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MAY 1 2 2015

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Ms. April Webb
Acting Interim Federal Facility Agreement Manager
Division of Waste Management
Kentucky Department for Environmental Protection
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Frankfort, Kentucky 40601

Dear Ms. Corkran and Ms. Webb:

TRANSMITTAL OF THE SITEWIDE EVALUATION REPORT FOR THE SOILS OPERABLE UNIT AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY (DOE/LX/07-1256&D1)

Please find enclosed for your review the certified *Sitewide Evaluation Report for the Soils Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1256&D1.

If you have any questions or require additional information, please contact David Dollins at (270) 441-6819.

Sincerely,

Jennifer Woodard

Jennifer Woodard
Paducah Site Lead
Portsmouth/Paducah Project Office

Enclosures:

1. Certification Page
2. D1 Sitewide Evaluation Report

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CERTIFICATION

Document Identification: ***Sitewide Evaluation Report for the Soils Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah Kentucky*, DOE/LX/07-1256&D1**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

LATA Environmental Services of Kentucky, LLC

Mark J. Duff, Paducah Project Manager

5-12-15
Date Signed

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

U.S. Department of Energy

Jennifer Woodard, Site Lead
Portsmouth/Paducah Project Office

5/12/2015
Date Signed

DOE/LX/07-1256&D1
Primary Document

Sitewide Evaluation Report for the Soils Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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Primary Document

Sitewide Evaluation Report for the Soils Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—May 2015

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
LATA ENVIRONMENTAL SERVICES OF KENTUCKY, LLC
managing the
Environmental Management Activities at the
Paducah Gaseous Diffusion Plant
under contract DE-AC30-10CC40020

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PREFACE

This *Sitewide Evaluation Report for the Soils Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1256&D1, which is part of the Soils Operable Unit (OU), was prepared to document the identification of any previously unknown contaminated areas that may require evaluation under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and for completing the Resource Conservation and Recovery Act Environmental Indicators process for human exposure to soil at the Paducah Gaseous Diffusion Plant (PGDP). This report was prepared in order to comply with Section IX of the PGDP Federal Facility Agreement (FFA) (EPA 1998), as agreed upon among the FFA parties and documented in the Site Management Plan (SMP) (DOE 2014a). The SMP defined the scope and provided key planning assumptions. This evaluation included a radiological survey and visual walkover survey to cover U.S. Department of Energy (DOE)-owned property outside the Limited Area at PGDP [including property licensed to the Commonwealth of Kentucky and managed by West Kentucky Wildlife Management Area (WKWMA)] that is not designated as a solid waste management unit (SWMU) or area of concern (AOC). (Aerial surveys of the portion of WKWMA property that is owned by the Commonwealth of Kentucky also were evaluated. Based upon this evaluation, radiological and visual walkover surveys of this area were not needed.) This evaluation also included a focused radiological survey and judgmental sampling effort performed for 25 of the previously identified 534 anomalies covering DOE-owned property outside the Limited Area at PGDP to validate the conclusions of the previous effort. The April 2008 letter from DOE to KDWM presents a flowchart prepared as a condition to be met for DOE to receive an Environmental Indicator (EI) of “Yes” with regard to the Government Performance and Results Act milestone of having human exposures under control (DOE 2008a). The Flow Chart for Uncertainty Management was used to evaluate the data collected for this sitewide evaluation. The radiological survey and visual walkover survey information was evaluated, along with the focused radiological survey and judgmental sampling effort performed for the 25 selected anomalies covering DOE-owned property outside the Limited Area at PGDP. The conclusion from the evaluation of the results of the surveys and their associated analyses is that no areas were identified that require either CERCLA evaluation under the PGDP FFA or designation as SWMUs or AOCs. The results demonstrate that these anomalies do not represent unknown areas of contamination that pose a threat to the public or environment. Considering this information, empirical data were obtained to complete step one of the Flow Chart for Uncertainty Management; however, the data establish that there is no contamination present in any areas where it previously was not present. No further evaluation is necessary in accordance with the flowchart steps; therefore, the information used to conclude that “Human exposures are under control,” is not challenged by new information and supports a continued categorization of “Yes” for this EI.

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CONTENTS

FIGURES

TABLES

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ACRONYMS

ANSI	American National Standards Institute
AOC	area of concern
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cpm	counts per minute
DCGL	derived concentration guideline level
$DCGL_W$	DCGL for average concentrations over a wide area, used with statistical tests
DEM	digital elevation model
DOE	U.S. Department of Energy
EI	Environmental Indicator
EPA	U.S. Environmental Protection Agency
FFA	Federal Facility Agreement
FIDLER	Field Instrument for the Detection of Low-Energy Radiation
FS	feasibility study
GPS	Global Positioning System
KDFWR	Kentucky Department of Fish and Wildlife Resources
LiDAR	Light Detection and Ranging
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
N/A	not available
OU	operable unit
PAL	project action level
PGDP	Paducah Gaseous Diffusion Plant
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RGA	Regional Gravel Aquifer
RI	remedial investigation
RPD	relative percent difference
SAP	sampling and analysis plan
SER	site evaluation report
SMP	Site Management Plan
SWMU	solid waste management unit
WAG	waste area grouping
WKWMA	West Kentucky Wildlife Management Area
XRF	X-ray fluorescence

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EXECUTIVE SUMMARY

This Sitewide Evaluation Report presents the results of the comprehensive effort completed for areas outside the Limited Area and surrounding the Paducah Gaseous Diffusion Plant (PGDP) on U.S. Department of Energy (DOE)-owned property [including property licensed to the Commonwealth of Kentucky and managed by West Kentucky Wildlife Management Area (WKWMA)] and areas owned by the Commonwealth of Kentucky and managed by WKWMA. The overall project objectives were to identify unknown contaminated areas originating from PGDP that may require Comprehensive Environmental Response, Compensation, and Liability Act evaluation and to develop information for determining Environmental Indicators (EIs) used for measuring the Resource Conservation and Recovery Act Corrective Action process.

To meet the project objectives, a number of survey efforts, including a recent confirmatory field effort, were conducted. An aerial radiological survey was conducted from October 28–November 2, 2009, over the PGDP and surrounding area, encompassing an area of approximately 25 square miles. The purpose of the survey was to measure the terrestrial radiological environment within and around the PGDP. An aerial survey, which included aerial photography, topographic mapping, digital orthophotos, and Light Detection and Ranging, encompassed an area of approximately 32 square miles. The purpose of this survey was to provide surface contours and images that aided in identification of anomalies. No anomalies were identified on Commonwealth of Kentucky-owned property by the aerial surveys; therefore, no visual or radiological surveys were performed for Commonwealth of Kentucky-owned property based upon evaluation of the results of the aerial surveys.

Radiological and visual walkover surveys were conducted over DOE-owned property (including property licensed to the Commonwealth of Kentucky), encompassing an area of approximately 2,676 acres. The purpose of these surveys was to identify anomalies visually and to complete a radiological scoping survey of the entire area with a targeted radiological survey of anomalies. These surveys were completed between January 5, 2009, and April 23, 2010, in accordance with the *Sitewide Evaluation Work Plan at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0228&D2 (DOE 2011a).

Anomalies are defined as any area that exhibits two times instrument background and/or are piles, dips, debris, or other potentially man-made disturbances. There were 633 anomalies identified by the visual walkover on DOE-owned property. After crosswalking the anomalies with previously identified anomalies, 99 were found to be part of previous evaluations/investigations and were not evaluated further in this effort. The remaining 534 new anomalies were evaluated as part of this Sitewide Evaluation. Based on the results of the walkover surveys, all of the 534 anomalies were less than the radiological criterion of two times instrument background in the work plan.

DOE completed the 2009–2010 surveys and no previously unknown contaminated areas were identified, no areas were found to have radiological readings greater than twice instrument background, and no areas required removal based on criteria established in the work plan. Consistent with Federal Facility Agreement (FFA) (EPA 1998) and the approaches set forth in the National Contingency Plan, the results of this evaluation determined that no removal or remedial actions are required for the 534 anomalies identified and there is no need to establish solid waste management unit (SWMU) assessment reports.

A confirmatory field effort was executed from October 2014 to January 2015 that included a focused radiological survey and judgmental sampling effort for 25 of the previously identified 534 anomalies to validate the conclusions of the previous 2009–2010 field effort. This evaluation was completed in accordance with the *Sitewide Evaluation Work Plan for Anomalies Located Outside the Limited Area at* *the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1288&D2 (DOE 2014b). This evaluation validated the conclusions from the previous 2009–2010 field effort.

The April 2008 letter from DOE to KDWM presents a flowchart prepared as a condition to be met for DOE to receive an EI of "Yes" with regard to the Government Performance and Results Act milestone of having human exposures under control (DOE 2008a). The Flow Chart for Uncertainty Management was used to evaluate the data collected for this Sitewide Evaluation. The radiological survey and visual walkover survey information was evaluated, along with the focused radiological survey and judgmental sampling effort performed for the 25 selected anomalies covering DOE-owned property outside the Limited Area at PGDP. The conclusion from the evaluation of the results of the surveys and their associated analyses is that no areas were identified that required either further Comprehensive Environmental Response, Compensation, and Liability Act evaluation under the PGDP FFA or designation as SWMUs or areas of concern. The results demonstrate that these anomalies do not represent unknown areas of contamination that pose a threat to the public or environment. Considering this information, empirical data were obtained to complete step one of the Flow Chart for Uncertainty Management; however, the data establish that there is no contamination present in any areas where it was unknown before this investigation. No further evaluation is necessary in accordance with the flowchart steps; therefore, the information used to conclude that "Human exposures are under control," is not challenged by new information and supports a continued categorization of "Yes" for this EI.

1. INTRODUCTION

1.1 PROJECT SCOPE

This *Sitewide Evaluation Report for the Soils Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1256&D1 (SER), documents work performed as part of the Soils Operable Unit (OU) under two field efforts. The first occurred in 2009–2010 and was conducted to identify previously unknown contaminated areas originating from the Paducah Gaseous Diffusion Plant (PGDP) that may require evaluation under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and for completing the Resource Conservation and Recovery Act (RCRA) Environmental Indicator (EI) process for human exposure to soil at PGDP. The second effort occurred in 2014–2015 and was a focused radiological survey and judgmental sampling effort planned for 25[1] selected anomalies to validate the conclusions from the previous 2009–2010 field effort.

The terms solid waste management unit (SWMU) and area of concern (AOC) are defined in the Paducah Federal Facility Agreement (FFA) (EPA 1998) as follows:

> SWMU means any discernible unit at which solid wastes have been placed at any time, irrespective of whether the unit was intended for the management of solid or Hazardous Waste. Such units include any area at a facility at which routine and systematic releases of hazardous wastes or hazardous constituents has occurred.
>
> AOC shall include any area having a probable or known release of a hazardous waste, hazardous constituent or hazardous substance which is not from a solid waste management unit and which poses a current or potential threat to human health or the environment. Such areas of concern may require investigations and remedial action, in accordance with the requirements of this Agreement.

According to the Site Management Plan (SMP) (DOE 2014a), the "scope of the project includes a survey of the U.S. Department of Energy (DOE)-owned property outside the limited/controlled area. A sitewide evaluation will be performed to identify any unknown contaminated areas requiring further CERCLA evaluation and to develop information usable when completing the RCRA EIs process." Within this document, Limited Area and controlled area both refer to the fenced portion of DOE-owned property. The following are key DOE Planning Assumptions from the Life Cycle Baseline provided in the SMP. The flyover radiological survey in assumption (1) is presented in Figure 1.1, and the radiological walkover and visual walkover surveys in assumptions (2) and (4) are presented in Figure 1.2.

(1) A flyover rad survey has been conducted for a 25-square mile area.

(2) A visual walkover survey covered DOE-owned property that is outside the controlled area and not currently a SWMU/AOC (approximately 2,676 acres). DOE property licensed to Western Kentucky Wildlife Management Area (WKWMA) and areas owned by WKWMA identified as anomalies in the flyover also will be surveyed.

(3) Visual observation was used to identify piles, spills, buried materials, and other anomalies.

[1] Twenty-five is 5% of overall total anomalies (i.e., approximately 500).

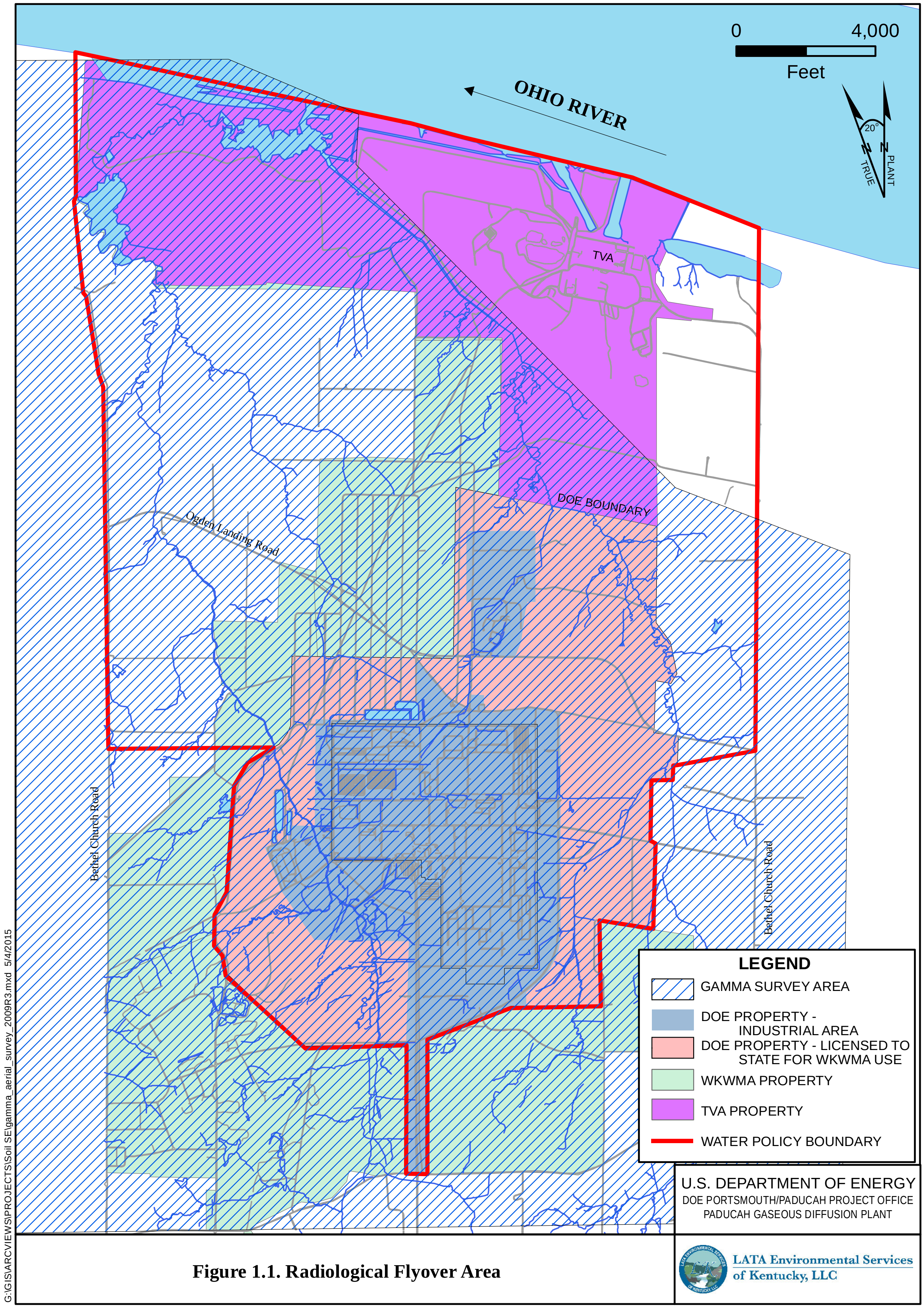

Figure 1.1. Radiological Flyover Area

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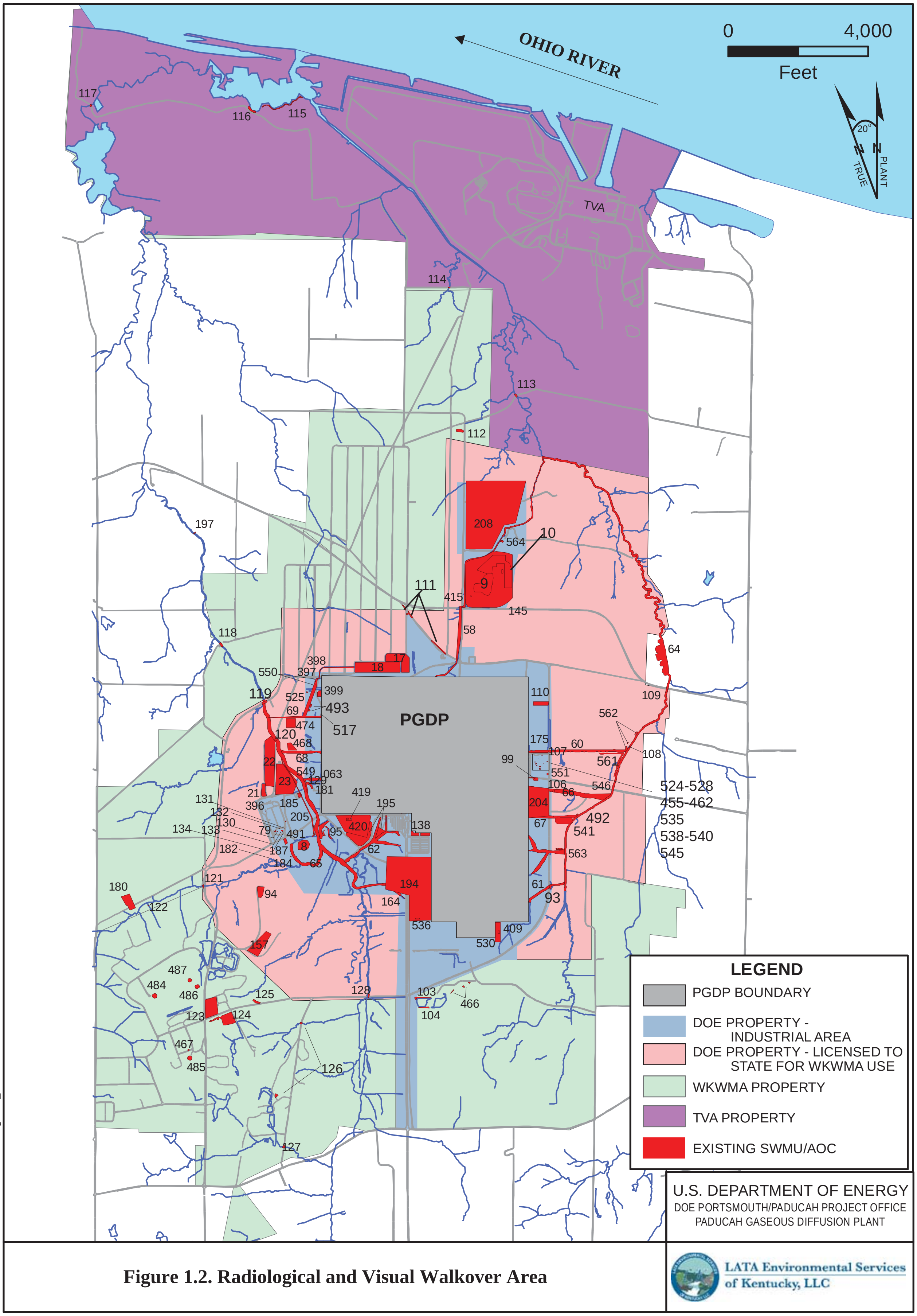

Figure 1.2. Radiological and Visual Walkover Area

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Date: 05-04-2015

(4) A radiological walkover survey using Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) approach covered at least 10% of the property identified above (approximately 240 acres). All anomalies identified have been scanned regardless of what percentage of land they cover.

(5) All anomalies have been documented on a map and in a database, including location, description, photo, and data.

(6) Analytical sampling has been conducted if the rad scan indicates contamination (i.e., 2X background) or a release is visually identified.

(7) Information will be documented in a SER. SWMU assessment reports will be attached to the SER for any new SWMUs/AOCs identified during this evaluation.

(8) Any newly identified SWMUs/AOCs will be addressed in the Soils OU Remedial Action (pre-PGDP shutdown). A separate removal action will not be performed.

(9) The D2 Sitewide Evaluation Work Plan will be modified via addendum to incorporate discussion among the FFA parties on May 25, 2012. Characterization activities required, based upon these discussions, will be conducted, results of the characterization activities will be discussed with the FFA parties, and the appropriate path forward will be incorporated into the D1 SER.

The SMP further states: "the FFA parties agree to survey 15 locations with highest counts per minute and 10 locations with the greatest delta in counts per minute per Kentucky's proposal for the Soils OU Sitewide sampling, dated May 25, 2012. The locations will be determined by the FFA parties prior to implementation. Upon completion of the survey, the surveys will be mapped, and X-ray fluorescence (XRF) sample for total uranium will be collected from the highest survey reading at each of the 25 locations." It was agreed during 2014 scoping that a new work plan (DOE 2014b), instead of an addendum, would be developed. Also during 2014 scoping, the identification of the 25 anomalies (Figure 1.3) deviated from the criteria outlined in the SMP. An integrated ranking method, as described in Section 4 of the Sitewide Evaluation Work Plan (DOE 2014b), and site walkdowns performed by the FFA parties during 2014 scoping were used to identify the 25 anomalies.

1.2 PROJECT OBJECTIVES

The objective of the 2009–2010 field effort was to identify unknown contaminated areas originating from PGDP requiring CERCLA evaluation and to provide information for completing the RCRA EI process for human exposure to soil at PGDP. The work plan was tailored to include additional steps for soil sampling based on the visual and radiological survey results. Specifically the evaluation was designed to obtain data to support the following objectives:

- Identify anomalies on DOE-owned and Commonwealth of Kentucky-owned property and confirm DOE origin;

- For anomalies confirmed to be of DOE origin, establish the presence or absence of DOE-related contaminants [metals, polychlorinated biphenyls (PCBs), and radionuclides];

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Figure 1.3. Locations of Selected Anomalies

- Collect data and screen to determine if the anomalies may pose risks to human health under current use scenarios and to support future decisions; and

- Determine appropriate path forward per the FFA (EPA 1998).

Anomalies were defined as any area that exhibits two times instrument radiological background and/or were piles, dips, debris, or other potential man-made disturbances.

The objective of the 2014–2015 field effort was to evaluate a subset of all of the previously identified anomalies to determine if additional evaluation was required of the other anomalies. The 25 selected anomalies served as proxies for the remaining 509 identified anomalies. This activity relied on radiological walkover survey and *ex situ* XRF analysis to measure total uranium concentration associated with the selected anomalies. Total uranium was used as a surrogate for other contaminants due to its being the primary radiological constituent found at PGDP.

1.3 REGULATORY OVERVIEW

PGDP was placed on the National Priorities List on May 31, 1994. In accordance with Section 120 of CERCLA, DOE entered into an FFA with the U.S. Environmental Protection Agency (EPA) Region 4 and Kentucky. The FFA established one set of consistent requirements for achieving comprehensive site remediation in accordance with CERCLA and RCRA, including stakeholder involvement.

DOE is responsible for environmental management activities associated with PGDP and serves as the lead agency for response actions at PGDP. EPA Region 4 and Kentucky Department for Environmental Protection serve as the regulatory oversight agencies for the facility.

This report was prepared in order to comply with Section IX of the PGDP FFA, as agreed on among the FFA managers and documented in the SMP. In accordance with the FFA, this report uses historical and recently acquired aerial photographs, along with systematic inspections and field data to determine if there was a potential for any previously unknown contaminated areas originating from PGDP. The examination of the data generated during the site evaluation resulted in determining that the sites inspected do not pose a threat to public health and the environment. The manner in which the data was collected and evaluated is explained in detail in the following sections of this report.

1.4 PROJECT BACKGROUND

Based on previous experience, anomalies were expected to consist of bare soil areas, soil piles, and rubble areas. Many of the soil piles and rubble areas are not investigated herein, but are being investigated under other aspects of the Soils OU (DOE 2014a) and are located adjacent to PGDP outfalls, Little Bayou and Bayou Creeks, along the unnamed tributary, and the North-South Diversion Ditch. Previously unidentified contaminated areas were expected to be found near surface water drainages, near the edges of woods, and near roadways. Proximity to surface water drainage could result in several potential secondary exposure routes that, if resulting from a contaminated area, could impact human health and the environment. The majority of the secondary routes assume that contaminated soils have been released to adjacent waterways. Precipitation could result in contaminant migration; however, PGDP historical monitoring data over the past 5–10 years indicates little migration is occurring because contaminant levels in surrounding creeks are stable or decreasing.

The 20-plus-year history of environmental investigation of soils and surface water at PGDP has resulted in defining DOE-indicator contaminants as metals, PCBs, and radionuclides. Based on experience gained through execution of the other aspects of the Soils OU (DOE 2007a; DOE 2007b; DOE 2008b; DOE 2008c; DOE 2008d; DOE 2008e; DOE 2009a; DOE 2009b; DOE 2009c), and as discussed in the work plan (DOE 2011a), the presence or absence of volatile organic compounds and polycyclic aromatic hydrocarbons can be assumed using these DOE-indicator contaminants.

1.5 CONCEPTUAL SITE MODEL

Recreational activities known to take place in parts of the evaluation area include hunting and field trials (horses and dogs). Other recreational uses, such as hiking, also are possible; therefore, recreational user exposure to surface soils is the primary exposure pathway. The recreational user could be exposed to contaminants by contact with surface soils through the following exposure routes:

- External exposure (ionizing radiation)
- Dermal contact
- Incidental ingestion
- Inhalation

Industrial workers[2] have potential for being exposed to soils on the DOE-owned property under investigation; however, this would not be on a regular basis. Exposure would be limited to performance of tasks associated with site evaluation, maintenance, and remedial action. In areas outside the Limited Area, the recreational user[3] and outdoor worker would have a greater opportunity for exposure to contaminants than the industrial worker.

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[2] The exposure frequency/duration for the industrial worker is 250 days/year for 25 years (DOE 2011).
[3] The exposure frequency/duration for the teen recreator is 140 days/year for 12 years (DOE 2011).

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2. AREA DESCRIPTION

PGDP, located within the Jackson Purchase region of western Kentucky, is an inactive uranium enrichment facility owned by DOE. PGDP first was owned and managed by the Atomic Energy Commission and the Energy Research and Development Administration, DOE's predecessors; DOE then managed PGDP until 1993. On July 1, 1993, the United States Enrichment Corporation assumed management and operation of the PGDP enrichment facility under a lease agreement with DOE until October 2014. DOE retains ownership of the enrichment complex. Figure 2.1 illustrates PGDP and surrounding area.

Of the 3,423 acres plus 133 acres of easements (total 3,556 acres) owned by DOE, approximately 650 acres of this parcel are inside the PGDP fenced area. Most of the facilities formerly used to support enrichment operations are located in this area. Outside PGDP, several support facilities for the DOE missions can be found. The support facilities include landfills (both active and closed), modular office complexes, a water treatment facility, groundwater remediation systems, decontamination facilities, storage areas, a storm water retention basin, and liquid effluent treatment facilities. Of the remaining DOE land, approximately 1,986 acres is licensed to the Commonwealth of Kentucky Department of Fish and Wildlife Resources (KDFWR) and serves as a portion of the WKWMA. The licensed portion of the WKWMA is used by the public for hunting and horse and dog field trials. KDFWR staff work in the licensed area performing wildlife management activities.

The topography of DOE property is level to slightly rolling. It is rural and predominantly open grasslands with scattered wooded areas of mature hardwoods and brush. Approximately 60% of the total area outside PGDP but on DOE-owned property is grasslands; much of this nonwooded area contains electrical power lines.

Two creeks—Bayou Creek and Little Bayou Creek—pass through DOE-owned property, draining north into the Ohio River. Multiple permitted drainage outfalls and ditches from PGDP discharge to these two creeks. There are approximately 36,100 ft of combined drainage ditches and creeks that potentially have been impacted by PGDP discharges. Areas in and near outfall ditches were surveyed previously and are posted appropriately.

Contamination sources may be present within the WKWMA that are not of DOE origin; for example, the former Kentucky Ordnance Works occupies an area of the WKWMA southwest of PGDP. Substantial work has been performed in areas on DOE-owned property to identify and appropriately manage material originating from PGDP. Ongoing efforts are being performed under the Soils OU, Surface Water OU, and Burial Grounds OU. Under the Soils OU and of relevance to this sitewide evaluation are the work efforts that have been performed in support of soils and rubble area evaluations. Results of historical studies of rubble areas at PGDP and surrounding areas are presented in five reports (IT Corp. 1989; PGDP 1992; CH2M HILL 1992; DOE 1995; DOE 1997, DOE 2008e, DOE 2009a, DOE 2009b, DOE 2009c, DOE 2011b).

Metals, radionuclides, and PCBs are the primary DOE-indicator contaminants for pre-PGDP shutdown. The Soils OU focuses on accessible surface soils [ground surface to 10 ft below ground surface (bgs) and 16 ft bgs in the vicinity of pipelines] (DOE 2014a). A series of Soils OU actions have been completed to date and a removal action for soils at SWMUs 19 (C-410-B HF Neutralization Lagoon) and 181 (C-218 Outdoor Firing Range) has been completed as a CERCLA non-time-critical removal action (DOE 2010a).

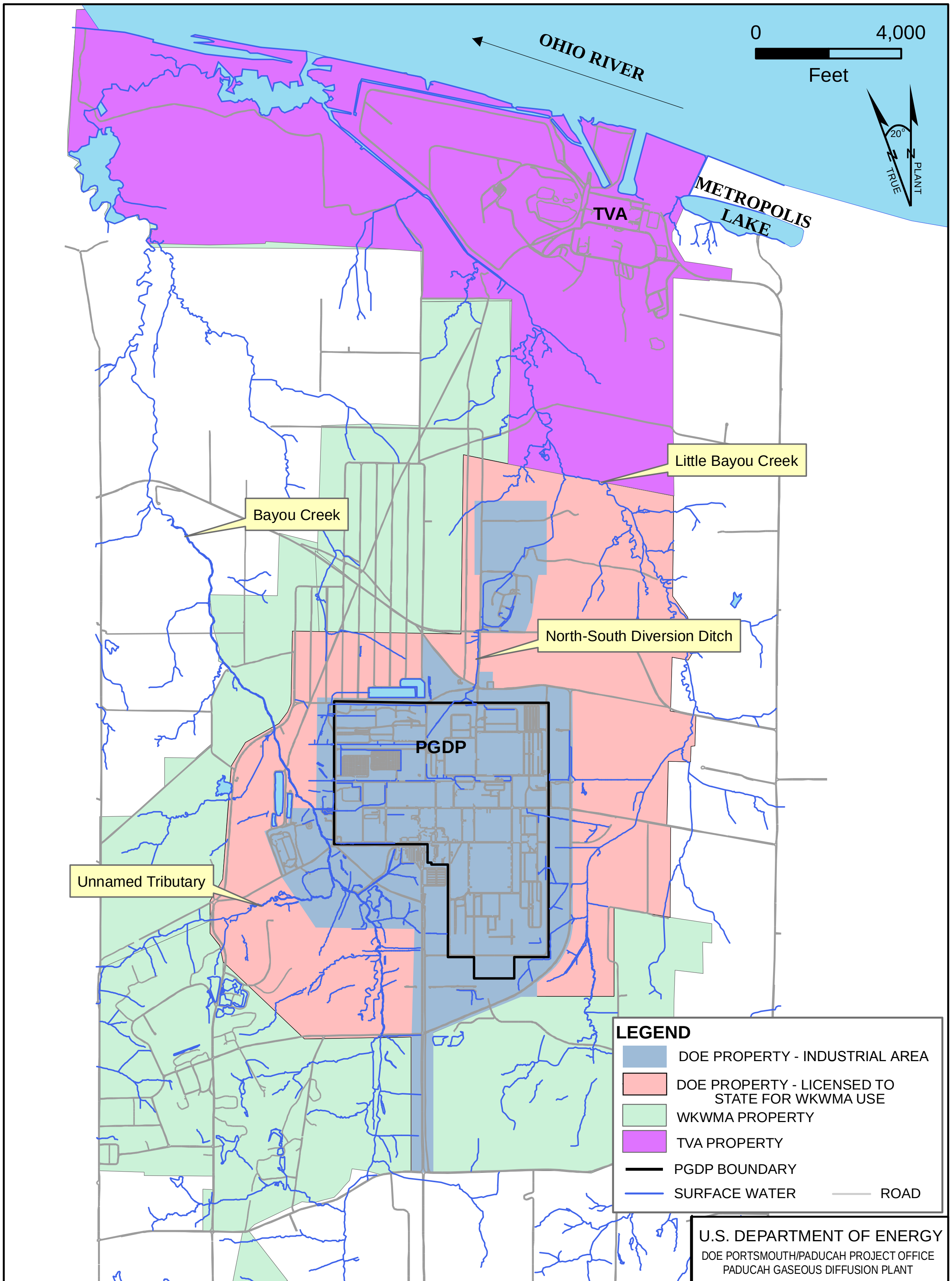

Figure 2.1. Map of PGDP and Surrounding Area

LATA Environmental Services of Kentucky, LLC

On November 2, 2006, DOE and its remediation contractor radiological control technicians and Kentucky Division of Waste Management personnel observed and surveyed a series of soil piles on DOE-owned property. As a result of a comprehensive survey conducted by DOE in 2007, additional soil and rubble areas were identified in a letter for possible inclusion as SWMUs/AOCs (DOE 2007c). This letter, dated February 17, 2007, noted that "a total of 150 areas, consisting of soil and rubble have been identified to date." Of those 150 areas, 28 areas previously had been identified as SWMUs or AOCs and 13 areas had sufficient data to make a SWMU or AOC determination, leaving 109 areas (85 soil areas and 24 rubble areas) to be evaluated. The letter contained a planning schedule for characterization and notification for the soil and rubble areas on DOE-owned property. The evaluation of all soil and rubble areas was incorporated into the SMP under the Soils OU. All of the soil areas were on DOE-owned property whereas only 6 of the 24 rubble areas were on DOE-owned property. All of the soil and rubble areas described above, as well as two additional soil piles (AOCs 492 and 541), were evaluated and the results reported in the following documents.

- Soil Piles Sampling and Analysis Plan (SAP) (DOE 2007a) and associated addenda
- Addendum 1-A—SAP (DOE 2007b); SER (DOE 2008b)
- Addendum 1-B—SAP (DOE 2008c); SER (DOE 2009a)
- Addendum 2—SAP (DOE 2008d); SER (DOE 2009b)
- Rubble Areas SAP (DOE 2008e); SER (DOE 2009c).

SWMU assessment reports that were developed and submitted with the SERs were incorporated into the Soils OU Remedial Investigation (RI)/Feasibility Study (FS) Work Plan (DOE 2010b). The Soils OU RI/FS Work Plan was approved and implemented (DOE 2010b). An addendum to the Soils OU RI/FS Work Plan also was approved and implemented (DOE 2014c). Remedial actions will be addressed in the upcoming CERCLA documents that follow the Soils OU RI Report (DOE 2011b) and the subsequent RI Report currently in development.

2.1 GEOLOGY AND SOILS

PGDP is located in the Jackson Purchase region of western Kentucky, which represents the northern tip of the Mississippi Embayment portion of the Coastal Plain. The Jackson Purchase region is an area of land that includes all of Kentucky west of the Tennessee River. The stratigraphic sequence in the region consists of Cretaceous, Tertiary, and Quaternary sediments unconformably overlying Paleozoic bedrock.

Relative to the shallow groundwater flow system in the vicinity of PGDP, the continental deposits and the overlying loess and alluvium are of key importance. The continental deposits locally consist of an upper silt member, with lesser sand and gravel interbeds, and a thick, basal sand and gravel member, which fills a buried river valley. A subcrop of the Porters Creek Clay, located beneath and immediately south of PGDP marks the southern extent of the buried river valley. Fine sand and clay of the McNairy Formation directly underlie the continental deposits. These continental deposits are continuous from beneath PGDP northward beyond the present course of the Ohio River.

The general soil map for Ballard and McCracken counties indicates that three soil associations are found within the vicinity of PGDP (USDA 1976): the Rosebloom-Wheeling-Dubbs association, the Grenada-Calloway association, and the Calloway-Henry association. The predominant soil association in the vicinity of PGDP is the Calloway-Henry association, which consists of nearly level, somewhat poorly drained, medium-textured soils on upland positions. Many of the characteristics of the original soil have been lost due to industrial activity that has occurred over the past 50-plus years. Activities that have disrupted the original soil classifications include filling, mixing, and grading. The soil type present in these disturbed areas is characterized as urban.

2.2 HYDROGEOLOGY

PGDP is located in the western portion of the Ohio River drainage basin, approximately 15 miles downstream of the confluence of the Ohio River with the Tennessee River and approximately 35 miles upstream of the confluence of the Ohio River with the Mississippi River. Locally, PGDP is within the drainage areas of the Ohio River, Bayou Creek, and Little Bayou Creek.

PGDP is situated on the divide between the two creeks. Bayou Creek is a perennial stream on the western boundary of the plant that flows generally northward, from approximately 2.5 miles south of the plant site to the Ohio River. Little Bayou Creek becomes a perennial stream at the east outfalls of PGDP. The Little Bayou Creek drainage originates within WKWMA and extends northward and joins Bayou Creek near the Ohio River. The drainage basins for both creeks are located in rural areas; however, they receive surface drainage from numerous swales that drain residential and commercial properties, including WKWMA, PGDP, and Tennessee Valley Authority Shawnee Fossil Plant. The confluence of the two creeks is approximately 3 miles north of the plant site, just upstream of the location at which the combined flow of the creeks discharges into the Ohio River (DOE 2006).

Most of the flow within Bayou and Little Bayou Creeks is from process effluents or surface water runoff from PGDP. Contributions from PGDP comprise approximately 85% of flow within Bayou Creek and near 100% of flow within Little Bayou Creek. A network of ditches discharges effluent and surface water runoff from PGDP to the creeks. Plant discharges are monitored at the Kentucky Pollutant Discharge Elimination System outfalls prior to discharge into the creeks.

The local groundwater flow system at PGDP occurs within the sands of the Cretaceous McNairy Formation, Pliocene Terrace Gravel, Plio-Pleistocene lower continental gravel deposits and upper continental deposits, and Holocene alluvium. The primary local aquifer is the Regional Gravel Aquifer (RGA). The RGA consists of the Quaternary sand and gravel facies of the lower continental deposits and Holocene alluvium found adjacent to the Ohio River and is of sufficient thickness and saturation to constitute an aquifer. These deposits have an average thickness of 30 ft. Groundwater flow is predominantly north toward the Ohio River (DOE 2006).

3. DATA EVALUATION

3.1 2009–2010 DATA EVALUATION

Radiological and visual walkover surveys were conducted to identify anomalies on DOE-owned property outside the Limited Area (including property licensed to the Commonwealth of Kentucky). Anomalies were identified based on the following criteria:

- Radiological readings at greater than twice instrument background, or
- A release visually identified, or
- Process knowledge.

Anomalies identified by the visual walkover survey were radiologically surveyed. Readings were compared to criteria (i.e., two times instrument background) established for the survey.

In addition to the criteria above, results of a radiological flyover survey and an aerial (topography) flyover survey were evaluated. This evaluation was completed to identify anomalies on Commonwealth of Kentucky-owned property. Maps produced by the radiological flyover survey were examined for indications of elevated radioactivity indicating potential anomalies that could be attributed to DOE activity. Photographs produced by the aerial flyover survey were examined along with historical aerial photographs to identify anomalies based on earth disturbance, unnatural earth mounds, or rubble material. No anomalies were identified on Commonwealth of Kentucky-owned property through this evaluation.

3.2 2014–2015 DATA EVALUATION

Radiological surveys were conducted to identify a sample location from either a surface soil location with adjacent high count rate measurements or a location with a single high count rate measurement. The radiological survey surface soil data set was collected for each selected anomaly as outlined in the Survey Plan for Anomalies Located Outside the Limited Area at the Paducah Gaseous Diffusion Plant within Appendix A of the *Sitewide Evaluation Work Plan for Anomalies Located Outside the Limited Area at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1288&D2 (DOE 2014b). For simplicity, Appendix A is referred to as the "Survey Plan."

In order to aid in selection of the locations or areas within an anomaly with the highest count rate, probability plots were constructed of count rate [counts per minute (cpm)] vs. cumulative probability (percent) for each anomaly using the radiological survey data set collected in accordance to the Survey Plan. Graphical probability plots were used to identify data above an inflection/break point or data greater than the 95% level if an inflection/break point was not easily discernable. Probability plots could have single or multiple inflection/break points, which could indicate multiple locations or areas with different natural or anthropogenic subpopulations. Because the purpose of the radiological survey was to identify the locations or areas with the highest count rate, the count rate association with the last inflection/break point or 95% level always was used to separate the data set.

The following steps were used to analyze the survey data sets in order to identify the highest count rate areas or locations within an anomaly.

- The logged survey data was downloaded to a Microsoft Excel file from the Field Instrument for the Detection of Low-Energy Radiation (FIDLER)/Global Positioning System (GPS) coupled system. The downloaded data set included fields for the gross count rate data in cpm and State Plane coordinates (feet), Kentucky South. The data fields also included time stamps and other fields related to the survey.

- The Microsoft Excel file containing the downloaded survey data set for the anomaly was converted to a comma delimited Excel file.

- The comma delimited Excel survey data set file for the anomaly was imported into and overlaid on a PGDP base map (State Plane, feet) constructed using ArcGIS 10.1.

- Using ArcGIS, the data for the anomaly was assessed for coverage as indicated in the Survey Plan. If the coverage was determined to be sufficient for the anomaly, a probability plot and inflection/break point analysis was conducted for the anomaly's survey data set to identify data greater than the last inflection/break point or 95% level.

- The survey data set for the anomaly was used to develop a probability plot by the following steps:

  (a) The survey gross count rate and coordinate data for the anomaly were ordered by applying the SORT function in the Data pull down menu of Excel.

  (b) The PERCENTRANK.EXC in the Formula pull down menu was used to return the rank of the gross count rate, cpm, for the data set as a percentage of the data set.

  (c) The probability plot, Figure 3.1, was developed from the gross count rate, cpm, and the percent (0 to 1) for the data set.

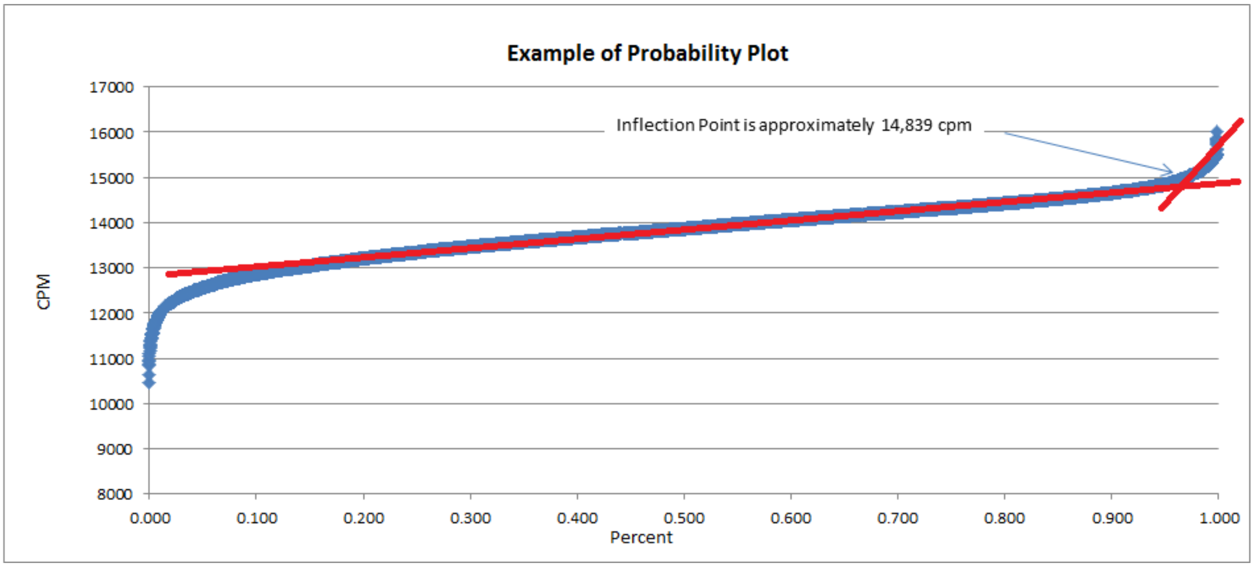

Figure 3.1. Example of Probability Plot for Determination of Inflection/Break Point

- In accordance with the Survey Plan, the count rate associated with the inflection/break point was chosen from the probability plot; however, if the anomaly survey data set lacked a discernable inflection/break point the 95% value was chosen for the data set.

- The gross count rate data, greater than either the inflection/break point or the 95% value, was extracted from the data set and was overlaid on the anomaly's survey gross count rate data ArcGIS map developed for the anomaly.

- In order to determine the locations and areas with the highest count rate from the extracted data within an anomaly, the following approach was employed:

  (a) The counting uncertainty was determined for the maximum count rate level for the extracted data above the inflection/break point or 95% (Type B evaluation of uncertainty, Chapter 19, NUREG-1576).

  (b) A coverage factor of two (twice the counting uncertainty) for the maximum count rate level was used to determine the locations and areas within the anomaly with a count rate that fell within the coverage factor for the highest count rate.

- Once locations and areas within the anomaly were selected based on the previous steps, a confirmation survey per the Survey Plan, using the same detector/GPS-coupled system, was performed for each of the selected locations and areas that fell within the coverage factor for the highest count rate.

- Using the ArcGIS map developed for the anomaly from the survey data set and the inflection/break point analysis data set, the gross count rate data set from the confirmation survey for each location and area within the anomaly was overlaid on the anomaly.

- Utilizing the ArcGIS mapped data sets overlay that included the original survey sample data set, the inflection point/break point analysis data set, and the confirmation survey data set, a location was chosen from either a location with adjacent high count rate measurements or a location with a single high count rate measurement.

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4. INVESTIGATION SUMMARY

4.1 INVESTIGATION OVERVIEW

Four types of surveys were performed during the 2009–2010 field effort to identify anomalies that were defined in the work plan as any area that exhibits two times instrument radiological background and/or were piles, dips, debris, or other potential man-made disturbances. On DOE-owned property outside the Limited Area at PGDP (including property licensed to the Commonwealth of Kentucky), identification of anomalies was by radiological and visual walkover surveys, with anomalies determined to be of DOE origin by any of the following:

- Radiological readings at greater than twice instrument background; or
- A release is visually identified; or
- Process knowledge.

Property owned by the Commonwealth of Kentucky was subjected to radiological and aerial photographic flyover surveys. Figure 4.1 is the decision flowchart from the work plan (DOE 2011a).

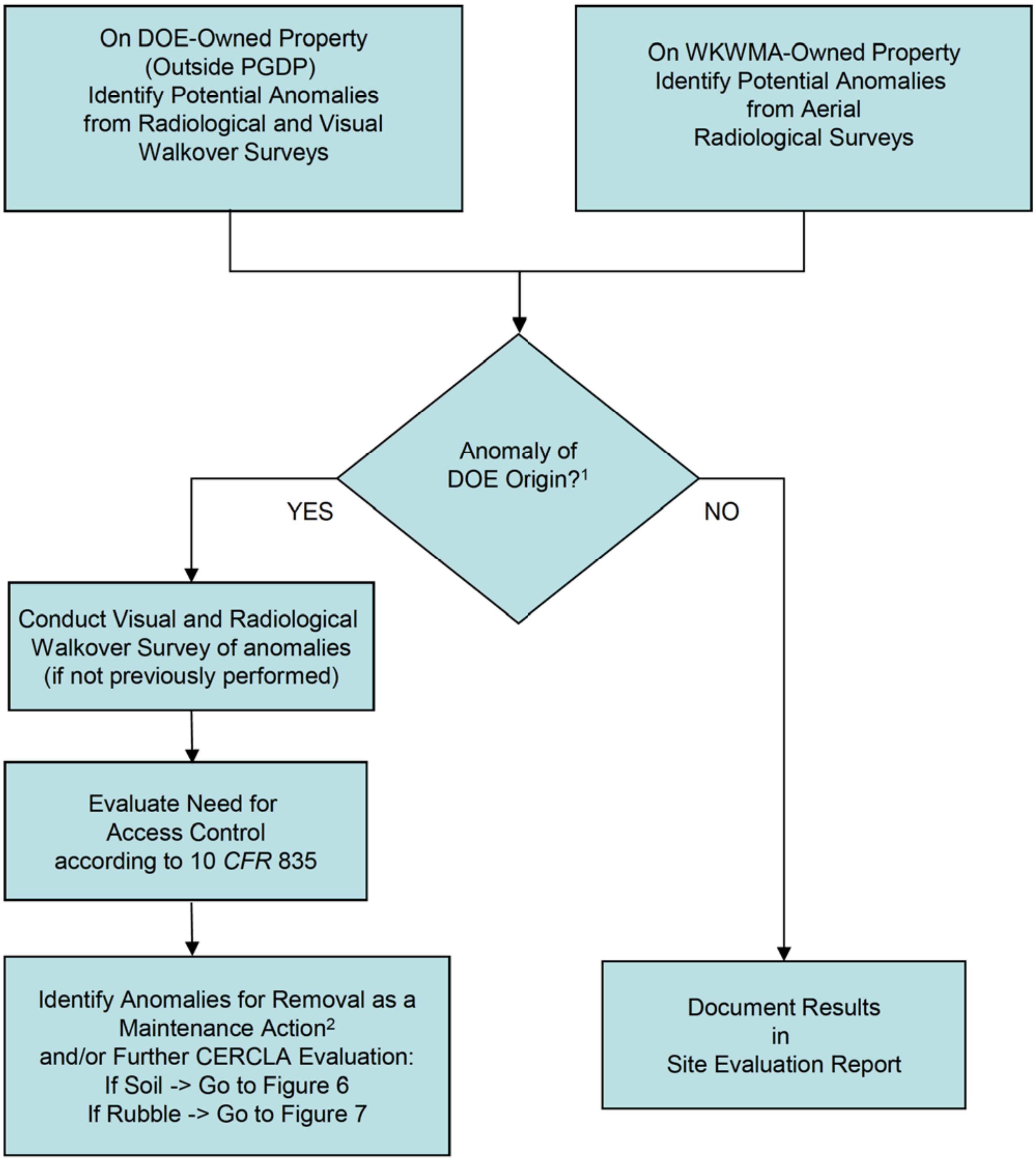
A focused radiological walkover survey and judgmental soil sampling were performed during the 2014–2015 field effort to validate the conclusions of the previous 2009–2010 field effort. A radiological survey was performed on 25 of the anomalies identified by the 2009–2010 field effort. Soil samples were analyzed by *ex situ* XRF analysis to measure total uranium concentration associated with the selected anomalies.

4.2 2009–2010 RADIOLOGICAL AND VISUAL SURVEYS

4.2.1 Aerial Photographic Survey

The aerial photographic survey, which included aerial photography, topographic mapping, digital orthophotos, and Light Detection and Ranging (LiDAR), was conducted over PGDP and the surrounding area. The purpose of the survey was to acquire high resolution aerial photographs and surface contours that would aid in the identification of anomalies. A survey firm was used to provide survey data for photograph control. This included targets that did not move for the entire length of time of the photographic shoot. The aerial photographic survey was performed on April 8, 2009.

LiDAR was used to develop a digital elevation model (DEM). This DEM provided delineation of current surface features, including watersheds, drainage pathways, roads, and land cover. An example of the output from the DEM is shown in Figure 4.2. The aerial photography survey also produced a topographic map with 2-ft surface model contours and all planimetric detail appropriate for that map scale. These 2-ft contours are shown on Figure 4.3 and are available for use on http://padgis.latakentucky.com/padgis/default.jsp. No anomalies were identified as a result of the aerial photographic survey. No visual or radiological surveys were performed based upon the evaluation of the results of the survey.



[1] On DOE-owned property outside the Limited Area, potential anomalies will be identified by radiological readings at greater than twice instrument background or where a release is visually identified or where an anomaly is identified by process knowledge. On Commonwealth of Kentucky-owned property potential anomalies will be identified by radiological flyover surveys.

[2] Rubble areas only - if the anomaly is removed as a maintenance action, conduct a radiological scan, collect a sample of underlying soil and document the results in the SER.

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Figure 4.1. Work Plan Decision Flowchart for SWMUs/AOCs

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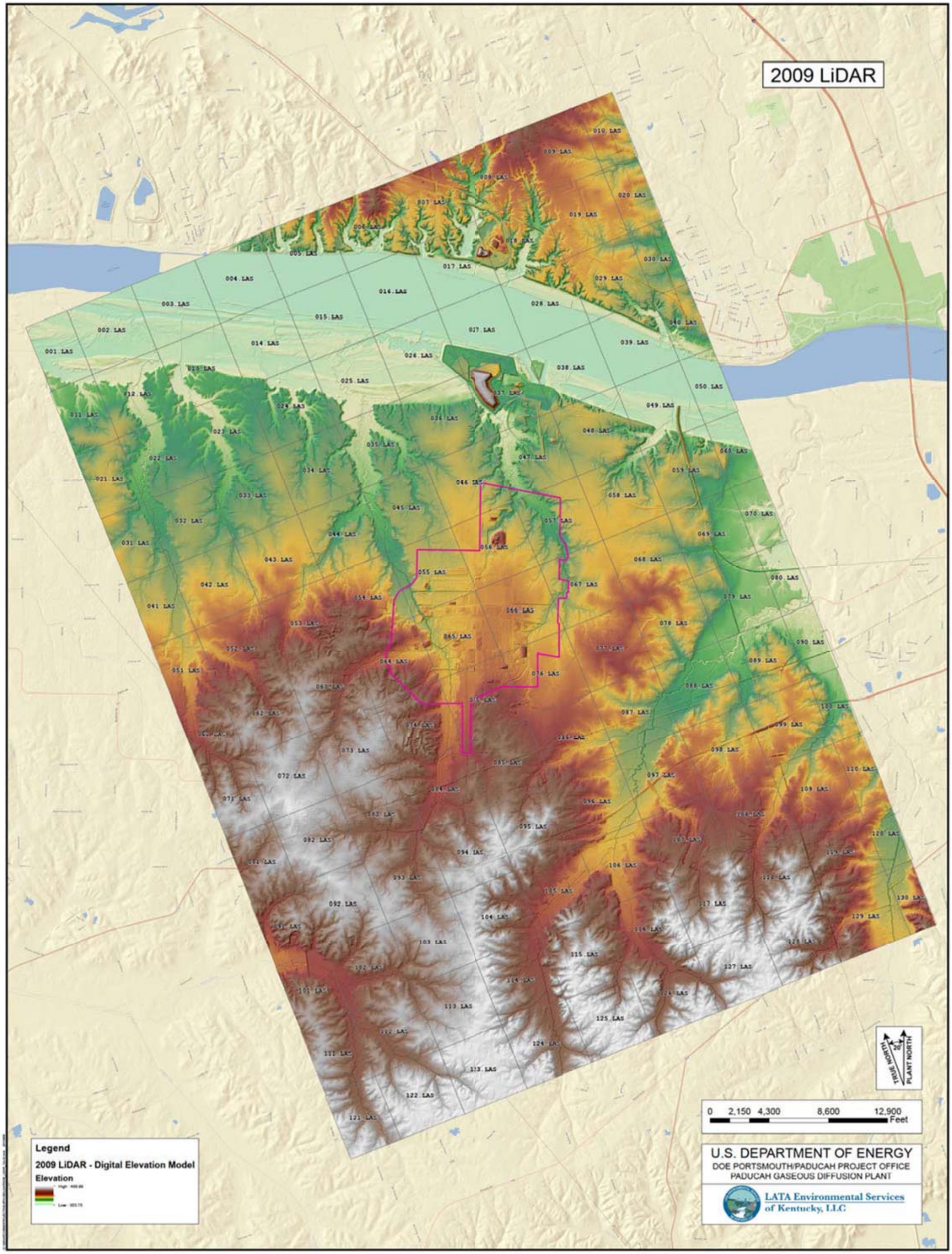

Figure 4.2. Digital Elevation Model

Figure 4.3. Surface Model Contours

4.2.2 Aerial Radiological Survey

An aerial radiological survey was conducted over the PGDP and surrounding area. The purpose of the survey was to measure the terrestrial radiological environment within and around the PGDP. The survey was performed from October 28–November 2, 2009, utilizing a large array of helicopter-mounted sodium iodide (NaI) gamma-ray detectors. The aerial survey was flown at an altitude of ~150 ft along a series of parallel lines spaced 250 ft apart and encompassing an area of approximately 25 square miles and bordered on the north by the Ohio River (Figure 4.4).

The results of the aerial radiological survey are reported as implied exposure rate, man-made activity, and depleted uranium activity, which are presented in the form of contour maps superimposed on imagery of the surveyed area. Exposure rate measurements were acquired using a pressurized ionization chamber at 10 specific locations on the ground to validate the data derived from the aerial measurements.

The conclusions from the aerial radiological survey report from Remote Sensing Laboratory can be found in Appendix A, which states that the current survey data is in general agreement with previous surveys of the PGDP and surrounding area. No anomalies were identified as a result of the aerial radiological survey.

4.2.3 Visual Survey

The visual survey of the 2,676 acres (see Figure 4.5) was accomplished by visually observing and physically locating an anomaly and recording the location, physical size, type of anomaly, and any other pertinent information. This included all of the DOE-owned property outside the Limited Area (including property licensed to Commonwealth of Kentucky). (Based upon evaluation of the aerial surveys of the portion of WKWMA property owned by the Commonwealth of Kentucky, a visual walkover survey of this area was not needed.)

The visual survey was conducted from January 5–March 20, 2009. Due to the ice storm of 2009, the wooded areas were not accessible until the following year. The survey for the wooded areas took place from February 1–April 23, 2010.

There were 633 anomalies visually identified. After crosswalking the anomalies with previously identified anomalies, 99 were found to be part of previous or ongoing evaluations/investigations [i.e., Soil Piles Addendum 2, Rubble Piles SER, Waste Area Grouping (WAG) 17, existing SWMUs] or part of anthropogenic structures (i.e., construction of rail/road beds, Kentucky Ordnance Works bunkers) and were removed from further evaluation in this effort. The remaining 534 new anomalies, presented on Figure 4.6, were evaluated as part of this SER. None of the 534 remaining anomalies exhibited the criteria established in the work plan (DOE 2011a) for determining DOE origin; therefore, the criteria for a maintenance action or soil sampling were not met. Appendix B contains the photographs of the 534 anomalies.

A summary of the visual survey of the anomalies is provided in Tables 4.1–4.22, and Figures 4.7–4.32 present the locations of the 534 anomalies that were evaluated, alternating sequentially (e.g., Table 4.1 summarizes the surveys in Grid B. Figure 4.8 follows Table 4.1 and presents the locations of the anomalies in Grid B). No anomalies were identified in Grids A, C, T, and Z.

Each anomaly was radiologically surveyed, and the average and maximum readings were recorded based on the technicians' observations. Anomaly surveys were performed using either 2x2 or 3x3 NaI (gamma) detector. GPS data loggers were not available for the anomaly surveys. No anomalies were found to be greater than twice instrument background established for the survey.

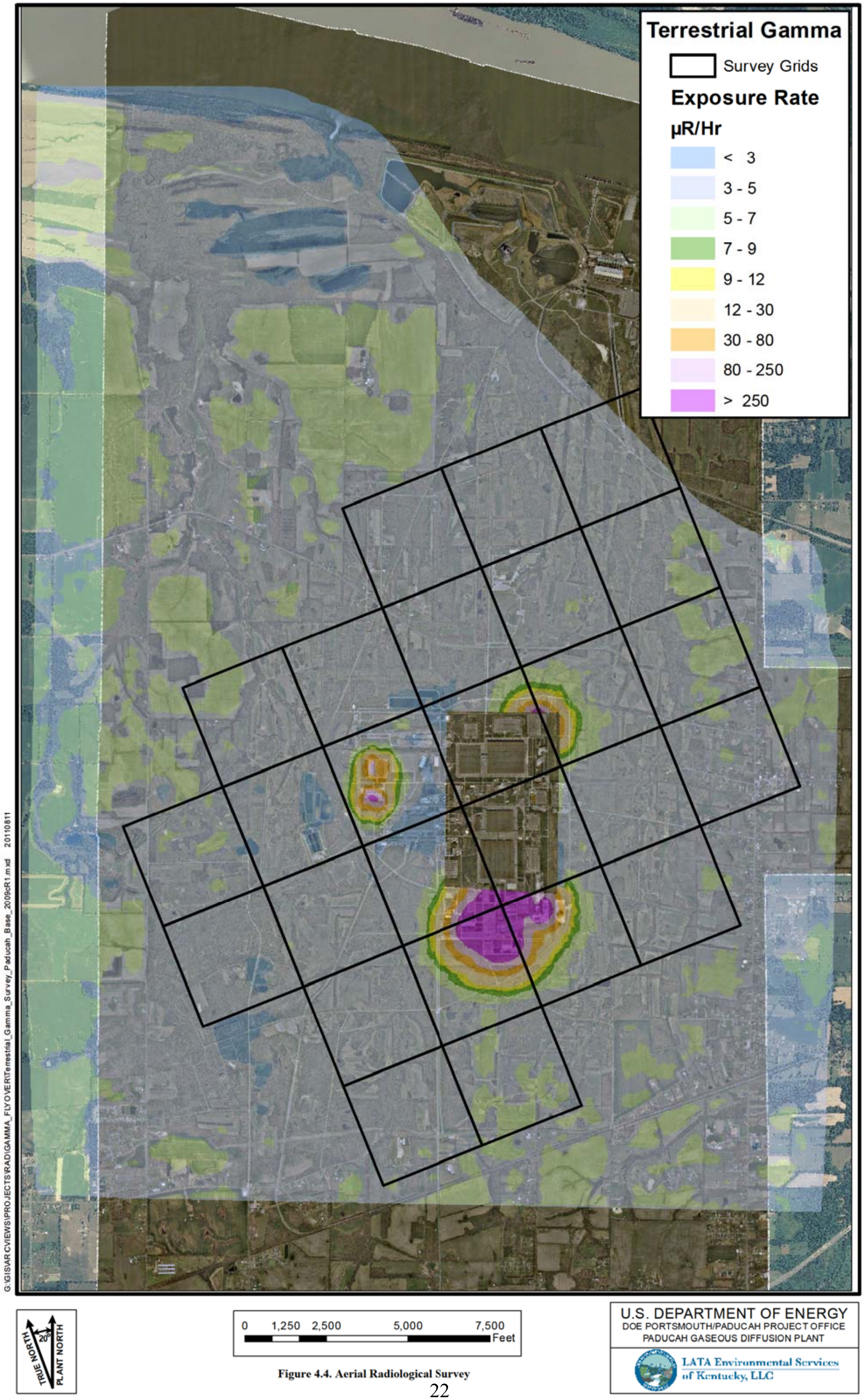

Figure 4.4. Aerial Radiological Survey

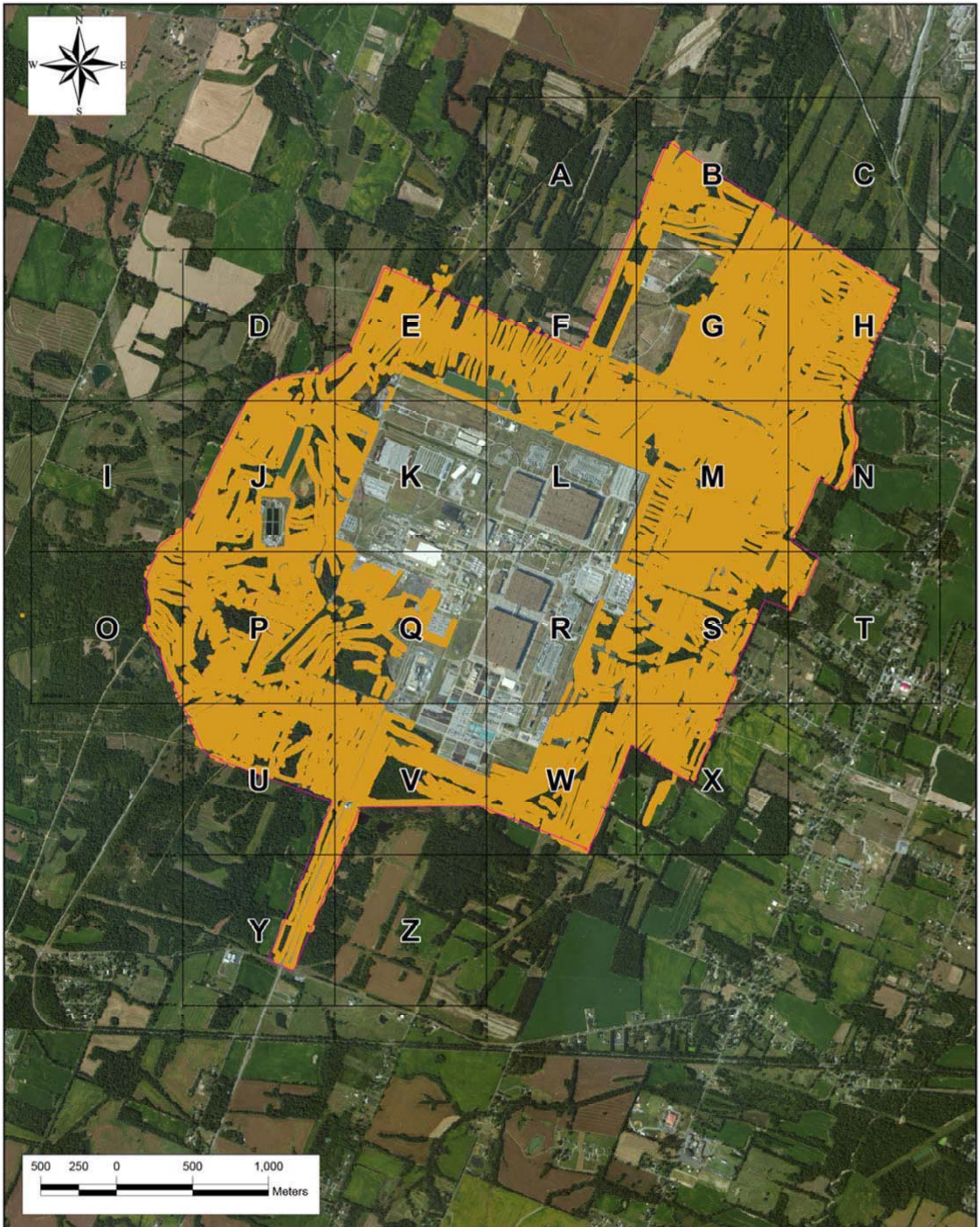

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Figure 4.5. Visual Walkover

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DATE: 3-12-2015

Visual_WalkOver.mxd

Figure 4.6. Anomalies with Grid

Figure 4.7. Visual Anomaly Map Area A

Table 4.1. Anomalies within Area B

Anomaly Name	Photo	Description
PA-15-03-V-1	x	dirt mound
PA-15-03-V-2	x	dirt mound
PA-15-03-V-3	x	dirt mound
PA-15-03-V-4	x	dirt mound
PA-15-03-V-6	x	dirt mound
PA-15-03-V-7	x	dirt mound
PA-15-03-V-8	x	dirt mound
PA-15-03-V-9	x	dirt mound
PB-13-02-V-1	x	dirt mound
PB-13-02-V-2	x	dirt mound

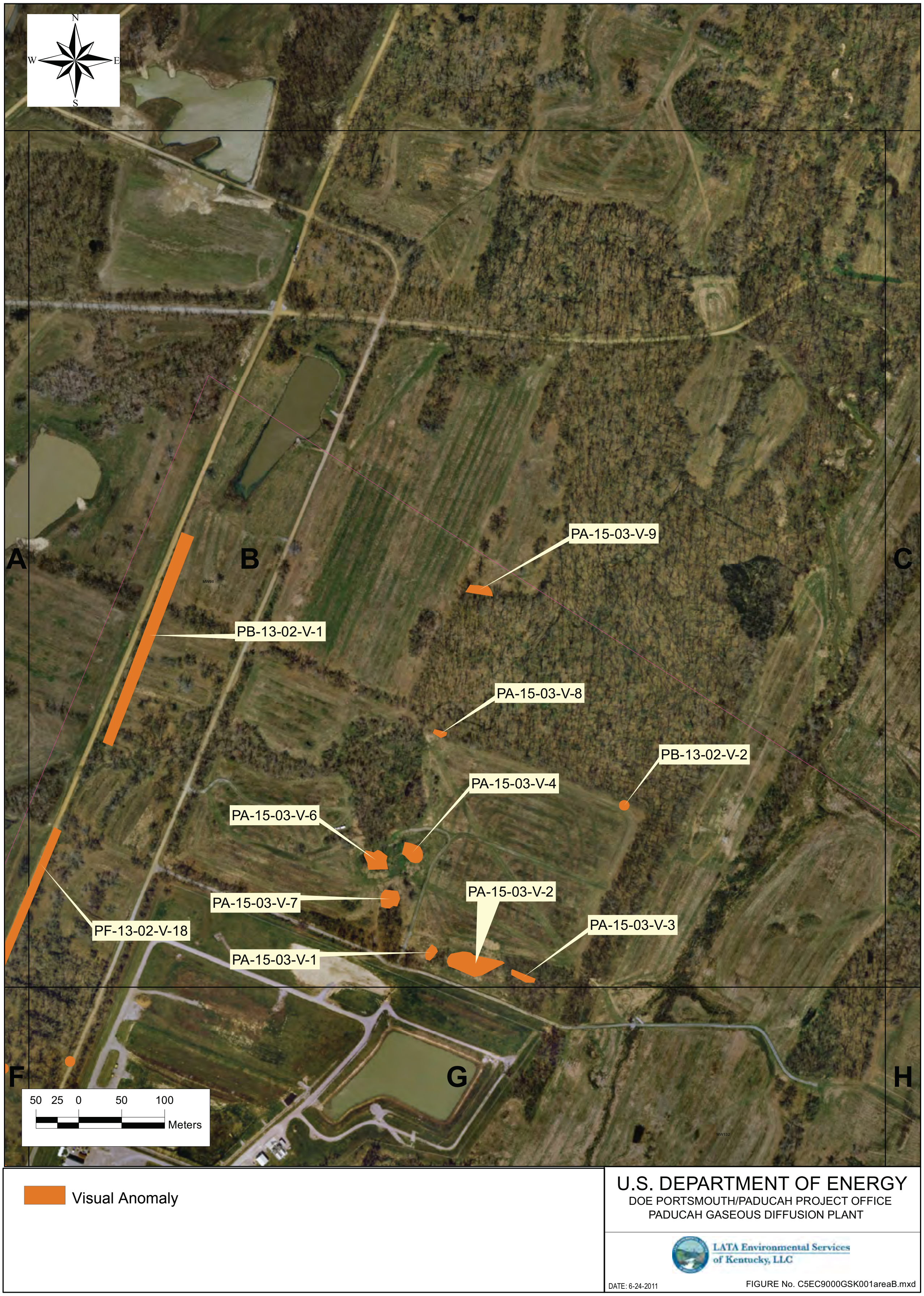

Figure 4.8. Visual Anomaly Map Area B

Figure 4.9. Visual Anomaly Map Area C

Table 4.2. Anomalies within Area D

Anomaly Name	Photo	Description
PD-04-03-V-1	x	dirt mound
PD-05-03-V-17	x	dirt mound
PD-05-03-V-18	x	metal pipe
PD-12-04-V-1	x	dirt mound
PE-09-02-V-7	x	soil, holding ponds, cable

Figure 4.10. Visual Anomaly Map Area D

Table 4.3. Anomalies within Area E

Anomaly Name	Photo	Description
PE-01-03-V-19	x	dirt mound, limbs, tree debris
PE-01-03-V-20	x	dirt mound, limbs, tree debris
PE-01-03-V-21	x	dirt mound, limbs, tree debris
PE-01-03-V-22	x	dirt mound, limbs, tree debris
PE-01-03-V-23	x	barrel strapped to tree
PE-01-03-V-24	x	dirt mound, limbs, tree debris
PE-01-03-V-25	x	dirt mound, limbs, tree debris
PE-02-03-V-1	x	dirt mound, limbs, tree debris
PE-02-03-V-10	x	railroad ties and pipe
PE-02-03-V-11	x	wood planks
PE-02-03-V-12	x	concrete culvert
PE-02-03-V-13	x	dirt mound, limbs, tree debris
PE-02-03-V-14	x	dirt mound, limbs, tree debris
PE-02-03-V-15	x	dirt mound, limbs, tree debris
PE-02-03-V-16	x	concrete culvert
PE-02-03-V-17	x	square pond.
PE-02-03-V-18	x	dirt mound, limbs, tree debris
PE-02-03-V-19	x	dirt mound, limbs, tree debris, barbed wire
PE-02-03-V-2	x	metal pipe
PE-02-03-V-3	x	dirt mound, limbs, tree debris
PE-02-03-V-4	x	railroad ties
PE-02-03-V-5	x	dirt mound, limbs, tree debris
PE-02-03-V-6	x	dirt mound, limbs, tree debris
PE-02-03-V-7	x	wood bench
PE-02-03-V-8	x	gravel
PE-02-03-V-9	x	gravel
PE-03-03-V-1	x	dirt mound at end of path
PE-03-03-V-10	x	dirt mound, limbs, tree debris
PE-03-03-V-11	x	dirt mound around depression filled with water
PE-03-03-V-12	x	dirt mound, limbs, tree debris
PE-03-03-V-13	x	dirt mound around depression filled with water
PE-03-03-V-14	x	dirt mound, limbs, tree debris
PE-03-03-V-15	x	dirt mound, limbs, tree debris
PE-03-03-V-2	x	dirt mound around depression filled with water

Table 4.3. Anomalies within Area E (Continued)

Anomaly Name	Photo	Description
PE-03-03-V-3	x	small dirt mounds with ice storm debris
PE-03-03-V-4	x	dirt mound, limbs, tree debris
PE-03-03-V-5	x	small depression
PE-03-03-V-6	x	small depression
PE-03-03-V-7	x	metal fence post
PE-03-03-V-8	x	depression
PE-03-03-V-9	x	dirt mound
PE-05-03-V-1	x	dirt mound
PE-05-03-V-12	x	concrete
PE-05-03-V-13	x	concrete, dirt mounds
PE-05-03-V-14	x	bare soil
PE-05-03-V-15	x	concrete, dirt mounds
PE-05-03-V-16	x	dirt mound
PE-05-03-V-19		dirt mound
PE-05-03-V-2	x	dirt mound
PE-05-03-V-20		dirt mound
PE-05-03-V-3	x	dirt mound
PE-05-03-V-4	x	dirt mound
PE-05-03-V-5	x	dirt mound
PE-05-03-V-6	x	depression
PE-05-03-V-7	x	bucket of soil
PE-09-02-V-12	x	dirt mounds, miscellaneous debris
PE-09-02-V-17	x	railroad ties, soil
PE-09-02-V-2	x	dirt mounds, miscellaneous debris
PE-09-02-V-24	x	dirt mounds
PE-09-02-V-3	x	dirt mound
PE-09-02-V-5	x	concrete, well, manhole
PE-09-02-V-6	x	metal beams, railroad tracks, dirt mounds
PE-09-02-V-8	x	concrete, dirt mounds
PK-11-03-V-1		N/A
PK-11-03-V-2	x	dirt mound
PK-17-03-V-5	x	dirt mounds, concrete, pipe, miscellaneous debris

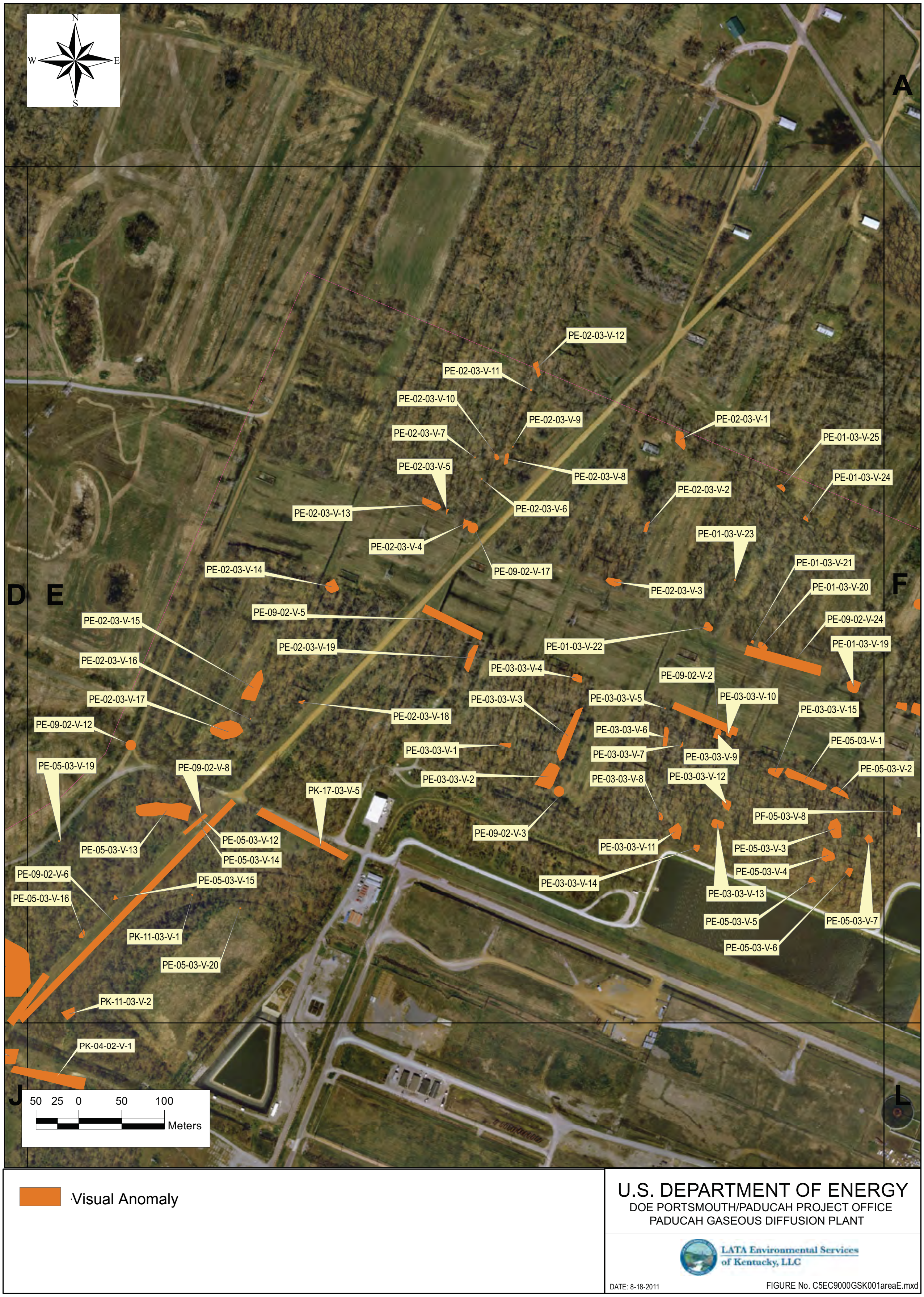

Figure 4.11. Visual Anomaly Map Area E

Table 4.4. Anomalies within Area F

Anomaly Name	Photo	Description
PE-01-03-V-18	x	dirt mound, limbs, tree debris
PF-01-03-V-1	x	depression
PF-01-03-V-10	x	pipe
PF-01-03-V-11	x	plastic bucket, wood, moss covered solidified substance
PF-01-03-V-12	x	dirt mound
PF-01-03-V-13	x	dirt mound
PF-01-03-V-14	x	dirt mound
PF-01-03-V-15	x	dirt mound
PF-01-03-V-16	x	dirt mound
PF-01-03-V-17	x	concrete pipe
PF-01-03-V-2	x	dirt mound
PF-01-03-V-3	x	dirt mound
PF-01-03-V-4	x	dirt mound
PF-01-03-V-5	x	concrete pipe
PF-01-03-V-6	x	dirt mound
PF-01-03-V-7	x	dirt mound
PF-01-03-V-8	x	dirt mound
PF-01-03-V-9	x	dirt mound
PF-05-03-V-10	x	dirt mound
PF-05-03-V-11	x	dirt mound, limbs, tree debris
PF-05-03-V-8	x	dirt mound, railroad ties
PF-05-03-V-9	x	dirt mound, limbs, tree debris
PF-12-02-V-1	x	concrete pipe
PF-12-02-V-10	x	dirt mound
PF-12-02-V-11	x	dirt mound
PF-12-02-V-12	x	dirt mound
PF-12-02-V-13	x	dirt mound
PF-12-02-V-2	x	dirt mound
PF-12-02-V-3	x	dirt mound
PF-12-02-V-4	x	dirt mound, grappler, barrel
PF-12-02-V-5	x	dirt mound, buried railroad ties
PF-12-02-V-6	x	dirt mound
PF-12-02-V-9	x	pipe
PF-13-02-R-1	x	dirt mound, concrete
PF-13-02-R-2	x	dirt mound
PF-13-02-V-14	x	concrete pipe, dirt mounds
PF-13-02-V-15	x	dirt mound
PF-13-02-V-16	x	dirt mound
PF-13-02-V-18	x	dirt mound
PF-18-02-V-19	x	concrete pipe, dirt mounds
PF-18-02-V-20	x	dirt mound
PF-18-02-V-21	x	dirt mound
PF-18-02-V-23	x	dirt mounds, railroad ties, concrete
PF-24-02-V-1	x	dirt mound, limbs, tree debris
PF-24-02-V-2	x	dirt mound
PF-24-02-V-3	x	dirt mound
PF-24-02-V-4	x	gravel
PF-24-02-V-5	x	dirt mound
PF-24-02-V-6	x	dirt mound
PF-24-02-V-9	x	dirt mound
PF-25-02-V-10	x	barrel, crushed
PF-26-02-V-1	x	dirt mound

Table 4.4. Anomalies within Area F (Continued)

Anomaly Name	Photo	Description
PF-26-02-V-10	x	barrel
PF-26-02-V-11	x	dirt mound
PF-26-02-V-12	x	dirt mound
PF-26-02-V-14	x	dirt mound
PF-26-02-V-15	x	dirt mound
PF-26-02-V-16	x	dirt mound
PF-26-02-V-17	x	dirt mound with pond
PF-26-02-V-18	x	dirt mound, limbs, tree debris
PF-26-02-V-19	x	dirt mound
PF-26-02-V-2	x	dirt mound
PF-26-02-V-20	x	concrete
PF-26-02-V-21	x	dirt mound
PF-26-02-V-22	x	dirt mound
PF-26-02-V-23	x	concrete, metal
PF-26-02-V-24	x	dirt mound
PF-26-02-V-3	x	dirt mound, limbs, tree debris
PF-26-02-V-4	N/A	N/A
PF-26-02-V-5	x	dirt mound beside depression
PF-26-02-V-6	x	dirt mound
PF-26-02-V-7	x	dirt mound, lumber
PF-26-02-V-8	x	dirt mound
PF-26-02-V-9	x	dirt mound
PG-24-02-V-7	x	dirt mound
PG-24-02-V-8	x	dirt mound

Figure 4.12. Visual Anomaly Map Area F

Table 4.5. Anomalies within Area G

Anomaly Name	Photo	Description
PF-18-02-V-22	x	dirt mound
PG-02-03-R-2	x	dirt mound
PG-17-02-V-5	x	dirt mound
PG-17-02-V-6	x	concrete
PG-17-02-V-7	x	dirt mound
PG-17-02-V-8	x	concrete
PG-17-02-V-9	x	dirt mound
PG-19-02-V-1	x	soil and gravel mound
PG-19-02-V-2	x	dirt mound
PG-19-02-V-3	x	dirt mound
PG-19-02-V-4	x	dirt mound
PG-19-02-V-5	x	dirt mound

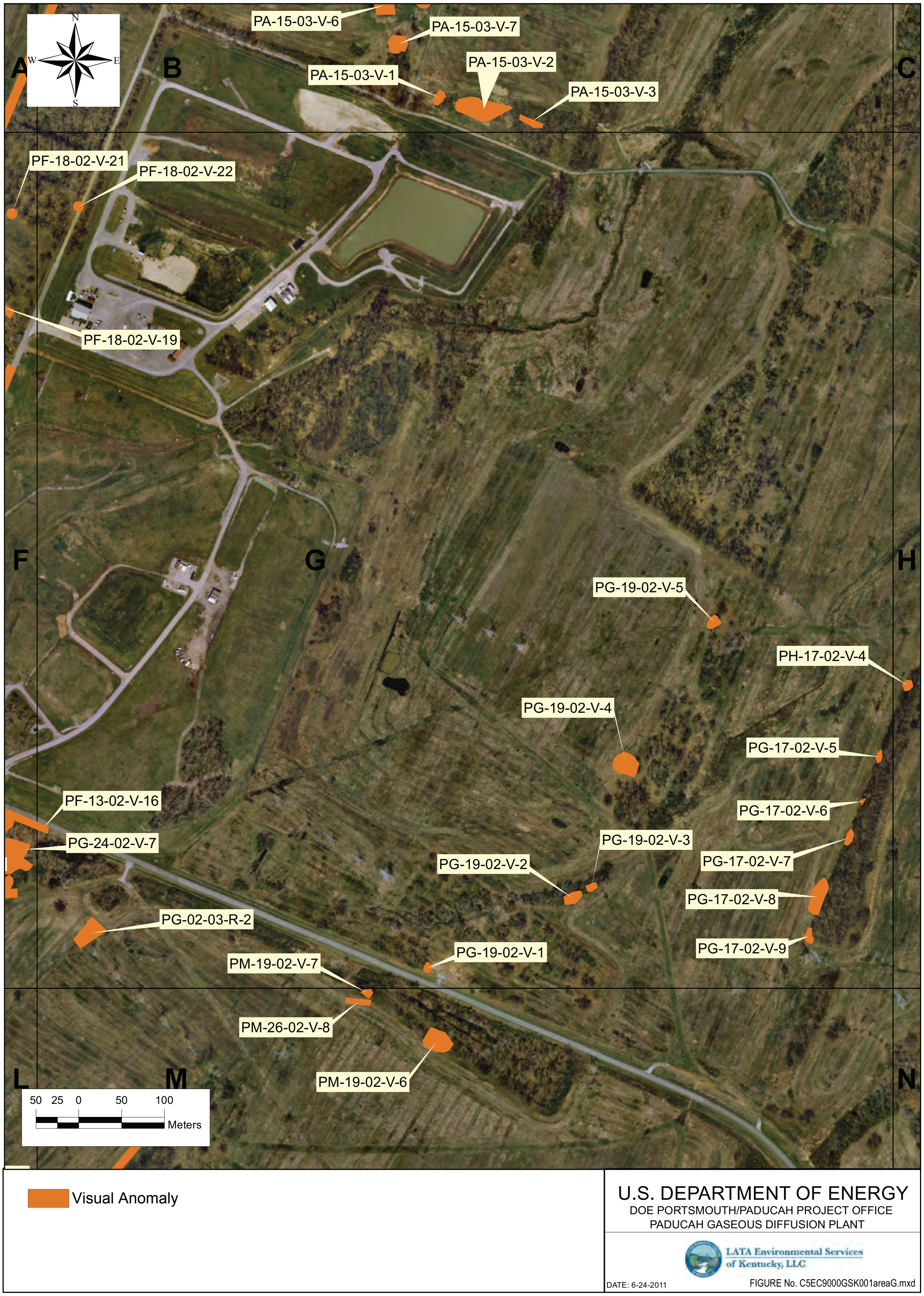

Figure 4.13. Visual Anomaly Map Area G

Table 4.6. Anomalies within Area H

Anomaly Name	Photo	Description
PH-12-02-V-1	x	dirt mound by monitoring well
PH-16-02-V-1	x	dirt mounded by pond/depression
PH-16-02-V-3	x	dirt mound
PH-16-02-V-4	x	dirt mound
PH-16-02-V-5	x	dirt mound by pond/depression
PH-16-02-V-6	x	dirt mound, railroad ties
PH-17-02-V-1	x	dirt mound
PH-17-02-V-10	N/A	N/A
PH-17-02-V-11	N/A	N/A
PH-17-02-V-12	x	dirt mound
PH-17-02-V-3	x	dirt mound
PH-17-02-V-4	x	dirt mound, limbs, tree debris
PH-19-02-V-2	x	dirt mound

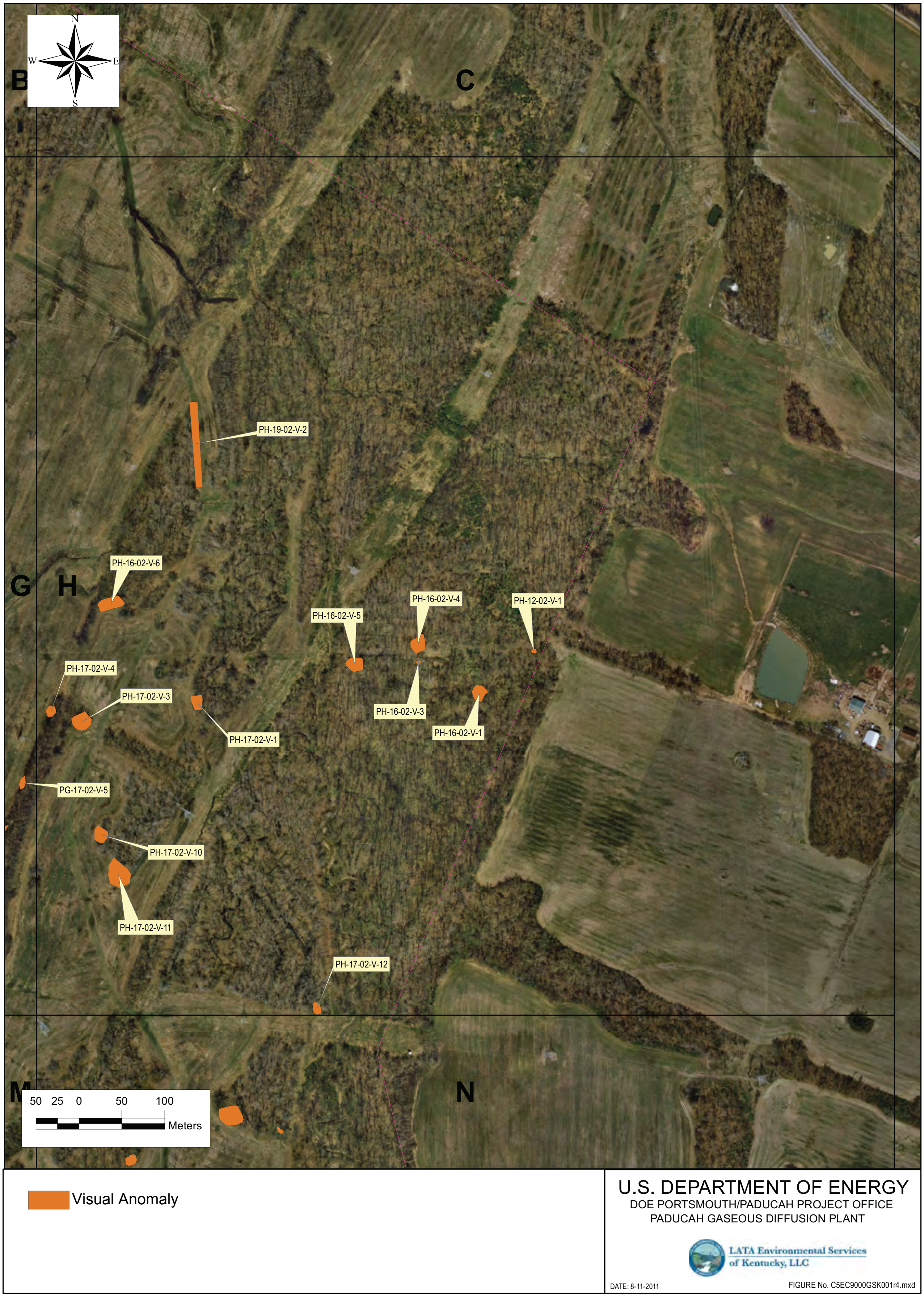

Figure 4.14. Visual Anomaly Map Area H

Table 4.7. Anomalies within Area I

Anomaly Name	Photo	Description
PI-04-03-V-1	x	dirt mound
PI-04-03-V-2	x	dirt mound
PI-06-04-V-1	x	dirt mound
PI-06-04-V-2	x	concrete
PI-06-04-V-3	x	dirt mound
PI-06-04-V-4	x	dirt mound

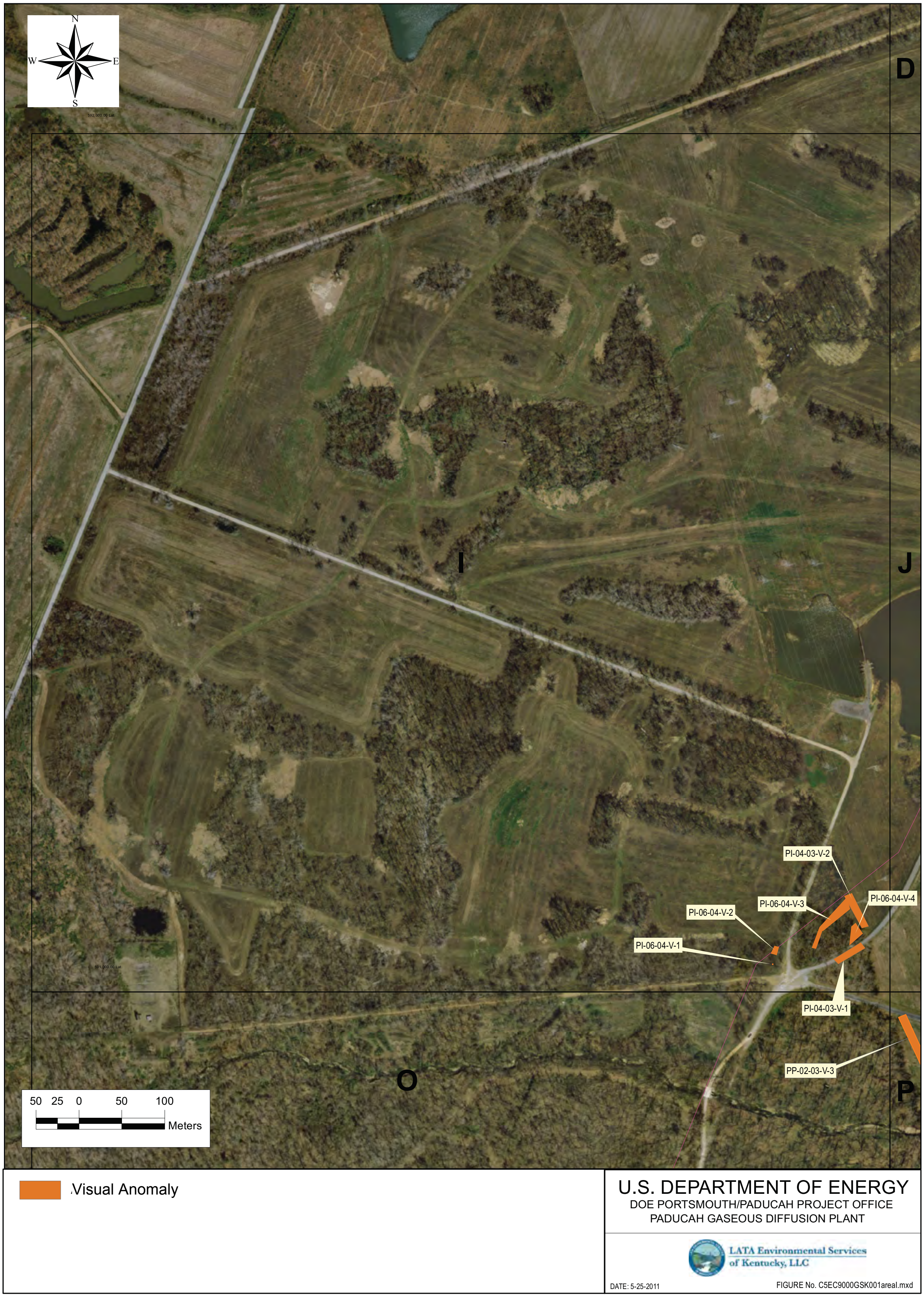

Figure 4.15. Visual Anomaly Map Area I

Table 4.8. Anomalies within Area J

Anomaly Name	Photo	Description
PD-12-04-V-2	x	dirt mound
PJ-04-03-V-5	x	dirt mound
PJ-04-03-V-6	x	dirt mound
PJ-04-03-V-7	x	dirt mound
PJ-04-03-V-8	x	dirt mound
PJ-05-02-R-1	x	(snow fencing, lumber, metal cables, fence post, buckets, pipes)
PJ-05-02-V-1	x	concrete and metal culvert
PJ-08-04-V-1	x	plastic bucket
PJ-08-04-V-10	x	dirt mound
PJ-08-04-V-11	x	dirt mound
PJ-08-04-V-12	x	dirt mound
PJ-08-04-V-13	x	dirt mound
PJ-08-04-V-14	x	dirt mound
PJ-08-04-V-15	x	dirt mound
PJ-08-04-V-16	x	dirt mound
PJ-08-04-V-17	x	dirt mound
PJ-08-04-V-18	x	dirt mound
PJ-08-04-V-19	N/A	dirt mound, concrete
PJ-08-04-V-2	x	metal culvert
PJ-08-04-V-3	x	concrete
PJ-08-04-V-4	x	dirt mound
PJ-08-04-V-5	x	dirt mound by pond/depression
PJ-08-04-V-6	x	dirt mound
PJ-08-04-V-7	x	dirt mound
PJ-08-04-V-8	x	dirt mound
PJ-08-04-V-9	x	dirt mound
PJ-12-04-V-1	x	metal
PJ-12-04-V-10	x	dirt mound
PJ-12-04-V-11	x	concrete
PJ-12-04-V-12	x	dirt mound
PJ-12-04-V-13	x	trash, paper, plastic
PJ-12-04-V-14	x	dirt mound
PJ-12-04-V-16	x	N/A
PJ-12-04-V-2	x	dirt mound
PJ-12-04-V-5	x	dirt mound
PJ-12-04-V-6	x	concrete
PJ-12-04-V-7	x	concrete
PJ-12-04-V-8	x	dirt mound
PD-12-04-V-2	x	dirt mound
PJ-04-03-V-5	x	dirt mound
PJ-04-03-V-6	x	dirt mound
PJ-04-03-V-7	x	dirt mound
PJ-04-03-V-8	x	dirt mound
PJ-05-02-R-1	x	(snow fencing, lumber, metal cables, fence post, buckets, pipes)
PJ-05-02-V-1	x	concrete and metal culvert
PJ-08-04-V-1	x	plastic bucket
PJ-08-04-V-10	x	dirt mound

Table 4.8. Anomalies within Area J (Continued)

Anomaly Name	Photo	Description
PJ-08-04-V-11	x	dirt mound
PJ-08-04-V-12	x	dirt mound
PJ-08-04-V-13	x	dirt mound
PJ-08-04-V-14	x	dirt mound
PJ-08-04-V-15	x	dirt mound
PJ-08-04-V-16	x	dirt mound
PJ-08-04-V-17	x	dirt mound
PJ-08-04-V-18	x	dirt mound
PJ-08-04-V-19	N/A	dirt mound, concrete
PJ-08-04-V-2	x	metal culvert
PJ-08-04-V-3	x	concrete
PJ-08-04-V-4	x	dirt mound
PJ-08-04-V-5	x	dirt mound by pond/depression
PJ-08-04-V-6	x	dirt mound
PJ-08-04-V-7	x	dirt mound
PJ-08-04-V-8	x	dirt mound
PJ-08-04-V-9	x	dirt mound
PJ-12-04-V-1	x	metal
PJ-12-04-V-10	x	dirt mound
PJ-12-04-V-11	x	concrete
PJ-12-04-V-12	x	dirt mound
PJ-12-04-V-13	x	trash, paper, plastic
PJ-12-04-V-14	x	dirt mound
PJ-12-04-V-16	x	N/A
PJ-12-04-V-2	x	dirt mound
PJ-12-04-V-5	x	dirt mound
PJ-12-04-V-6	x	concrete
PJ-12-04-V-7	x	concrete
PJ-12-04-V-8	x	dirt mound

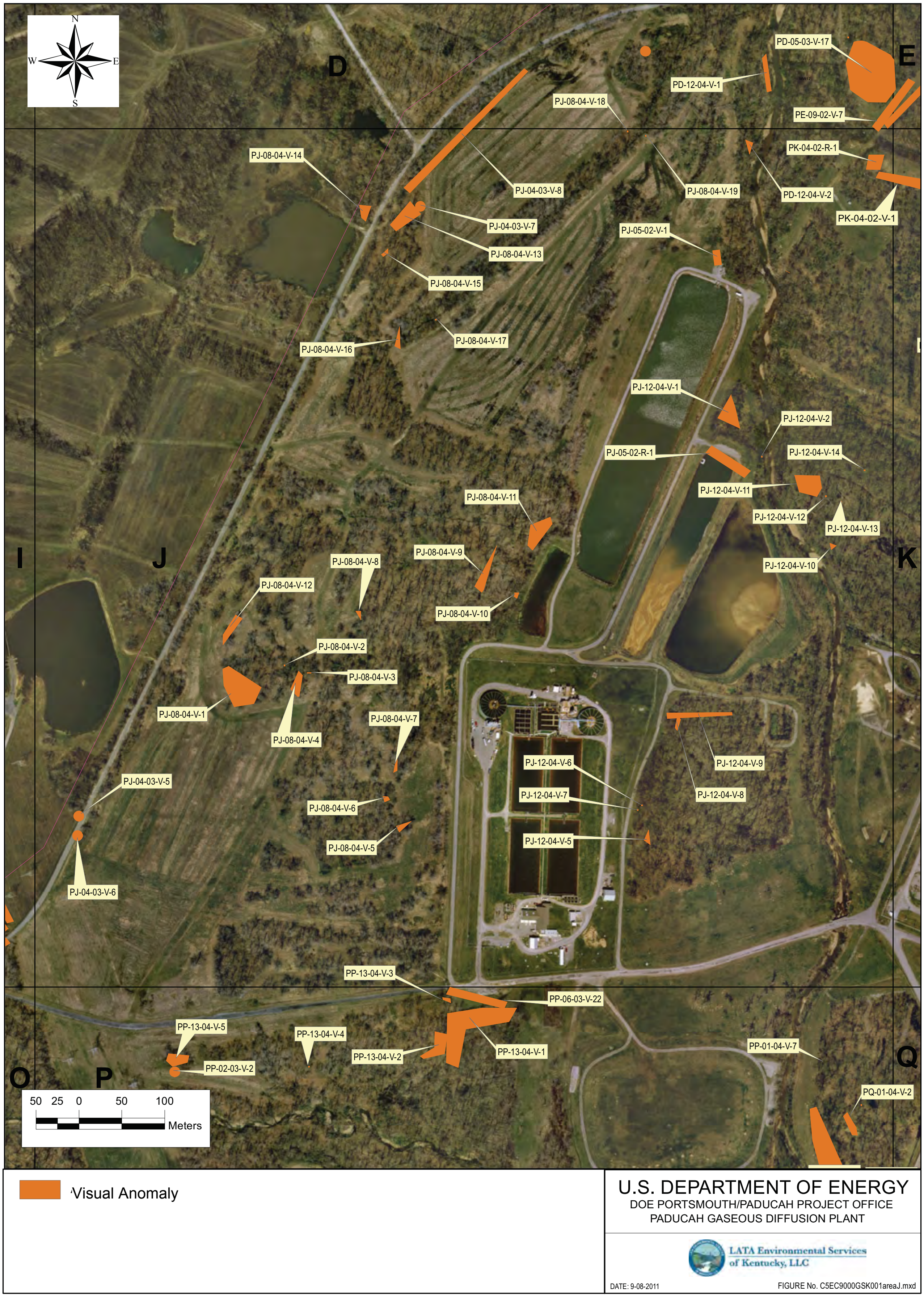

Figure 4.16. Visual Anomaly Map Area J

Table 4.9. Anomalies within Area K

Anomaly Name	Photo	Description
PK-04-02-V-1	x	steel beams, concrete, metal pipe, dirt mounds, miscellaneous debris
PK-11-03-V-3	x	concrete, metal

Figure 4.17. Visual Anomaly Map Area K

Table 4.10. Anomalies within Area L

Anomaly Name	Photo	Description
PF-11-03-V-25	x	dirt mounds
PF-12-02-V-7	x	dirt mound
PF-12-02-V-8	x	pipe
PL-11-03-V-4	x	concrete block
PL-13-03-R-1	x	dirt mounds, buried concrete
PL-24-02-V-10	x	metal, wood, limbs, tree debris
PL-24-02-V-11	x	clay pipe
PL-25-02-V-1	x	dirt mound
PL-25-02-V-11	x	dirt mound
PL-25-02-V-2	x	dirt mound
PL-25-02-V-3	x	dirt mound
PL-25-02-V-5	x	dirt mound, limbs, tree debris
PL-25-02-V-6	x	dirt mound, limbs, tree debris
PL-25-02-V-7	x	dirt mound
PL-25-02-V-8	x	dirt mound
PL-25-02-V-9	x	dirt mound, limbs, tree debris
PL-26-02-V-2	x	dirt mound
PL-26-02-V-3	x	dirt mound

Figure 4.18. Visual Anomaly Map Area L

Table 4.11. Anomalies within Area M

Anomaly Name	Photo	Description
PL-13-03-V-5	x	dirt mound, gravel
PM-13-03-V-11	x	dirt mounds, metal pipe, misc. debris
PM-16-03-V-1	x	chevron oil can
PM-16-03-V-2	x	concrete, metal
PM-16-03-V-3	x	dirt mound, limbs, tree debris
PM-16-03-V-4	x	dirt mound, concrete, tree debris
PM-16-03-V-5	x	dirt mound
PM-16-03-V-6	x	concrete
PM-16-03-V-7	x	riprap, dirt mound
PM-16-03-V-8	x	dirt mound
PM-16-03-V-9	x	dirt mound
PM-17-03-V-10	x	concrete
PM-17-03-V-11	x	dirt mound
PM-17-03-V-12	x	concrete
PM-17-03-V-13	x	dirt mound
PM-17-03-V-14	x	dirt mound
PM-17-03-V-15	x	dirt mound
PM-17-03-V-16	x	dirt mound
PM-17-03-V-17	x	dirt mound, limbs, tree debris
PM-17-03-V-18	x	dirt mound, limbs, tree debris
PM-17-03-V-19	x	dirt mound
PM-17-03-V-20	x	dirt mound
PM-17-03-V-21	x	dirt mound, limbs, tree debris
PM-17-03-V-22	x	dirt mound
PM-17-03-V-23	x	dirt mound
PM-17-03-V-3	x	dirt mound
PM-17-03-V-4	x	dirt mound
PM-17-03-V-5	x	dirt mound, metal, trash, wood
PM-17-03-V-6	x	dirt mound
PM-17-03-V-7	x	dirt mound
PM-17-03-V-8	x	metal culvert
PM-17-03-V-9	x	dirt mound
PM-19-02-V-6	x	square pond
PM-19-02-V-7	x	dirt mound
PM-19-03-V-1	x	dirt mound
PM-19-03-V-2	x	dirt mound
PM-19-03-V-3	x	dirt mound
PM-19-03-V-4	x	depression
PM-23-03-V-1	x	dirt mound by concrete barricade
PM-23-03-V-2	x	chip mulch and soil
PM-25-02-V-1	x	dirt mound
PM-25-02-V-2	x	dirt mound
PM-25-02-V-3	x	dirt mound
PM-25-02-V-4	x	dirt mound, bucket
PM-26-02-R-1	x	concrete blocks
PM-26-02-R-2	x	concrete blocks
PM-26-02-R-3	x	bricks
PM-26-02-V-10	x	dirt mound
PM-26-02-V-5	x	concrete, dirt mounds
PM-26-02-V-6	x	dirt mound
PM-26-02-V-7	x	dirt mound
PM-26-02-V-8	x	dirt mounds covered in tree limbs inside wooded area
PM-26-02-V-9	x	trash can, fence, debris
PS-19-03-V-6	x	dirt mound

Figure 4.19. Visual Anomaly Map Area M

Table 4.12. Anomalies within Area N

Anomaly Name	Photo	Description
PN-18-02-V-1	x	dirt mound
PN-18-02-V-2	x	dirt mound
PN-19-02-V-8	x	dirt mound

Figure 4.20. Visual Anomaly Map Area N

Table 4.13. Anomalies within Area O

Anomaly Name	Photo	Description
PO-06-04-V-1	x	dirt mound
PO-06-04-V-10	x	dirt mound
PO-06-04-V-11	x	dirt mound
PO-06-04-V-12	x	dirt mound
PO-06-04-V-13	x	dirt mound
PO-06-04-V-2	x	dirt mound
PO-06-04-V-3	x	concrete
PO-06-04-V-4	x	dirt mound
PO-06-04-V-5	x	dirt mound
PO-06-04-V-6	x	concrete
PO-06-04-V-7	x	dirt mound
PO-06-04-V-8	x	metal pipe
PO-06-04-V-9	x	dirt mound

Visual Anomaly

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC

DATE: 5-31-2011

FIGURE No. C5EC9000GSK001areaO.mxd

Figure 4.21. Visual Anomaly Map Area O

Table 4.14. Anomalies within Area P

Anomaly Name	Photo	Description
PP-01-04-V-5	x	dirt mound
PP-01-04-V-6	x	dirt mound
PP-01-04-V-8	x	dirt mound
PP-02-03-V-2	x	dirt mound, brick
PP-02-03-V-4	x	dirt mound
PP-02-03-V-5	x	dirt mound
PP-02-03-V-6	x	dirt mound
PP-02-03-V-7	x	dirt mound
PP-02-04-V-1	x	dirt mound, limbs, tree debris
PP-02-04-V-13	x	dirt mound
PP-02-04-V-14	x	dirt mound
PP-02-04-V-2	x	depression
PP-02-04-V-21	x	dirt mound
PP-02-04-V-3	x	dirt mound
PP-02-04-V-4	x	concrete
PP-02-04-V-5	x	dirt mound
PP-02-04-V-7	x	dirt mound
PP-02-04-V-8	x	dirt mound
PP-02-04-V-9	x	depression
PP-03-03-V-10	x	dirt mounds
PP-03-03-V-11	x	dirt mounds
PP-03-03-V-12	x	dirt mounds
PP-03-03-V-13	x	dirt mounds, concrete
PP-03-03-V-14	x	dirt mounds
PP-03-03-V-15	x	dirt mounds
PP-03-03-V-16	x	pipe, dirt mound
PP-03-03-V-18	x	dirt mounds
PP-03-03-V-8	x	dirt mounds
PP-03-03-V-9	x	dirt mounds
PP-05-04-V-1	x	soil, limbs, debris
PP-05-04-V-5	x	soil, concrete
PP-05-04-V-7	x	dirt mound
PP-06-03-V-20	x	dirt mound
PP-06-03-V-21	x	small dirt mound with fragments of clay pipe on mound
PP-06-03-V-22	x	dirt mound, concrete
PP-06-04-V-1	x	soil, concrete
PP-06-04-V-2	x	depression
PP-06-04-V-3	x	concrete
PP-13-04-V-1	x	dirt mound
PP-13-04-V-2	x	dirt mound
PP-13-04-V-3	x	rock, dirt mound
PP-13-04-V-4	x	dirt mound
PP-13-04-V-5	x	concrete
PP-31-03-V-10	x	dirt mound
PP-31-03-V-7	x	concrete
PQ-01-04-V-2	x	concrete
PQ-01-04-V-3	x	dirt mound
PQ-01-04-V-5	x	dirt mound
PU-05-04-V-10	x	concrete
PU-05-04-V-5	x	dirt mound
PU-05-04-V-6	x	dirt mound
PU-05-04-V-7	x	dirt mound
PU-05-04-V-8	x	dirt mound

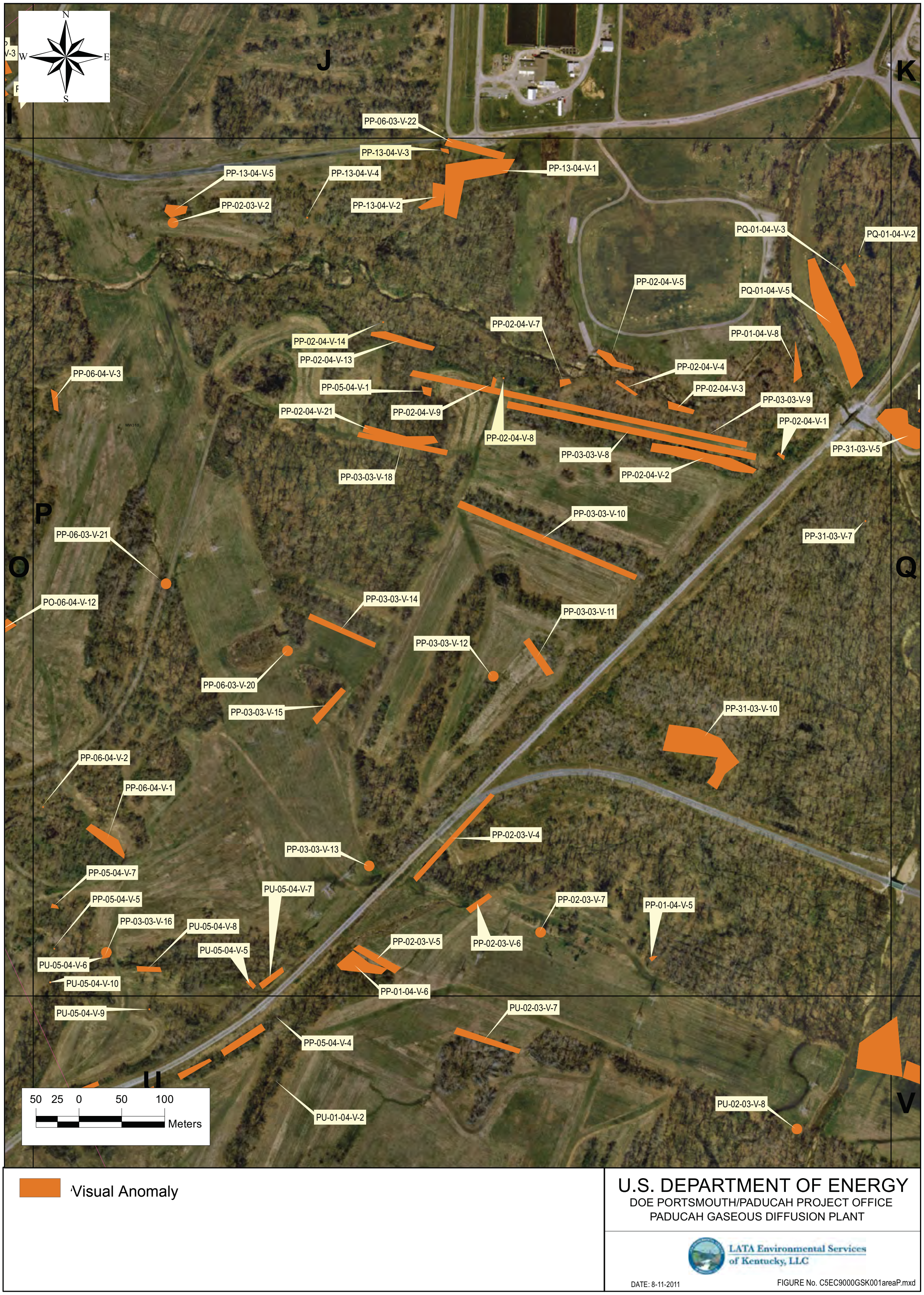

Figure 4.22. Visual Anomaly Map Area P

Table 4.15. Anomalies within Area Q

Anomaly Name	Photo	Description
PP-31-03-V-2	x	depression
PP-31-03-V-3	x	concrete
PP-31-03-V-4	x	concrete
PP-31-03-V-5	x	concrete
PQ-30-03-V-1	x	dirt mound
PQ-30-03-V-10	x	depression
PQ-30-03-V-11	x	metal
PQ-30-03-V-12	x	dirt mound
PQ-30-03-V-13	x	dirt mound
PQ-30-03-V-14	x	dirt mound
PQ-30-03-V-15	x	metal
PQ-30-03-V-16	x	depression
PQ-30-03-V-2	x	dirt mound
PQ-30-03-V-3	x	dirt mound
PQ-30-03-V-4	x	dirt mound
PQ-30-03-V-5	x	soil, limbs, debris
PQ-30-03-V-6	N/A	N/A
PQ-30-03-V-7	x	concrete
PQ-30-03-V-8	x	concrete
PQ-30-03-V-9	x	dirt mound
PQ-31-03-V-1	x	concrete/rock
PQ-31-03-V-2	x	dirt mound

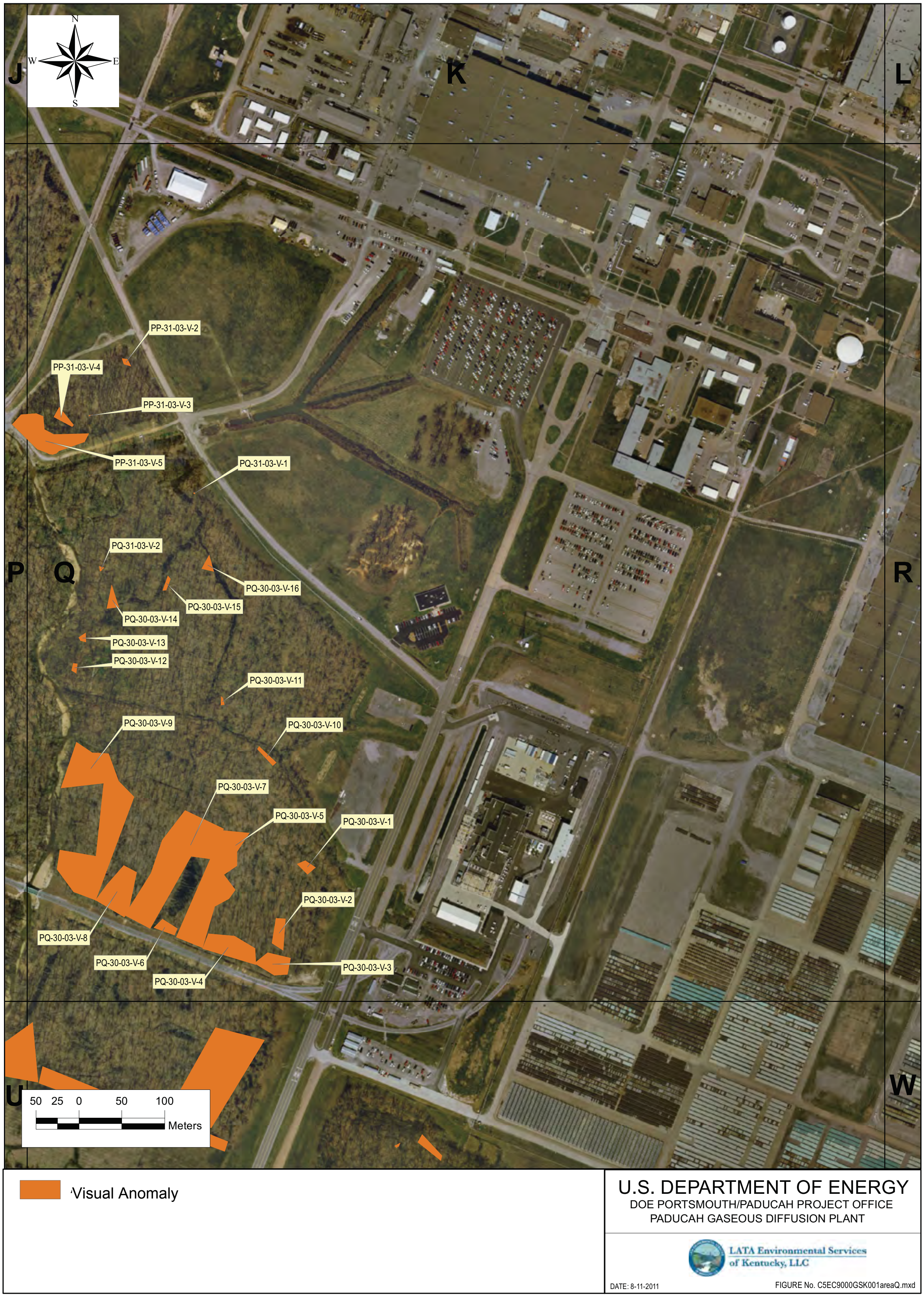

Figure 4.23. Visual Anomaly Map Area Q

Table 4.16. Anomalies within Area R

Anomaly Name	Photo	Description
PR-13-03-V-1	x	N/A
PR-13-04-V-1	x	dirt mound
PR-14-04-V-1	x	concrete
PR-14-04-V-2	x	dirt mound
PR-14-04-V-3	x	metal
PR-19-03-V-10	x	concrete
PR-19-03-V-11	x	telephone pole, concrete
PR-19-03-V-12	x	concrete, riprap
PR-19-03-V-15	x	metal pipe
PR-19-03-V-16	x	concrete
PS-28-02-V-8	x	dirt mound, plastic

Figure 4.24. Visual Anomaly Map Area R

Table 4.17. Anomalies within Area S

Anomaly Name	Photo	Description
PR-19-03-V-9	x	depression
PS-16-03-V-10	x	tire
PS-16-03-V-11	x	dirt mound
PS-16-03-V-12	x	concrete
PS-16-03-V-13	x	concrete
PS-16-03-V-14	N/A	concrete
PS-17-03-V-2	N/A	dirt mound
PS-19-03-V-13	x	concrete
PS-19-03-V-14	x	concrete
PS-19-03-V-17	N/A	trash, paper, plastic
PS-19-03-V-20	x	dirt mound
PS-19-03-V-21	x	dirt mound
PS-19-03-V-22	x	dirt mound
PS-19-03-V-23	x	concrete
PS-19-03-V-24	x	barbed wire
PS-19-03-V-25	x	metal
PS-19-03-V-26	x	depression
PS-19-03-V-27	x	dirt mound
PS-19-03-V-28	x	dirt mound
PS-19-03-V-29	x	dirt mound
PS-19-03-V-5	x	dirt mound
PS-19-03-V-7	x	dirt mound
PS-19-03-V-8	x	trash, plastic
PS-23-03-V-11	x	depression
PS-23-03-V-12	x	dirt mound
PS-23-03-V-13	x	trash, plastic
PS-23-03-V-14	x	dirt mound
PS-23-03-V-15	x	dirt mound
PS-23-03-V-3	x	trash, paper, plastic
PS-23-03-V-4	x	dirt mound, concrete
PS-23-03-V-5	x	concrete, telephone poles
PS-23-03-V-6	x	dirt mound
PS-23-03-V-7	x	dirt mound
PS-23-03-V-8	x	concrete
PS-23-03-V-9	x	trash, paper, plastic
PS-26-02-V-1	x	dirt mound
PS-26-02-V-2	x	dirt mound
PS-26-02-V-3	x	dirt mound
PS-27-02-V-4	x	dirt mound
PS-27-02-V-5	x	dirt mound
PS-27-02-V-6	x	metal pipe
PS-27-02-V-7	x	concrete
PS-28-02-V-10	x	dirt mound
PS-28-02-V-9	x	dirt mound, concrete, pipe
PT-13-04-V-1	x	concrete
PT-17-03-V-1	x	dirt mound
PX-23-03-V-16	x	dirt mound, limbs, tree debris

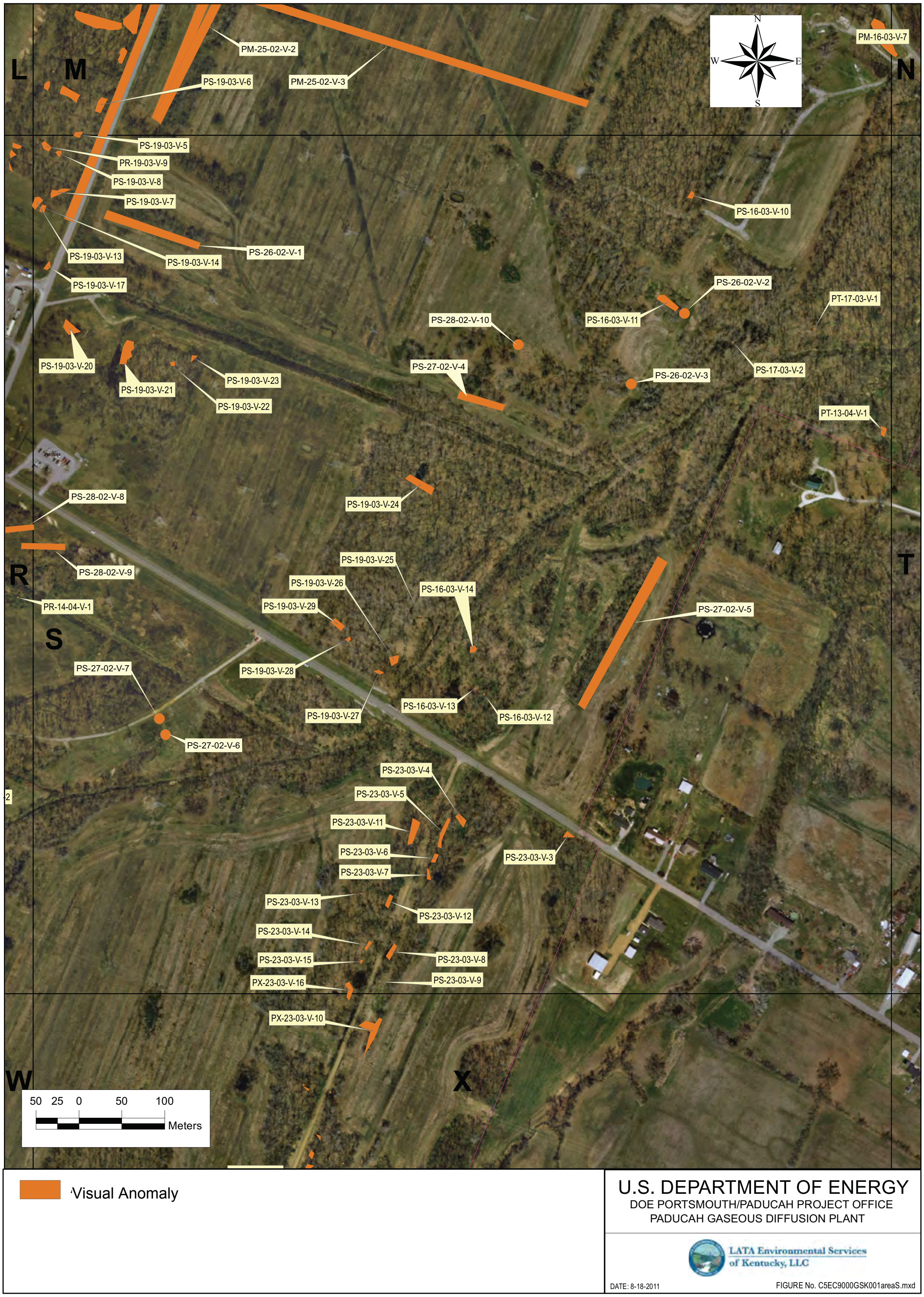

Figure 4.25. Visual Anomaly Map Area S

Figure 4.26. Visual Anomaly Map Area T

Table 4.18. Anomalies within Area U

Anomaly Name	Photo	Description
PU-02-03-V-10	x	dirt mound
PU-02-03-V-7	x	dirt mound
PU-02-03-V-8	x	dirt mound
PU-05-04-V-1	x	dirt mound, concrete
PU-05-04-V-2	x	concrete
PU-05-04-V-3	x	dirt mound
PU-05-04-V-4	x	dirt mound
PU-05-04-V-9	x	dirt mound
PU-24-01-V-4	x	dirt mound
PU-24-01-V-5	x	dirt mound
PU-24-01-V-6	x	dirt mound, plastic construction fencing

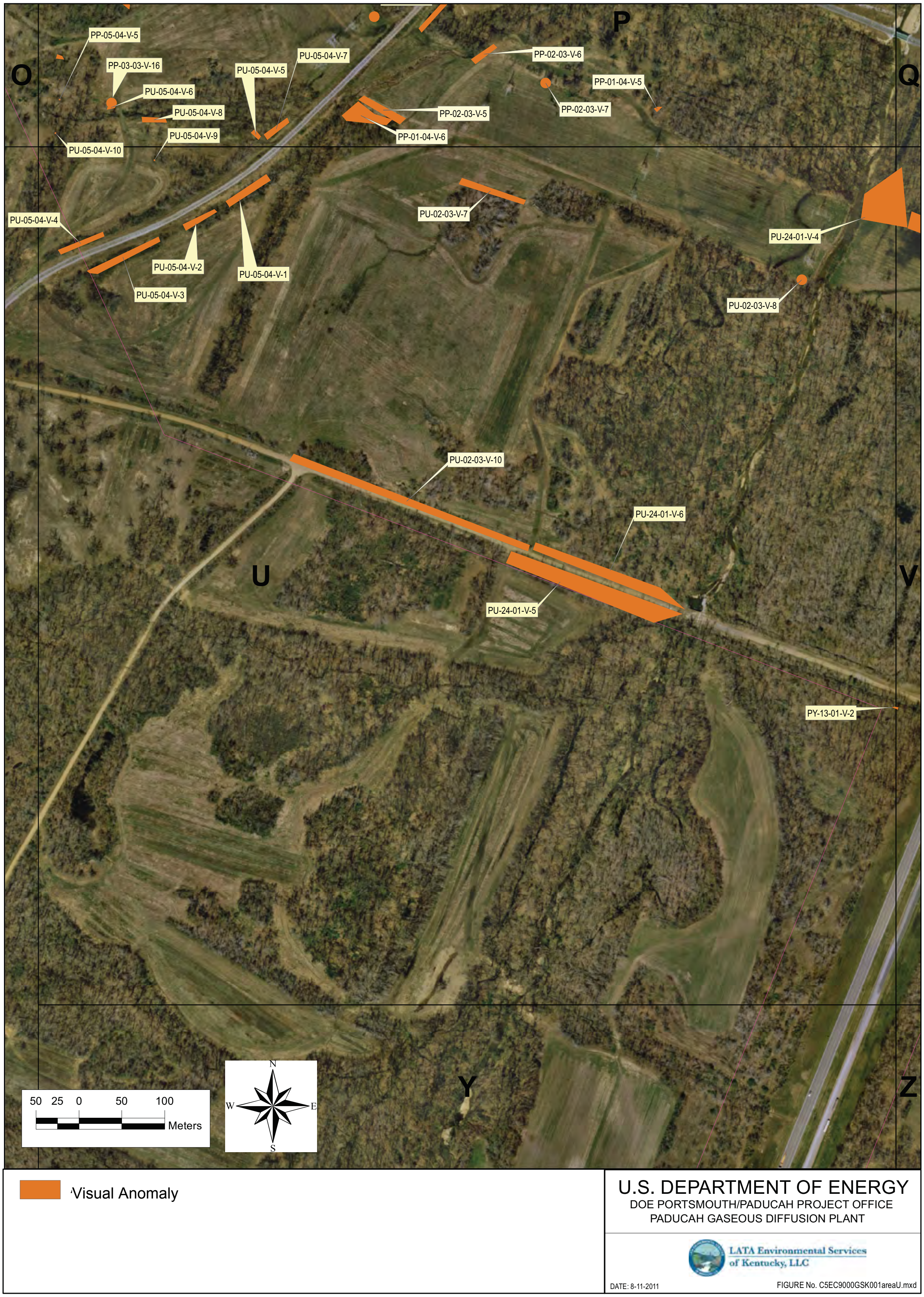

Figure 4.27. Visual Anomaly Map Area U

Table 4.19. Anomalies within Area V

Anomaly Name	Photo	Description
PV-21-01-V-5	x	dirt mound
PV-21-01-V-6	x	dirt mound
PV-21-01-V-7	x	concrete, dirt mounds
PV-24-01-V-8	N/A	dirt mound
PV-29-03-V-12	x	dirt mound
PV-29-03-V-13	x	concrete
PV-29-03-V-14	x	concrete
PV-29-03-V-17	x	dirt mound
PV-29-03-V-18	x	dirt mound
PV-29-03-V-19	x	concrete
PV-29-03-V-22	x	depression
PV-29-03-V-23	x	concrete
PV-29-03-V-8	x	dirt mound
PY-13-01-V-2	x	concrete pipe
PY-13-01-V-4	x	dirt mound
PY-13-01-V-5	x	concrete

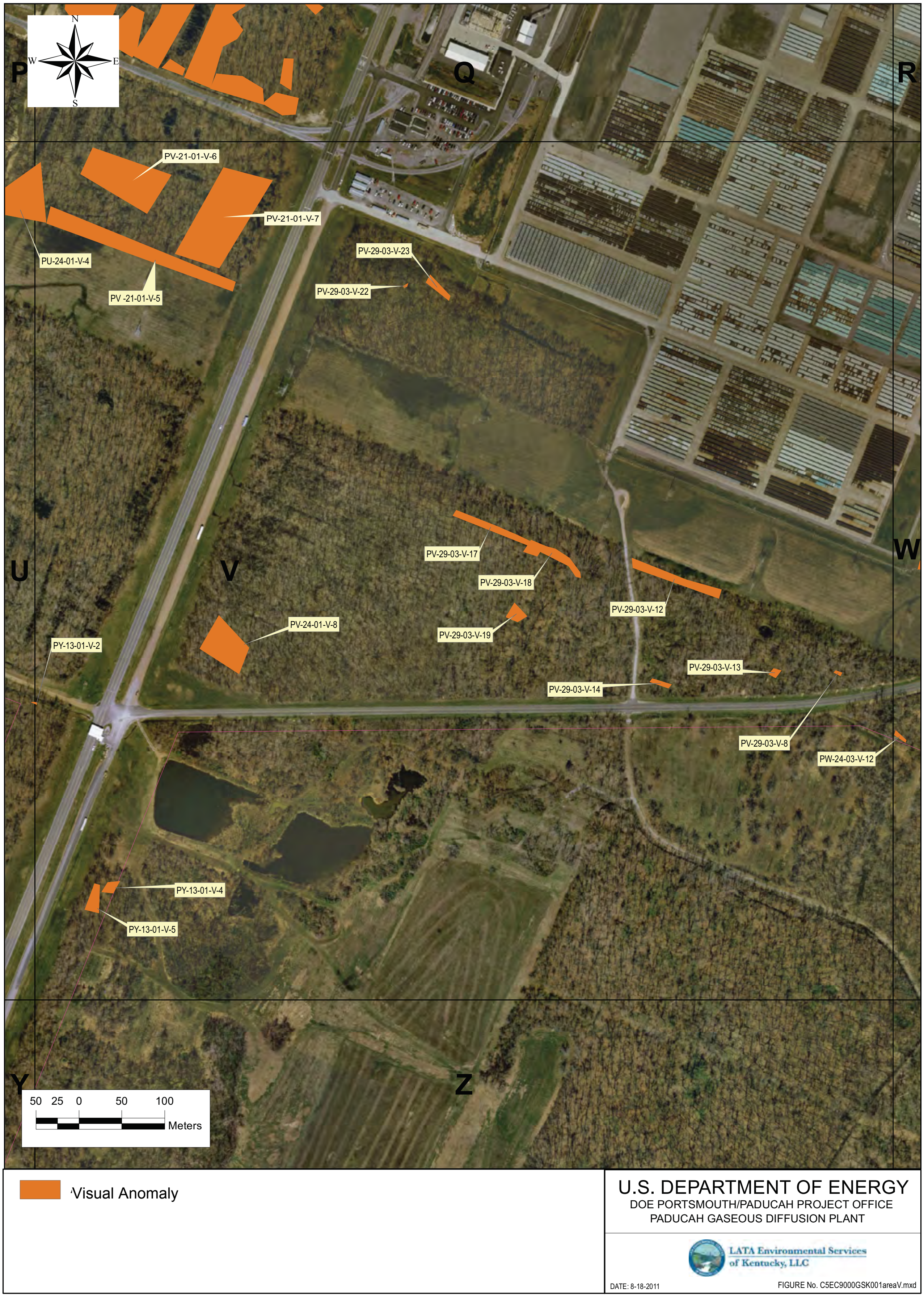

Figure 4.28. Visual Anomaly Map Area V

Table 4.20. Anomalies within Area W

Anomaly Name	Photo	Description
PR-29-03-V-1	x	dirt mound
PW-13-03-V-5	x	dirt mound
PW-13-04-V-1	x	concrete
PW-13-04-V-2	x	dirt mound
PW-13-04-V-3	x	soil, metal
PW-13-04-V-4	x	metal pipe
PW-17-03-V-8	x	dirt mound
PW-24-03-V-11	x	dirt mound
PW-24-03-V-12	x	dirt mound
PW-24-03-V-13	x	concrete
PW-24-03-V-14	x	soil, limbs, tree debris
PW-24-03-V-15	x	soil, limbs, tree debris
PW-24-03-V-16	x	soil, limbs, tree debris
PW-26-03-V-1	N/A	soil, limbs, tree debris
PW-26-03-V-10	x	soil, limbs, tree debris
PW-26-03-V-11	x	soil, limbs, tree debris
PW-26-03-V-12	x	soil, limbs, tree debris
PW-26-03-V-14	x	soil, limbs, tree debris
PW-26-03-V-15	x	soil, limbs, tree debris
PW-26-03-V-16	x	soil, limbs, tree debris
PW-26-03-V-2	x	soil, limbs, tree debris
PW-26-03-V-3	x	soil, limbs, tree debris
PW-26-03-V-4	x	soil, limbs, tree debris
PW-26-03-V-5	x	soil, limbs, tree debris
PW-26-03-V-6	x	soil, limbs, tree debris
PW-26-03-V-7	x	soil, limbs, tree debris
PW-26-03-V-8	x	soil, limbs, tree debris
PW-26-03-V-9	N/A	soil, limbs, tree debris
PW-28-02-V-1	x	metal pipe
PW-28-02-V-2	x	red brick on south side of well
PW-28-02-V-3	x	concrete, dirt mounds
PW-28-02-V-4	x	dirt mound
PW-29-03-V-2	x	dirt mound by pond/depression
PW-29-03-V-3	x	dirt mound
PW-29-03-V-4	x	dirt mound
PW-29-03-V-5	x	dirt mound, limbs, tree debris
PW-29-03-V-6	x	dirt mound
PW-29-03-V-7	x	dirt mound

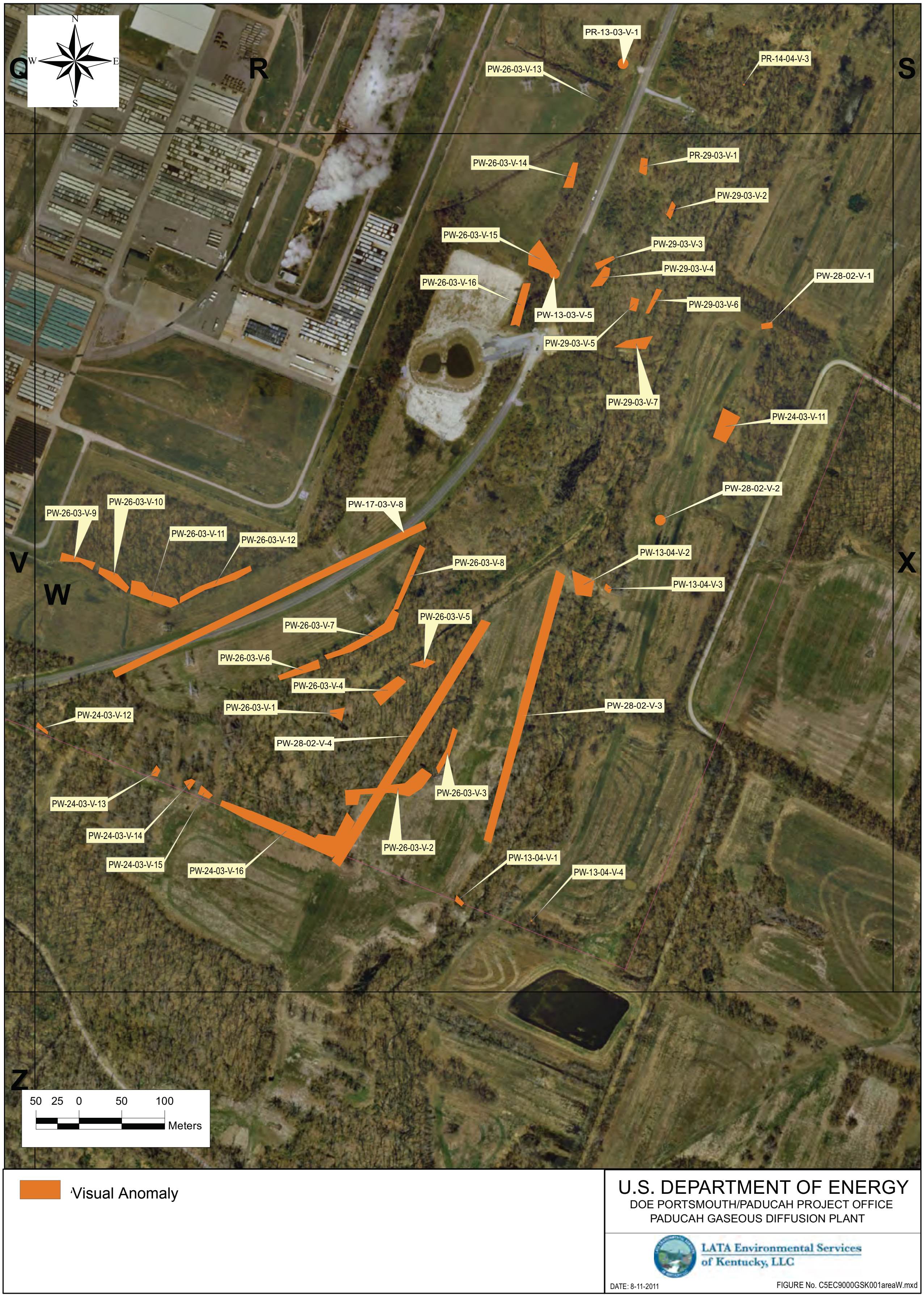

Figure 4.29. Visual Anomaly Map Area W

Table 4.21. Anomalies within Area X

Anomaly Name	Photo	Description
PS-28-02-V-1	N/A	dirt mound
PX-23-03-V-10	x	dirt mound, limbs, tree debris
PX-23-03-V-17	x	concrete
PX-23-03-V-17A	N/A	concrete
PX-23-03-V-18	x	dirt mound
PX-23-03-V-19	x	dirt mound
PX-24-03-V-1	N/A	dirt mound
PX-24-03-V-10	x	dirt mound
PX-24-03-V-2	N/A	dirt mound
PX-24-03-V-3	x	dirt mound
PX-24-03-V-4	x	dirt mound
PX-24-03-V-5	x	trash can
PX-24-03-V-6	x	dirt mound
PX-24-03-V-7	x	dirt mound
PX-24-03-V-8	x	dirt mound
PX-24-03-V-9	x	dirt mound

Figure 4.30. Visual Anomaly Map Area X

Table 4.22. Anomalies within Area Y

Anomaly Name	Photo	Description
PY-14-01-V-6	x	dirt mound
PY-14-01-V-7	x	dirt mound, concrete
PY-14-01-V-8	x	dirt mound

Figure 4.31. Visual Anomaly Map Area Y

Visual Anomaly

NOTE: No visual anomalies were identified in the mapped grid

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FIGURE No. C5EC9000GSK001areaZ.mxd

Figure 4.32. Visual Anomaly Map Area Z

4.2.4 Radiological Survey

Radiological surveys of the cleared areas on DOE-owned property (including property licensed to the Commonwealth of Kentucky) were performed using a 3x3 NaI (gamma) detector with a GPS data logger (DOE 2011a). (Based upon the evaluation of the aerial surveys of the portion of the WKWMA property owned by the Commonwealth of Kentucky, a radiological survey of this area was not needed.)

Uranium-238 was used as the target radionuclide. DOE-owned property was evaluated with a performance target of 100% for visual survey and a minimum of 10% for radiological walkover surveys. All identified anomalies (on DOE-owned property) were surveyed in accordance with MARSSIM (DOE 2000) guidance for performance of scoping surveys as Class 3 areas and in accordance with the Soils OU Work Plan (DOE 2011a). The radiological survey was performed concurrently with the visual survey.

Data from prior investigations, available at the time of scoping, served as the basis for the Class 3 MARRSIM determination of the investigation area (DOE 2011a). A review of existing data confirmed that concentrations of the radioisotopes of concern in the investigation area were less than 10% of the established derived concentration guideline level (DCGL) of 528 pCi/g uranium-238 (DOE 2011a). MARRSIM defines a Class 3 area as follows:

> Class 3 Areas: Any impacted areas that are not expected to contain any residual radioactivity, or are expected to contain levels of residual radioactivity at a small fraction of the $DCGL_W$, based on site operating history and previous radiation surveys. Examples of areas that might be classified as Class 3 include buffer zones around Class 1 or Class 2 areas, and areas with very low potential for residual contamination but insufficient information to justify a non-impacted classification.

While distinct areas of contamination were thought to be possible, the bulk of the property surveyed was considered to be nonimpacted. As a result of this radiological survey, no areas were identified above the criteria established in the work plan (DOE 2011a) (i.e., two times instrument background); therefore no anomalies were identified. Figure 4.33 illustrates the radiological survey of the DOE-owned property.

In accordance with the work plan (DOE 2011a), the radiological survey was designed with a minimum detection limit of 528 pCi/g uranium-238. For comparison, the approved Authorized Limit[4] for outside the Limited Area is 540 pCi/g (DOE 2014d).

The radiological survey in open areas was performed using an LM 2221 survey meter equipped with 3x3 NaI probes. Where the terrain was suitable, the probes were affixed to a Polaris Ranger 700 6x6. A nominal scanning speed of approximately 5 mph (2.2 meters per second) was used where allowed by the terrain. In many cases, the scan speed was slower. With a 2 second observation internal, the scanning sensitivity was 21 pCi/g of depleted uranium using NUREG-1507 calculation methodologies. Where the terrain was not suitable for driving, the team covered the area on foot using a nominal scanning speed of

[4] An Authorized Limit is a limit on the concentration or quantity of residual radioactive material on the surfaces or within property that has been derived consistent with DOE directives including the ALARA (as low as reasonably achievable) process requirements. An Authorized Limit may also include conditions or measures that limit or control the disposition of property (DOE O 458.1, Ch. 2; June 6, 2011). In other words, an Authorized Limit is a level of residual radioactive material that shall not be exceeded if the remedial action is to be considered completed and the property is to be released without restrictions on the use due to residual radioactive material (draft "Guide to Good Practice for Establishing Authorized Limits for the Release of Waste and Property Contaminated with Residual Radioactivity," March 30, 1999).

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Figure 4.33. Radiological Walkover

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DATE: 3-12-2015

Radiological_WalkOver.mxd

up to 0.5 m/sec. The meter was held approximately 4 inches from the ground during the survey. Instrumentation was performance-checked at the start of the work day to ensure proper functionality.

Anomalies observed during the performance of the drive-over surveys also were surveyed by hand using a 3x3 detector.

The monitoring systems were calibrated to the American National Standards Institute (ANSI) N323A–1997. In addition, each instrument passed a rigorous set-up procedure at the site, which applied 20 repetitive measurements to establish ambient background. The average instrument background reading for the 3x3 NaI was 25,000 cpm. Instruments were required to satisfy daily instrument background and source check requirements. The detectors were calibrated with cesium-137 and operated at a voltage of approximately 1,000 V, with a discriminator set at approximately 10 mV. Table 4.23 contains the acres per grid and the percentage of each that was radiologically surveyed. A total of 40% of the prescribed area was surveyed with 8% of the total survey being wooded areas. Surveyed areas were biased to the open areas (not wooded) due to the 2009 ice storm causing the wooded areas to be inaccessible until the following year. The radiological survey data is presented in Appendix B.

Wooded area anomalies were surveyed with a 2x2 NaI during February 1–April 23, 2010. The average instrument background number used for the 2x2 NaI was 9,000 cpm. The instrument background number was established by surveying soils near the ranger's residence in the Ballard County Wildlife Management Area. The selection criteria for soil background locations were that the soil was known to be uncontaminated and that it had been developed on the same loess that underlies the PGDP site. Instrument background values for beta and gamma radiation of soil were defined as two times the average of the data acquired during the walkover surveys at the background locations. Instrument calibration and operational parameters mirrored those for the 3x3 detectors.

Table 4.23. Radiological Survey Area

Grid	Included Acres	10% Radiological Survey Area in Acres	Actual Acres Surveyed	Grid % Surveyed
A	2.2822	0.2282	0.6	26.29%
B	84.2676	8.4268	42.5	50.43%
C	6.9649	0.6965	2.4	34.46%
D	20.2272	2.0227	5.8	28.67%
E	140.019	14.0019	35.9	25.64%
F	118.6076	11.8608	41.9	35.33%
G	180.7963	18.0796	109.4	60.51%
H	132.3759	13.2376	35.9	27.12%
I	3.6601	0.366	1	27.32%
J	146.5532	14.6553	66.8	45.58%
K	33.242	3.3242	16.2	48.73%
L	59.9712	5.9971	36.1	60.20%
M	242.6191	24.2619	127.5	52.55%
N	64.8262	6.4826	25.8	39.80%
O	42.306	4.2306	5.2	12.29%
P	232.5647	23.2565	70.5	30.31%
Q	98.7894	9.8789	34.3	34.72%
R	59.3899	5.939	23.2	39.06%
S	187.2553	18.7255	51.8	27.66%
T	10.4204	1.042	0	0.00%
U	118.769	11.8769	53.7	45.21%
V	129.4478	12.9448	77.1	59.56%
W	141.7521	14.1752	56	39.51%
X	52.8448	5.2845	14.6	27.63%

Table 4.23. Radiological Survey Area (Continued)

Grid	Included Acres	10% Radiological Survey Area in Acres	Actual Acres Surveyed	Grid % Surveyed
Y	35.5349	3.5535	11.7	32.93%
Z	0.5275	0.0528	0.5	94.79%
Total	2346.0143	234.6014	946.4	40.34%

4.3 2014–2015 RADIOLOGICAL SURVEYS AND SAMPLING

A focused radiological walkover survey and judgmental soil sampling were performed during the 2014–2015 field effort to validate the conclusions of the previous 2009–2010 field effort. A radiological survey was performed on 25 of the previously identified 534 anomalies; 25 selected anomalies served as proxies for the remaining 509 identified anomalies. Soil samples were analyzed by *ex situ* XRF analysis to measure total uranium concentration associated with the selected anomalies. Total uranium was used as a surrogate for other contaminants due to its being the primary radiological constituent found at PGDP.

The following Decision Rules were established for the 2014–2015 field effort.

- If the 25 selected anomalies show no uranium concentration above 10 mg/kg in soil,[5] then the other 509 anomalies are assumed not to be contaminated at a level of concern and, therefore, do not meet the definition of a SWMU or AOC.

- If one or more of the selected 25 anomalies show uranium concentration above 10 mg/kg in soil, then an evaluation of the remaining (509) anomalies by the FFA parties is necessary to determine whether a follow up action is needed (e.g., survey plan for individual survey units and the anomalies they contain).

4.3.1 Radiological Walkover Survey

Radiological surveys were conducted from October 2014 to January 2015 to determine the area, areas, single location, or a combination of the preceding with the highest count rate(s) for identifying sample locations within the selected 25 anomalies. The survey data is presented in Appendix B. Appendix C contains photographs of the 25 anomalies. A summary of the survey data is provided in Table 4.24. The average gamma readings for the 25 anomalies ranged from 9,598 to 14,547 cpm. The maximum gamma readings for the 25 anomalies ranged from 11,569 to 23,961 cpm. The highest single point reading was 23,961 cpm recorded in anomaly PQ-30-03-V-7. In accordance with the work plan (DOE 2014b), a confirmation survey was performed within a 5 m × 5 m square area centered on the single point. The confirmation readings ranged from 8,951 to 11,711 cpm. The 23,961 cpm reading could not be reproduced.

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[5] The project action level (PAL) for uranium (10 mg/kg) was set to ensure the data quality objectives, agreed to by the FFA parties, were met using the XRF analytical method. The PAL approaches the PGDP surface soil background concentration of 4.9 mg/kg for uranium and is below the risk-based no action level of 64.4 mg/kg for the child recreational user (DOE 2011c). Finally, an acknowledged XRF subject matter expert confirmed detection at the PAL could be achieved reliably with an XRF calibrated to detect uranium.

Table 4.24. Selected Anomalies

Anomaly Name	Average cpm	Max cpm	Date Surveyed	Area (m^2)	Description
PV-21-01-V-6	12,648	15,197	12/23/2014	4,046	dirt mound, barrels, miscellaneous debris
PG-02-03-R-2	12,642	13,475	10/22/2014	660	dirt mound
PM-26-02-R-3	12,474	13,369	10/20/2014	433	buried bricks
PE-01-03-V-18	11,876	13.020	11/7/2014	91	dirt mound, limbs, tree debris
PP-06-03-V-20	12,303	13,171	11/6/2014	113	dirt mounds
PS-26-02-V-1	12,711	17,438	11/12/2014	1,063	dirt mounds
PP-05-02-R-1a	11,924	13,732	10/20/2014	90	dirt mounds
PU-24-01-V-5	9,694	13,032	10/10/2014	3,594	dirt mound, concrete, miscellaneous debris
PU-24-01-V-4	12,154	13,415	11/6/2014	2,411	dirt mound, concrete, miscellaneous debris
PY-13-01-V-2	12,022	12,825	11/5/2014	10	concrete pipe debris
PF-13-02-V-16	12,353	13,926	10/24/2014	1,432	dirt mounds
PV-24-01-V-8	11,363	13,631	11/7/2014	1,962	dirt mounds, miscellaneous debris
PY-13-01-V-5	11,986	12,938	10/28/2014	374	dirt mounds, concrete debris
PF-13-02-R-1	10,835	12,198	11/7/2014	532	dirt mound, concrete
PF-18-02-V-20	11,669	13,262	12/16/2014	306	dirt mounds
PQ-30-03-V-5	14,547	17,262	12/19/2014	4,248	dirt, limbs, debris
PY-14-01-V-7	11,181	12,612	11/5/2014	1,351	dirt mounds, concrete debris
PY-13-01-V-4	12,596	13,646	10/24/2014	170	dirt mounds
PQ-30-03-V-6	13,324	15,579	11/13/2014	248	dirt mound, concrete
PE-01-03-V-24	12,176	12,826	11/7/2014	22	dirt mound, limbs, tree debris
PF-18-02-V-19	10,992	13,043	10/15/2014	357	concrete pipe, dirt mounds
PY-14-01-V-8	11,960	12,803	11/4/2014	29	dirt mound
PY-14-01-V-6	12,045	13,258	11/21/2014	145	dirt mound
PQ-30-03-V-7	12,176	23,961	12/19/2014	5,686	dirt mound, concrete
PU-24-01-V-6	9,598	11,569	10/27/2014	1,894	dirt mound, concrete, miscellaneous debris

Some anomalies could not receive 100% survey due to physical obstructions. Physical obstructions included trees/tree clusters, steep slopes, ditches, creek banks, and brush/thicket piles. The physical obstructions are identified on figures provided in Appendix D.

Radiological surveys were performed as specified in the work plan (DOE 2014b) using a REXON G5 FIDLER with a GPS data logger (DOE 2014b). Per the manufacturer's specification sheet, the REXON G5 FIDLER is a 5-inch diameter by 1/16-inch thick NaI (thallium) crystal coupled to a photo multiplier tube encased in 0.020-inch thick aluminum housing. The crystal is optimized for low-energy X-ray and gamma radiation detection. Its recommended energy range is 15–1,000 keV. The ruggedized version of the G5 FIDLER has an aluminum, open-mesh, screen covering a 0.10-inch thick beryllium window.

4.3.1.1 Survey Quality Control

Survey quality control (QC) was performed throughout the life of the project. Prior to the start of fieldwork, a baseline survey was performed at AOC 492 to establish a reference data set. The data sets from two locations within AOC 492 were used to establish control charts for daily QC checks for each detector. The survey consisted of a minimum of 200 logged measurements at the QC locations adjacent to AOC 492 and was performed with the detector approximately 4 inches above the ground in a reproducible geometry. Control charts were established based on the mean plus or minus two standard deviations for each QC location.

Each day prior to fieldwork, quality control field measurements were performed at two quality control locations adjacent to AOC 492. The measurements included a one-minute static count and a logged count with a minimum of 100 measurements.

On 6 of the 48 days the field QC measurements for QC-1 and 8 of the 48 days for QC-2 the field QC measurements were collected for detector 176961, the average, without taking into account the uncertainty in the field measurements and standard deviation, was outside the 2-sigma control value. The controlled laboratory QC for detector 176961 was; however, within the control value on all days. Because the controlled QC measurement fell within the control value, the detector was not taken out of service. This action was justified based on combined assessment of the uncertainty in the field measurements, such as soil water content and the controlled laboratory measurements. For detector 262339, the average field QC measurements for QC-1 and QC-2 were within the 2-sigma control value. For detector 262330, the average field QC measurements for QC-1 were within the 2-sigma control value. However, for 16 of the 39 days the field QC measurements for QC-2 were collected for detector 262330, the average, without taking into consideration the uncertainty in the measurements and standard deviation, was outside the 2-sigma control value. Taking into account the QC for QC-1 and the controlled QC measurements, detector 262330 was not taken out of service. For detector 250964, the average QC measurements for QC-1 were within the 2-sigma control value. For detector 250964, the average field QC measurements for QC-2 were in control, except for 1 day. Because the QC for QC-1 and the controlled QC measurements were in control, the detector was not taken out of service.

In addition to field quality assurance measurements, laboratory QC measurements were made in accordance with standard procedures and ANSI standards for portable radiological instrumentation. Measurements included morning and evening collection of static counts for background and a reference radiation source. All measurements were in established control limits of +/- 20% with the exception of 1 suspect background measurement for instrument 262339. A review of the data found that the remaining 81 background measurements were in range as were all source measurements. After interviewing the survey technician, it was determined that there was a potential for a transcription error associated with the recording of the background measurement. Taking into account the prior QC measurements and the corresponding QC-1 and QC-2, detector 262339 was not taken out of service.

Additionally at each anomaly, gamma dose rate measurements were taken at the perimeter of the area to assess potential impacts from activities within the PGDP Limited Area.

During the review of the initial radiological survey data for PS-26-02-V-1, unusually high count rates were observed in the data set for detector 262330. Multiple resurveys of the area with the unusually high count rate measurements were performed in the field to determine the validity of the measurements. These resurveys did not reproduce the original elevated measurements. A review of daily performance check and QC survey data did not reveal any issues with detector 262330. Upon further investigation, it was determined that the detector window of detector 262330 was punctured, which allowed light to impinge upon the detector resulting in elevated count rates measurements. The puncture was limited to a very small area of the detector window behind the protective screen. As a result of the puncture in the window, elevated count rate measurements only were observed when the detector was used in direct sunlight. The detector window was repaired and placed back into service.

A review of other data generated by detector 262330 was performed to determine if unusually high count rate measurements were observed at other anomalies. If elevated count rates were observed, resurveys were performed to verify the count rate measurements. If the count rate measurements could not be confirmed, the original data generated by detector 262330 was considered suspect and the area resurveyed. It also was determined that due to the multiple layers of confirmation survey activities performed; no sampling points were selected based solely on the measurements from detector 262330.

4.3.2 Media Sampling

Surface soil sample locations were selected based on inflection point analysis, as described in Section 3. The inflection point analysis for each anomaly is presented in Figures 4.34–4.58.

One 5-point composite surface soil sample from each of the 25 selected anomalies was collected and analyzed for total uranium by *ex situ* XRF method. The 5-point composite soil samples were collected from 0-4 inches[6] below surface distributed from a 1-m^2 area centered on the location with the highest count rate. Because the radiological survey implements an approach that ensures a data density of at least one measurement per 1 m^2, the collection of the soil sample represented a one square meter area consistent with the radiological survey.

The sample analyte for this investigation was total uranium. All samples were delivered under chain-of-custody to the field laboratory for analysis. All of the planned 25 samples were collected and analyzed by *ex situ* XRF for total uranium. All analytical results, presented in Table 4.25, show that total uranium was found to be less than 10 mg/kg for each of the 25 selected anomalies.

Table 4.25. Analytical Results for the 25 Selected Anomalies

Project Sample ID	Analysis	Result[1]	Detection Limit	Unit	Method
PE-03-01-V-18	Total Uranium	10U	10	mg/kg	XRF
PE-03-01-V-24	Total Uranium	10U	10	mg/kg	XRF
PF-13-02-R-1	Total Uranium	10U	10	mg/kg	XRF
PF-13-02-V-16	Total Uranium	10U	10	mg/kg	XRF
PF-18-02-V-19	Total Uranium	10U	10	mg/kg	XRF
PF-18-02-V-20	Total Uranium	10U	10	mg/kg	XRF
PG-02-03-R-2	Total Uranium	10U	10	mg/kg	XRF
PM-26-02-R-3	Total Uranium	10U	10	mg/kg	XRF
PP-05-02-R-1a	Total Uranium	10U	10	mg/kg	XRF
PP-06-03-V-20	Total Uranium	10U	10	mg/kg	XRF
PQ-30-03-V-5	Total Uranium	10U	10	mg/kg	XRF
PQ-30-03-V-6	Total Uranium	10U	10	mg/kg	XRF
PQ-30-03-V-7	Total Uranium	10U	10	mg/kg	XRF
PS-26-02-V-1	Total Uranium	10U	10	mg/kg	XRF
PU-24-01-V-4	Total Uranium	10U	10	mg/kg	XRF
PU-24-01-V-5	Total Uranium	10U	10	mg/kg	XRF

[6] The selection of 0–4 inches was based on the depth of contamination the radiological instrument measures.

Table 4.25. Analytical Results for the 25 Selected Anomalies (continued)

Project Sample ID	Analysis	Result[1]	Detection Limit	Unit	Method
PU-24-01-V-6	Total Uranium	10U	10	mg/kg	XRF
PV-21-01-V-6	Total Uranium	10U	10	mg/kg	XRF
PV-24-01-V-8	Total Uranium	10U	10	mg/kg	XRF
PY-13-01-V-2	Total Uranium	10U	10	mg/kg	XRF
PY-13-01-V-4	Total Uranium	10U	10	mg/kg	XRF
PY-13-01-V-5	Total Uranium	10U	10	mg/kg	XRF
PY-14-01-V-6	Total Uranium	10U	10	mg/kg	XRF
PY-14-01-V-7	Total Uranium	10U	10	mg/kg	XRF
PY-14-01-V-8	Total Uranium	10U	10	mg/kg	XRF

[1]10U indicates result was less than level of detection (10 mg/kg) (i.e., total uranium was not detected at or above the detection limit).

Precision, accuracy, and completeness objectives were presented in Section 6 of the work plan (DOE 2014b). An assessment of these objectives for field analytical data was performed. The results of this assessment are provided in Table 4.26.

Table 4.26 QA Assessment for Field Laboratory Measurements of Data

Parameter	Method	Matrix	Precision (%)	Completeness (%)	Accuracy (%)
Uranium	SW-846-6200 (XRF)	Soil	100	100	100

Precision refers to the level of agreement among repeated measurements of the same characteristic, usually under a given set of conditions. To determine the precision of the field laboratory analysis, results of reanalysis of field samples were evaluated. The absolute difference between the two values calculated is referred to as the relative percent difference (RPD). Precision was determined for this project by determining RPD between the two results. Quality assurance (QA) objectives for precision given in the work plan are performance based, with RPDs to be 35%. These objectives were met by the data collected during this project.

Accuracy refers to the nearness of a measurement to an accepted reference or true value. To determine the accuracy of a field laboratory method, method blanks/instrument blanks are analyzed. Accuracy for this project was determined by reviewing results of method blanks/instrument blanks. QA objectives for accuracy given in the work plan are performance based; no concentrations of target compounds greater than the quantitation limits in method/instrument blanks. This objective was achieved for the project data set. Additionally, field laboratory results were compared to fixed-base analytical results. All fixed-base analytical results agreed with the results reported using the field laboratory.

Representativeness is the degree to which discrete samples accurately and precisely reflect a characteristic of a population, variations at a sampling location, or an environmental condition. Representativeness is a qualitative parameter and will be achieved through careful, informed selection of sampling sites, drilling sites, drilling depths, and analytical parameters and through the proper collection and handling of samples to avoid interference and minimize contamination and sample loss. This objective was achieved for the Sitewide Evaluation by evaluating field condition before and during the data acquisition process to ensure that the most representative sample set possible was collected.

Completeness is a measure of the percentage of valid, viable data obtained from a measurement system compared with the amount expected under normal conditions. The goal of completeness is to generate a sufficient amount of valid data to satisfy project needs. Completeness also is a measure of samples collected during the field effort with respect to those targeted for collection in the work plan. All soil samples targeted for collection during this project were collected.

Comparability is the extent to which comparisons among different measurements of the same quantity or quality will yield valid conclusions. Comparability was assessed in terms of field standard operating procedures, analytical methods, QC, and data reporting. In addition, data validation assesses the processes employed by the laboratory that affect data comparability.

Sensitivity or lower limit of detection can be established from actual measured performance based on spike recoveries in the matrix of concern or from acceptable method performance on a certified referenced material of the appropriate matrix and within the appropriate calibration range for the application. The field instrument met the sensitivity established in the data quality objectives for this project.

Measurement performance criteria for the XRF measurements were established in the work plan (DOE 2014b). All criteria were met as follows:

- Relative percent differences for field samples were 0%.
- No target compounds were detected in method blanks/instrument blanks.
- Data were 100% complete.

Additionally, the accuracy of the XRF measurements was verified by comparing fixed-base laboratory measurements. All fixed-base laboratory measurements agreed with the results reported using the XRF instrument (i.e., uranium results were reported < 10 mg/kg).

4.4 FIELD RESULTS

DOE completed the 2009–2010 surveys and no previously unknown contaminated areas were identified, no areas were found to have radiological readings greater than twice instrument background, and no markings or other visual evidence (including process knowledge) were identified. There were 633 anomalies identified by the visual walkover. After crosswalking the anomalies with previously identified anomalies, 99 were found to be part of previous and ongoing evaluations/investigations and were not evaluated further in this effort. The 99 identified anomalies that are not evaluated further were identified previously as part of the Soil Piles Addendum 2, WAG 17, existing SWMUs, or known existing structures (i.e., Kentucky Ordnance Works bunkers). The remaining 534 identified anomalies were evaluated as part of this SER.

Based on the survey findings, no sampling was required. Because the data collected did not exceed current and future land use thresholds, there is no need to establish new SWMUs or AOCs for these anomalies, nor is there any need to identify future corrective actions for the anomalies.

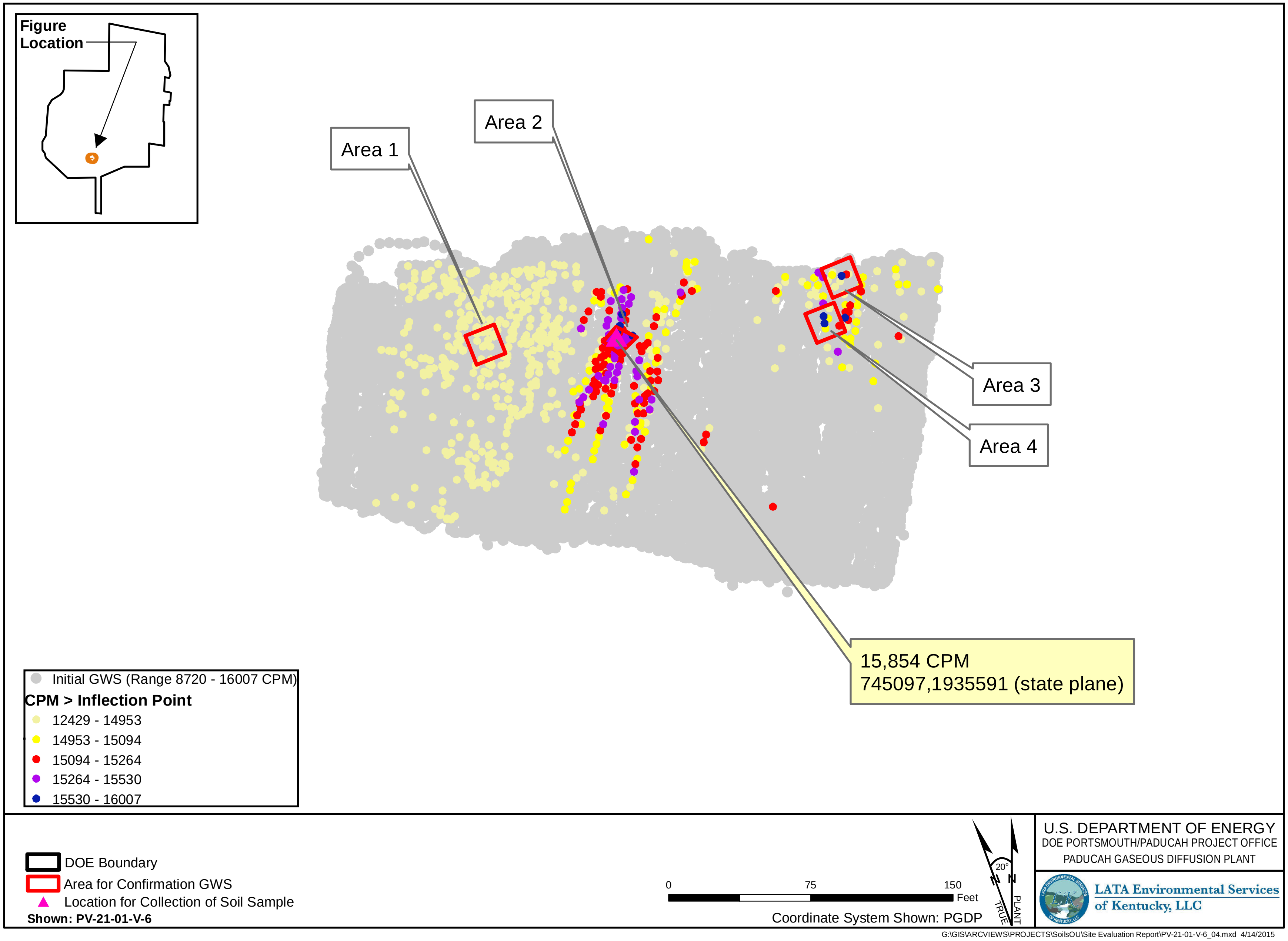


Figure 4.34. Anomaly PV-21-01-V-6

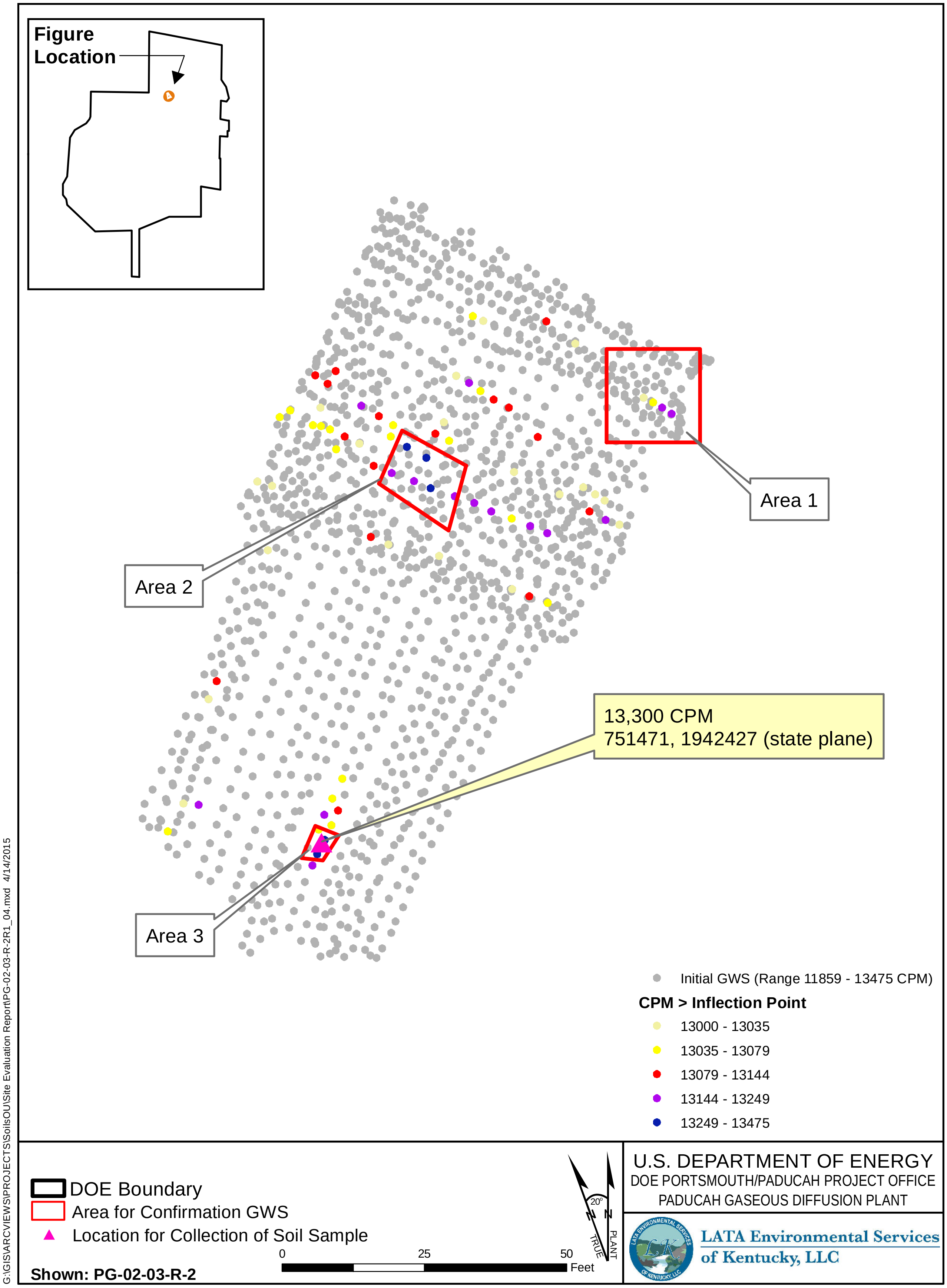


Figure 4.35. Anomaly PG-02-03-R-2

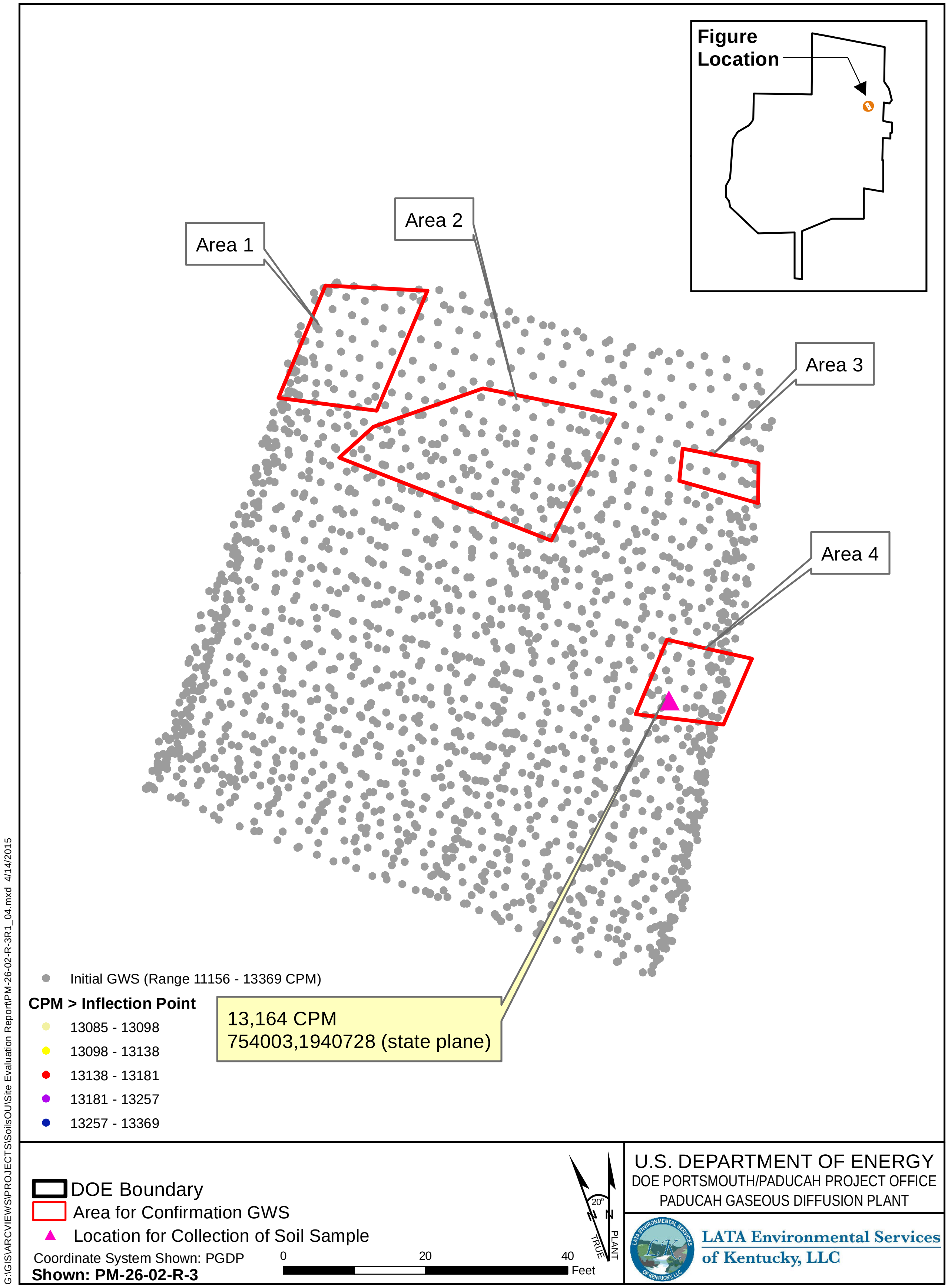


Figure 4.36. Anomaly PM-26-02-R-3

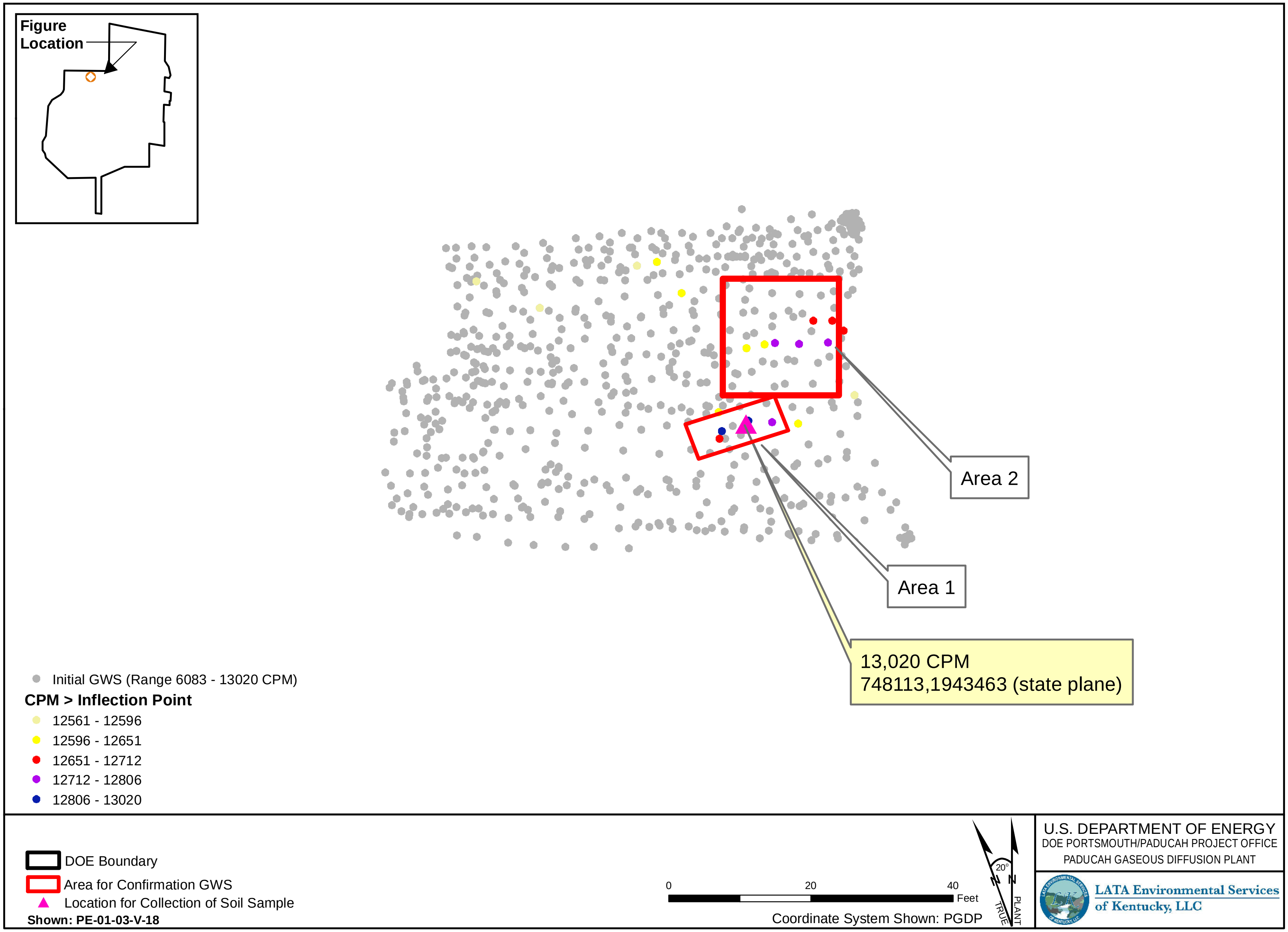


Figure 4.37. Anomaly PE-01-03-V-18

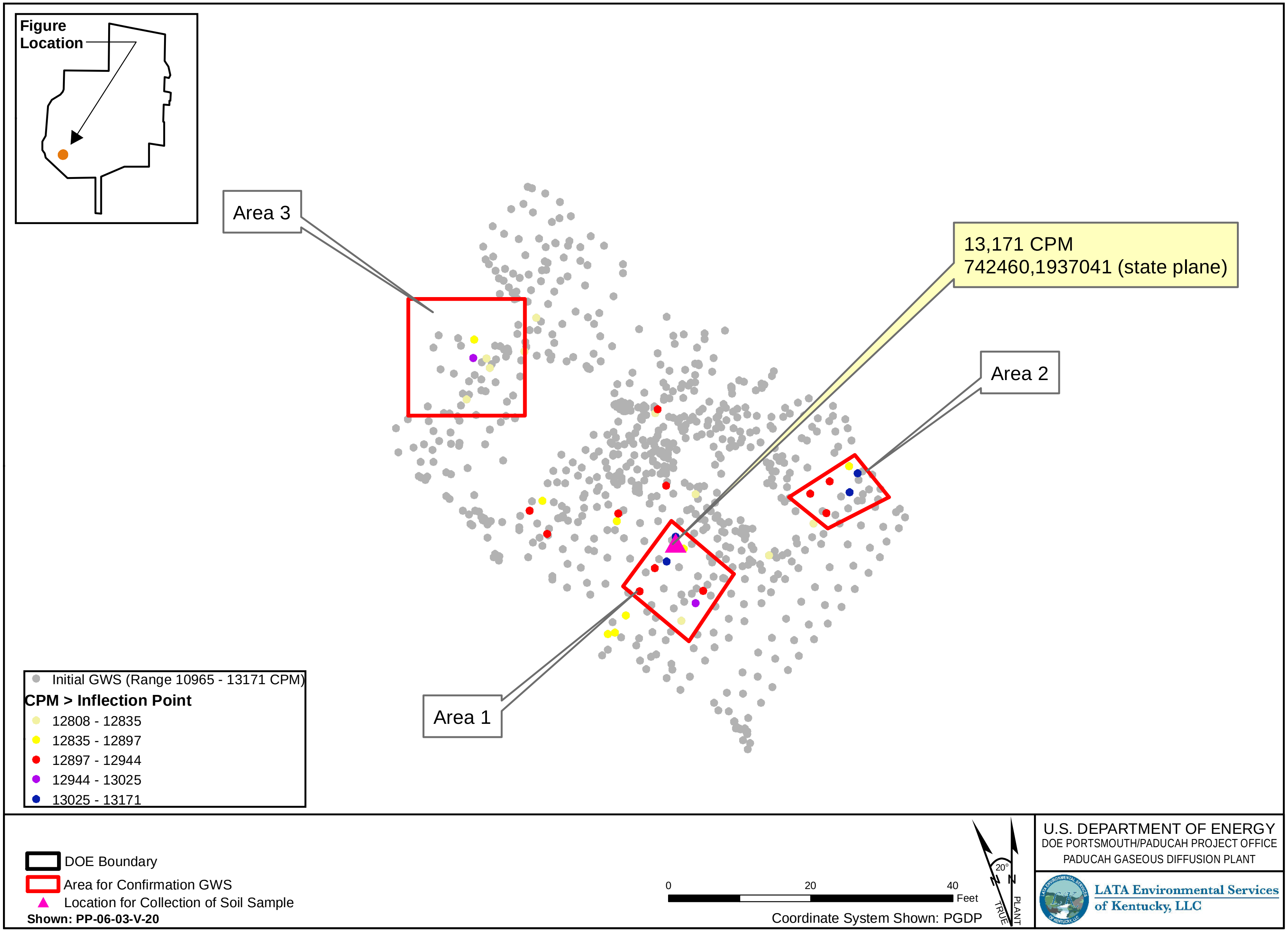
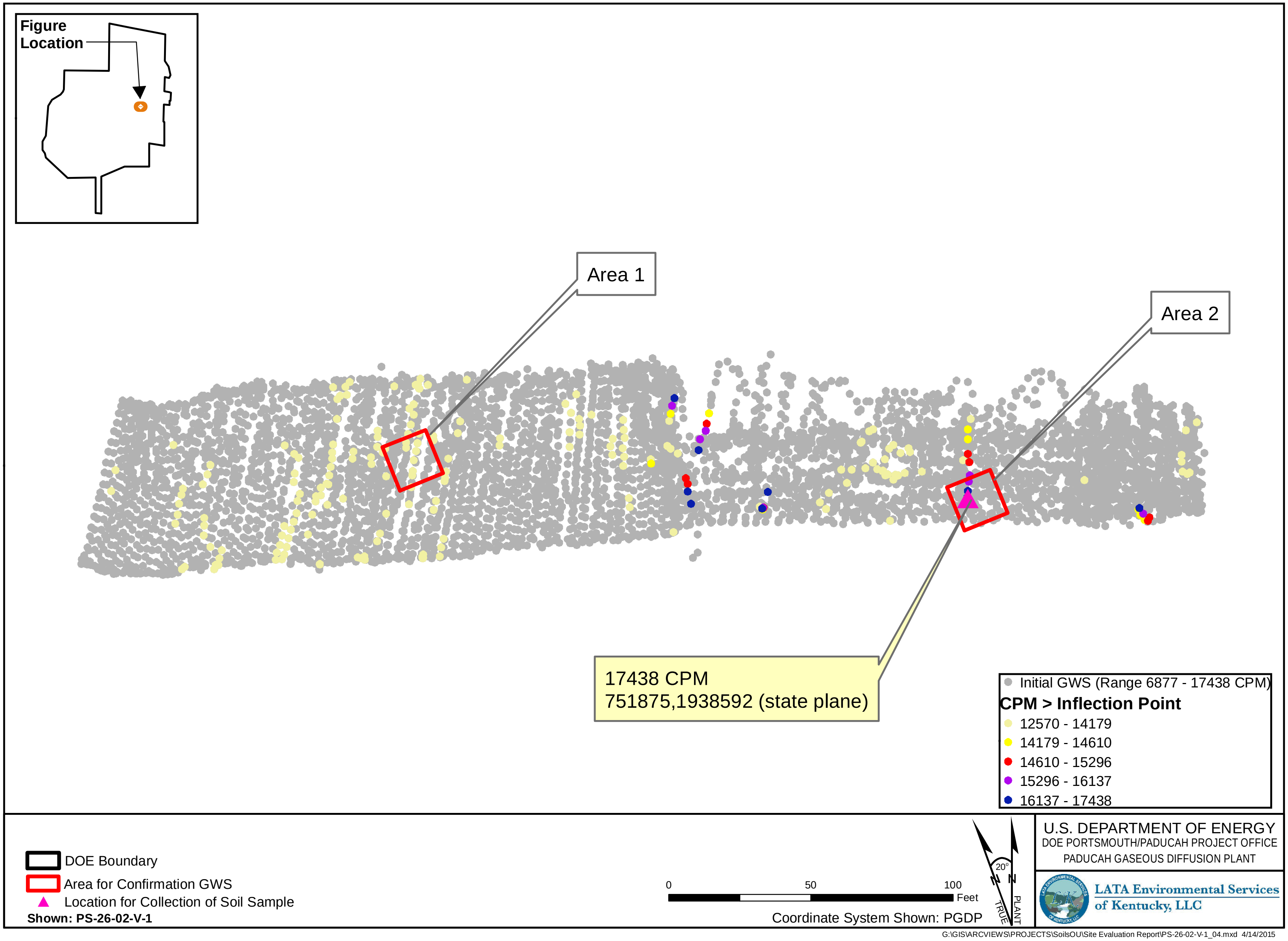


Figure 4.38. Anomaly PP-06-03-V-20



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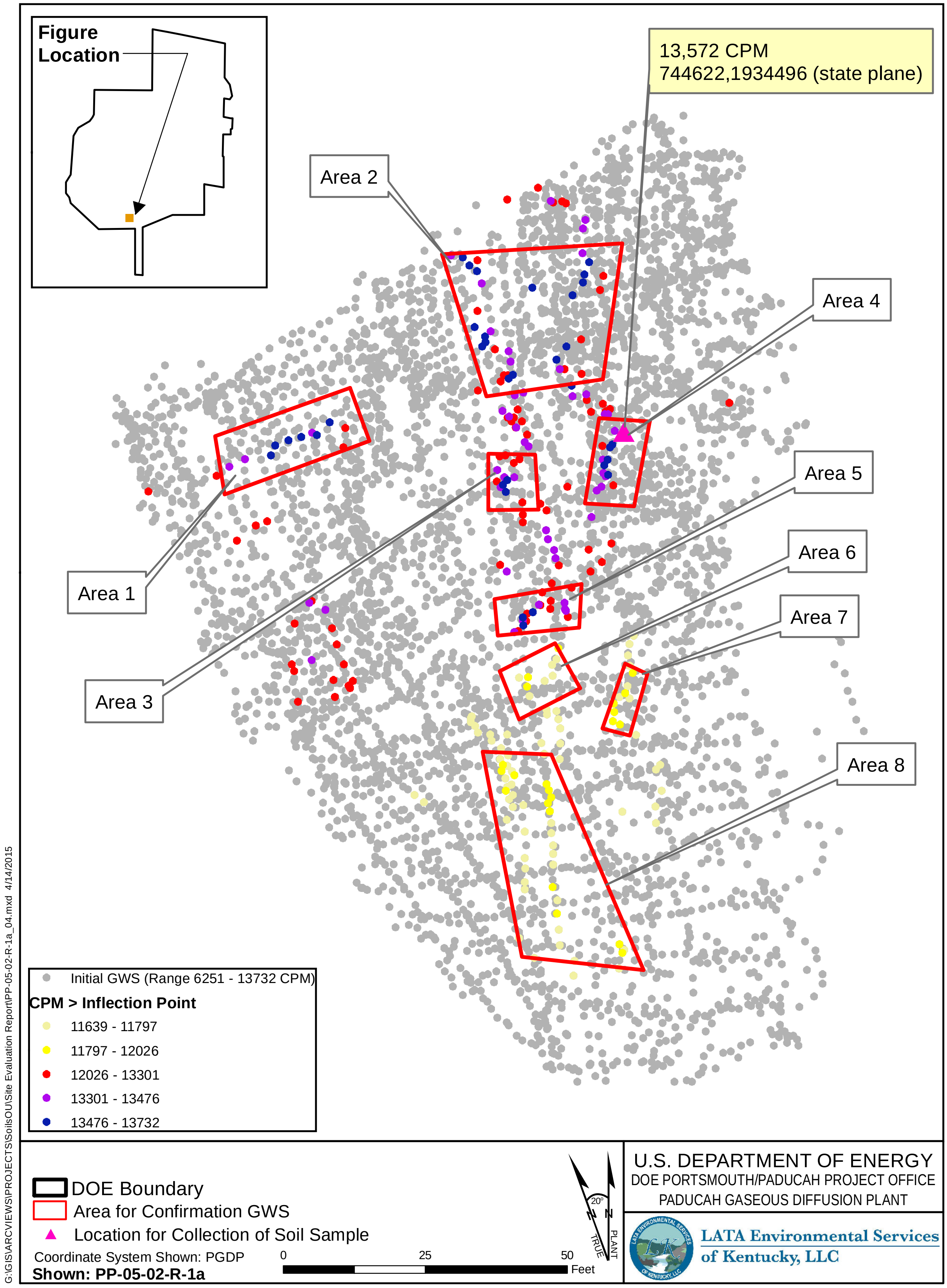

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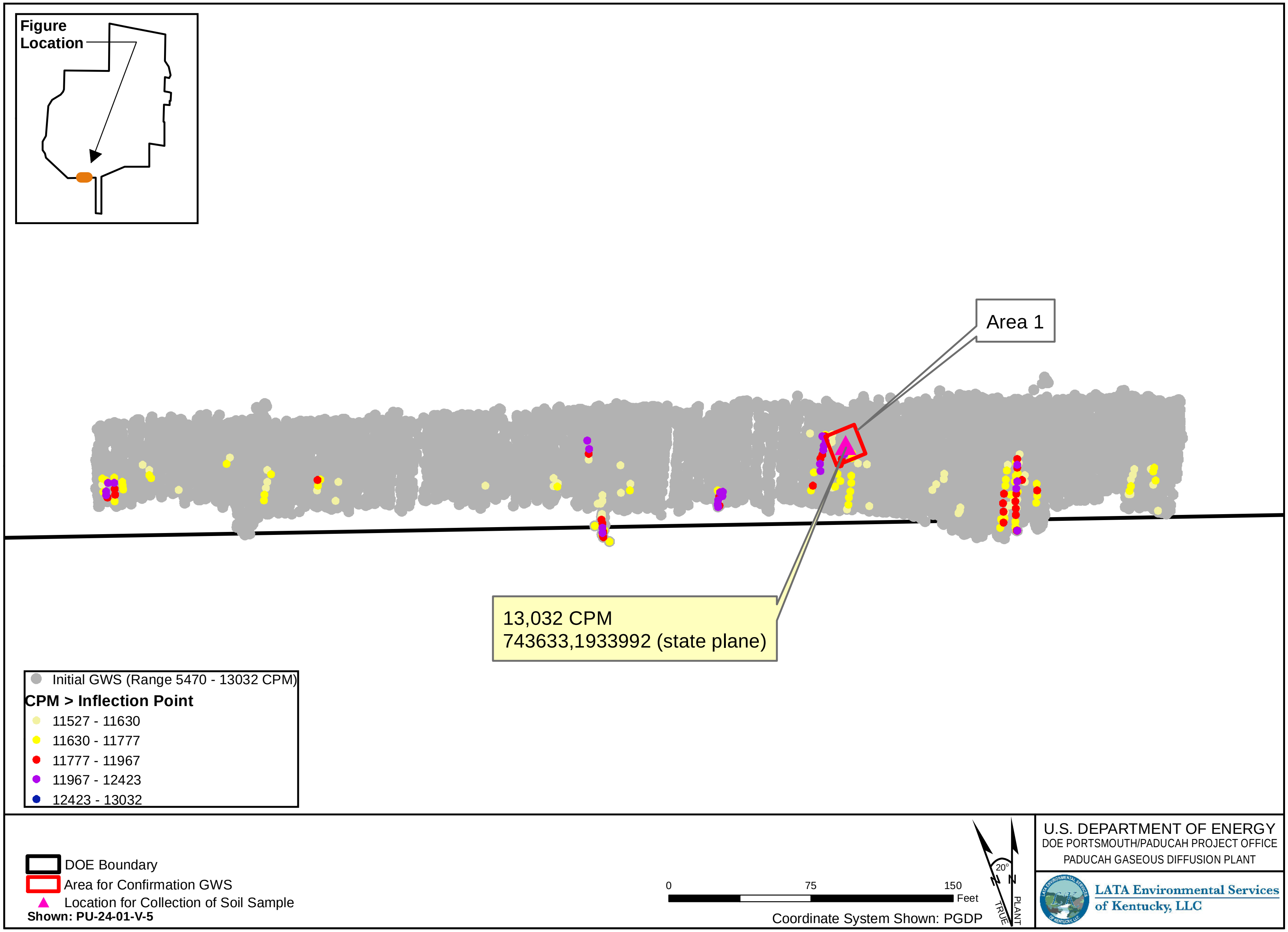
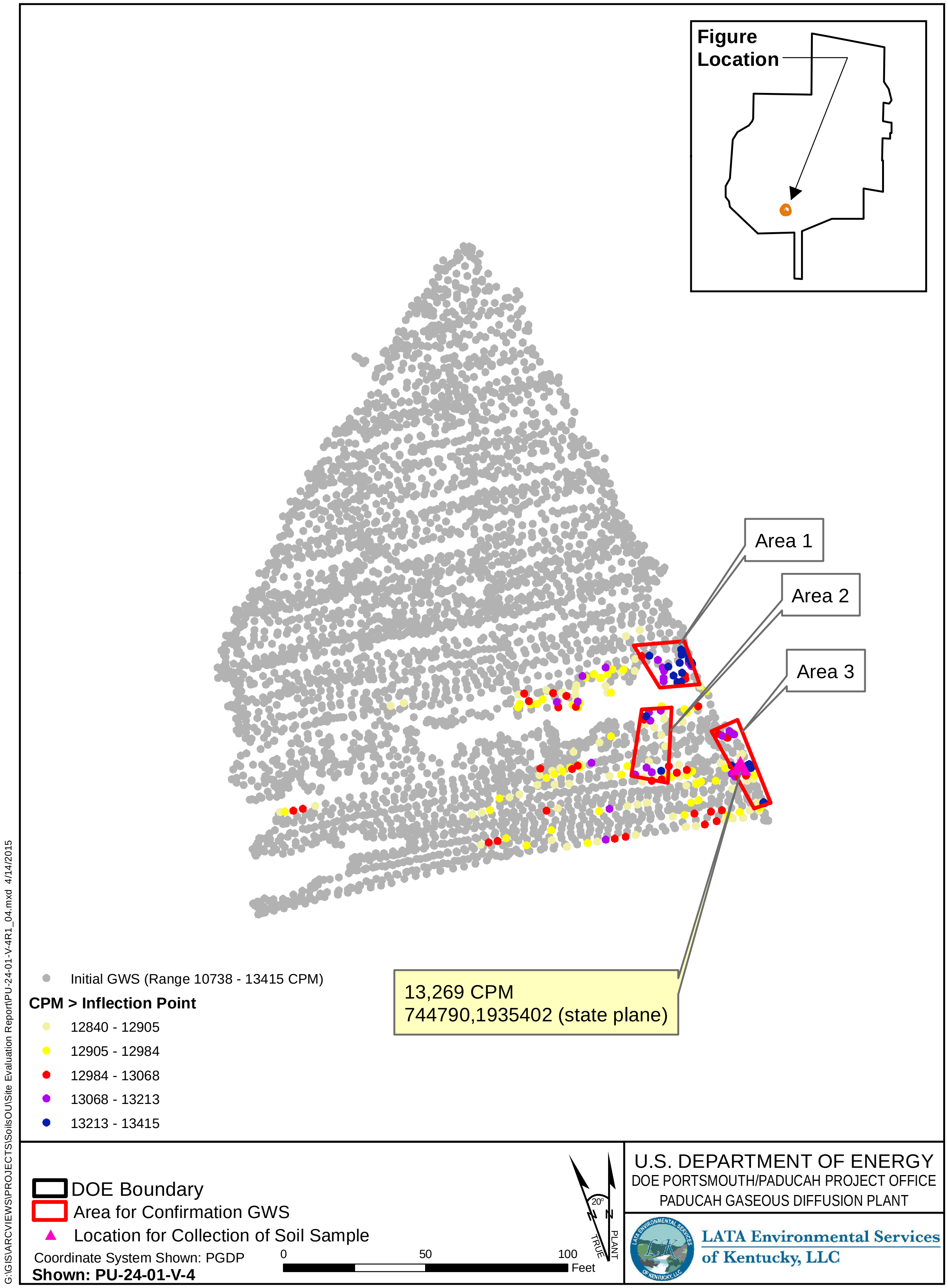


Figure 4.41. Anomaly PU-24-01-V-5



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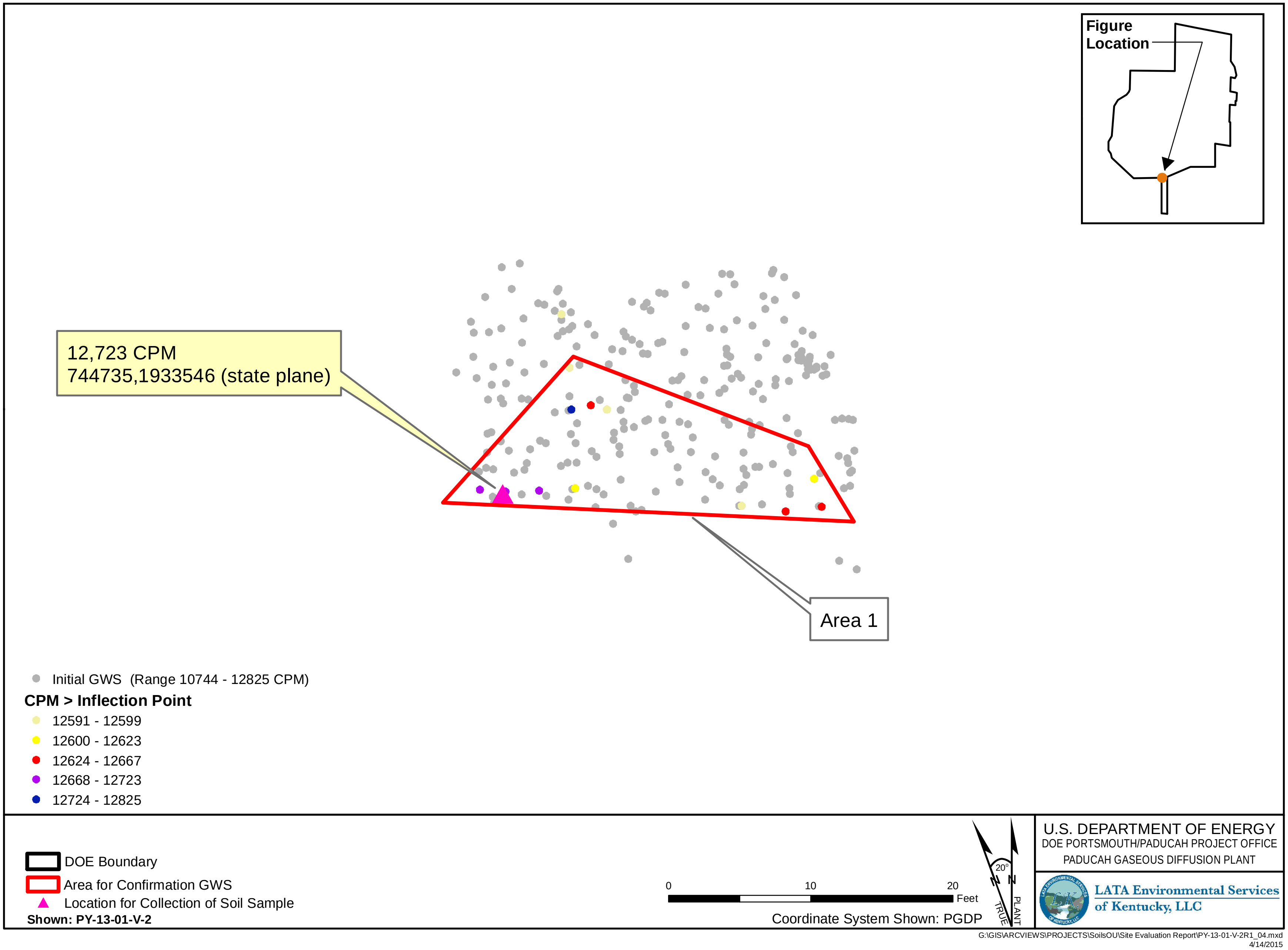


Figure 4.43. Anomaly PY-13-01-V-2

Figure 4.44. Anomaly PF-13-02-V-16

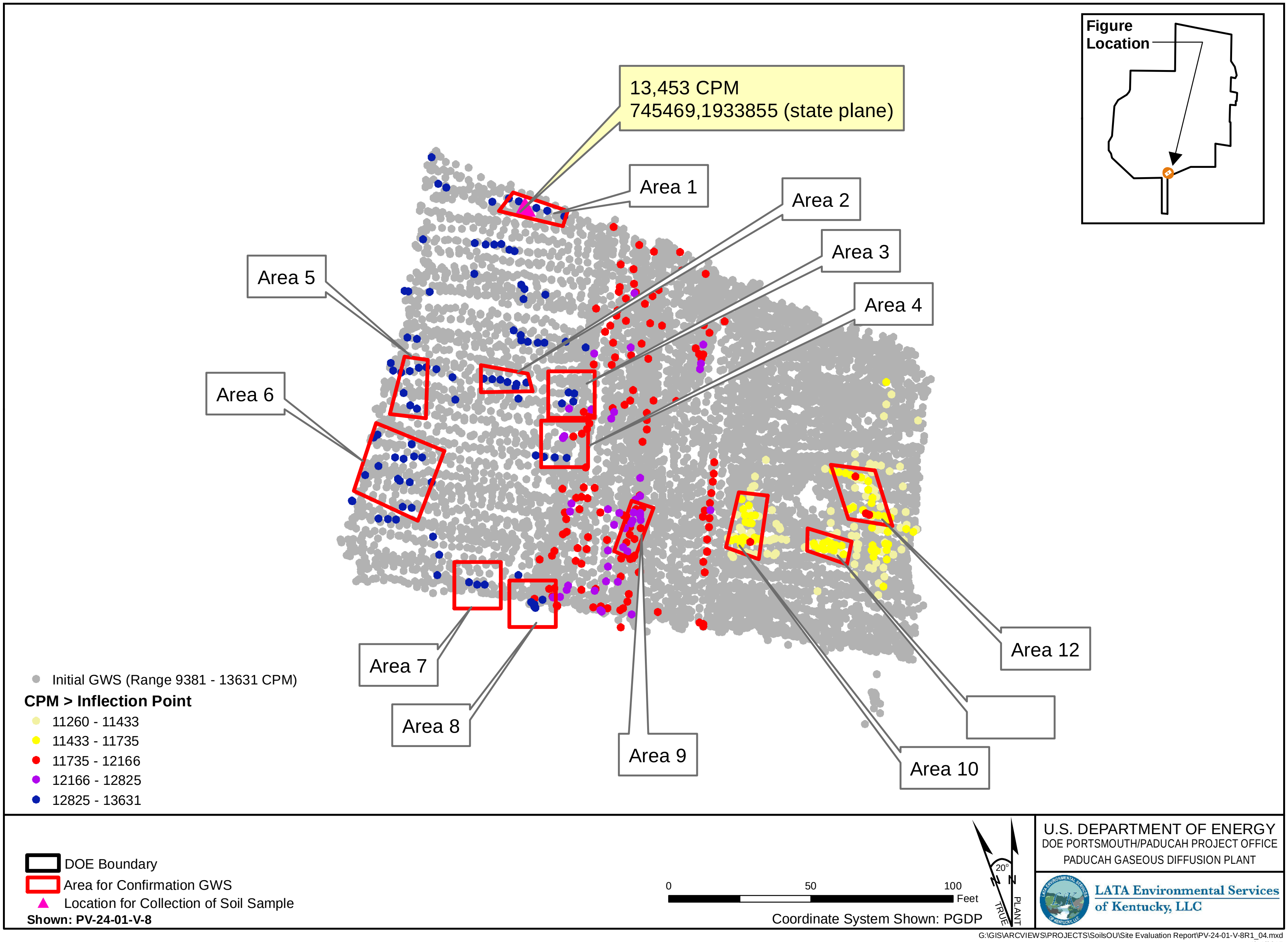
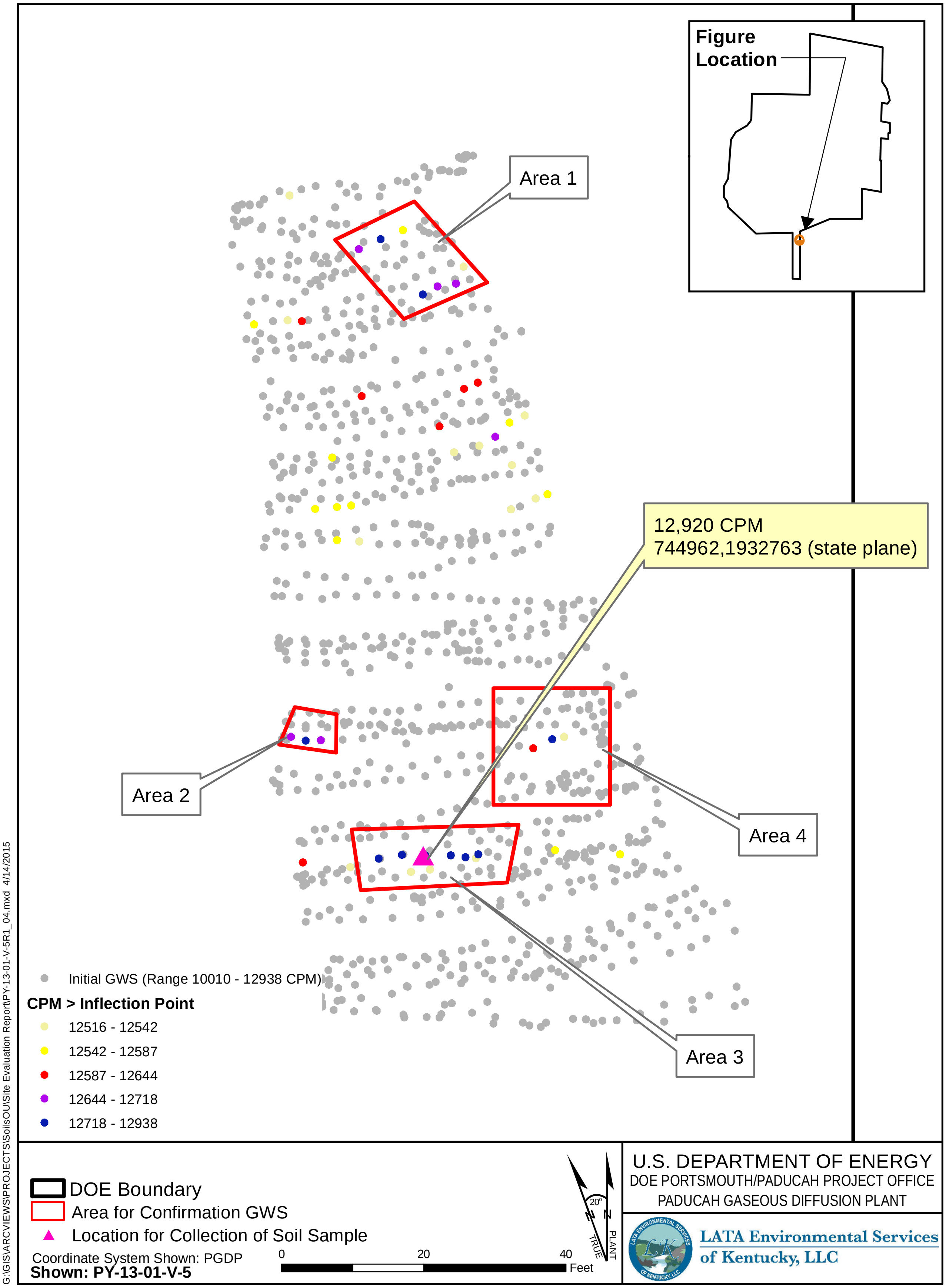


Figure 4.45. Anomaly PV-24-01-V-8



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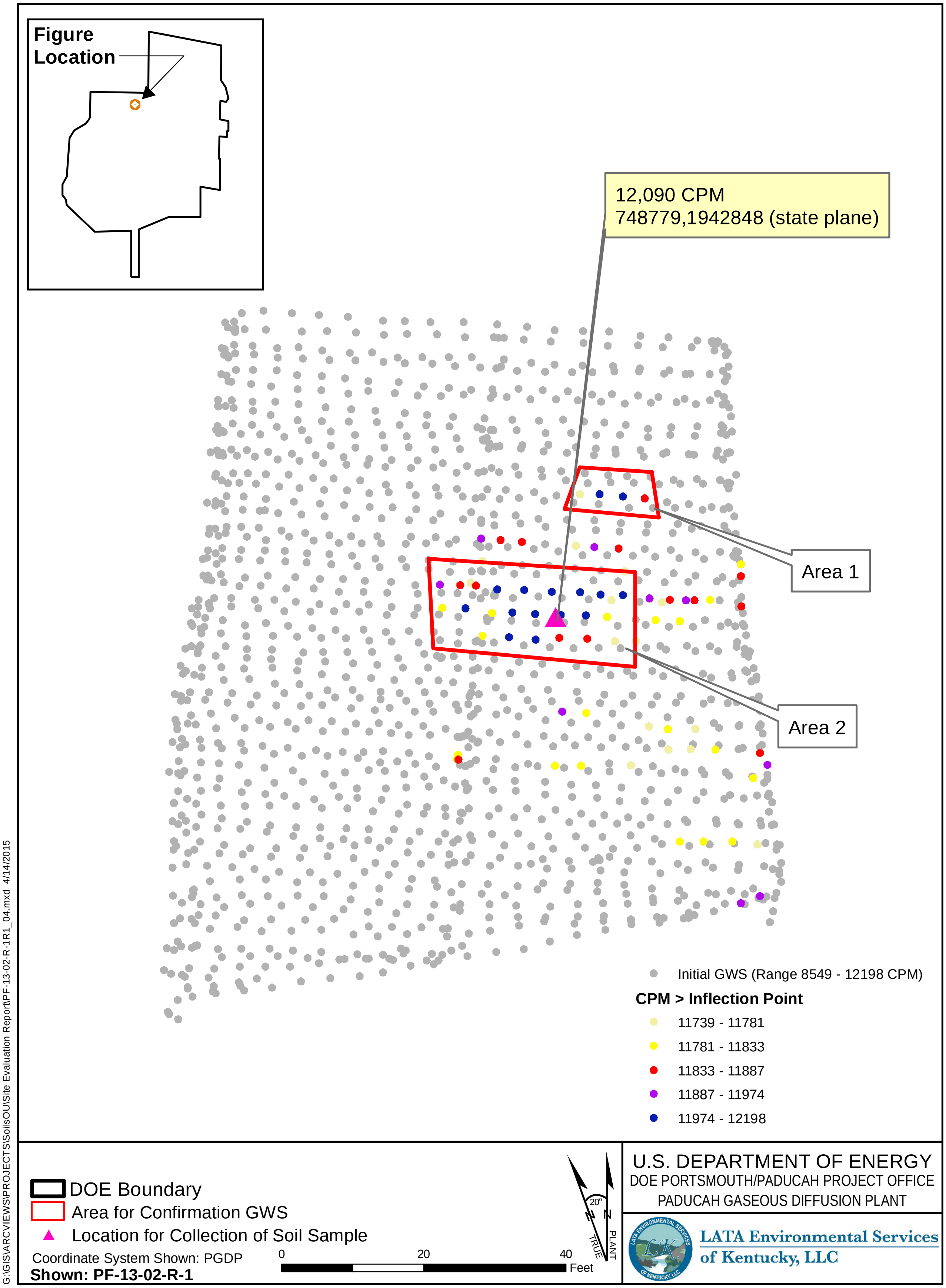

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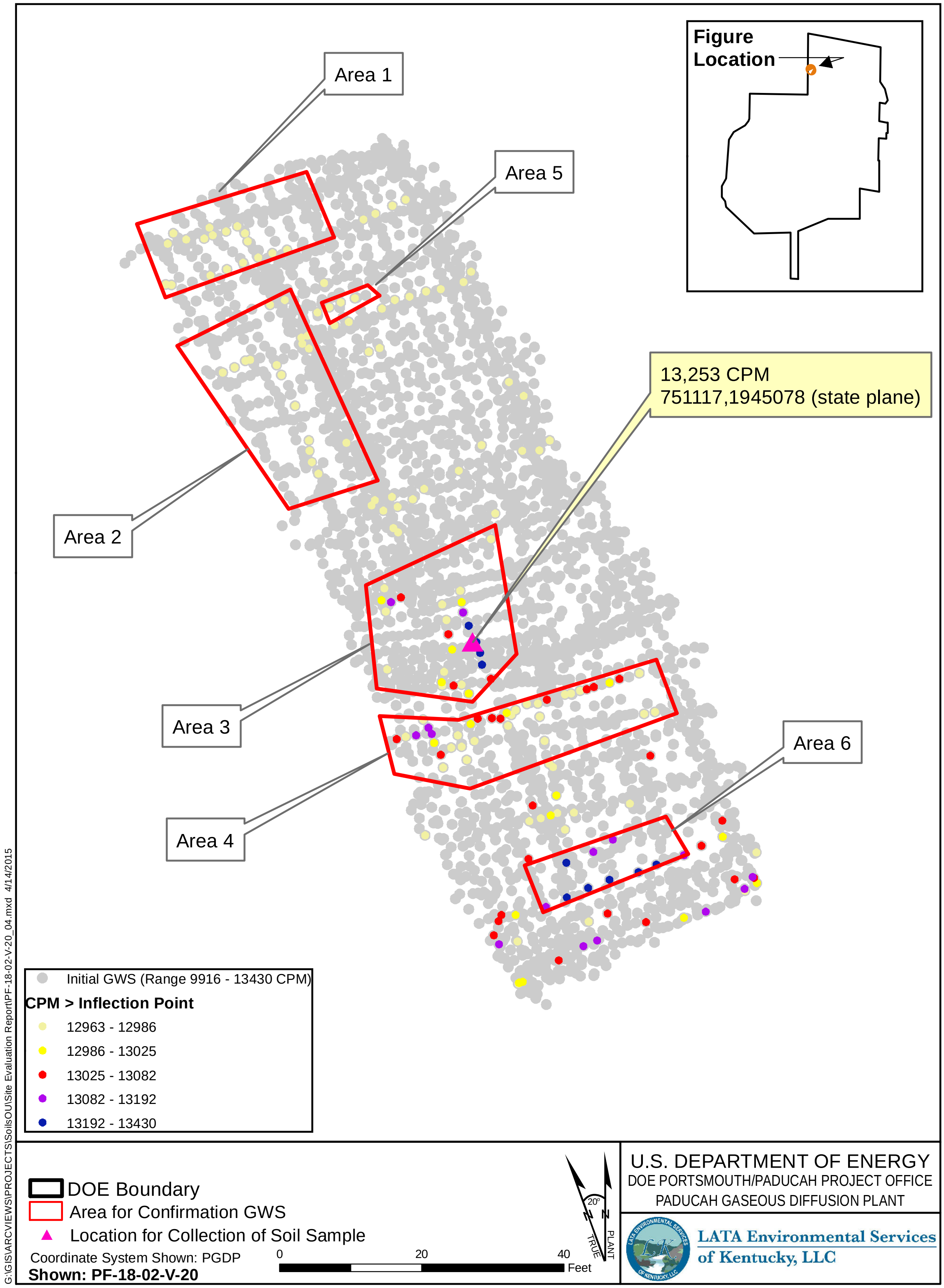

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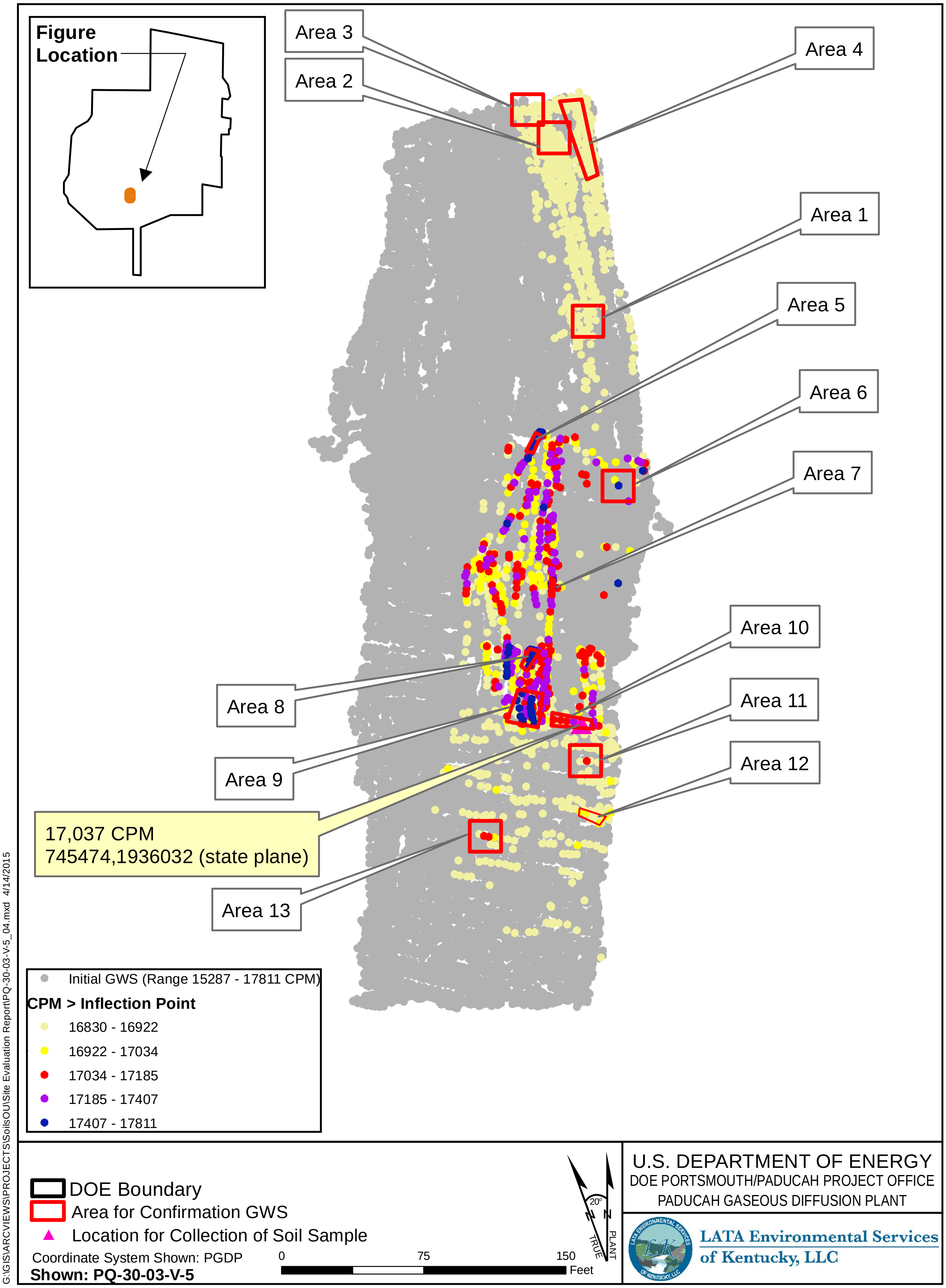

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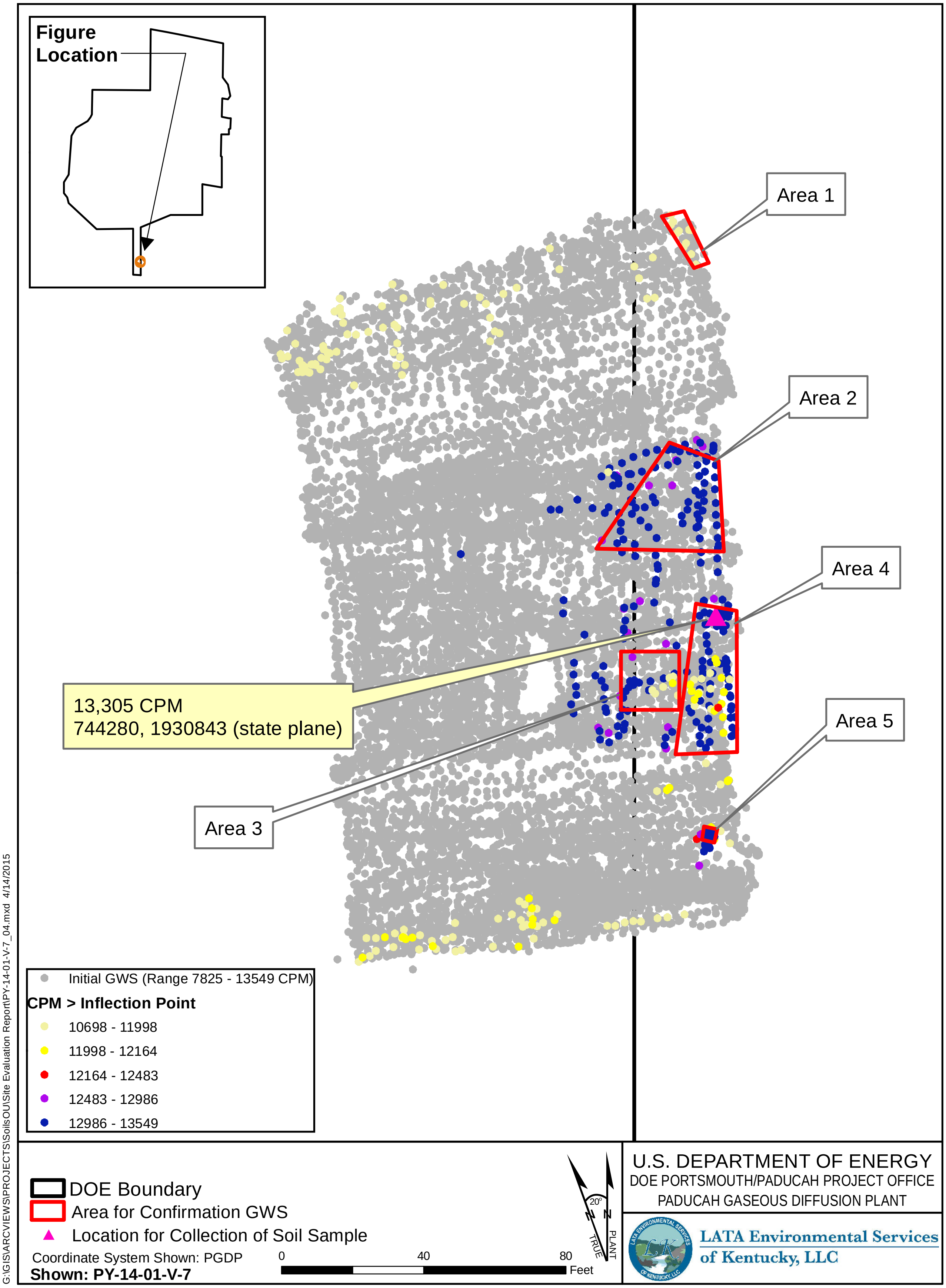

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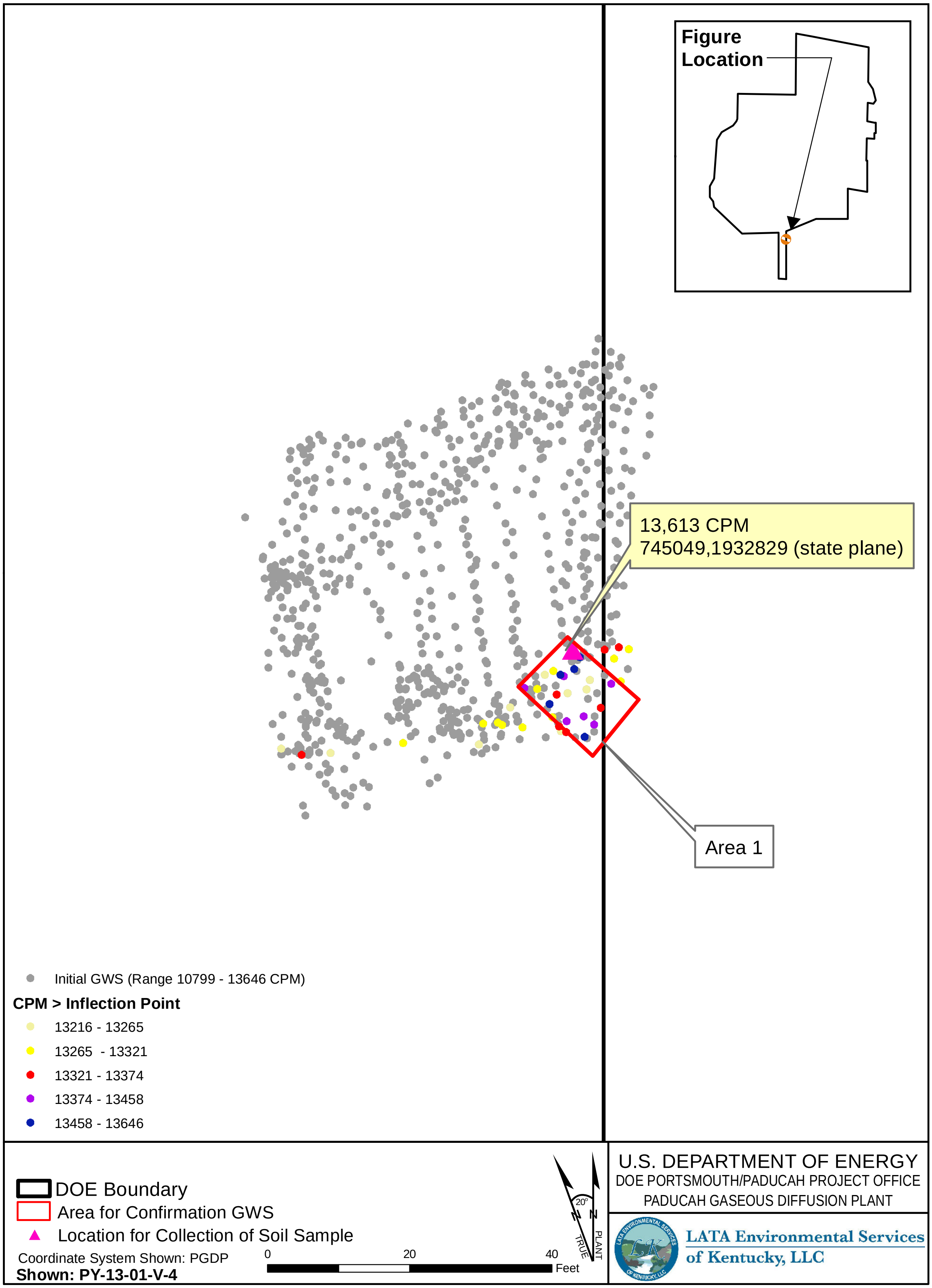

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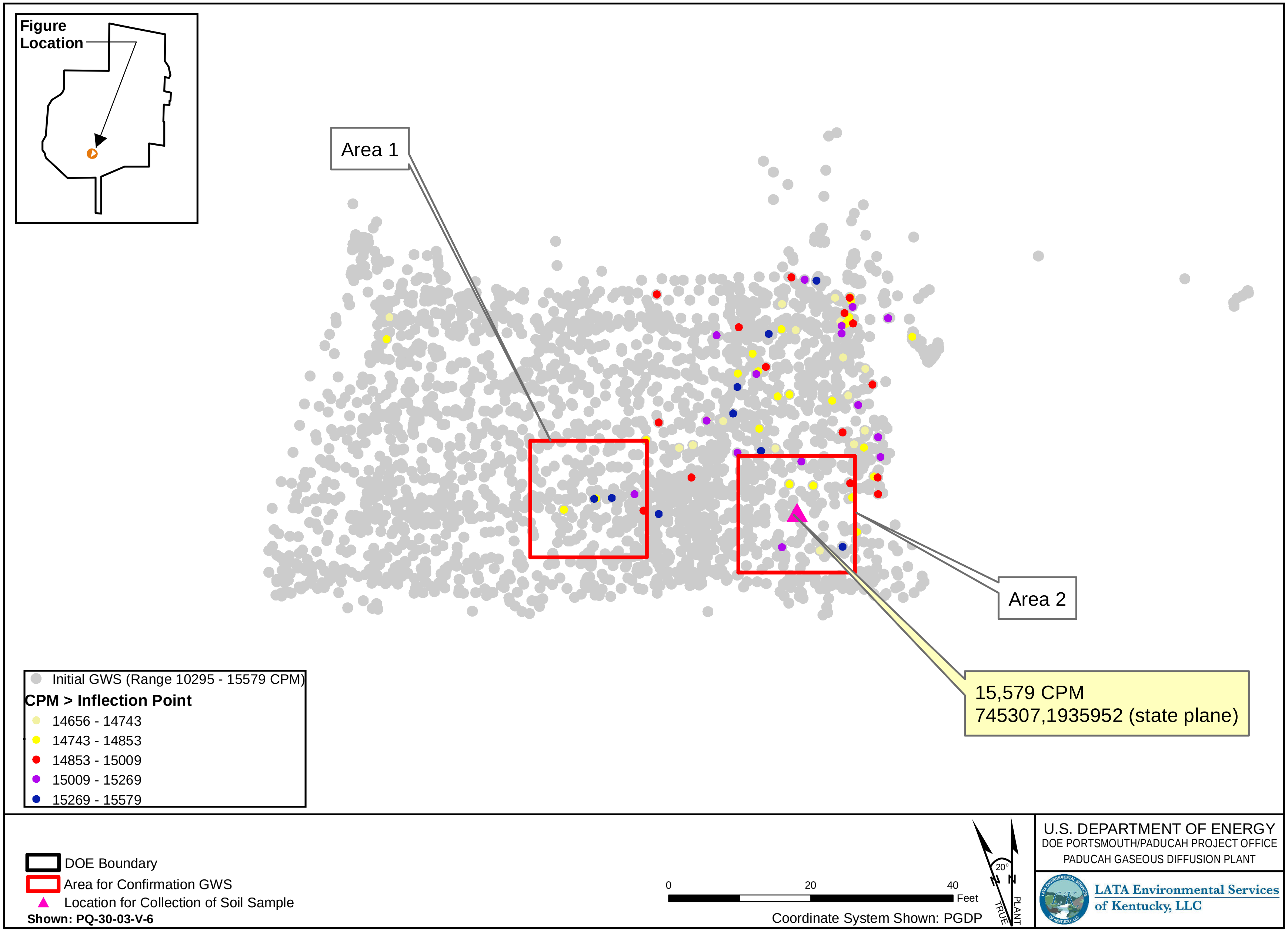

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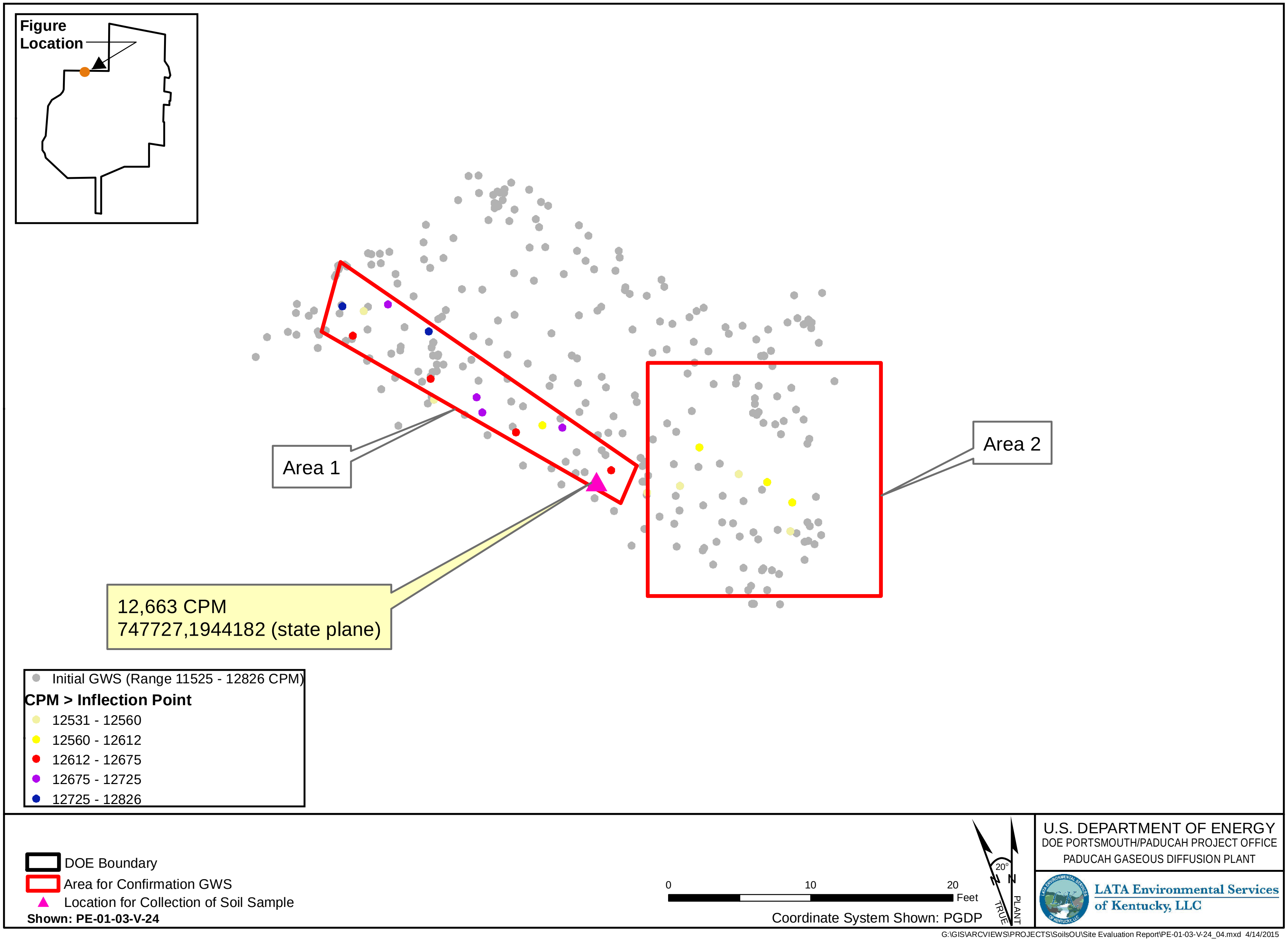
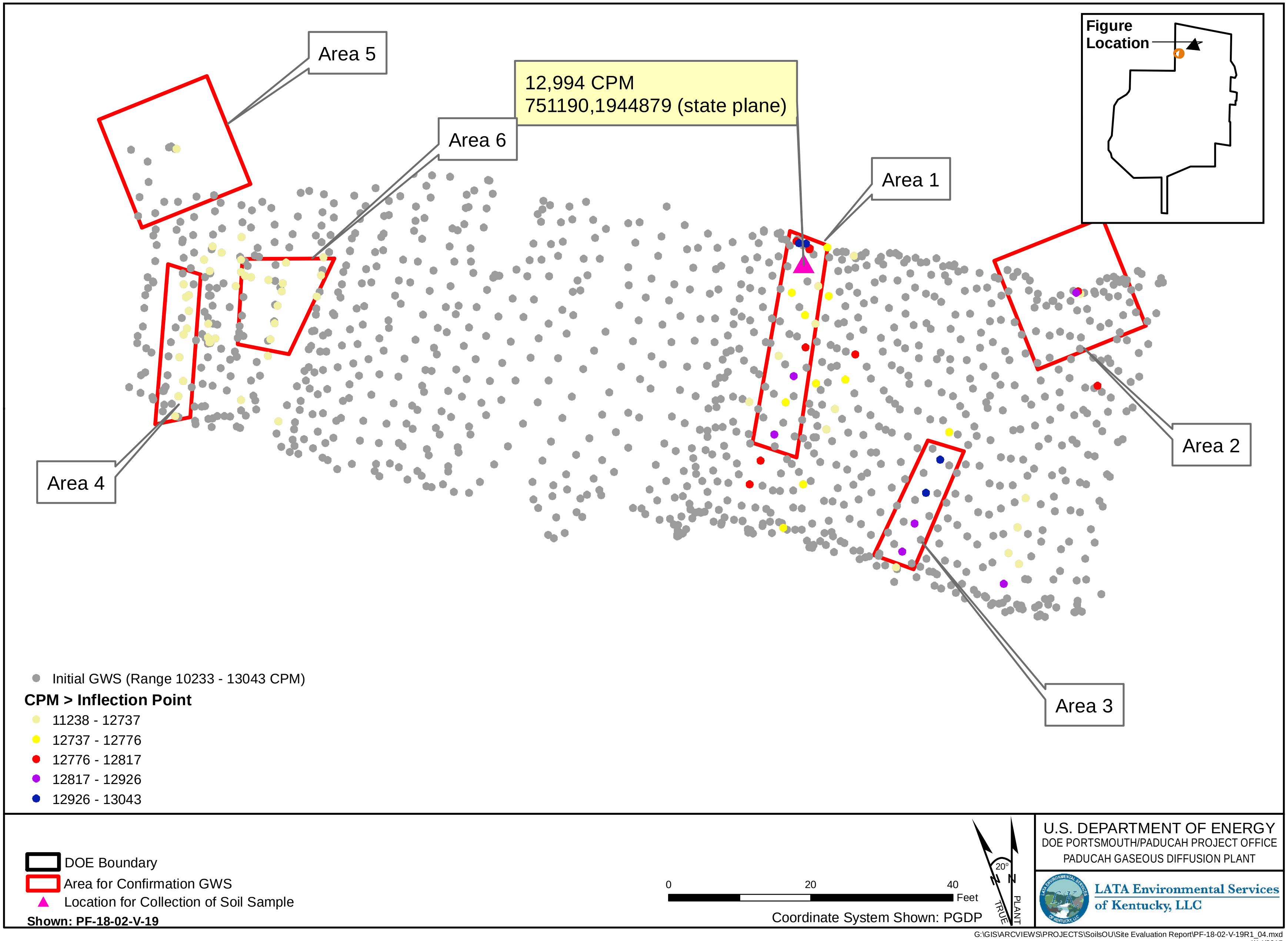


Figure 4.53. Anomaly PE-01-03-V-24



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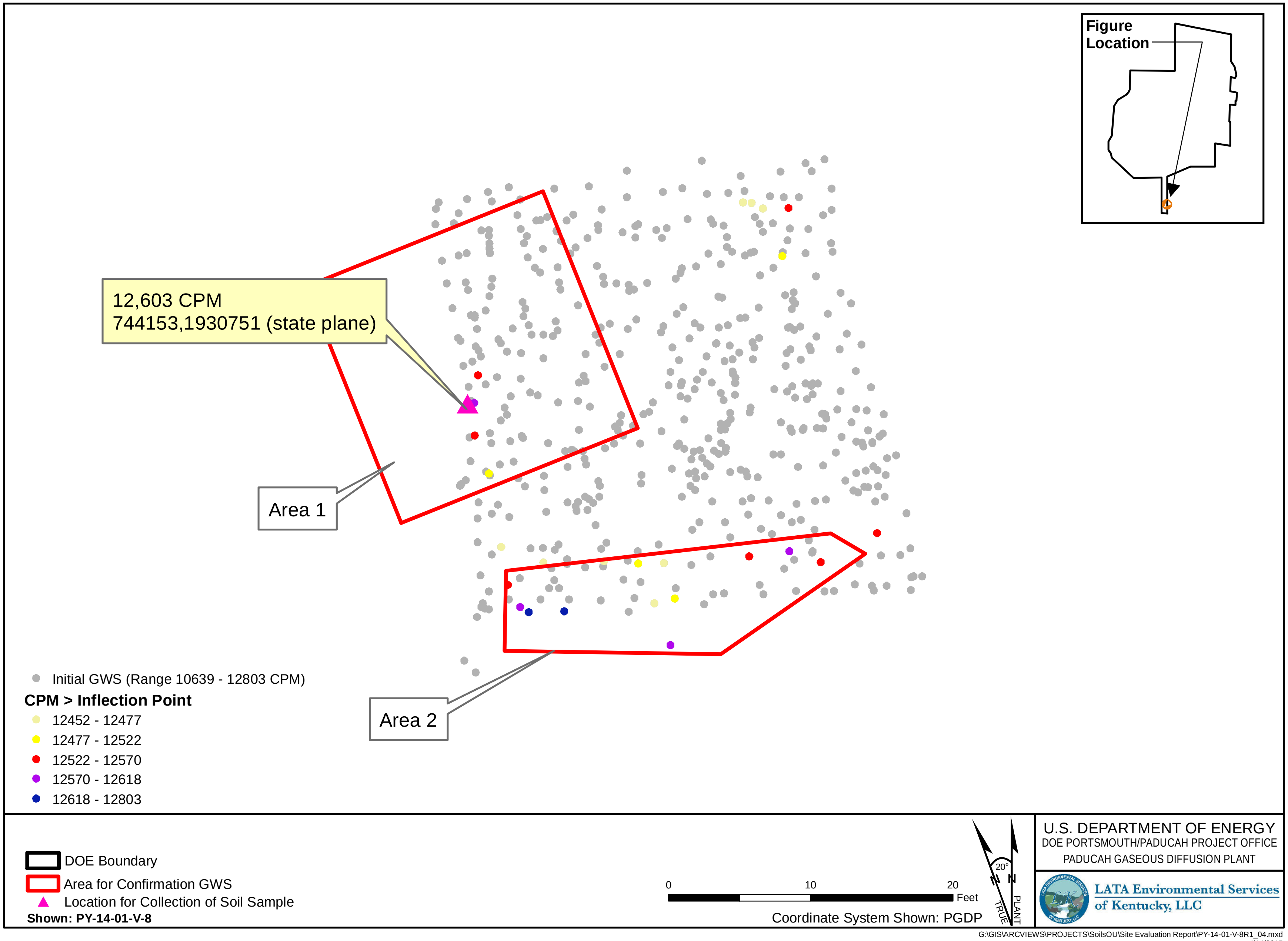
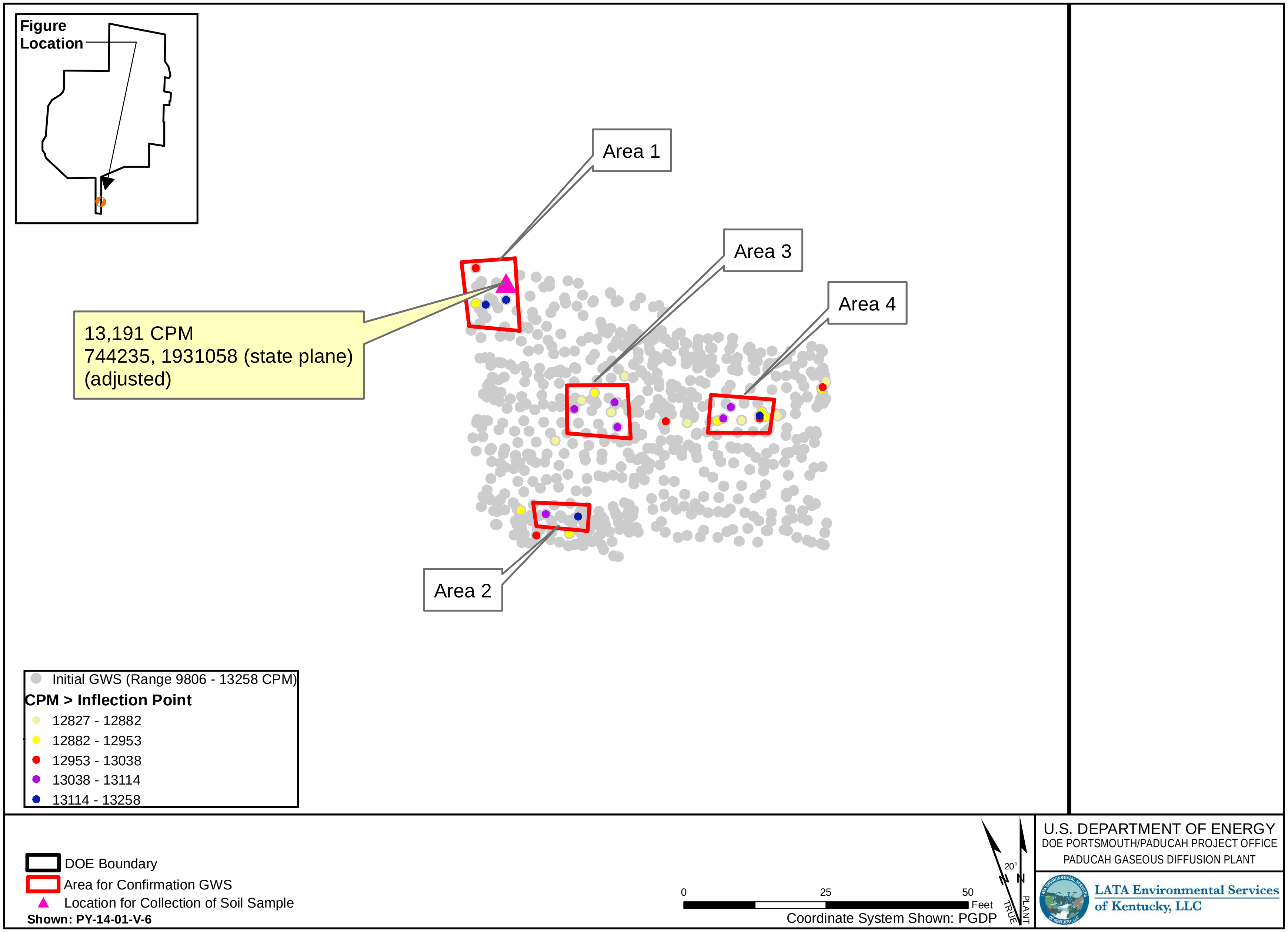


Figure 4.55. Anomaly PY-14-01-V-8



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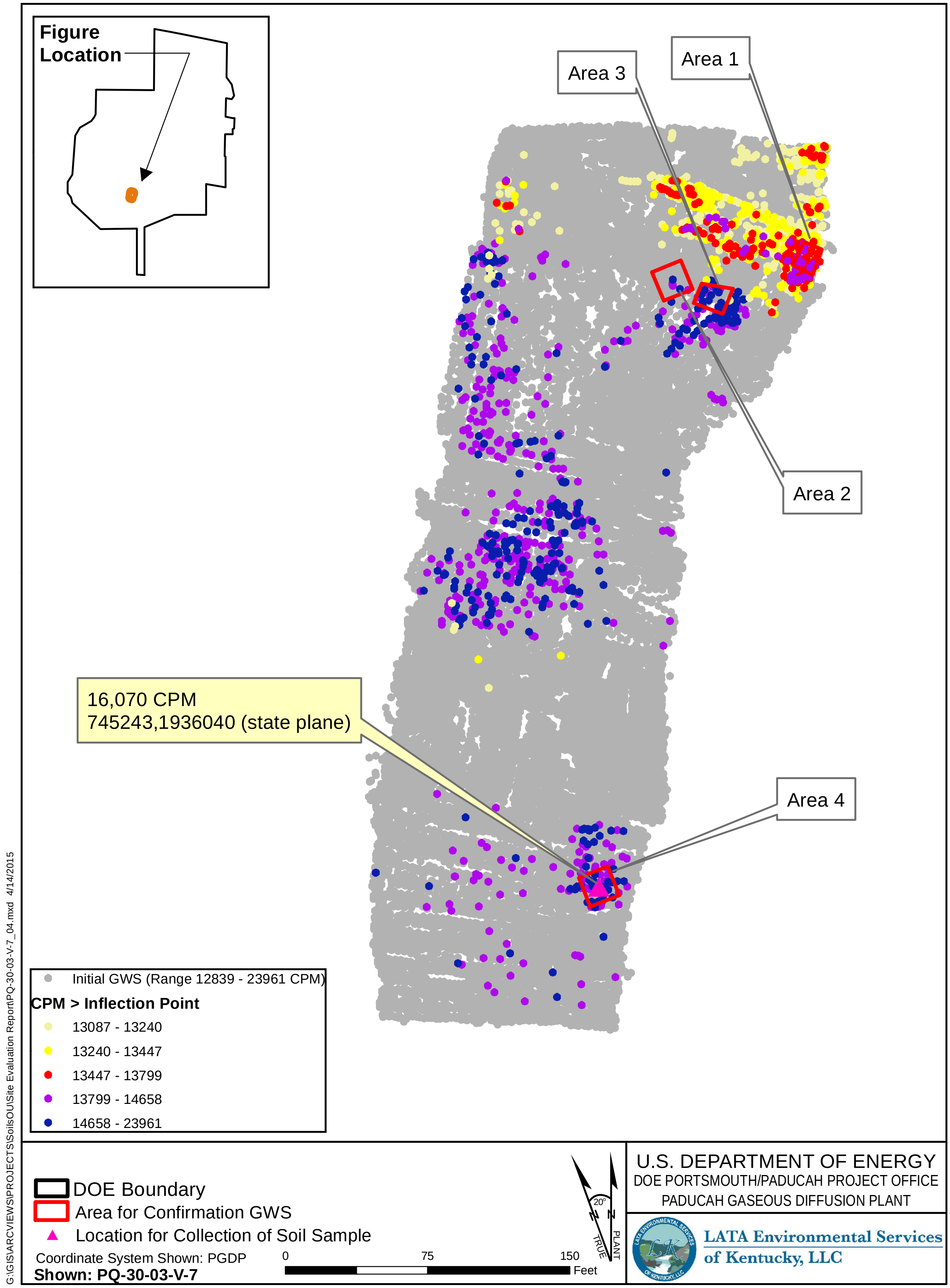

Figure 4.57. Anomaly PQ-30-03-V-7

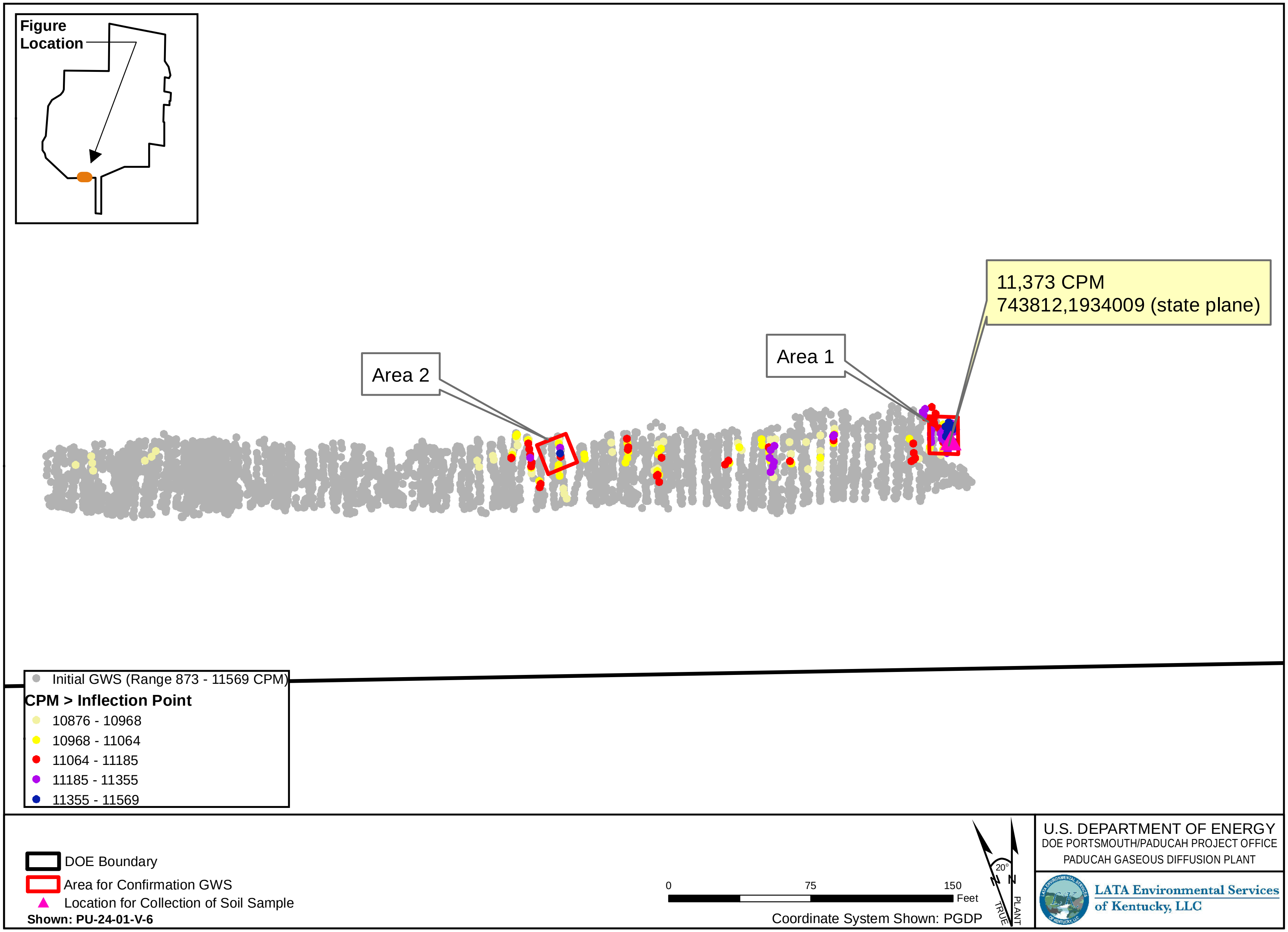

Figure 4.58. Anomaly PU-24-01-V-6

According to Section 5.3 of the work plan (DOE 2011a), DOE had the option to remove rubble areas as a maintenance action, if identified as being of DOE origin. No rubble area was determined to be of DOE origin; therefore, no maintenance action took place, and no soil samples were collected.

DOE also completed the 2014–2015 field effort and all analytical results show that total uranium was found to be less than 10 mg/kg, specified in the decision rules (DOE 2014b), for each of the 25 selected anomalies.

Because no soil sample from any of the 25 anomalies exceeded the 10 mg/kg total uranium limit established by the decision rules (DOE 2014b), the remaining 509 identified anomalies are not considered to be contaminated at a level of concern and therefore do not meet the definition of a SWMU or AOC. Additional evaluation is not required for the remaining 509 identified anomalies. This evaluation validates the conclusions from the previous 2009–2010 field effort.

5. INVESTIGATION FINDINGS

5.1 NATURE AND EXTENT OF CONTAMINATION

Aerial surveys, walkover surveys, and soil sampling were used to determine nature and extent of contamination. No anomalies were identified as a result of the aerial surveys. The radiological walkover surveys found no readings twice instrument radiological background; therefore, no anomalies were identified. The visual walkover surveys identified 534 anomalies. Radiological surveys were conducted for each of the 534 visually identified anomalies. The surveys found no readings twice instrument radiological background. Soil samples were collected from 25 of the anomalies. Analytical results were less than the decision rule value of 10 mg/kg (DOE 2014b). Based on individual results from these activities and the overall weight-of-evidence, the conclusion is reached that no contaminated areas were found.

5.2 ASSESSMENT OF HUMAN HEALTH RISKS

In accordance with the work plan (DOE 2011a), the radiological survey was designed with a minimum detection limit, a scan of less than 528 pCi/g uranium-238. For comparison, the approved Authorized Limit for outside the Limited Area is 540 pCi/g (DOE 2014d). As a result of this radiological survey, no areas were identified above the criteria established in the work plan (two times instrument background); therefore no anomalies were identified. The radiological surveys did not indicate levels above the designated minimum limits that are protective of the teen recreator and the future industrial worker.

Anomalies selected for the 2014–2015 field effort were evaluated using *ex situ* XRF analysis to measure total uranium concentration. Total uranium was used as a surrogate for other contaminants due to its being the primary radiological constituent found at PGDP. The PAL established for total uranium was 10 mg/kg in soil. The PAL was set to ensure the DQOs, agreed to by the FFA parties, was met using the *ex situ* XRF analytical method. The PAL approaches the PGDP surface soil background concentration of 4.9 mg/kg for soluble uranium, and is below the risk-based no action level of 64.4 mg/kg for the child recreational user (DOE 2011c). Results of this field effort indicated that these anomalies do not represent unknown areas of contamination that pose a threat to the public or environment.

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6. CONCLUSIONS AND RECOMMENDATIONS

The overall objective of the sitewide evaluation was to identify unknown contaminated areas originating from PGDP requiring further CERCLA evaluation and to compile information usable when completing the RCRA EI process for human exposure to soil at PGDP.

The following summarizes the results, conclusions, and recommendations of the sitewide evaluation based on the project objectives as identified during scoping phases of this project. Based on individual results from these activities and the overall weight-of-evidence, the conclusion is reached that no contaminated areas were found.

The aerial photography survey produced a topographic map with 2-ft surface model contours and planimetric detail and a DEM that provided delineation of current surface features, including watersheds, drainage pathways, roads, and land cover. No unknown contaminated areas were identified as a result of the aerial photographic survey.

The aerial radiological survey measured the terrestrial radiological environment using NaI gamma-ray detectors. The survey concluded that the current survey data is in general agreement with previous surveys of PGDP and surrounding area. No unknown contaminated areas were identified as a result of the aerial radiological survey.

No anomalies were identified on Commonwealth of Kentucky-owned property by the aerial surveys; therefore, no visual or radiological surveys were performed for Commonwealth of Kentucky-owned property based upon the evaluation of the results of the aerial surveys.

The visual survey was accomplished by visually observing and physically locating an anomaly. DOE-owned property (including property licensed to the Commonwealth of Kentucky) was evaluated with a performance target of 100%. There were 633 anomalies visually identified. After crosswalking the anomalies with previously identified anomalies, 99 were found to be part of previous or ongoing evaluations/investigations (i.e., Soil Piles Addendum 2, Rubble Piles SER, WAG 17, existing SWMUs) or part of anthropogenic structures (i.e., construction of rail/road beds, Kentucky Ordnance Works bunkers) and were removed from further evaluation in this effort. The remaining 534 new anomalies were subjected to a radiological survey. No anomalies were found to be greater than twice instrument background established for the survey, meaning that no unknown contaminated areas were identified as a result of the visual survey.

The radiological survey was performed using a 3x3 NaI (gamma) detector with a GPS data logger. Uranium-238 was used as the target radionuclide. DOE-owned property was evaluated with a performance target of a minimum of 10%. No areas were found to be greater than twice instrument background established for the survey, meaning that no unknown contaminated areas were identified as a result of the radiological survey.

A focused radiological walkover survey and judgmental sampling were performed on 25 of the previously identified 534 anomalies. The 25 selected anomalies served as proxies for the remaining 509 identified anomalies. Soil samples were analyzed by *ex situ* XRF analysis to measure total uranium concentration associated with the selected anomalies. Total uranium was used as a surrogate for other contaminants due to its being the primary radiological constituent found at PGDP. For each of the 25 selected anomalies, total uranium was found to be less than the 10 mg/kg criterion established in the decision rules (DOE 2014b), meaning no unknown contaminated areas were identified.

The April 2008 letter from DOE to KDWM presents a flowchart prepared as a condition to be met for DOE to receive an EI of "Yes" with regard to the Government Performance and Results Act milestone of having human exposures under control (DOE 2008a). The Flow Chart for Uncertainty Management, Figure 6.1, was used to evaluate the data collected for this sitewide evaluation. The radiological survey and visual walkover survey information was evaluated, along with the focused radiological survey and judgmental sampling effort performed for 25 of the previously identified 534 anomalies covering DOE-owned property outside the Limited Area at PGDP. The conclusion from the evaluation of the results of the surveys and their associated analyses is that no areas were identified that required either further CERCLA evaluation under the PGDP FFA (EPA 1998) or designation as SWMUs or AOCs. The results demonstrate that these anomalies do not represent unknown areas of contamination that pose a threat to the public or environment. Considering this information, empirical data was obtained to complete step one of the Flow Chart for Uncertainty Management; however, the data establish that there is no contamination present in any areas where it previously was not present. No further evaluation is necessary in accordance with the flowchart steps; therefore, the information used to conclude that "Human exposures are under control," is not challenged by new information and supports a continued categorization of "Yes" for this EI.

Data obtained supports the following objectives.

- Identify anomalies on DOE-owned and Commonwealth of Kentucky-owned property and confirm DOE origin.

  — Approximately 633 anomalies were identified by visual walkovers on DOE-owned property (including property licensed to the Commonwealth of Kentucky). Of these, 534 had not been the subject of previous investigations or evaluations (DOE 2011a). Each of these anomalies was addressed according to the steps outlined in the work plan (DOE 2011a). None were identified as being of DOE origin, and no documentation exists to indicate the presence of PGDP wastes.

  — No anomalies were identified on Commonwealth of Kentucky-owned property.

- For anomalies confirmed to be of DOE origin, establish the presence or absence of DOE-related contaminants (metals, PCBs, and radionuclides).

  — There was no evidence to indicate that any of the anomalies were of DOE origin; therefore, there was no need to implement the steps required by this objective, collecting samples and analyzing them for DOE-related contaminants.

- Collect data and screen to determine if the anomalies may pose risks to human health under current use scenarios and to support future decisions:

  — The radiological walkover survey conducted did not result in readings that indicated that any of the anomalies pose a risk to human health under current use scenarios, nor did the data indicate that risks would be posed when compared to the most restrictive, reasonably probable future use scenario.

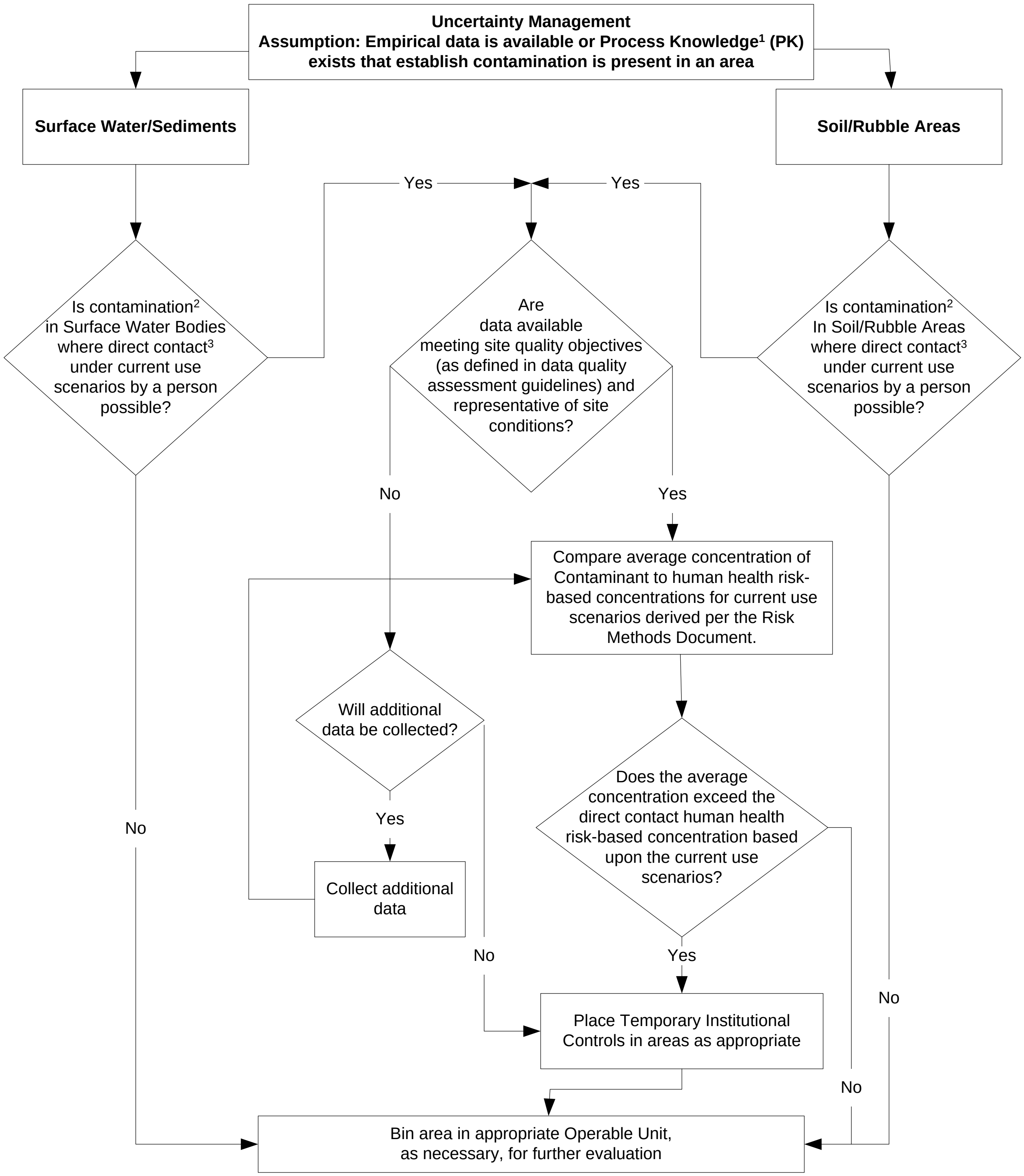
  — For the RCRA EI process, there is no evidence or data that indicate unacceptable human exposures to contamination in soil associated with the anomalies under current use scenarios.

- Determine appropriate path forward per the FFA (EPA 1998).

  — Consistent with FFA and the approaches set forth in the National Contingency Plan, the results of this evaluation determined that no removal or remedial actions are required for the 534 anomalies identified, and there is no need to establish SWMU Assessment Reports.

Flow Chart for Uncertainty Management

This flowchart applies to newly identified areas of contamination that may be identified in the future on DOE-owned property licensed for use at the Paducah Gaseous Diffusion Plant, which are outside the controlled area and not currently assigned to an operable unit under the Federal Facility Agreement. The flowchart describes uncertainty management for non-worker exposures associated with DOE-owned property described above.



[1] "Process Knowledge" is defined as information identifying releases from past or current processes at the PGDP.
[2] "Contamination" is defined in the Risk Methods Document as the presence of a constituent at a concentration greater than background.
[3] "Direct contact" is exposure by a human to environmental medium [i.e., surface soil, sediment, debris (e.g., rubble), and surface water] through ingestion, dermal contact, inhalation (particulates and vapors), or external exposure.

Figure 6.1. Flow Chart for Uncertainty Management

Further Explanation of Flow Chart Steps

Flow Chart Step	Explanation
Uncertainty Management Assumption: Empirical data is available or Process Knowledge[1] (PK) exists that establish contamination is present in an area	This flowchart applies to newly identified areas of contamination that may be identified in the future on DOE-owned property licensed for use at the Paducah Gaseous Diffusion Plant, which are outside the controlled area and are not currently assigned to an operable unit under the Federal Facility Agreement. The flowchart describes uncertainty management for non-worker exposures associated with DOE-owned property described above. Sufficient data or credible Process Knowledge must exist for this process to be activated.
Is contamination[2] in Surface Water Bodies or Soil/Rubble Areas where direct contact[3] under current use scenarios by a person possible?	Contamination definition is identified in Footnote 2. The process focuses on areas of surface soil, sediment, debris (e.g., rubble), and surface water that are located in the licensed area and available for direct contact exposure. Examples of exposure scenarios are riding horses or ATVs in the creek and bank areas, walking or hiking through wildlife habitat, or hunting.
Are data available meeting site quality objectives (as defined in data quality assessment guidelines) and representative of site conditions?	An evaluation of the available data will be performed to determine if data area of sufficient quality to be used for risk assessment. Additional data may be collected to determine appropriate protective actions.
Compare average concentration of contaminant to human health risk-based concentrations for current use scenarios derived per the Risk Methods Document	Average concentrations for existing data will be compared to the human health risk-based concentrations. Risk-based concentrations used will be based on guidance in the current Risk Methods Document.
Place Temporary Institutional Controls in areas as appropriate	Temporary institutional controls may vary depending on the nature of contamination. DOE may place temporary institutional controls under CERCLA, perform a maintenance action, or post under 10 *CFR* 835.
Bin areas in appropriate Operable Unit, as necessary, for further evaluation	DOE, EPA, and KY will determine the appropriate Operable Unit under which the areas may be placed for future evaluation in accordance with the FFA. These agencies will determine if immediate actions such as sampling or removal actions are warranted based on potential risk and exposure to the public.

Figure 6.1. Flow Chart for Uncertainty Management (Continued)

- Evaluate a subset of all of the anomalies to determine if additional evaluation is required of the other anomalies. The 25 selected anomalies served as proxies for the remaining 509 identified anomalies.

  — Based on the results of this field effort, the remaining 509 identified anomalies are not considered to be contaminated in accordance with the decision rules of the work plan (DOE 2014b) at a level of concern; therefore, the remaining 509 identified anomalies do not meet the definition of a SWMU or AOC. Additionally, based on the decision rules, additional evaluation is not required for the remaining 509 identified anomalies. This evaluation validates the conclusions from the previous 2009–2010 field effort.

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APPENDIX A

AERIAL RADIOLOGICAL SURVEY

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DOE/NV/25946--931
April 2010

An Aerial Radiological Survey of the Paducah Gaseous Diffusion Plant and Surrounding Area

Survey Dates: October 28–November 2, 2009

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DOE/NV/25946—931
April 2010

An Aerial Radiological Survey of the Paducah Gaseous Diffusion Plant and Surrounding Area

Paducah, Kentucky

Survey Dates: October 28–November 2, 2009

Matthew R. Kiser
Project Manager

Michael S. Reed
Project Scientist

National Security Technologies, LLC
Las Vegas, Nevada

This document is UNCLASSIFIED

Reviewed by
David P. Colton, February 17, 2010
Derivative Classifier

ABSTRACT

An aerial radiological survey was conducted over the Paducah Gaseous Diffusion Plant (PGDP) and surrounding area in Paducah, Kentucky. The purposes of the survey were to 1) measure the terrestrial radiological environment within and around the PGDP in order to update previous radiological survey data from 1976 and 1990, and 2) provide information that will be used in the radiological verification for the PGDP's remedial closure effort. The survey was performed from October 28–November 2, 2009 utilizing a large array of helicopter-mounted sodium iodide gamma-ray detectors. The aerial survey was flown at an altitude of 150 feet (~46 meters) along a series of parallel lines spaced 250 feet (~76 meters) apart and encompassing an area of 24 square miles (62 square kilometers), bordered on the north by the Ohio River.

The results of the aerial survey are reported as implied exposure rate, man-made activity, and depleted uranium activity, which are presented in the form of contour maps superimposed on imagery of the surveyed area. Exposure rate measurements were acquired using a pressurized ionization chamber at 10 specific locations on the ground to validate the data derived from the aerial measurements.

Throughout most of the surveyed area, the detected radioisotopes and their associated gamma-ray exposure rates were consistent with those expected from normal background emitters. At specific locations within the PGDP, man-made activity was detected that was consistent with the operational history of the plant. In particular, protactinium-234m, a radioisotope indicative of uranium-238, was detected within the PGDP. The aerial survey data indicated no anomalies outside of the depleted uranium cylinder yards.

TABLE OF CONTENTS

Appendices

Figures

ACRONYMS AND ABBREVIATIONS

AGL	above ground level
AMS	Aerial Measuring System
cps	counts per second
DGPS	Differential Global Positioning System
DOE	U.S. Department of Energy
DU	depleted uranium
ER	exposure rate
K-40	potassium-40
MMGC	man-made gross counts
NaI(Tl)	thallium-doped sodium iodide
NIST	National Institute of Standards and Technology
NORM	naturally occurring radioactive material
Pa-234m	protactinium-234m
PC-REDAC	PC-based Radiation and Environmental Data Analysis Computer
PGDP	Paducah Gaseous Diffusion Plant
PIC	pressurized ionization chamber
RA	radar altimeter
RF	radio frequency
REDAR-V	Radiation and Environmental Data Acquisition and Recorder, Version V
ROI	region of interest
RSL	Remote Sensing Laboratory
μR/h	microroentgens per hour

1. Introduction

At the request of the U.S. Department of Energy (DOE), an aerial radiological survey of the Paducah Gaseous Diffusion Plant (PGDP) in Paducah, Kentucky, was conducted from October 28–November 2, 2009. The survey covered a region of approximately 4 × 6 miles (~6.4 × 9.7 kilometers) for a total area of 24-square miles (~62-square kilometers) surrounding the Paducah plant. This region encompassed the PGDP, the West Kentucky Wildlife Management Area, and the nearby area extending north to the Ohio River. The survey was conducted by a team from the DOE National Nuclear Security Administration's Remote Sensing Laboratory (RSL), which is maintained and operated by National Security Technologies, LLC, at Nellis Air Force Base in Las Vegas, Nevada and Andrews Air Force Base, Maryland.

Radiological surveys of the PGDP were conducted in 1976[1] and 1990[2]. The purpose of those surveys was to determine the extent to which plant operations may have impacted the radiological signature of the plant surroundings. The purposes of the current survey were to (1) update the results of those earlier surveys to determine changes in the radiological signature of the PGDP and adjacent areas, and (2) provide information that will be used in the radiological verification for the PGDP's remedial closure effort. The RSL aerial survey data is presented in the form of contour maps superimposed on imagery of the surveyed area, which provide the gamma-ray exposure rates (ER) attributable to natural and man-made radionuclides.

The data were collected by the Aerial Measuring System (AMS) Radiation and Environmental Data Acquisition and Recorder, Version V (REDAR-V) using an array of twelve 2" × 4" × 16" sodium iodide detectors flown onboard a twin-engine Bell 412 helicopter. The data were geo-referenced using a differential Global Positioning System (DGPS). Gamma-ray energy spectra were collected continuously each second during the survey. This spectral data provides the capability to distinguish between ordinary fluctuations in natural background radiation levels and radiological signatures produced by man-made radioactive sources. Spectral data can also be used to identify specific radioisotopes and produce isotope-specific contour maps.

The current survey data is in general agreement with previous surveys of the PGDP and surrounding area[1, 2]. However, the anomalous radiation area detected outside the plant boundary during the 1990 survey[2] was not observed in the current survey because the NRC-licensed facility operating at that location in 1990 has since been decommissioned.

2. Survey Site Description

The PGDP, which is leased and operated by the United States Enrichment Corporation, is the only operational uranium enrichment facility in the United States. The plant is located on a large, government-owned reservation 4 miles (~6.4 kilometers) south of the Ohio River and 15 miles (24 kilometers) west of the city of Paducah, Kentucky. The PGDP is contained in a 1.2 square-mile (~ 3 square-kilometers) fenced area with an average elevation of approximately 375 feet (~114 meters) above sea level. The West Kentucky Wildlife Management Area borders the PGDP to the west, and the area surrounding the plant is primarily forest and farm land with some residential development to the east of the plant.

3. Survey Procedure

3.1 Aerial Survey

The aerial survey collected gamma radiation data over a 24-square mile (~62-square kilometer) area around the PGDP. The primary roads servicing the facility, as well as the facility perimeter, were taken into consideration when defining the survey boundaries.

The area was surveyed at a nominal ground speed of 70 knots (~36 meters per second) and a nominal altitude of 150 feet (~46 meters) above ground level (AGL). Parallel sets of flight lines spaced 250 feet (~76 meters) apart were flown. Due to flight restrictions over the PGDP, the survey area was broken into four regions, as shown in Figure 1. For the regions to the north and south of the restricted flight zone, the flight lines were flown in roughly an easterly or westerly direction. Conversely, the flight lines were flown in a generally northerly or southerly direction for the regions to the east and west of the restricted area. To assure data integrity and to monitor/correct for variations in detector background count rate due to aircraft, radon, and cosmic rays, measurements were made over a fixed test line and water line before and after each flight. The fixed test line was located along Ogden Landing Road, which is outside the eastern boundary of the survey area, and the fixed water line was over the Ohio River just to the northeast of the survey area.

3.2 Ground-Based Measurements

Ground-based pressurized ionization chamber (PIC) measurements were acquired at 10 locations within the survey area and two locations along the fixed test line. These measurements were taken to provide comparative exposure rates and support the integrity of the aerial data. The PIC measurements were averaged over a period of approximately 5 minutes at a height of 1 meter AGL.

Figure 1: Survey Setup for PGDP Aerial Survey. (The open region in the center of the survey area was a restricted flight zone.)

4. Survey Equipment

4.1 Aerial Survey

The aerial survey was conducted using AMS detection assets. The AMS detection system consists of a Bell-412 helicopter, a REDAR-V system, a Trimble DGPS and two large detector pods externally mounted on each side of the helicopter. Each pod contains six 2″ × 4″ × 16″ thallium-doped sodium iodide, NaI(Tl), gamma-ray detectors.

4.1.1 Data Recording

The preamplifier signal from each detector was calibrated using naturally occurring potassium-40 (K-40) and americium-241 (Am-241) gamma check sources. Normalized outputs from the 12 detectors were combined in a summing amplifier, and the signal was adjusted in the analog-to-digital converter so that the calibration photopeaks appeared in preselected channels in the REDAR-V multichannel analyzer. The data from the multichannel analyzer were used to produce time-stamped records that contain the number of gamma rays detected at each specific energy (channel) for each one-second sample. Each record, therefore, constitutes a geo-referenced gamma-ray spectrum. As every radioactive material, natural or man-made, has its own unique set of gamma rays, the spectra can be used to identify and distinguish the nature of the detected gamma radiation.

The REDAR-V, which produces the gamma-ray spectra described above, is a multi-processor data acquisition and real-time analysis system custom-designed by the RSL to operate in the severe environments associated with platforms such as helicopters, fixed-wing aircraft, and various ground-based vehicles. The system displays radiation and positional information to the operator in real time via video displays and multiple digital readouts. Gamma-ray spectra, aircraft position, meteorological parameters, real-time clock, and other data reference information are recorded at one-second intervals on digital data storage devices for post-flight analyses.

4.1.2 Helicopter Positioning

The helicopter's position was established by using two systems: a Trimble DGPS (utilizing OmniSTAR differential corrections) and a radar altimeter (RA). The DGPS provides continuous position information (latitude and longitude) using a constellation of satellites. The DGPS has a horizontal positional accuracy (1 sigma) of ±1 meter (3 feet). The RA determines the helicopter's altitude above the present terrain by measuring the round-trip propagation time of a RF signal reflected off the ground. The manufacturer's nominal accuracy of the RA is quoted as 2 feet or 2%, whichever is greater.

4.1.3 Data Processing

For each flight, the aerial survey data were downloaded into the PC-based Radiation and Environmental Data Analysis Computer (PC-REDAC) software package for processing. This RSL in-house-developed software package provided onsite preliminary analysis of the aerial data on a flight-by-flight basis and monitored pre- and post-flight quality assurance checks.

4.2 Ground-Based Measurements

Ground level exposure rates were measured at the PGDP using a portable, battery-powered Reuter-Stokes pressurized ion chamber (PIC) calibrated to the National Institute of Standards and Technology (NIST) standards. This instrument incorporates a 10-inch (25-centimeter) diameter metal sphere filled with 25 atmospheres of argon gas, a high voltage bias supply, an electrometer, and readout components. This unit has a sensitivity of approximately 3×10^{-14} amps per microroentgens per hour (μR/h) and has the capability of digitally and graphically displaying the total exposure rate data. The ground measurements were compared to the exposure rates inferred by the aerial measurements to validate the data analysis.

5. Analysis Procedures

5.1 Aerial Data Analysis

The photon radiation signal measured by the REDAR-V system is comprised of contributions from the naturally occurring terrestrial radionuclides, man-made radionuclides, naturally occurring airborne radon, cosmic rays, and trace amounts of radioactive materials present onboard the aircraft. Aerial data analysis techniques are used to distinguish and quantify each of these constituents using the measured radiation data. This section briefly describes some of the fundamental methodologies used to generate the data products for the aerial survey of the PGDP. The primary data products consist of contour maps overlaying satellite imagery of the survey area which depict the type and quantity of radiation sources present in the PGDP and surrounding area. Also included are the measured spectral signatures associated with radiological anomalies that were observed. These spectra indicate the source of the radiation giving rise to these anomalies.

5.1.1 Terrestrial Gamma Gross Count Rate

The terrestrial gamma gross count rate (GC_{terr}) is obtained by subtracting the estimated radon, cosmic, and aircraft contributions from the REDAR-V measured count rate. The remaining detected activity is then due to radioisotopes lying on or in the ground. A flight line over water conducted at the beginning and end of each survey flight provides an estimate of the count rate due to non-terrestrial sources. This water line is subsequently subtracted from the measured detection rate on a second-by-second basis. Additionally, a test line over an easily identified land feature is flown at the start and end of each survey flight. This test line data is used to account for flight-to-flight variations, such as differences in the moisture content in the ground, and may be written as a scale factor appearing in the equation for GC_{terr}:

$$GC_{terr} = f\left(GC_{tot} - B_{wl}\right) \tag{1}$$

where

GC_{terr} = terrestrial gamma gross count rate from 38 to 3026 keV (cps)
f = inter-flight variability scale factor (unitless)
GC_{tot} = total measured count rate from 38 to 3026 keV (cps)
B_{wl} = water-line count rate measured from 38 to 3026 keV (cps).

The terrestrial gamma gross count rate is used as an indication of the presence of radiation on or in the vicinity of the ground throughout the survey area. This simple algorithm does not take into account natural fluctuations in background, nor does it yield information on the nature of radiation sources giving rise to the detector response. The algorithm is nonetheless effective for determining regions within the survey area where further analysis should be performed.

5.1.2 Man-Made Gross Counts

Naturally occurring radioactive materials (NORM) are present in the environment throughout the world. Because these materials are found in the soil, rocks, and building materials, the background radiation level associated with their presence may fluctuate significantly in different geographic locations. The man-made gross counts (MMGC) algorithm is a two-window extraction algorithm that is designed to suppress the natural variations in background radiation levels. This algorithm takes advantage of the fact that while background radiation levels may vary by a factor of two or more within a survey area, the background spectral shape remains relatively stable. More specifically, the ratio of natural components in any two regions (windows) of the energy spectrum will remain nearly constant.

In order to increase the sensitivity to detect man-made anomalies, the MMGC algorithm utilizes spectral energy extraction techniques. Application of the MMGC algorithm yields the portion of the gross counts that are directly attributable to gamma rays emitted from man-made radionuclides. In practice, virtually all man-made radioisotopes appear below 1394 keV in the gamma-ray energy spectrum. This is in contrast to the naturally occurring radioisotopes, which occur throughout the energy spectrum up to 3026 keV. The MMGC rate is calculated by integrating the detector response from 38 to 1394 keV and subtracting the NORM contribution, which is determined by taking a scaled response from the energy window extending from 1394 to 3026 keV. The *MMGC* rate can be expressed analytically in terms of the integrated count rates in these spectral windows:

$$MMGC = \sum_{E=38\text{keV}}^{1394\text{keV}} S(E) - K_{mm} \cdot \sum_{E=1394\text{keV}}^{3026\text{keV}} S(E) \tag{2}$$

$$K_{mm} = \left. \frac{\sum_{E=38\text{keV}}^{1394\text{keV}} S(E)}{\sum_{E=1394\text{keV}}^{3026\text{keV}} S(E)} \right|_{Background} \tag{3}$$

where

$MMGC$ = man-made gross count rate (cps)

$S(E)$ = measured energy dependent count rate (cps)

K_{mm} = mean energy window ratio, measured in area with only NORM (unitless).

This MMGC algorithm is sensitive to low levels of man-made radiation even in the presence of large variations in the natural background. In regions of background radiation the algorithm yields a distribution of values statistically centered about zero. When man-made radioactivity is indicated a detailed analysis of the gamma energy spectrum is conducted to ascertain which particular radionuclides are present.

5.1.3 DU-Specific Isotope Extraction Algorithm

As a decay product of uranium-238 (U-238), protactinium-234m (Pa-234m) is indicative of depleted uranium (DU, or U-238). Two common gamma rays emitted by Pa-234m result in photopeaks at 766 keV and 1,001 keV in the measured gamma-ray energy spectra. The variable natural background also contributes to these photopeaks, but a spectral extraction algorithm can remove the variable background contribution in a second-by-second operation. The DU-specific extraction algorithm employed for the PGDP survey may be written as:

$$DU = \sum_{E=936\text{keV}}^{1124\text{keV}} S(E) - K_{DU} \cdot \sum_{E=1140\text{keV}}^{1320\text{keV}} S(E) \tag{4}$$

$$K_{DU} = \left. \frac{\sum_{E=936\text{keV}}^{1124\text{keV}} S(E)}{\sum_{E=1140\text{keV}}^{1320\text{keV}} S(E)} \right|_{Background} \tag{5}$$

where

DU = net photopeak count rate from the 1001 keV photon arising from Pa-234m (cps)

$S(E)$ = measured energy dependent count rate (cps)

K_{DU} = mean energy window ratio, measured in area with only NORM (unitless).

The DU-specific extraction algorithm yields the net count rate in the 1001 keV photopeak. The net photopeak is obtained using a time-varying continuum subtraction that is formed by the background energy window extending from 1140 to 1320 keV. This window is selected to provide a satisfactory estimate of the baseline continuum while remaining unaffected by presence of depleted uranium. The DU extraction algorithm yields a statistical distribution of counts centered about zero in regions of NORM only. If a statistically significant amount of DU is present, its activity will be indicated as an anomaly outside the statistical bounds associated with the natural background activity.

5.1.4 Terrestrial Exposure Rate

One way of quantifying the total radiation level present in an environment is through use of the gamma exposure rate, which is related to the amount of charge separation in air created by the passage of ionizing radiation. The terrestrial exposure rate at ground level may be derived from the integral count rate in the gamma energy spectrum range between 38 and 3,026 keV. The terrestrial gamma gross count rate, measured in cps at survey altitude, is converted to exposure rate in µR/h at 1 meter AGL using the following equation:

$$ER = \frac{GC_{terr}}{C} \cdot e^{\mu(z-z_0)} \quad (6)$$

where

ER = derived exposure rate at ground level for sample (µR/hr)

GC_{terr} = terrestrial gamma gross count rate from 38 to 3026 keV from Eq. (1) (cps)

C = exposure rate conversion factor at nominal survey altitude (1712 cps/µR/hr)

μ = gamma ray air absorption coefficient (0.00176 ft^{-1})

z = actual altitude for sample (feet)

z_0 = nominal altitude for survey (feet).

The exponential appearing in Eq. (6) accounts for detector sensitivity changes associated with slight variations in the aircraft's altitude. The air absorption coefficient (μ) was determined from test line data at multiple altitudes to be 0.001761 $feet^{-1}$ (0.005778 $meter^{-1}$). The conversion factor (1,712 cps/µR/h) for 150 feet (46 meters) AGL was determined from documented calibration test lines located in Calvert County, Maryland[3]. The conversion factor assumes a uniformly distributed radiation source; i.e., 1) covering an area that is large in comparison with the field of view of the detector system (a circle with a diameter roughly twice the altitude of the aircraft), and 2) having a gamma-ray energy distribution similar to that of the natural background of the calibration test line.

5.2 Ground-Based Measurements

A PIC is a device that directly measures the gamma exposure rate. Using a PIC, the gamma exposure rate at a height of 1 meter AGL was measured at 10 locations within the survey area and two locations along the test line. Most of these locations were not near any obvious radiation anomalies. The PIC measurements were collected to perform validation of the exposure rates inferred from the aerial data. A PIC measurement inherently includes contributions from airborne radon and cosmic rays. For direct comparison to aerial data, it is therefore necessary to account for these non-terrestrial contributions.

Given a sufficiently large data set, PIC measurements may be used to derive the exposure rate conversion factor appearing in Eq. (6). Such a procedure was outside the scope of the current survey. Instead, calibration data taken in a similar geographic location were used, and the PIC measurements collected at the PGDP were used to validate this assumption.

6. Results

6.1 Terrestrial Gamma Gross Counts Contour Map

Processing of the aerial measurement data removes radiological contributions from cosmic rays, radon, and the aircraft. The resulting gross counts are then due to terrestrial background radiation or man-made radioisotopes. The terrestrial gross count rate over the PGDP survey area, measured in counts per second at survey altitude, is shown in Figure 2.

The locations of five regions of interest (ROIs) are also indicated in Figure 2. The ROI labeled as "Background" is the region from which a representative spectrum of the terrestrial background was extracted. ROIs 1, 2, and 3 correspond to areas of elevated radiation levels where further spectral analysis was performed. ROI 4 is a region outside the plant boundary in which elevated radiation levels were detected during the 1990 survey[2] but were not observed in the current survey because the NRC-licensed facility operating at that location in 1990 has since been decommissioned.

6.2 Man-Made Gross Counts Map

The MMGC algorithm (discussed in the Section 5.1.2) was used to analyze the aerial data for man-made radionuclides in the survey area. The activity attributable to gamma radiation from man-made radioisotopes is shown on the MMGC map (Figure 3) with the variable natural background component removed. The magnitude of the count rates provides an indicator of the relative intensities for the radiation sources. There is evidence of elevated man-made radiation in ROIs 1, 2, and 3, as suggested by the spectra in Figure 6. Note that the anomalous MMGC radiation area that was detected outside the plant boundary during the 1990 aerial survey[2] was not observed in the current survey (ROI 4).

6.3 DU (Pa-234m) Extracted Isotope Counts Map

The Pa-234m specific isotope extraction algorithm (discussed in Section 5.1.3) was used to analyze the aerial data for radiological signatures of DU. The activity due to Pa-234m is shown in Figure 4 with the variable natural background component subtracted. As with the MMGC, the magnitude of the count rates provides an indicator of the relative intensities for the radiation sources. The locations of elevated Pa-234m activity correspond to the cylinder yards (i.e., areas with cylinders containing DU) adjacent to the PGDP facilities.

6.4 Exposure Rate Contour Map

The terrestrial gamma exposure rate at 1 meter AGL inferred from the aerial data is shown in Figure 5 in the form of a contour map superimposed on imagery of the survey area. Using current processing techniques, data from the 1990 radiological aerial survey was reprocessed, and the results are included for comparison purposes. This ER map indicates elevated levels of radiation at the locations identified as cylinder yards within the plant. Over most of the survey area, the inferred terrestrial exposure rates are less than 7 μR/h and are typical for natural background in the Paducah area[4]. These background exposure rates are in good agreement with previous survey data[1, 2]. The exposure rates inferred at the cylinder yards confirm some changes in the configuration of the storage areas have occurred since the 1990 aerial survey[2]. In particular, the footprint of the elevated terrestrial exposure rate region at the southern cylinder yard has increased since 1990, while that of the western cylinder yard has decreased. Additionally, near the river on the northern side of the survey area, the low-lying regions give rise to low terrestrial exposure rates due to the presence of water. This effect is amplified in the current data due to high water levels resulting from precipitation during the survey period.

6.5 Net Spectral Extractions

For each anomaly observed on the GC contour map shown in Figure 2, a net-energy spectrum was produced by subtracting an appropriately scaled background spectrum from the measured energy spectrum associated with the spatial ROI. Spectral data extracted from the background region as well as net spectra corresponding to ROIs 1, 2, and 3 are shown in Figure 6. The representative background spectrum shown is indicative of the NORM present in this region. The origins of some of the prominent peaks are labeled for reference. The spectra from ROIs 1–3 clearly indicate the presence of Pa-234m. This is in agreement with the known operational history of the PGDP and previous surveys[1, 2].

6.6 Ground-Based Measurements

Ground-based PIC measurements are compared with the inferred aerial exposure rates in Figure 7. The ground-based point data is displayed as an overlay on the inferred exposure rate contour map. An estimated cosmic ray contribution[5] of 3.7 μR/h has been subtracted from the ground-based PIC measurements for comparison to the exposure rate inferred from the aerial data. It should be noted that the PIC measurements still include a radon contribution. The differences between PIC and aerial measurements are quite acceptable, being a maximum of 1.5 μR/h for background regions. The measurement taken in the region of high man-made activity is not expected to compare well, since the aerial system and the ground system have significantly different measurement footprints. The data confirms the exposure rate conversion factors used in the survey. The PIC measurements are tabulated and included in Appendix B.

7. Summary

An aerial radiological survey of the Paducah Gaseous Diffusion Plant and surrounding areas was conducted between October 28 and November 2, 2009. The gross count rate, terrestrial gamma exposure rate, man-made activity, and DU activity for the PGDP and surrounding area were documented. The aerial data were benchmarked to ground measurements and shown to match within the uncertainties involved. No significant man-made gamma activity was detected outside the boundary of the PGDP. Within the plant boundary the current survey indicates changes to the configuration of the depleted uranium cylinder yards since the 1990 aerial radiological survey documentation.

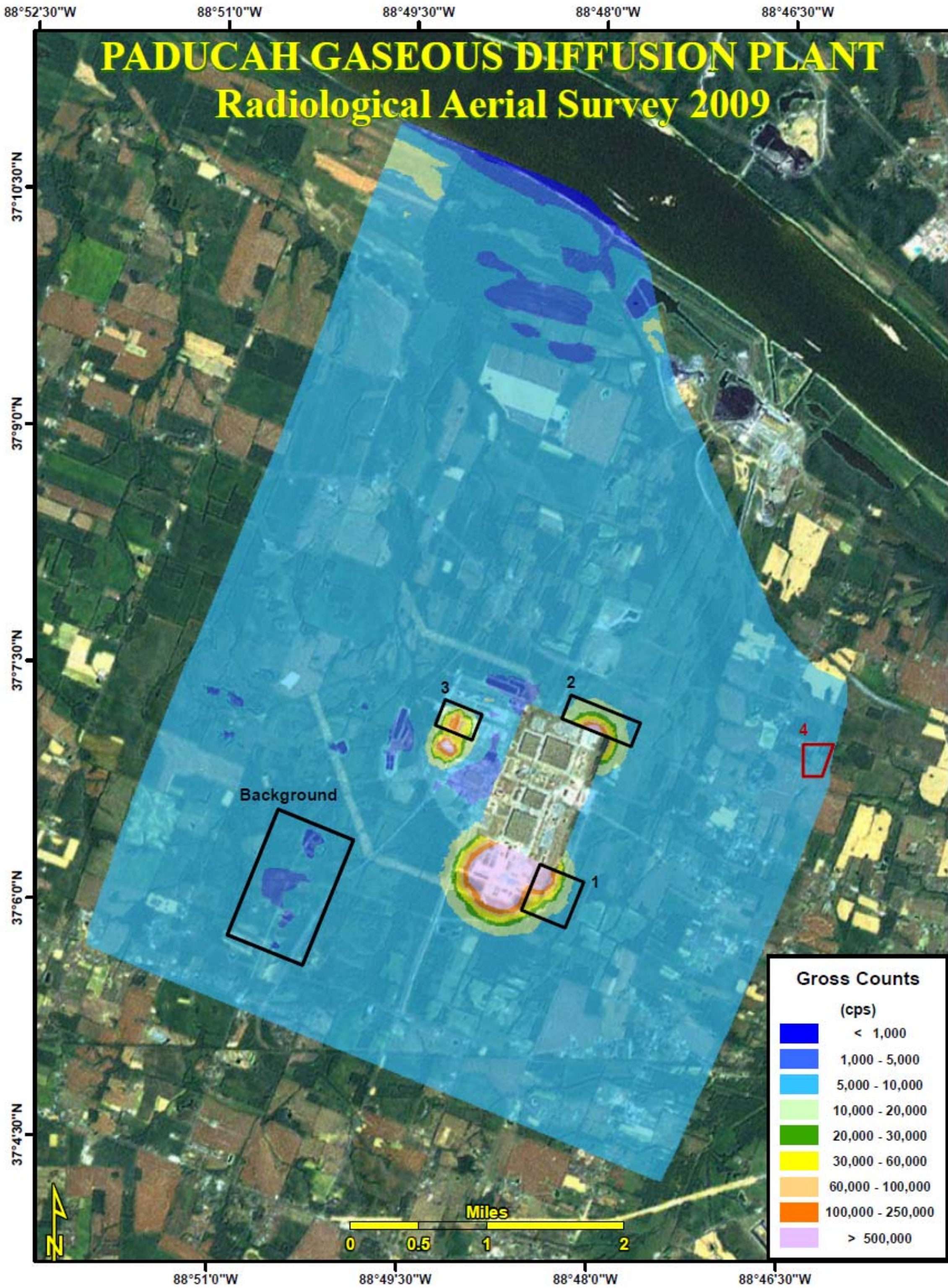

Figure 2: Gross Counts Contour Map with Regions of Interest Indicated.

ROIs 1-3 are areas of elevated radiation levels where further spectral analysis was performed. ROI 4 is a region in which elevated radiation levels were detected during the 1990 survey[2]. This anomaly was not observed in the current survey because the NRC-licensed facility operating at that location in 1990 has since been decommissioned.

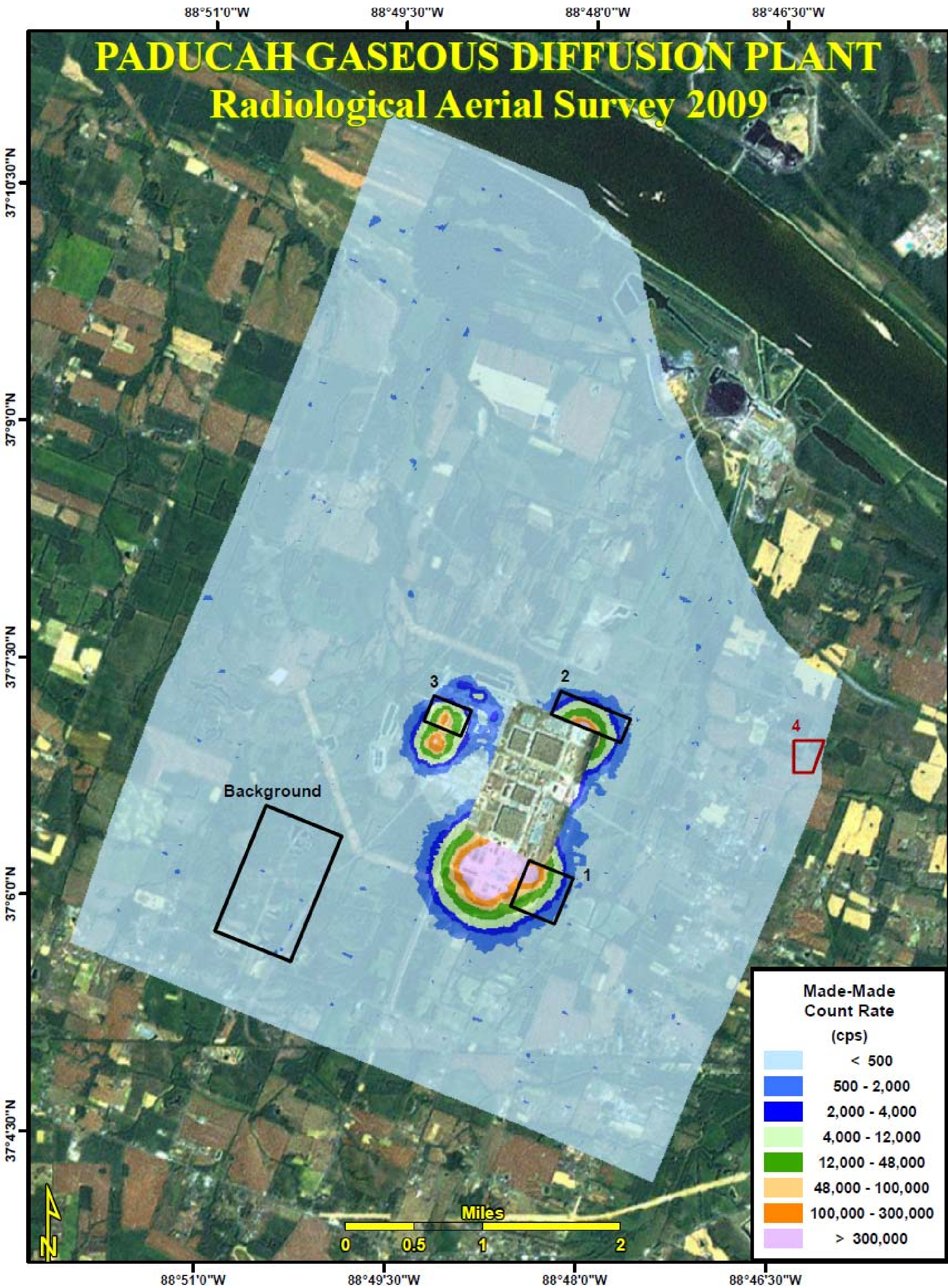

Figure 3: MMGC Count Rate Map with Regions of Interest Indicated (as in Figure 2).

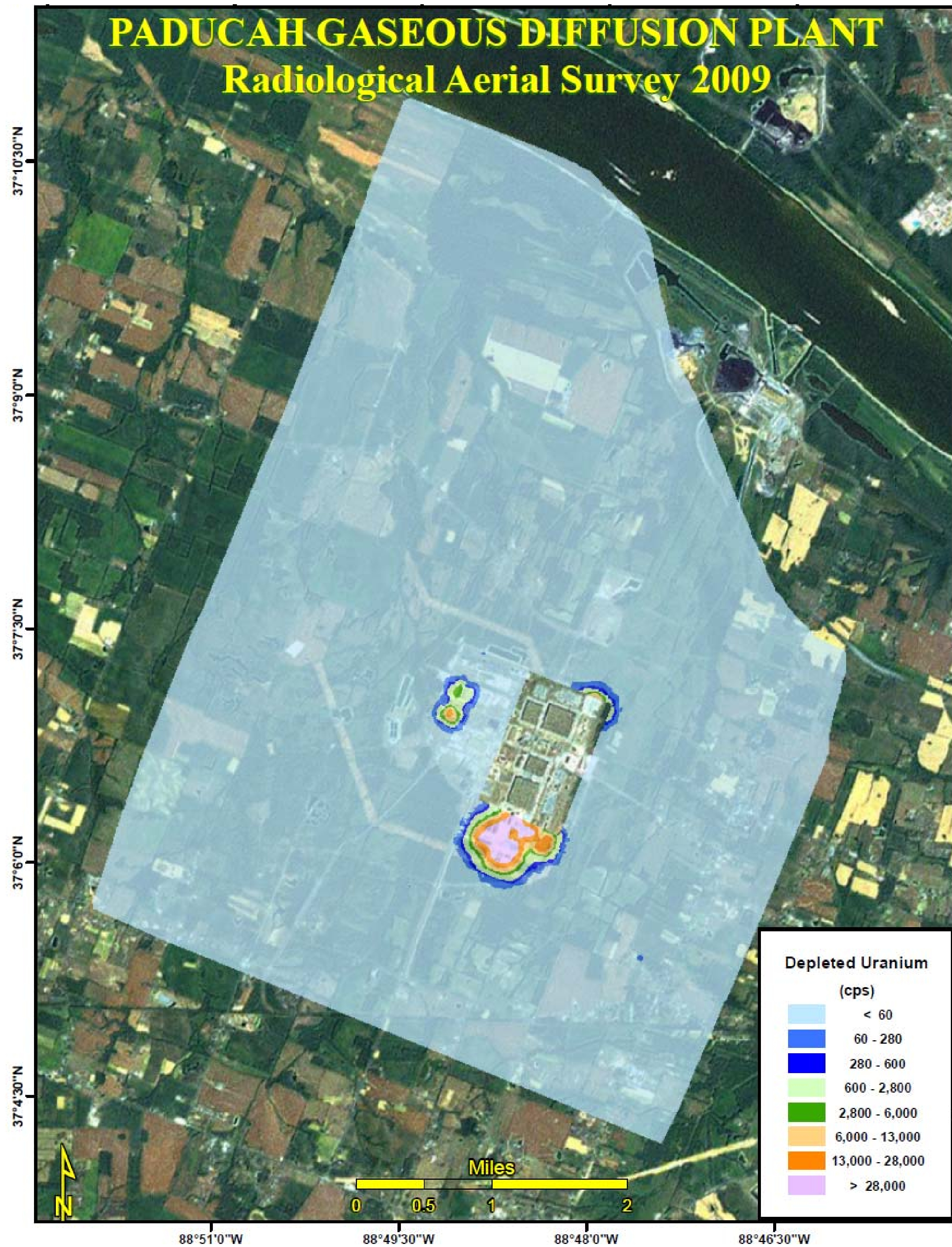

Figure 4: DU Extraction Count Rate Map

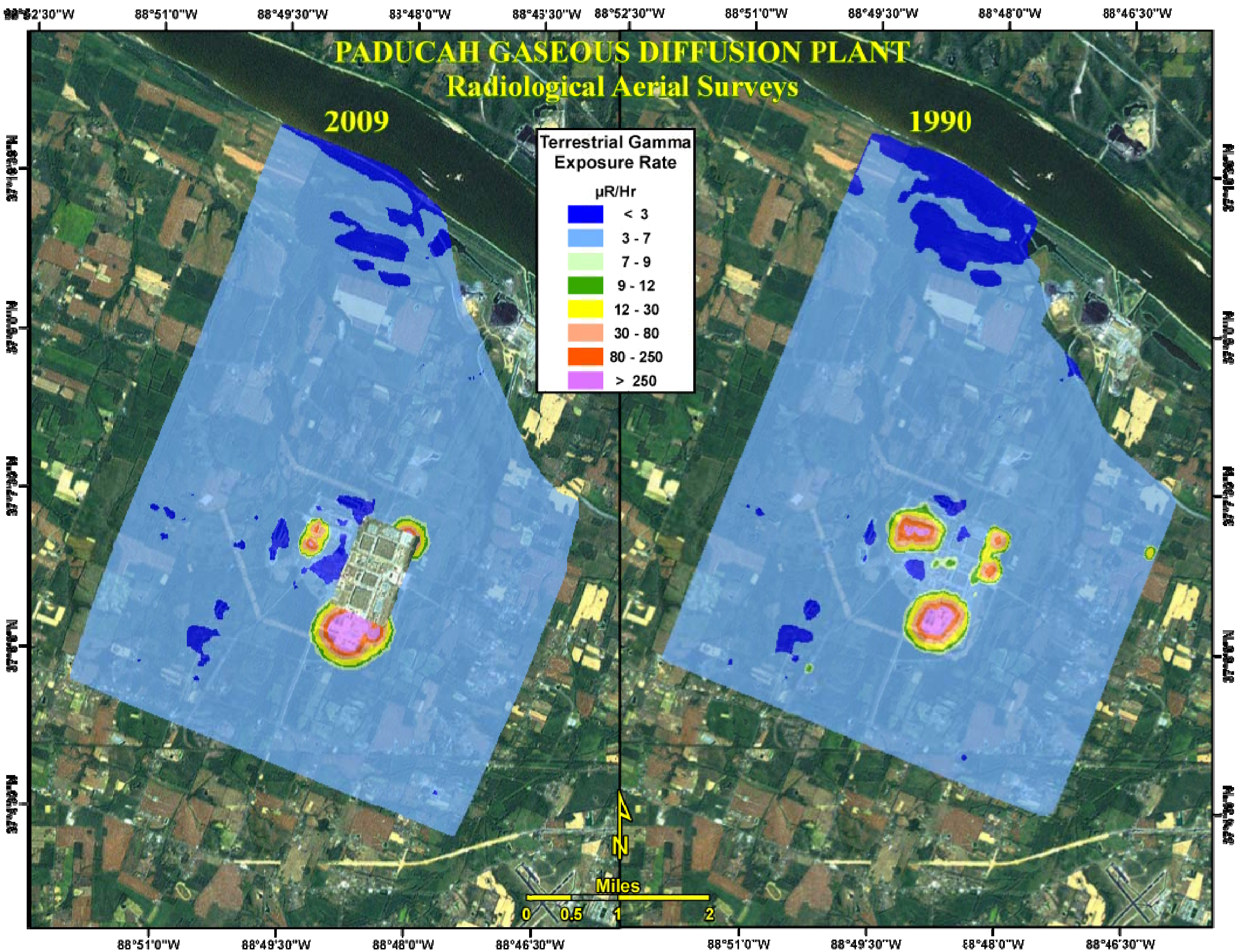

Figure 5: Terrestrial Gamma Exposure Rate Contour Map. Results from the previous survey[2](1990) are also shown for direct comparison.

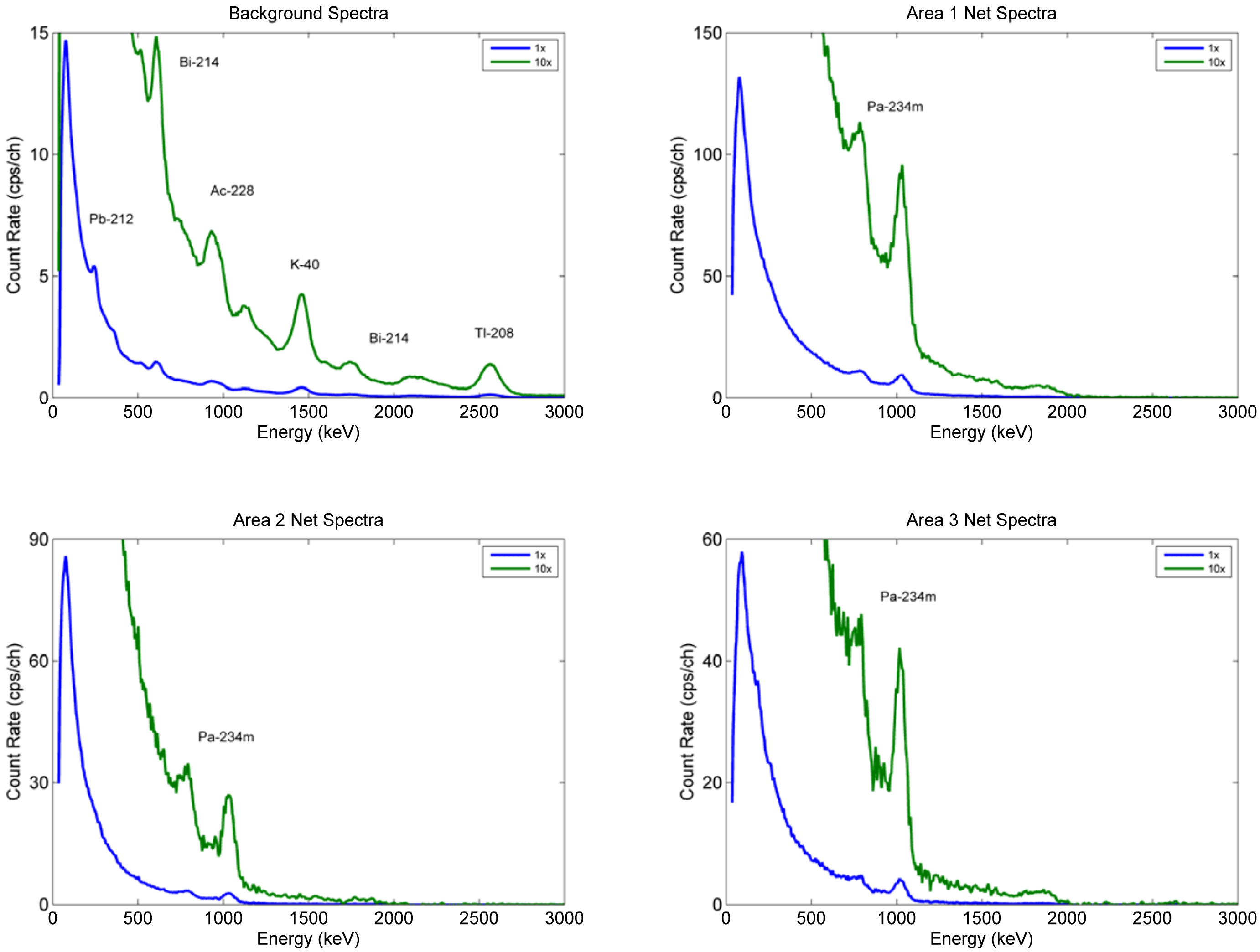

Figure 6: Spectra from Regions of Interest Indicated in Figures 2 and 3.

Each spectrum shows the counts per channel as a function of gamma-ray energy (where the energy conversion is 4 keV/channel) in a single 2”×4”×16” NaI(Tl) crystal.

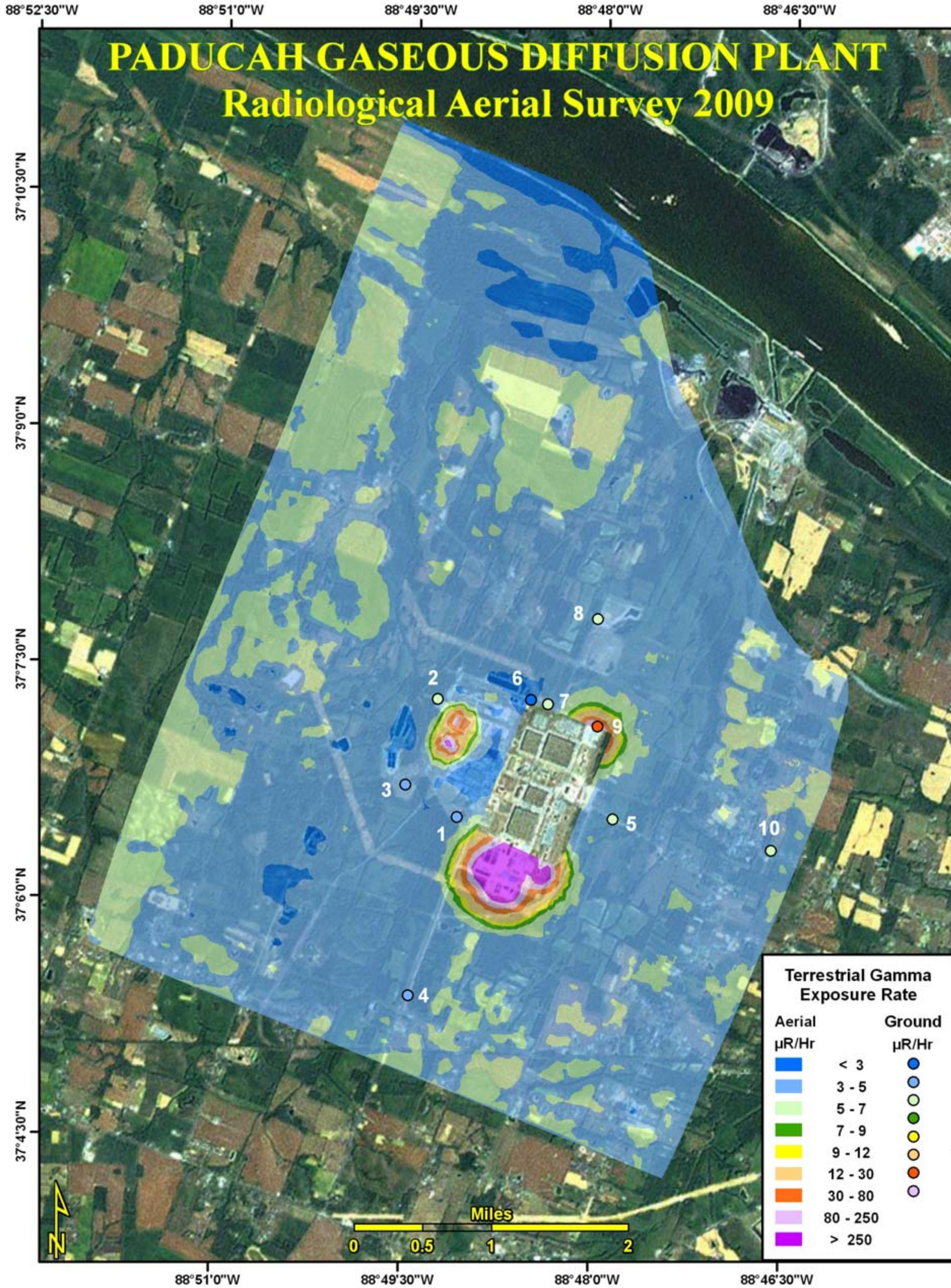

Figure 7: Comparison of PIC Ground-Based Measurements with Inferred Exposure Rate from Aerial Measurements. Values for the labeled data points are given in Appendix B

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APPENDIX A
Survey Parameters

Survey Site:	Paducah Gaseous Diffusion Plant, Paducah, Kentucky
Survey Coverage:	24 square miles (~62 square kilometers)
Survey Date:	October 28 – November 2, 2009
Survey Altitude:	150 feet (~46 meters)
Aircraft Speed:	70 knots (~36 miles per second)
Line Spacing:	250 feet (~76 meters)
Navigation System:	Trimble DGPS (OmniSTAR corrections)
Line Direction:	North-South and East-West
Detector Configuration:	Twelve 2″ × 4″ × 16″ NaI(Tl) detectors
Acquisition System:	REDAR-V
Conversion Factor:	1,712 cps/μR/h
Air Attenuation Coefficient:	0.001761/feet (0.005778/meters)
Aircraft:	Bell-412 Helicopter
Federal Team Lead:	Joe Ginanni
AMS Manager:	Karen McCall
Project Coordinator:	Elaine Hawkins
Project Manager:	Matthew Kiser
Project Scientist:	Michael Reed
Data Analysts:	Julia You Jezabel Stampahar Sonia Bonilla
Electronic Technicians:	Kevin Borders Tom Stampahar Dave Emery
Helicopter Pilots:	Jeff LeDonne Timothy Rourke
Aviation Mechanic:	Al Duncan

APPENDIX B

Ground-Based Measurements Compared to Inferred Aerial Measurements

Index	Latitude	Longitude	PIC Total (μR/h)	PIC Terrestrial (μR/h)	Aerial Terrestrial (μR/h)	PIC to Aerial Spread (μR/h)
1	37° 6’ 32.9”	-88° 49’ 5.8”	8.3	4.6	4.7	0.1
2	37° 7’ 17.7”	-88° 49’ 15.8”	8.9	5.2	4.0	1.2
3	37° 6’ 44.9”	-88° 49’ 30.5”	7.5	3.8	3.8	0.0
4	37° 5’ 24.5”	-88° 49’ 27.4”	8.2	4.5	4.1	0.4
5	37° 6’ 33.0”	-88° 47’ 51.8”	9.1	5.4	4.5	0.9
6	37° 7’ 18.1”	-88° 48’ 31.6”	6.4	2.7	2.6	0.1
7	37° 7’ 16.5”	-88° 48’ 23.5”	9.2	5.5	4.7	0.8
8	37° 7’ 49.4”	-88° 48’ 0.4”	9.2	5.5	4.0	1.5
9	37° 7’ 8.4”	-88° 47’ 59.7”	58.9	55.2	367.0	311.8
10	37° 6’ 22.1”	-88° 46’ 36.3”	9.0	5.3	4.1	1.2

The measured PIC data (PIC Total) intrinsically includes cosmic and radon contributions. An estimated cosmic ray contribution[5] of 3.7 μR/h was removed from the measured PIC value to get the PIC Terrestrial exposure rate. Note that this PIC Terrestrial exposure rate includes any radon contribution at the specific locations. Measured aerial data (Aerial Terrestrial) utilized test line and water line information to remove both the cosmic and radon contributions.

APPENDIX B

ANOMALY DATABASE

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APPENDIX B

ANOMALY DATABASE (CD)

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APPENDIX C

PHOTOGRAPHS OF 25 SELECTED ANOMALIES

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FIGURES

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Figure C.1. Anomaly PV-21-01-V-6

Figure C.2. Anomaly PG-02-03-R-2

Figure C.3. Anomaly PM-26-02-R-3

Figure C.4. Anomaly PE-01-03-V-18

Figure C.5. Anomaly PP-06-03-V-20

Figure C.6. Anomaly PS-26-02-V-1

Figure C.7. Anomaly PP-05-02-R-1a

Figure C.8. Anomaly PU-24-01-V-5

Figure C.9. Anomaly PU-24-01-V-4

Figure C.10. Anomaly PY-13-01-V-2

Figure C.11. Anomaly PF-13-02-V-16

Figure C.12. Anomaly PV-24-01-V-8

Figure C.13. Anomaly PY-13-01-V-5

Figure C.14. Anomaly PF-13-02-R-1

Figure C.15. Anomaly PF-18-02-V-20

Figure C.16. Anomaly PQ-30-03-V-5

Figure C.17. Anomaly PY-14-01-V-7

Figure C.18. Anomaly PY-13-01-V-4

Figure C.19. Anomaly PQ-30-03-V-6

Figure C.20. Anomaly PE-01-03-V-24

Figure C.21. Anomaly PF-18-02-V-19

Figure C.22. Anomaly PY-14-01-V-8

Figure C.23. Anomaly PY-14-01-V-6

Figure C.24. Anomaly PQ-30-03-V-7

Figure C.24. Anomaly PQ-30-03-V-7 (Continued)

Figure C.25. Anomaly PU-24-01-V-6

APPENDIX D

FIELD NOTES

NOTE: The following figures were prepared for field use only. The color coding shown has no significance within this document.

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FIGURES

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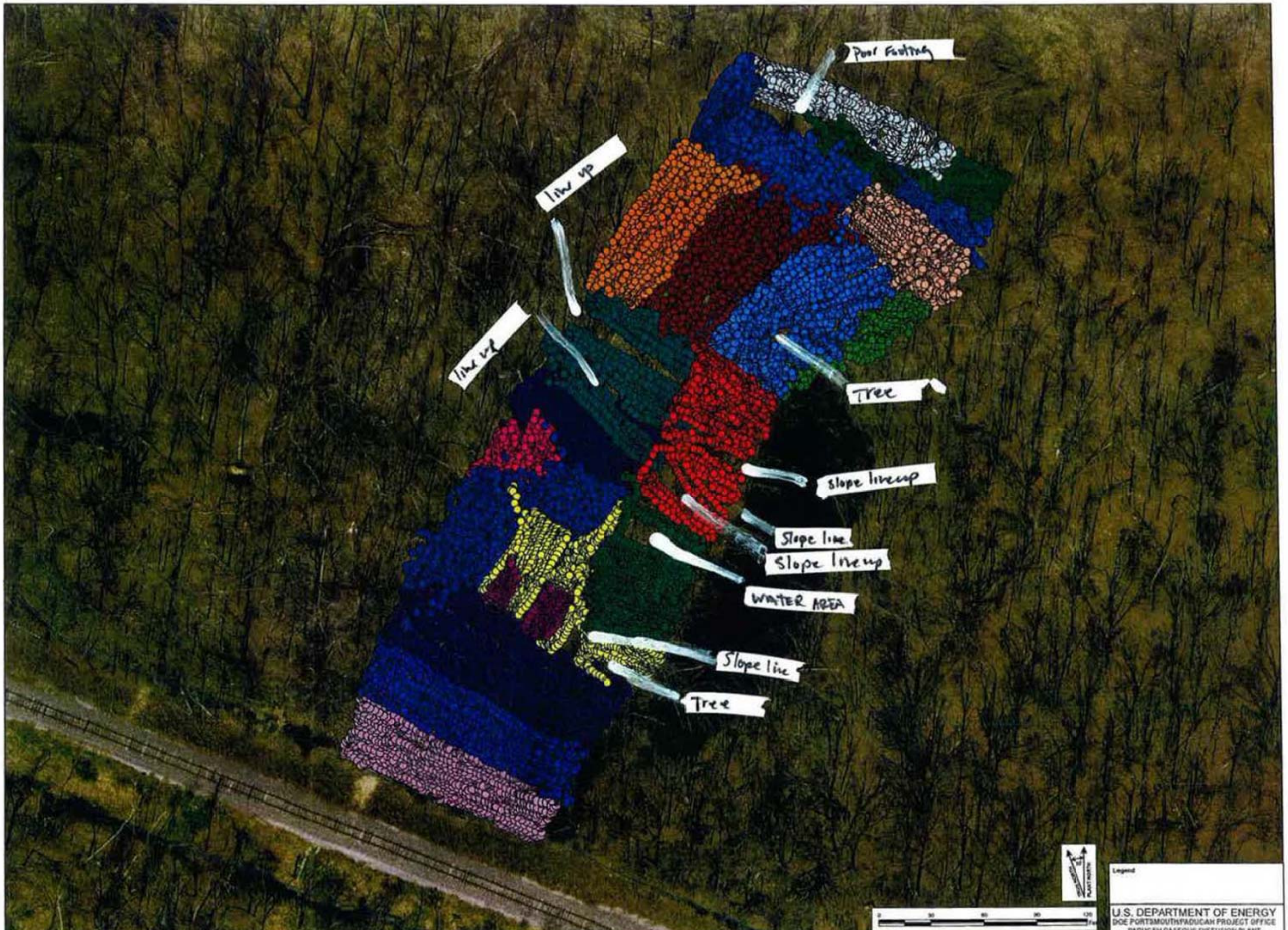
PE-01-03-V-18 MAP

PF-18-02-V-20 MAP

PP-06-03-V-20 MAP



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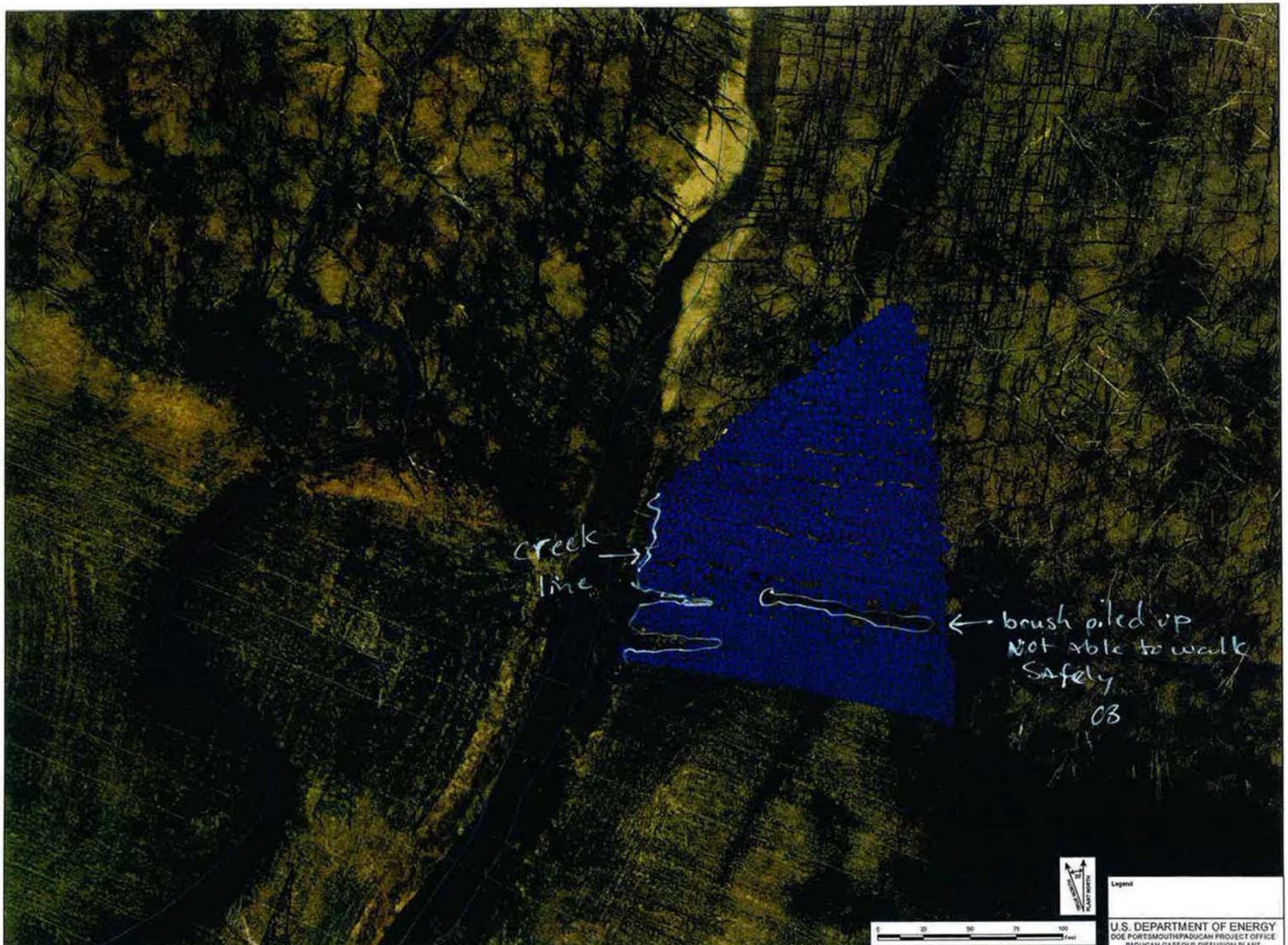
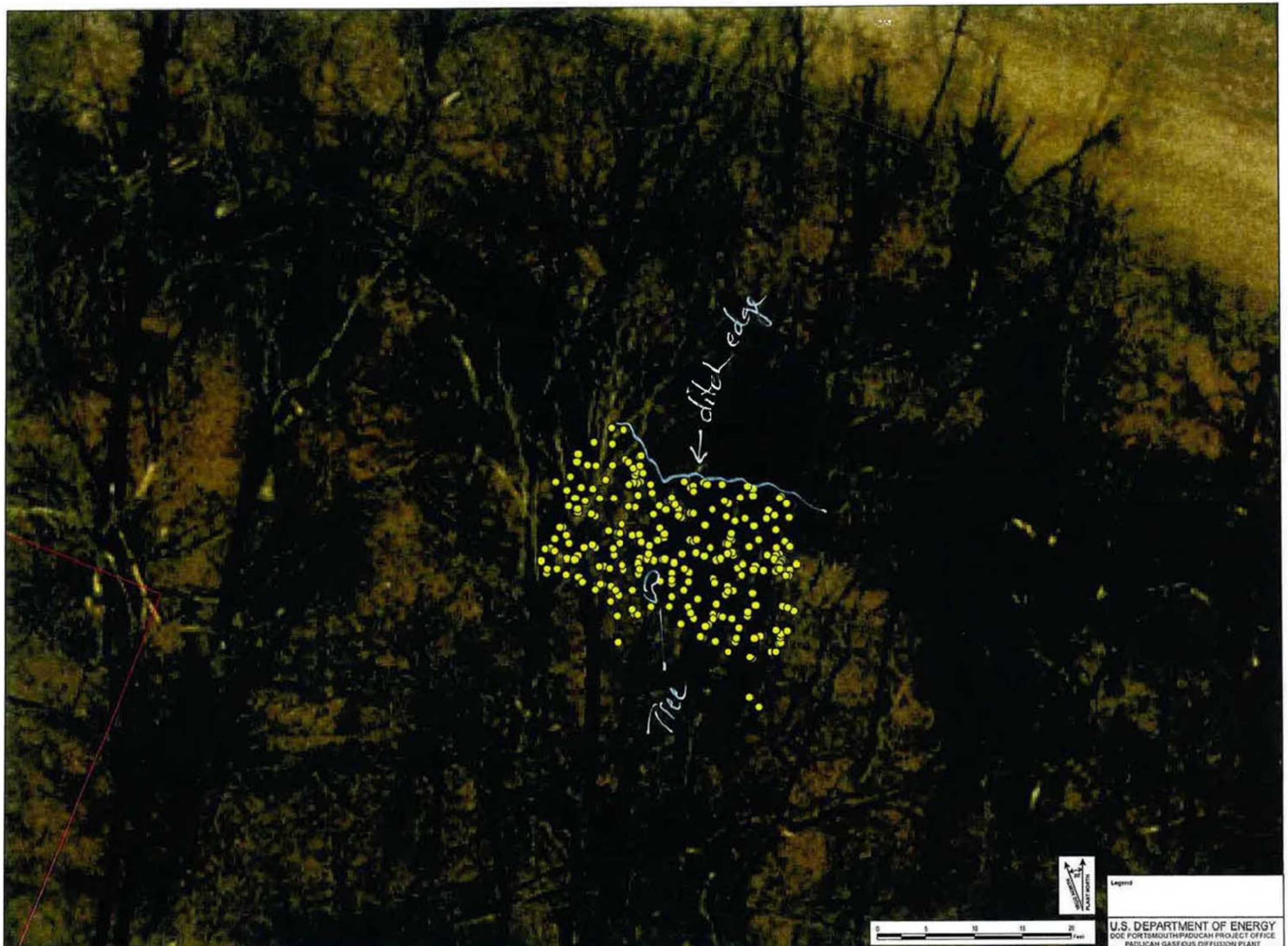
PQ-30-03-V-7 MAP

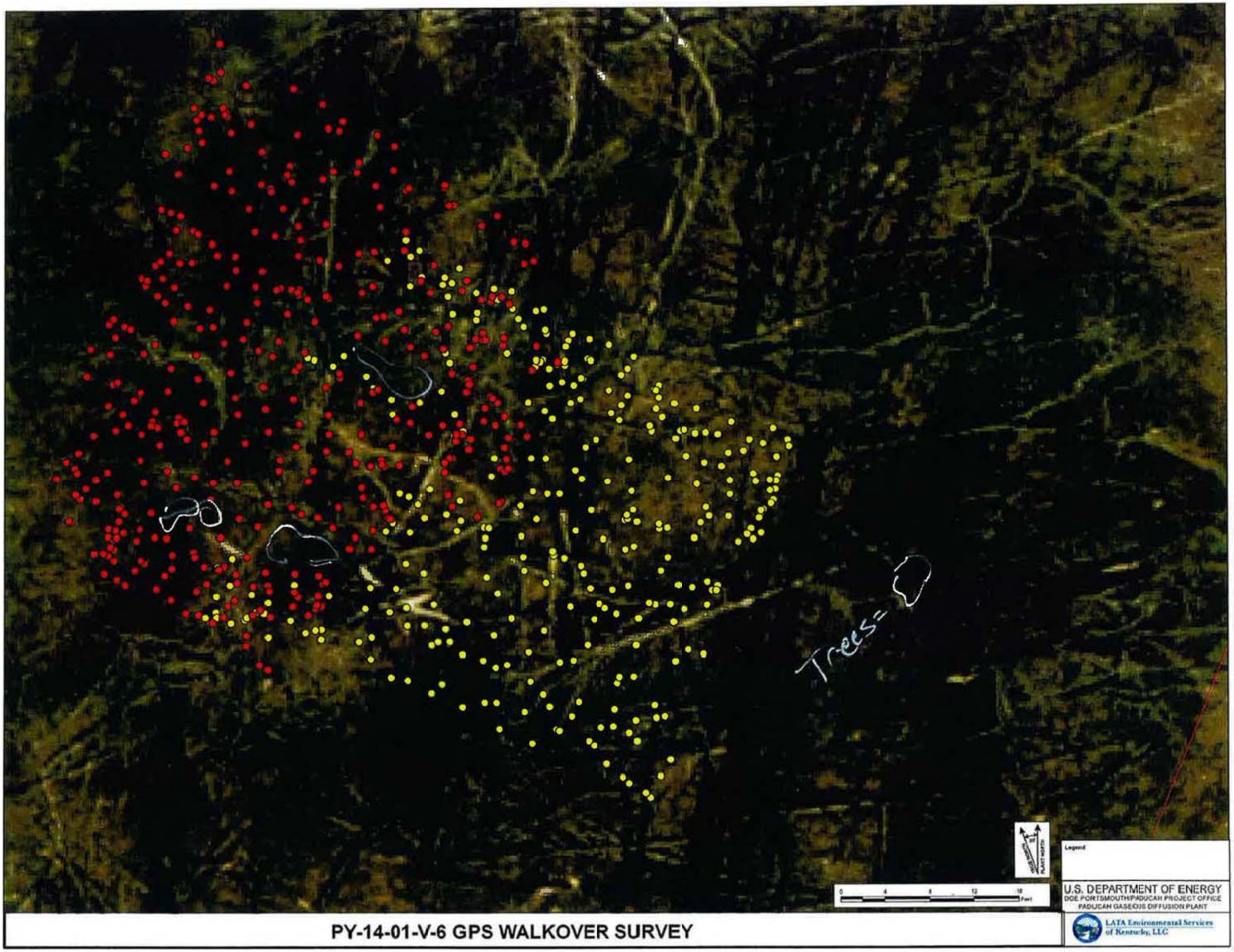


PU-24-01-V-4 MAP



PY-13-01-V-2 MAP

PU-24-01-V-6 MAP



PY-14-01-V-6 GPS WALKOVER SURVEY

Anomaly PY1301V4
13207 - 13400
13401 - 13412
13413 - 15646
1
2
3
4
Trees
N

1) 744194,1930962
2) 744311,1930951
3) 744313,1930937
4) 744195,1930945
5) 744206,1930925
6) 744283,1930905
7) 744204,1930908
8) 744283,1930892
9) 744196,1930902
10) 744219,1930895
11) 744179,1930846
12) 744202,1930841
13) 744263,1930878
14) 744291,1930872
15) 744251,1930841
16) 744280,1930834

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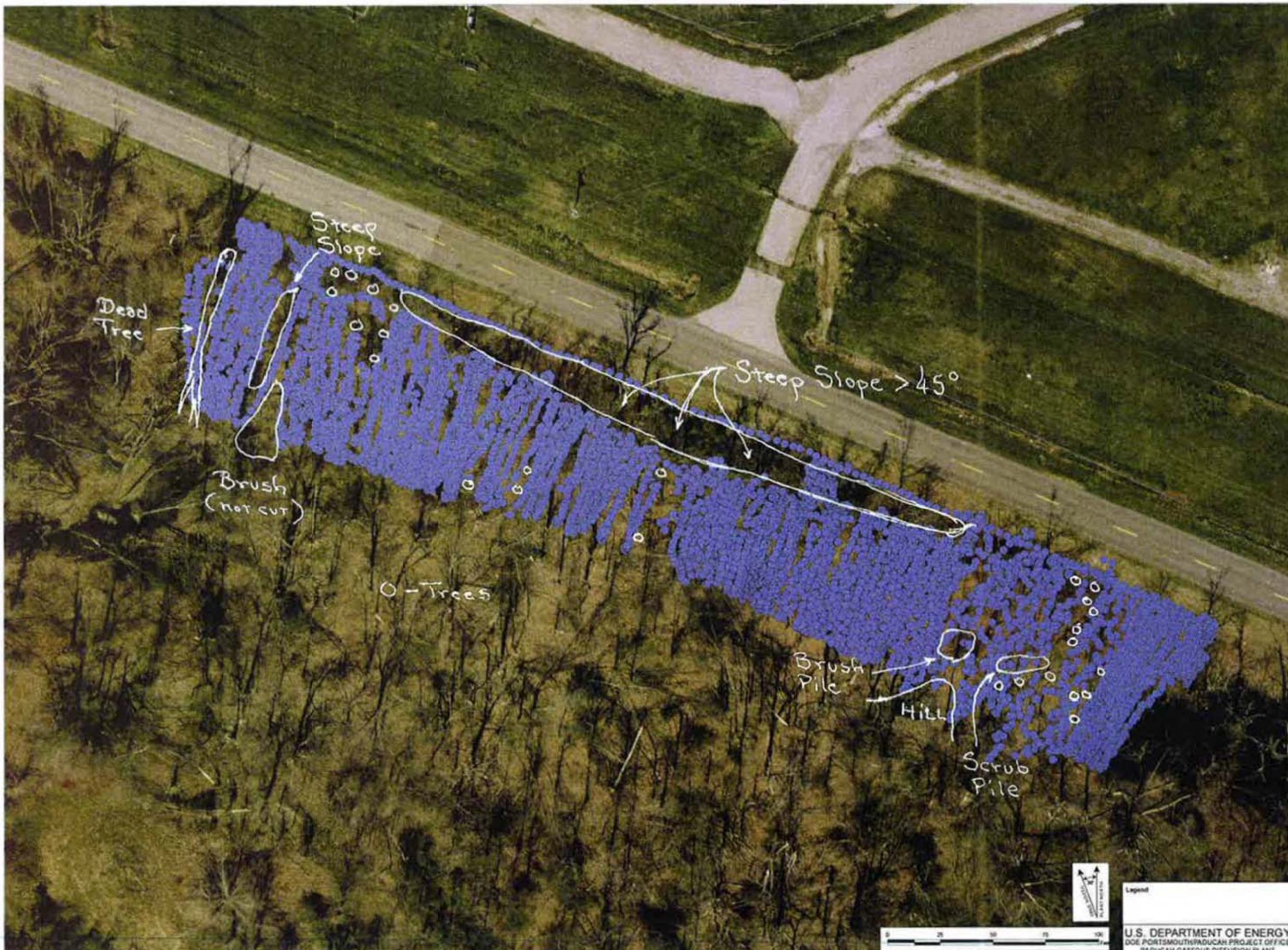
PY-14-01-V-7 MAP



PF-13-02-V-16 MAP

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