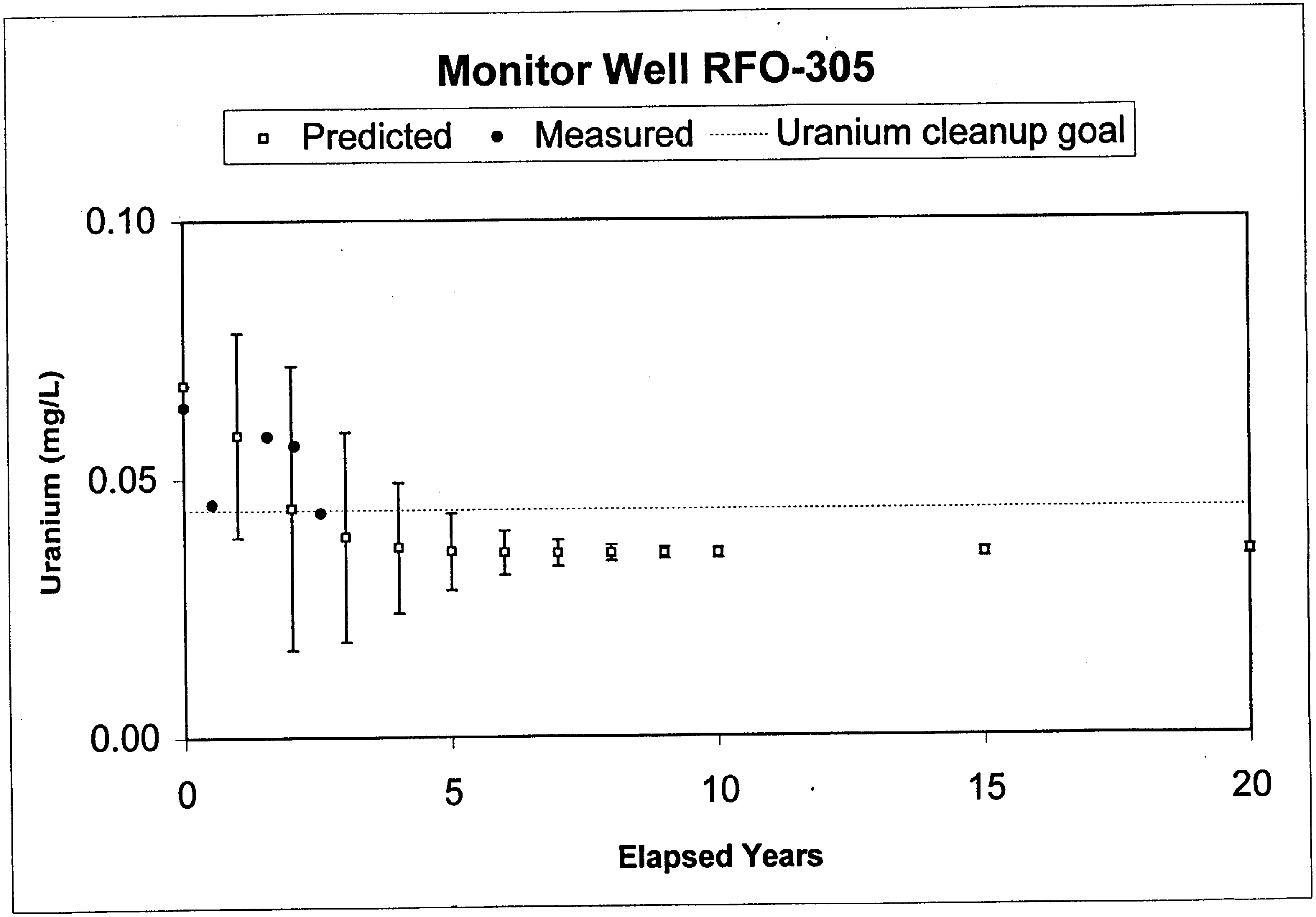
Monitor Well RFO-310
Predicted
Measured
Selenium cleanup goal
0.10
0.05
0.00
Selenium (mg/L)
0
20
40
60
80
100
Elapsed Years

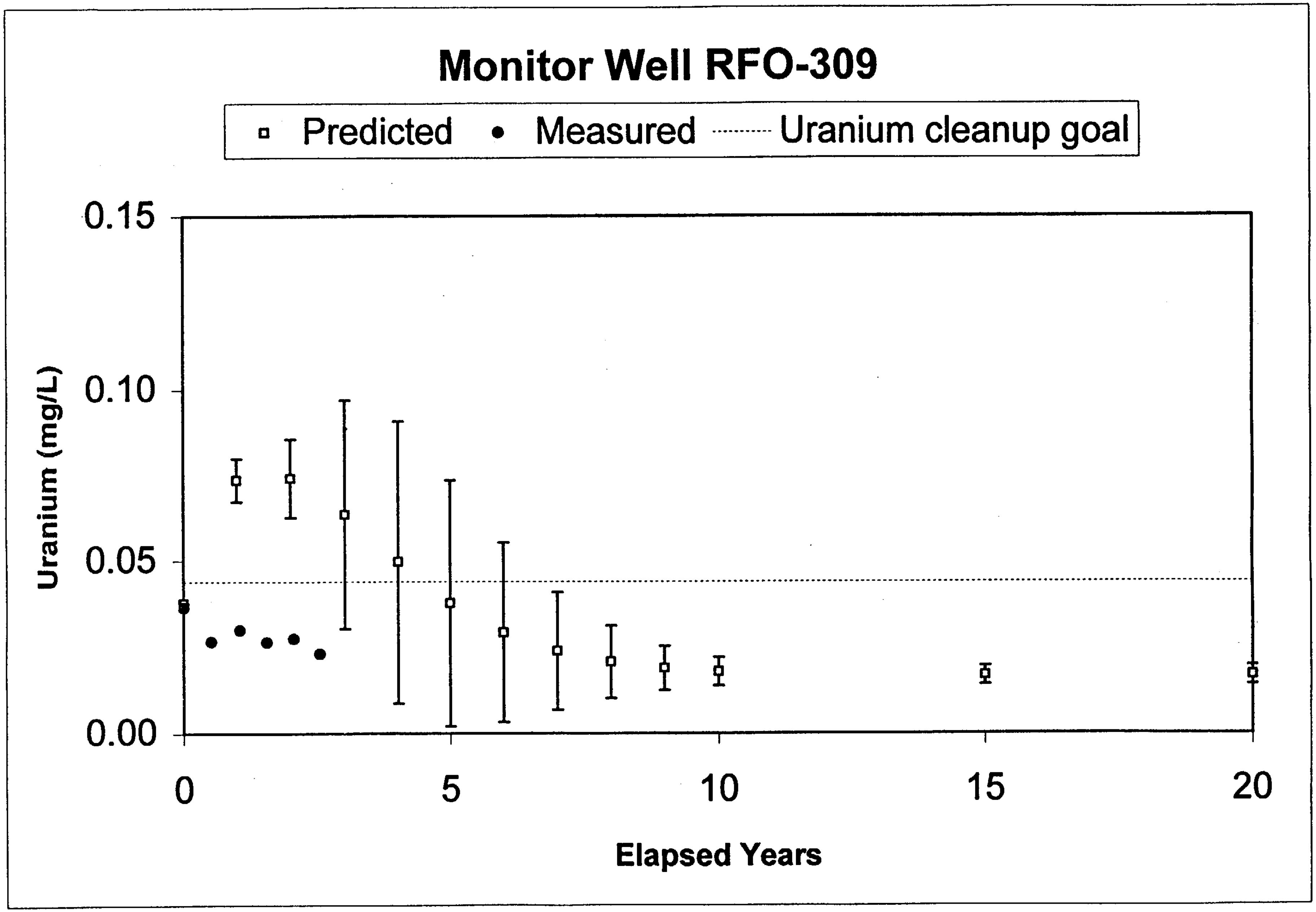

Monitor Well RFO-655
Predicted
Measured
Selenium cleanup goal
0.10
0.00
Selenium (mg/L)
0
20
40
60
80
100
Elapsed Years



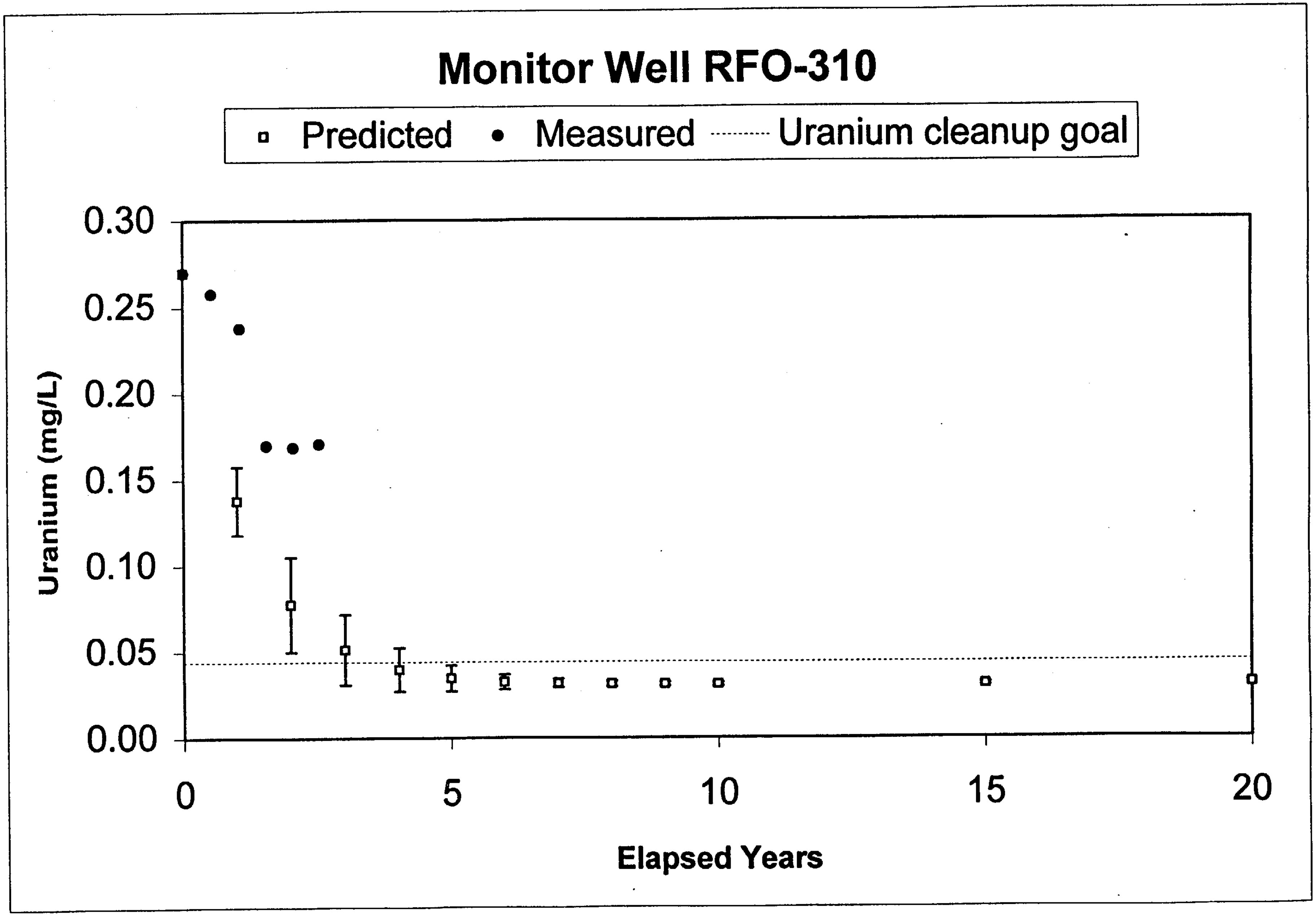
Monitor Well RFO-656
Predicted
Measured
Selenium cleanup goal
0.10
0.05
0.00
Selenium (mg/L)
0
20
40
60
80
100
Elapsed Years


Monitor Well RFO-304
Predicted
Measured
Uranium cleanup goal
0.10
0.05
0.00
Uranium (mg/L)
0
5
10
15
20
Elapsed Years

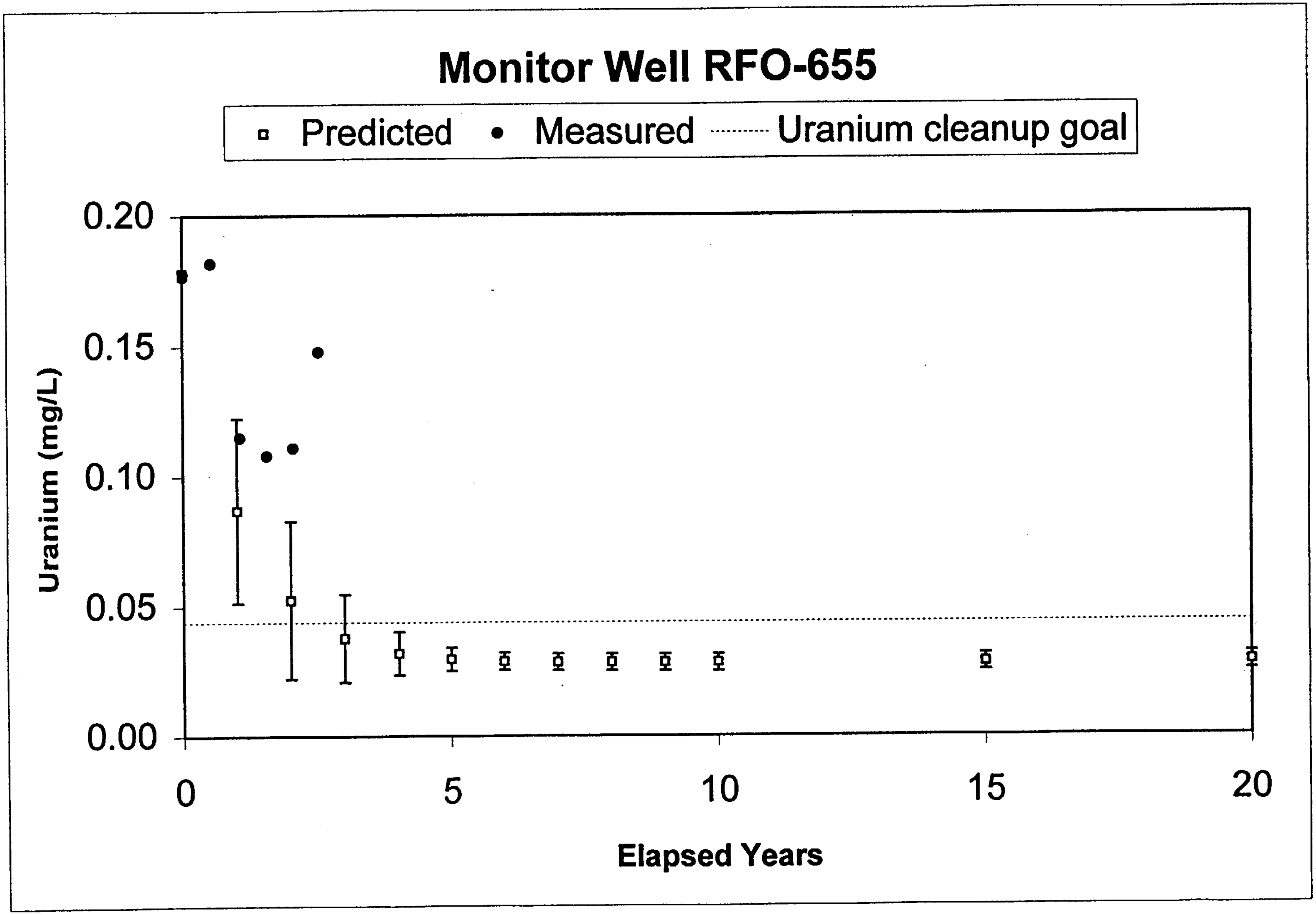

Monitor Well RFO-305
Predicted
Measured
Uranium cleanup goal
Uranium (mg/L)
0.10
0.05
0.00
0
5
10
15
20
Elapsed Years



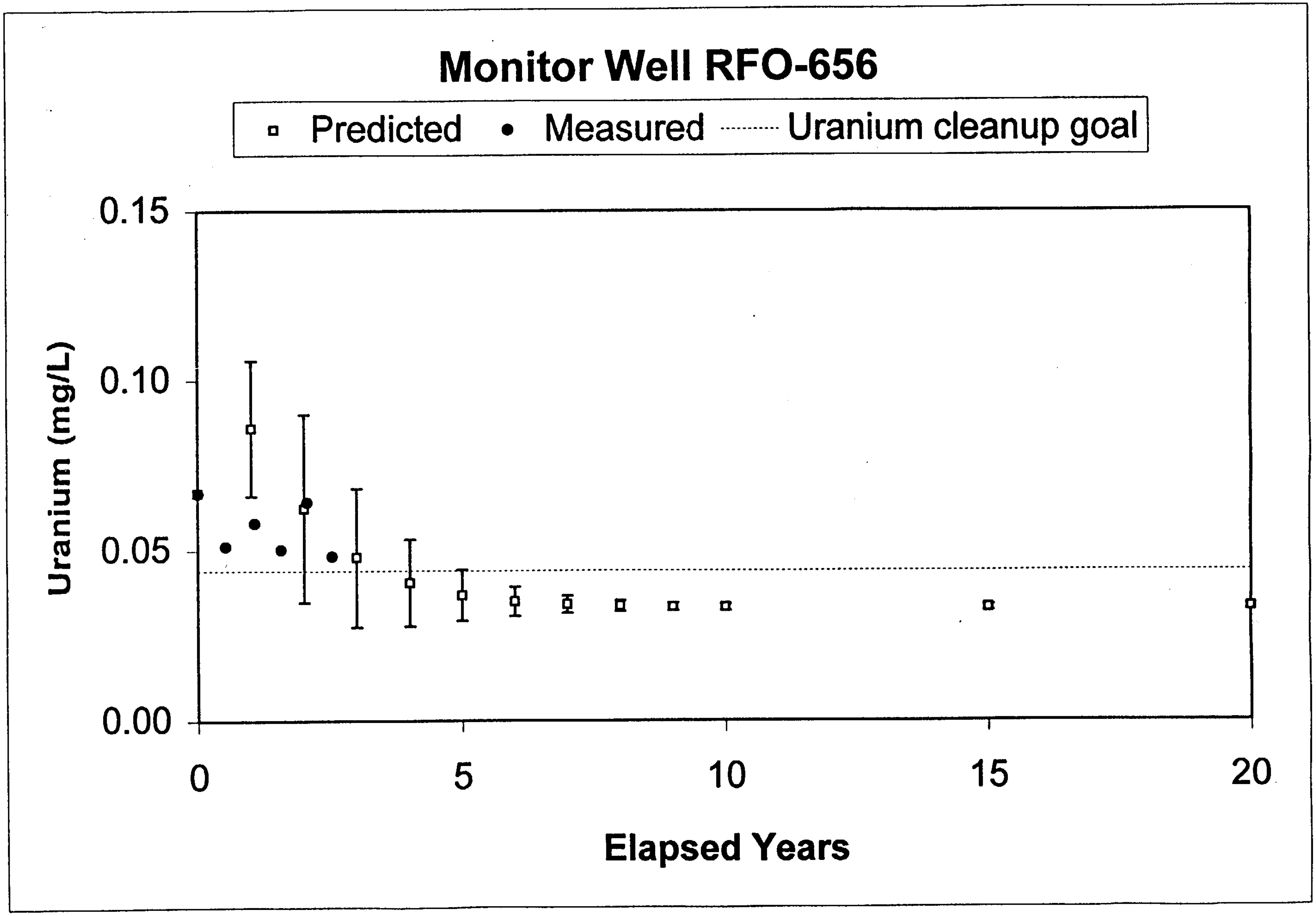
Monitor Well RFO-309
Predicted
Measured
Uranium cleanup goal
0.15
0.10
0.05
0.00
Uranium (mg/L)
0
5
10
15
20
Elapsed Years



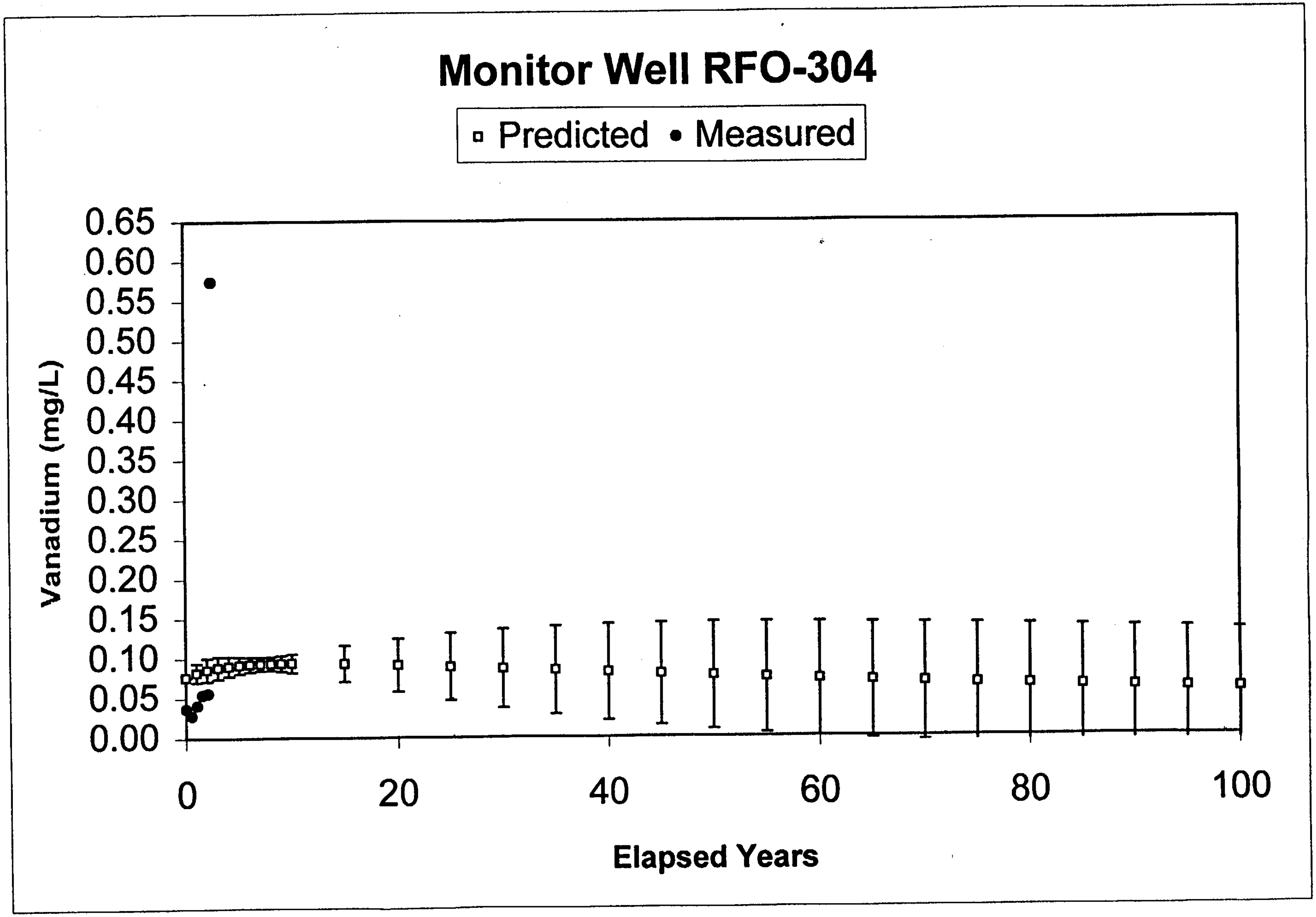
Monitor Well RFO-310
Predicted
Measured
Uranium cleanup goal
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Uranium (mg/L)
0
5
10
15
20
Elapsed Years



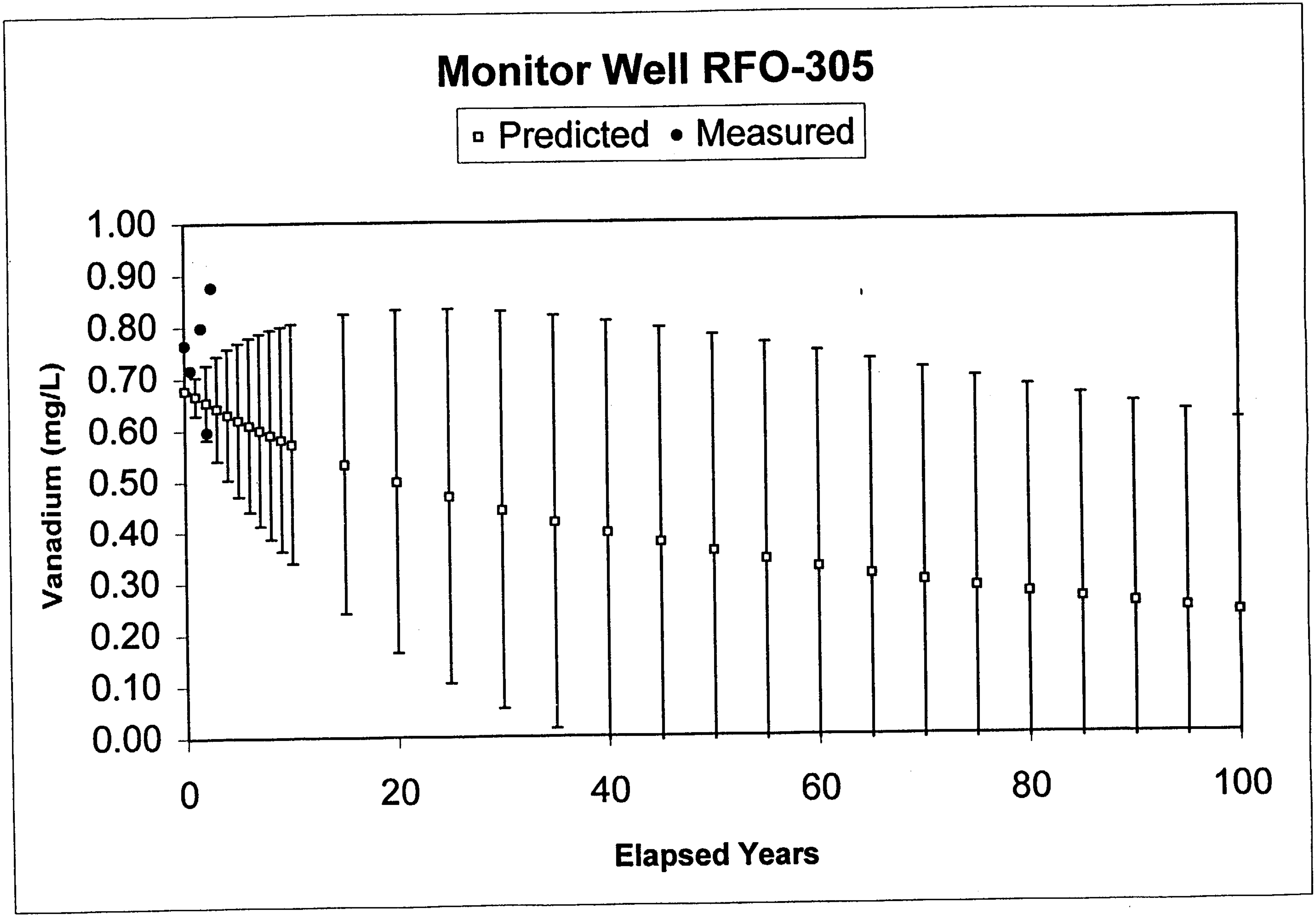
Monitor Well RFO-655
Predicted
Measured
Uranium cleanup goal
Uranium (mg/L)
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
Elapsed Years

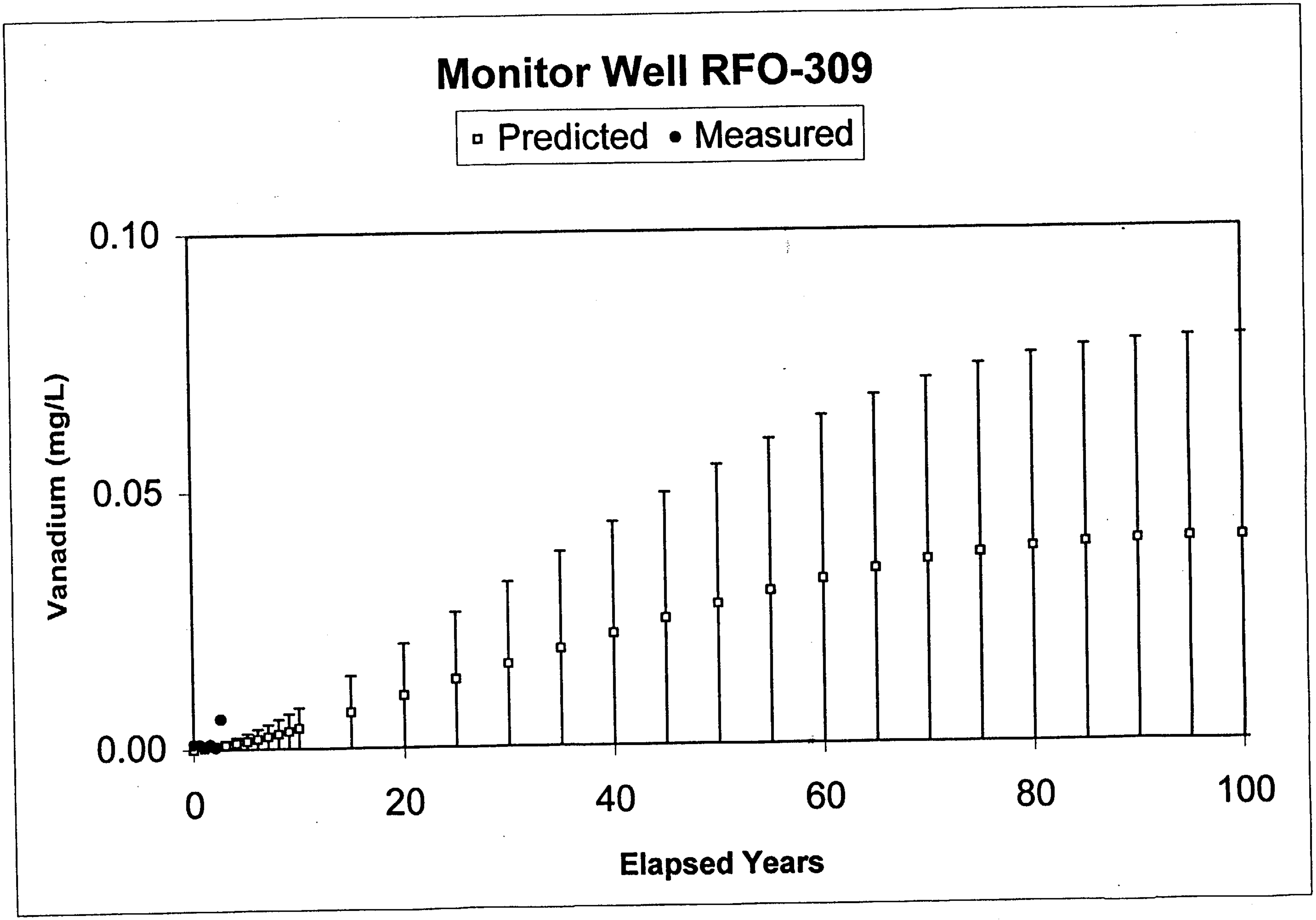


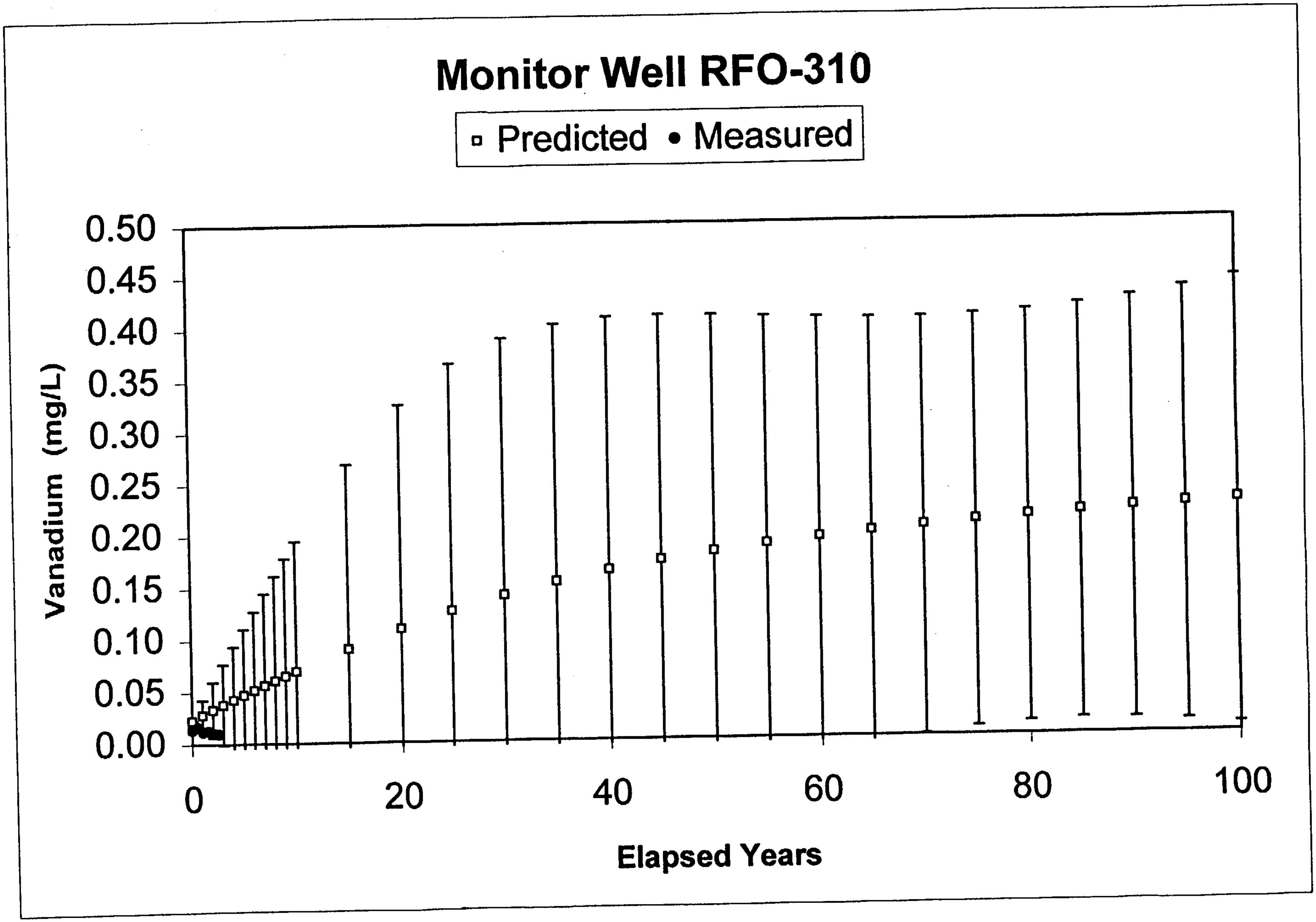
Monitor Well RFO-656
Predicted
Measured
Uranium cleanup goal
0.15
0.10
0.05
0.00
Uranium (mg/L)
0
5
10
15
20
Elapsed Years

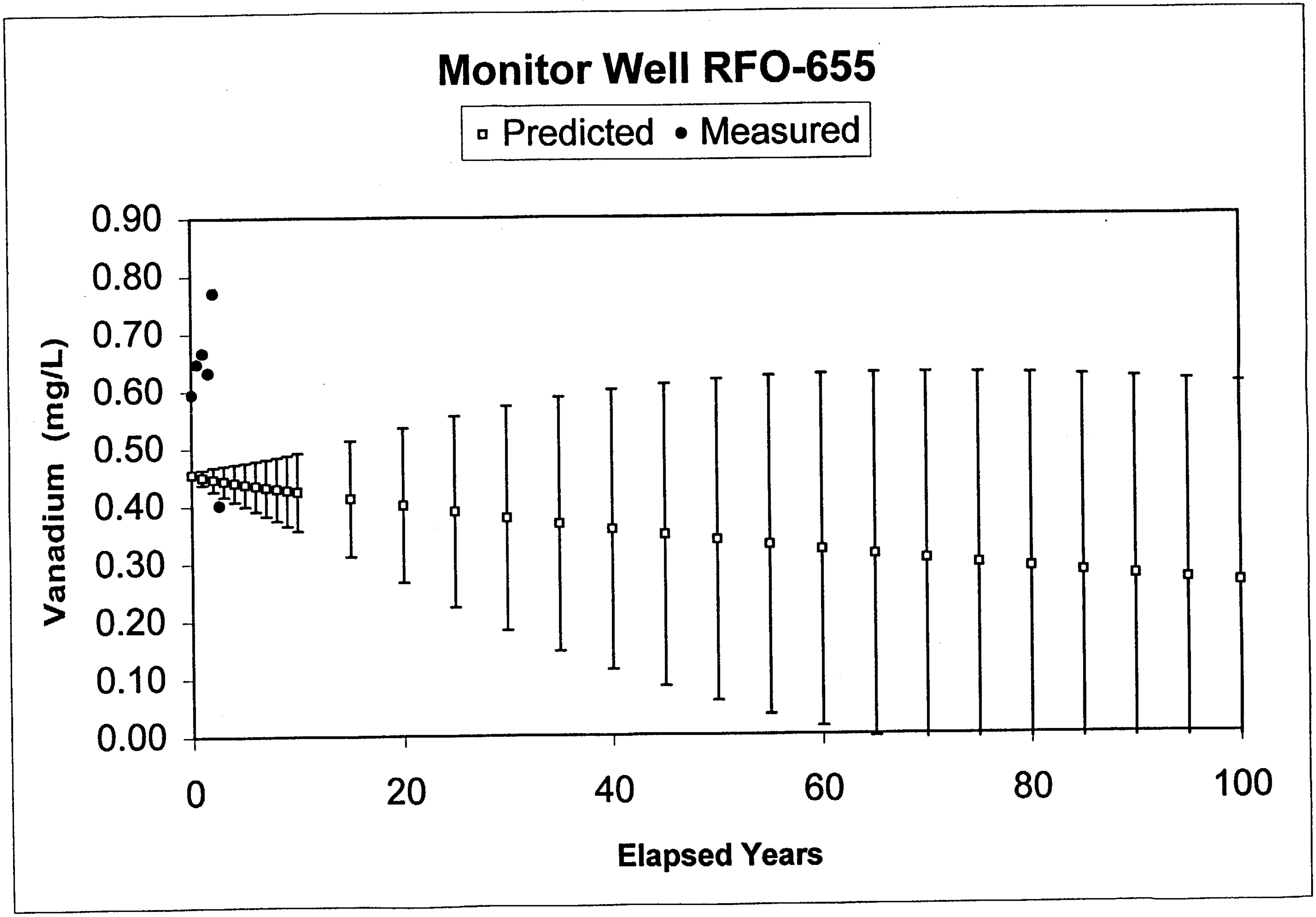


Monitor Well RFO-304
Predicted
Measured
Vanadium (mg/L)
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
20
40
60
80
100
Elapsed Years

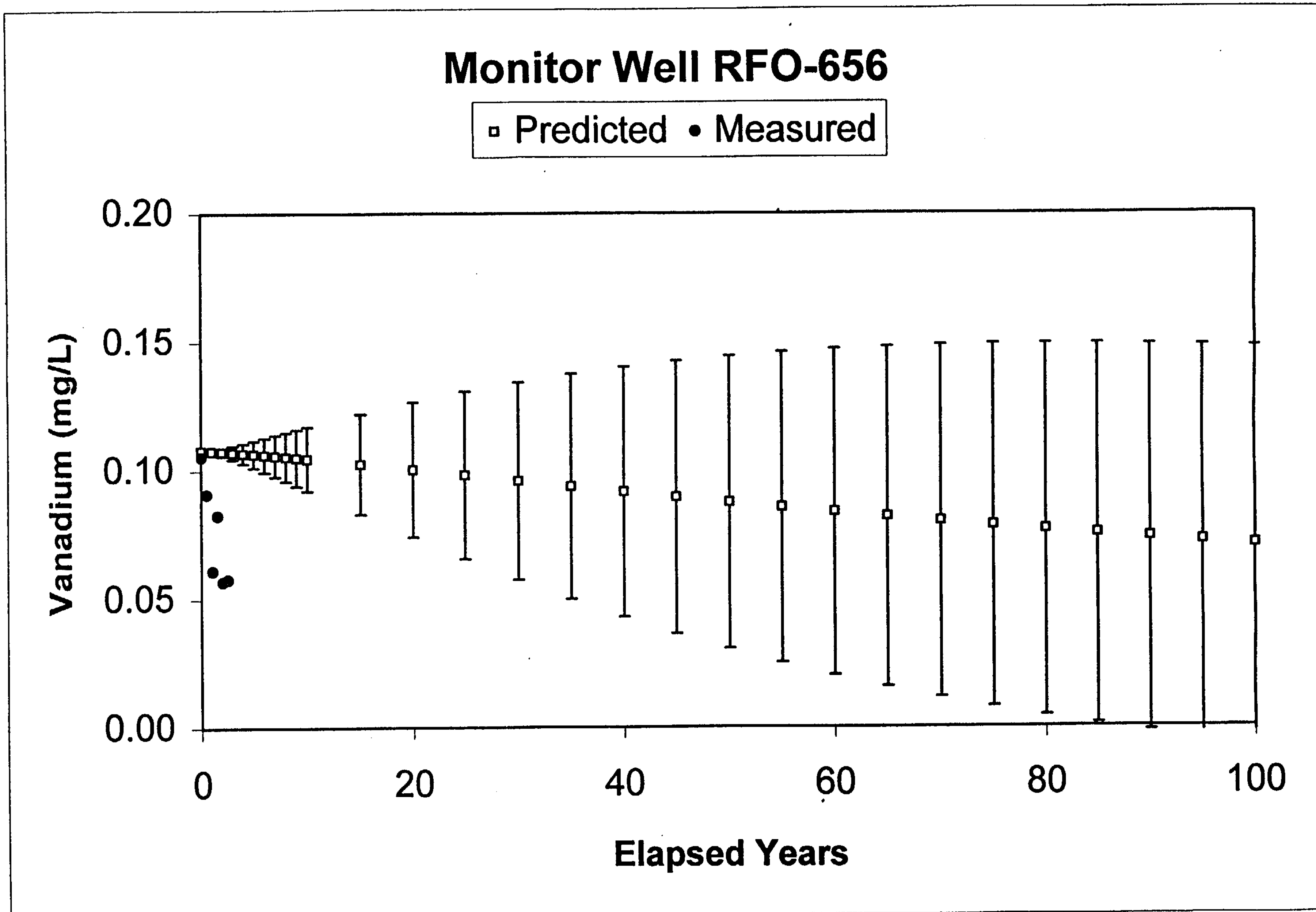

Monitor Well RFO-305
Predicted
Measured
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Vanadium (mg/L)
0
20
40
60
80
100
Elapsed Years


Monitor Well RFO-309
Predicted
Measured
0.10
0.05
0.00
Vanadium (mg/L)
0
20
40
60
80
100
Elapsed Years


Monitor Well RFO-310
Predicted
Measured
Vanadium (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
20
40
60
80
100
Elapsed Years



Monitor Well RFO-655
Predicted
Measured
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Vanadium (mg/L)
0
20
40
60
80
100
Elapsed Years


Monitor Well RFO-656
Predicted
Measured
0.20
0.15
0.10
0.05
0.00
Vanadium (mg/L)
0
20
40
60
80
100
Elapsed Years

Appendix B

Mann-Kendall Test Description

16.3.3 Intervention Analysis and Box-Jenkins Models

If a long time sequence of equally spaced data is available, intervention analysis may be used to detect changes in average level resulting from a natural or man-induced intervention in the process. This approach, developed by Box and Tiao (1975), is a generalization of the autoregressive integrated moving-average (ARIMA) time series models described by Box and Jenkins (1976). Lettenmaier and Murray (1977) and Lettenmaier (1978) study the power of the method to detect trends. They emphasize the design of sampling plans to detect impacts from polluting facilities. Examples of its use are in Hipel et al. (1975) and Roy and Pellerin (1982).

Box-Jenkins modeling techniques are powerful tools for the analysis of time series data. McMichael and Hunter (1972) give a good introduction to Box-Jenkins modeling of environmental data, using both deterministic and stochastic components to forecast temperature flow in the Ohio River. Fuller and Tsokos (1971) develop models to forecast dissolved oxygen in a stream. Carlson, MacCormick, and Watts (1970) and McKerchar and Delleur (1974) fit Box-Jenkins models to monthly river flows. Hsu and Hunter (1976) analyze annual series of air pollution SO_2 concentrations. McCollister and Wilson (1975) forecast daily maximum and hourly average total oxidant and carbon monoxide concentrations in the Los Angeles Basin. Hipel, McLeod, and Lennox (1977*a*, 1977*b*) illustrate improved Box-Jenkins techniques to simplify model construction. Reinsel et al. (1981*a*, 1981*b*) use Box-Jenkins models to detect trends in stratospheric ozone data. Two introductory textbooks are McCleary and Hay (1980) and Chatfield (1984). Box and Jenkins (1976) is recommended reading for all users of the method.

Disadvantages of Box-Jenkins methods are discussed by Montgomery and Johnson (1976). At least 50 and preferably 100 or more data collected at equal (or approximately equal) time intervals are needed. When the purpose is forecasting, we must assume the developed model applies to the future. Missing data or data reported as trace or less-than values can prevent the use of Box-Jenkins methods. Finally, the modeling process is often nontrivial, with a considerable investment in time and resources required to build a satisfactory model. Fortunately, there are several packages of statistical programs that contain codes for developing time series models, including Minitab (Ryan, Joiner, and Ryan 1982), SPSS (1985), BMDP (1983), and SAS (1985). Codes for personal computers are also becoming available.

16.4 MANN-KENDALL TEST

In this section we discuss the nonparametric Mann-Kendall test for trend (Mann, 1945; Kendall, 1975). This procedure is particularly useful since missing values are allowed and the data need not conform to any particular distribution. Also, data reported as trace or less than the detection limit can be used (if it is acceptable in the context of the population being sampled) by assigning them a common value that is smaller than the smallest measured value in the data set. This approach can be used because the Mann-Kendall test (and the seasonal Kendall test in Chapter 17) use only the relative magnitudes of the data rather

From Gilbert, Richard O., 1987. Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold, NY, 320 p.

than their measured values. We note that the Mann-Kendall test can be viewed as a nonparametric test for zero slope of the linear regression of time-ordered data versus time, as illustrated by Hollander and Wolfe (1973, p. 201).

16.4.1 Number of Data 40 or Less

If n is 40 or less, the procedure in this section may be used. When n exceeds 40, use the normal approximation test in Section 16.4.2. We begin by considering the case where only one datum per time period is taken, where a time period may be a day, week, month, and so on. The case of multiple data values per time period is discussed in Section 16.4.3.

The first step is to list the data in the order in which they were collected over time: $x_1, x_2, \ldots, x_n$, where x_i is the datum at time i. Then determine the sign of all $n(n - 1)/2$ possible differences $x_j - x_k$, where $j > k$. These differences are $x_2 - x_1, x_3 - x_1, \ldots, x_n - x_1, x_3 - x_2, x_4 - x_2, \ldots, x_n - x_{n-2}, x_n - x_{n-1}$. A convenient way of arranging the calculations is shown in Table 16.1.

Let $\text{sgn}(x_j - x_k)$ be an indicator function that takes on the values 1, 0, or -1 according to the sign of $x_j - x_k$:

$$\begin{aligned} \text{sgn}(x_j - x_k) &= 1 \quad \text{if } x_j - x_k > 0 \\ &= 0 \quad \text{if } x_j - x_k = 0 \\ &= -1 \quad \text{if } x_j - x_k < 0 \end{aligned} \qquad \textbf{16.1}$$

Then compute the Mann-Kendall statistic

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sgn}(x_j - x_k) \qquad \textbf{16.2}$$

which is the number of positive differences minus the number of negative differences. These differences are easily obtained from the last two columns of Table 16.1. If S is a large positive number, measurements taken later in time tend to be larger than those taken earlier. Similarly, if S is a large negative number, measurements taken later in time tend to be smaller. If n is large, the computer code in Appendix B may be used to compute S. This code also computes the tests for trend discussed in Chapter 17.

Suppose we want to test the null hypothesis, H_0, of no trend against the alternative hypothesis, H_A, of an upward trend. Then H_0 is rejected in favor of H_A if S is positive and if the probability value in Table A18 corresponding to the computed S is less than the a priori specified α significance level of the test. Similarly, to test H_0 against the alternative hypothesis H_A of a downward trend, reject H_0 and accept H_A if S is negative and if the probability value in the table corresponding to the absolute value of S is less than the a priori specified α value. If a two-tailed test is desired, that is, if we want to detect either an upward or downward trend, the tabled probability level corresponding to the absolute value of S is doubled and H_0 is rejected if that doubled value is less than the a priori α level.

EXAMPLE 16.1

We wish to test the null hypothesis H_0, of no trend versus the alternative hypothesis, H_A, of an upward trend at the $\alpha = 0.10$

Table 16.1 Differences in Data Values Needed for Computing the Mann-Kendall Statistic S to Test for Trend

Data Values Listed in the Order Collected Over Time							*No. of + Signs*	*No. of − Signs*
x_1	x_2	x_3	x_4	$\cdots$	x_{n-1}	x_n		
	$x_2 - x_1$	$x_3 - x_1$	$x_4 - x_1$	$\cdots$	$x_{n-1} - x_1$	$x_n - x_1$		
		$x_3 - x_2$	$x_4 - x_2$	$\cdots$	$x_{n-1} - x_2$	$x_n - x_2$		
			$x_4 - x_3$	$\cdots$	$x_{n-1} - x_3$	$x_n - x_3$		
				$\ddots$	$\vdots$	$\vdots$		
					$x_{n-1} - x_{n-2}$	$x_n - x_{n-2}$		
						$x_n - x_{n-1}$		
						$S =$	(sum of + signs) +	(sum of − signs)

Table 16.2 Computation of the Mann-Kendall Trend Statistic S for the Time Ordered Data Sequence 10, 15, 14, 20

Time *Data*	*1* *10*	*2* *15*	*3* *14*	*4* *20*		*No. of +* *Signs*		*No. of −* *Signs*
		15 − 10	14 − 10	20 − 10		3		0
			14 − 15	20 − 15		1		1
				20 − 14		1		0
				S	=	5	−	1 = 4

significance level. For ease of illustration suppose only 4 measurements are collected in the following order over time or along a line in space: 10, 15, 14, and 20. There are 6 differences to consider: 15 − 10, 14 − 10, 20 − 10, 14 − 15, 20 − 15, and 20 − 14. Using Eqs. 16.1 and 16.2, we obtain $S = +1 + 1 + 1 - 1 + 1 + 1 = +4$, as illustrated in Table 16.2. (Note that the sign, not the magnitude of the difference is used.) From Table A18 we find for $n = 4$ that the tabled probability for $S = +4$ is 0.167. This number is the probability of obtaining a value of S equal to +4 or larger when $n = 4$ and when no upward trend is present. Since this value is greater than 0.10, we cannot reject H_0.

If the data sequence had been 18, 20, 23, 35, then $S = +6$, and the tabled probability is 0.042. Since this value is less than 0.10, we reject H_0 and accept the alternative hypothesis of an upward trend.

Table A18 gives probability values only for $n \leq 10$. An extension of this table up to $n = 40$ is given in Table A.21 in Hollander and Wolfe (1973).

16.4.2 Number of Data Greater Than 40

When n is greater than 40, the normal approximation test described in this section is used. Actually, Kendall (1975, p. 55) indicates that this method may be used for n as small as 10 unless there are many tied data values. The test procedure is to first compute S using Eq. 16.2 as described before. Then compute the variance of S by the following equation, which takes into account that ties may be present:

$$\mathrm{VAR}(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{g} t_p(t_p - 1)(2t_p + 5)\right] \qquad \mathbf{16.3}$$

where g is the number of tied groups and t_p is the number of data in the pth group. For example, in the sequence {23, 24, trace, 6, trace, 24, 24, trace, 23} we have $g = 3$, $t_1 = 2$ for the tied value 23, $t_2 = 3$ for the tied value 24, and $t_3 = 3$ for the three trace values (considered to be of equal but unknown value less than 6).

Then S and VAR(S) are used to compute the test statistic Z as follows:

$$Z = \frac{S-1}{[\mathrm{VAR}(S)]^{1/2}} \quad \text{if } S > 0$$
$$= 0 \quad \text{if } S = 0$$
$$= \frac{S+1}{[\mathrm{VAR}(S)]^{1/2}} \quad \text{if } S < 0 \qquad \mathbf{16.4}$$

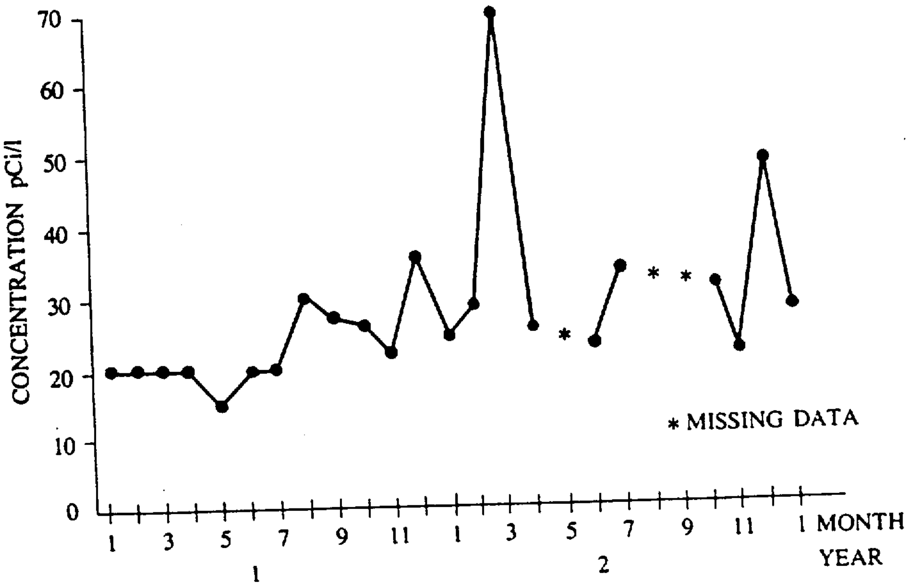


Figure 16.2 Concentrations of ^{238}U in ground water in well E at the former St. Louis Airport storage site for January 1981 through January 1983 (after Clark and Berven, 1984).

A positive (negative) value of Z indicates an upward (downward) trend. If the null hypothesis, H_0, of no trend is true, the statistic Z has a standard normal distribution, and hence we use Table A1 to decide whether to reject H_0. To test for either upward or downward trend (a two-tailed test) at the α level of significance, H_0 is rejected if the absolute value of Z is greater than $Z_{1-\alpha/2}$, where $Z_{1-\alpha/2}$ is obtained from Table A1. If the alternative hypothesis is for an upward trend (a one-tailed test), H_0 is rejected if Z (Eq. 16.4) is greater than $Z_{1-\alpha}$. We reject H_0 in favor of the alternative hypothesis of a downward trend if Z is negative and the absolute value of Z is greater than $Z_{1-\alpha/2}$. Kendall (1975) indicates that using the standard normal tables (Table A1) to judge the statistical significance of the Z test will probably introduce little error as long as $n \geq 10$ unless there are many groups of ties and many ties within groups.

EXAMPLE 16.2

Figure 16.2 is a plot of $n = 22$ monthly ^{238}U concentrations $x_1, x_2, x_3, \ldots, x_{22}$ obtained from a groundwater monitoring well from January 1981 through January 1983 (reported in Clark and Berven, 1984). We use the Mann-Kendall procedure to test the null hypothesis at the $\alpha = 0.05$ level that there is no trend in ^{238}U groundwater concentrations at this well over this 2-year period. The alternative hypothesis is that an upward trend is present.

There are $n(n - 1)/2 = 22(21)/2 = 231$ differences to examine for their sign. The computer code in Appendix B was used to obtain S and Z (Eqs. 16.2 and 16.4). We find that $S = +108$. Since there are 6 occurrences of the value 20 and 2 occurrences of both 23 and 30, we have $g = 3$, $t_1' = 6$, and $t_2 = t_3 = 2$. Hence, Eq. 16.3 gives

$$\text{VAR}(S) = \tfrac{1}{18}[22(21)(44 + 5) - 6(5)(12 + 5) - 2(1)(4 + 5) - 2(1)(4 + 5)]$$
$$\doteq 1227.33$$

or $[\text{VAR}(S)]^{1/2} = 35.0$. Therefore, since $S > 0$, Eq. 16.4 gives $Z = (108 - 1)/35.0 = 3.1$. From Table A1 we find $Z_{0.95} = 1.645$. Since Z exceeds 1.645, we reject H_0 and accept the alternative hypothesis of an upward trend. We note that the three missing values in Figure 16.2 do not enter into the calculations in any way. They are simply ignored and constitute a regrettable loss of information for evaluating the presence of trend.

16.4.3 Multiple Observations per Time Period

When there are multiple observations per time period, there are two ways to proceed. First, we could compute a summary statistic, such as the median, for each time period and apply the Mann-Kendall test to the medians. An alternative approach is to consider the $n_i \geq 1$ multiple observations at time i (or time period i) as ties in the time index. For this latter case the statistic S is still computed by Eq. 16.2, where n is now the sum of the n_i, that is, the total number of observations rather than the number of time periods. The differences between data obtained at the same time are given the score 0 no matter what the data values may be, since they are tied in the time index.

When there are multiple observations per time period, the variance of S is computed by the following equation, which accounts for ties in the time index:

$$\text{VAR}(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{g} t_p(t_p-1)(2t_p+5) - \sum_{q=1}^{h} u_q(u_q-1)(2u_q+5)\right] + \frac{\sum_{p=1}^{g} t_p(t_p-1)(t_p-2)\sum_{q=1}^{h} u_q(u_q-1)(u_q-2)}{9n(n-1)(n-2)} + \frac{\sum_{p=1}^{g} t_p(t_p-1)\sum_{q=1}^{h} u_q(u_q-1)}{2n(n-1)} \qquad 16.5$$

where g and t_p are as defined following Eq. 16.3, h is the number of time periods that contain multiple data, and u_q is the number of multiple data in the qth time period. Equation 16.5 reduces to Eq. 16.3 when there is one observation per time period.

Equations 16.3 and 16.5 assume all data are independent and, hence, uncorrelated. If observations taken during the same time period are highly correlated, it may be preferable to apply the Mann-Kendall test to the medians of the data in each time period rather than use Eq. 16.5 in Eq. 16.4.

Table A18 Probabilities for the Mann-Kendall Nonparametric Test for Trend

S	Values of n: 4	5	8	9
0	0.625	0.592	0.548	0.540
2	0.375	0.408	0.452	0.460
4	0.167	0.242	0.360	0.381
6	0.042	0.117	0.274	0.306
8		0.042	0.199	0.238
10		$0.0^{2}83$	0.138	0.179
12			0.089	0.130
14			0.054	0.090
16			0.031	0.060
18			0.016	0.038
20			$0.0^{2}71$	0.022
22			$0.0^{2}28$	0.012
24			$0.0^{3}87$	$0.0^{2}63$
26			$0.0^{3}19$	$0.0^{2}29$
28			$0.0^{4}25$	$0.0^{2}12$
30				$0.0^{3}43$
32				$0.0^{3}12$
34				$0.0^{4}25$
36				$0.0^{5}28$

S	Values of n: 6	7	10
1	0.500	0.500	0.500
3	0.360	0.386	0.431
5	0.235	0.281	0.364
7	0.136	0.191	0.300
9	0.068	0.119	0.242
11	0.028	0.068	0.190
13	$0.0^{2}83$	0.035	0.146
15	$0.0^{2}14$	0.015	0.108
17		$0.0^{2}54$	0.078
19		$0.0^{2}14$	0.054
21		$0.0^{3}20$	0.036
23			0.023
25			0.014
27			$0.0^{2}83$
29			$0.0^{2}46$
31			$0.0^{2}23$
33			$0.0^{2}11$
35			$0.0^{3}47$
37			$0.0^{3}18$
39			$0.0^{4}58$
41			$0.0^{4}15$
43			$0.0^{5}28$
45			$0.0^{6}28$

Source: From Kendall, 1975. Used by permission.
Repeated zeros are indicated by powers; for example, $0.0^{3}47$ stands for 0.00047.
Each table entry is the probability that the Mann-Kendall statistic *S* equals or exceeds the specified value of S when no trend is present.
This table is used in Section 16.4.1.