# Groundwater at the Rocky Flats Site

# Part 2

Rocky Flats Stewardship Council

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# Agenda

- Summary of Part 1 presentation
- Groundwater monitoring network and analytes
- Groundwater treatment
- RFLMA data evaluation protocols (flowcharts)

# Summary of Groundwater Presentation, Part 1

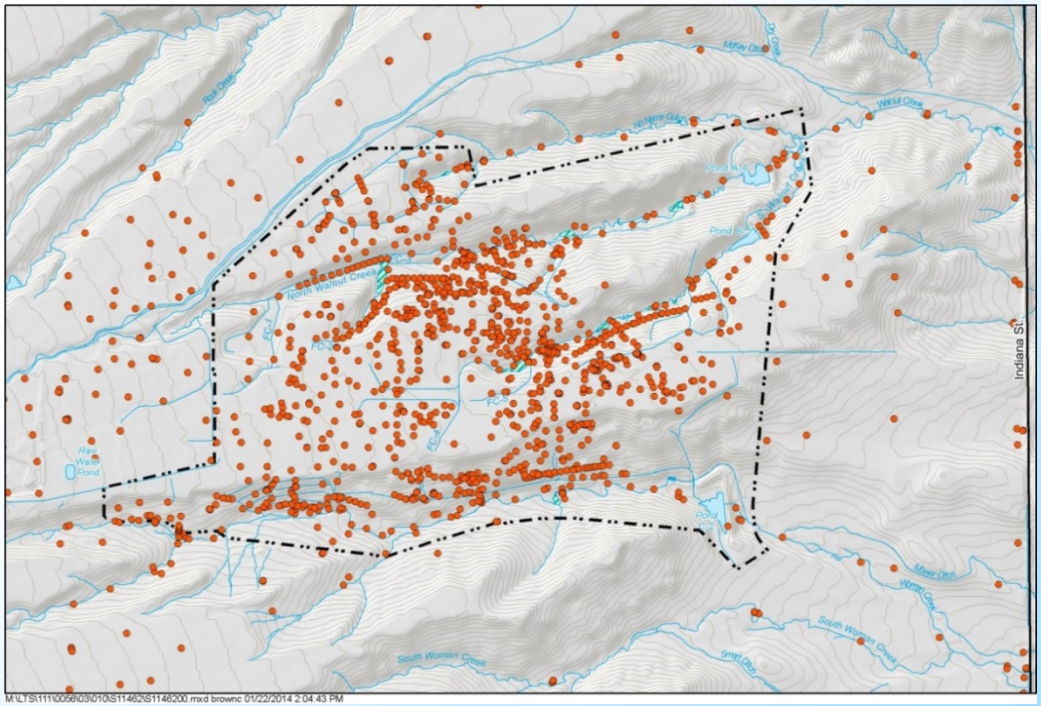
- Geology
  - Predominantly low-permeability alluvium/surficial materials overlying lower-permeability claystone bedrock
  - Deeper units (regional aquifers) are separated by hundreds of feet of dense claystone
- Semiarid climate
  - 12 to 15 inches of precipitation per year
    - Only 1-2 inches recharges the groundwater, rest lost to ET
- Groundwater
  - Movement controlled by bedrock surface
    - Similar to ground surface topography
  - Flow moves west to east, diverting toward drainages and discharging to surface water

➢ ***We monitor the groundwater to watch for threats to surface water***

# Summary of Groundwater Presentation, Part 1 (continued)

# Summary of Groundwater Presentation, Part 1 (continued)

- Upper hydrostratigraphic unit (UHSU) – shallow; past operations impacted groundwater in some areas
- Lower hydrostratigraphic unit (LHSU) – deeper; hydraulically isolated from UHSU
- Over 1,400 wells and hundreds of boreholes installed since 1950s to characterize the site




*Wells within and nearest the COU*

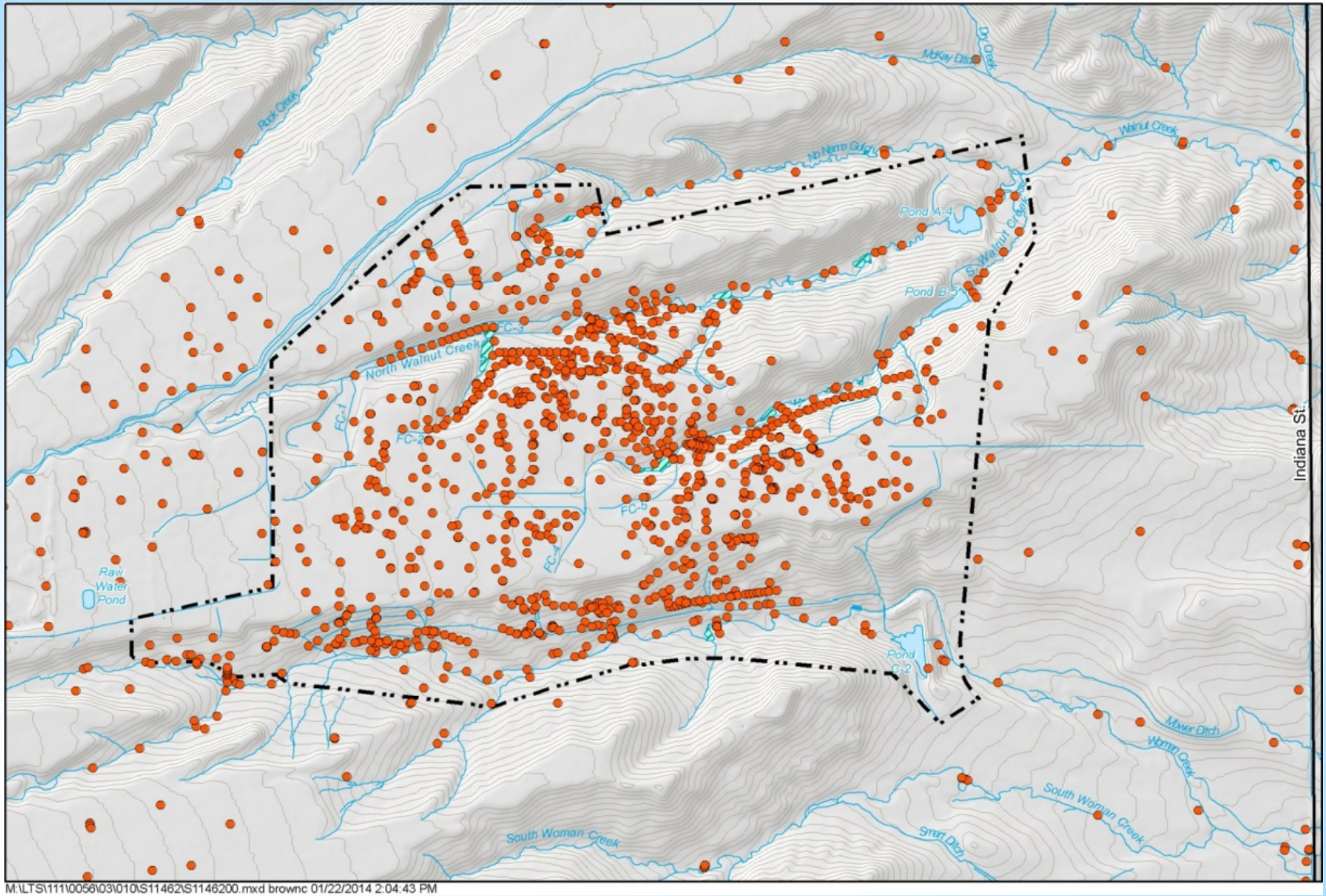
# Groundwater at the Rocky Flats Site, Part 2

- Groundwater monitoring network
  - Locations, frequencies, analytical suites
- Groundwater treatment
  - Rocky Flats has four groundwater treatment systems
- RFLMA data evaluation protocols
  - Attachment 2 includes flowcharts that specify protocols

# Developing the Monitoring Network

- Iterative process
- Characterization identified areas of contaminated groundwater, contaminants of concern (COCs), flow directions
  - Primary well installation targets
    - Areas of contamination (known and suspected)
    - Potential data gaps (particularly along flowpaths to surface water)
  - Analytical suites
    - Initially broad
    - Narrowed to reflect local conditions
  - Hydrogeologic data
    - Hydraulic conductivity, recharge rates, water levels, subsurface geology, etc.

# Developing the Monitoring Network (continued)

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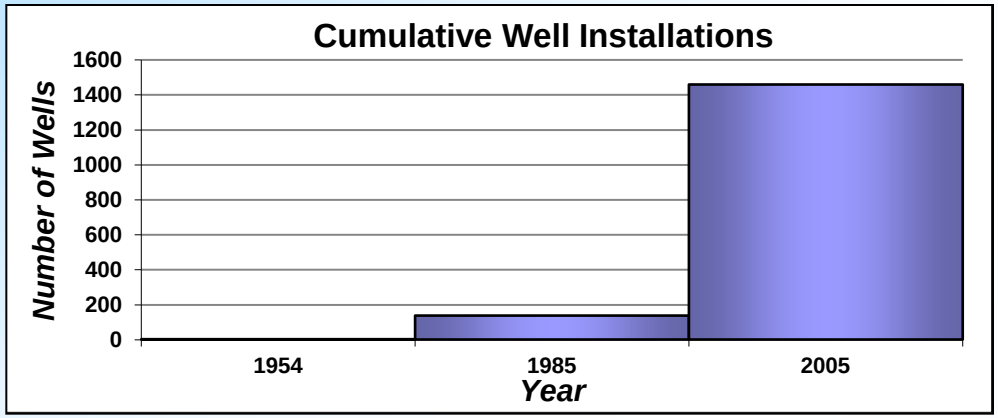
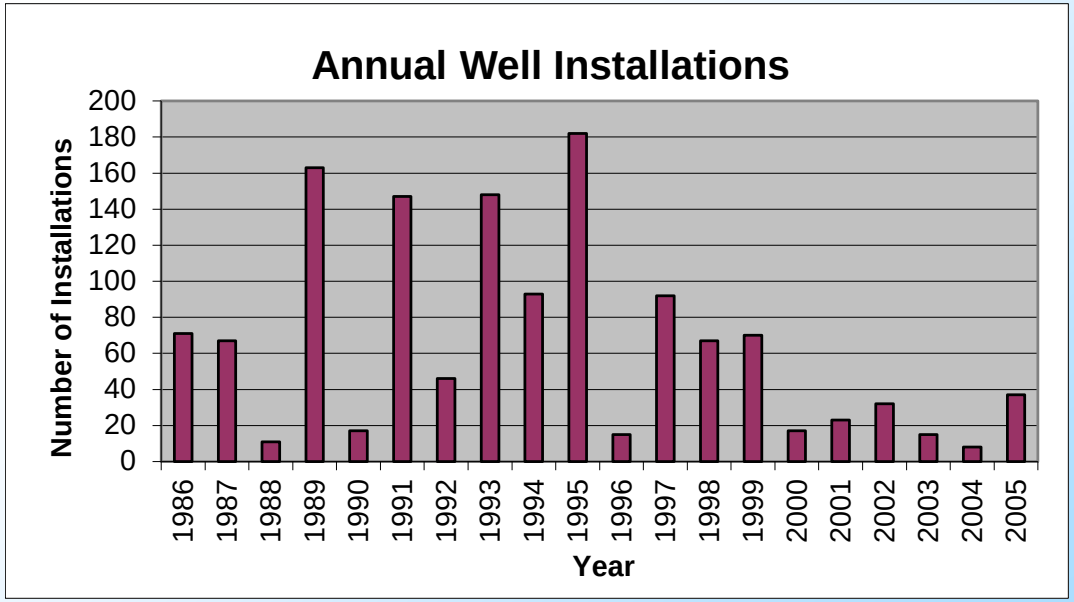
# Developing the Monitoring Network (continued)

- Monitoring wells have been installed since 1954
- Last 2 decades before site closure were the most active

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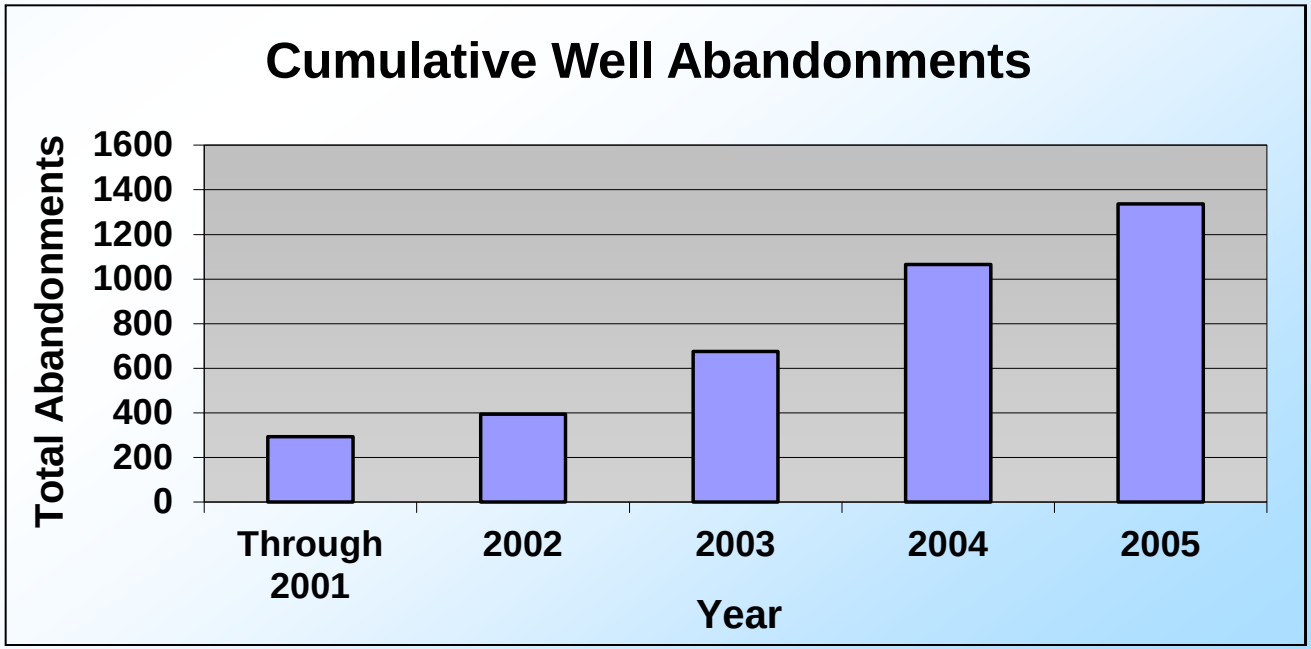
# Developing the Monitoring Network (continued)

- Sampling frequencies varied, depending on data needs
  - Weekly, monthly, quarterly, semiannually, one-time, as-requested
- Analytical suites also varied
  - Radionuclides (tritium; isotopes of plutonium, americium, uranium, cesium, strontium, neptunium, radium, thorium, others)
  - Metals (including some of potential special interest, such as beryllium), metalloids (including special interest, such as arsenic)
  - Organics (VOCs, SVOCs, total petroleum hydrocarbons, others)
  - Various nonmetals, halogens, cations, and anions (sulfate, sulfide, orthophosphate, fluoride, silica, chloride, etc.)
  - Constituents of potential interest (nitrate, nitrite, ammonia, cyanide, total organic carbon, etc.)

# Developing the Monitoring Network (continued)

- Location-specific groundwater data drove monitoring, well installations/abandonments, remediation
- Wells abandoned as appropriate
  - Abandonment methods follow State of Colorado guidelines
  - Abandoned wells that were damaged, unnecessary, in the way
  - Wells needing design improvement were also abandoned, then replaced



# Developing the Monitoring Network (continued)

- Depictions of groundwater contamination
  - Well evaluation reports
  - Operable Unit work plans and reports
  - Annual RCRA and RFCA reports

  - Groundwater IM/IRA
  - RI/FS – Defined the ultimate COCs

# Developing the Monitoring Network (continued)

- VOC-contaminated groundwater: “composite plumes”
  - Example: annual RFCA reports issued prior to closure
  - Most recent: RFLMA Attachment 2, Figure 2
  - Plume maps are no longer updated; well network does not support detailed mapping
- Chemical and hydrologic data used in models
  - Groundwater modeling performed as early as 1980s
  - Predictive modeling – simulate future conditions
  - Modeling performed for site-closure purposes was “fully integrated” – surface water, groundwater, and associated processes (snowmelt, ET, saturated and unsaturated flow, etc.)
  - Modeling results included aspects of contaminant transport, flow directions, and groundwater availability after closure

# Developing the Monitoring Network (continued)

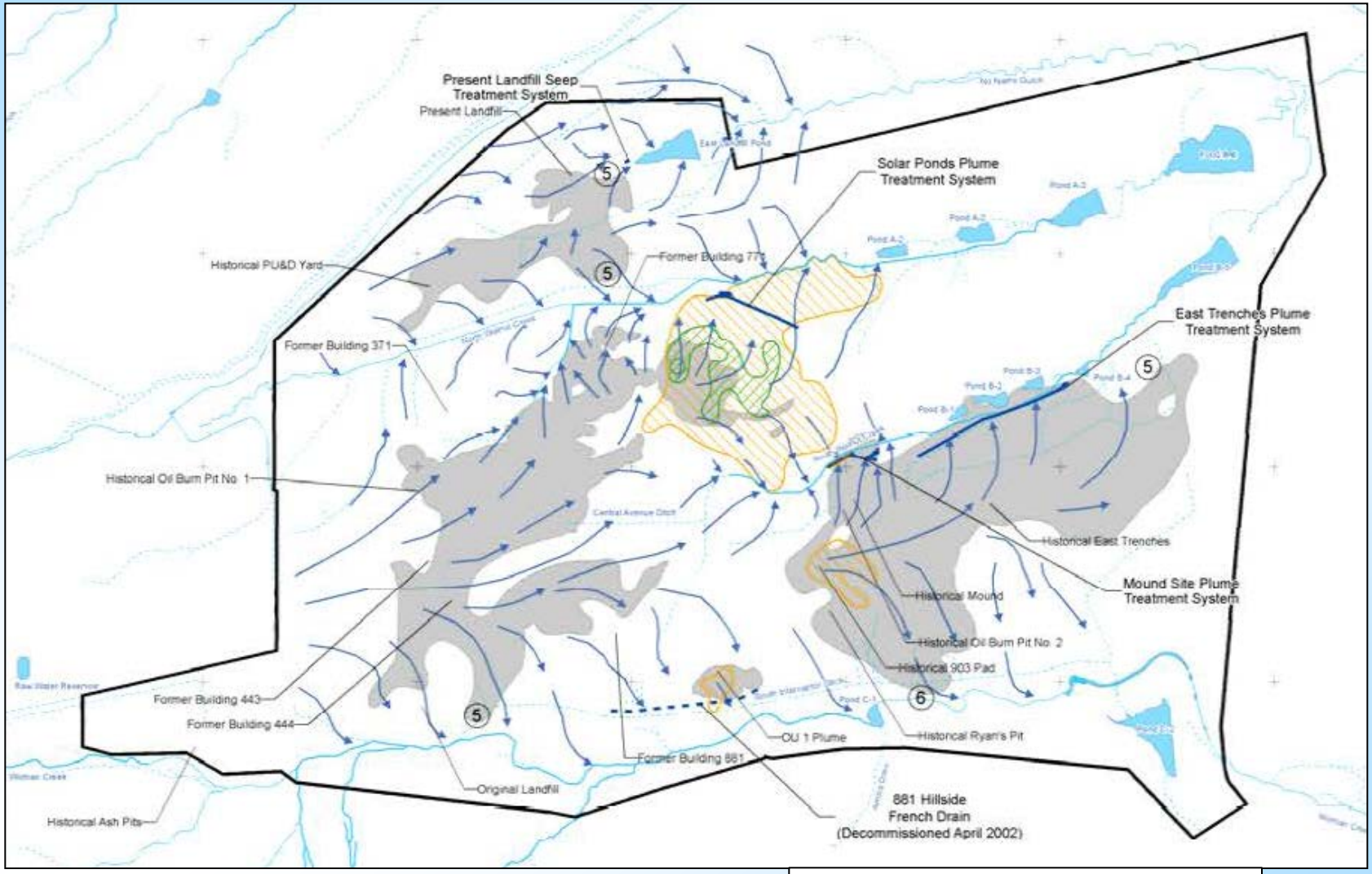



*Figure 2. Composite Plume Map*

*Modified after:*

December 2012
Attachment 2, Page 25

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# Developing the Monitoring Network (continued)

- Primary objective of groundwater monitoring is to evaluate potential impact of groundwater on surface-water quality
  - Groundwater discharges to surface water
  - Conditions change slowly in/near source areas (less-frequent sampling is appropriate)
  - More-frequent monitoring at plume fronts in drainages and along pathways to surface water
- Input on final monitoring network design
  - Community representatives, stakeholders
  - Regulators
  - Site staff
  - Many, many meetings in the years leading up to closure to evolve the focus of the network (locations, analytical suites, data evaluation) from characterization to long-term stewardship

# Developing the Monitoring Network (continued)

- Groundwater COCs: VOCs, nitrate, uranium
  - VOCs: chlorinated solvents – mainly carbon tetrachloride, tetrachloroethene (PCE), trichloroethene (TCE), and their breakdown products
    - Example: used in machining applications (coolants, degreasers)
  - Nitrate from nitric acid
    - Example: used to keep radioactive metals in solution (e.g., plutonium)
  - Uranium from manufacturing weapons-related products
- Additional constituents monitored per agreements
  - Metals at the OLF and PLF, SVOCs at OLF
  - Plutonium and americium at 5 wells downgradient of former B371 and B771

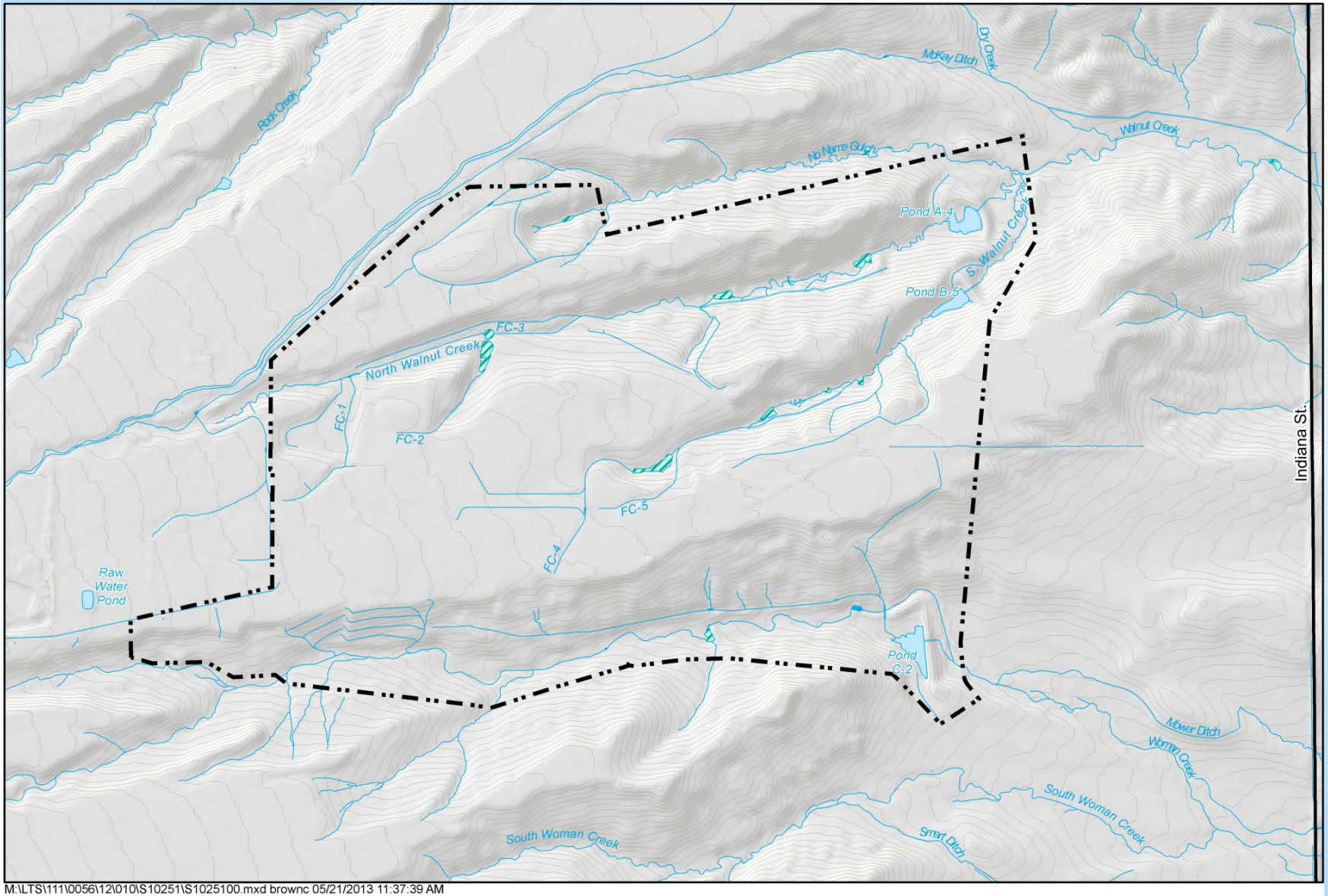
# RFLMA Groundwater Monitoring

- **Primary objective: Protection of surface-water quality**
  - Evaluation wells
    - Closest to source areas
    - Monitored biennially (second quarter, even-numbered years)
  - Sentinel wells
    - Along downgradient plume edges and pathways to surface water
    - Monitored twice annually (second and fourth quarters)
  - AOC wells, Surface Water Support location
    - Downgradient of plume(s), within drainage
    - Monitored twice annually (second and fourth quarters)
    - Reportable-condition criteria

# RFLMA Groundwater Monitoring

- RCRA wells
  - RCRA identified as “applicable or relevant and appropriate requirement” to groundwater monitoring at both landfills
  - Upgradient and downgradient at PLF and OLF
  - Monitored quarterly
  - Results can trigger consultation
- Groundwater treatment systems
  - Influent, effluent, and surface-water performance locations
  - Monitored twice annually (second and fourth quarters)

# Groundwater Monitoring Network (continued)

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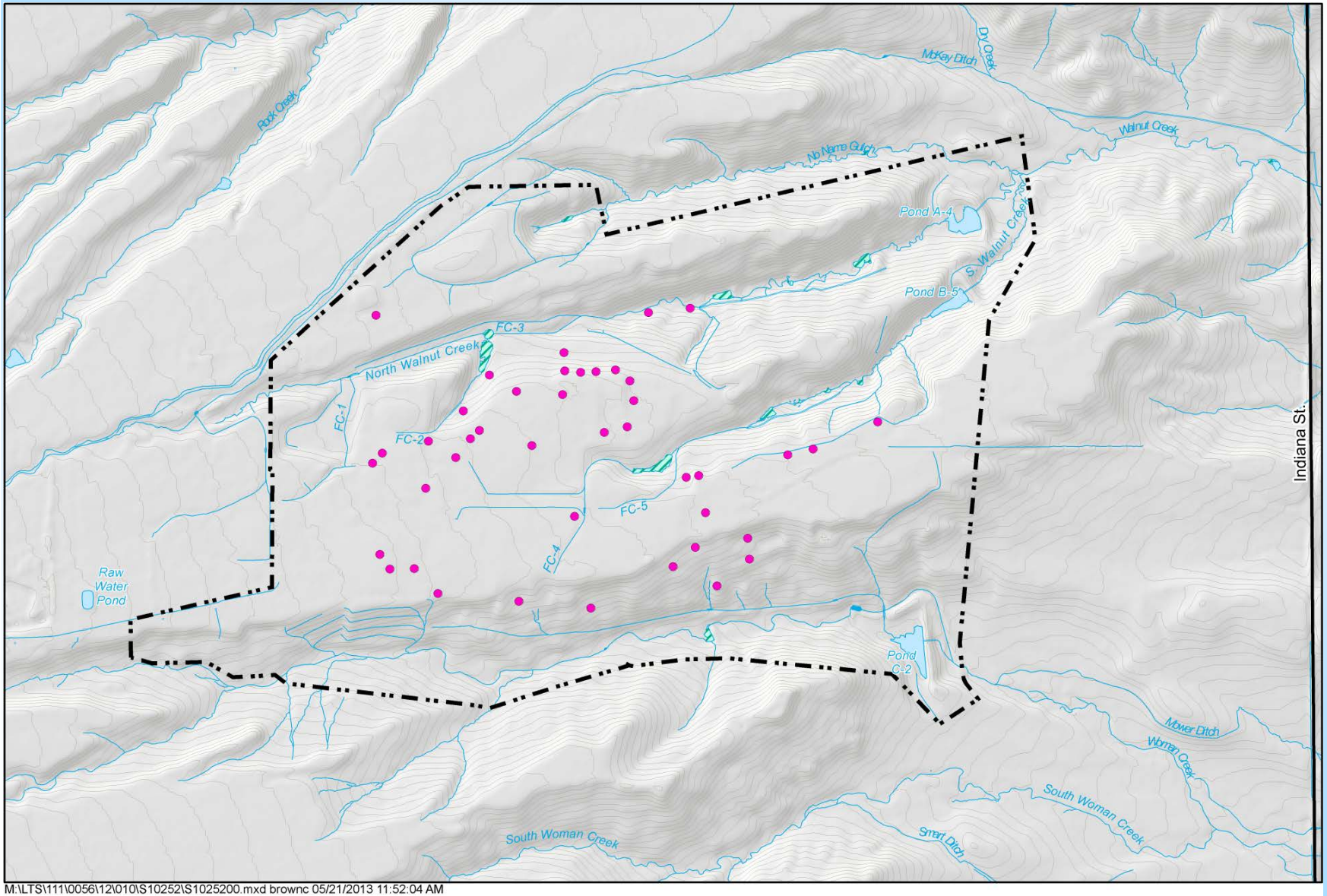
# Evaluation Wells

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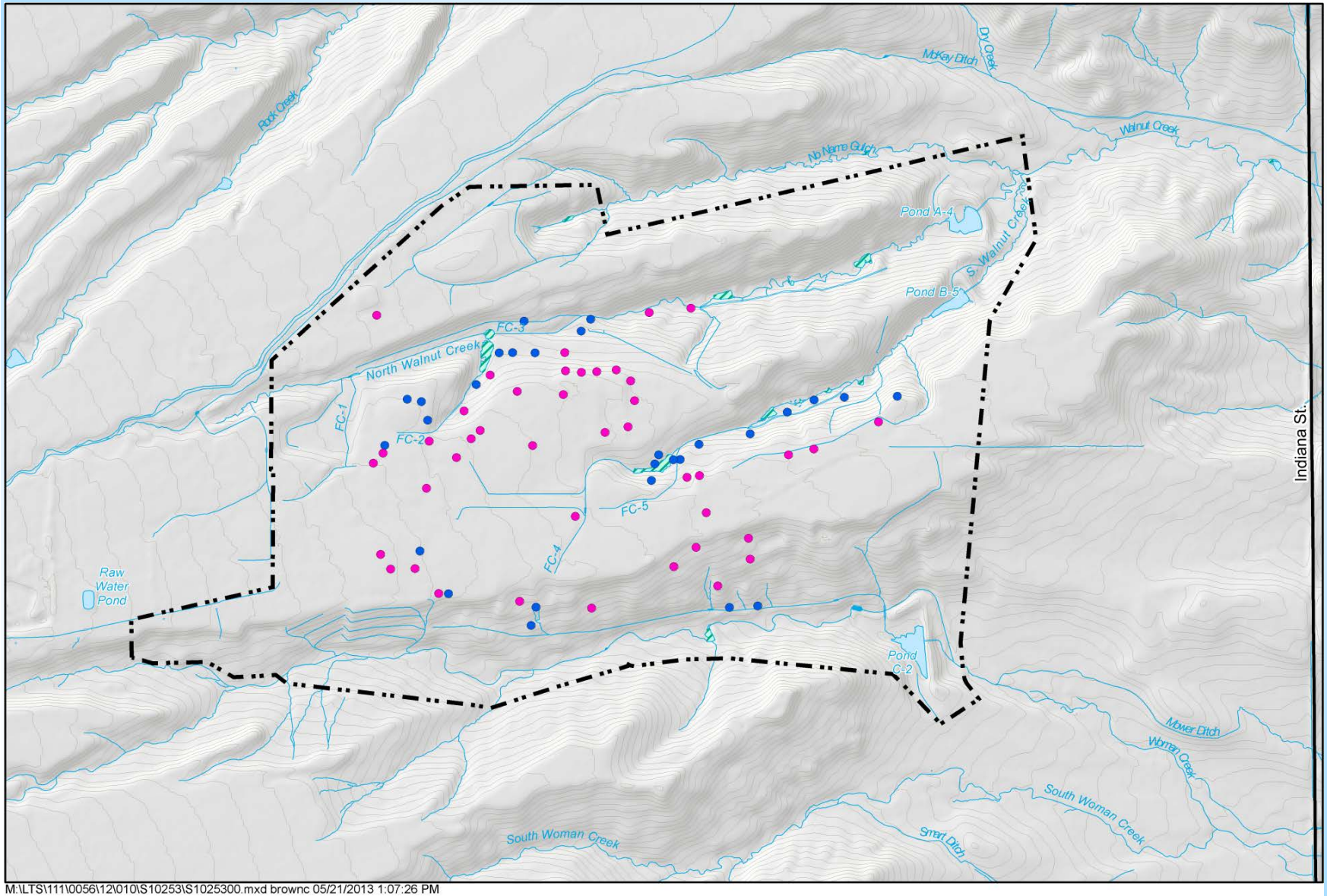
# Evaluation, Sentinel Wells

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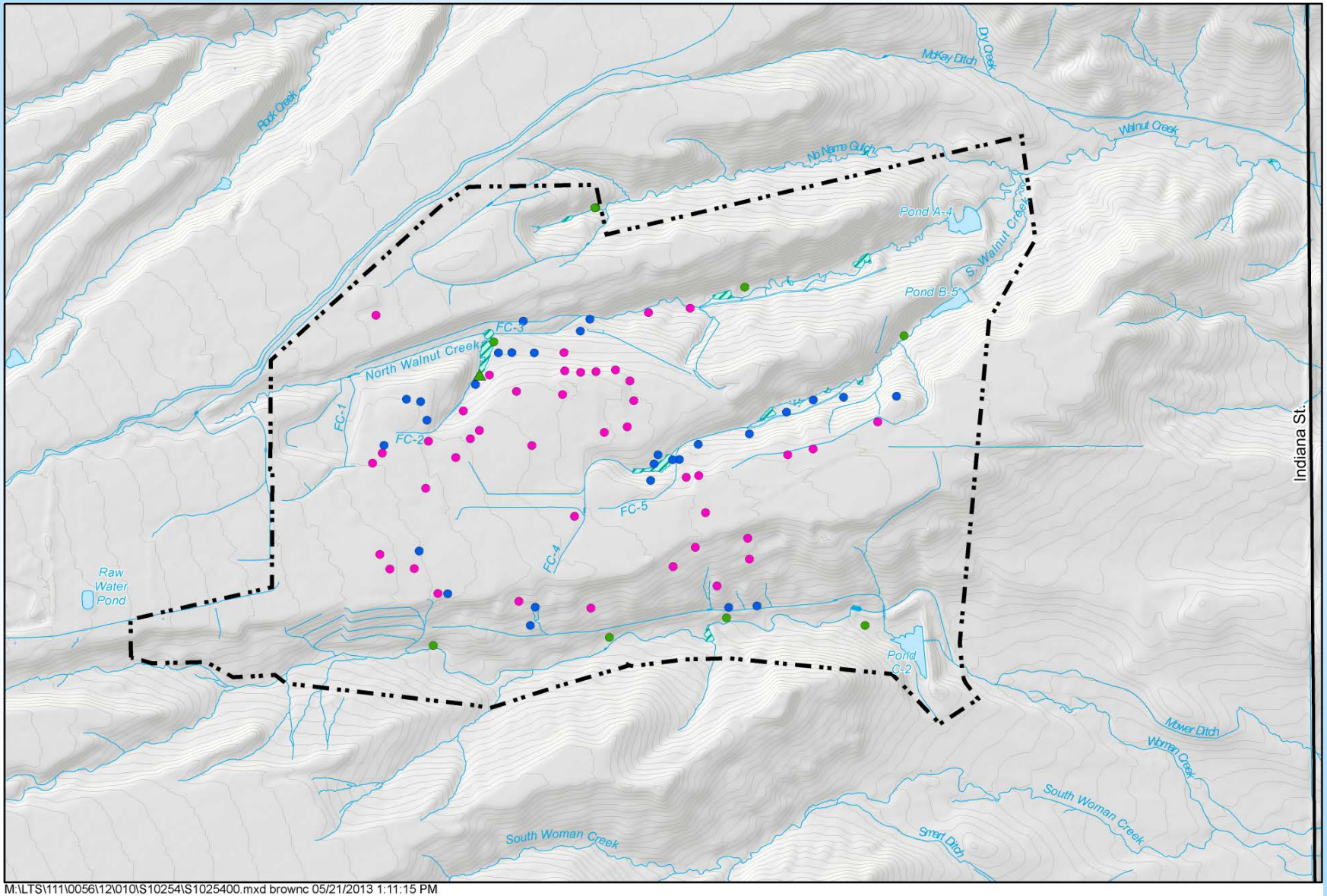
# Evaluation, Sentinel, AOC Wells

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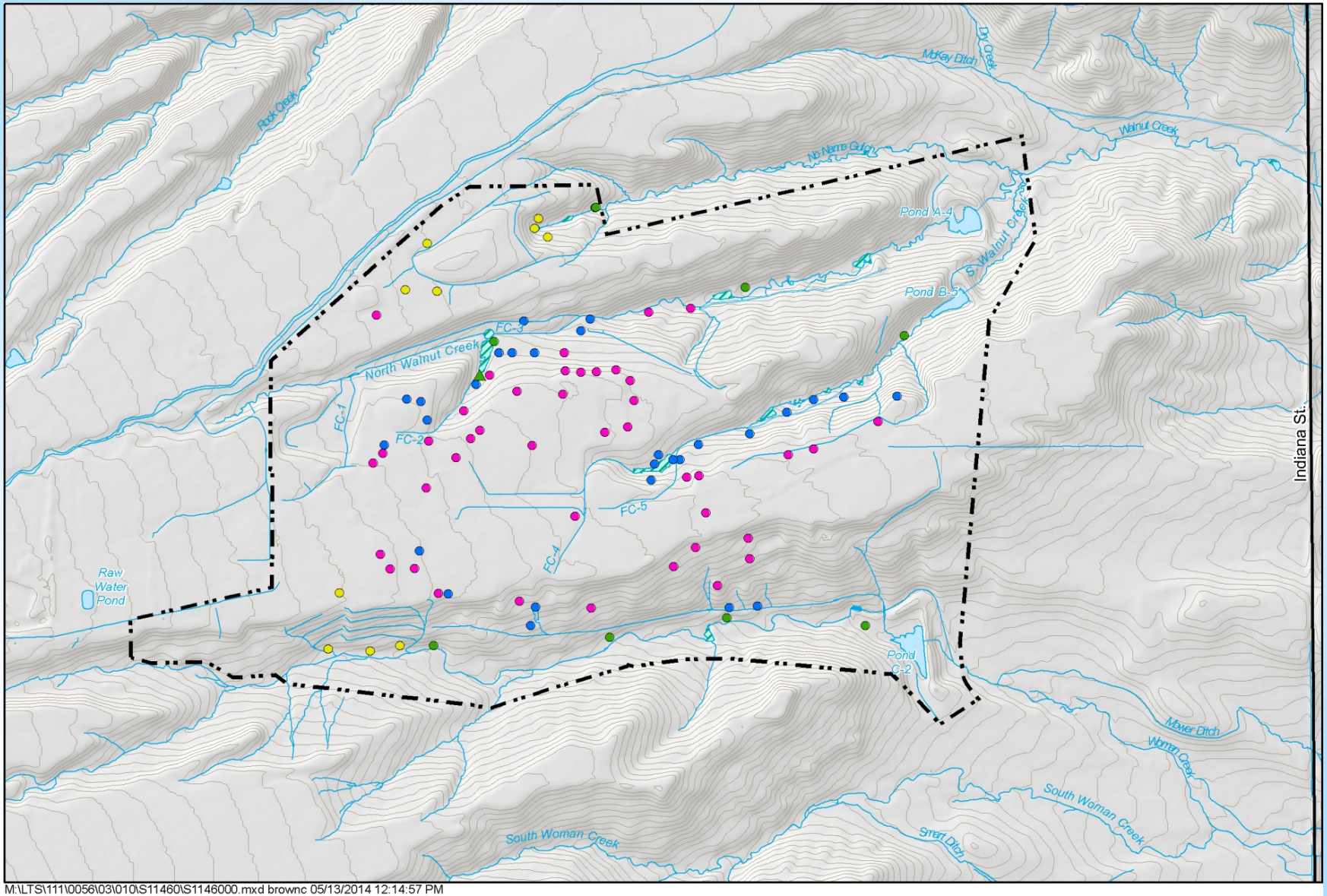
# Evaluation, Sentinel, AOC, RCRA Wells

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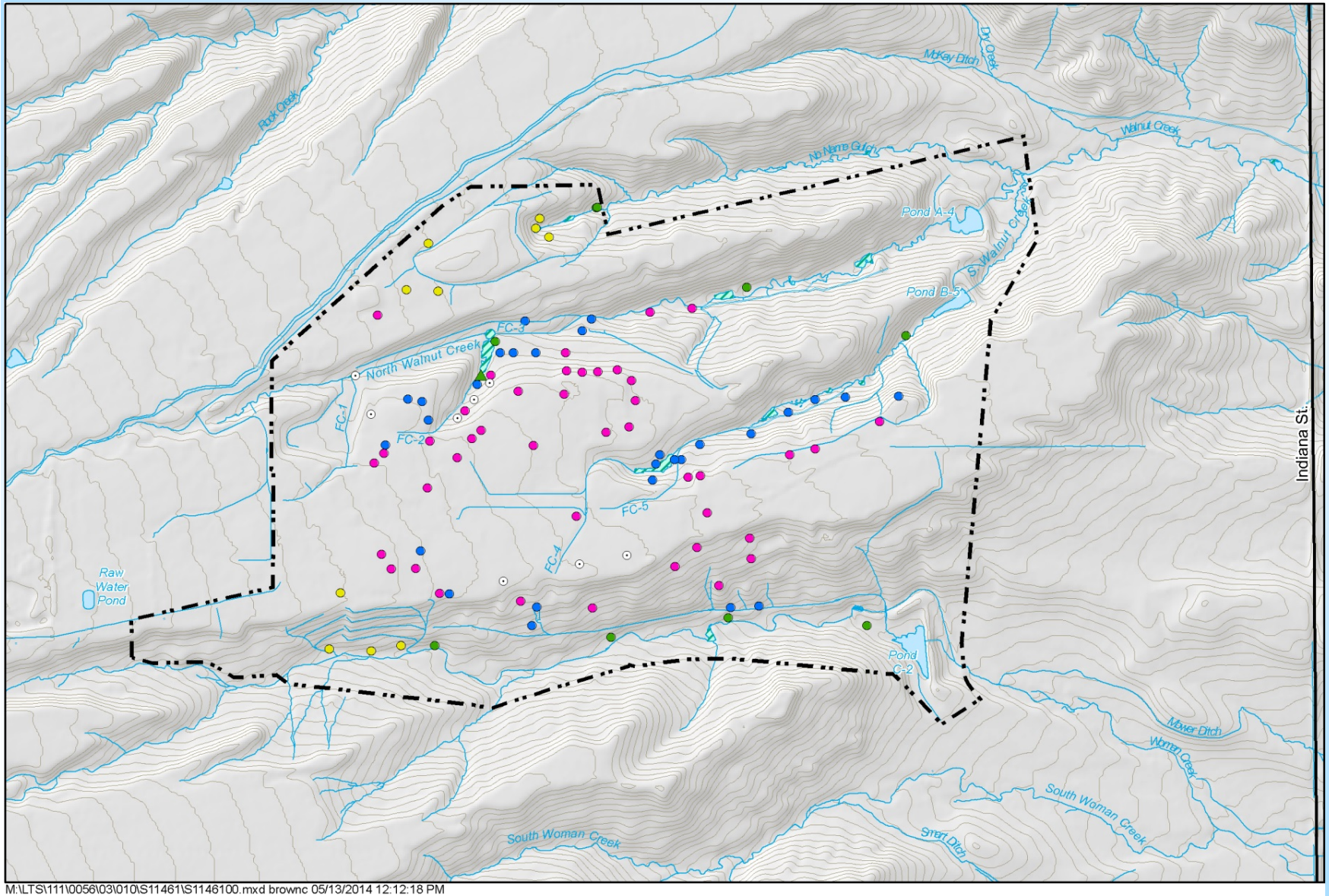
# Evaluation, Sentinel, AOC, RCRA, Water Level Wells

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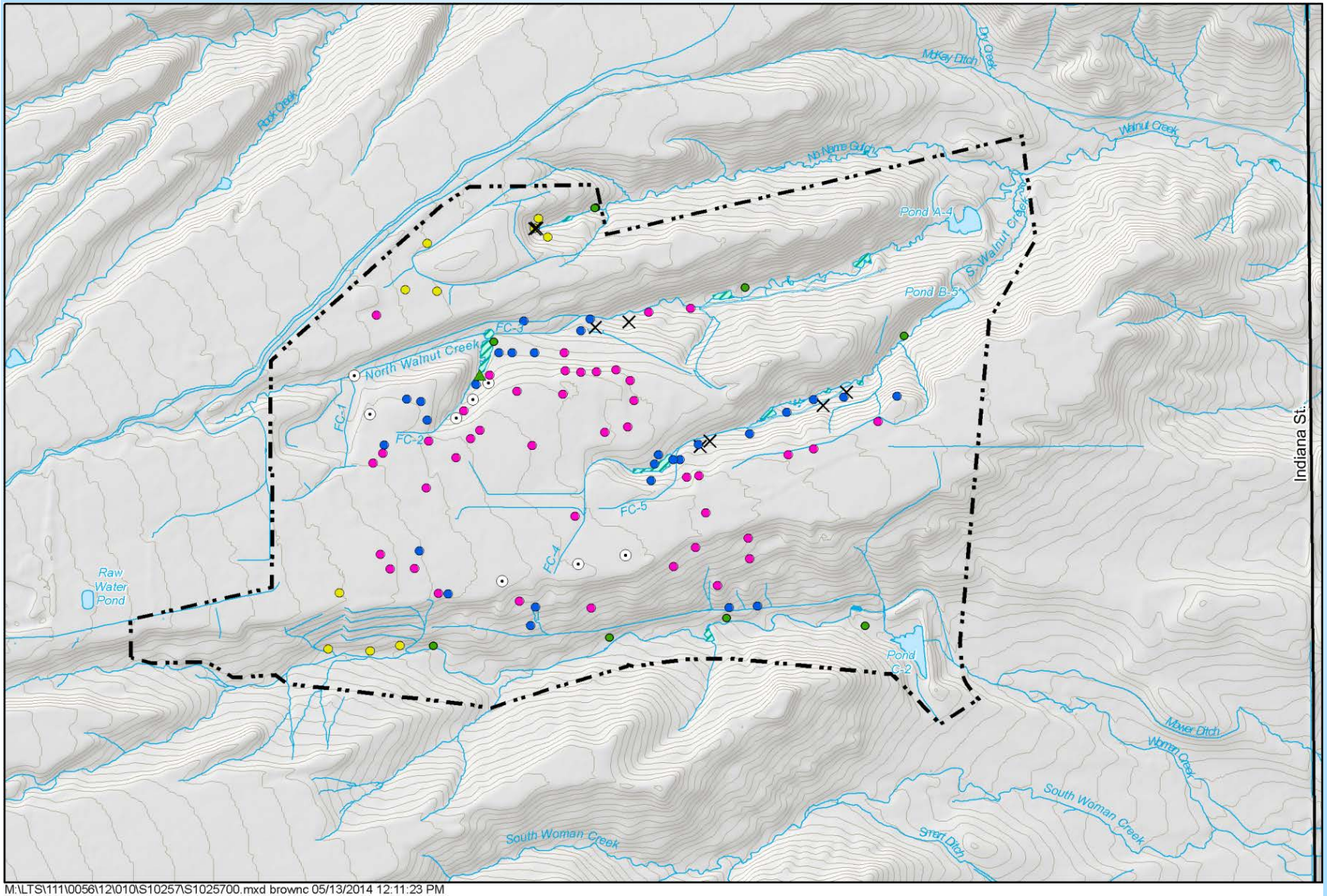
# Evaluation, Sentinel, AOC, RCRA, Water Level Wells, Treatment Systems

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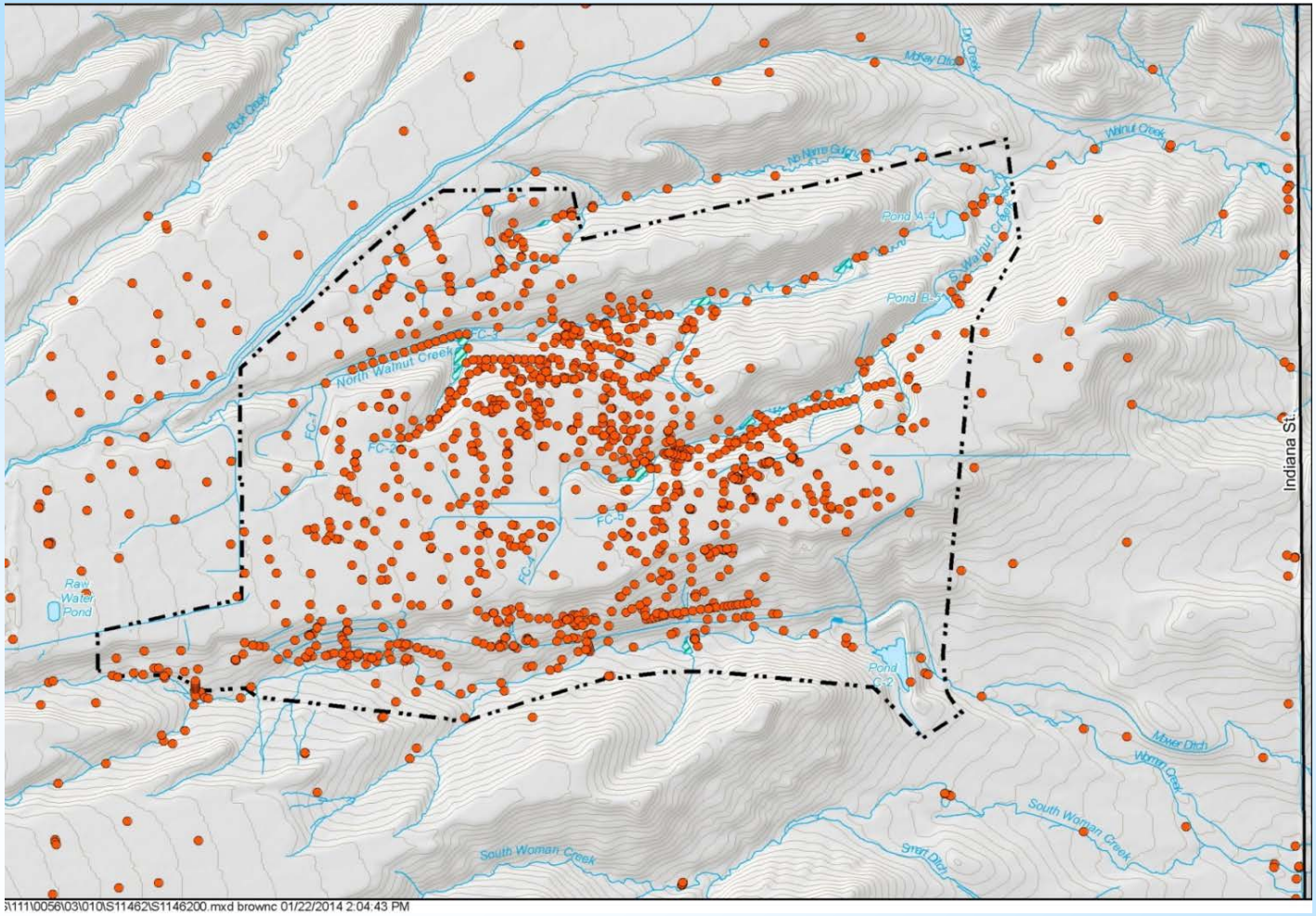
# Wells Installed to Support Characterization

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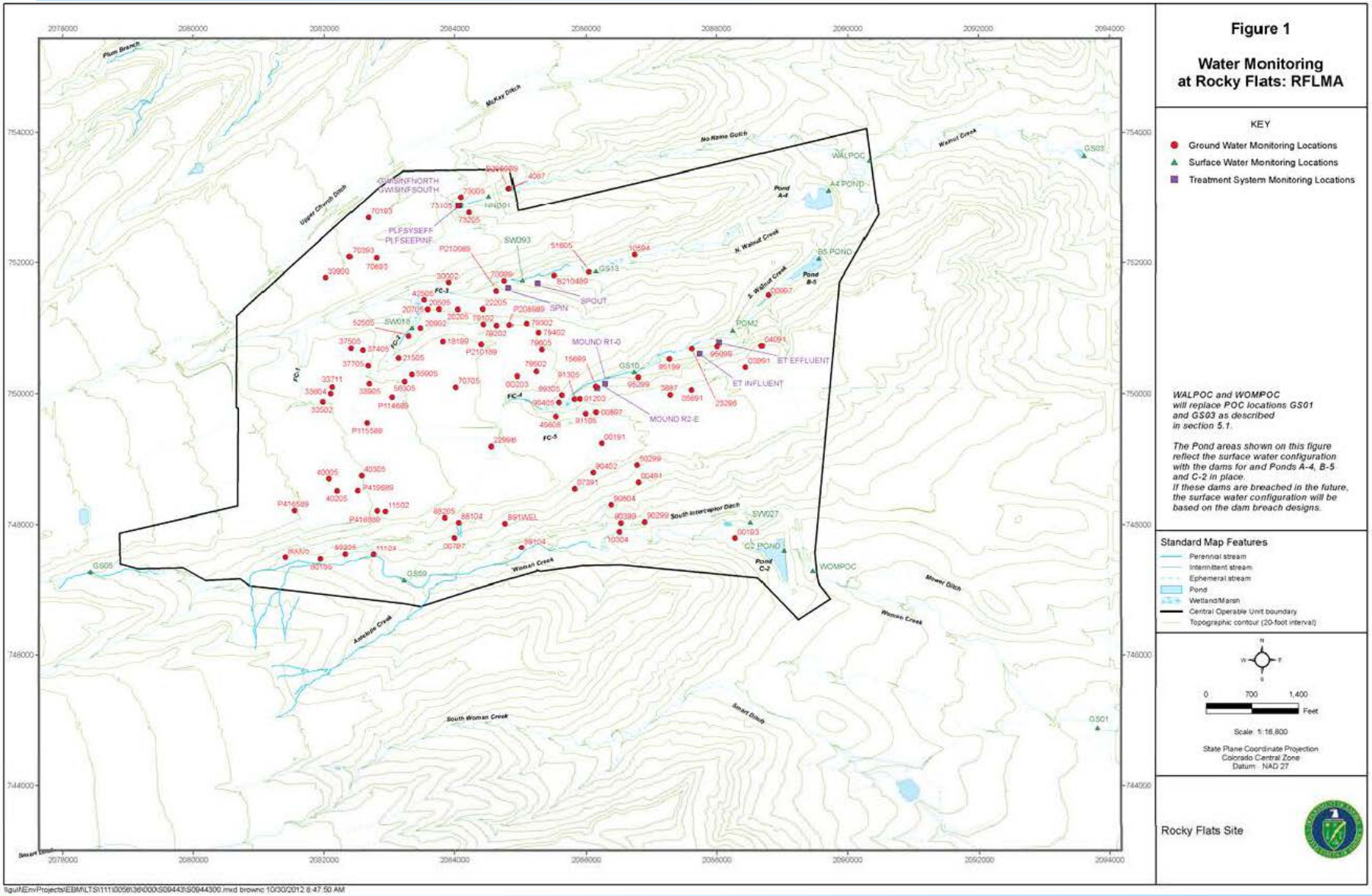
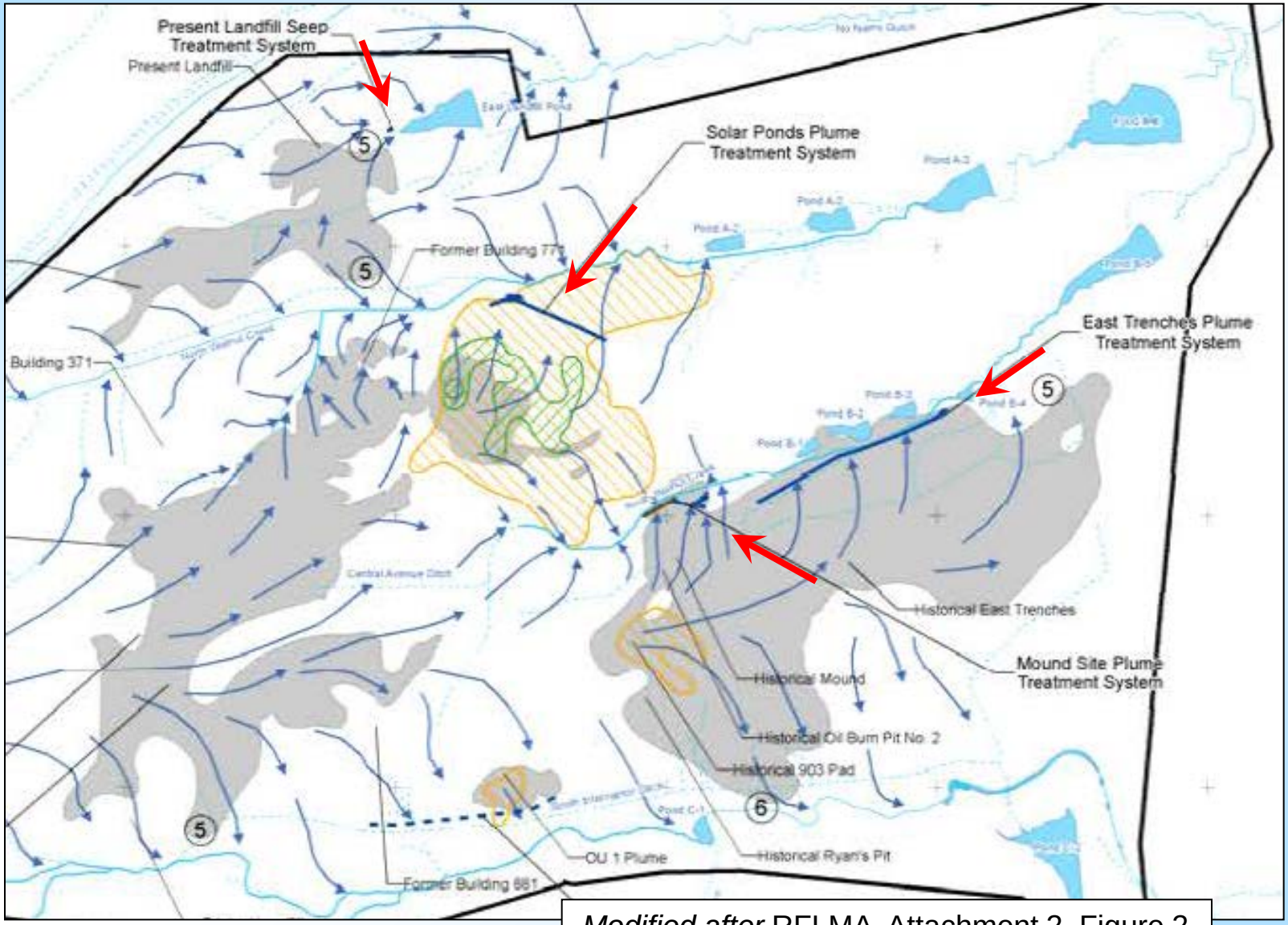
# RFLMA Water Monitoring Network, 2012



# Groundwater Treatment Systems




*Modified after* RFLMA Attachment 2, Figure 2, December 2012, Page 25

# Groundwater Treatment Systems (continued)

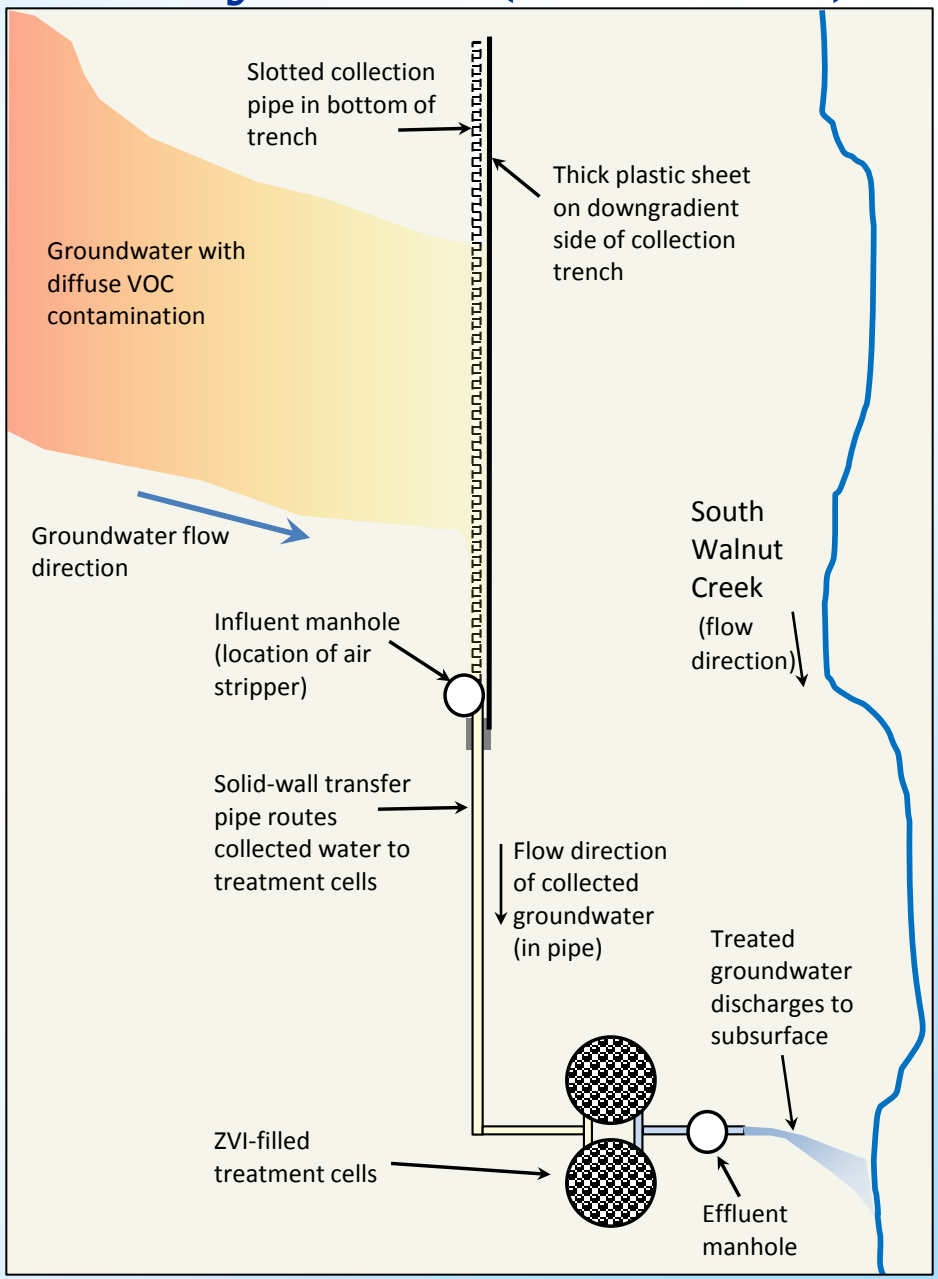
- Treatment system locations
  - Contaminated groundwater detected at or near surface water and fed by source area
  - Knew systems were appropriate at
    - PLF
    - South Walnut Creek downgradient of Mound source area (former seep SW059)
    - South Walnut Creek downgradient of East Trenches source area
    - North Walnut Creek downgradient of Solar Ponds source area
  - Modeling evaluated whether treatment was needed in other areas

# Groundwater Treatment Systems (continued)

- Four treatment systems at Rocky Flats
  - Present Landfill Treatment System (PLFTS)
    - Designed to treat very low levels of VOCs by cascade aeration
  - Mound Site Plume Treatment System (MSPTS)
    - Originally designed to treat VOCs by passing water through ZVI
  - East Trenches Plume Treatment System (ETPTS)
    - Originally designed to treat VOCs by passing water through ZVI
  - Solar Ponds Plume Treatment System (SPPTS)
    - Originally designed to treat nitrate and uranium by passing water through sawdust and ZVI
- Each system incorporates a groundwater intercept component

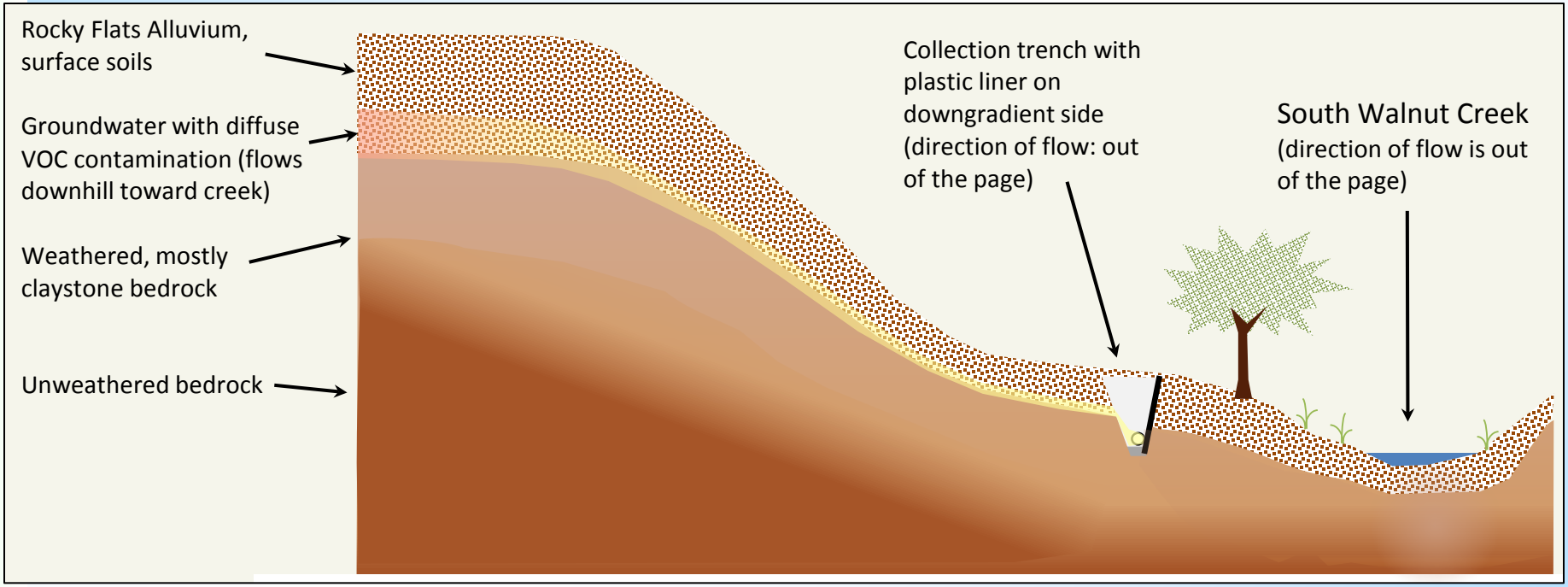
# Groundwater Treatment Systems (continued)

- Conceptual design (ETPTS example)
  - Contaminated groundwater from source area flows downgradient
  - Intercept trench captures groundwater
  - Collected groundwater flows to treatment cells
  - Treated water is discharged at discharge gallery
- Same concept at MSPTS, SPPTS



# Groundwater Treatment Systems (continued)

- Conceptual design (ETPTS example)



# Groundwater Treatment Systems (continued)

- Except for PLFTS, systems have required modification since closure
  - Originally designed to reduce contaminant loads
  - With RFLMA, effluent compared with Table 1 standards
- Each system treats a very low flow of water
  - MSPTS ~0.75 gpm
  - ETPTS ~1.5 gpm
  - SPPTS ~1 gpm (PLFTS about the same)
  - Comparisons:
    - Garden hose on “full” is often about 10 gpm
    - Recommended minimum flow rate for a household-supply spring or well is typically at least 5 to 6 gpm

# Groundwater Treatment Systems (continued)

- MSPTS, ETPTS
  - Dissolved chlorinated solvents
  - ZVI reacts chemically with solvent molecules
  - Results of complete treatment: chlorine, carbon dioxide, water (ethene, ethane also possible)
  - Result of incomplete treatment: partially-dechlorinated compounds
  - Example: Tetrachloroethene, PCE ($C_2Cl_4$)
    Trichloroethene, TCE ($C_2HCl_3$)
    cis-1,2-dichloroethene, cis-1,2-DCE ($C_2H_2Cl_2$)
    Vinyl chloride, VC ($C_2H_3Cl$)
    Ethene ($C_2H_4$)
  - Have added air strippers to assist ZVI-based treatment
- PLFTS: also chlorinated solvents, treated via cascade aeration

# Groundwater Treatment Systems (continued)

- SPPTS
  - Nitrate and uranium
  - Sawdust: carbon source for denitrifying bacteria
  - ZVI: removes uranium
    - Large mass in a tank versus small amounts in “microcells”
  - Testing lagoons for treating nitrate
    - Nearly-stagnant water with abundant denitrifying bacteria
    - Influent dosed with nutrients
    - Bacteria convert the nitrate ($NO_3$) to nitrogen gas ($N_2$)

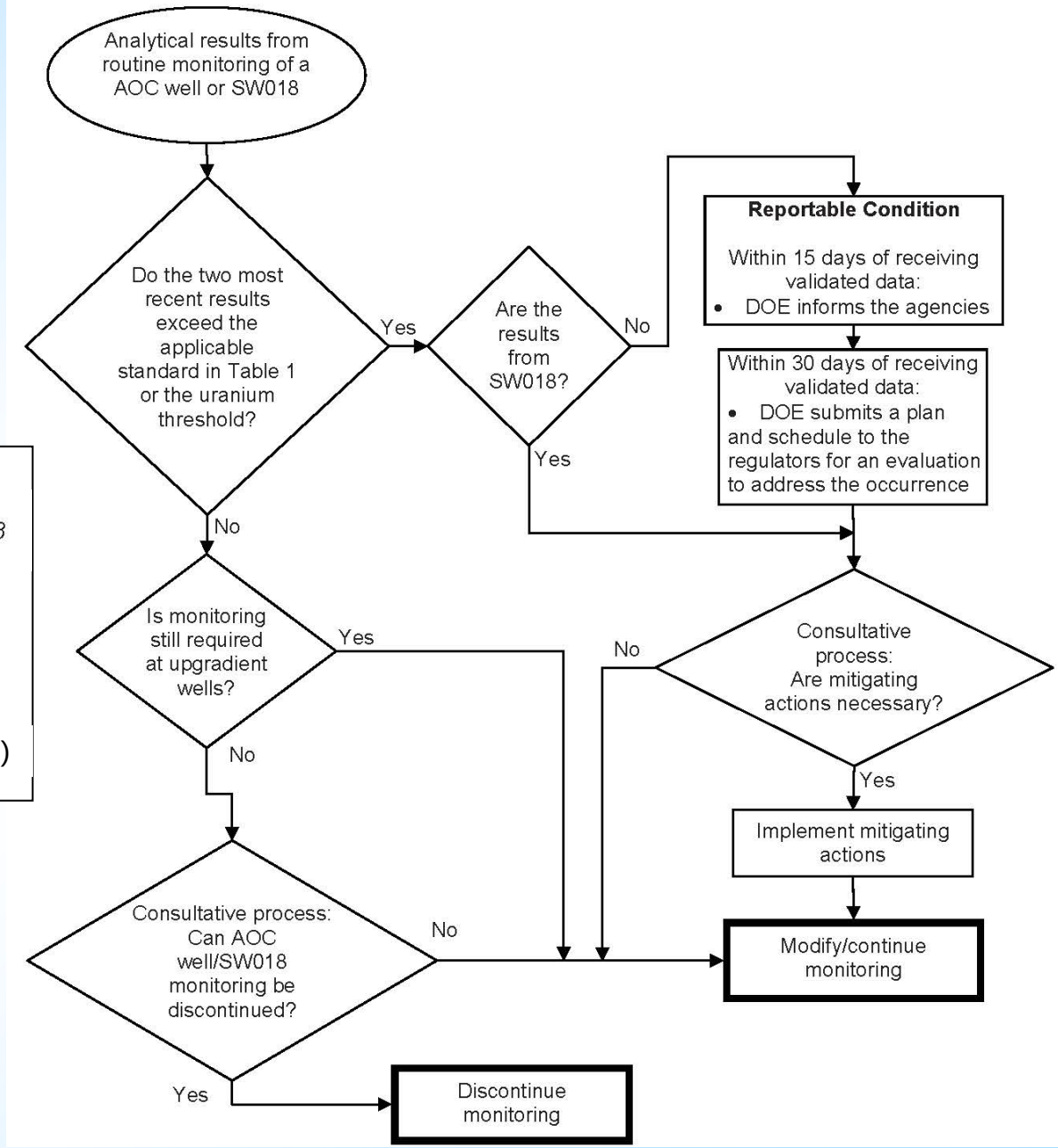
# Groundwater Treatment Systems (continued)

- PLFTS
  - Very low concentrations of VOCs
  - Water flows over “stair steps”; essentially no maintenance
- MSPTS, ETPTS
  - Higher concentrations of VOCs
  - Require periodic replacement of media (ZVI)
  - Air strippers require maintenance to address clogging
    - Biological accumulations, mineral precipitates (hard-water scale)
- SPPTS
  - Requires periodic media replacement (ZVI, organic)
  - Lagoons – no media to replace; replenish nutrient solution
- Plumbing, meters, pumps, probes, etc. require periodic servicing

# RFLMA Groundwater Monitoring

- RFLMA Attachment 2
  - Defines well classes and objectives
  - Presents data evaluation protocols (flowcharts)
  - Evaluation protocols incorporate use of statistics
    - Calculation of trends
    - Calculation of 85th-percentile concentrations
    - Comparison of upgradient versus downgradient concentrations (RCRA wells)
  - Examples: AOC wells, Sentinel wells

# RFLMA Data Evaluation Protocols:
## AOC Wells




*Modified after RFLMA Attachment 2,*
*Figure 7. Area of Concern Wells and SW018*

December 2012
Attachment 2, Page 30

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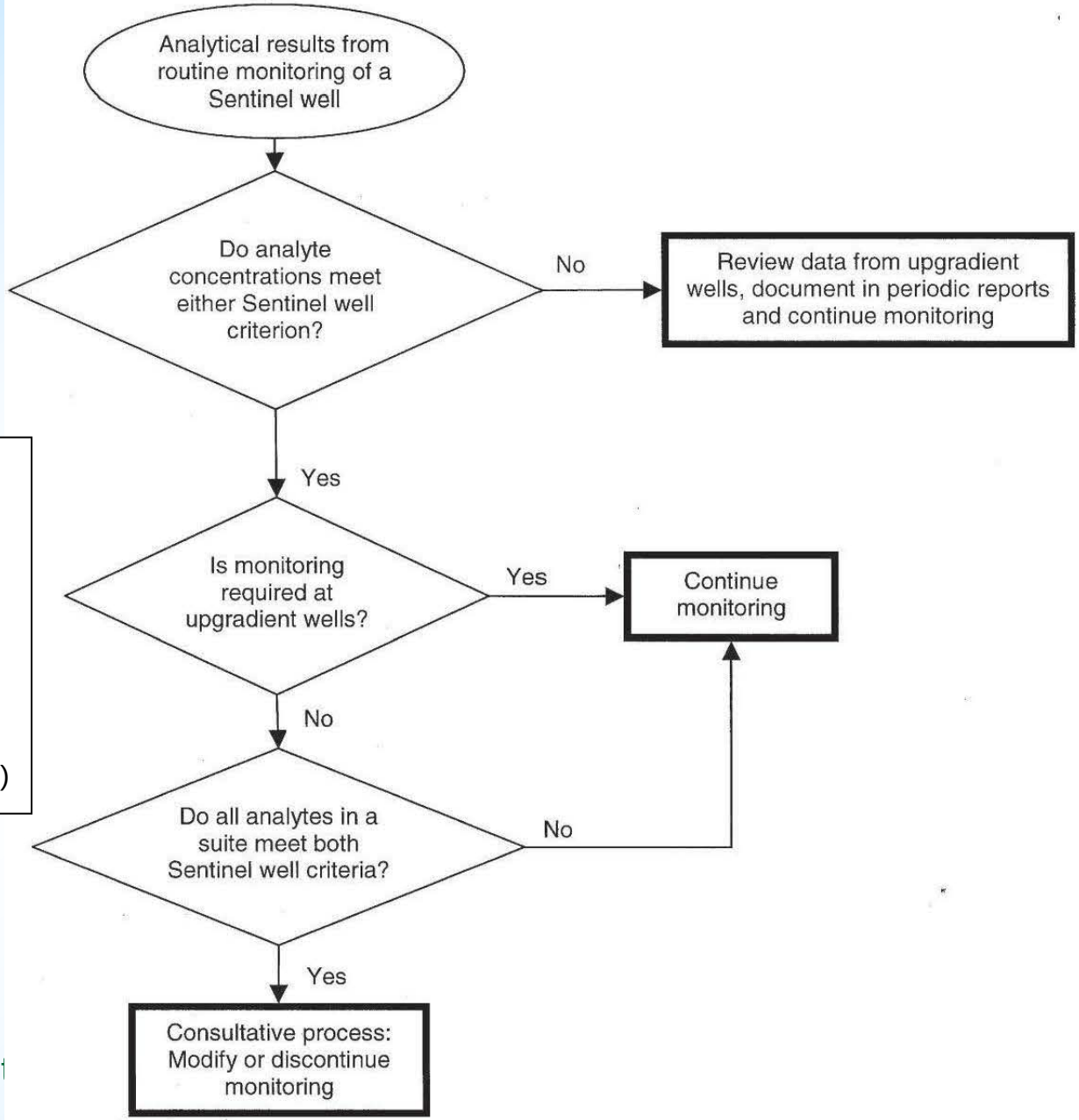
# RFLMA Data Evaluation Protocols:
## Sentinel Wells




*Modified after RFLMA Attachment 2,*

*Figure 8. Sentinel Wells*

December 2012
Attachment 2, Page 31

(Notes omitted for improved legibility.)

# RFLMA Data Evaluation Protocols

- Also provided for Evaluation wells, RCRA wells, treatment system locations
- Flowchart notes address:
  - Monitoring frequencies
  - Concentrations for comparison
  - Statistical approach
- Absolute concentrations, trends, upgradient/downgradient comparisons
- Annual reports: results of statistical evaluations plus other charts, tables, information

# Questions?