Geospatial applications in the Alaska AML Program

Examples & Practical Results from an Alaskan User's Perspective

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Geospatial Concepts
What is it?

Definition (Wikipedia) -- commonly known as geomatics, refers to technology used for visualization, measurement, and analysis of features or phenomena that occur on the earth. This terminology has become common in the U.S., and synonymous with Spatial Information Technology.

Geospatial Concepts

Wikipedia Definition (cont'd) -- Geospatial technology includes three different technologies related to mapping features on the surface of the earth. These are

- GPS (global positioning systems)
- GIS (geographical information systems)
- RS (remote sensing).

Geospatial Tools

Roger's Definition – AML Geospatial technologies comprise multiple tools related to mapping features on earth surfaces or subsurfaces. These are

- Georeferenced rasters & topo maps
- GPS hardware & software
  - Trimble & Arcpad platforms
- AutoCAD and SurvCADD
- ArcMap GIS software

Geospatial Tools

AK AML Geospatial technologies (cont'd)

- Surface Terrestrial survey equipment
  - Theodolite, spirit level, EDM, rangefinder
- Geophysical Equipment -- subsufrace
  - ES-1225 Seismograph for Seismic Refraction surveys
- Borehole data – T, CO, lithology

This talk illustrates various examples of their use, related to AML project work.

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GPS Application Examples -- AML

Map Inventory Existing & Asbuilt Features

- Locate / map waypoints, monuments & control pts.
- Road, path, stream, RR alignments
- Impoundment shorelines
- WQ sampling sites
- Dangerous openings — shafts, adits
- Vegetation coverages
- Delineate highwall tops & bottoms
- Work area boundaries, disturbed area limits
- Layout & as-built – borehole patterns, cut/fill lines
- Spoils fires -- surface hot spots
- Historical structures, hazardous equipment & facilities

Application Examples -- AML

Inventory Existing Features

- road, path, stream, RR alignments
- Disturbed area limits
- Vegetation coverages
- Spoils fires -- surface hot spots
- Delineate highwall tops & bottoms
- Impoundment shorelines
- WQ sampling sites
- Historical structures, hazardous equipment & facilities
- Dangerous openings — shafts, adits

Geoexplorer II – features, specs

C/A, 6 channels, tracks 8 satellites

88KB memory (1997 vintage)

Internal antenna, external ant. Optional

Operating Temperature ~ +14°F to +122°F

Rated accuracy 2-5m post-processed (68%/1s)

Submeter solutions in high-accuracy mode, collecting L1 carrier phase data

RTCM capable

Runs ~12 hrs. on 12V 2amp- hr. 350CV camcorder battery, 3-4 hrs. on 4xAA batteries; 120V adapter

Settable PDOP, SNR, elev. mask, collection rate. Stores ~9,000 points,100 waypoints, >100 worldwide datums

Collects point, line, area features

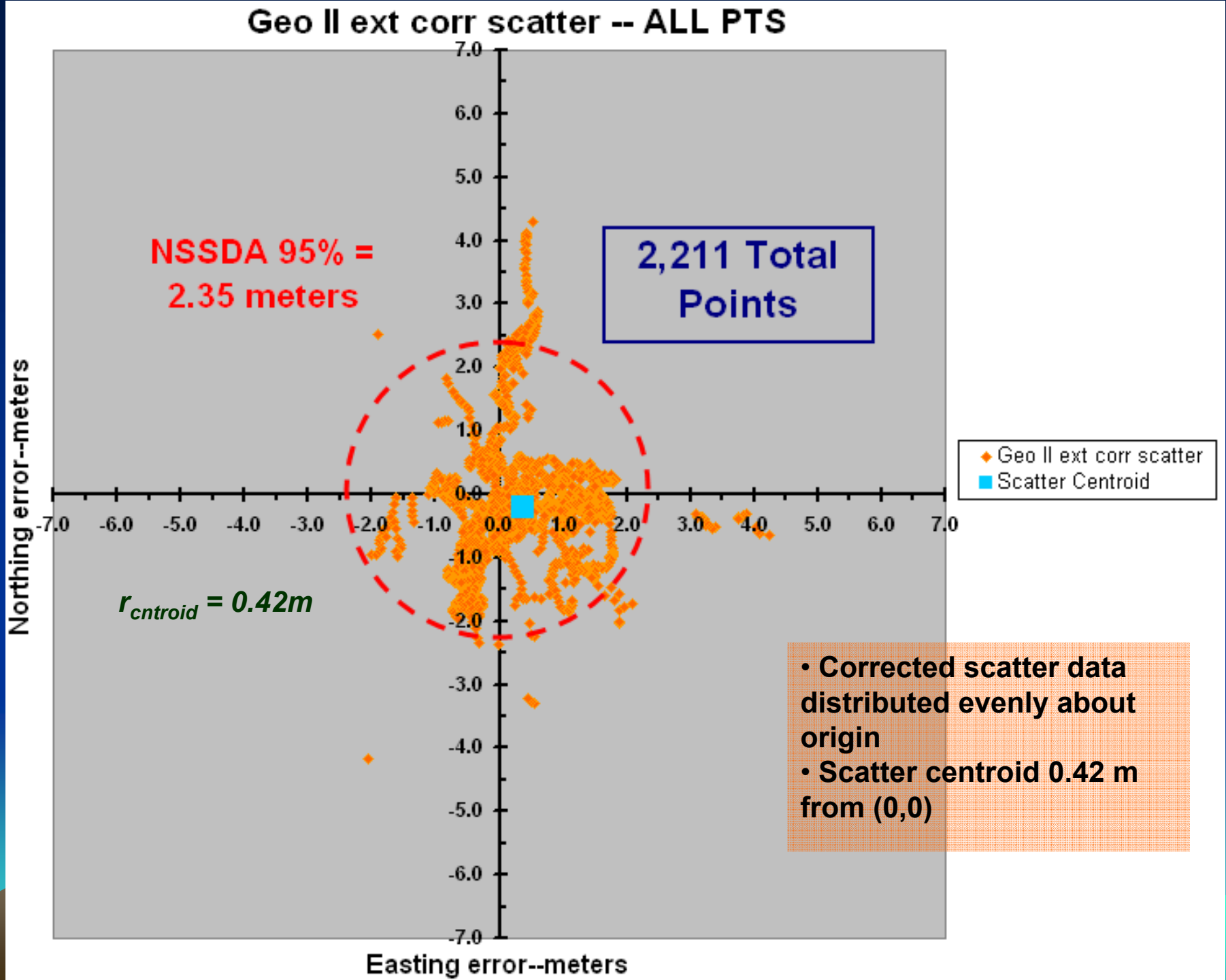
Navigation--range, bearing, cross-track error

Data dictionary – supports feature names, assigning attribute data

Interfaces with PF Office for mapping planning, diff. correction, data dictionary creation, GIS output

Small, lightweight

Cost: ~$3495 ca. 1998, ceased prod. ca. 2000.



- **Corrected scatter data distributed evenly about origin**
- **Scatter centroid 0.42 m from (0,0)**

CE/XT Geoexplorer -- specs

DEVICE

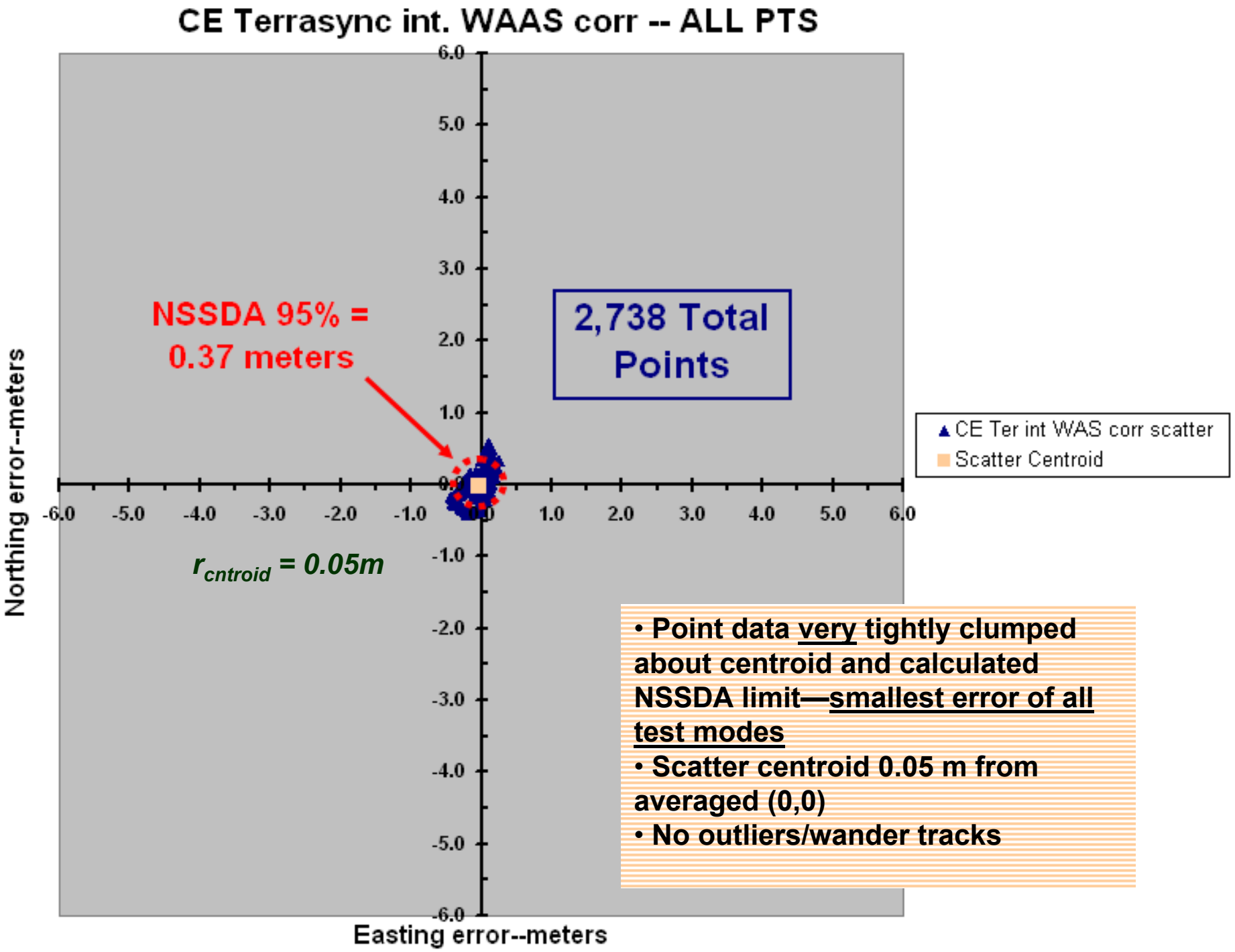
C/A, 12 channels, tracks at least 9 satellites continuously
Cable-free handheld
Size: 8”x4”x3”, weight 1.6 lbs.
Operating Temperature +14°F to +122°F
OS: Microsoft Windows CE, 206 MHz CPU
Memory: 32MB Main, 524MB disk
Bluetooth wireless connectivity
USB v1.1 via support module
Backlit color touchscreen, virtual keyboard
Runs ~10-14 hrs. on internal 21 WH Li battery (temperature dependent)
Internal antenna, external ant. Optional
Microphone and speaker, record and playback utilities

GPS

Accuracy: **2-5m autonomous, submeter** post-processed, 30cm in high-accuracy mode (L1 carrier phase data
Real-time supported – DGPS WAAS, RTCM BoB
Collects with Terrasync, Arcpad, GPS Pathfinder tools, GPS correct, or custom software
Use Trimble Pathfinder Office or GPS Analyst for post-processing
EVEREST multipath rejection technology
NMEA and TSIP protocol support

Terrasync

Settable PDOP, SNR, elev. Mask, collection rate.
Hundreds of worldwide datums
Navigation mode--range, bearing, velocity
Data dictionary – supports features and attributes
Cost: ~$4295 standalone, $495 Arcpad, $1795 Terrasync, $6585 Total

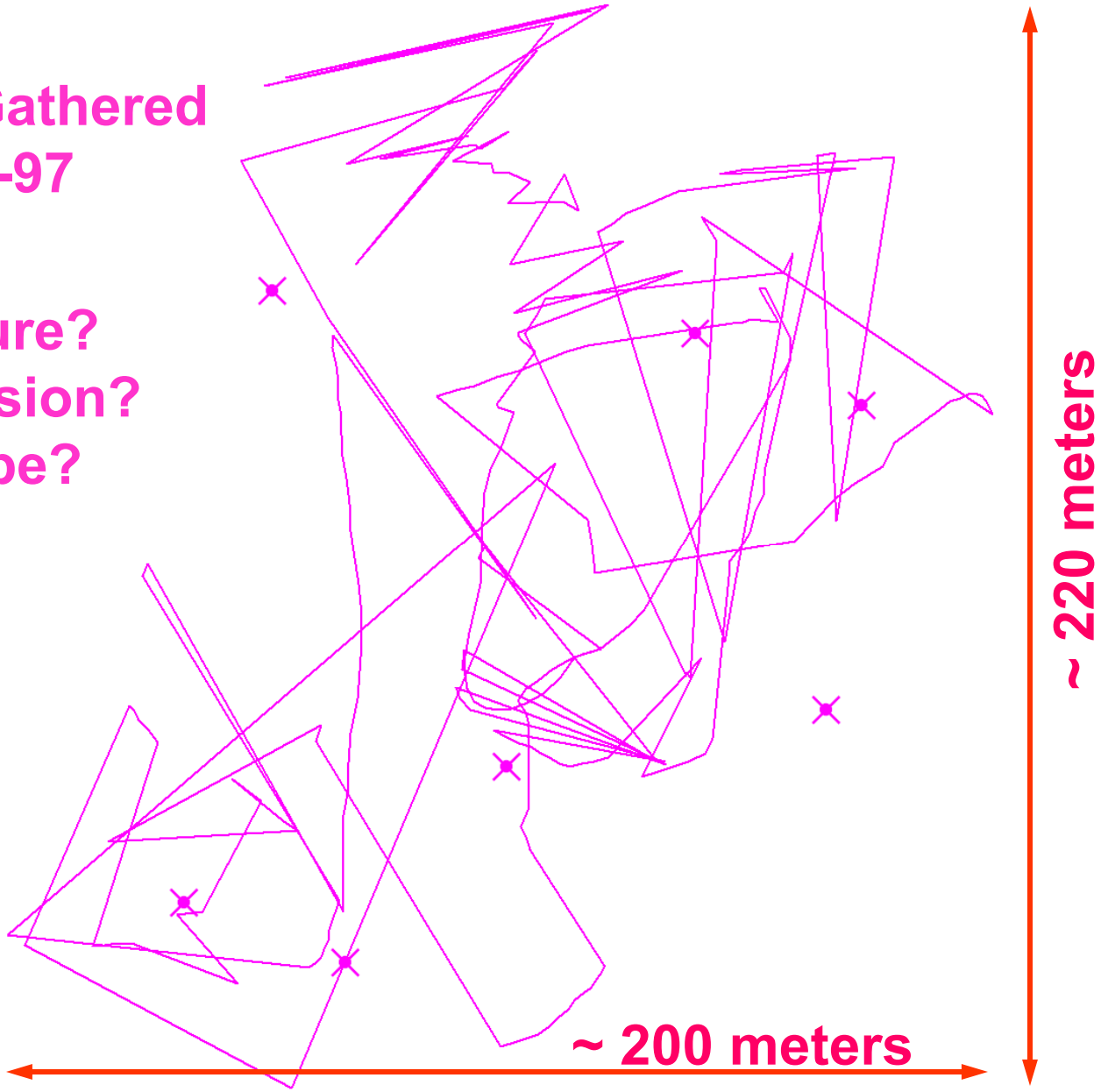


- **Point data very tightly clumped about centroid and calculated NSSDA limit—smallest error of all test modes**
- **Scatter centroid 0.05 m from averaged (0,0)**
- **No outliers/wander tracks**

Raw GPS Features with SA on

*ssf file Gathered
10-9-97

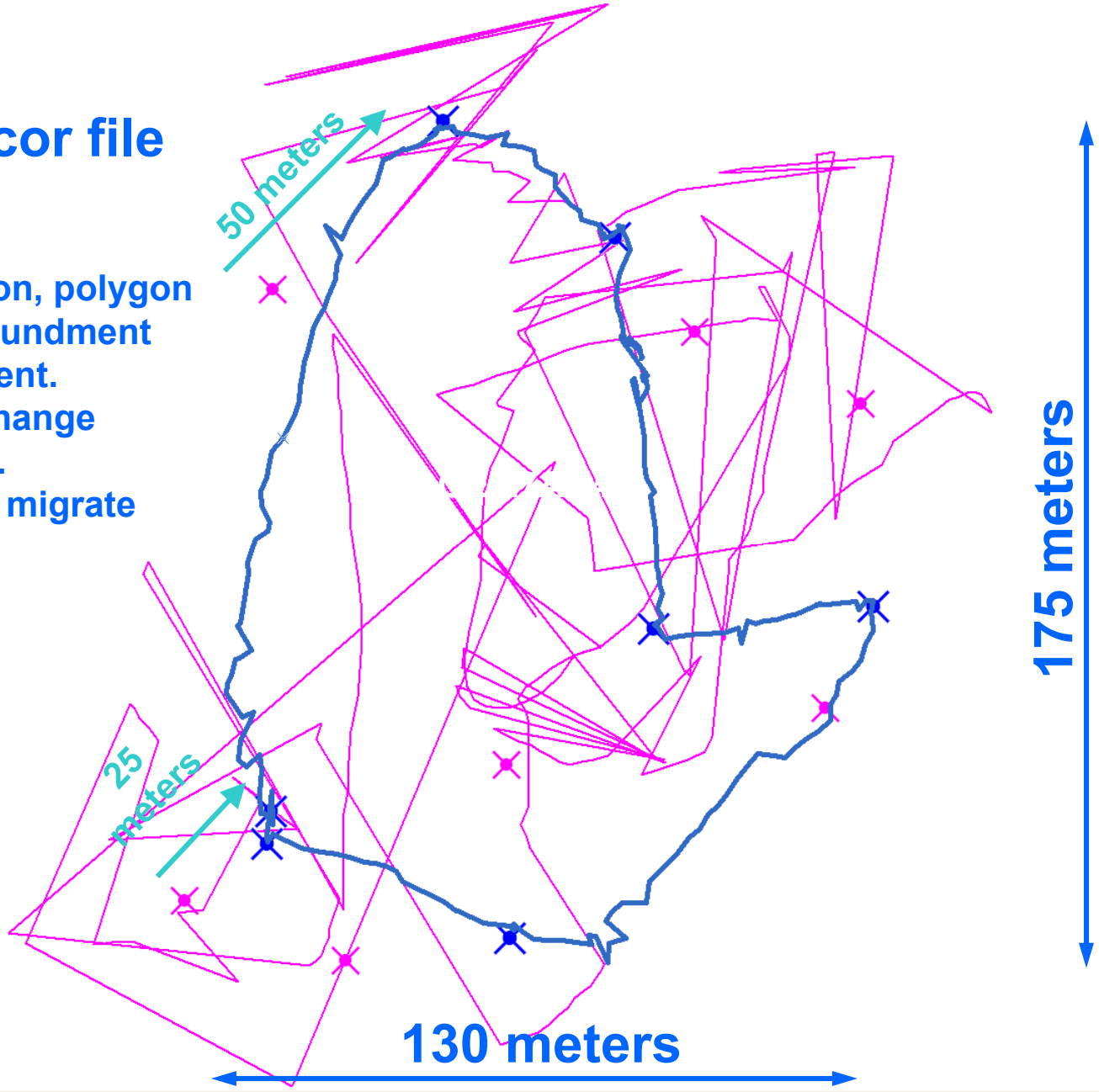
Feature?
Dimension?
Shape?



SA on -- Raw + Corr Features

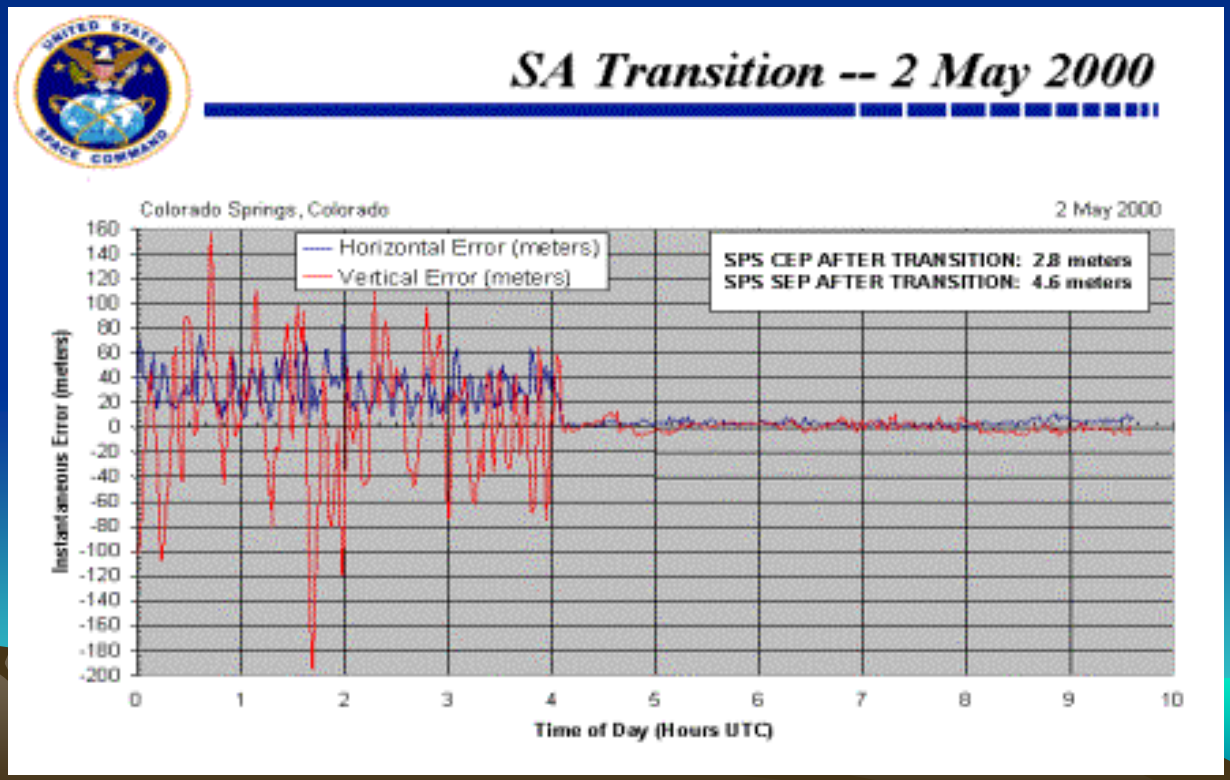
*ssf & *cor file

Upon correction, polygon shape of impoundment becomes evident.
Dimensions change 45 - 70 meters.
Point features migrate 25 - 50 meters



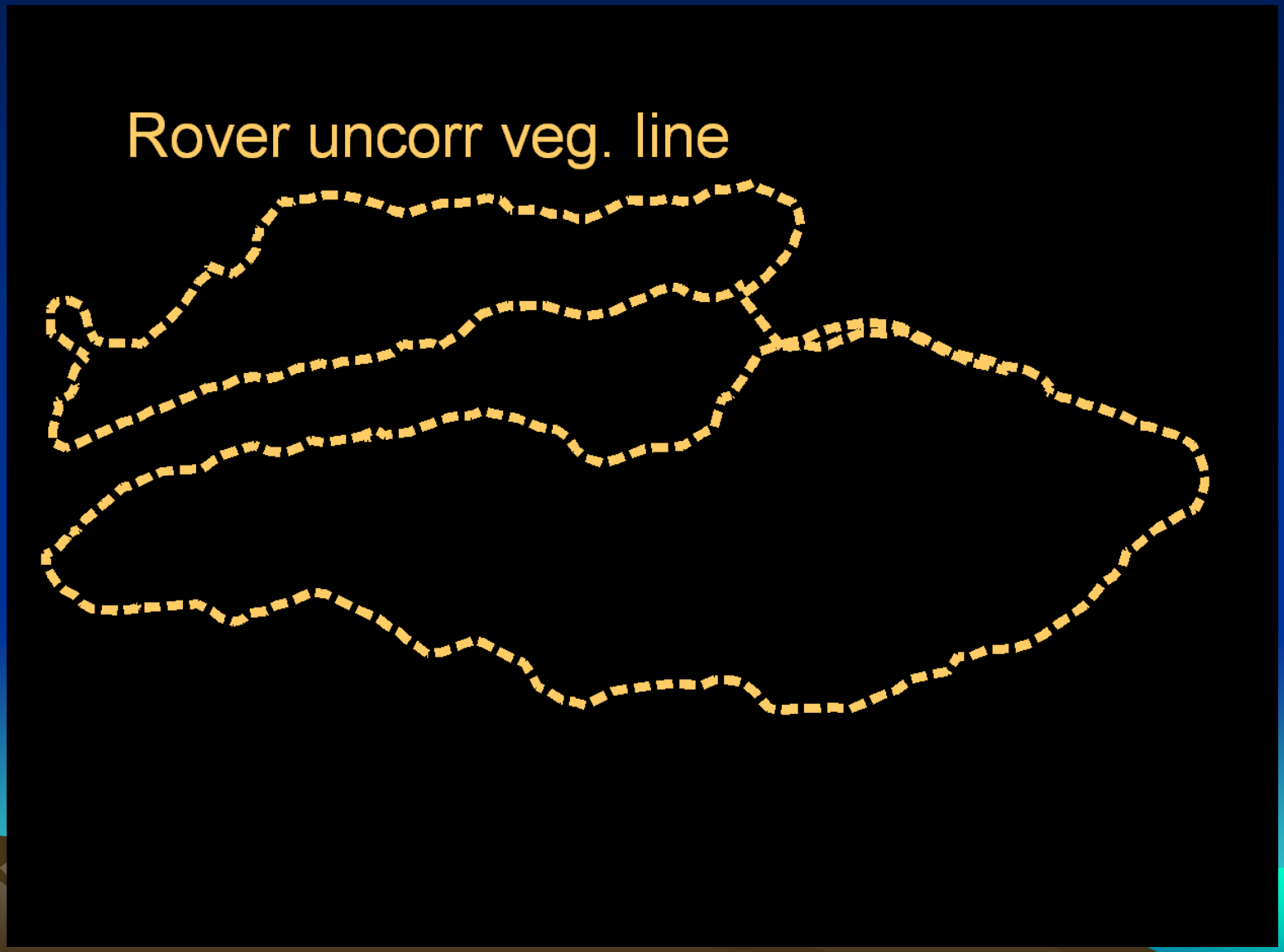
SA – turned off by Presidential order May 2 2000, 0405 UTC

- Positional accuracy increased from +/- 100m to < +/- 10m
- Greatly enhanced potential civil and commercial use



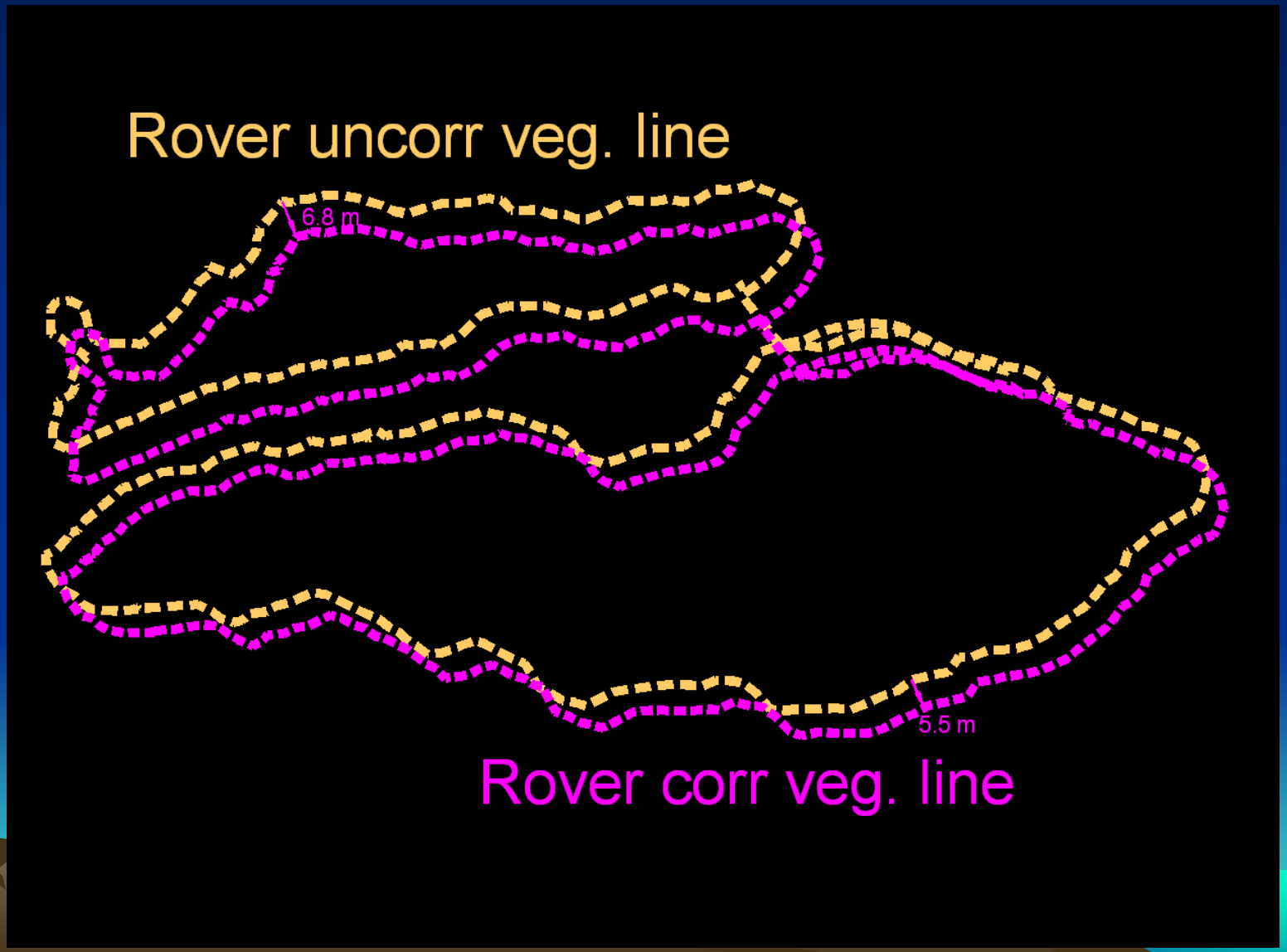
Feature with SA off -- Example

Autonomous *.ssf file, collected 3-14-02



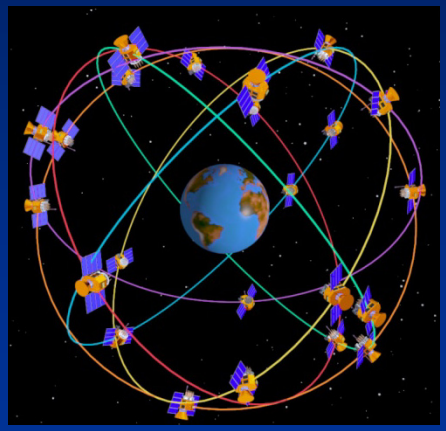
Feature with SA off -- Example

Autonomous and *corr file, collected 3-14-02



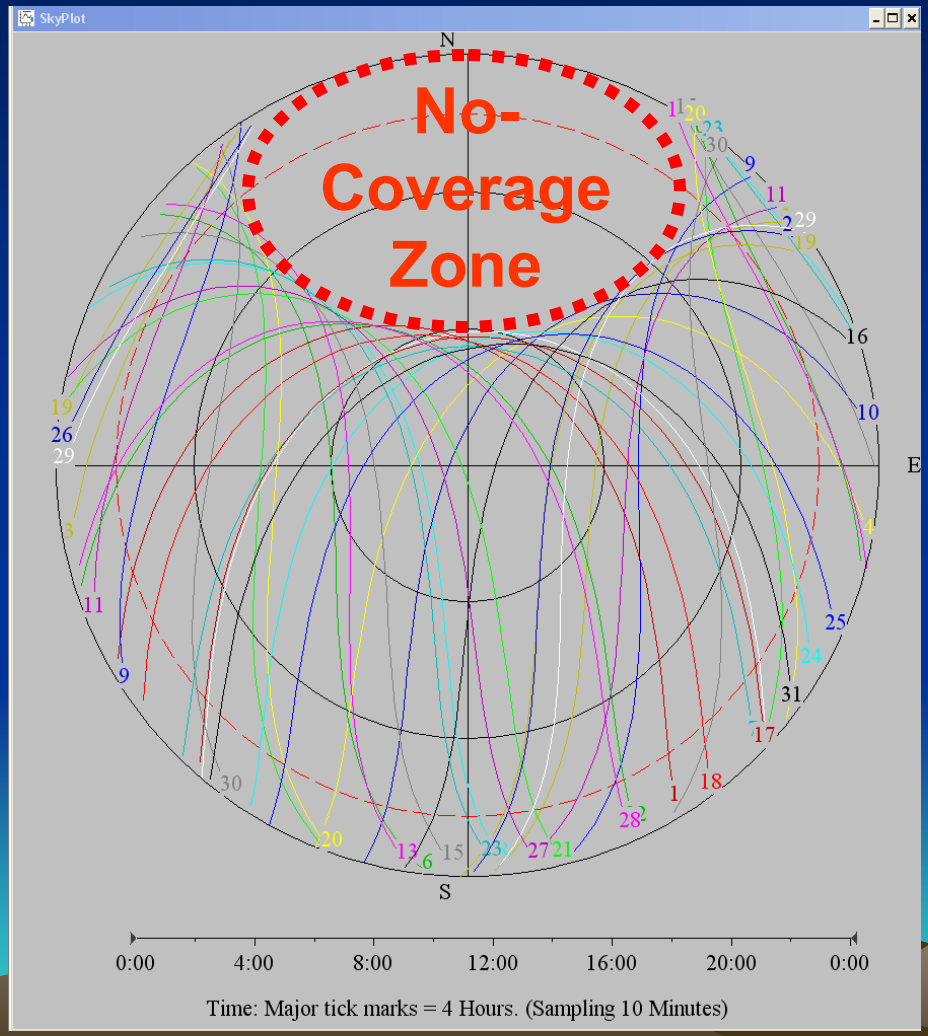
NAVSTAR orbital inclination

- Presently ~29 satellites occupy 6 orbital planes
- Orbital planes are inclined at 55°
- Creates optimal constellation for lower 48, but
- Polar regions not covered
- Creates “halo” effect, migrating overhead to S with increasing latitude

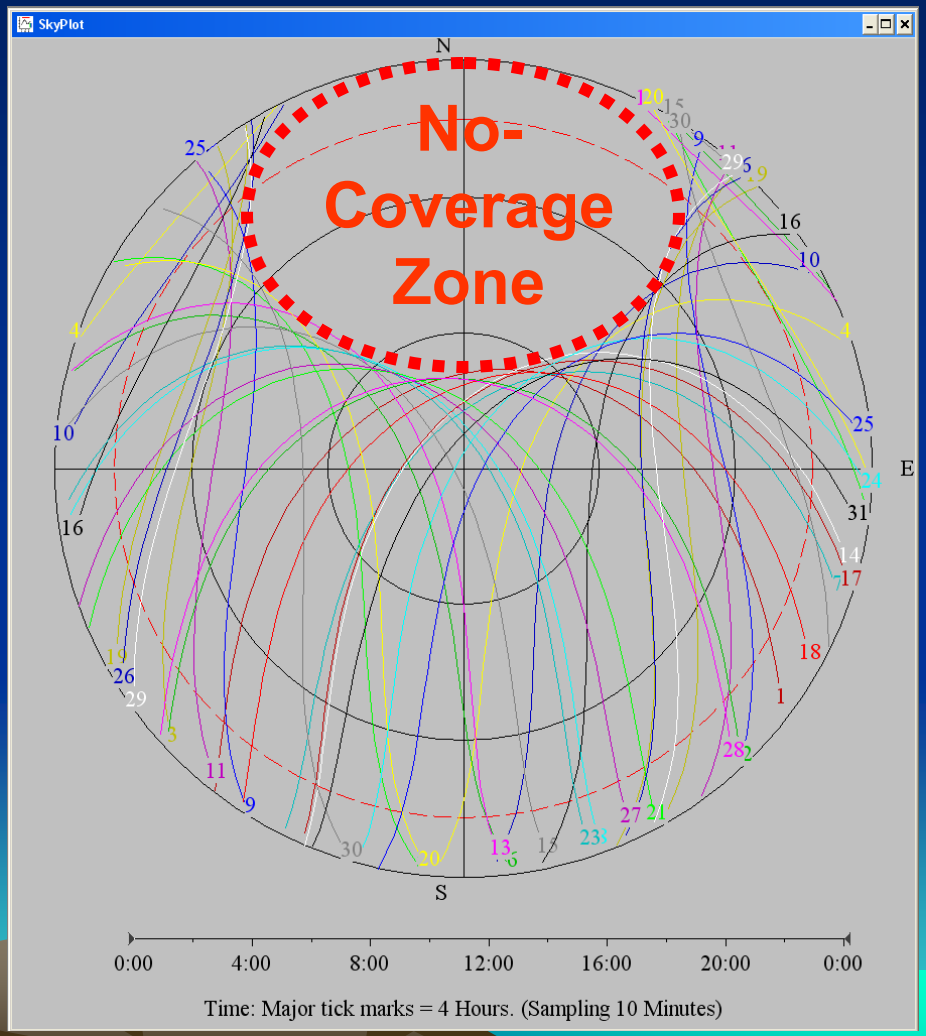


Lower-mid 48 GPS coverage

Atlanta – 33°38’N

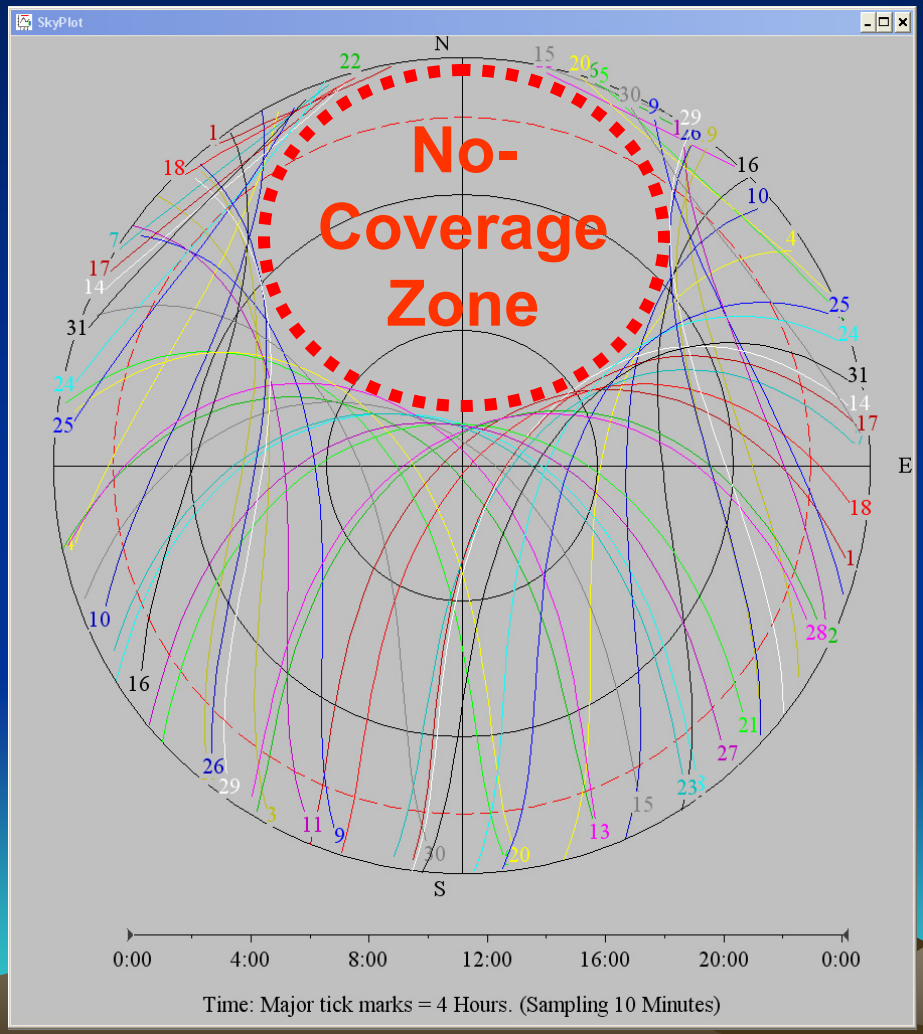


Denver – 39°47’N

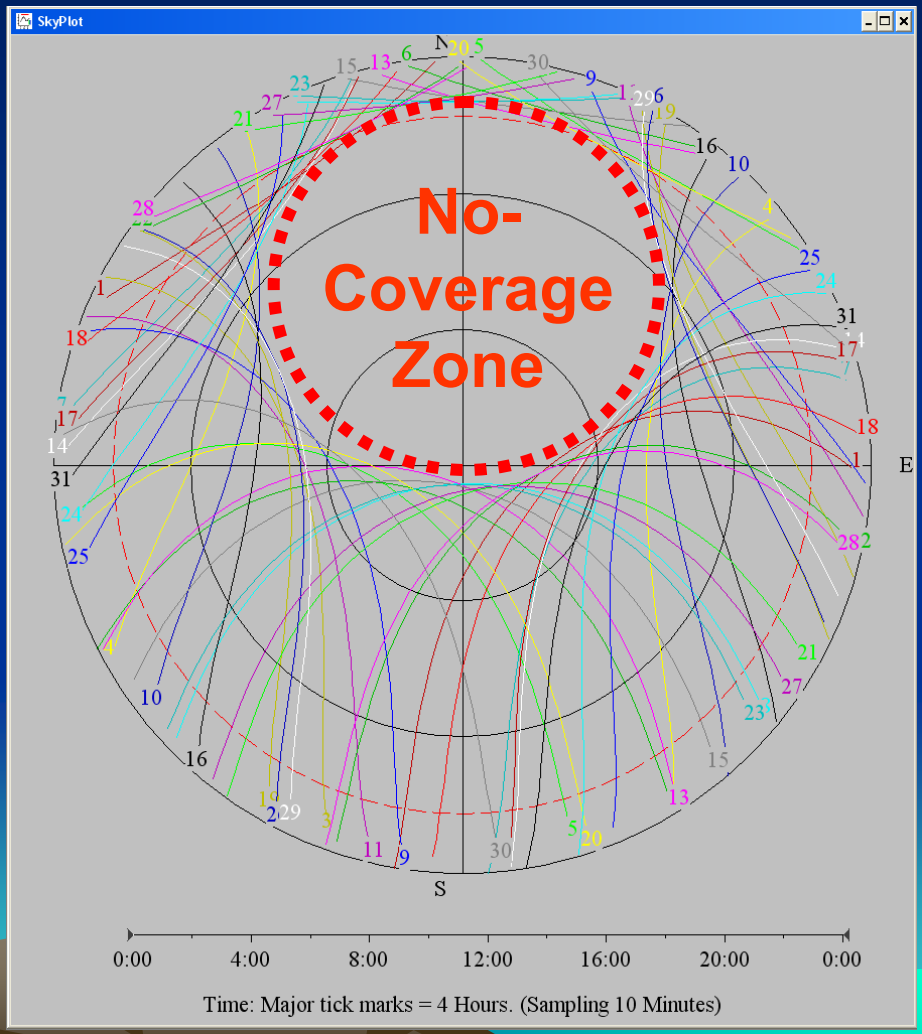


Northern Cities GPS coverage

Seattle – 47°26'N

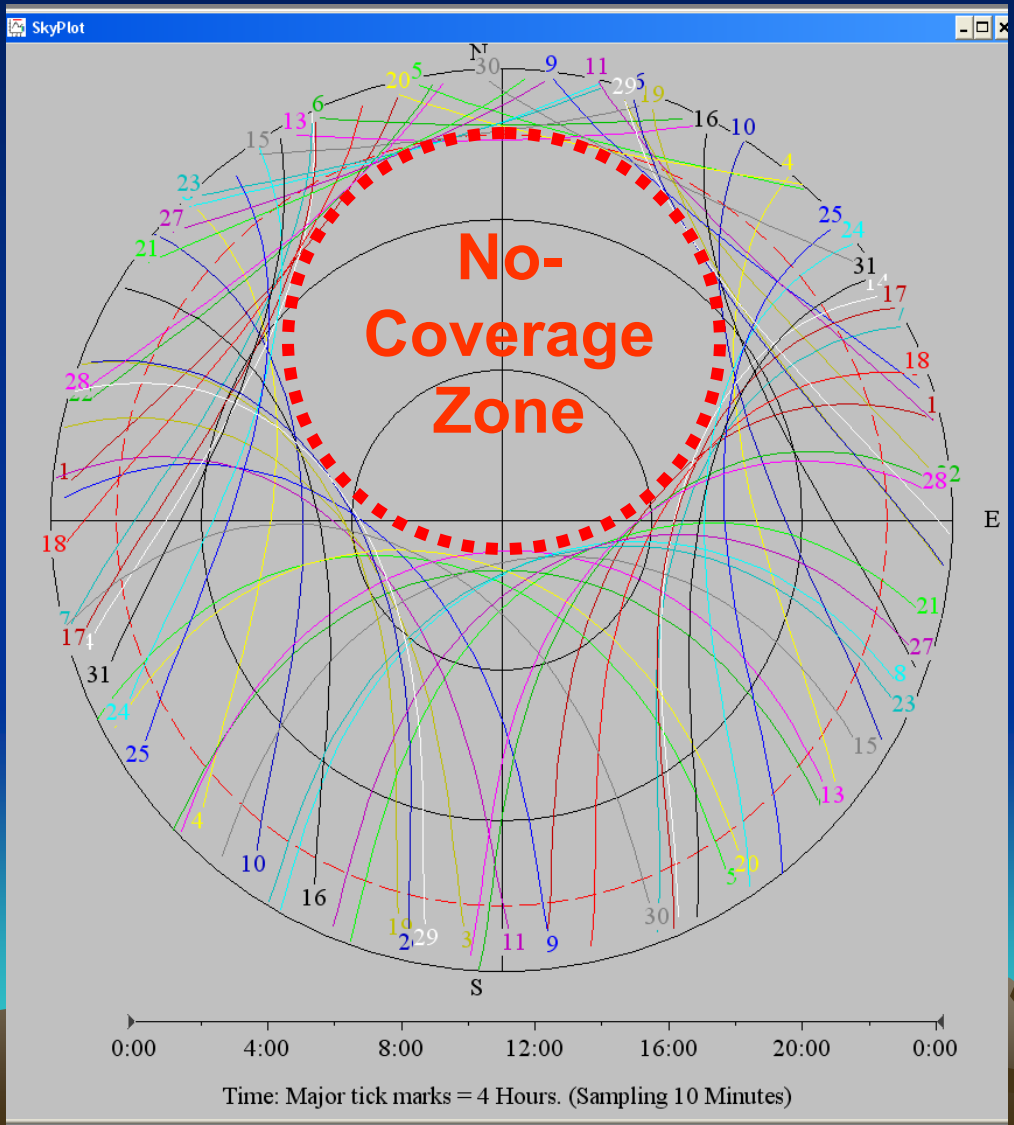


Juneau - 58°21'N



Northern latitude GPS coverage

NAVSTAR halo – Anchorage – 61°11'N ~ Yellowknife Latitude -- 62°30'N



- **Despite constellation hole and satellite concentration to the south, good PDOPs are regularly seen in SC Alaska**
- **Newer GPS devices that track 8 or more satellites achieve 2.x-4.x PDOPs most of the day, at times <2.0**

Alaskan WAAS Issues

- In Anchorage area, Pacific WAAS satellite is located at 187° Azimuth, **13° elevation**
- Creates limited visibility when working around topography, buildings, or tree canopy.
- Question arises: Might Alaskan users experience less accurate WAAS solutions than elsewhere?

Problems Encountered

- Won't collect data or navigate when in canyons, sky blocked to south;

  i.e. less optimum satellite solution
- Signal strength degrades under canopy, esp. wet or ice on leaves
- Rover saw satellites base station did not--because elevation mask set too low, or base station antenna view of sky blocked

Problems Encountered (cont'd)

- Multipath from nearby reflectors caused line feature offsets up to 15 meters
- WAAS data accuracy variable; sometimes less accurate than autonomous when post-processed

GPS Operation -- Environmental Limitations

- Works in most weather ranges — heat, wind, rain, snow
- Primarily land-based—some helicopter acquisition
- Seems unaffected by rain, dust
- Biggest environmental limiting factor– touch screens stop working in **low temperatures**

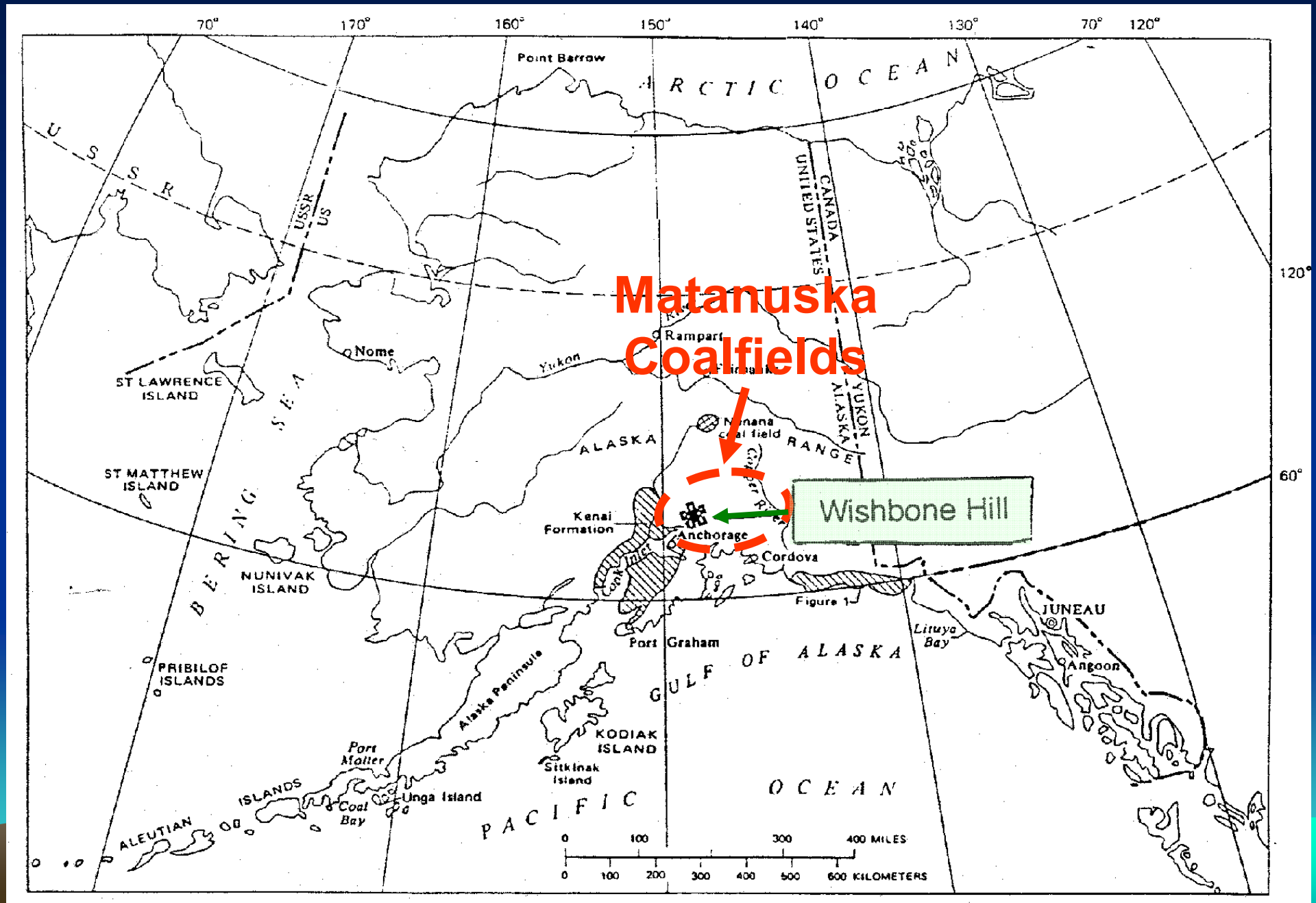
Accuracy

Open sky measured – 95% NSSDA

- Autonomous: -- 2.4-3.8 meter
- Post-processed -- 0.37-1.04 meter
- Terrasync captures PDOP, HDOP, and VDOP

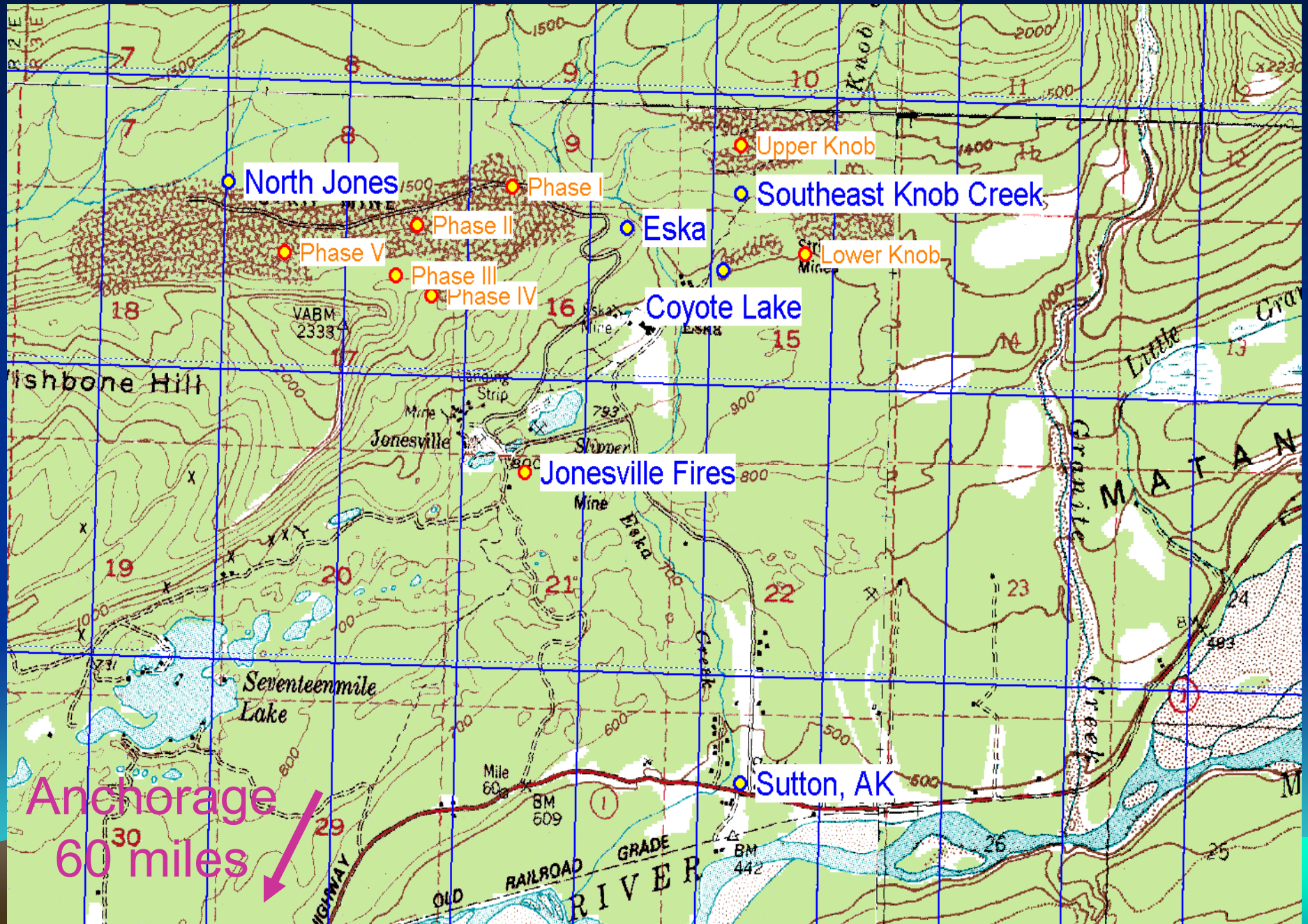
  Position-, Horizontal-, and Vertical Dilution of Precision are scalar representations of relative accuracy, can be used to filter data.

State Location map – WB/Jones/Knob



Inventory & Recon – Coal Creek

Sutton Area Coalfields -- Project Map



Pit 6 Terraces –post-construction, fall

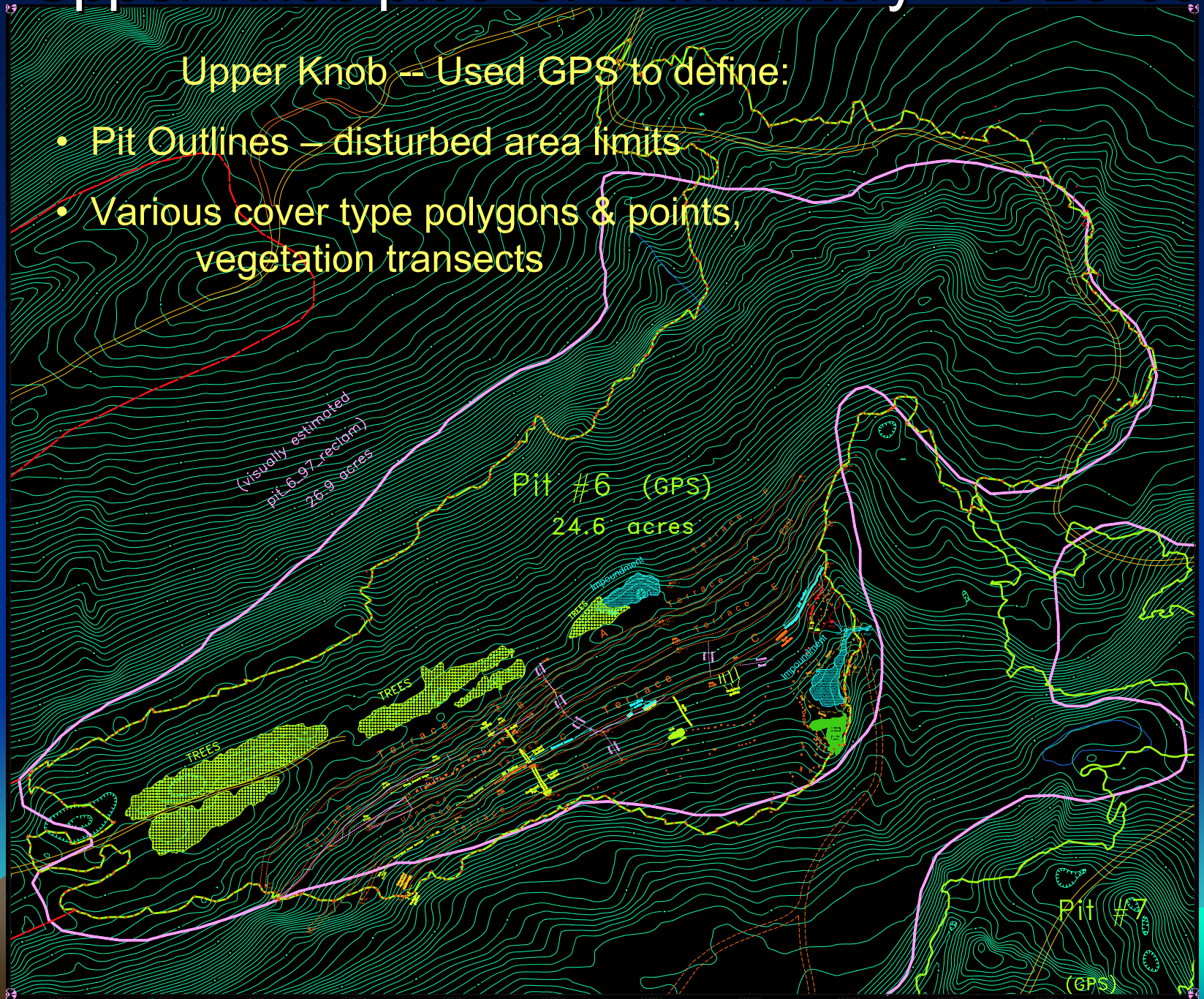
Upper Knob -- Pit 6 Terraces cut

Pit 6 Terraces – incipient vegetation

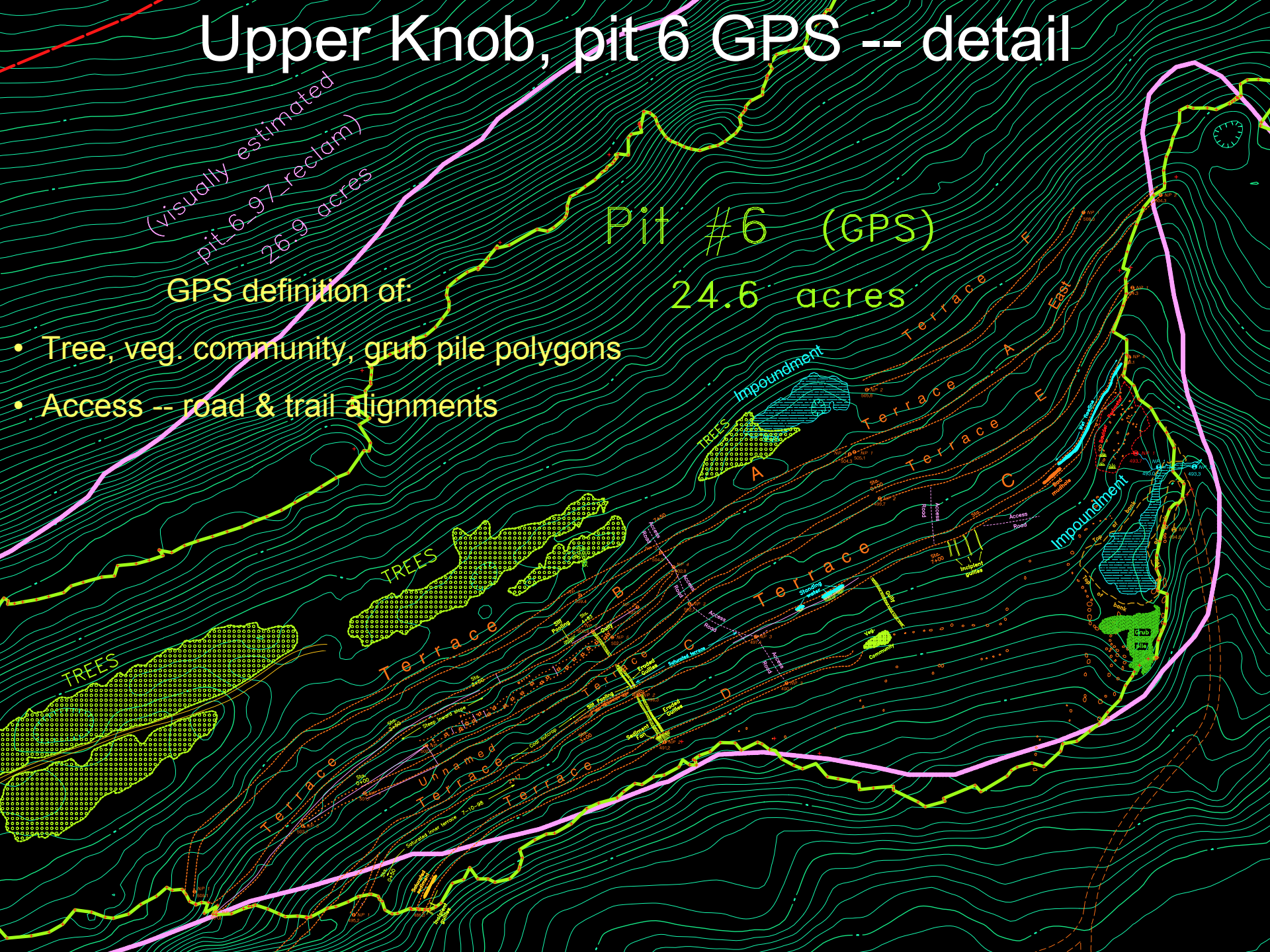
Pit 6 Revegetation – grass cover

Pit 6 Revegetation – grass cover

Upper Knob pit 6 GPS Inventory – 3-26-99

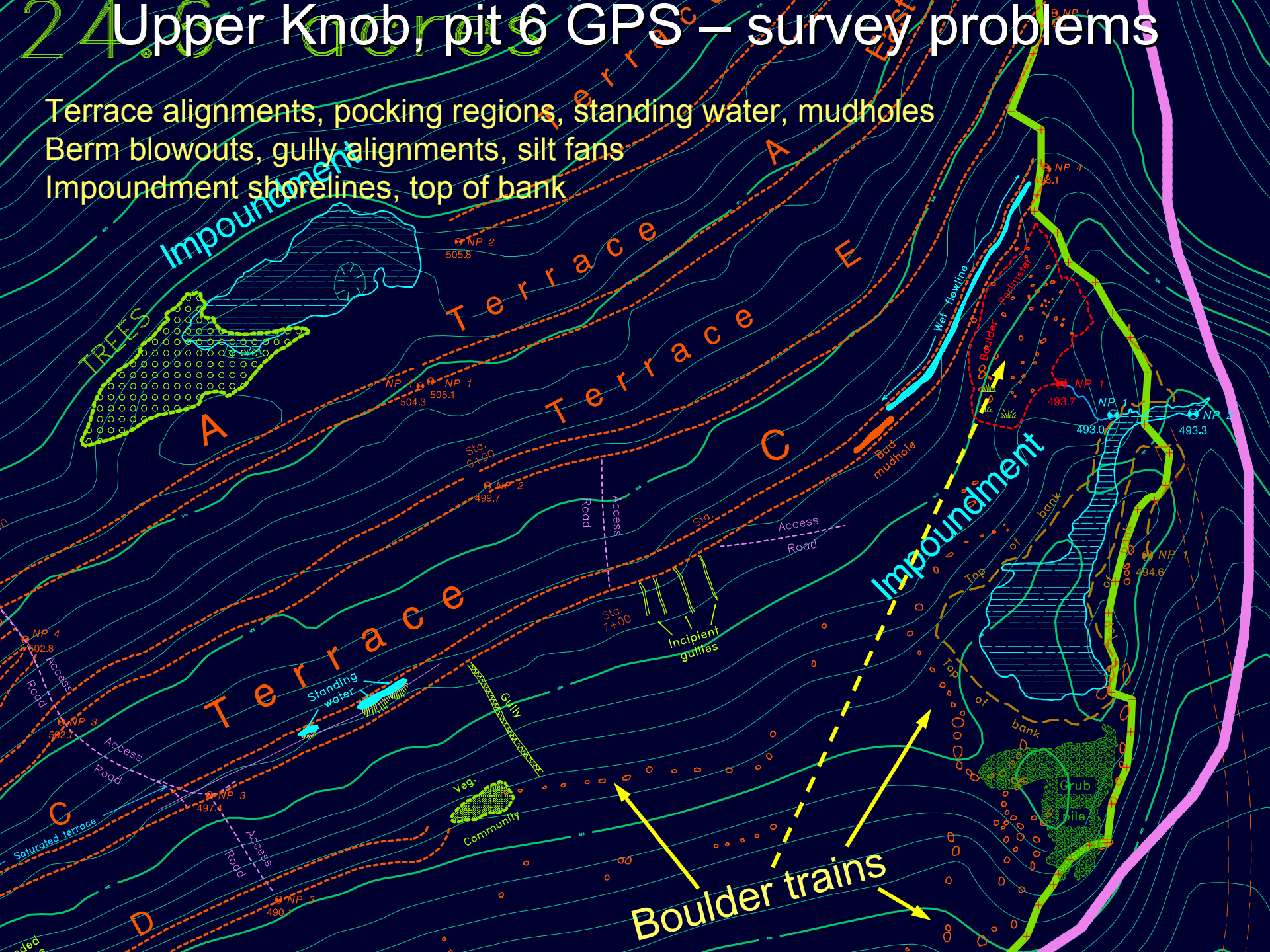


Upper Knob, pit 6 GPS -- detail



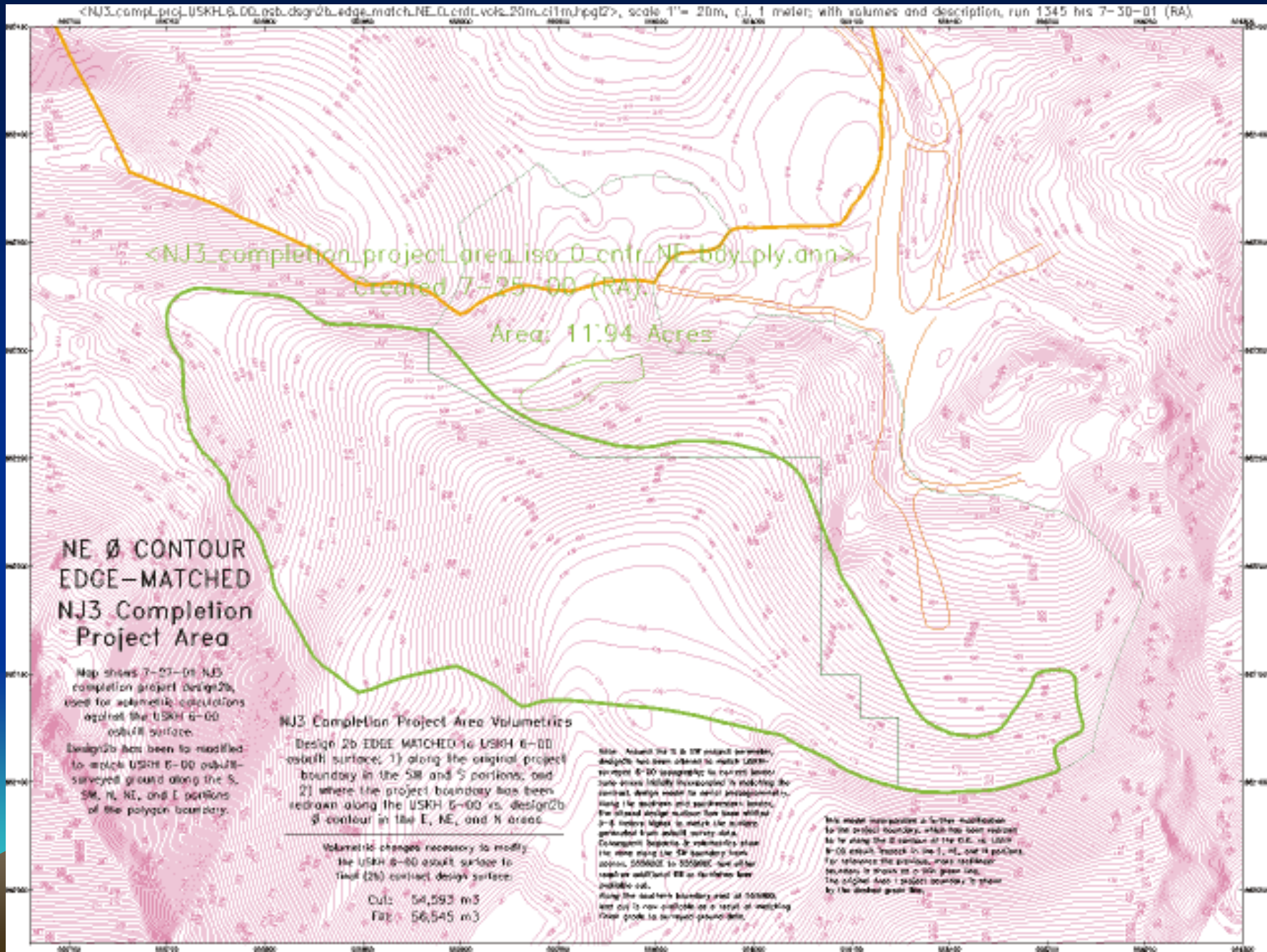
Upper Knob, pit 6 GPS – survey problems

Terrace alignments, pocking regions, standing water, mudholes
Berm blowouts, gully alignments, silt fans
Impoundment shorelines, top of bank

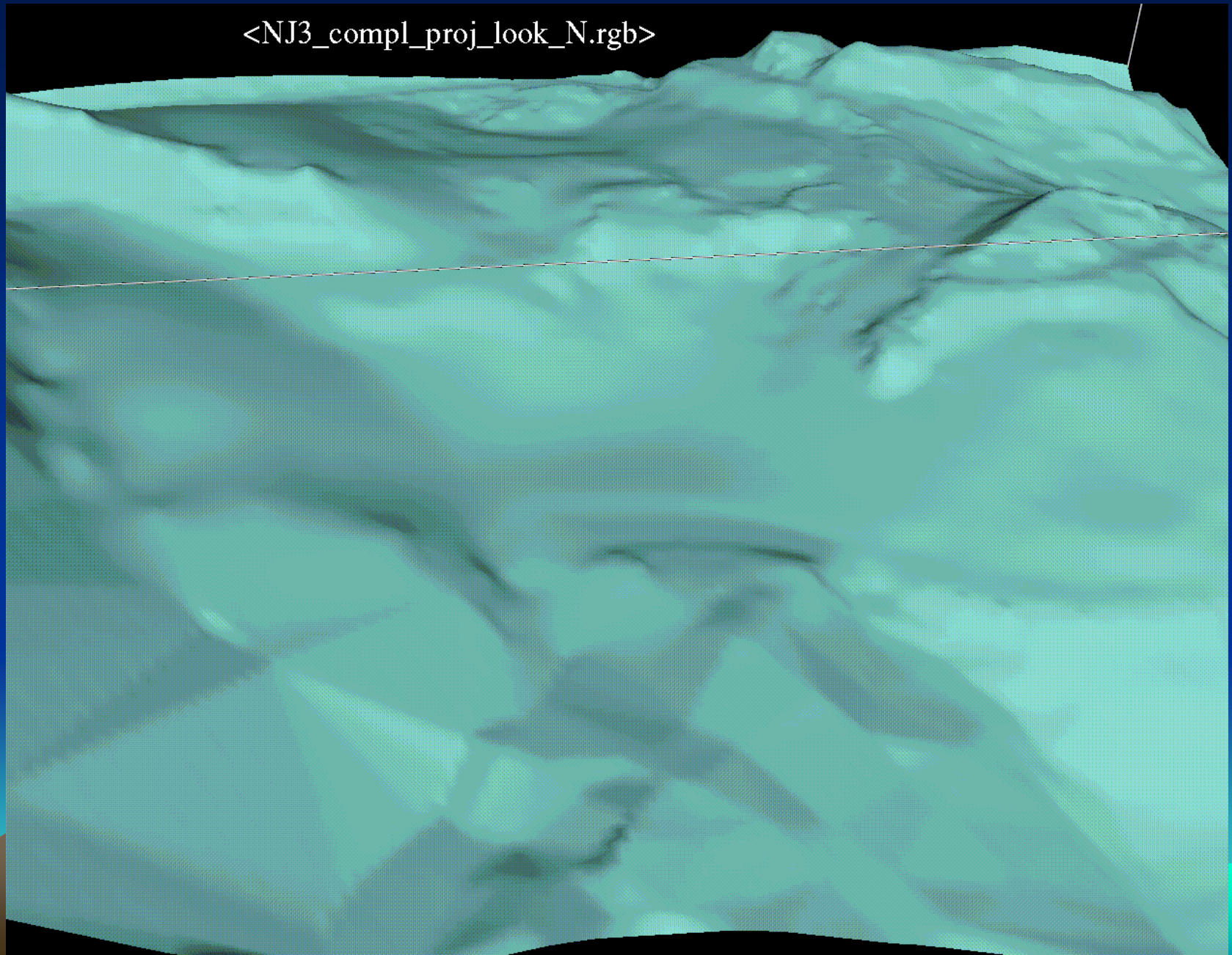


North Jones Dragline Pits ~ 1993

NJ3 completion project design – 10.7 acres

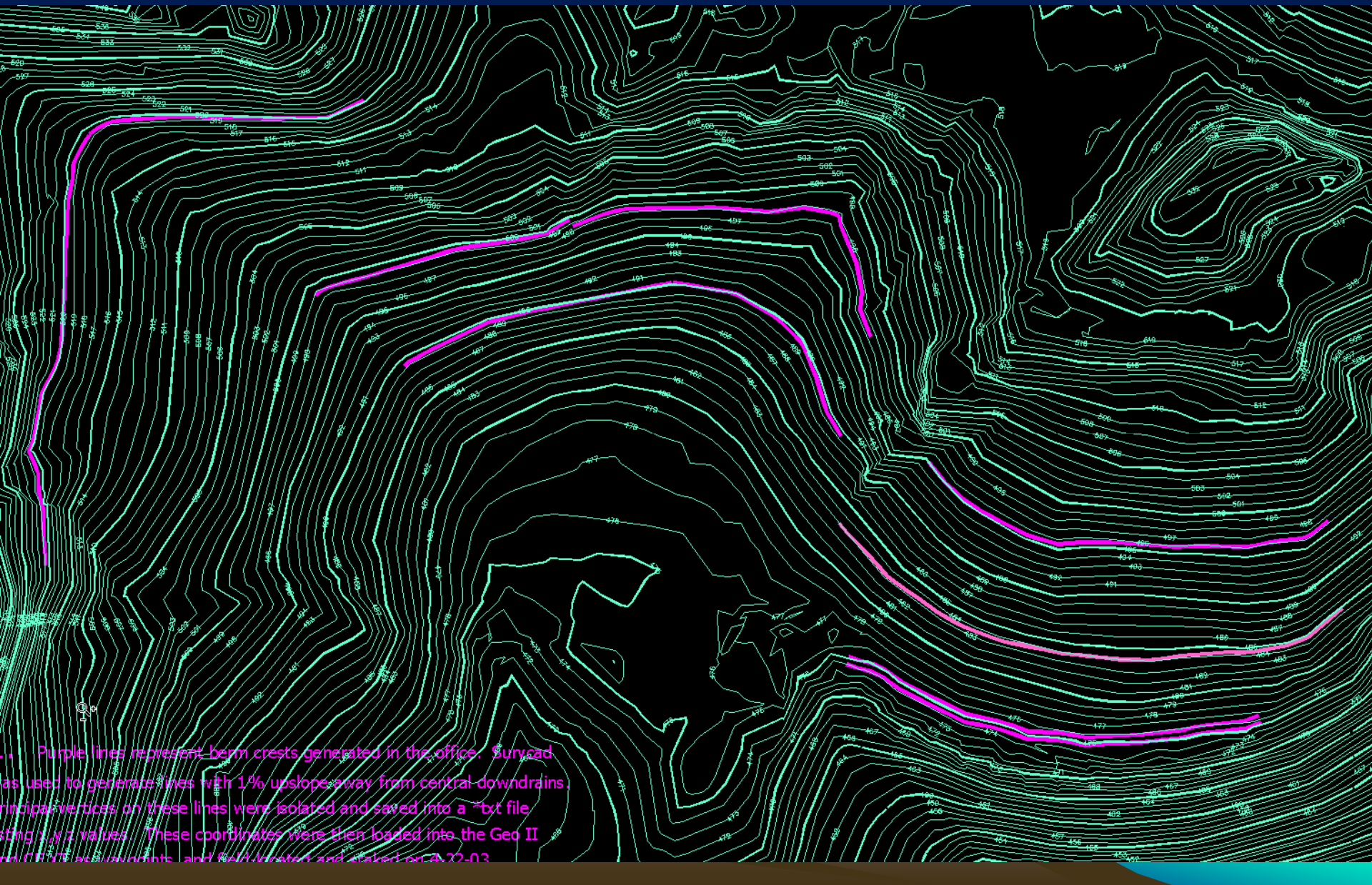


NJ3 completion project 3D, look N

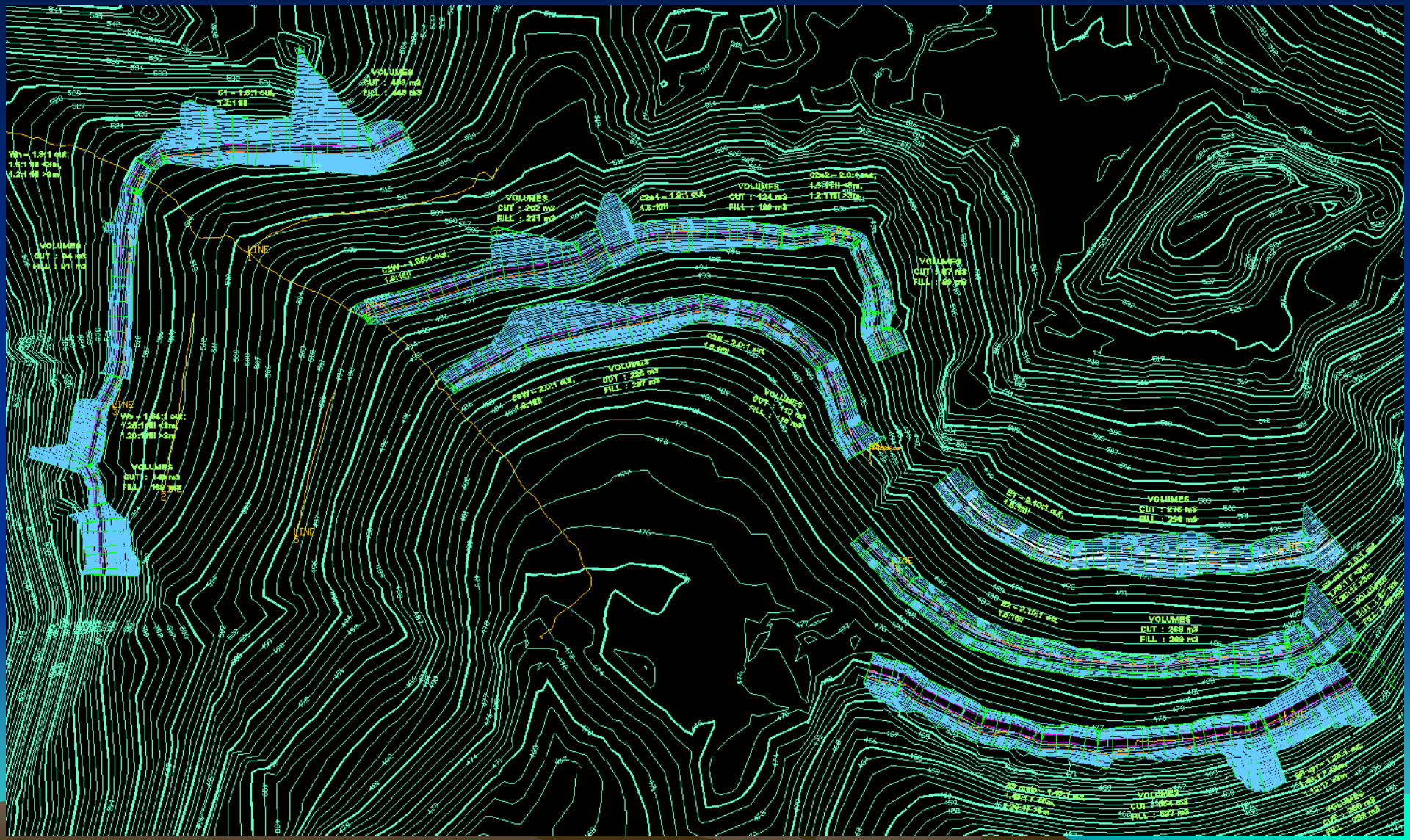


NJ3 Completion – 2000 season

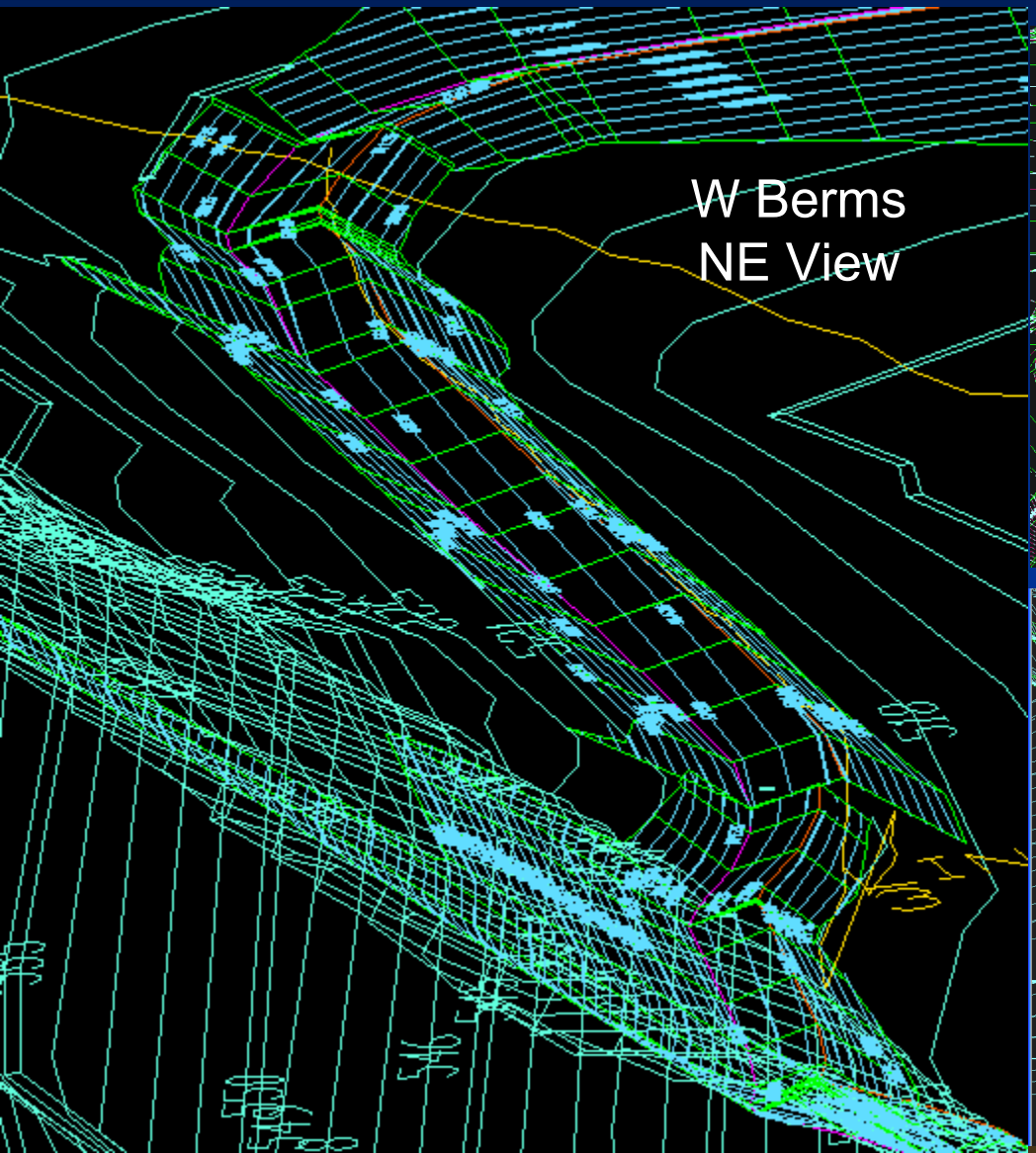
NJ3 GPS berm alignments – 1-03

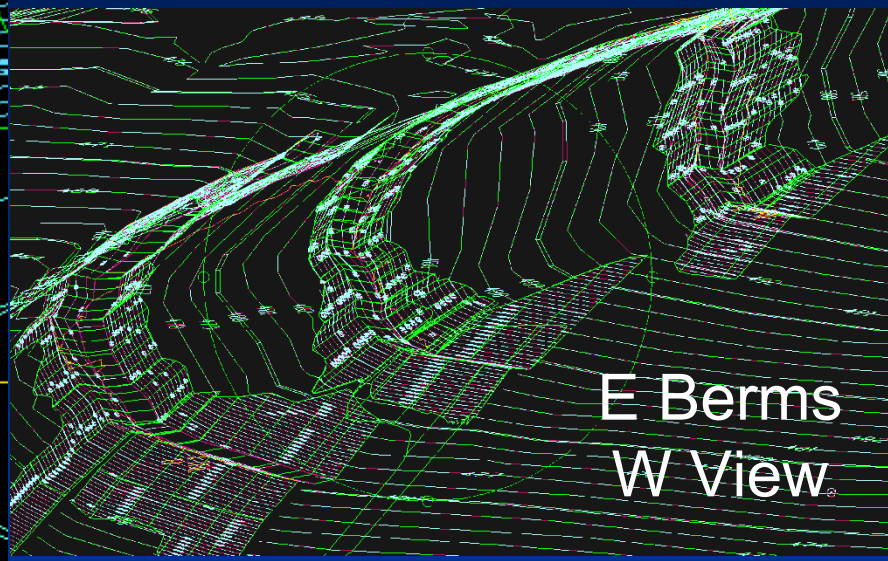


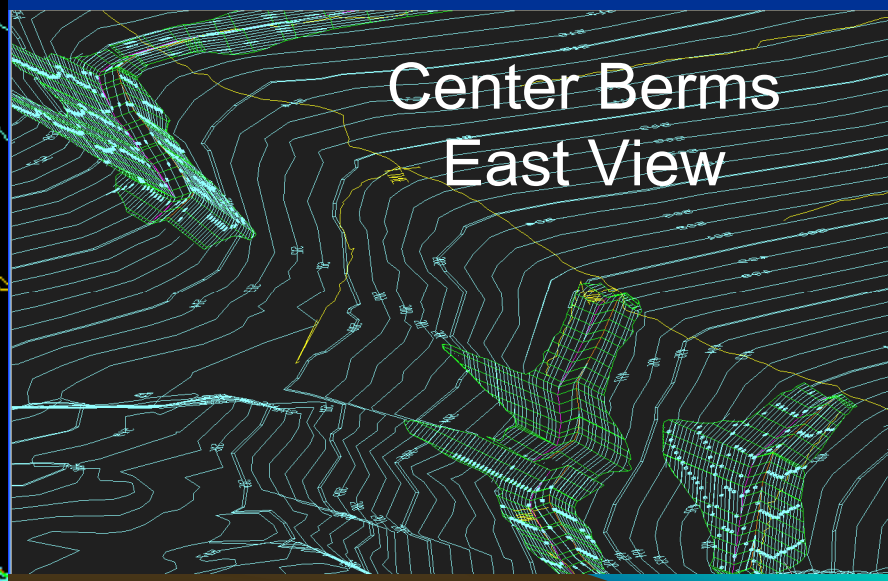
NJ3 GPS berm DESIGN – 1-03



NJ3 GPS berm DESIGN – 3D views

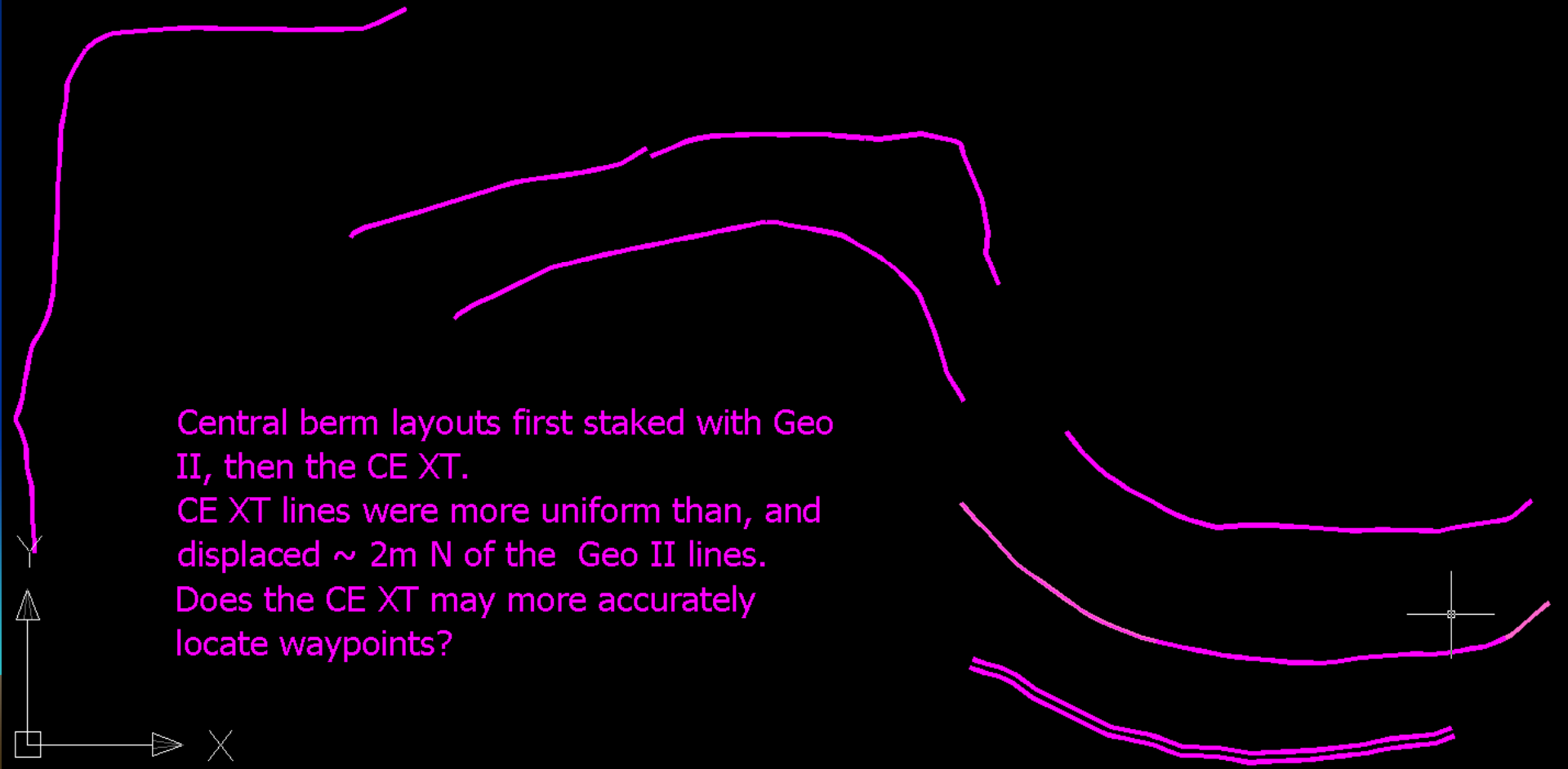






NJ3 GPS Berm Layouts – 4-03

Berm crests generated in the office.
Survcad used to generate lines with 1% upslope away from downdrains.
Principal line vertices saved to *txt xyz file
Coordinates loaded into Geo II and CE XT as waypoints
Waypoints Field-located and staked 4-22-03.



Central berm layouts first staked with Geo II, then the CE XT.
CE XT lines were more uniform than, and displaced ~ 2m N of the Geo II lines.
Does the CE XT may more accurately locate waypoints?

NJ3 GPS berm layout – 4-03

NJ3 GPS berm layout – 4-03

NJ3 GPS Berm Layouts – 4-03

After staking lines with CE XT, alignments were surveyed with Geo II.
Corrected lines (yellow) show overall agreement purple design layouts.
Along eastern berms, asbuilt vs. design x,y variance ranges from 1/2 to 1 meter.
N central and W alignments diverge from design up to 4 meters.
Cause: Multipath from steep backslopes, & partially blocked view of the sky.

Note probable multipath offsets in the lower E berms, upper middle berm, & ends of NW and W lines.

NJ3 Dozer-cut terraces – 5-29-03

NJ3 Terraces completed

East Outslope, 6-11-03

West slopes and downdrain, 6-25-03

NJ3 Berm lines – Geo II vs. CE/XT

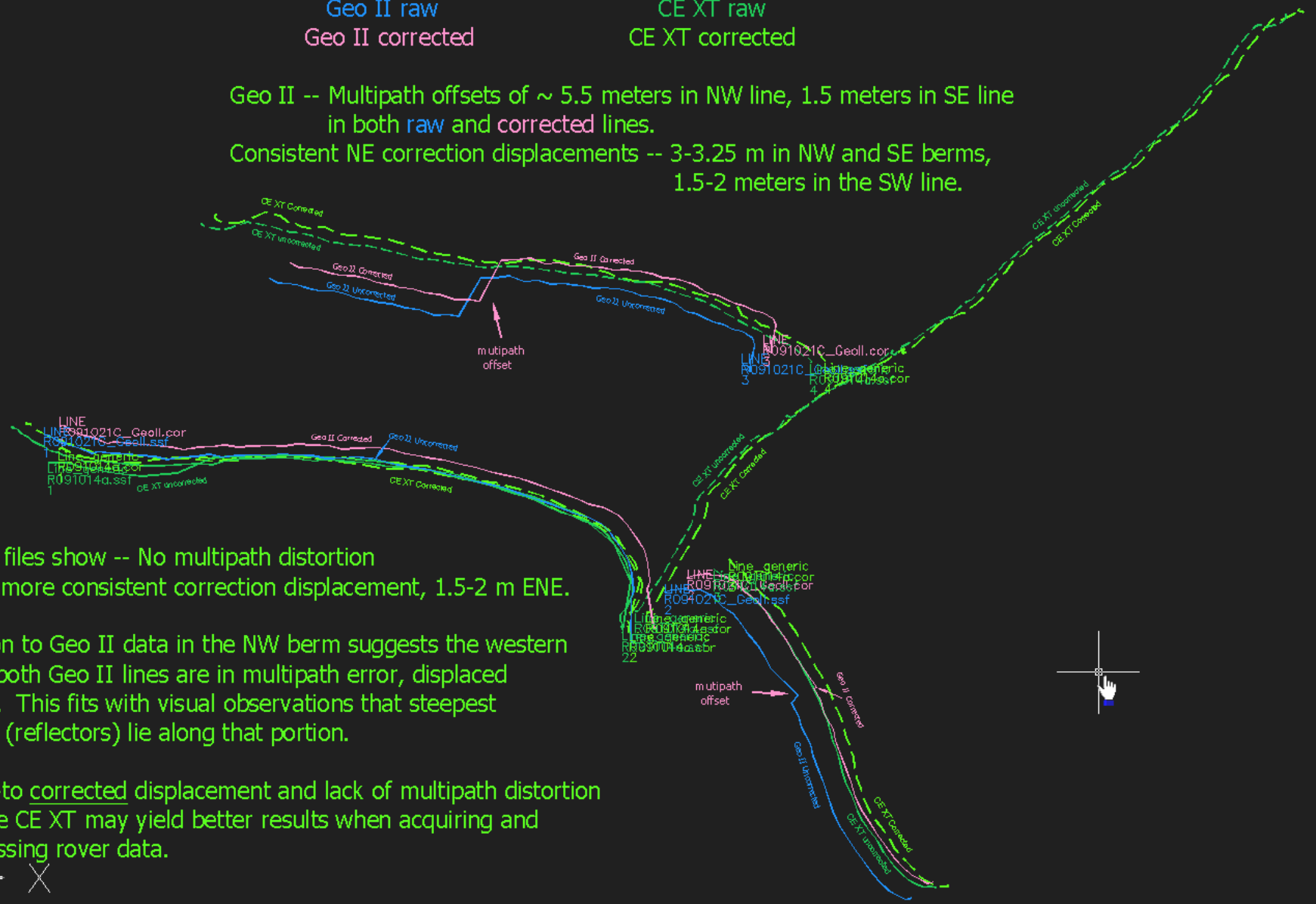
9-10-03 as-built surveys of central berm inverts, comparing

Geo II raw — CE XT raw

Geo II corrected — CE XT corrected

Geo II -- Multipath offsets of ~ 5.5 meters in NW line, 1.5 meters in SE line in both raw and corrected lines.

Consistent NE correction displacements -- 3-3.25 m in NW and SE berms, 1.5-2 meters in the SW line.



The CE XT files show -- No multipath distortion
less & more consistent correction displacement, 1.5-2 m ENE.

Comparision to Geo II data in the NW berm suggests the western portion of both Geo II lines are in multipath error, displaced southward. This fits with visual observations that steepest backslopes (reflectors) lie along that portion.

Lower raw-to corrected displacement and lack of multipath distortion suggest the CE XT may yield better results when acquiring and post-processing rover data.

NJ III -- Revegetation Phase 2003

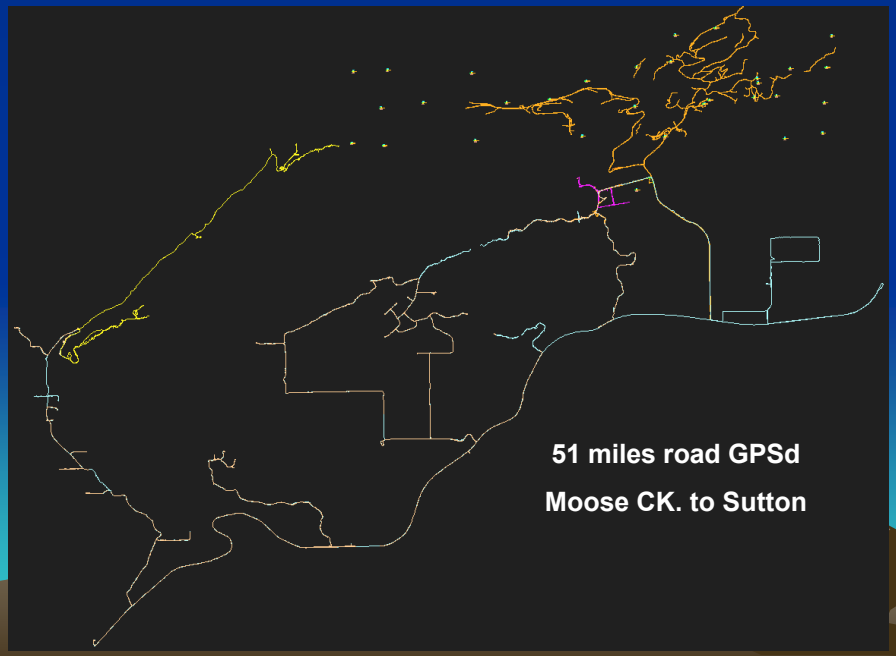
(View W)

NJ3 reveg. project
$146,982 total cost June-Aug. 2003

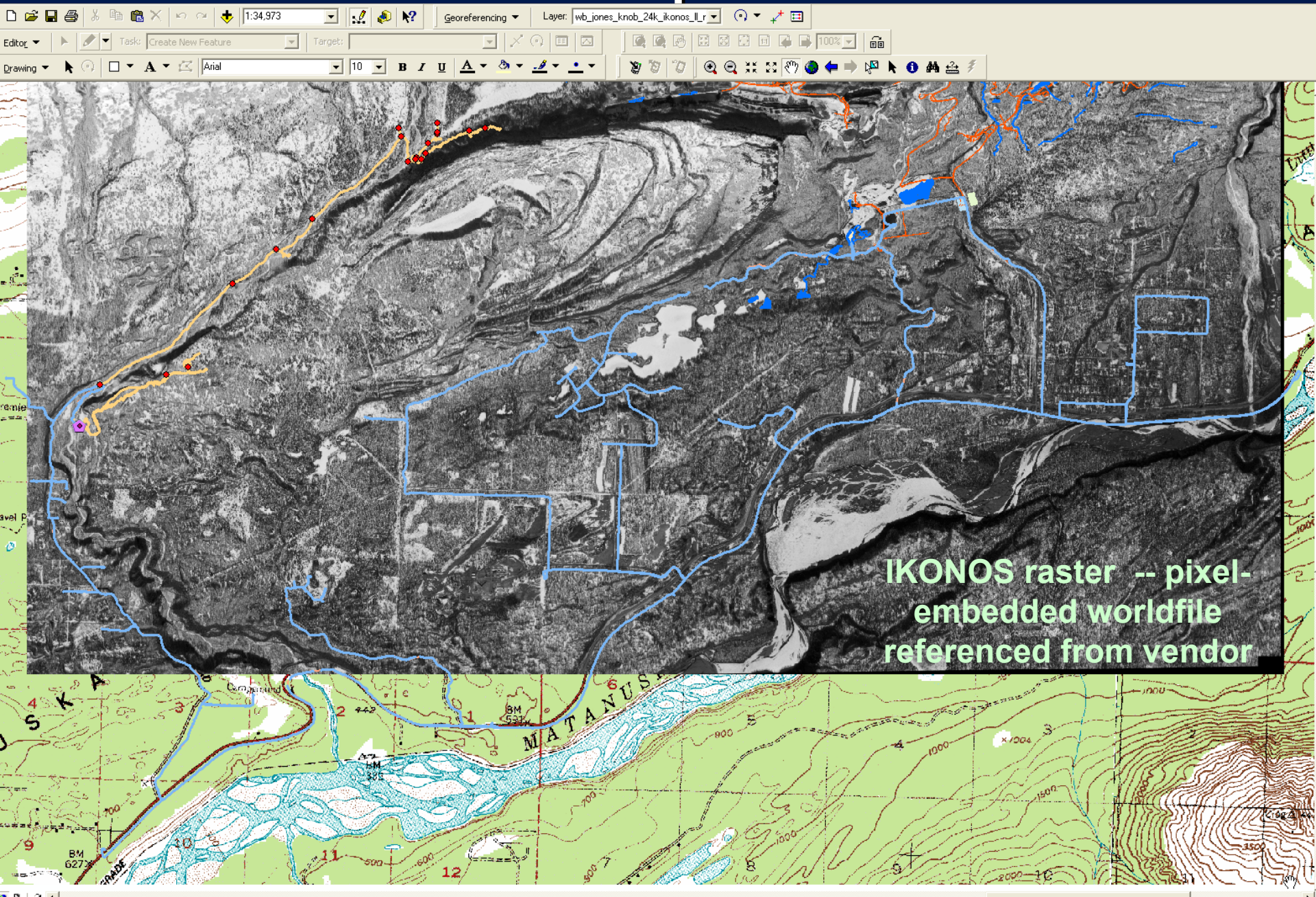
NJ III -- Revegetation July 2005

GPS – Monument recovery & mapping

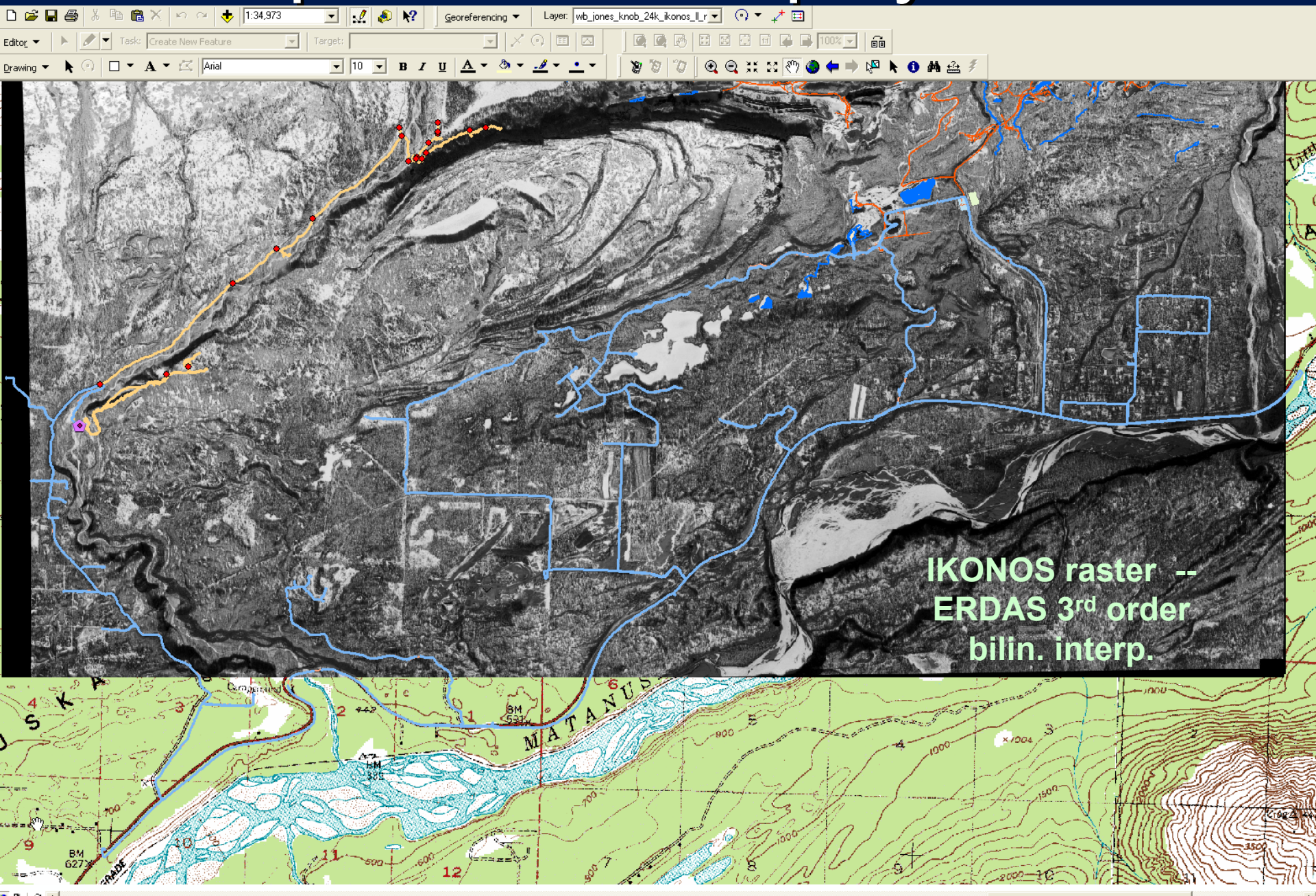
Examples – Vector collection



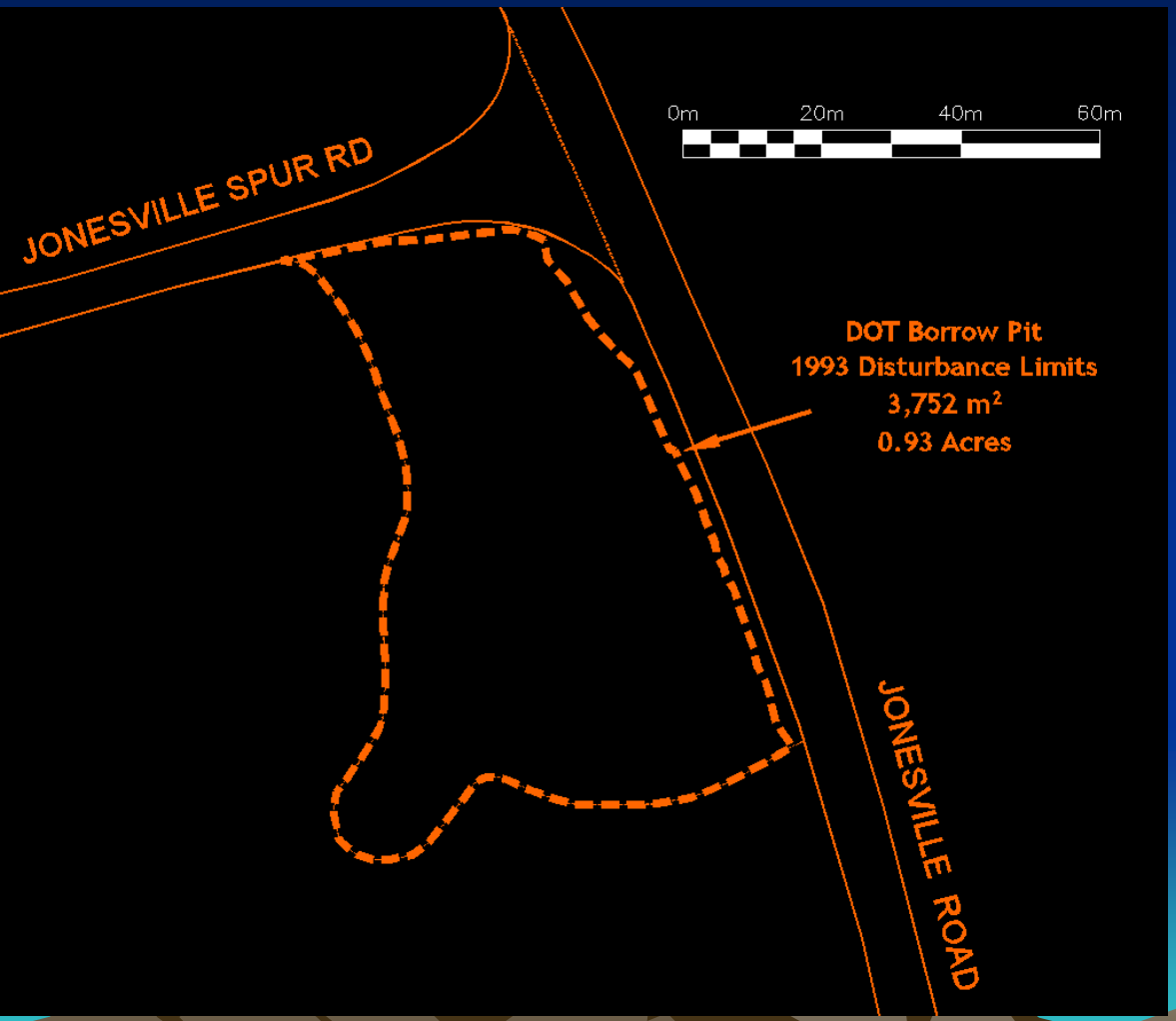
IKONOS Raster -- pseudo-corrected



Examples – Raster poly-correct.



Gravel Extraction Area Measurement & Permit Reconstruction



Dated disturbance limits interpreted on 1993 aerial mapping

Area excavated for borrow through 2003 for several projects – much enlarged

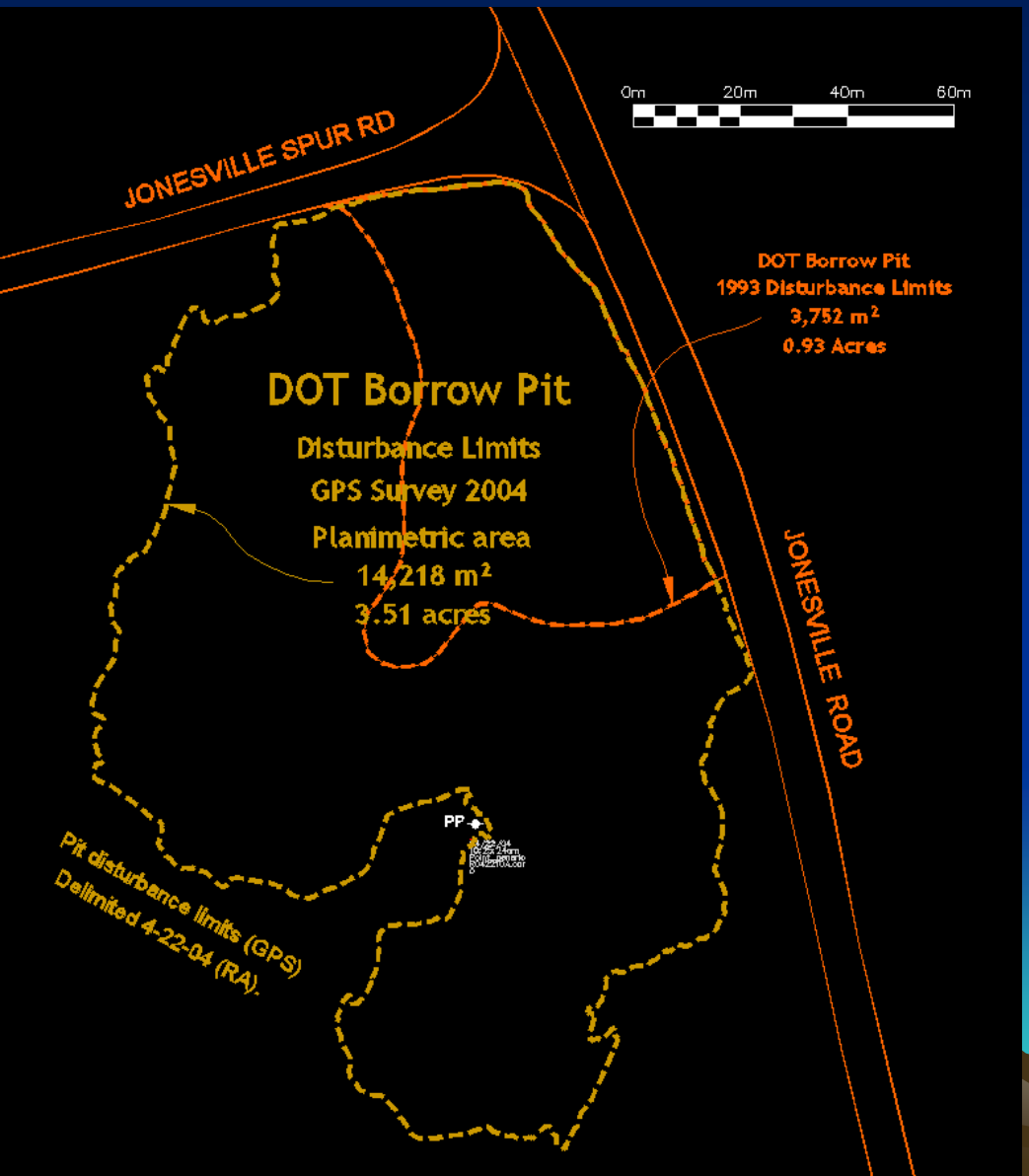
No boundaries or topography surveyed since 1993

Gravel Extraction Area Measurement & Permit reconstruction

GPS survey of disturbance boundaries in April 2004

Survey lines displayed atop 2005 USDA imagery

Gravel Extraction -- 2004 Measurement of Enlarged Area



Disturbance boundaries GPS surveyed in April 2004

Significant excavation enlargement of >3.5X

Question: how much extractable gravel remained in permit area?

Sufficient quantities to supply 2005 AML spoils fire reclamation project?

Enlargement Raises Boundary Issues
GPS collection of existing features

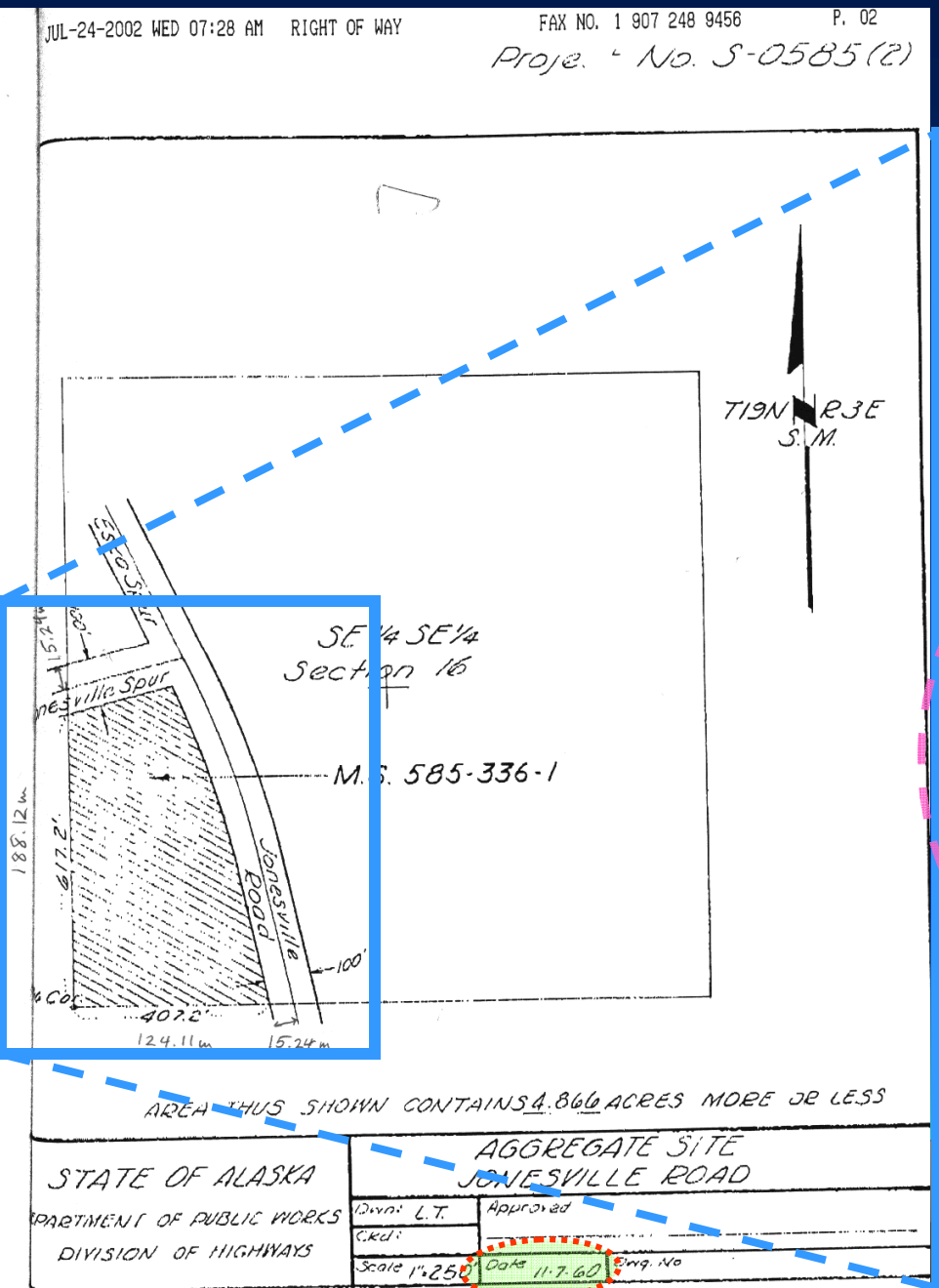
Question: where are the permit boundaries?

Collected GPS road CL and ditch/edge alignments

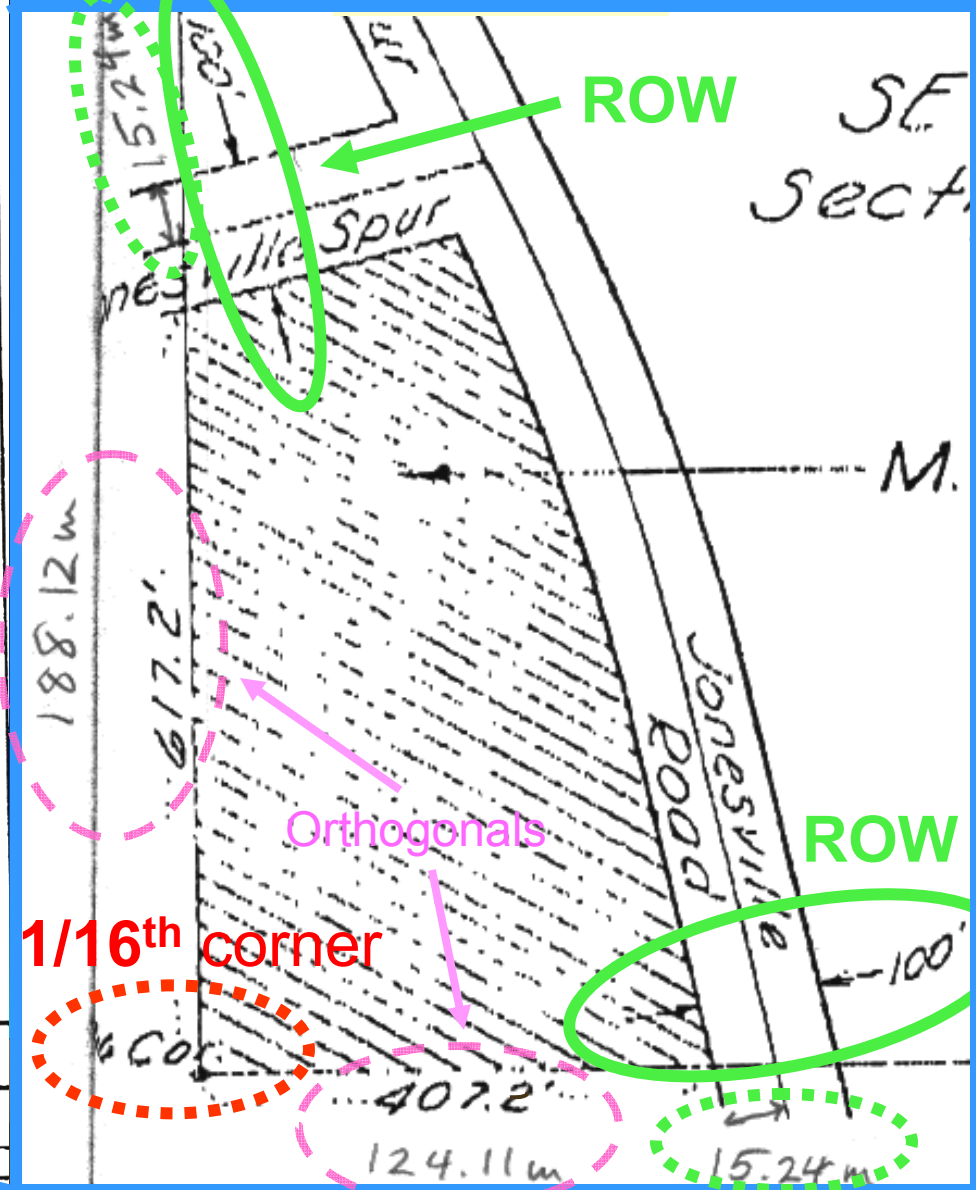
Always a good idea to collect utility and structure GPS location data when in the field

May prove useful when compared with plat, engineering plans, or geographic data

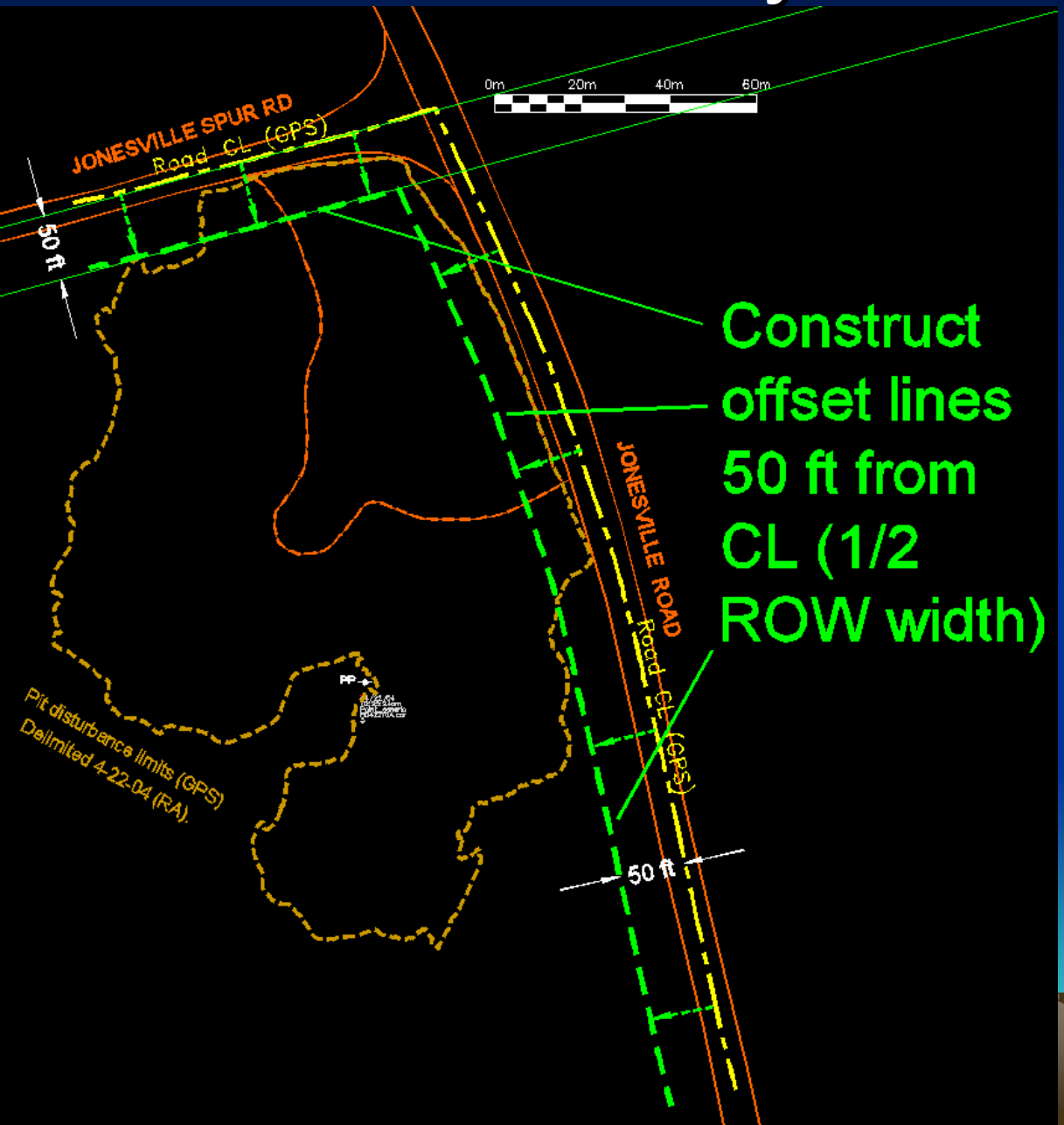
Permit found -- drawing with dimensions



INSET

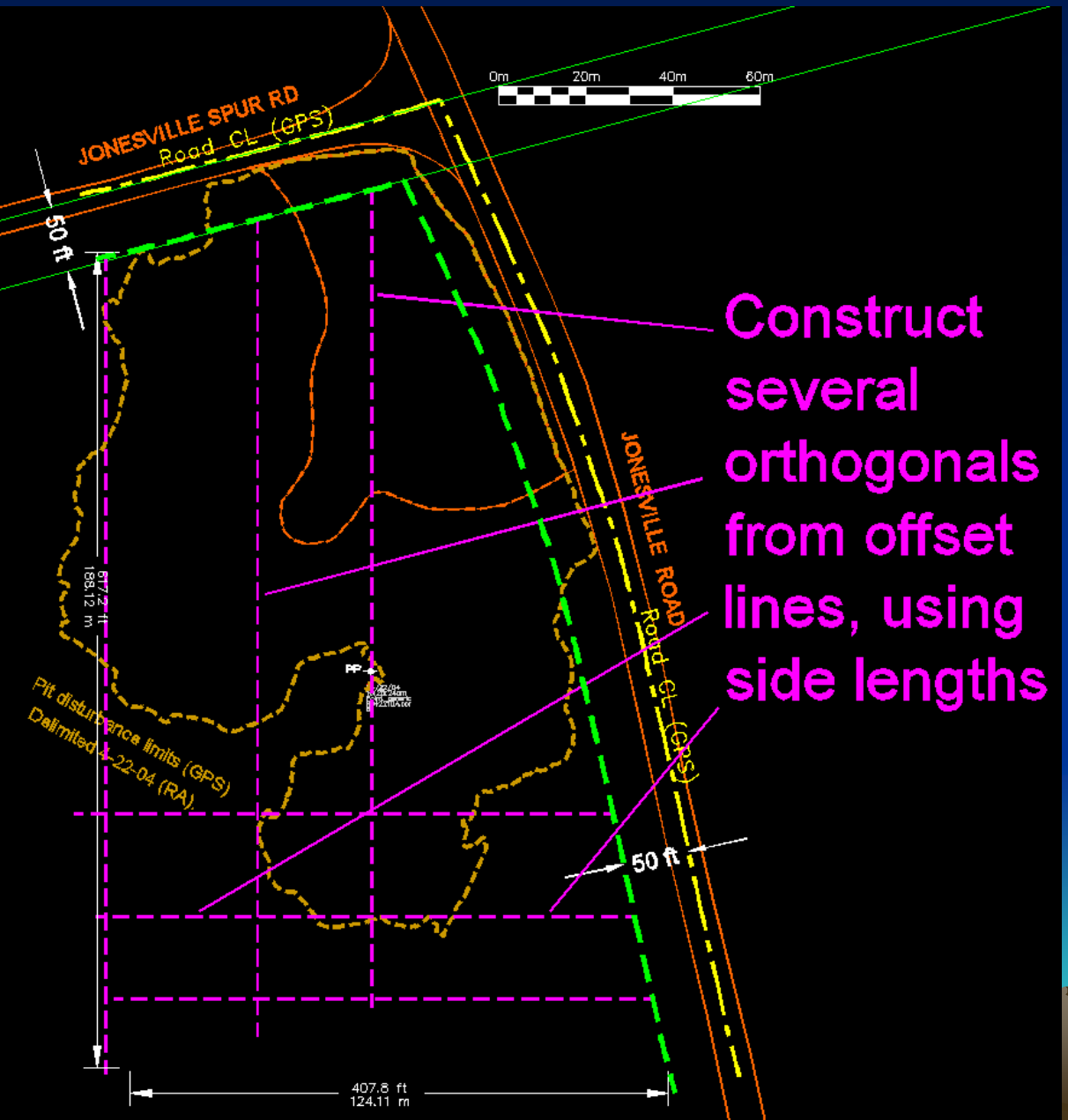


DOT Pit Boundary Permit Reconstruct



1st -- reconstruct boundary portion at 50 ft offset from GPSd road CL

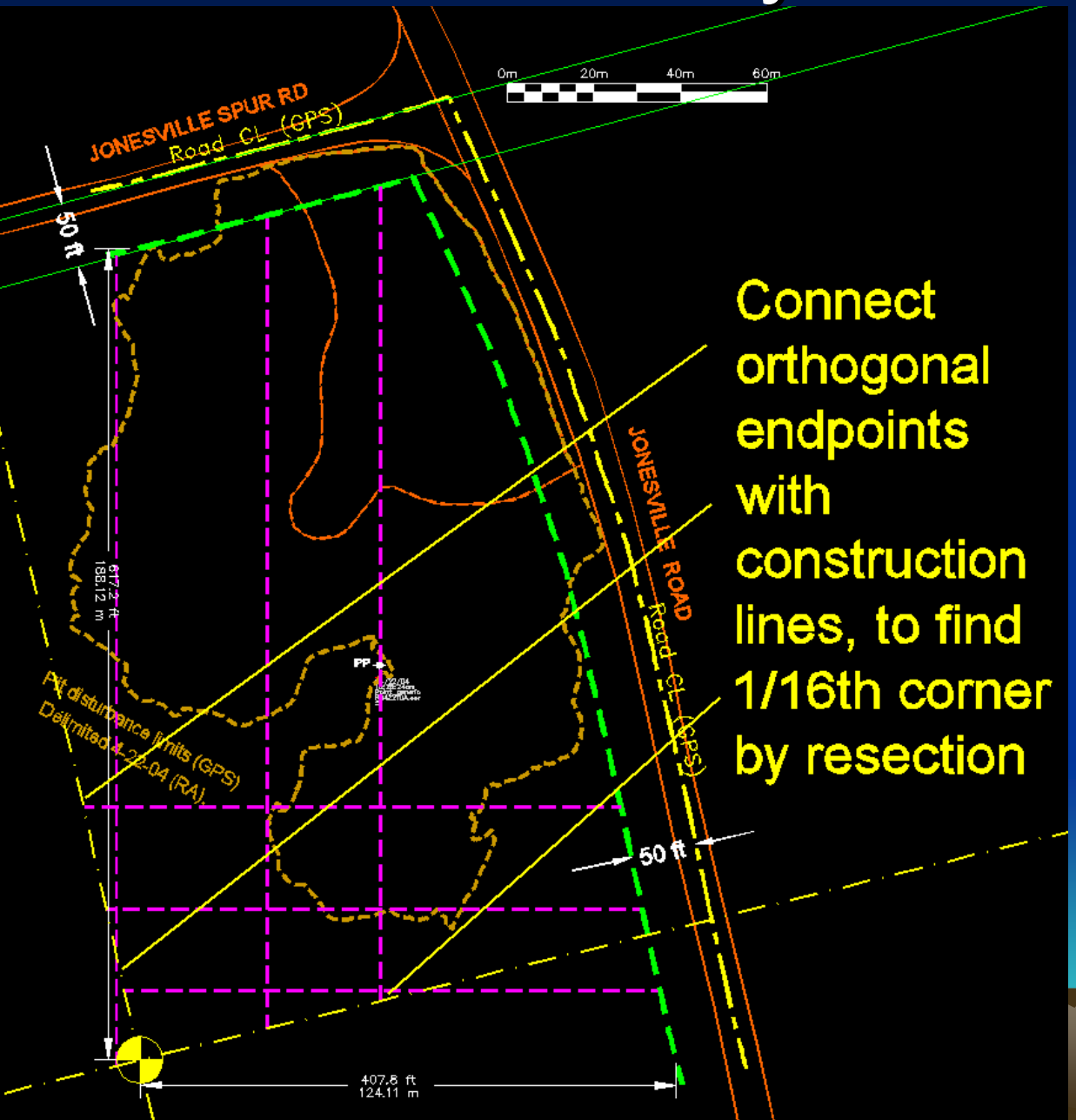
DOT Pit Boundary Permit Reconstruct



Construct several orthogonals from offset lines, using side lengths

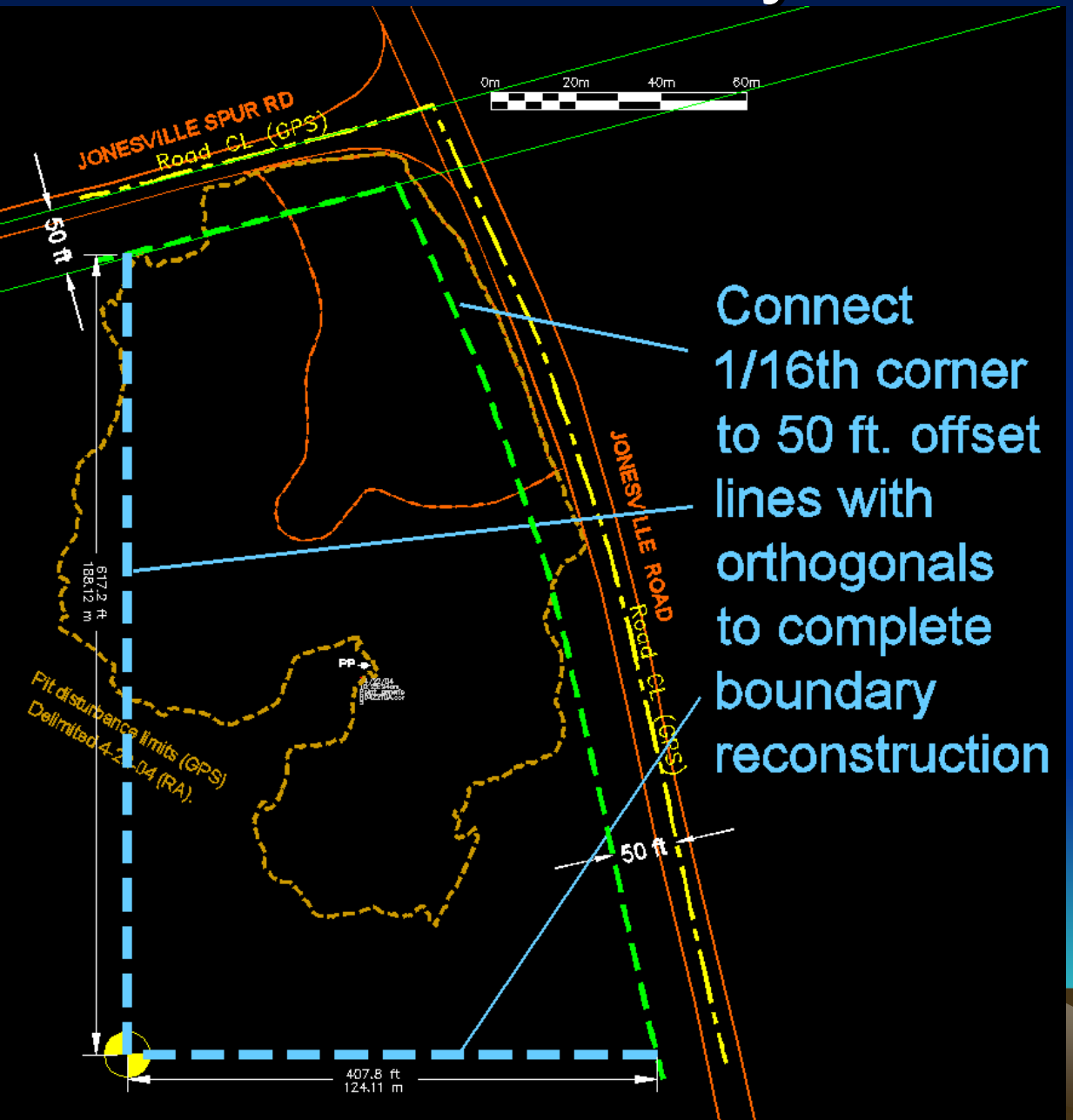
2nd – run N-S and E-W orthogonals from offset lines, using the West and South side lengths

DOT Pit Boundary Permit Reconstruct



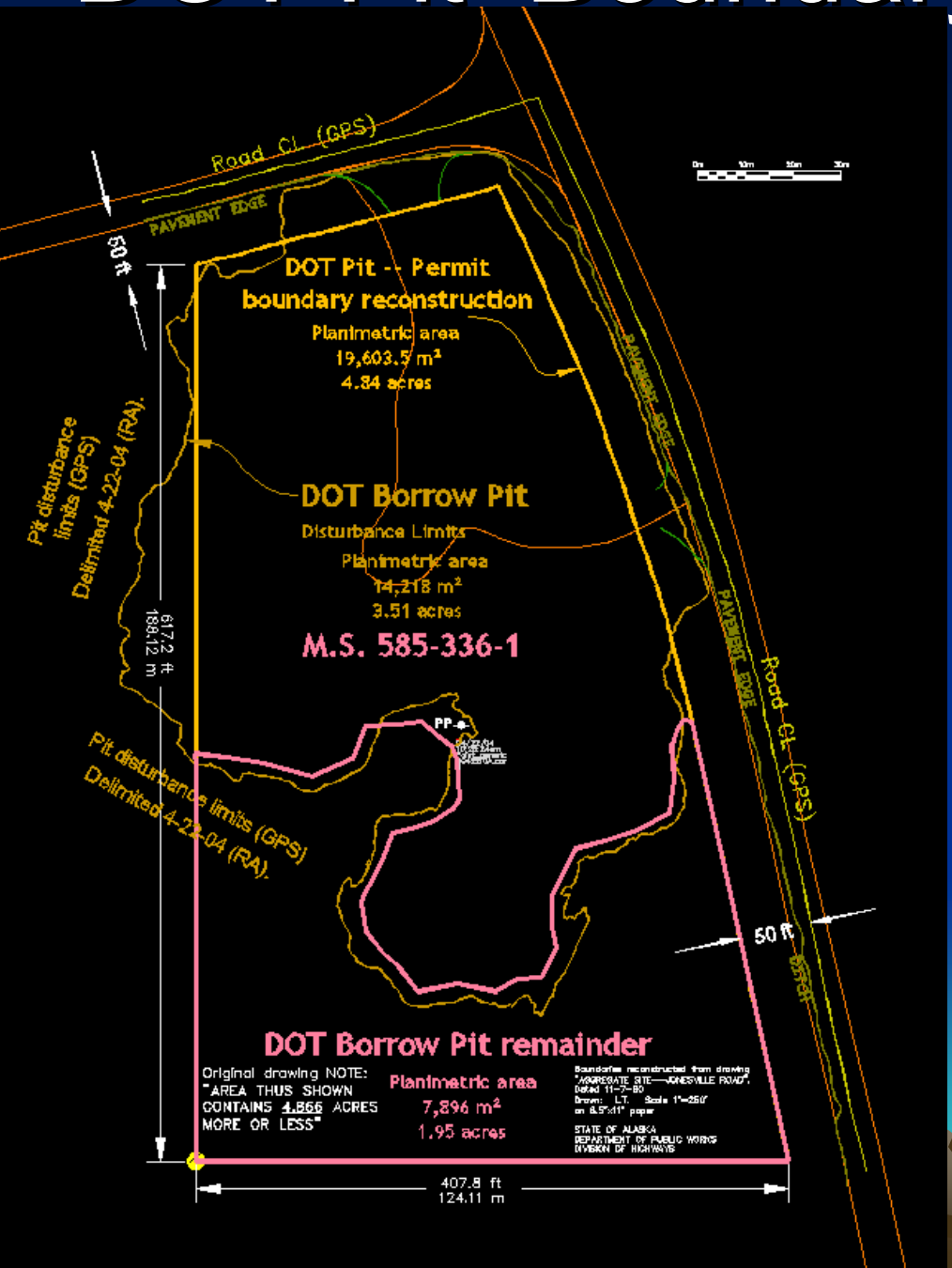
3rd – connect orthogonals' endpoints to resect 1/16th corner.

DOT Pit Boundary Permit Reconstruct



4th – connect 1/16th corner to ROW offset to finish boundary reconstruction

DOT Pit Boundary cf. disturbance



RESULTS

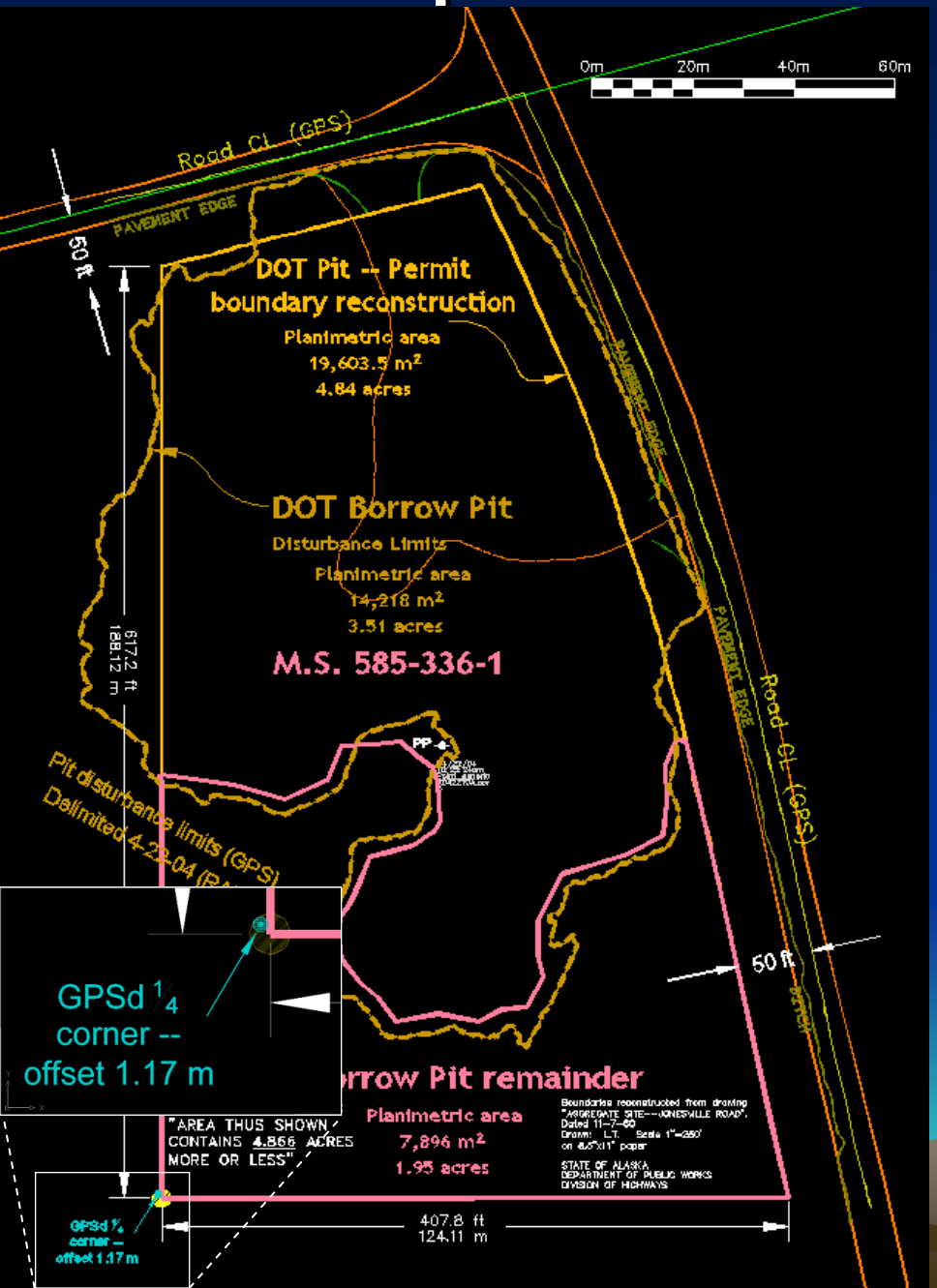
Excavation disturbance strayed somewhat outside west side permit boundary

Reconstructed permit acreage very close to 1960 drawing area -- Δ 0.02 acres

Calculated ~7900 m2 of remaining undisturbed area within permit boundary

More than enough probable gravel volume available for 2005 fires AML construction

Examples – Plat reconstruction



No topography or boundaries surveyed on the ground

Gathered line features on disturbance limits, road centerlines

Used corr. line features and 1960 plat dimensions to reconstruct boundaries of permitted gravel extraction area

Calculated remaining area to estimate probable borrow volumes

Jonesville Fires -- History

- Fires are known to have been burning for many years, since spoils dumping began
- No major effort to isolate & extinguish
- Previous wash plant reject was disposed of or used for construction material throughout the nearby area
- Old miners relate spoils fires continually threatened to ignite wooden wash plant buildings

Jonesville Fires -- Need for the Work

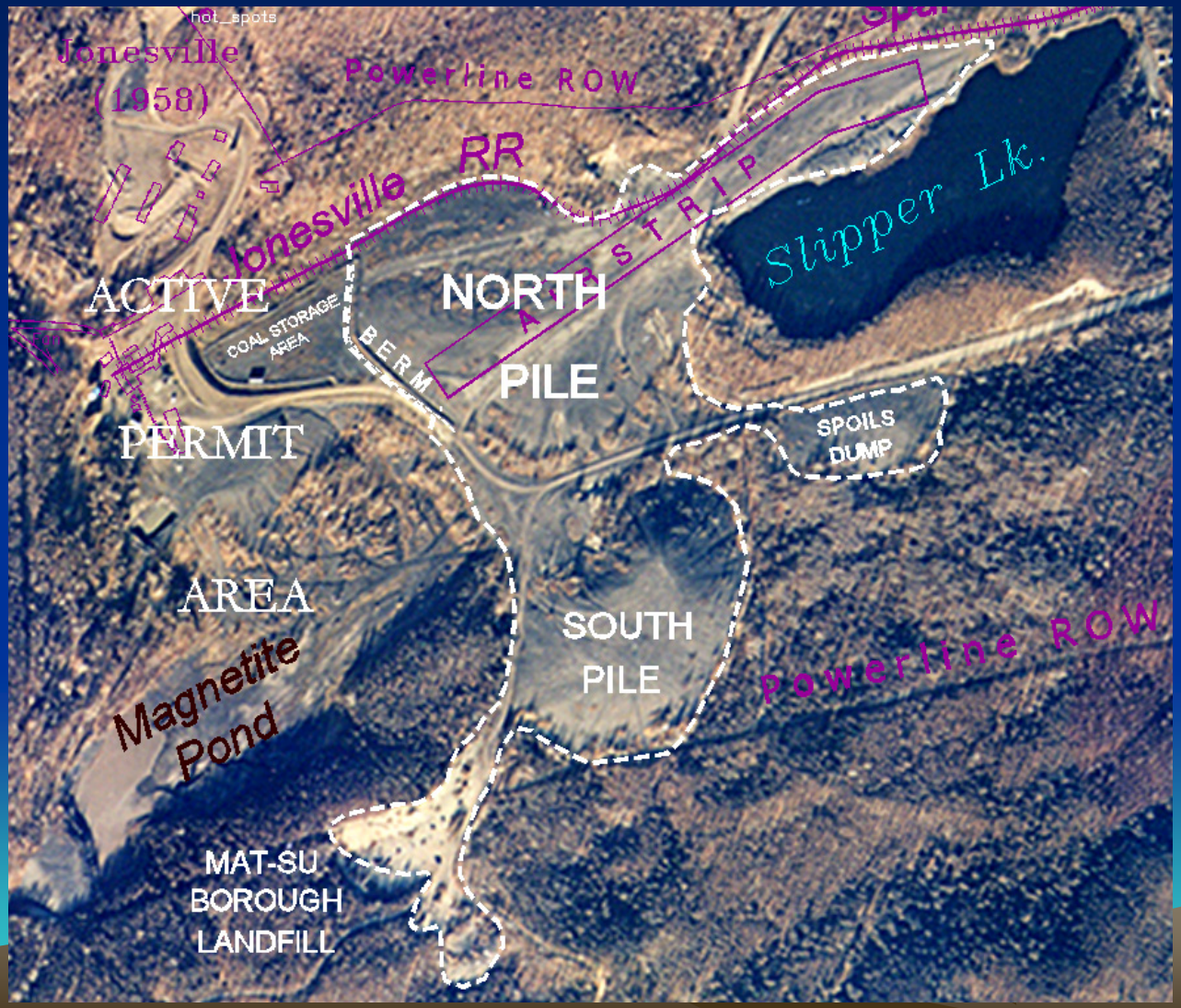
- Water diverted from cross-cut tunnel to flood burning areas – didn't work (early '90's)
  - Dissolved O_2 fueled fires
  - Subsidence and ground cracks developed
- Forest fire ignited May 1999, due to permittee negligence – burned approx. ½ acre
- Fire pond area covered with sand & gravel, but didn't work – more subsidence & ground cracks developed

Jonesville Fires -- Need for the Work

- Proposed project and adjacent area covered by active coal lease and exploration and mining permits
- Local airstrip has existed north of Slipper Lake since at least the 1950's.
- Extensive public use of general area for ATV/ORV riding, hunting and fishing, camping, shooting, snowmachining, skiing, hiking…
- Public use of the area increases annually

Jones Fires -- AML-Eligible Areas

Surface features – work area targets



- N boundary – RR fill
- NW boundary -- berm
- Physically, potential areas for AML work segregate into:
- The North Pile
- South Pile
- Flat area in between
- Old spoils dump to E
- Matanuska-Susitna Borough Landfill – possible fill stockpile area

Historic Jonesville

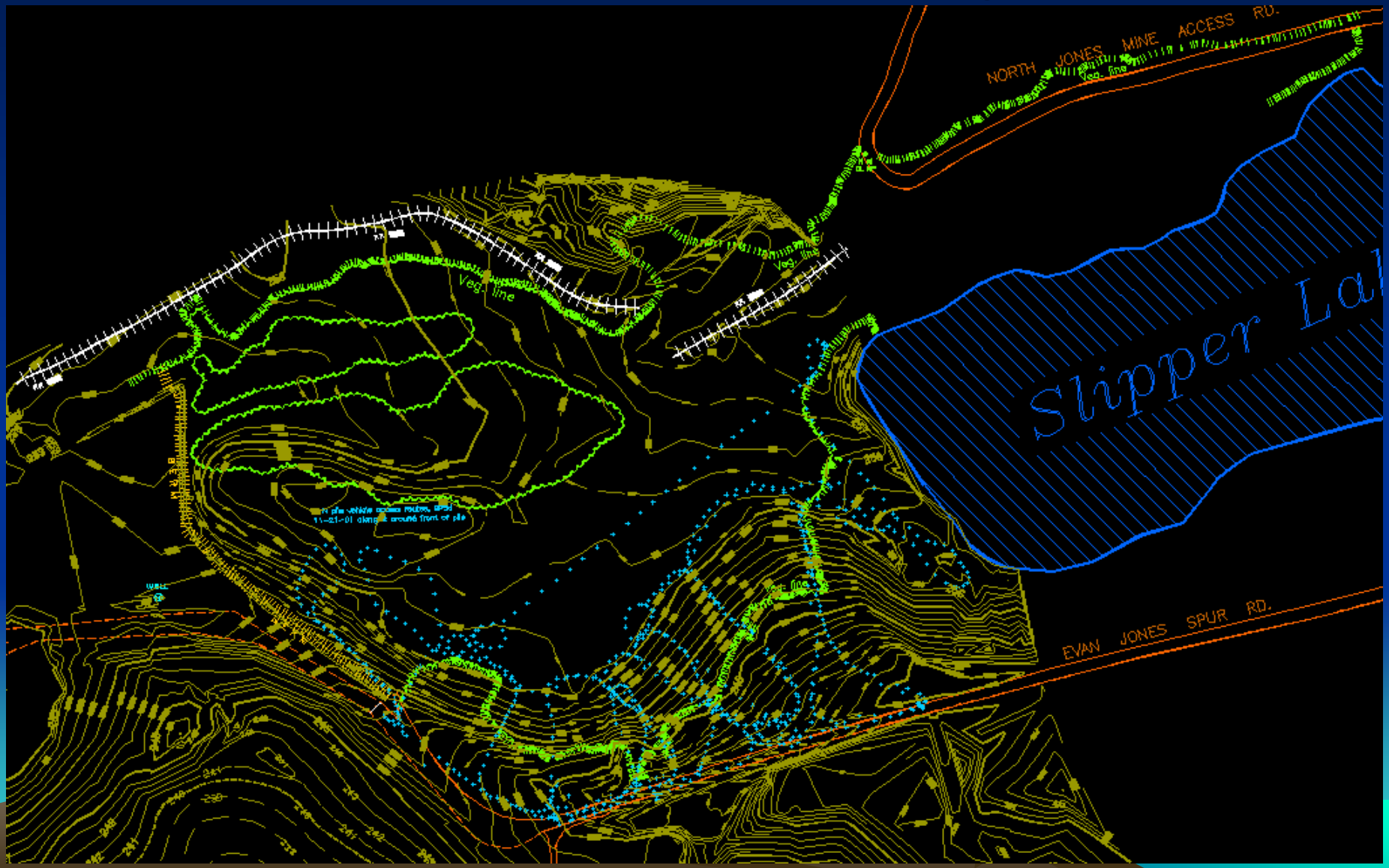
Design Phase
GPS Boundary definition

Work area Boundary -- begin by tracing outline of natural limits with GPS
- -- RR fill along N side @ base of mountain
- -- top of berm along W side
- -- road shoulder/ditch along SW & S
- -- vegetation limits at base of forested slope along E side
- -- Boundary in NE corner defined lack of heat in borehole line NW of Slipper Lake

Vegetation zones – GPSd to define clearing limits—a contract pay item

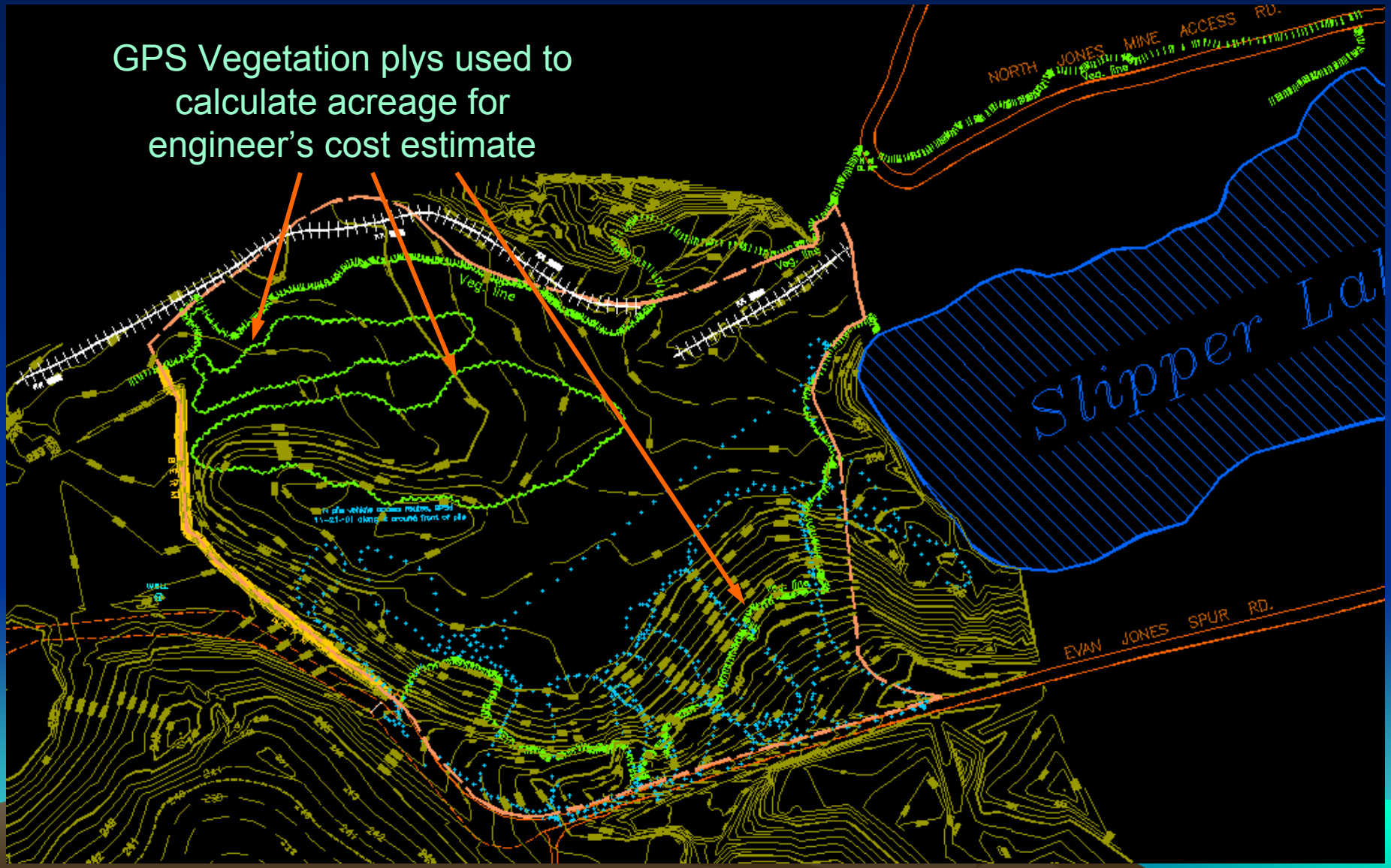
Jones Fires GPS boundary definition

Access, RR fill, berm, vegetation



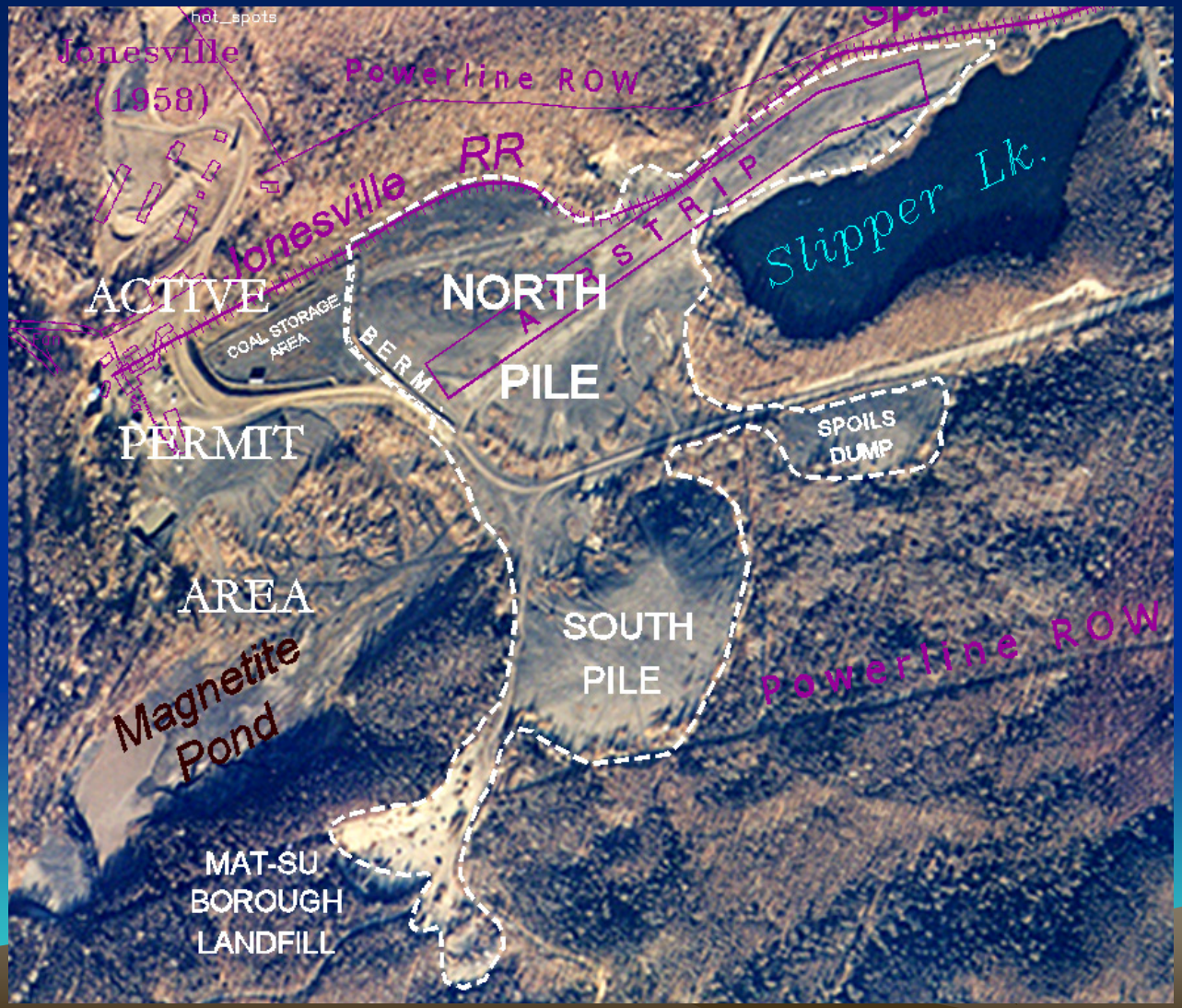
Jones Fires -- Project Boundary

Drawn based on GPS work



Fires: AML-eligible area definition

Subsurface properties – poorly known



Issues--need to assess:

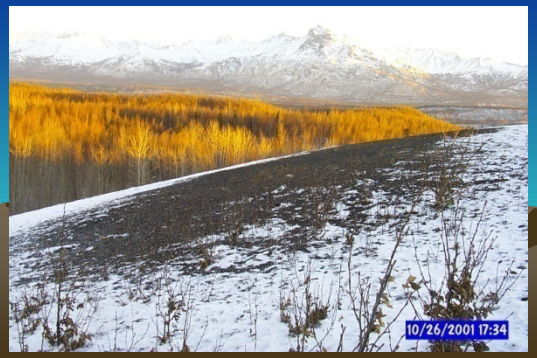
Thickness & lithologies of coaly spoils.

Depth to & type of natural ground underlying spoils

Distribution & degree of burning spoils in 3D space –

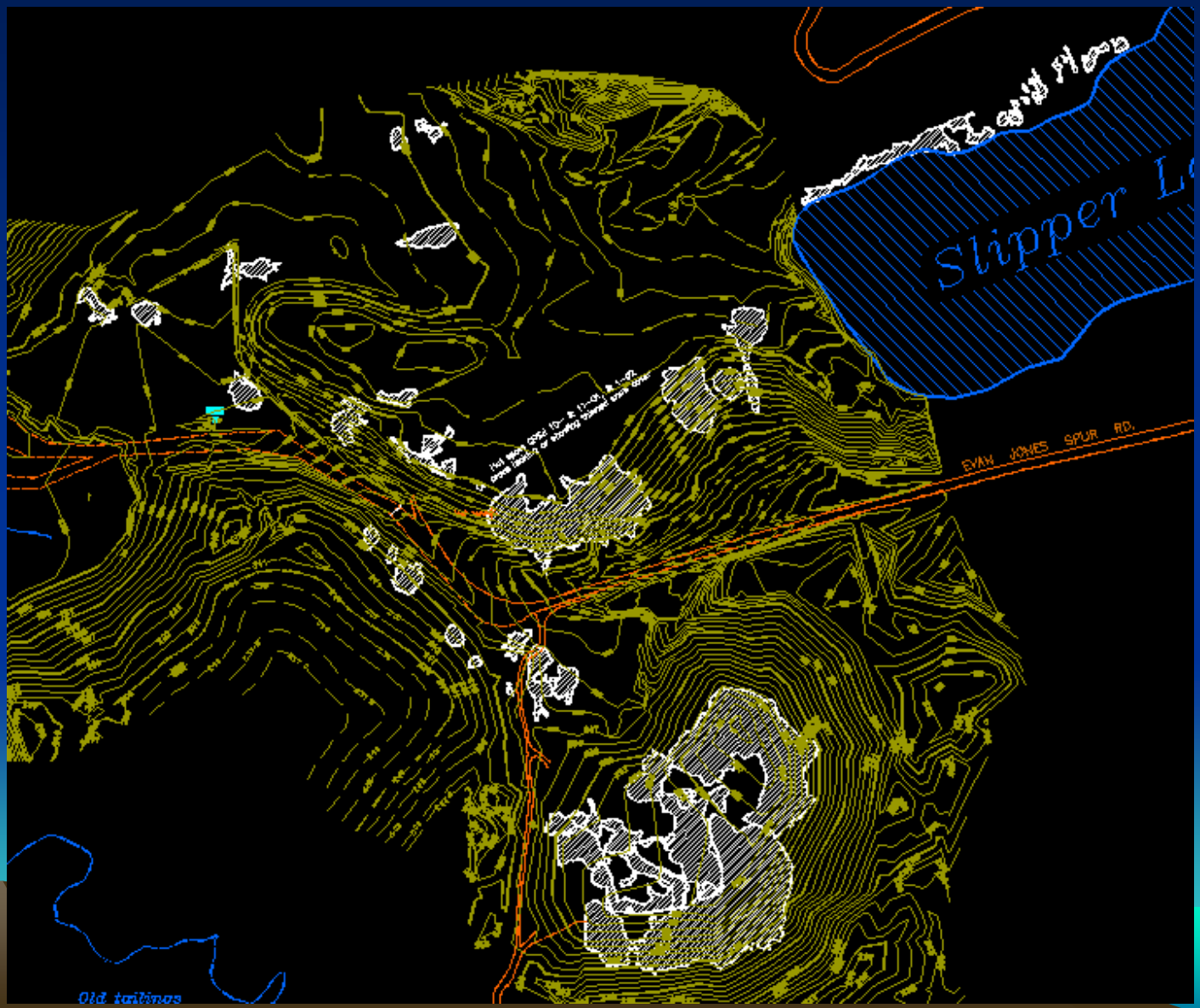
Distribution of carbon-containing spoils with potential to burn

Hot spots – surface snowmelt

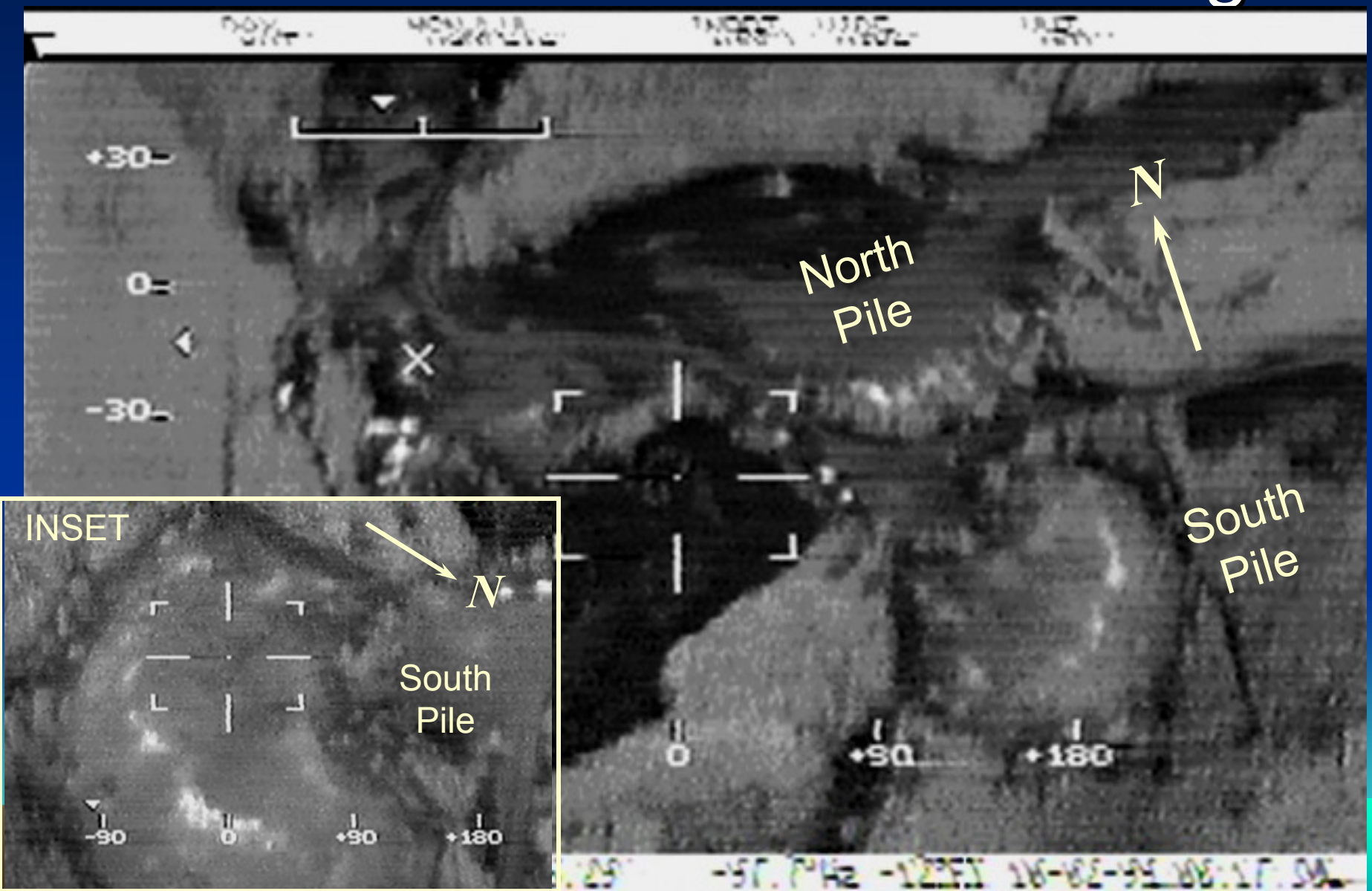


Hot spots -- GPS definition

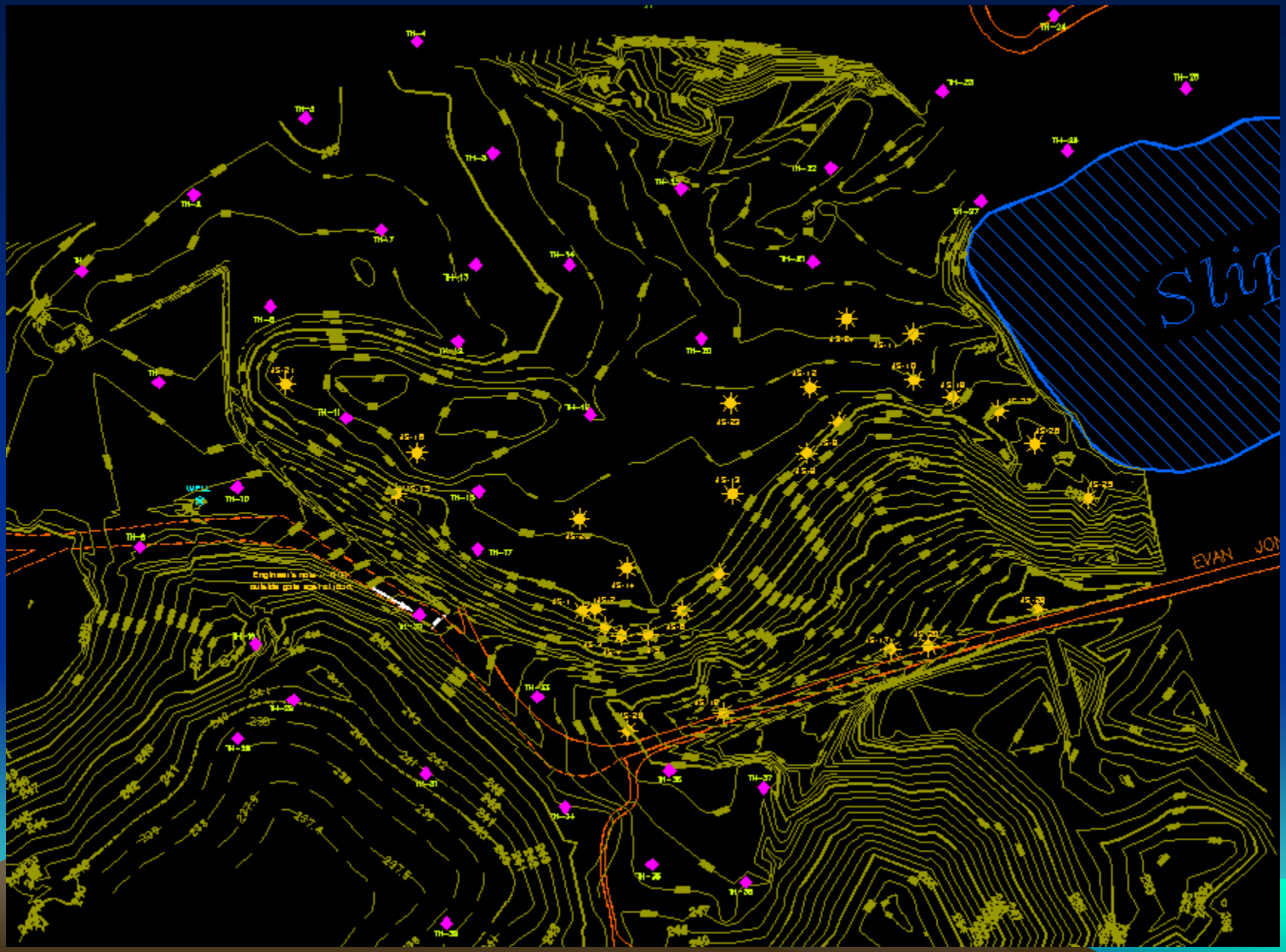
Oct. 2001 - Jan. 2002



Jonesville Fires – FLIR imagery
Surface Heat Video Recording



Jones Fires Jan. 2002 drilling coverage grid



Trimble Geoexplorer II

Used to locate DH site waypoints

Geo II rover used to field-locate BH sites using waypts.

Actual locations probably accurate within 2-3 meters

Hole sites staked, painted, marked

Drilling & Sampling Program

October-November 2001 – 1st phase

Site Drilling Oct. – Nov. 2001

Found some heat, fumes, BOCM

Coaly fines, some airborne ash

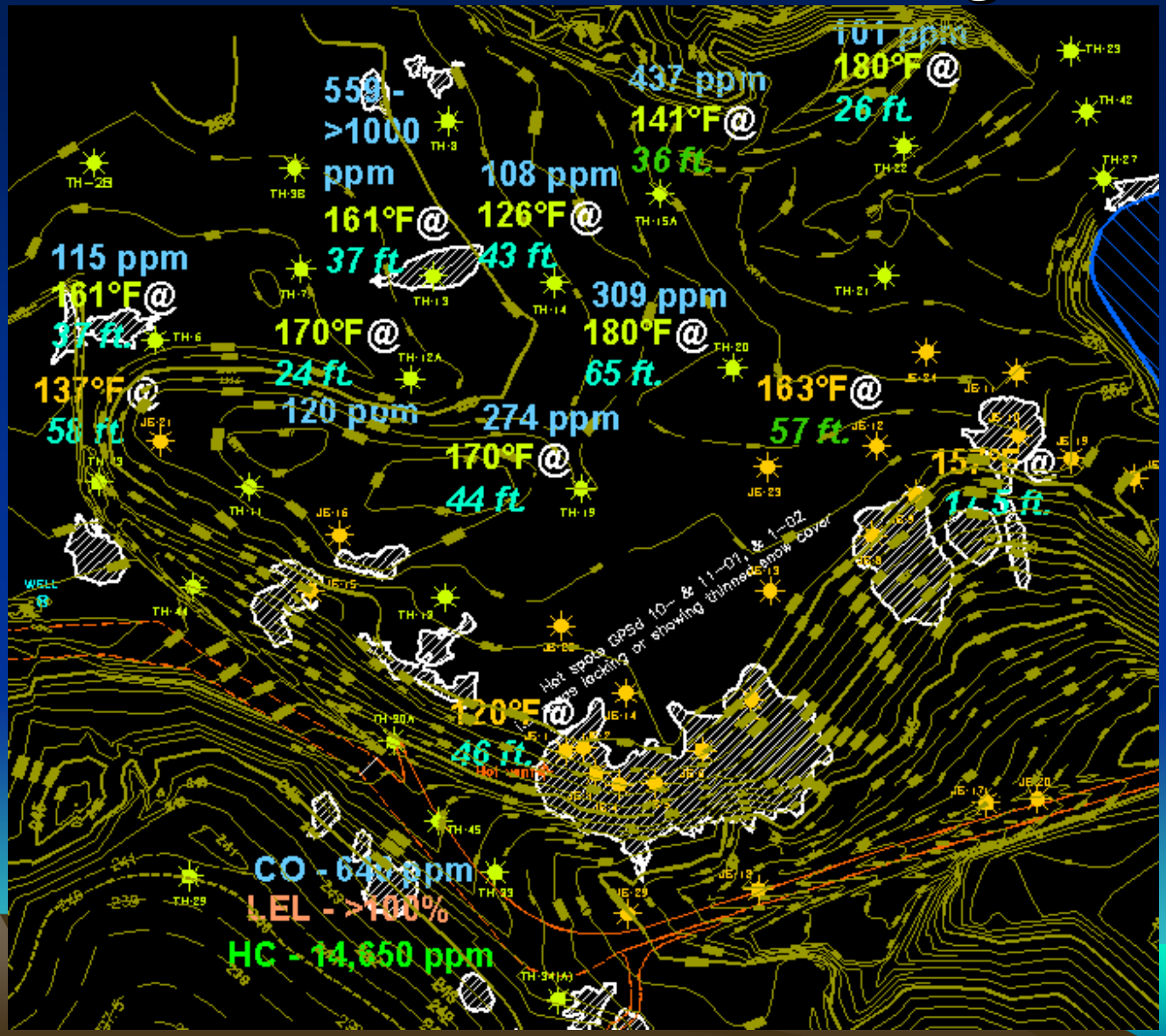
Hot zones occasionally exhibit fumes from cuttings & bell housing while drilling

BOCM intersected, highest heat range, wet gravelly clayey silt

Jan. 2002 drillhole asbuilt locations

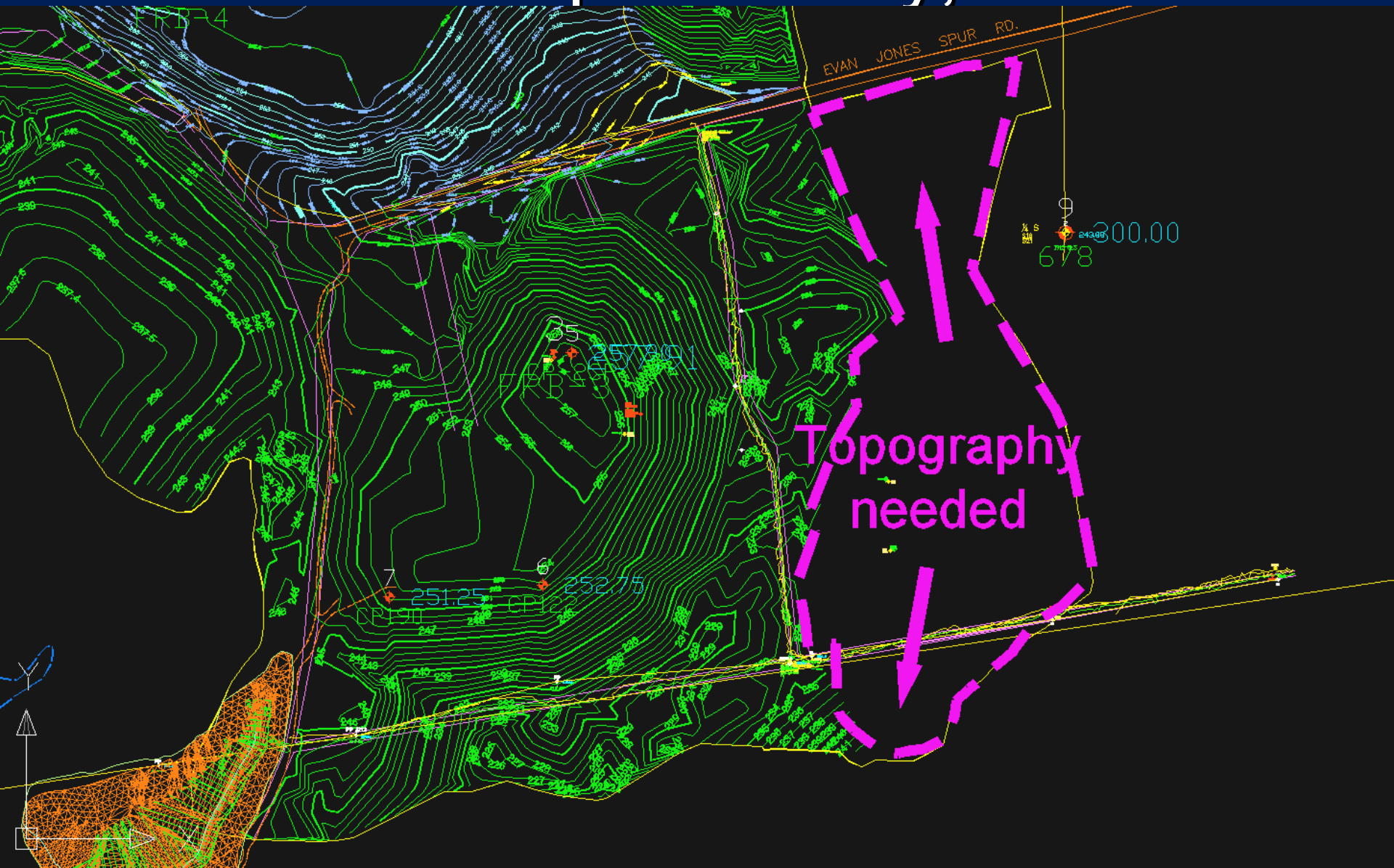
Heat & CO in N pile

Oct. 2001 - Jan. 2002 drilling results

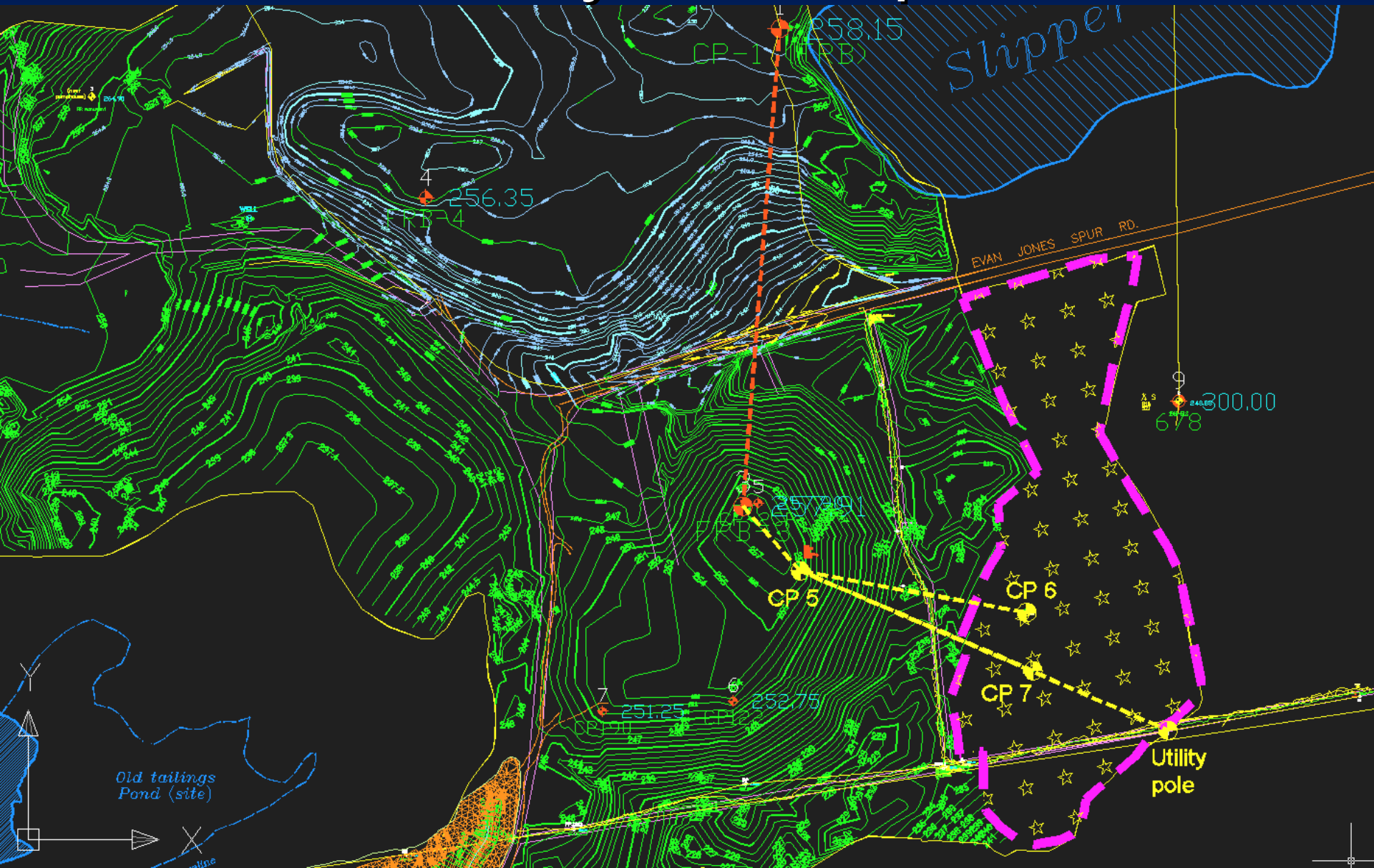


Survey error detection & correction

E side S pile survey, 2-04

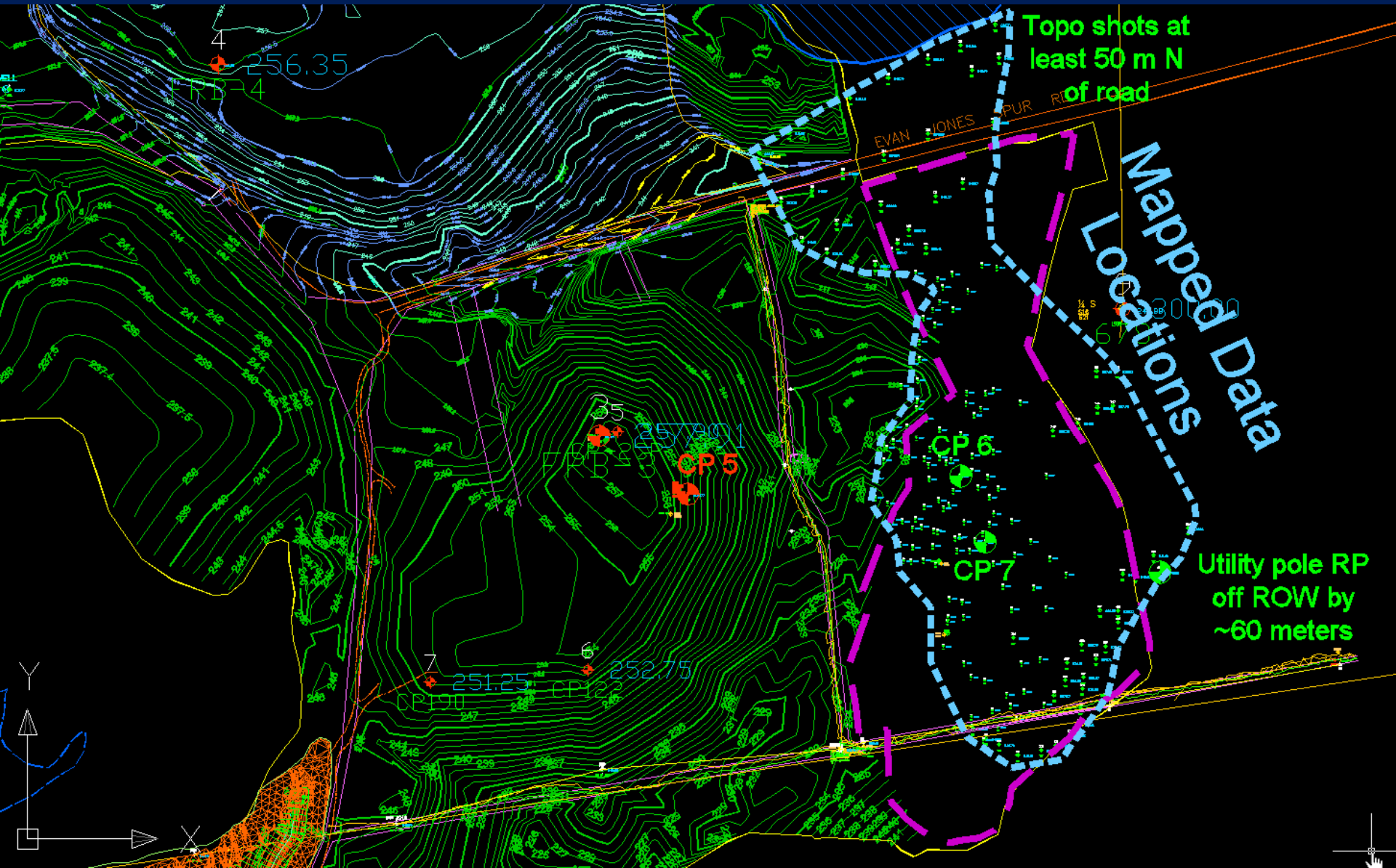


BS -- FS – Established control & RPs, Surveyed data pts



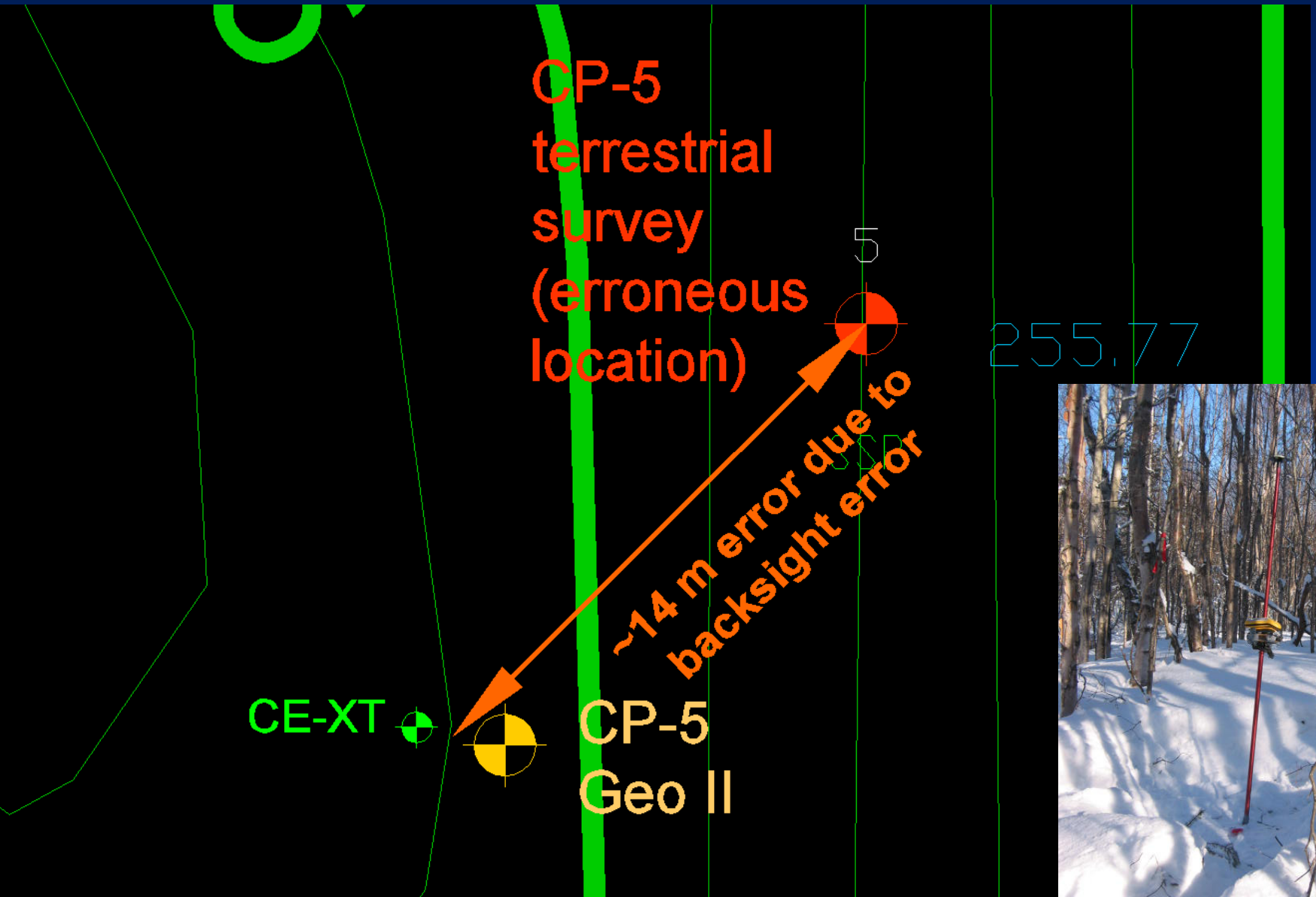
Back in Office – data didn't look right

Data, RPs displaced too far N

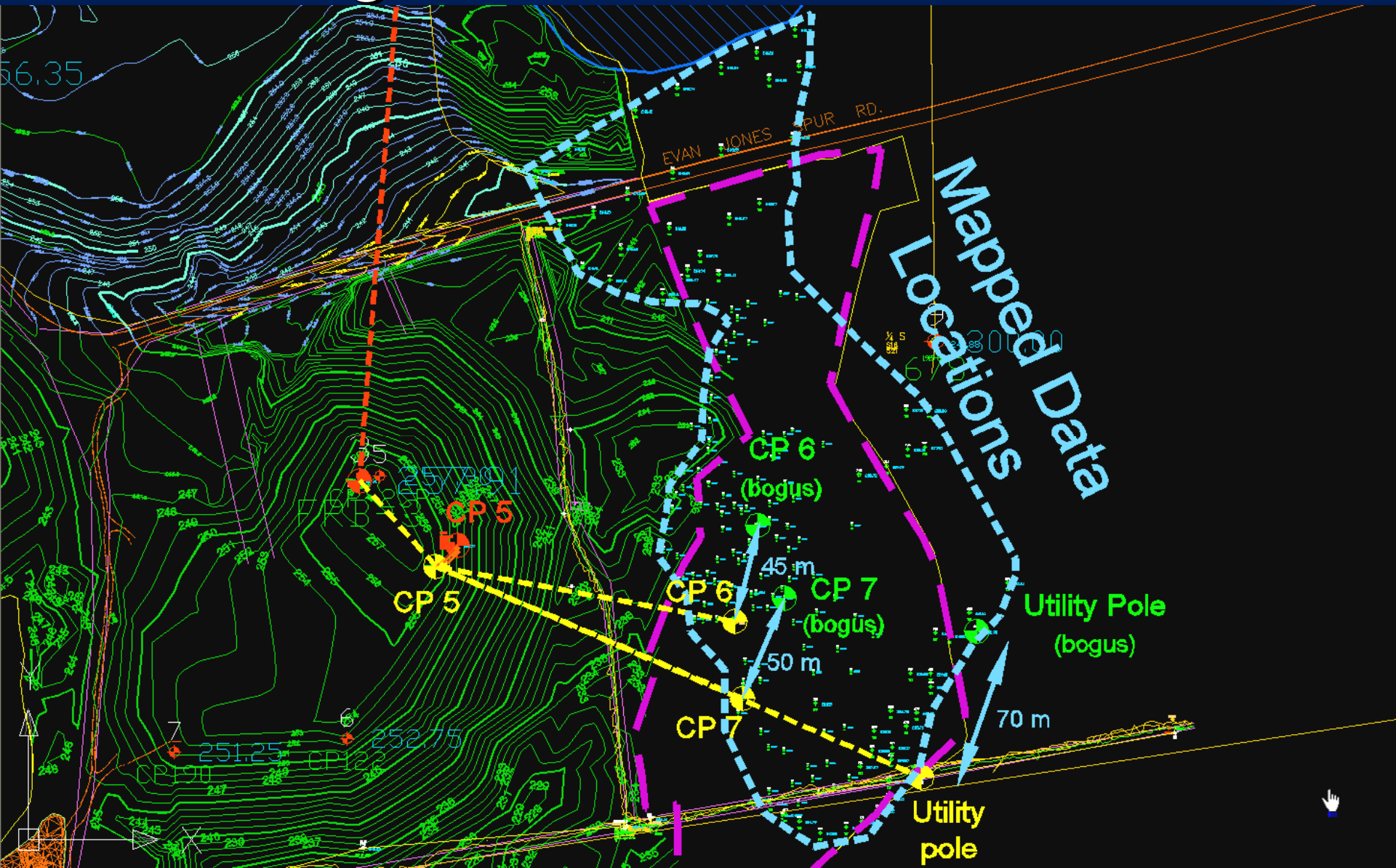


Returned to field – GPSd control PTs

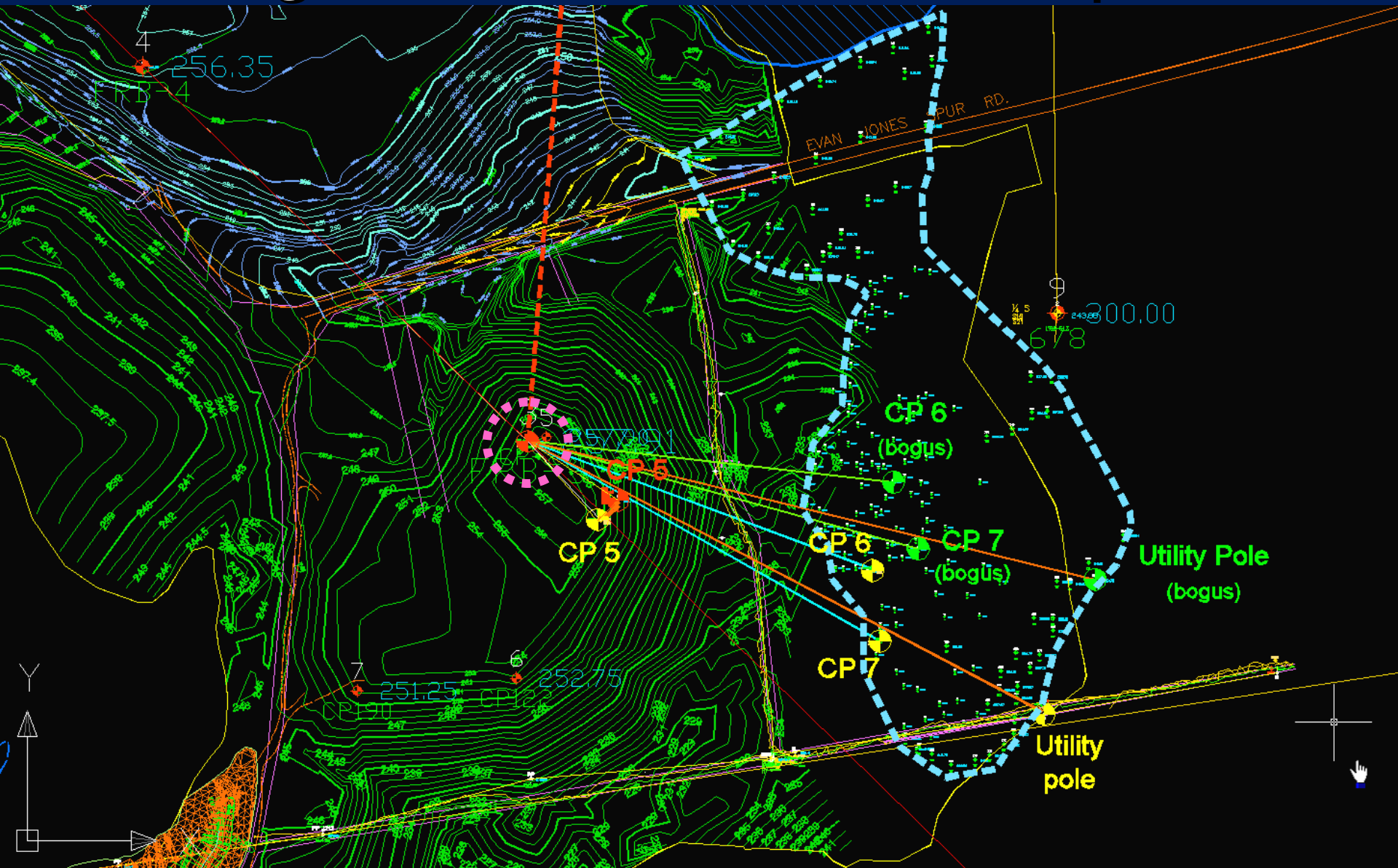
Waypoint location of CP#5 in error



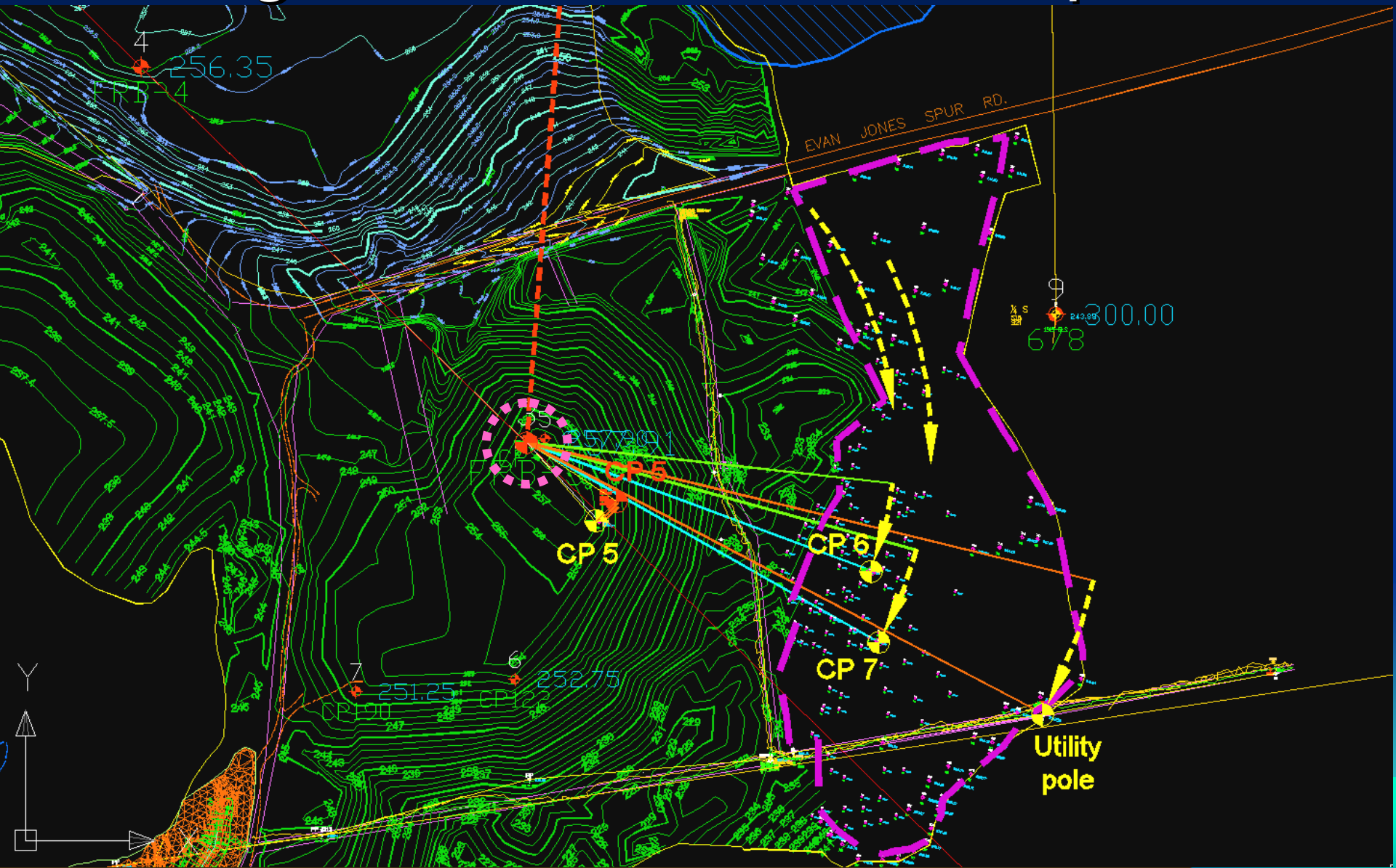
Back in office – mapped corrected GPS vs. bogus control & RP locations



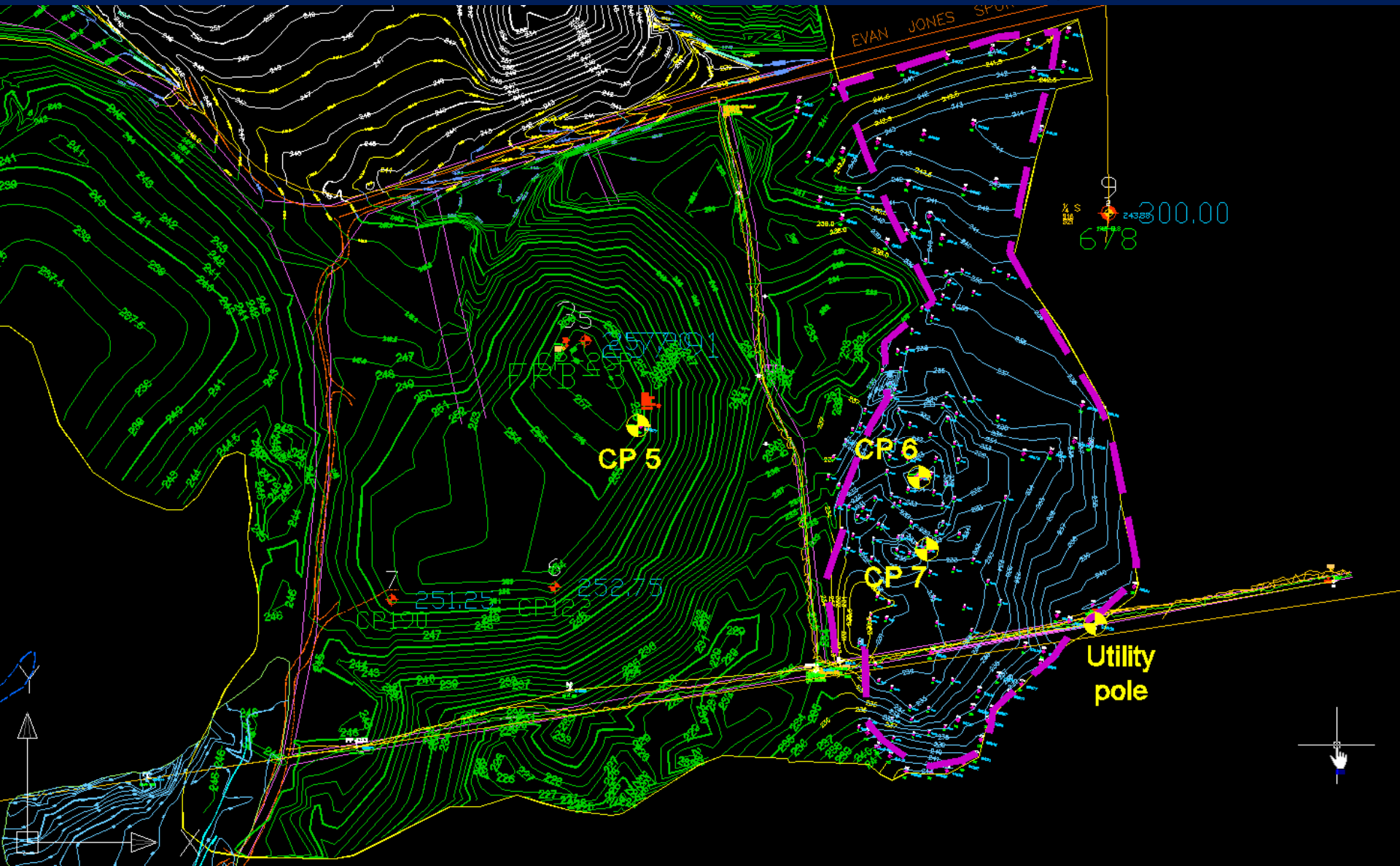
Constructed rotation ray pairs for each bogus-to-GPS Control Pt. pair



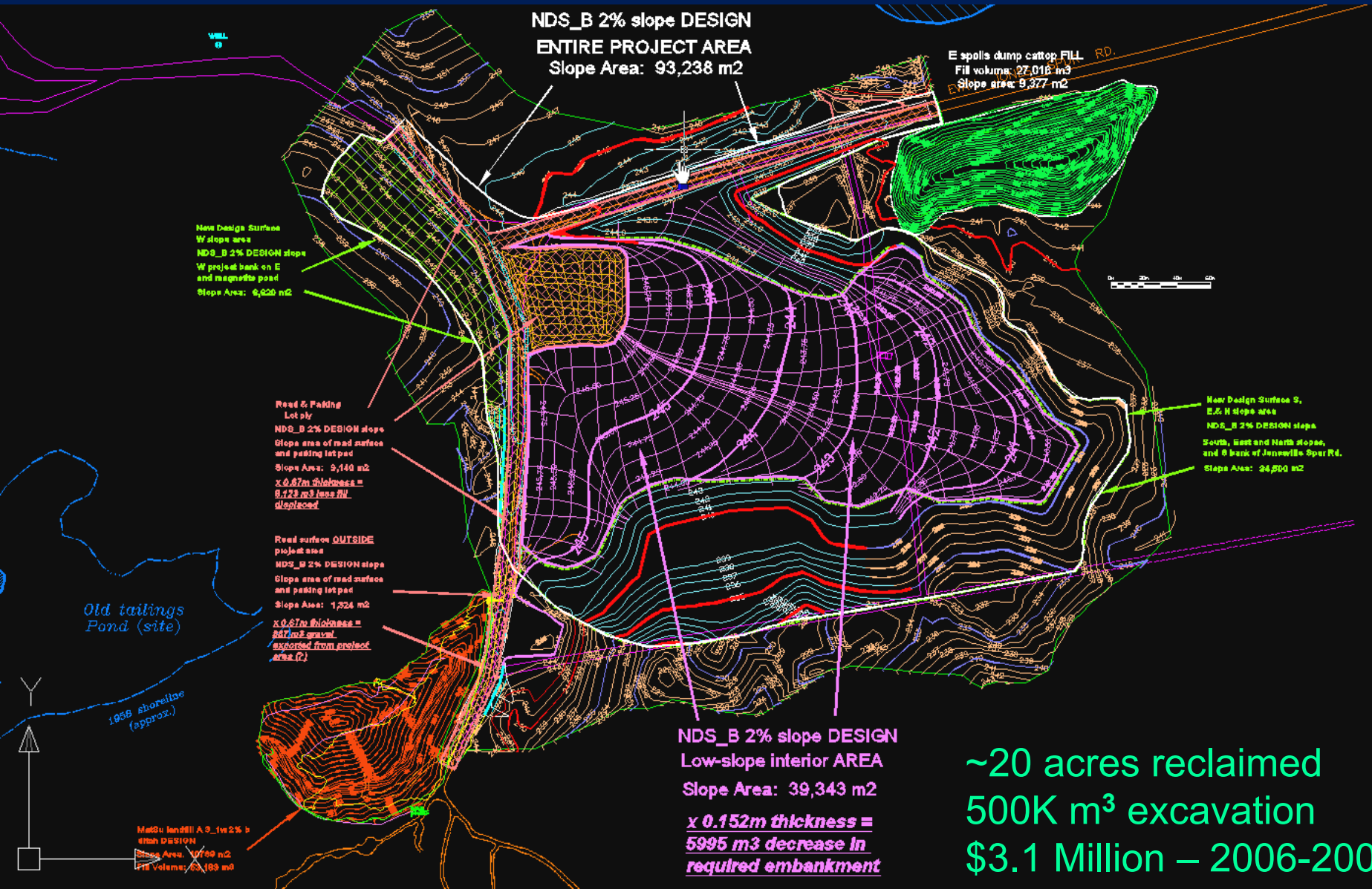
Rotated survey data about CP3 using bogus-to-GPS Control Pt. pairs



Constructed S pile E side OG contours from GPS-corrected survey data



Based Design & volumetrics off OG contours & borehole data



~20 acres reclaimed
500K m³ excavation
$3.1 Million – 2006-2007

JFII– MatSu Dump Composite

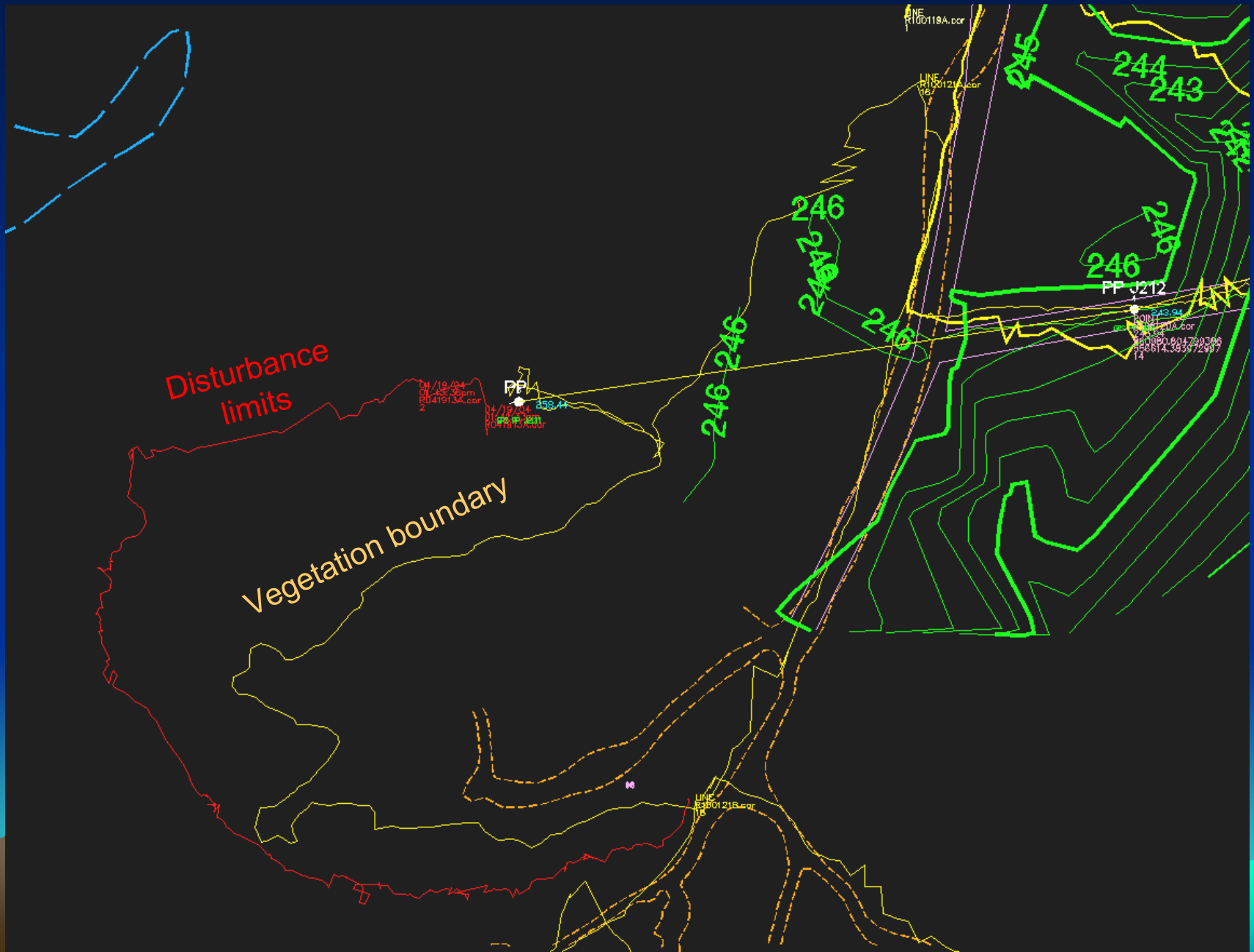
View NE -- 4-22-2004

SW corner of project

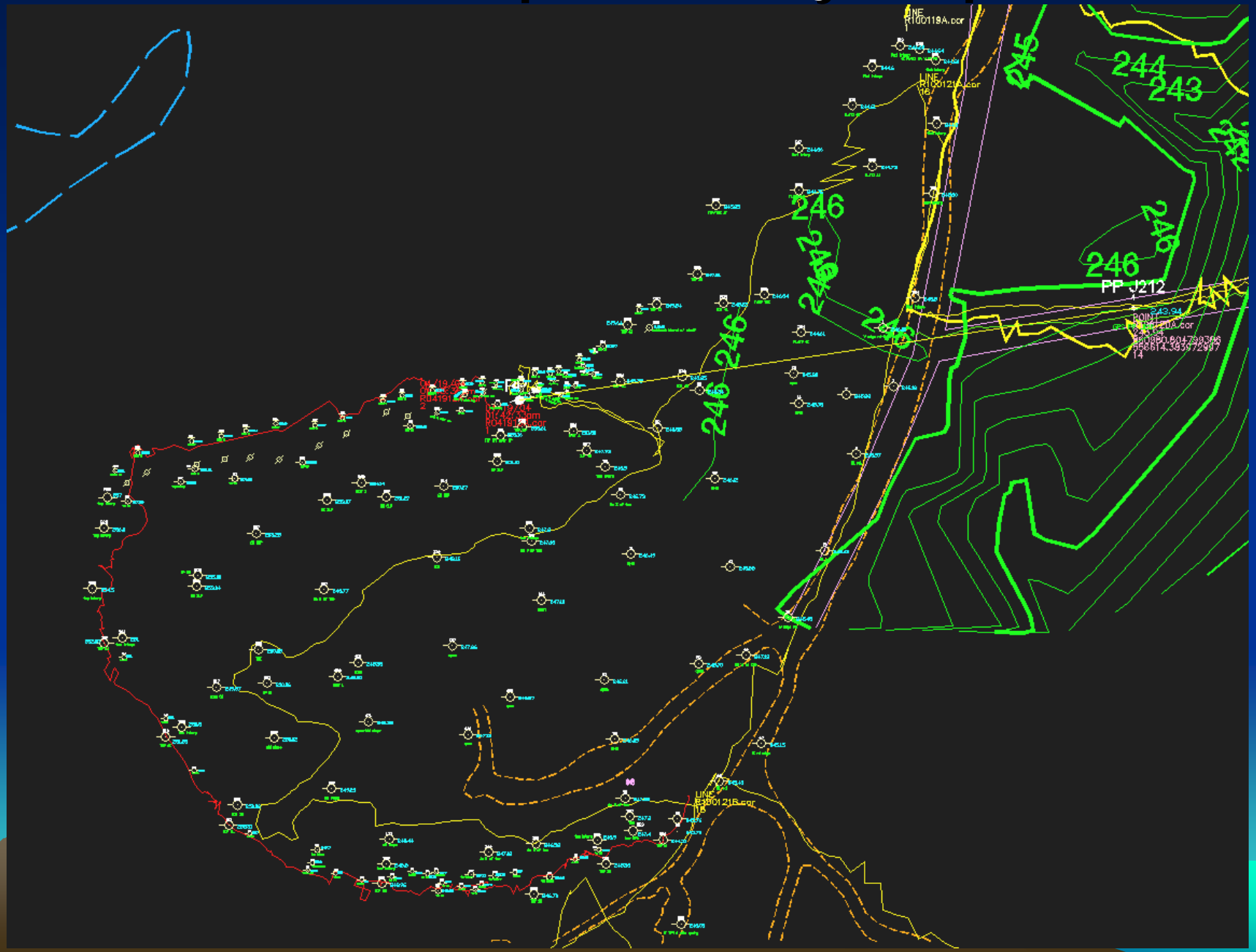
Design spoils stockpile area

Examples – MatSu Dump Survey

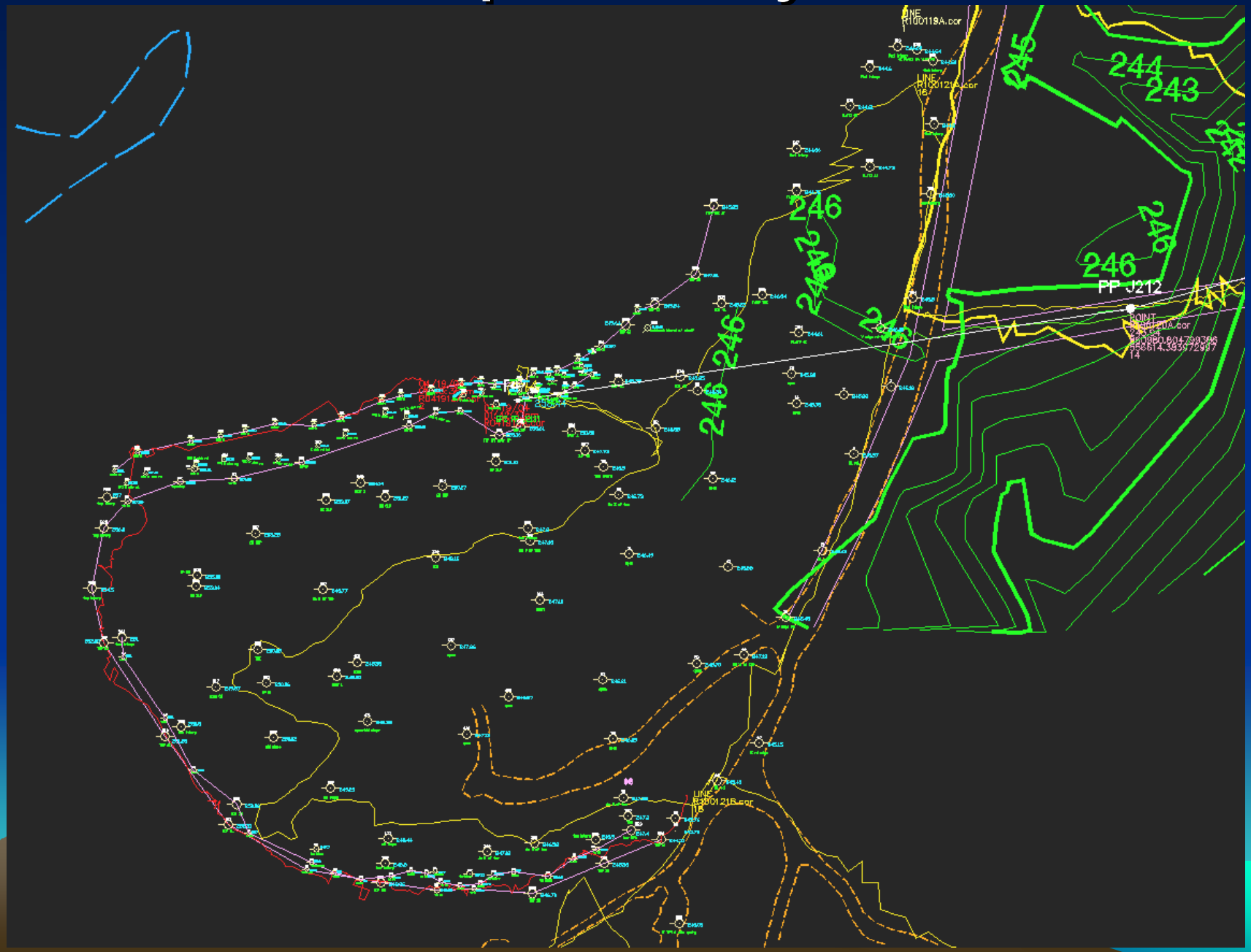
MatSu Dump Survey -- boundaries



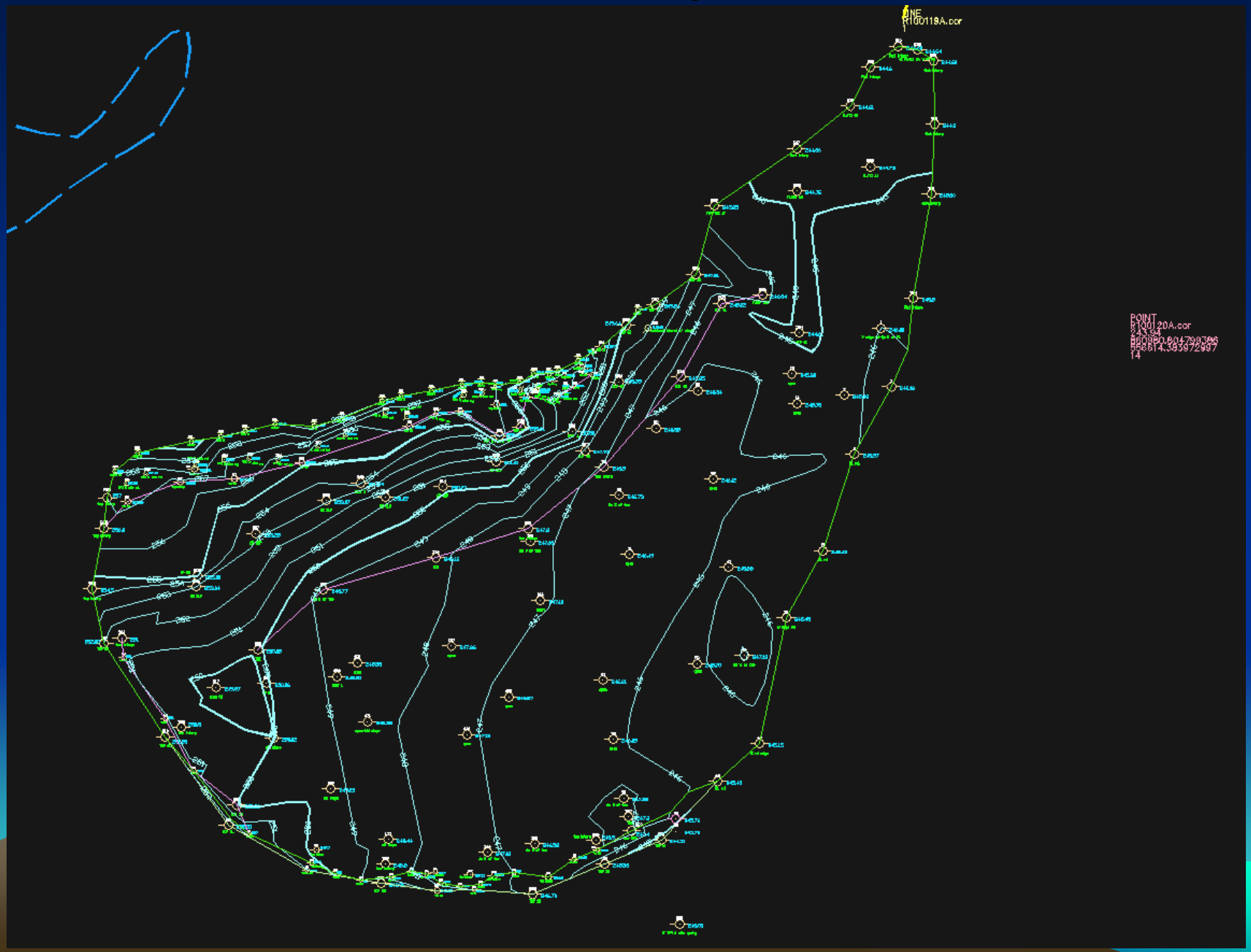
MatSu Dump Survey -- points



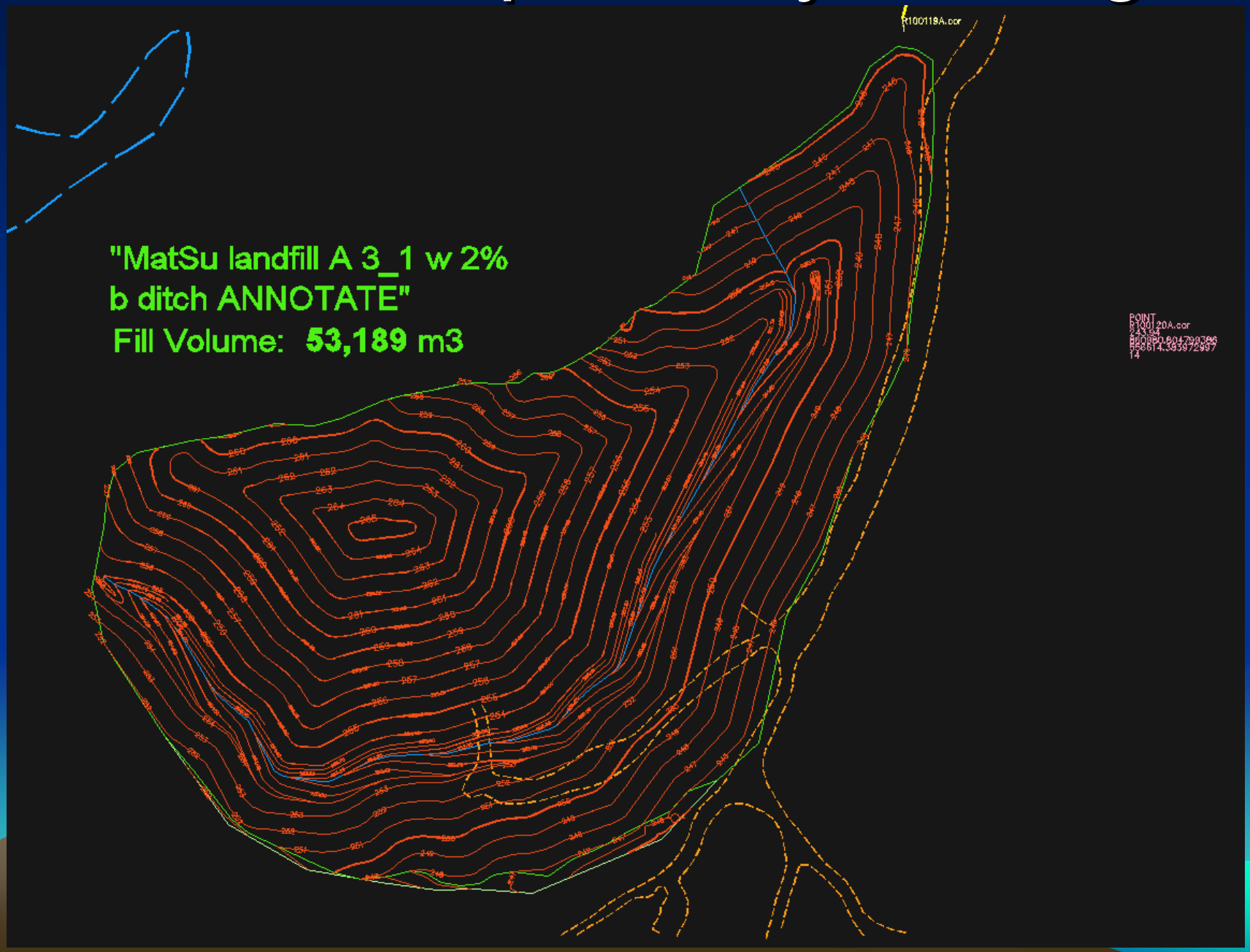
MatSu Dump Survey -- brklines



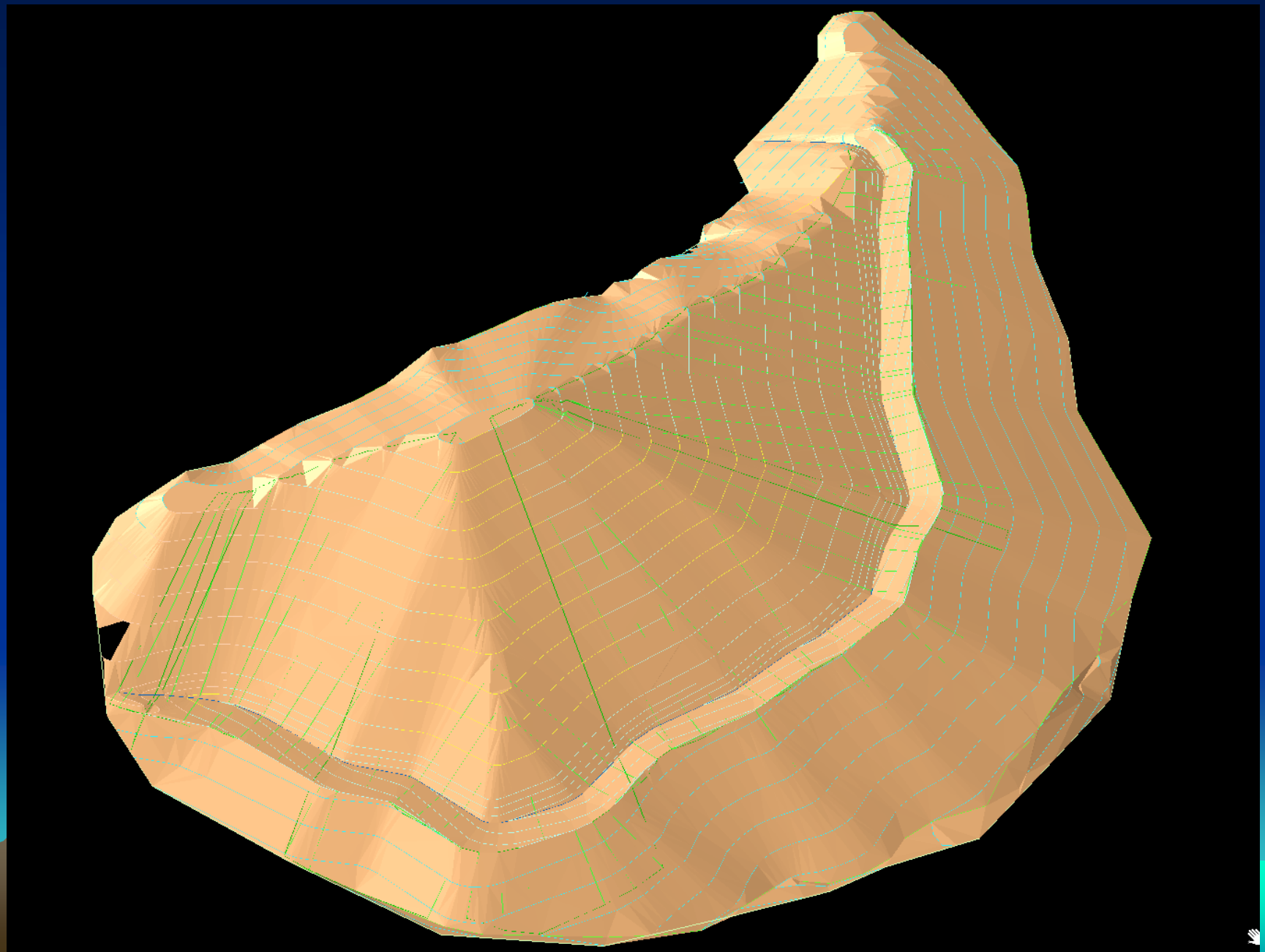
MatSu Dump Survey – OG contours



MatSu Dump Survey -- design

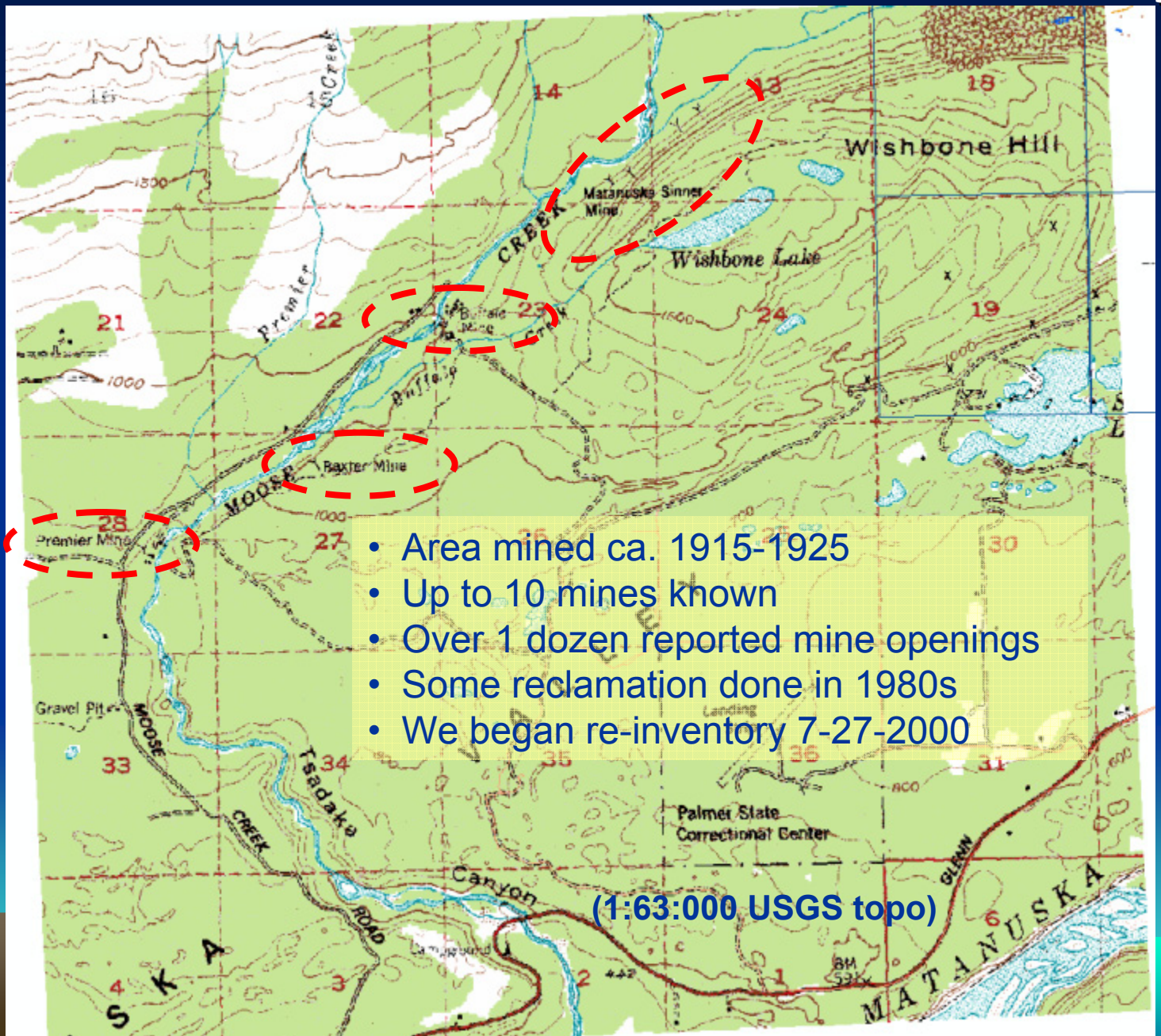


MatSu Dump Design – 3D

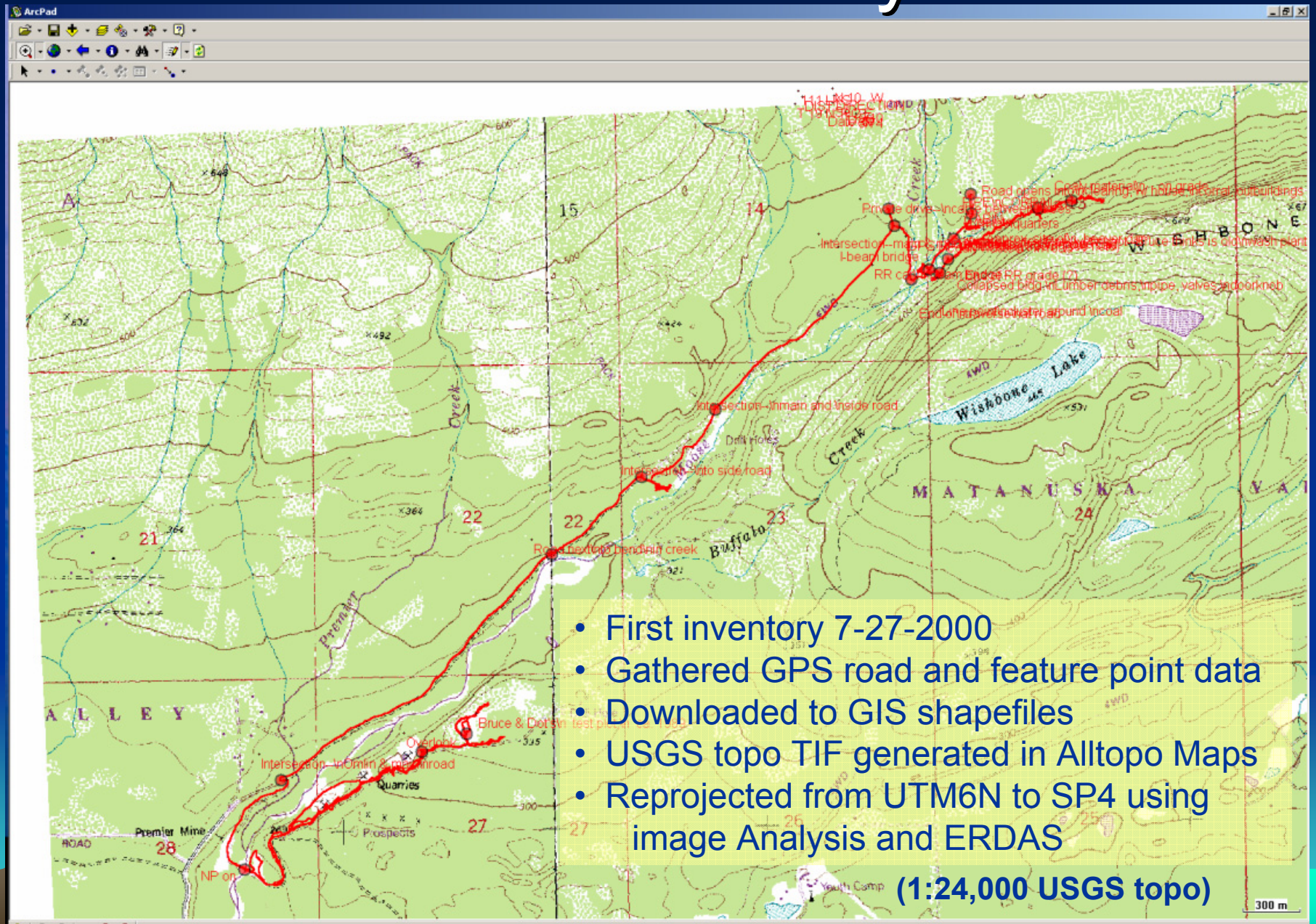


MatSu Dump Asbuilt – May 2007

West Wishbone Mine Inventory



West WB Mine Inventory 7-27-2000

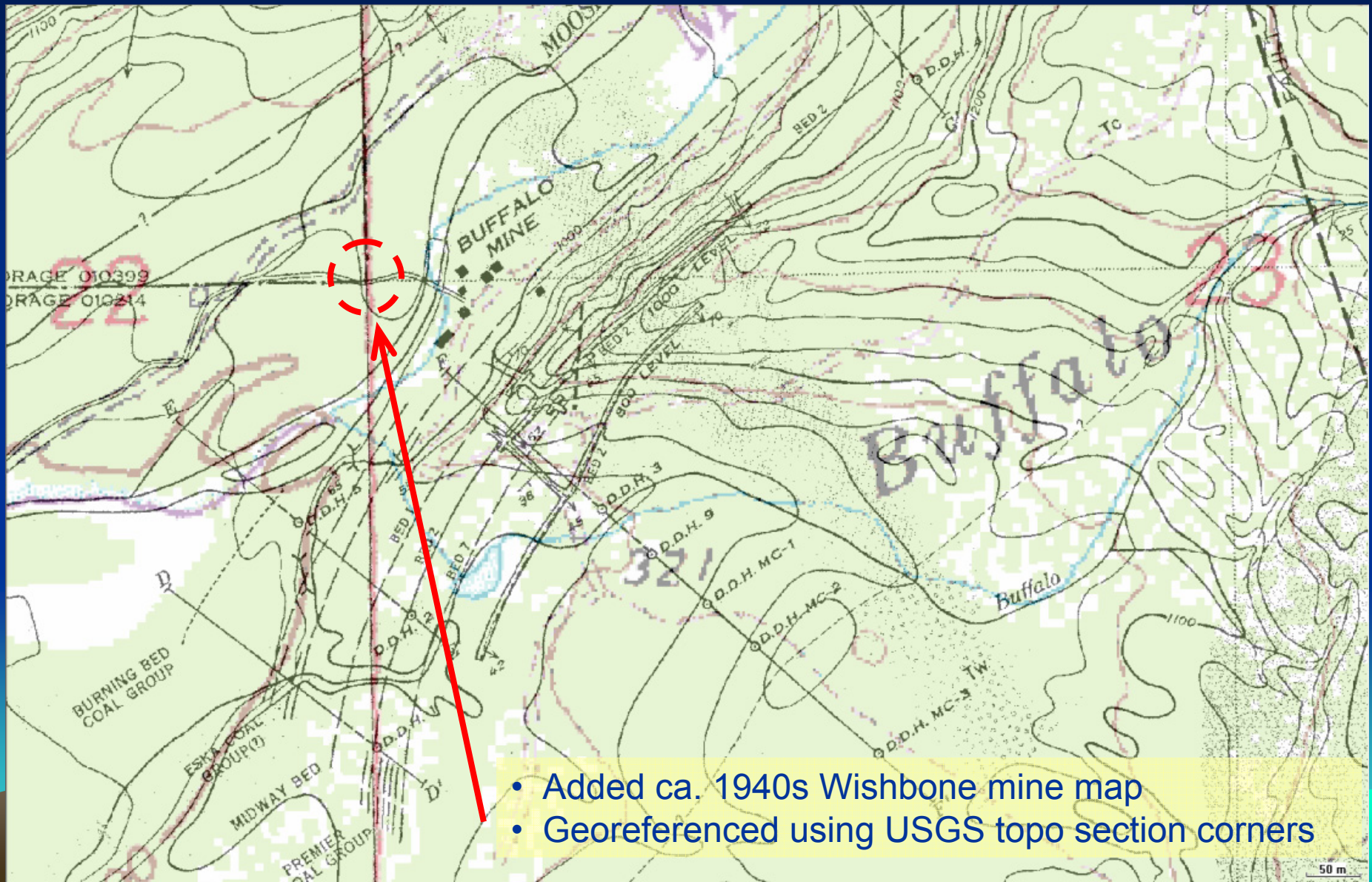


- First inventory 7-27-2000
- Gathered GPS road and feature point data
- Downloaded to GIS shapefiles
- USGS topo TIF generated in Alltopo Maps
- Reprojected from UTM6N to SP4 using image Analysis and ERDAS

(1:24,000 USGS topo)

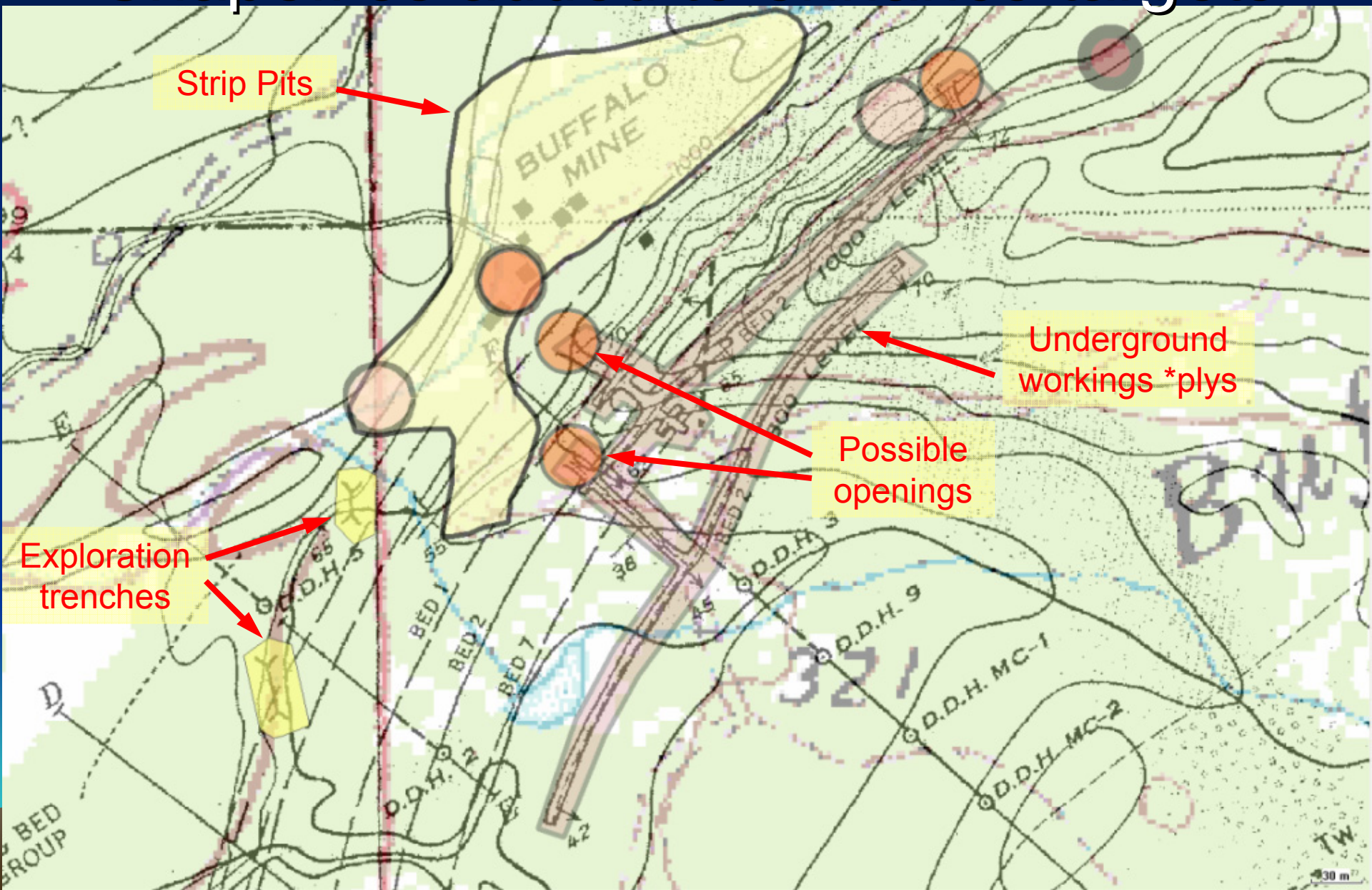
GIS preparation for 11-06 Inventory

1940s Georeferenced mine map added



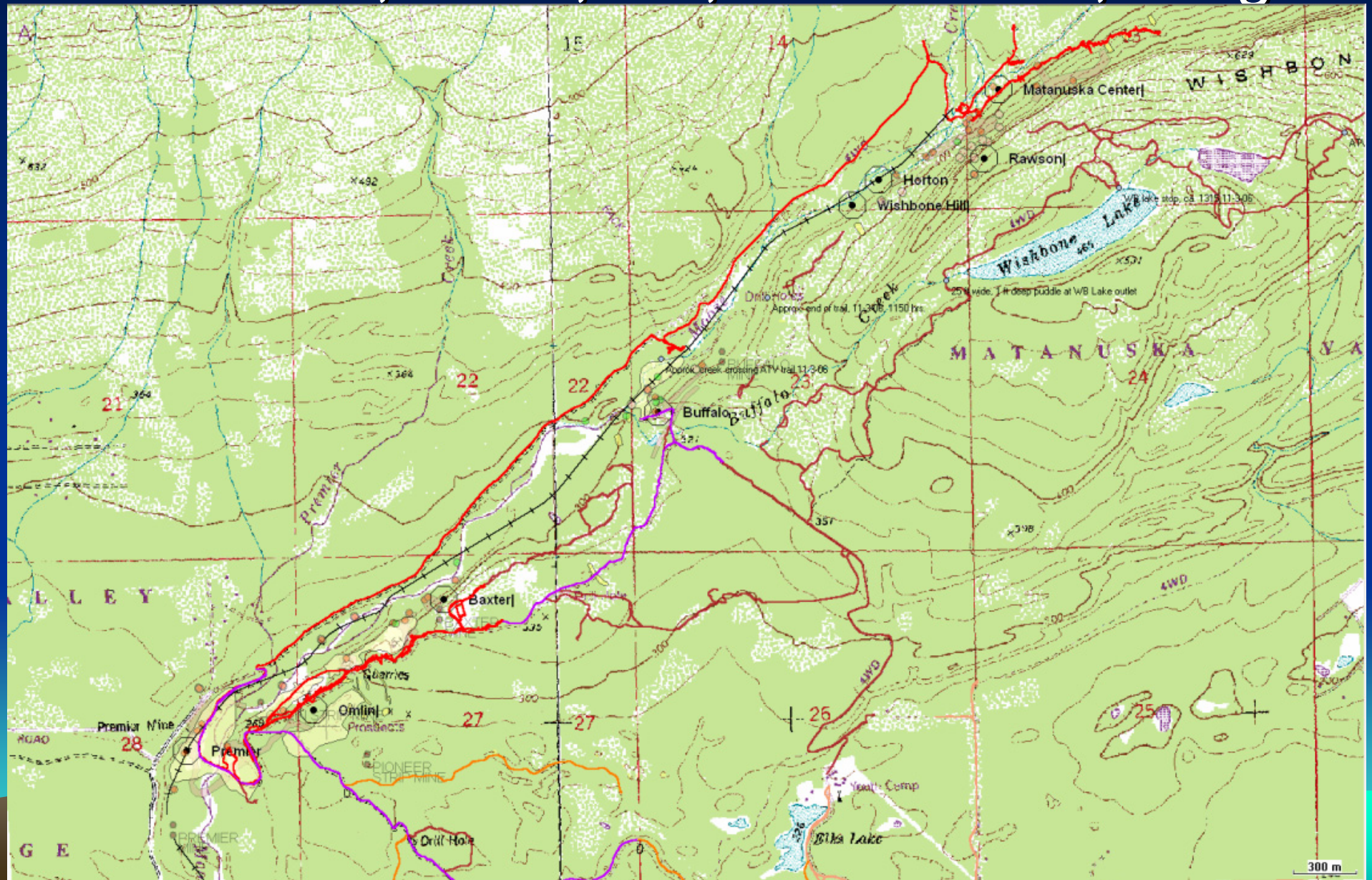
- Added ca. 1940s Wishbone mine map
- Georeferenced using USGS topo section corners

GIS preparation for 11-06 Inventory
Shapefiles added to enhance targets



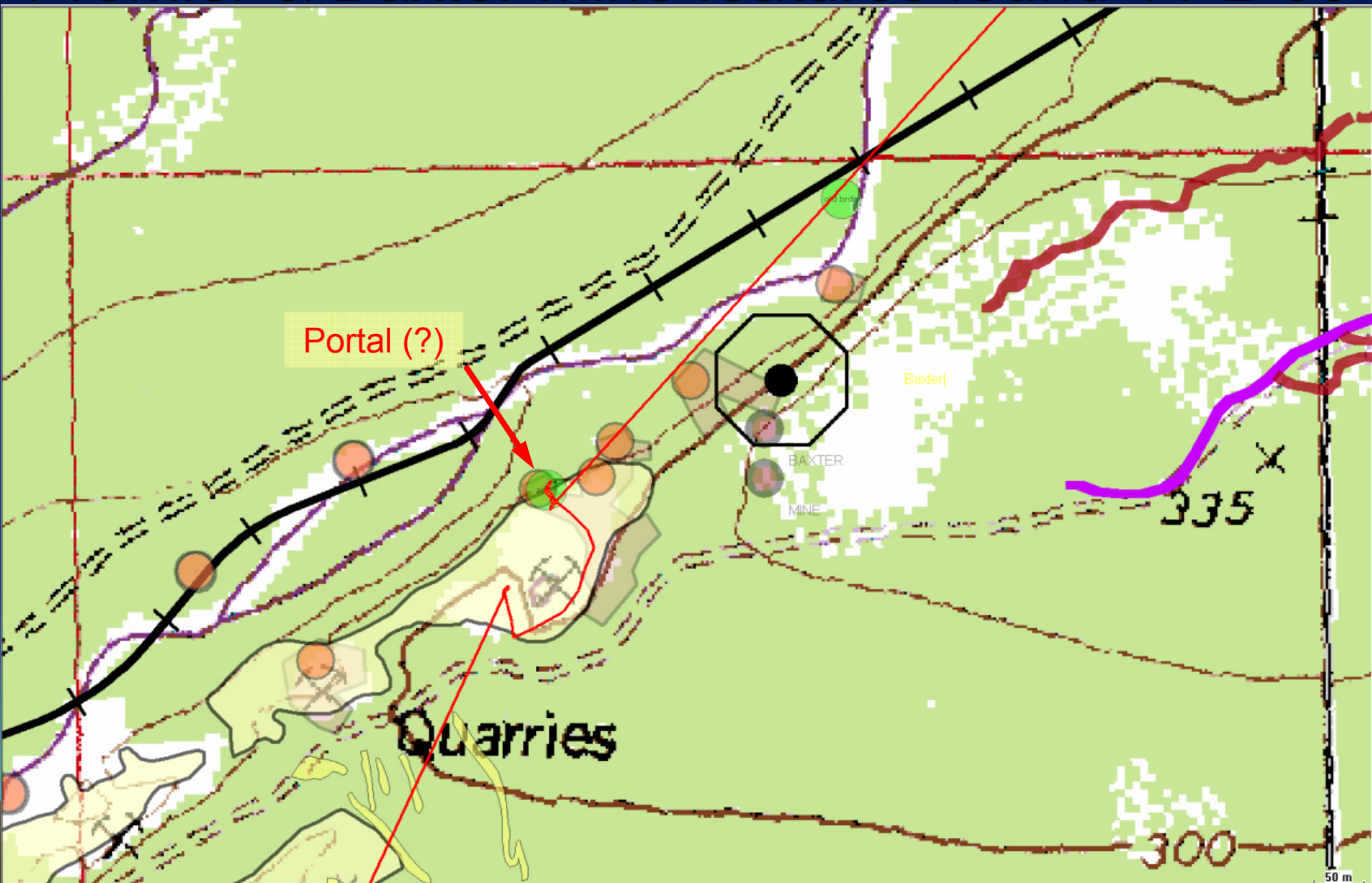
GIS preparation for 11-06 Inventory

Added trails, roads, RR, mine names, bridges



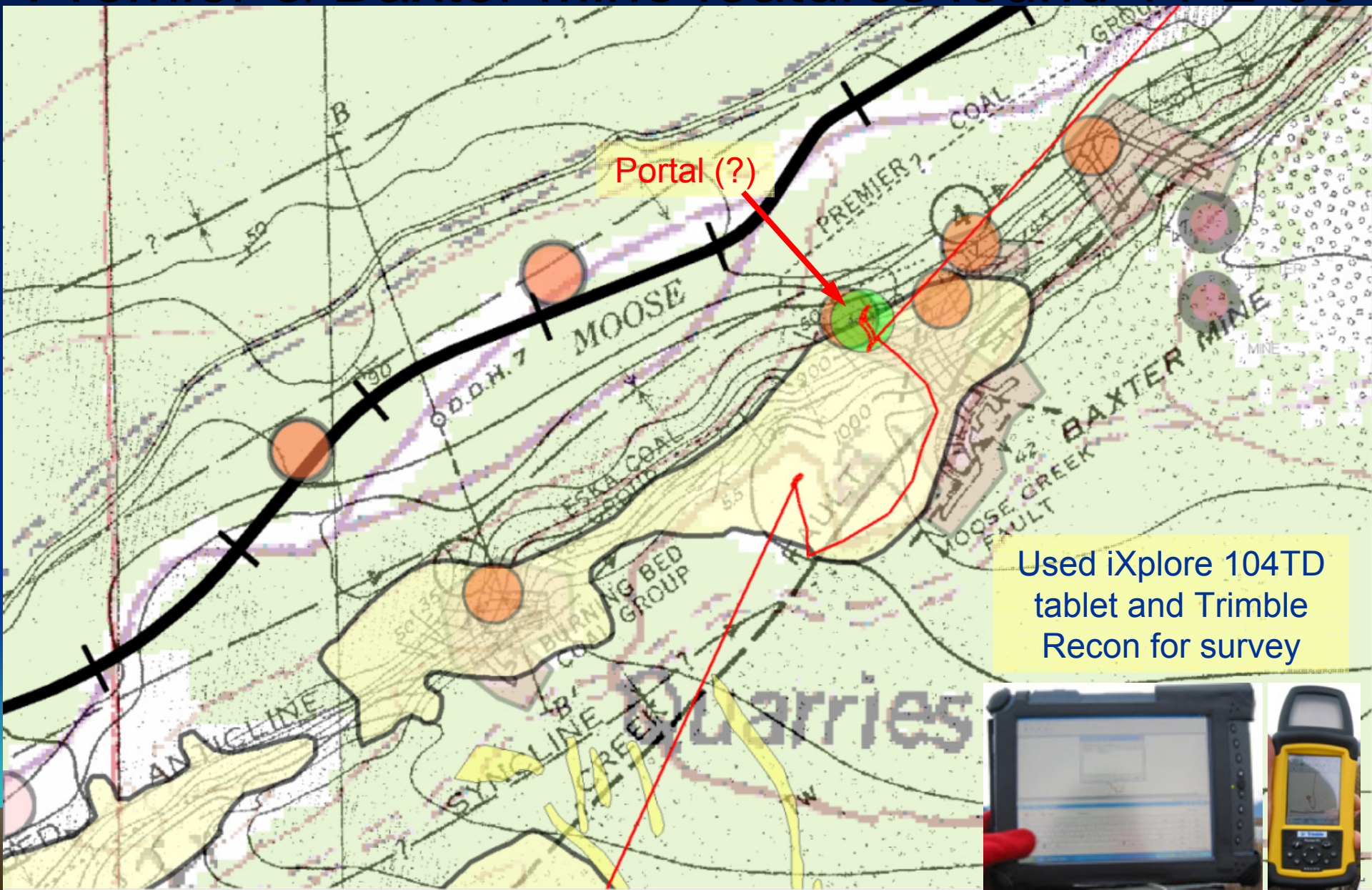
Features found in 11-06 Inventory

Premier & Baxter Mine features found 11-2-06



Features found in 11-06 Inventory

Premier & Baxter Mine features found 11-2-06



Used iXplore 104TD tablet and Trimble Recon for survey

GIS preparation for 11-06 Inventory

Baxter Mine features found 11-3-06

Small Shaft

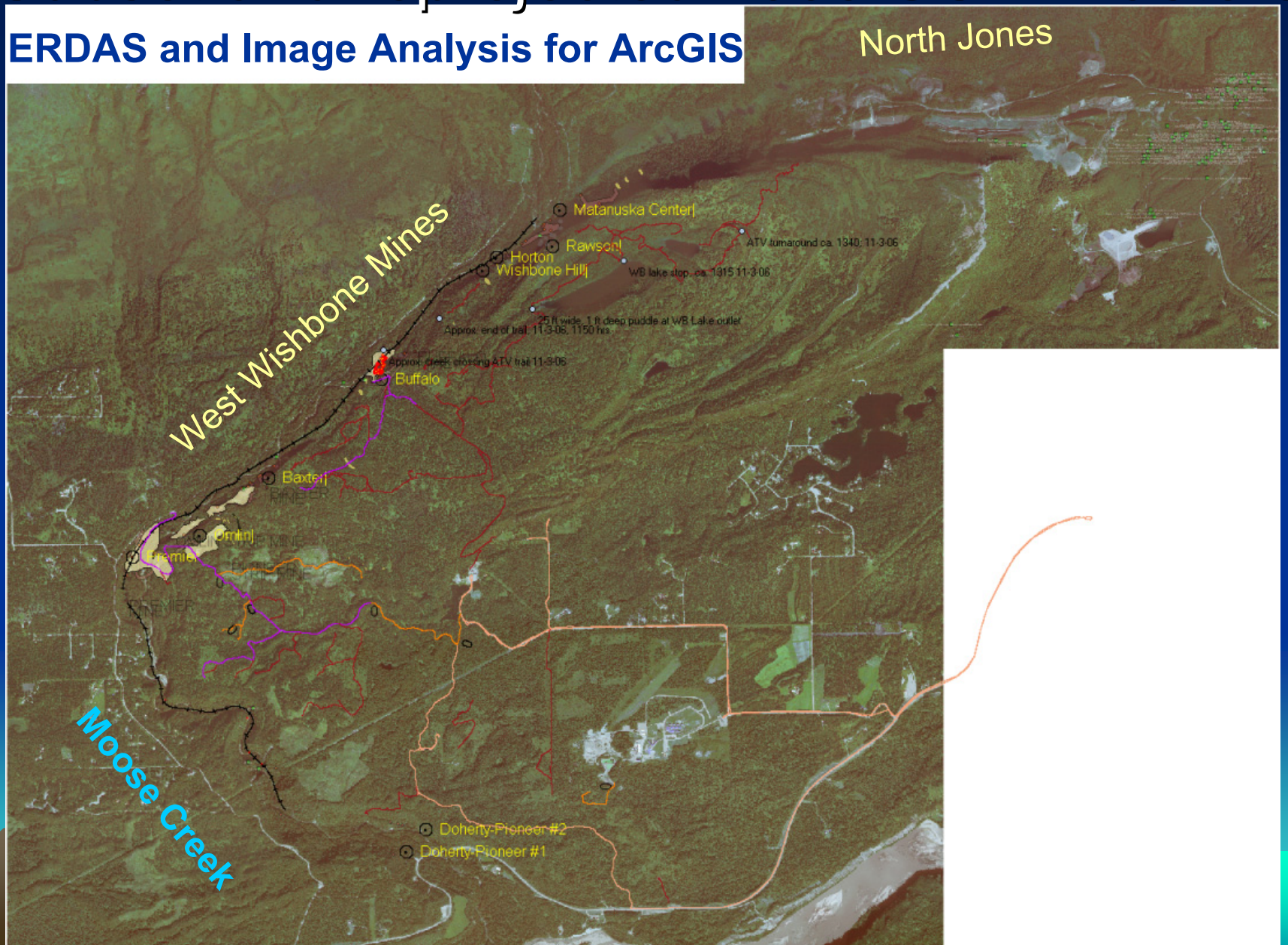
Filled Portal

Boiler

GIS preparation for 5-11-07 Overflight

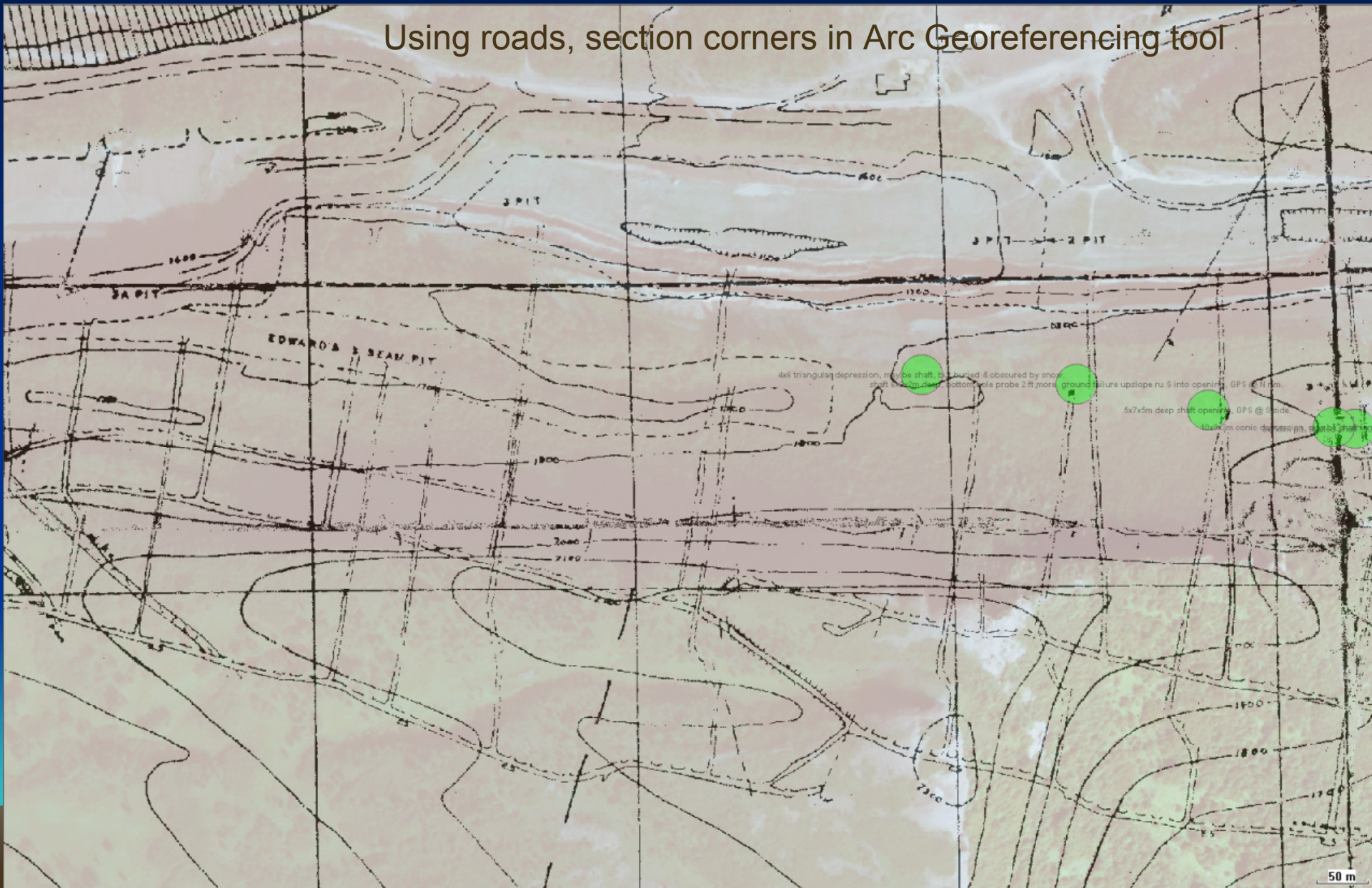
Subset and reprojected 2005 USDA rasters

ERDAS and Image Analysis for ArcGIS



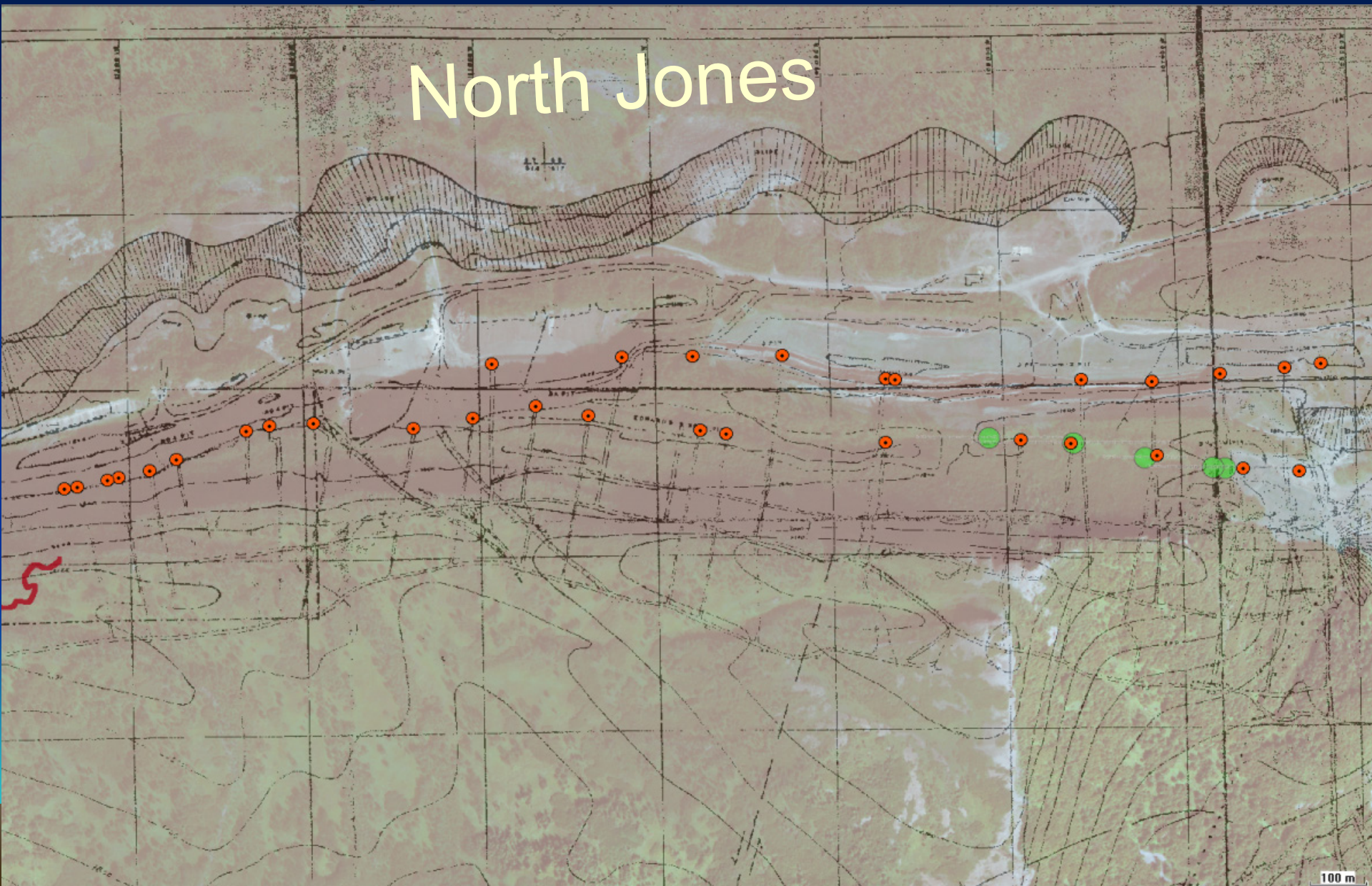
GIS preparation for 5-11-07 Overflight

Georeferenced 1982 N Jones UG mine map



GIS preparation for 5-11-07 Overflight

Created target points at mapped slope portals



West Wishbone 11-2&3-06 inventory
Few reclaimable targets found

Results

- Few reclaimable targets found
- Problems with iXplore 104TD and Recon screens failed to work below +15˚F
- iXplore screen not readable in direct sunlight

Arcpad guidance, 5-11-07 flight track

Seeking mapped target points on GPS tablet

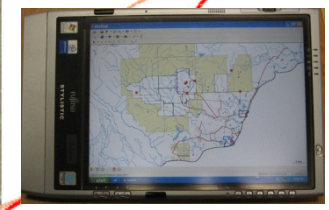
ERDAS and Image Analysis for ArcGIS

North Jones

West Wishbone Mines

Moose Creek

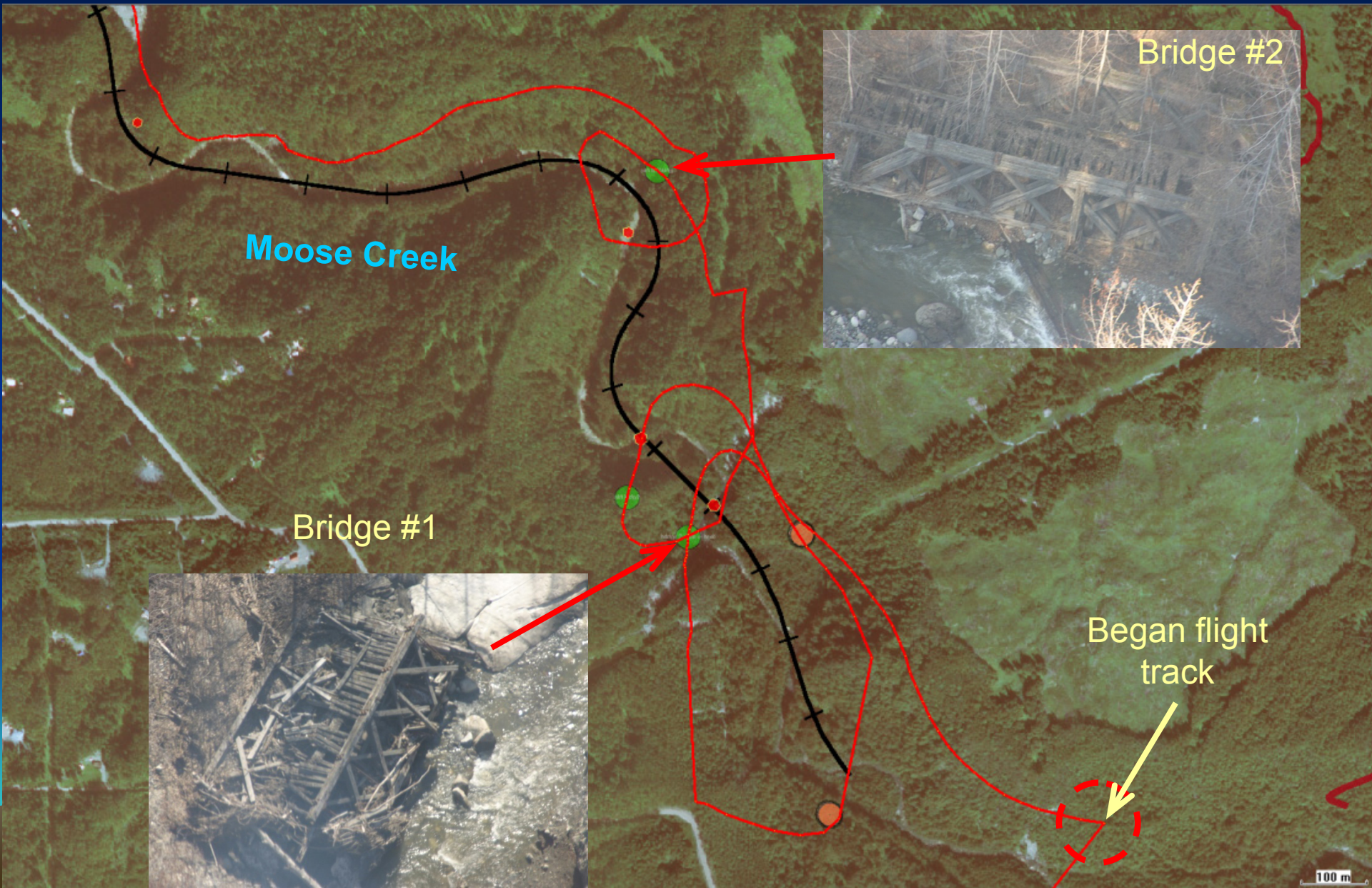
Used Fujitsu 5022D tablet and Trimble GPS XB receiver



Flew Robinson R44

Arcpad guidance, 5-11-07 flight track

Digitized collapsed bridge locations in-flight



Arcpad guidance, 5-11-07 flight track

Digitized defunct bridge locations in-flight

Bridge #4

Bridge #3

Moose Creek

Buffalo

Baxter

Arcpad guidance, 5-11-07 flight track

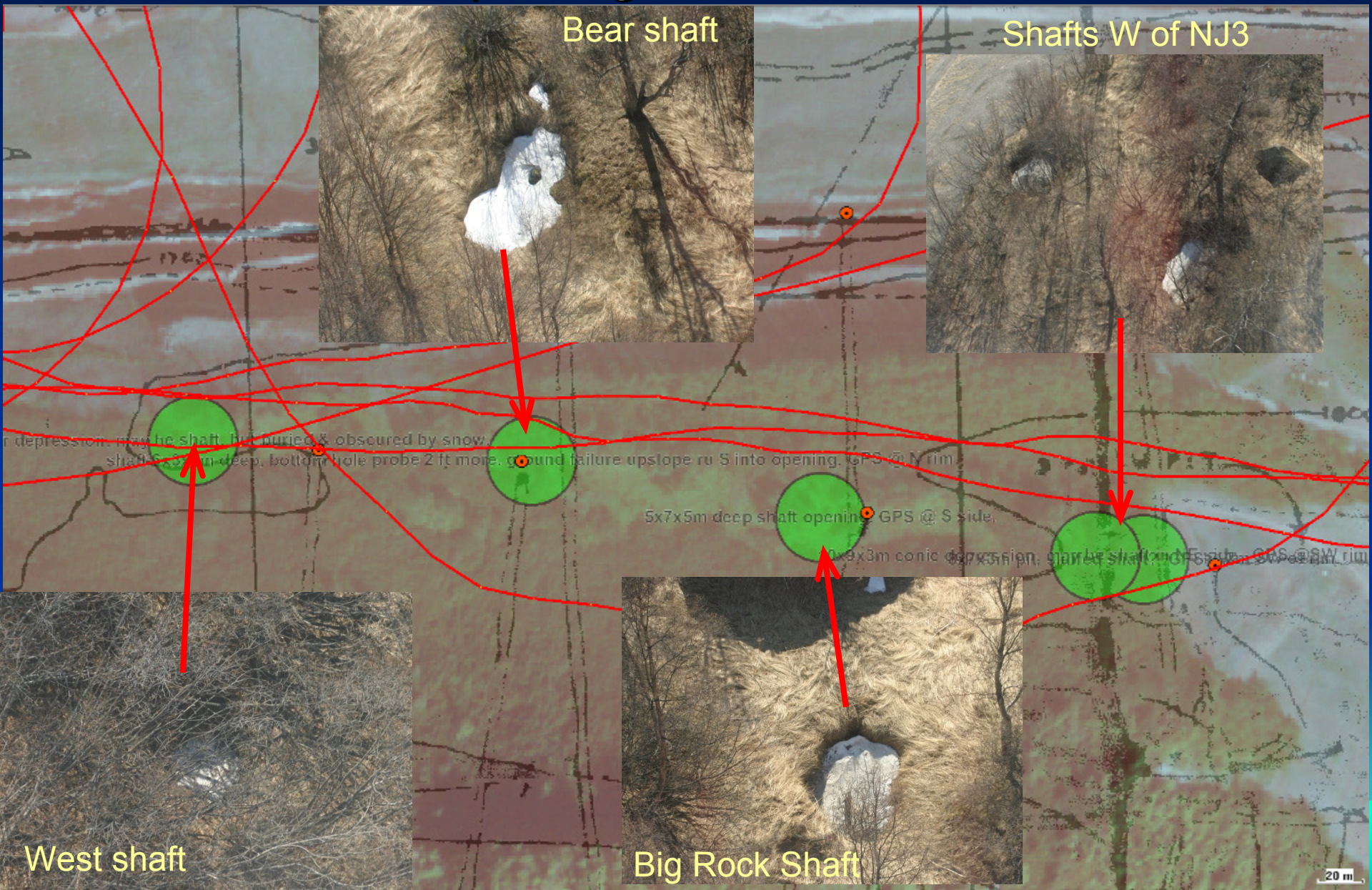
Observing North Jones Adit Target Points

Wishbone Hill, look W

100 m

Arcpad guidance, 5-11-07 flight track

Found no new openings, North Jones VOs shown



West Wishbone/Jonesville 5-11-07 overflight
No new / reclaimable targets found

West Wishbone -- Search Results

- Only observed and marked bridge ruins in Moose Creek
- No new openings or mining features evident from the air

North Jones Adits -- Search Results

- No new openings found on repeated airborne passes along high ridges

Eska Inventory -- October 2005

Multiple seams underground mined in Eska and Jonesville from 1910s through 1940s

Variety of mining hazards left behind

- shafts, adits, subsidence features, hazardous equipment and facilities

Eska Inventory -- October 2005

Early AK AML Program Work

Eska Reclamation

Mid -1980s

- Main adits closed, spoils reshaped
- Eska Wash Plant --HEF & buildings removed

1993 -- several dangerous shafts closed along North Jones Road

Eska Inventory -- October 2005

Desire to document remaining hazards in Eska / Jonesville area

Target descriptions compiled from maps and literature by AML staff

- ~70 targets were located on a CAD layer

Eska Inventory -- October 2005

Reconnaissance map preparation

CAD layer targets exported as shapefile to GIS for Arcpad use

A ‘Found AML features’ point file created in Arcpad

- created forms for data entry
- allowed export of attribute data to a GIS shapefile table
  - dimensions, condition, time of visit

Eska Inventory -- October 2005

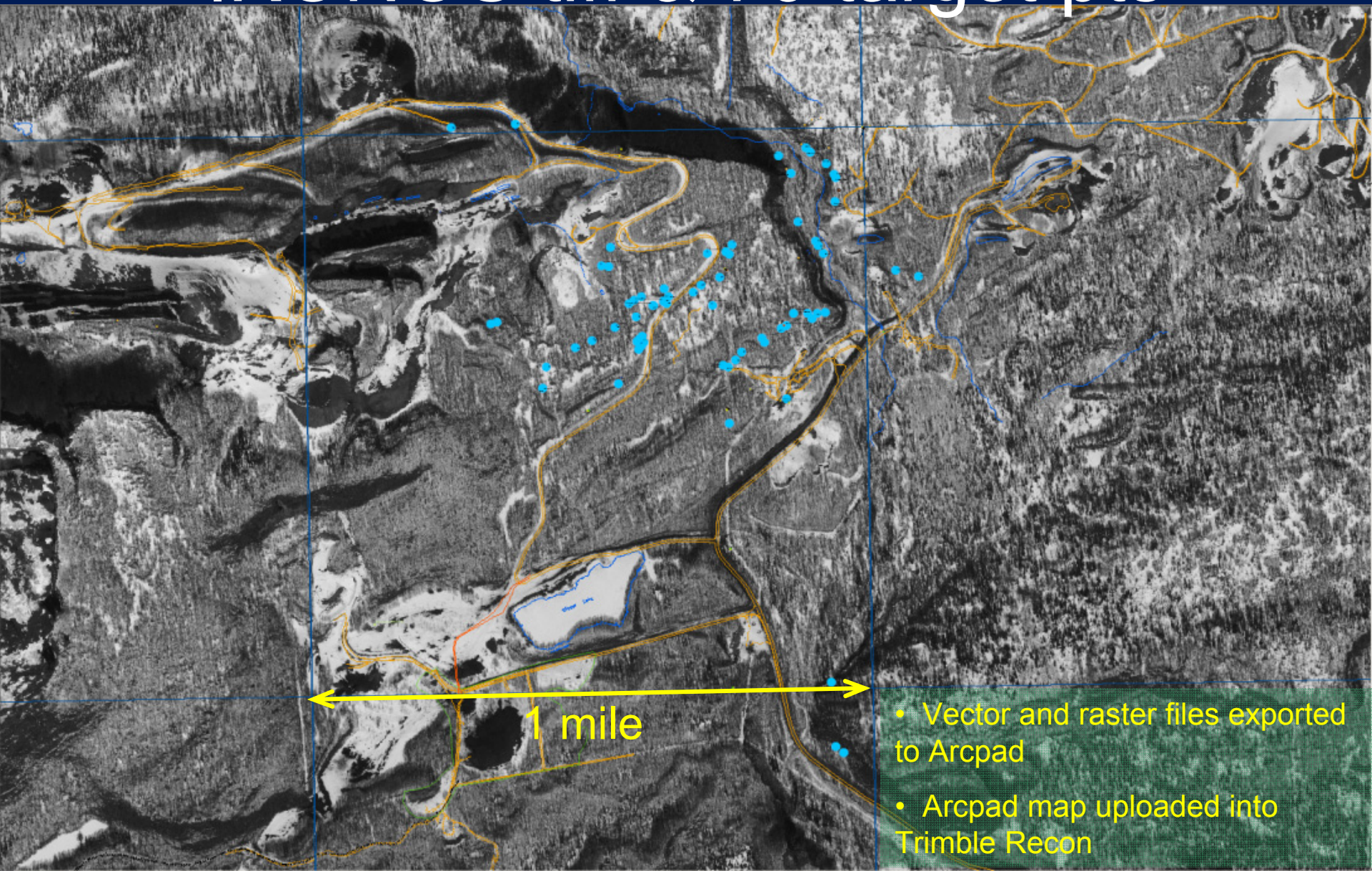
Raster backgrounds generated

- IKONOS image subset, reprojected, polynomial-corrected in ERDAS
- 1943 USGS plate 1016 Eska mine map scanned and georeferenced

Images converted to TIFF and MrSid for Arcpad use.

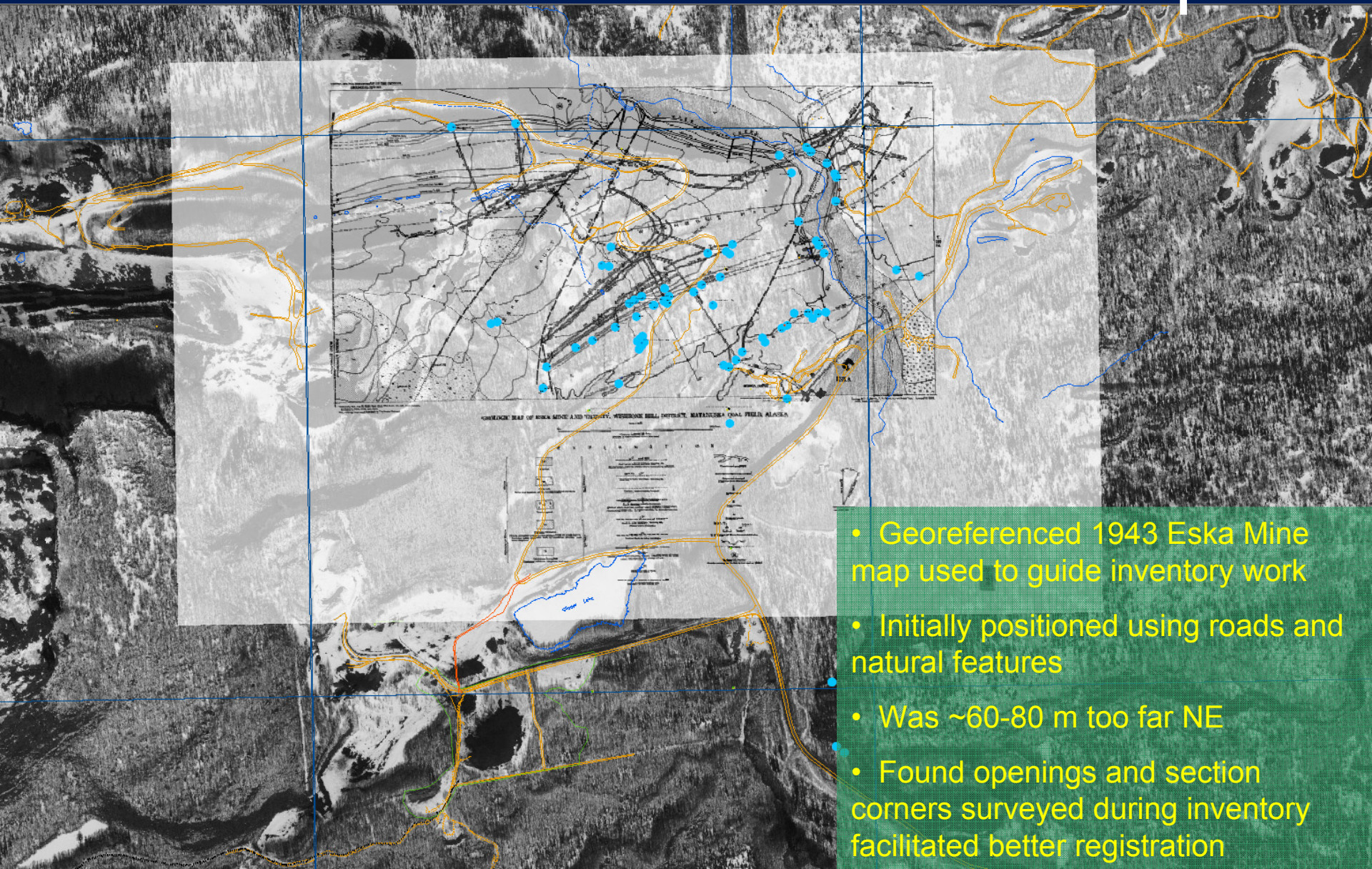
Eska Inventory -- October 2005

IKONOS tiff & 70 target pts



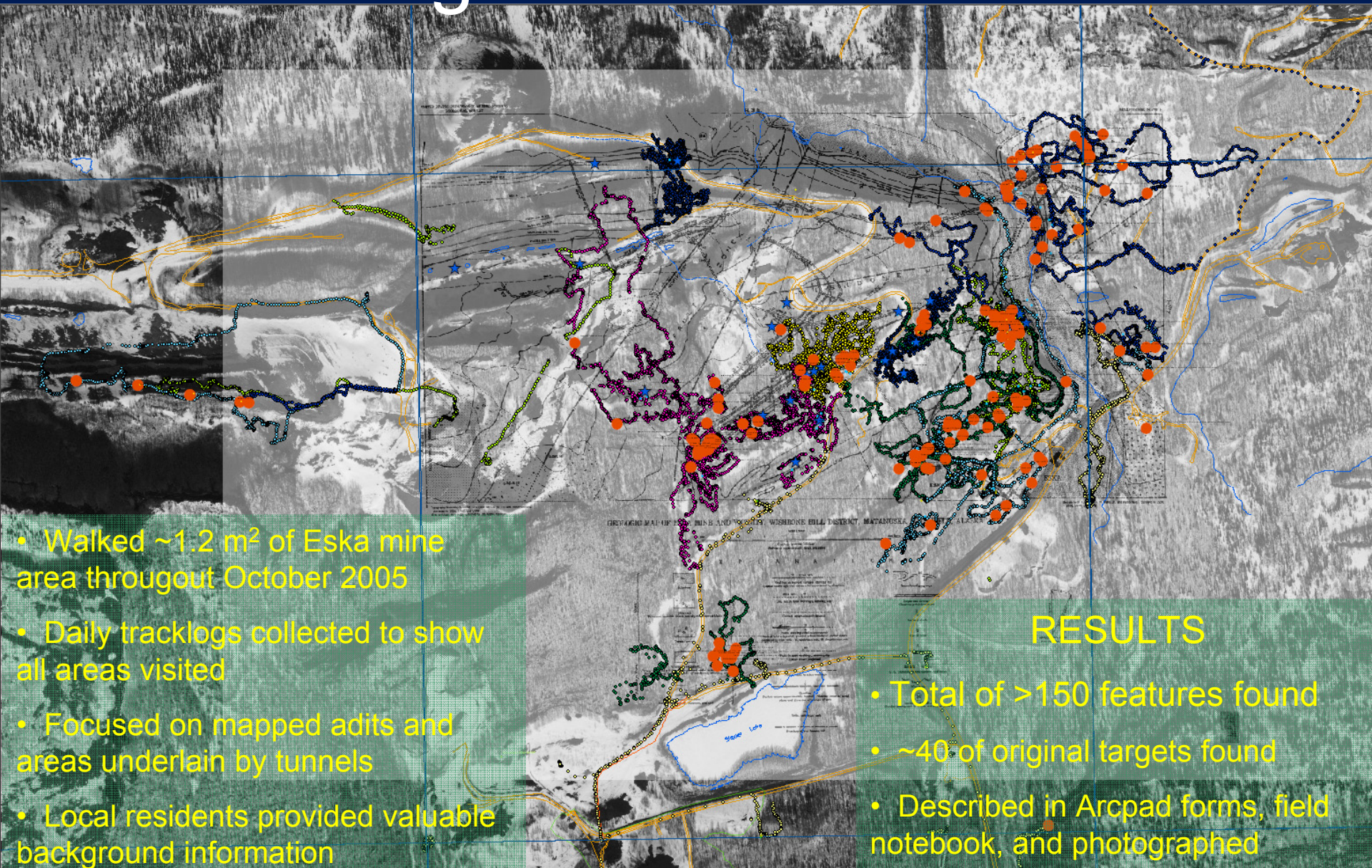
- Vector and raster files exported to Arcpad
- Arcpad map uploaded into Trimble Recon

Eska Inventory -- October 2005
IKONOS tiff & Eska Mine map



- Georeferenced 1943 Eska Mine map used to guide inventory work
- Initially positioned using roads and natural features
- Was ~60-80 m too far NE
- Found openings and section corners surveyed during inventory facilitated better registration

Eska Inventory -- October 2005
Tracklogs and found features

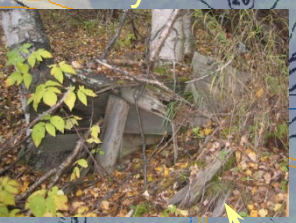


- Walked ~1.2 m² of Eska mine area througout October 2005
- Daily tracklogs collected to show all areas visited
- Focused on mapped adits and areas underlain by tunnels
- Local residents provided valuable background information

RESULTS

- Total of >150 features found
- ~40 of original targets found
- Described in Arcpad forms, field notebook, and photographed

Inventory work – GPS-located feature correlation with UG mine map



Airway shaft

Airway shaft

1/2 mile

Shafts, sinkholes, & exploration pits

Eska Portals

Slump trenches

Triangular opening

Airway shafts

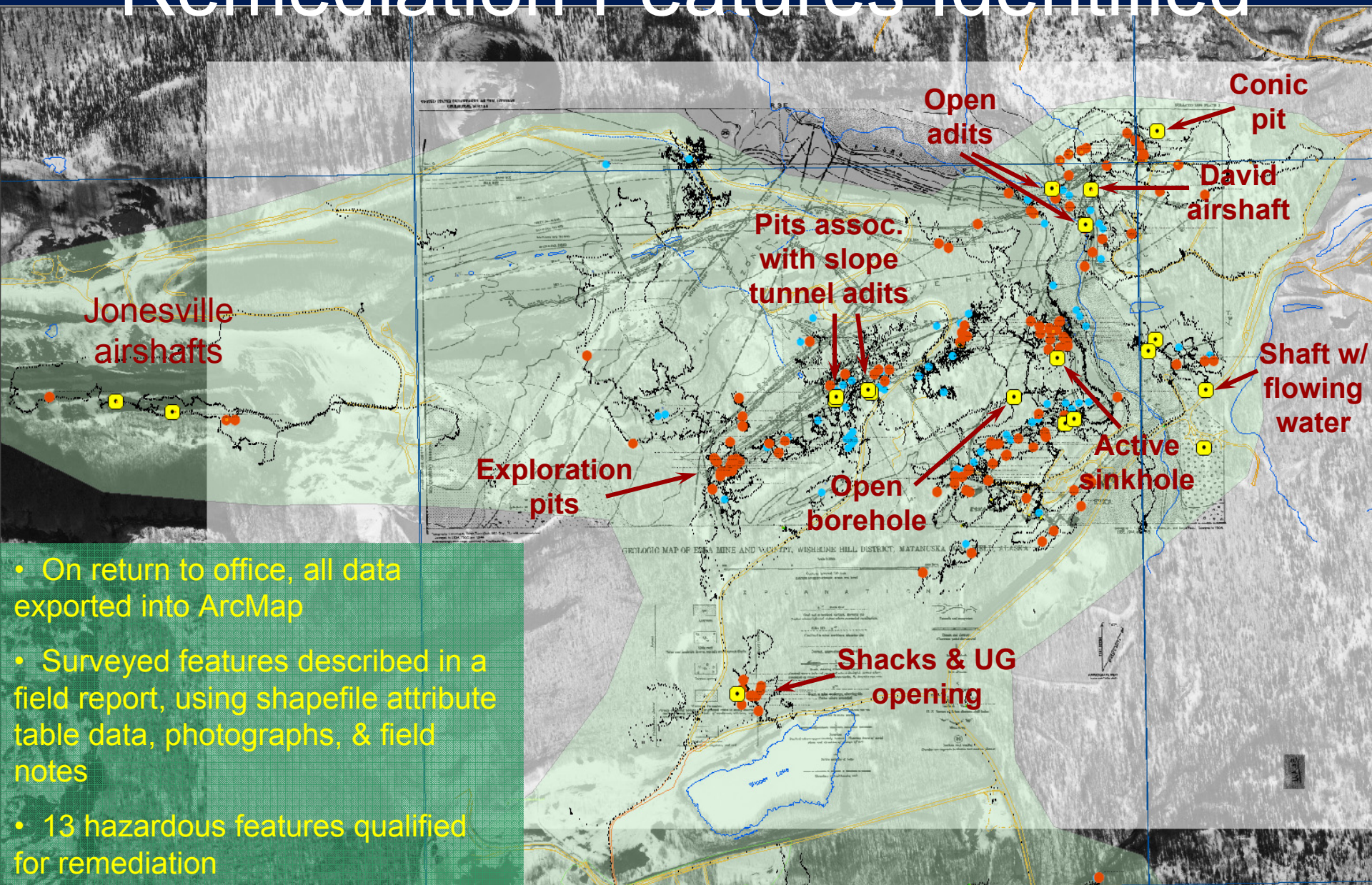
VO pits

Exploration trenches

Crosscut tunnel openings

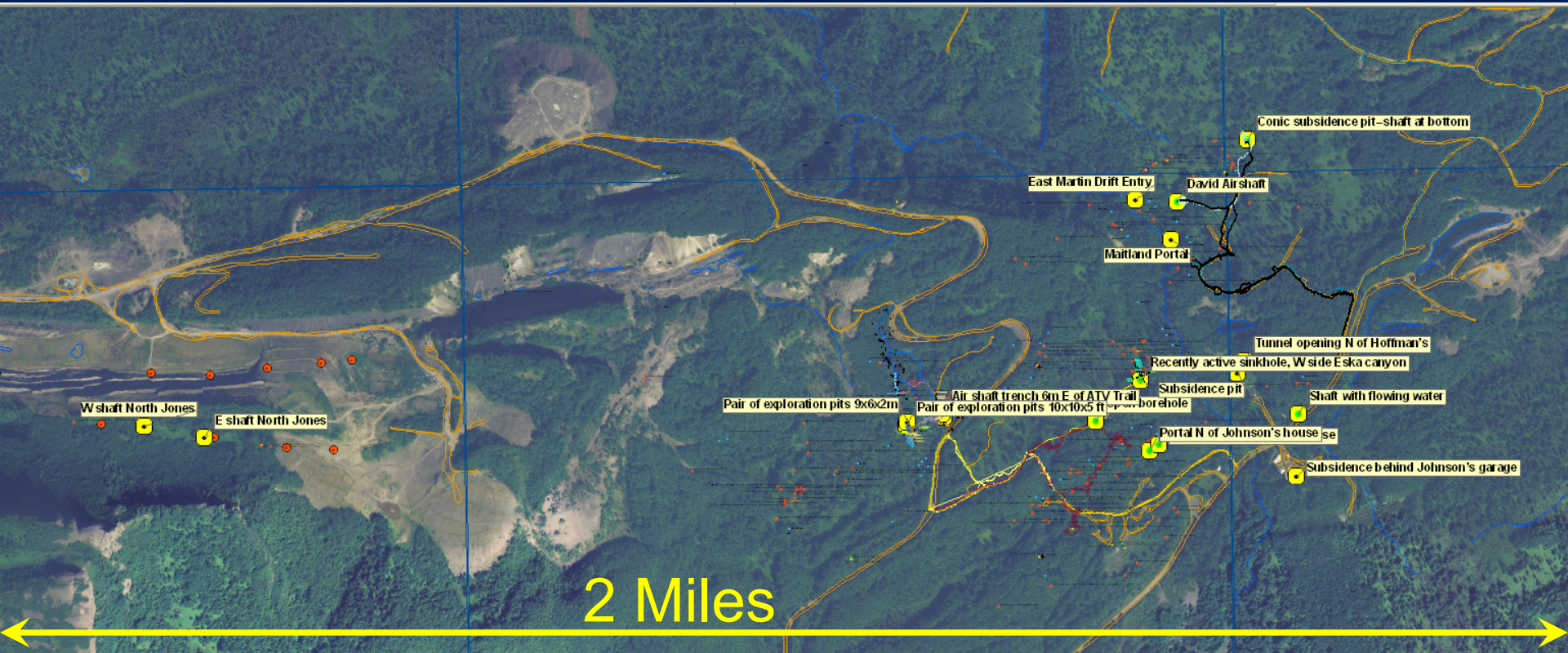
Sinks overlying adits

Eska Inventory -- October 2005
Remediation Features Identified



- On return to office, all data exported into ArcMap
- Surveyed features described in a field report, using shapefile attribute table data, photographs, & field notes
- 13 hazardous features qualified for remediation

Inventory work – October 2005
Remediation Features Identified



Hazards Qualifying for Remediation

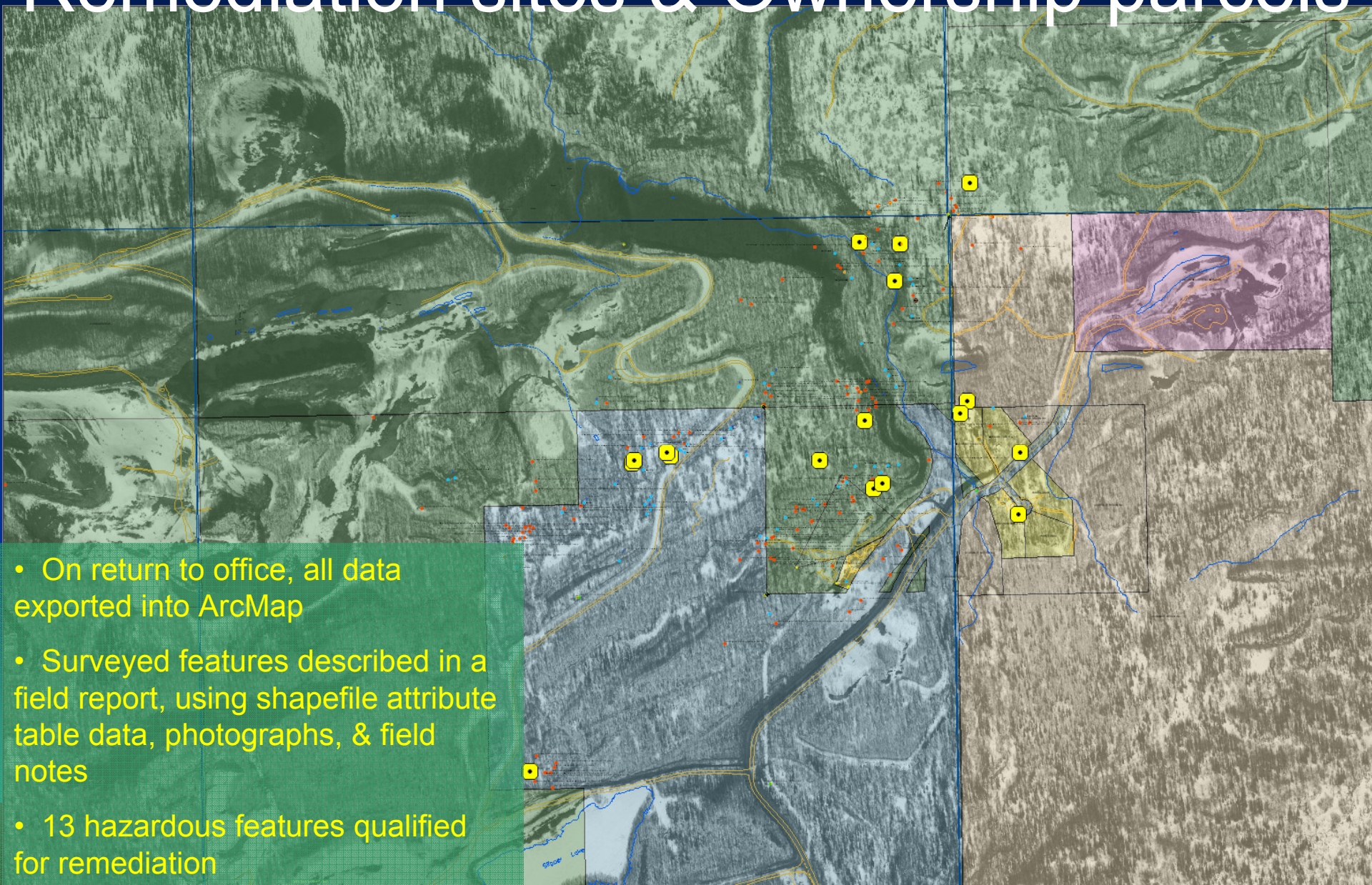
- Seven partially filled airshafts with vertical drops of 6-12 feet
- one 10-foot deep active sinkhole
- one water-filled shaft

Remediation candidates (cont'd.)

- one framed UG opening
- Two adits in Eska Ck. Canyon being kept open as active bear dens (1/4 mile from residences)

Eska remediation Planning

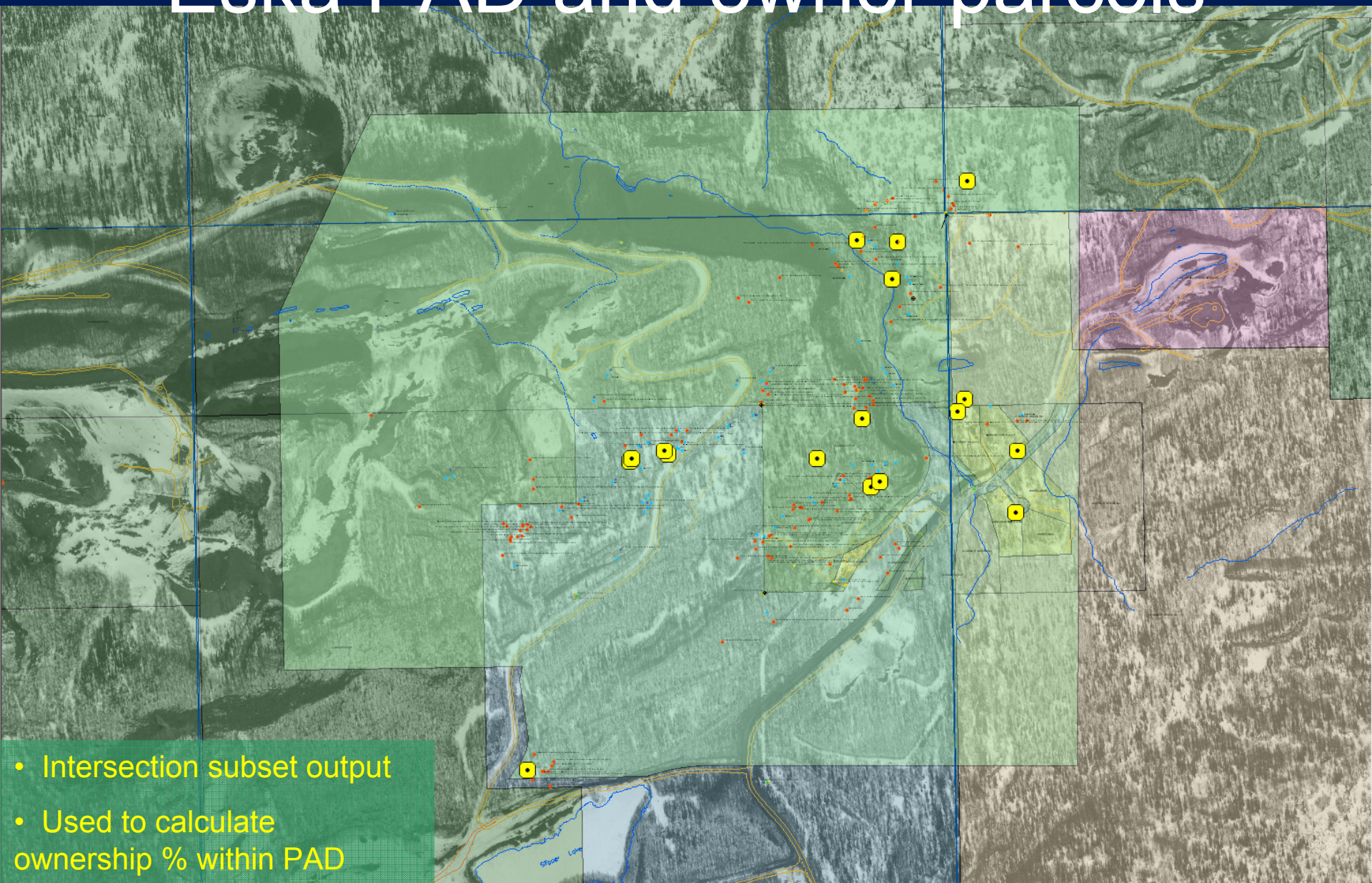
Remediation sites & Ownership parcels



- On return to office, all data exported into ArcMap
- Surveyed features described in a field report, using shapefile attribute table data, photographs, & field notes
- 13 hazardous features qualified for remediation

Eska Remediation Planning

Eska PAD and owner parcels



- Intersection subset output
- Used to calculate ownership % within PAD

Eska remediation Planning

Owner parcels intersecting Eska PAD

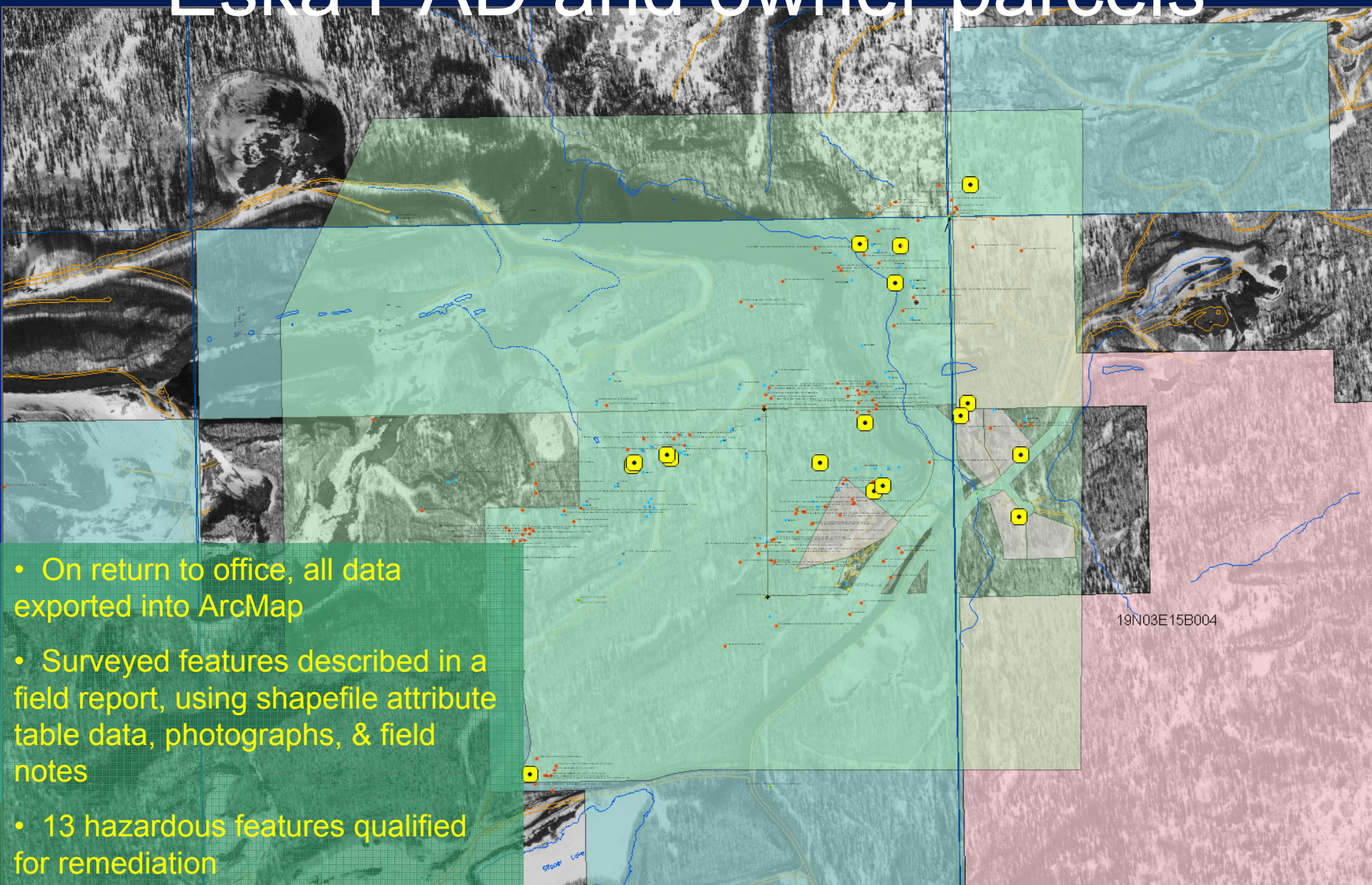
Output

Ownership percentages for AMLIS

- 86% state/local government
- 11% Tribal Lands
- 3% Private

Eska remediation Planning

Eska PAD and owner parcels



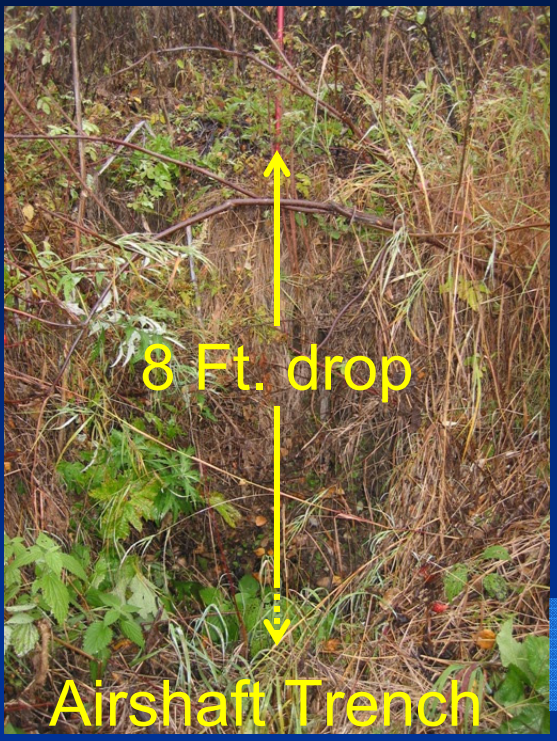
- On return to office, all data exported into ArcMap
- Surveyed features described in a field report, using shapefile attribute table data, photographs, & field notes
- 13 hazardous features qualified for remediation

Eska remediation Planning
Parcels containing AML sites

- Parcel ownership determined to obtain right of entry consent

Jones & Eska Project Sites

Inventoried October 2005




Airshaft 6m E of ATV trail – July 2005


Framed UG opening

Subsiding N. Jones Airshaft

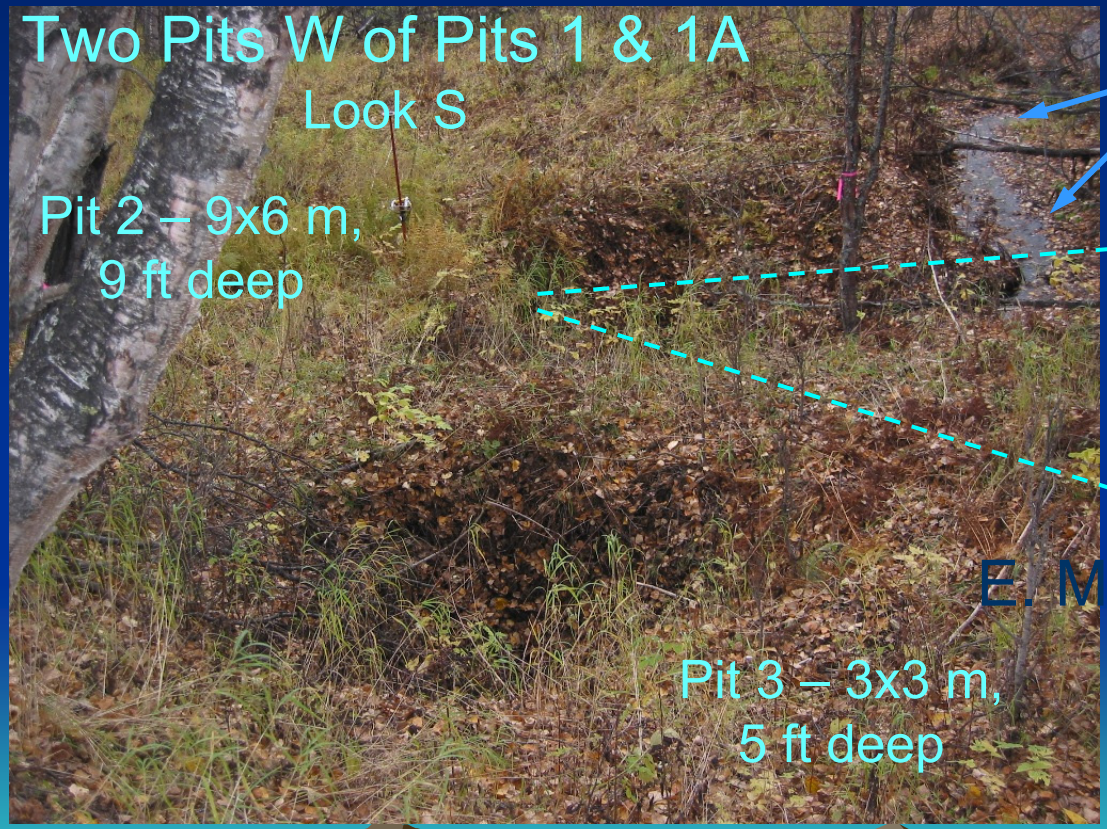

Water-filled shaft – flowing


1998 – hoist ruins aboveground


Oct. 2005 –ruins collapsed into pit

15 ft. deep & growing

Eska Project Sites
Inventoried October 2005



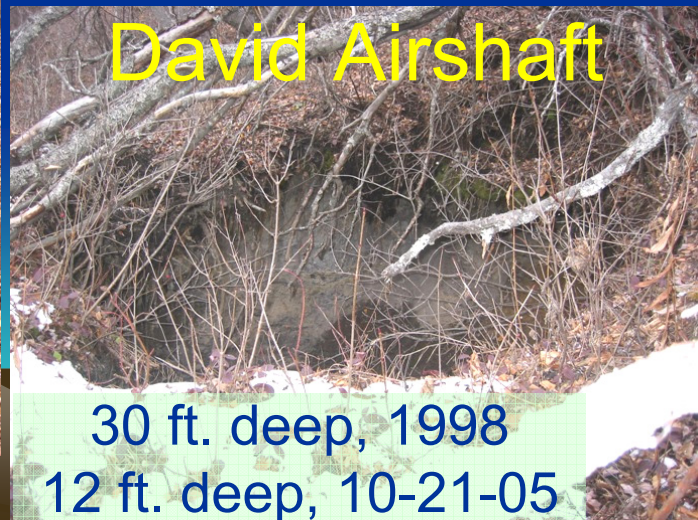
Eska Project Sites
Inventoried October 2005

Conic subsidence pit

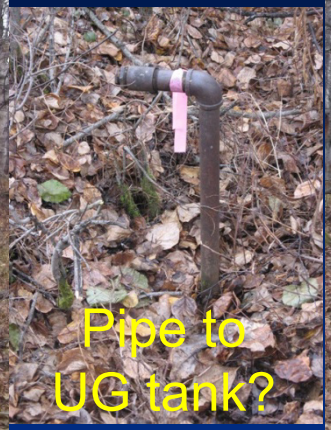
8” Open borehole
next to ATV trail

10 ft. deep sinkhole
above Eska adits

Collapsed Portals along RR grade

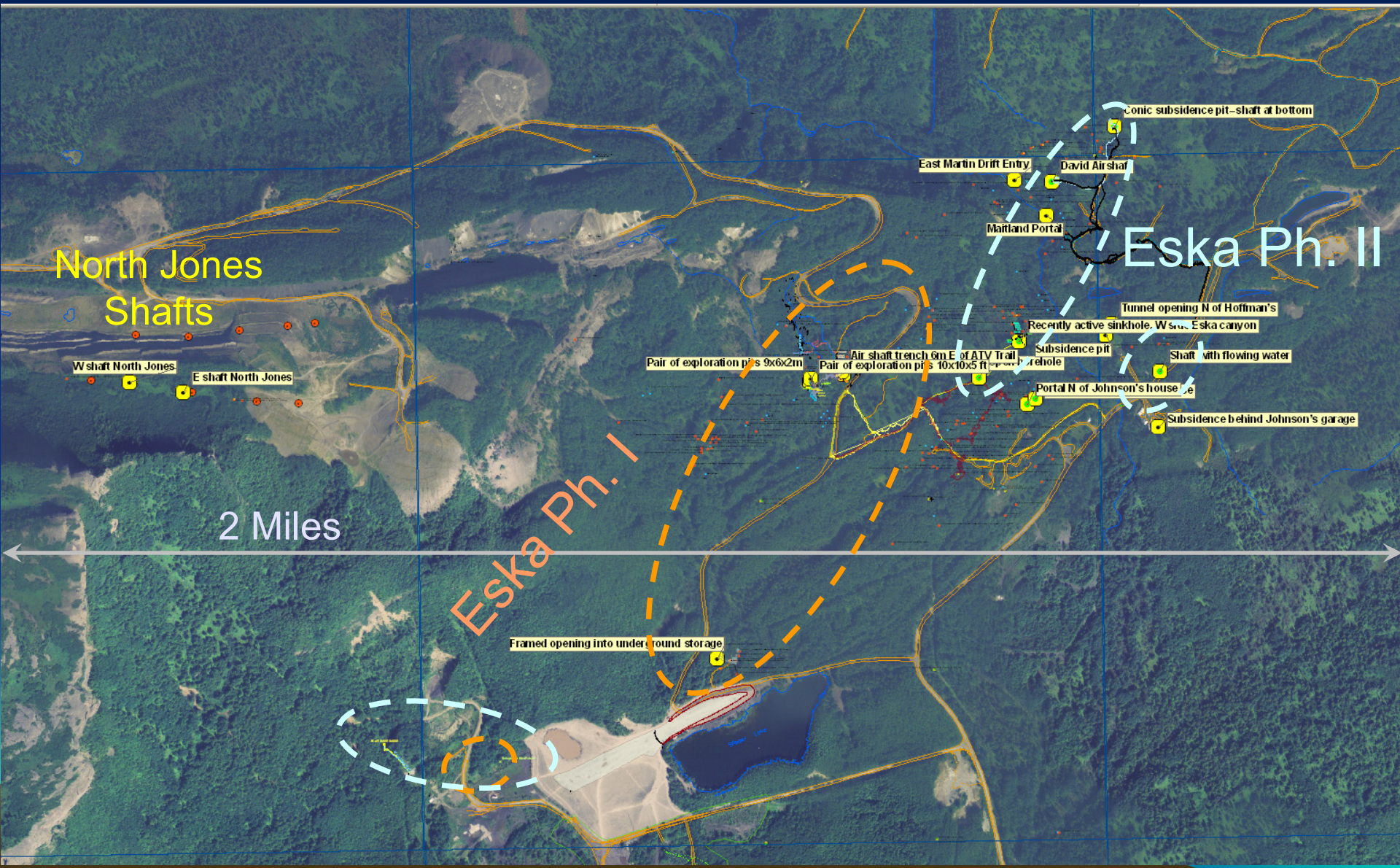


Inventory – Shacks in Gorderville



Inventory – Adit Portals at Eska

Remediation – May - October 2007
Eska Phases I & II



Eska Remediation Design
VO / Subsurface considerations

Our program planned to close 8 Eska area vertical openings in 2007

- Surface depressions 6-13 ft. deep
- Some exhibited soft bottom zones
- BR known to be shallow beneath some, suspected to be beneath others
- overlain by unconsolidated overburden

Eska Remediation Design
VO / Subsurface considerations

Experts advise designers closing VOs determine depth to bedrock or shaft collars overlain by unconsolidated overburden

- Openings act as control surfaces in case of catastrophic overburden collapse.
- Illustrated by the 1982 Pinebrook shaft incident)

Eska Remediation Design
VO / Subsurface considerations

AK AML decided against a separate exploration drilling program to determine opening depths and dimensions

- Decided to combine exploration and remediation phases
- Rather, excavate to daylight openings, stopper with boulders, backfill with graded aggregate

Eska Remediation Design
VO / Subsurface considerations

Decided I needed to know BR depth around raveling or recently active features, to

- Determine safe surface setback distances, using angle of repose of overlying materials
- Determine digging depths to properly size equipment

Eska Remediation Design
Seismic Refraction survey

October 2006 -- Surveyed six seismic refraction lines around three closure sites

- 6-foot deep ATV pit
- Pair of pits 6 and 9 feet deep
- 10-ft. deep recently active sinkhole

Eska Remediation Design
Seismic Refraction survey

- Two spreads surveyed at each site, crossing at near right angles near target openings
- Geophone spacing varied from 4-10 ft., based on line length
- Shot energy generated with 4-lb. sledge striking an aluminum plate

Eska Remediation Design
Seismic Refraction survey

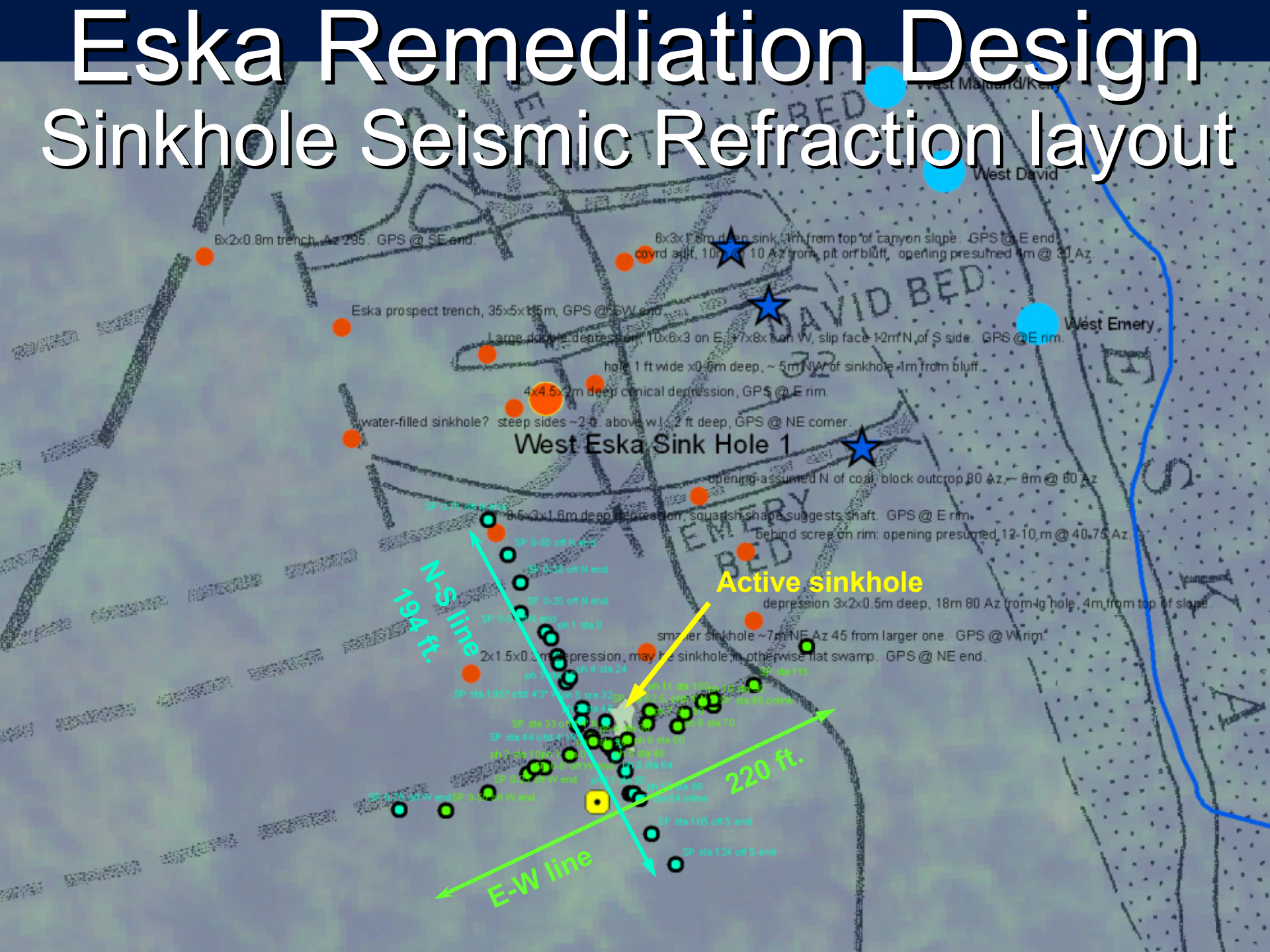
- Geometrics 12-channel ES-1225 used to gather first-arrival data
- Shots stacked to optimize returns
- Geophone traces & acquisition parameters output to printer tapes
- First-arrival times noted on printer tapes in field, w/ aid of seismograph display

Eska Remediation Design
Seismic Refraction survey

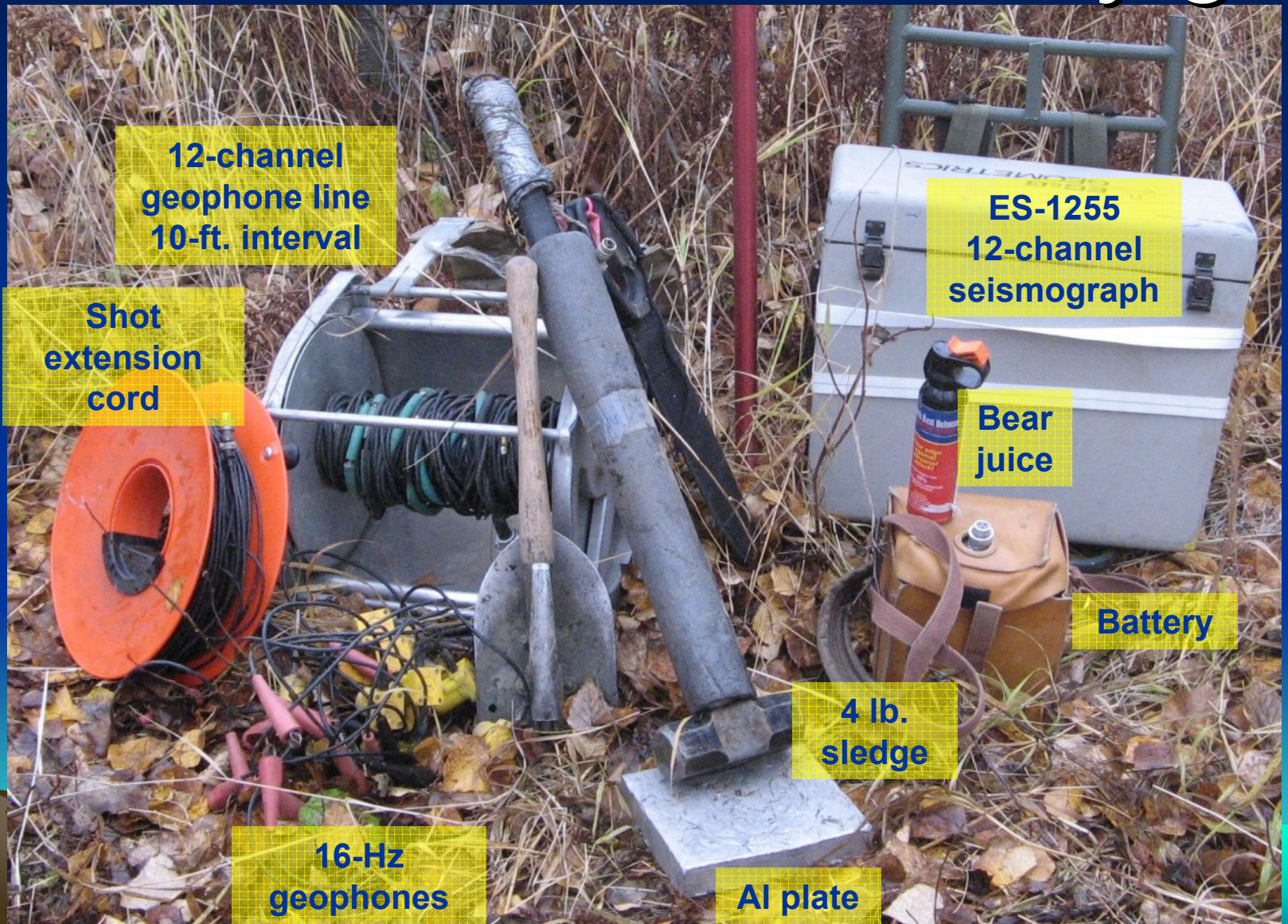
- Shots fired on line ends, off the ends, and spaced within line interiors
- Assured overlap of 1st arrivals from each refractor in both directions
- Facilitates delay-time depth computations for each interface, beneath each geophone.

Eska Remediation Design

Sinkhole Seismic Refraction layout



Eska Remediation Design
Seismic Refraction survey gear



Eska Remediation Design
Seismic Refraction survey

Line laid out with lath & measuring tape
Geophone locations marked

Pits

2 Pits E-W Line Layout

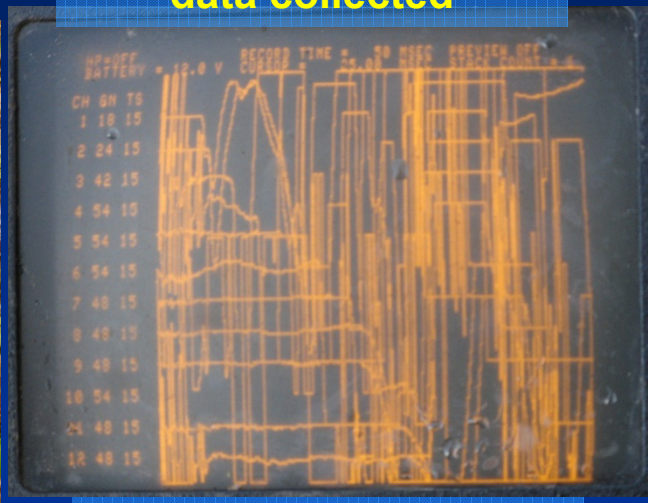
Geophones planted

Shot data collected

Eska Remediation Design
Seismic Refraction survey

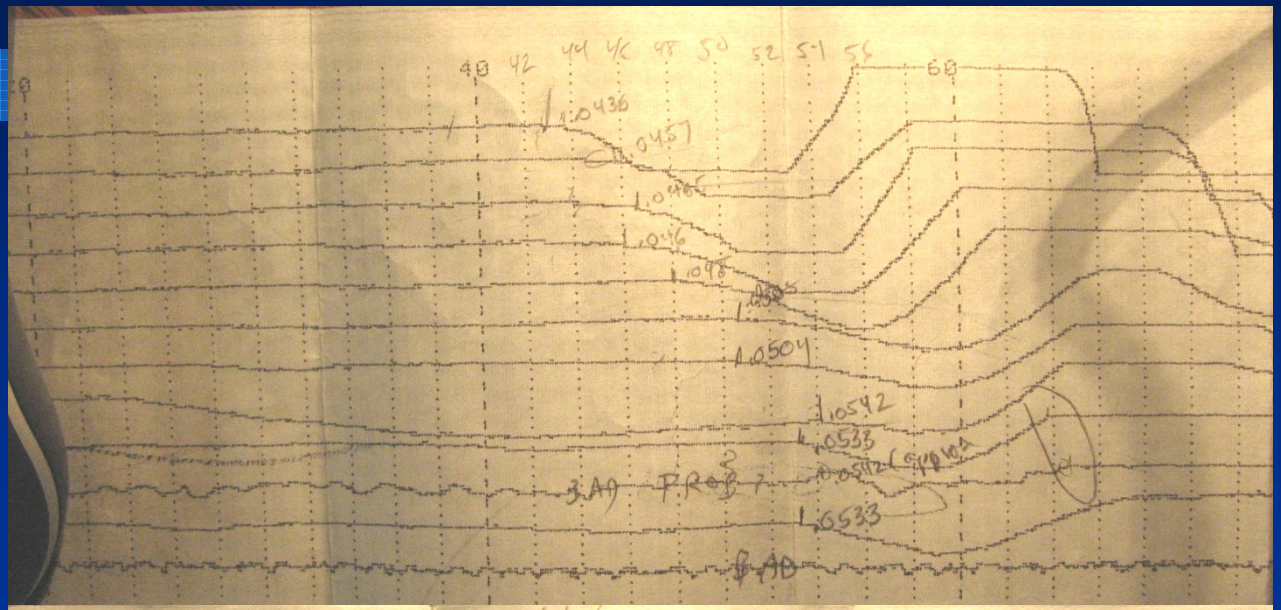
Data collected in seismograph, stacking multiple shots

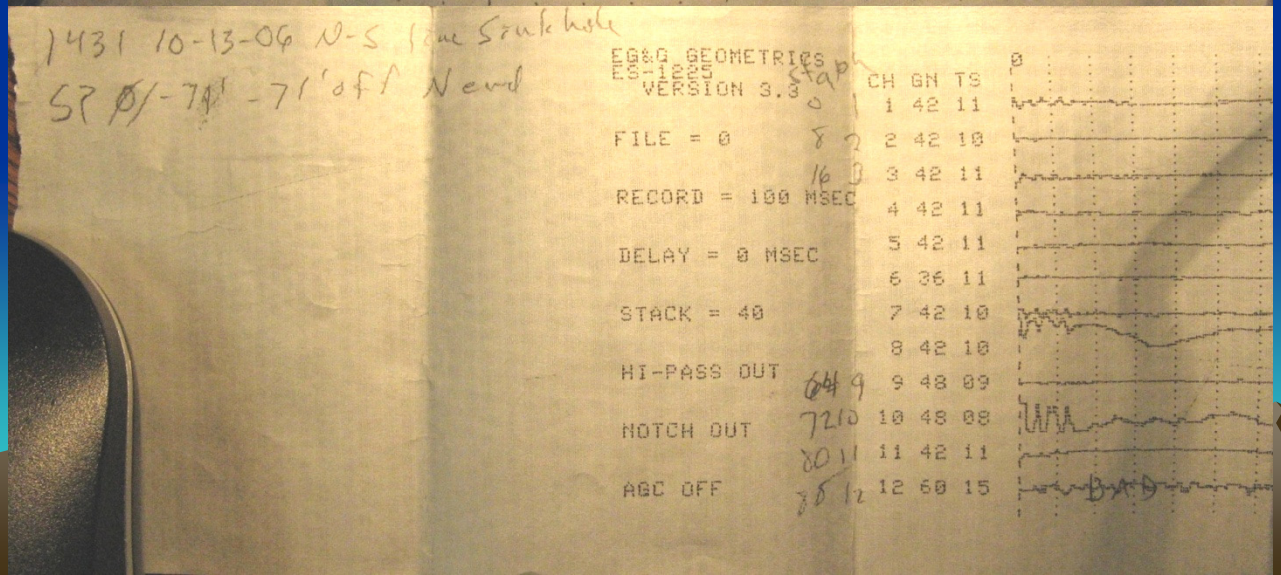
Channels frozen as data collected



Geophone traces optimized to show 1st arrivals for printout

Eska Remediation Design
Seismic Refraction survey





Optimized geophone traces printed out.

First-arrivals times circled on the printout, with aid of seismograph screen cursor

More precise times picked later during office analysis

Printout header shows acquisition parameters — Channel, trace size, gain, record length, delay, filters on/off, # shots stacked

Active Sinkhole, on approach

Eska Remediation Design
Seismic Refraction survey

Geophone and shotpoint GPS located as Terrasync points

Shot point, geophone, and feature elevations level surveyed, benchmarked off geophone location

Eska Remediation Design
Seismic Refraction survey analysis

- Geophone and shotpoint elevations calculated in Excel, benchmarked off a GPS elevation at each site
- Point surface elevations used to construct local site topo contours in CAD.

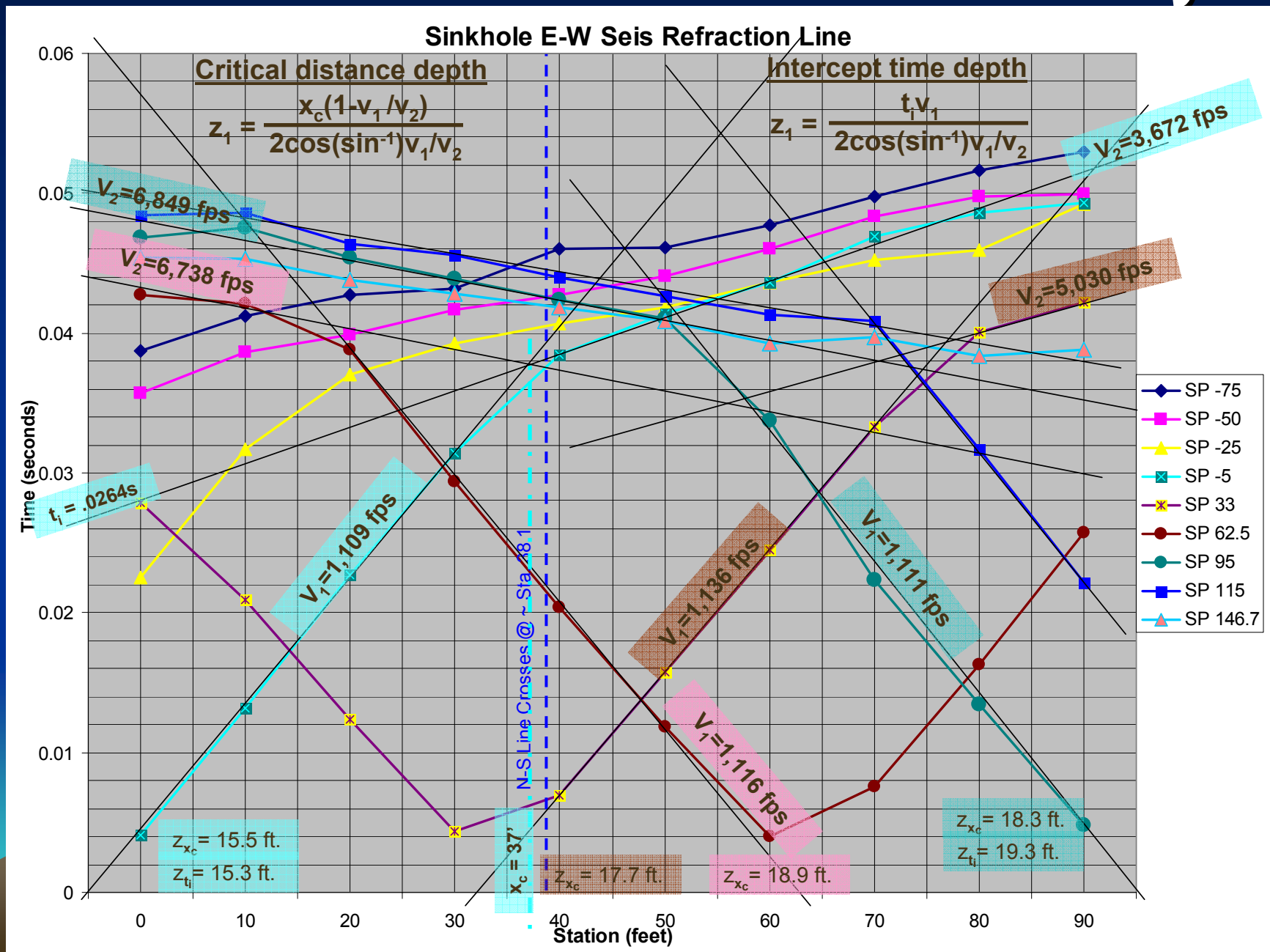
Eska Remediation Design

Seismic Refraction survey analysis

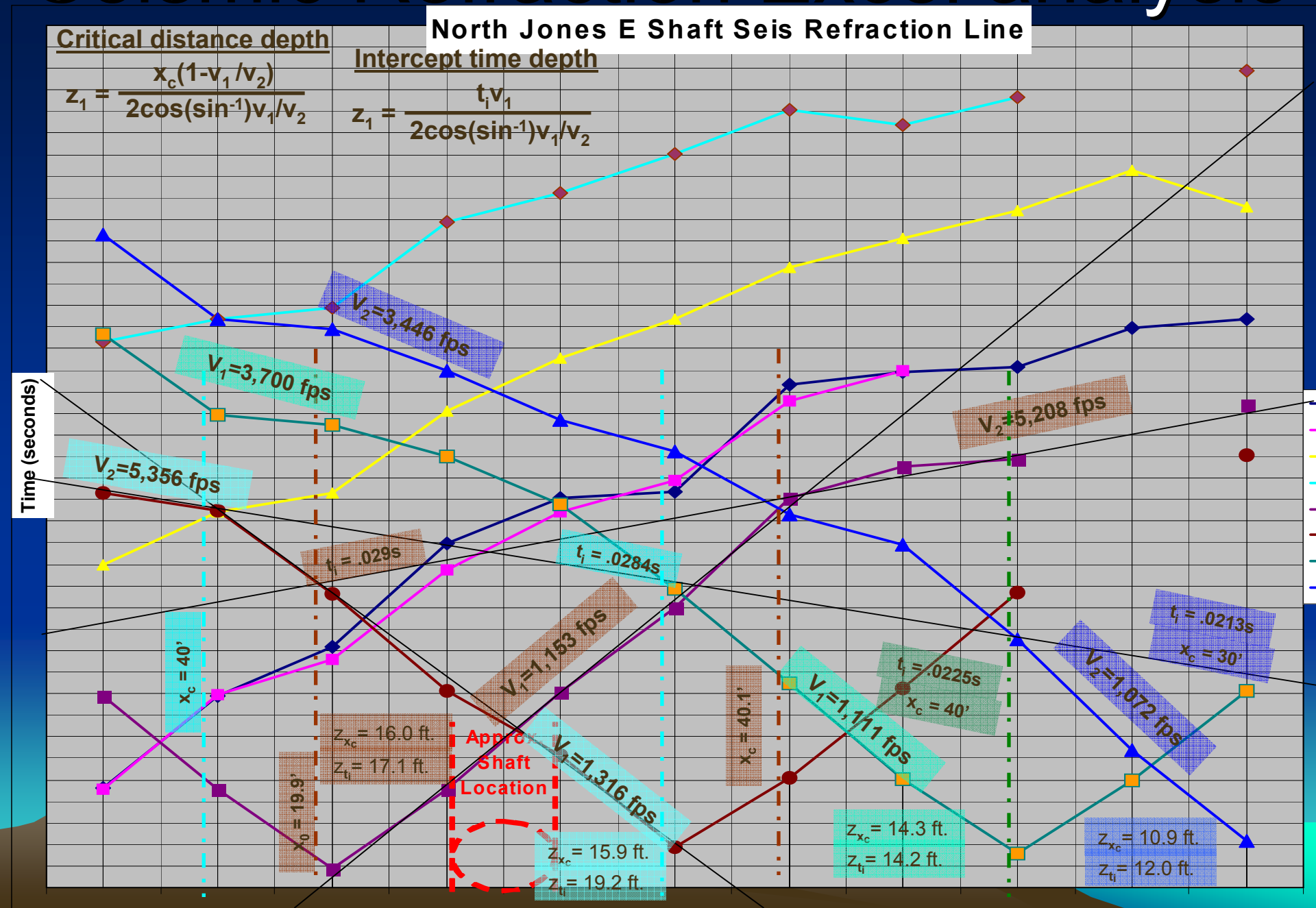
Printer tape arrival times and geophone distances put into Excel.

- Time-distance graphs plotted
- Refractor layers picked
- apparent velocities determined
- Ballpark depths calculated using critical time and critical distance formulas

Seismic Refraction Excel analysis



Seismic Refraction Excel analysis



Eska Remediation Design

SIPT Seismic Refraction survey analysis

SIPT program used to calculate interface depths beneath each phone

- Routine calculates delay-time depths
- then runs inverse ray-trace iterations
  - calculates and adjusts interfaces where raypaths emerge enroute to each geophone

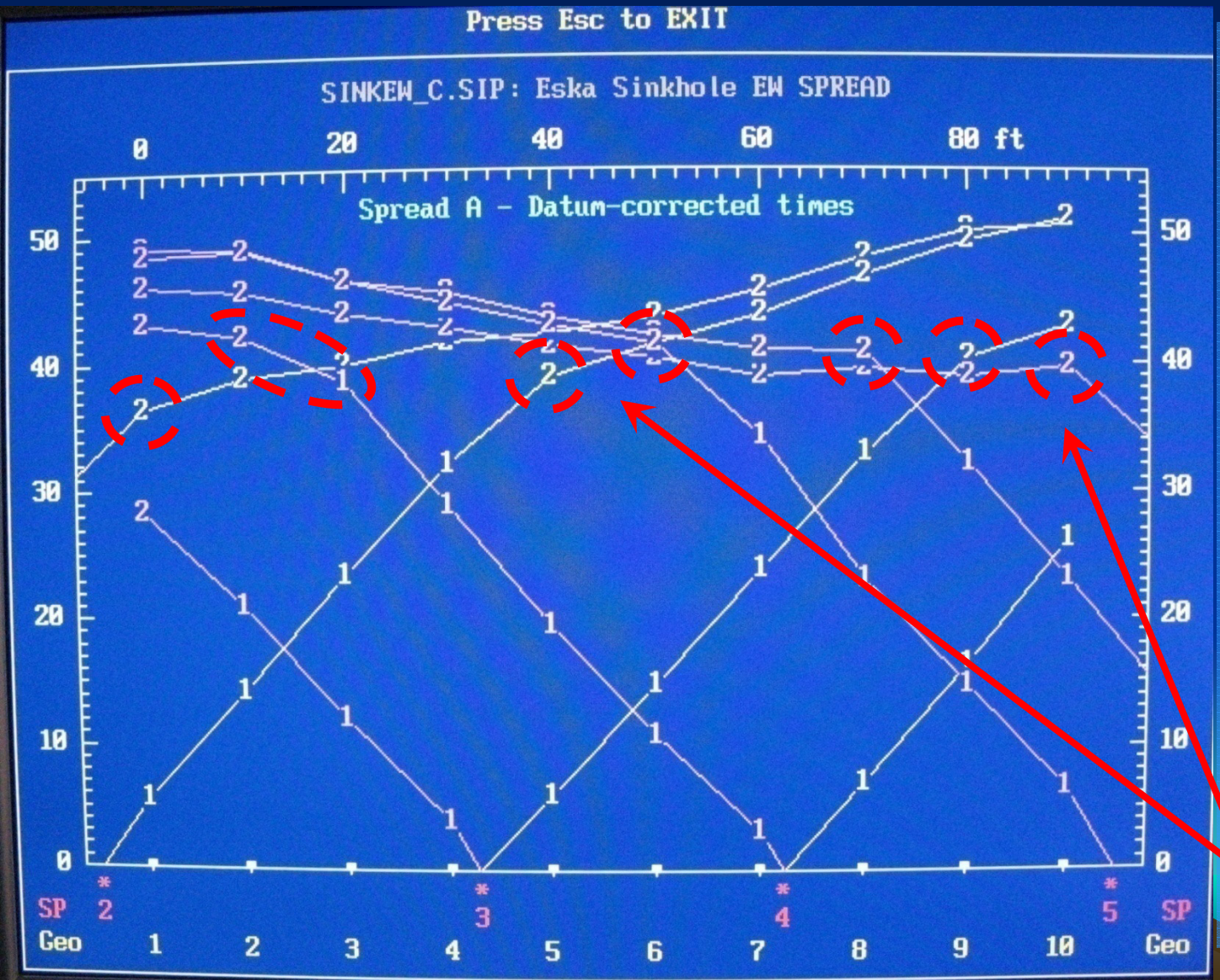
Eska Remediation Design

SIPT Seismic Refraction survey analysis

- First-arrival time input
- Time-distance graphs displayed
- Refractor arrivals picked
- Analyses run until solutions converged

Eska Remediation Design

SIPT Seismic Refraction analysis



- SIPT program displays datum-corrected arrivals
- Aids picking correct layers for each geophone from screen display
- Also aided by velocity tables, depth tables, and depth plot
- Solutions are iterated until convergence on satisfactory model
- Critical factor making correct layer assignments near the critical distance

Eska Remediation Design

SIPT Seismic Refraction analysis

Refractor depths beneath each shotpoint

3	53.0	1035.7	19.3	1016.4
4	62.5	1035.6	21.4	1013.6
5	95.0	1032.7	21.1	1011.6

SIPT depth table, showing refractor depths beneath each shotpoint and geophone

Geo	X-Loc	Surface Elev	Layer 2 Depth	Layer 2 Elev
1	0.0	1035.6	17.4	1018.2
2	10.0	1035.8	18.8	1017.0
3	20.0	1035.9	19.3	1016.6
4	30.0	1035.8	19.1	1016.7
5	40.0	1035.9	20.2	1015.7
6	50.0	1035.7	20.9	1014.8
7	60.0	1035.2	21.3	1013.9
8	70.0	1034.7	22.0	1012.7
9	80.0	1033.8	21.9	1011.9
10	90.0	1033.0	21.3	1011.7

Velocities used to formulate the Depth Mod

Refractor depths beneath each geophone

SIPT velocity tables, showing calculated weighted-average layer velocities– L_1 and L_2

				1122
4	3	42.7	1100	
4	4	32.8	1114	
4	5	22.9	1121	
4	6	13.1	1114	
4	7	4.7	1100	
4	8	8.5	1119	
4	9	18.0	1104	
4	10	27.9	1084	
				1117
5	7	35.1	1041	
5	8	25.1	1125	
5	9	15.0	1122	
5	10	5.0	1044	
				1083
6	9	35.0	1105	
6	10	25.0	1127	
				1116

ocity computed for Layer 1 = 1117

VELOCITY ANALYSIS TABLES for SINKEW_C.SIP

Avg = 6547 for 44 Pts

Layer 2 Velocity computed by Hobson-Overton method

Spread A SPs	Geos	V	Avg TdSP	Std Err Overall	4 Highest Err	Geo	Std Err	Geo				
1 4	1 2	5706	-4.8	0.000	-0.000	1	0.000	2				
1 5	1 6	6866	-4.8	0.276	-0.483	2	0.394	4	0.229	1	-0.129	6
1 6	1 8	6975	-3.3	0.198	0.400	3	-0.234	2	-0.198	6	0.134	4
1 7	1 10	8161	3.1	0.807	-1.920	10	0.997	7	0.817	9	-0.785	1
2 5	5 6	4998	-1.9	0.000	0.000	5	0.000	6				
2 6	5 8	5684	0.0	0.206	0.261	6	-0.221	5	-0.181	8	0.141	7
2 7	5 10	6884	6.6	0.719	-1.129	10	0.860	9	0.747	7	-0.675	5
3 7	9 10	11688	3.5	0.000	0.000	10	-0.000	9				

Avg = 7186 for 40 Pts

Wtd Avg Velocity computed for Layer 2 = 6959

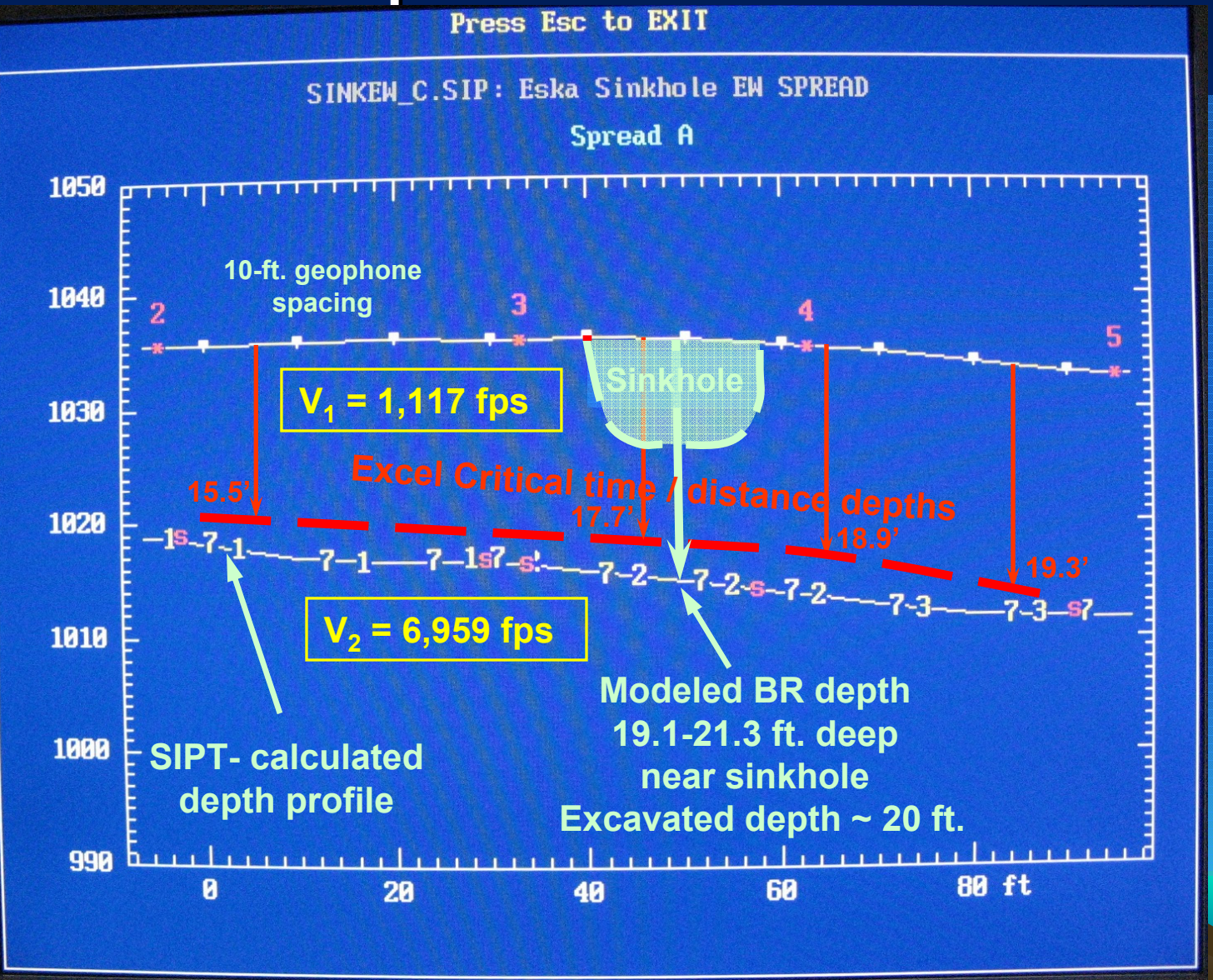
Use ↑ ↓ arrows, Home/End, PgUp/Dn keys to scroll table. Press Esc when finished.

Layer 1 calculated velocity

Layer 2 calculated velocity

Eska Remediation Design

SIPT Depth Plot – E-W Sinkhole Line



SIPT Depth Plot

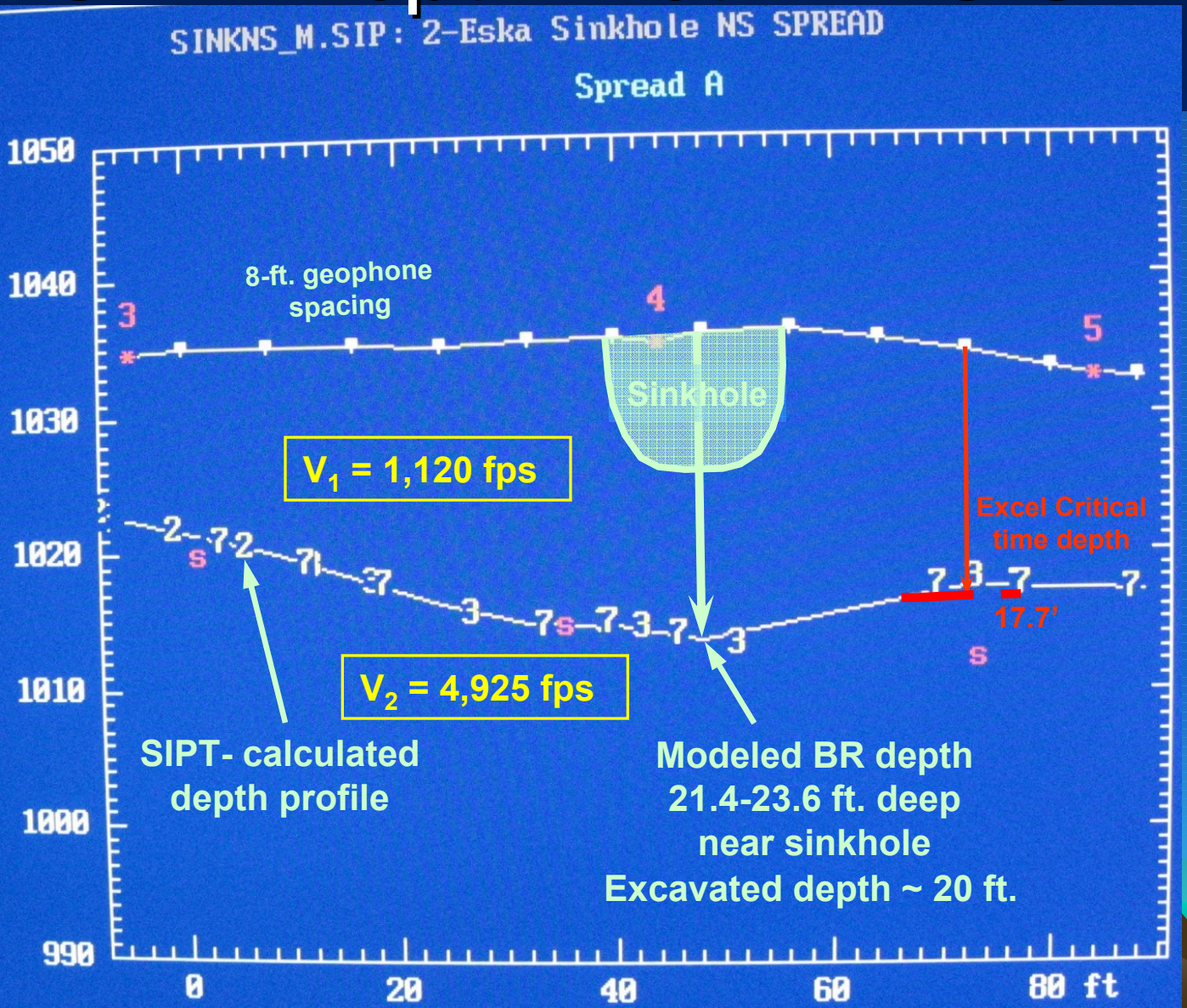
Geophone locations correlated with surface features to gauge BR depth beneath features of interest

Refractor depth models generally solve within 5% of actual interface depths

Two-layer solutions generally resolve better than three-layer models.

Eska Remediation Design

SIPT Depth Plot – N-S Sinkhole Line



SIPT Depth Plot

Modeled bedrock depths beneath sinkhole similar to E-W line solution.

Lower average bedrock acoustic velocities probably due lateral velocity variations, or discontinuous weathered zones.

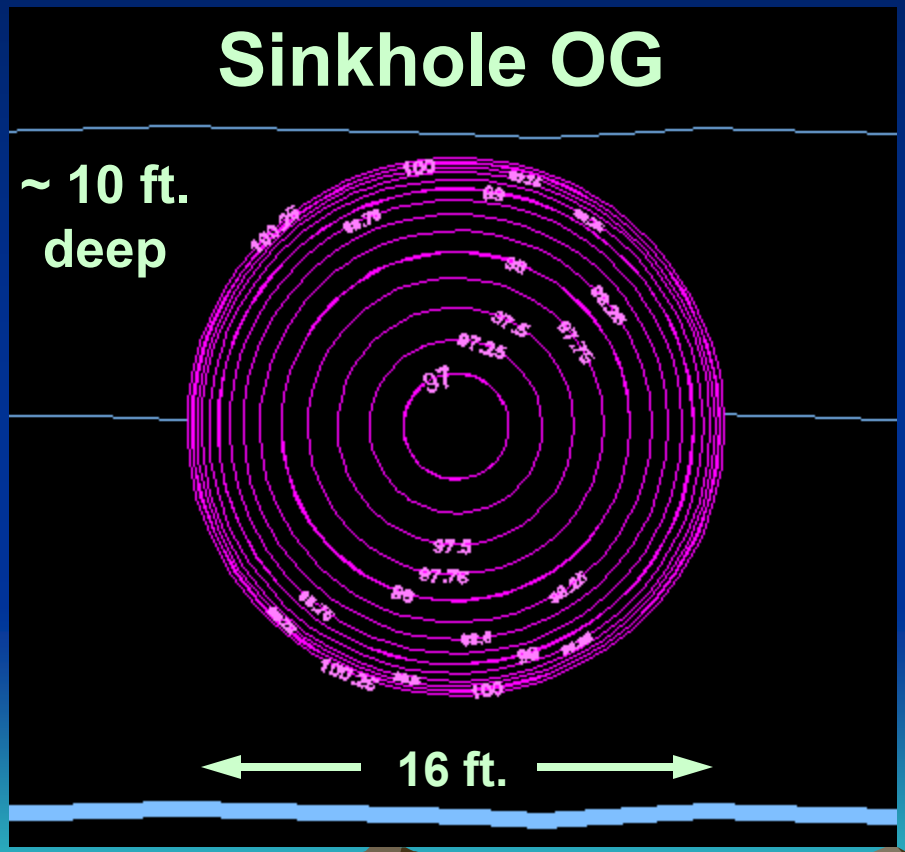
Two-layer solution showed better resolution than the 3-layer model.

Eska Remediation Design

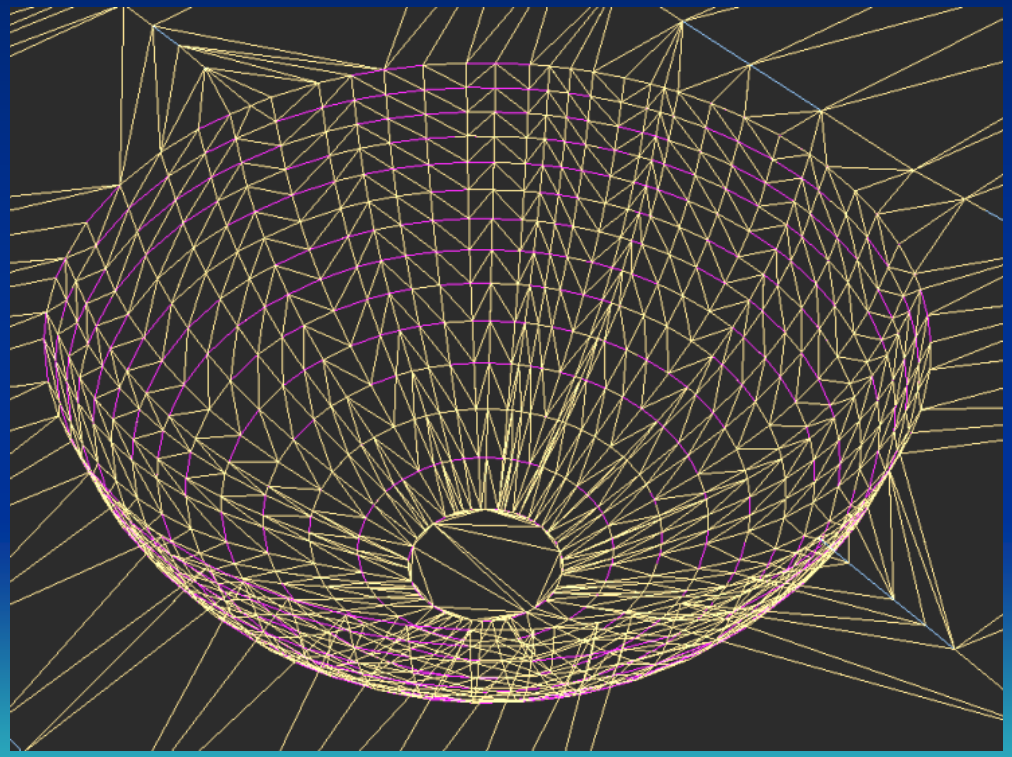
Sinkhole CAD model for volumes

Approximate OG dimensions and topography

Sinkhole OG



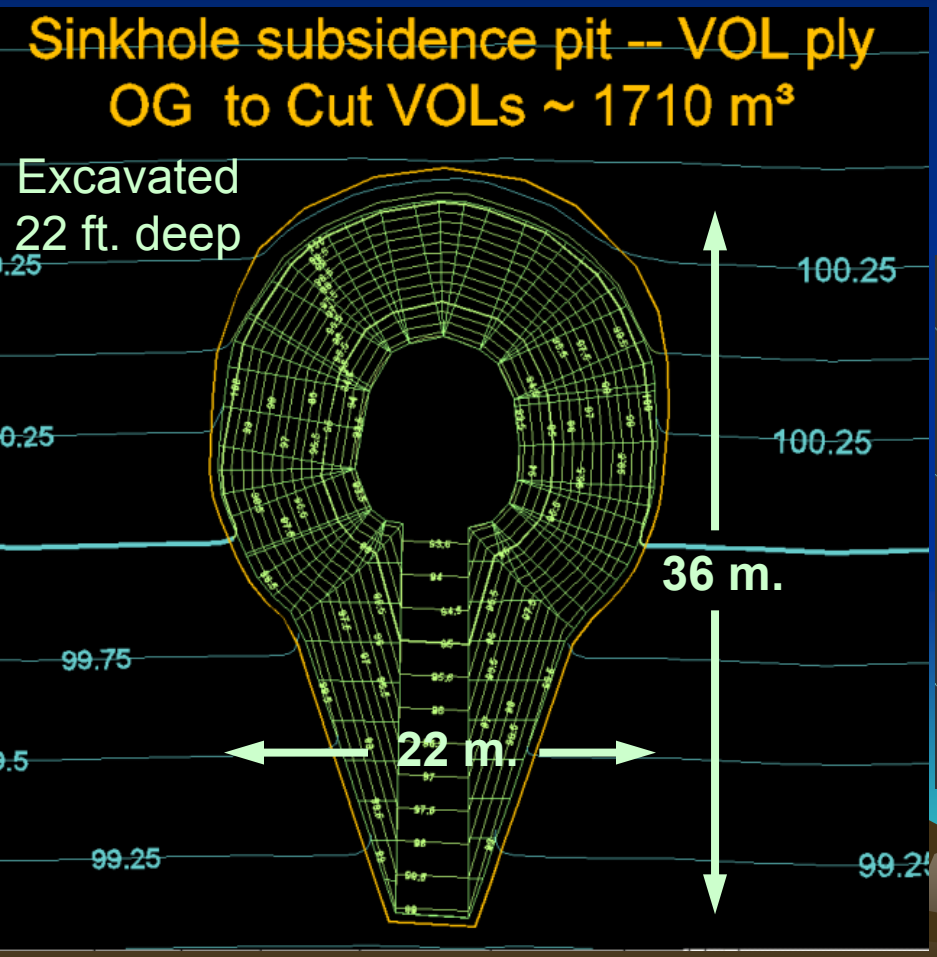
Sinkhole OG – oblique 3D



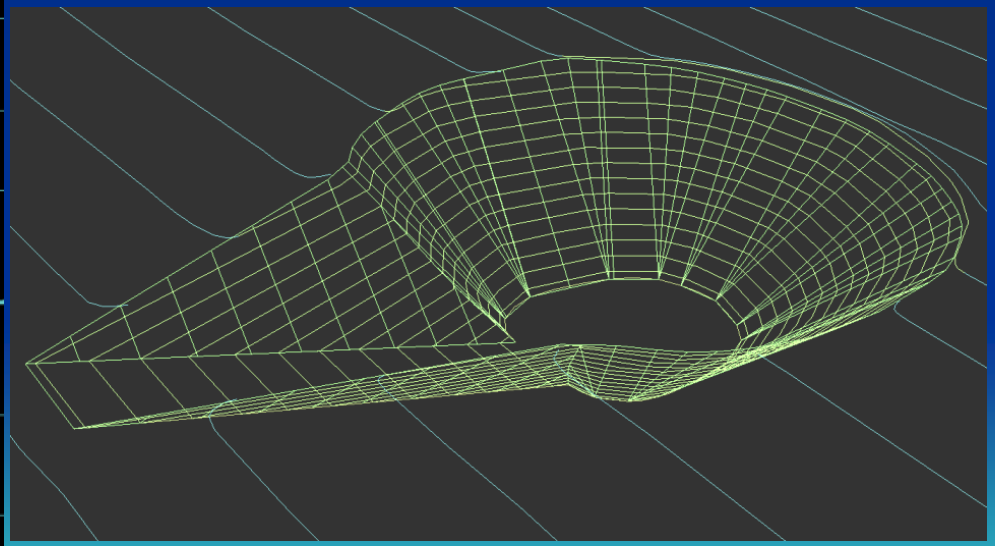
Eska Remediation Design

Sinkhole CAD model for volumes

Excavation dimensions and volumes based on SIPT seismic depth models



Sinkhole Excavation model -- oblique 3D

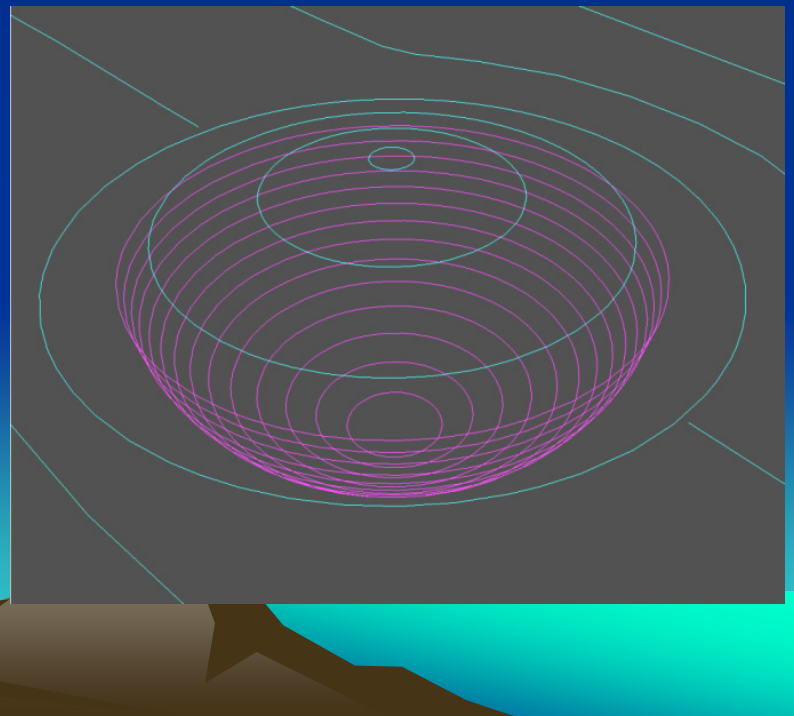


Eska Remediation Design

Sinkhole CAD model for volumes

Excavation dimensions and volumes based on SIPT seismic depth models

Sinkhole Excavation vs. Fill 3D model --



PH II -- Sinkhole Remediation

Sinkhole excavation progresses

PH II -- Sinkhole Remediation

Excavation below BR at 20 ft., 5 ft. deep into shaft, exposes flowing water on floor

More exhumed timbers

Timbers in bucket

Boulder bottom fill

Emplacing large aggregate fill

9 ft. log ladder

Emergency Project – Pit 1a

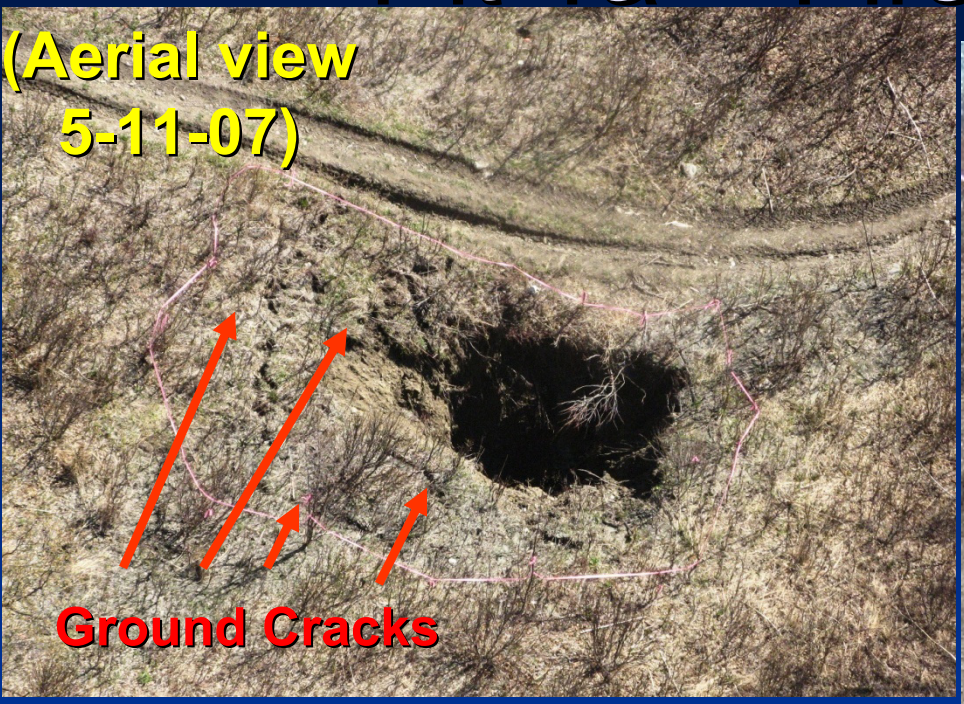
Eska Remediation Design

Eska 1993 VO closure data – photos.

Shafts open and raveling, 15-25 ft deep

Remediated by removing overburden, filling w/ unclassified fill.

Pit 1a – First Response



Pit 1a Emergency – Temporary remediation

Diversion Point

Upper Diversion Channel

Diversion Channel (Dry)

Devil's Club Patch

Rerouted Channel

Lower diversion channel

ATV Trail

Head of 3' deep gully

End of swale

Rechanneled stream

Water running into pit

Pit 1

Pit 1A

Pit 1a

Pit 1

Pit 3

Pit 2

NORTH JONES ROAD

5-5-07 Investigation

GPS Map

Traced water back to source—coming off road ditch uphill

Created temporary diversion to dry up water flowing into pit

Traced diverted channel back downslope to determine new flow pattern

Channel dried up before returning to pit area

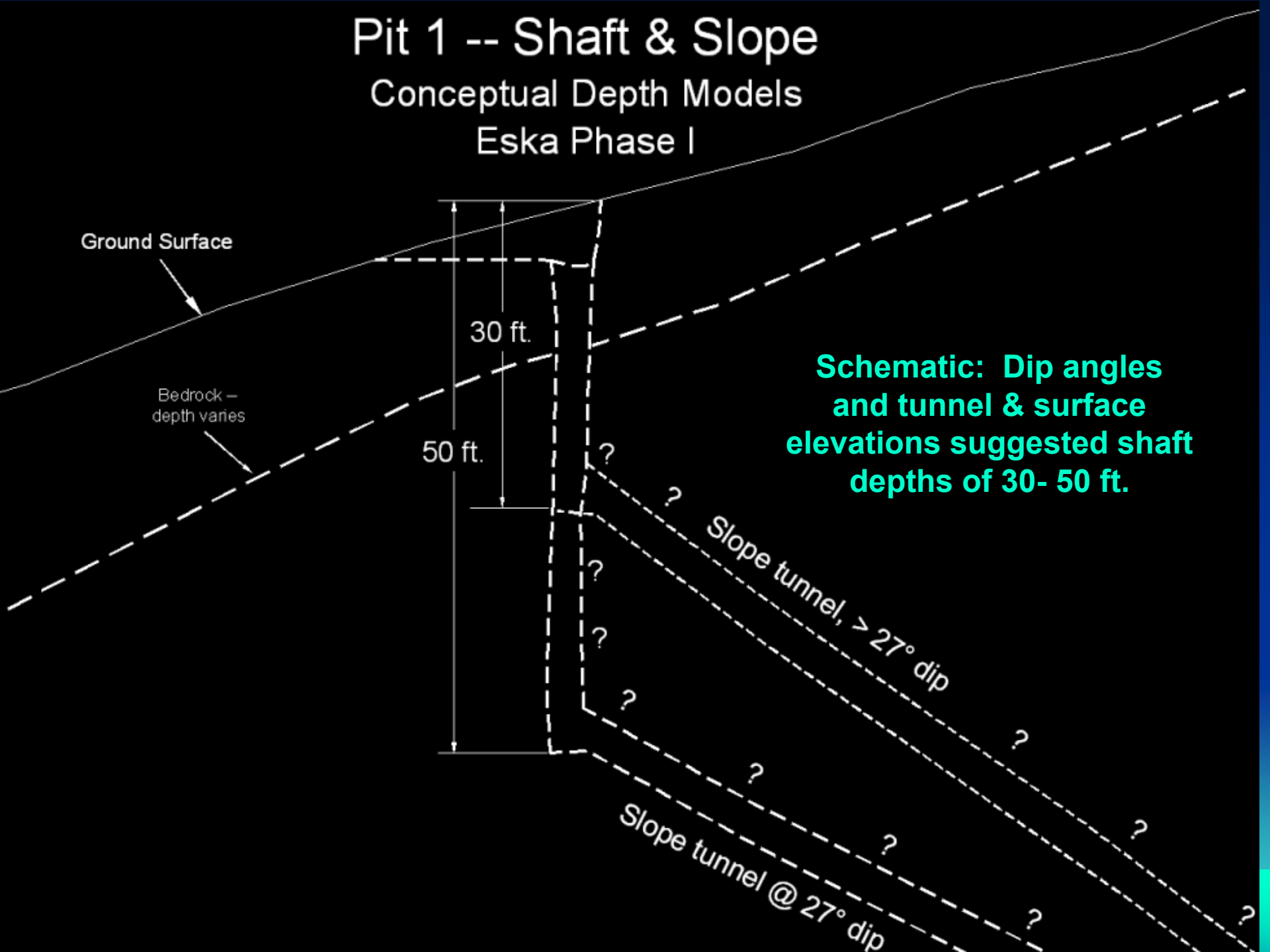
Eska Remediation Design

Eska historic mine data – georef. map

Pit 1 -- Shaft & Slope

Conceptual Depth Models

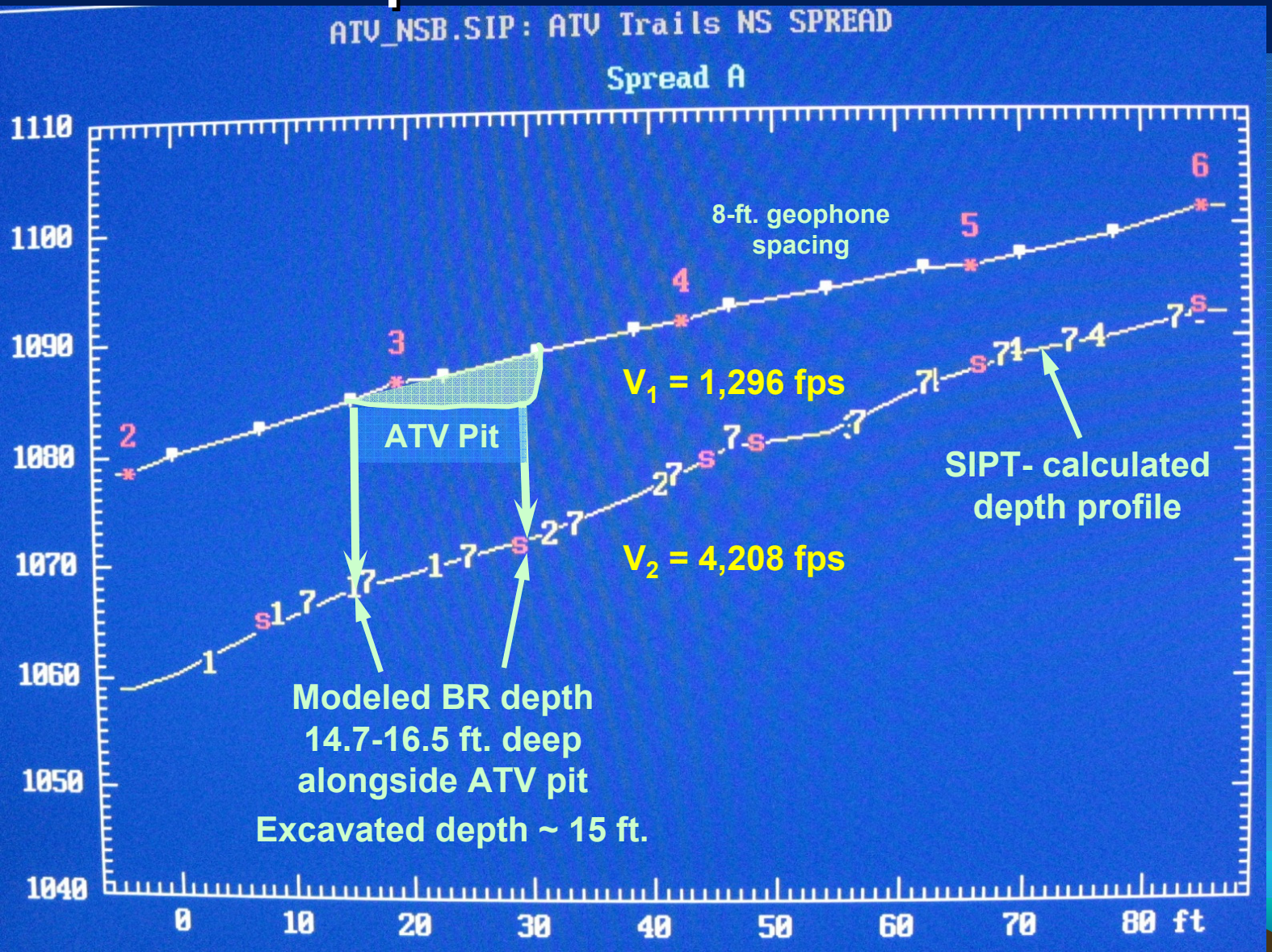
Eska Phase I



Schematic: Dip angles and tunnel & surface elevations suggested shaft depths of 30- 50 ft.

Eska Remediation Design

SIPT Depth Plot – N-S Sinkhole Line

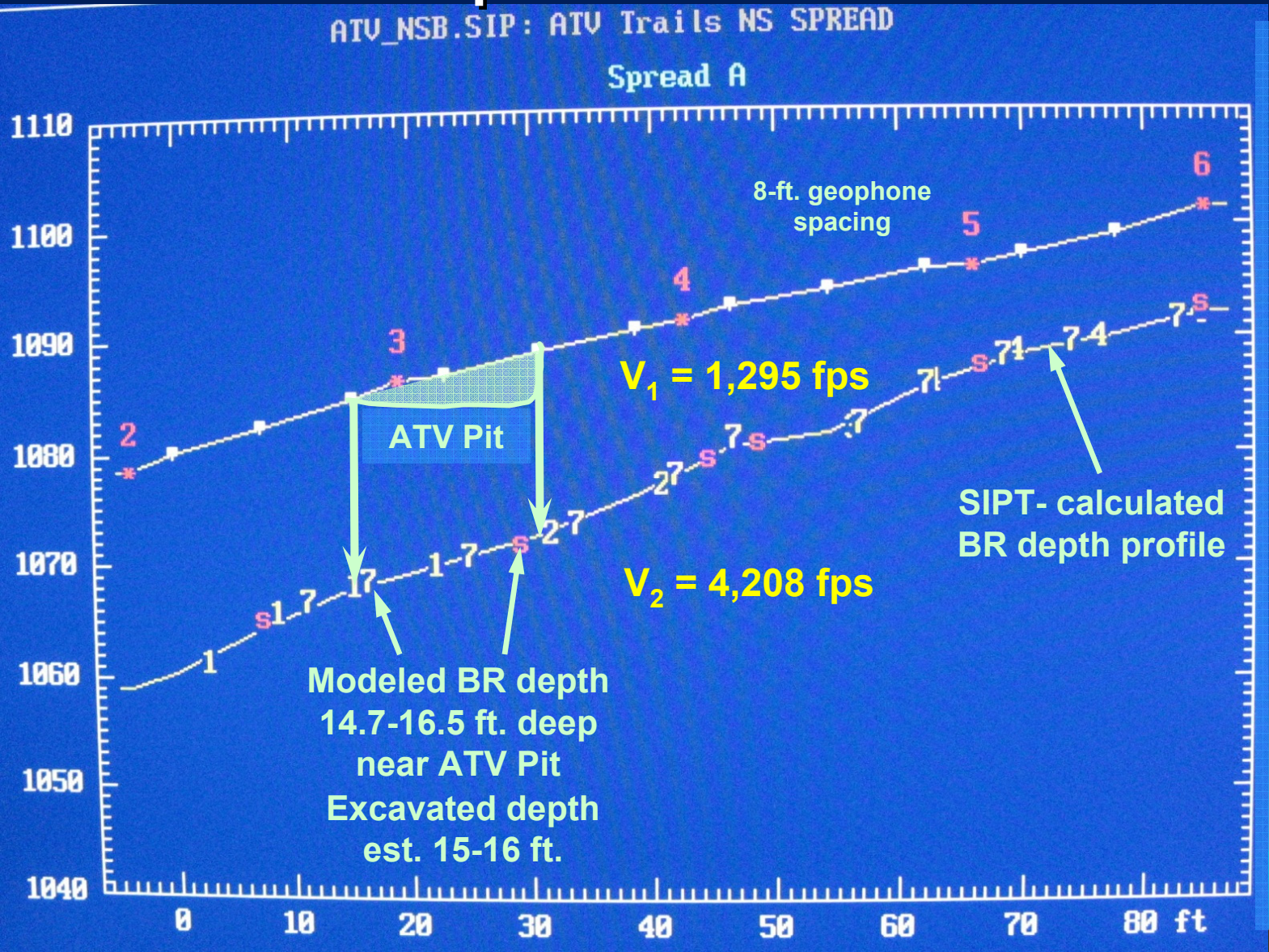


SIPT Depth Plot

- BR layer model does not see size & shape of openings
- No information about VO condition or depth into BR
- Question: how to determine proper size and type of equipment to clean out possible shafts?

Eska Remediation Design

SIPT Depth Plot – N-S ATV Line



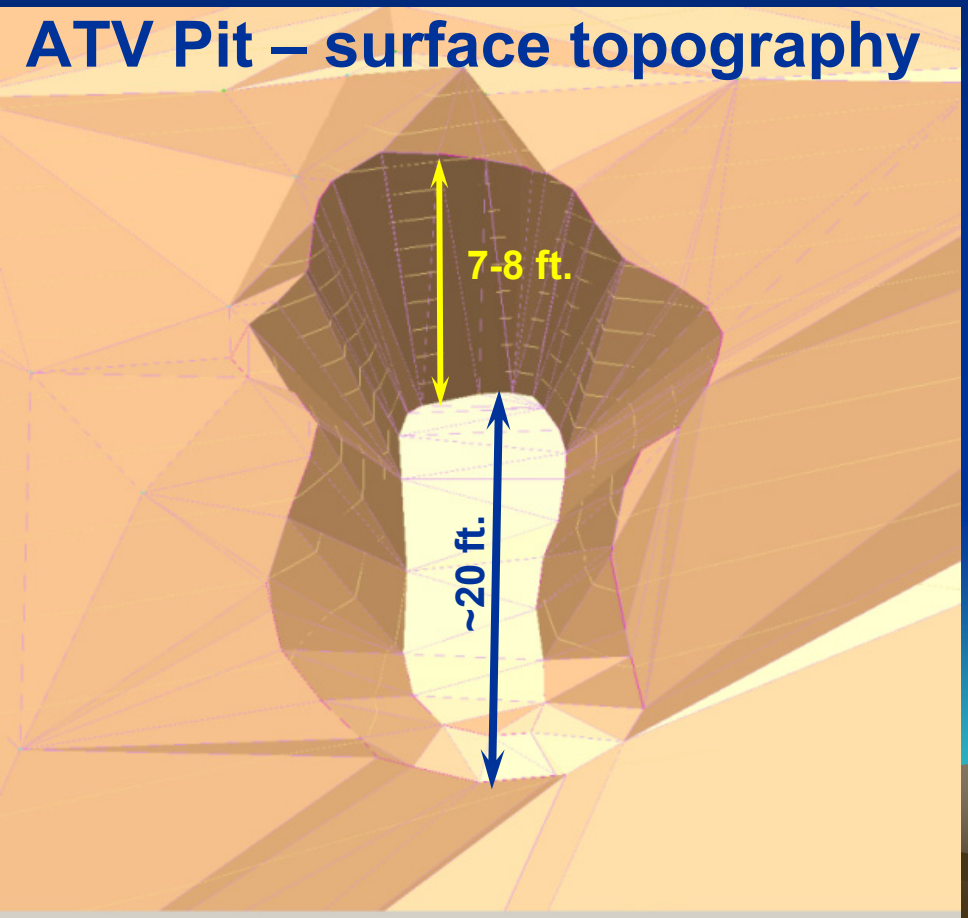
SIPT Depth Plot

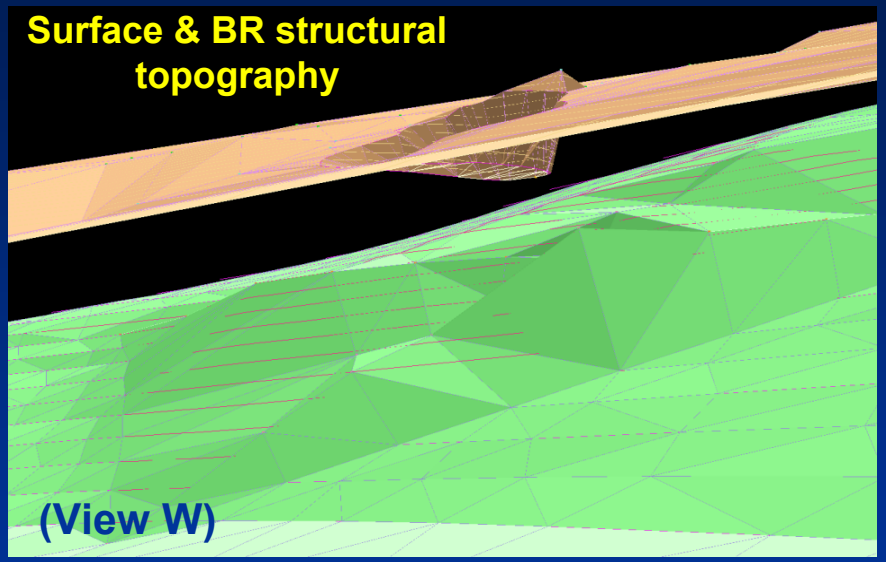
- Predicts bedrock depth
- Seismic refraction doesn't see shaft opening size or depth
- Uncertainty concerning existence, condition of opening, and type and size of equipment required for closure.

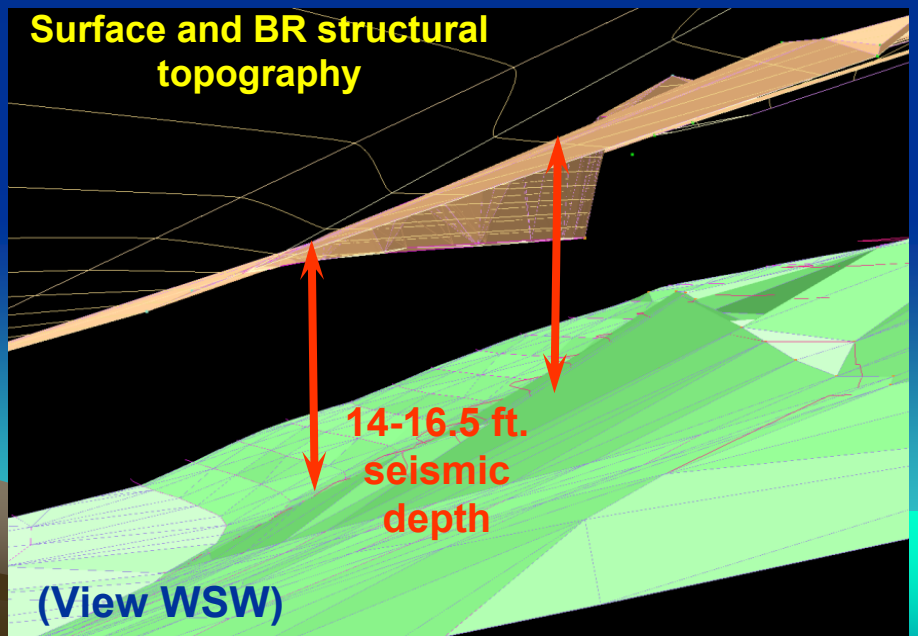
Eska Remediation Design

ATV Pit--3D models from seismic data

How to assess buried VO depth and condition? -- not evident from surface & BR models.

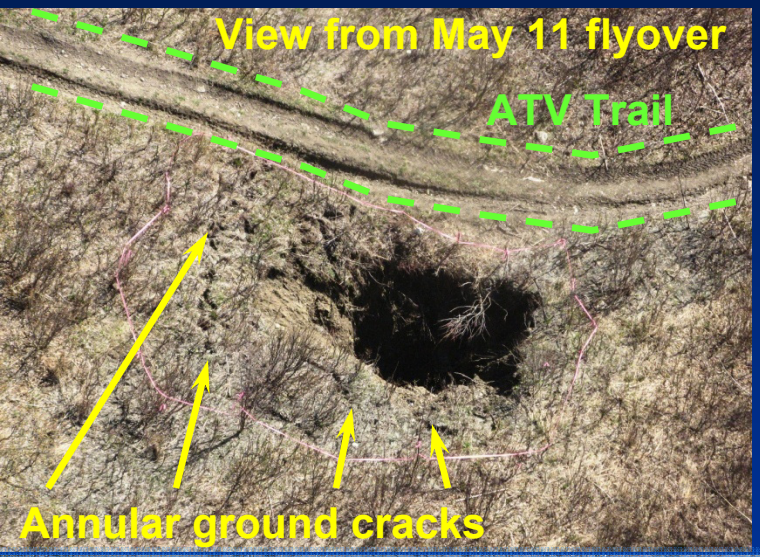


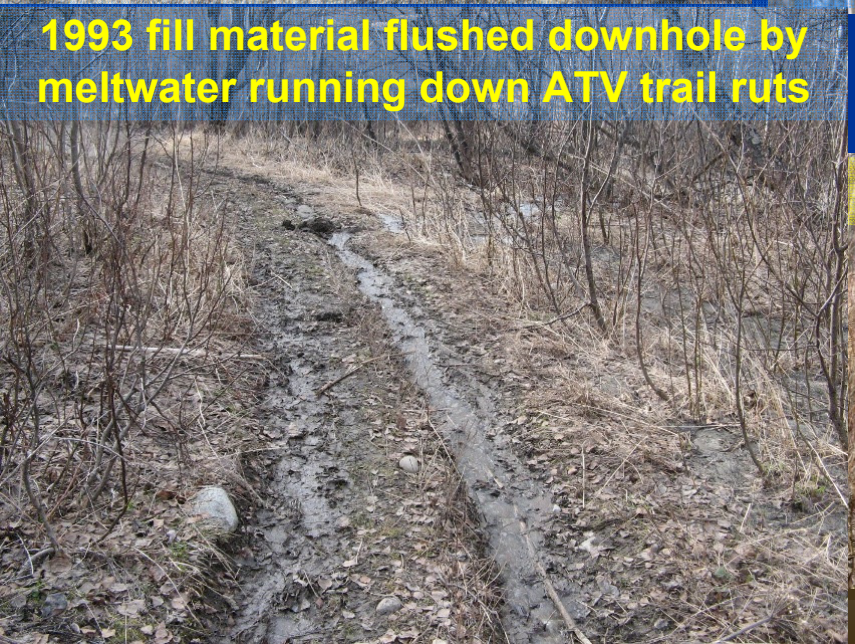




Eska Closure Emergency May 2007

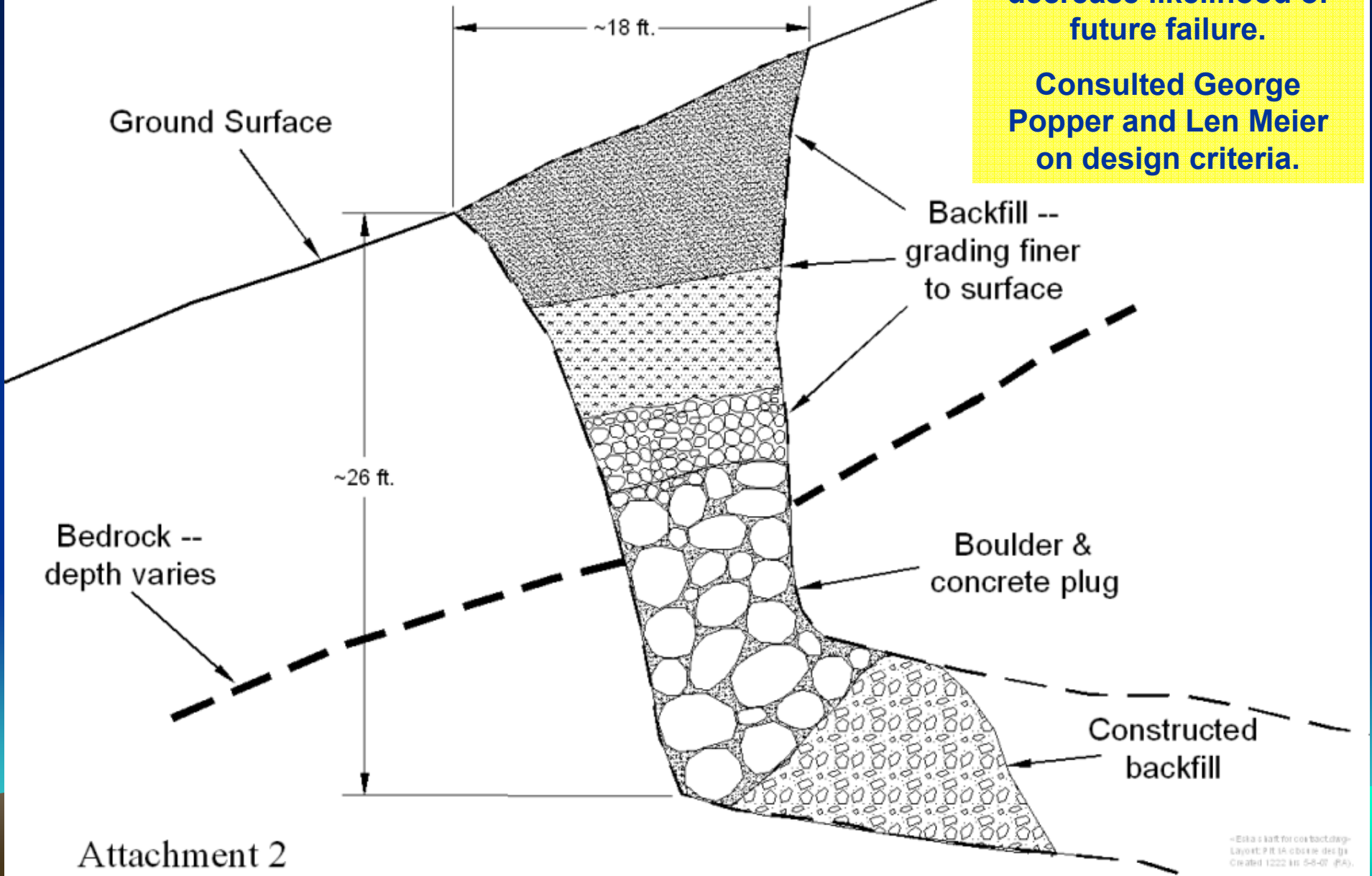
A 2nd pit opens just west of pit 1– May 5 visit





Pit 1a Closure Design

Eska Phase I



Our program decided to implement a more permanent closure to decrease likelihood of future failure.

Consulted George Popper and Len Meier on design criteria.

Attachment 2

Phase I Excavation -- Pits 1, 1a, 2 & 3


Access pushed in


Inspecting Pit 1a


Pit 1a bottom


Beam above adit opening, Pit 1a


Pit 1 — fill across adit


Nighttime inspector


Pit 3 opening collapse


Pit 2 piping feature

Phase I -- Pits 1 & 1a Remediation


New diversion ditch


Stockpile – boulders & large dimension fill

Inspecting Pit 1a


Constructing boulder & concrete plug


2nd course of boulders, concrete, & rebar


Large-dimension fill atop concrete plug

Pit 1a – visitor's calling card

Phase I finished -- Pits 1 & 1a

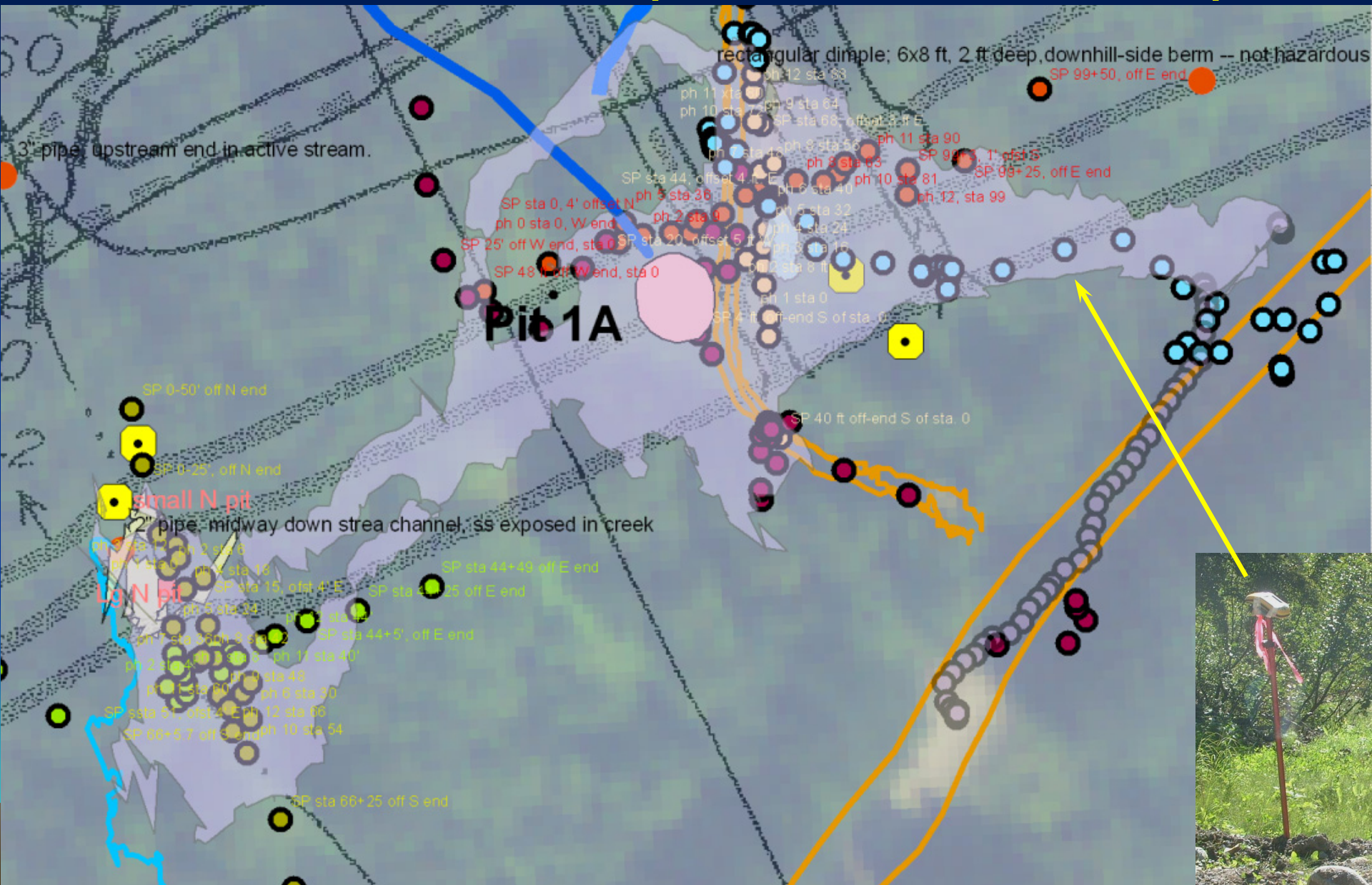
NW-to-NE pan, 8-17-07

E pan, 9-21-07

GPS disturbed area perimeter

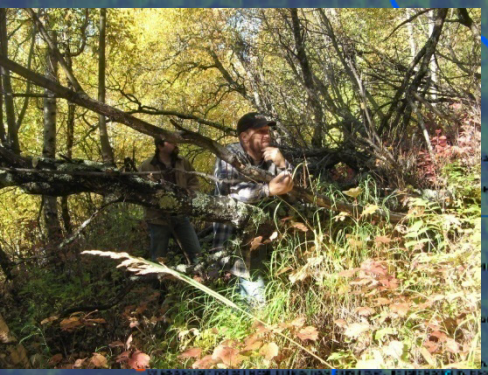
Phase I – Pit remediation disturbed Area

Documented for maps and closeout report



East Eska PhII – Old mining Road

Question: How to find it?



Conic Pit

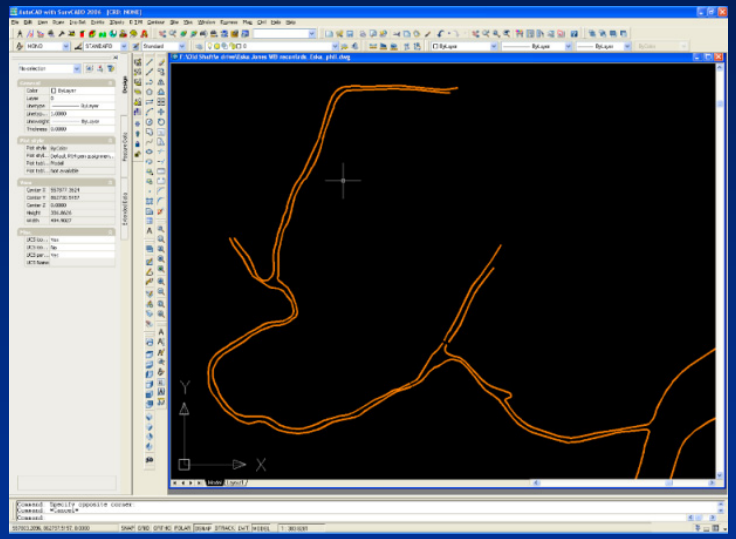
David Airshaft

Overgrown Access Road

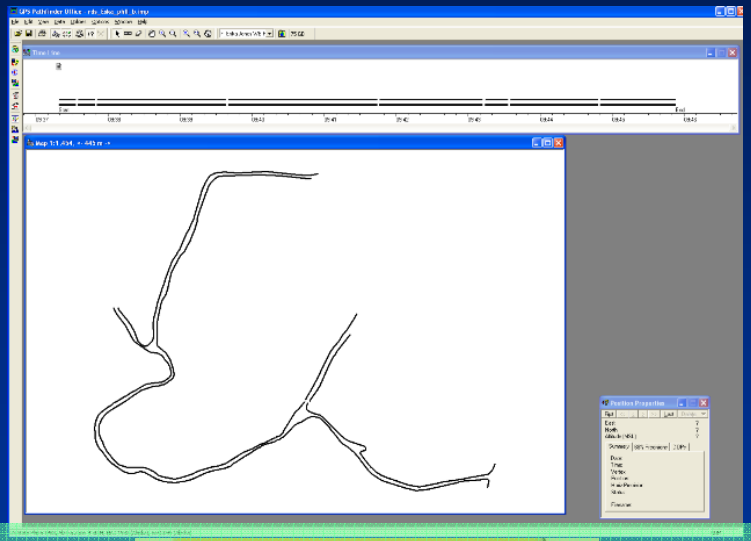
Eska Creek

To Walk the Old mining Road Trace
Put it on the GPS

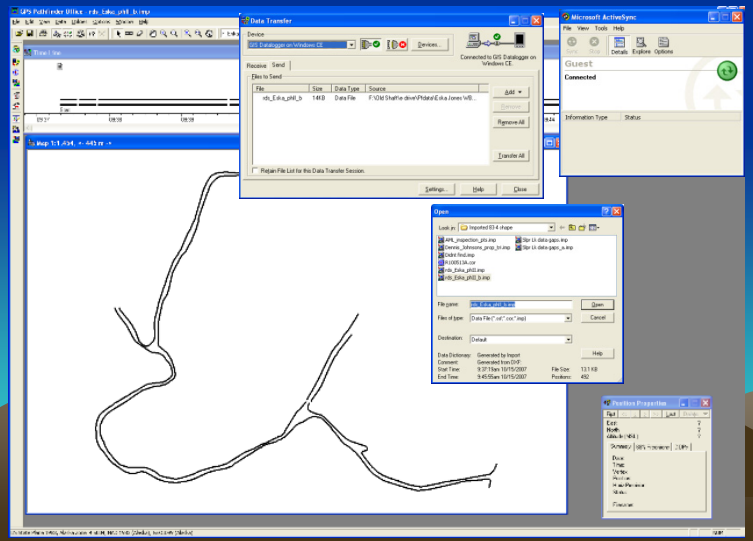
1. Export from CAD as shapefile or DXF



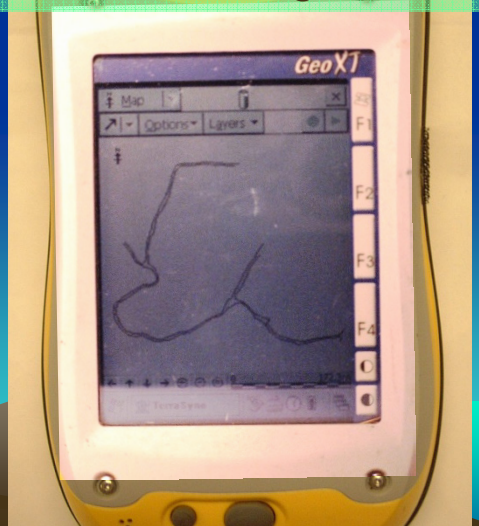
2. Import into PFO, save as *.imp file



3. Upload *.imp file into a Trimble GPS



4. Ready for field use – follow the feature on the ground.



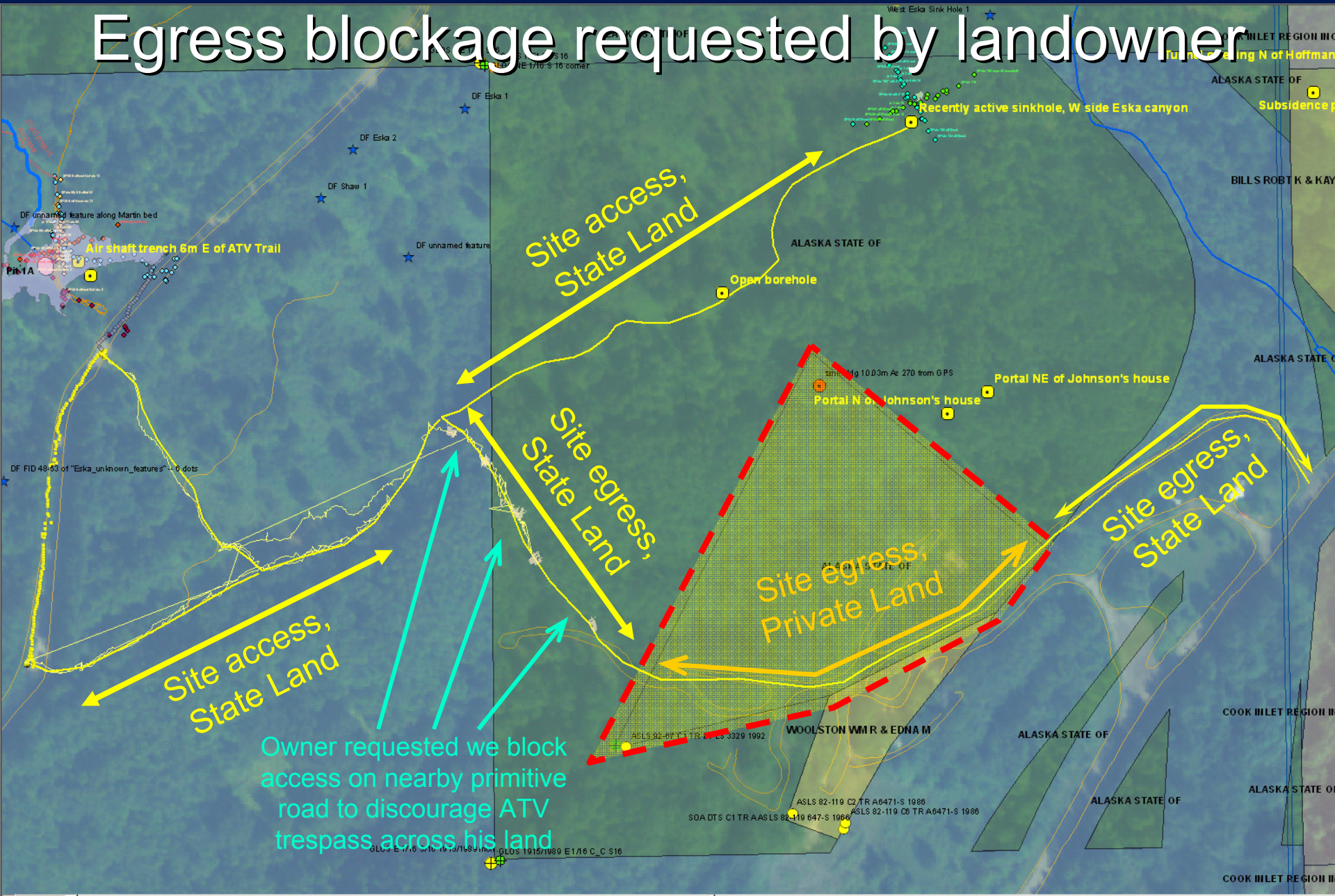
Walk the Old mining Road Trace
Follow the GPS file

Marking access for heavy equipment road

Easier to follow road when not overgrown

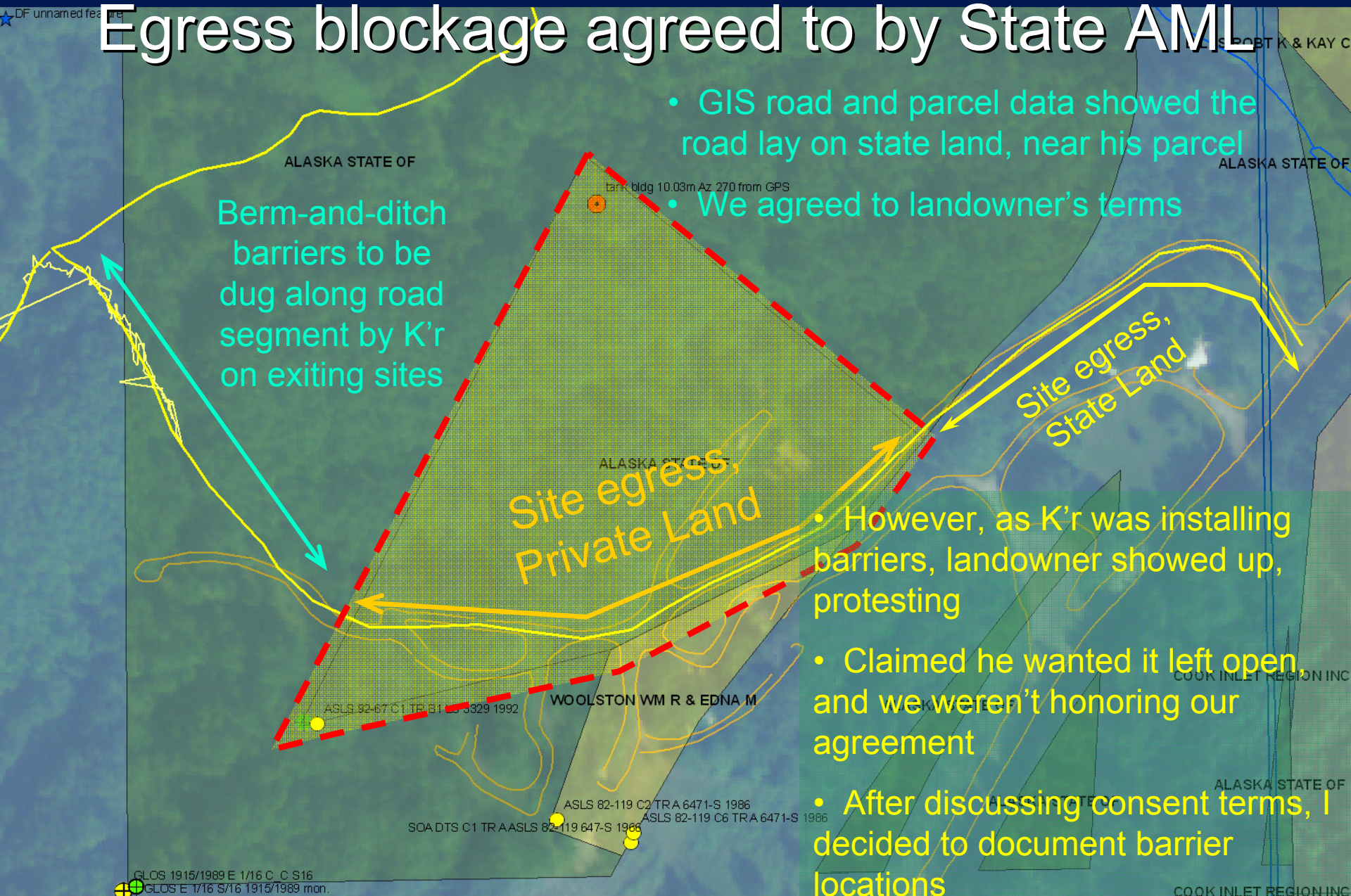
Eska PhII – Work Site / Landownership Clarification

Egress blockage requested by landowner



Eska PhII – Land Ownership Clarification

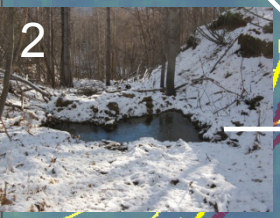
Egress blockage agreed to by State AML

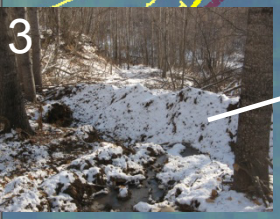


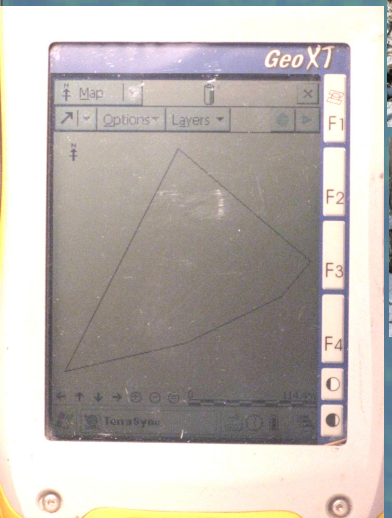
- GIS road and parcel data showed the road lay on state land, near his parcel
- We agreed to landowner's terms
- However, as K'r was installing barriers, landowner showed up, protesting
- Claimed he wanted it left open, and we weren't honoring our agreement
- After discussing consent terms, I decided to document barrier locations

Eska PhII – Land Ownership Clarification

Egress blockage & property lines documented







Terrasync NIF tracklog pts

GPS asbuilt locations of trench and berms

Ribboned marker sites

~36 m

ESKA Water Tower

ALASKA STATE OF

WOOLSTON W1 R & EDNA M

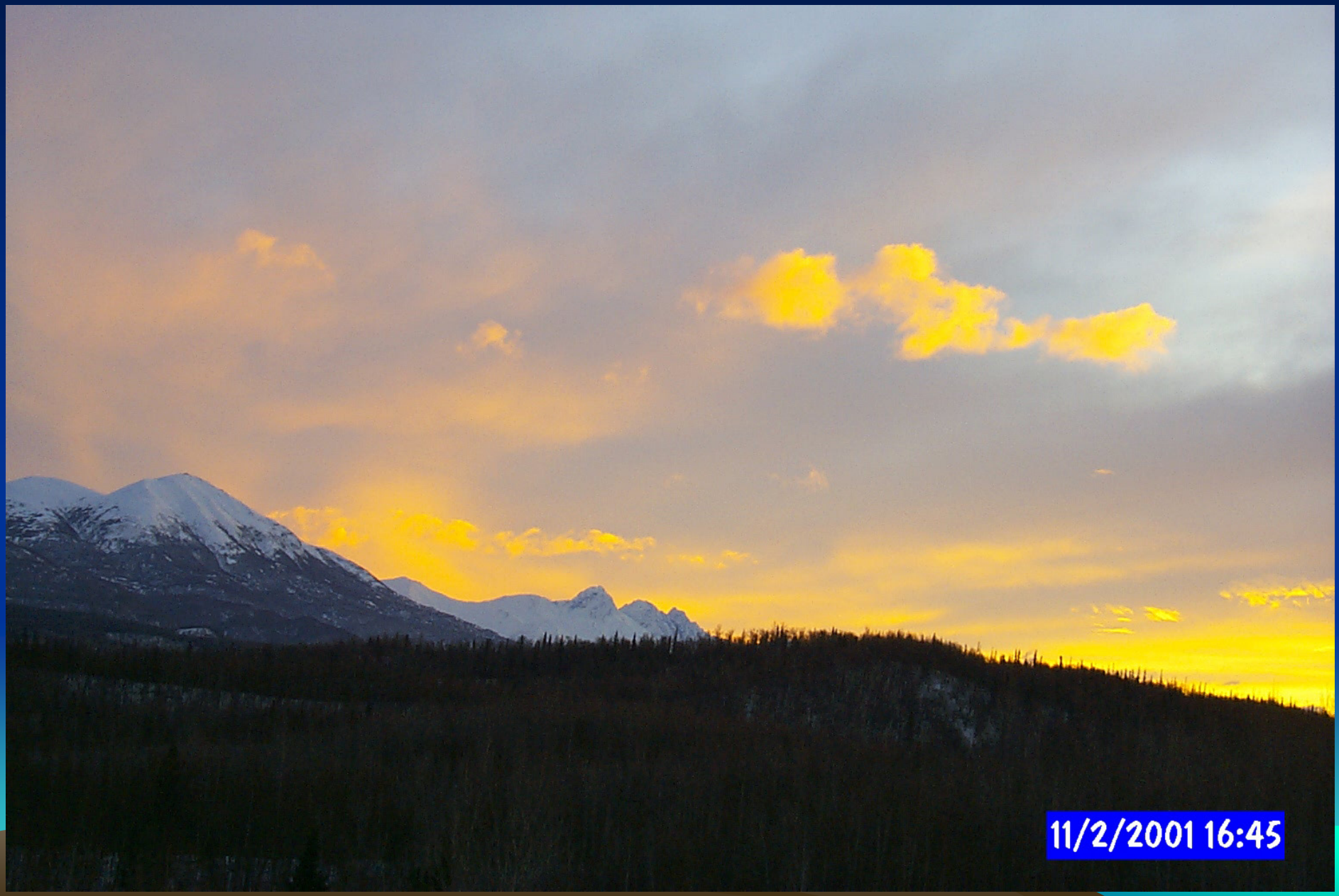
CLS 92-67 C1 TR B1 LS 3329 1992

ALASKA STATE OF

- Uploaded parcel into Terrasync as *import file on CE/XT, off GIS
- Traced GPS rover file polygons around asbuilt barriers
- Took point data at parcel corner
- Traced GPS parcel line nearest divots, ribboned
- Collected 1s NIF tracklog data of all field work

FINIS

FINIS



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