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Operational Design Adjustments-1 WSA Phase-II Groundwater Remediation Design Fernald Preserve

March 2014

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Abbreviations

DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GMA	Great Miami Aquifer
gpm	gallons per minute
µg/L	micrograms per liter
OA	optimization alternative
Ohio EPA	Ohio Environmental Protection Agency
OU	Operable Unit
ROD	Record of Decision
TI	Technical Impracticability
WSA	Waste Storage Area

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Executive Summary

This report presents a proposal to accelerate cleanup of uranium contaminated groundwater in the South Plume and southern South Field Areas. These areas are identified in Figure 1. It should be noted that differentiation of the South Field into a northern and southern half is new for this report.

The accelerated cleanup is anticipated to be achieved by implementing the following recommended operational adjustments.

- Increase the pumping rate at extraction wells RW-6 and RW-7 in the South Plume from 200 gallons per minute (gpm) to 300 gpm each, to shorten the predicted cleanup of the South Plume by 1–2 years.
- Turn off extraction well EW-28a (Waste Storage Area) and extraction wells EW-31 and EW-32 (South Field) because they have served their purpose and no longer provide benefit to the ongoing remediation.
- Re-allocate the pumping budget gained by turning off extraction wells EW-28a, EW-31, and EW-32 to existing extraction wells in the southern portion of the South Field to shorten the model predicted cleanup time of the southern South Field by 8–9 years. Details concerning individual well pumping changes in the southern South Field are provided in Table 2 and discussed in Section 5. It should be noted that the southern South Field is the area of the on-DOE property plume that is closest to the DOE property line.

The recommended operational adjustments result in a groundwater remediation that meets the cleanup standards sooner in the South Plume and the southern South Field than the current groundwater remediation. It also meets surrounding community expectations in that modeling predicts that with the adjustments, both the off-DOE-property portion of the plume and the on-DOE-property portion of the plume that is closest to the DOE property boundary (southern South Field) will clean up faster.

With the operational adjustments, the target pumping rate for the groundwater remediation system would be increased by 300 gpm for the first 8 years to provide an "operational boost." Field verification of remediation progress would continue during the boost period. Site protocols outlined in the approved *Fernald Groundwater Certification Plan* will be used at the end of the 8-year operational boost to certify that predicted cleanup objectives in the South Plume and the southern South Field have been met. If cleanup objectives have been certified as being met in these two areas, the target pumping rate for the groundwater remediation system will be reduced and adjusted to efficiently target the remaining on-DOE-property plumes (Waste Storage Area and northern South Field).

Operational costs are slightly higher during the first 8 years due to increased pumping, but the upfront increase in costs would be offset by later predicted savings; resulting in an overall predicted savings of approximately $6.0 million.

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1.0 Introduction

1.1 Purpose of this Report

This report presents a proposal to accelerate cleanup of uranium contaminated groundwater in the South Plume and southern South Field Areas. These areas are identified in Figure 1. It should be noted that the differentiation of the South Field into a northern and southern half is new for this report. The proposal to accelerate groundwater cleanup in the South Plume and southern South Field does not involve the installation of any new additional extraction wells.

This report also discusses groundwater remediation issues in the former Waste Storage Area (WSA) that have the potential for impacting remediation success. Additional work is recommended in the WSA to gain insight into these issues in order to maximize the potential for achieving final cleanup certification in the WSA.

The work presented in this report was prompted by two issues: (1) Uranium data collected in 2011 indicated that the groundwater model used to design the current remediation system was initially loaded in 2005 with uranium concentration data that underestimated the size and concentration of the uranium plume that was actually present in some areas of the aquifer, and (2) Metrics being used to track remediation progress indicated that the pump-and-treat operation was becoming less effective over time (an observation that is common for pump-and-treat remedies).

Loading updated uranium concentration data into the model and modeling forward in time provided model predictions that extended cleanup of the South Plume by 6 years, the South Field by 6 years, and the WSA by 9 years when compared to previous remediation design cleanup time predictions.

In light of the extended model-predicted completion times, 16 different remediation alternatives to the current groundwater remediation were modeled to determine if the remediation could be shortened and/or the effectiveness improved. Results showed that the predicted cleanup times can be shortened in the South Plume and southern South Field if the following operational adjustments are made:

- Increase the pumping rate at extraction wells RW-6 and RW-7 in the South Plume from 200 gallons per minute (gpm) to 300 gpm each to shorten the predicted cleanup of the South Plume by 1–2 years.
- Turn off extraction well EW-28a (WSA) and, EW-31 and EW-32 (South Field) because they have served their purpose and no longer provide benefit to the ongoing remediation.
- Re-allocate the pumping budget gained by turning off extraction wells EW-28a, EW-31, and EW-32 to existing extraction wells in the southern portion of the South Field to shorten the model predicted cleanup time of the southern South Field by 8–9 years. Details concerning individual well pumping changes in the southern South Field are provided in Table 2 and discussed in Section 5. It should be noted that the southern South Field is the area of the on-DOE property plume that is closest to the DOE property line.

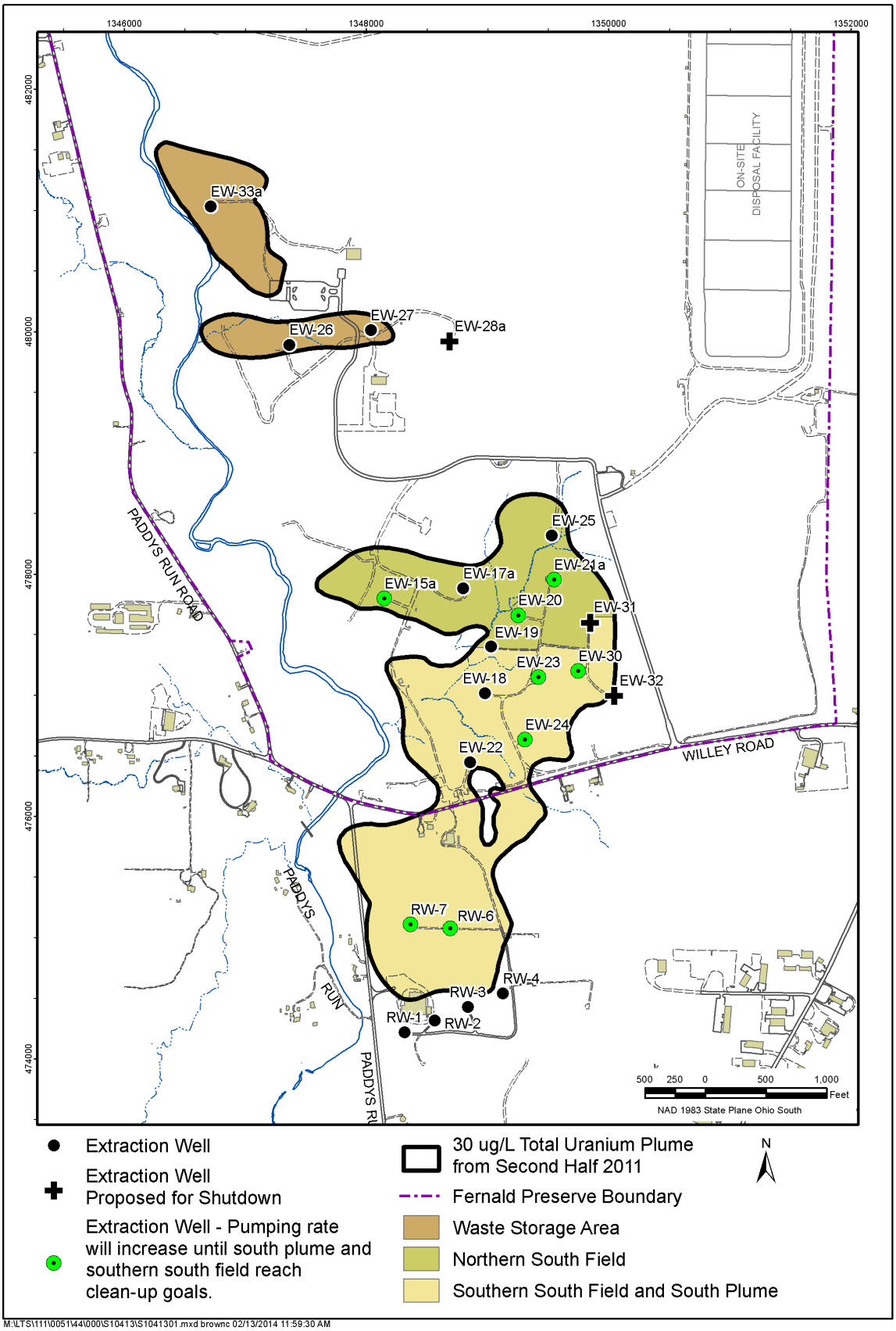

Figure 1. WSA Phase II Design Well Locations and 2011 Maximum Uranium Plume Footprint

The recommended operational adjustments result in a groundwater remediation that meets the cleanup standards sooner in the South Plume and the southern South Field than the current groundwater remediation approach that was established in 2005. It also meets surrounding community expectations in that modeling predicts that with the adjustments, both the off-DOE-property portion of the plume and the on-DOE-property portion of the plume that is closest to the DOE property boundary (southern South Field) will clean up faster.

1.2 Report Organization

This report is divided into eight sections and one appendix. Sections 2 thru 4 provide background information concerning the current remedy referred to as the Baseline. Regulatory commitments are revisited, the status of the current remedy is discussed, and information is presented to explain why DOE took the initiative to take an innovative look at how the groundwater remedy might be improved. Information is also provided concerning the modeling issues and considerations that were factored into the modeling exercises conducted for this report. Section 5 presents the proposed accelerated cleanup design referred to as the Modified Baseline. Additional details concerning the modeling are provided in the appendix. Specifics concerning each section are presented below.

- **Section 1.0, "Introduction":** Presents the purpose of the report and how the report is organized.
- **Section 2.0, "Background":** Describes regulatory commitments, the groundwater remediation design, the current status of the aquifer remediation, and the need to redefine modeled uranium concentration data.
- **Section 3.0, "Baseline Alternative":** Looks at the impact to the current remediation design caused by the additional uranium concentration data.
- **Section 4.0, "Modeling Considerations":** Presents the considerations that were factored into the alternatives modeled.
- **Section 5.0, "Modified Baseline Alternative":** Presents recommended operational adjustments.
- **Section 6.0, "Groundwater Remediation in the WSA":** Information is presented that indicates that remediation of groundwater in the WSA may not be achieved as predicted by the current groundwater modeling runs. Discussions are presented on determining how the remediation in the WSA might best proceed.
- **Section 7.0, "Summary."**
- **Section 8.0, "Recommendations."**
- **Section 9.0, "References."**
- **Appendix A, "Modeling Information."**

2.0 Background

The Fernald Preserve became a DOE Office of Legacy Management site in November 2006, following completion of the majority of the Comprehensive Environmental Response, Compensation, and Liability Act environmental remediation and site restoration.

The ongoing groundwater remediation at the Fernald Preserve uses pump-and-treat technology. Twenty-three extraction wells are operating at a target system pumping rate of 4,775 gpm. Metrics used to track remedy performance have shown that the pump-and-treat remedy is effectively removing uranium contamination from the Great Miami Aquifer (GMA). As of December 2012, 11,314 pounds of uranium had been removed from the GMA. However, the metrics show that the effectiveness of uranium removal via the pump-and-treat operation is slowly decreasing (a common observation for pump-and-treat remedies) and that operational adjustments should be considered.

In addition to the decrease in uranium removal, additional uranium concentration data collected in 2011 in one part of the uranium plume indicated that the groundwater model used to design the groundwater remediation was initially loaded with uranium concentration data in that area that underestimated the size and concentration of the uranium plume that was actually present. The additional uranium concentration data were loaded into the groundwater model, and the model predicted that cleanup dates would be extended.

Sixteen different remediation alternatives were modeled to determine if model-predicted cleanup dates could be shortened and if the effectiveness of the groundwater remediation could be improved. With new uranium concentration values loaded into the site groundwater model, the model was used to determine the optimum alternative. Only pumping rates were adjusted for the analysis. In a few of the alternatives, additional extraction wells were also modeled.

The conclusion from modeling the 16 different alternatives was that:

- With 6 years of additional uranium data loaded into the model, the predicted cleanup of the uranium plume would take longer than originally predicted.
- Cleanup of the South Plume could be accelerated by 2 years.
- Three extraction wells were identified (EW-28a, EW-31, and EW-32) that no longer provide benefit to the groundwater remediation. Pumping in these three wells should be stopped.
- If freed-up pumping budget from turning off extraction wells EW-28a, EW-31, and EW-32 is re-allocated to extraction wells in the southern portion of the South Field, cleanup of that portion of the plume can be accelerated.

This report presents the recommended path forward resulting from the modeling work.

2.1 Regulatory Commitments

The Operable Unit 5 (OU5) Record of Decision (ROD) commits to the "Extraction of contaminated groundwater from the Great Miami Aquifer to the extent necessary to provide reasonable certainty that final remediation levels have been attained at all affected areas of the aquifer" (DOE 1996). The final remediation level for uranium in groundwater in the GMA is 30 micrograms per liter (µg/L) and is based on U.S. Environmental Protection Agency (EPA) Primary Drinking Water Standards.

The *Fernald Groundwater Certification Plan* (DOE 2006) defines a programmatic strategy for certifying completion of the groundwater remedy at the Fernald Preserve. The plan also defines the area of the aquifer targeted for certification. The Groundwater Certification Plan was

developed in cooperation with and approved by EPA and the Ohio Environmental Protection Agency (Ohio EPA). The preferred outcome of the plan is to certify that the OU5 ROD groundwater remediation goals have been achieved using pump-and-treat technology. The plan also covers potential contingencies and exit scenarios.

Contingencies and exit strategies presented in the Groundwater Certification Plan include:

- **Operational adjustments:** Operational adjustments would use the existing pump-and-treat infrastructure and would not require changes to either the remedial action goals or the point of compliance.
- **Explanation of Significant Differences:** An OU5 ROD Explanation of Significant Differences would be required if it is decided to use a new technology such as bioremediation or monitored natural attenuation.
- **Technical Impracticability (TI) Waiver:** A request for a TI Waiver would be pursued only if (1) pump-and-treat operations have failed to achieve remediation goals, (2) the use of other promising technologies has been exhausted, and (3) it is shown that the design was proper, the system operated properly, and appropriate technology was used. Under a TI Waiver, new remediation goals or points of compliance can be pursued.

Only operational adjustments are being recommended at this time. As discussed in this report, monitored natural attenuation may be a viable option in the future for the WSA, but additional work is needed in the WSA to support the decision-making process. Given the continuing progress that pump-and-treat is making, a TI Waiver discussion is not warranted at this time.

The area of the aquifer targeted for cleanup was identified in the 2006 Groundwater Certification Plan as the Aquifer Remediation Footprint. In 2009, the area was renamed the Target Certification Footprint.

The Target Certification Footprint is defined as the areas contained within a composite of all previous 20 µg/L maximum uranium plume interpretations through 2000, and 30 µg/L maximum uranium plume interpretations subsequent to 2000. This change in concentration mirrors the EPA drinking water standard changing from 20 µg/L to 30 µg/L. The Target Certification Footprint of the aquifer (updated through 2012) is shown in Figure 2.

2.2 Current Groundwater Remediation Design

The design of the pump-and-treat remediation system currently in use at the Fernald Preserve has evolved through a series of progressive designs, listed below.

- *Feasibility Study Report for Operable Unit 5* (DOE 1995)
- *Baseline Remedial Strategy Report, Remedial Design for Aquifer Restoration (Task 1)* (DOE 1997)
- *Design for Remediation of the Great Miami Aquifer in the Waste Storage and Plant 6 Areas* (DOE 2001)
- *Design for Remediation of the Great Miami Aquifer, South Field (Phase II) Module* (DOE 2002)
- *Comprehensive Groundwater Strategy Report* (DOE 2003)
- *Waste Storage Area Phase II Design Report* (DOE 2005)

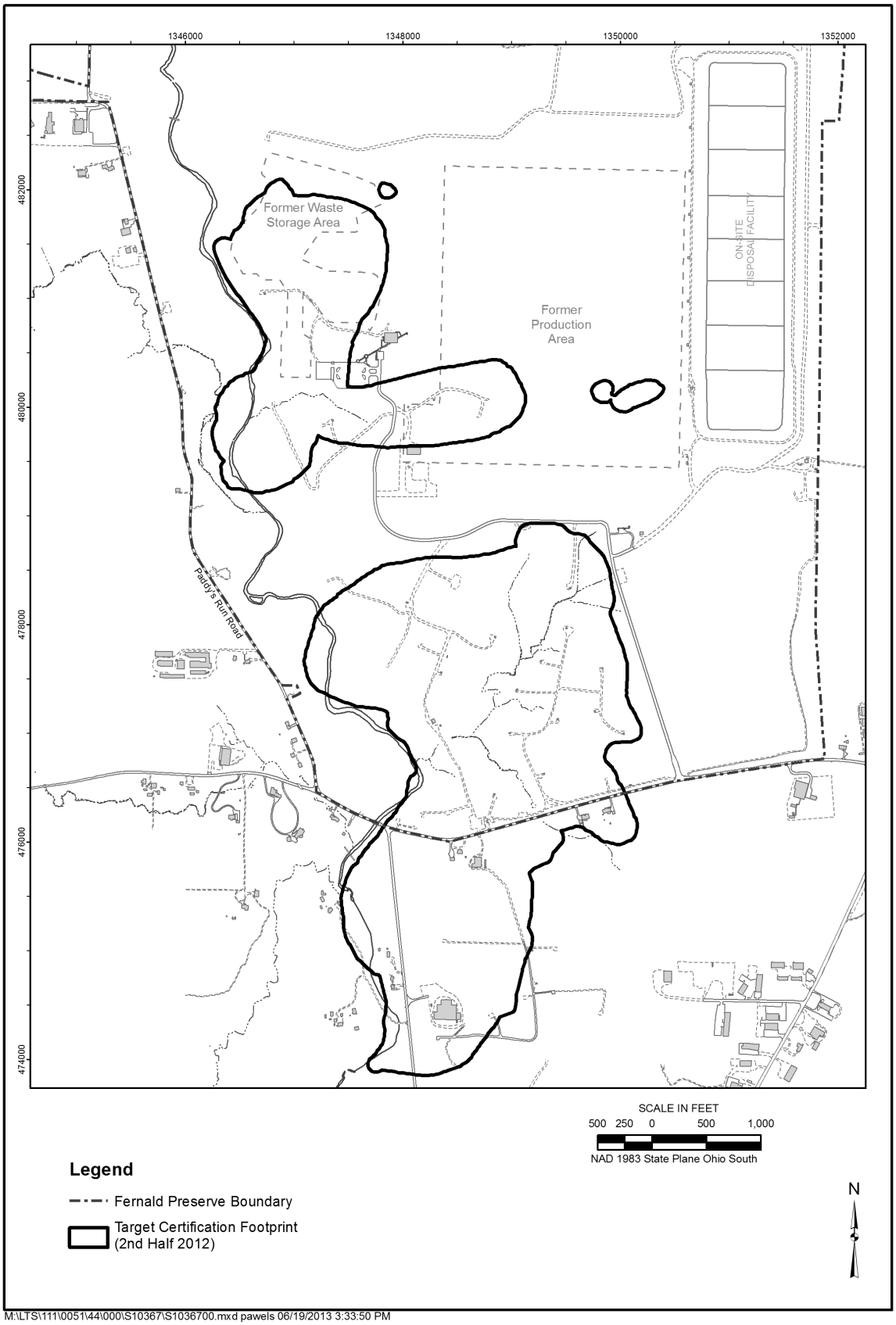

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Figure 2. Target Certification Footprint

The current operating system of extraction wells is the WSA Phase II Design. Twenty-three wells are pumped at a target system pumping rate of 4,775 gpm. Individual well pumping rates range from 100 gpm to 300 gpm. Figure 1 shows where the wells are located in relation to the 2011 uranium plume footprint. The 2011 uranium plume footprint is shown because uranium concentration data collected through December 31, 2011, were used for the modeling presented in this report.

Water levels within the aquifer rise and fall annually. From 2006 through 2012 the average annual fluctuation ranged from 2.46 feet to 7.50 feet. Extended periods of high or low water levels can impact how contamination migrates and interacts with aquifer sediments. Therefore, the groundwater model used at Fernald is run under three different sets of boundary conditions (i.e., dry, nominal, and wet) to help bracket the model uncertainty caused by changing water levels. Dry boundary conditions correspond to years when water levels are low, wet boundary conditions correspond to years when water levels are high.

A major objective of the Fernald Groundwater Remediation is to clean up the off-DOE-property portion of the plume as soon as possible. As shown on Figure 1, the off-DOE-property portion is south of Willey Road and is referred to in this report as the South Plume. Under the WSA Phase II Design (DOE 2005), the South Plume is modeled as cleaning up first (as early as 2015), the South Field second (as early as 2022), and the WSA last (as early as 2023).

2.3 Current Status of the Pump-and-Treat Remedy

As reported in the *Fernald Preserve 2012 Site Environmental Report* (DOE 2013), the current pump-and-treat remedy continues to operate well. In calendar year 2012, 508.5 pounds of uranium were removed from the GMA. From August 1993 through December 2012, 11,313 pounds of uranium were removed from the GMA.

A variety of metrics are used to track how the pump-and-treat operation is progressing, and they are reported each year in the Site Environmental Report. These metrics show that model-predicted aquifer cleanup concentrations closely match groundwater model predictions; however, since 2011 the predictions have become slightly more optimistic than the actual data indicate. The metrics also show that the overall effectiveness of the pump-and-treat operation is decreasing over time (decreasing concentrations are trending asymptotically), which is common for pump-and-treat operations in general. Operational effectiveness can be viewed as the general degree of contamination cleanup achieved. Pump-and-treat remediations are based on the operation of extraction wells. The level of contamination measured at monitoring wells may be greatly reduced in a moderate period of time, but low levels of contamination may persist. The contaminant mass removed may decline over time and gradually approach a residual level. At that point, large volumes of water are pumped to remove small amounts of contamination (EPA 1992). This can be caused by the diffusion of contaminants in low-permeability sediments, and/or hydrodynamic isolation within well fields. Operational adjustments can be used to change hydrodynamic conditions within the aquifer in an attempt to increase operational effectiveness.

Both observations noted above (asymptotic concentration trends and decreasing operational effectiveness) present a challenge to achieving cleanup final remediation levels. Additional discussions on these challenges are provided in Appendix A.

2.4 Need to Redefine Modeled Uranium Concentration Data

As reported in the Fernald Preserve 2010 Site Environmental Report (DOE 2011a), assessments of the groundwater model indicate that groundwater model predictions have remained reasonable over time in that the range of difference between model-predicted concentrations and actual field concentrations has not increased over time. Even though groundwater model predictions have remained reasonable, the need to redefine modeled uranium concentration data has developed.

Seven years of additional uranium concentration data have been collected since the model was last run. Additional uranium concentration data collected in 2011 in the South Plume indicates that the model used for the WSA Phase II Design was initially loaded in an area of the South Plume with uranium concentration data that underestimated the size and concentration of the plume that was actually present. This implies that the WSA Phase II Design likely underestimated the amount of time that it will actually take to reach remediation goals in this area.

In 2012 additional uranium concentration data were kriged and used in the groundwater model to determine the impact that the additional data would have on model-predicted cleanup times. Kriging is a mathematical process that uses known values from nearby sampled locations to estimate unknown values at regularly spaced model node locations. Additional information on the need to reload uranium concentration data into the groundwater model and the kriging that was conducted on the uranium data is provided in Appendix A.

3.0 Baseline Alternative

The Baseline Alternative for this report is the WSA Phase II Design (created in 2005) modeled with the newly kriged uranium plume (based on additional uranium concentration data through 2011). Modeling was programmed to begin at a start date in April 2012. No other model parameters were changed (e.g., hydraulic conductivity, boundary conditions, and distribution coefficients). The model was run under wet, nominal, and dry boundary conditions (using the same boundary condition files used in the WSA Phase II Design) to help address model uncertainty. The table below summarizes predicted cleanup dates for each plume area.

Predicted Cleanup Dates for Baseline Alternative

Plume Area	Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
South Plume	2020	2021	2020
South Field	2028	2028	2027
Waste Storage Area	2032	2030	2032

To be conservative, the longest predicted cleanup date (among the three boundary conditions) was selected for comparison to predicted cleanup dates from the WSA Phase II Design. The comparison is summarized in the table below. The comparison shows that loading additional uranium concentration data into the model and modeling forward in time provides model predictions with later cleanup dates for the remediation in all plume areas.

Comparison of Predicted Cleanup Dates (WSA Phase II Design vs. Baseline Alternative)

Alternative	South Plume Cleanup Date	South Field Cleanup Date	WSA Cleanup Date
WSA Phase II Design	2015	2022	2023
Baseline Alternative	2021	2028	2032
Increase in Years	6	6	9

3.1 Baseline Alternative Costs

Estimated costs for the Baseline Alternative are based on budgeted Life-Cycle Baseline costs (direct dollars) for the operation and maintenance of the WSA Phase II Design well field currently operating at the Fernald Preserve. Direct dollars means that the costs do not include fee, general and administrative, program management, or task/subtask management costs. Costs presented in this report are rounded to the nearest thousand.

Operations and maintenance of the current well field is budgeted at $1,178,000 per year. Based on an additional 20 years of operation (2012 to 2032) the Baseline Alternative remedy is estimated to cost $23,560,000. A breakdown of the costs by plume area is provided below:

Baseline Alternative Cost by Plume Cleanup Location (2012 to 2032)

South Plume	South Field Plume	WSA Plume	Total Cost
$10,602,000	$8,246,000	$4,712,000	$23,560,000

The annual volume of water targeted for pumping under the Baseline Alternative is 2.27 billion gallons. Dividing this volume target into the budgeted annual operations and maintenance costs and multiplying by 1,000 gallons equates to a cost metric of $0.52 for every 1,000 gallons pumped. This cost metric ($0.52 per 1,000 gallons pumped) was used to compare costs between the Baseline Alternative and the Modified Baseline Alternative presented in this report.

4.0 Modeling Considerations

The VAM3D groundwater model at the Fernald Preserve is designed to simulate three-dimensional flow of water and/or contaminant transport in fully saturated porous media. Although the VAM3D modeling code can be run in both saturated and unsaturated modes, the Fernald groundwater model was not built to account for unsaturated or perched water zones above the GMA. The GMA model was built to simulate the hydrogeologic conceptual model defined for the GMA at the site: a fully saturated and unconfined, buried valley aquifer. The hydrogeologic conceptual model was defined by sampling and testing the aquifer materials and environment then entering parameters into the model that define both physical and transport characteristics of the aquifer system that was tested (e.g., hydraulic conductivity, porosity,

contaminant distribution coefficients, seasonal water levels, and infiltration rates from surface water).

The physical and transport parameters entered into the model estimate and represent average aquifer conditions. However, since the GMA is a heterogeneous glacial outwash deposit, a certain degree of uncertainty will always exist between the model and the actual sampling data. This uncertainty limits how well the model can predict actual field conditions. While the model uncertainty is recognized, it remains a valuable prediction and performance-tracking tool, particularly when used to compare results of various remediation scenarios. Model uncertainties, assumptions, strengths, and sensitivities have all been previously discussed and reported (HydroGeoLogic 1998, HydroGeoLogic 2000, and DOE 2000).

In order to make direct comparisons between modeling results in this report and modeling results from the WSA Phase II Design report, no model parameters within the model were changed, other than pumping rates and new initial uranium concentrations. Therefore, the same modeling assumptions, strengths, and sensitivities that governed modeled fate and transport of uranium in the approved WSA Phase II Design also apply to the current modeling results.

In its current state, the Fernald groundwater model is good for predicting hydraulic containment of the uranium plume given different pumping conditions, and for making cleanup estimations that appear to have remained reasonable over time. Overall it remains a good tool for helping to predict how to manage the groundwater remedy at the Fernald site.

Because water levels in the aquifer fluctuate from season to season and year to year, the groundwater model at Fernald is run under three different sets of boundary conditions (dry, nominal, and wet) to help bracket the uncertainty that changing water levels have on the conceptual model used to predict cleanup times.

As discussed in Appendix A, predicted cleanup times that are within a year of each other are probably within the range of model uncertainty for the Fernald groundwater model. Differences greater than a year are considered to be significant.

Modeling provides the opportunity to compare possible outcomes to the conceptual model when one or more parameters within the model are changed and the others held constant. The modeling changes made for this report fall under the category of operational changes. A number of considerations, including those listed below, entered into how alternatives were modeled for this report.

- Issues presented in the *Third Five-Year Review Report for the Fernald Preserve* (DOE 2011b) that have the potential to delay cleanup
- Impacts to the surrounding community
- Individual well-pumping limitations recognized through operational experience
- Acceptable net-system extraction rates
- Correlation of field data to modeling-run start times
- Maintaining hydraulic containment of the 30 µg/L maximum total uranium plume

Additional information on these modeling considerations is provided in Appendix A.

The operational adjustments recommended in this report were modeled as beginning in 2012. Therefore, model-predicted cleanup dates are based on the 2012 start date. If the operational adjustments are implemented, completion dates will need to be adjusted to take into consideration the actual start date.

5.0 Modified Baseline Alternative

Sixteen different remediation alternatives were modeled to select the key set of operational adjustments that could be used to modify the Baseline Alternative such that groundwater would be cleaned up faster in the South Plume and southern South Field.

As described earlier, the South Plume is the portion of the uranium plume that extends off DOE property. A main objective of the Fernald groundwater remediation is to clean up this portion of the plume first. The southern South Field is the on-DOE-property plume that is closest to the DOE property line (Figures 1 and 2).

Ten of the 16 alternatives were modeled to determine whether the South Plume could be cleaned up quicker and/or more efficiently than predicted by the Baseline Alternative. As was done for the Baseline Alternative, model runs were programmed to begin in 2012 using the newly kriged uranium plume. Other than adding the additional uranium concentration data into the model, no other conceptual design model parameters were changed (e.g., hydraulic conductivity, boundary conditions, and distribution coefficients). The model was run under wet, nominal, and dry boundary conditions to help bracket model uncertainty. To be conservative, the longest cleanup date determined for dry, nominal, or wet boundary conditions was selected as the predicted cleanup date for each alternative for comparison purposes. Seven of the 10 alternatives involved the addition of one or two new extraction wells. Additional information is provided in Appendix A.

Table 1 provides a description of each of the 10 modeled South Plume alternatives and a summary of results. Included in Table 1 is a description of the alternative, an indication of whether there is an infrastructure impact, the cleanup time prediction compared to the Baseline Alternative, an indication of whether there is an impact to off-DOE-property owners, and risks.

As shown in Table 1, modeling the 10 alternatives indicates that cleanup of the South Plume can be shortened by approximately 2 years (at best) given the modeling considerations listed earlier. Alternative 2 showed that with extraction wells SP-6 and SP-7 pumping at 300 gpm each instead of 200 gpm each, cleanup of the South Plume could be accelerated by approximately 1–2 years. Alternative 2 also required no new infrastructure. Additional information on these alternatives can be found in Appendix A.

Table 1. Summary of Modeling Results for South Plume Alternatives

South Plume Alternative	Description	Infrastructure Impact	Cleanup Prediction (years less than Baseline Alternative)	Impact to Off-DOE Property Owner	Risk Level	Risk Explanation
1	Increase the pumping rate of SP-6 from 200 gpm to 400 gpm	No	2	No	High	May not be able to maintain a pumping rate of 400 gpm.
2	Increase the pumping rate of SP-6 and SP-7 from 200 gpm each to 300 gpm each	No	2	No	Medium	Should be able to maintain 300 gpm at each of these wells.
3	Increase the pumping rate of SP-6 and SP-7 from 200 gpm each to 400 gpm each	No	2	No	High	May not be able to maintain a pumping rate of 400 gpm from these wells.
4	Install a new on-property well (IW-11) and pump it at 200 gpm	Yes[a]	1	No	Medium	May not be able to convert abandoned injection well to an extraction well and maintain desired yield.
5	Install a new on-property well (IW-11) and pump it at 400 gpm	Yes[a]	1	No	High	May not be able to convert abandoned injection well to an extraction well and maintain desired yield.
6	Install a new off-property well (KN-1) and pump it at 200 gpm	Yes	1	Yes	Medium	Normal issues associated with off-DOE-property wells.
7	Install a new off-property well (KN-1) and pump it at 400 gpm	Yes	2	Yes	High	May not be able to easily maintain a pumping rate of 400 gpm in this well given aquifer conditions in the area.
8	Install a new on-property well (IW-11) and off-property well (KN-1) and pump both at a rate of 200 gpm	Yes[a]	1	Yes	Medium	May not be able to convert abandoned injection well to an extraction well.
9	Install a new on-property well (IW-11) and a new off-property well (KN-1) and pump both at a rate of 400 gpm	Yes[a]	2	Yes	High	May not be able to convert abandoned injection well to an extraction well and maintain 400 gpm pumping rates in both wells.
10	Pump extraction wells SP-6 and SP-7 at 300 gpm each and install a new off-property well (KN-1) and pump it at 200 gpm	Yes	2	Yes	Medium	Normal issues associated with off-DOE-property wells.

Note:
[a] Convert an inactive injection well to an extraction well. Locations for the wells are provided in Appendix A.

After having determined that cleanup of the South Plume could be accelerated without installing any new wells, six different alternatives (identified as OA1 through OA6) were modeled to explore options for further optimizing cleanup of the on-DOE-property portion of the uranium plume. Modeling information is provided in Appendix A.

- OA1: Let the WSA plume naturally attenuate following cleanup of the South Plume.
- OA2: Let a small portion of the WSA plume naturally attenuate following cleanup of the South Plume.
- OA3: Turn off extraction wells EW-31 and EW-32 in the South Field.
- OA4: Turn off extraction well EW-28a in the WSA.
- OA5: Used results from OA1 through OA4 to define a pumping schedule that would optimize the remediation operation while maintaining aggressive pumping rates. Four different designs were modeled (OA5a through OA5d). OA5c was selected as the best.
- OA6: Used results from OA1 through OA4 to define a pumping schedule that would optimize the remediation operation while not maintaining an aggressive pumping rate.

A meeting was held with EPA and Ohio EPA on August 21, 2013, in which the different modeling alternatives and results were briefly discussed. The discussion focused on Alternative OA5c as a potential path forward. Under Alternative OA5c:

- The pumping rates at extraction wells RW-6 and RW-7 in the South Plume are modeled at 300 gpm each.
- The pumping rates at extraction wells EW-33a, EW-28a, EW-31, and EW-32 are modeled at 0 gpm.
- Freed up pumping capacity from these four wells is reassigned in the model to extraction wells located in the southern half of the South field. Additional information on Alternative OA5c is provided in Appendix A.

A decision was made to move forward with a "modified" version of Alternative OA5c and to prepare this report. In this report, the selected alternative is referred to as the Modified Baseline Alternative.

The difference between OA5c and the selected Modified Baseline Alternative is that extraction well EW-33a remains pumping at 300 gpm for 22 years. A discussion as to why it was decided to continue to pump extraction well EW-33a is provided in Sections 6.0 through 6.3 of this report. The following two operational adjustments are discussed below.

- Pumping rates at extraction wells EW-28a, EW-31, and EW-32 are modeled at 0 gpm.
- Freed-up pumping budget from EW-28a, EW-31, and EW-32 (700 gpm) was reassigned in the model to extraction wells located in the southern half of the South Field.

<u>Turn off Extraction Wells EW28a, EW-31, and EW-32</u>

At the end of 2011, the uranium concentration in water being pumped at one extraction well in the WSA (EW-28a) and two extraction wells in the South Field (EW-31 and EW-32) had fallen well below the cleanup uranium concentration goal of 30 µg/L (10.2 µg/L, 13.8 µg/L, and 4.9 µg/L, respectively). A particle track assessment of the wells in relation to the maximum

uranium plume at the end of 2011 was conducted to provide further insight into why the concentrations were so low. A particle track assessment conceptualizes the path that a drop of water takes in the model over a defined time period. In this case, the assessment was used to indicate if water being pumped to a well was coming from the plume area or from outside the plume area.

Figure 3 shows the 10-year time-of-travel particle paths (based on WSA Phase II Design pumping rates) in relation to the maximum uranium plume map from December 2011. The particle paths leading to the three extraction wells indicate that the wells are pulling water from outside (or mostly outside) the uranium plume. Based on the WSA Phase II Design, all three wells are scheduled to continue pumping until 2023. Modeling indicated that upon removing these wells, nearby wells compensated and maintained hydraulic containment of the maximum uranium plume. Modeling further indicated that removing these wells could be a viable option for increasing the effectiveness of the pump-and-treat operation if the unused pumping capacity could be redirected to other wells in order to accelerate the cleanup.

Increase Pumping in the Southern Half of the South Field

Freed-up pumping budget from turning off extraction wells EW-28a, EW-31, and EW-32 was reassigned to extraction wells in the southern half of the South Field to accelerate cleanup in that area. The pumping changes are presented in Table 2. Groundwater flow direction in the southern portion of the South Field is toward the DOE property boundary. Cleanup of the southern portion of the South Field reduces the possibility for existing on-DOE-property uranium contamination to migrate off DOE property.

5.1 Modified Baseline Modeling Results (Proposed Alternative)

Modeling was conducted under steady-state conditions to assess hydraulic containment of the maximum uranium plume under all three pumping periods modeled for the Modified Baseline Alternative. Table 2 provides a pumping schedule for the Modified Baseline Alternative and shows the three different pumping periods for the alternative (2012 to the South Plume and southern South Field Clean, South Plume and southern South Field Clean to Northern South Field Clean, and Entire South Field clean to End when WSA is clean).

Table 2. Proposed Pumping Rates for Modified Baseline

System/Well ID			Pumping Rates (gpm)		
			2012 to South Plume and Southern South Field Clean[a]	South Plume and Southern south Field Clean to northern South Field Clean	Entire South Field Clean to End
South Plume					
SP-1	RW-1	3924	200	0	0
SP-2	RW-2	3925	200	0	0
SP-3	RW-3	3926	200	0	0
SP-4	RW-4	3927	200	0	0
SP-6	RW-6	32308	**200**/300	0	0
SP-7	RW-7	32309	**200**/300	0	0
South Plume Subtotal			**1,200**/1,400	0	0

Table 2 (continued). Proposed Pumping Rates for Modified Baseline

System/Well ID			Pumping Rates (gpm)		
			2012 to South Plume and Southern South Field Clean[a]	**South Plume and Southern south Field Clean to northern South Field Clean**	**Entire South Field Clean to End**
South Field					
SF-31	EW-15a	33262	**200**/300	**300**/400	0
SF-17	EW-17	31567	175	175	0
SF-18	EW-18	31550	100	**100**/0	0
SF-19	EW-19	31560	100	**100**/300	0
SF-20	EW-20	31561	**100**/200	400	0
SF-21	EW-21a	33298	**200**/300	**300**/400	0
SF-22	EW-22	32276	300	**400**/0	0
SF-23	EW-23	32447	**300**/500	**400**/0	0
SF-24	EW-24	32446	**300**/400	**300**/0	0
SF-25	EW-25	33061	100	**100**/300	0
SF-32	EW-30	33264	**200**/400	**400**/0	0
SF-33	EW-31	33265	**300**/0	**400**/0	0
SF-34	EW-32	33266	**300**/0	**200**/0	0
South Field Subtotal			**2,575**/2,875	**3,575**/1,975	0
WSA					
WSA-1	EW-26	32761	300	500	500
WSA-2	EW-27	33062	200	300	**200**/300
WSA-4	EW-28a	33334	**200**/0	200/0	**200**/0
WSA-5	EW-33a	33347	300	300	300
WSA Subtotal			**1000**/800	1,100	1,100
Total Pumping			**4,775**/5,075	**4,775**/3,075	**1,200**/1,100

[a] Operational adjustments were modeled as beginning in 2012. Therefore, model predicted cleanup dates are based on a 2012 start date. If the operational adjustments are implemented, model predicted completion dates will need to be adjusted to take into consideration the actual start date.

Proposed pumping rate changes for specific wells are highlighted by showing the currently planned pumping rates **(BOLD RED)** along with the proposed new rates when the rates differ.

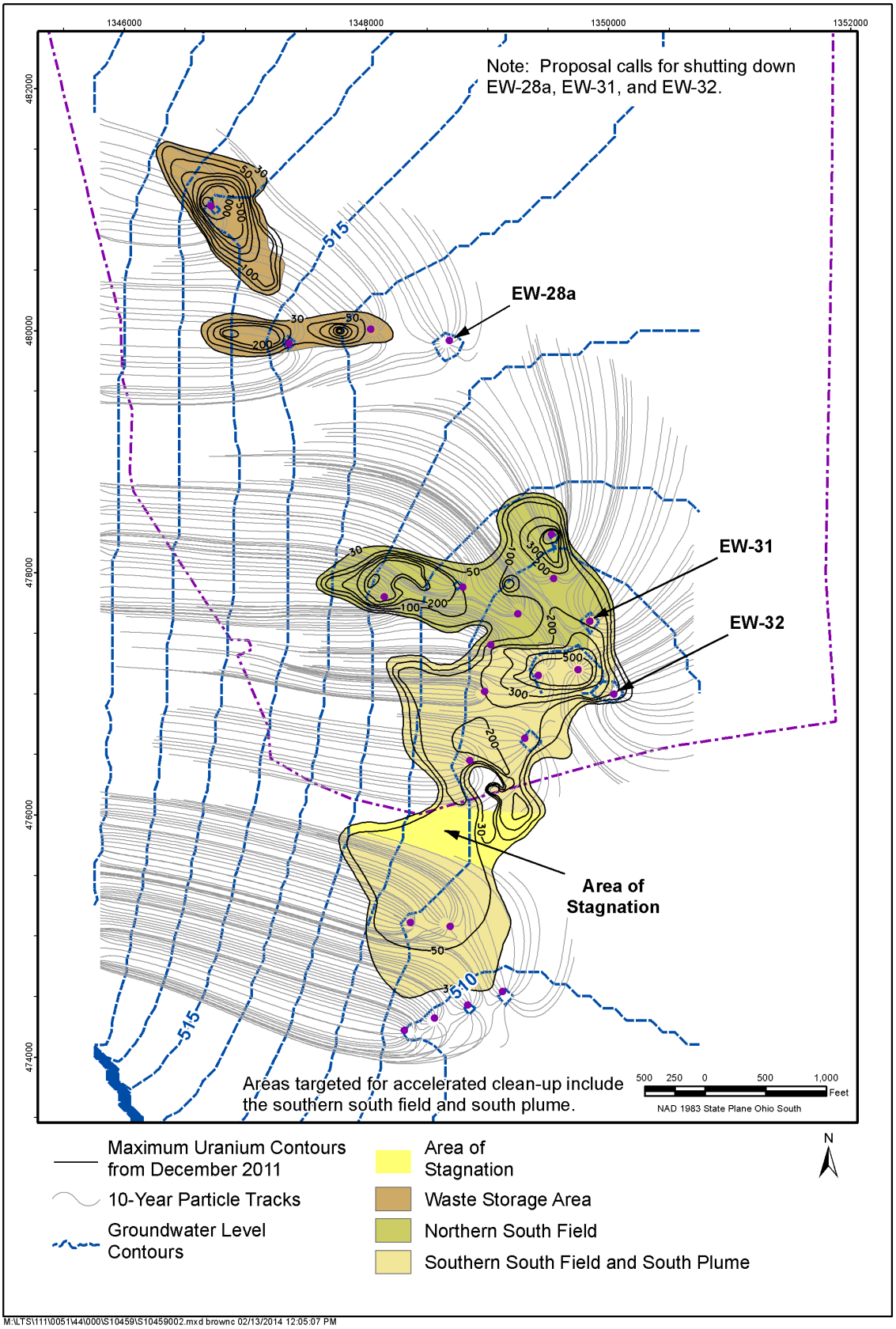


Figure 3. Maximum Uranium Plume from December 2011 with 10-Year Particle Tracks from WSA Phase II Design

Ten-year time-of-travel particle tracks were modeled under steady-state conditions and compared to predicted water level contours to illustrate capture of the footprint of the maximum uranium plume from December 2011. Figure 4 shows 10-year particle tracks for dry boundary conditions for all three pumping periods.

Figure 5 shows 10-year particle tracks for wet boundary conditions for all three pumping periods. The maximum uranium plume from 2011 is also shown in Figures 4 and 5 for perspective.

The footprint of the maximum uranium plume from December 2011 provides a conservative visualization reference for capture of the various plume areas. Predicted water level contours and particle tracks shown on the figures, indicate that the maximum uranium plume will be contained under the Modified Baseline Alternative. Under the Modified Baseline Alternative, the South Plume and the southern portion of the South Field cleans up earlier. This represents a predicted improvement over the current remedy (Baseline Alternative). The earlier predicted cleanup is attributed to the use of higher pumping rates, which result in: More drawdown (approximately 1-foot on average across the stagnation zone area), Uranium being removed from the aquifer at a faster rate, and More water being flushed through the area.

It should be noted that under both the Current Baseline and Modified Baseline, solute transport modeling predicts that the area beneath Willey road will be remediated to cleanup standards. As shown in Figure 3, the area beneath Willey Road is shown as a stagnation zone area. Within the area of this stagnation zone exists a pumping induced groundwater divide separating the South Plume Extraction Wells and the South Field Extraction Wells. This divide slows down remediation beneath Willey Road, but does not prevent it. The area is still influenced by, and will benefit from the proposed increase in pumping. This is evident through the predicted increase in drawdown and hydraulic gradient. As reported above, drawdown is predicted to increase by approximately 1 foot.

Though Figure 4 and Figure 5 show that a portion of the South Plume near Willey road is not within the predicted 10 year non-retarded time of travel, solute transport modeling predicts cleanup of the entire South Plume area within 9 years (2012 to 2021). This indicates that the model predicts that the uranium concentration based cleanup goal will be achieved in two ways: (1) Pulling uranium from the aquifer, and (2) Flushing enough water through the plume to reduce uranium concentrations below the cleanup FRL.

Predicted cleanup dates for the Modified Baseline Alternative are provided below.

Predicted Cleanup Dates for the Modified Baseline Alternative

Plume Area	Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
South Plume **and southern South Field**	2019	2020	2019
Rest of South Field	2027	2028	2026
WSA	2033	2028	2033

Figures 6, 7, and 8 are maximum uranium plume maps for the years in which the South Plume and southern South Field are predicted to achieve cleanup goals under dry, nominal, and wet boundary conditions, respectively. As shown above, cleanup of the South Plume and southern

South Field are predicted between 2019 and 2020. Cleanup of the remainder of the South Field is predicted to occur between 2026 and 2028. Cleanup of the WSA is predicted to occur between 2028 and 2033.

Figures 9, 10, and 11 are maximum uranium plume maps for the years in which the remaining South Field (northern South Field) is cleaned up under the Modified Baseline Alternative under dry, nominal, and wet boundary conditions, respectively. Since both the remaining South Field and WSA are predicted to be cleaned up in 2028 under nominal boundary conditions, only the map for 2027 is shown for nominal boundary conditions.

Under wet boundary conditions, the predicted size of the WSA plume in 2026 is approximately 1.659 acres. Under dry boundary conditions, the predicted size of the WSA in 2027 is approximately 1.187 acres.

Comparing predicted cleanup dates from the Modified Baseline Alternative to predicted cleanup dates for the Baseline Alternative is not straightforward because cleanup of the southern South Field is accelerated under the Modified Baseline Alternative. The comparison provided below is for complete cleanup of the South Field and WSA. To be conservative, the most distant predicted cleanup dates (regardless of boundary condition) are compared.

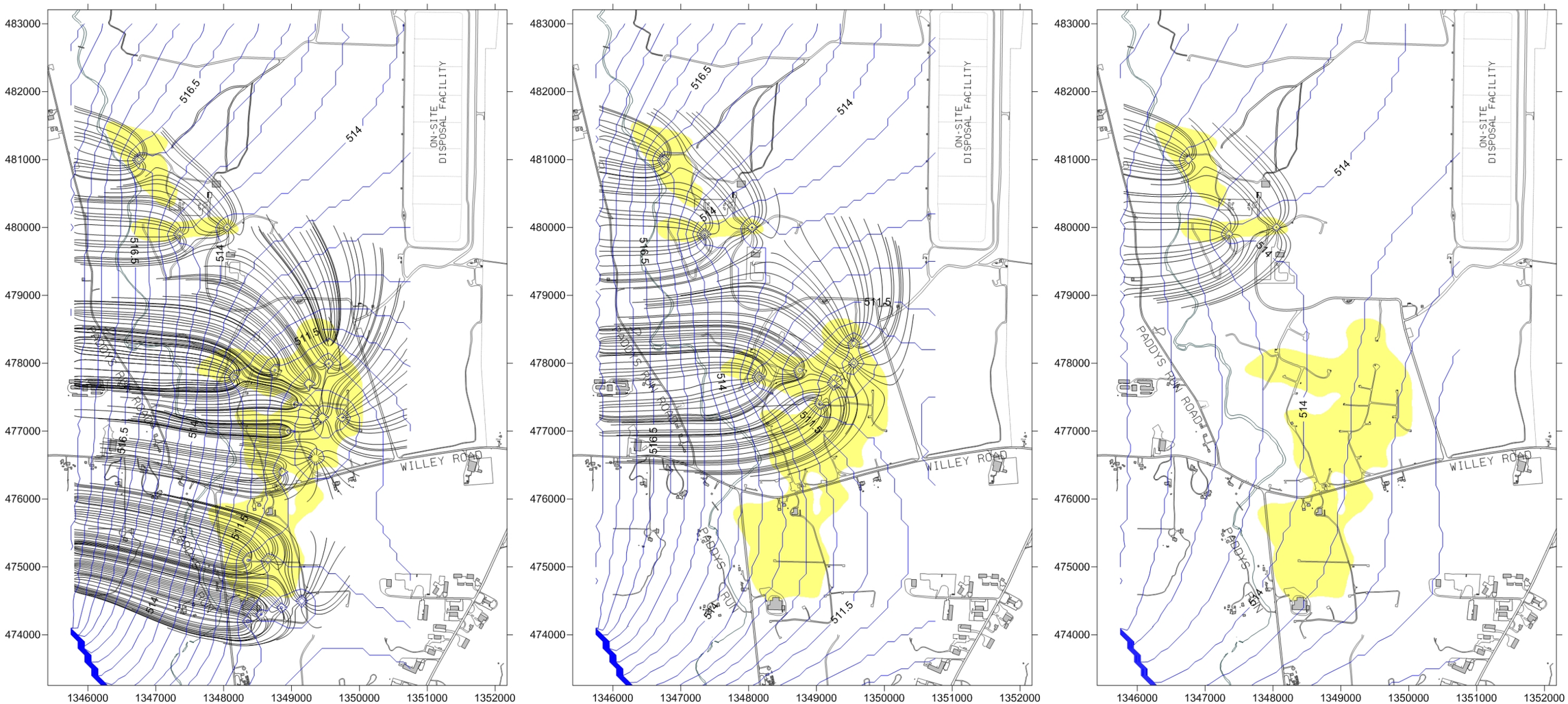
Comparison of Predicted Cleanup Dates
(Baseline Alternative vs. Modified Baseline Alternative)

Alternative	South Plume Clean Date	South Field Clean Date	WSA Clean Date
Baseline Alternative	2021	2028	2032
Modified Baseline Alternative	2020	2028	2033

As shown above, the model-predicted cleanup times for the Modified Baseline Alternative are within a year of predicted cleanup times for the Baseline Alternative, but these comparisons do not reveal the benefits of the operational adjustments found in the Modified Baseline Alternative. The main benefit being that the southern portion of the South Field is cleaned up approximately 8 years earlier under the Modified Baseline Alternative.

Figure 12 illustrates what the system pumping rates will be over time with the operational adjustments planned for the Modified Baseline Alternative. Figure 12 also illustrates that under the current Baseline Alternative, no pumping reductions are planned. System pumping under the Baseline Alternative remains at 4,775 gpm for the entire 20 years. The benefits of increasing the pumping rate by 300 gpm for the first 8 years under the Modified Baseline Alternative is gained beginning in year 9, when both the South Plume and southern South Field are predicted to be cleaned up. In year 9, pumping rates are reduced from a system total of 5,075 gpm to 3,075 gpm. Less pumping is needed because only the northern South Field plume area is predicted to remain. Cleanup of the northern South Field is predicted in year 16. Therefore, in year 17, pumping rates are once again reduced, this time to 1,100 gpm to focus on the only remaining plume in the WSA.

Planned system pumping reductions in the later years of the remediation are predicted to lead to a cost savings of approximately $6 million over the life of the remediation. A breakdown of estimated costs is provided below for both the Baseline Alternative and the Modified Baseline Alternative.

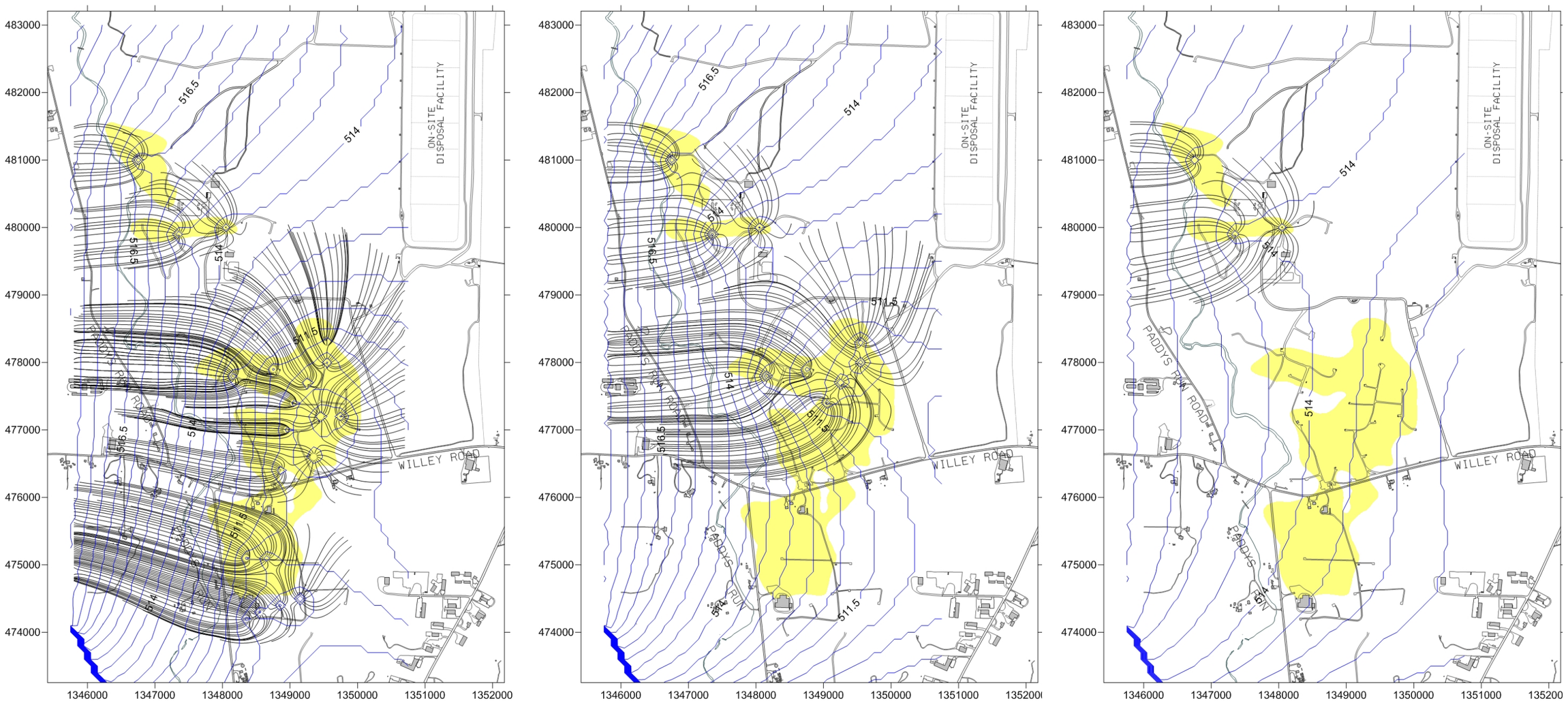


2012 to South Plume and Southern South Field Clean

South Plume and Southern South Field Clean to Entire South Field Clean

South Field Clean to WSA Clean

Figure 4. 10-year Particle Tracks for Dry Boundary Conditions, Modified Baseline Alternative (Water Level Contours Shown in Blue) Yellow shading is Uranium Plume in 2011



2012 to South Plume and Southern South Field Clean

South Plume and Southern South field Clean to Entire South Field Clean

South Field Clean to WSA Plume Clean

Figure 5. 10-year Particle Tracks for Wet Boundary Conditions, Modified Baseline Alternative (Water Level Contours Shown in Blue) Yellow shading is uranium plume in 2011

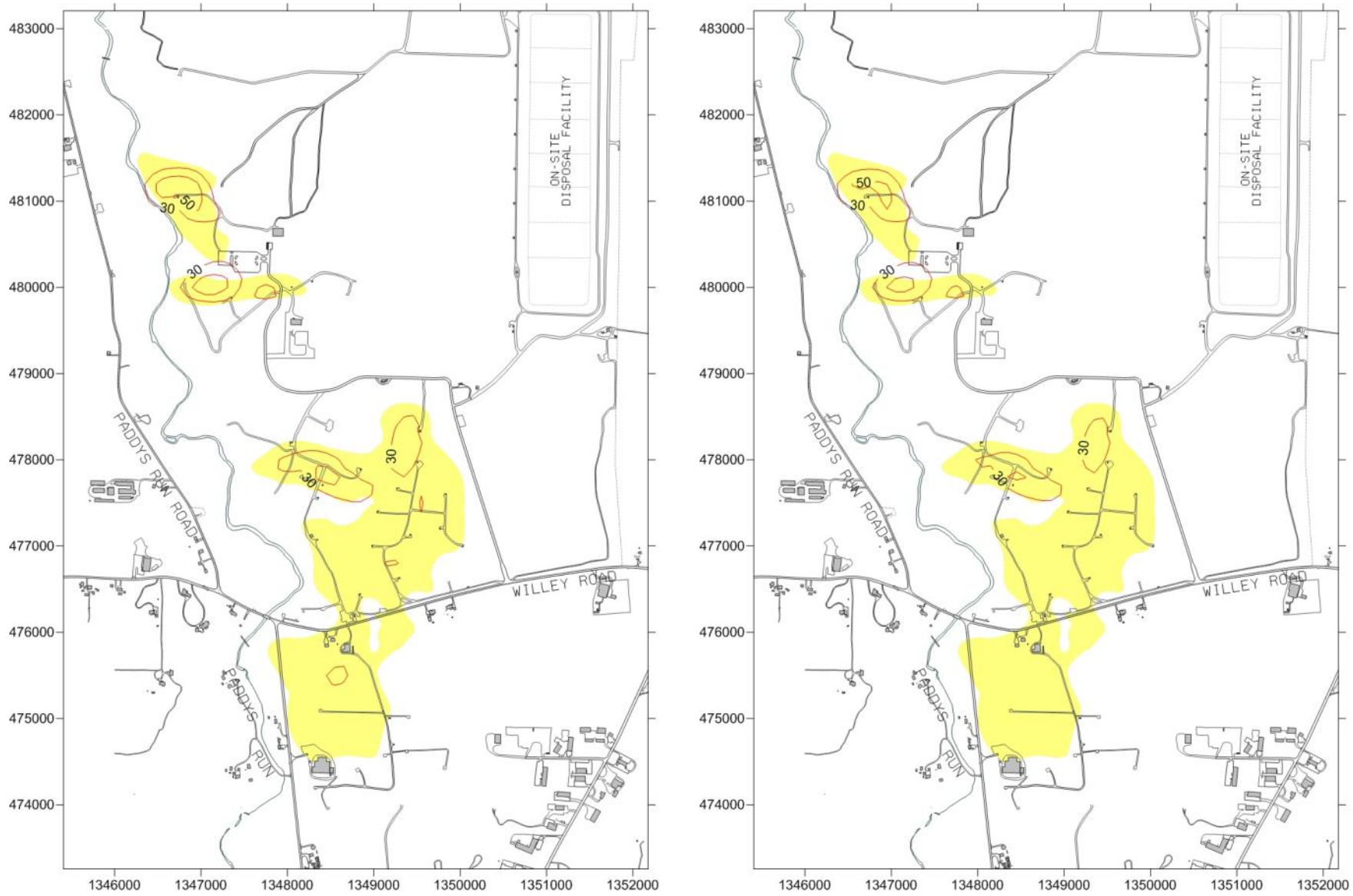


Figure 6. Maximum Uranium Concentration Contours, Modified Baseline Alternative, Dry Boundary Conditions
Yellow Shading is Uranium Plume in 2011

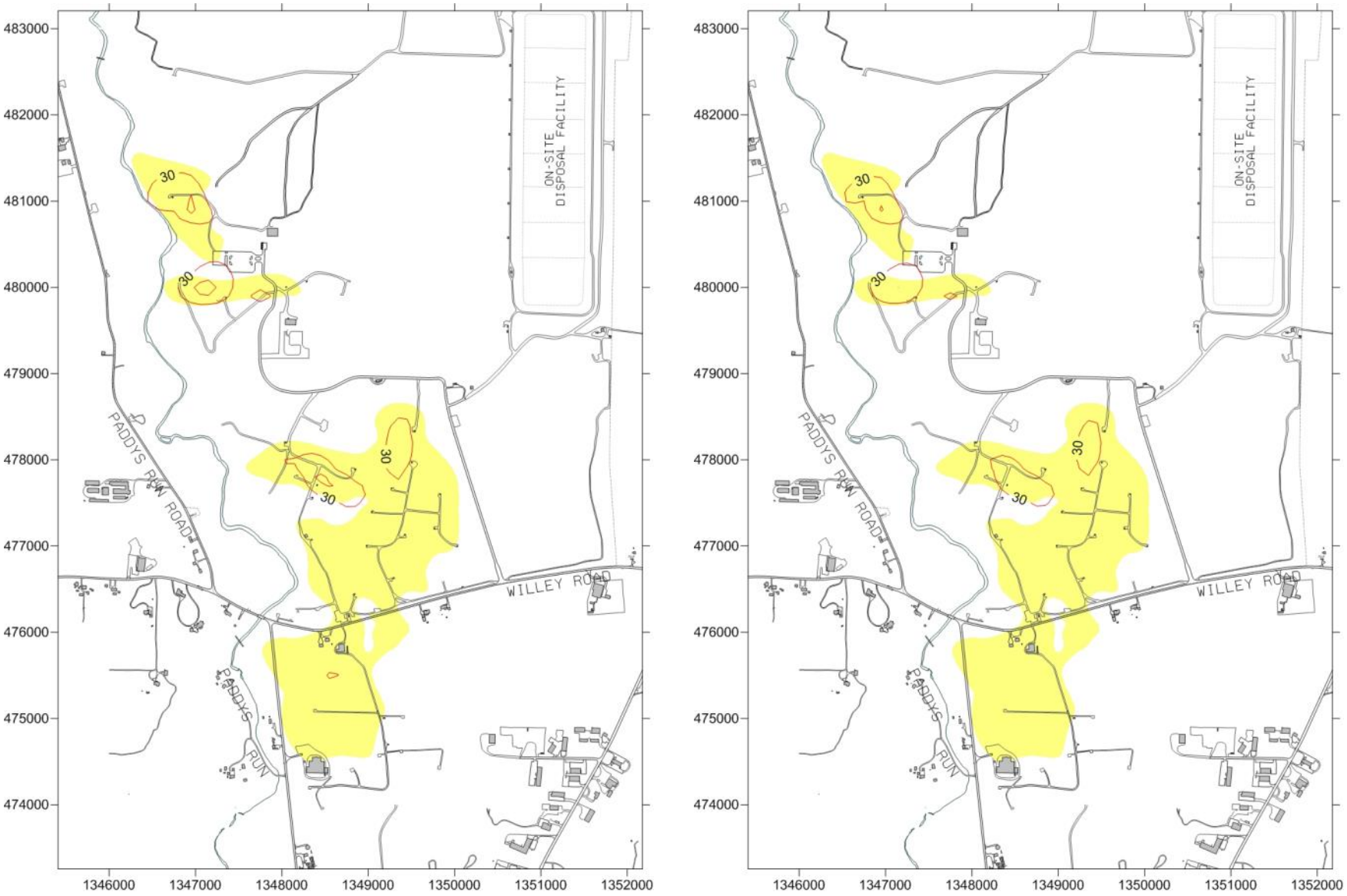
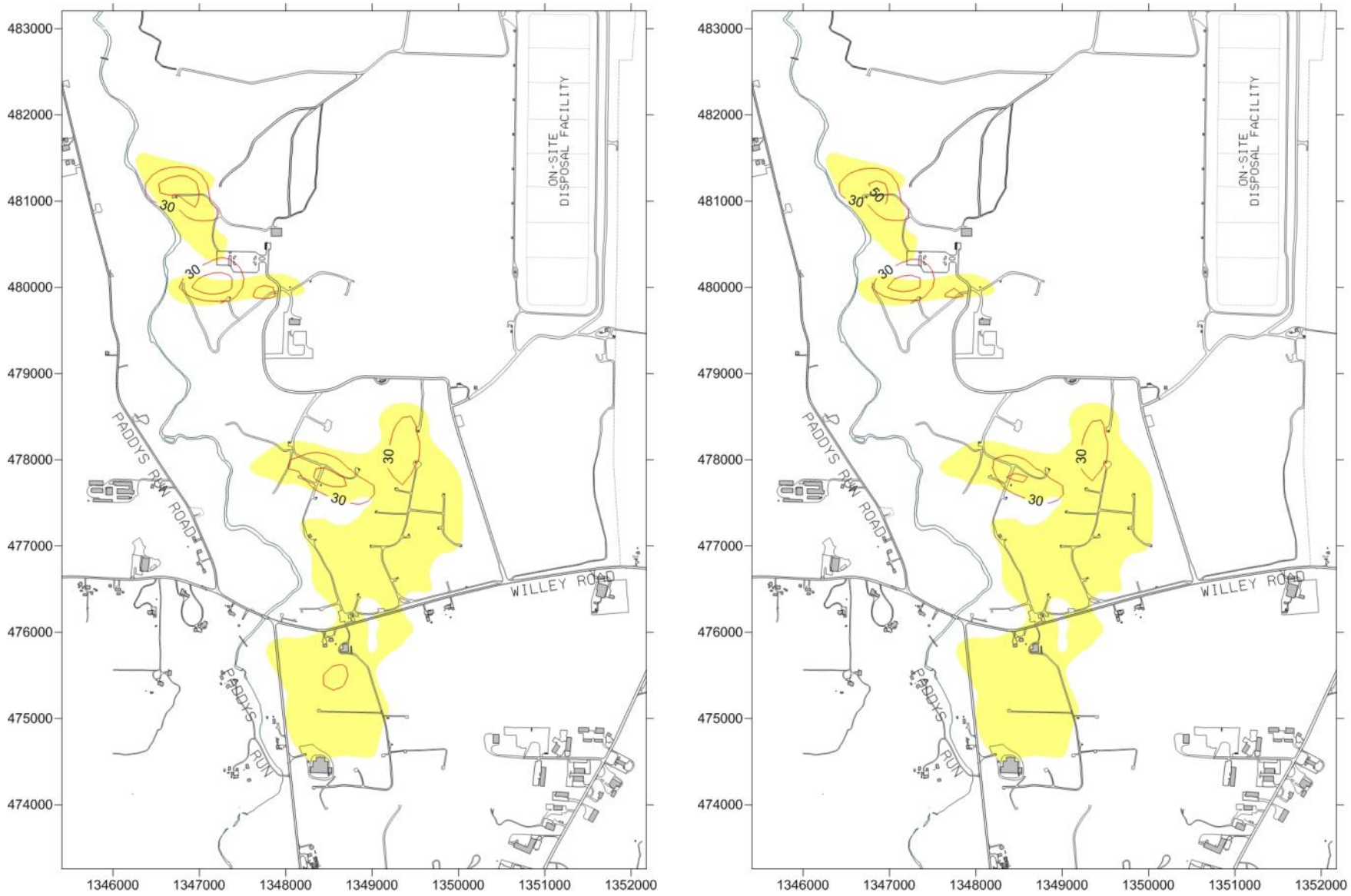


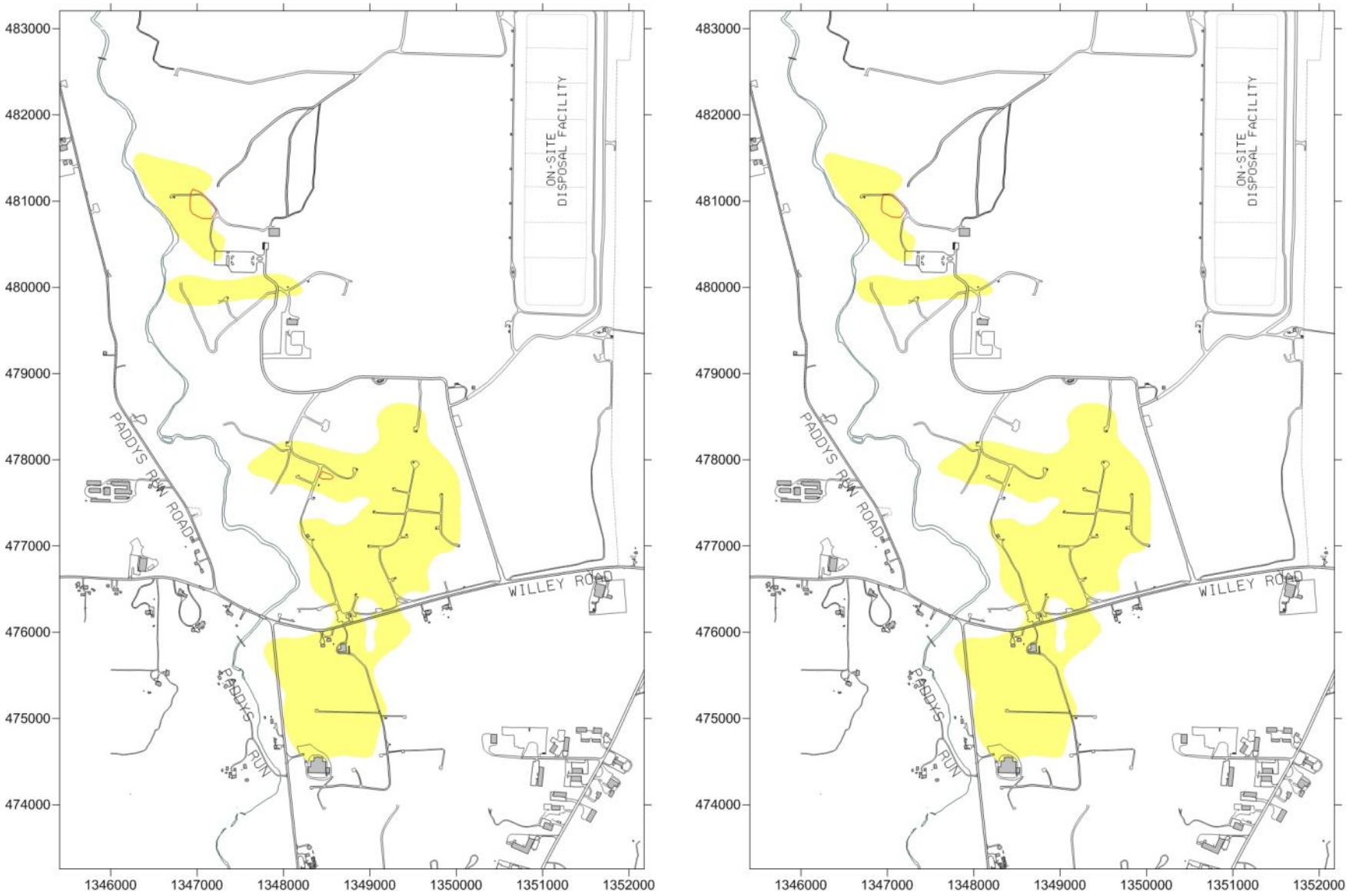
Figure 7. Maximum Uranium Concentration Contours, Modified Baseline Alternative, Nominal Boundary Conditions
Yellow shading is Uranium Plume in December 2011



Model Year 2018

Model Year 2019

Figure 8. Maximum Uranium Concentration Contours, Modified baseline Alternative, Wet Boundary Conditions
Yellow shading is Uranium Plume in December 2011



Model Year 2026

Model Year 2027

Figure 9. Maximum Uranium Plume Concentration Contours, Modified Baseline Alternative, Dry Boundary Conditions
Yellow shading is Uranium Plume in December 2011

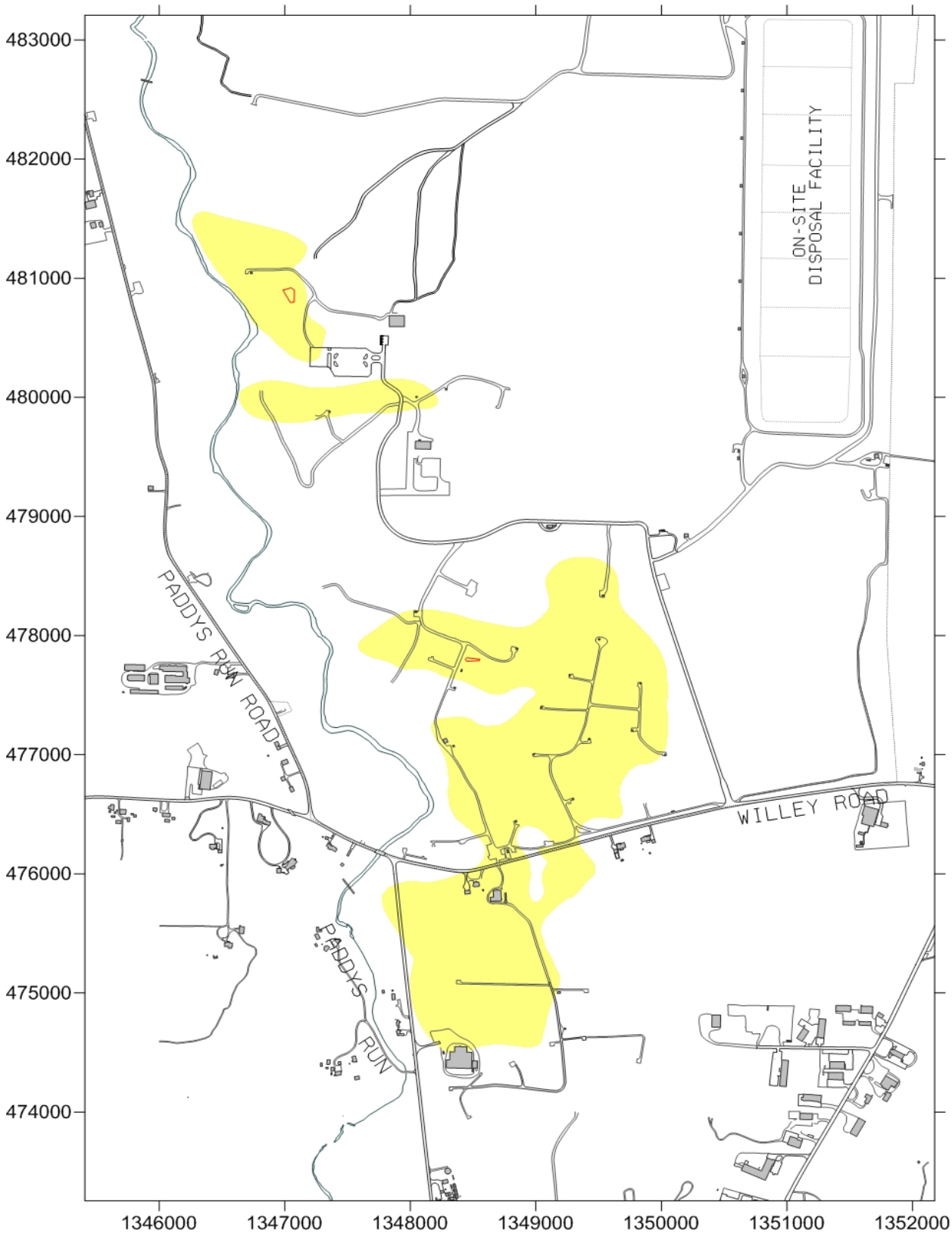
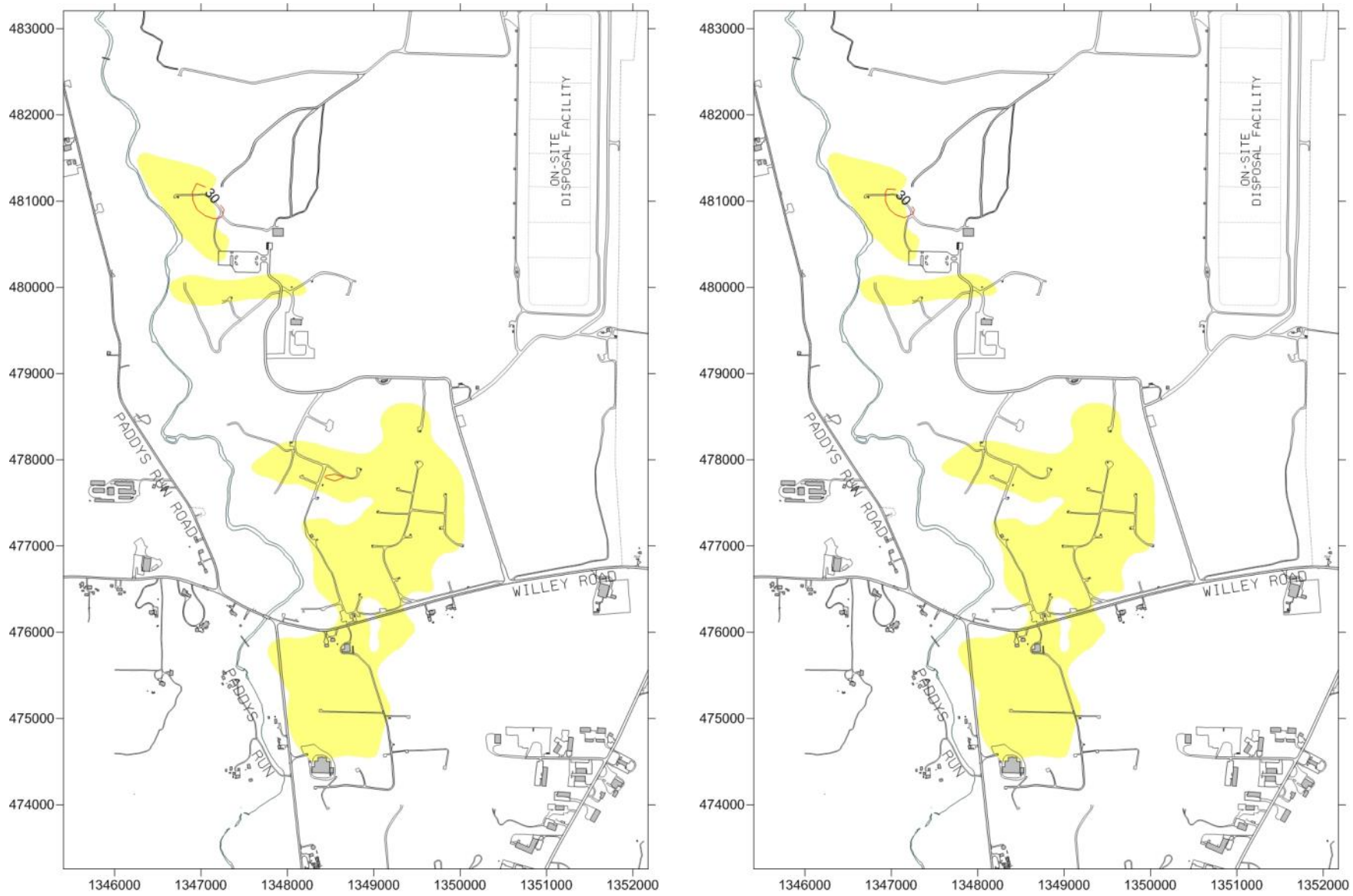


Figure 10. Maximum Uranium Concentration Contours, Modified Baseline Alternative, Nominal Boundary Conditions, Model Year 2027
Yellow Shading is Uranium Plume in December 2011



Model Year 2025 *Model Year 2026*

Figure 11. Maximum Uranium Concentration contours, Modified Baseline Alternative, Wet Boundary Conditions
Yellow shading is Uranium Plume in December 2011

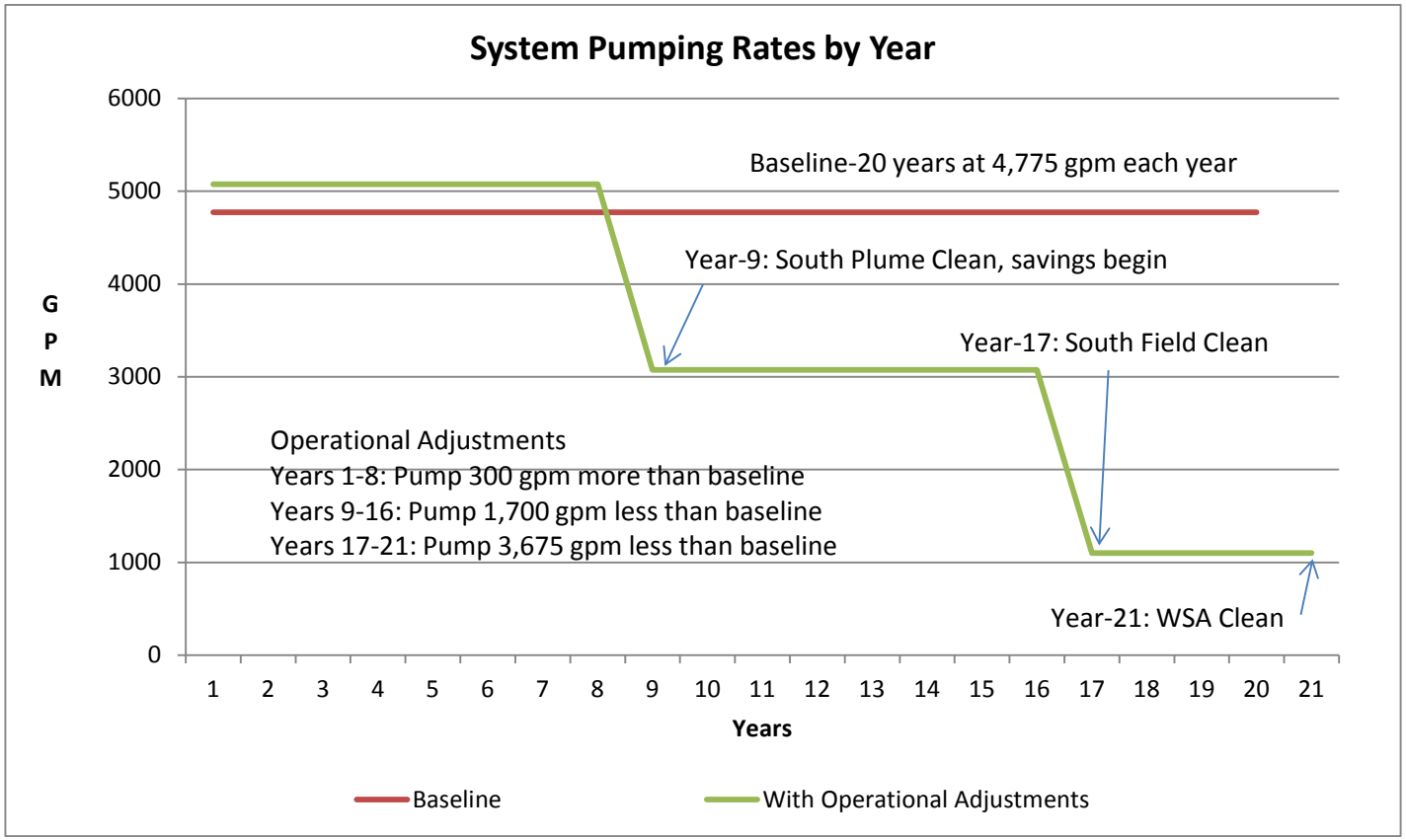


Figure 12. System Pumping Rates by Year, Baseline vs. Operational Adjustments

Remediation Costs Modified Baseline Alternative versus Baseline Alternative by Plume Area Cleanup Location (2012 to 2033)

	South Plume	South Field	WSA	Total Cost
Baseline	$10,602,000	$8,246,000	$4,712,000	$23,560,000
Modified Baseline	$10,032,000	$6,080,000	$1,360,000	$17,472,000
Difference	$570,000	$2,166,000	$3,352,000	$6,088,000

Because the model predicts that the South Plume will clean up faster under the Modified Baseline Alternative, predicted cleanup costs for the South Plume are less under the Modified Baseline Alternative than under the Baseline Alternative even though pumping rates are increased.

Figure 13 provides a visual representation of the cumulative costs over time between the two alternatives. As shown in the figure, after slightly higher costs in the first 8 years (due to the increase in pumping), savings are predicted to begin in model year 9 because pumping rates can be substantially reduced.

Monitoring would continue to track remediation progress, and the certification process presented in the *Fernald Groundwater Certification Plan* (DOE 2006) would continue to be followed. This means that predicted opportunities to reduce pumping levels under the Modified Baseline Alternative would only be implemented if the area predicted to be clean is certified as being clean through the agreed-to process in the Certification Plan. Annual measures of success (i.e., predicted average annual uranium mass removal, predicted annual average uranium discharge concentration, and plume capture) will be reported in Site Environmental Reports.

The future planned pumping reductions shown in Figure 12 for the Modified Baseline Alternative are not automatic. Data must show that groundwater cleanup goals have been achieved before system pumping reductions are implemented. If it appears that modeling predictions will not be met as planned, DOE will work with EPA and Ohio EPA on how best to proceed.

The pumping rates under the Modified Baseline Alternative for three wells (EW-23 at 500 gpm, EW-24 at 400 gpm, and EW-30 at 400 gpm) are higher than the highest pumping rate currently being pumped for the groundwater remedy (300 gpm). Increasing individual well pumping rates to these levels will likely result in the need for increased maintenance to the pumps, motors, and well screens due to iron fouling and plugging. Newly installed (April 2013) epoxy coated pumps are currently being tested for use in mitigating maintenance problems related to iron fouling inside the pumps. However, only through long term operational experience will the feasibility of maintaining the wells at these higher rates be proven. Should operational experience show that maintaining these higher pumping rates requires excessive maintenance and is not cost effective; individual well pumping rates may need to be reduced.

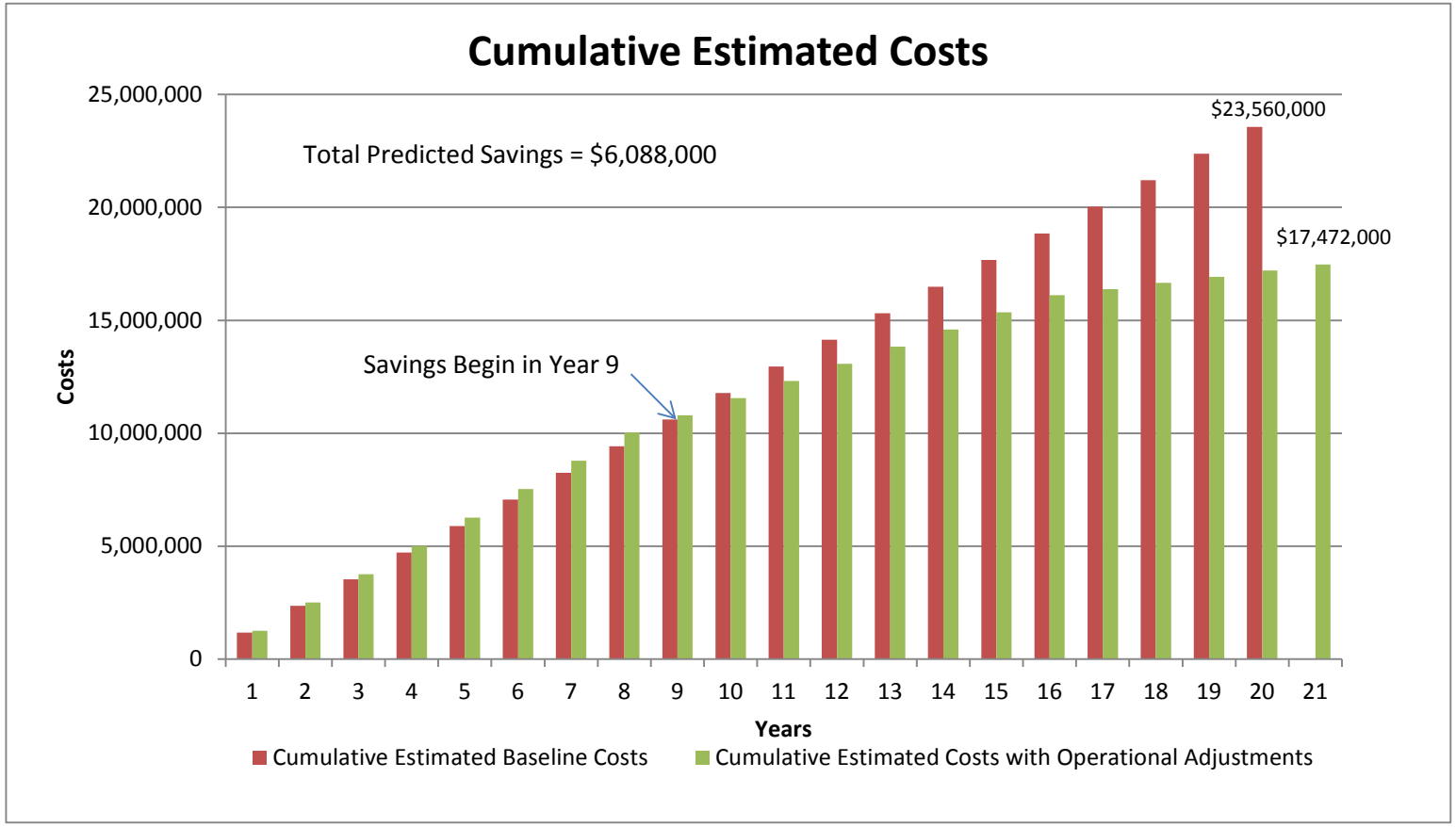


Figure 13. Cumulative Estimated Costs

Lower individual well pumping rates could result in increased cleanup times. If maintaining the higher pumping rates is not feasible, as indicated by excessive maintenance costs, reduction in pumping rates may be necessary. The groundwater model will be used to help determine the impact that the reduction in pumping rates will have on predicted cleanup times. Any proposed pumping change that results in a remedy design modification will require review and approval by both EPA and Ohio EPA prior to implementation.

As was done for the WSA Phase-II design, an Excel spreadsheet called TestPump was used to calculate uranium discharge metrics for the Modified Baseline Alternative (average uranium concentration of the pumped water and annual pounds of uranium discharged). Very conservative uranium concentrations (actual uranium concentrations measured in May 2013 at the extraction wells) were used to calculate that the uranium concentration of the discharged water would be 30.7 µg/L. If this concentration is maintained for the entire year, TestPump indicates that the pounds of uranium discharged to the river would be 683 pounds. Both these values exceed established discharge limits to the Great Miami River (average monthly concentration of 30 µg/L and annual discharge of no more than 600 pounds).

The TestPump calculation does not take into account: 1) The annual month-long well field shutdown and 2) That operational experience has shown that uranium concentrations in the pumped water will continue to decrease over time. Therefore, it is predicted that very little to no treatment will be required in order to meet established discharge limits should the Modified Baseline Alternative be implemented. Additional information can be found in Section A7.0 of Appendix A.

5.2 Conclusions

Groundwater modeling predicts that implementing the operational adjustments defined in the Modified Baseline Alternative will:

- Result in a remedy that accelerates cleanup of the uranium plume in the South Plume and southern South Field. It also meets surrounding community expectations in that modeling predicts that with the adjustments, both the off-DOE property portion of the plume and the on-DOE property portion of the plume (near the DOE property boundary where the potential for migrating off DOE-property is greatest) will clean up faster.
- Make the remedy more effective. Shutting down three extraction wells (one in the WSA and two in the South Field) that are no longer providing significant benefit to the ongoing pump-and-treat operation and re-allocating the pumping budget from those wells to extraction wells in the South Field is predicted to clean up the southern South Field approximately 8 years earlier than predicted under the Baseline Alternative.
- Require very little to no treatment in order to meet established discharge limits.
- Be cost effective. A potential savings of approximately $6 million could be realized.

6.0 Groundwater Remediation in the WSA

In addition to predicting an approach to optimize the current groundwater remediation design through operational changes, recent modeling also provided insight on contamination issues, modeling limitations, and remediation strategies in the WSA.

- There is a potential that uranium concentrations in the vadose zone of the WSA will cause rebound in the aquifer above cleanup levels once pumping operations end.
- The Fernald groundwater model has a limitation in the WSA in that it currently does not account for a continuing source of uranium contamination in the WSA (created by sorbed uranium in the vadose zone of the aquifer), and it does not accurately reflect potential current surface water infiltration rates.
- A monitored natural attenuation approach to remediate all or part of the WSA plume should be further evaluated as a future potentially viable option that could provide a more effective and protective cleanup alternative.

6.1 Sorbed Uranium Contamination in the Vadose Zone

Modeling results for both the Baseline Alternative and the Modified Baseline Alternative predict that cleanup of the WSA will be achieved between 2028 and 2033, depending on the boundary condition. A breakdown is provided below.

Comparison of Predicted Cleanup Dates
(Baseline Alternative vs. Modified Baseline)

Alternative	Dry	Nominal	Wet
Baseline Alternative	2032	2030	2032
Modified Baseline	2033	2028	2033

These cleanup date predictions do not account for the possibility that an ongoing source of uranium contamination appears to be present in the vadose zone of the aquifer, and that surface water infiltration rates in areas of the WSA may be higher than those currently defined for the groundwater model.

As discussed in Appendix A, uranium contamination is bound to aquifer sediments in the unsaturated portion of the GMA beneath former contamination source areas. This contamination will remain bound unless water levels in the aquifer rise and saturate the sediments, allowing the bound contamination to desorb and partition into the groundwater. Uranium concentration data collected at monitoring well 8337 in the WSA indicate that a significant amount of uranium contamination is present at this location at an elevation at and above 513.2 feet above mean sea level. Therefore, continued pumping in the WSA through 2032 (as currently planned) lowers water levels in an area where water levels need to be as high as possible. Rebound of water levels in the future could dissolve uranium that is sorbed to aquifer sediments in the vadose zone, causing dissolved uranium concentrations to increase above final remediation levels.

6.2 Model Limitations in the WSA

Modeling discussions provided in Appendix A indicate that the model-predicted outcomes in the WSA are limited by how uranium concentration is loaded into model layer 13 and how the modeled elevation of the water table interacts with model layer 13. Specifically:

- Under wet boundary conditions (when water levels would be the highest), there was a 5-year difference in the predicted cleanup time between different kriged versions of the plume (Section A4.0).
- Under pumping conditions, water levels were lowered and model layer 13 was unsaturated. Under non pumping conditions, water levels were higher and model layer 13 was saturated (Section A6.5).

When model layer 13 is unsaturated, the contribution to contaminant transport is limited to vertical percolation of surface water through the vadose zone (modeled at 5 inches per year where glacial overburden is present). When model layer 13 is saturated, the contribution to contaminant transport in the model is both from vertical percolation of surface water through the vadose zone and from upgradient model nodes via transport through the saturated media (as controlled by hydraulic gradient and hydraulic conductivity). In other words, more uranium moves out of layer 13 and into model layer 12 under saturated conditions than under unsaturated conditions.

It was concluded that current modeling results for the WSA could be exaggerated due to the kriging process and the surface infiltration rates currently loaded into the model for the WSA. The kriging process could have assigned a larger amount of uranium to model layer 13 than is actually present. Moreover, given the changes that have been made to the land surface in the WSA since soil remediation ended in 2005, the estimate of a uniform surface infiltration rate of 5 inches per year may be too low in some areas.

6.3 Other Potentially Viable Remediation Options for the WSA

Several of the optimization alternatives presented in Appendix A (OA1, OA2, and OA5) considered natural attenuation for all or a portion of the WSA plume rather than continued remediation through a pumping operation. The goal behind the modeling was to gain insight into whether a better remediation might result if water levels were not lowered through pumping, and if the approach would be protective of human health and the environment. As discussed above, higher water levels in the WSA during the remediation are preferred because uranium contamination is present in the vadose zone of the aquifer in the WSA.

The model predicted that if pumping were to stop in the WSA, uranium concentrations in the WSA plume would attenuate to 30 µg/L (the groundwater final remediation level) while remaining safely on DOE property and under the protection of institutional controls. The modeling also predicted that if pumping was stopped in extraction well EW-33a, partial penetration effects of continued pumping in extraction wells EW-27 and EW-28a would pull uranium deeper into the aquifer.

Given the modeling limitations discussed above for the WSA, additional modeling work should be conducted (i.e., redefine surface infiltration rates in the WSA and evaluate the impact of a

continuing residual uranium source in the WSA on predicted cleanup dates) before deciding on operational changes in the WSA.

It is also possible that the sorbed uranium contamination in the WSA could be addressed by flushing the contamination down to the water table by increasing the potential for more surface water infiltration to reach the aquifer. This could be accomplished by re-contouring the topography so that precipitation events provide the additional infiltration or through engineering by designing, constructing, and operating an infiltration gallery in the former source area of the WSA.

7.0 Summary

Loading additional uranium concentration data (2006–2011) into the site groundwater model and modeling forward in time provided model predictions that extended cleanup of the South Plume by 6 years, the South Field by 6 years, and the WSA by 9 years when compared to previous remediation design cleanup predictions. This model run was identified as the Baseline Alternative.

In light of the extended model-predicted completion times of the Baseline Alternative, 16 different remediation alternatives to the groundwater remediation were modeled to determine if the South Plume and southern South Field could be remediated earlier. Modeling results showed that the predicted cleanup times for the South Plume and the southern South Field can be shortened if the following operational adjustments are made:

- Increase the pumping rate at extraction wells RW-6 and RW-7 in the South Plume from 200 gpm to 300 gpm each, to shorten the predicted cleanup of the South Plume by 1–2 years.
- Turn off extraction well EW-28a (WSA) and extraction wells EW-31 and EW-32 (South Field) because they have served their purpose and no longer provide benefit to the ongoing remediation.
- Re-allocate the pumping budget gained by turning off extraction wells EW-28a, EW-31, and EW-32 to existing extraction wells in the southern portion of the South Field to shorten the model predicted cleanup time of the southern South Field by 8–9 years. It should be noted that the southern South Field is the area of the on-DOE-property plume that is closest to the DOE property line.

The selected alternative containing these operational adjustments was identified as the Modified Baseline Alternative. Groundwater modeling predicts that implementing the Modified Baseline Alternative will:

- Result in a remedy that will clean up the South Plume and southern South Field sooner than the current groundwater remediation. It also meets surrounding community expectations in that modeling that with the adjustments, both the off-DOE-property portion of the plume and the on-DOE-property portion of the plume (near the property boundary where the potential for migrating off-DOE property is greatest) will clean up faster.
- Make the remedy more effective. Shutting down three extraction wells (one in the WSA and two in the South Field) that are no longer providing significant benefit to the ongoing

pumping operation and re-allocating the pumping budget from those wells to extraction wells in the southern South Field is predicted to clean up the southern South Field approximately 8–9 years earlier than predicted under the Baseline Alternative.

- Require very little to no treatment in order to meet discharge limits.
- Be cost effective—A potential savings of approximately $6 million could be realized.

Recent modeling also shed some additional insight on contamination issues, modeling limitations, and remediation strategies in the former WSA, specifically:

- There is a potential that uranium concentrations in the vadose zone of the WSA will rebound above cleanup levels once pumping operations end.
- The Fernald groundwater model has limitations in the WSA in that it currently does not account for a continuing source of uranium contamination in the WSA (created by sorbed uranium in the vadose zone of the aquifer), and it does not accurately reflect potential surface water infiltration rates.
- A monitored natural attenuation approach to remediate all or part of the WSA plume may be a viable option in the future that is protective of human health and the environment and could also hold the potential for providing a more effective cleanup alternative.
- Sorbed uranium contamination in the vadose zone of the WSA could be addressed either by raising the water table or by increasing the potential for surface water infiltration, or a combination of both. Additional work is required to determine the best approach.

8.0 Recommendations

Operational adjustments are recommended for the groundwater remediation at the Fernald Preserve, near Cincinnati, Ohio. Specifically:

- Increase the pumping rate at extraction wells RW-6 and RW-7 in the South Plume from 200 gpm to 300 gpm each, to shorten the predicted cleanup of the South Plume by 1–2 years.
- Turn off extraction well EW-28a (WSA) and EW-31 and EW-32 (South Field) because they have served their purpose and no longer provide significant benefit to the ongoing remediation.
- Re-allocate the pumping budget gained by turning off extraction wells EW-28a, EW-31, and EW-32 to existing extraction wells in the southern portion of the South Field to shorten the model predicted cleanup time of the southern South Field by 8–9 years. It should be noted that the southern South Field is the area of the on-DOE property plume that is closest to the DOE property boundary.

The recommended operational adjustments result in a groundwater remediation that meets the cleanup standards sooner in the South Plume and southern South Field areas than the current groundwater remediation design that was established in 2005. It also meets surrounding community expectations in that modeling predicts that with the adjustments, both the off-DOE-property portion of the plume and the on-DOE-property portion of the plume (near the property boundary where the potential for migrating off DOE property is greatest) will clean up faster.

Additional work is recommended for the WSA. Modeling limitations (i.e., continued potential source, surface water infiltration rates) need to be addressed. A way to address the sorbed uranium contamination in the vadose zone of the aquifer needs to be determined. Possibilities include raising the water table by limiting or stopping pumping, or flushing the contamination down to the water table through more surface water infiltration, or some combination of both.

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Appendix A

Modeling Information

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Abbreviations

amsl	above mean sea level
DOE	U.S. Department of Energy
FRL	final remediation level
MNA	monitored natural attenuation
µg/L	micrograms per liter
OA	optimization alternative
SER	Site Environmental Report
WSA	Waste Storage Area

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A1.0 Appendix Organization

Information presented in this appendix supplements information presented in the *Operational Design Adjustments WSA Phase-II Groundwater Remediation Design* report. This appendix is divided into eight sections.

- Section A1: Provides an overview of how Appendix A is organized.
- Section A2: Presents background information on why groundwater modeling was conducted. Topics include the current status of the pump-and-treat remedy, model predictions assessment, and the need to add additional uranium concentration data into the model.
- Section A3: Provides information on the groundwater model. Topics include how the uranium concentration data was kriged and modeling considerations.
- Section A4: Presents modeling results for the Baseline Alternative.
- Section A5: Presents modeling results for South Plume Alternatives.
- Section A6: Presents modeling results for Optimization Alternatives.
- Section A7: Presents an assessment on predicted water treatment needs.
- Section A8: References cited.

A2.0 Background

A2.1 Current Status of the Pump-and-Treat Remedy

Metrics used to track remedy performance indicate that although the remediation continues to operate efficiently, the effectiveness of the pump-and-treat operation is slowly decreasing. Decreasing effectiveness is not unexpected. It is common for pump-and-treat systems to become less effective over time if operational adjustments are not made.

Data reported each year in Appendix A.1 of the Annual Site Environmental Report (SER) show that annual uranium concentrations measured in the field are in close agreement with model-predicted concentrations. Figure A-1 is an example of a uranium concentration versus time plot for extraction well EW-17a, one of the 23 extraction wells currently operating. A regression trend of the uranium concentration data set, a regression trend of the 95 percent upper confidence limit of the uranium concentration data set, and the model-predicted concentration trend for the extraction well are presented. The regression trend lines were constructed using Microsoft Excel software. As shown in Figure A-1, the data set trend and model prediction trends are in close agreement for extraction well 17a. Figure A-2 provides a prediction of yearly pounds of uranium to be pumped from the aquifer (model predictions versus data trends) using concentration data collected through 2012. As the figure illustrates, the data trend and model predictions are in close agreement.

Table A-1 provides mass removal predictions for the groundwater remediation and three estimates of mass removal completeness based on the trend of the concentration data and model-predicted concentrations. As shown in the table, there is close agreement between the actual data

and the model predictions. At the bottom of the table is a summary of estimations of mass removal completeness based on both the concentration data and the model predictions. The concentration data through 2010 showed a slightly higher percentage than the model predictions did; however, in 2011 the percentage based on model predictions was for the first time slightly higher than the percentage based on the actual concentration data. This trend repeated again in 2012. This indicates that, since 2011, model-predicted aquifer cleanup concentrations have been slightly more optimistic than the actual data indicate. This observation is common for pump-and-treat operations, and it indicates that the operation is becoming slightly less effective over time.

In addition to reporting decreasing operational effectiveness in the annual SERs, a discussion was also presented in the *Third Five-Year Review Report for the Fernald Preserve* (DOE 2011). As discussed in the Third Five-Year Review Report, data indicate that between 2006 and 2009 (4 years) the estimate of mass removal completeness increased by approximately 13 percent. The data indicated that it would take 13 more years (from 2010 to 2023) to gain another 13 percent increase (Figure A-3).

Both observations noted above—asymptotic concentration trends and decreasing operational effectiveness—present a challenge to achieving cleanup Final Remediation Levels (FRLs). Data reported in the 2012 SER indicate that 6 of the 23 extraction wells (RW-6, EW-21a, EW-23, EW-24, EW-30, and EW-27) have uranium concentrations above 30 micrograms per liter (µg/L), and plots of concentrations versus time display an asymptotic trend. Changing pumping rates in and around these wells may help to increase the uranium concentration of the water being pumped from them.

Figure A-4 is a monitoring well location map. The figure shows monitoring well locations in relation to the maximum total uranium plume map from the second half of 2011. The monitoring wells with uranium concentrations of 30 µg/L or higher are identified on the map. As shown by the map, uranium concentrations vary across the plume, with some areas presenting a greater challenge for achieving groundwater FRLs than others. Also identified on the map is an area in the Waste Storage Area (WSA) where uranium concentrations indicate that sorbed uranium contamination (a remaining residual source) is present in the vadose zone of the aquifer. As discussed in Section A.3.2, sorbed uranium contamination in the vadose zone could keep the area from being certified clean once pumping operations end.

A2.2 Model Predictions Assessment

Every 5 years the U.S. Department of Energy (DOE) compares actual uranium concentrations measured at a set group of monitoring wells to model-predicted uranium concentrations for the wells. The objective is to assess if the model predictions are remaining reasonable over time. Two comparisons have been done. The first was done in 2005 and the second in 2010. Results from both were reported in the SER for those years. Results reported in the 2010 SER are provided below.

Statistics	May 2005 vs. Modeled Initial Conditions (µg/L)	2nd-Half 2005 vs. Model-Predicted 4/1/2006 (µg/L)	1st-Half 2010 vs. Model-Predicted 4/1/2010 (µg/L)
Mean Residual	19.1	30.5	29.4
Standard Deviation	78.8	87.9	75.6
Maximum Residual	273.7	330	300
Minimum Residual	−256.1	−131	−85.1
Residual Range	529.8	461	385

As reported in the 2010 SER, the small change in the mean residual of observed versus modeled concentrations between 2005 and 2010 (30.5 µg/L and 29.4 µg/L, respectively) indicated that groundwater model predictions remained reasonable.

A2.3 Need to Update Uranium Concentration Data in the Groundwater Model

Groundwater monitoring wells in the Great Miami Aquifer (GMA) are routinely sampled (as prescribed by the Integrated Environmental Monitoring Plan) for the purpose of updating maximum uranium plume maps. The maps are presented each year in the SER. As discussed in the SERs, the maximum uranium plume maps are considered to be conservative, because they present a worst-case interpretation of the size of the uranium plume in the aquifer. The largest uranium concentration measured at a monitoring location, regardless of depth, is honored on the map for the purpose of constructing concentration contours. A reduction of the mapped uranium plume footprint at any location is only made when a complete vertical profile of concentrations has been obtained. A vertical profile of uranium concentrations is obtained either by sampling a fixed multilevel monitoring well or by collecting samples through a direct-push (Geoprobe) tool.

A direct-push sampling tool creates a temporary monitoring well. A hollow rod with an attached sampling screen is pushed into the ground, and samples are collected at several depth intervals. As described in the Integrated Environmental Monitoring Plan (DOE 2013), up to 27 locations are sampled each year using a direct-push sampling tool for the purpose of obtaining vertical profile concentration data to update the maximum uranium plume map.

Figure A-5 compares the maximum uranium plume map from December 2010 (shaded light blue) with the maximum uranium plume map from December 2011 (shaded yellow). The groundwater FRL (30 µg/L) is used to define the footprints of the maximum uranium plumes. As shown in the figure, the light-blue areas were removed from the 2011 plume interpretation. Between 2010 and 2011 the interpreted plume footprint decreased in size by approximately 40 acres. This does not mean that 40 acres were cleaned up in one year; rather, data indicated that uranium concentrations in the 40 acres were all below the groundwater FRL in 2011.

As shown on Figure A-5, a couple of lobes of the maximum uranium plume along the eastern edge of the South Field were included in the acreage that was removed from the map in 2011. However, a third lobe, just outside of DOE property, south of Willey Road in the South Plume (within the hatched boxed area of Figure A-5) was found to be larger than expected and had higher uranium concentrations than expected. Figure A-6 provides a closer look at the area within the hatched box. In 2011, eight new locations were sampled using a direct-push sampling

tool (locations 13420, 13423, 13424, 13425, 13426, 13297A, 13357A, and 13421A). Prior to the direct-push sampling in 2011, it was expected that uranium concentrations in this area would be below 30 µg/L. This expectation was due in part to modeling predictions.

Table A-2 provides a comparison between model-predicted uranium concentrations (2012) and actual direct-push sample concentrations (2011). The table correlates direct-push sample depths with model layers. As shown in Table A-2, the model predicted that by 2012 the concentration of uranium at all eight direct-push locations would be below 30 µg/L. Direct-push sample results indicate that the actual maximum uranium concentration measured at the eight direct-push sampling locations ranged from 2.7 µg/L (location 13426) to 149.2 µg/L (location 13421A), with an average of 49.35 µg/L.

Based on the data that were available in 2005 when the WSA Phase II modeling was conducted, uranium concentrations in this area of the plume were correctly loaded into the groundwater model. In 2005 this area of the uranium plume was defined by two direct-push sampling locations (location 12196 sampled in 1996, and location 13269 sampled in 2002). Results for both sampling locations are provided below:

Location 12196, Sampled in 1996

Elevation (feet amsl)	Total Uranium (µg/L)
518.3	0.5
509.3	0.3
499.3	0.7
489.3	0.5
479.3	0.3
469.3	0.5
459.3	0.7
449.3	0.4
439.3	1.6

amsl = above mean sea level

Location 13269, Sampled in 2002

Elevation (feet amsl)	Total Uranium (µg/L)	Model Layer
518.4	1.5	13
509.4	2.2	12
499.4	192	12
489.4	68	11
479.4	4.9	10
469.4	2.5	10
459.4	1.1	9

amsl = above mean sea level

As shown above, only location 13269 had uranium concentrations above the FRL of 30 µg/L. The maximum uranium concentration (192 µg/L) was measured from the sample collected at an elevation of 499.4 feet above mean sea level (amsl). Samples collected at elevations of 509.4 feet amsl and 499.4 feet amsl correlate to model layer 12. A maximum uranium concentration of 97.1 µg/L (i.e., the average of 2.2 µg/L and 192 µg/L) was therefore loaded into the groundwater model for Layer 12 for the WSA Phase II Design.

Figure A-7 illustrates modeled initial uranium concentrations for the WSA Phase II Design groundwater model (red contours) compared to the actual plume footprint when the model was loaded in December 2004 (yellow footprint). As shown in Figure A-7, the fit between modeled initial concentrations and the actual footprint was good.

Figure A-8 shows the model-predicted uranium plume for April 2012 (red contours) compared to the actual plume footprint measured at the end of 2011 (yellow footprint). As shown in Figure A-8, the model predicted that remediation of the South Plume would be complete by April 2012. As discussed above, data collected in 2011 in the area of the lobe show that the model was not correct. The modeling error is attributed to having a limited amount of uranium concentration data available for the area in 2005, which led to initial uranium concentrations in the model that underestimated the size and concentration of the plume that was actually present. Figure A-8 also indicates that a few other disconnects also exist between model predictions and actual field conditions in the WSA and the South Field. Potential causes for the other disconnects are discussed in Section A3.2.

Given that the disconnect between modeled predictions and actual conditions for the South Plume appears to be the result of having underestimated the size and concentration of the plume used for initial conditions in the model, the decision was made to load the more recent, additional uranium concentration data into the model and run the model forward in time to determine the impact to predicted cleanup times in all areas of the uranium plume.

A3.0 Groundwater Model

The groundwater model used in this report is the same model that was used to design the current groundwater remediation system—the WSA Phase II Design. Groundwater modeling was conducted using the VAM3D flow and transport modeling code and the 14-layer zoom model described in detail in Section 3 of the *Design for Remediation of the Great Miami Aquifer, South Field (Phase II) Module* (DOE 2002). The 14-layer zoom model consists of 72,114 finite difference nodes (101 rows, 51 columns, 14 layers) with a spacing of 100 feet in both the *x* and *y* directions. Other than adding additional uranium concentration data and adjusting pumping rates, no other changes were made to the model for this report.

A3.1 Adding Additional Uranium Concentration Data to the Model

Additional uranium concentration data were loaded into the model (i.e., monitoring well data, and direct-push sampling data collected through the end of 2011). If a direct-push sampling location had been sampled more than once, the most recent sample results were used.

As was done for the WSA Phase II Design (DOE 2005), Mining Visualization System (MVS) software from C Tech was used to krige the updated uranium concentrations data set. Kriging done in support of the WSA Phase II Design in 2005 used MVS version 7.9.1. This version of MVS is no longer supported by C Tech, so the version used for this modeling project was MVS version 9.8.

The use of MVS 9.8 instead of MVS 7.9.1 resulted in a difference in the way the horizontal and vertical search radii were set for the kriging process. For the WSA Phase II Design in 2005, the monitoring data were evaluated with a variogram modeling software package, SAGE 2001, to determine the semi-variogram range and thus the optimum search radii for kriging. The semi-variogram range was determined to be 300 feet, so a 300-foot horizontal search radius was used for kriging with MVS 7.9.1. Figure A-9 shows the horizontal variograms used for the data set loaded into the WSA Phase II Design (DOE 2005). A horizontal to vertical anisotropy ratio of 15 was also used for an effective vertical search radius of 20 feet.

An attempt was made to use the same kriging radii with the more recent MVS 9.8 software, but error messages resulted, indicating that the kriging matrices were singular for these radii (300 feet horizontal and 20 feet vertical). The default kriging radii from MVS 9.8 had to be used, and these were much larger than those used for kriging with MVS 7.9.1. MVS 9.8 uses a default horizontal kriging radius of two-thirds the maximum distance between sample data points, or 7,331 feet for the 2011 monitoring data set. With a vertical anisotropy of 15, the vertical kriging search radius was 488.7 feet.

The longer kriging search radii used with MVS 9.8 resulted in a total uranium plume that tended to be smeared or stretched horizontally and vertically in the groundwater model layers. These differences between MVS 7.9.1 and MVS 9.8 kriging methodologies were assessed by kriging the 2011 data set with MVS 7.9.1 and MVS 9.8 and comparing the model layer 13 kriged total uranium concentrations (Figure A-10). The larger search radius in MVS 9.8 resulted in a slightly larger plume footprint than the smaller MVS 7.9.1 search radius of 300 feet. The most significant difference between the two methodologies is in the former WSA, where the plume kriged with MVS 9.8 extends west to the model edge and beyond Paddys Run. Since there is no source in the area where the contours are smeared, and groundwater flow direction is to the east, this kriged concentration in model layer 13 is not correct.

To bound this incorrect kriging result, six imaginary wells (referred to as “pseudo borings”) with uranium concentrations of 0 µg/L were loaded into the data set. The locations of the six pseudo borings are shown in Figure A-11. When the data set was kriged with the pseudo borings included, the resulting kriged uranium plumes (7,331-foot horizontal search radius vs. 300-foot horizontal search radius) closely matched in shape, size, and concentrations. Figure A-12 shows the comparison for a composite of model layers 7 through 13 combined. The kriged plume with the larger horizontal search radius is slightly larger than the kriged plume with the smaller search radius. A comparison of the maximum uranium values between the two kriging approaches by model layer is provided below.

Comparison of Maximum Uranium Concentrations (by Model Layer) Between the Two Kriging Approaches

Model Layer	Max. Uranium Concentration (µg/L); MVS 9.8, 7,331-foot Horizontal Search Radius (with pseudo borings)	Max. Uranium Concentration (µg/L); MVS 7.9.1, 300-foot Horizontal Search Radius (with pseudo borings)
13	1,363.6	1,781.4
12	733.3	705.7
11	244.7	243.7
10	335.8	322.3
9	140.5	136.5
8	64.1	53.3
7	17.5	45.7

The comparison shows that for model layers 11 and 12 (where most of the uranium plume is located), the larger search radius resulted in slightly larger maximum uranium concentrations but that concentrations between the two approaches were very similar.

Figure A-13 is a comparison of initial uranium concentrations (i.e., the maximum uranium plume footprint from December 2011) for (1) initial plume conditions kriged using MVS 9.8 and (2) initial plume conditions kriged using MVS 7.9.1. The red contours on both figures are the initial conditions loaded into the model, and the yellow footprint is the 30 µg/L maximum uranium plume footprint from December 2011. The initial condition plumes appear to be in close agreement. To document how the different plumes impacted modeling results, the Baseline Alternative was modeled using both versions of the kriged plume. Results are provided in Section A4.

A3.2 Modeling Considerations

As discussed in Section A4, several modeling considerations entered into the selection of the alternatives modeled for this report. Considerations included issues presented in the *Third Five-Year Review Report for the Fernald Preserve* (DOE 2011) that have the potential to delay cleanup, impacts to non-DOE-property owners, individual well pumping limitations recognized through operational experience, net system extraction rates, correlation of field data to modeling runs, treatment considerations, and maintaining containment of the maximum uranium plume.

A3.2.1 Third Five-Year Review Report Issues

Three issues identified and discussed in the Third Five-Year Review Report (DOE 2011) were considered for the modeling conducted for this report:

- Sorbed uranium contamination in the vadose zone of the aquifer
- Stagnation zones within the uranium plume
- Preferential flushing pathways within the uranium plume

These three issues are discussed below.

A3.2.1.1 Sorbed Uranium Contamination in the Vadose Zone of the Aquifer

Uranium contamination is bound to aquifer sediments in the unsaturated portion of the GMA beneath former contamination source areas. This contamination will remain bound unless water levels in the aquifer rise and saturate the contaminated sediments, allowing the bound contamination to dissolve into the groundwater. In an attempt to flush some of these zones, planned well field shutdowns have been conducted since 2007 to allow water levels in the aquifer to rise as high as possible to saturate aquifer material that is normally not saturated. To achieve the highest water level rise possible, the well field shutdowns are planned to coincide with seasonal high-water levels in the aquifer. Results are reported annually in the SER.

One area where sorbed uranium contamination is known to be present above the water table of the aquifer is in the former WSA at monitoring well 83337. Figure A-14 shows the location of this monitoring well in relation to the footprint of the 2011 maximum uranium plume. Monitoring well 83337 is a multilevel well with three monitoring depths. The highest elevation channel is channel 1 (C1). Figure A-15 is a concentration versus time plot for monitoring well 83337. As shown in the figure, the uranium concentration measured in channel 1 exceeded 2,000 µg/L several times. The elevation of the base of the screen in Channel 1 is 513.197 feet amsl. This indicates that a significant amount of contamination is present at this location at an elevation at and above 513.197 feet amsl. Pumping in this area lowers the water table and could actually be interfering with the cleanup. Therefore, continued pumping through 2023 (as currently planned in the WSA Phase II Design) will probably leave contamination at an elevation at or above 513.97 feet amsl. Rebound of water levels in the future could cause dissolved uranium concentrations to increase, which could impact the certification effort for this area.

A3.2.1.2 Stagnation Zones Within the Uranium Plume

Stagnation zones exist within the uranium plume. These stagnation zones are created by the competition of extraction wells for water within the aquifer. A stagnation zone between the South Plume extraction wells and the South Field extraction wells appears to be impacting the remediation of the South Plume. Figure A-16 shows the location of this stagnation zone. As discussed in the Third Five-Year Review Report (DOE 2011), changes to the aquifer remedy may be needed to address this stagnation zone. Changes that could be considered include changing the pumping rates of existing extraction wells, converting an out-of-service injection well just north of the stagnation zone into an extraction well, and/or installing a new extraction well off DOE property.

A3.2.1.3 Preferred Flushing Pathways Within the Uranium Plume

The GMA is both heterogeneous and anisotropic. Groundwater flowing through the aquifer matrix seeks the pathway of least resistance to the extraction wells. A result is that coarser-grained material is flushed of contamination more effectively than the finer-grained aquifer material because more water is moving thorough the coarser material. Geochemical factors also contribute to this effect. More surface area is available in the finer-grained material for contamination to sorb to. This means that more uranium will often sorb to the finer-grained materials that are less flushed than to the coarser-grained materials that are often flushed better.

Contamination sorbed to the finer-grained aquifer material slowly leaches out into the more active flow paths. Over time, this ineffective flushing of the finer-grained material results in reduced cleanup efficiency and prolonged cleanup times. The constant pumping rate being maintained at each extraction well might be contributing to this possible condition. The asymptotic nature of the decreasing uranium concentration trends of the extraction wells is indirect evidence that preferential flow paths may have been established. Operational changes to the aquifer remedy might be needed to address this issue. Operation changes could include changing the pumping rates of existing extraction wells, pulse-pumping the existing extraction wells, and/or installing additional extraction wells.

A3.2.2 Impact to Off-DOE-Property Owners

Several of the South Plume alternatives considered include the addition of a new well off DOE property to help optimize remediation in an identified stagnation zone. The stagnation zone underlies a planted field, and the property owner understandably wants to minimize disruptions to his farming operation. Preliminary discussions with the impacted property owner indicate that a well located strategically along the edge of an existing crop field, and near existing underground infrastructure, would be acceptable.

A3.2.3 Individual Well Pumping Limitations Recognized Through Operational Experience

Operational experience indicates that it may be difficult to maintain a 400 gallon per minute (gpm) pumping rate in some areas of the plume. One such area is within the stagnation zone south of Willey Road. The additional maintenance required through chemical treatments and well rehabilitations would be avoided if an alternative could be found that uses a lower pumping rate but is just as effective.

A3.2.4 Net System Extraction Rate

As identified in the Baseline Remedial Strategy Report for Operable Unit 5 (OU5) (DOE 1997), the net groundwater extraction rate for the pumping system should not exceed the recharge rate of the regional aquifer, nor should it cause excessive water table drawdown. A technical evaluation conducted for the OU5 Feasibility Study identified 4,000 gpm as the limit for the net extraction rate for the aquifer (DOE 1995). The maximum pumping rate for any individual well was identified as not to exceed 500 gpm. This net extraction limit has been adjusted upward over the years through both operational experience and additional design studies, resulting in a net groundwater extraction rate for the WSA Phase II Design of 4,775 gpm. Operational experience and modeling results indicate that a slightly higher target system rate of 5,075 gpm would be acceptable.

A3.2.5 Correlation of Field Data to Modeling Runs

Correlation of field data into the groundwater model results in a potential time shift of approximately 6 to 9 months. The aquifer is sampled twice a year over a 6-month time period. Data collected over the 6-month time period are used to prepare updated maximum uranium plume maps. Modeling for the WSA Phase II Design was programmed to begin in April of 2005. Thirty-six time steps of 10 days each were modeled for each year, resulting in a modeling year of

360 days. To maintain consistency with the WSA Phase II Design, the same approach was used for the modeling conducted for this report. The second half uranium plume map from 2011 was used to begin modeling in April 2012. This indicates a potential time shift of 6 to 9 months between field data and the timing of model runs. A difference in cleanup time of 1 year between alternatives is therefore considered as being insignificant and within the inherent accuracy range of the model.

A3.2.6 Maintain Hydraulic Containment of the Maximum Uranium Plume

In addition to modeling predicted cleanup dates, alternatives were also modeled to demonstrate that hydraulic control of the maximum uranium plume would be maintained. This was accomplished by modeling steady-state flow conditions and producing particle path maps to illustrate hydraulic capture of the plume. No alternative was selected for further evaluation unless full hydraulic capture of the maximum uranium plume was demonstrated for each pumping period in an alternative.

A3.2.7 Treatment Considerations

Re-allocation of budgeted pumping capacity from areas of the aquifer where uranium concentrations are low to areas of the aquifer where uranium concentration are higher could result in the need for groundwater treatment prior to discharge in order to meet discharge limits at the Great Miami River (i.e., a monthly average no greater than 30 µg/L and no more than 600 pounds per year). Therefore, a flow-weighted average of the discharge concentration and an estimate of pounds of uranium discharged for the selected remedy was completed to see what the predicted impact would be to treatment needs. Additional information is provided in Section A7.0.

A4.0 Baseline Alternative Modeling Results

The Baseline Alternative consisted of modeling cleanup of the aquifer using the WSA Phase II Design and additional uranium data collected through 2011. The objective was to determine how the additional uranium data impacted cleanup predictions.

As described earlier, MVS version 7.9.1 was used in 2005 to krige the plume for the WSA Phase II Design. MVS version 9.8 was used to krige the plume for the modeling conducted for this report. A comparison of modeling results was warranted to determine if and how the different kriged versions would impact modeling predictions. Modeling the Baseline Alternative using both plumes provided the comparison.

Predicted cleanup dates for the South Plume are provided below.

Comparison of Predicted Cleanup Dates for the South Plume (MVS 9.8 vs. 7.9.1)

	Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
MVS 9.8	2020	2021	2020
MVS 7.9.1	2019	2020	2019

The results are within a year of each other, which is considered to be within the accuracy range of the model given the situation concerning the correlation of field data to modeling runs (as discussed in Section A3.2.5). Figure A-17 through Figure A-19 illustrate the model-predicted plume that remains on DOE property during the year that South Plume cleanup is achieved under each boundary condition, for both kriged plumes (MVS 9.8 vs. MVS 7.9.1).

Final predicted cleanup dates for the remaining plumes (South Field and WSA) are provided below.

Comparison of Predicted Cleanup Dates for the Remaining Plumes (MVS 9.8 vs. 7.9.1)

	Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
MVS 9.8	2032	2030	2032
MVS 7.9.1	2031	2031	2027

The results are within a year of each other, except for wet boundary conditions.

Under wet boundary conditions (when water levels would be the highest), there was a 5-year difference in the predicted cleanup time (2027 vs. 2032) between the version 9.8 plume and the version 7.9.1 plume. The 5-year difference is attributed to:

- Model layer 13 being saturated when water levels are high.
- More uranium loaded in model layer 13 in the version 9.8 plume.

Model layer 13 is usually unsaturated. Under unsaturated conditions, layer 13 contributes only one term to the solute fate and transport of uranium. That one term results from the percolation of surface waters (currently modeled at 5 inches per year). During high water levels, portions of layer 13 become saturated. When saturated, layer 13 fully participates in the solute transport process, and transport contributions are made from both upgradient model nodes as well as the vertical percolation of surface waters. In other words, when layer 13 is unsaturated, less uranium is moved in the model vertically down to model layer 12 than when layer 13 is saturated.

Figure A-20 and Figure A-21 illustrate the impact made by model layer 13 to predicted cleanup dates when it becomes saturated. Figure A-20 compares the maximum uranium plume map for the Baseline Alternative (model layers 7–12 under wet boundary conditions) in model year 2026 for the MVS 7.9.1 plume, and the same for the MVS 9.8 plume. The comparison shows that the footprint for the MVS 9.8 plume in model year 2026 is larger than the footprint of the MVS 7.9.1 plume in 2026.

Figure A-21 shows why the plume footprint in Figure A-20 is larger for the MVS 9.8 plume compared to the MVS 7.9.1 plume. Figure A-21 shows the predicted difference in size in 2026 between the 30 µg/L plumes in model layer 13, which is above model layer 12, for both the MVS 9.8 plume and the MVS 7.9.1 plume. As the figure indicates, the MVS 9.8 plume in model layer 13 is larger than the MVS 7.9.1 plume in model layer 13. The larger source of uranium in model layer 13, coupled with higher water levels, results in more uranium moving from model

layer 13 into model layer 12, which results in the longer cleanup time. This shows that using the MVS 9.8 plume under high water level conditions results in longer (but probably more realistic) cleanup time predictions in the WSA than using the MVS 7.9.1 plume.

To be conservative, the longest cleanup time determined (regardless of boundary condition) for the modeling conducted with the MVS 9.8 kriged plume was selected for comparison to predicted cleanup times for the original WSA Phase II Design. Cleanup times reported for the WSA Phase II Design are for model layer 12. Layer 12 was used in the WSA Phase II Design because it is close to the top of the aquifer and contained most of the uranium plume (DOE 2005). Cleanup times reported for the Baseline Alternative are for model layers 7–12. In most cases, model layer 12 could have been used alone for the Baseline Alternative, as it was found to contain most of the uranium plume. The comparison is provided below and indicates that predicted cleanup times are longer with the additional uranium data loaded into the model.

Comparison Between Predicted Cleanup Times (Baseline vs. WSA Phase II)

	South Plume Cleanup	South Field Cleanup	WSA Cleanup
WSA Phase II	2015	2022	2023
Baseline Alternative	2021	2028	2032
Increase in Years	6	6	9

A5.0 South Plume Alternative Modeling Results

A5.1 Steady-State Flow Evaluations and Particle Track Analysis

Steady-state flow modeling and 10-year particle tracks were prepared in order to visualize how additional extraction wells might be used to better capture the area of the South Plume discussed in Section A2.3 and to reduce the size of the of the stagnation zone located between the South Field and South Plume extraction wells.

Three additional extraction well locations were considered in the South Plume alternatives. Two of the additional locations were on DOE property (IW-10 and IW-11); the third was off DOE property (KN-1). Figure A-22 shows the locations of the additional wells in relation to the 2011 plume footprint. The location of KN-1 is east (downgradient) of the stagnation zone, and southwest (downgradient) of the off-DOE-property plume lobe. Locations IW-10 and IW-11 are north (upgradient) of the off-DOE-property plume lobe at two abandoned injection well locations. The abandoned injection well locations were considered desirable because installation costs for a new well at either location would be greatly reduced, as much of the infrastructure needed to support a new well is already in place.

The location of the additional off-DOE-property well (KN-1) was carefully selected to minimize impact to the off-DOE-property owner. It was located next to an existing air trap in the South Plume discharge system and close to where the outfall line is already buried. This location is on the edge of a field that is currently used to grow crops. The landowner indicated that he would accept this location for the new well.

Ten steady-state flow modeling runs were made (under dry boundary conditions) to screen each potential new extraction well location, as outlined below. Dry boundary conditions were selected to screen the different modeling runs because the stagnation zone shows up as being larger under dry boundary conditions. Unless the pumping rate of a specific well is identified as being changed for a South Plume alternative, pumping rates were modeled at WSA Phase II Design rates. Ten-year particle track figures are provided for each flow model run to illustrate capture, as indicated below.

Steady-State Modeling Runs

Location of Pumping Change from WSA Phase II Design Rates	Pumping Rate	Figure
IW-10	200 gpm	A-23
IW-11	200 gpm	A-24
IW-10	400 gpm	A-25
IW-11	400 gpm	A-26
IW-10 and IW-11	200 gpm	A-27
IW-10 and SP-6	IW-11 (200 gpm) and SP-6 (300 gpm)	A-28
KN-1	200 gpm	A-29
KN-1	400 gpm	A-30
IW-11 and KN-1	200 gpm (Dry Boundary Conditions)	A-31
IW-11 and KN-1	200 gpm (Wet Boundary Conditions)	A-32

The steady-state modeling runs indicated that:

- The location of IW-11 produced better capture of the off-DOE-property lobe than the location of IW-10.
- IW-10 and IW-11 combined did not appear to provide any significant additional capture of the off-DOE-property lobe compared to the capture from location IW-11 alone.
- A combination of a new well at the location of IW-11 and a new off-DOE-property well (KN-1) provided the best results for capture of the South Plume and reduction of the stagnation zone. A figure showing the 10-year particle paths for this modeling run under wet boundary conditions is also provided to illustrate model uncertainty (Figure A-32).

A5.2 Transport Modeling Results

Ten transport modeling alternatives were modeled to determine if the South Plume could be cleaned up faster and/or more efficiently than predicted by the Baseline Alternative. New extraction wells modeled at locations IW-11 and KN-1 were included in some of the modeling runs since the steady-state flow modeling (discussed above) indicated that they provided the best results for capture. Transport modeling was programmed to start in 2012 using the up-to-date kriged uranium plume from the MVS version 9.8. Other than updating the plume and changing pumping rates, no other modeled parameters were changed (e.g., hydraulic conductivity, boundary conditions, and distribution coefficients). The transport model was run under wet, nominal, and dry boundary conditions to bracket model uncertainty, which is consistent with the way the model was run for the WSA Phase II Design. To be conservative, the longest predicted

cleanup time (regardless of the boundary condition used) was selected for the alternative for comparison purposes.

For well locations, refer to Figure A-22. Table A-3 provides a summary of the pumping rates that were modeled for each alternative. Net total system pumping rate ranged from 4,775 gpm to 5,575 gpm. Table A-4 provides a summary of the predicted cleanup dates for the South Plume under each alternative. Total uranium plume maps for model layer 12, which illustrate cleanup of the South Plume for each alternative, are provided in Figures A-33 through A-42. Model layer 12 was used to screen the alternatives because most of the uranium plume is contained within this layer.

Individual alternative summaries are provided below.

South Plume Alternative 1: Increase the pumping rate of SP-6 from 200 gpm up to 400 gpm.

- Infrastructure impact: No (involves an operational change to one existing well).
- Cleanup prediction: Two years less than the Baseline Alternative.
- Impact to off-DOE-property owners: None.
- Risks: High (might not be able to maintain a pumping rate of 400 gpm from this well).

South Plume Alternative 2: Increase the pumping rate of SP-6 and SP-7 from 200 gpm each to 300 gpm each.

- Infrastructure impact: No (involves an operational change to two existing wells).
- Cleanup prediction: Two years less than the Baseline Alternative.
- Impact to off-DOE-property owners: None.
- Risks: Medium (should be able to maintain 300 gpm from each of these wells).

South Plume Alternative 3: Increase the pumping rate of SP-6 and SP-7 from 200 gpm each to 400 gpm each.

- Infrastructure impact: No (involves an operational change to two existing wells).
- Cleanup prediction: Two years less than the Baseline Alternative.
- Impact to off-DOE-property owners: None.
- Risks: High (might not be able to maintain a pumping rate of 400 gpm from these wells).

South Plume Alternative 4: Install a new well (IW-11) on DOE property and pump it at 200 gpm.

- Infrastructure impact: Yes (convert an abandoned injection well into an extraction well).
- Cleanup prediction: One year less than the Baseline Alternative.
- Impact to off-DOE-property owners: None.
- Risks: Medium (might not be able to convert abandoned injection well to an extraction well and maintain desired yield).

South Plume Alternative 5: Install a new well (IW-11) on DOE property and pump it at 400 gpm.

- Infrastructure impact: Yes (convert an abandoned injection well into an extraction well).
- Cleanup prediction: One year less than the Baseline Alternative.
- Impact to off-DOE-property owners: None.
- Risks: High (might not be able to convert an abandoned injection well to an extraction well and maintain desired yield).

South Plume Alternative 6: Install a new off-DOE-property well (KN-1) and pump it at 200 gpm.

- Infrastructure impact: Yes (one new off-DOE-property well).
- Cleanup prediction: One year less than the Baseline Alternative.
- Impact to off-DOE-property owners: Yes, but property owner has indicated he would accept the location of the new well.
- Risks: Medium (normal issues associated with off-DOE-property wells).

South Plume Alternative 7: Install a new off-DOE-property well (KN-1) and pump it at 400 gpm.

- Infrastructure impact: Yes (one new off-DOE-property well).
- Cleanup prediction: Two years less than the Baseline Alternative.
- Impact to off DOE-property owners: Yes, but property owner has indicated he would accept the location of the new well.
- Risks: High (might not be able to maintain a pumping rate of 400 gpm from this well, given aquifer conditions in the area).

South Plume Alternative 8: Install a new well (IW-11) on DOE property and a new off-DOE-property well (KN-1) and pump both at 200 gpm.

- Infrastructure impact: Yes (two new wells, one on DOE property and one off DOE property).
- Cleanup prediction: One year less than the Baseline Alternative.
- Impact to off-DOE-property owners: Yes, but property owner has indicated he would accept the location of the new off-DOE-property well.
- Risks: Medium (might not be able to convert an abandoned injection well into an extraction well).

South Plume Alternative 9: Install a new well (IW-11) on DOE property and a new off-DOE-property well (KN-1), and pump both at 400 gpm.

- Infrastructure impact: Yes (two new wells, one on DOE property and one off DOE property).
- Cleanup prediction: Two years less than the Baseline Alternative.

- Impact to off-DOE-property owners: Yes, but property owner has indicated he would accept the location of the new off-DOE-property well.
- Risks: High (might not be able to convert an abandoned injection well to an extraction well. Might not be able to maintain a pumping rate of 400 gpm from these wells, given aquifer conditions in the area).

South Plume Alternative 10: Pump extraction wells SP-6 and SP-7 at 300 gpm each and install a new off-DOE-property well (KN-1) and pump it at 200 gpm.

- Infrastructure impact: Yes (one new off-DOE-property well).
- Cleanup prediction: Two years less than the Baseline Alternative.
- Impact to off-DOE-property owners: Yes, but property owner has indicated he would accept the location of the new off-property well.
- Risks: Medium (normal issues associated with off-DOE-property wells).

Transport modeling results indicate that cleanup of the South Plume can be shortened by approximately 2 years under the modeling considerations discussed earlier. South Plume Alternative 2 is the best alternative, based on infrastructure impact, cleanup time, impact to property owner, cost, and risk. It has extraction wells SP-6 and SP-7 pumping at 300 gpm each instead of 200 gpm each, and it shortens the cleanup of the South Plume by approximately 2 years.

A6.0 Optimization Alternatives

Six optimization alternatives (OAs) were modeled, identified as OA1 through OA6. Alternatives OA1 through OA4 examined various ways to optimize the operation of the existing pump-and-treat system. Information learned from OA1 through OA4 (as well as the South Plume alternatives) was then incorporated into OA5 and OA6. The modeling runs for OA5 and OA6 were accelerated by being programmed to begin in 2012 rather than waiting an estimated 9 years to begin after the South Plume had been remediated. For both OA5 and OA6, extraction wells SP-6 and SP-7 were modeled at a pumping rate of 300 gpm each.

Optimization Alternative Overview

Alternatives OA1 and OA2: These two alternatives were modeled to explore the possibility of allowing the WSA plume, or a portion of the WSA plume, to naturally attenuate with monitoring following cleanup of the South Plume. This approach is referred to as monitored natural attenuation (MNA). Since the Fernald Preserve is protected by institutional controls, as long as the plume remains on DOE property while it dissipates to cleanup levels, it is protective of human health and the environment. Use of MNA would require an OU5 Record of Decision Explanation of Significant Differences.

Use of MNA in the WSA might provide the potential for a better cleanup than the present pump-and-treat remediation. The WSA plume is located beneath a former source area where uranium contamination is known to be sorbed to aquifer sediments above the water table in the aquifer (i.e., in the vadose zone) resulting in a potential residual source (Figure A-4). Pumping can

remove uranium contamination only from aquifer sediments that are below the water table. Pumping the aquifer lowers the water table, putting sorbed contamination in the vadose zone further out of reach of the pump-and-treat remediation. The result is that uranium contamination is left in the vadose zone after pump-and-treat operations end. This can present a problem in the future if the water table rises enough to saturate the sediments and dissolve the uranium into the groundwater (referred to as "rebound").

Rebounding uranium concentrations may hinder certification of the groundwater in the WSA following pump-and-treat. Whenever water levels in the area rise high enough to come into contact with the remaining sorbed contamination in the vadose zone, the potential to exceed cleanup levels will exist. Therefore, even if pumping continues through 2023 (as currently planned for the WSA Phase II Design), contamination will likely remain at this location and hinder cleanup certification.

Two alternatives (OA1 and OA2) were modeled to assess how MNA might impact the remediation of the WSA. For OA1, extraction wells EW-26, EW-27, EW-28a, and EW-33a were all turned off (see Figure A-22). The rest of the wells were modeled at WSA Phase II Design rates. For OA2, only extraction well EW-33a was turned off (see Figure A-22). The rest of the wells were modeled at WSA Phase II Design rates.

Alternatives OA3 and OA4: These two alternatives were modeled based on information learned from a particle track assessment. A particle track assessment conceptualizes the path that a drop of water takes in the model over a defined time period. In this case, the assessment was used to indicate if water being pumped to a well was coming from the plume area or from outside the plume area.

Figure A-16 shows 10-year time-of-travel particle paths (based on WSA Phase II Design pumping rates) in relation to the maximum uranium plume map from December 2011. The particle paths leading to three wells (EW-28a, EW-31, and EW-32) indicate that the wells are pulling water from outside (or mostly outside) the area of the uranium plume. Based on the WSA Phase II Design, all three wells are scheduled to continue pumping until 2023. Alternatives OA3 and OA4 were modeled with one or more of these wells turned off to determine how the remediation would be impacted. For OA3, extraction wells EW-31 and EW-32 were turned off, and the rest of the wells were modeled at WSA Phase II Design rates. For OA4, extraction well 28A was turned off. The rest of the wells were modeled at WSA Phase II Design rates.

Alternative OA5: This alternative was modeled to begin in 2012. Incorporating information learned from modeling OA1 through OA4, Alternative OA5 was modeled as follows:

- WSA extraction wells EW-33a and EW-28a, and South Field extraction wells EW-31 and EW-32 were modeled as not pumping.
- Freed-up pumping capacity from EW-33a, EW-28a, EW-31, and EW-32 was re-allocated in the model to extraction wells located in the South Field to accelerate cleanup of the South Field plume.
- The net system extraction rate was maintained at 4,775 gpm.

Four iterations were modeled (Alternatives OA5a through OA5d) to determine the optimum pumping scheme. More than one iteration was required because modeling more aggressive pumping in the South Field impacted the stagnation zone that is present between the South

Plume and South Field and resulted in longer South Plume remediation times. The location of the stagnation zone is shown in Figure A-16. Water in a stagnation zone is being pulled from opposite directions, and the result is that it moves very little or "stagnates." In the case of the stagnation zone shown in Figure A-16, pumping in the South Field to the north is pulling against pumping in the South Plume to the south.

Alternative OA6: This alternative was also modeled to begin in 2012. It is similar in design to OA5, with the exception that freed-up pumping capacity was not modeled as being re-allocated to extraction wells in the South Field. OA6 was modeled as follows:

- WSA extraction wells EW-33a, EW-28a, and South Field extraction wells EW-31 and EW-32 were modeled as not pumping.
- Freed-up pumping capacity was not re-allocated to the South Field to accelerate remediation of the South Field plume.
- The net system extraction rate was reduced from 4,775 gpm to 2,875 gpm.

A6.1 Modeling Results for Alternative OA1

OA1 models the possibility of letting the WSA plume naturally attenuate following cleanup of the South Plume. Figure A-43 is a well location map for OA1. As shown in Figure A-43, only wells in the South Field are modeled in the alternative. Extraction wells EW-26, EW-27, EW-28a, and EW-33a (located in the WSA) are modeled as not pumping. Table A-5 provides pumping rates for individual extraction wells that are pumping. OA1 has a total system pumping rate of 3,575 gpm compared to the Baseline Alternative rate of 4,775 gpm.

Figure A-44 is a 10-year particle track map for OA1 under steady-state conditions compared to the 2011 plume footprint. The 2011 plume footprint provides a conservative visualization reference for capture of the South Field and WSA plumes. Under OA1, the South Plume is already remediated, so that portion of the 2011 footprint can be ignored. As expected, with the WSA extraction wells off, particle tracks do not extend across the WSA plume. The water level map indicates that the plume will migrate southeast toward the South Field.

Transport modeling results for model layers 7–12 are provided to be consistent with results reported for the Baseline Alternative. The results indicate that a conservative prediction for cleanup of the South Field is between 2027 and 2028 under nominal boundary conditions (Figure A-45).

Predicted Cleanup Dates for South Field Plume Under OA1

Plume	Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
South Field	2027	2028	2027

Considering all three boundary conditions, the footprint of the uranium plume (greater than 30 µg/L) remaining in the WSA upon cleanup of the South Field ranges from 7.9 acres to 13.1 acres. The remaining plume is divided into a north and south plume. An acreage breakdown is provided below.

Size of the WSA Plume (Acres) Left to Naturally Attenuate, in the Year that the South Field Plume Cleans Up

Plume >30 µg/L	Dry Boundary Conditions in 2027 (Acres)	Nominal Boundary Conditions in 2028 (Acres)	Wet Boundary Conditions in 2027 (Acres)
North WSA Plume	8.7	4.7	8.2
South WSA Plume	4.3	3.2	4.9
Total	13.0	7.9	13.1

Figure A-46 shows the 13.1-acre plume footprint that remains in the WSA under wet boundary conditions in model year 2027.

Considering all three boundary conditions, the maximum uranium concentration that remains in the WSA to undergo MNA ranges from 36.84 µg/L to 45.17 µg/L. Under all three boundary conditions the maximum uranium concentration remaining resides in model layer 12. A breakdown of maximum uranium concentrations by model layer is provided below. As shown below, FRL exceedances are limited to model layers 11 and 12.

Maximum Uranium Concentration in WSA Plume (by Model Layer) Upon Cleanup of the South Field Plume

Layer	Dry Boundary Conditions in 2027 (µg/L)	Nominal Boundary Conditions in 2028 (µg/L)	Wet Boundary Conditions in 2027 (µg/L)
12	43.61	36.84	45.17
11	34.05	28.50	34.85
10	27.57	15.40	27.89
9	22.42	17.71	21.85
8	20.79	16.01	19.29
7	20.36	15.40	17.95

Transport modeling predicts that the plumes remaining in the WSA could conservatively take until 2064 to dissipate below 30 µg/L, but those plumes remain on DOE property. Predicted cleanup times by boundary condition are provided below.

Predicted Natural Attenuation Times for Dissipation of the WSA Plumes

Plume	Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
North Plume	2048	2037	2064
South Plume	2035	2034	2040

A6.2 Modeling Results for Alternative OA2

OA2 models the possibility of letting a portion of the WSA naturally attenuate following cleanup of the South Plume. Figure A-47 is a well location map for OA2. As shown in Figure A-47, extraction well EW-33a is modeled as not pumping. Table A-5 provides pumping rates for individual extraction wells that are pumping. OA2 has a total system pumping rate of 4,575 gpm compared to the Baseline Alternative rate of 4,775 gpm.

Figure A-48 is a 10-year particle track map for OA2 under steady-state conditions compared to the 2011 plume footprint. The 2011 plume footprint provides a conservative visualization reference for capture of the South Field and WSA plumes. Under OA2, the South Plume is already remediated, so that portion of the 2011 footprint can be ignored. Figure A-48 indicates that the maximum uranium plumes in the South Field and WSA are fully captured by the particle tracks.

Transport modeling results for model layers 7–12 are provided for consistency with results reported for the Baseline Alternative. The results indicate that a conservative prediction for cleanup of the South Field is between 2028 and 2029 under nominal boundary conditions (Figure A-49).

Predicted Cleanup Dates for South Field Under OA2

Plume	Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
South Field	2028	2029	2027

Considering all three boundary conditions, the footprint of the uranium plume (greater than 30 µg/L) remaining in the WSA upon cleanup of the South Field ranges from 0.3 acre to 6.5 acres. An acreage breakdown is provided below.

Size of WSA Plume (Acres) Left to Naturally Attenuate
In the Year that the South Field Plume Cleans Up

Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
5.6 acres	0.3 acre	6.5 acres

Figure A-50 shows the 6.5-acre plume footprint that remains under wet boundary conditions in model year 2027.

Considering all three boundary conditions, the maximum uranium concentration that is predicted to remain in the WSA to undergo MNA ranges from 30.25 µg/L to 40.14 µg/L. Under all three boundary conditions, the maximum uranium concentration remaining resides in model layer 12. A breakdown of maximum uranium concentrations by model layer is provided below. As shown, FRL exceedances are limited to model layers 11 and 12.

Maximum Uranium Concentration in WSA Plume (by Model Layer) Upon Cleanup of the South Field Plume

Layer	Dry Boundary Conditions in 2028 (µg/L)	Nominal Boundary Conditions in 2029 (µg/L)	Wet Boundary Conditions in 2027 (µg/L)
12	37.15	30.25	40.14
11	29.30	24.31	31.31
10	23.78	12.81	25.06
9	18.88	15.36	19.33
8	16.40	13.63	16.47
7	15.18	12.81	15.05

Transport modeling predicts that the plume remaining in the WSA would conservatively take until 2044 to dissipate below 30 µg/L. The plume remains on DOE property. Predicted cleanup dates by boundary condition are provided below.

Predicted Cleanup Dates for Dissipation of the WSA Plume

Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
2037	2031	2044

A6.3 Modeling Results for Alternative OA3

OA3 models the possibility of turning off extraction wells EW-31 and EW-32. Figure A-51 is a well location map for OA3. Table A-5 provides pumping rates for individual extraction wells that are pumping. OA3 has a total system pumping rate of 4,275 gpm compared to the Baseline Alternative rate of 4,775 gpm.

Figure A-52 is a 10-year particle track map for OA3 under steady-state conditions compared to the 2011 plume footprint. The 2011 plume footprint provides a conservative visualization reference for capture of the South Field and WSA plumes. Under OA3, the South Plume is already remediated, so that portion of the 2011 footprint can be ignored. Figure A-52 indicates that the maximum uranium plume in the South Field and WSA is fully captured by the particle tracks.

Transport modeling results for model layers 7–12 are provided for consistency with results reported for the Baseline Alternative. The results indicate that a conservative prediction for cleanup of the South Field is between 2029 and 2030 under nominal boundary conditions. Figure A-53 shows where the last remaining portion of the uranium plume is located in the South Field in model year 2029 under nominal boundary conditions. A conservative prediction for cleanup of the WSA plume is between 2032 and 2033 under wet boundary conditions.

Figure A-54 shows where the last remaining portion of the uranium plume is located in the WSA in model year 2032 under wet boundary conditions.

Predicted Cleanup Dates South Field and WSA under OA3

Plume	Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
South Field	2029	2030	2027
WSA	2033	2028	2033

Modeling indicates that removing EW-31 and EW-32 increases cleanup time in the South Field by approximately 4 years compared to the Baseline Alternative. Removing these two wells could be a viable option if unused pumping capacity from EW-31 and EW-32 could be redirected to other wells in the South Field to accelerate the cleanup.

A6.4 Modeling Results for Alternative OA4

OA4 models the possibility of turning off extraction well EW-28a. Figure A-55 is a well location map for OA4. Table A-5 provides pumping rates for individual extraction wells that are pumping in this alternative. OA4 has a total system pumping rate of 4,575 gpm compared to the Baseline Alternative rate of 4,775 gpm.

Figure A-56 is a 10-year particle track map for OA4 under steady-state conditions compared to the 2011 plume footprint. The 2011 plume footprint provides a conservative visualization reference for capture of the South Field and WSA plumes. Under OA4, the South Plume is already remediated, so that portion of the 2011 footprint can be ignored. Figure A-56 indicates that the maximum uranium plume in the South Field and WSA is fully captured by the particle tracks.

Transport modeling results for model layers 7–12 are provided for consistency with results for the Baseline Alternative. The results indicate that a conservative prediction for cleanup of the South Field is between 2028 and 2029 under nominal boundary conditions. Figure A-57 shows the location of the plume left in the South Field in 2028.

A conservative prediction for cleanup of the WSA plume is between 2033 and 2034 under wet boundary conditions. Figure A-58 shows the location of the plume left in the WSA in 2033.

Predicted Cleanup Dates for the South Field and WSA Under OA4

Plume	Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
South Field	2028	2029	2027
WSA	2033	2028	2034

Modeling indicates that removing EW-28a increases cleanup time in the South Field by approximately 3 years and in the WSA by approximately 1 year compared to the Baseline Alternative. Removing EW-28a could be a viable option if unused pumping capacity from EW-28a could be redirected to other wells in the South Field to accelerate the cleanup.

A6.5 Modeling Results for Alternatives OA5a to OA5d

Alternatives OA5a through OA5d model the possibility of shutting down extraction wells EW-28a, EW-31, EW-32, and EW-33a, and re-allocating the freed-up pumping capacity to wells pumping in the South Field to maintain a total system extraction rate of 4,775 gpm. The alternatives are modeled as beginning in 2012. Figure A-59 is a well location map for OA5a through OA5d. Table A-6 provides pumping rates for four different pumping combinations modeled for cleanup of the South Plume.

Since the operational changes were modeled with a start date of 2012, the first objective was to determine if and how changing pumping rates in the South Field might impact the South Plume cleanup. The runs were all modeled with SP-6 and SP-7 pumping at 300 gpm each. Four iterations of OA5 (OA5a through OA5d) were run to arrive at the shortest South Plume cleanup time. Particle track maps indicate that capture of the uranium plume is maintained. Modeling results are summarized below:

- OA5a: South Plume cleanup took 9 years. Increased pumping in the South Field impacted the stagnation zone in the model between the South Field and the South Plume, resulting in the need to pump an additional 2 years to clean up the South Plume. The location of the stagnation zone is shown in Figure A-16. Therefore, additional model runs were made to try different pumping re-allocations to reduce the impact to the stagnation zone.
- OA5b: South Plume cleaned up in 8 years. Pumping rates just north of the stagnation zone were reduced slightly compared to pumping rates modeled in OA5a.
- OA5c: South Plume cleanup took 8 years. Pumping rates just north of the stagnation zone were reduced slightly compared to pumping rates modeled in OA5b. Compared to OA5b the South Field cleaned up slightly faster.
- OA5d: South Plume cleanup took 8 years. As shown in Figures A-62 and A-63, a comparison of the remediation of the South Field in model year 2019 indicates that Alternative OA5c was slightly better than OA5d.

A comparison of transport modeling results for model layer 12 for the year 2019 under nominal boundary conditions illustrates that OA5c provided the best pumping configuration for accelerating cleanup of both the South Plume and the South Field. Figures A-60 through A-63 illustrate the size of the uranium plume predicted to remain in the year 2019 for OA5a through OA5d. The model predicted that the pumping rates modeled for OA5c would result in less plume remaining in the South Field and South Plume in 2019 than the other pumping rate configurations (OA5a, OA5b, and OA5d).

Table A-7 provides pumping rates used for OA5c. Figure A-64 is a 10-year particle track map for OA5c under steady-state conditions compared to the 2011 plume footprint. The 2011 plume footprint provides a conservative visualization reference for capture of the total uranium plume. Figure A-64 indicates that the maximum uranium plumes in the South Plume, South Field, and WSA are fully captured by the particle tracks.

Transport modeling results for model layers 7–12 are provided for consistency with results reported for the Baseline Alternative. The results indicate that a conservative prediction for

cleanup of the South Plume is between 2019 and 2020 under nominal boundary conditions (Figure A-65).

Predicted Cleanup Dates for South Plume Under OA5c

Plume	Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
South Plume	2019	2020	2019

Transport modeling results indicate that a conservative prediction for cleanup of the South Field is between 2027 and 2028 under nominal boundary conditions (Figure A-66).

Predicted Cleanup Dates for South Field Under OA5c

Plume	Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
South Field	2027	2028	2026

Considering all three boundary conditions, the footprint of the uranium plume (greater than 30 µg/L) remaining in the WSA upon cleanup of the South Field ranges from 19.8 acres to 22.3 acres. An acreage breakdown is provided below.

Size of WSA Plume (Acres) Left to Naturally Attenuate
In the Year That the South Field Cleans Up

Conc. of Footprint	Dry Boundary Conditions in 2027	Nominal Boundary Conditions in 2028	Wet Boundary Conditions in 2026
>30 µg/L	19.8 acres	22.3 acres	19.7 acres
>50 µg/L	10.5 acres	9.3 acres	12.1 acres
>100 µg/L	1.1 acres	0 acres	3.8 acres

Figure A-67 shows the 22.3-acre plume footprint that remains under nominal boundary conditions in model year 2028.

Considering all three boundary conditions, the maximum uranium concentration that is predicted to remain in the WSA upon cleanup of the South Field ranges from 81.82 µg/L to 146.68 µg/L. Under all three boundary conditions, the maximum uranium concentration resides in model layer 12. A breakdown of maximum uranium concentrations by model layer is provided below. As shown below, FRL exceedances are distributed in model layers 7 through 12.

Maximum Uranium Concentration in WSA Plume (by Model Layer) Upon Cleanup of the South Field Plume

Layer	Dry Boundary Conditions in 2027 (µg/L)	Nominal Boundary Conditions in 2028 (µg/L)	Wet Boundary Conditions in 2026 (µg/L)
12	112.02	81.82	146.68
11	80.21	62.81	109.07
10	61.55	50.33	80.94
9	46.43	38.42	56.70
8	39.28	33.49	46.07
7	36.00	31.21	40.62

Under OA5c, cleanup of the remaining WSA plume could proceed through pumping or through MNA. For pumping, EW-26 and EW-27 were modeled as pumping at a combined rate of 800 gpm. Predicted cleanup dates for the remaining WSA plume (pumping or not pumping) are provided below.

Predicted Cleanup Dates for the WSA Plume Under OA5c

Plume	Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
WSA (Pumping)	2058	2052	2078
WSA (Not Pumping)	2096	2081	>2126

Figure A-68 illustrates the predicted size of the uranium plume left in the WSA in model year 2077 under wet boundary conditions with extraction wells EW-26 and EW-27 pumping at a combined rate of 800 gpm. Figure A-69 illustrates the size of the uranium plume predicted to be left in the WSA in model year 2134 with no pumping past cleanup of the South Field. The WSA plume remains on DOE property.

As indicated above, model predictions for OA5c show that lack of pumping in EW-33a results in uranium FRL exceedances in model layers 7 through 12 in the WSA at the time that the South Field was predicted to be clean. As described in Sections A6.1 and A6.2, OA1 and OA2 were modeled to evaluate leaving the WSA or part of the WSA to remediate under an MNA approach. Results for OA1 and OA2 indicated that uranium FRL exceedances in the WSA were only present in model layers 12 and 11 at the time that the South Field was predicted to be clean. This means that OA5c would result in uranium FRL exceedances in the WSA in deeper layers of the model than would OA1 or OA2.

A comparison between Alternatives OA2 and OA5c for model layer 8 provides additional insight. These two alternatives (OA2 and OA5c) provide a good comparison because they were both modeled with extraction well EW-33a (in the WSA) not pumping. In OA5c, pumping in EW-33a was modeled as being turned off in 2012. In OA2, pumping in EW-33a was modeled as being turned off in 2019, 7 years later. Figure A-70 illustrates that in model year 2012, the concentration of uranium in model layer 8 is the same for both alternatives.

Figure A-71 illustrates the uranium plumes for model layer 8 for both alternatives in model year 2020. Note that uranium concentrations in model layer 8 (under the WSA) have increased for both alternatives. The uranium concentrations for OA5c have increased more than those for OA2. The only operational difference between the two alternatives between model years 2012 and 2020 was that pumping in the WSA continued in extraction well EW-33a for 7 additional years in OA2. This means that for 7 years, water levels for OA2 were lower than for OA5c. An additional comparison in model year 2028 indicates that uranium concentrations continue to move into the deeper model layers in the WSA under both alternatives when pumping in extraction well EW-33a is stopped (see Figure A-72).

The partial penetration effect of continued pumping in extraction wells EW-26 and EW-27 is probably the cause for uranium contamination being pulled into deeper layers of the model. Whether or not model layer 13 is saturated appears to be the cause for whether or not this results in uranium FRL exceedances in model layer 8.

Under pumping conditions (i.e., OA2), water levels were lowered and model layer 13 was unsaturated. Under nonpumping conditions (i.e., OA5c), water levels were higher and model layer 13 was saturated. When model layer 13 is unsaturated, the contribution to contaminant transport is vertical percolation of surface water through the vadose zone (modeled at 5 inches per year where the glacial overburden is present). When model layer 13 is saturated, the contribution to contaminant transport in the model is from both vertical percolation of surface water through the vadose zone and from upgradient model nodes via transport through the saturated media (as controlled by hydraulic gradient and hydraulic conductivity). In other words, more uranium moves out of model layer 13 and into model layer 12 under saturated conditions than under unsaturated conditions. In this case, the additional contamination modeled as coming out of model layer 13 is pulled into deeper layers of the model by the partial penetration effects of pumping wells to the south.

Therefore, the model predicts that remediation of the WSA becomes a tradeoff between attempting to get a more effective cleanup by allowing water levels to rise versus pulling uranium contamination into deeper portions of the aquifer.

It is possible that this modeling result in the WSA is exaggerated due to the kriging process and the surface infiltration rates currently loaded into the model for the WSA. The kriging process could have assigned a larger amount of uranium to model layer 13 than is actually present. Moreover, given the changes that have been made to the land surface in the WSA since soil remediation ended in 2005, the estimate of a uniform surface infiltration rate of 5 inches per year may be too low in some areas.

A6.6 Modeling Results for Alternative OA6

OA6 also incorporates information learned from OA1 through OA4. But unlike OA5, pumping capacity gained from shutting down extraction wells EW-28a, EW-31, EW-32, and EW-33a is not re-allocated to the South Field to maintain a system extraction rate of 4,775 gpm. Instead, the freed-up pumping capacity is removed from the alternative and the system is modeled at a lower system pumping rate. The objective was to reduce the impact that was seen to the stagnation

zone when OA5 was modeled. Well locations for OA6 are provided in Figure A-73. Pumping rates for OA6 are provided in Table A-8. Predicted cleanup dates for OA6 are provided below.

Predicted Cleanup Dates for OA6

Plume	Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
South Plume	2019	2019	2019
South Field	2030	2031	2029

Transport modeling results for model layers 7–12 are provided for consistency with results reported for the Baseline Alternative. The results indicate that a conservative prediction date for cleanup of the South Field is between 2030 and 2031 (Figure A-74).

Considering all three boundary conditions, the footprint of the uranium plume (greater than 30 µg/L) remaining in the WSA upon cleanup of the South Field ranges from 20.1 acres to 21.4 acres, and the maximum uranium concentration remaining is 125.33 µg/L.

Size of WSA Plume Remaining Following Cleanup of the South Field

Cons. of Footprint	Dry Boundary Conditions in 2030 (Acres)	Nominal Boundary Conditions in 2031 (Acres)	Wet Boundary Conditions in 2029 (Acres)
>30 µg/L	20.1	21.4	20.7
>50 µg/L	9.5	7.0	11.9
>100 µg/L	0	0	2.5

Figure A-75 shows the largest predicted WSA plume that remains under all three boundary conditions after the South Field is clean.

A breakdown of the maximum uranium concentration that remains in the WSA (by model layer) in the year that South Field plume cleanup is achieved is provided below.

Maximum Uranium Concentration in WSA Plume (by Model Layer) Upon Cleanup of the South Field Plume

Layer	Dry Boundary Conditions in 2030 (µg/L)	Nominal Boundary Conditions in 2031 (µg/L)	Wet Boundary Conditions in 2029 (µg/L)
12	93.88	67.50	125.33
11	68.76	54.37	95.77
10	55.22	44.77	75.11
9	43.53	35.82	56.03
8	37.85	31.42	45.50
7	35.06	29.48	40.87

If OA6 is selected, after cleanup of the South Field is achieved, cleanup of the WSA could proceed with limited pumping in the WSA or through natural attenuation. Continued pumping was modeled with extraction wells EW-26 and EW-27 pumping at a combined rate of 800 gpm. Predicted cleanup times are provided below.

Predicted Cleanup Dates for OA6

Plume	Dry Boundary Conditions	Nominal Boundary Conditions	Wet Boundary Conditions
WSA (Pumping)	2057	2052	2077

The size of the plume left in the WSA under OA6 (following cleanup of the South Field) is similar to the size of the plume left in the WSA under OA5c (21.4 acres vs. 22.3 acres). The time required to achieve remediation of the remaining WSA plume for OA6 is also similar to that for OA5c (if pumping continued, 2077 vs. 2078). Therefore, the time required for the plume to dissipate naturally under OA6 is assumed to be comparable to the time modeled for OA5c.

As noted above, modeling results for OA6 indicate that, upon cleanup of the South Field, uranium FRL exceedances are modeled as being located in model layers 7 through 12. Similar modeling results were obtained when OA5c was modeled, and the discussion presented for OA5c also pertains to OA6.

Reducing the total system pumping capacity as was modeled in OA6 resulted in a cleanup date for the South Field that was 3 years longer than for OA5c (2028 vs. 2031). Therefore, OA5c was selected as the better alternative.

A7.0 Water Treatment Assessment

As was done for the WSA Phase II Design, an Excel spreadsheet called TestPump was used to calculate a flow-weighted average uranium concentration for the water that would be pumped for the selected alternative. TestPump was also used to calculate the pounds of uranium that would be discharged for the selected alternative.

TestPump was run for the Modified Baseline Alternative to determine if the agreed-to discharge limits at the Great Miami River would be met (i.e., a monthly average uranium concentration of 30 µg/L and no more than 600 pounds of uranium per year).

Uranium concentrations measured in May 2013 and Modified Baseline pumping rates were entered into the TestPump spreadsheet. Since concentrations are predicted to decrease over time, loading current concentrations into the spreadsheet is considered to be conservative from a water treatment perspective.

Table A-9 is a printout of the TestPump calculation. The resulting flow-weighted average uranium concentration predicted for the Modified Baseline Alternative is 30.7 µg/L. This value is identified as “Concentration to Bypass (ppb)” in Table A-9. TestPump predicts that the Modified Baseline Alternative will send 683 pounds of uranium per year to the Great Miami

River. This value is identified as "Groundwater Bypass Mass/Year" in Table A-9. These amounts exceed the agreed-to discharge limits. However, the TestPump predictions do not take into account the monthly well field shutdown. Taking the annual shutdown into consideration, and decreasing uranium concentrations in the pumped water over time, very little to no treatment will be required in order to meet established discharge limits.

A8.0 References

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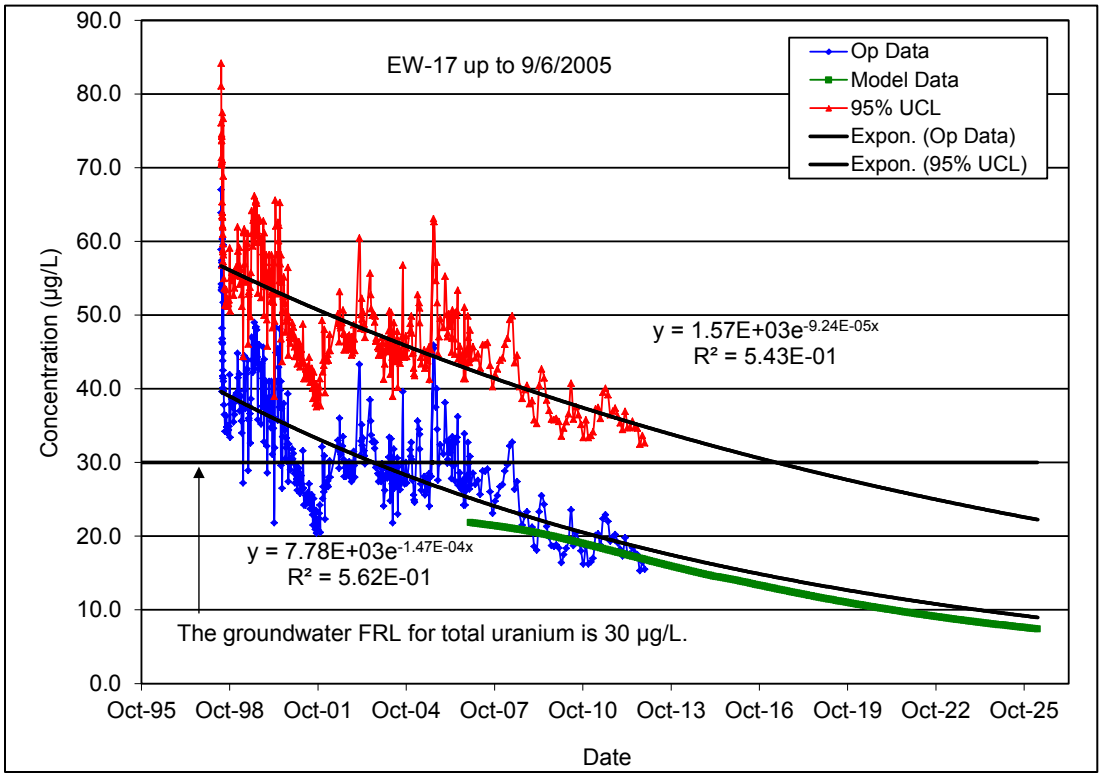

Figure A-1. Total Uranium Concentration vs. Time Plot for Extraction Well 31567 (EW-17)/33326 (EW-17a) with Regression Analysis

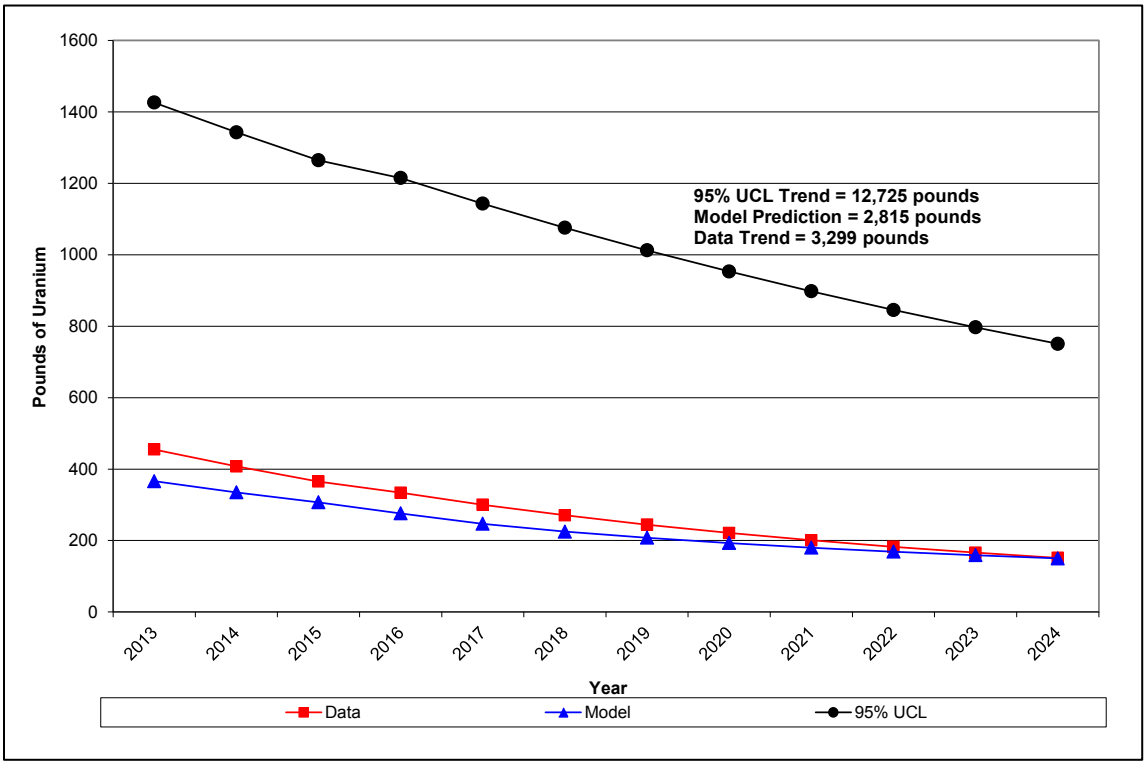

Figure A-2. Estimate of Yearly Pounds of Uranium to be Pumped from Aquifer (Model Predictions vs. Measured Concentration Trends) Using Data Collected Through 2012

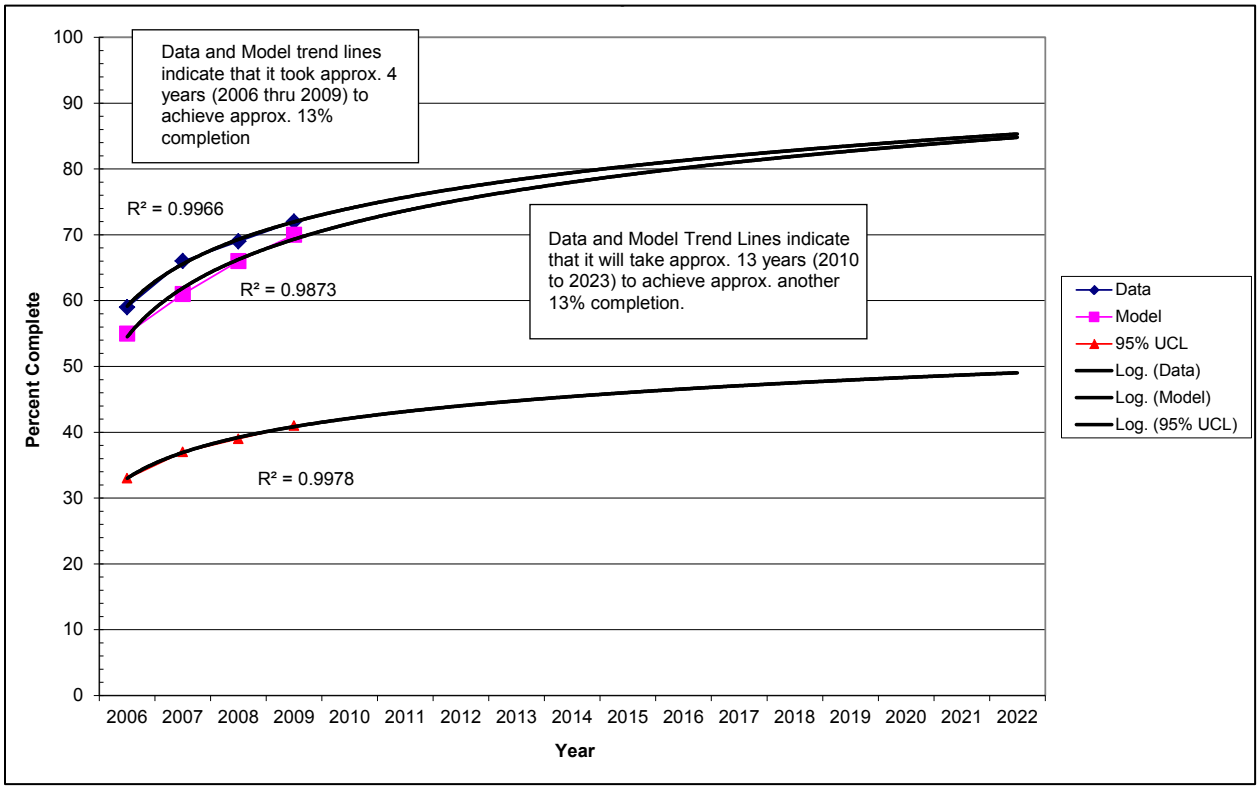

Figure A-3. Estimate of Mass Removal Completeness

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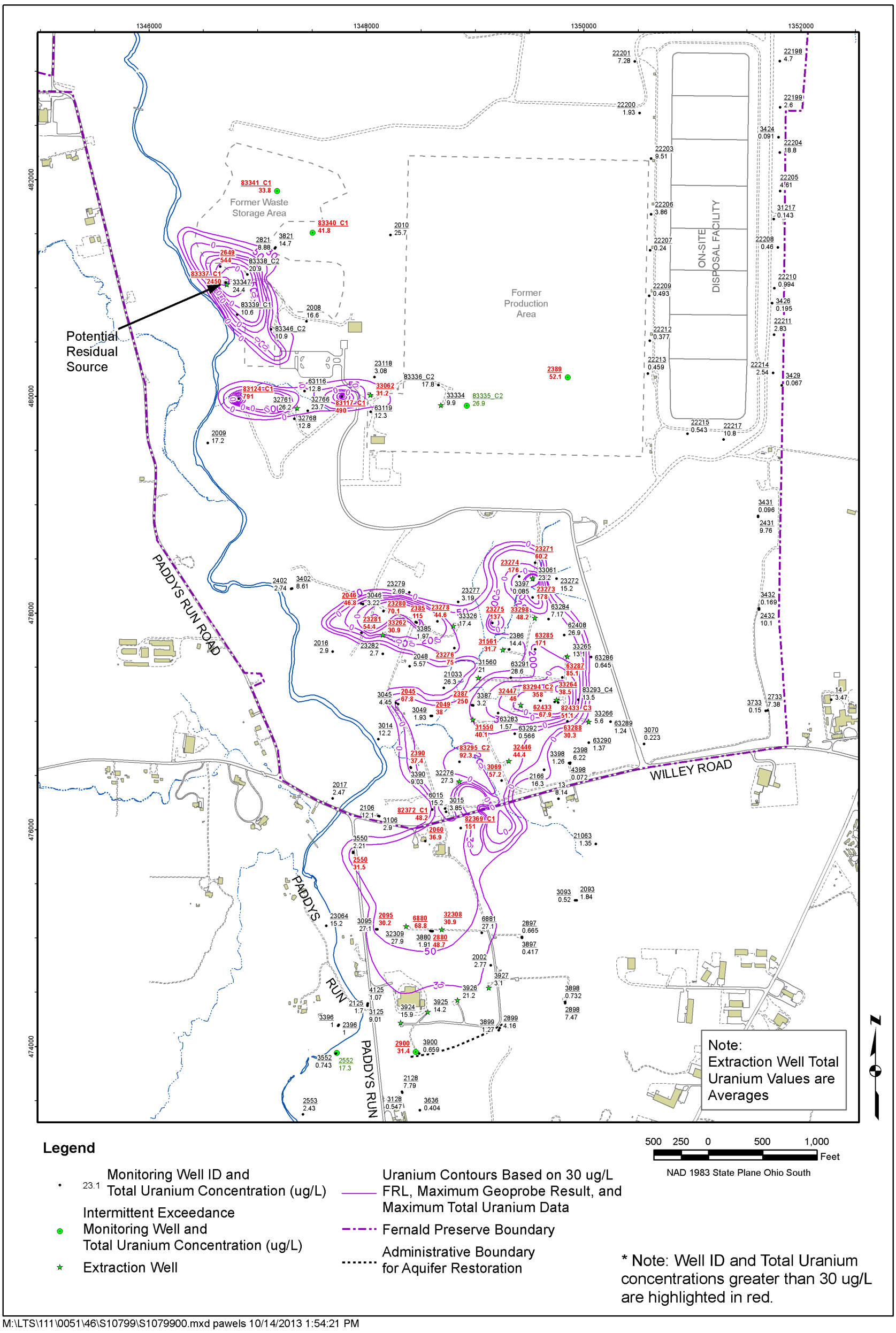


Figure A-4. Monitoring Well Data and Maximum Detected Total Uranium Plume Through the Second Half of 2011

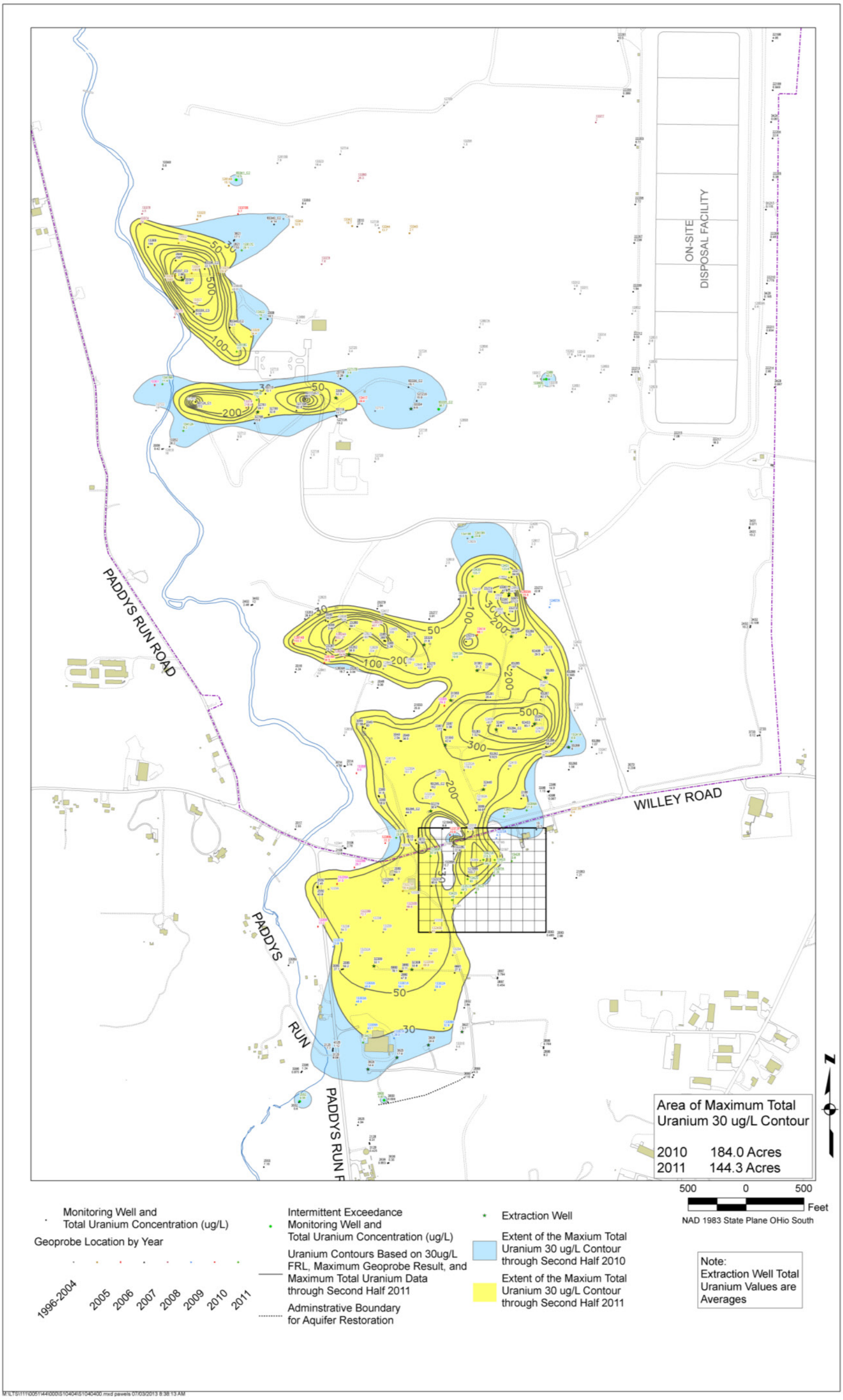


Figure A-5. 2010 vs. 2011 Maximum Uranium Plume Maps

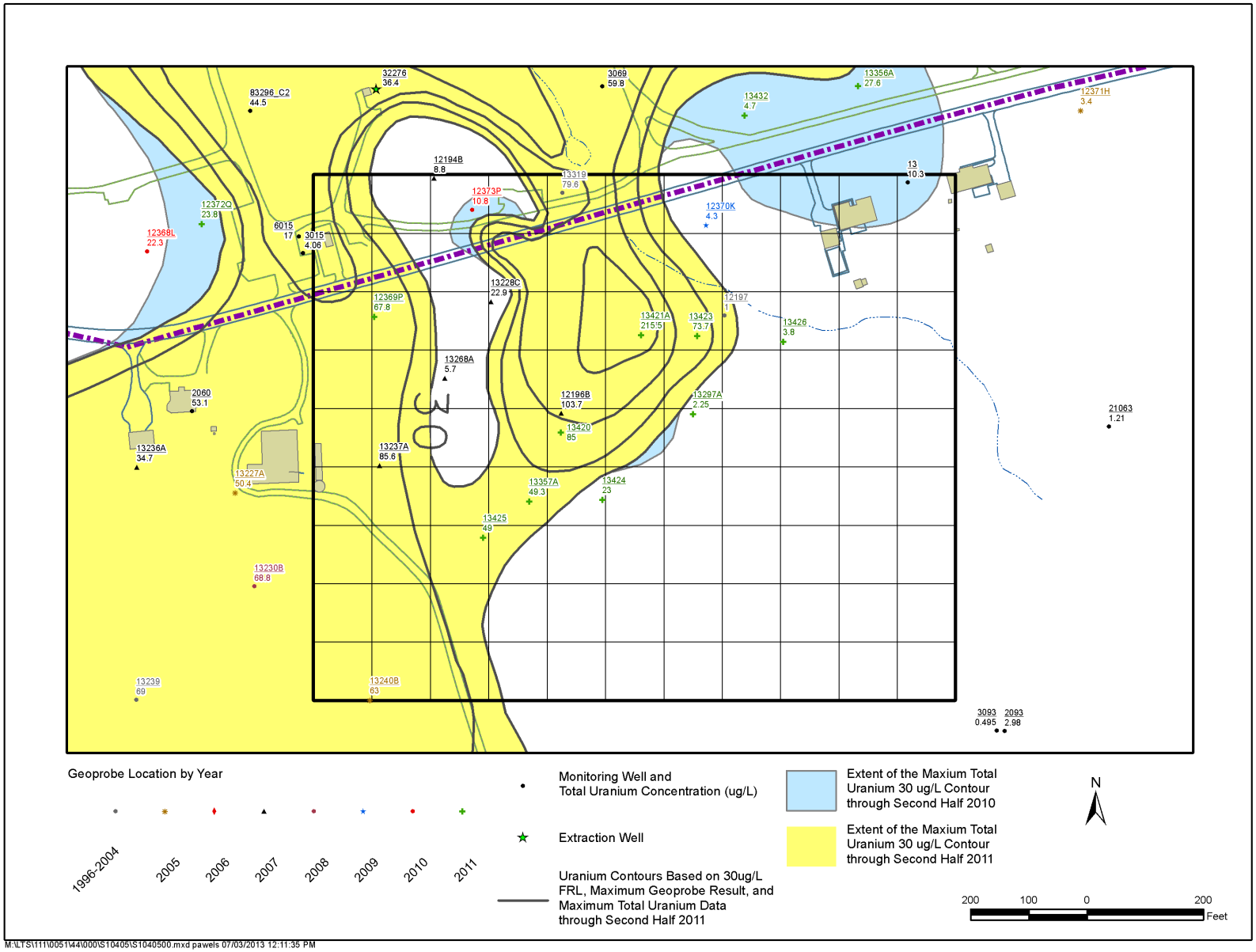


Figure A-6. Close-Up Look at Area Within the South Plume

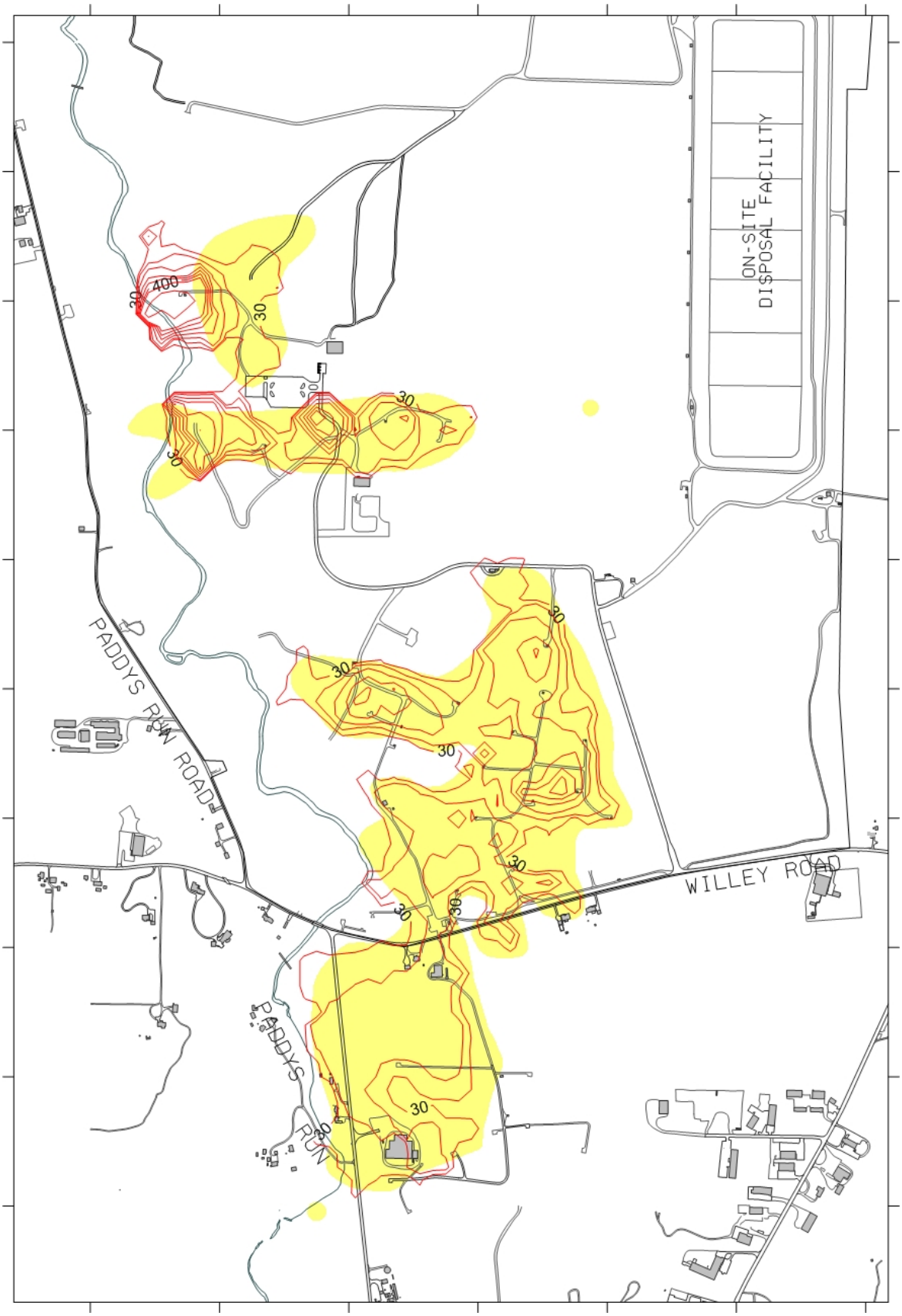


Figure A-7. Initial Uranium Concentration Contours for the WSA Phase II Design (Model Layers 7–13) vs. Footprint of Maximum Uranium Plume, December 2004 (Shown in Yellow)

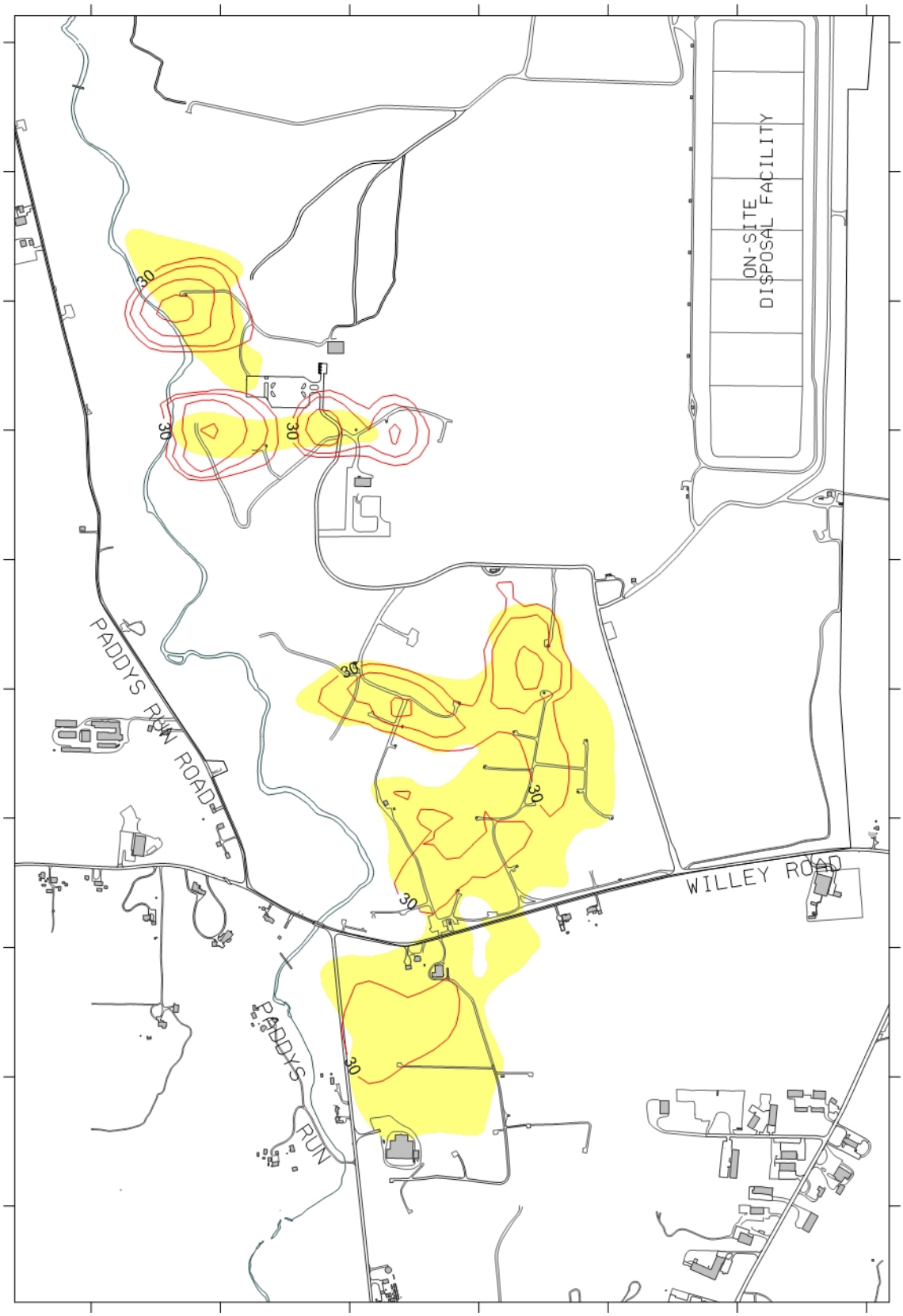


Figure A-8. Model-Predicted Uranium Concentration Contours—April 2012, WSA Phase II Design (Model Layers 7–13, Nominal Boundary Conditions) vs. Footprint of Maximum Uranium Plume, December 2011 (Shown in Yellow)

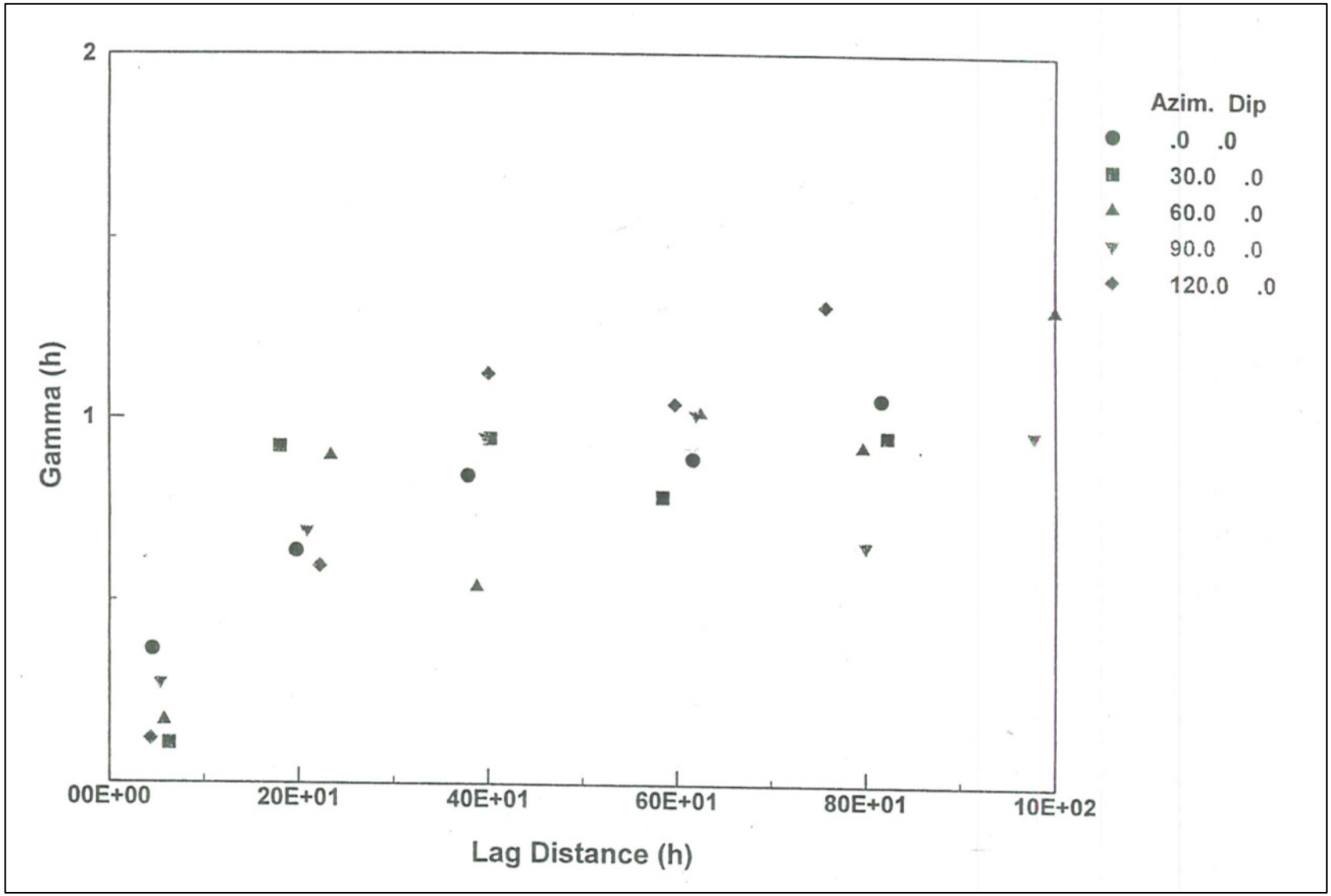
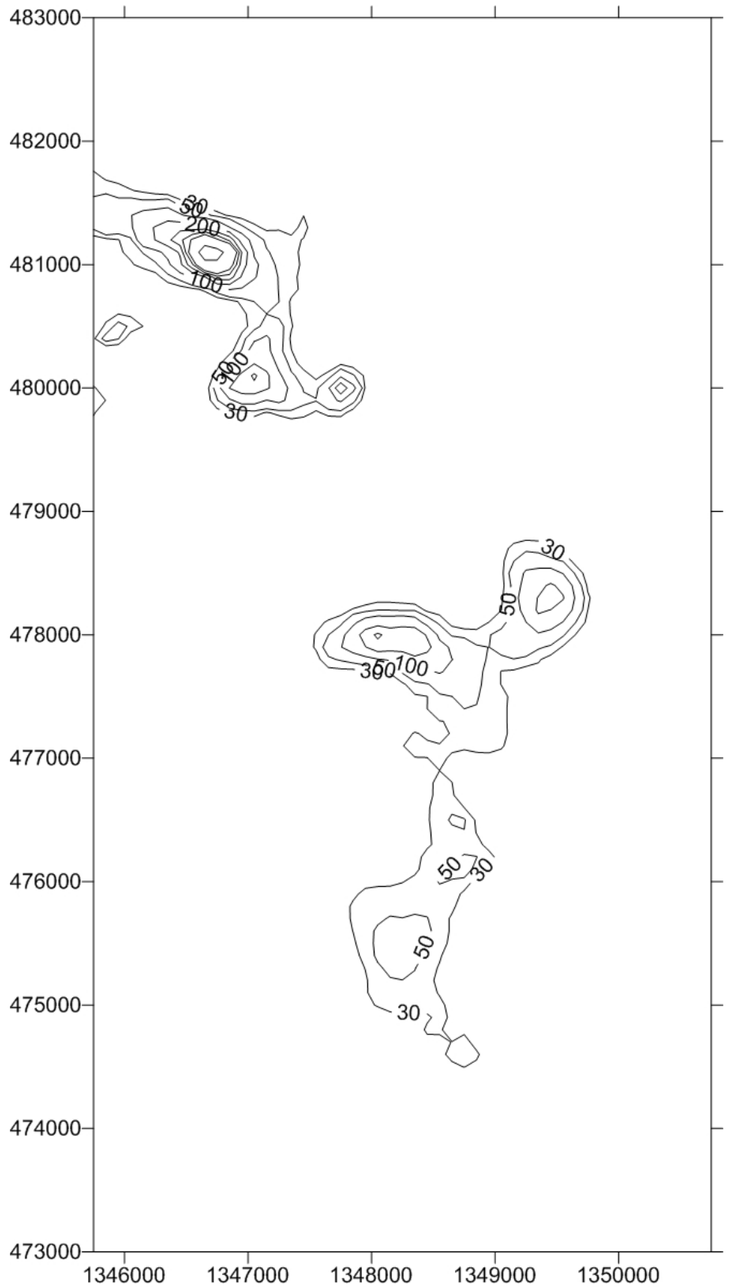


Figure A-9. Horizontal Variograms Used in the WSA Phase II Design to Krige December 2004 Uranium Data



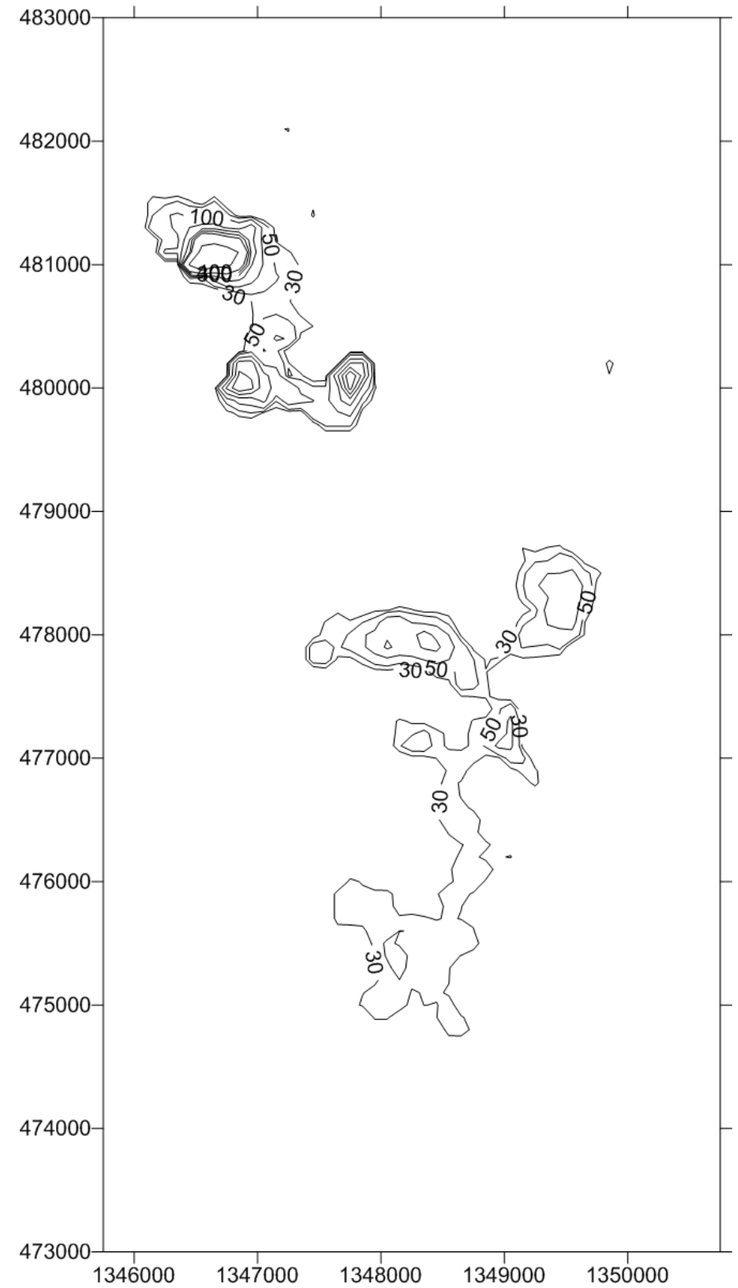
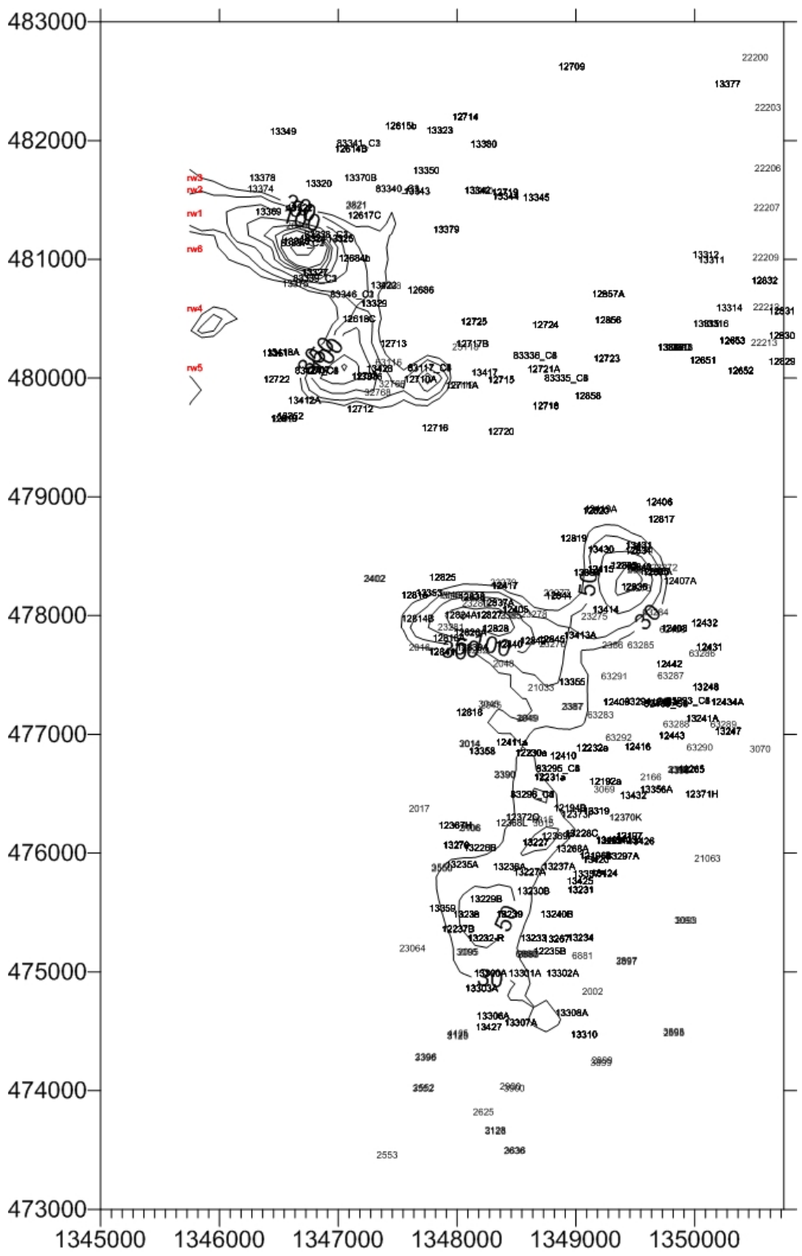


Figure A-10. Maximum Uranium Concentration Contours, Model Layer 13

MVS Version 9.8, Horizontal Search Radius = 7,331 feet

MVS Version 7.9.1, Horizontal Search Radius = 300 feet



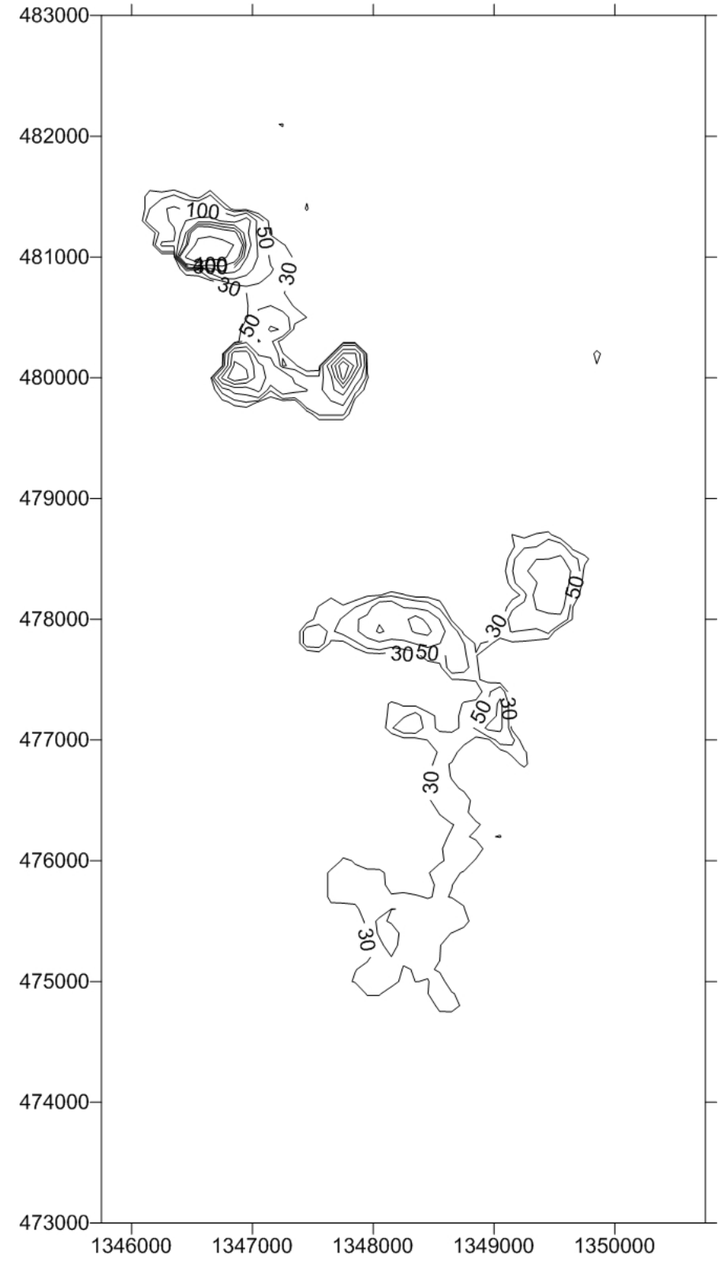
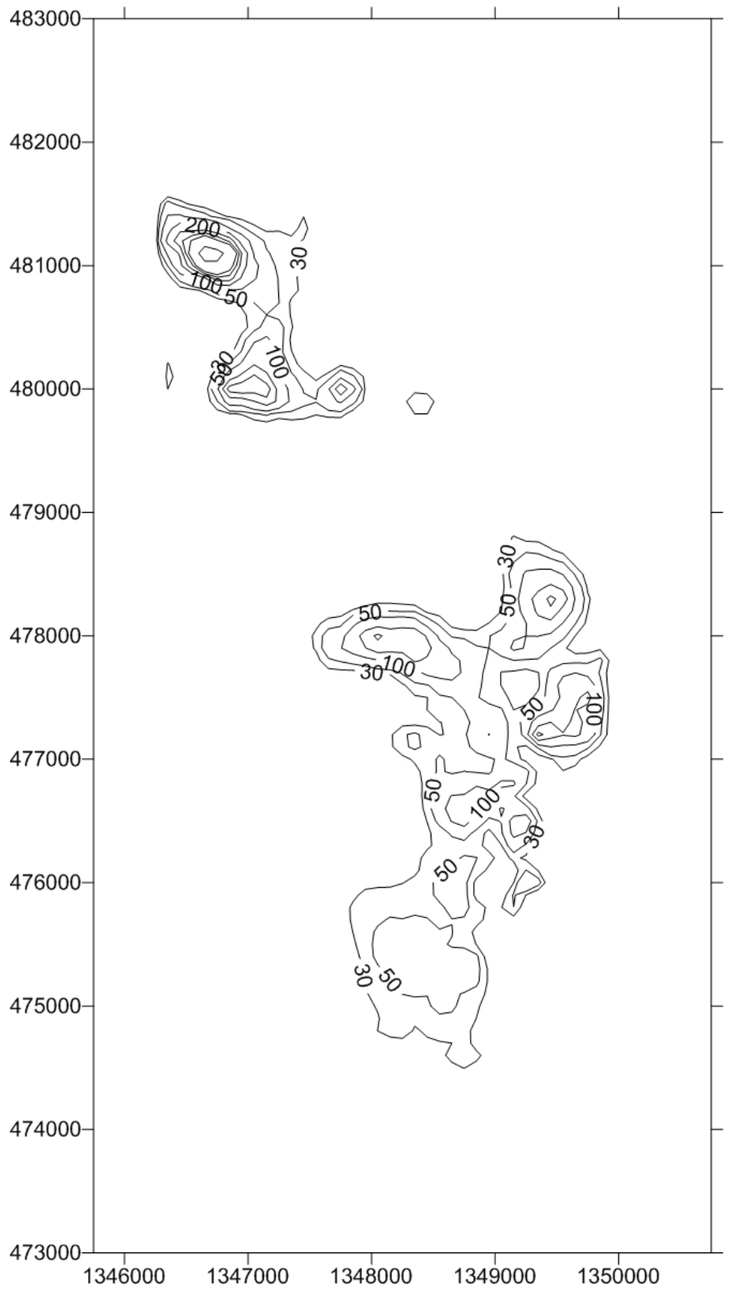


Figure A-11. Maximum Uranium Concentration Contours, Model Layer 13 (with Pseudo Borings)

MVS Version 9.8, Horizontal Search Radius = 7,331 feet, Proposed Locations for Pseudo Wells RW1–RW6

MVS Version 7.9.1, Horizontal Search Radius = 300 feet



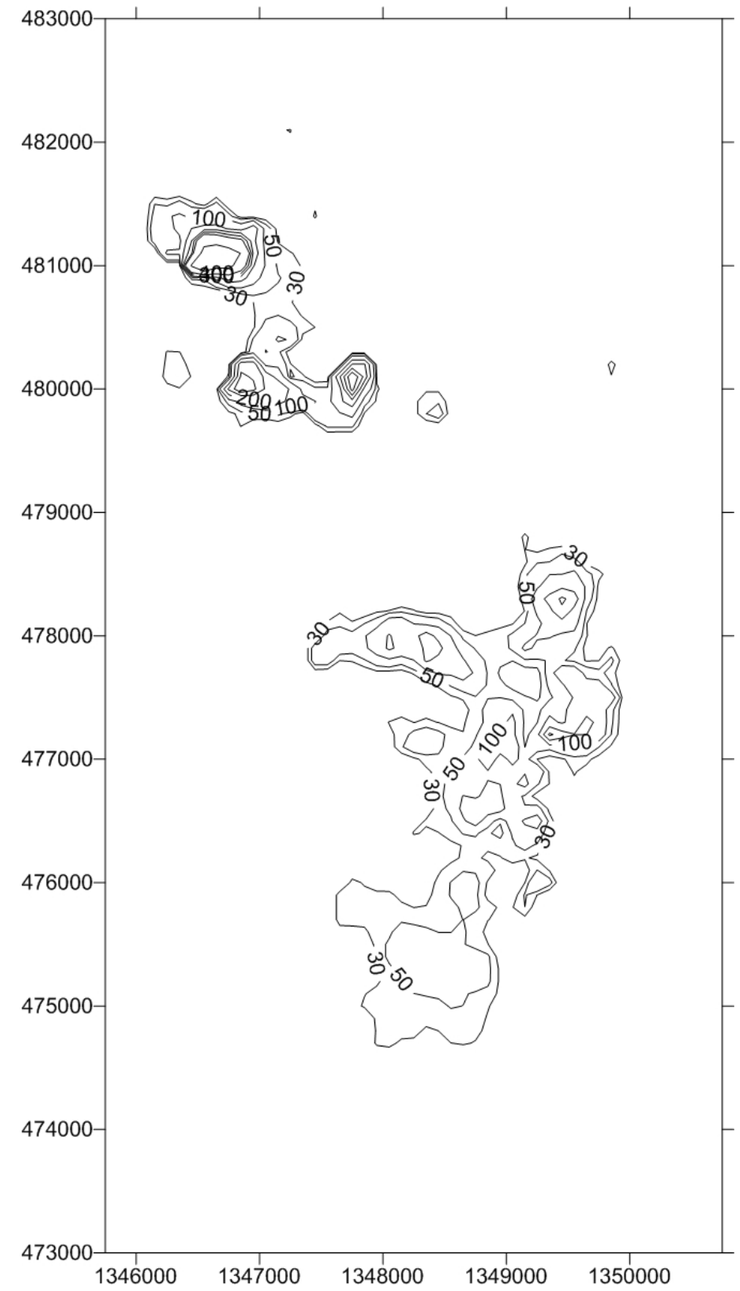
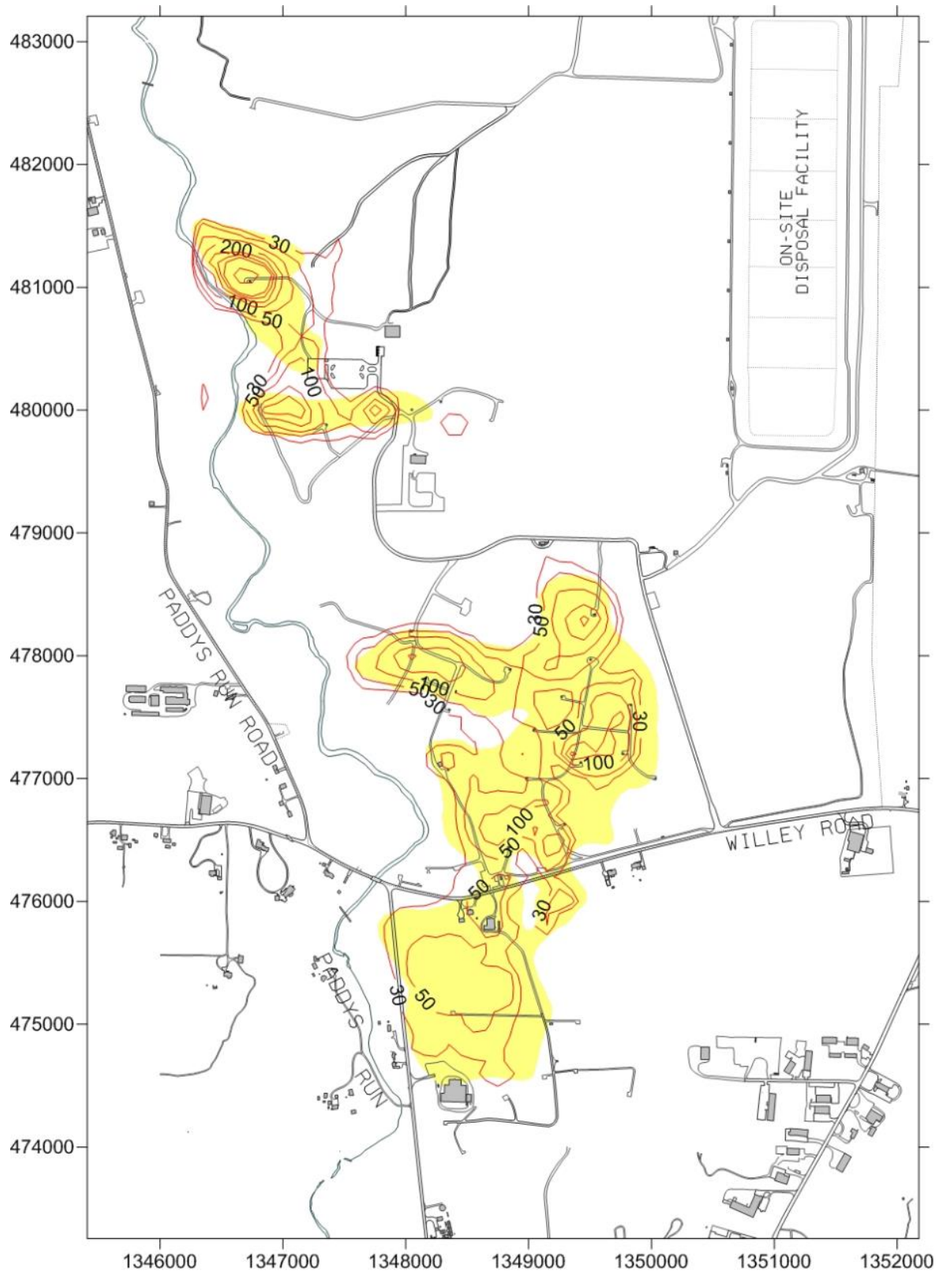


Figure A-12. Maximum Uranium Concentration Contours, Model Layers 7–13 (with Pseudo Borings)

MVS Version 9.8, Horizontal Search Radius = 7,331 feet

MVS Version 7.9.1, Horizontal Search Radius = 300 feet



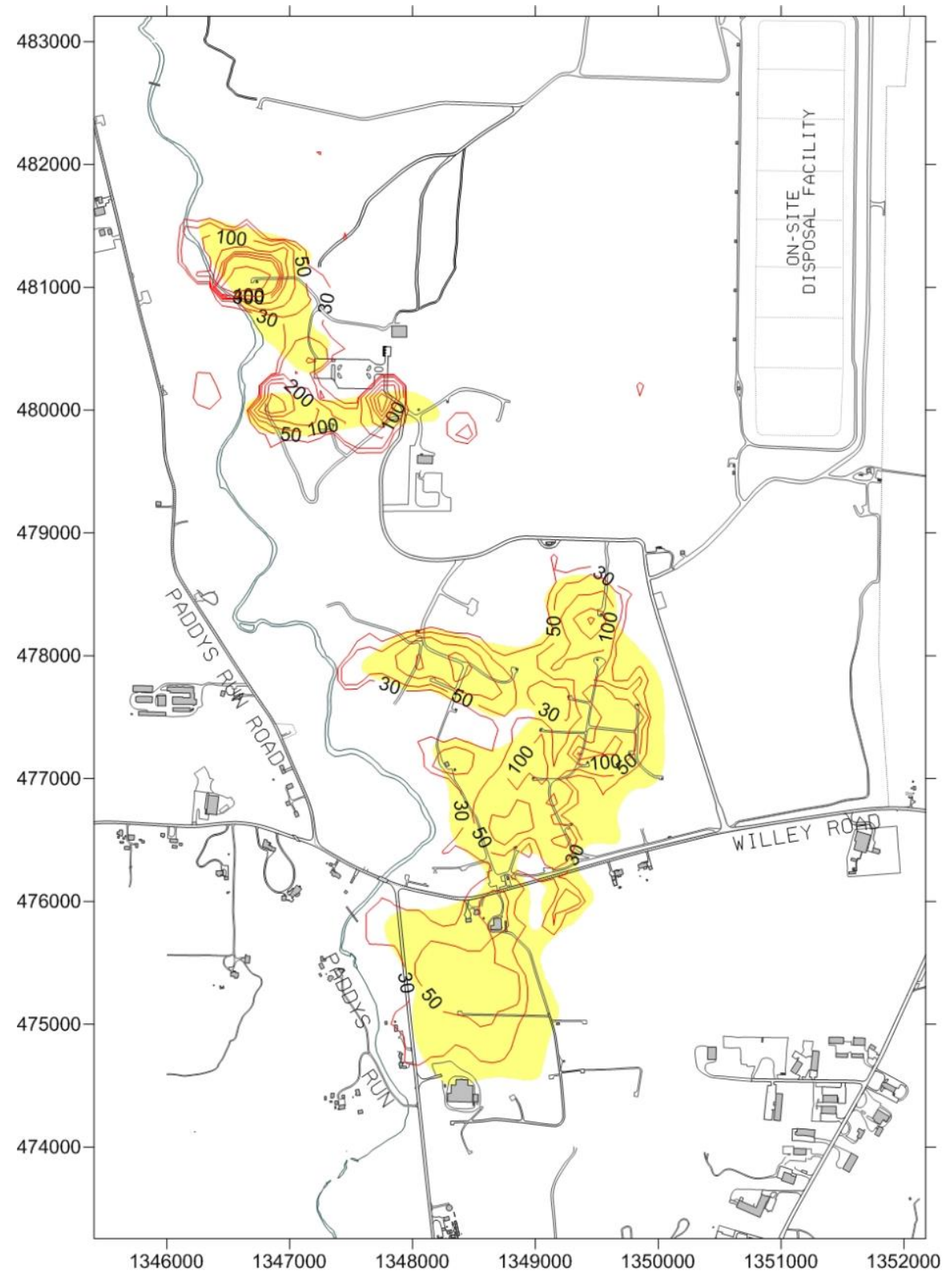


Figure A-13. Initial Uranium Concentration Contours

Kriged using MVS Version 9.8
Horizontal Search Radius = 7,331 feet. Model Layers 7–13 (Red Contours)
Compared to the 2011 Max. Uranium Footprint (Yellow)

Kriged using MVS Version 7.9.1
Horizontal Search Radius = 300 feet. Model Layers 7–13 (Red Contours)
Compared to the 2011 Max. Uranium Footprint (Yellow)

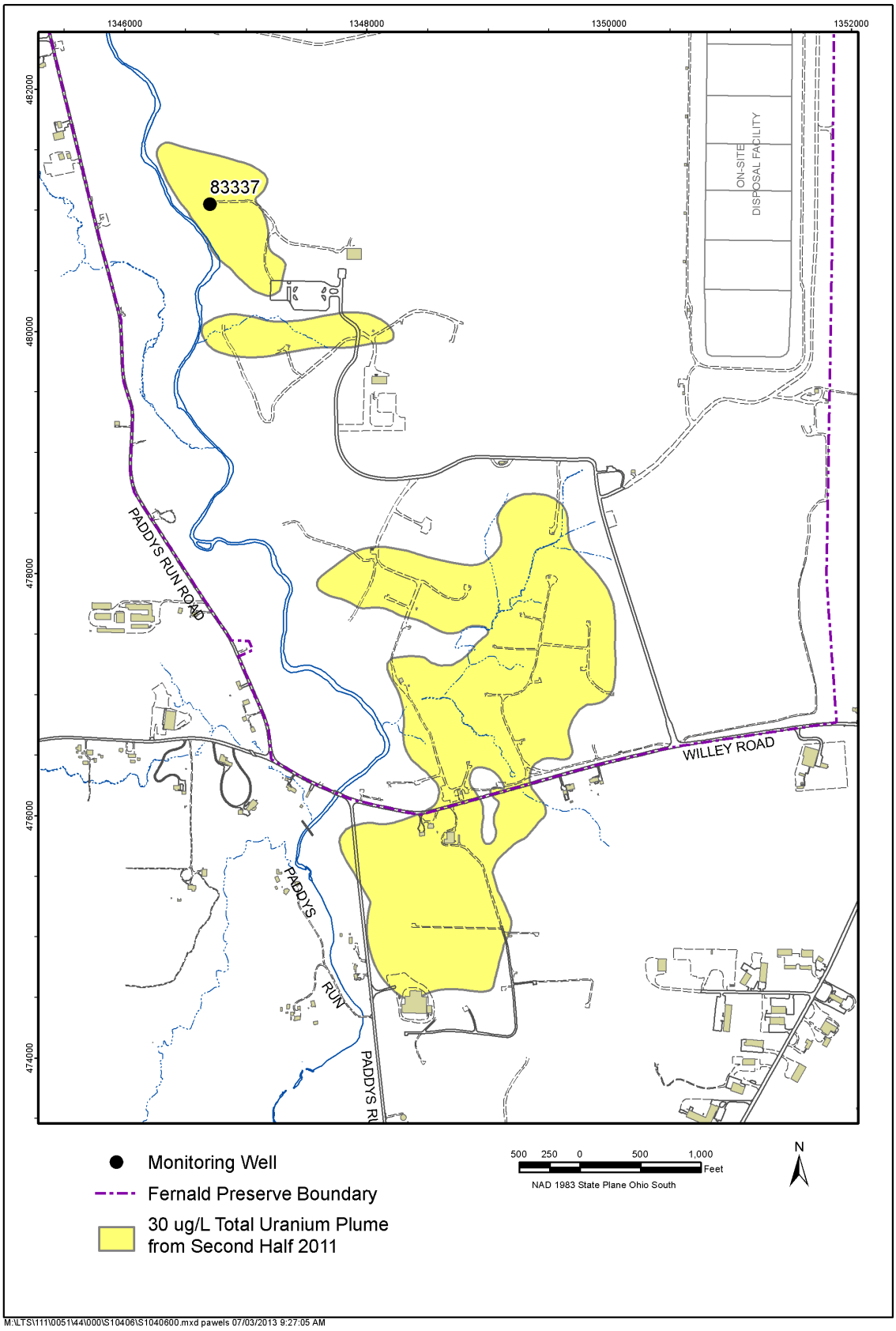


Figure A-14. Location of Monitoring Well 83337

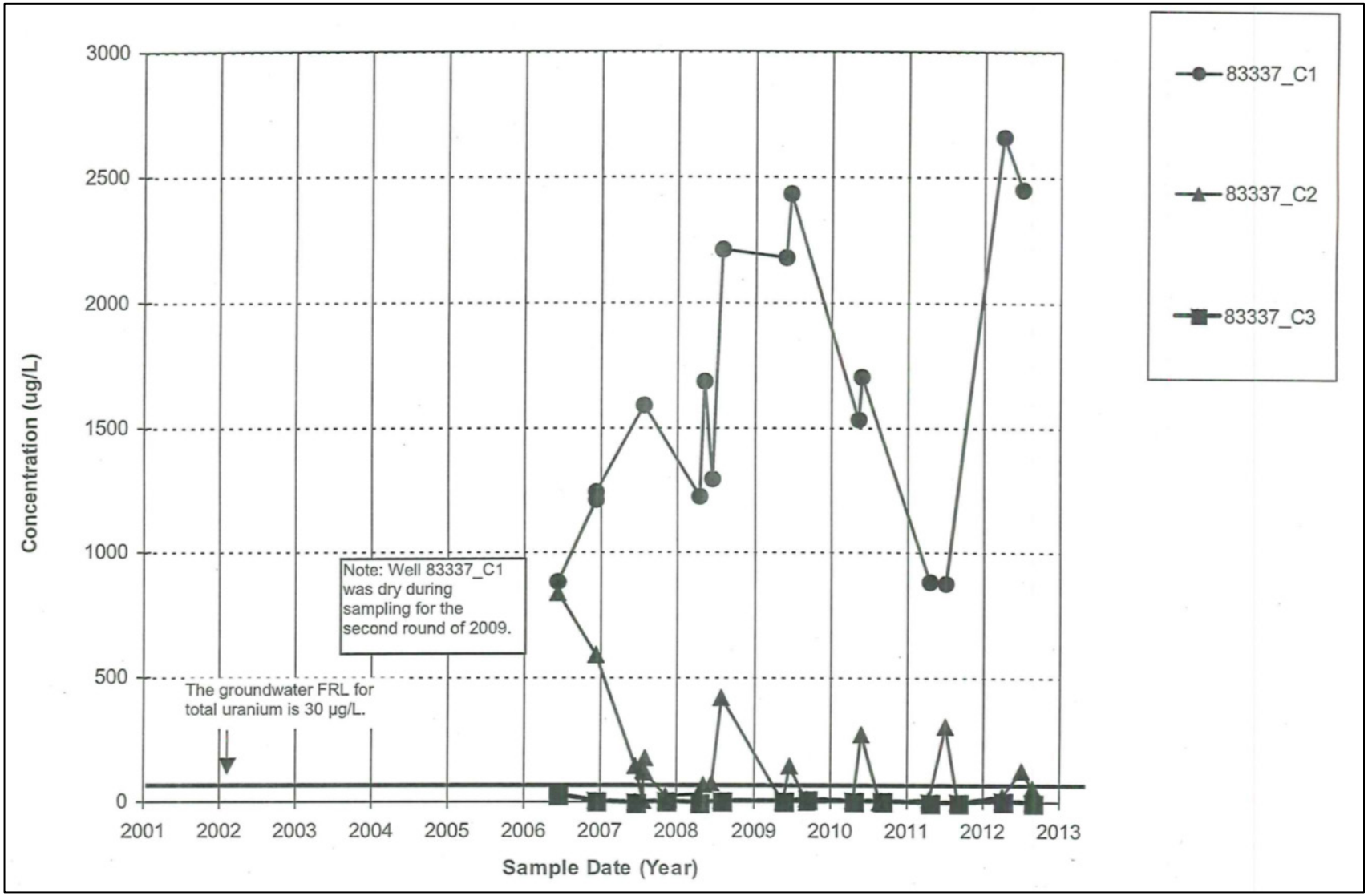


Figure A-15. Total Uranium Concentration vs. Time Plot for Monitoring Well 83337

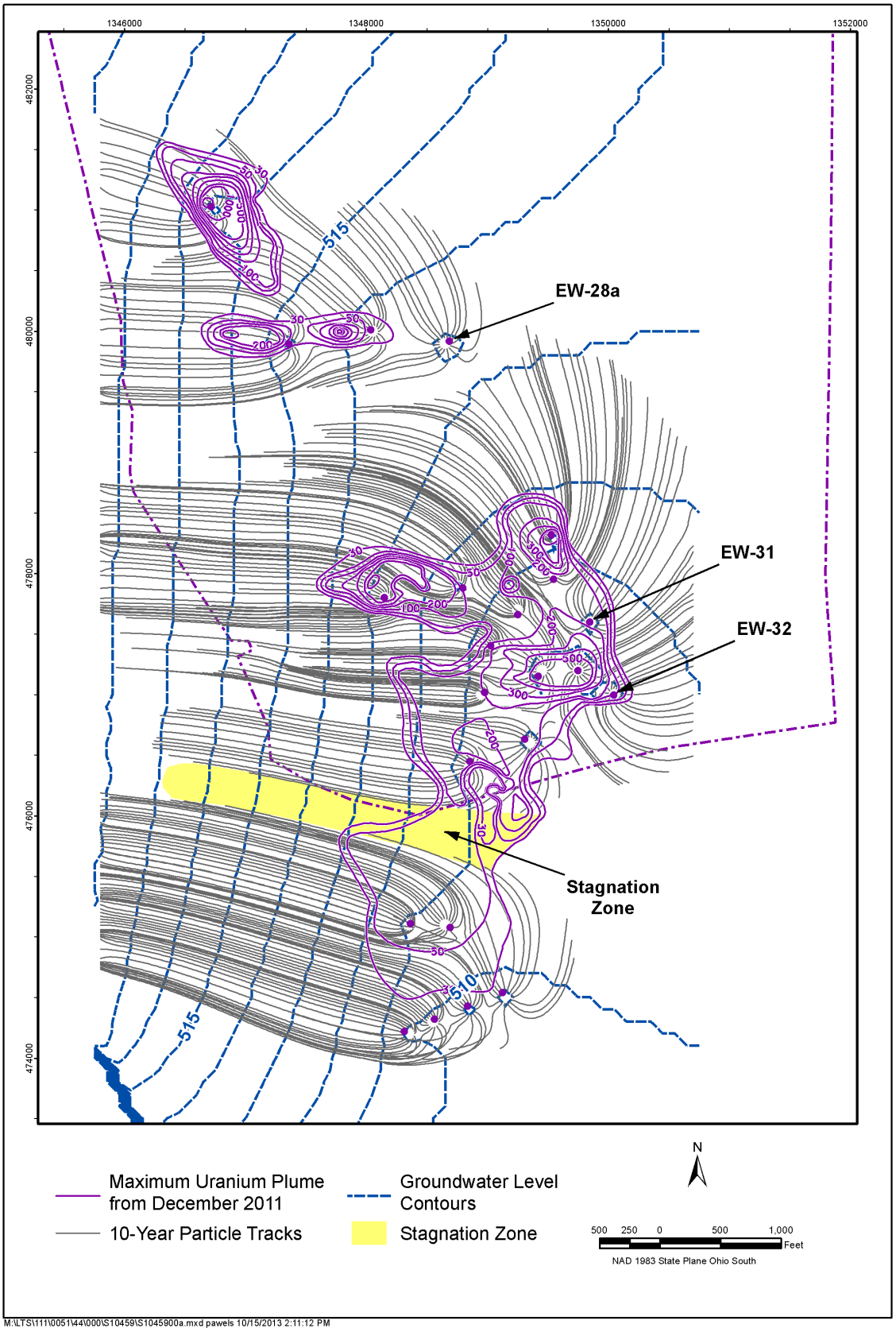


Figure A-16. Particle Track Map, WSA Phase II Design, 10-Year Tracks, Uranium Concentration Contours from December 2011

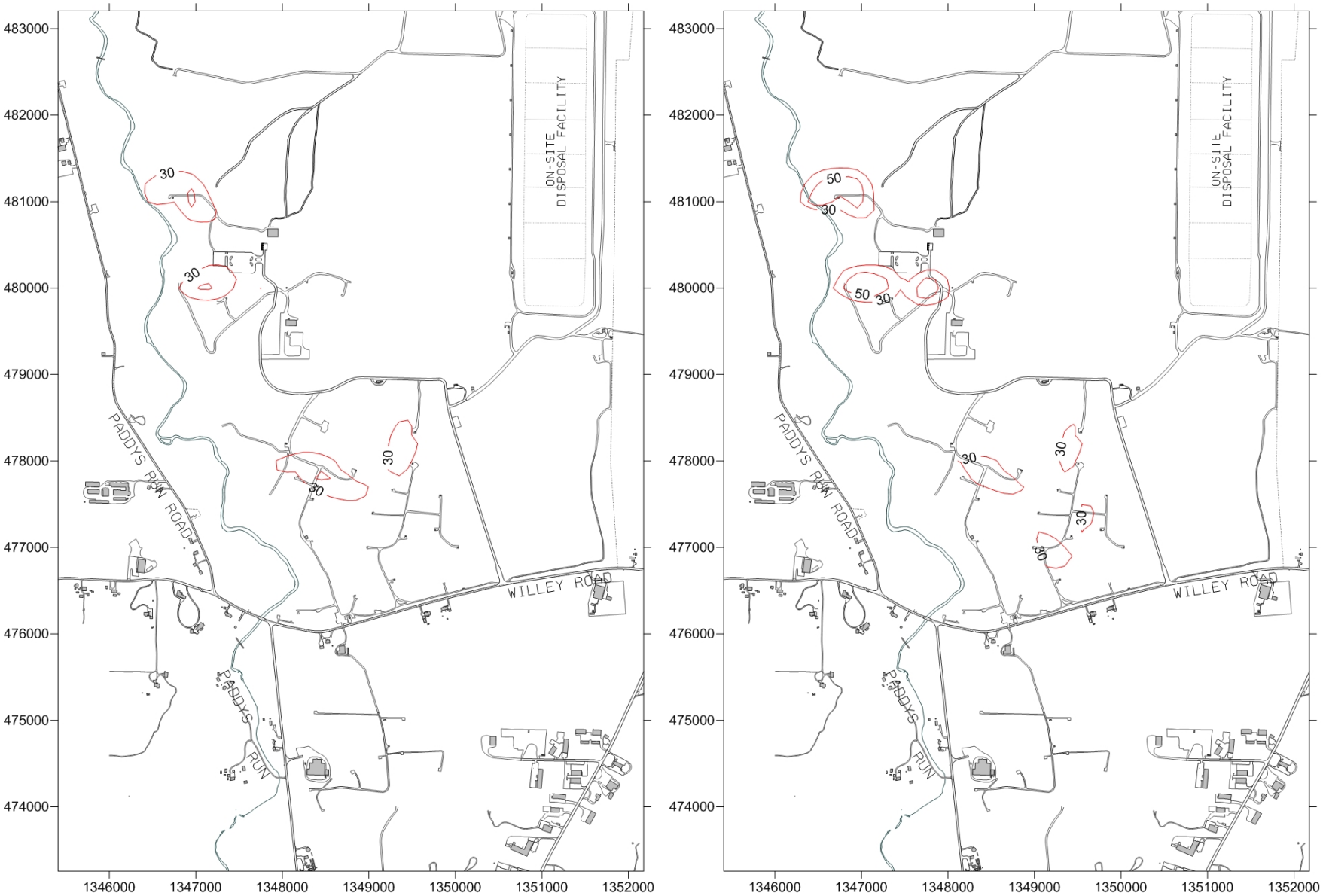


Figure A-17. Maximum Uranium Concentration Contours, Baseline Alternative, Model Layers 7–12, Dry Boundary Conditions

MVS 9.8, April 2020 *MVS 7.9.1, April 2019*

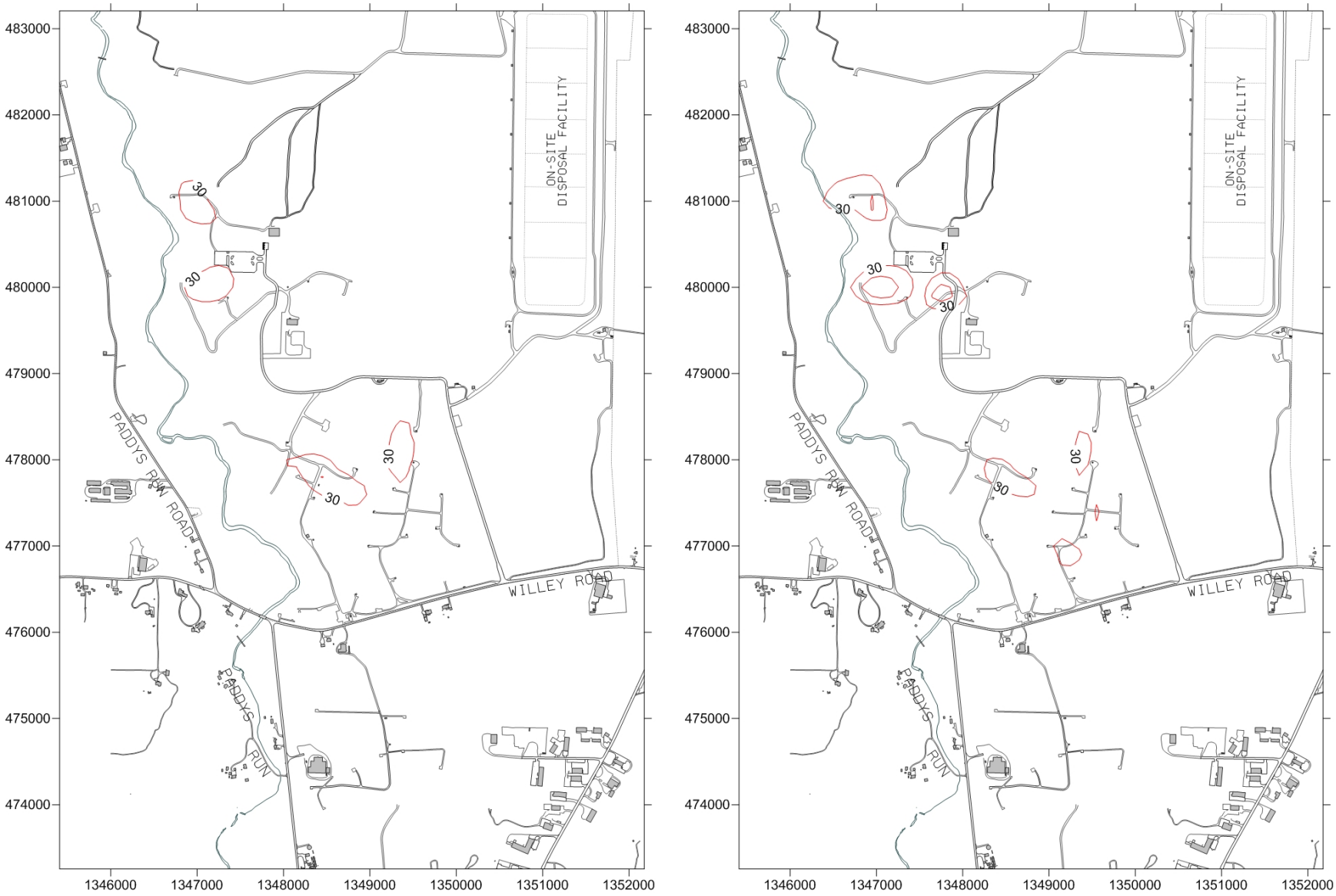


Figure A-18. Maximum Uranium Concentration Contours, Baseline Alternative, Model Layers 7–12, Nominal Boundary Conditions
MVS 9.8, April 2021 *MVS 7.9.1 April 2020*

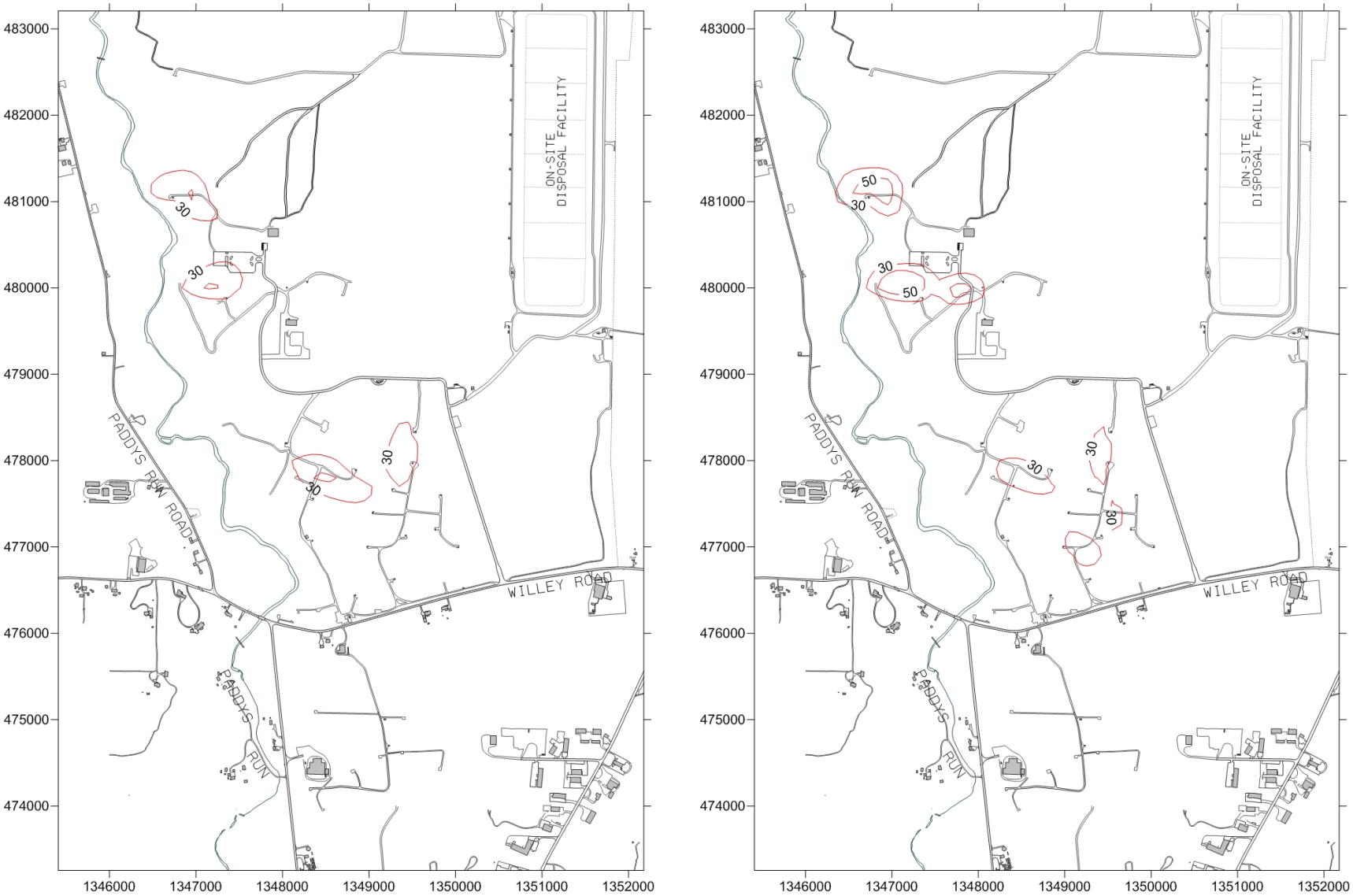


Figure A-19. Maximum Uranium Concentration Contours, Baseline Alternative, Model Layers 7–12, Wet Boundary Conditions
MVS 9.8, April 2020 *MVS 7.9.1 April 2019*

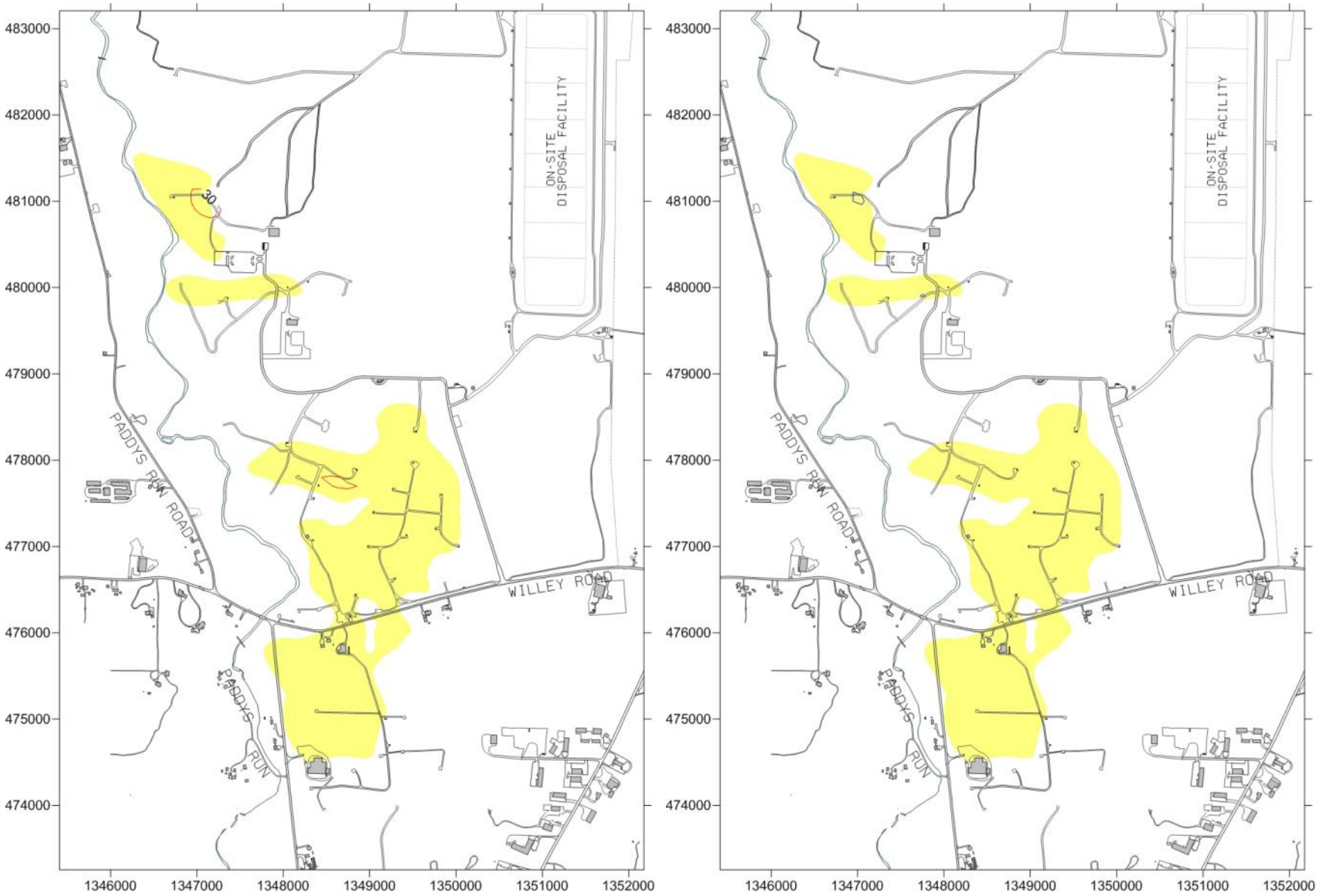


Figure A-20. Maximum Uranium Concentration Contours, Baseline Alternative, Model Layers 7–12, April 2026

MVS 9.8, Wet Boundary Condition, (Yellow Shading is Plume in 2011) *MVS 7.9.1, Wet Boundary Condition (Yellow shading is plume in 2011)*

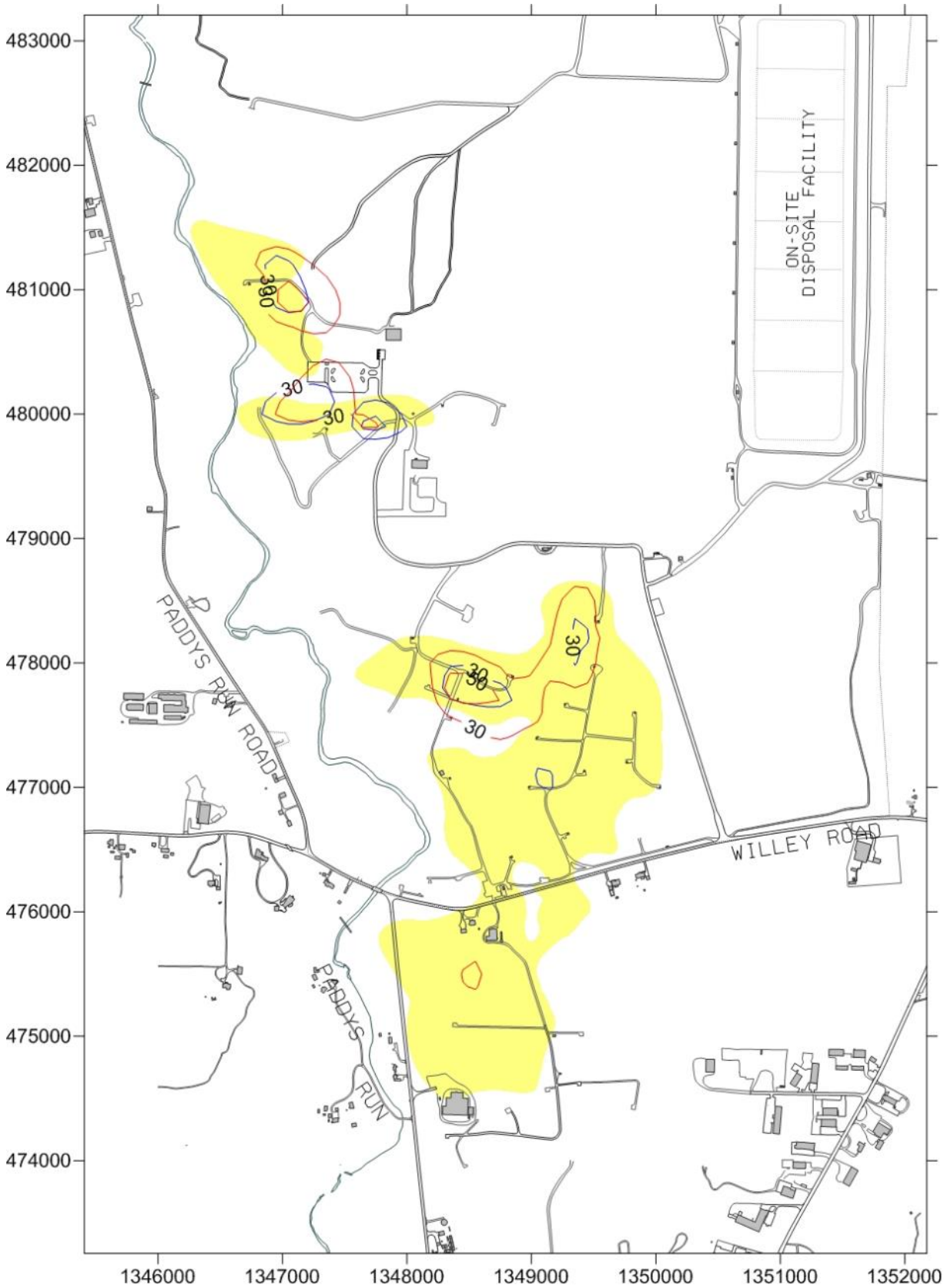


Figure A-21. Uranium Concentration Contours, Model Layer 13, April 2026
(Blue contours = 30 µg/L plume from MVS 7.9.1; Red contours = 30 µg/L plume from MVS 9.8)

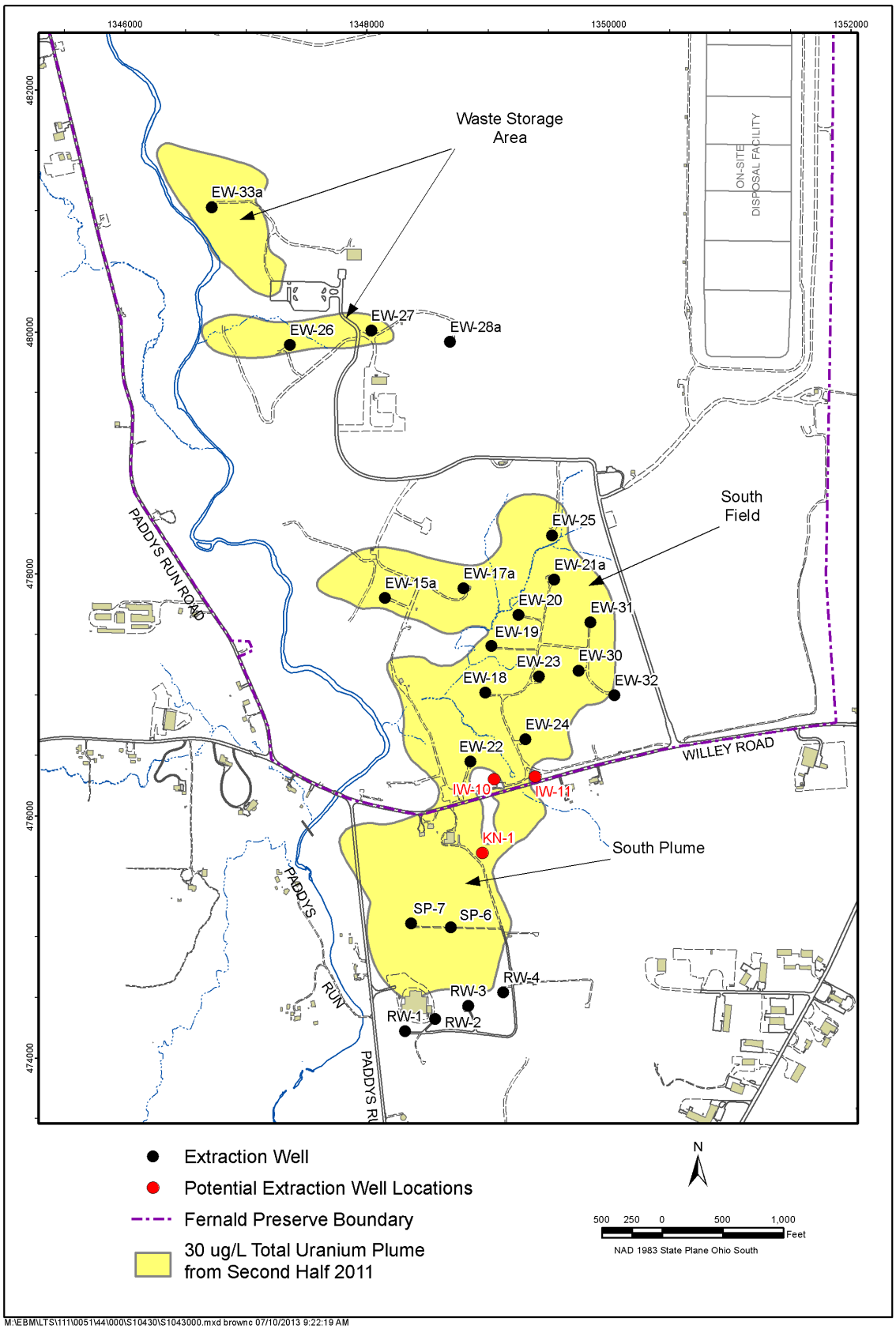


Figure A-22. Well Location Map for South Plume Alternatives

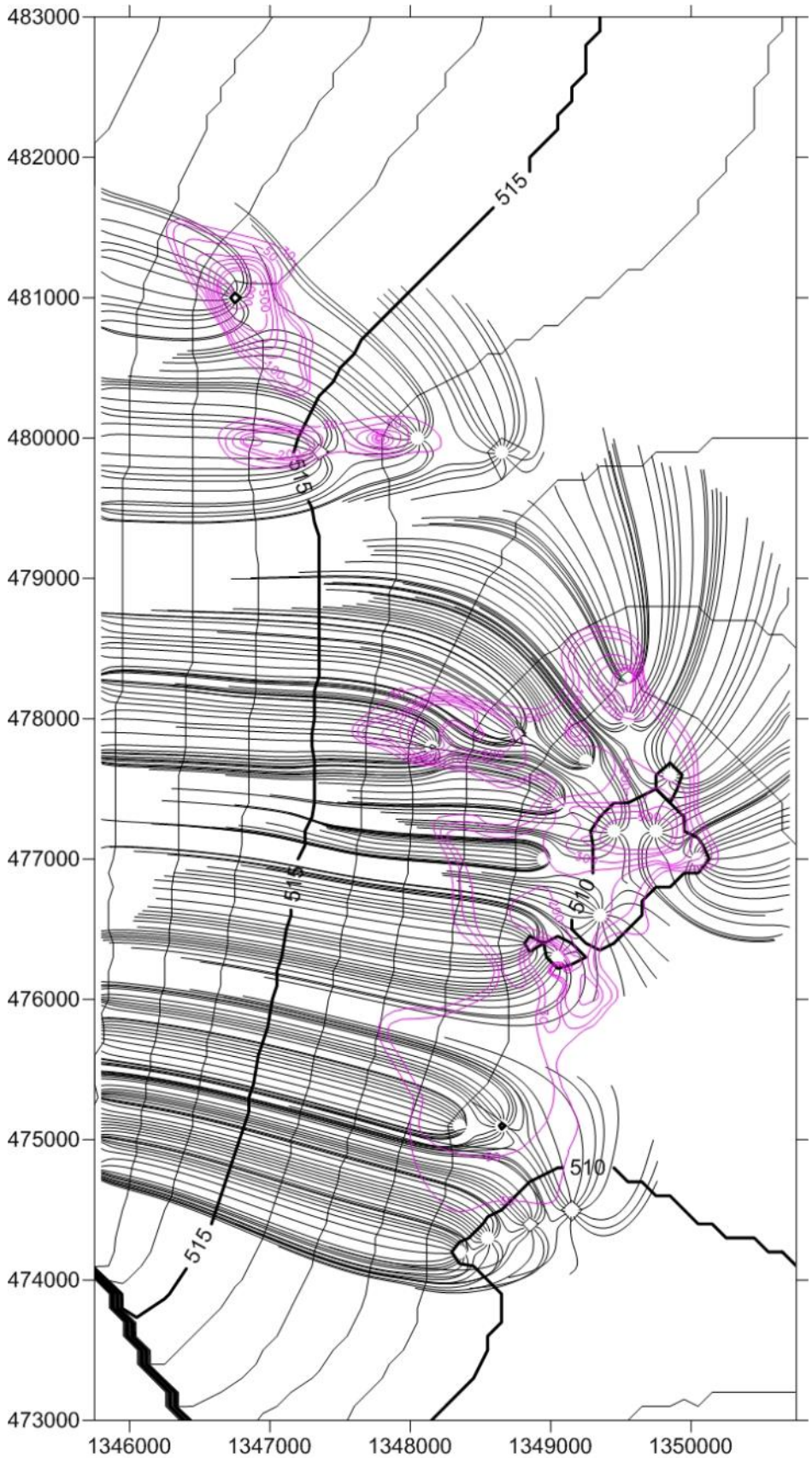


Figure A-23. Particle Track Map (IW-10, 200 gpm, Dry Boundary Conditions)

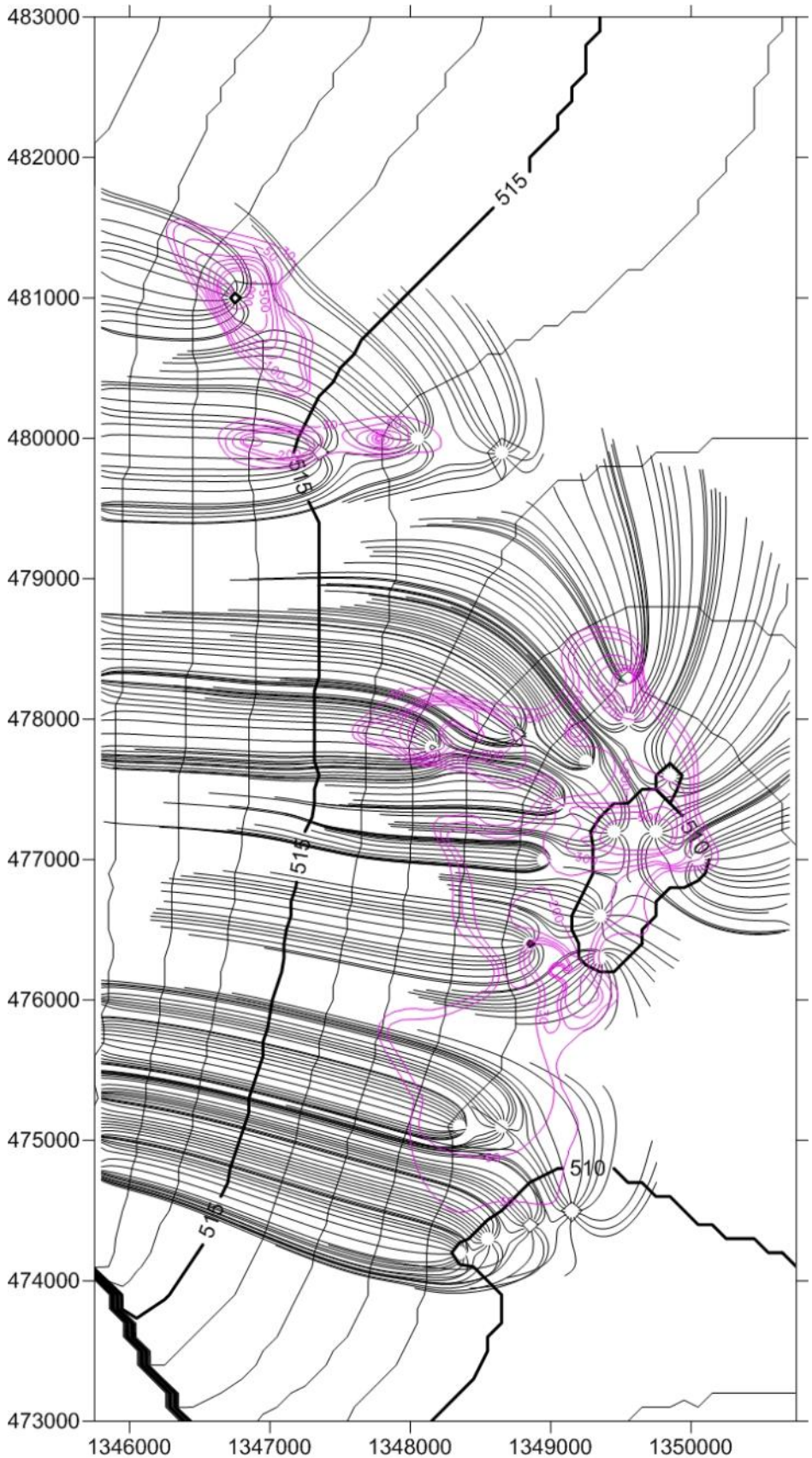


Figure A-24. Particle Track Map (IW-11, 200 gpm, Dry Boundary Conditions)

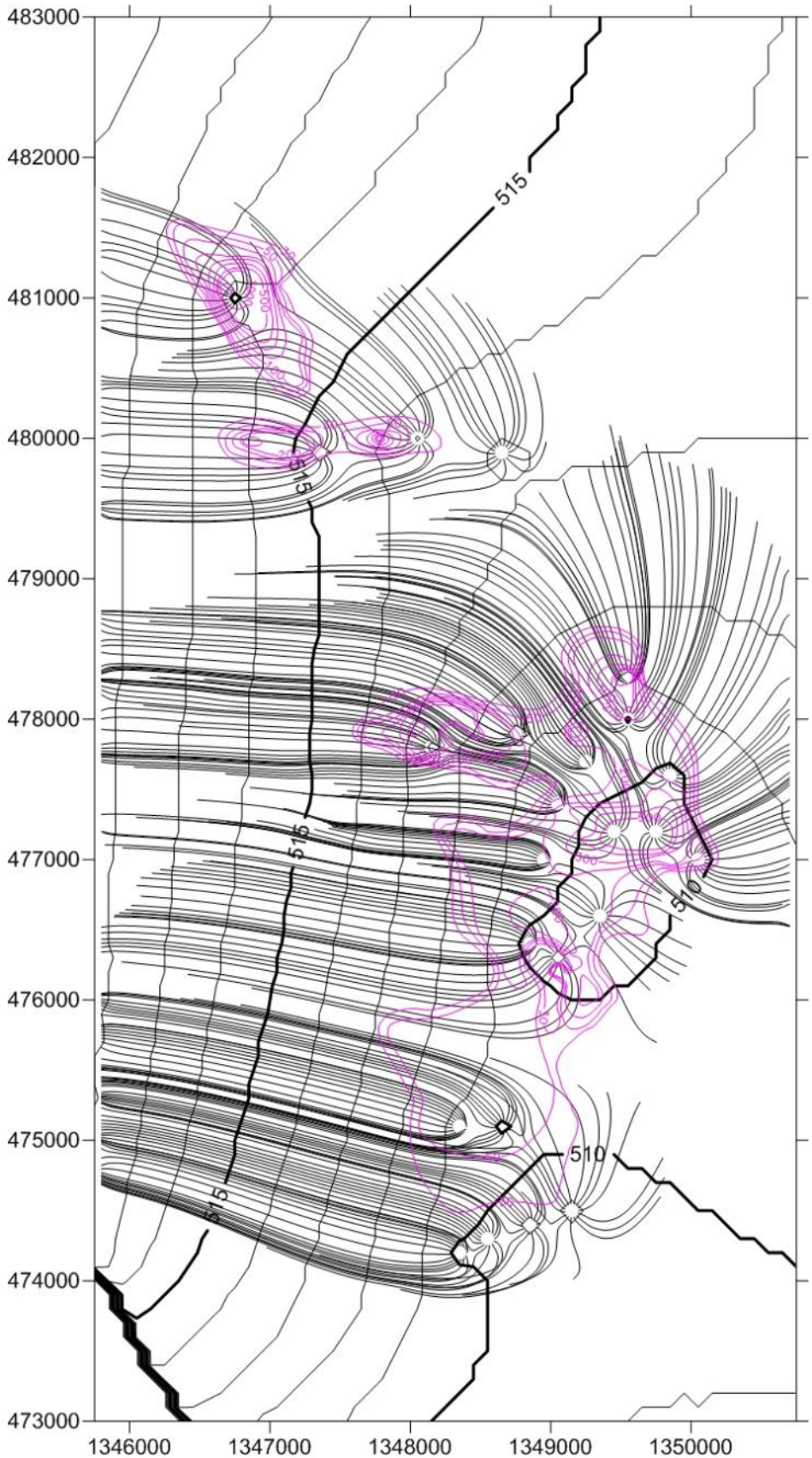


Figure A-25. Particle Track Map (IW-10, 400 gpm, Dry Boundary Conditions)

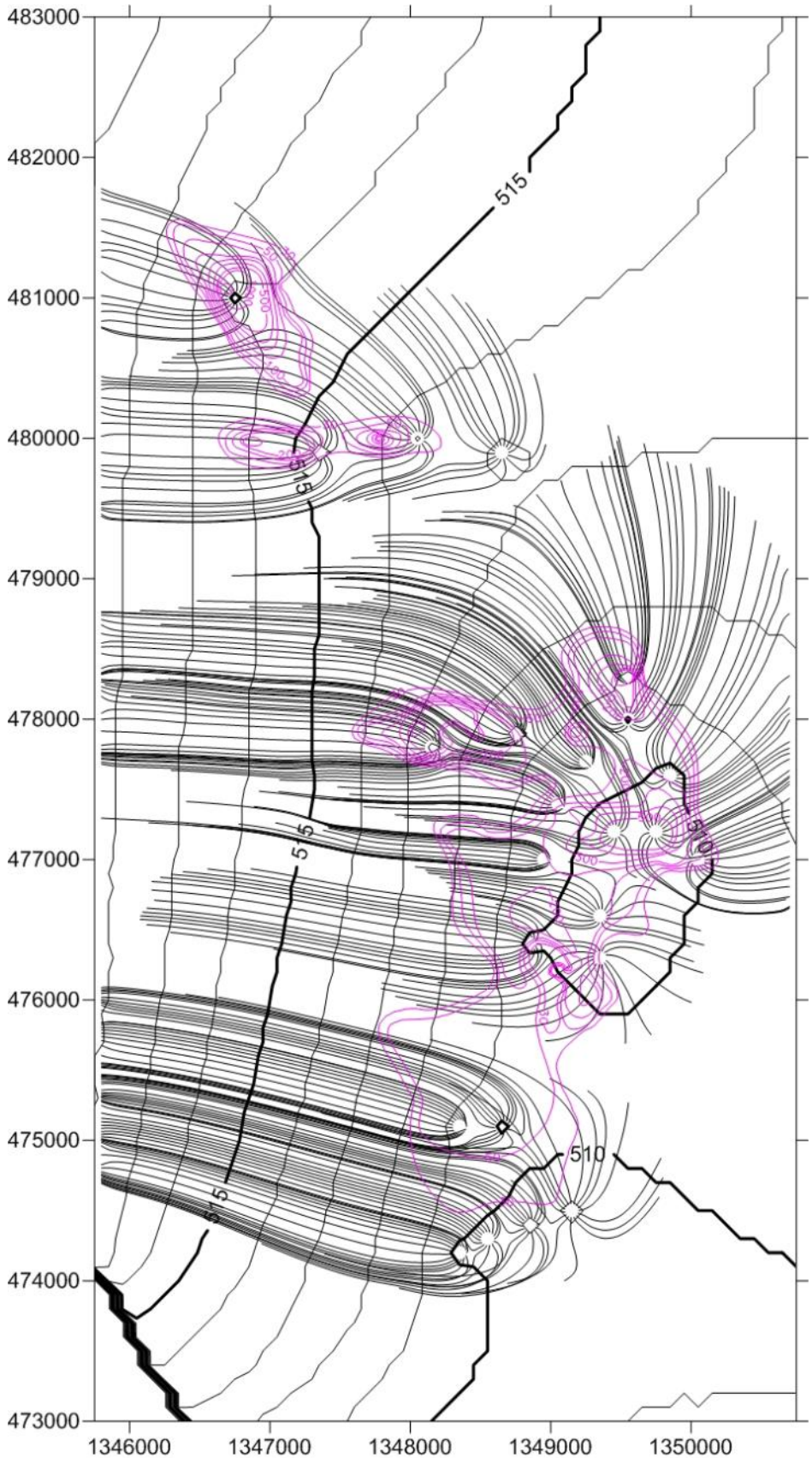


Figure A-26. Particle Track Map (IW-11, 400 gpm, Dry Boundary Conditions)

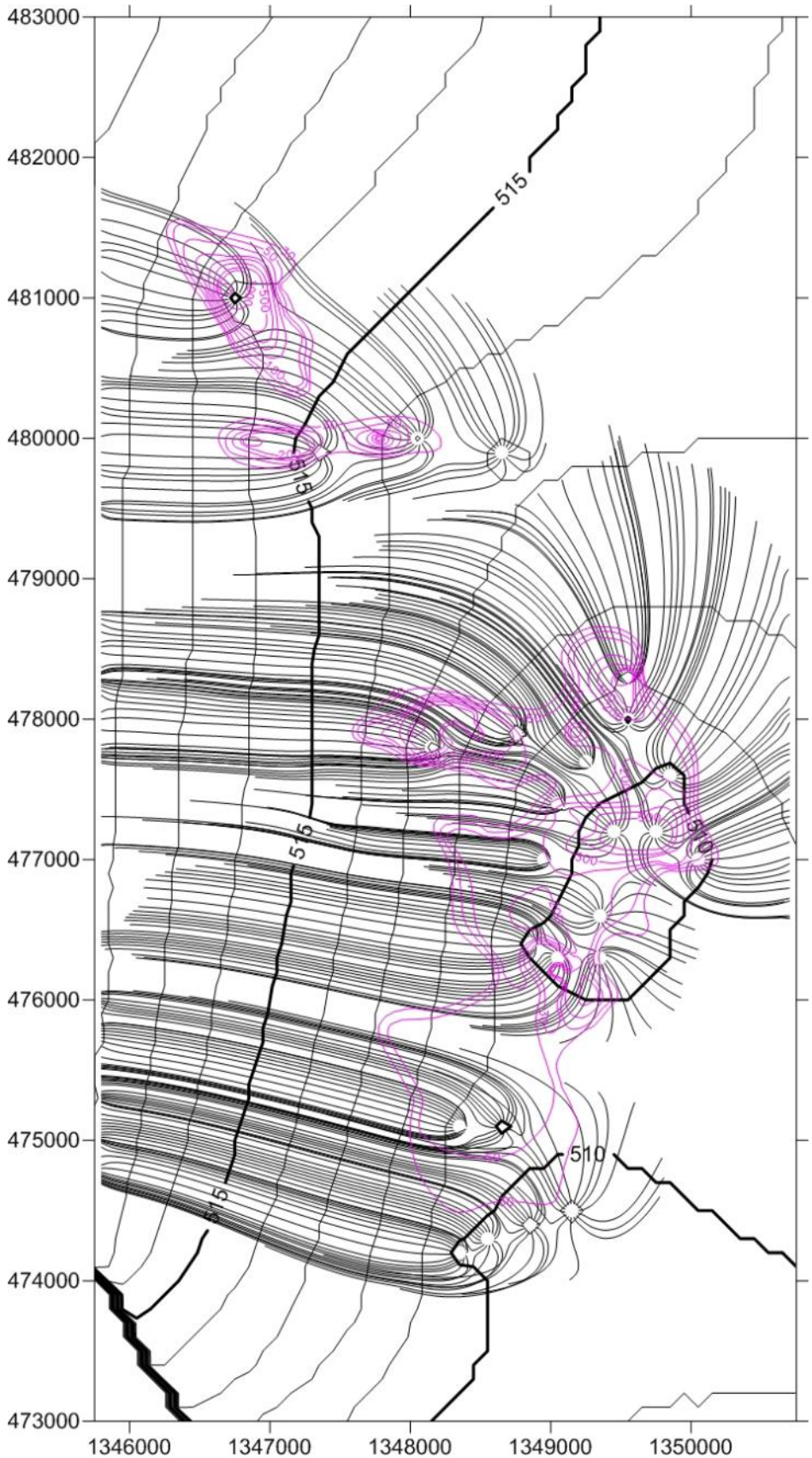


Figure A-27. Particle Track Map (IW-10 and IW-11, 200 gpm, Dry Boundary Conditions)

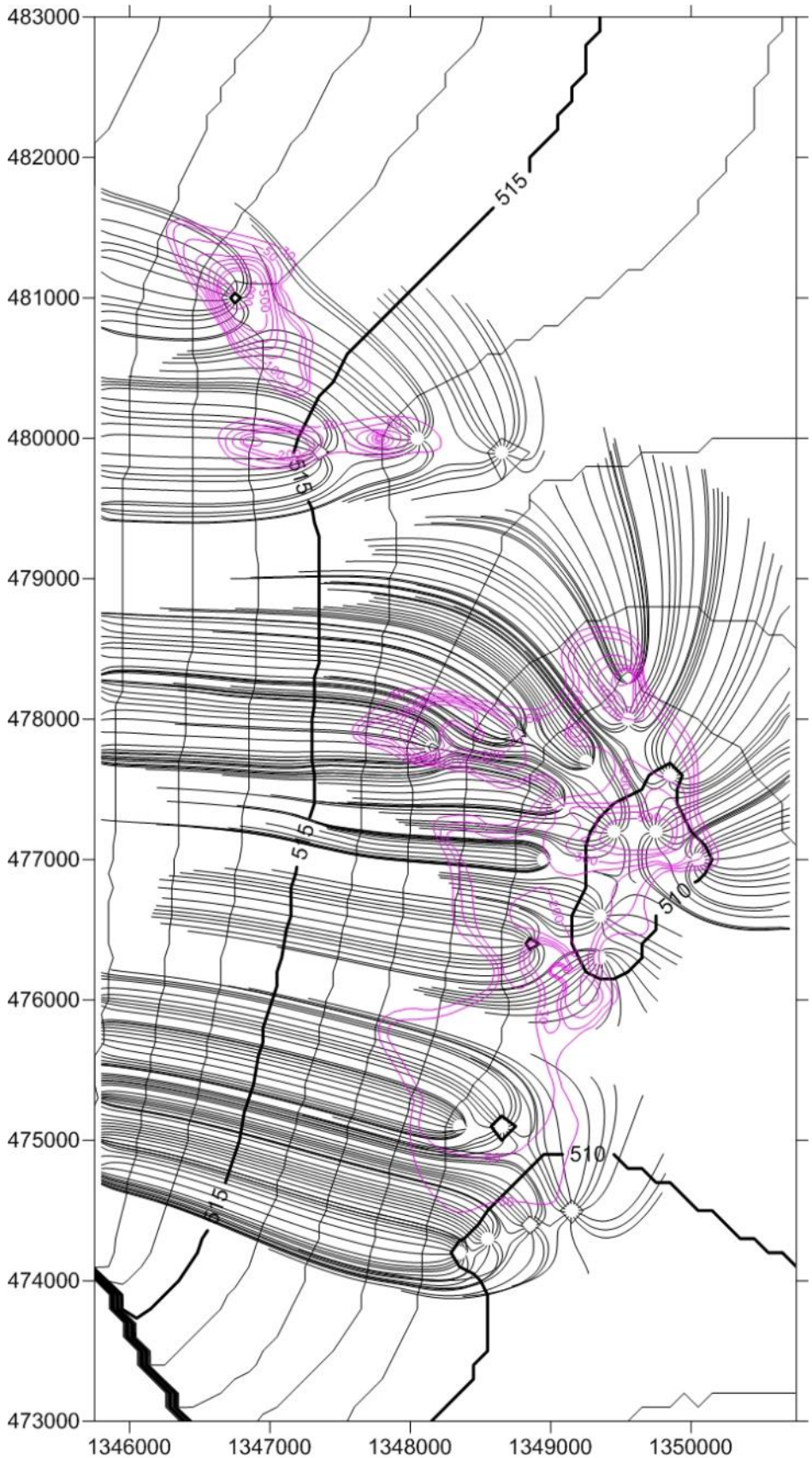


Figure A-28. Particle Track Map (IW-11 at 200 gpm, SP-6 at 300 gpm, Dry Boundary Conditions)

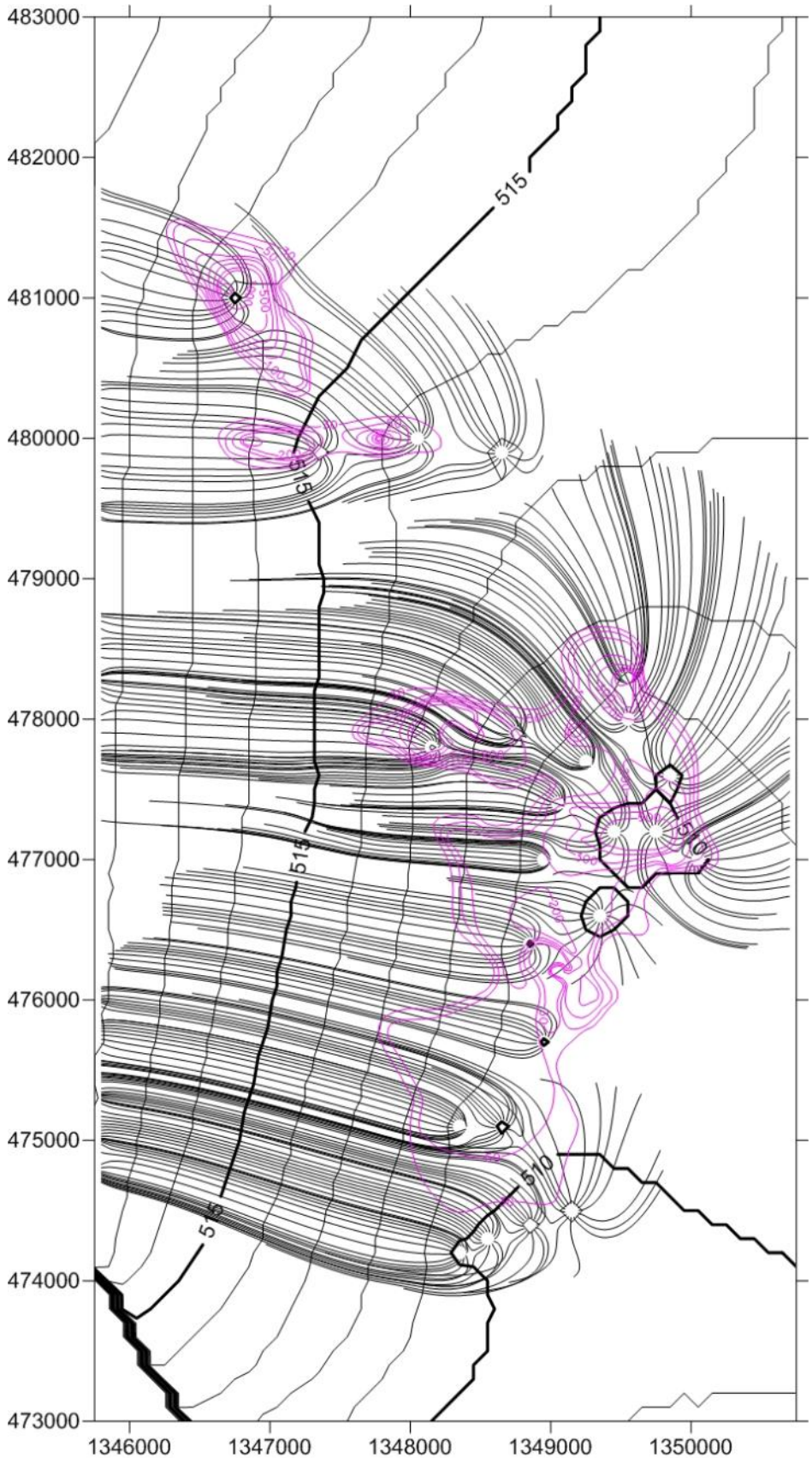


Figure A-29. Particle Track Map (KN-1, 200 gpm, Dry Boundary Conditions)

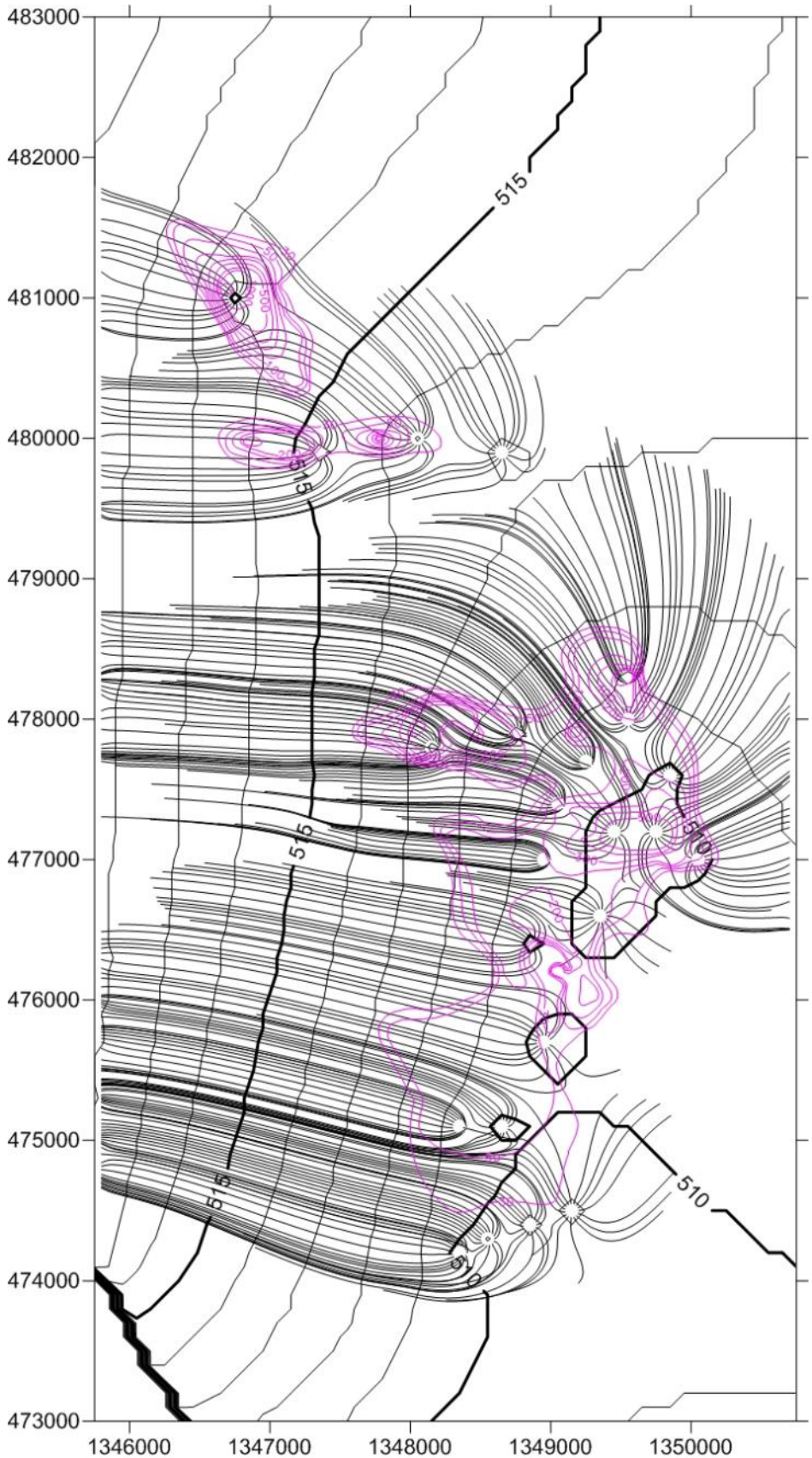


Figure A-30. Particle Track Map (KN-1, 400 gpm, Dry Boundary Conditions)

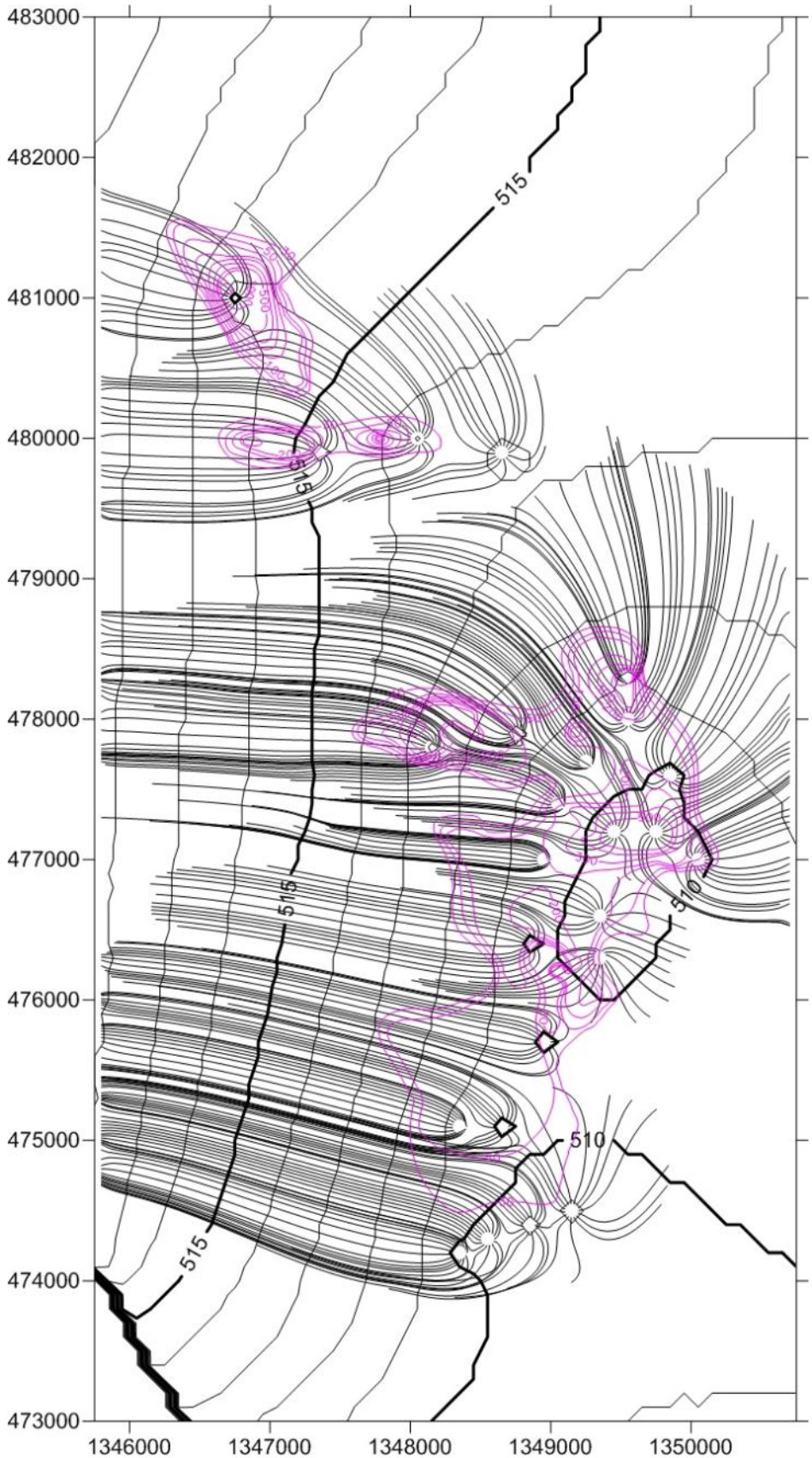


Figure A-31. Particle Track Map (IW-11 and KN-1 at 200 gpm, Dry Boundary Conditions)

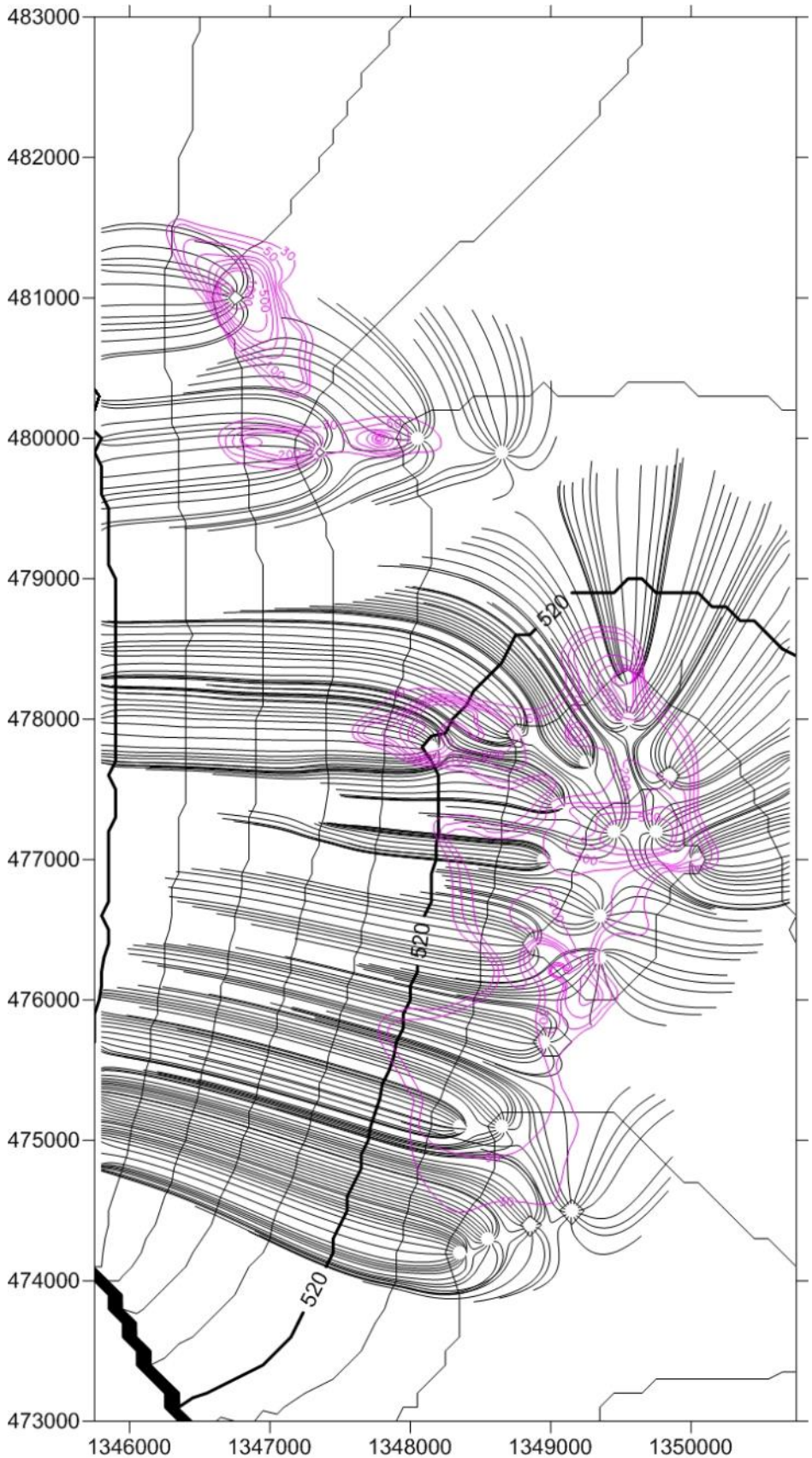


Figure A-32. Particle Track Map (IW-11 and KN-1 at 200 gpm, Wet Boundary Conditions)

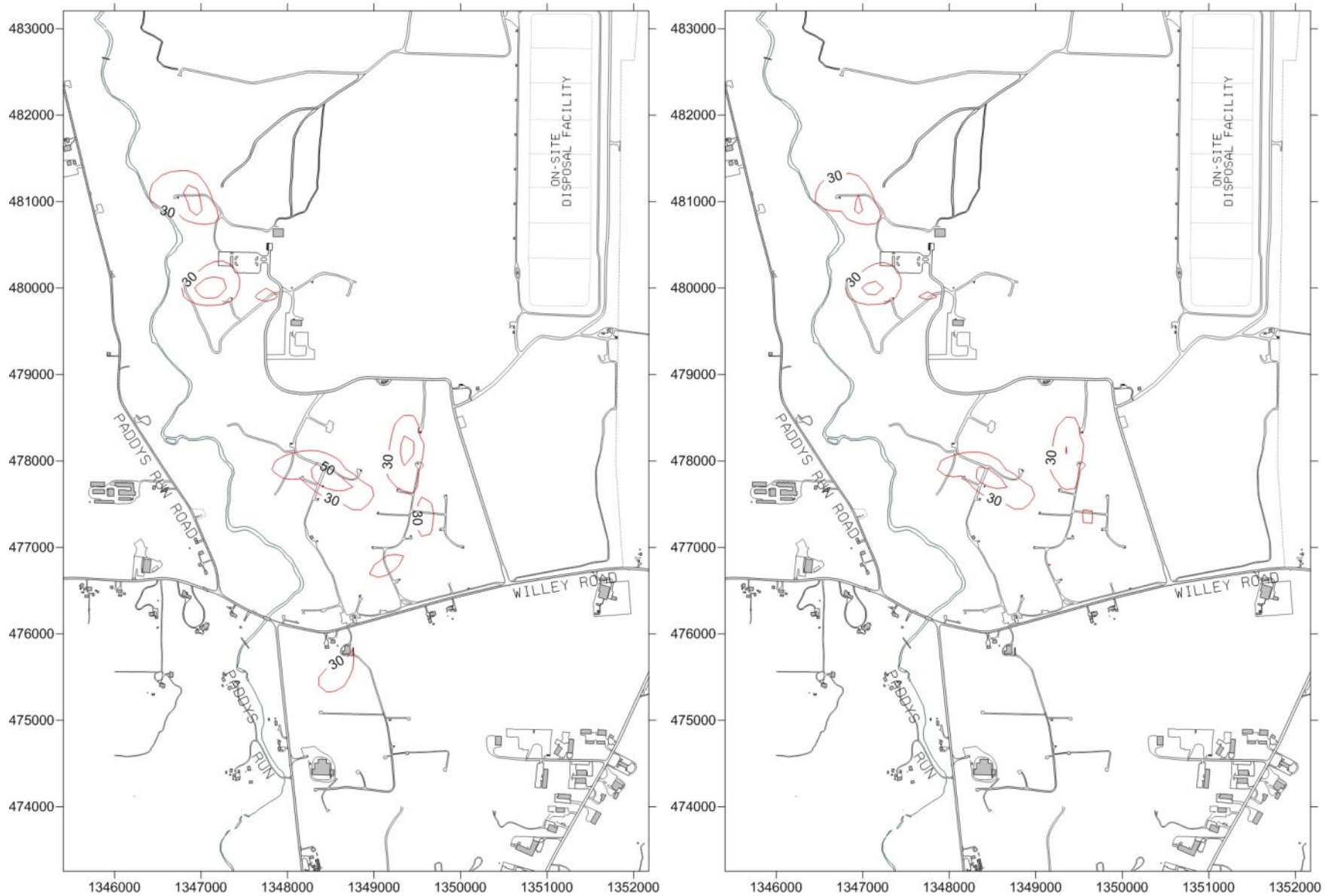


Figure A-33. Maximum Uranium Concentration Contours, South Plume Alternative 1, Model Layer 12

April 2018, Nominal Boundary Conditions *April 2019, Nominal Boundary Conditions*

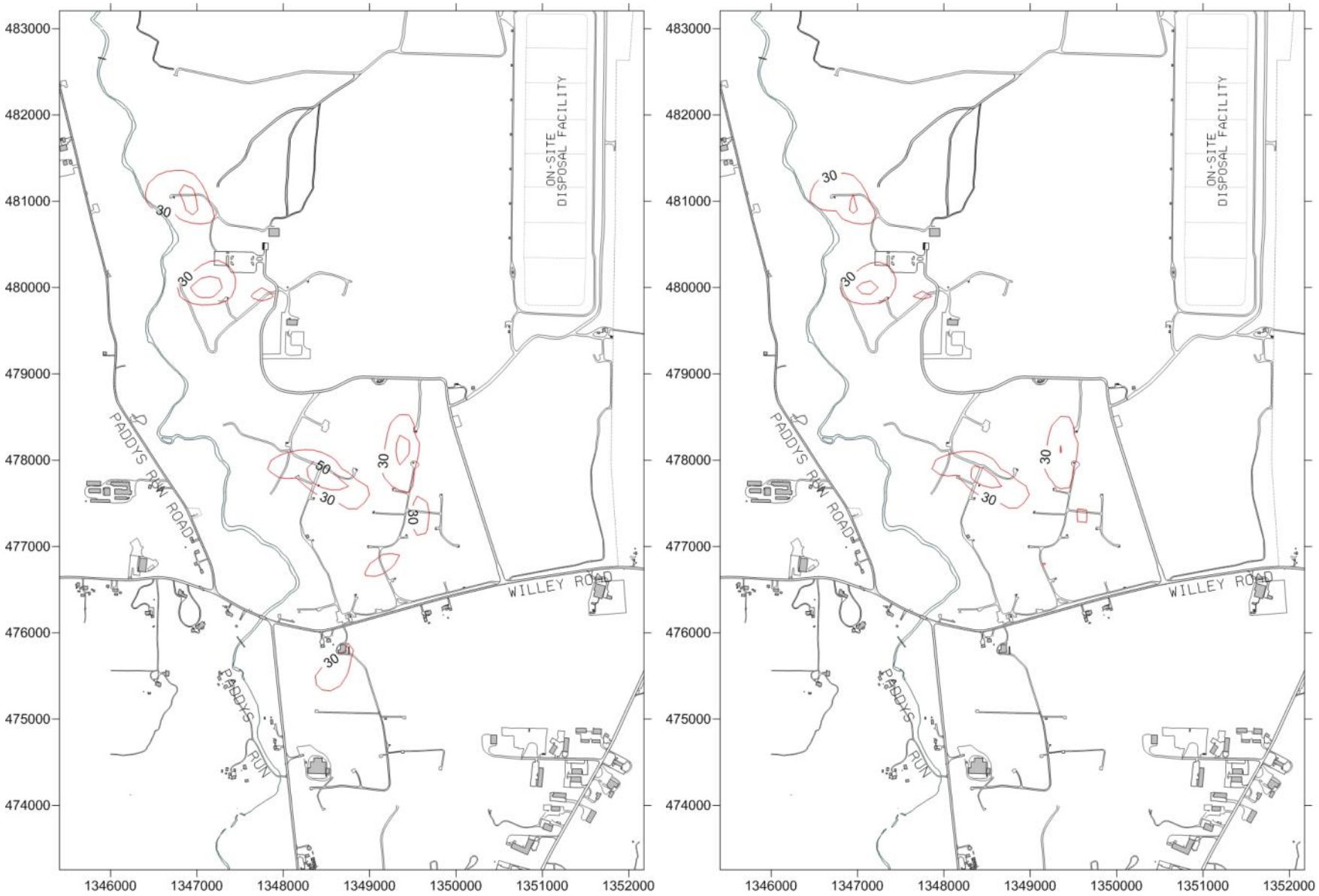


Figure A-34. Maximum Uranium Concentration Contours, South Plume Alternative 2, Model Layer 12

April 2018, Nominal Boundary Conditions *April 2019, Nominal Boundary Conditions*

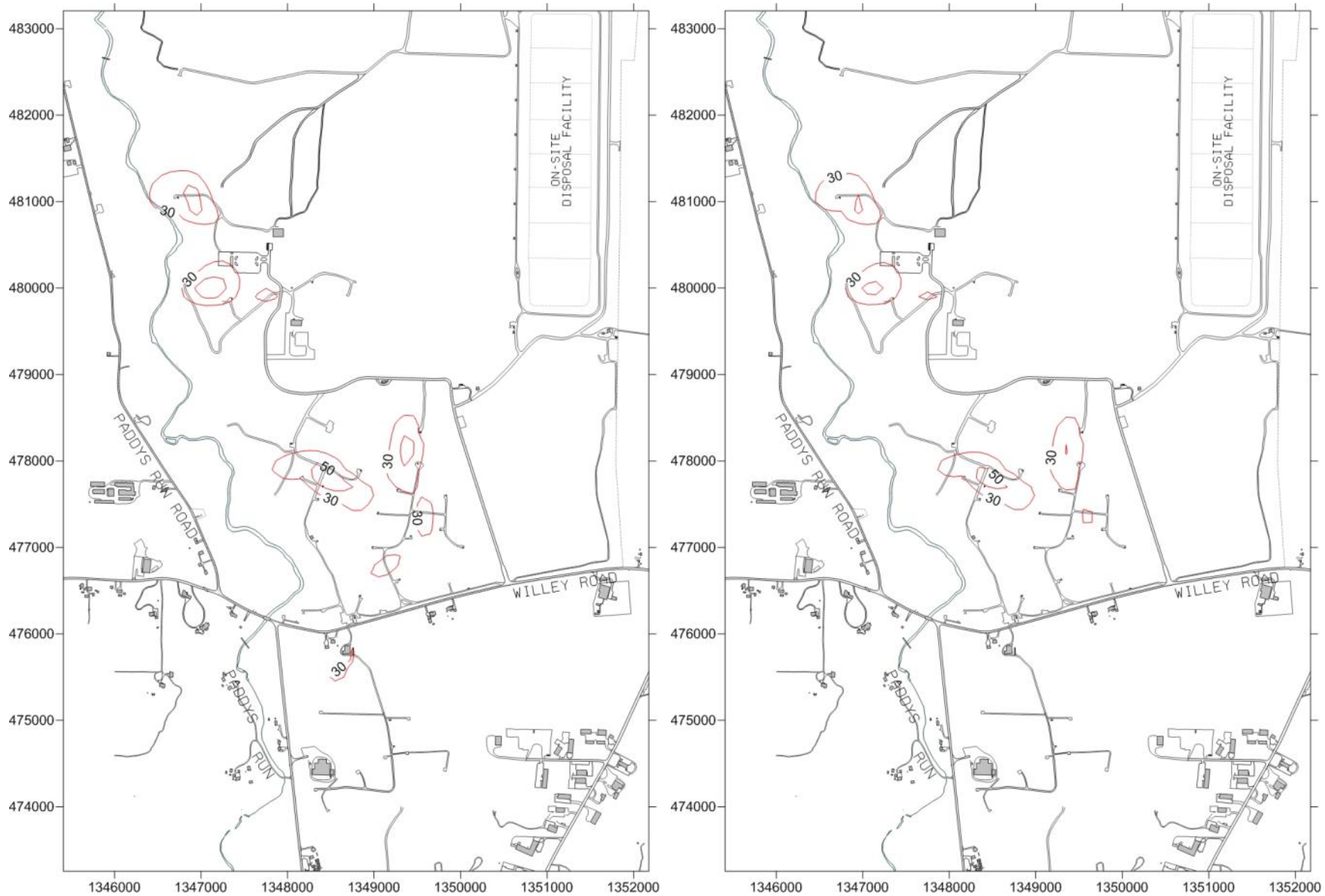


Figure A-35. Maximum Uranium Concentration Contours, South Plume Alternative 3, Model Layer 12

April 2018, Nominal Boundary Conditions *April 2019, Nominal Boundary Conditions*

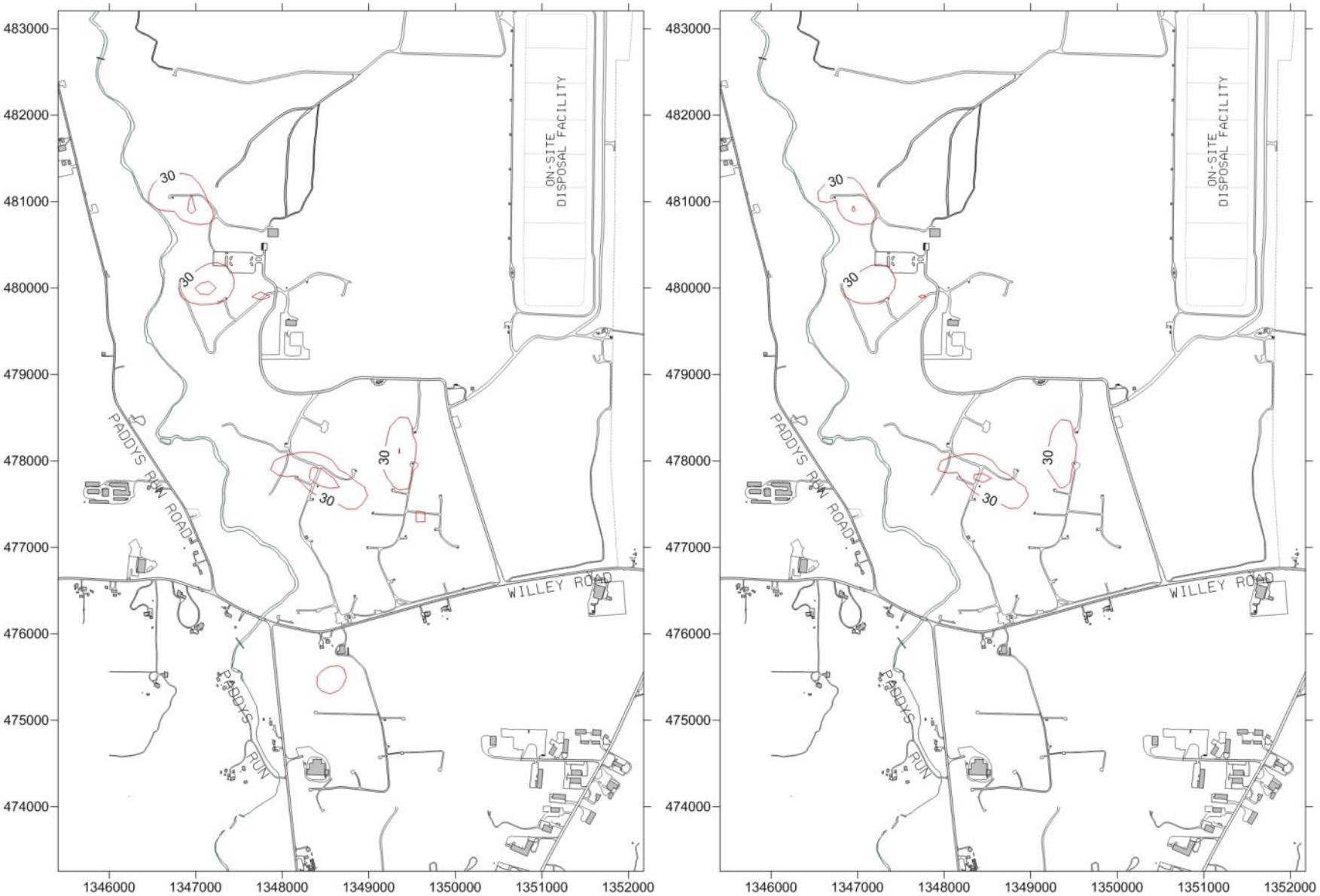


Figure A-36. Maximum Uranium Concentration Contours, South Plume Alternative 4, Model Layer 12

April 2019, Nominal Boundary Conditions *April 2020, Nominal Boundary Conditions*

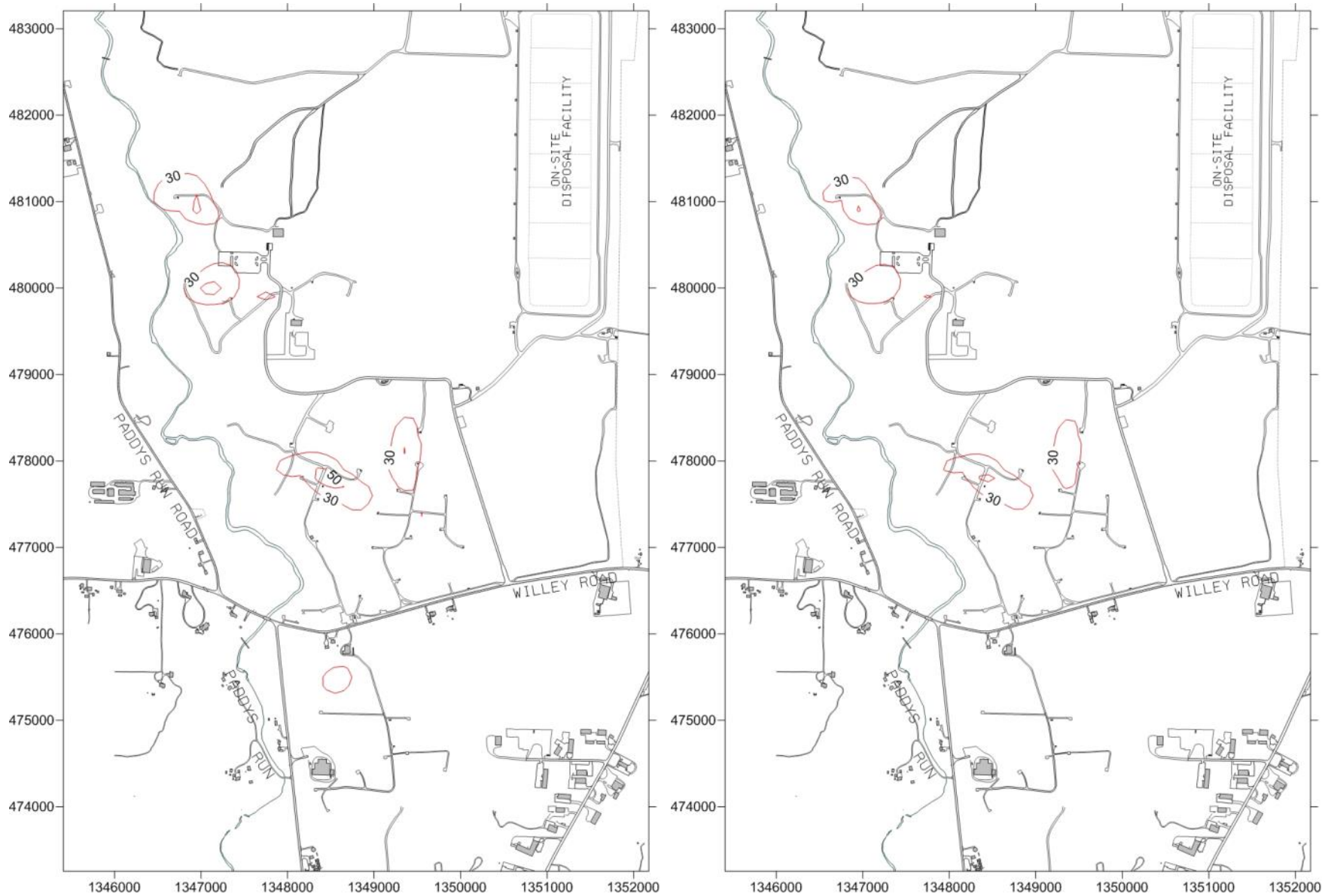


Figure A-37. Maximum Uranium Concentration Contours, South Plume Alternative 5, Model Layer 12

April 2019, Nominal Boundary Conditions *April 2020, Nominal Boundary Conditions*

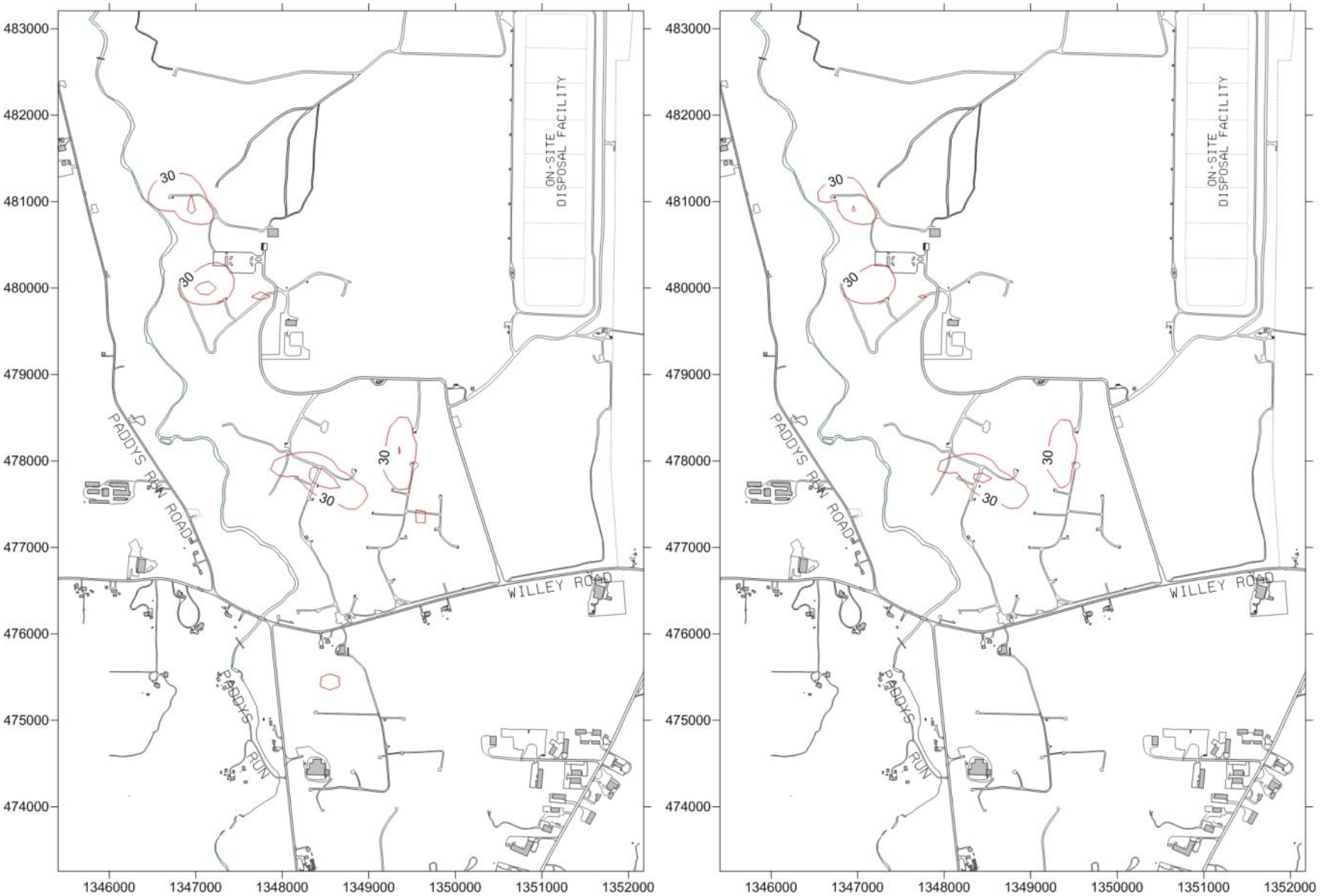


Figure A-38. Maximum Uranium Concentration Contours, South Plume Alternative 6, Model Layer 12

April 2019, Nominal Boundary Conditions *April 2020, Nominal Boundary Conditions*

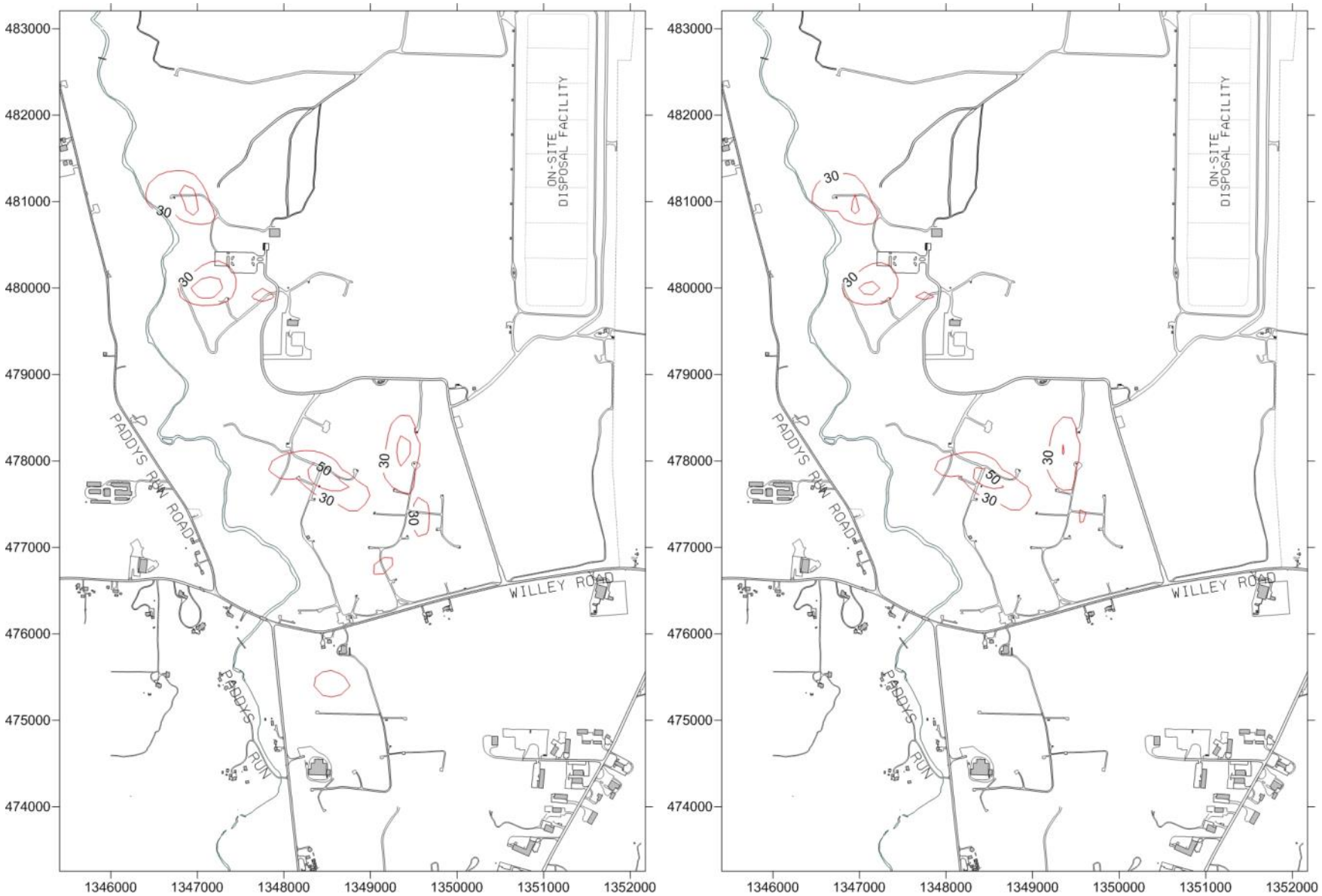


Figure A-39. Maximum Uranium Concentration Contours, South Plume Alternative 7, Model Layer 12

April 2018, Nominal Boundary Conditions *April 2019, Nominal Boundary Conditions*

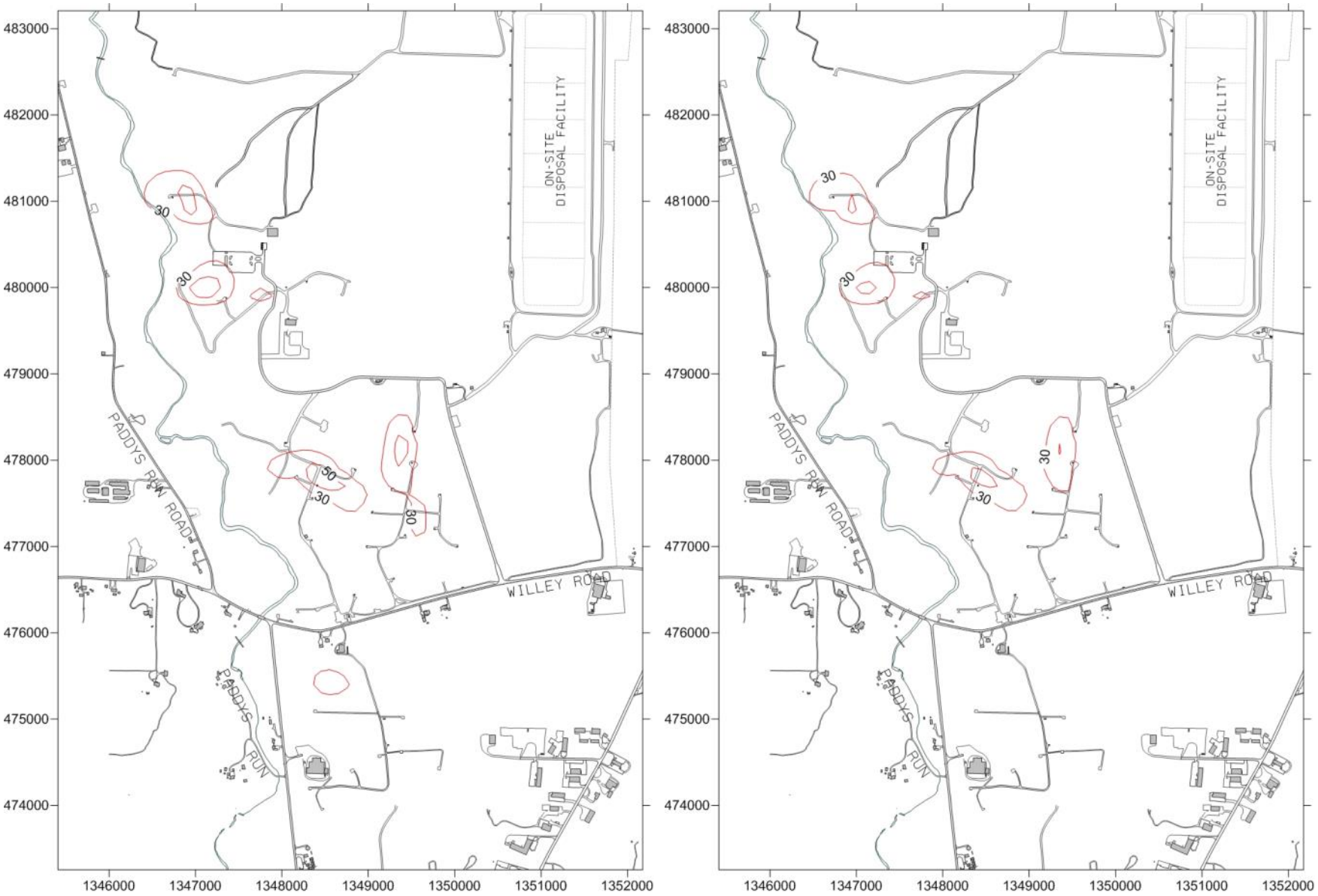


Figure A-40. Maximum Uranium Concentration Contours, South Plume Alternative 8, Model Layer 12

April 2019, Nominal Boundary Conditions *April 2020, Nominal Boundary Conditions*

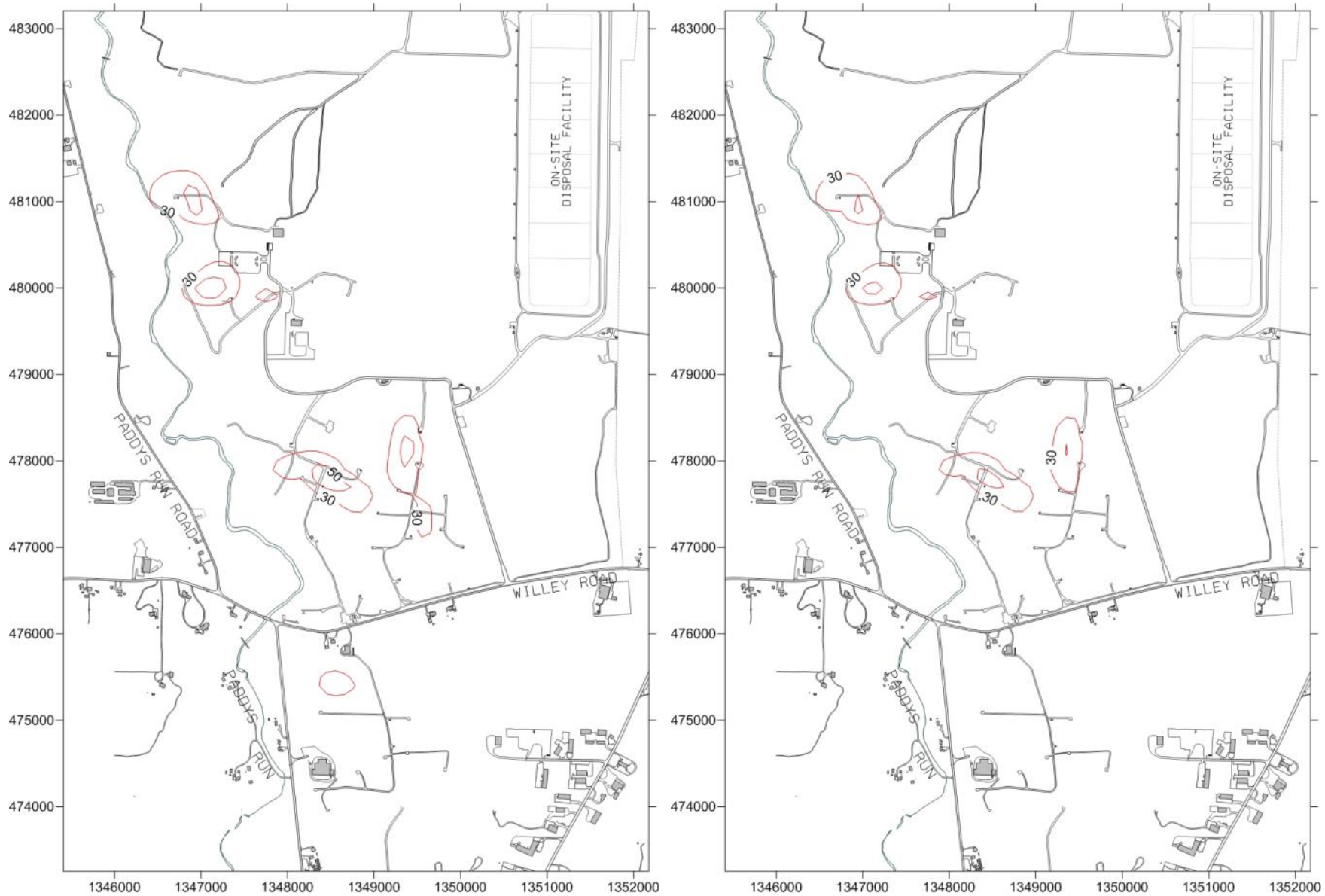


Figure A-41. Maximum Uranium Concentration Contours, South Plume Alternative 9, Model Layer 12

April 2018, Nominal Boundary Conditions *April 2019, Nominal Boundary Conditions*

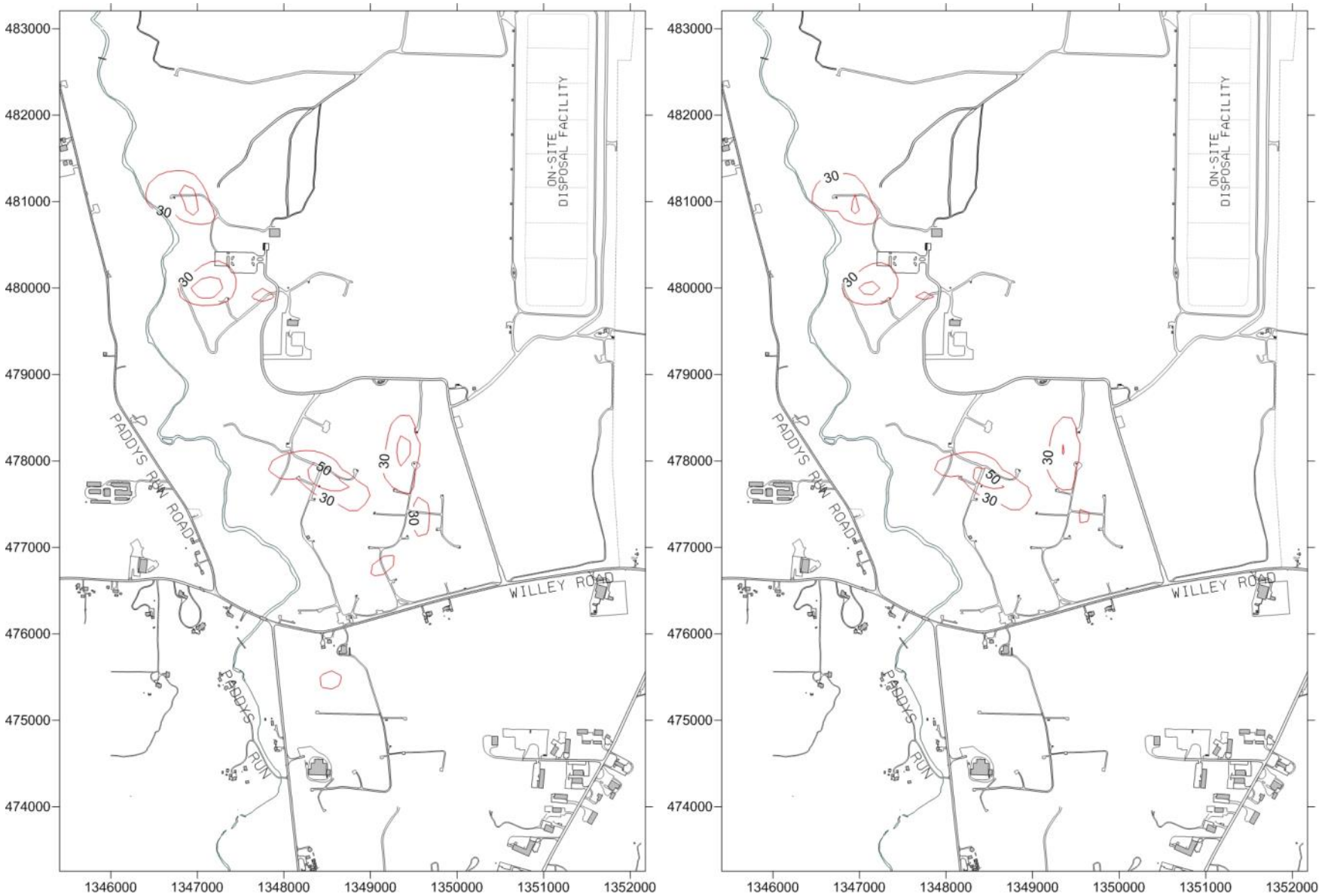


Figure A-42. Maximum Uranium Concentration Contours, South Plume Alternative 10, Model Layer 12

April 2018, Nominal Boundary Conditions *April 2019, Nominal Boundary Conditions*

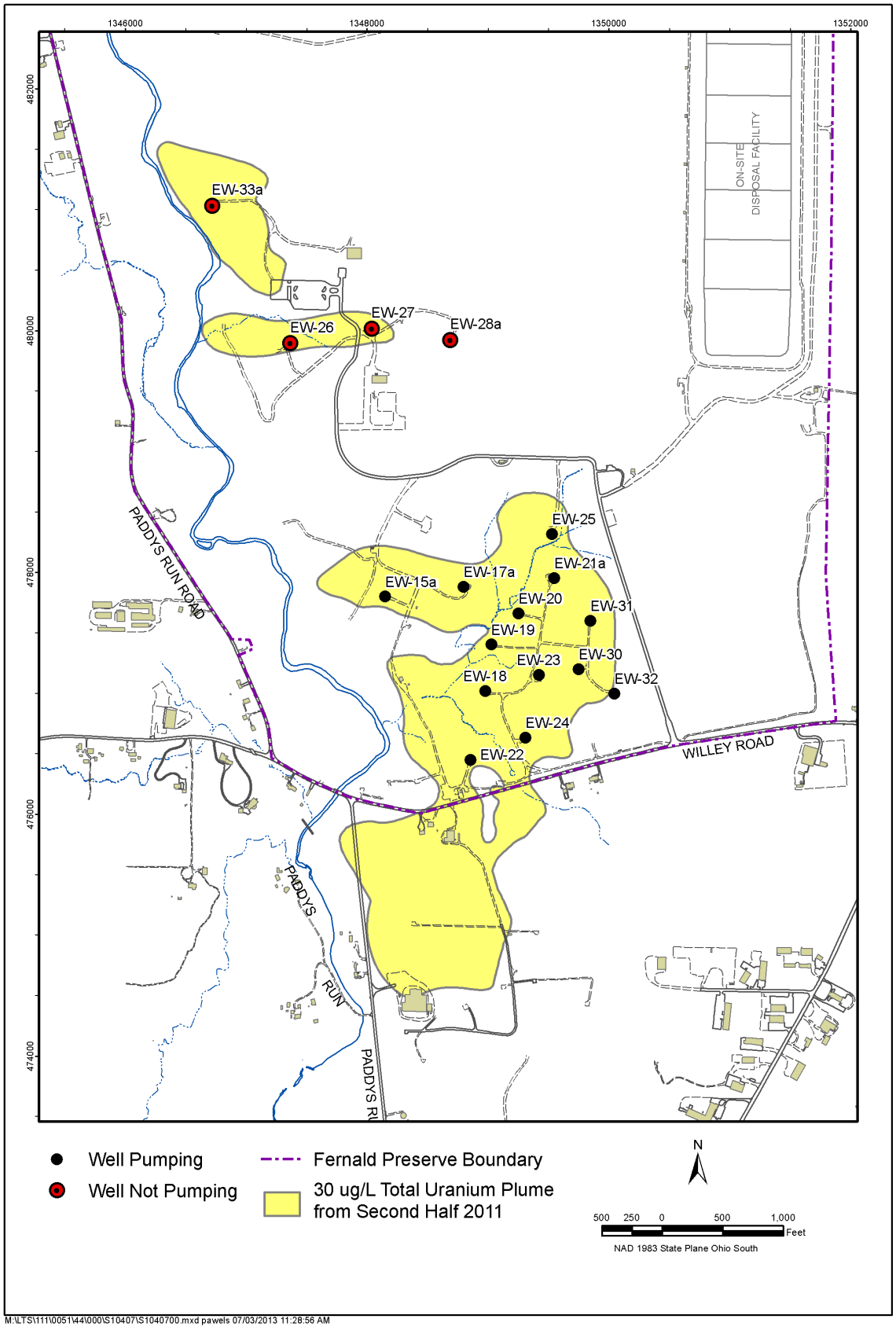


Figure A-43. Well Location Map for OA1

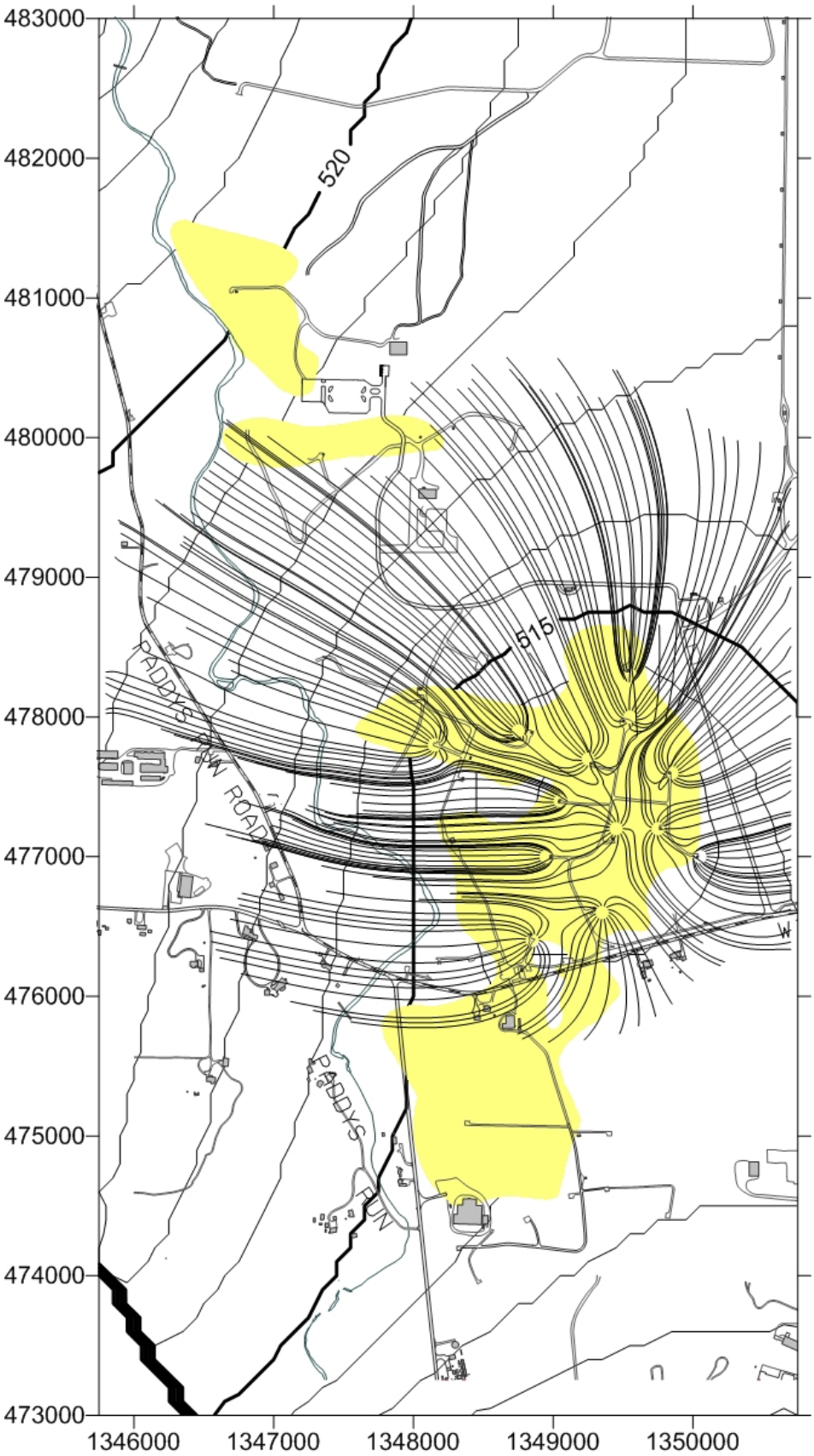


Figure A-44. Particle Track Map, Alternative OA1, Nominal Boundary Conditions, 10-Year Capture Yellow Shading Is Plume in December 2011

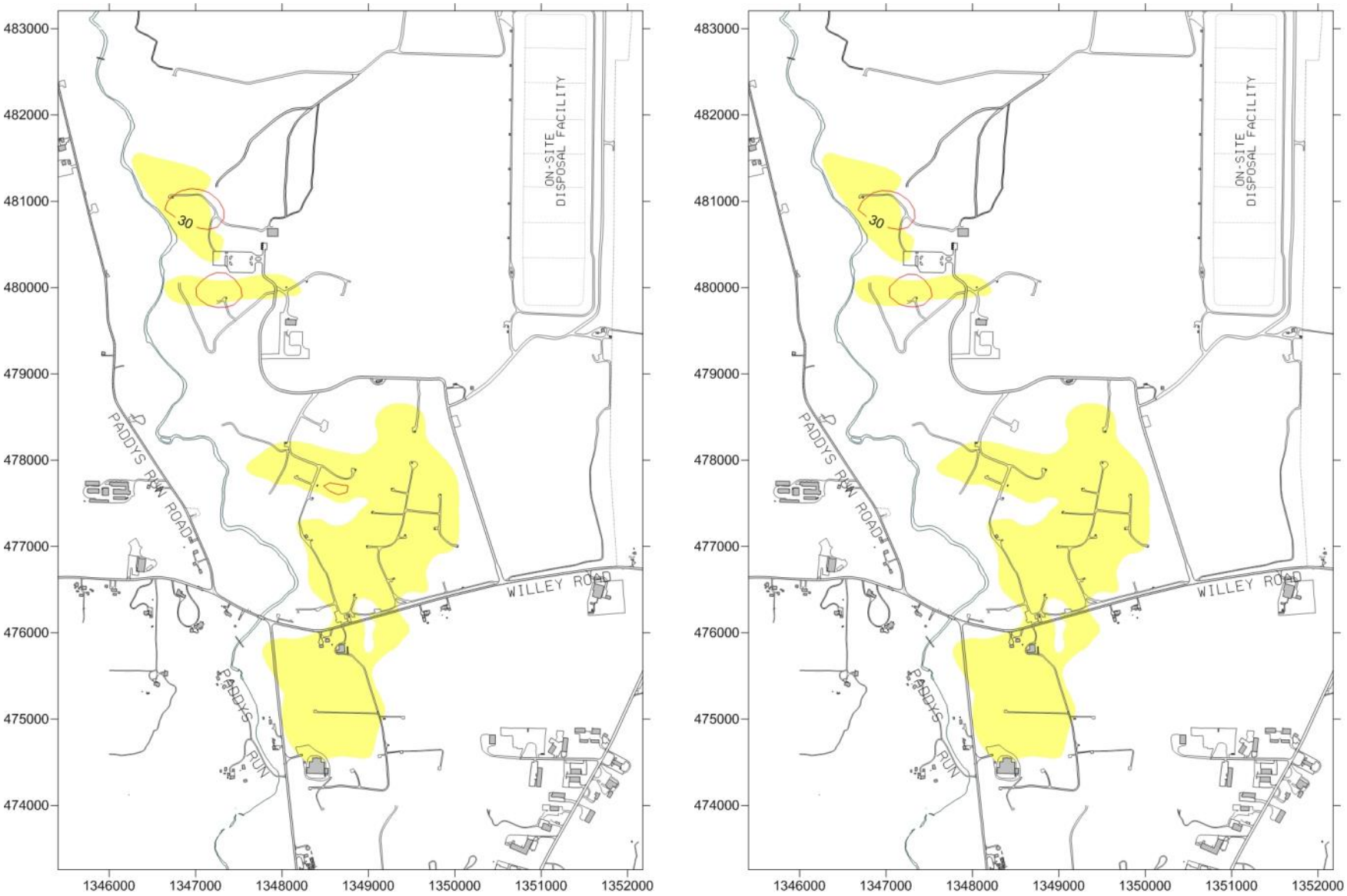
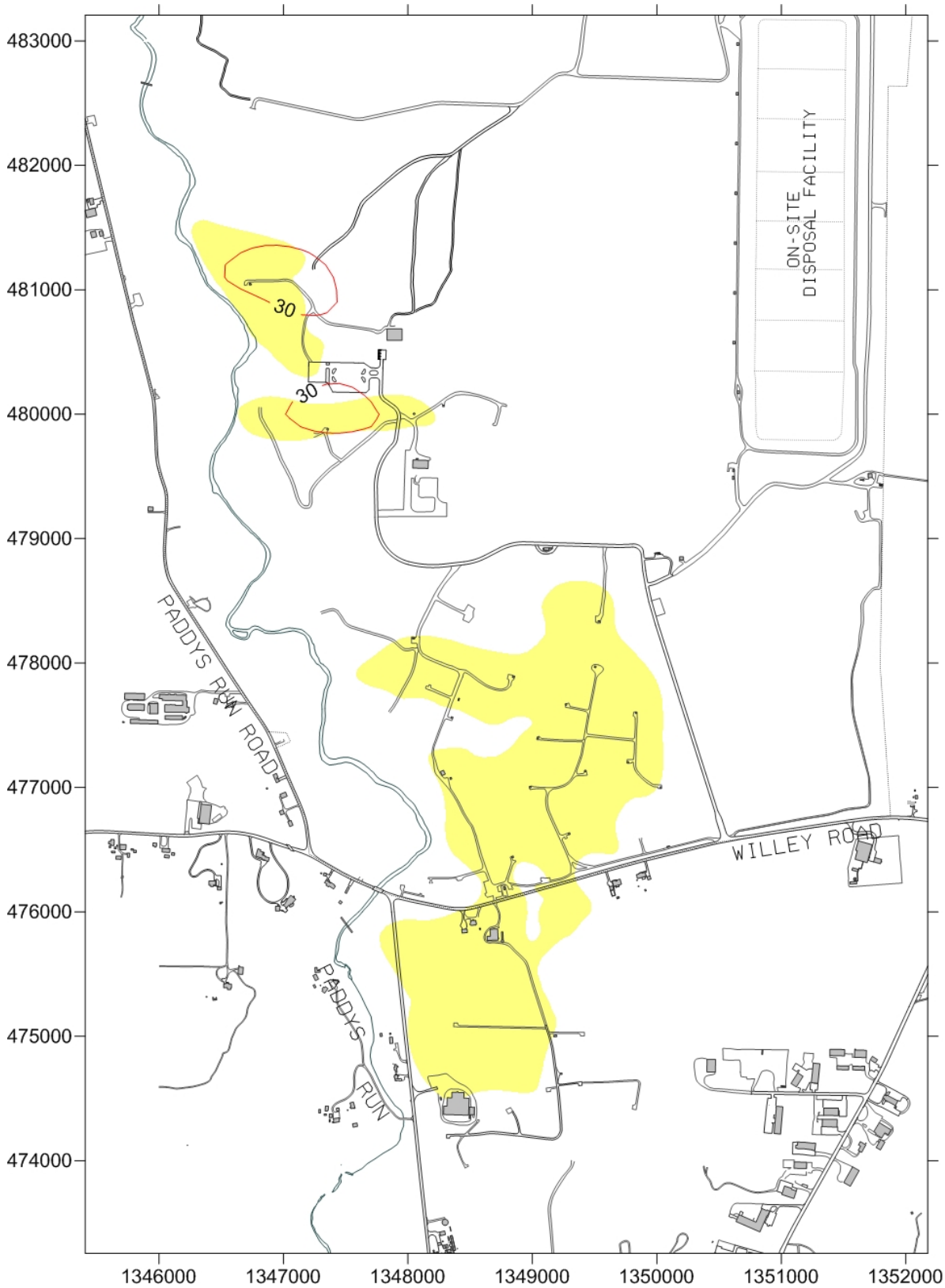


Figure A-45. Maximum Uranium Concentration Contours, Alternative OA1, Model Layers 7–12

April 2027, Nominal Boundary Conditions, Yellow Shading is Plume in December 2011

April 2028, Nominal Boundary Conditions, Yellow Shading is Plume in December 2011



The red lines are uranium concentration contours. The yellow shading is the footprint of the maximum plume in December 2011.

Figure A-46. Modeled Uranium Plume, Alternative OA1, Layers 7–12, April 2027, Wet Boundary Conditions

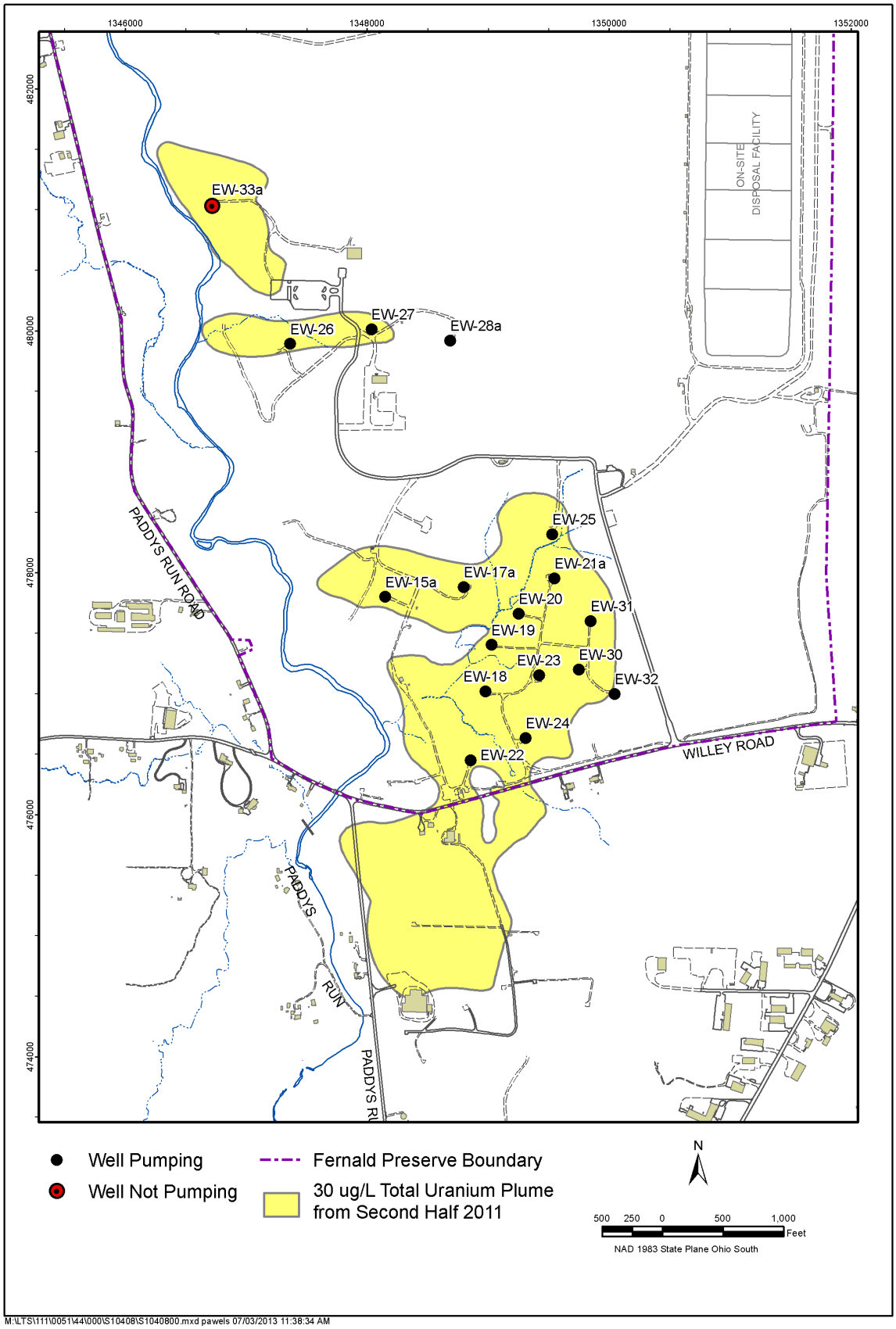


Figure A-47. Well Location Map for OA2

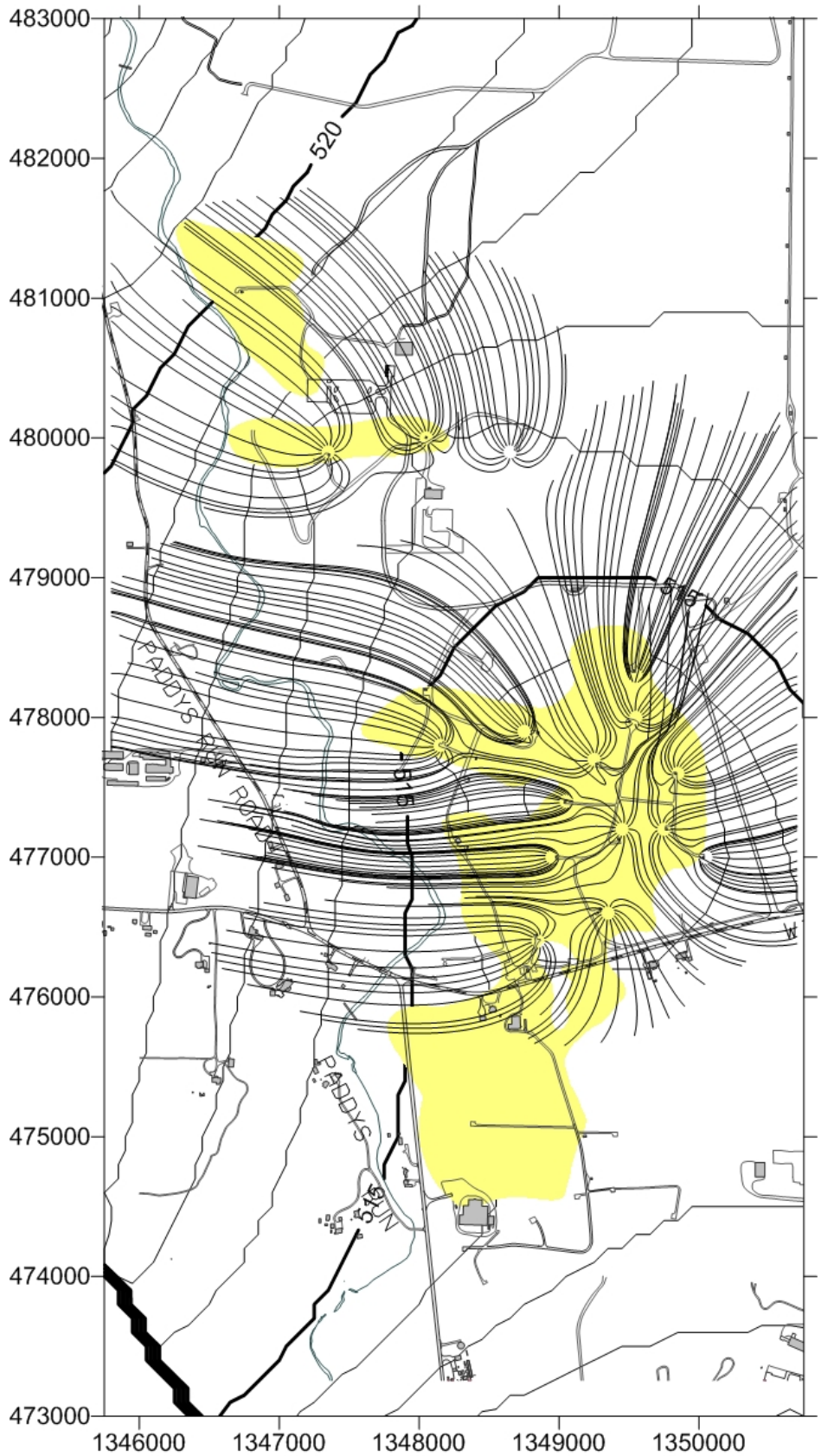


Figure A-48. Particle Track Map, *Alternative OA2, Nominal Boundary Conditions, 10-Year Capture Yellow Shading Is Plume in December 2011*

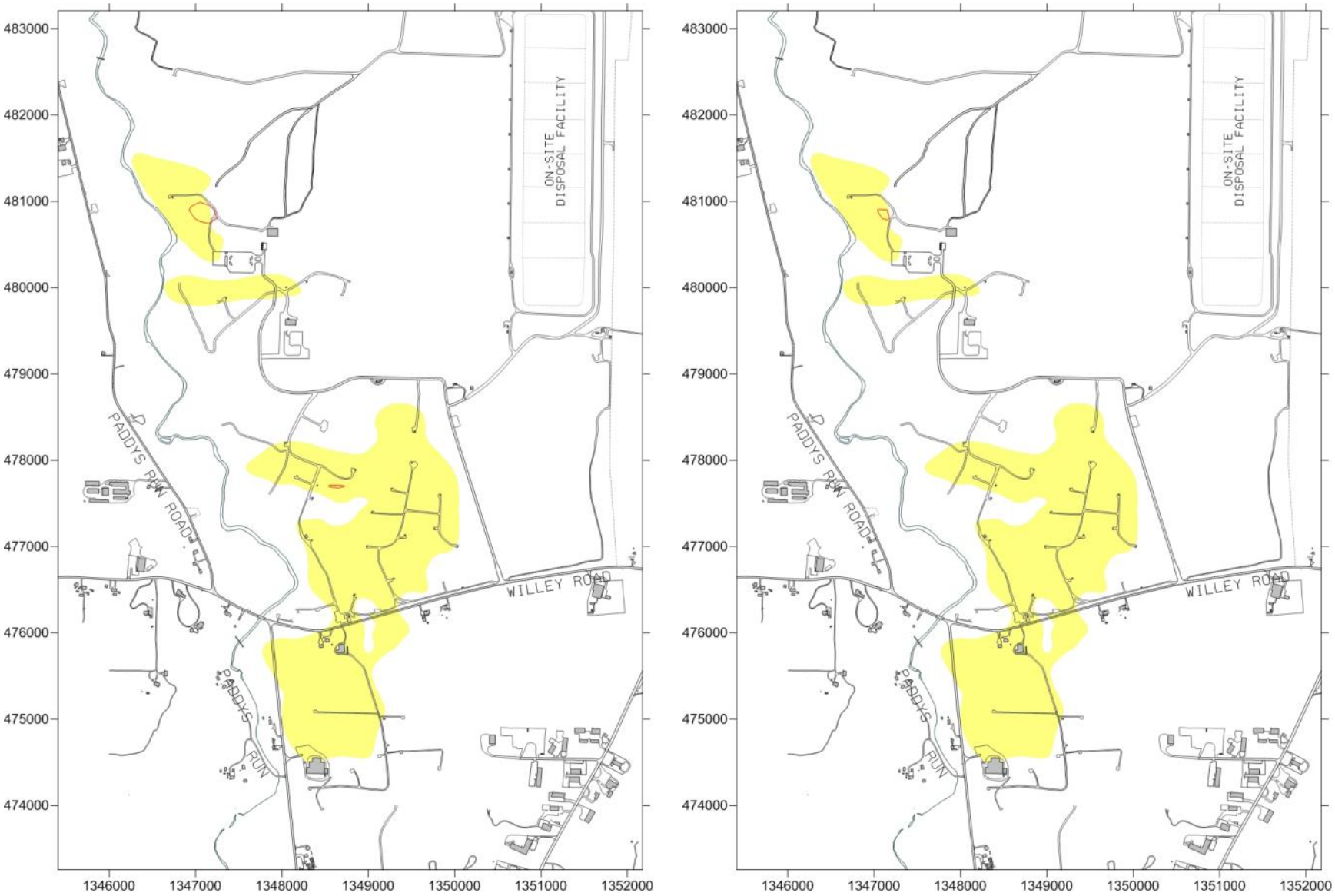
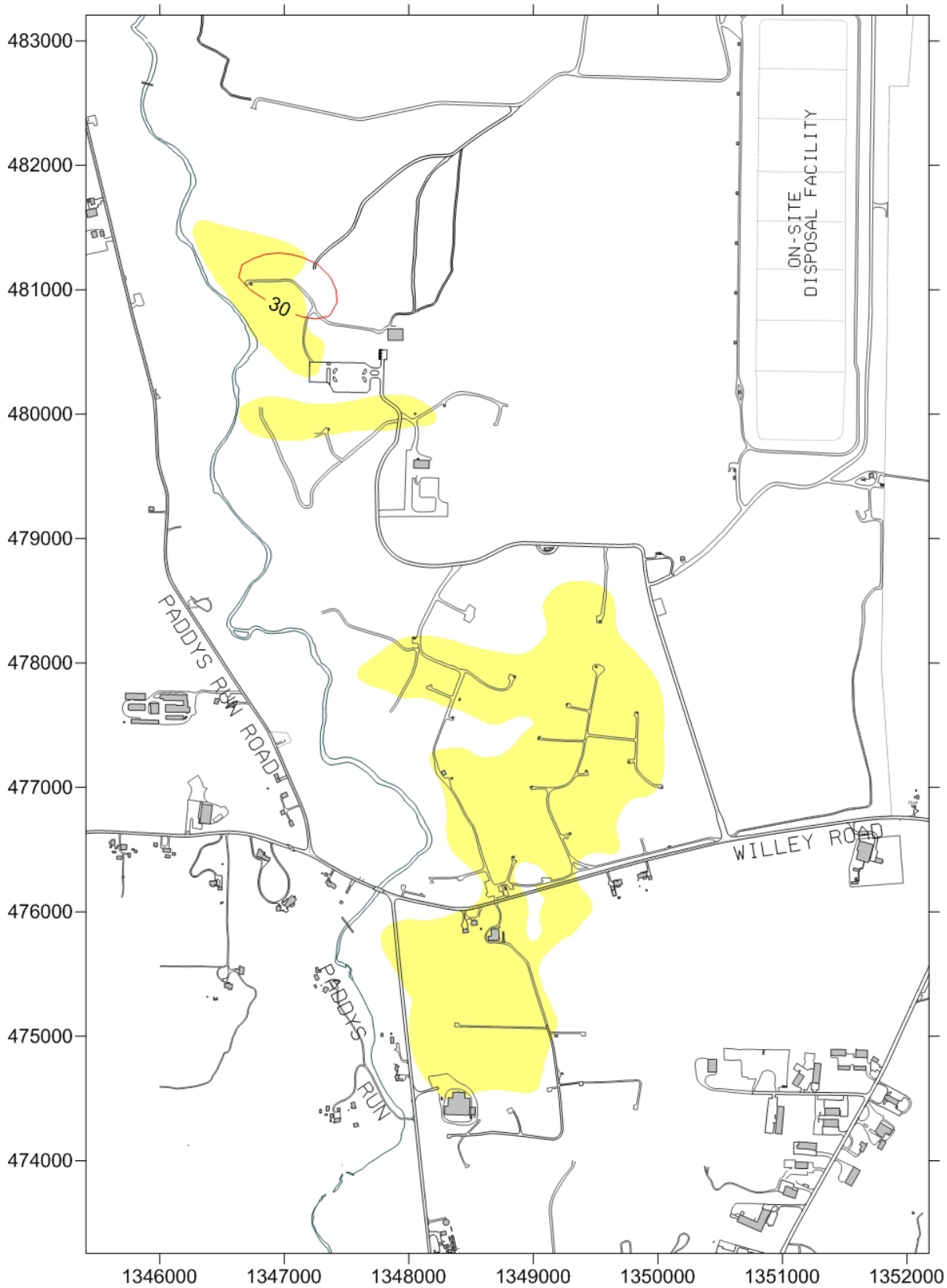


Figure A-49. Maximum Uranium Concentration Contours, Alternative OA2, Model Layers 7–12

April 2028, Nominal Boundary Conditions, Yellow Shading is Plume in December 2011

April 2029, Nominal Boundary Conditions, Yellow Shading is Plume in December 2011



The red lines are uranium concentration contours. The yellow shading is the footprint of the maximum plume in December 2011.

Figure A-50. Modeled Uranium Plume, Alternative OA2, Model Layers 7–12, April 2027, Wet Boundary Conditions

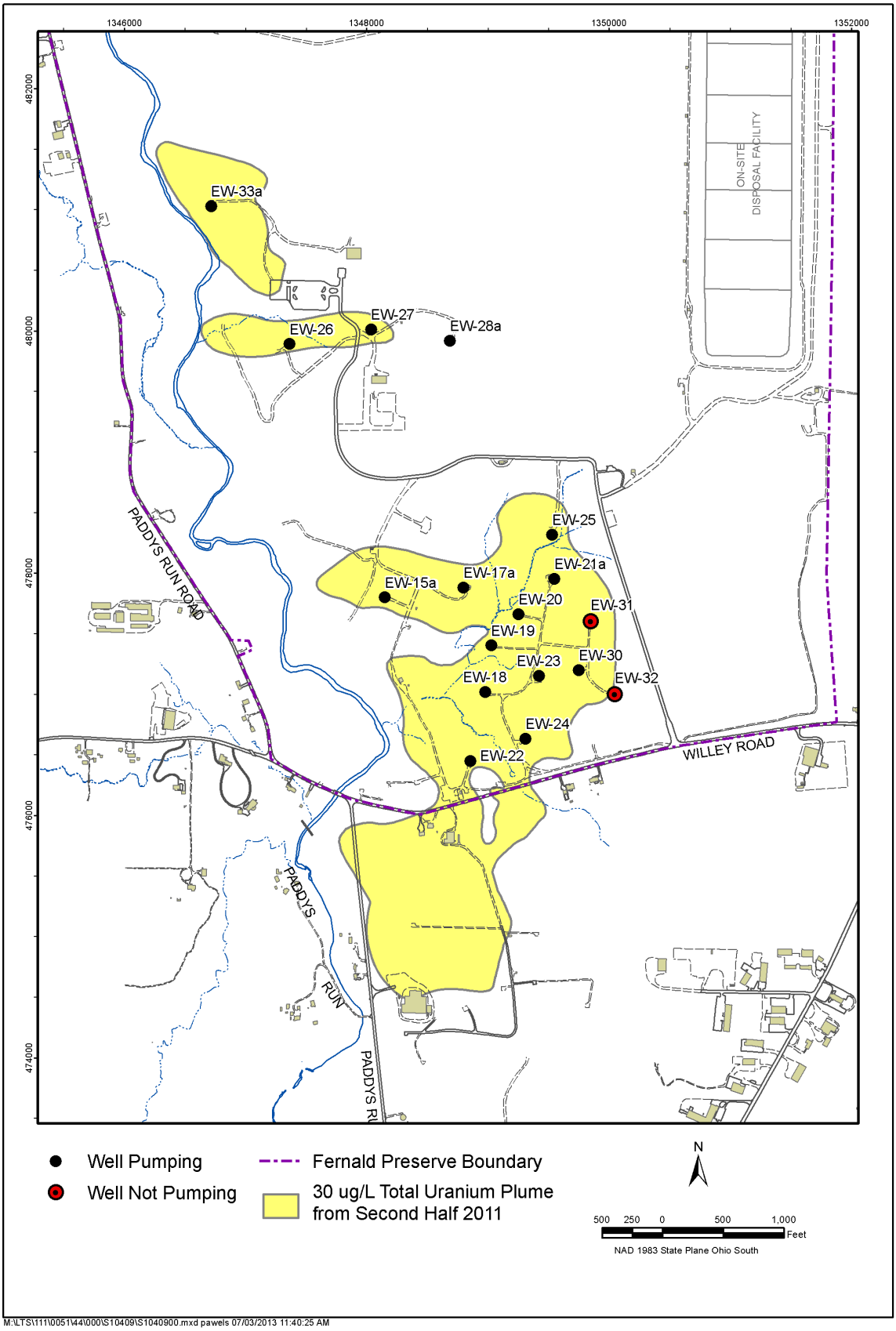


Figure A-51. Well Location Map for OA3

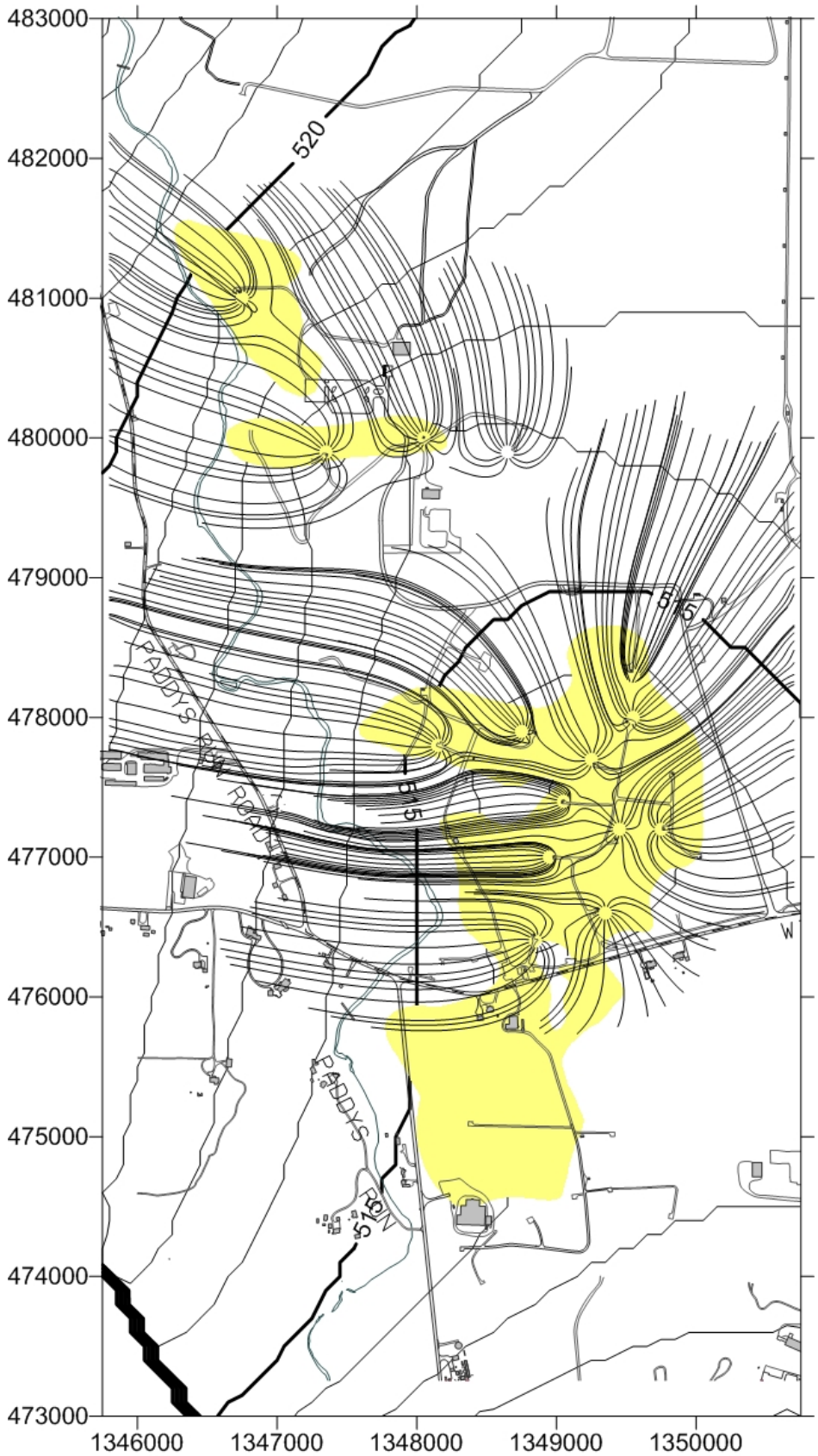


Figure A-52. Particle Track Map, Alternative OA3, Nominal Boundary Conditions, 10-Year Capture Yellow Shading Is Plume in December 2011

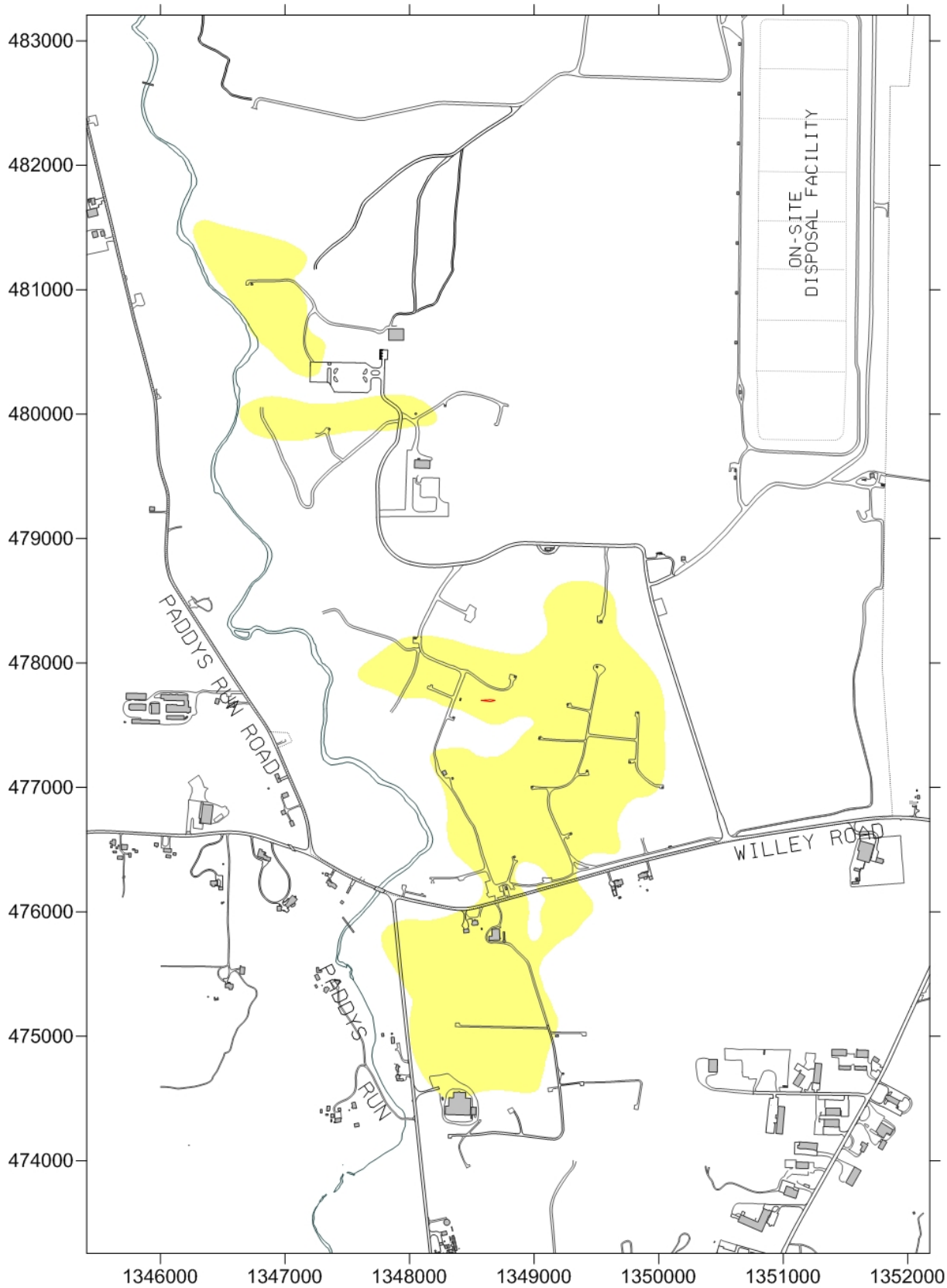


Figure A-53. Maximum Uranium Concentration Contours, Alternative OA3, Model Layers 7–12, April 2029, Nominal Boundary Conditions
Yellow Shading is Plume in December 2011

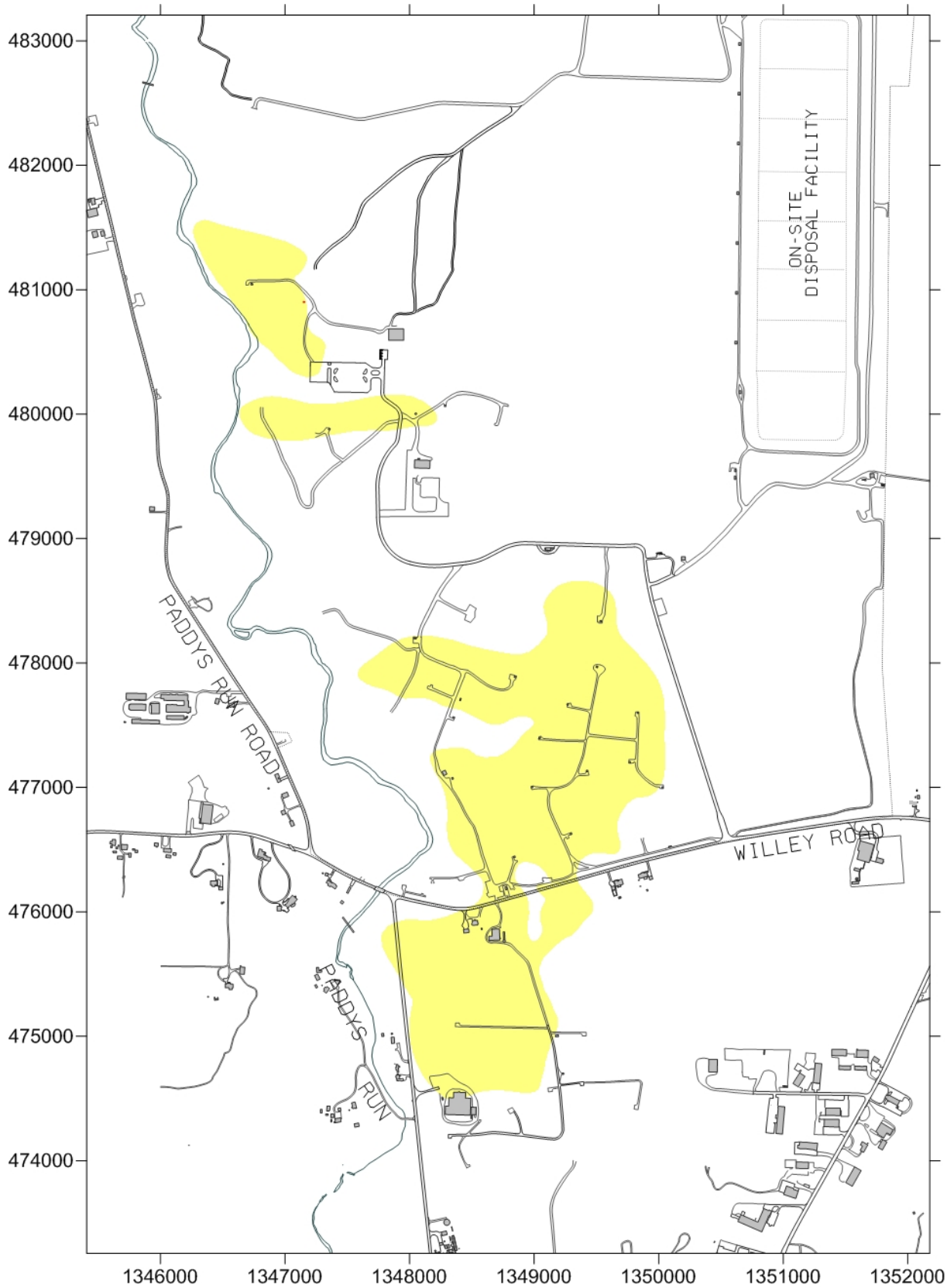


Figure A-54. Maximum Uranium Concentration Contours, Alternative OA3, Model Layers 7–12, April 2032, Wet Boundary Conditions
Yellow Shading Is Plume in December 2011

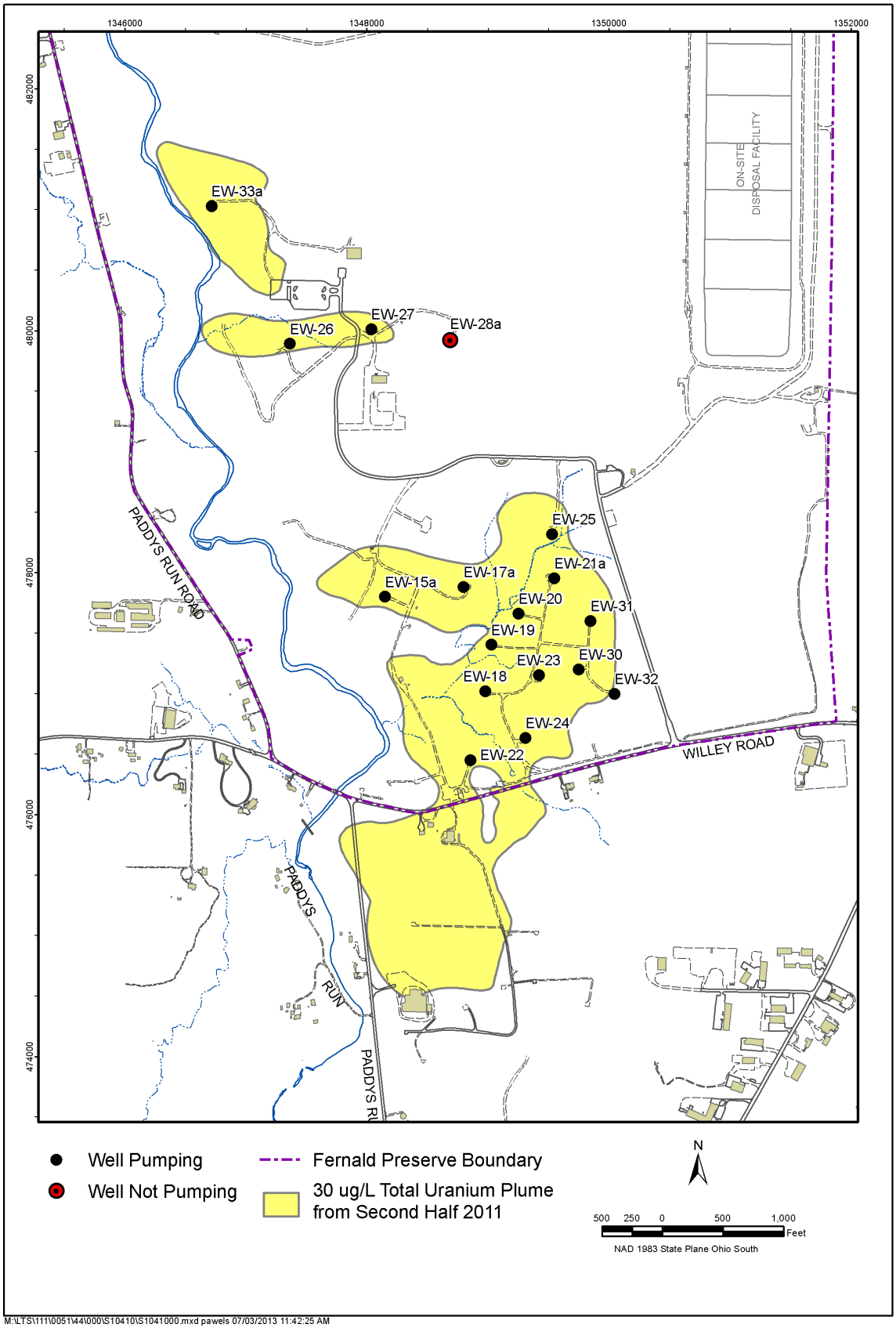


Figure A-55. Well Location Map for OA4

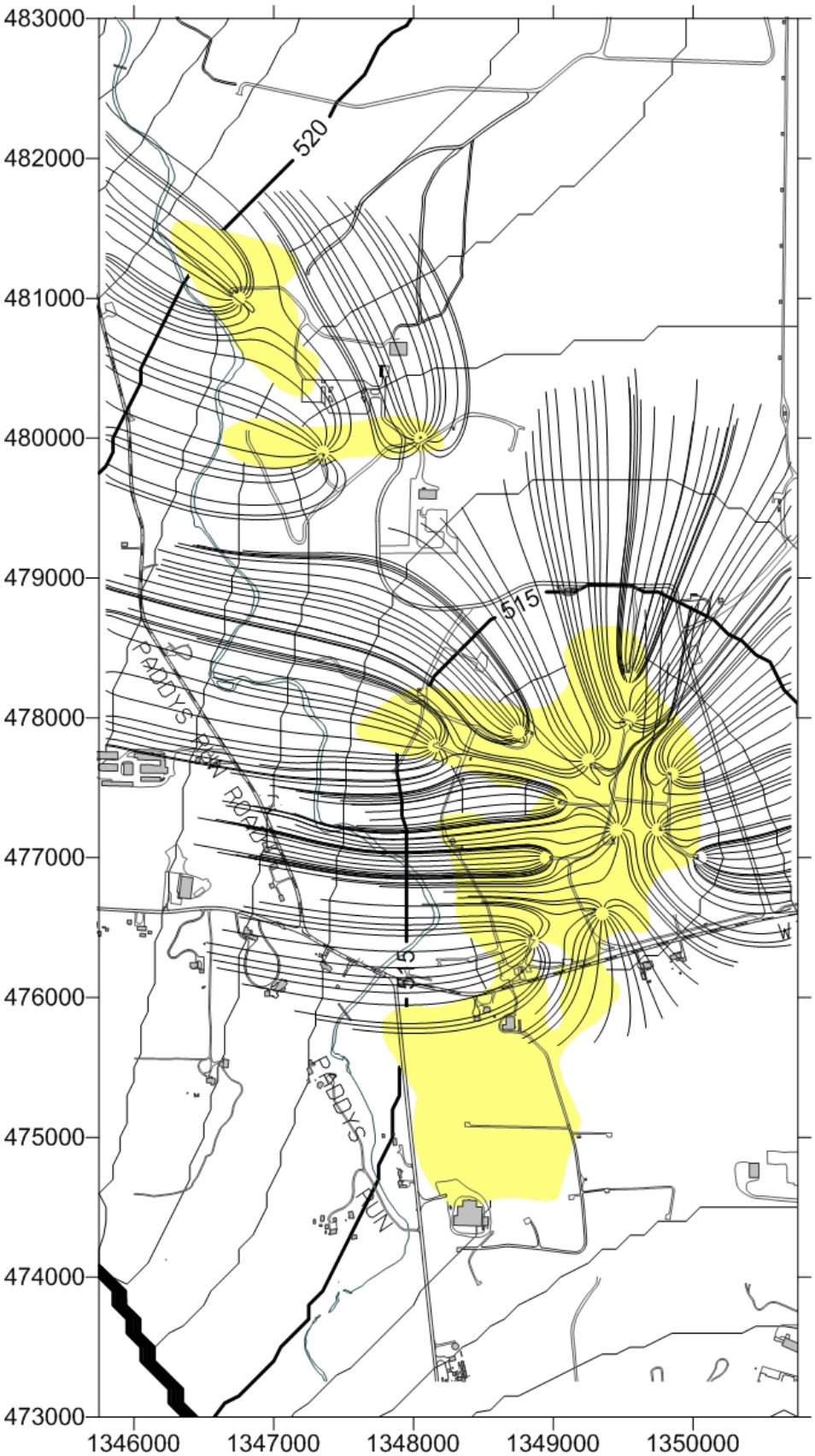


Figure A-56. Particle Track Map, Alternative OA4, Nominal Boundary Conditions, 10-Year Capture Yellow Shading Is Plume in December 2011

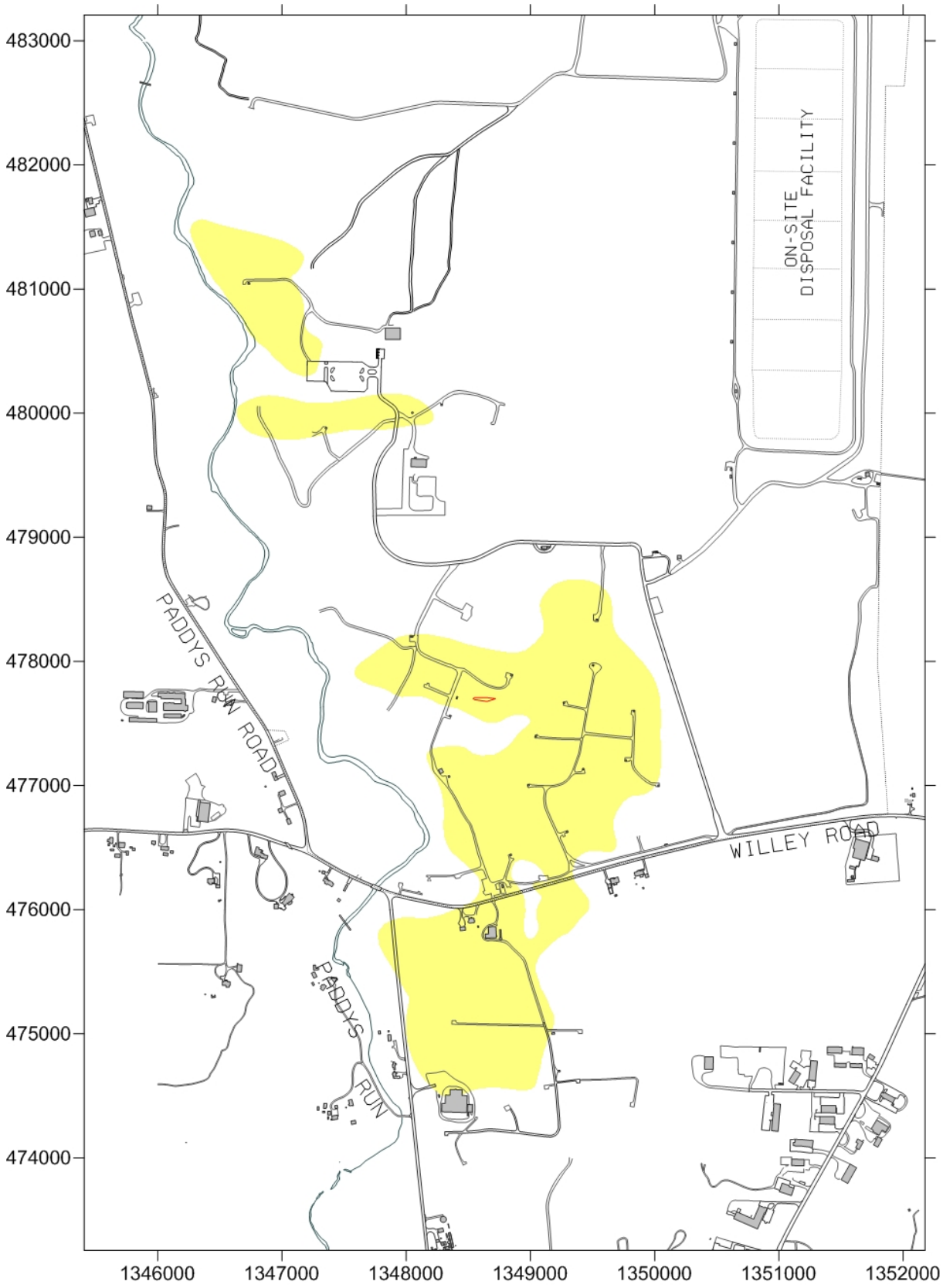


Figure A-57. Maximum Uranium Concentration Contours, Alternative OA4, Model Layers 7–12, April 2028, Nominal Boundary Conditions
Yellow Shading Is Plume in December 2011

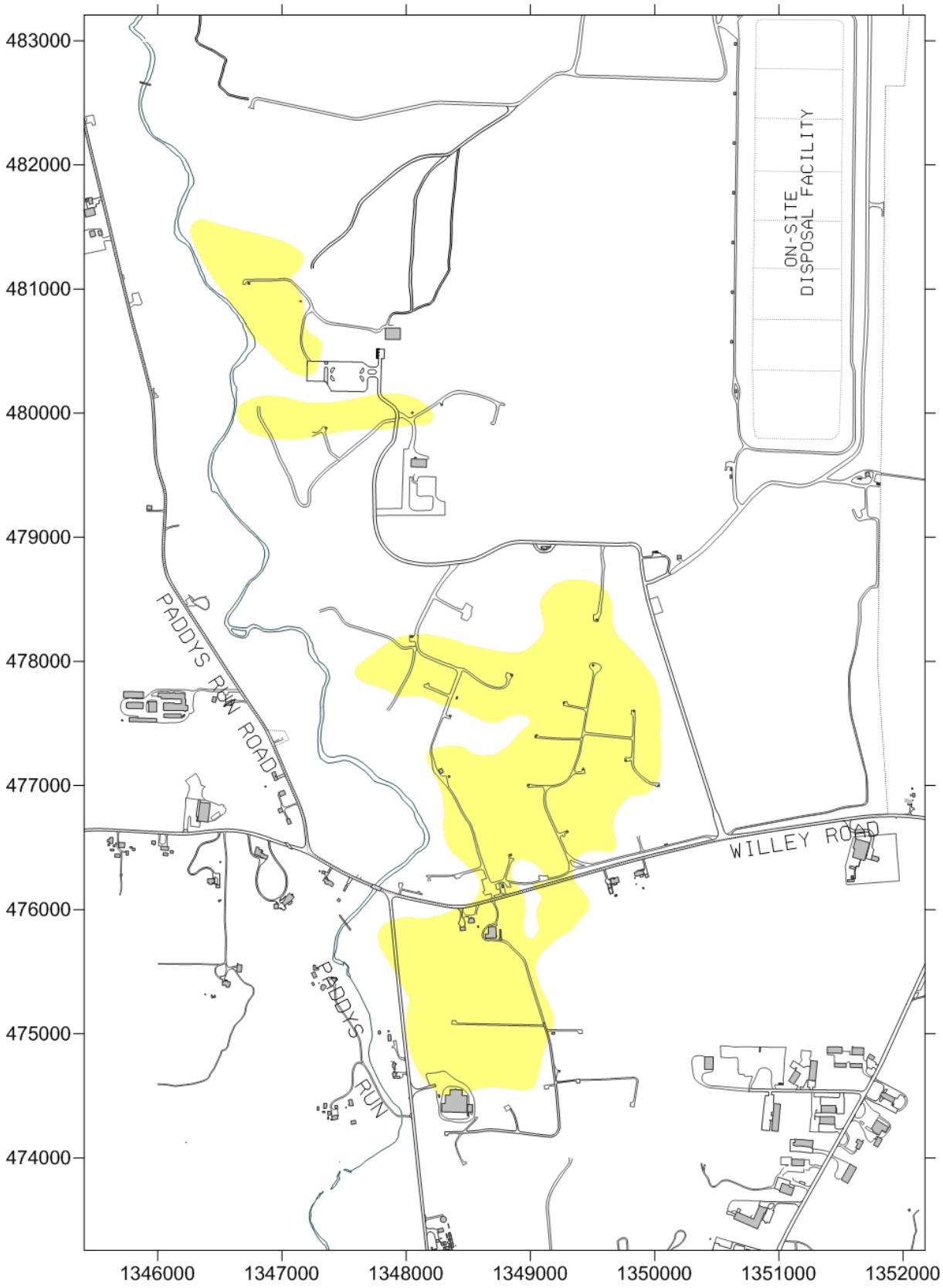


Figure A-58. Maximum Uranium Concentration Contours, Alternative OA4, Model Layers 7–12, April 2033, Wet Boundary Conditions
Yellow Shading Is Plume in December 2011

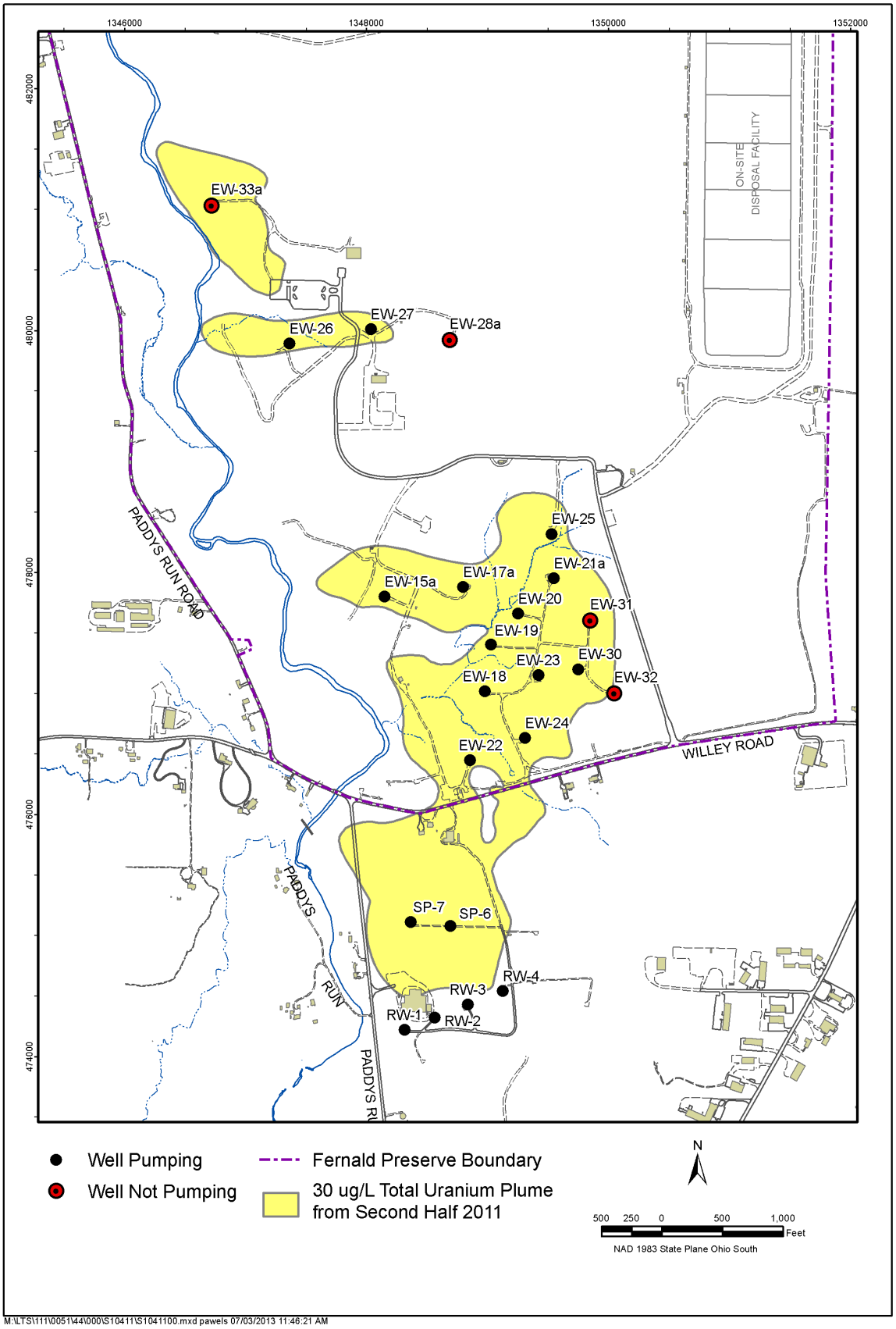


Figure A-59. Well Location Map for OA5a Through OA5d

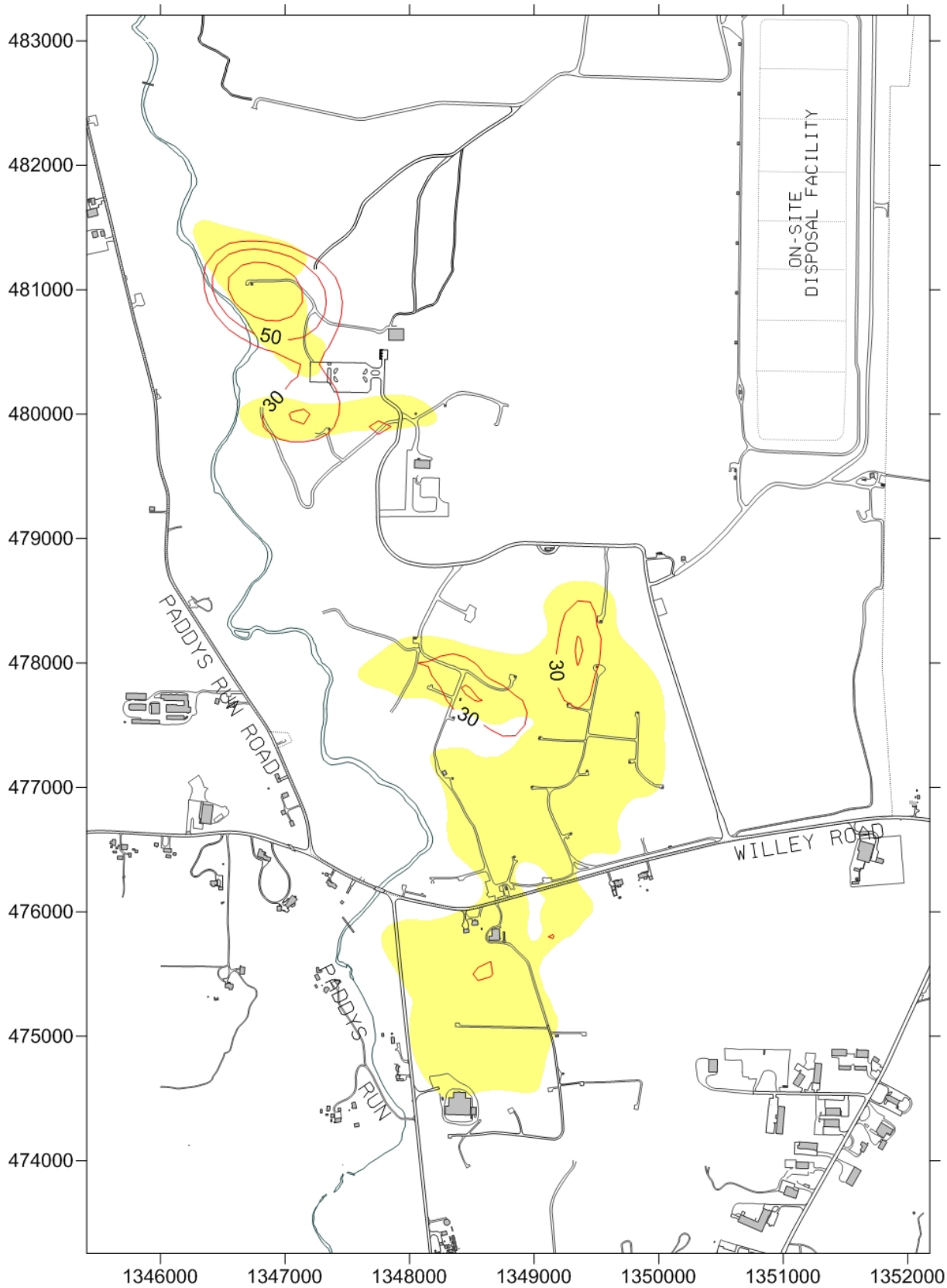


Figure A-60. Maximum Uranium Concentration Contours, Alternative OA5a, Model Layer 12, April 2019, Nominal Boundary Conditions
Yellow Shading Is Plume in December 2011

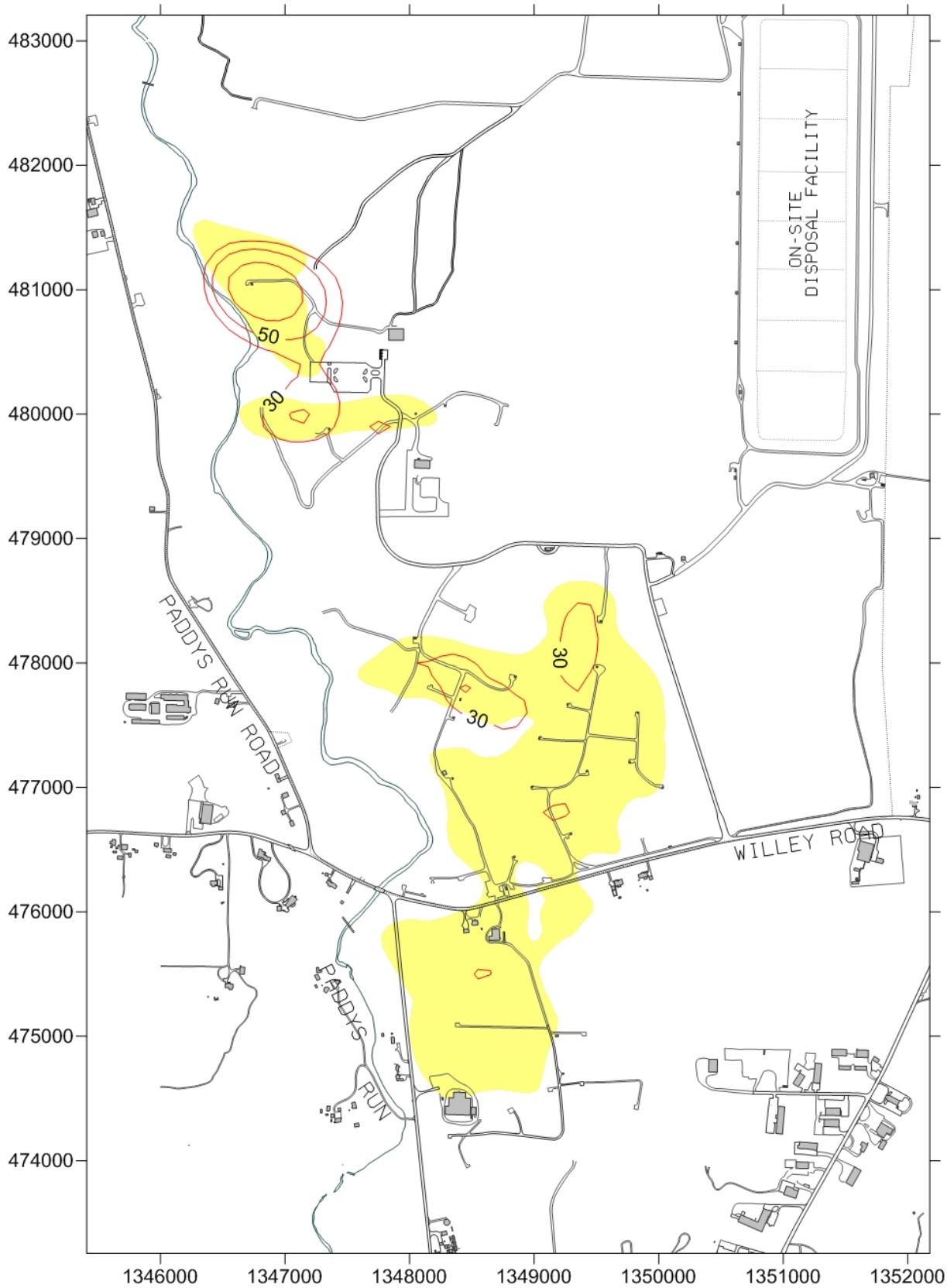


Figure A-61. Maximum Uranium Concentration Contours, Alternative OA5b, Model Layer 12, April 2019, Nominal Boundary Conditions
Yellow Shading Is Plume in December 2011

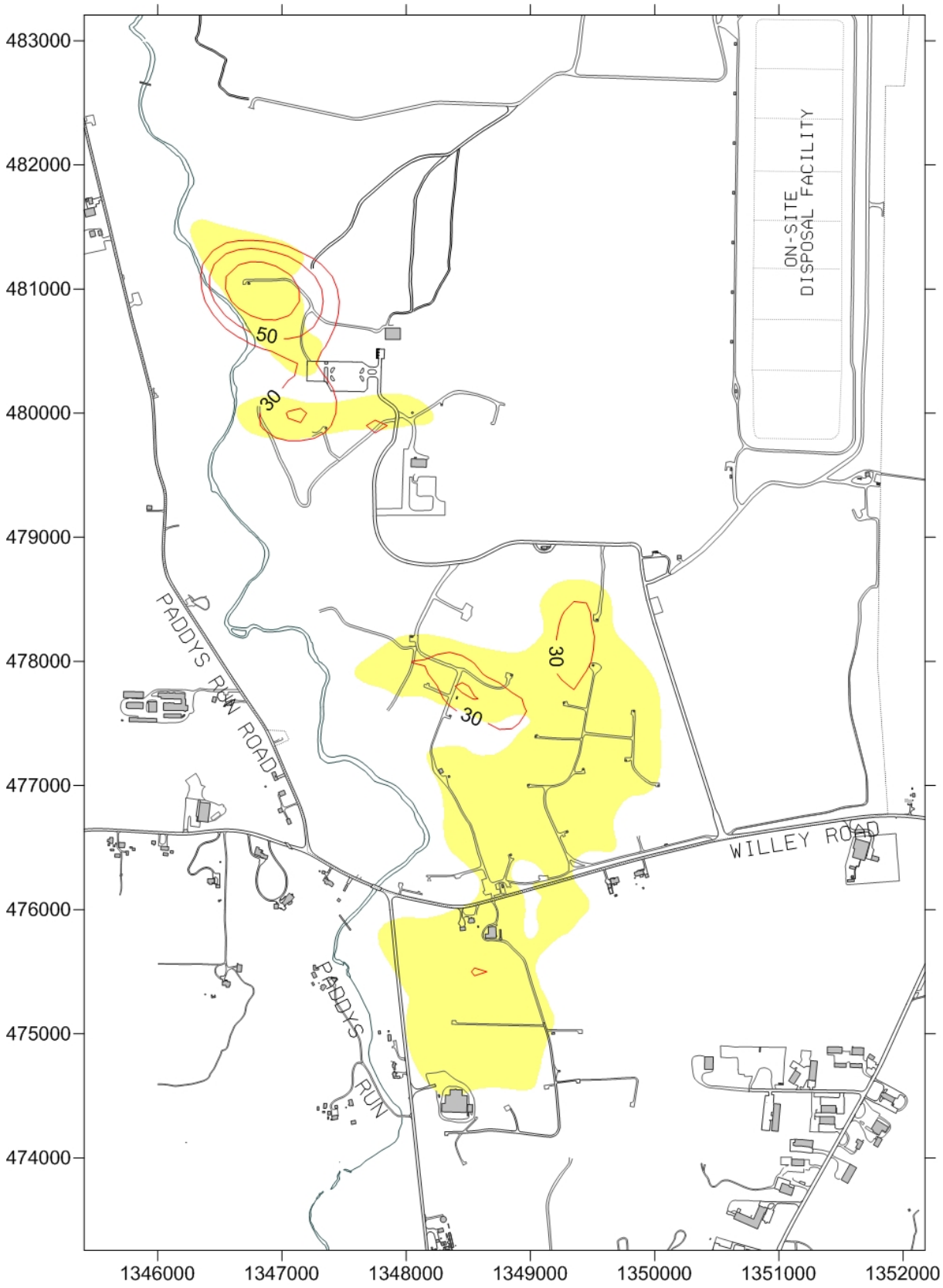


Figure A-62. Maximum Uranium Concentration Contours, Alternative OA5c, Model Layer 12, April 2019, Nominal Boundary Conditions
Yellow Shading Is Plume in December 2011

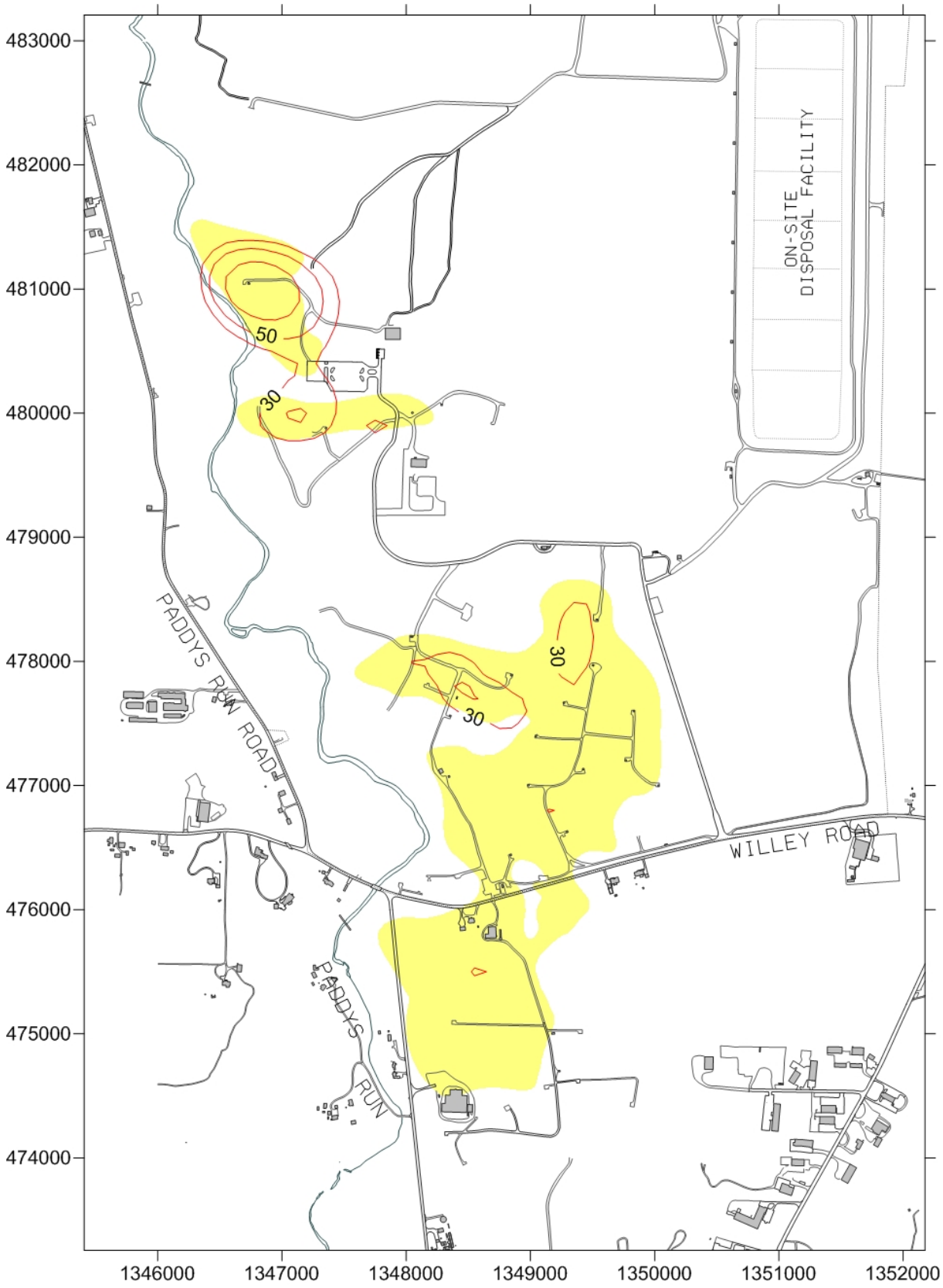


Figure A-63. Maximum Uranium Concentration Contours, Alternative OA5d, Model Layer 12, April 2019, Nominal Boundary Conditions
Yellow Shading Is Plume in December 2011

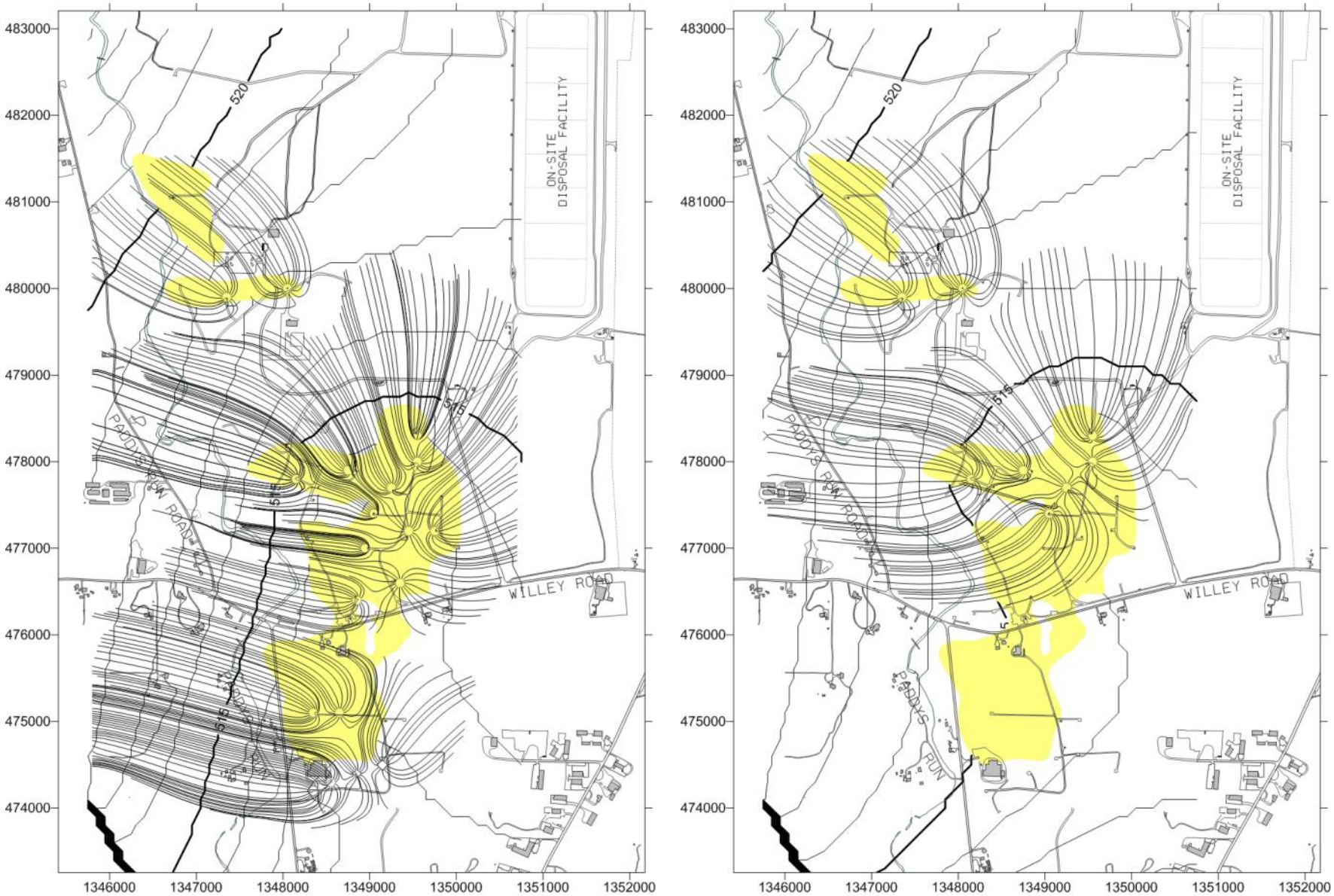


Figure A-64. Particle Track Maps, Alternative OA5c

2012 to 2020, Nominal Boundary Conditions, 10-Year Capture, Yellow Shading Is Plume in December 2011

2020 to 2028, Nominal Boundary Conditions, 10-Year Capture, Yellow Shading Is Plume in December 2011

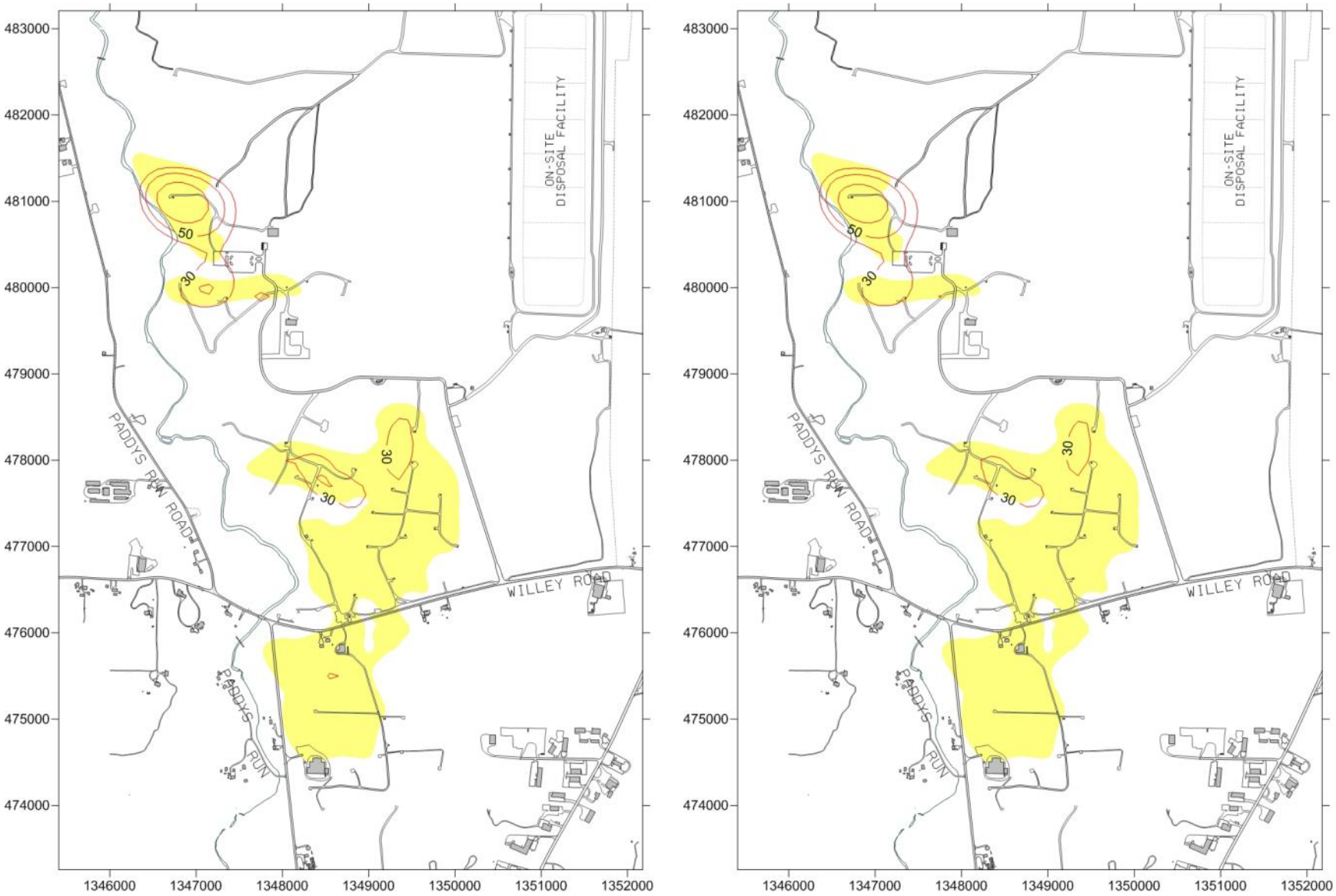


Figure A-65. Maximum Uranium Concentration Contours, Alternative OA5c, Model Layers 7–12, South Plume Clean

April 2019, Nominal Boundary Conditions, Yellow Shading Is Plume in December 2011

April 2020, Nominal Boundary Conditions, Yellow Shading Is Plume in December 2011

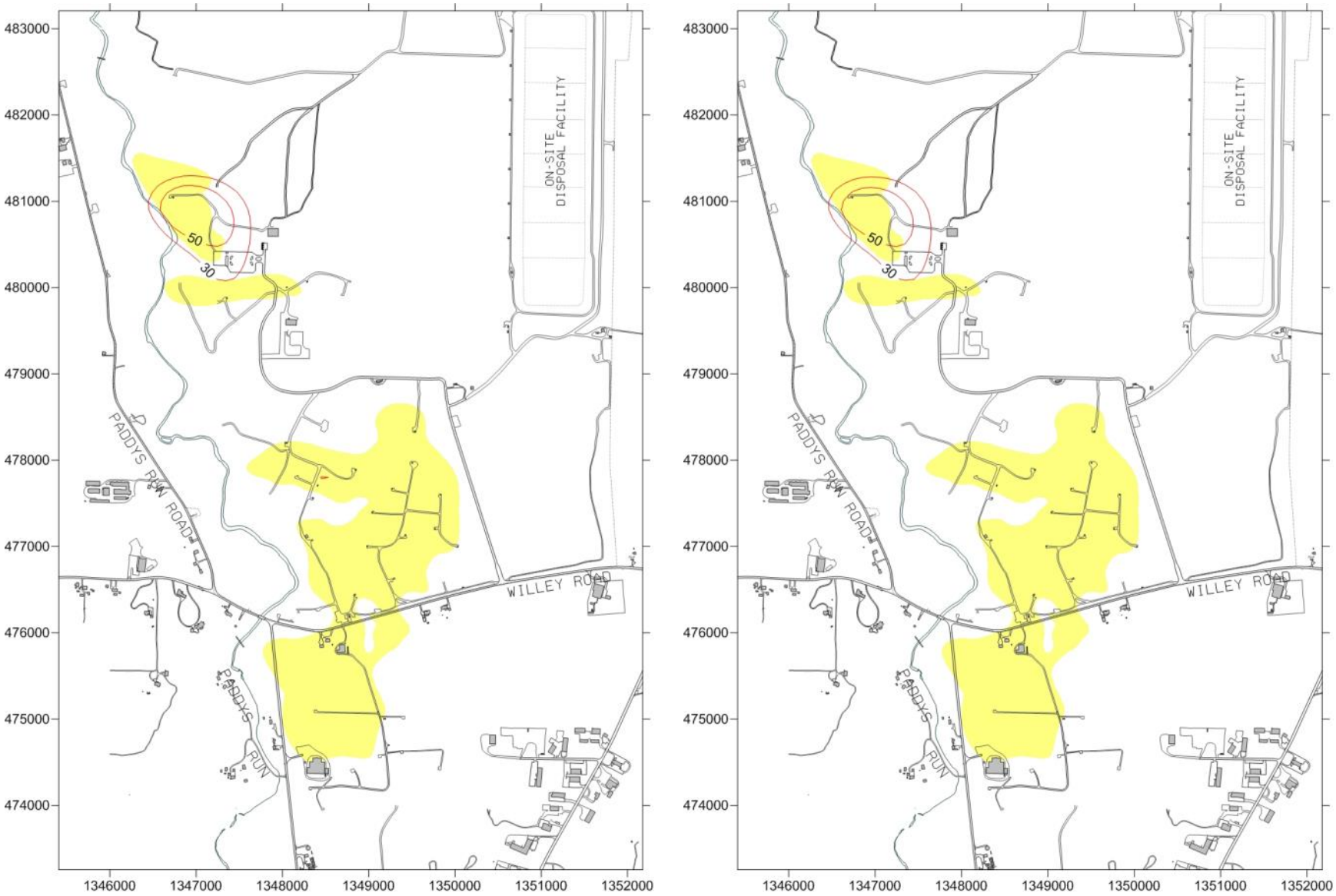
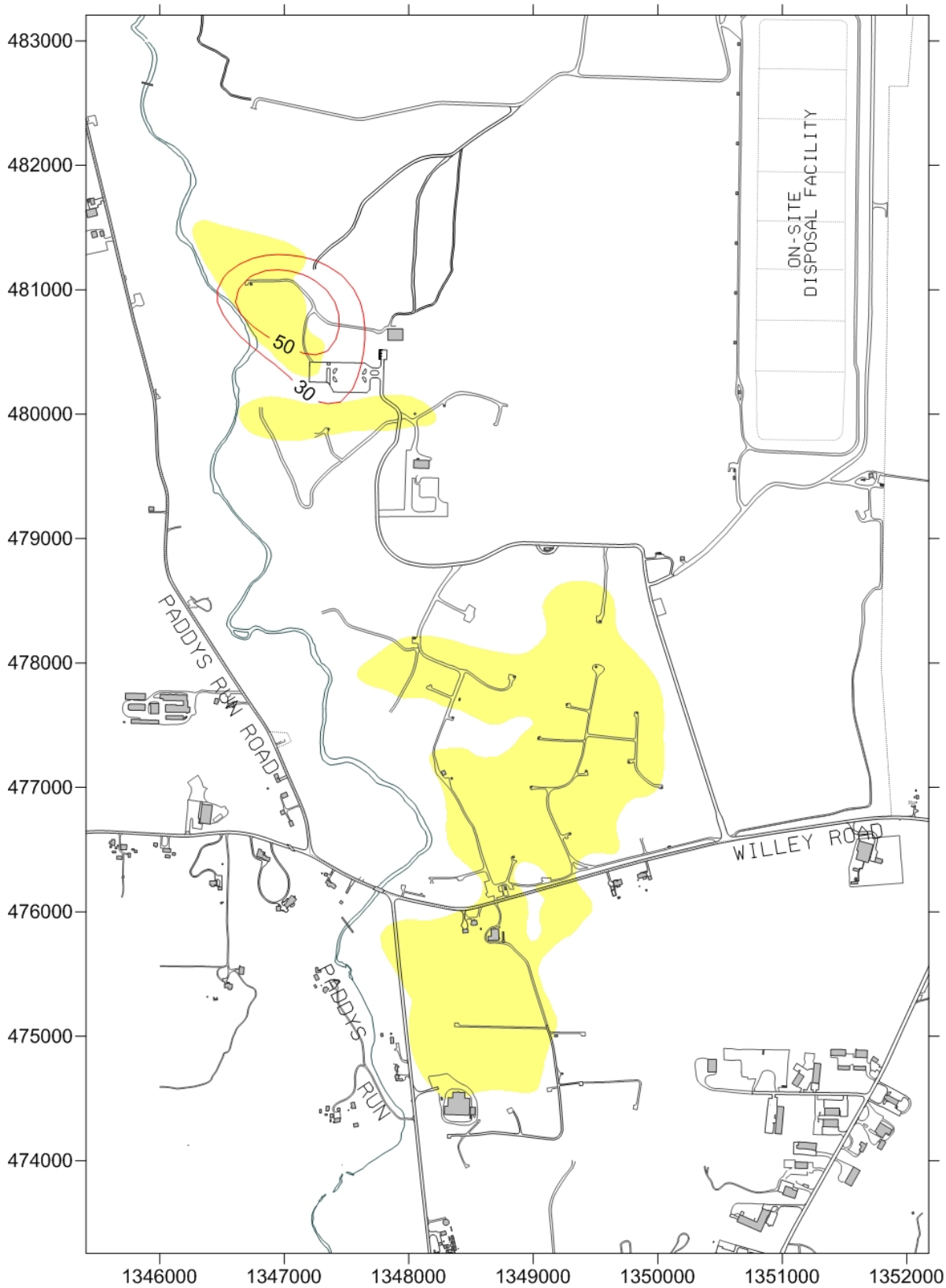


Figure A-66. Maximum Uranium Concentration Contours, Alternative OA5c, Model Layers 7–12, South Field Clean

April 2027, Nominal Boundary Conditions, Yellow Shading Is Plume in December 2011

April 2028, Nominal Boundary Conditions, Yellow Shading Is Plume in December 2011



The red lines are uranium concentration contours. The yellow shading is the footprint of the maximum plume in December 2011.

Figure A-67. Modeled Uranium Plume, Alternative OA5c, Layers 7–12, April 2028, Nominal Boundary Conditions

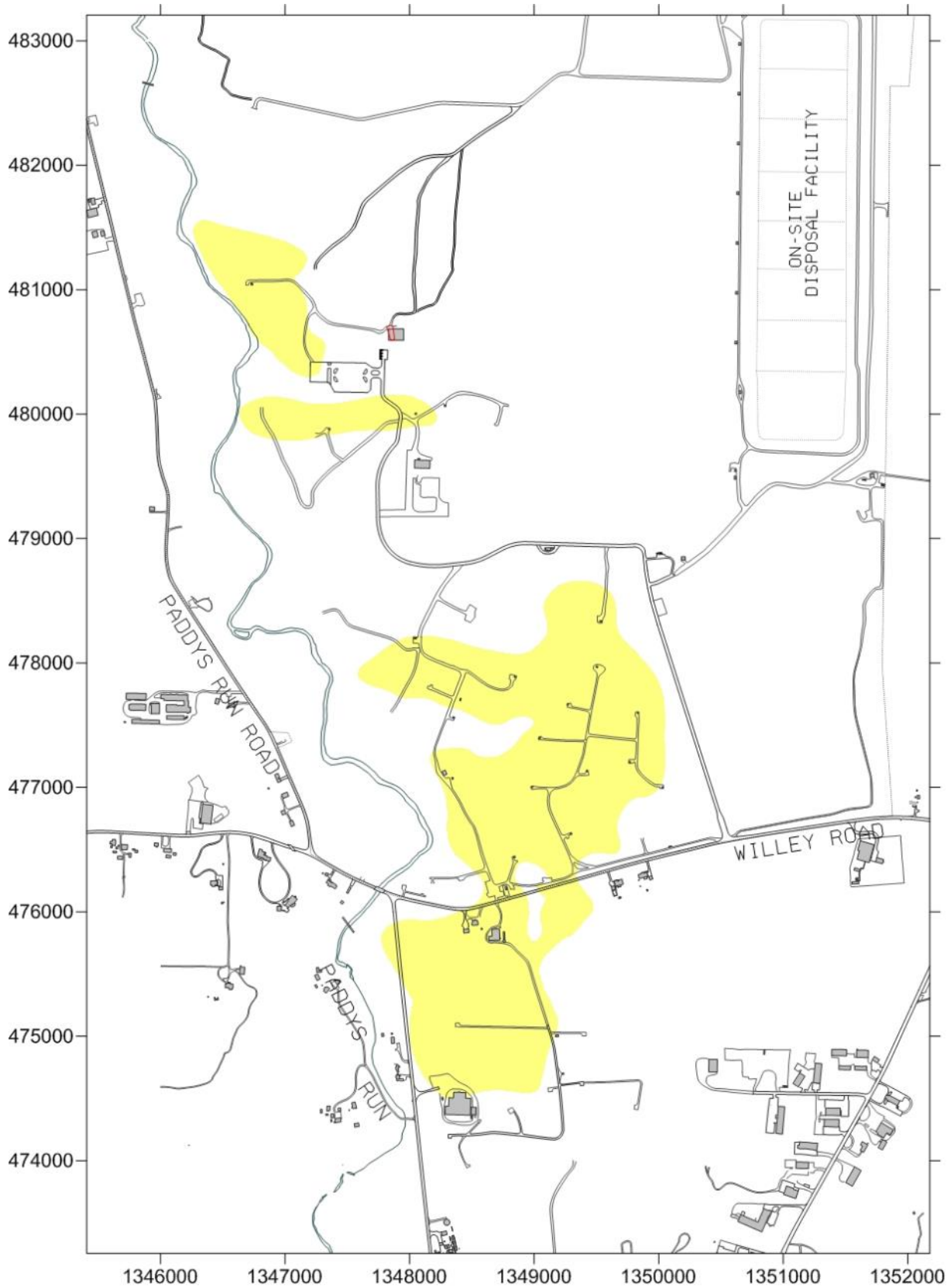


Figure A-68. Maximum Uranium Concentration Contours, Alternative OA5c, Model Layers 7–12, with Pumping, April 2077, Wet Boundary Conditions
Yellow Shading Is Plume in December 2011

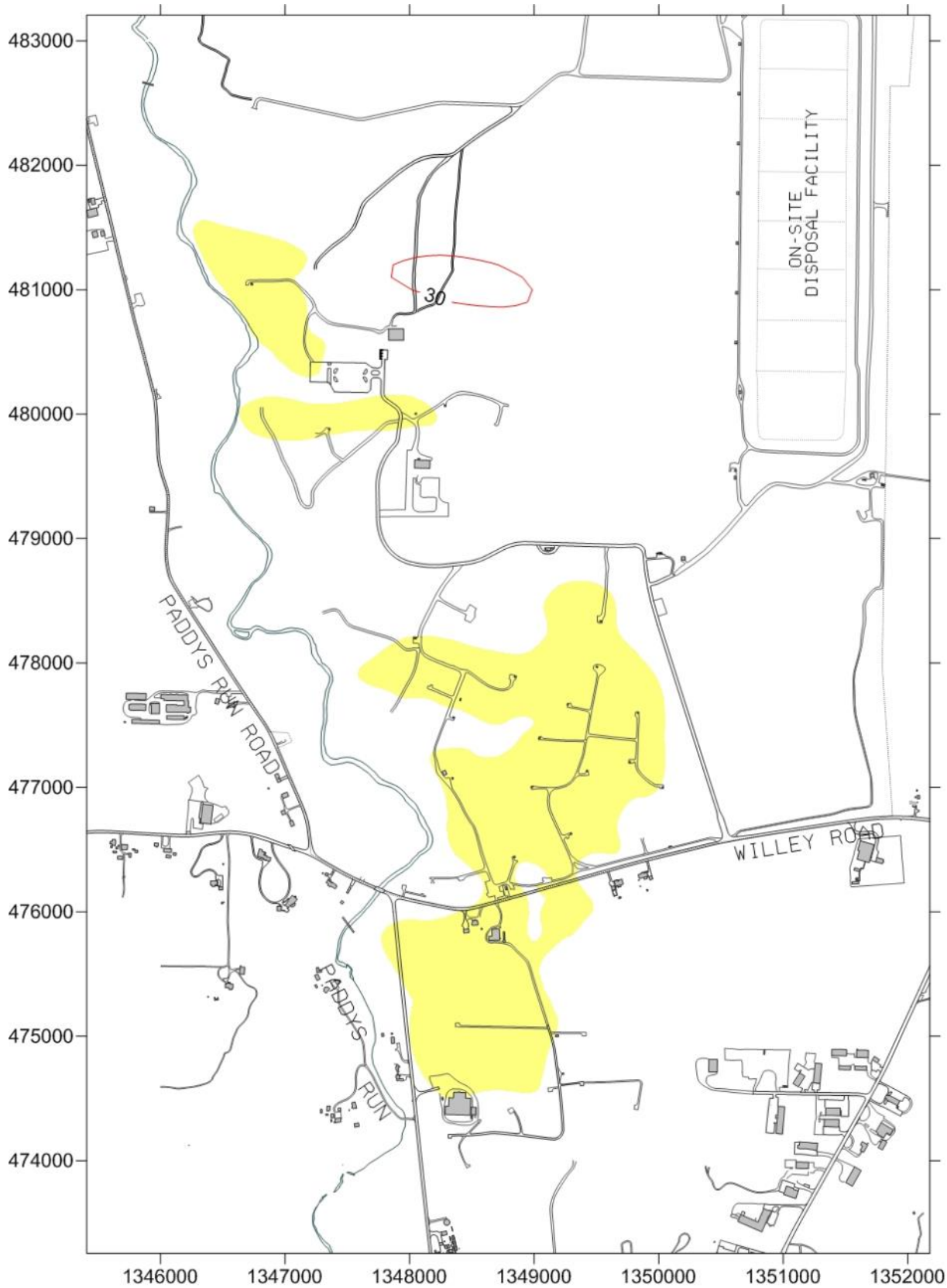


Figure A-69. Maximum Uranium Concentration Contours, Alternative OA5c, Model Layers 7–12, No Pumping, April 2134, Wet Boundary Conditions Yellow Shading Is Plume in December 2011

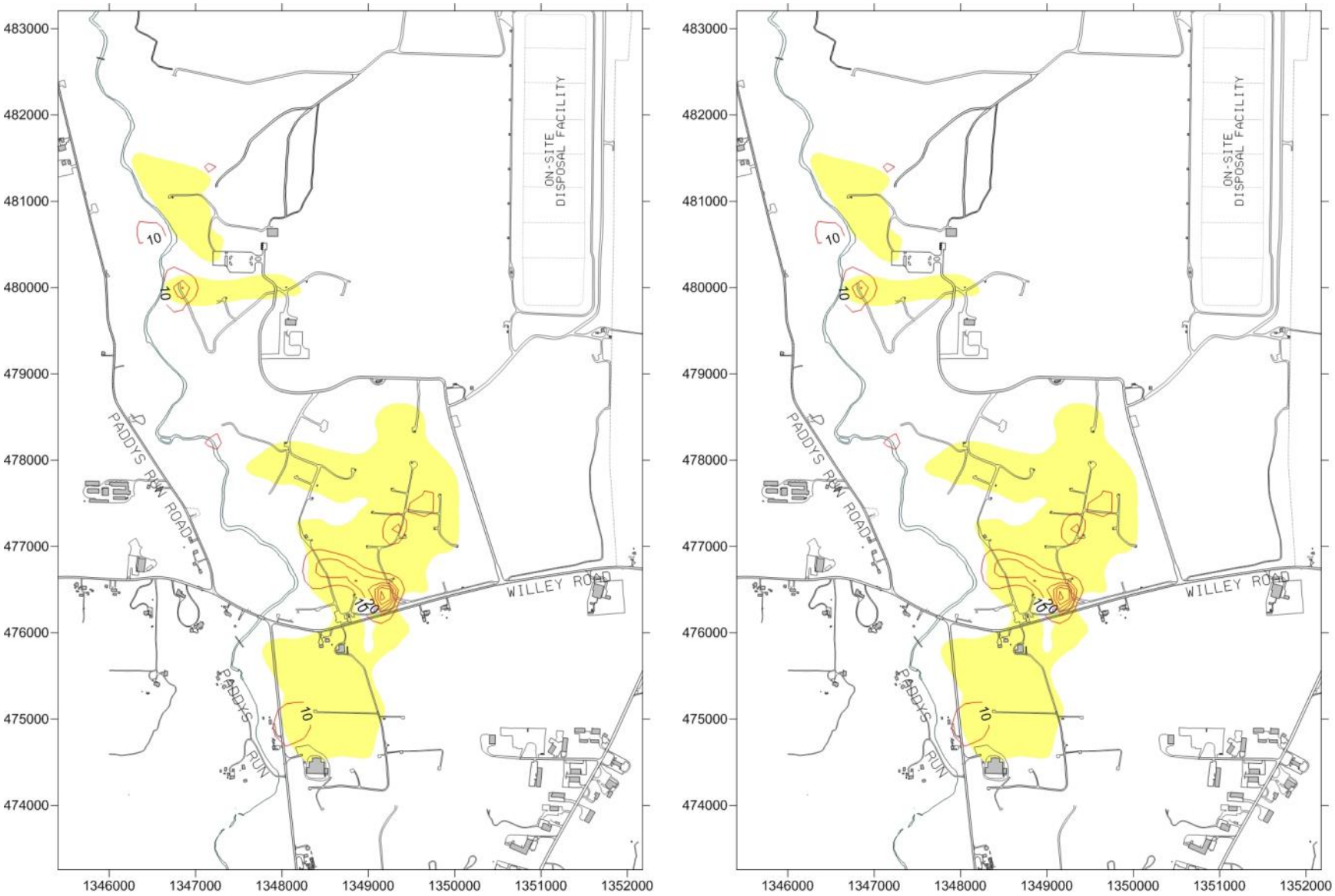


Figure A-70. Uranium Concentration Contours, Model Layer 8, April 2012

Alternative OA2, Wet Boundary Conditions, Yellow Shading Is Plume in December 2011

Alternative OA5c, Wet Boundary Conditions, Yellow Shading Is Plume in December 2011

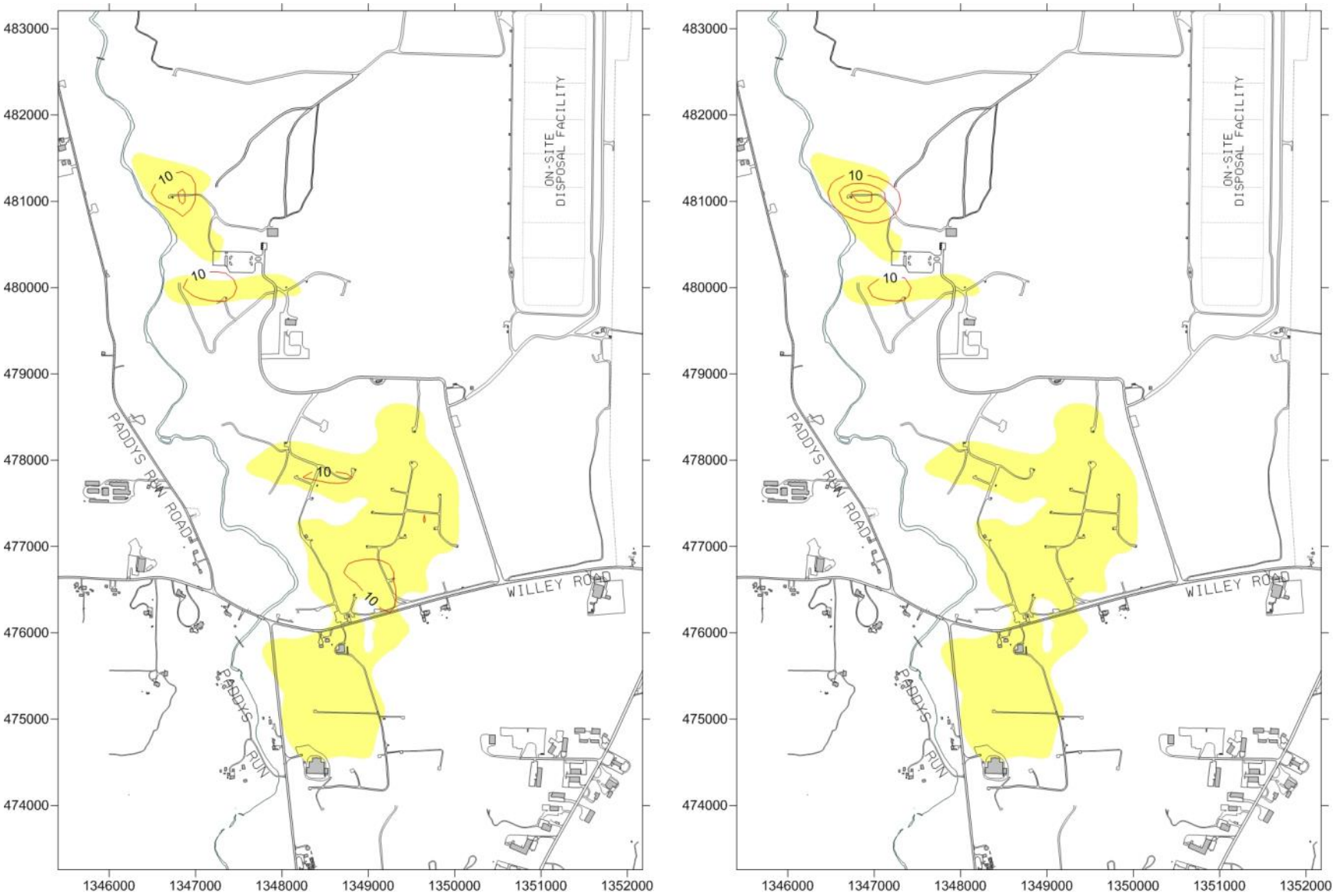


Figure A-71. Uranium Concentration Contours, Model Layer 8, April 2020

Alternative OA2, Wet Boundary Conditions, Yellow Shading Is Plume in December 2011

Alternative OA5c, Wet Boundary Conditions, Yellow Shading Is Plume in December 2011

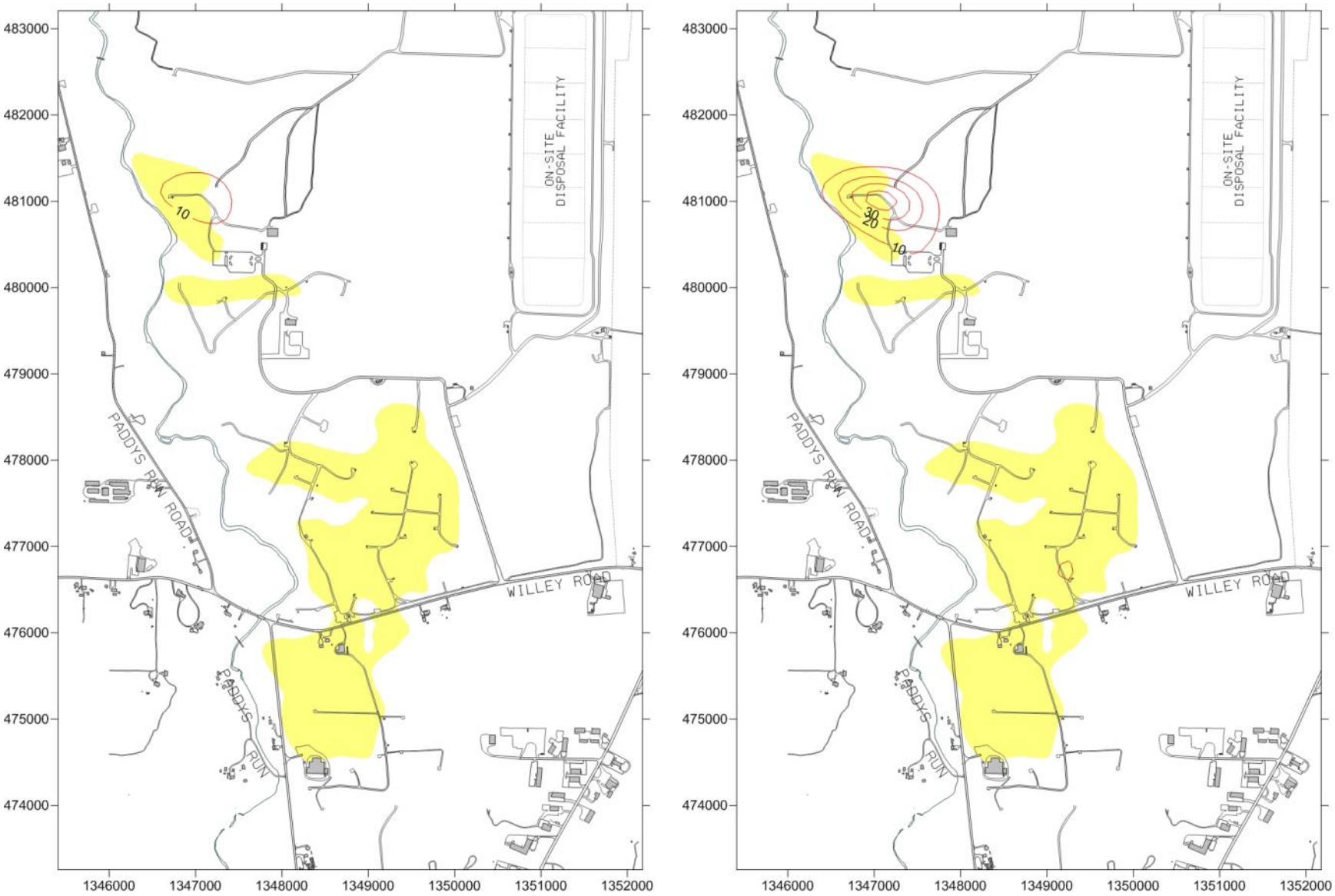


Figure A-72. Uranium Concentration Contours, Model Layer 8, April 2028

Alternative OA2, Wet Boundary Conditions, Yellow Shading Is Plume in December 2011

Alternative OA5c, Wet Boundary Conditions, Yellow Shading Is Plume in December 2011

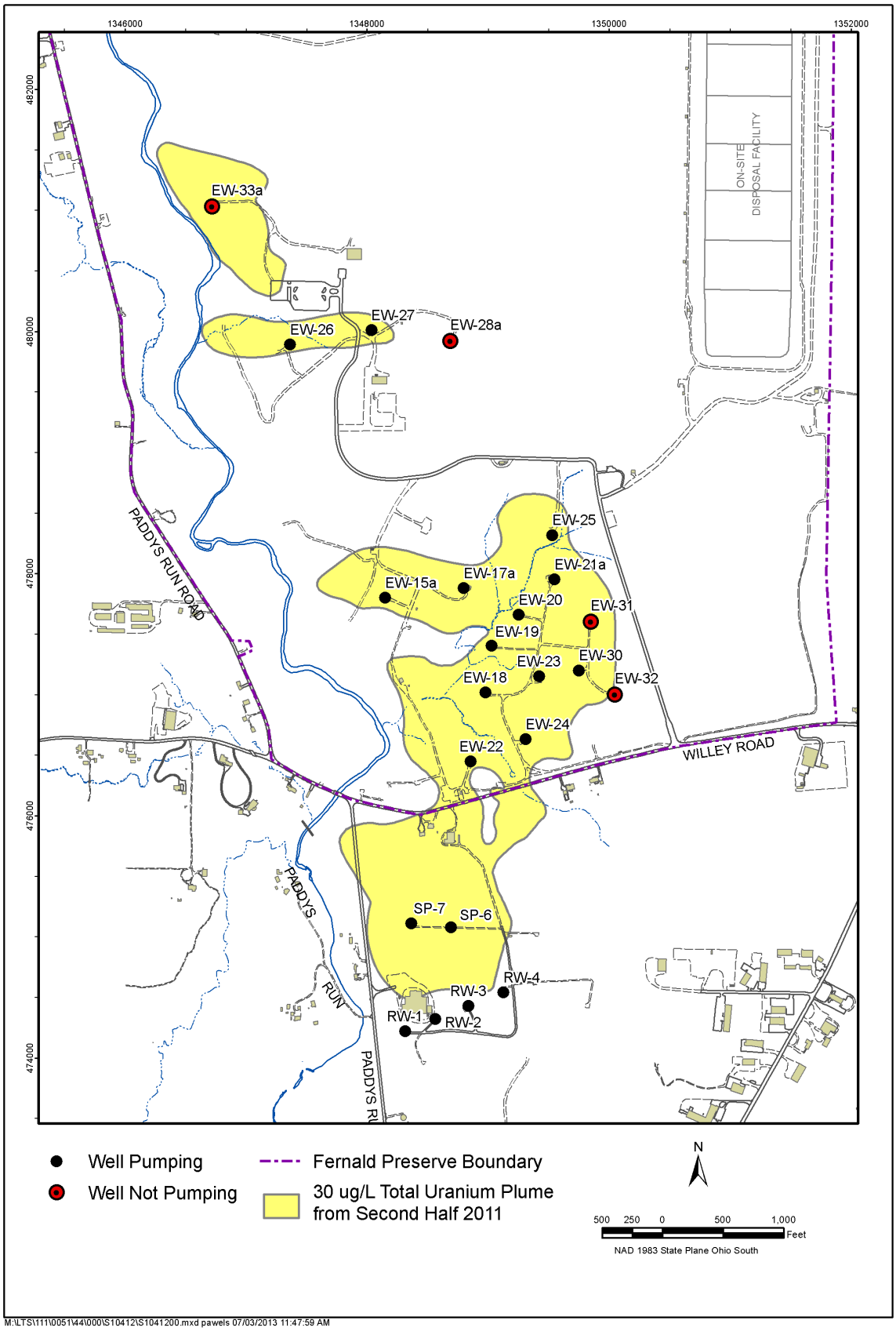


Figure A-73. Well Location Map for OA6

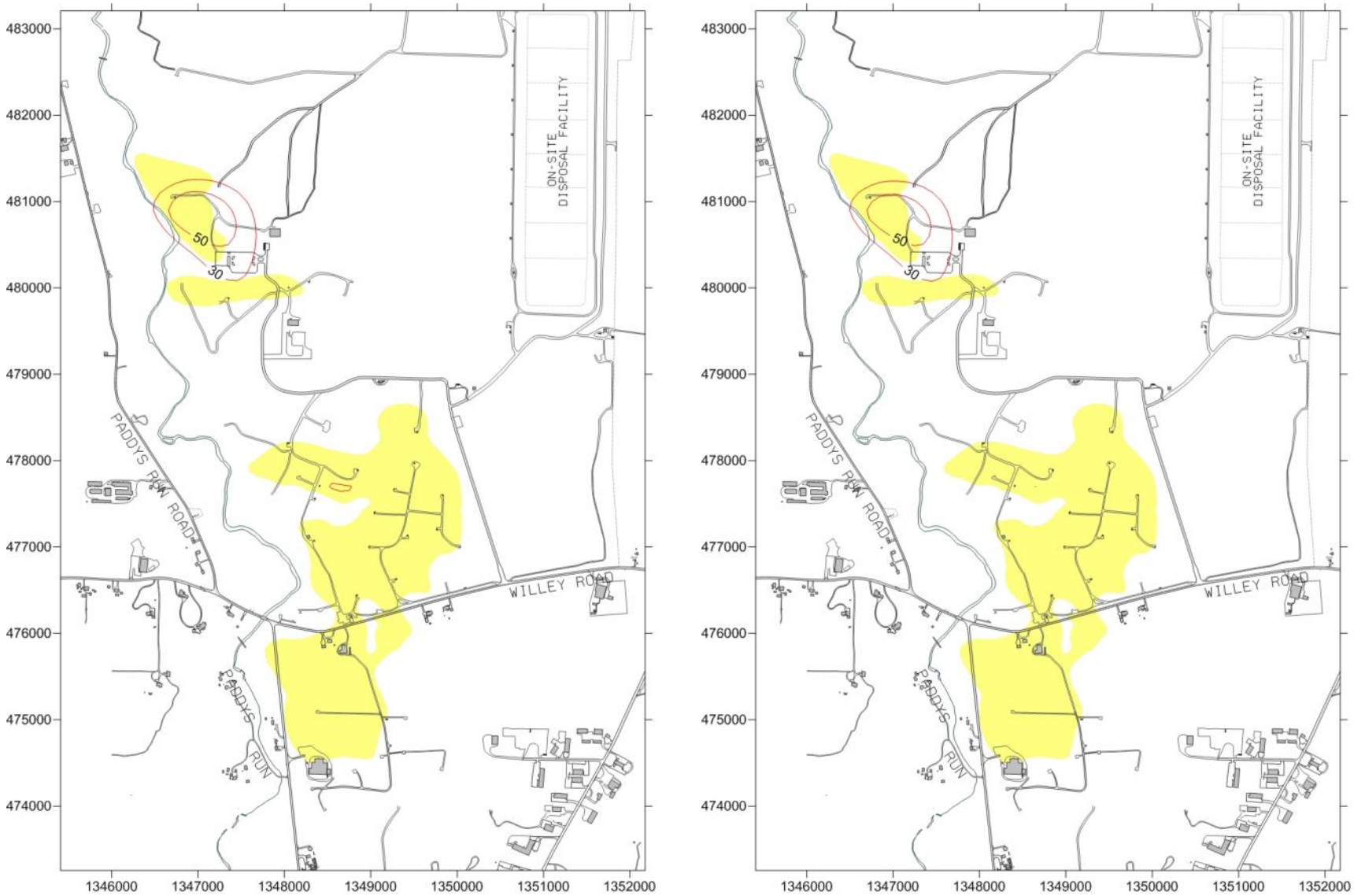
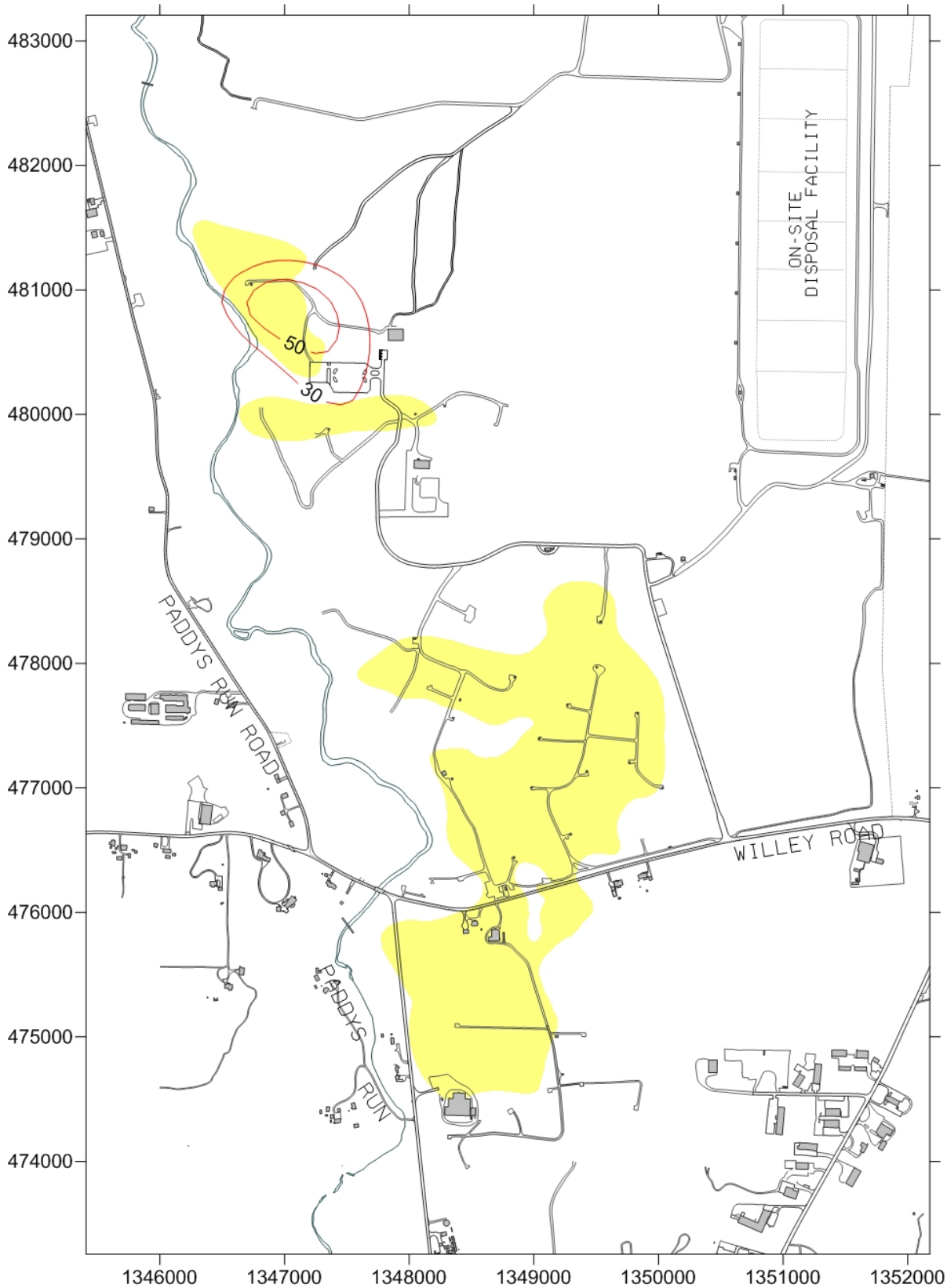


Figure A-74. Maximum Uranium Concentration Contours, Alternative OA6, Model Layers 7–12, South Field Clean

April 2030, Nominal Boundary Conditions, Yellow Shading Is Plume in December 2011

April 2031, Nominal Boundary Conditions, Yellow Shading Is Plume in December 2011



The red lines are uranium concentration contours. The yellow shading is the footprint of the maximum plume in December 2011.

Figure A-75. Modeled Uranium Plume, Alternative OA6, Layers 7–12, April 2031, Nominal Boundary Conditions

Table A-1. Estimate of Mass Removal Completeness Based on Pounds of Uranium Removed from the Aquifer

Year	Annual Uranium To Be Extracted From GMA (pounds) Based on Conc. Data	Annual Uranium To Be Extracted From GMA (pounds) Based on Model	Annual Uranium To Be Extracted From GMA (pounds) Based on 95% UCL
2013	455	366	1,426
2014	408	335	1,343
2015	365	307	1,265
2016	334	276	1,215
2017	300	247	1,143
2018	271	225	1,076
2019	244	208	1,013
2020	221	193	953
2021	201	180	898
2022	182	169	846
2023	166	159	797
2024	152	150	751
Total To Be Extracted	**3,299**	**2,815**	**12,725**
Pounds Already Extracted Through 12-31-2012	11,313	11,313	11,313
Total	**14,612**	**14,128**	**24,038**
% Complete Based on Pounds (2012)	**77**	**80**	47
% Complete Based on Pounds (2011)	**76**	**77**	45
% Complete Based on Pounds (2010)	75	74	43
% Complete Based on Pounds (2009)	72	70	41
% Complete Based on Pounds (2008)	69	66	39
% Complete Based on Pounds (2007)	66	61	37
% Complete Based on Pounds (2006)	59	55	33

95% UCL = 95% upper confidence level on the mean

Table A-2. Model-Predicted Uranium Concentrations for 2012 versus Geoprobe Data from 2011

Geoprobe Location	Model Layer	2011 Geoprobe Concentration (µg/L)	WSA Phase II Model Predictions—Model Year 2012		
			Dry Boundary Conditions Uranium Concentration (µg/L)	Nominal Boundary Conditions Uranium Concentration (µg/L)	Wet Boundary Conditions Uranium Concentration (µg/L)
13420	12	55.1	12.81	8.18	13.04
	11	85.0	15.46	11.33	14.15
	10	4.1	12.25	7.56	10.20
	9	4.9	7.75	3.97	5.86
13423	13	1.2	1.06	0.92	1.03
	12	3.7	3.38	0.81	2.54
	11	44.9	5.89	1.05	4.39
	10	3.5	4.58	0.76	2.90
	9	0.5	2.73	0.55	1.60
	8	2.7	1.40	0.41	0.80
13424	13	2.9	1.33	1.08	1.49
	12	22.7	7.38	2.99	7.05
	11	5.2	9.82	3.46	7.32
	10	9.7	7.52	2.16	4.86
	9	5.3	4.36	1.23	2.60
	8	5.7	1.93	0.65	1.09
	7	4.4	0.59	0.27	0.36
13425	13	2.6	4.18	3.05	5.60
	12	20.7	19.87	17.18	19.88
	11	33.2	21.45	18.91	20.70
	10	1.1	16.75	13.22	15.27
	9	0.5	10.73	7.20	9.00
	8	1.3	5.65	3.03	4.19
	7	1.6	1.85	0.87	1.25
13426	13	2.7	0.91	0.90	0.90
	12	0.5	1.34	0.75	0.80
	11	2.5	2.42	0.71	0.85
	10	0.5	1.88	0.62	0.63
	9	2.0	1.13	0.54	0.47
13297A	12	10.2	1.69	0.55	1.32
	11	0.5	3.30	0.53	2.15
	10	1.4	2.60	0.50	1.42
	9	0.8	1.51	0.47	0.85
13357A	12	46.9	13.41	8.31	13.34
	11	3.4	15.90	9.83	13.94
	10	1.3	12.28	6.49	9.77
	9	0.8	7.47	3.35	5.39
13421A	13	3.7	1.50	1.10	1.63
	12	116.0	6.52	3.22	6.36
	11	149.2	9.52	8.54	9.96
	10	5.1	7.57	4.58	6.87
	9	3.5	4.69	2.17	3.82
	8	7.2	2.57	1.10	1.92
	7	6.4	0.82	0.34	0.55

Table A-3. Pumping Rates, South Plume Alternatives

System/Well ID			WSA Phase II Design (gpm)	Alt-1 (gpm)	Alt-2 (gpm)	Alt-3 (gpm)	Alt-4 (gpm)	Alt-5 (gpm)	Alt-6 (gpm)	Alt-7 (gpm)	Alt-8 (gpm)	Alt-9 (gpm)	Alt-10 (gpm)
SP-1	RW-1	3924	200	200	200	200	200	200	200	200	200	200	200
SP-2	RW-2	3925	200	200	200	200	200	200	200	200	200	200	200
SP-3	RW-3	3926	200	200	200	200	200	200	200	200	200	200	200
SP-4	RW-4	3927	200	200	200	200	200	200	200	200	200	200	200
SP-6	RW-6	32308	200	**400**	**300**	**400**	200	200	200	200	200	200	**300**
SP-7	RW-7	32309	200	200	**300**	**400**	200	200	200	200	200	200	**300**
KN-1	NA	NA	0	0	0	0	0	0	**200**	**400**	**200**	**400**	**200**
South Plume Subtotal			1,200	1,400	1,400	1,600	1,200	1,200	1,400	1,600	1,400	1,600	1,600
SF-31	EW-15a	33262	200	200	200	200	200	200	200	200	200	200	200
SF-17	EW-17	31567	175	175	175	175	175	175	175	175	175	175	175
SF-18	EW-18	31550	100	100	100	100	100	100	100	100	100	100	100
SF-19	EW-19	31560	100	100	100	100	100	100	100	100	100	100	100
SF-20	EW-20	31561	100	100	100	100	100	100	100	100	100	100	100
SF-21	EW-21a	33298	200	200	200	200	200	200	200	200	200	200	200
SF-22	EW-22	32276	300	300	300	300	300	300	300	300	300	300	300
SF-23	EW-23	32447	300	300	300	300	300	300	300	300	300	300	300
SF-24	EW-24	32446	300	300	300	300	300	300	300	300	300	300	300
SF-25	EW-25	33061	100	100	100	100	100	100	100	100	100	100	100
SF-32	EW-30	33264	200	200	200	200	200	200	200	200	200	200	200
SF-33	EW-31	33265	300	300	300	300	300	300	300	300	300	300	300
SF-34	EW-32	33266	200	200	200	200	200	200	200	200	200	200	200
IW-11	NA	NA	0	0	0	0	**200**	**400**	0	0	**200**	**400**	0
South Field Subtotal			2,575	2,575	2,575	2,575	2,775	2,975	2,575	2,575	2,775	2,975	2,575
WSA-1	EW-26	32761	300	300	300	300	300	300	300	300	300	300	300
WSA-2	EW-27	33062	200	200	200	200	200	200	200	200	200	200	200
WSA-4	EW-28a	33334	200	200	200	200	200	200	200	200	200	200	200
WSA-5	EW-33a	33347	300	300	300	300	300	300	300	300	300	300	300
WSA Subtotal			1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Total Pumping			4,775	4,975	4,975	5,175	4,975	5,175	4,975	5,175	5,175	5,575	5,175

Red Font indicates a pumping rate change from the WSA Phase II Design

NA = Not Applicable

Table A-4. South Plume Alternative Results

South Plume Alternative	Alternative Description	Year South Plume Clean (Nominal Boundary Conditions)	Years to South Plume Cleanup (Nominal Boundary Conditions)	Figure Number
1	SP-6 @ 400	2019	7	Figure A-33
2	SP-6 and SP-7 @ 300	2019	7	Figure A-34
3	SP-6 and SP-7 @ 400	2019	7	Figure A-35
4	IW-11 @ 200	2020	8	Figure A-36
5	IW-11 @ 400	2020	8	Figure A-37
6	KN-1 @ 200	2020	8	Figure A-38
7	KN-1 @ 400	2019	7	Figure A-39
8	IW-11 & KN-1 @ 200	2020	8	Figure A-40
9	IW-11 & KN-1 @ 400	2019	7	Figure A-41
10	SP-6 and SP-7 @ 300 and KN-1 @ 200	2019	7	Figure A-42

Table A-5. Pumping Rates for OA1 Through OA4

System/Well ID			OA1 Pumping Rates (gpm)	OA2 Pumping Rates (gpm)	OA3 Pumping Rates (gpm)	OA4 Pumping Rates (gpm)
SP-1	RW-1	3924	0	0	0	0
SP-2	RW-2	3925	0	0	0	0
SP-3	RW-3	3926	0	0	0	0
SP-4	RW-4	3927	0	0	0	0
SP-6	RW-6	32308	0	0	0	0
SP-7	RW-7	32309	0	0	0	0
South Plume Subtotal			0	0	0	0
SF-31	EW-15a	33262	300	300	300	300
SF-17	EW-17	31567	175	175	175	175
SF-18	EW-18	31550	100	100	100	100
SF-19	EW-19	31560	100	100	100	100
SF-20	EW-20	31561	400	400	400	400
SF-21	EW-21a	33298	300	300	300	300
SF-22	EW-22	32276	400	400	400	400
SF-23	EW-23	32447	400	400	400	400
SF-24	EW-24	32446	300	300	300	300
SF-25	EW-25	33061	100	100	100	100
SF-32	EW-30	33264	400	400	400	400
SF-33	EW-31	33265	400	400	0	400
SF-34	EW-32	33266	200	200	0	200
South Field Subtotal			3,575	3,575	2,975	3,575
WSA-1	EW-26	32761	0	500	500	500
WSA-2	EW-27	33062	0	200	200	200
WSA-4	EW-28a	33334	0	300	300	0
WSA-5	EW-33a	33347	0	0	300	300
WSA Subtotal			0	1,000	1,300	1,000
Total Pumping			3,575	4,575	4,275	4,575

Table A-6. Pumping Rates, Optimization Alternatives OA5a Through OA5d, 2012 to South Plume Clean

System/Well ID			OA5a Pumping Rates (gpm)	OA5b Pumping Rates (gpm)	OA5c Pumping Rates (gpm)	OA5d Pumping Rates (gpm)
SP-1	RW-1	3924	200	200	200	200
SP-2	RW-2	3925	200	200	200	200
SP-3	RW-3	3926	200	200	200	200
SP-4	RW-4	3927	200	200	200	200
SP-6	RW-6	32308	300	300	300	300
SP-7	RW-7	32309	300	300	300	300
South Plume Subtotal			1,400	1,400	1,400	1,400
SF-31	EW-15a	33262	300	300	300	300
SF-17	EW-17	31567	175	175	175	175
SF-18	EW-18	31550	200	100	100	100
SF-19	EW-19	31560	100	200	100	100
SF-20	EW-20	31561	100	200	200	200
SF-21	EW-21a	33298	200	300	300	350
SF-22	EW-22	32276	400	300	300	300
SF-23	EW-23	32447	500	500	500	500
SF-24	EW-24	32446	400	300	400	350
SF-25	EW-25	33061	100	100	100	100
SF-32	EW-30	33264	400	400	400	400
SF-33	EW-31	33265	0	0	0	0
SF-34	EW-32	33266	0	0	0	0
South Field Subtotal			2,875	2,875	2,875	2,875
WSA-1	EW-26	32761	300	300	300	300
WSA-2	EW-27	33062	200	200	200	200
WSA-4	EW-28a	33334	0	0	0	0
WSA-5	EW-33a	33347	0	0	0	0
WSA Subtotal			500	500	500	500
Total Pumping			4,775	4,775	4,775	4,775

Table A-7. Pumping Rates for Alternative OA5c

System/Well ID			Pumping Rates (gpm)		
			2012—South Plume Clean	**South Plume Clean to South Field Clean**	**South Field Clean to End**
SP-1	RW-1	3924	200	0	0
SP-2	RW-2	3925	200	0	0
SP-3	RW-3	3926	200	0	0
SP-4	RW-4	3927	200	0	0
SP-6	RW-6	32308	300	0	0
SP-7	RW-7	32309	300	0	0
South Plume Subtotal			1,400	0	0
SF-31	EW-15a	33262	300	400	0
SF-17	EW-17	31567	175	175	0
SF-18	EW-18	31550	100	0	0
SF-19	EW-19	31560	100	300	0
SF-20	EW-20	31561	200	400	0
SF-21	EW-21a	33298	300	400	0
SF-22	EW-22	32276	300	0	0
SF-23	EW-23	32447	500	0	0
SF-24	EW-24	32446	400	0	0
SF-25	EW-25	33061	100	300	0
SF-32	EW-30	33264	400	0	0
SF-33	EW-31	33265	0	0	0
SF-34	EW-32	33266	0	0	0
South Field Subtotal			2,875	1,975	0
WSA-1	EW-26	32761	300	500	500
WSA-2	EW-27	33062	200	300	300
WSA-4	EW-28a	33334	0	0	0
WSA-5	EW-33a	33347	0	0	0
WSA Subtotal			500	800	800
Total Pumping			4,775	2,775	800

Table A-8. Pumping Rates for Alternative OA6

System/Well ID			Pumping Rates (gpm)		
			2012—South Plume Clean	South Plume Clean to South Field Clean	South Field Clean to End
SP-1	RW-1	3924	200	0	0
SP-2	RW-2	3925	200	0	0
SP-3	RW-3	3926	200	0	0
SP-4	RW-4	3927	200	0	0
SP-6	RW-6	32308	300	0	0
SP-7	RW-7	32309	300	0	0
South Plume Subtotal			1,400	0	0
SF-31	EW-15a	33262	200	200	0
SF-17	EW-17	31567	175	175	0
SF-18	EW-18	31550	100	100	0
SF-19	EW-19	31560	100	100	0
SF-20	EW-20	31561	100	100	0
SF-21	EW-21a	33298	200	200	0
SF-22	EW-22	32276	300	300	0
SF-23	EW-23	32447	300	300	0
SF-24	EW-24	32446	300	300	0
SF-25	EW-25	33061	100	100	0
SF-32	EW-30	33264	200	200	0
SF-33	EW-31	33265	0	0	0
SF-34	EW-32	33266	0	0	0
South Field Subtotal			2,075	2,075	0
WSA-1	EW-26	32761	300	500	500
WSA-2	EW-27	33062	200	300	300
WSA-4	EW-28a	33334	0	0	0
WSA-5	EW-33a	33347	0	0	0
WSA Subtotal			500	800	800
Total Pumping			3,975	2,875	800

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Table A-9. TestPump Output for Well Field Systems,
Modified Baseline with May 2013 Uranium Concentrations

South Plume Module		
Well ID	Pumping Rate (gpm)	Total U Concentration (ppb)
RW-1	200	17.3
RW-2	200	16.7
RW-3	200	19.8
RW-4	200	3.8
RW-6	300	31.4
RW-7	300	29.0
S. Plume	1400	21.2

South Field Module		
Well ID	Pumping Rate (gpm)	Total U Concentration (ppb)
EW 15A	300	30.6
EW 17a	175	18.2
EW 18	100	38.5
EW 19	100	18.6
EW 20	200	28.5
EW 21a	300	42.7
EW 22	300	26.0
EW 23	500	45.7
EW 24	400	40.8
EW 25	100	27.6
EW 30	400	43.4
EW 31	0	13.2
EW 32	0	4.9
S. Field	2875	36.1

Waste Storage Area Module		
Well ID	Pumping Rate (gpm)	Total U Concentration (ppb)
EW 26	300	29.5
EW 27	200	31.8
EW 28a	0	9.3
EW 33 a	300	24.8
WSA/PPDD	800	28.3

Sorted Well List	T=Treat S = Split B = Bypass X = Not Pumping	Groundwater to Treatment	Groundwater to Bypass
EW 23	B	0	500
EW 30	B	0	400
EW 21a	B	0	300
EW 24	B	0	400
EW 18	B	0	100
EW 27	B	0	200
EW 15A	B	0	300
EW 26	B	0	300
EW 20	B	0	200
EW 25	B	0	100
EW 22	B	0	300
EW 33 a	B	0	300
S. Plume	B	0	1400
EW 19	B	0	100
EW 17a	B	0	175
EW 31	X	0	0
EW 28a	X	0	0
EW 32	X	0	0

Groundwater to Treatment (gpm)	Concentration to Treatment (ppb)
0	0.0

Total Pumping All Systems (gpm)
5075

Groundwater to Bypass (gpm)	Concentration to Bypass (gpm)
5075	30.7

Groundwater Bypass Mass/Day (lbs)	Groundwater Bypass Mass/Year (lbs)
1.9	683.0

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Department of Energy
Washington, DC 20585

April 1, 2014

Mr. Timothy Fischer
U.S. Environmental Protection Agency
Region V-SRF-6J
77 W. Jackson Blvd.
Chicago, IL 60604-3590

Mr. Thomas A. Schneider
Ohio Environmental Protection Agency
401 East 5th Street
Dayton, Ohio 45402

Dear Mr. Fischer and Mr. Schneider:

SUBJECT: Transmittal of Response to Ohio Environmental Protection Agency Comments on the Operational Design Adjustments-1 WSA Phase-II Groundwater Remediation Design, Fernald Preserve, October 2013 and Revised Document

REFERENCE: Letter, T. Schneider to G. Hooten, "Draft Comments – Operational Design Adjustments-1, WSA Phase-II Groundwater Remediation Design, Fernald Preserve, October 2013, dated December 20, 2013

Enclosed for your review and approval are responses to Ohio Environmental Protection Agency (Ohio EPA) comments on the Operational Design Adjustments-1 WSA Phase-II Groundwater Remediation Design, Fernald Preserve, October 2013 and a revised document that incorporates the comment responses.

The enclosed comment responses and revised document represents the outcome of a series of informal emails and meetings involving LM and Ohio EPA between January 16 and February 28, 2014.

Please call me at (513) 648-3333 if you have any questions regarding either the comment responses or revised document. Please address any correspondence to:

U.S. Department of Energy
Office of Legacy Management
10995 Hamilton-Cleves Highway
Harrison, OH 45030

Printed with soy ink on recycled paper

Sincerely,

Gwendolyn Hooten
Fernald Preserve Site Manager
DOE-LM-20.2

Enclosure

cc w/enclosure:
T. Schneider, OEPA (three copies of enclosure)
File: FER 115.02.05(A) (rc ohio)
Administrative Records (thru B. Irvine)

cc w/o enclosure:
(electronic)
K. Reed, DOE
D. Shafer, DOE
K. Broberg, Stoller
B. Hertel, Stoller

Responses to Ohio EPA Comments on the Operational Design Adjustments-1, WSA Phase II-Groundwater Remediation Design, Fernald Preserve, October 2013

General Comments

1. Commenting Organization: Ohio EPA
Section: General
Comment: Please add an anticipated timeframe to general statements in the Executive Summary, the Introduction, the Summary, and elsewhere that proposed pumping modifications will "result in a remedy that meets cleanup standards sooner..."

Response: The Executive Summary, Introduction, and the Summary have been revised as requested, and the report is being re-issued as final.

Action: As stated in the response.

2. Commenting Organization: Ohio EPA
Section: General
Comment: According to the proposal (Executive Summary, the Introduction, the Modified Baseline Alternative section, and the Summary), pumping saved through shutdown of WSA well EW-28A and South Field extraction wells EW-31 and EW-32 will be reallocated to the "southern portion of the South Field." In the proposal discussion please identify the locations of the three proposed wells, as specified in Appendix 5.0 and depicted in Figure A-22. Please modify the proposal to clarify that wells are proposed not only in the southern portion of the South Field (wells IW-10 and IW-11), but also in the South Plume (well KN-1).

Response: The report has been revised as requested. Figures 1 and 3 identify the three wells proposed for shutdown. Table 2 identifies pumping changes. The report is being re-issued as final.

Action: As stated in the response.

Specific Comments

3. Commenting Organization: Ohio EPA
Section: Section 5.0 Page: 17
Comment: Please add discussion addressing how uranium cleanup of the South Plume underlying Wiley Road will be achieved, despite an apparent lack of ten-year capture zone interception under both current and Modified Baseline Alternative pumping conditions. Appendix Section A.3.2.1.2 notes that the latest Five-Year Review Report (2011) stated that extraction system changes might be needed to address this stagnation zone. As shown in Modified Baseline Alternative Figures 4 and 5, no ten-year particle traces for the "2012 to South Plume Clean" time period intercept the Wiley Road area.

Response: The requested discussion has been added to Section 5.1. Water level contours were added to Figures 4 and 5 to aid the discussion. The report is being re-issued as final.

Action: As stated in the response.

4. Commenting Organization: Ohio EPA
Section:
Comment: Please provide explanation as to why the Wiley Road stagnation zone area will not be intercepted under the Modified Baseline Alternative (Figures 4 and 5). With an additional 700 gpm of pumping proposed amongst three new wells to be located in the southern portion of the South Field and the South Plume, and with a proposed pumping increase at South Plume extraction wells RW-6 and RW-7, the South Plume capture area would be expected to increase.

Response: This comment is similar to Comment 3. Please see response to Comment 3.

Action: Please see response to Comment 3..

5. Commenting Organization: Ohio EPA
Section:
Comment: Please clarify why the Wiley Road stagnation area referenced in this proposal is not depicted in the Site Environmental Report (see Figure A.3-5, Appendix A.3, 2012). According to the SER, the entirety of the uranium plume is intercepted under current pumping conditions, including the Wiley Road stagnation area.

Response: This comment is similar to Comment 3. Please see response to Comment 3.

Action: Please see action to Comment 3.

6. Commenting Organization: Ohio EPA
Section: 5.1 Page: 18
Comment: Please clarify the apparent discrepancy between predicted timeframes for South Plume cleanup under the Modified Baseline Alternative. According to the second paragraph, cleanup will be achieved in 9 years. However, according to the table at the top of the page, the South Plume cleanup date is year 2020, which would equate to 6 years presuming start-up beginning in 2014.

Response: As explained on the bottom of page 10; the operational adjustments recommended in this report were modeled as beginning in 2012. Therefore, model-predicted cleanup dates are based on the 2012 start date. If the operational adjustments are implemented, completion dates will need to be

adjusted to take into consideration the actual start date. Revisions have been made to Section 5 to clarify timeframes. The report is being re-issued as final.

Action: As stated in the response.

7. Commenting Organization: Ohio EPA
Section: 5.1 Page: 29
Comment: This section states changes to the pumping would be discussed with the agencies. Ohio EPA believes this type of change will require review and approval by the agencies not just discussion.

Response: Agree. Text has been revised to read as follows: "Any proposed pumping change that results in a remedy design modification will require review and approval by both EPA and Ohio EPA prior to implementation." The report is being re-issued as final.

Action: As stated in the response.

8. Commenting Organization: Ohio EPA
Section: 5.1 Page: 29
Comment: The potential uranium discharge concentrations and mass are closer to the limits than they have been in a number of years. It will be essential to have the treatment system operational to make sure limits are not exceeded. Ohio EPA believes it may be oversimplifying to suggest no or limited treatment will be needed.

Response: Agree. DOE has a current commitment to maintain a treatment capacity of 500 to 600 gpm. This treatment capacity is anticipated to be more than adequate to address any treatment needs created by adopting the Modified Baseline Alternative pumping rates. Also, please note that numerous years of operational experience and familiarity with the Testpump spreadsheet were factored into the conclusion that little or no treatment will be required in order to meet discharge limits.

DOE anticipates additional discussions with EPA and Ohio EPA regarding wastewater treatment will be occurring in the next year or two as the current facility (CAWWT) was only intended to operate until ~2012. The age and condition of CAWWT are such that DOE intends to complete condition assessment and alternatives analysis for the facility in the next year. DOE will keep the EPA and Ohio EPA informed regarding the condition assessment /alternatives analysis and will seek EPA/Ohio EPA input and approval regarding any changes to the currently agreed to treatment capacity of 500 to 600 gpm.

Action: As noted in the response

9. Commenting Organization: Ohio EPA
Section: 5.1 Page: 29

Comment: In order to track progress of the Modified Baseline Alternative, Ohio EPA recommends the proposal discussion be modified to include provisions for reporting at least three measures of success annually as follows: 1) predicted average annual uranium mass removal as shown in Appendix Table A-1; 2) predicted average annual uranium discharge concentration; and 3) annually measured capture zone expanse. Ohio EPA recommends these measures be compared to predicted goals and reported annually for each year of system operation.

Response: Section 5 has been revised to state that these metrics will be addressed annually. The report is being re-issued as final.

Action: As stated in the response.

10. Commenting Organization: Ohio EPA
Section: 5.2 Page: 30
Comment: The second bullet suggests the proposed alternative will clean up the South Filed approximately 8 years earlier however the table on page 18 suggest no more than 1 year will be saved in any project area over the baseline. Please clarify this discrepancy.

Response: The text actually states "will clean up of the ***southern*** South Field approximately 8 years earlier than predicted under the Baseline Alternative." The table on page 18 only compares overall South Field cleanup between the two alternatives because under the Baseline Alternative the South Field is treated as one area. Under the Modified Baseline Alternative the South Field is treated as two areas; north and south. Revisions have been made to Section 5 to clarify this. The report is being re-issued as final.

Action: As stated in the response.

11. Commenting Organization: Ohio EPA
Section: 6.0 Page: 30
Comment: Ohio EPA disagrees with the third bullet and believes it is inappropriate to contemplate MNA for the WSA plume. Additional characterization and modelling of the plume and its source are necessary as well as evaluation of active remediation options prior to any consideration of MNA.

Response: The intent of the bullet is to propose that MNA be further evaluated. DOE agrees with Ohio EPA that additional characterization and modeling are necessary as well as evaluation of active remediation options in order to have a productive discussion on the potential future use of MNA.

Action: No action required.

12. Commenting Organization: Ohio EPA
Section: 6.3 Page: 32

Comment: A typographical error appears to exist in the last sentence of the first paragraph of page 32. Ohio EPA recommends the words "lower" and "higher", in relation to the discussion of modeled water levels, be reversed to state as follows: "higher water levels (resulting in potentially failing certification due to concentration rebound when the pumping stops) and lower water levels (with the potential in some cases for pulling uranium into deeper portions of the aquifer)."

Response: Section 6.3 has been revised to address this comment. The report is being re-issued as final.

Action: As stated in the response.