Rocky Flats
General Overview Briefing

Rocky Flats Stewardship Council Meeting

October 31, 2016

U.S. DEPARTMENT OF ENERGY | Legacy Management

Agenda

- Background
- Contaminant Characterization
- Regulatory Process and Controls
- Site Cleanup
- Long-Term Site Management
- Summary

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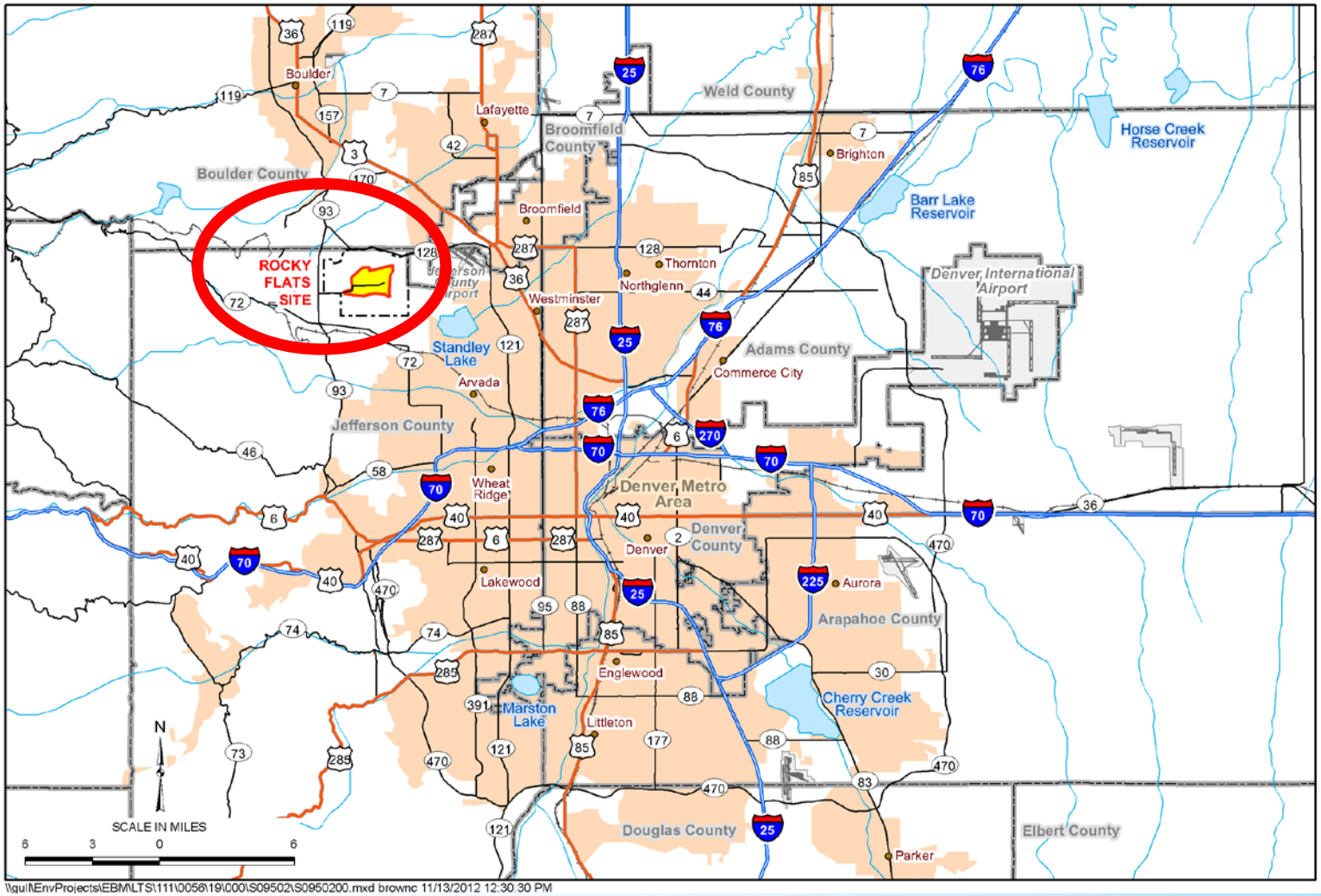
Background

Location



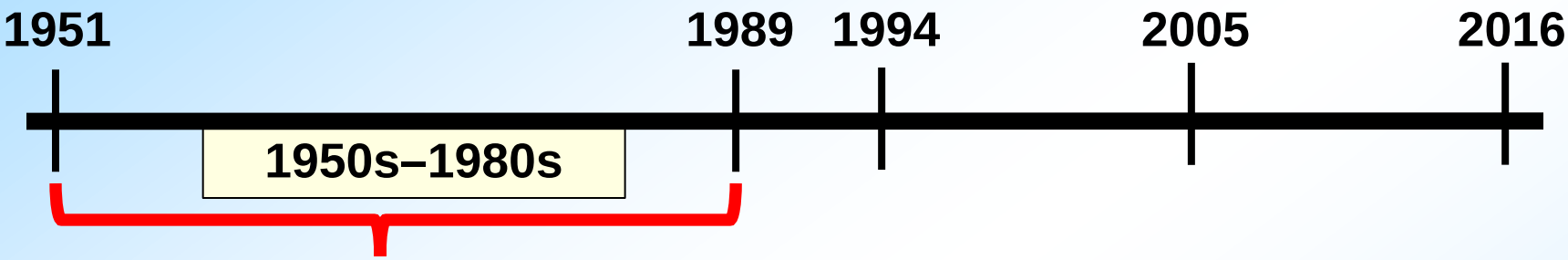
Background

Rocky Flats Timeline

1951 1989 1994 2005 2016

Background

Rocky Flats Timeline



Key site in the U.S. nuclear weapons complex

Industrial Area:
Approximately 385 acres
Buffer Zone:
Approximately 6,200 acres

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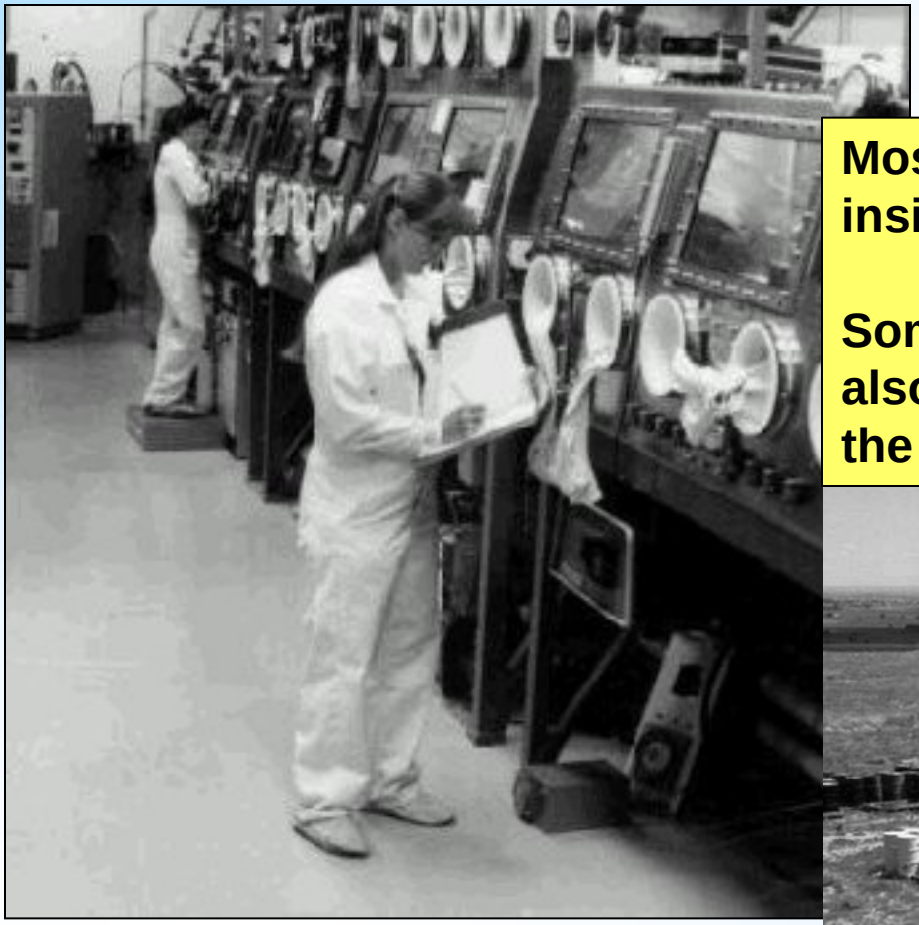
Background

1950s–1980s: Production



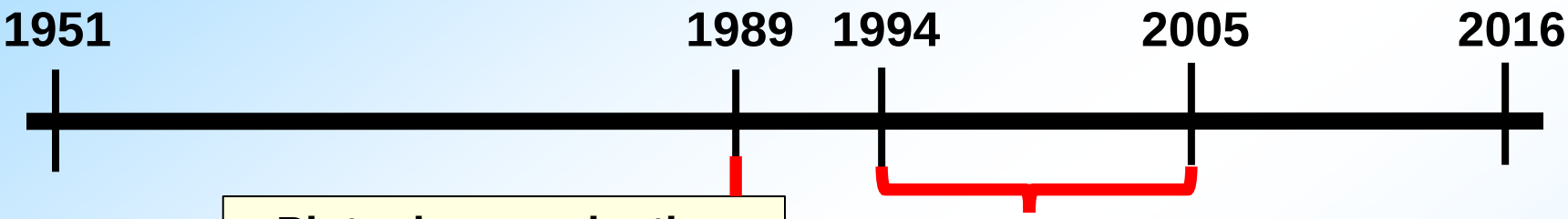
Most of the contamination was inside the buildings.

Some contamination was also released outside of the buildings.

Drums at the 903 Pad (in 1960s)

Background

Rocky Flats Timeline



Building decommissioning and decontamination (D&D)

Building demolition

Environmental remediation

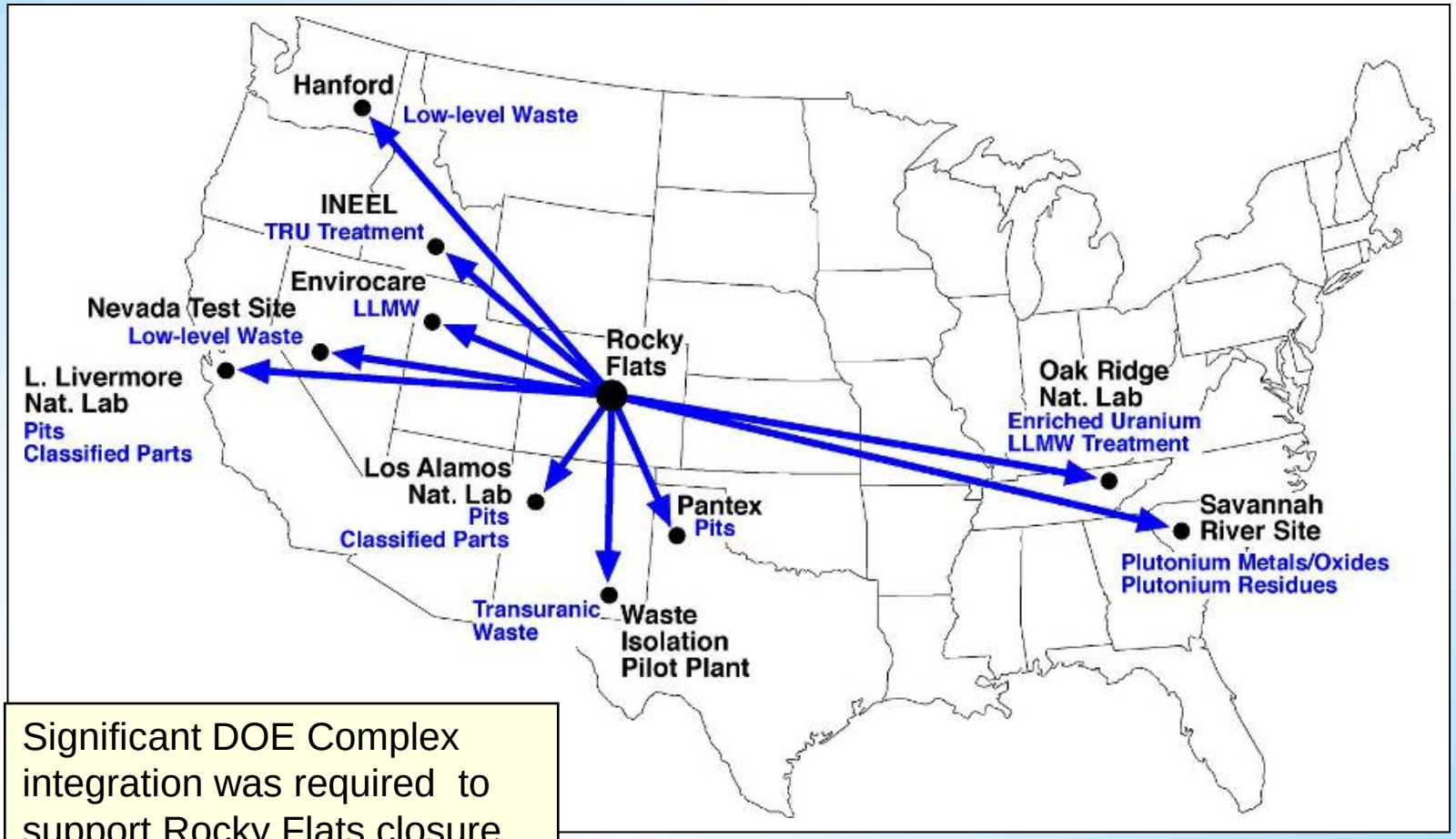
Background

1994–2005: Cleanup and Closure

Background

1994–2005: Cleanup and Closure

Shipping Special Nuclear Materials and Waste



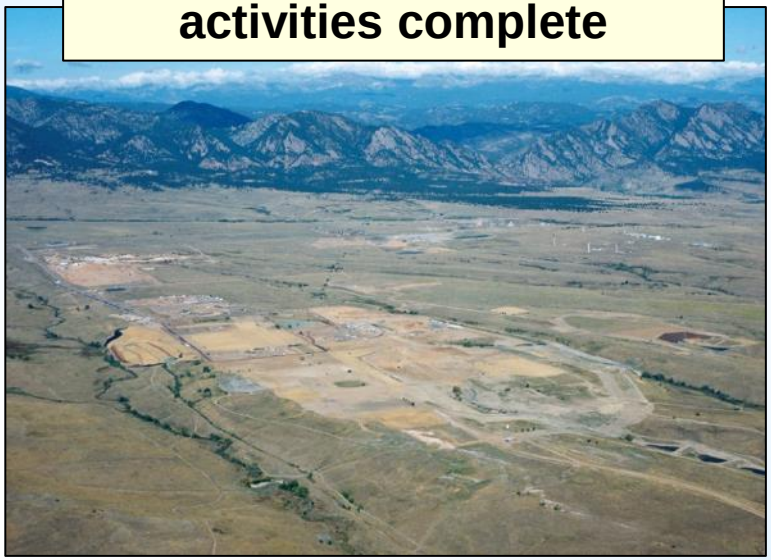
Significant DOE Complex integration was required to support Rocky Flats closure

Background

Rocky Flats Timeline

1951 — 1989 — 1994 — 2005 — 2016

2005
Cleanup and closure activities complete



Present day

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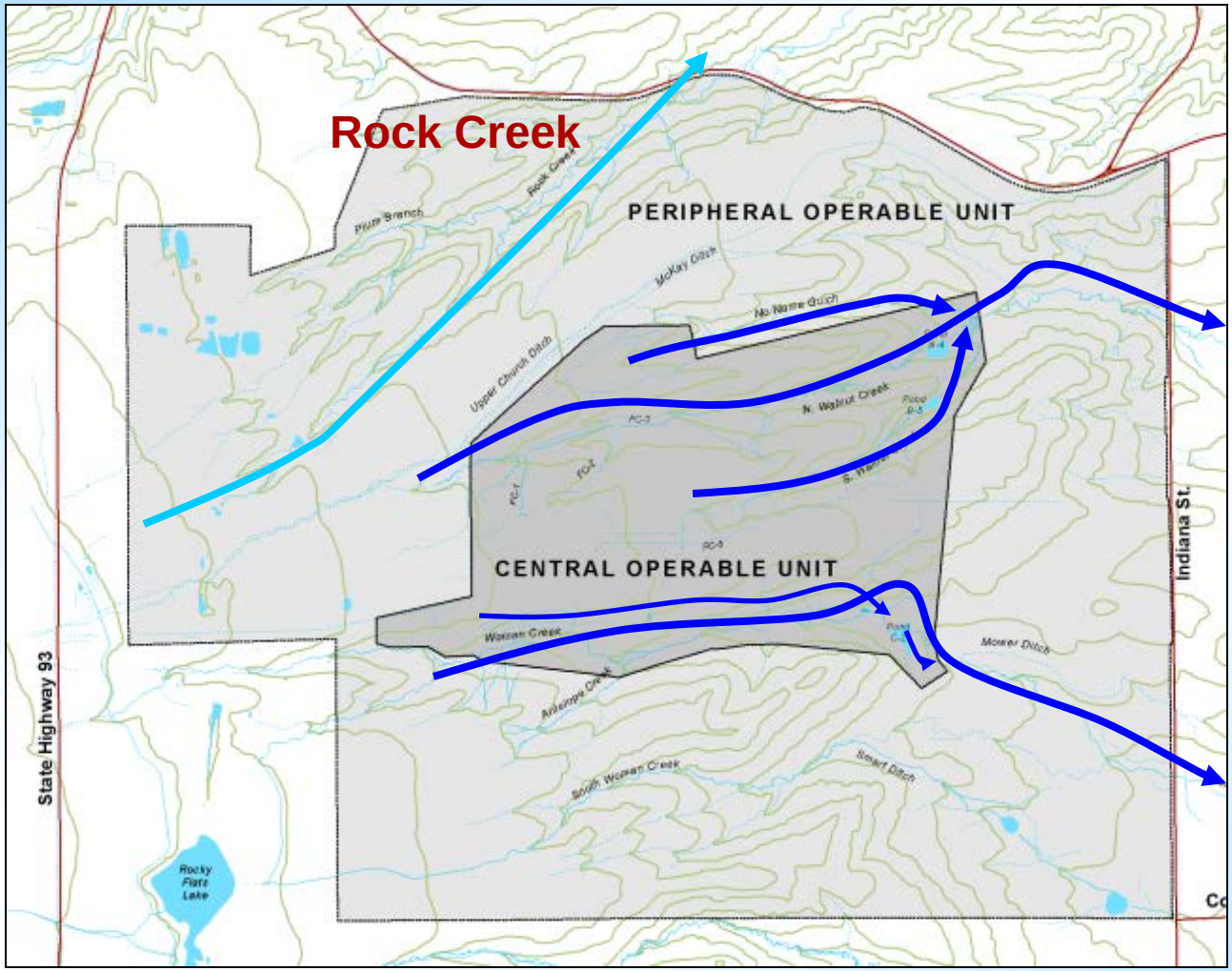
Background – Environmental Features

Surface Water – Main Drainages



Background – Environmental Features

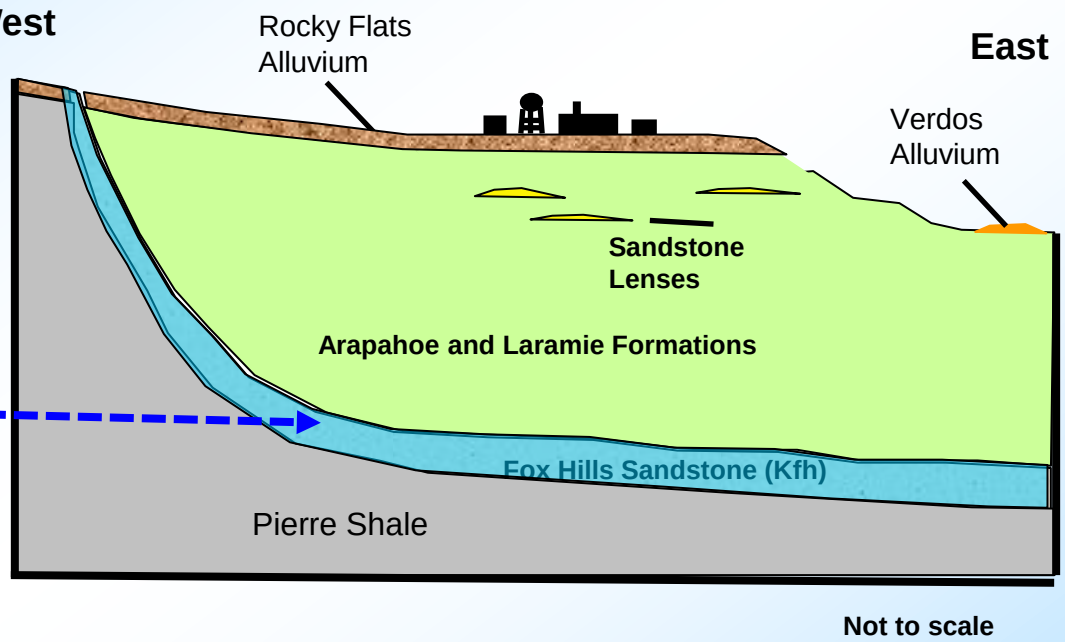
Hydrogeology/Groundwater

Shallow Groundwater

- Rocky Flats Alluvium
- Weathered bedrock
- **Potential transport pathway**

Deep Groundwater

- Regional Fox Hills Sandstone aquifer
  - 200 to 300 m below surface
- Isolated from shallow groundwater by Laramie Formation claystones (hydraulic conductivity 10^{-7} cm/sec)
- **Not a transport pathway**



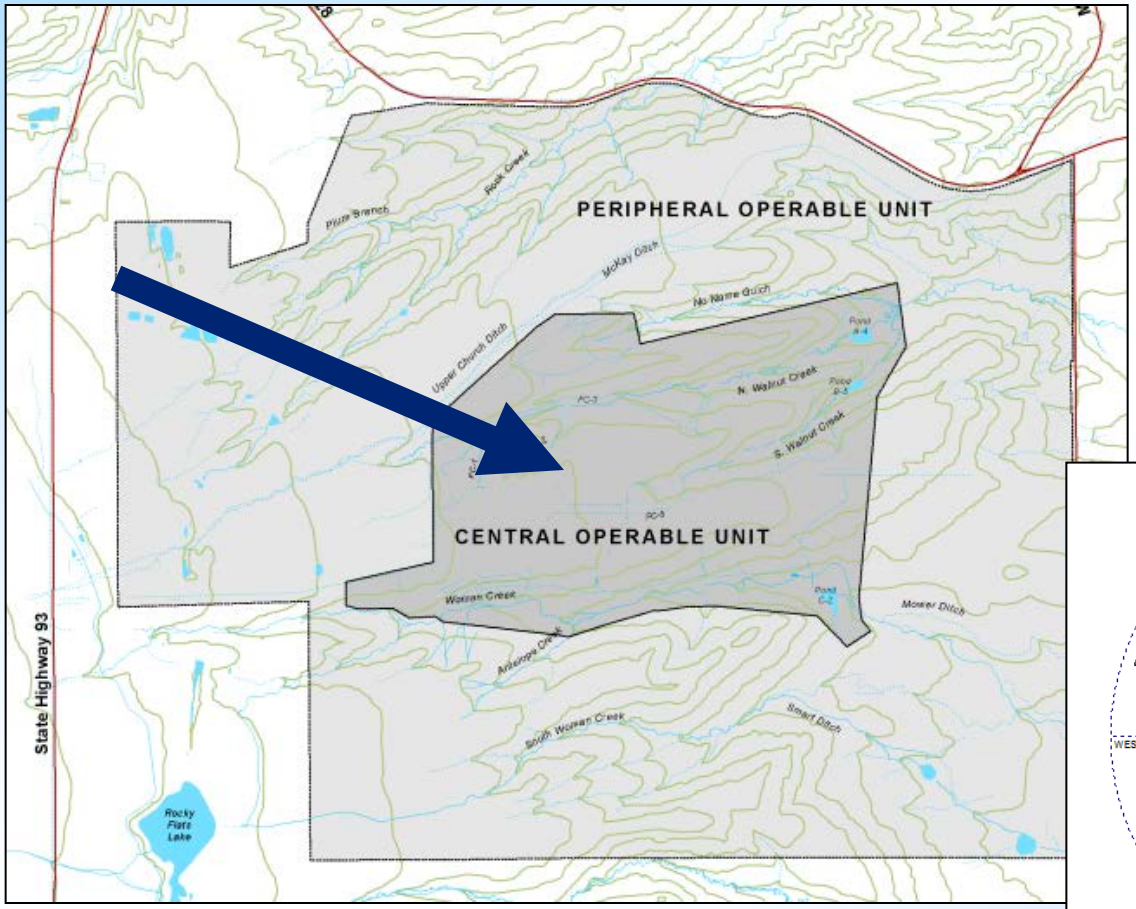
Generalized Geologic Cross-Section of Rocky Flats

The Rocky Flats site (RFS) does not impact any groundwater drinking water sources.

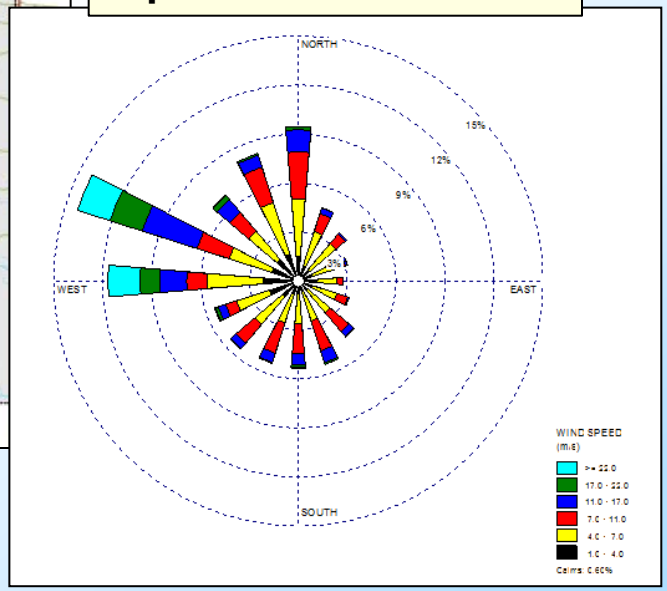
For more information on the hydrogeology at Rocky Flats, refer to: http://www.lm.doe.gov/Rocky_Flats/

Background – Environmental Features

Prevailing Winds



Frequency distribution of wind speeds and direction



Background

Historic Contaminants at Rocky Flats

- Historic, or “legacy,” contamination at Rocky Flats includes:
- Radionuclides
  - Plutonium (Pu)
  - Americium (Am)
  - Uranium (U)
- Other contaminants
  - Metals
  - Nitrate
  - Organic compounds (solvents)

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Contaminant Characterization

Historical Release Report (HRR)

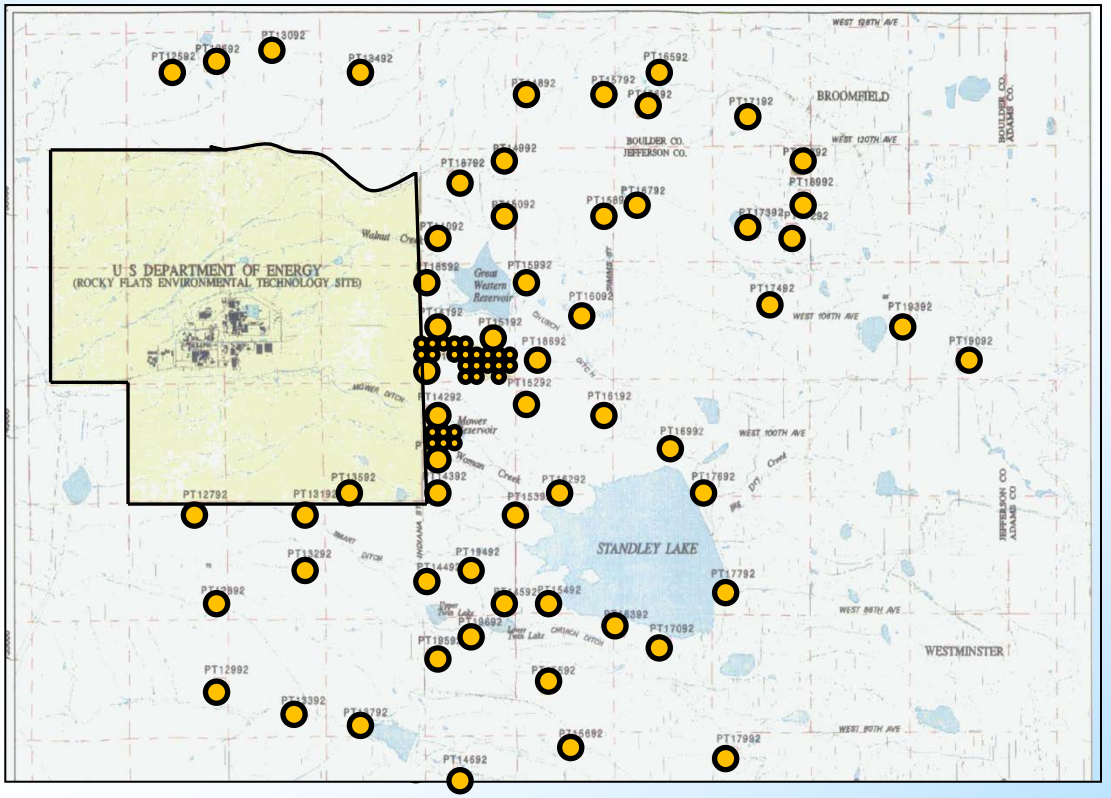
- Originally compiled in 1992 to capture existing information on historical incidents and plant practices involving hazardous substances at Rocky Flats
  - Review of written documentation: memoranda, letters, reports, log books, meeting minutes, photographs
  - Interviews with current and past employees
- Updated periodically over the next 12 years
- Identified areas for additional characterization and potential remediation (individual hazardous substance sites, potential areas of concern, potential incidents of concern, and under building contamination)

The HRR is Appendix B of the Resource Conservation and Recovery Act (RCRA) Facility Investigation – Remedial Investigation/Corrective Measures Study – Feasibility Study Report for the Rocky Flats Environmental Technology Site (http://www.lm.doe.gov/Rocky_Flats/Regulations.aspx)

Contaminant Characterization

Surface Soil – Offsite (Plutonium)

- Numerous studies collected offsite samples
- Some sample results immediately east of the site are above background levels (highest = 6.5 pCi/g; most are near background)
- Concentrations west, north, and south of the site are within range of background



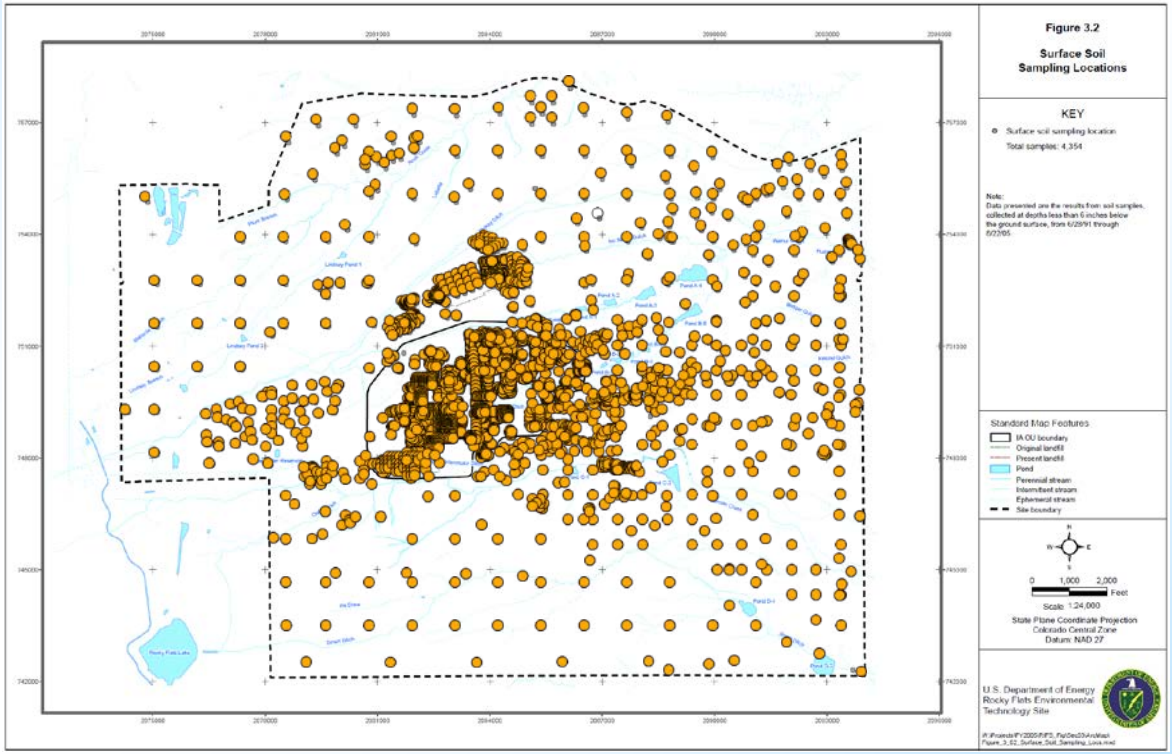
- **The final regulatory decision for Operable Unit 3 (offsite areas) was that no cleanup action was necessary to protect human health or the environment because contaminant levels were so low***

*This decision was based on a 3-volume RCRA Facility Investigation/Remedial Investigation report that provided data on surface water, groundwater, surface soil, subsurface soil, sediments, and air. See Volume I: http://www.lm.doe.gov/cercla/documents/rockyflats_docs/OU03/OU03-A-000465.pdf

Contaminant Characterization

Surface Soil – Onsite

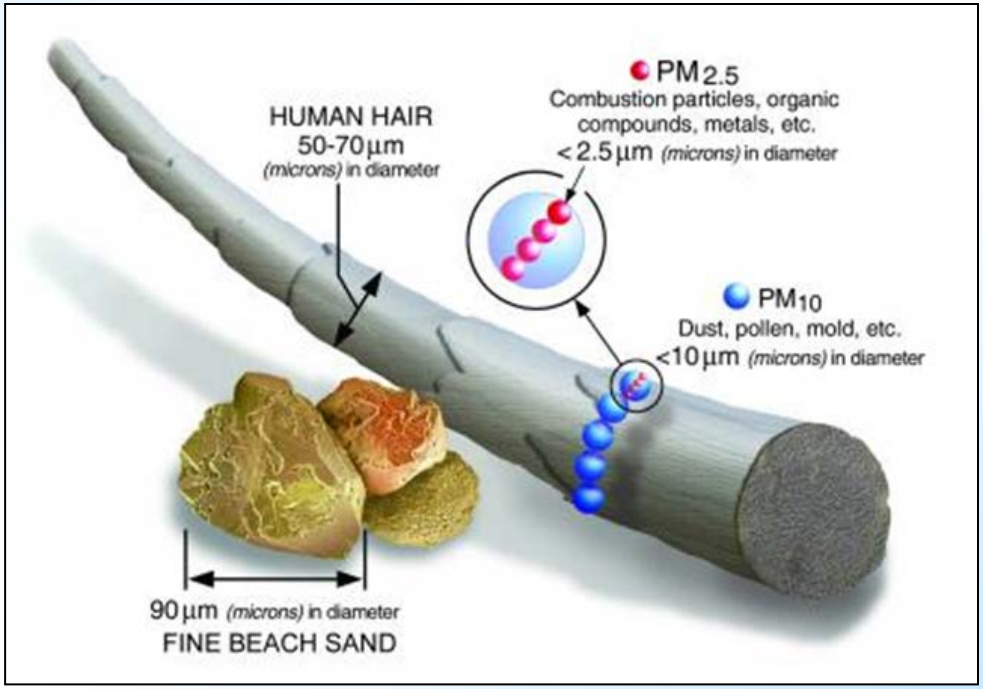
- More than 7,200 locations sampled since June 1991
- More than 220,000 results used to evaluate the nature and extent of surface-soil contamination



Map adapted from Section 3 of the RCRA Facility Investigation – Remedial Investigation/ Corrective Measures Study – Feasibility Study Report for the Rocky Flats Environmental Technology Site (http://www.lm.doe.gov/Rocky_Flats/Regulations.aspx)

Air – Particle Considerations

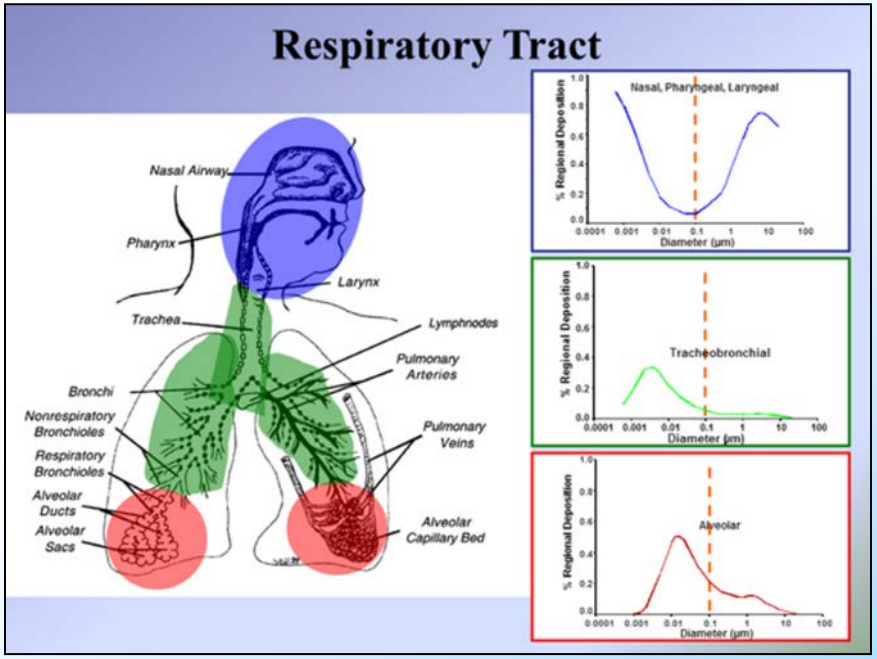
- Most radionuclides were released and dispersed as particles
  - Their behavior in air depends on shape and density
- Plutonium in the environment exists as PuO_2 particles attached to the soil matrix, not as individual plutonium particles
- Because very small particles condense or stick together to form larger aerosols, most plutonium is found with particles >3 microns (µm) diameter



Air – Inhalation Pathway

- Radioactive particles can damage lung tissue when they are inhaled and deposited in the lungs
- Larger particles (>10 µm) are screened out in the nose and upper airway and not retained by the body

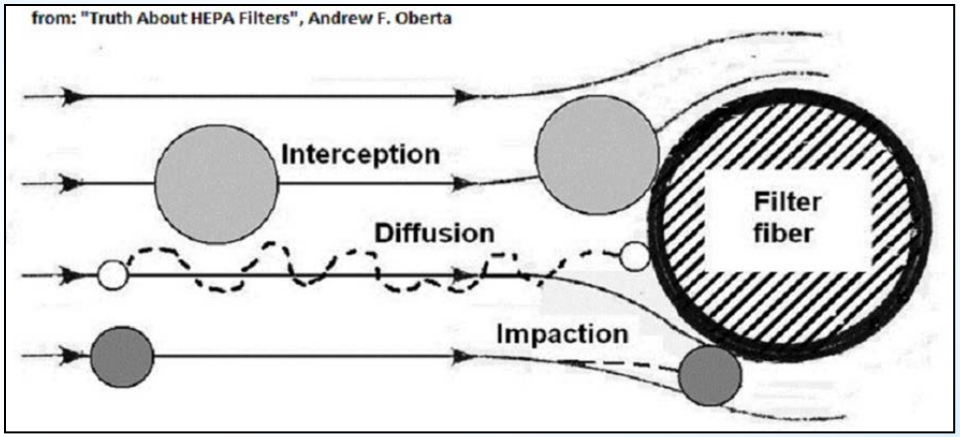
With respect to plutonium and the inhalation pathway, air monitoring must be able to effectively capture particles <10 µm diameter



Contaminant Characterization

Air – Monitoring

- Filters collect particles via the same mechanisms as the human respiratory tract
- Filters used in air monitors at Rocky Flats were tested and shown to be >99 percent efficient in capturing inhalable particles
  - Testing by the manufacturers
  - Wind tunnel testing by Colorado State University and U.S. Environmental Protection Agency (EPA)
  - Side by side comparisons with Colorado Department of Public Health and Environment and reference EPA samplers
  - Many research studies conducted at Rocky Flats, and elsewhere



Contaminant Characterization

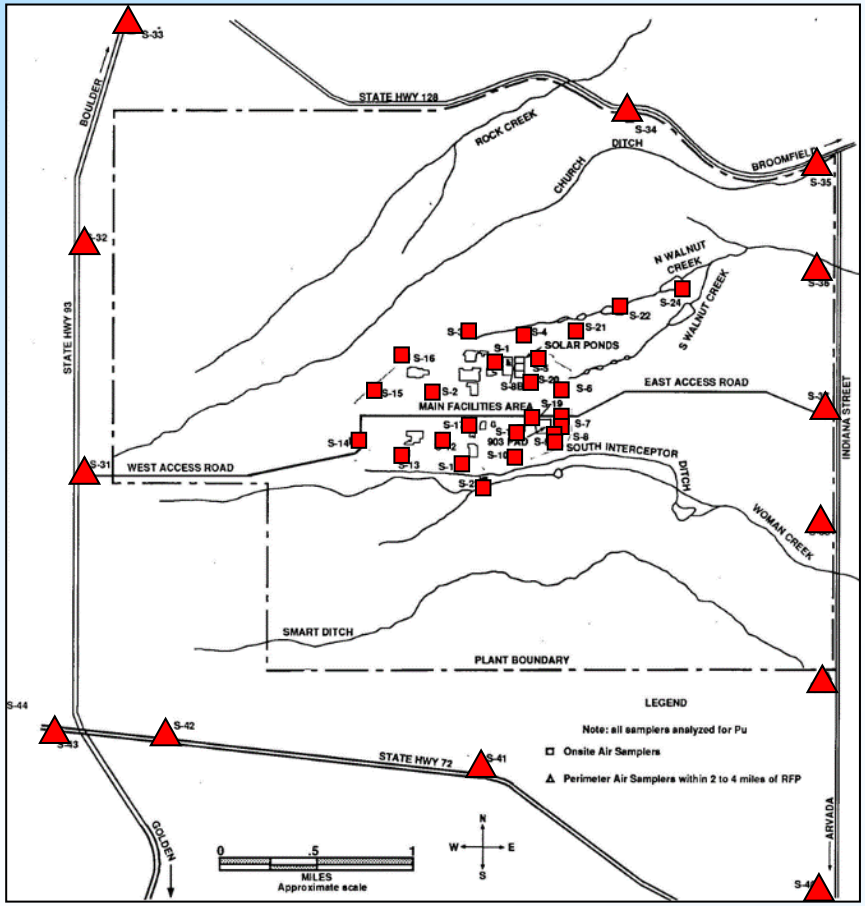
Air – Monitoring (continued)

- Effluent monitoring:
  - Emissions monitored in exhaust from building stacks and vents
  - Conducted from 1953 until flow in ducts was disrupted by building decommissioning
- Ambient monitoring:
  - Concentration of contaminants measured in the “outside” air (onsite, at the perimeter, and in the communities)
  - Conducted from 1952 until 2008

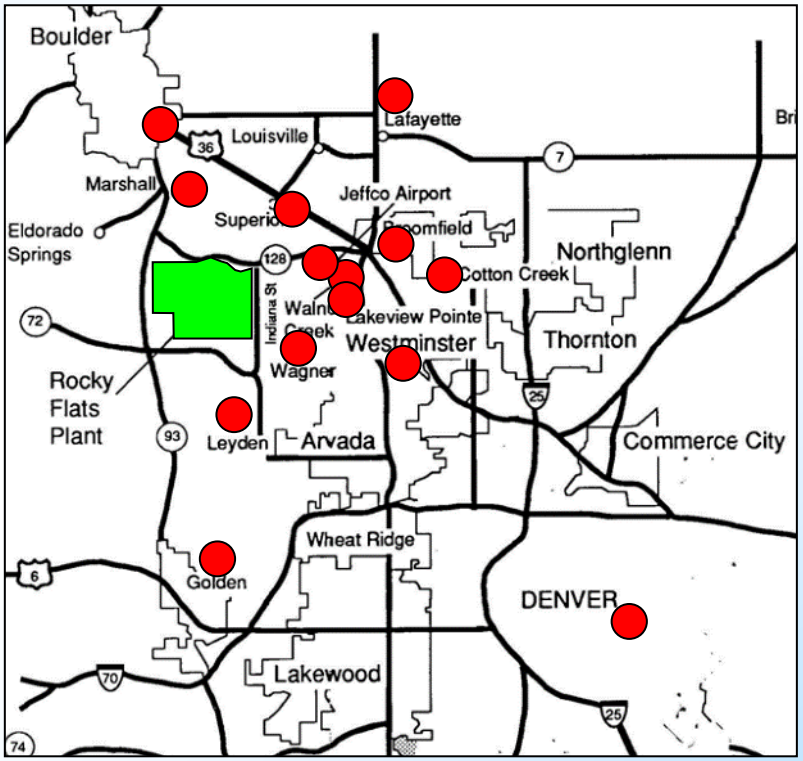
Monitoring equipment was upgraded periodically as regulations changed and science and technology advanced

Contaminant Characterization

Air – Monitoring (continued)



Onsite and perimeter ambient monitoring locations



Community ambient monitoring locations

(1990 snapshot of ambient monitoring configuration)

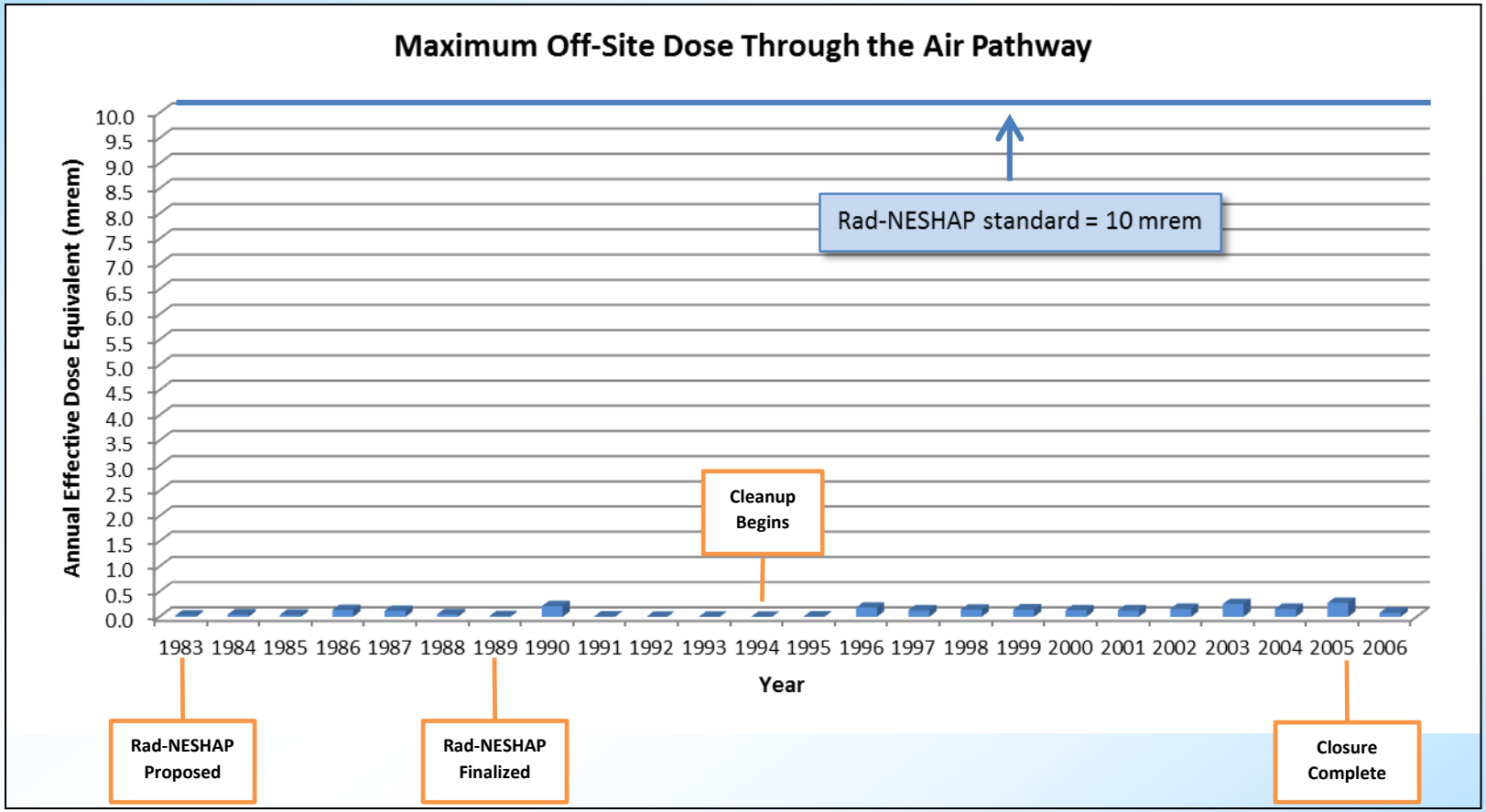
Air – Monitoring Results

- The *National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities* (Rad-NESHAP) is the primary regulation dealing with radionuclide air emissions (proposed 1983, finalized 1989)*
- Rad-NESHAP limits annual dose through the air pathway to any member of the public to 10 millirem (mrem)/year
- Average per person annual dose in U.S. due to all sources is **620 mrem** (up from **360 mrem in 1980** due to more medical testing)

Dose from air travel	1 mrem per 1,000 miles
Dose from cosmic radiation if you live in Colorado at 5,000 to 6,000 feet above sea level (e.g., Denver or Boulder)	29 mrem/yr
Dose from a mammogram	40 to 72 mrem
Dose living in a mountain town like Nederland or Crested Butte	90 mrem/yr
Dose from natural uranium/thorium in soil in Denver	70 mrem/yr
Dose from a full body CT scan	1,000 mrem

**See* Title 40 *Code of Federal Regulations* (CFR), Part 61 (effective 12/15/1989); *see also* 42 U.S.C. § 7401 *et seq* (Clean Air Act). More dose comparisons can be found at the U.S. Nuclear Regulatory Commission (NRC), Personal Annual Radiation Dose Calculator, available here: http://www.nrc.gov/about-nrc/radiation/around-us/calculator.html

Air – Monitoring Results (continued)

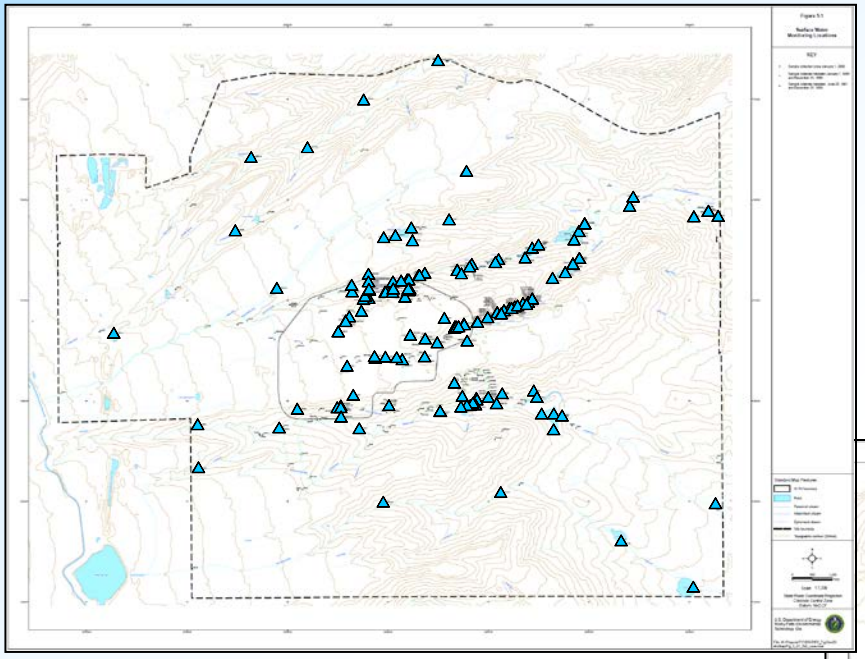


These data support the exclusion of air monitoring from the current monitoring program.

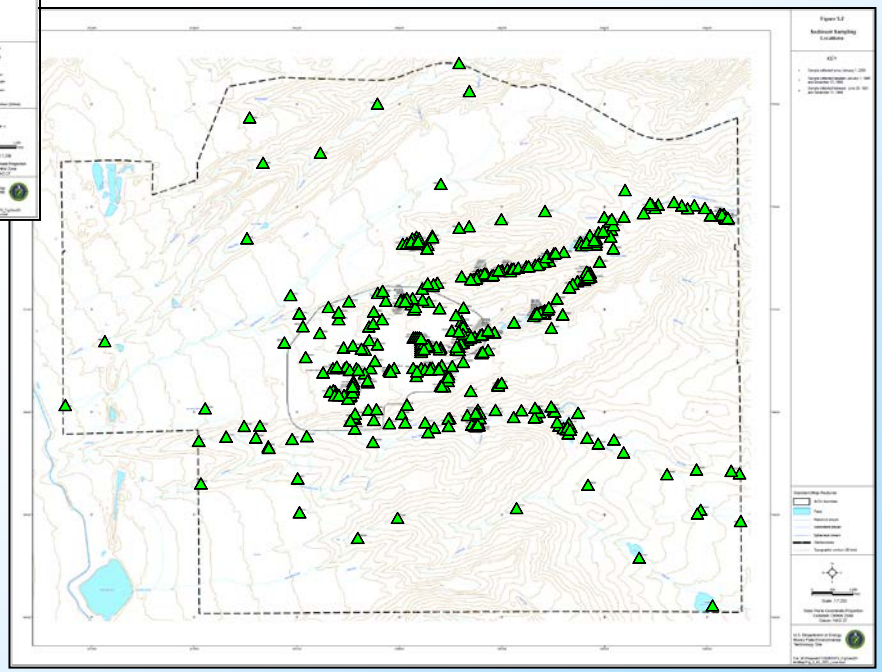
Air samplers collected not only site-derived radionuclides, but also naturally occurring and background radionuclides (particularly uranium isotopes). As a result, **naturally occurring uranium made up the majority of the reported annual measured dose.** Data are compiled from annual environmental monitoring and air emissions reports.

Contaminant Characterization

Surface Water and Sediment



- More than 400 surface-water locations sampled since June 1991
- Samples consisted of both grabs and automated flow-paced composites
- More than 38,000 results used to evaluate the nature and extent of surface-water contamination



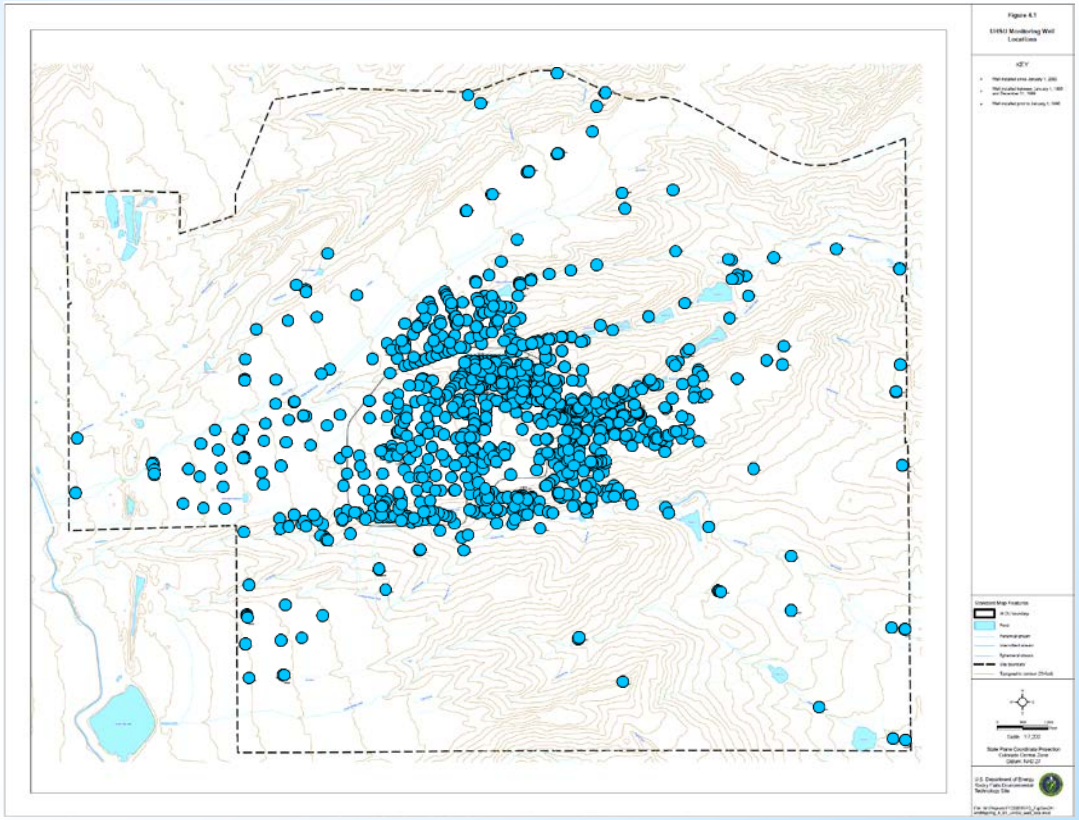
- More than 360 sediment locations sampled since June 1991
- More than 44,000 results used to evaluate the nature and extent of sediment contamination

Maps adapted from Section 5 of the RCRA Facility Investigation – Remedial Investigation/Corrective Measures Study – Feasibility Study Report for the Rocky Flats Environmental Technology Site (http://www.lm.doe.gov/Rocky_Flats/Regulations.aspx)

Contaminant Characterization

Groundwater

- More than 1,000 wells sampled since June 1991
- More than 500,000 results used to evaluate the nature and extent of groundwater contamination
- Groundwater was sampled at various depths using standard sampling techniques

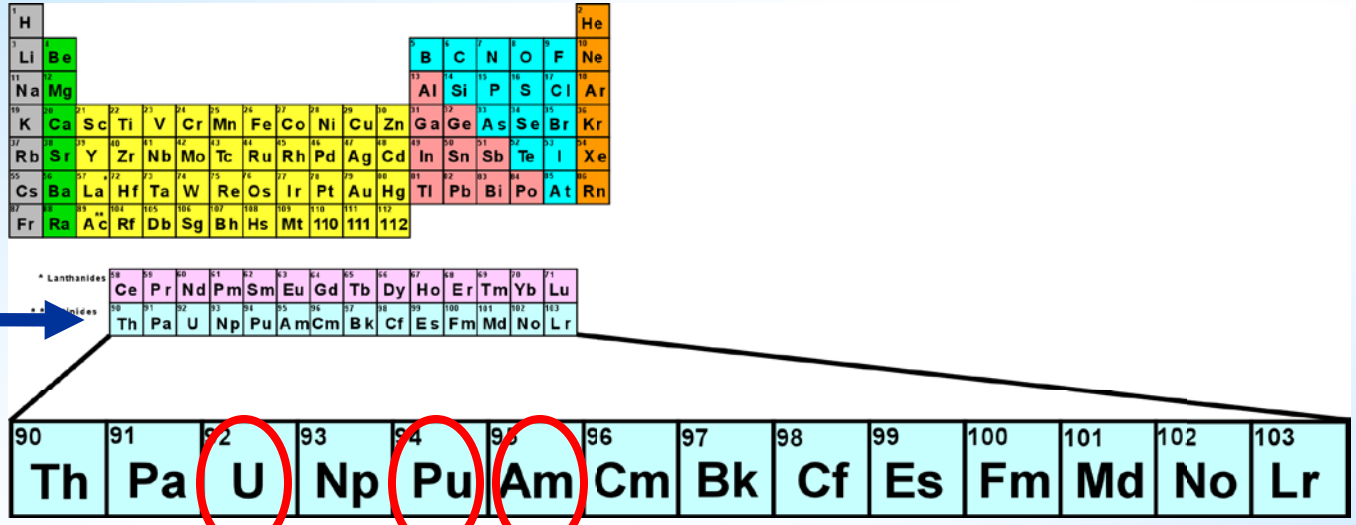


Map adapted from Section 4 of the RCRA Facility Investigation – Remedial Investigation/Corrective Measures Study – Feasibility Study Report for the Rocky Flats Environmental Technology Site (http://www.lm.doe.gov/Rocky_Flats/Regulations.aspx)

What is an Actinide?

Periodic Table

Actinides



Uranium

Plutonium

Americium

Uranium
Both natural and man-made forms.

- Man-made forms used at RFS in weapons production.

Plutonium
Man-made, used at RFS in weapons production.

Americium
Man-made, at RFS, Am is a "daughter" product of plutonium (caused by radioactive decay of plutonium).

Contaminant Characterization

"Background" Levels of Actinides

Plutonium and americium are found virtually everywhere on Earth

Plutonium and Americium "Background"

- Nuclear testing aboveground
  (More than 500 tests from 1945 to early 1960s)
- Distributed Pu and Am worldwide
  via atmospheric fallout
- "Background" levels in Front Range
  surface soil (per gram of soil):

- Pu-239/240:	0.04 pCi/g (+/- 0.01)
- Am-241:	0.01 pCi/g (+/- 0.01)

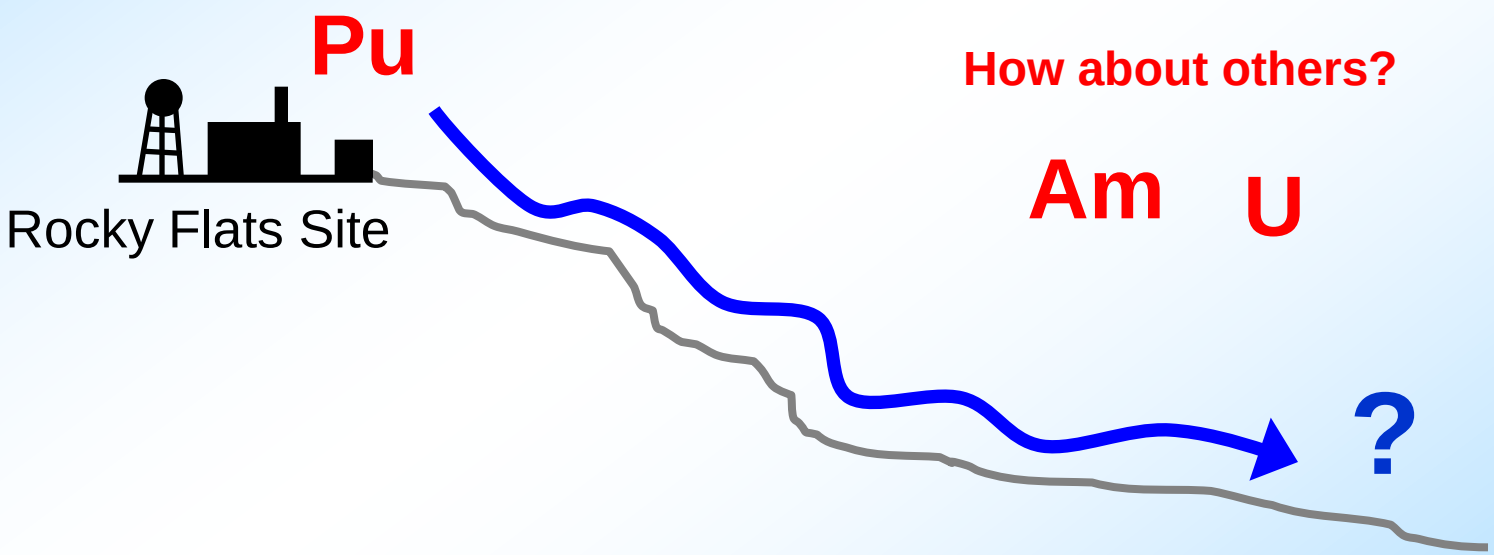
Uranium also found virtually everywhere

Naturally occurring "background" (concentrations vary)

(Source: Geochemical Characterization of Background Surface Soils, EG&G, 1995)

Fundamental Question

How do actinides (such as plutonium) get transported in the environment at Rocky Flats?



Contaminant Characterization

Actinide Migration Evaluation (AME) Panel

- 1996: AME panel formed
  - Independent experts brought to the site
    - Carefully examine site data
    - Direct collection of new data
    - Recommend and perform experiments and analyses with computer models (numerous studies conducted)
    - Help to quantify actinide migration pathways
- AME objective
  - Develop scientific understanding of actinide transport at the site
    - Help guide cleanup decisions based on science

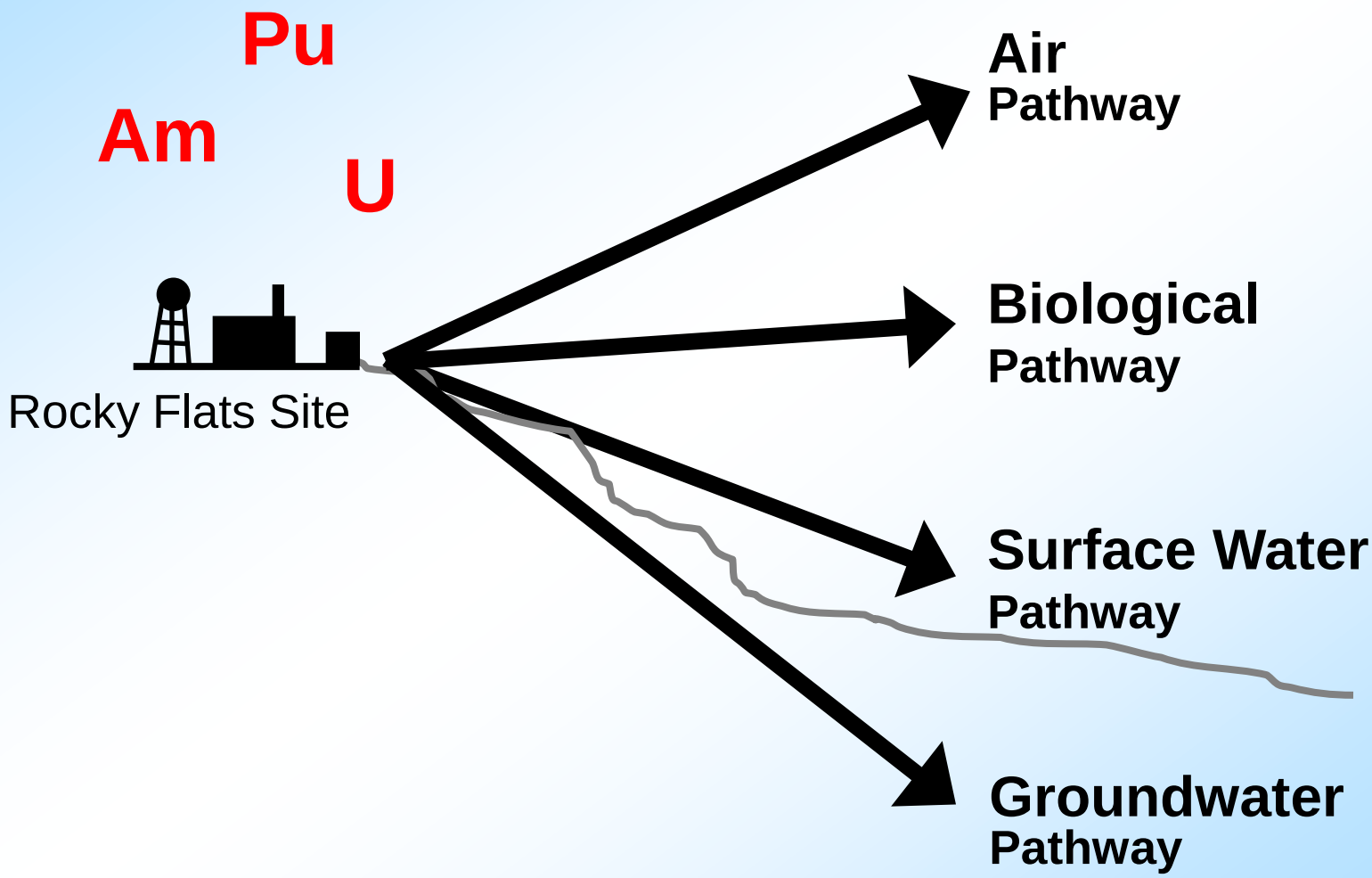
AME advisors – Quarterly site visit

Stakeholder interaction

The *AME Pathway Analysis Summary Report* can be found at:
http://www.lm.doe.gov/cercla/documents/rockyflats_docs/SW/SW-A-004544.PDF
The AME Pathway Analysis Report Technical Appendix can be found at:
http://www.lm.doe.gov/cercla/documents/rockyflats_docs/SW/SW-A-004547.pdf

Contaminant Characterization

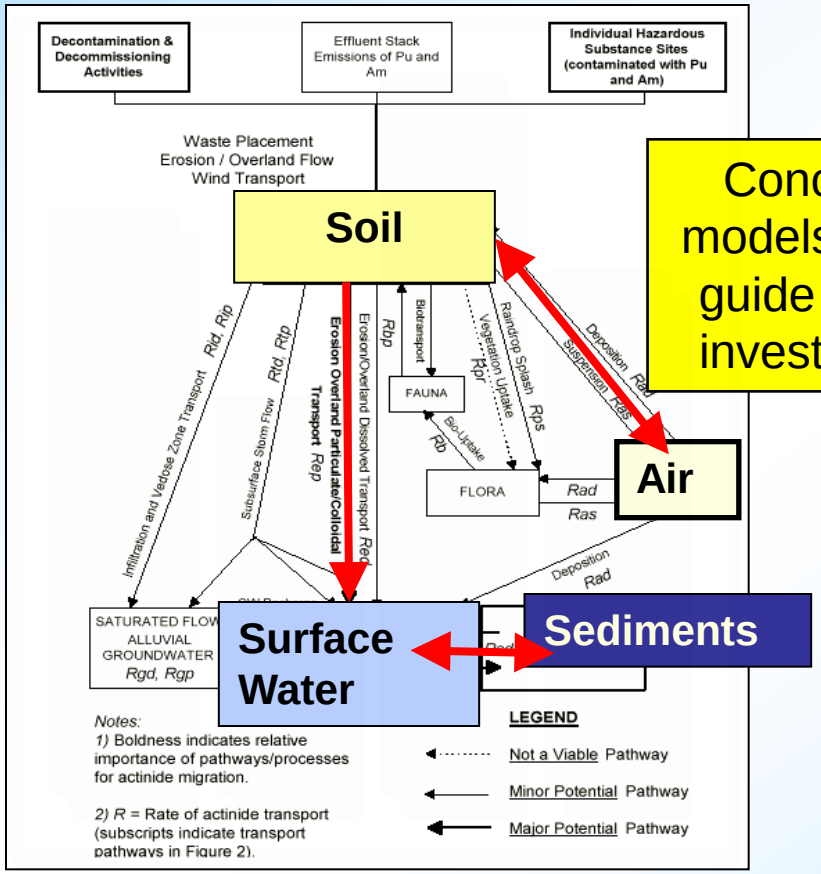
Actinide Transport Mechanisms/Pathways



Contaminant Characterization

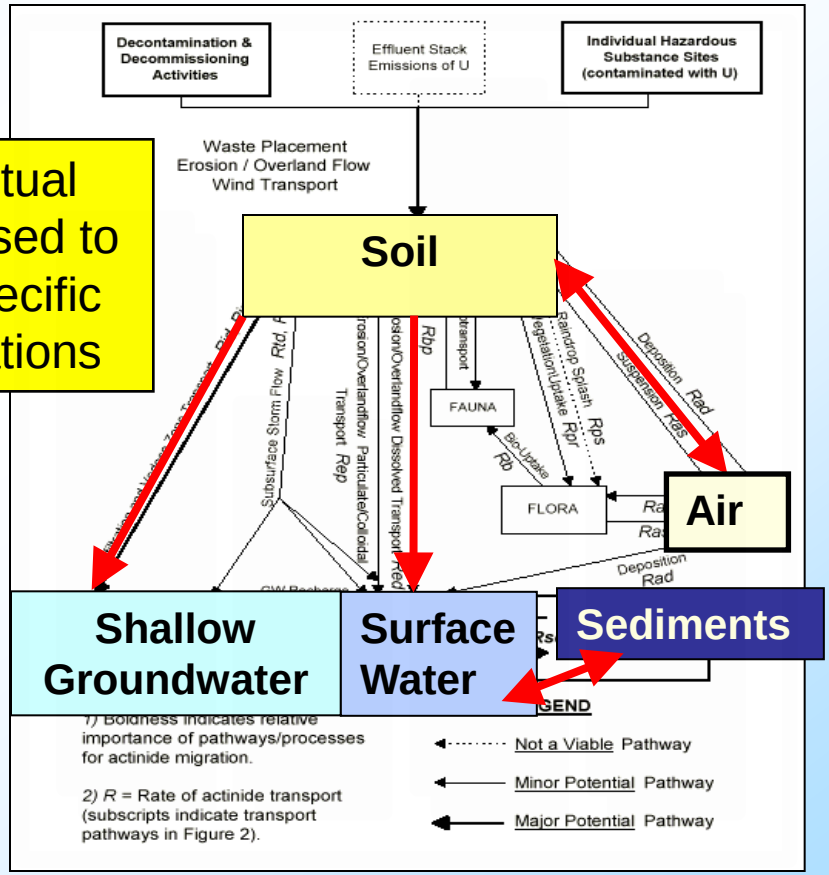
Conceptual Models for Transport of Actinides

Plutonium and Americium Transport



Conceptual models used to guide specific investigations

Uranium Transport

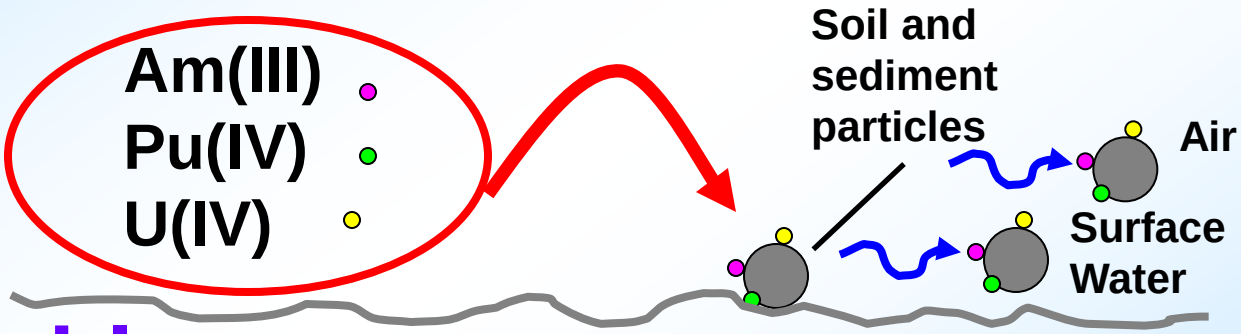


Contaminant Characterization

Actinide Solubility and Oxidation State

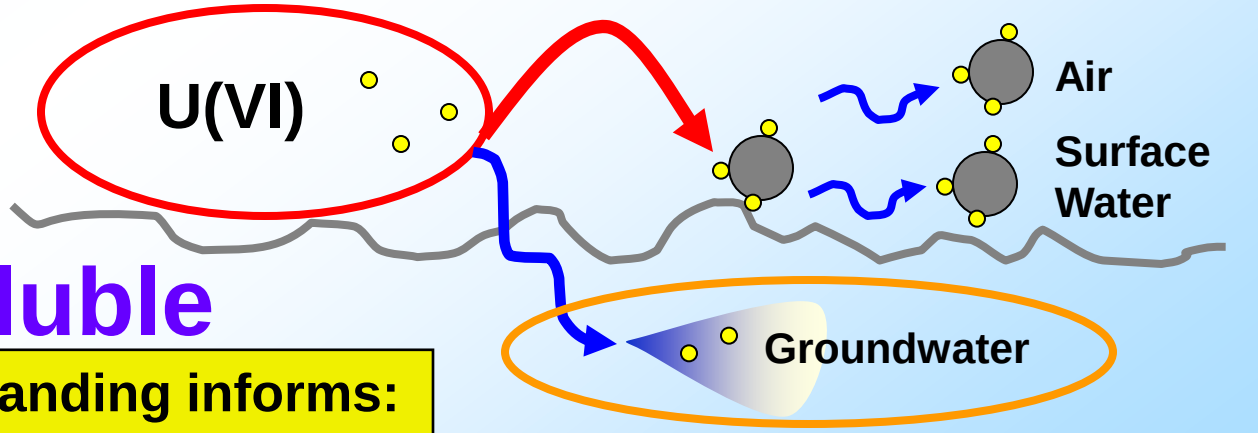
Oxidation State Affects Environmental Behavior

Lower Oxidation State



Less Soluble

Higher Oxidation State



More Soluble

Science-based understanding informs:
- Cleanup approach
- Future site maintenance and monitoring

Contaminant Characterization

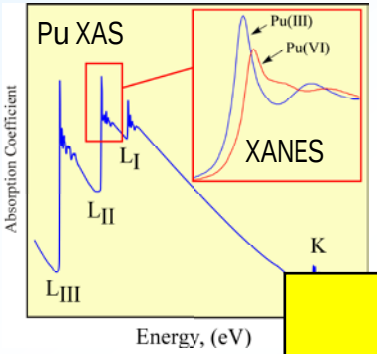
Example AME Study – Analysis of Pu Solubility

Soil sampling at 903 Pad

Synchrotron storage ring (Stanford University)
(Analysis by S. Conradson, Los Alamos National Laboratory [LANL])

Oxidation State

X-Ray Absorption Near Edge Spectroscopy (XANES)

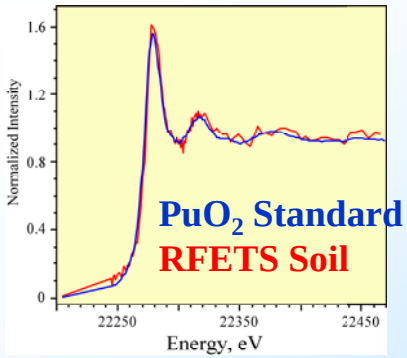


XANES Result:
Pu is Pu(IV)

Pu at 903 Pad:
virtually insoluble in nature
(~1 x 10^{-11} moles/liter)

Chemical Spe

X-Ray Absorption Fine Structure (XAFS)



XAFS Result:
Pu is $PuO_2 \cdot nH_2O$

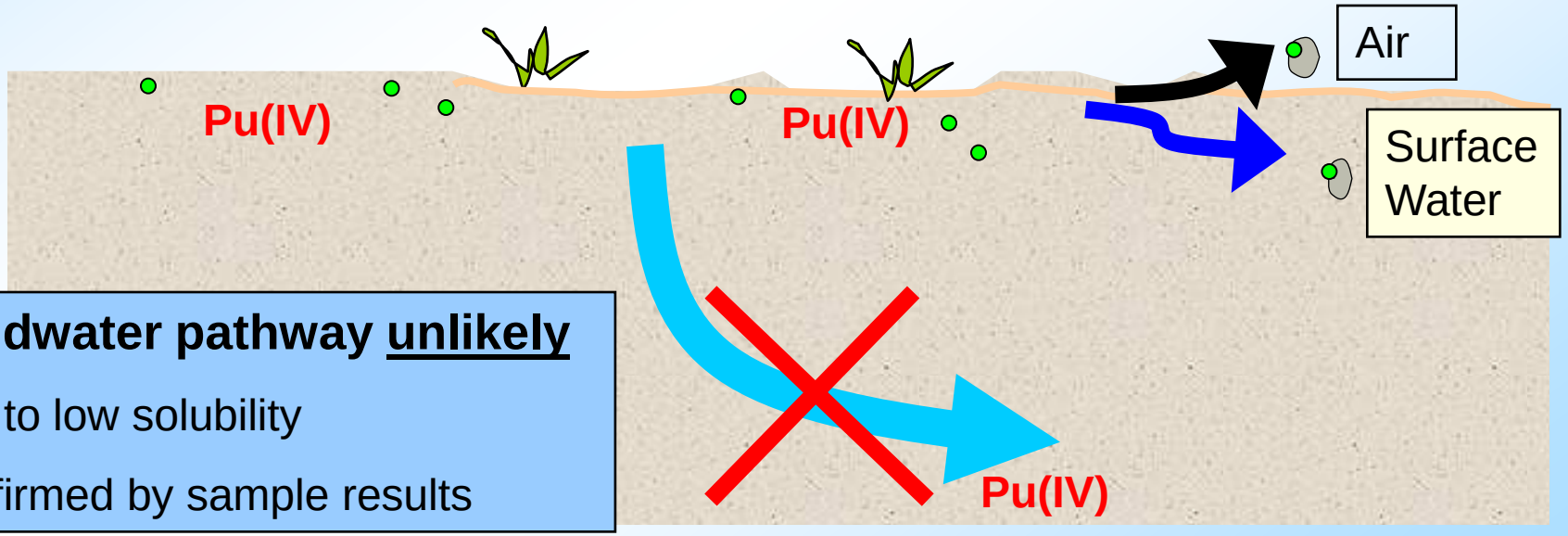
AME Conclusion: Pu Transport

Pu virtually insoluble in the environment

Per AME study results

Dominant Transport Mechanism

Erosion of **surface** soil, with Pu attached



Groundwater pathway unlikely

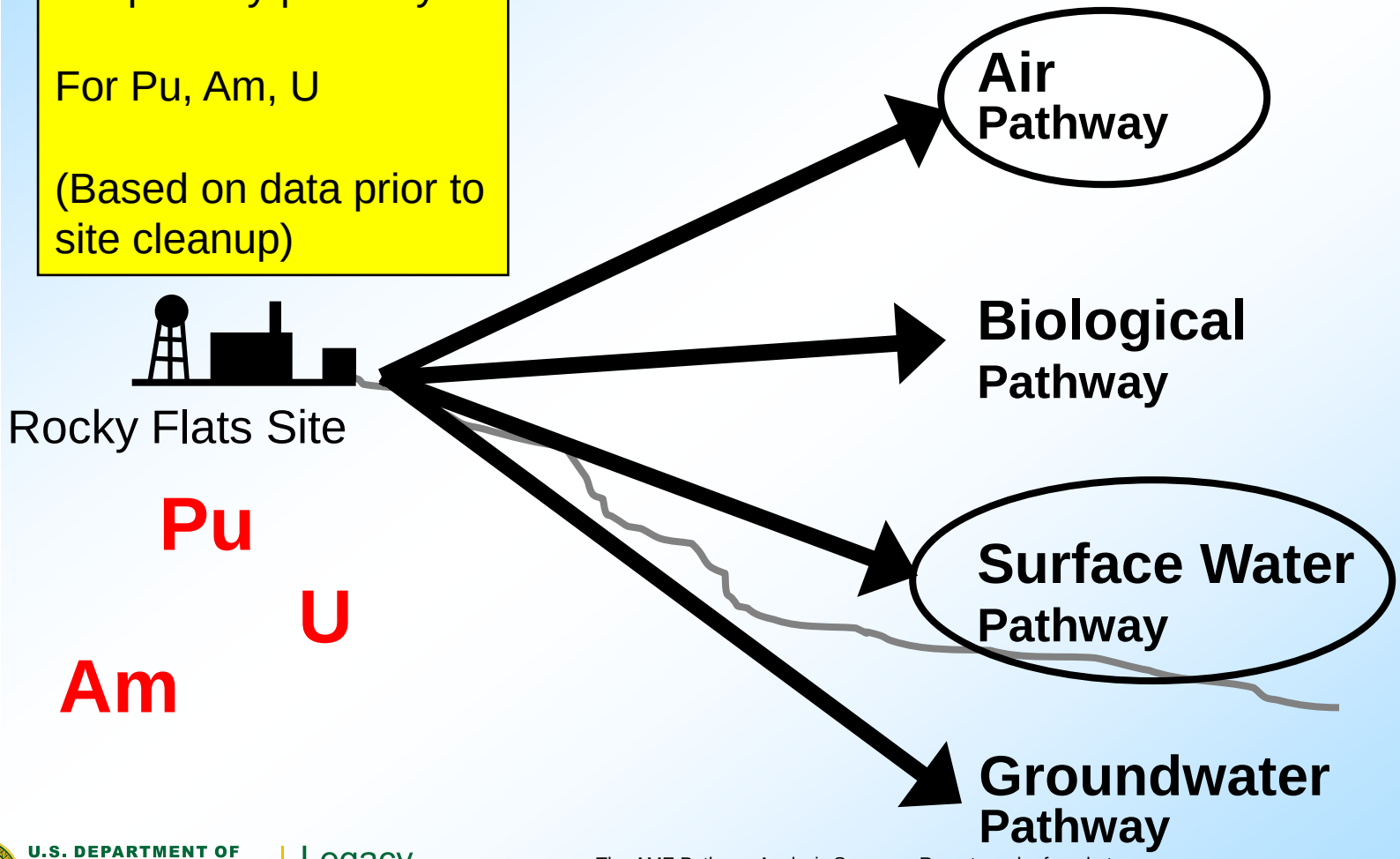
- Due to low solubility
- Confirmed by sample results

AME Conclusion: Actinide Transport Pathways

Air and surface water are primary pathways

For Pu, Am, U

(Based on data prior to site cleanup)



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Contaminant Characterization

Summary

- The Historical Release Report investigated contaminant releases using multiple information resources
- Extensive soil, sediment, surface water, air and groundwater data were collected to establish the nature and extent of contamination
- Air monitoring data support the exclusion of air monitoring from the current monitoring program
- Actinide Migration Evaluation (AME) studies confirm Pu is in a form with very low solubility (movement is via wind and/or surface water erosion versus a dissolved form transported in groundwater)
- AME study determines air and surface water are main transport pathways for radionuclides Pu, Am and U

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Regulatory Authority for Rocky Flats Cleanup

- The following agencies had regulatory authority for the Rocky Flats cleanup:
  - U.S. Department of Energy (DOE)
    - Under the Atomic Energy Act
  - U.S. Environmental Protection Agency (EPA)
    - Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (also known as Superfund) authority
  - Colorado Department of Public Health and the Environment (CDPHE)
    - Hazardous waste regulatory authority under the Colorado Hazardous Waste Act (CHWA)

Rocky Flats Cleanup Agreement

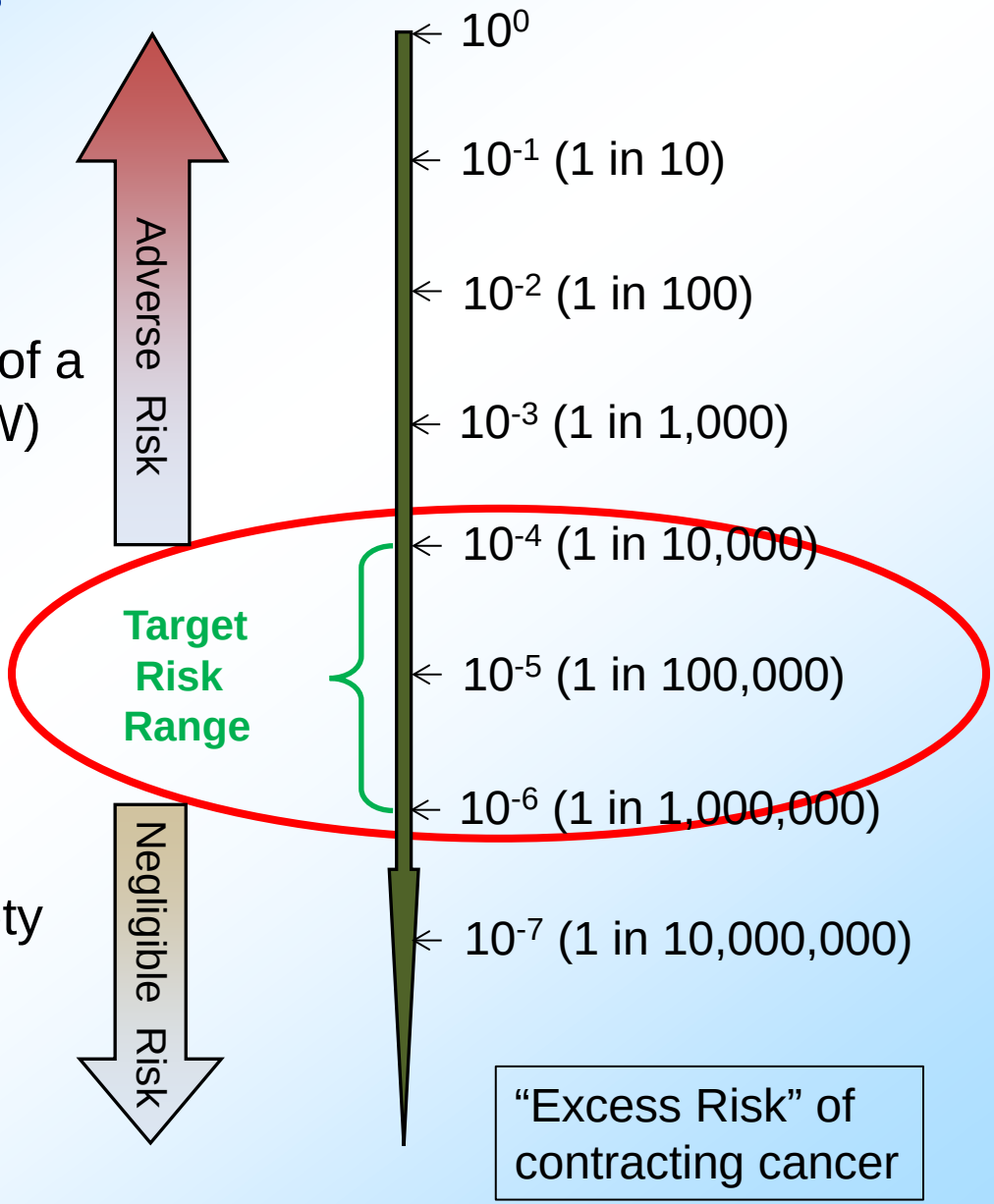
- Cleanup was directed by the 1996 Rocky Flats Cleanup Agreement (RFCA)
- Parties to RFCA: DOE, EPA, CDPHE
- RFCA applied a risk-based accelerated cleanup approach:
  - Developed with public involvement
  - Consistent with Rocky Flats vision
  - Future land use assumptions and end-state objectives presumed use of the site: wildlife refuge
  - Risk-based soil action levels based on conceptual model for exposure to surface soils and a risk screen for subsurface soils

Radionuclide Soil Action Levels (RSALs)

- 2003 – RFCA modifications
  - Established action levels and procedures for applying them
  - Definition: Action levels are numeric levels that, when exceeded, trigger an evaluation, remedial action, and/or management action
- 2003 – RSAL calculations risk-based
  - Based on input from:
    - AME advisory group
    - Stakeholder Focus Group
    - RSALs Oversight Panel
    - RSALs Working Group
      1) Regulatory analysis
      2) Computer modeling
      3) RSAL calculations
      4) New scientific information
      5) Determining cleanup levels at other sites

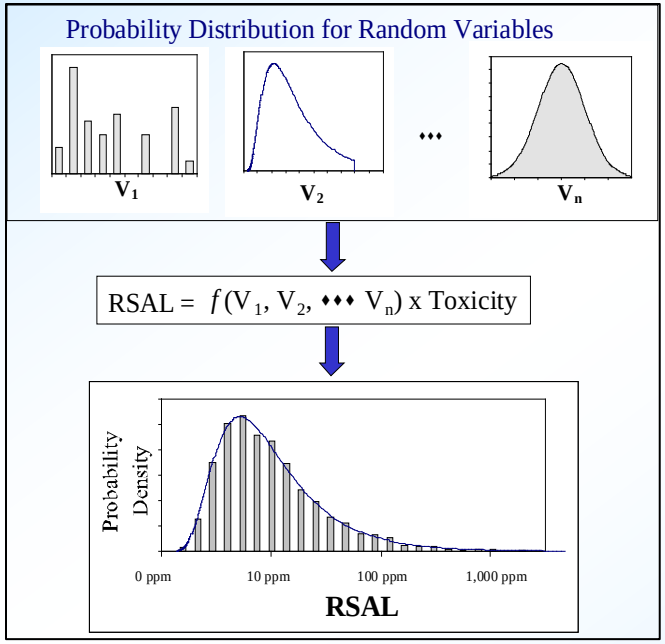
Soil Action Levels (SALs)

- Triggered remedial actions
- Calculated to be protective of a wildlife refuge worker (WRW) based on:
  1. A hazard index (HI) of 1 (toxicity), or
  2. 1 in 100,000 lifetime excess cancer risk
- Ecological action levels calculated to protect a variety of wildlife receptors



Calculation of 2003 RSALs

$$C_{(pCi/g)} = \frac{TR \times t_r \times \lambda}{ED_r \times \left(1-e^{-\lambda t_r}\right) \times \left[\left(SF_s \times IR_{sr} \times 10^{-3}\,(g/mg) \times EF_r\right) + \left(SF_i \times IR_r \times \frac{10^3\,(g/kg)}{PEF} \times EF_r \times \left[ET_{to} + (ET_{ti} \times DF_i)\right]\right) + \left(SF_e \times \frac{EF_r}{365\,(d/yr)} \times ACF \times \left[ET_o + (ET_i \times GSF)\right]\right) + \left(SF_f \times (CR_{fr} + CR_{rr}) \times 10^3\,(g/kg) \times TF_p \times CPF_r\right)\right]}$$



RSALs input parameters included:

- Soil ingestion rate
- Inhalation rate and mass loading
- Average annual wind speed
- Exposure duration
- Depth of soil mixing layer
- Cancer slope factors

2003 RSALs

Radionuclide	Wildlife Refuge Worker*
Americium-241	76 pCi/g
Plutonium-239/240	~~116 pCi/g~~ **50 pCi/g****

* Values represent a 0.00001 (or $1x10^{-5}$) lifetime excess cancer risk

**** Calculated value is 116 pCi/g; RFCA parties agreed to require actions for soils with Pu activity levels >50 pCi/g**

Key Points

- RSALs
  - Based on risk-based approach:
    - Lifetime excess cancer risk: 0.00001 (or 1×10^{-5})
    - Calculations include exposure time, exposure scenarios
  - Based on input from:
    - Multiple working groups
    - Citizen organizations
    - Computer models
- RFCA parties agreed to require actions for soils with Pu activity levels greater than 50 pCi/g
  - Actual risk-based calculated value: 116 pCi/g

Agenda

- Background
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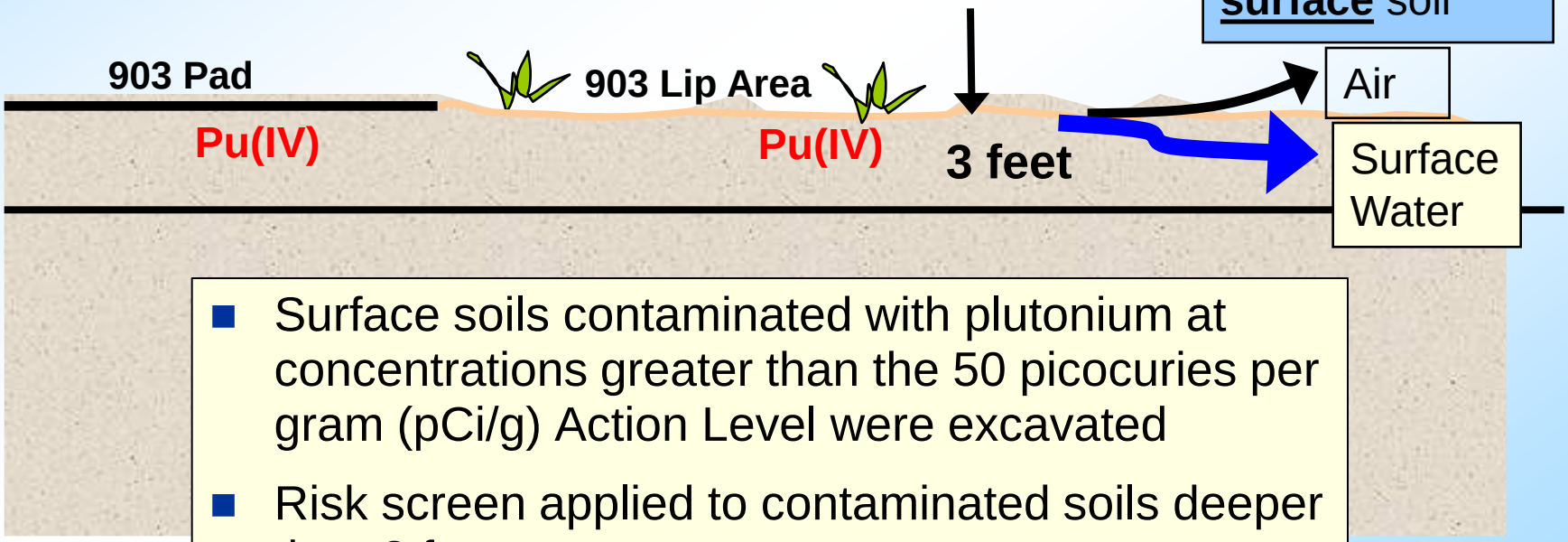
Contamination Removed to Below RSALs

Pu virtually insoluble

(per AME studies)

Address Dominant Transport Mechanism

Erosion of **surface** soil



- Surface soils contaminated with plutonium at concentrations greater than the 50 picocuries per gram (pCi/g) Action Level were excavated
- Risk screen applied to contaminated soils deeper than 3 feet

Site Cleanup

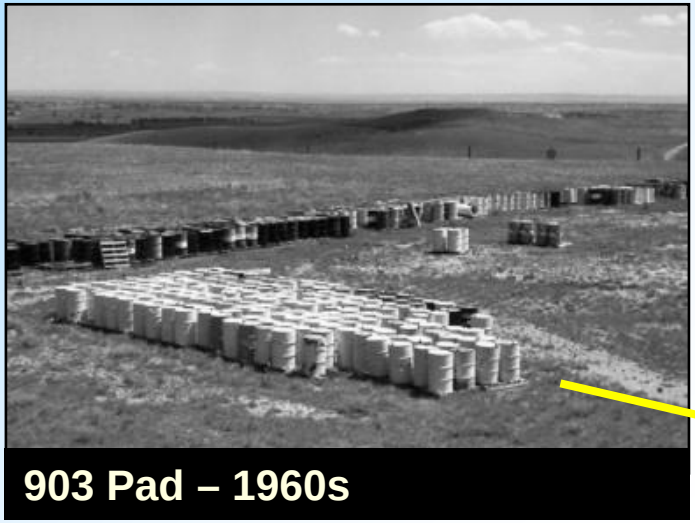
Accelerated Action Process

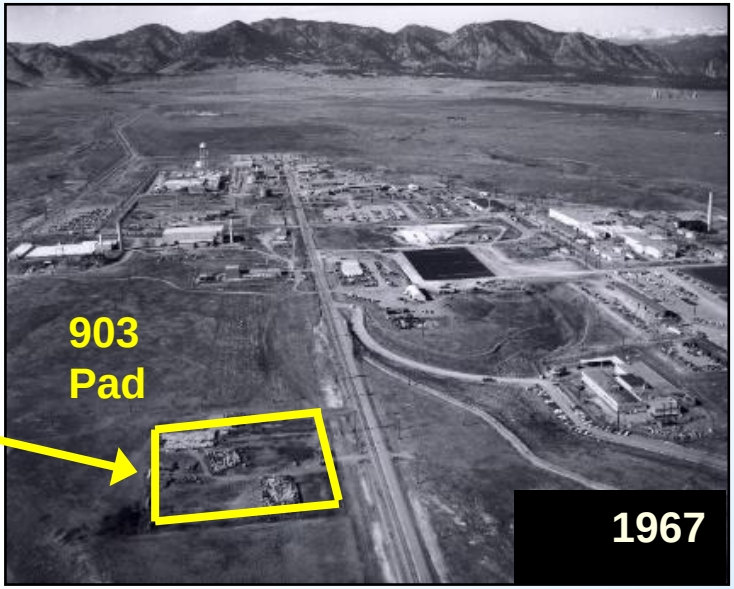
- Individual Hazardous Substance Sites (IHSSs) were investigated and characterized using EPA-approved methods in accordance with RFCA
- Contaminated soil was excavated, packaged and removed

- Remedial actions were completed and documented, then reviewed by regulatory agencies
- Approved actions were compiled in the HRR

The HRR is Appendix B of the RCRA Facility Investigation – Remedial Investigation/ Corrective Measures Study – *Feasibility Study Report for the Rocky Flats Environmental Technology Site* (http://www.lm.doe.gov/Rocky_Flats/Regulations.aspx)

Example Projects: 903 Pad and Lip Area





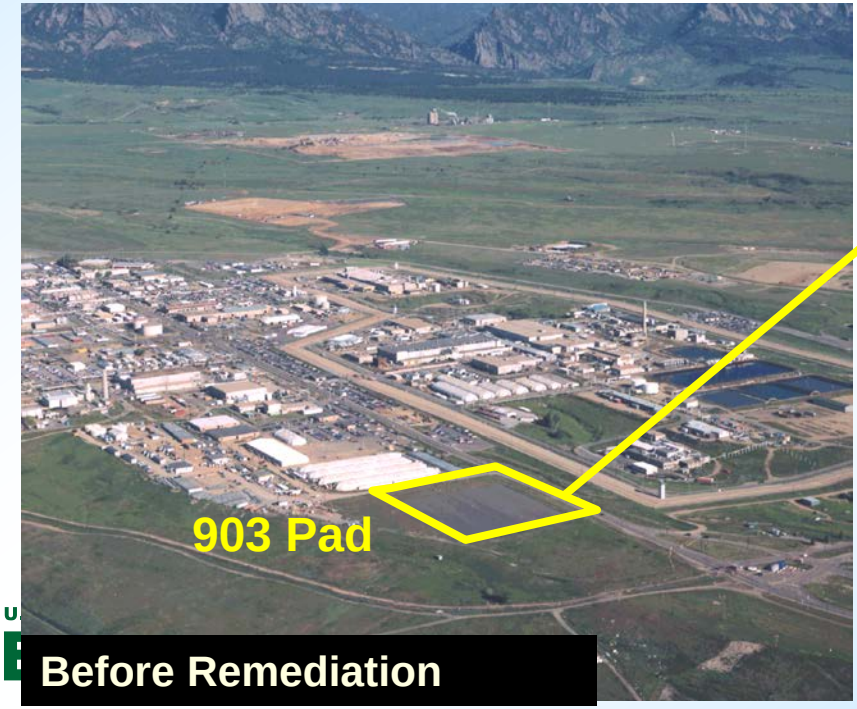
903 Pad area

Primary source of Pu and Am in surface soil at the site (Am distribution is similar to Pu)

Site Cleanup

Example Project: 903 Pad Soil Remediation

- "Tents" used to enclose excavation
- Removed 32,000 tons of soil
  - 900 grams of Pu
  - Clean fill added on top
- Air, water quality – continually compliant
- Completed December 2003



Before Remediation

2003

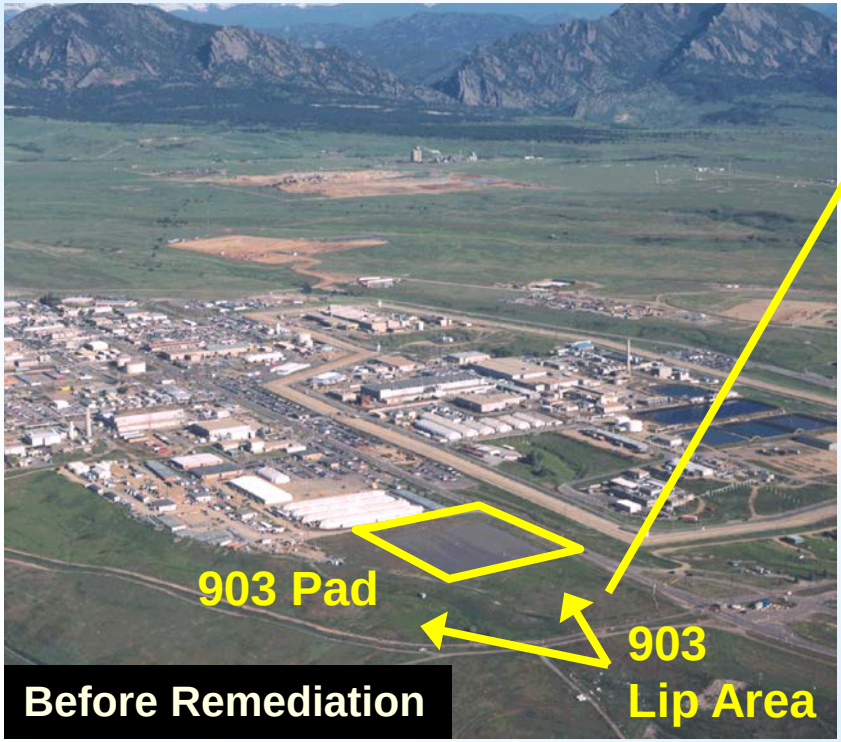
903 Pad – Weather Enclosures

Site Cleanup

Example Project: 903 Lip Area Soil Remediation

- 903 Lip Area (east of 903 Pad)
  - Remove soil >50 pCi/g
  - Around 34 acres
  - Stringent dust and erosion controls
  - Completed September 2004

Erosion “Blanket”

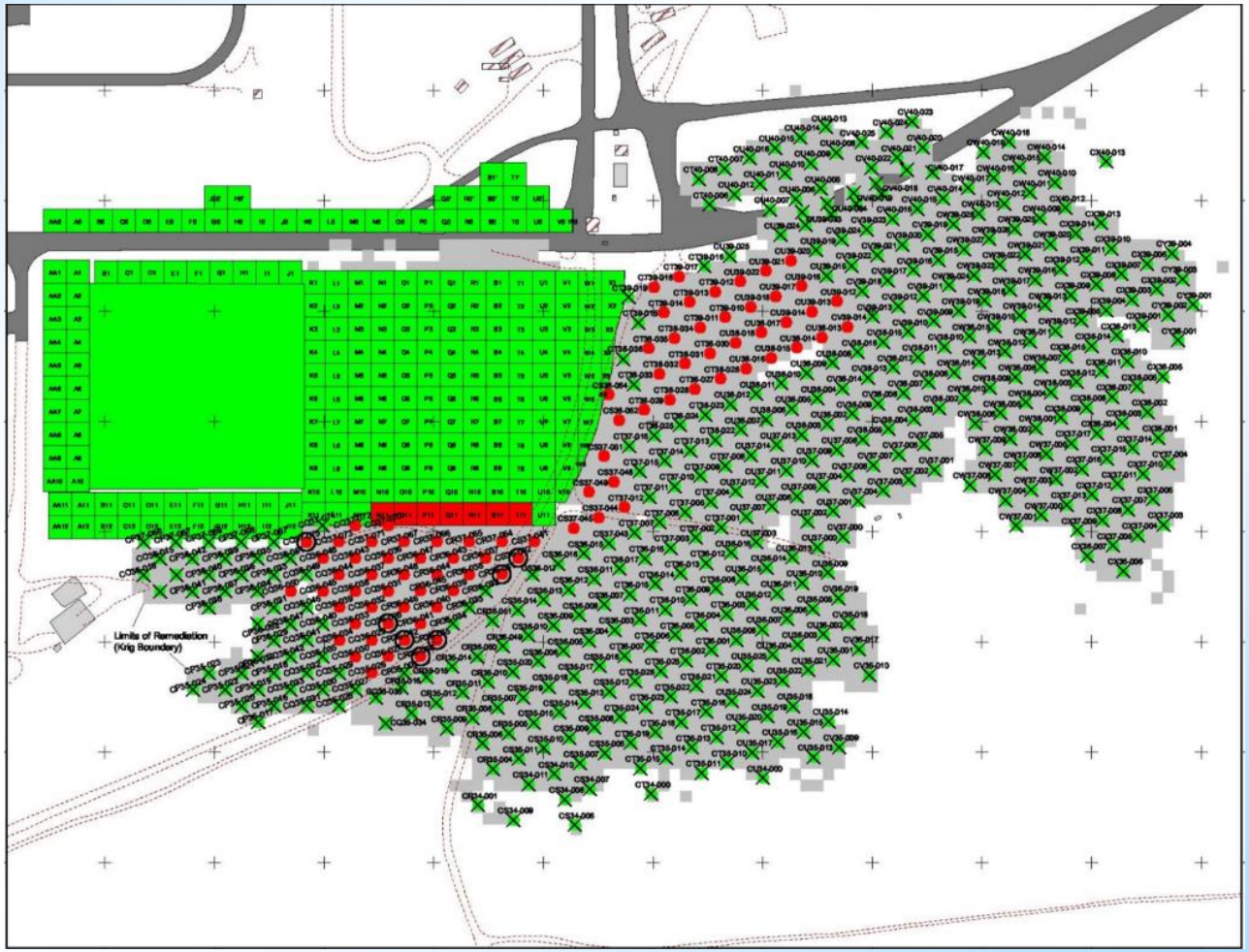


Before Remediation

Site Cleanup

Example Project: 903 Pad Lip Area

- 903 Pad Lip Area confirmation sampling



Interim Confirmation Status
(August 20, 2004, snapshot, not final status)

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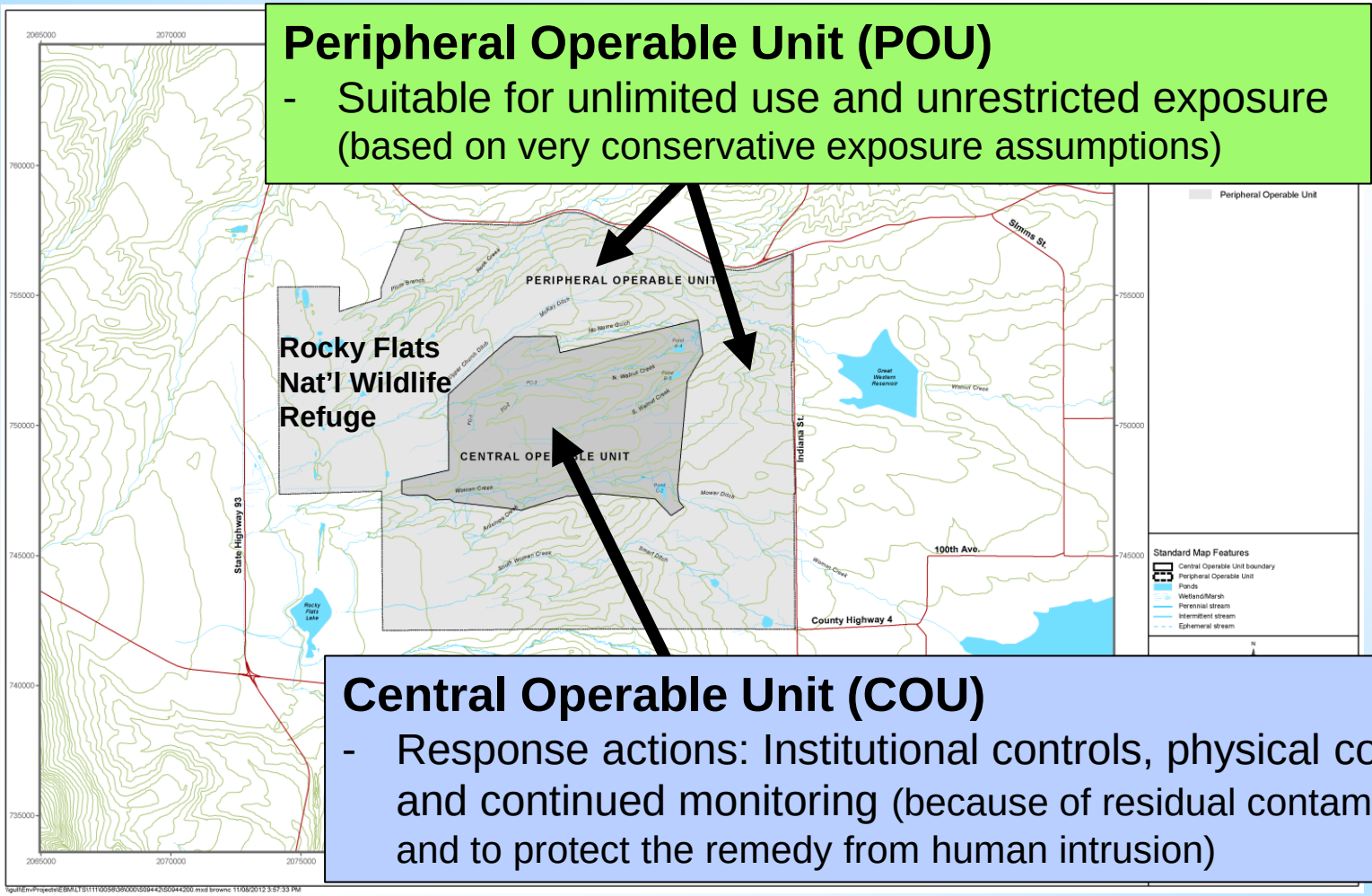
Long-Term Site Management

Site Remedy



Peripheral Operable Unit (POU)

- Suitable for unlimited use and unrestricted exposure (based on very conservative exposure assumptions)

Central Operable Unit (COU)

- Response actions: Institutional controls, physical controls, and continued monitoring (because of residual contamination and to protect the remedy from human intrusion)

The *Corrective Action Decision/Record of Decision for Rocky Flats Plant (USDOE) Peripheral Operable Unit and Central Operable Unit* (CAD/ROD) can be found at (http://www.lm.doe.gov/Rocky_Flats/Regulations.aspx)

Long-Term Site Management

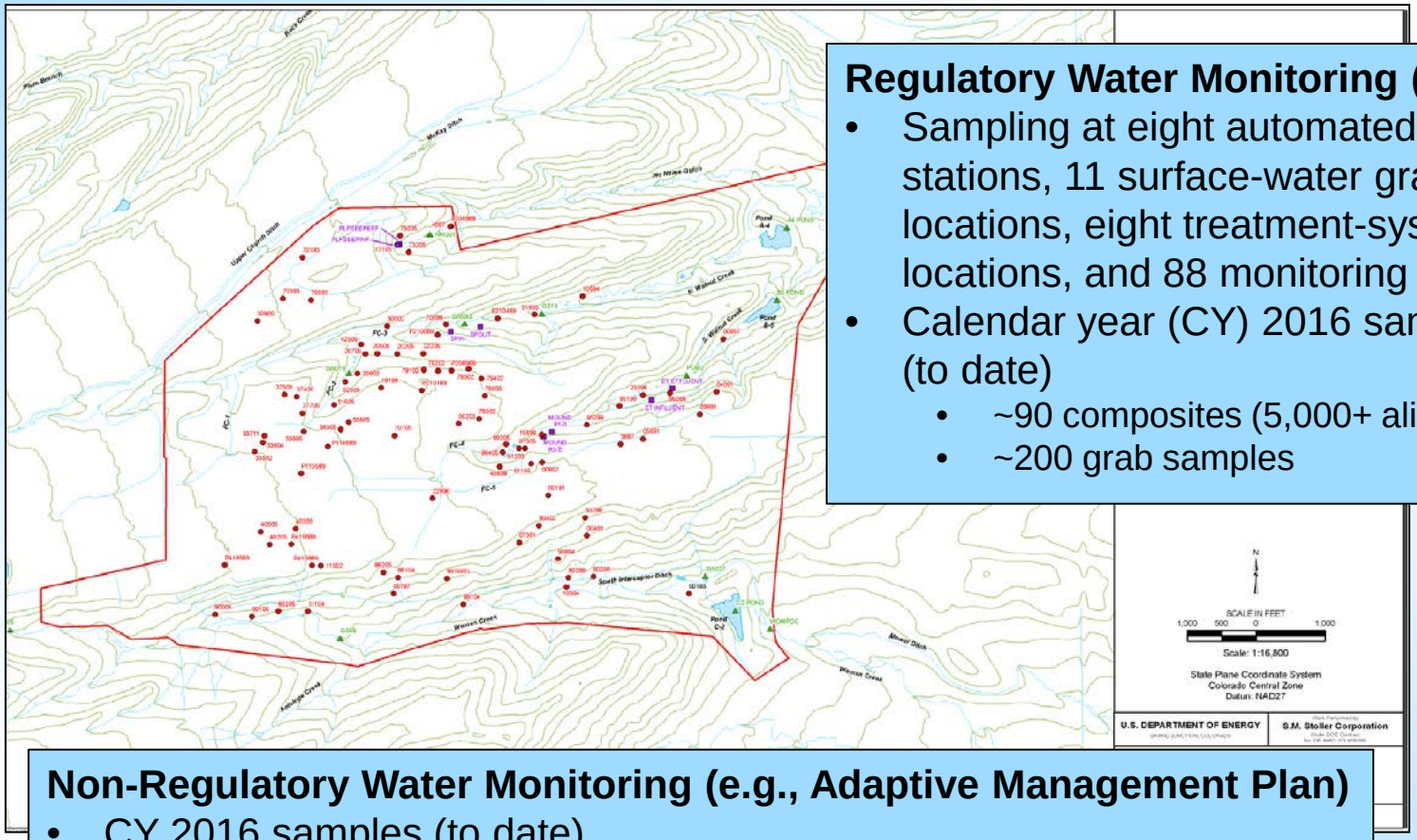
Oversight Framework

- Rocky Flats Legacy Management Agreement (RFLMA)
  - On March 14, 2007, DOE, EPA, and CDPHE entered into the RFLMA
  - Established the regulatory framework for implementing the final remedy for the Rocky Flats site and ensures it continues to protect human health and the environment
- DOE Office of Legacy Management (LM)
  - Responsible for long-term surveillance and maintenance of approximately 1,300 acres (COU)
  - The Rocky Flats Site Operations Guide (RFSOG) serves as the primary document to guide work, satisfy the requirements of the RFLMA, and implement best management practices at the site
- Rocky Flats National Wildlife Refuge
  - Managed by the U.S. Fish and Wildlife Service (USFWS)

The RFLMA can be found at (http://www.lm.doe.gov/Rocky_Flats/Regulations.aspx)
The RFSOG can be found at (http://www.lm.doe.gov/Rocky_Flats/SOG.aspx)

Long-Term Site Management

Continued Monitoring



Regulatory Water Monitoring (RFLMA)

- Sampling at eight automated gaging stations, 11 surface-water grab-sampling locations, eight treatment-system locations, and 88 monitoring wells
- Calendar year (CY) 2016 samples (to date)
  - ~90 composites (5,000+ aliquots)
  - ~200 grab samples

Non-Regulatory Water Monitoring (e.g., Adaptive Management Plan)

- CY 2016 samples (to date)
  - ~50 composites (1,800+ aliquots)
  - ~130 grab samples

U.S. DEPARTMENT OF ENERGY | Legacy Management

Map reproduced from the RFSOG (http://www.lm.doe.gov/Rocky_Flats/SOG.aspx)
AMP: *Surface Water Configuration Adaptive Management Plan for the Rocky Flats, Colorado, Site*

Long-Term Site Management

Site Evolution

1995

2005

Site Evolution (continued)

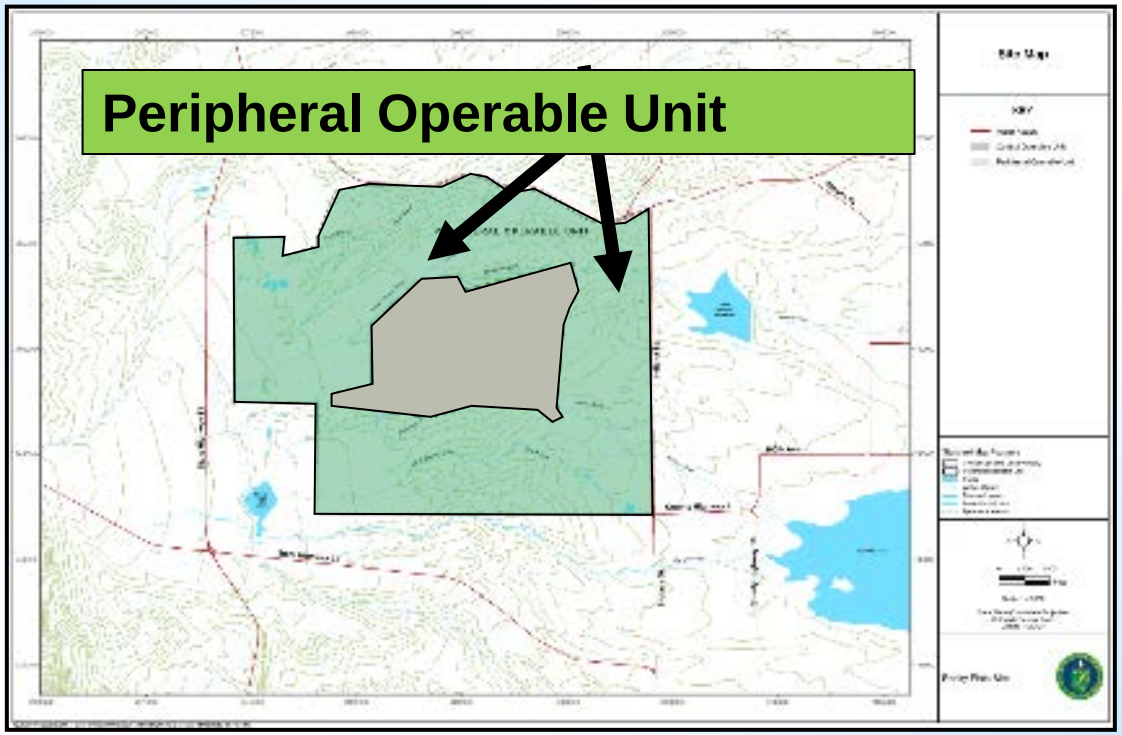
June 2007

Site Evolution (continued)

Present day

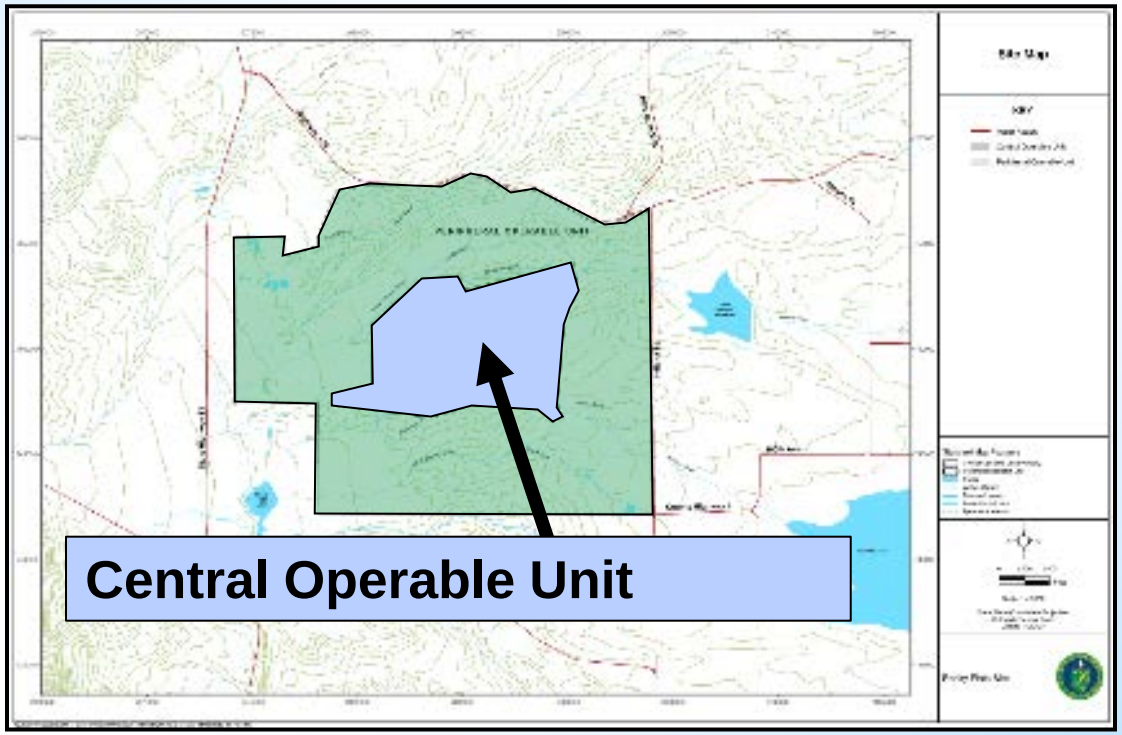
Key Points

- The POU is suitable for unlimited use and unrestricted exposure



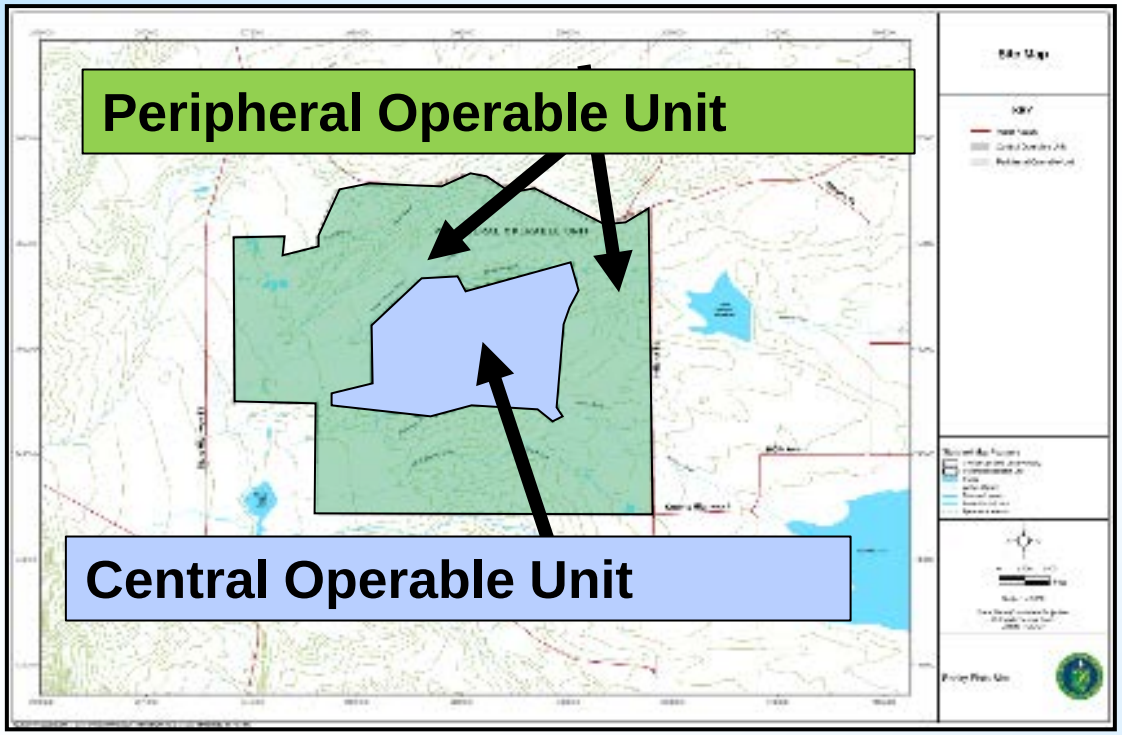
Key Points (continued)

- The COU is closed to recreational visitors
  - The remedy includes institutional controls, physical controls, and continued monitoring



Key Points (continued)

- Continued monitoring is accomplished through extensive sampling of surface water and groundwater



Key Points (continued)

- The monitoring program provides information on the movement of residual contamination
  - Surface-water monitoring provides a direct measurement of soil contamination being transported in water
  - Measured changes in concentrations of contaminants in surface water are an indicator of changes in the environment

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Recap

- Characterization of site contaminants
  - Extensively sampled
- Regulatory process to guide cleanup
  - Rigorous CERCLA process with public participation
- Cleanup standards
  - Conservative
- Resulting risk
  - Low
- Environmental monitoring
  - Long-term, ongoing monitoring

Questions?