Results from the Aerial Survey of the Western New York Nuclear Service Center

Survey dates: Sept. 22 – Oct. 4, 2014

Aerial Measuring System
Remote Sensing Laboratory
National Security Technologies, LLC

National Security Technologies LLC
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RSL
REMOTE SENSING LABORATORY

Outline

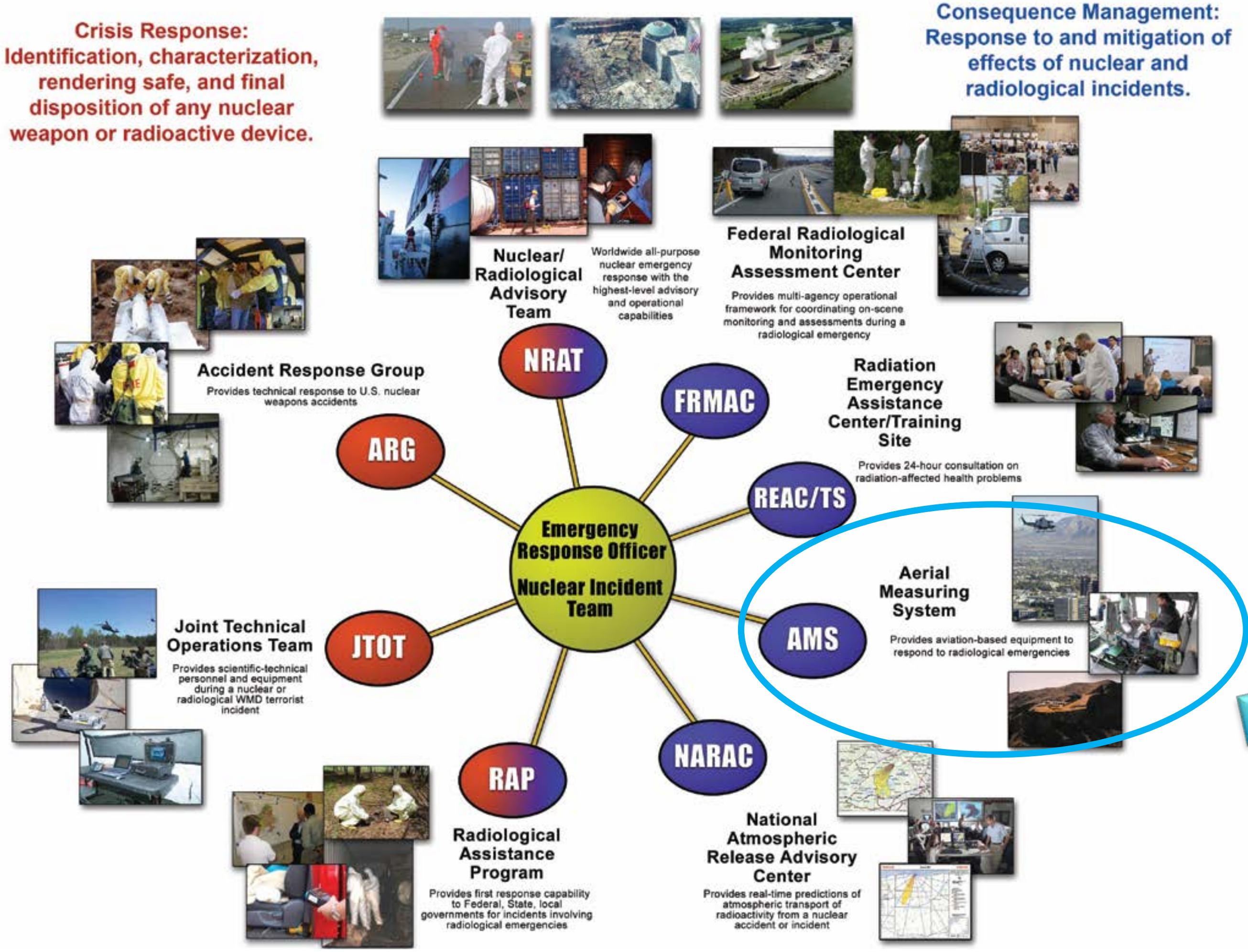
- Overview of Aerial Measuring System (AMS)
- Goals of survey
- Survey methods
  - Aerial and ground measurements
  - Data analysis and interpretation
- Survey results (maps)
  - Exposure rate
  - Anthropogenic extractions
  - Isotopic extractions
  - Comparison to 1984 survey

Aerial Measuring System

- AMS provides responsive aerial measurements to detect, analyze, and track radioactive material before and during emergencies
  - Mission planning, data acquisition, analysis, and reporting
- Established in 1960s
- Originally supported the nuclear testing program
- Current Mission:
  - Collect, analyze and interpret data to support overall federal radiological monitoring and assessment in response to an incident
  - Inform predictive atmospheric dispersion and deposition models, including National Atmospheric Release Advisory Center (NARAC)
  - Provide initial assessment of ground deposition over a wide area
  - Search for lost radioactive sources or scattered fragments

DOE/NNSA Office of Emergency Response

Mission:
Provide a versatile, capable, worldwide nuclear or radiological emergency response with the technical capability to respond to any radiological/nuclear incident worldwide.

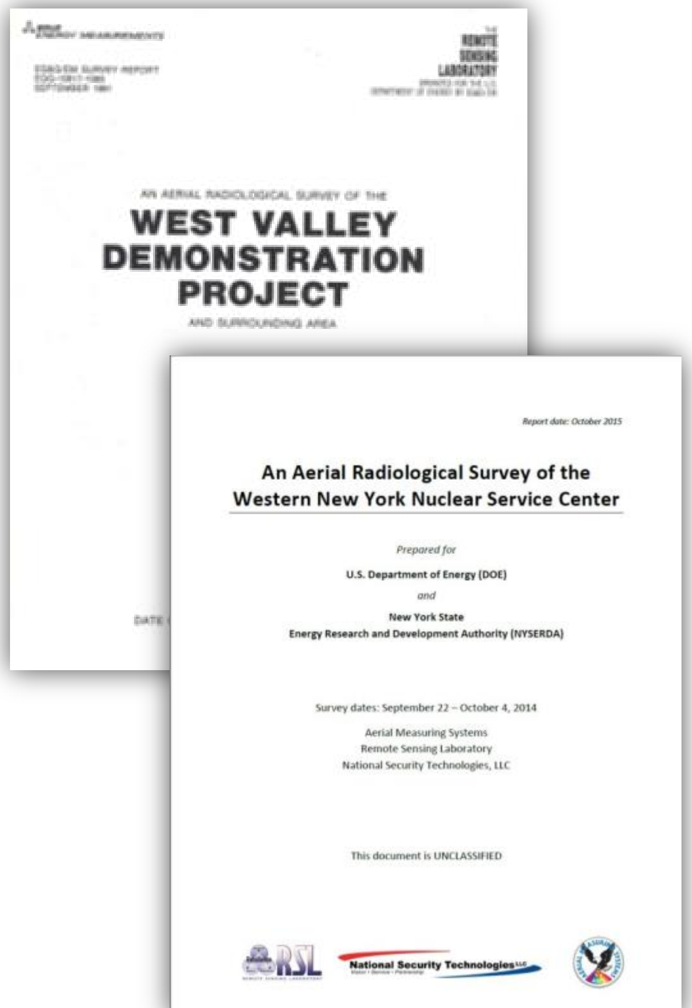


Fixed-wing
B-200

Helicopter
Bell 412

AMS Past Surveys (over 500 Surveys Conducted)

West Valley/WNYNSC Survey Goals


AN AERIAL RADIOLOGICAL SURVEY OF THE

WEST VALLEY DEMONSTRATION PROJECT

AND SURROUNDING AREA

Report date: October 2015

An Aerial Radiological Survey of the Western New York Nuclear Service Center

Prepared for

U.S. Department of Energy (DOE)

and

New York State Energy Research and Development Authority (NYSERDA)

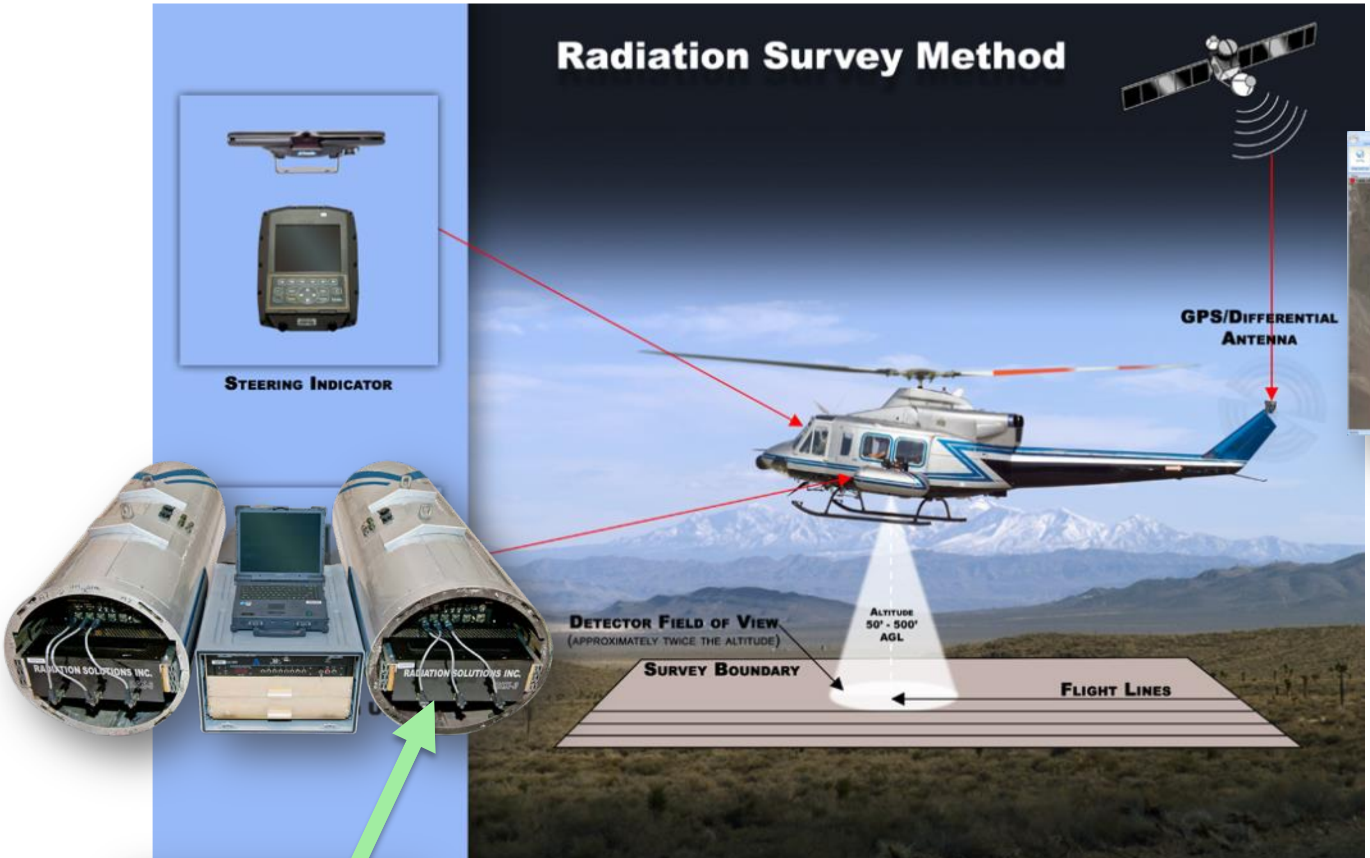
Survey dates: September 22 – October 4, 2014

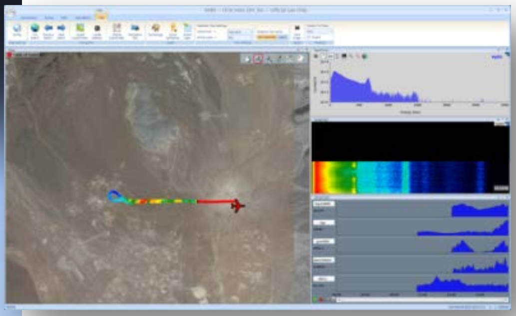
Aerial Measuring Systems
Remote Sensing Laboratory
National Security Technologies, LLC

This document is UNCLASSIFIED

- Obtain a current broad picture of contamination on and around WNYNSC and along Cattaraugus Creek
  - Update and extend past surveys from 1984, 1979, and earlier
- Reanalyze 1984 data for direct comparison
- Deliverable maps and GIS files:
  - Terrestrial exposure rate at ground level
  - Anthropogenic (“man-made”) sources in excess of background
  - Specific radioisotopes present in excess of background
- AMS requested to assist in identifying areas for follow-up

Aerial Measurements: Equipment and Method





Software:
Advanced Visualization and Integration of Data (AVID)

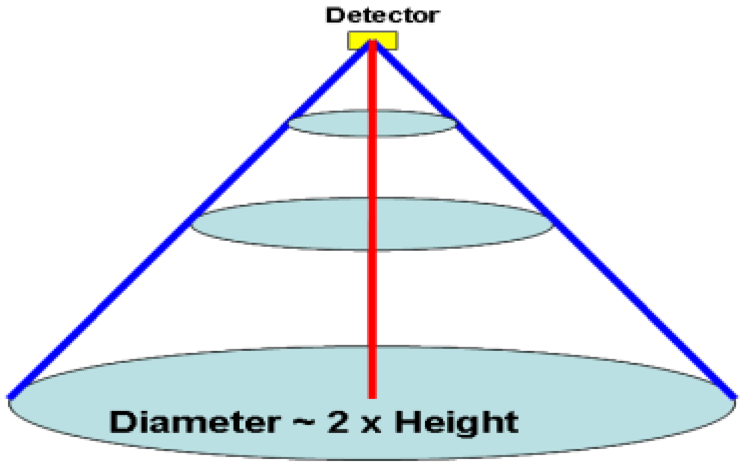
Twelve externally-mounted NaI(Tl) detectors

- One pod on each side of aircraft
- Each pod carries two RSX-3 units
- Each RSX-3 carries 3 detectors
- Each crystal is 2” × 4” × 16” (2 liters)

Altitude Trade-Offs

Low detector

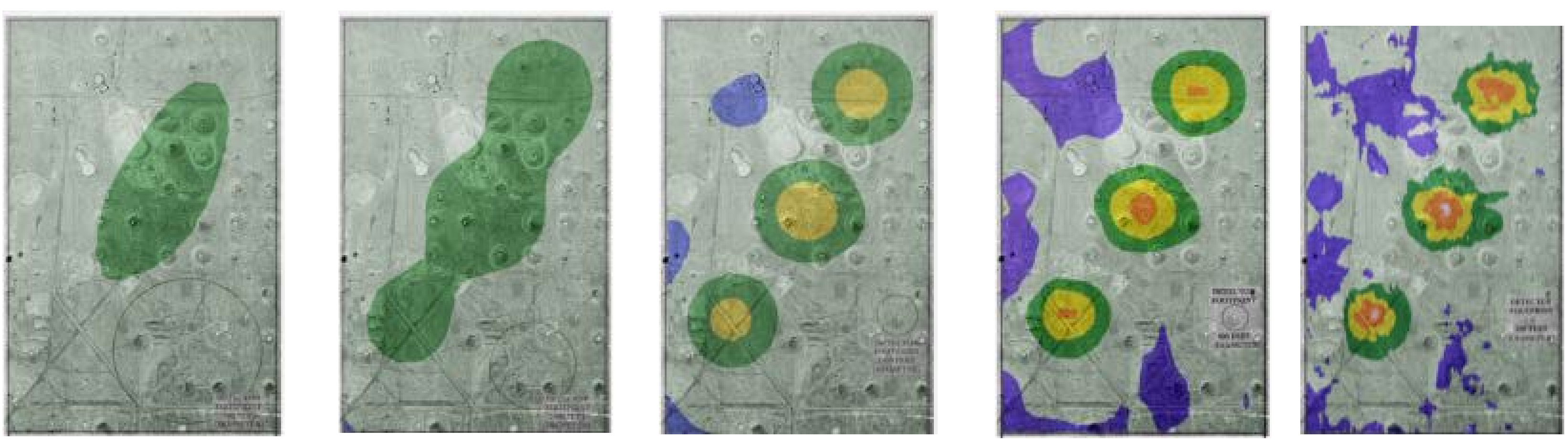
- High Resolution
- Discrete sampling
- Slow coverage
- Atmospheric attenuation is small

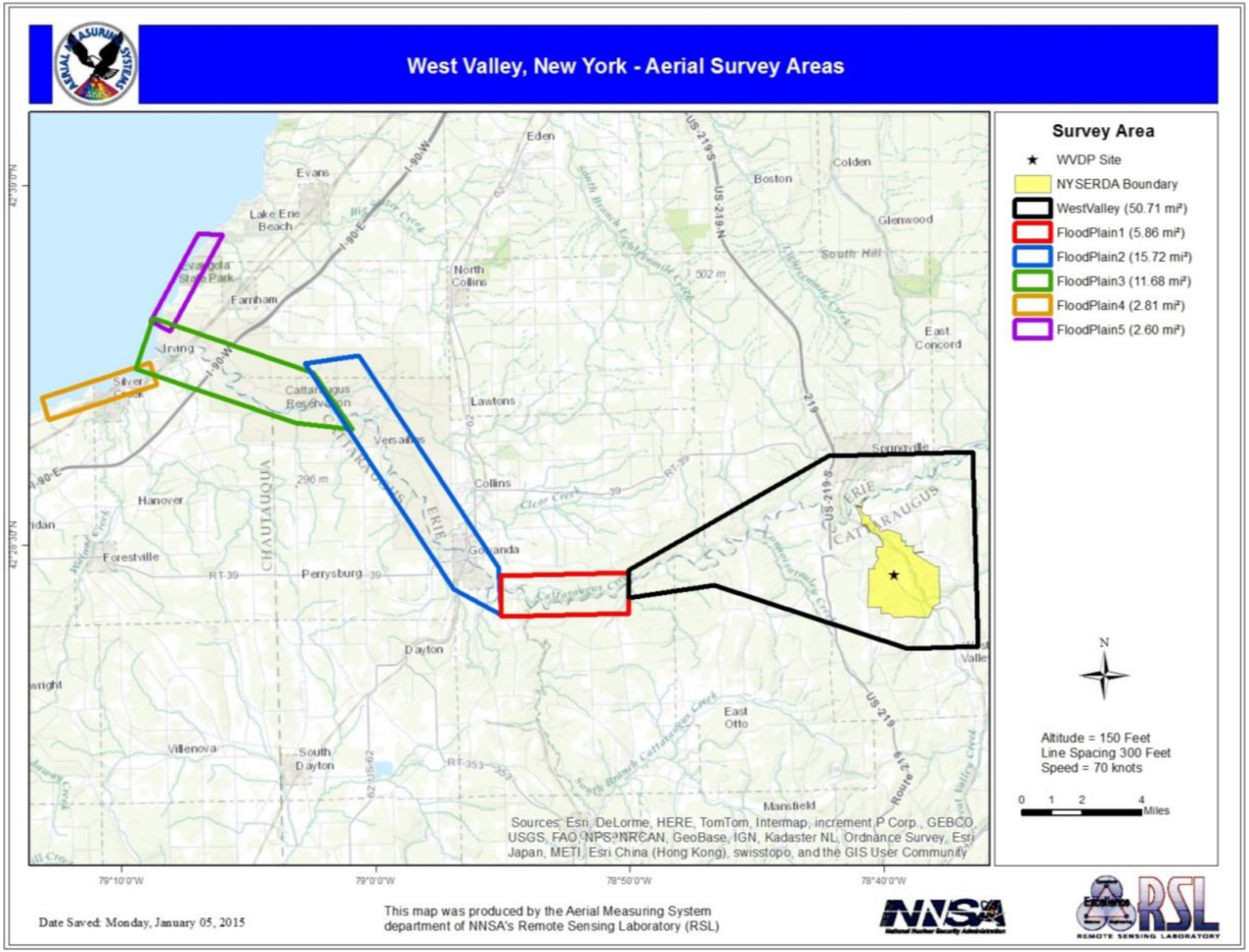


High detector

- Low resolution
- Area averaging
- Rapid coverage
- Significant sensitivity loss
- Atmospheric attenuation is large

1750 ft **1000 ft** **500 ft** **200 ft** **50 ft**




West Valley, New York - Aerial Survey Areas
Survey Area
WVDP Site
NYSERDA Boundary
WestValley (50.71 mi²)
FloodPlain1 (5.86 mi²)
FloodPlain2 (15.72 mi²)
FloodPlain3 (11.68 mi²)
FloodPlain4 (2.81 mi²)
FloodPlain5 (2.60 mi²)
N
Altitude = 150 Feet
Line Spacing 300 Feet
Speed = 70 knots
0 1 2 4 Miles
Eden
Evans
Lake Erie Beach
Farnham
Irving
North Collins
Boston
Colden
Glenwood
South Hill
East Concord
Lawtons
Versailles
Collins
Hanover
Forestville
Perrysburg
Gowanda
Springville
Dayton
East Otto
Villenova
South Dayton
Mansfield
CHAUTAUQUA
ERIE
CATTARAUGUS
Sources: Esri, DeLorme, HERE, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community
79°10'0"W
79°0'0"W
78°50'0"W
78°40'0"W
Date Saved: Monday, January 05, 2015
This map was produced by the Aerial Measuring System department of NNSA's Remote Sensing Laboratory (RSL)

Conduct of Aerial Survey

Survey Parameters

- Dates: Sept. 22 – Oct. 4, 2014
  - 2-3 flights/day (weather permitting)
- Area covered: ~ 90 sq mi
- Altitude: 150 ft
- Airspeed: 70 kts
- Line spacing: 300 ft

Survey Team

- Mission Manager (1)
- Pilots (4)
- Equipment Techs (4)
- Data Analysts (2)
- Mission Scientists (5)
- Aircraft Mechanics (2)

Ground Measurements: Equipment and Method

- Gamma exposure rate and high-resolution gamma spectra measured at several ground locations
  - Reuter-Stokes pressurized ionization chamber (PIC)
  - ORTEC high-purity germanium (HPGe) gamma-ray spectrometer
- Corroborate extractions of exposure rate and isotopic signatures from analysis of aerial data

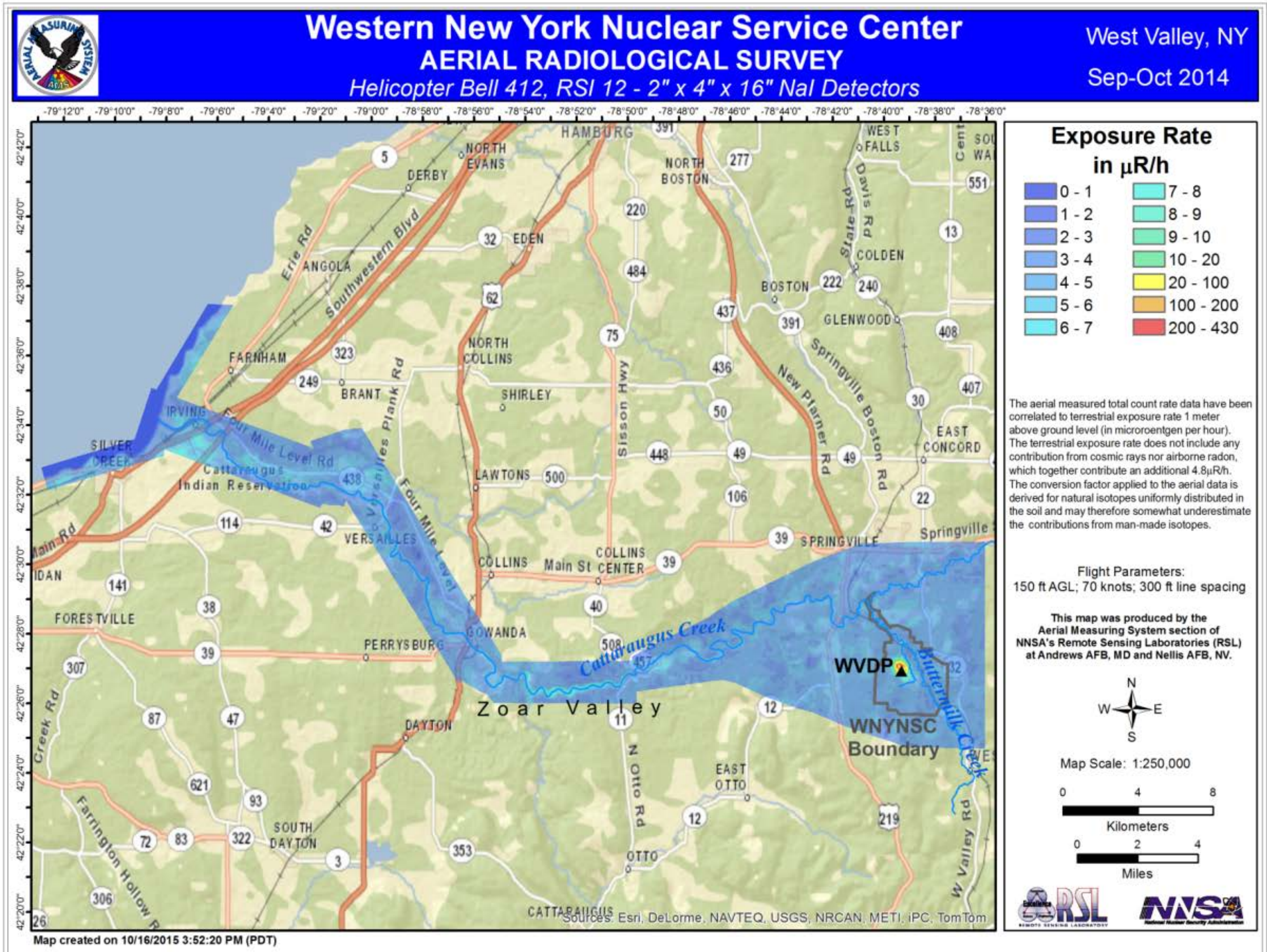
Data Analysis: Overview

- Terrestrial exposure rate at 1 meter above ground:
  - Subtract non-terrestrial contributions from cosmic rays and airborne radon/radon daughter products
  - Extrapolate counts seen in detector to equivalent counts on ground
  - Convert counts per second to exposure rate using empirically determined conversion factor (relies on some ground measurements)
- Anthropogenic extractions:
  - Radioactive elements that don’t occur naturally tend to have gamma signatures in the low-energy end of the spectrum
  - Calculate a metric that is > 0 when there is relative excess in the low end of the spectrum (as compared to an average background spectrum)
- Isotopic extractions:
  - For each isotope we see spectral evidence of, calculate a metric that is > 0 when there is a relative excess in its signature spectral peak (as compared to an average background spectrum)

For all three cases, interpolate points into a contour map

Terrestrial Exposure Rate Maps

- Background terrestrial exposure rates typically fall within 2–5 μR/h (excludes cosmic rays and airborne radon) in areas where no radioactive contamination would be expected
- Very slight visual evidence of "cesium prong" extending northwest from WVDP site
- Elevated terrestrial exposure rates (6–8 μR/h) extend north from WVDP to where Frank's & Buttermilk Creeks meet
  - 6–8 μR/h is comparable to variations seen elsewhere in survey area
- Apparent elevated exposure rates (6–8 μR/h) seen in Zoar Valley area
  - No corresponding evidence of cesium-137 in spectra from this area
  - Likely effect of terrain features
- All other areas consistent with expected normal variations in natural background
- Except for areas on the WVDP site, our ground measurements of exposure rate agreed with values extracted from aerial data



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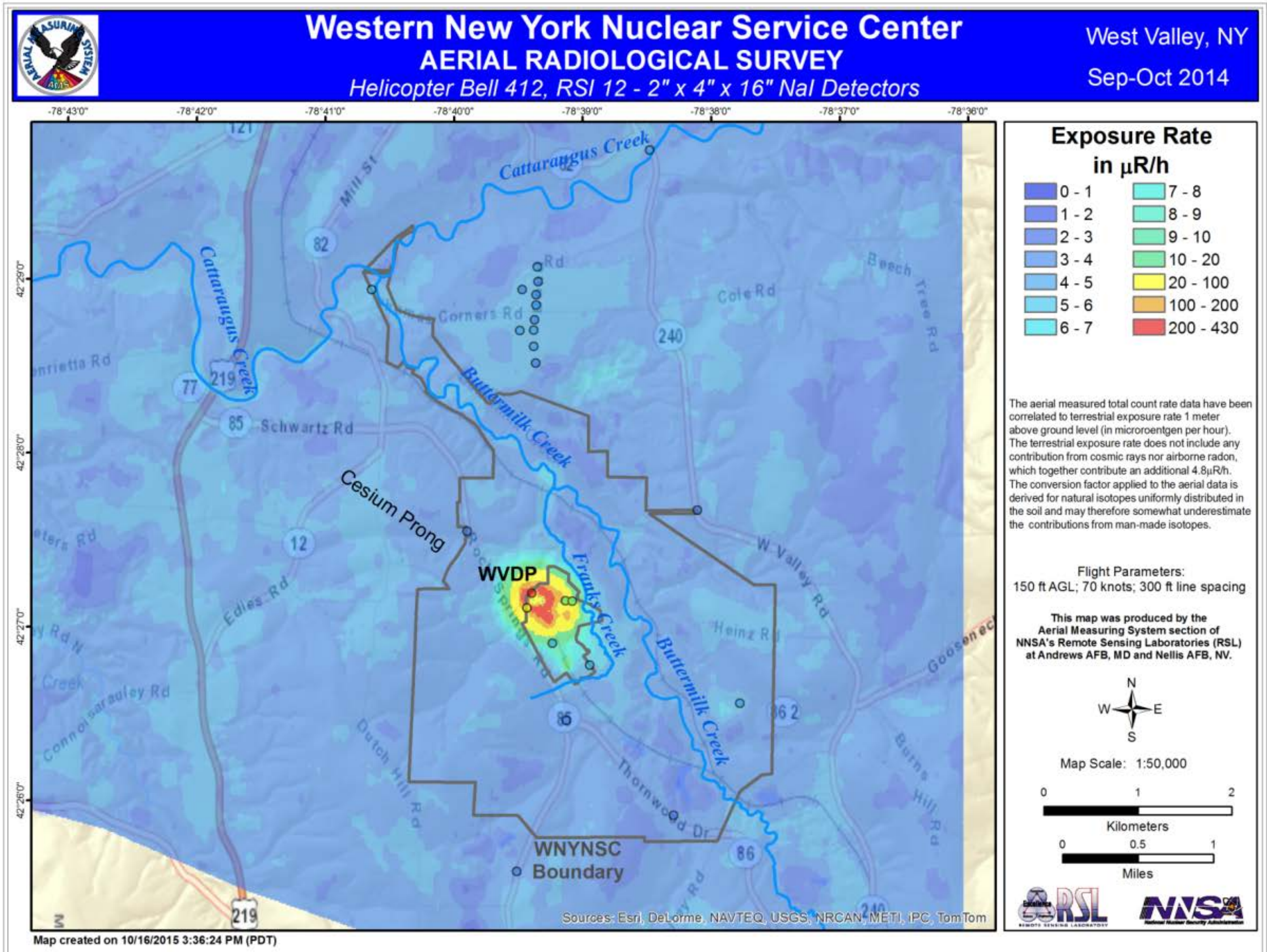
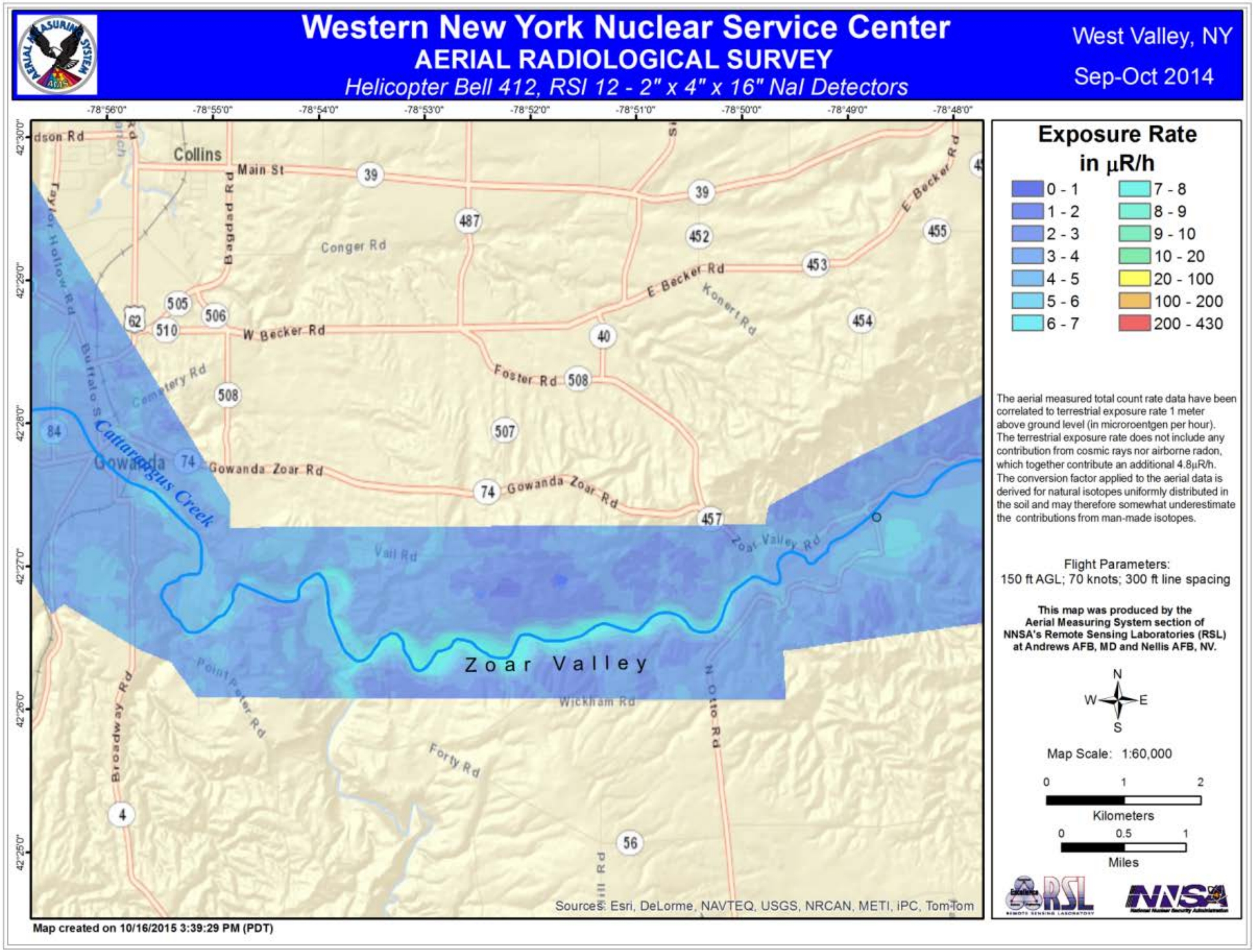

Western New York Nuclear Service Center
AERIAL RADIOLOGICAL SURVEY
Helicopter Bell 412, RSI 12 - 2" x 4" x 16" NaI Detectors
West Valley, NY
Sep-Oct 2014
Exposure Rate in μR/h
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10
10 - 20
20 - 100
100 - 200
200 - 430
The aerial measured total count rate data have been correlated to terrestrial exposure rate 1 meter above ground level (in microroentgen per hour). The terrestrial exposure rate does not include any contribution from cosmic rays nor airborne radon, which together contribute an additional 4.8μR/h. The conversion factor applied to the aerial data is derived for natural isotopes uniformly distributed in the soil and may therefore somewhat underestimate the contributions from man-made isotopes.
Flight Parameters:
150 ft AGL; 70 knots; 300 ft line spacing
This map was produced by the Aerial Measuring System section of NNSA's Remote Sensing Laboratories (RSL) at Andrews AFB, MD and Nellis AFB, NV.
N
W
E
S
Map Scale: 1:50,000
Kilometers
Miles
Cattaraugus Creek
Buttermilk Creek
Franks Creek
Cesium Prong
WVDP
WNYNSC Boundary
Schwartz Rd
Cole Rd
W. Valley Rd
Thornwood Dr
Sources: Esri, DeLorme, NAVTEQ, USGS, NRCAN, METI, iPC, TomTom
Map created on 10/16/2015 3:36:24 PM (PDT)



Western New York Nuclear Service Center
AERIAL RADIOLOGICAL SURVEY
Helicopter Bell 412, RSI 12 - 2" x 4" x 16" NaI Detectors
West Valley, NY
Sep-Oct 2014
Exposure Rate in μR/h
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10
10 - 20
20 - 100
100 - 200
200 - 430
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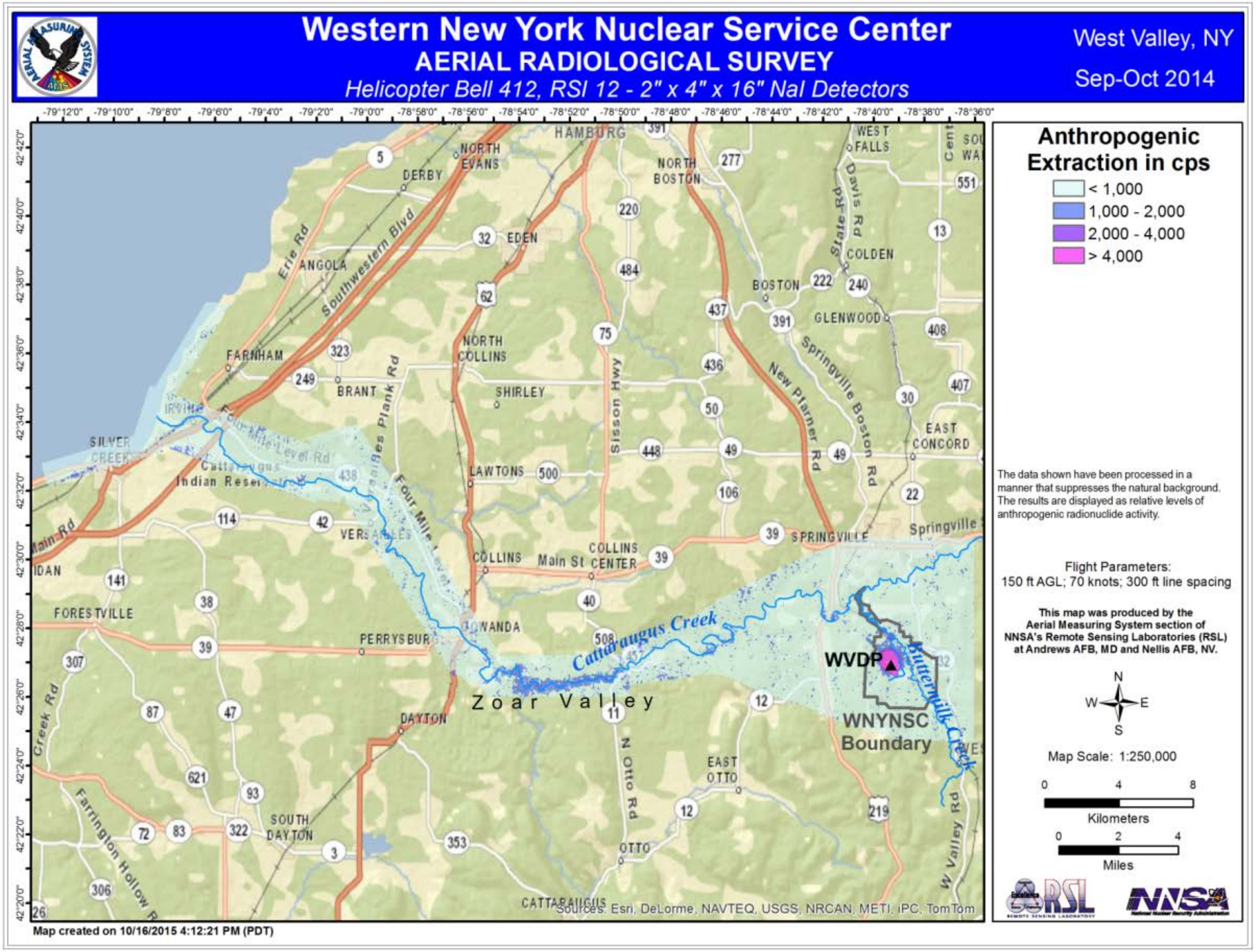
Map Scale: 1:60,000
Kilometers
Miles
Zoar Valley
Collins
Gowanda
Cattaraugus Creek
Sources: Esri, DeLorme, NAVTEQ, USGS, NRCAN, METI, iPC, TomTom
Map created on 10/16/2015 3:39:29 PM (PDT)

Anthropogenic Extraction Maps

- Background area for algorithm chosen to be circle w/ ~3500' radius approximately three miles southeast of WVDP
  - Carefully inspected spectra from this area to ensure no contaminant isotopes were observed
- Elevated areas along cesium prong and Frank's and Buttermilk Creeks more prominent compared to exposure rate maps
- Elevations (~2–4 std. dev. above background) observed in area north/northwest of Schwartz Rd
  - Don't appear to correlate with path of creek or other geographic features
  - Spectra do indicate cesium-137
- Elevations still present in Zoar Valley area, though only naturally occurring isotopes seen in spectra
- Elevations (~2–4 std. dev.) observed in wooded area south of Four Mile Level Rd.
  - Very slight indications of cesium-137 in spectra
- Algorithm is fairly sensitive to statistical fluctuations even when only naturally occurring isotopes are present (many false positives)


Western New York Nuclear Service Center
AERIAL RADIOLOGICAL SURVEY
Helicopter Bell 412, RSI 12 - 2" x 4" x 16" NaI Detectors
West Valley, NY
Sep-Oct 2014
Anthropogenic Extraction in cps
< 1,000
1,000 - 2,000
2,000 - 4,000
> 4,000
The data shown have been processed in a manner that suppresses the natural background. The results are displayed as relative levels of anthropogenic radionuclide activity.
Flight Parameters:
150 ft AGL; 70 knots; 300 ft line spacing
This map was produced by the Aerial Measuring System section of NNSA's Remote Sensing Laboratories (RSL) at Andrews AFB, MD and Nellis AFB, NV.
Map Scale: 1:250,000
Kilometers
Miles
WVDP
WNYNSC Boundary
Cattaraugus Creek
Buttermilk Creek
Zoar Valley
Sources: Esri, DeLorme, NAVTEQ, USGS, NRCAN, METI, iPC, TomTom
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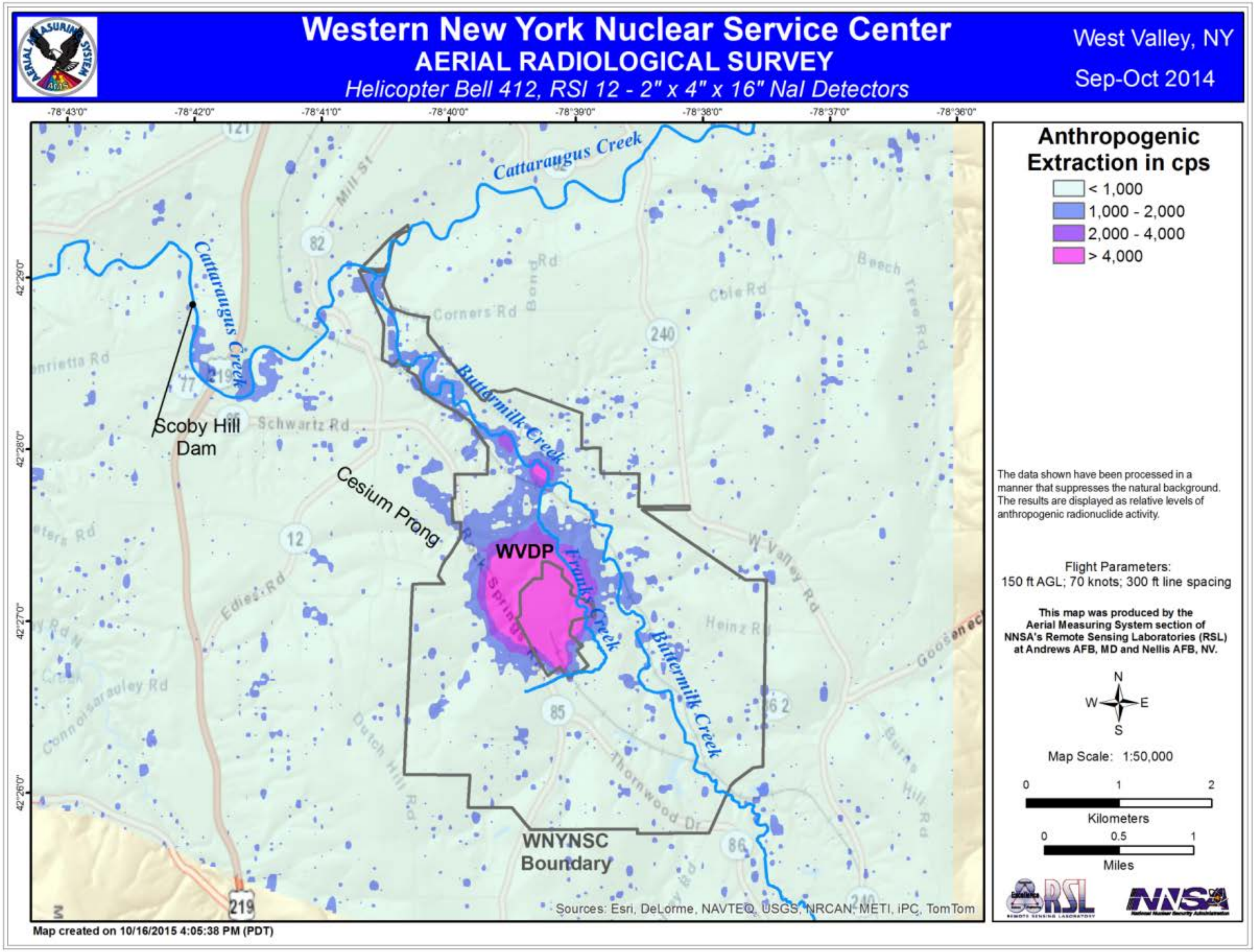
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West Valley, NY
Sep-Oct 2014
Anthropogenic Extraction in cps
< 1,000
1,000 - 2,000
2,000 - 4,000
> 4,000
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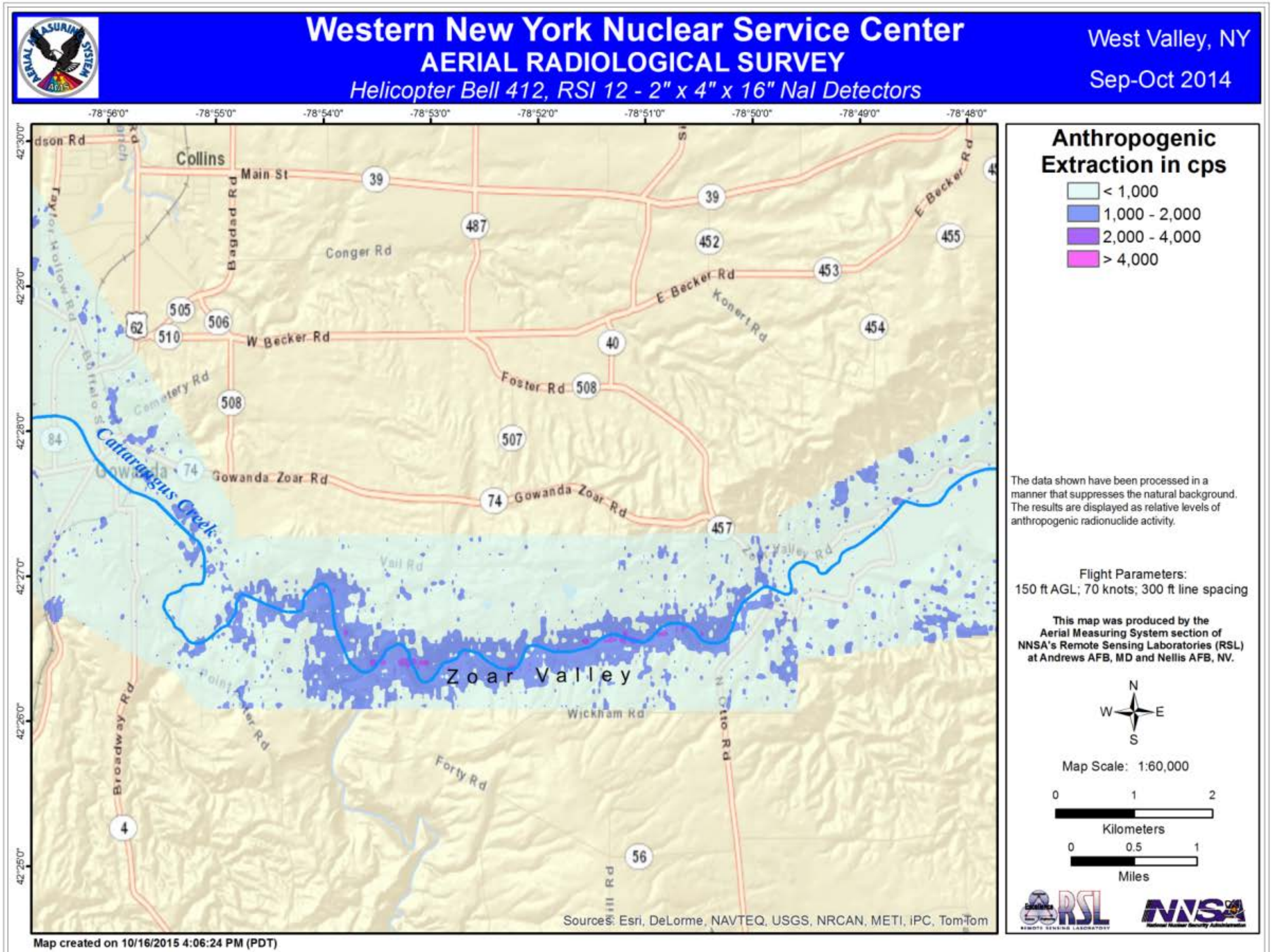
Map Scale: 1:50,000
Kilometers
Miles
Cattaraugus Creek
Buttermilk Creek
Franks Creek
Scoby Hill Dam
Cesium Prong
WVDP
WNYNSC Boundary
Schwartz Rd
Mill St
Cole Rd
Sources: Esri, DeLorme, NAVTEQ, USGS, NRCAN, METI, iPC, TomTom
Map created on 10/16/2015 4:05:38 PM (PDT)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Helicopter Bell 412, RSI 12 - 2" x 4" x 16" NaI Detectors
West Valley, NY
Sep-Oct 2014
Anthropogenic Extraction in cps
< 1,000
1,000 - 2,000
2,000 - 4,000
> 4,000
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Flight Parameters:
150 ft AGL; 70 knots; 300 ft line spacing
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Map Scale: 1:60,000
Kilometers
Miles
Collins
Zoar Valley
Cattaraugus Creek
Main St
Conger Rd
W Becker Rd
E Becker Rd
Foster Rd
Gowanda Zoar Rd
Wickham Rd
Forty Rd
Broadway Rd
Otto Rd
Sources: Esri, DeLorme, NAVTEQ, USGS, NRCAN, METI, iPC, TomTom
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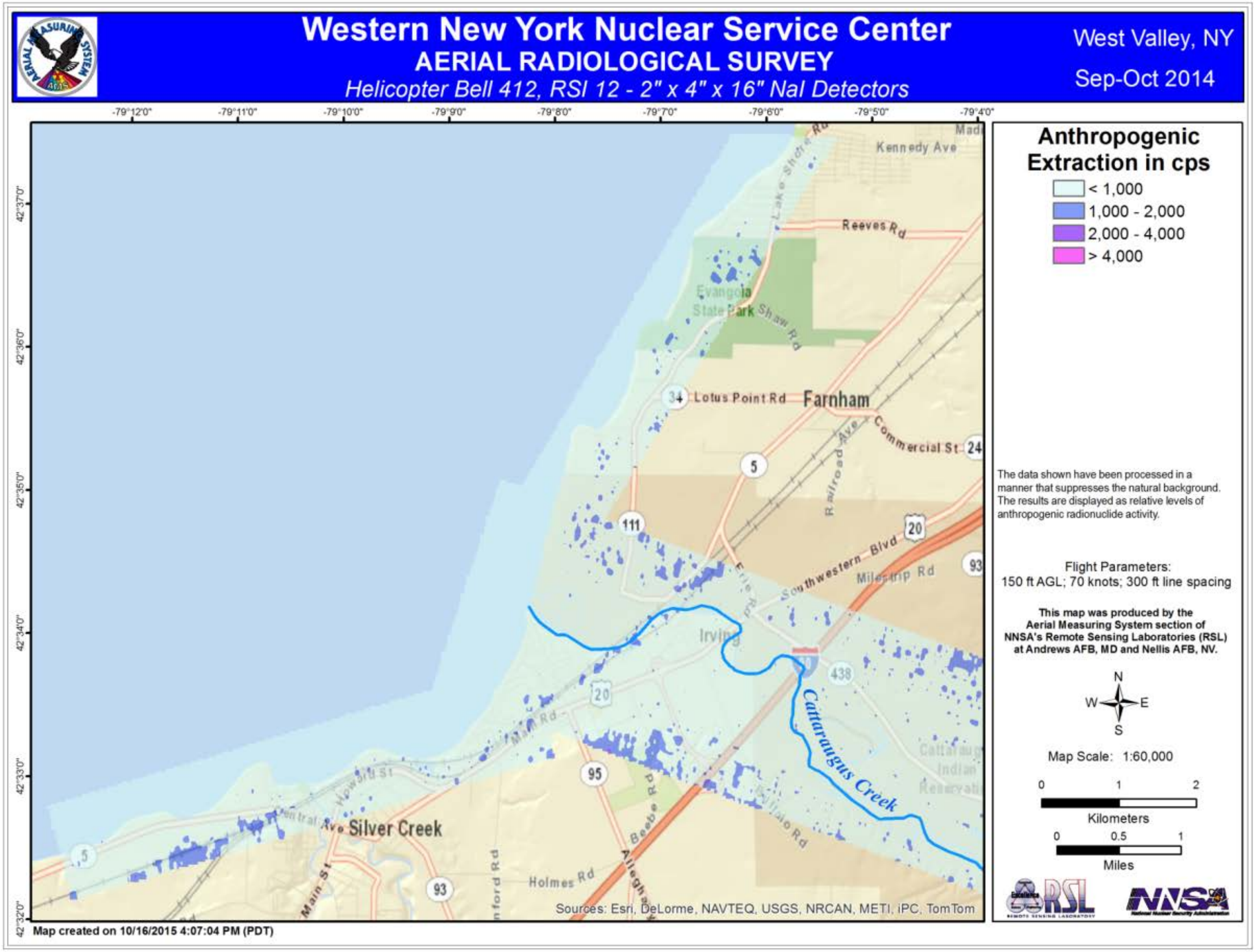
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Sep-Oct 2014
Anthropogenic Extraction in cps
< 1,000
1,000 - 2,000
2,000 - 4,000
> 4,000
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Map Scale: 1:60,000
Kilometers
Miles
Farnham
Silver Creek
Irving
Cattaraugus Creek
Evangola State Park
Lotus Point Rd
Reeves Rd
Kennedy Ave
Commercial St
Southwestern Blvd
Milestrip Rd
Holmes Rd
Sources: Esri, DeLorme, NAVTEQ, USGS, NRCAN, METI, iPC, TomTom
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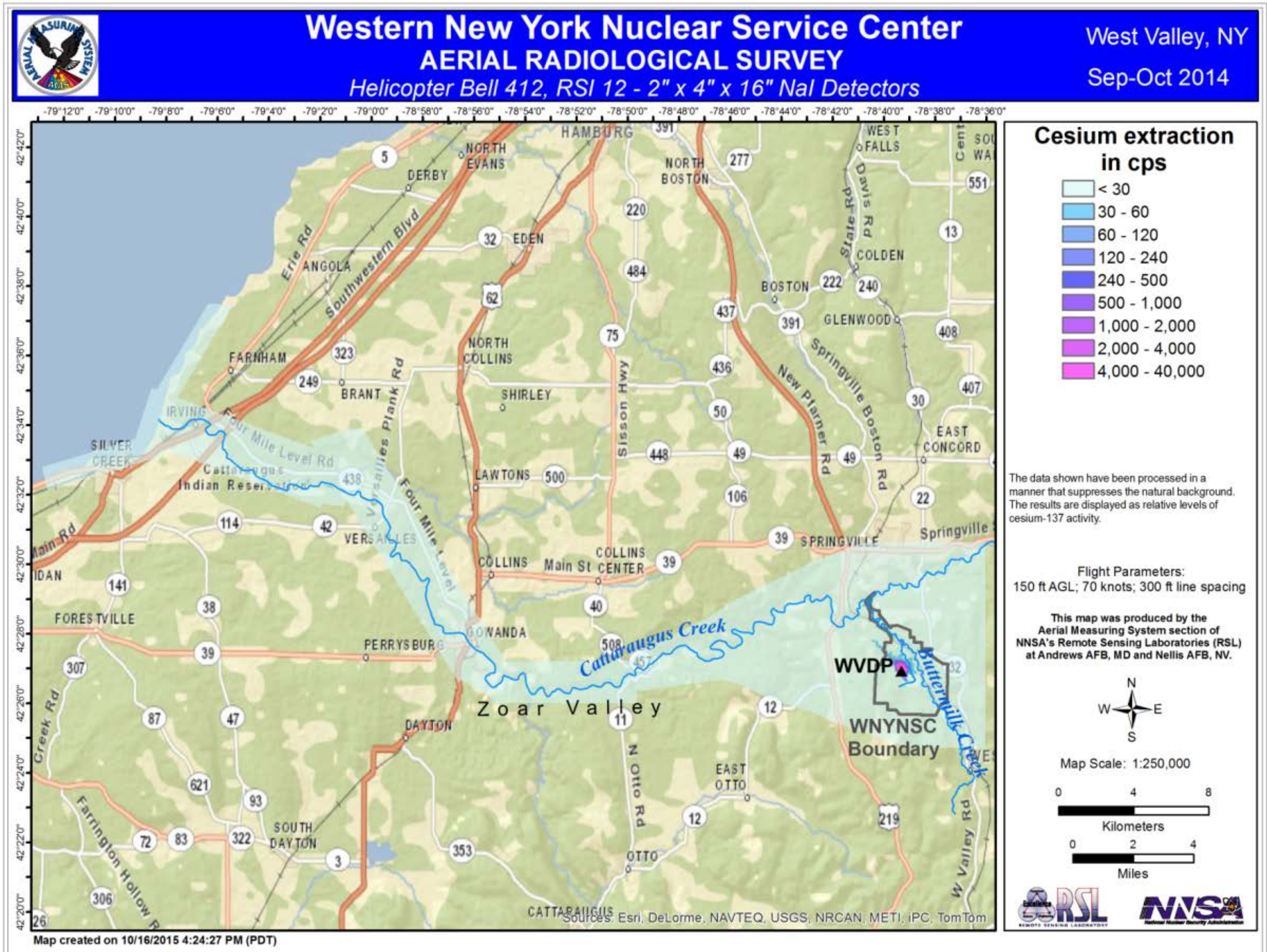
Isotopic Extraction Maps

- Primarily cesium-137 was observed
  - Cobalt-60 seen within the WVDP site
  - Technetium-99m (medical isotope) isolated signature observed over a building in Irving between Four Mile Level Rd. and Thomas Indian School Dr.
- Cesium prong much more clearly defined
- Along Buttermilk Creek, cesium signature more localized
  - Algorithm is more sensitive to isotopes present at soil surface than deeper within the soil column
- No elevations observed in Zoar Valley area
  - Supports claim that elevations seen in other analyses were artifacts of topography
- Very slight indications of cesium elevations seen north of Schwartz Rd., but not quite in the same places as anthropogenic
- Slightly elevated (~2–4 std. dev.) areas seen in wooded area south of Four Mile Level Rd.


Western New York Nuclear Service Center
AERIAL RADIOLOGICAL SURVEY
Helicopter Bell 412, RSI 12 - 2" x 4" x 16" NaI Detectors
West Valley, NY
Sep-Oct 2014
Cesium extraction in cps
< 30
30 - 60
60 - 120
120 - 240
240 - 500
500 - 1,000
1,000 - 2,000
2,000 - 4,000
4,000 - 40,000
The data shown have been processed in a manner that suppresses the natural background. The results are displayed as relative levels of cesium-137 activity.
Flight Parameters:
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Map Scale: 1:250,000
Kilometers
Miles
WVDP
WNYNSC Boundary
Cattaraugus Creek
Buttermilk Creek
Zoar Valley
Sources: Esri, DeLorme, NAVTEQ, USGS, NRCAN, METI, iPC, TomTom
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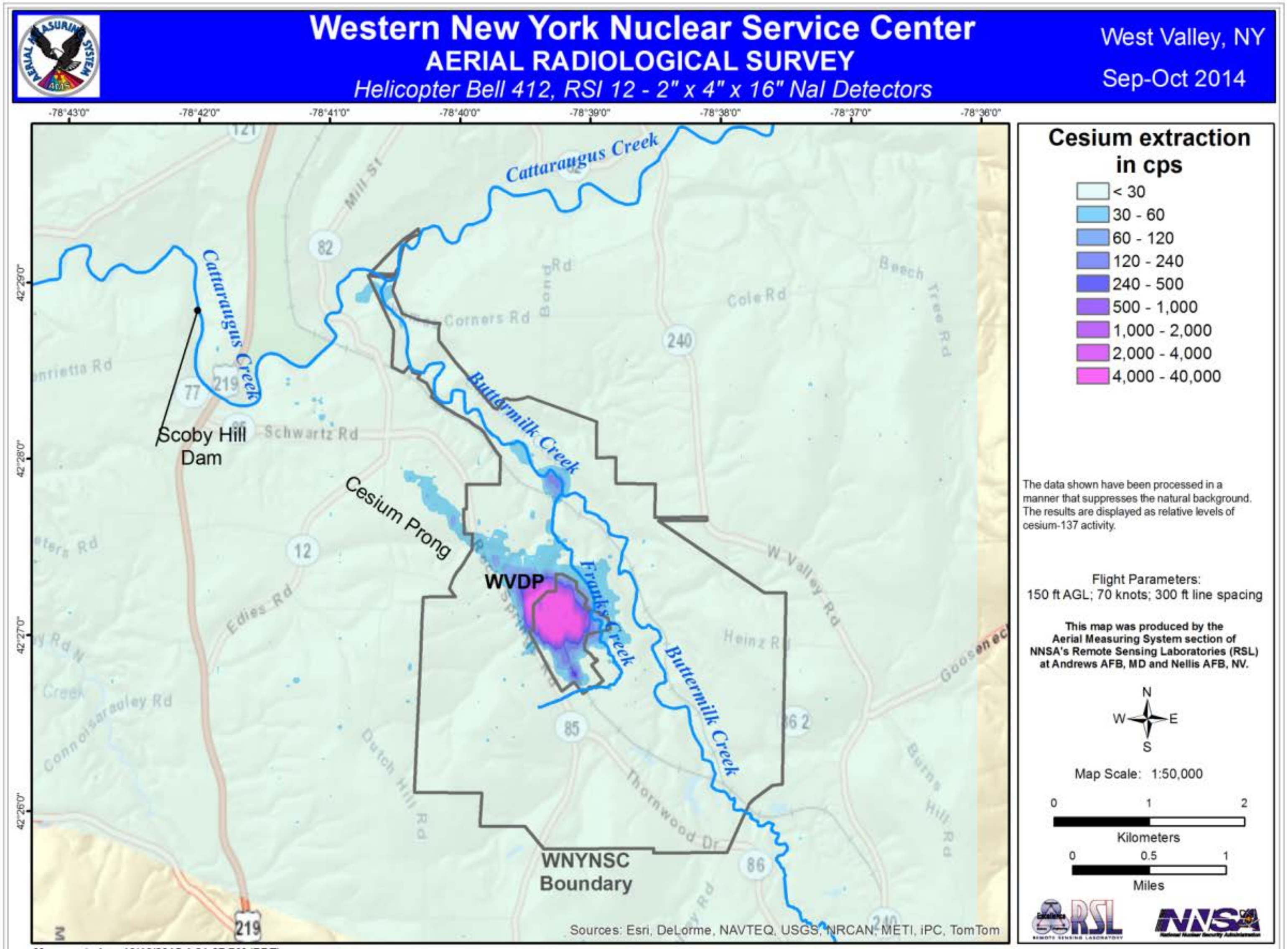

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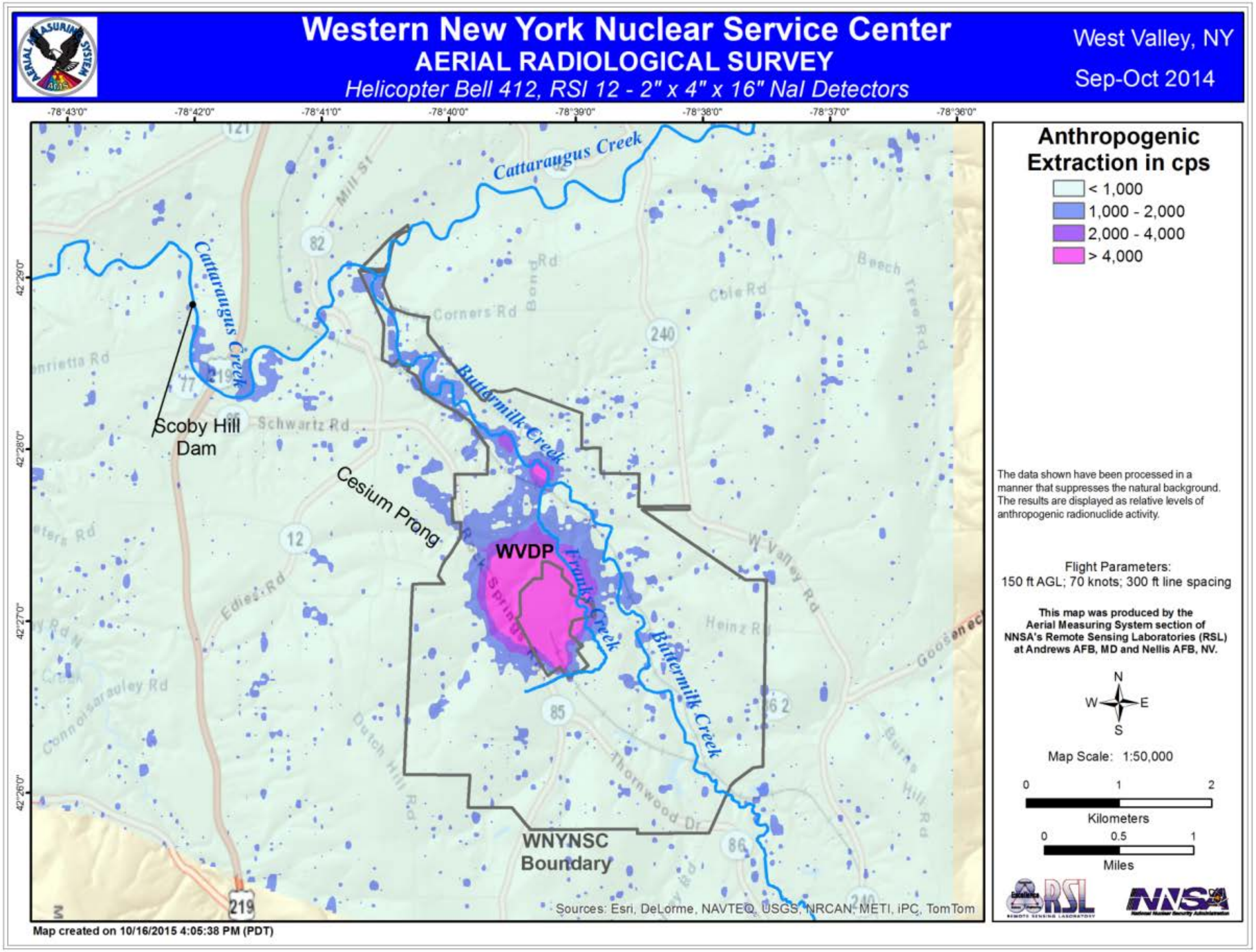
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West Valley, NY
Sep-Oct 2014
Anthropogenic Extraction in cps
< 1,000
1,000 - 2,000
2,000 - 4,000
> 4,000
Cattaraugus Creek
Buttermilk Creek
Franks Creek
Scoby Hill Dam
Cesium Prong
WVDP
WNYNSC Boundary
The data shown have been processed in a manner that suppresses the natural background. The results are displayed as relative levels of anthropogenic radionuclide activity.
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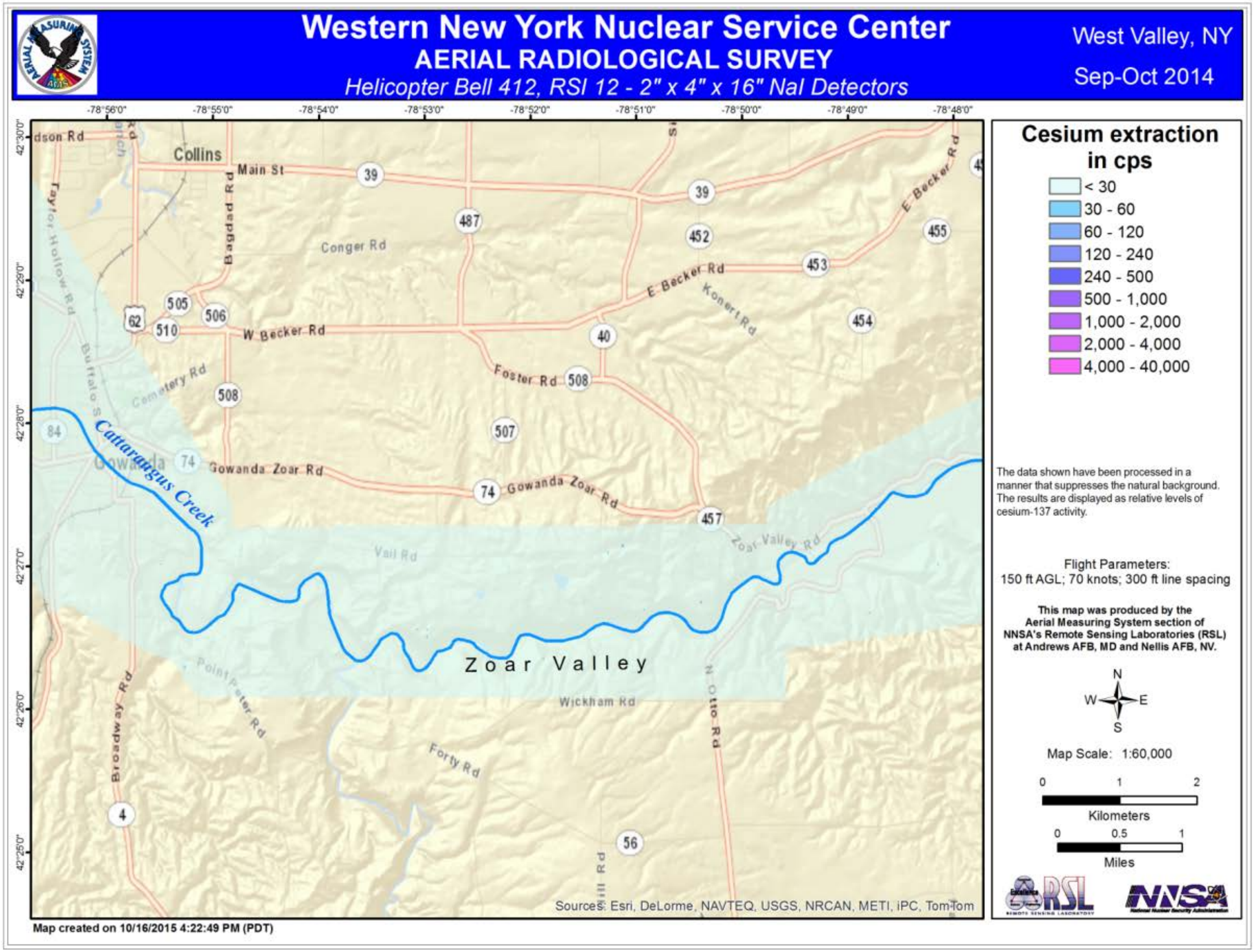
Map Scale: 1:50,000
Kilometers
Miles
Sources: Esri, DeLorme, NAVTEQ, USGS, NRCAN, METI, iPC, TomTom
Map created on 10/16/2015 4:05:38 PM (PDT)



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West Valley, NY
Sep-Oct 2014
Cesium extraction in cps
< 30
30 - 60
60 - 120
120 - 240
240 - 500
500 - 1,000
1,000 - 2,000
2,000 - 4,000
4,000 - 40,000
The data shown have been processed in a manner that suppresses the natural background. The results are displayed as relative levels of cesium-137 activity.
Flight Parameters:
150 ft AGL; 70 knots; 300 ft line spacing
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Map Scale: 1:60,000
Kilometers
Miles
Collins
Zoar Valley
Cattaraugus Creek
Sources: Esri, DeLorme, NAVTEQ, USGS, NRCAN, METI, iPC, TomTom
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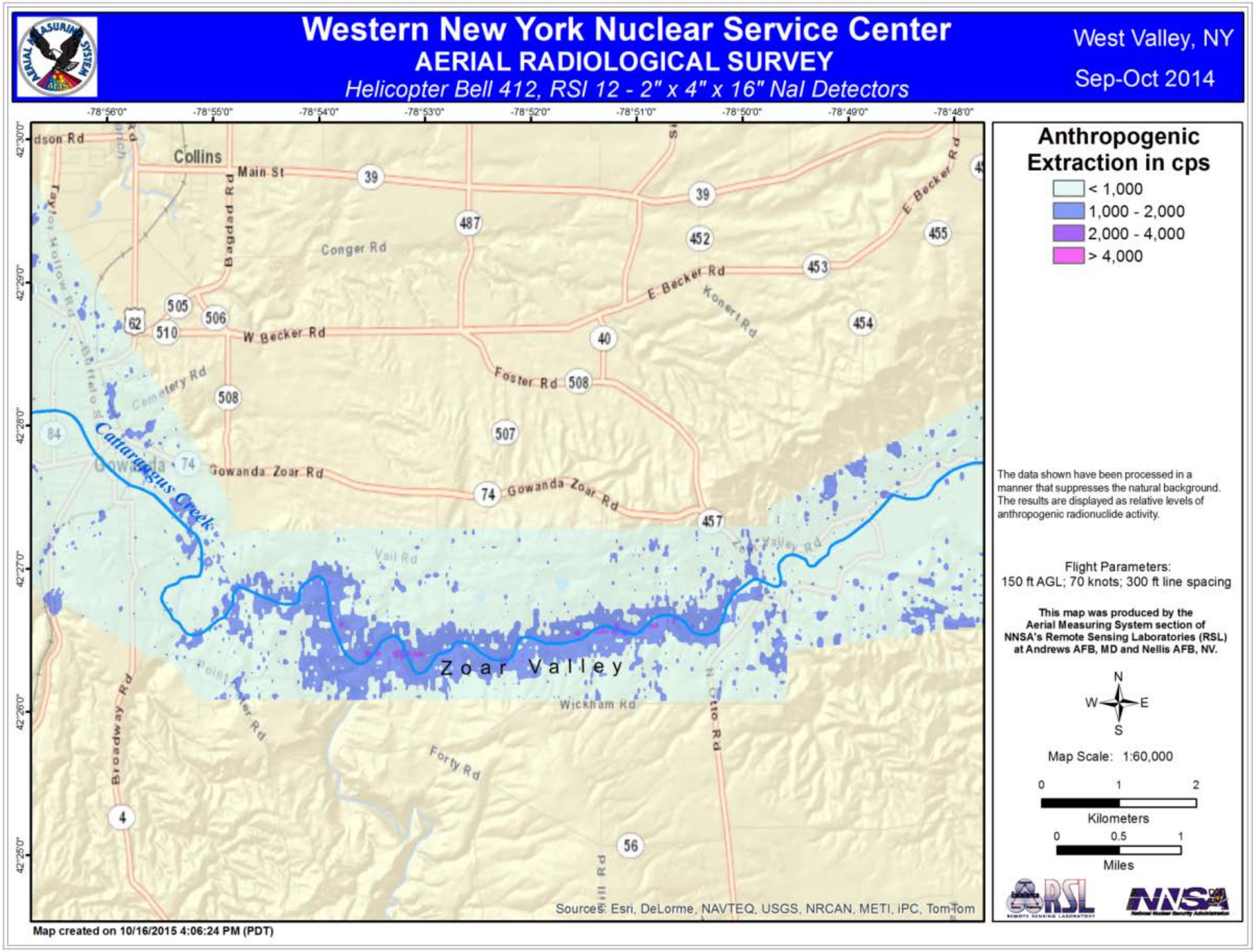

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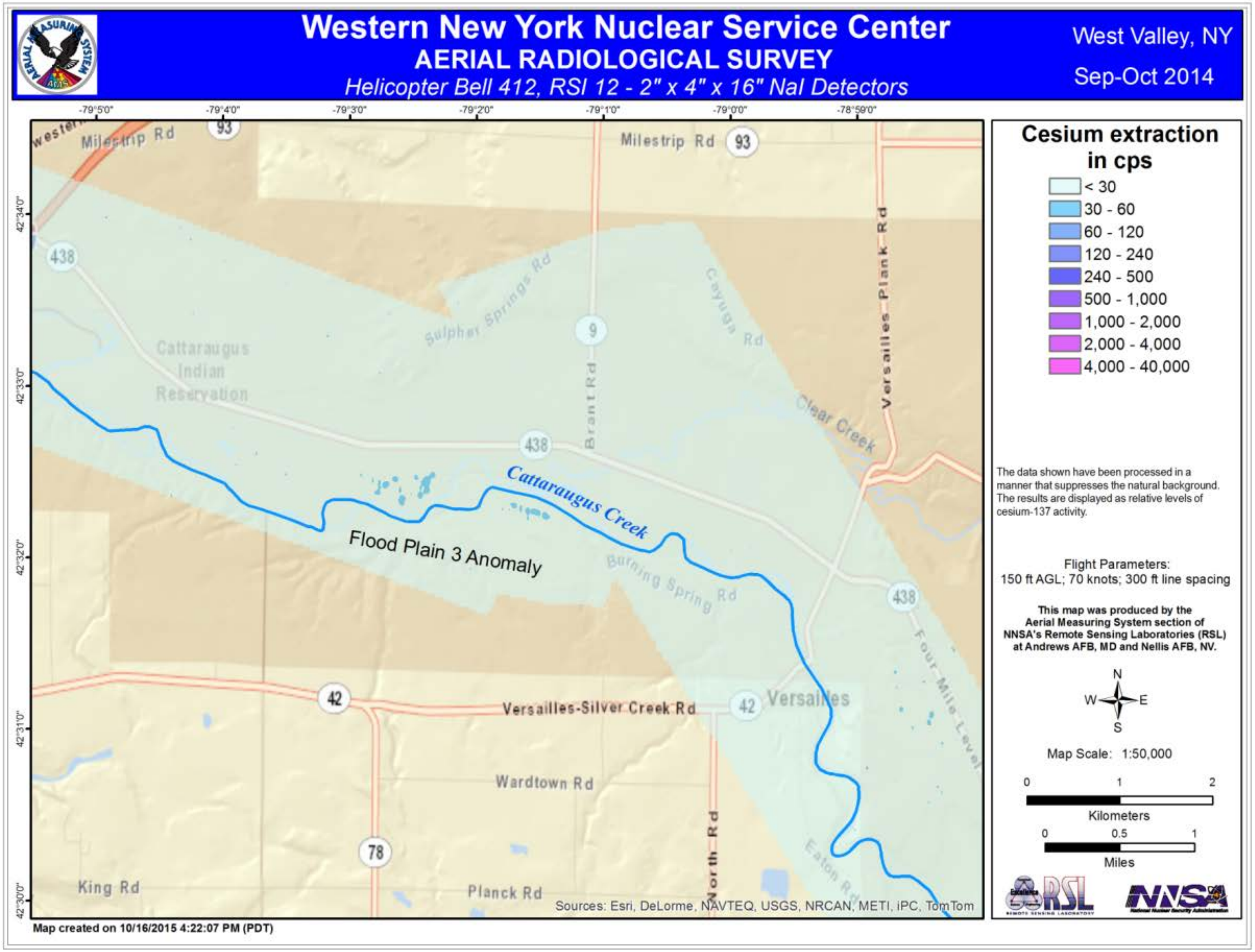

Western New York Nuclear Service Center
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West Valley, NY
Sep-Oct 2014
Cesium extraction in cps
< 30
30 - 60
60 - 120
120 - 240
240 - 500
500 - 1,000
1,000 - 2,000
2,000 - 4,000
4,000 - 40,000
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Map Scale: 1:50,000
Kilometers
Miles
Flood Plain 3 Anomaly
Cattaraugus Creek
Cattaraugus Indian Reservation
Milestrip Rd
Versailles-Silver Creek Rd
Wardtown Rd
King Rd
Planck Rd
Versailles
Sources: Esri, DeLorme, NAVTEQ, USGS, NRCAN, METI, iPC, TomTom
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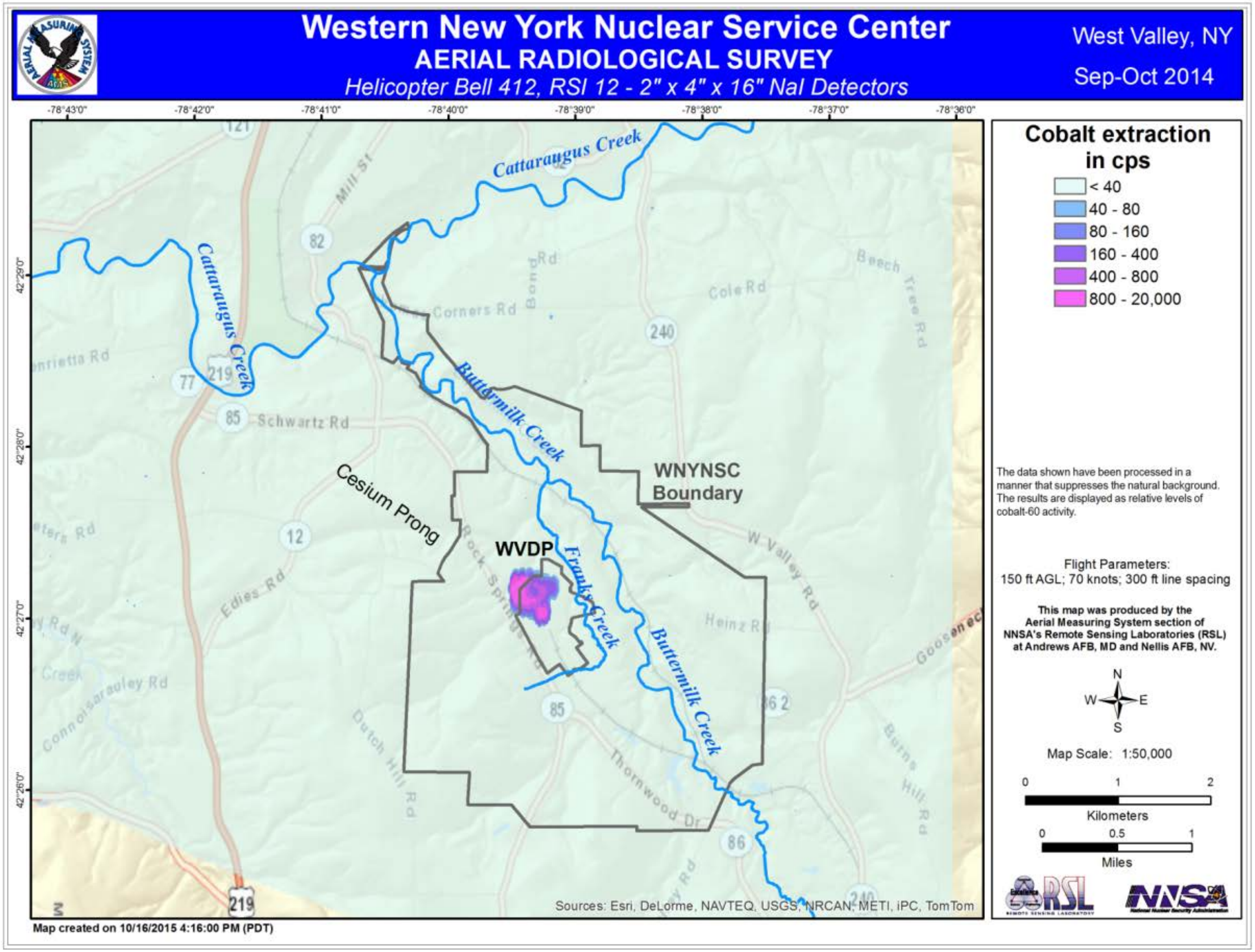
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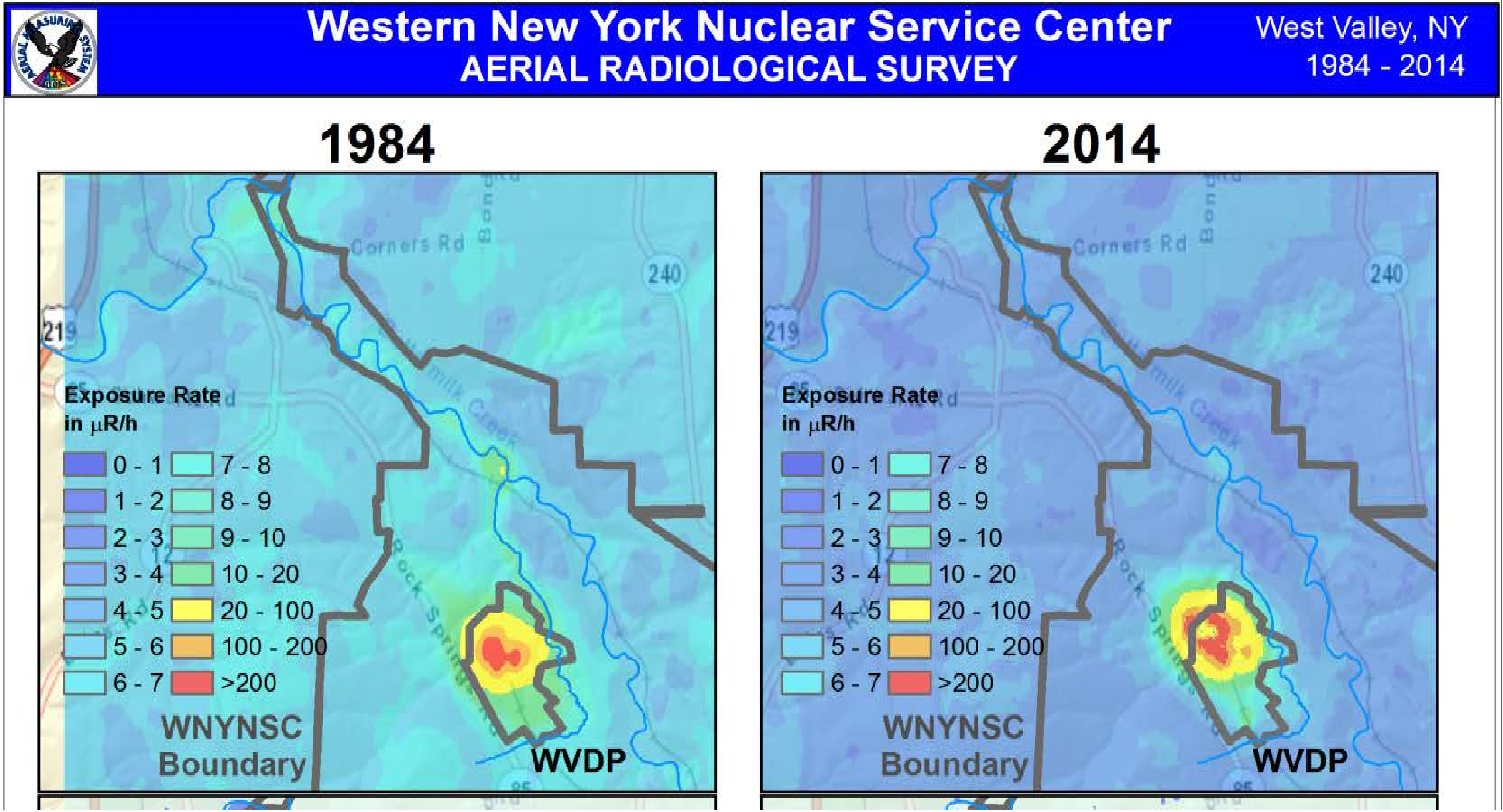
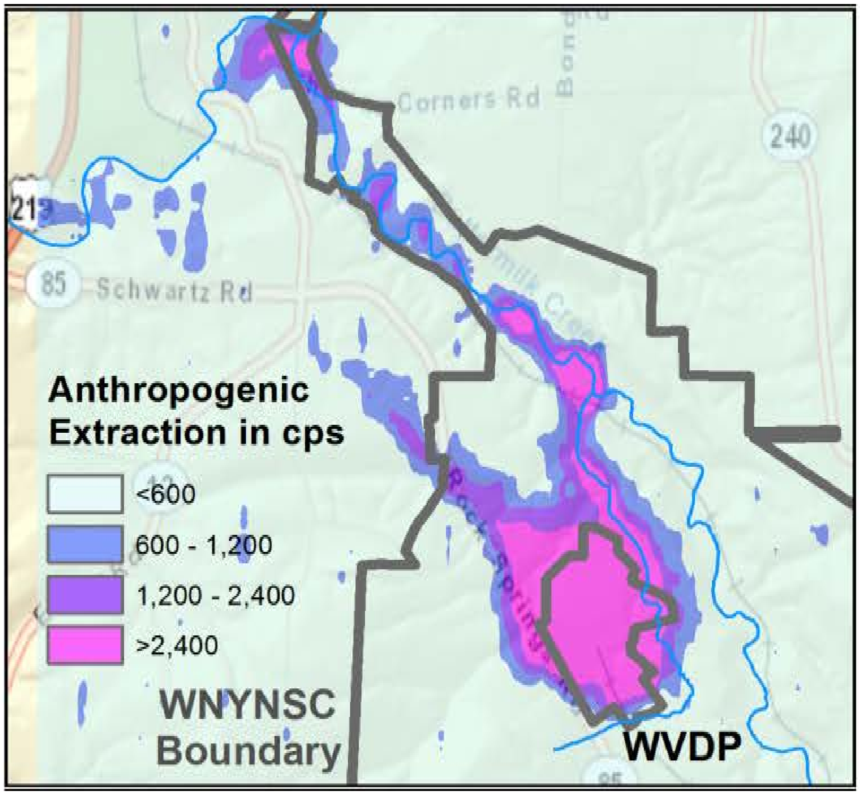
Helicopter Bell 412, RSI 12 - 2" x 4" x 16" NaI Detectors
West Valley, NY
Sep-Oct 2014
Cobalt extraction in cps
< 40
40 - 80
80 - 160
160 - 400
400 - 800
800 - 20,000
The data shown have been processed in a manner that suppresses the natural background. The results are displayed as relative levels of cobalt-60 activity.
Flight Parameters: 150 ft AGL; 70 knots; 300 ft line spacing
This map was produced by the Aerial Measuring System section of NNSA's Remote Sensing Laboratories (RSL) at Andrews AFB, MD and Nellis AFB, NV.
Map Scale: 1:50,000
Kilometers
Miles
Cattaraugus Creek
Buttermilk Creek
Franks Creek
WNYNSC Boundary
Cesium Prong
WVDP
Schwartz Rd
Cole Rd
Heinz Rd
W Valley Rd
Thornwood Dr
Dutch Hill Rd
Edies Rd
Sources: Esri, DeLorme, NAVTEQ, USGS, NRCAN, METI, iPC, TomTom
Map created on 10/16/2015 4:16:00 PM (PDT)

Comparison: Exposure Rate

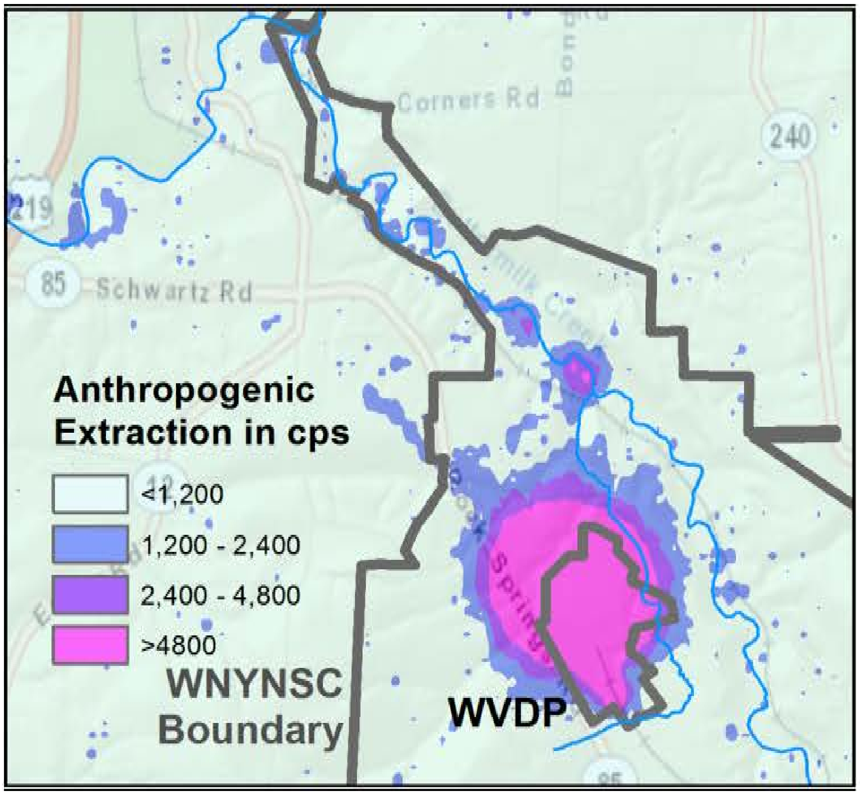


Comparison: Anthropogenic

1984

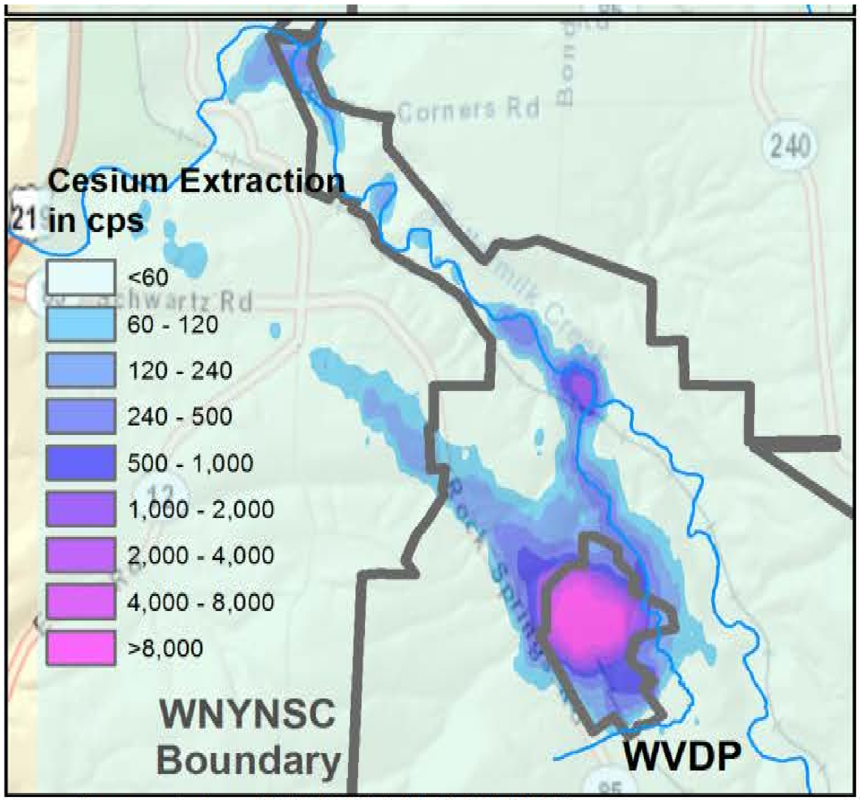


2014



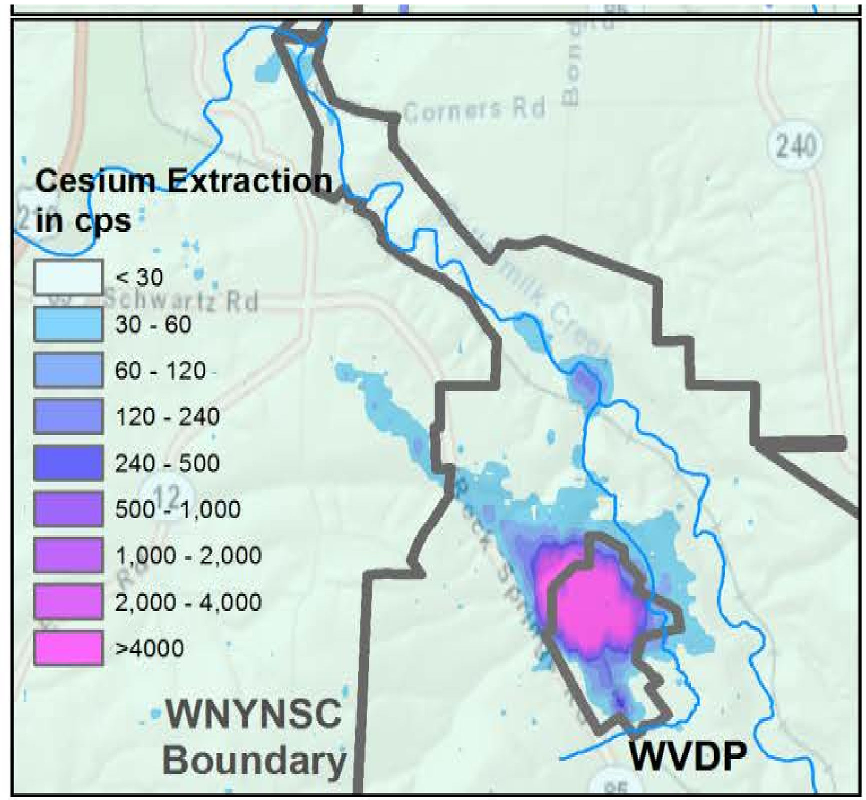
Comparison: Cesium-137

1984

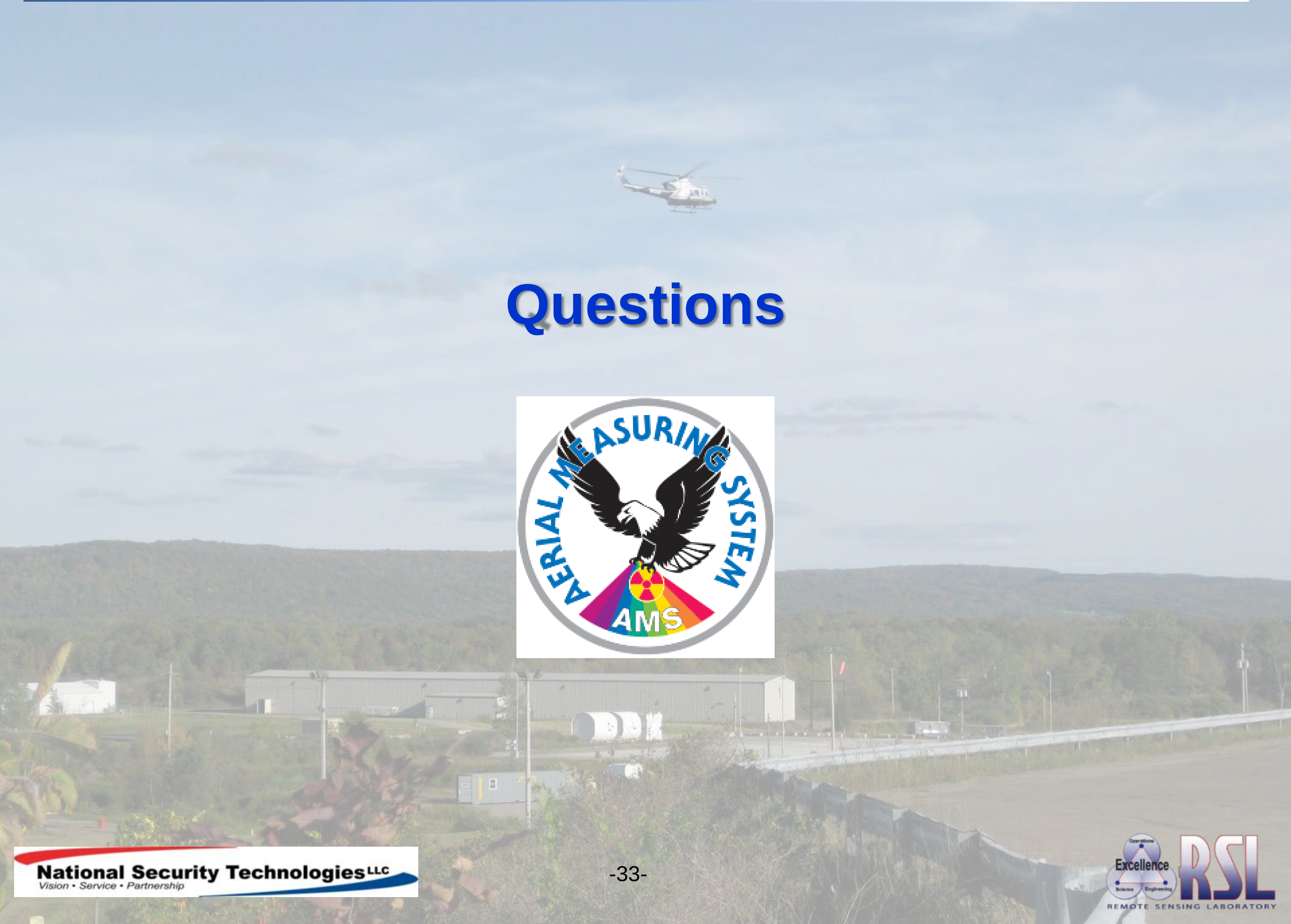


Map created on 10/16/2015 4:45:41 PM (PDT)

2014



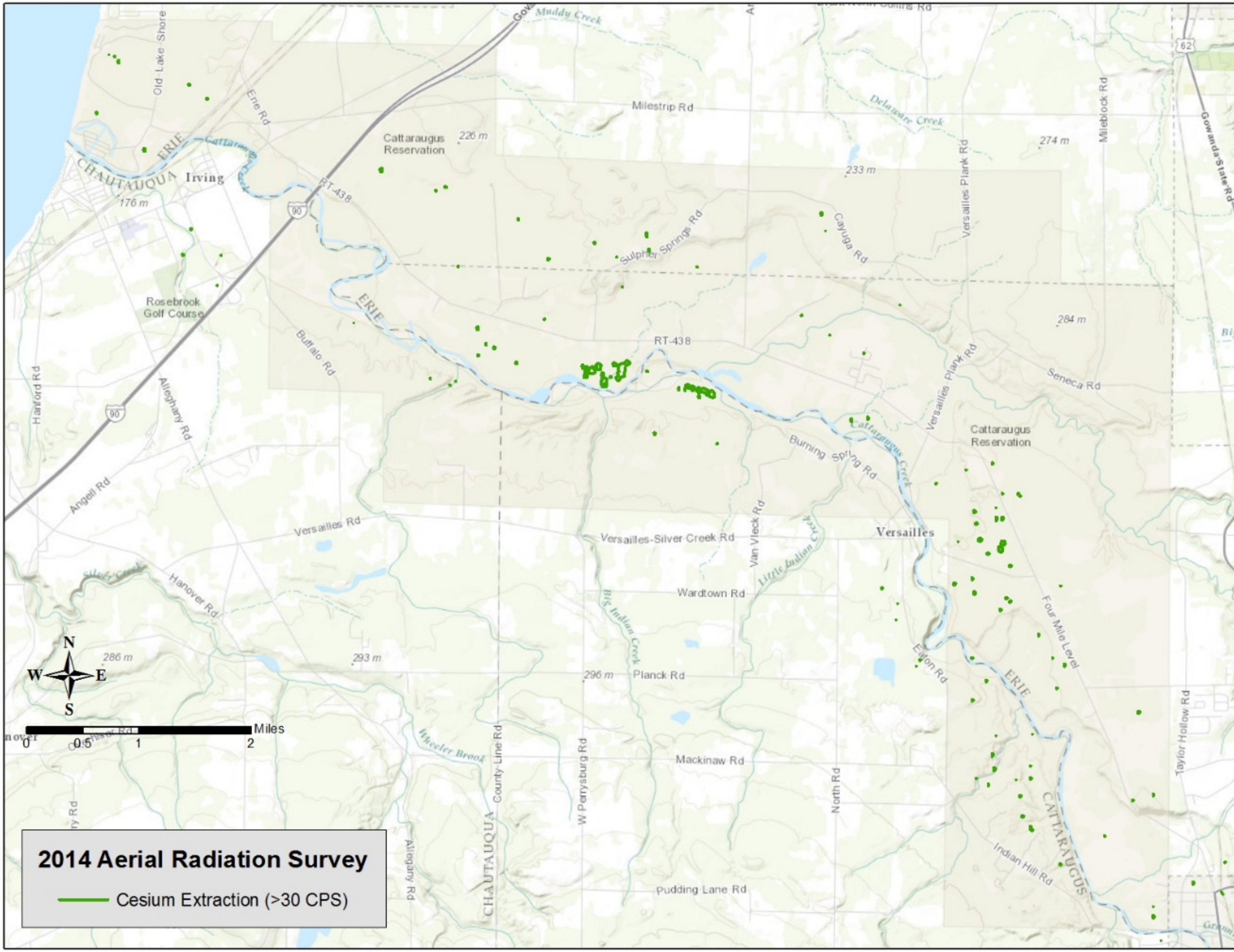
Questions



Identification of Areas for Follow-Up

- Individual metrics by themselves are more or less susceptible to statistical noise depending on what you need to be able to measure
  - Reasonable choice of threshold for anthropogenic algorithm still produces many false positives from varying natural elemental background and terrain features
  - Narrow windows in 3-window cesium extraction can produce false negatives, e.g. where cesium is deeper in soil (down-scattered photons, fewer in photopeak)
- Consider some combination of the two metrics. How?
  - One possibility: investigate where the two overlap; make some reasonable assumptions about the geographic proximity and spatial averaging effect of aerial measurements
- Expected/desired result is a bounding case

Note: spectral data was always examined in parallel


2014 Aerial Radiation Survey
Cesium Extraction (>30 CPS)
Miles
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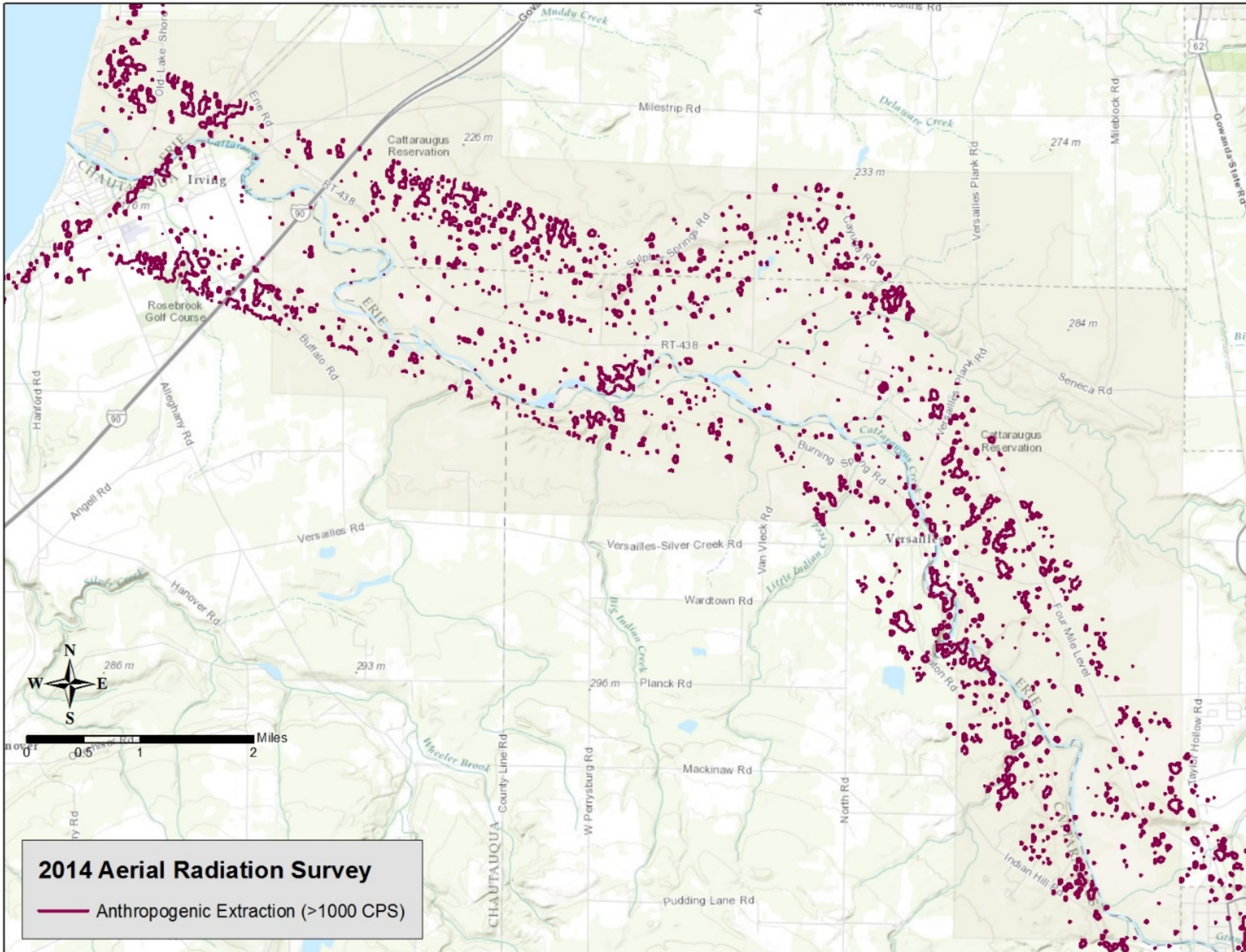
Cattaraugus Reservation
Irving
Rosebrook Golf Course
Versailles
Milestrip Rd
Sulpher Springs Rd
RT-438
Cayuga Rd
Seneca Rd
Burning Spring Rd
Versailles Rd
Versailles-Silver Creek Rd
Wardtown Rd
Planck Rd
Mackinaw Rd
Pudding Lane Rd
Four Mile Level
Indian Hill Rd
Eaton Rd
Van Vleck Rd
North Rd
County Line Rd
W Perrysburg Rd
Allegany Rd
Angell Rd
Buffalo Rd
Hanover Rd
Hanford Rd
Erie Rd
Old Lake Shore
Versailles Plank Rd
Mileblock Rd
Gowanda State Rd
Taylor Hollow Rd
Muddy Creek
Delaware Creek
Cattaraugus Creek
Big Indian Creek
Little Indian Creek
Silver Creek
Wheeler Brook
ERIE
CHAUTAUQUA
CATTARAUGUS
226 m
233 m
274 m
284 m
176 m
286 m
293 m
296 m


2014 Aerial Radiation Survey
Anthropogenic Extraction (>1000 CPS)
Miles
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Cattaraugus Reservation
Irving
Rosebrook Golf Course
Milestrip Rd
Delaware Creek
Muddy Creek
Sulphur Springs Rd
RT-438
Buffalo Rd
Allegheny Rd
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Big Indian Creek
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Mackinaw Rd
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Seneca Rd
Versailles Plank Rd
Four Mile Level
Indian Hill Rd
Mileblock Rd
Gowanda State Rd
Taylor Hollow Rd
Old Lake Shore
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Cattaraugus Creek
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274 m
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286 m
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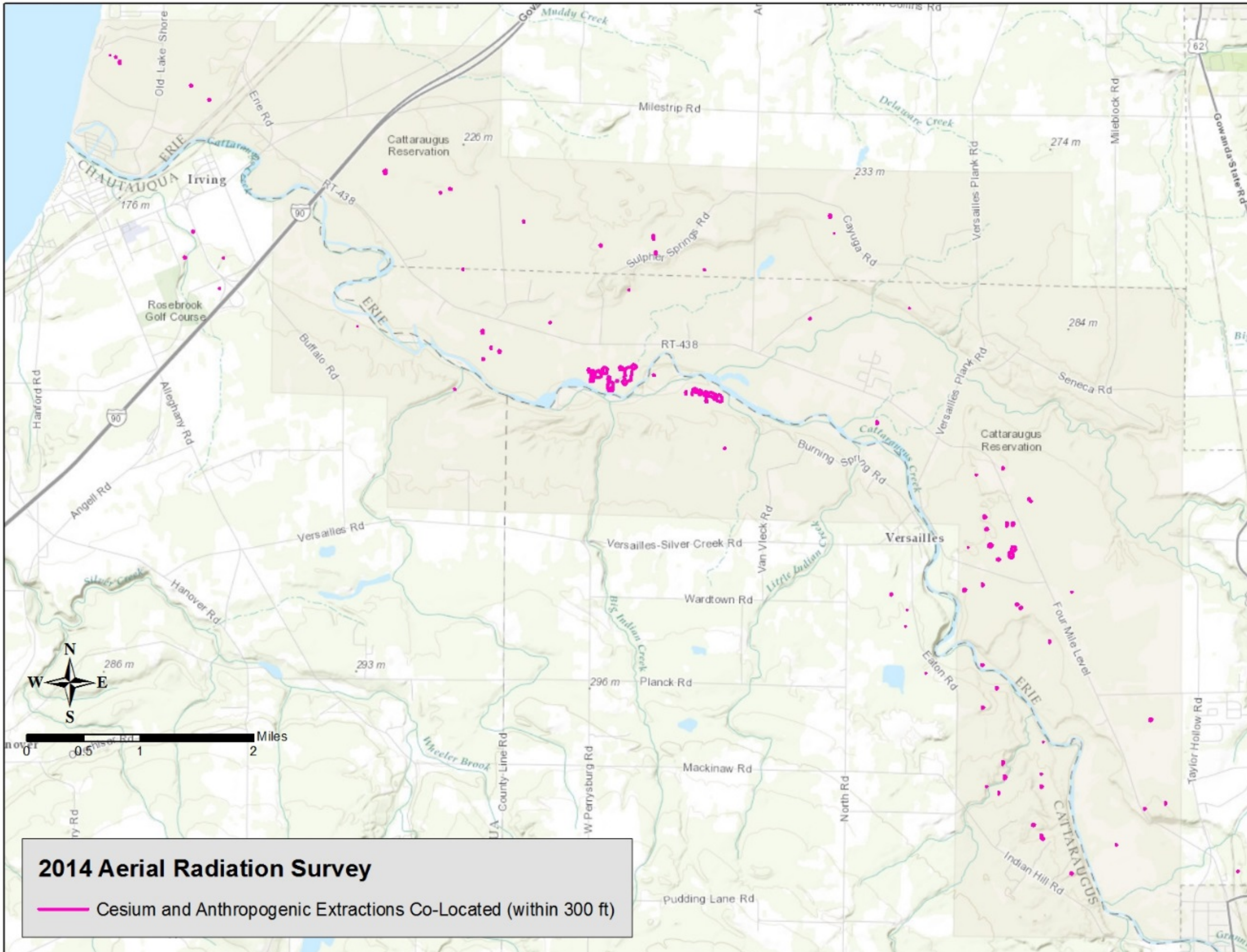

2014 Aerial Radiation Survey
Cesium and Anthropogenic Extractions Co-Located (within 300 ft)
Miles
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0.5
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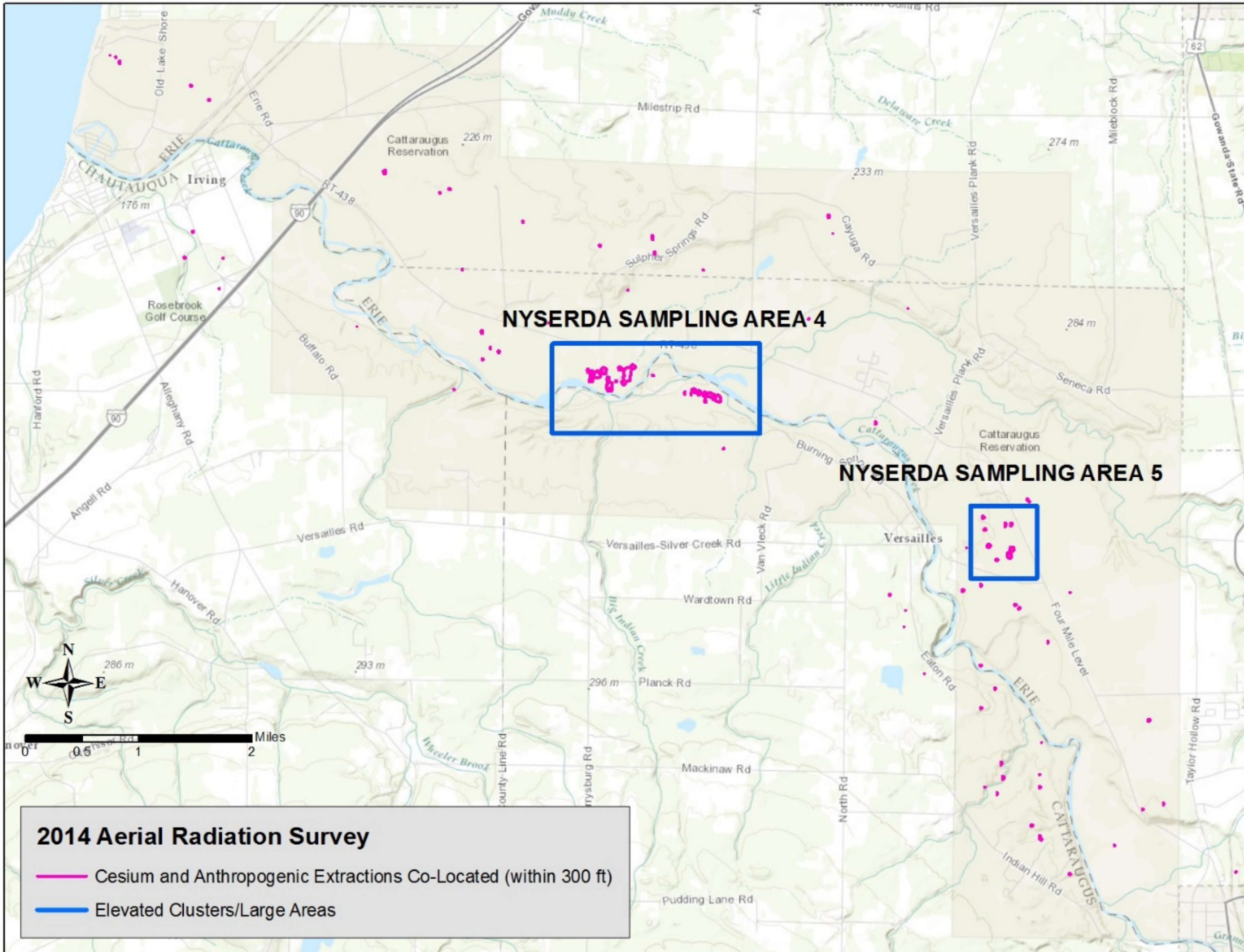
Cattaraugus Reservation
Irving
Rosebrook Golf Course
Versailles
Milestrip Rd
Sulpher Springs Rd
Cayuga Rd
Versailles Plank Rd
Seneca Rd
Burning Spring Rd
Versailles Rd
Versailles-Silver Creek Rd
Van Vleck Rd
Wardtown Rd
Hanover Rd
Planck Rd
Mackinaw Rd
Pudding Lane Rd
Indian Hill Rd
Four Mile Level
Eaton Rd
North Rd
County Line Rd
W Perrysburg Rd
Angell Rd
Allegheny Rd
Buffalo Rd
Hanford Rd
Old Lake Shore
Erie Rd
Milebock Rd
Gowanda State Rd
Taylor Hollow Rd
RT-438
Muddy Creek
Delaware Creek
Cattaraugus Creek
Little Indian Creek
Big Indian Creek
Silver Creek
Wheeler Brook
ERIE
CHAUTAUQUA
CATTARAUGUS
226 m
233 m
274 m
284 m
176 m
286 m
293 m
296 m

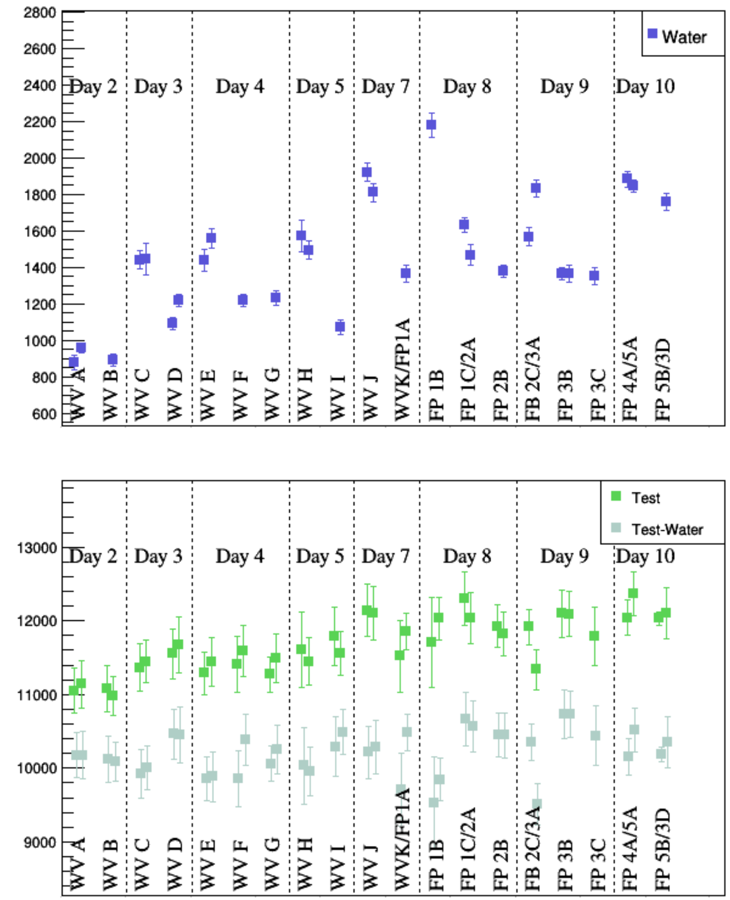

NYSERDA SAMPLING AREA 4
NYSERDA SAMPLING AREA 5
2014 Aerial Radiation Survey
Cesium and Anthropogenic Extractions Co-Located (within 300 ft)
Elevated Clusters/Large Areas
Cattaraugus Reservation
Irving
Rosebrook Golf Course
Versailles
Milestrip Rd
Sulpher Springs Rd
Cayuga Rd
Seneca Rd
Versailles Rd
Versailles-Silver Creek Rd
Wardtown Rd
Planck Rd
Mackinaw Rd
Pudding Lane Rd
Eaton Rd
Four Mile Level
Indian Hill Rd
Buffalo Rd
Allegheny Rd
Angell Rd
Hanover Rd
Van Vleck Rd
North Rd
Taylor Hollow Rd
Gowanda State Rd
Versailles Plank Rd
Erie Rd
Old Lake Shore
Hanford Rd
County Line Rd
Big Indian Creek
Little Indian Creek
Delaware Creek
Muddy Creek
Wheeler Brook
Silver Creek
RT-438
Miles
0 0.5 1 2
N S E W

Backup slides

Data Analysis: Inferred Terrestrial Exposure Rate

- Several times each day, a "water line" is flown to measure cosmic-ray and radon contributions to gamma-ray background
  - At sufficient distance from shore, counts in detector due only to cosmic rays and airborne radon (and daughters)
- Before and after each sortie, a "test line" is flown to monitor variation of count rate due to airborne radon
  - Test line candidates chosen during survey planning
  - Flat area with relatively uniform radiological signature
- Result: corrected count rates due only to terrestrial sources

Water Line (above) and Test Line (below) mean count rates, by flight



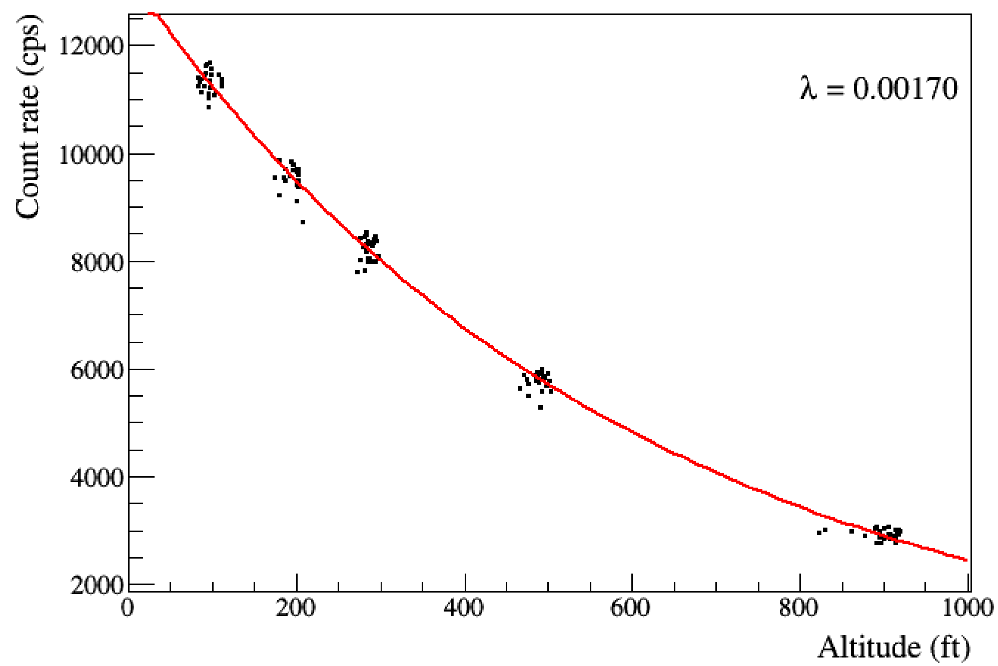
Data Analysis: Inferred Terrestrial Exposure Rate

- Gamma rays from terrestrial sources are exponentially attenuated by air
- Attenuation coefficient λ determined empirically by flying over a designated line at multiple altitudes
- Extrapolate corrected count rates down to 1 meter above ground
- Convert corrected counts at 1m to exposure rate (F = 2950 cps·h/μR)

$$C_H = (C_G - C_{NT})e^{\lambda(A-H)}$$

C_H	=	net count rate at height H above ground due to terrestrial sources (cps)
C_G	=	gross count rate measured at survey altitude (cps)
C_{NT}	=	non-terrestrial contribution to count rate from radon, cosmic rays, etc. (cps)
l	=	empirical air attenuation factor (ft^{-1})
A	=	altitude as measured by radar altimeter (ft)
H	=	height above ground at which exposure rate is inferred (1 m = 3.3 ft)

Exposure rate at 1m: $\dot{X} = \frac{C_H}{F}$



Data Analysis: Anthropogenic Extraction

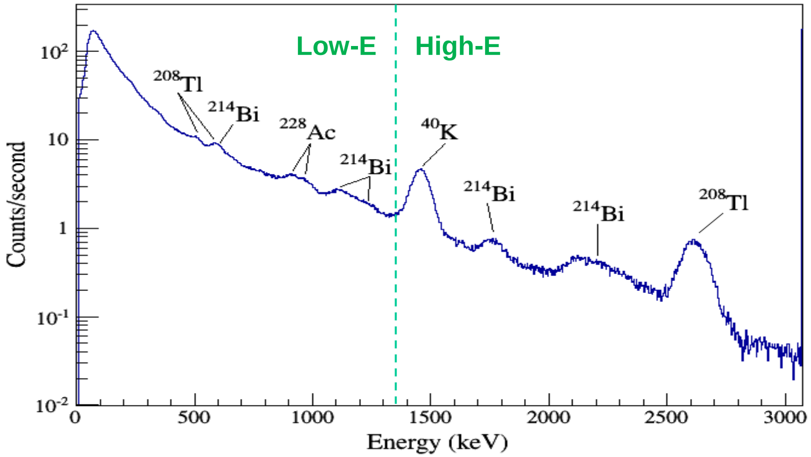
- Elevations in naturally occurring radioactive material (NORM) occur at all spectral energies, roughly uniformly
- Non-naturally occurring isotopes tend to have peaks in the low-energy end of the gamma-ray spectrum
- Anthropogenic algorithm compares low-energy (below ~1400 keV) and high-energy count rates
  - Result > 0 implies excess in low-energy end of spectrum, which may indicate non-natural sources
- Somewhat "noisy" algorithm (sensitive to statistical fluctuations)

$$C = (\text{low-energy counts}) - K \cdot (\text{high-energy counts})$$

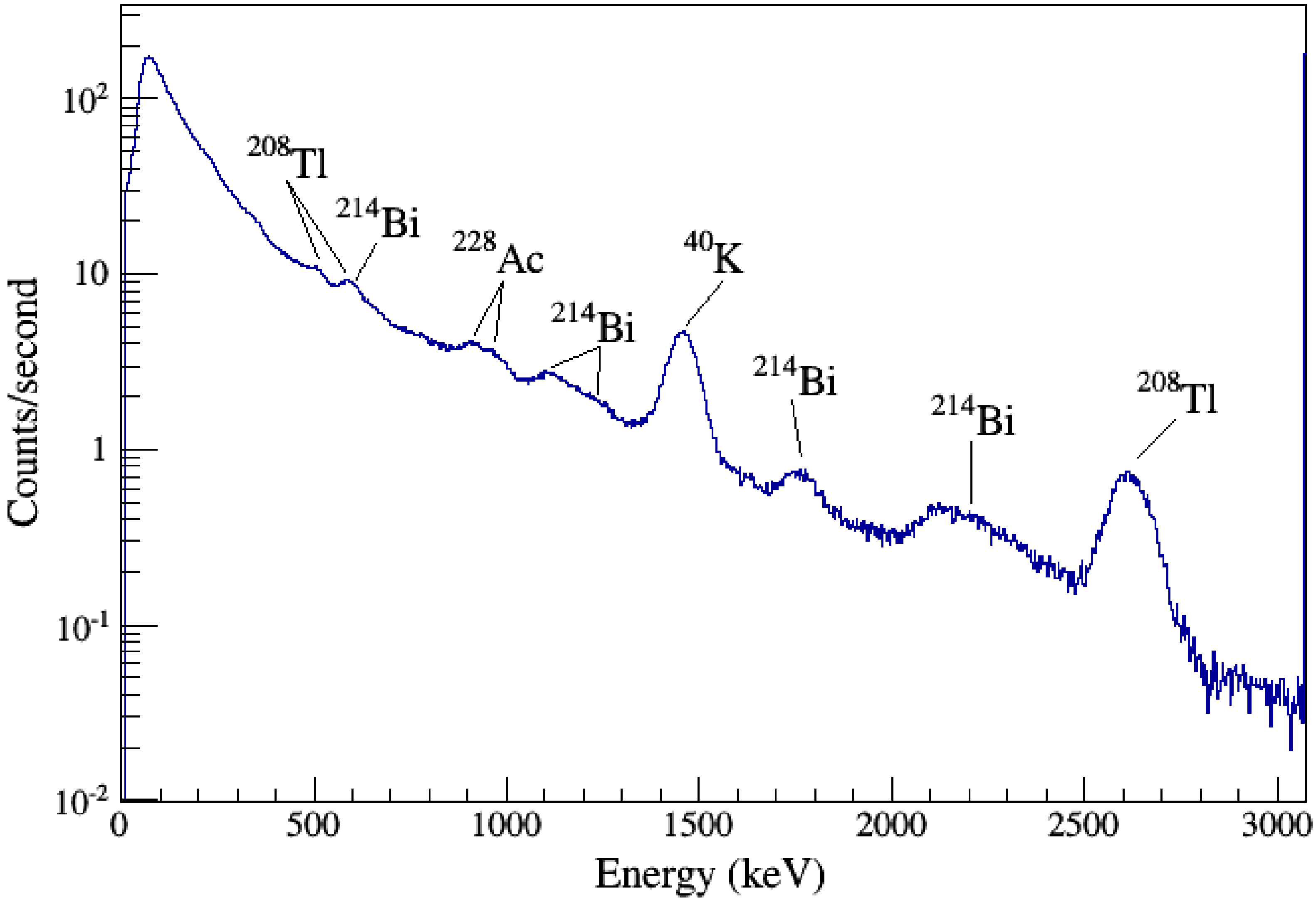
where

$$K = \frac{\text{low-energy counts}}{\text{high-energy counts}}$$

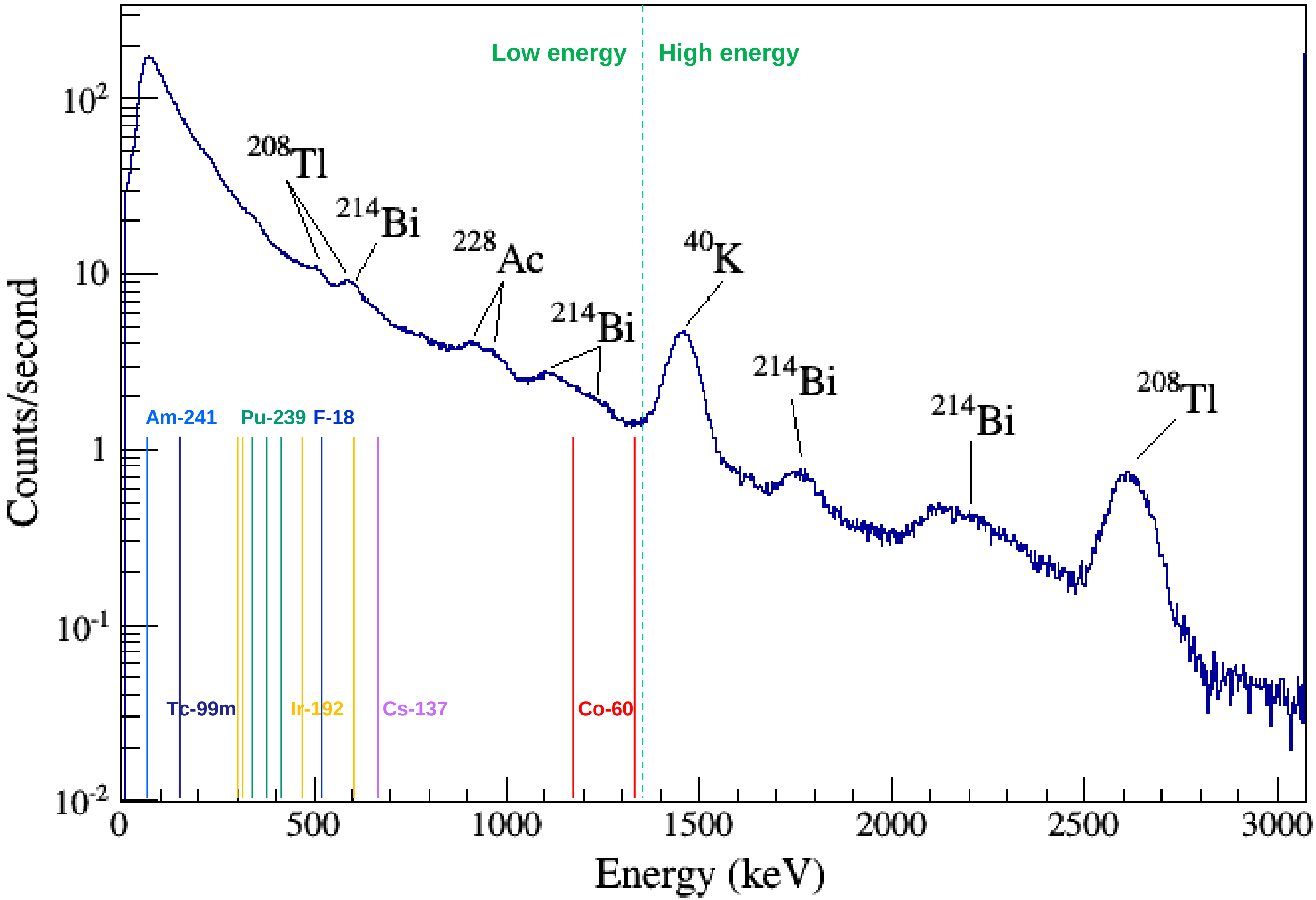
is calculated from a survey area known to contain only naturally-occurring isotopes



Typical Background Spectrum



Common Non-Naturally Occurring Isotopes



Data Analysis: Isotopic Extraction

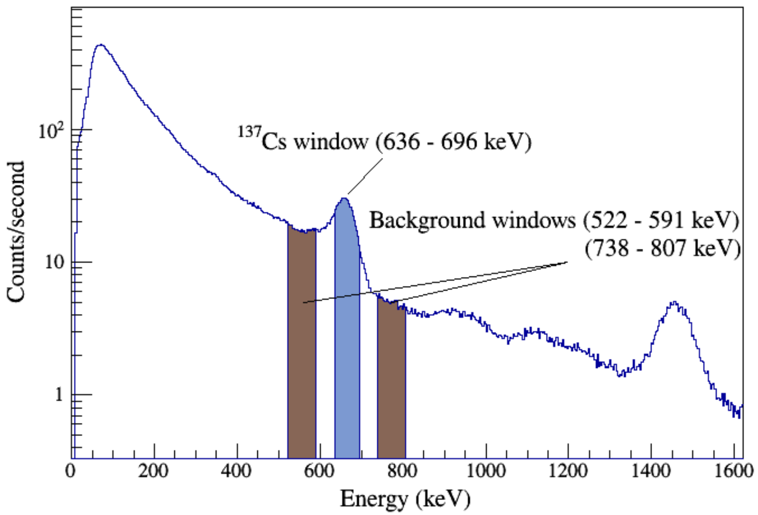
- Radioactive isotopes produce spectral peaks at unique energies
- Three-window isotopic algorithm compares excess counts in a window encompassing the signature peak to counts in two background windows on either side
  - Result > 0 implies counts in isotope's signature peak in excess of that expected from background
- Not sensitive to scattered gamma-rays from the isotope of interest that fall outside of the signature peak (e.g. shielded or partially buried)

$$C = (\text{counts in } ^{137}\text{Cs window}) - K \cdot (\text{counts in bkgd windows})$$

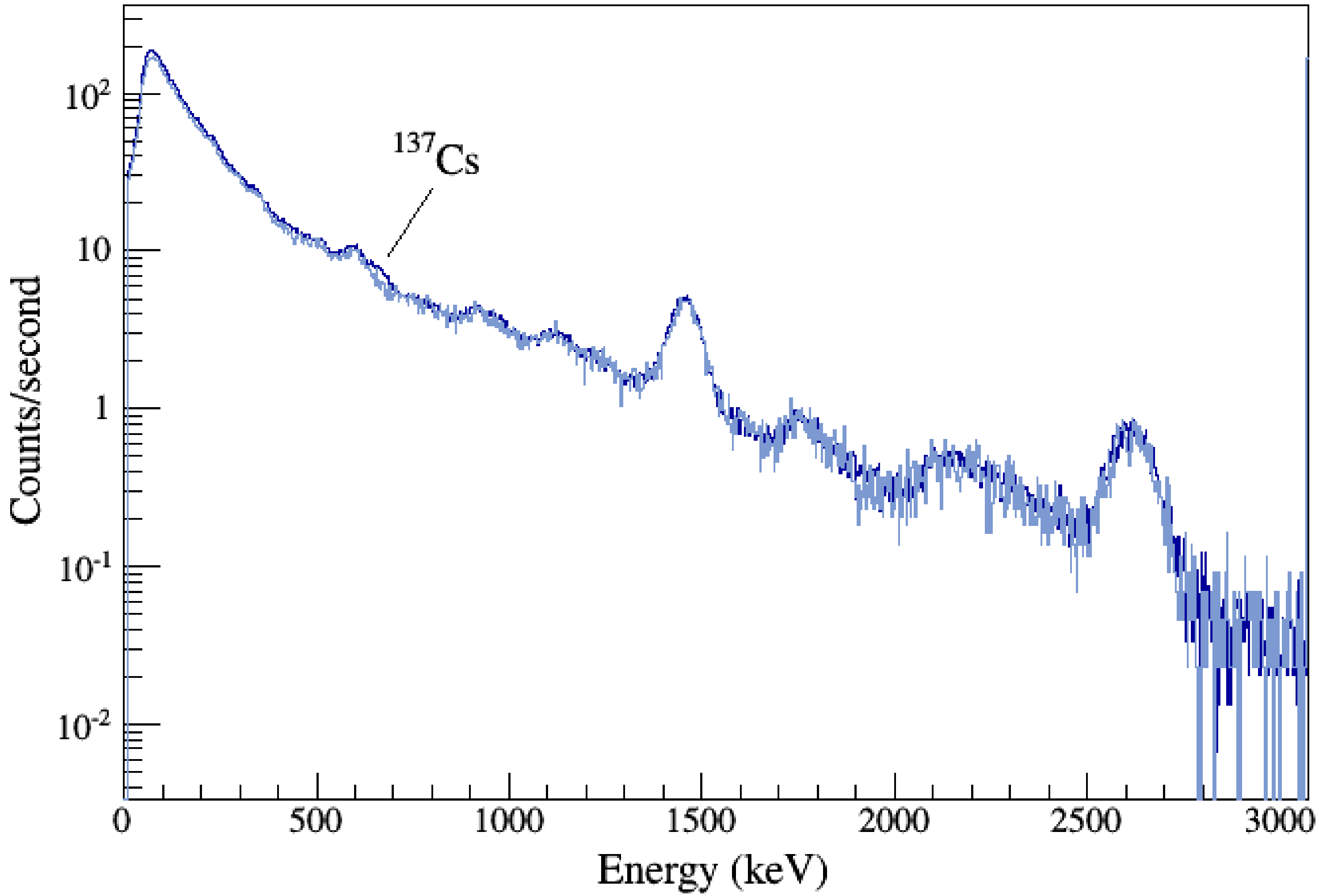
where

$$K = \frac{\text{counts in Cs window}}{\text{counts in background windows}}$$

is calculated from a survey area known to contain only naturally-occurring isotopes



Representative Spectrum from Flood Plain 3 Anomaly



Development of guidance for follow-up measurements

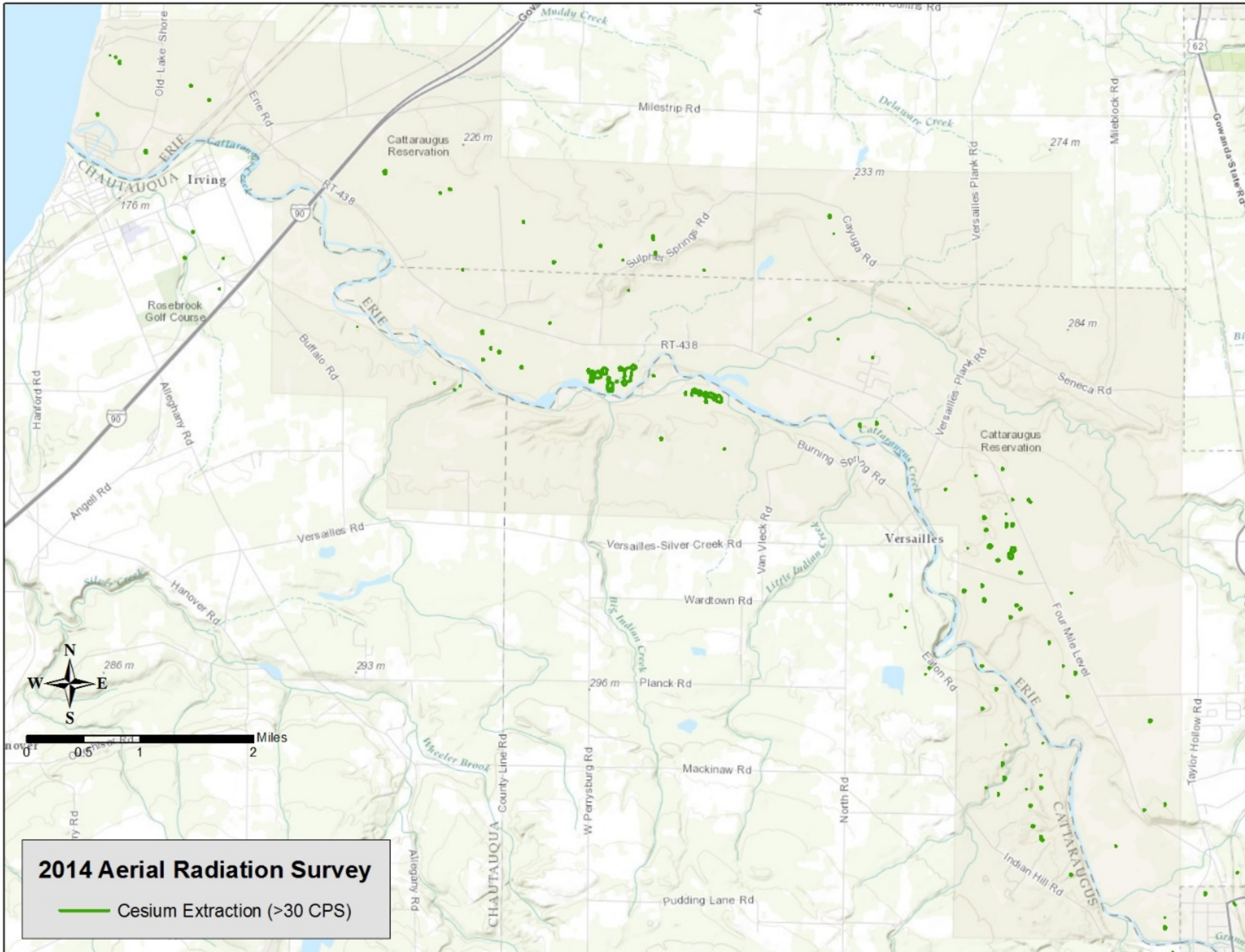
- Aerial survey does not directly measure potential contaminant concentrations in soil
- Aerial survey results can be used to inform more focused direct measurements taken on the ground
- NYSERDA requested RSL develop guidance for areas where NYSERDA should focus follow-up ground surveys and soil sampling
- Guidance would require the identification of criteria supported by the aerial survey data for delineation of potential follow-up areas.

Development of guidance for follow-up measurements

- RSL identified 4 criteria that when met in combination would identify appropriate areas for follow-up measurements:
  1. Cesium-137 radiation data exceed 2 standard deviations above background
  2. Anthropogenic (man-made) radiation data exceed 2 standard deviations above background
  3. Elevated cesium-137 radiation data and elevated anthropogenic radiation data occur in close proximity
  4. Elevated cesium-137 radiation data and elevated anthropogenic radiation data occur in clusters or extend over large area.

Criterion 1: Elevated cesium-137 data

- Aerial Survey data show that outside the WNYNSC, radiation levels are at or slightly elevated above background.
- 2 standard deviations above background allows filtering of data within statistical "noise" around background level.
- These are **very small** deviations above background and could simply be due to expected statistical variance, but results indicate this conservative approach is practical and reasonable given the nature of the data.
- Cesium extraction algorithm has relatively smaller variance but can contain false negatives, e.g., where Cs-137 may be indicated in spectral data though not strongly within the photopeak



2014 Aerial Radiation Survey
Cesium Extraction (>30 CPS)
N
W
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Miles
0
0.5
1
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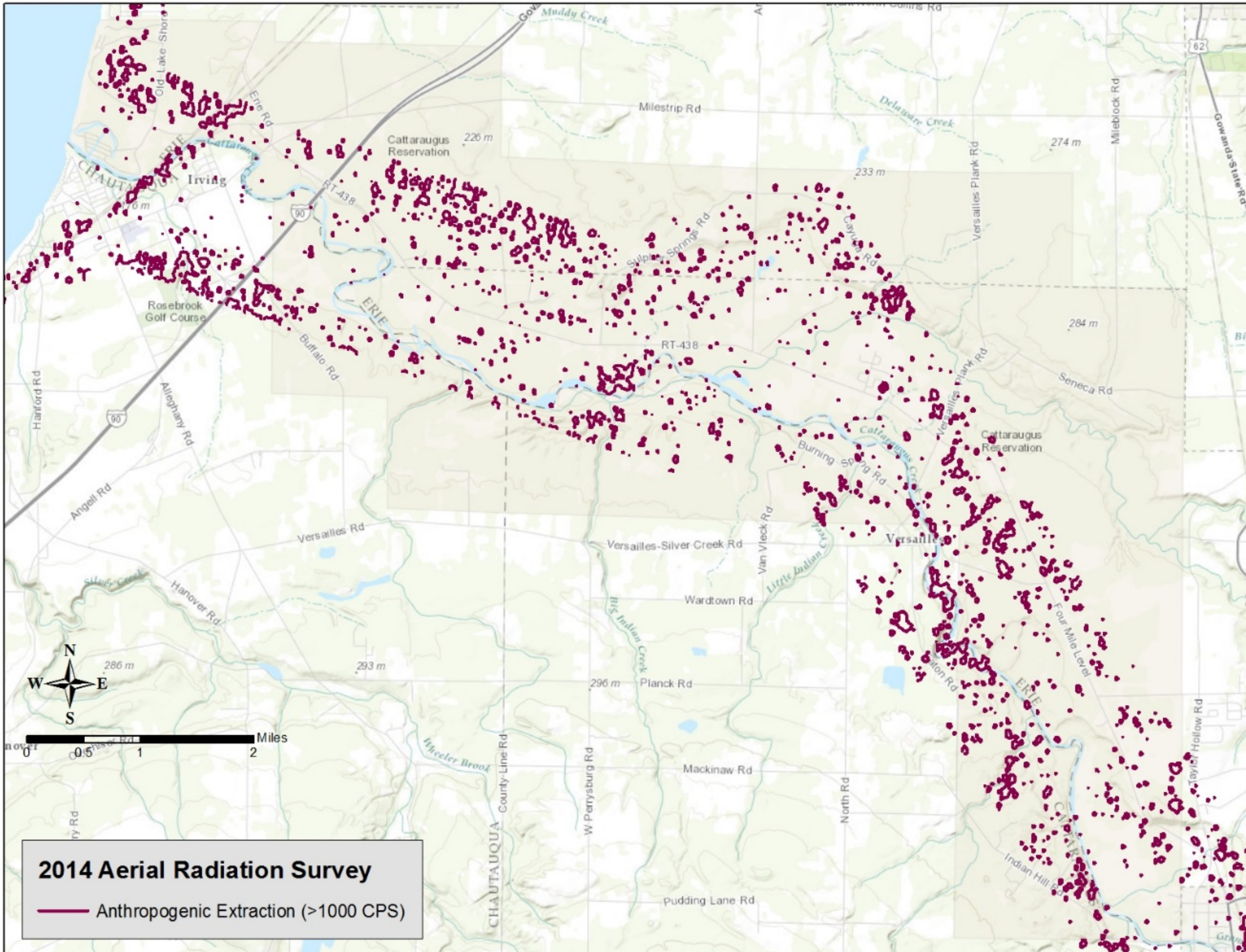
Muddy Creek
Milestrip Rd
Delaware Creek
Cattaraugus Reservation
226 m
233 m
274 m
Mileblock Rd
Gowanda State Rd
62
Old Lake Shore
Erie Rd
ERIE
CHAUTAUQUA
Irving
176 m
RT-438
90
Sulpher Springs Rd
Cayuga Rd
Versailles Plank Rd
Rosebrook Golf Course
Buffalo Rd
284 m
Seneca Rd
Hanford Rd
Allegheny Rd
Burning Spring Rd
Cattaraugus Creek
Cattaraugus Reservation
Angell Rd
Versailles Rd
Versailles-Silver Creek Rd
Van Vleck Rd
Little Indian Creek
Versailles
Silver Creek
Hanover Rd
Wardtown Rd
Big Indian Creek
Four Mile Level
286 m
293 m
296 m
Planck Rd
Eaton Rd
Wheeler Brook
County Line Rd
W Perrysburg Rd
Mackinaw Rd
North Rd
Taylor Hollow Rd
CATTARAUGUS
Indian Hill Rd
Allegany Rd
Pudding Lane Rd

Criterion 2: Elevated anthropogenic data

- Aerial Survey data show that outside the WNYNSC, radiation levels are at or slightly elevated above background.
- 2 standard deviations above background allows filtering of data within statistical "noise" around background level.
- These are **very small** deviations above background and could simply be due to expected statistical variance, but results indicate this conservative approach is practical and reasonable given the nature of the data.
- Anthropogenic extraction algorithm has a large variance and can produce false positives if used to look for a specific isotope (e.g. Cs-137)


2014 Aerial Radiation Survey
Anthropogenic Extraction (>1000 CPS)
Miles
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Cattaraugus Reservation
Irving
Rosebrook Golf Course
Versailles
Milestrip Rd
RT-438
Buffalo Rd
Versailles Rd
Versailles-Silver Creek Rd
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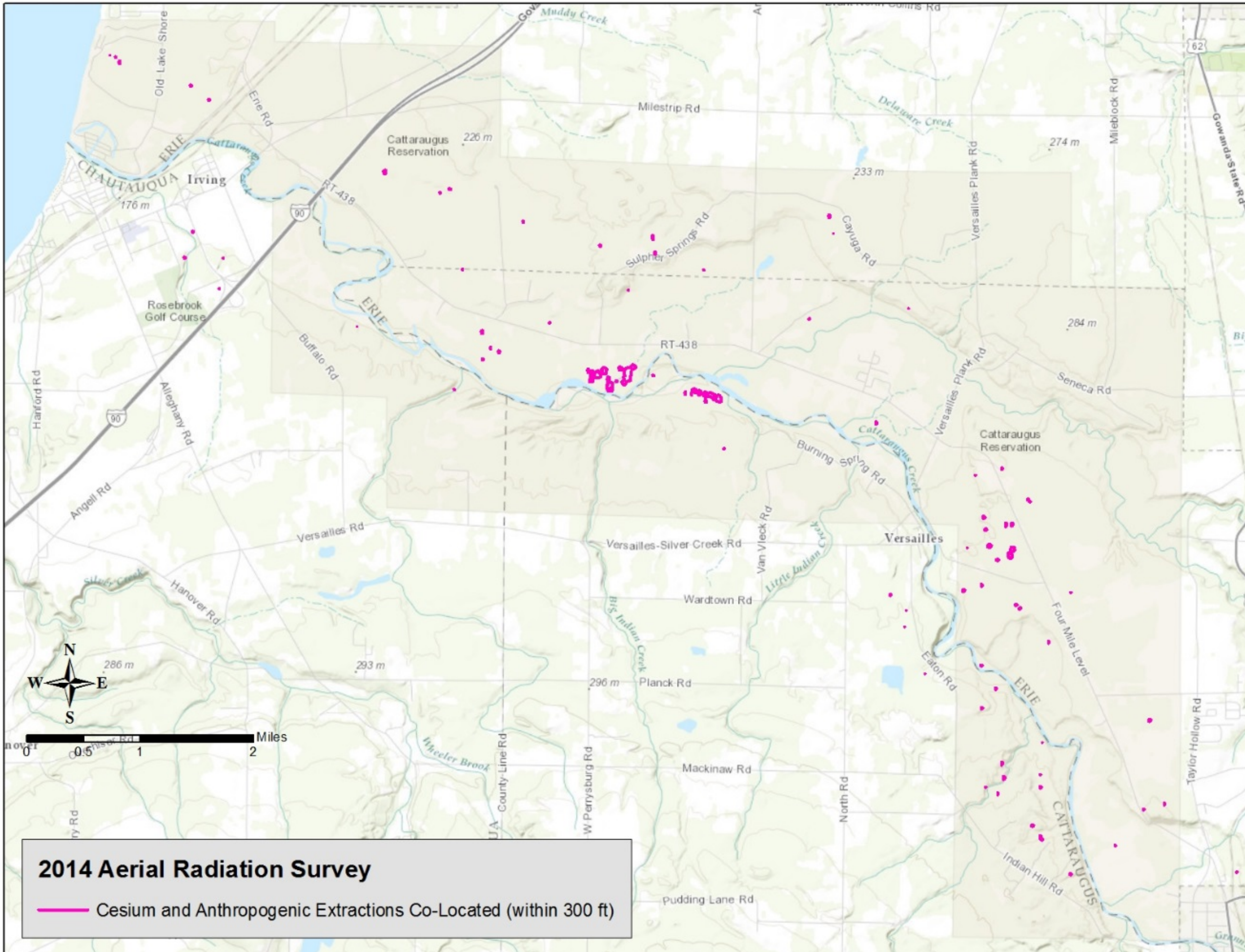
Hanover Rd
Allegheny Rd
Hanford Rd
Erie Rd
Old Lake Shore
Taylor Hollow Rd
Muddy Creek
Delaware Creek
Cattaraugus Creek
Silver Creek
Big Indian Creek
Little Indian Creek
Wheeler Brook
CHAUTAUQUA
ERIE
226 m
233 m
274 m
284 m
286 m
293 m
296 m

Criterion 3 – Cesium and anthropogenic data are co-located (in close proximity)

- When both cesium and anthropogenic elevations are in close proximity, the data support identification of follow-up measurements
- Because of averaging effects in aerial data, delineating areas where the two exceedances directly overlap is not conservative
- RSL examined a range of distance thresholds to help NYSERDA determine what was both a practical and conservative definition of "in close proximity"
- Practically achievable distance thresholds from 30-300 feet were evaluated
- NYSERDA chose the most conservative 300ft value for follow on measurements


2014 Aerial Radiation Survey
Cesium and Anthropogenic Extractions Co-Located (within 300 ft)
Miles
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Cattaraugus Reservation
Irving
Rosebrook Golf Course
Versailles
Milestrip Rd
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Taylor Hollow Rd
Muddy Creek
Delaware Creek
Cattaraugus Creek
Little Indian Creek
Big Indian Creek
Silver Creek
Wheeler Brook
ERIE
CHAUTAUQUA
CATTARAUGUS
226 m
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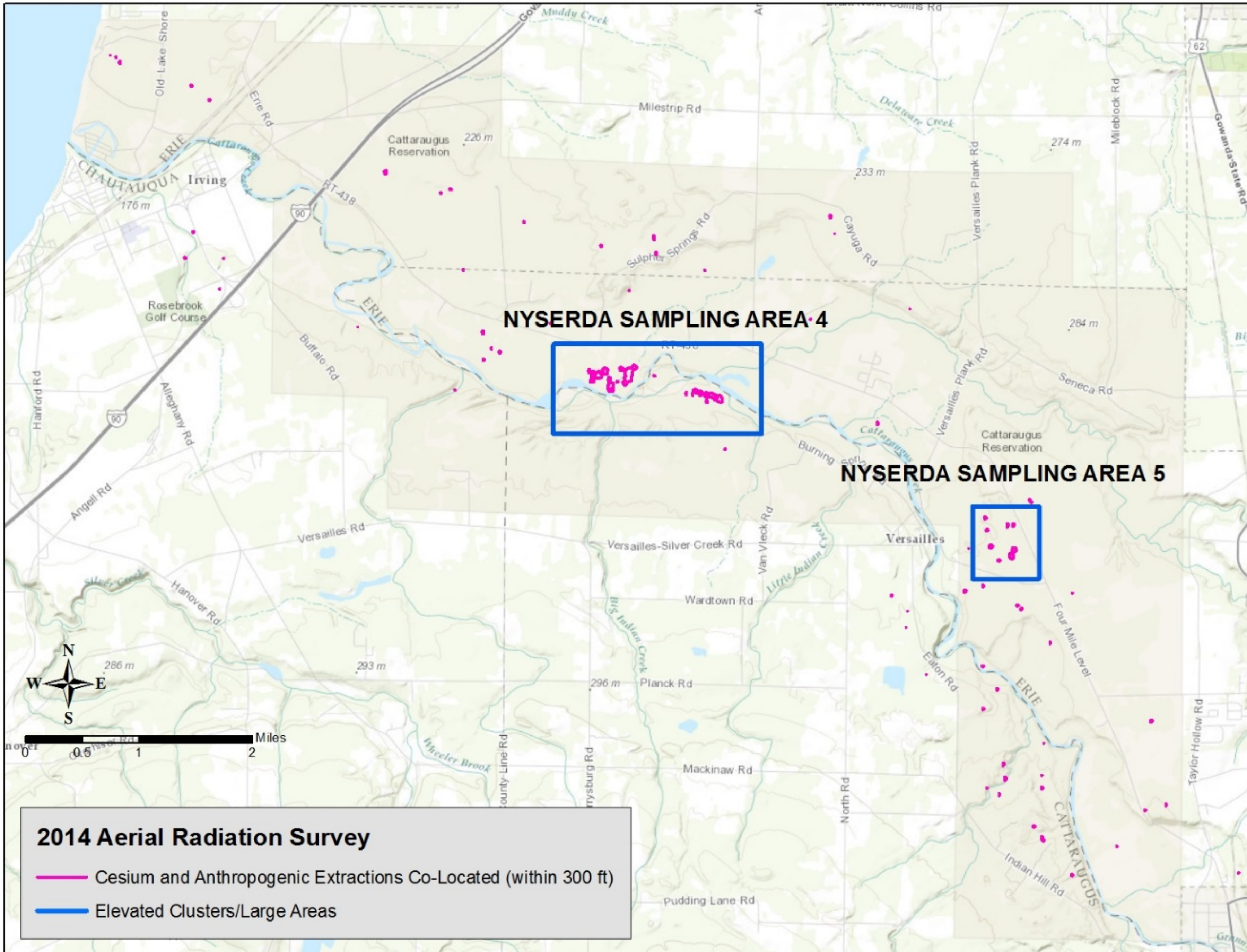
274 m
284 m
176 m
286 m
293 m
296 m

Criterion 4 – Co-located, elevated data are clustered or extend over large area

- Applying the first 3 criteria results in a dataset that is still indicative of statistical noise
- To further focus the follow-up measurements, the data support the identification of clusters of areas or extended areas for follow-up measurements.


NYSERDA SAMPLING AREA 4
NYSERDA SAMPLING AREA 5
2014 Aerial Radiation Survey
Cesium and Anthropogenic Extractions Co-Located (within 300 ft)
Elevated Clusters/Large Areas
Miles
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Cattaraugus Reservation
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Muddy Creek
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