

Accuracy, Precision and Ground-Truthing of Mine Maps

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Office of Mines and Minerals

AML Division

Accuracy, Precision and Ground-Truthing of Mine Maps

It's a NAD, NAD, NAD, NAD World
We Live In

Accuracy and Precision

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- “Precision measures exactness. ... It is a measure of the control over random error.”

Accuracy and Precision Standards

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90% of “well-defined points” must be plotted to within $1/50^{\text{th}}$ an inch accuracy on a 1:24,000 scale map (which is the equivalent of 40 feet on ground surface).



The 'uncertainty' or 'error' of any point depicted on an USGS topographic map (1:24,000). In this example, shown as a 40 foot error radius encircling a benchmark location.

Accuracy and Precision Standards

- “Well-defined points are easily visible or recoverable on the ground, such as the following: monuments or markers, property boundary monuments; intersection of roads and railroads; corners of large buildings or structures (or center points of small buildings).”

Geo-Referencing and Coordinate Systems

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- **For conformity with USGS topographic maps the mine maps are referenced to UTM NAD 27.**

Geo-Referencing and Coordinate Systems

- Section line corners and surface features common to both topographic and mine maps are used to rectify Illinois mine map images.

Geo-Referencing and Coordinate Systems

- Section line corners and surface features common to both topographic and mine maps are used to rectify Illinois mine map images.
- Topographic maps from the same time era as mining operations are used when available – to minimize location changes.

Ground-Truthing Procedures

Ground-Truthing Procedures With Commonly Used GPS Devices

- First - validate the accuracy of geo-referenced USGS topographic map images.

Ground-Truthing Procedures With Commonly Used GPS Devices

- First - validate the accuracy of geo-referenced USGS topographic map images.
- Then - validate accuracy of geo-referenced mine images with respect to the USGS topographic maps and ground surface.

GPS Devices Used In Study

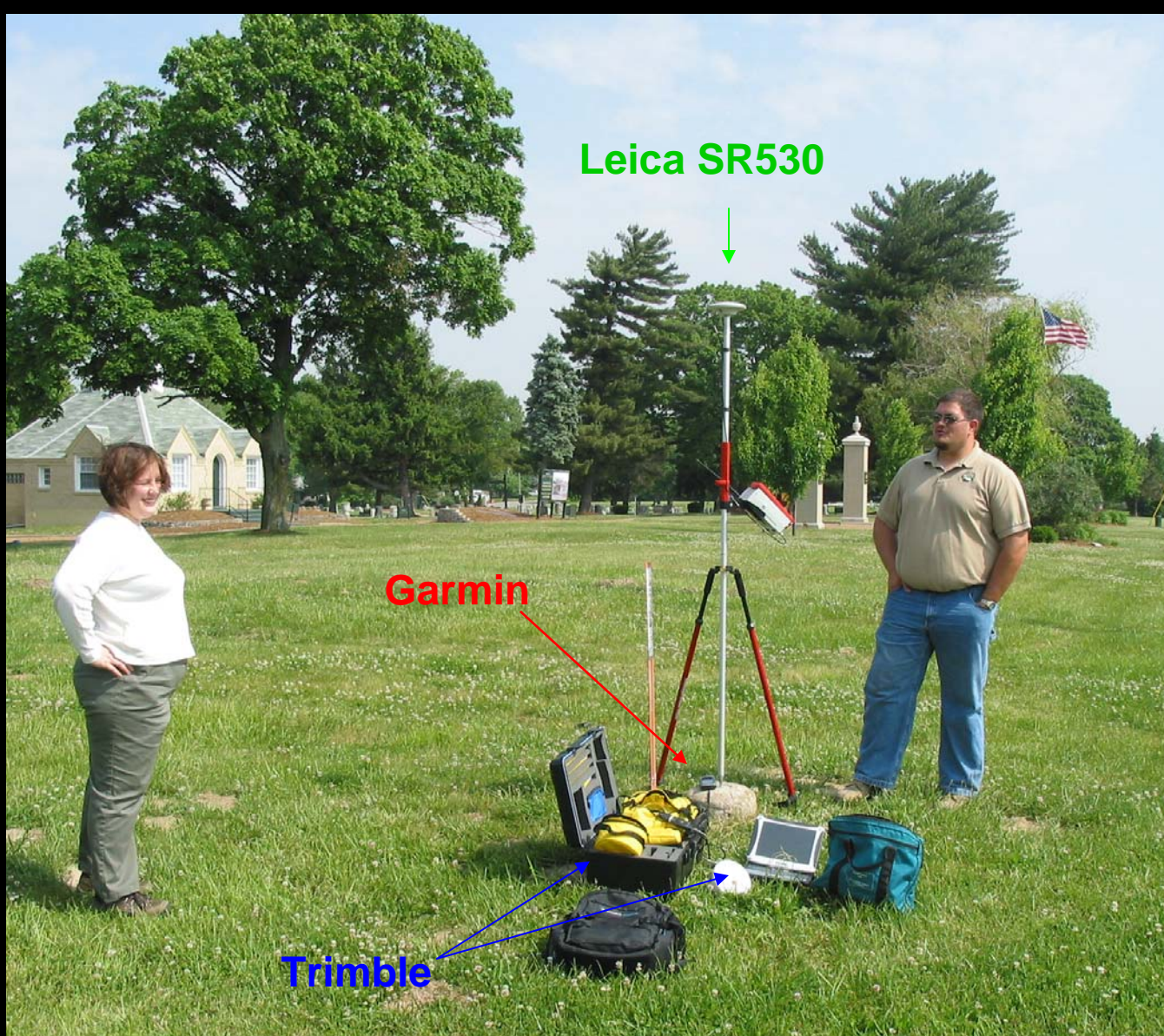
- Garmin GPSmap 76. Accuracy < 3m WAAS enabled.

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GPS Devices Used In Study

- Garmin GPSmap 76. Accuracy < 3m WAAS enabled.
- Trimble with ArcPad. Accuracy < 1m
- Leica SR 530. Survey grade accuracy 1 cm.



Kevin Garnett and Stephanie Self (OSMRE) provide GPS expertise. **Leica SR530** shown set up over USGS monument. **Trimble with ArcPad** setup in foreground. **Garmin GPS Map 76** resting on USGS monument.

NAD 27 and NAD 83 GPS Measurements

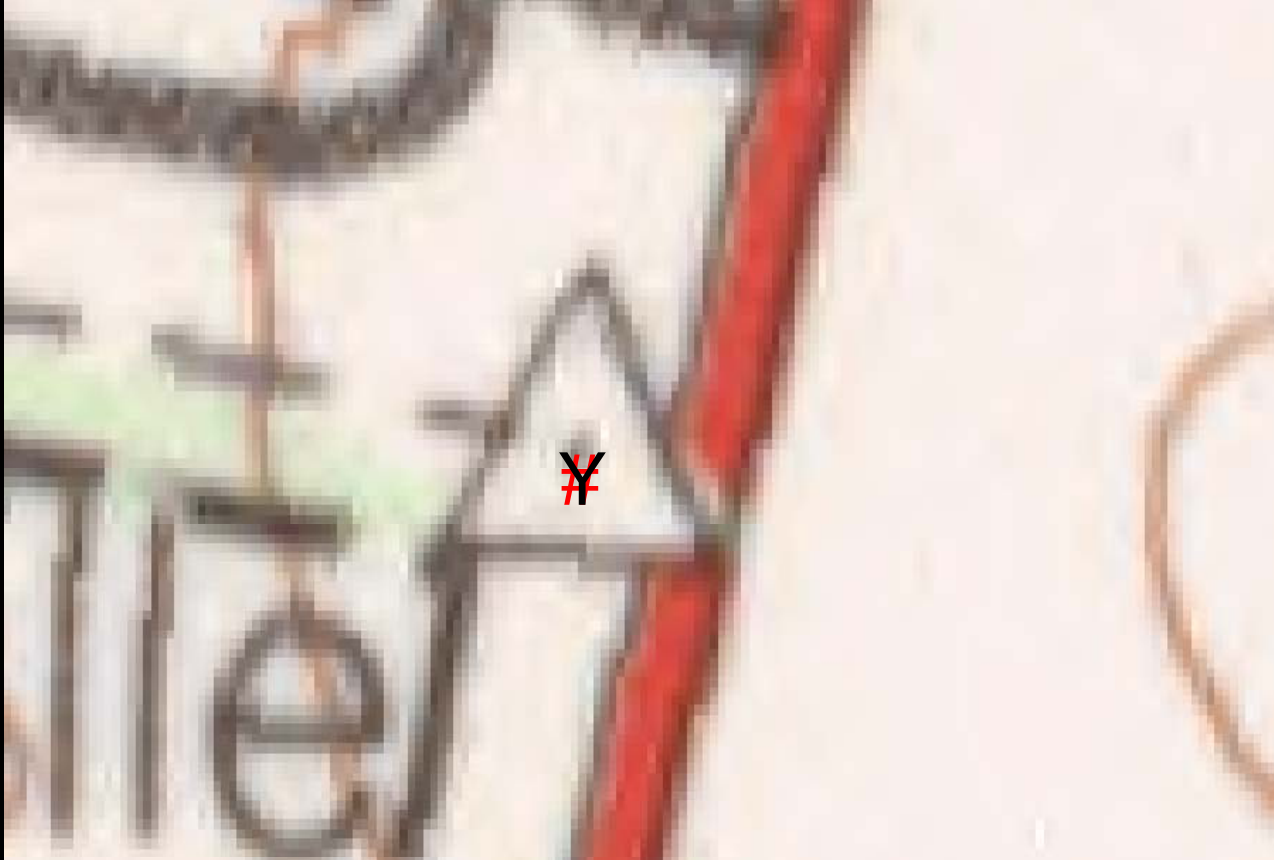
Projected on NAD 27 Base Maps
in ArcView



Device: **Garmin GPS Map 76 continuous reading**

Measurement Coordinate System: NAD 27 CONUS

Map Coordinate System: NAD 27



Device: **Garmin GPS Map 76 Average Position**

Measurement Coordinate System: NAD 27 CONUS

Map Coordinate System: NAD 27

Distance from BM: 8.6 feet



Device: [Trimble with ArcPad](#)

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 27

Distance from BM: 32.1 feet



Device: **Leica SR530**

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 27

Distance from BM: 32.8 feet



Device: Leica SR530

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 27 – AutoCad shapefile

Distance from BM: 2.5 feet

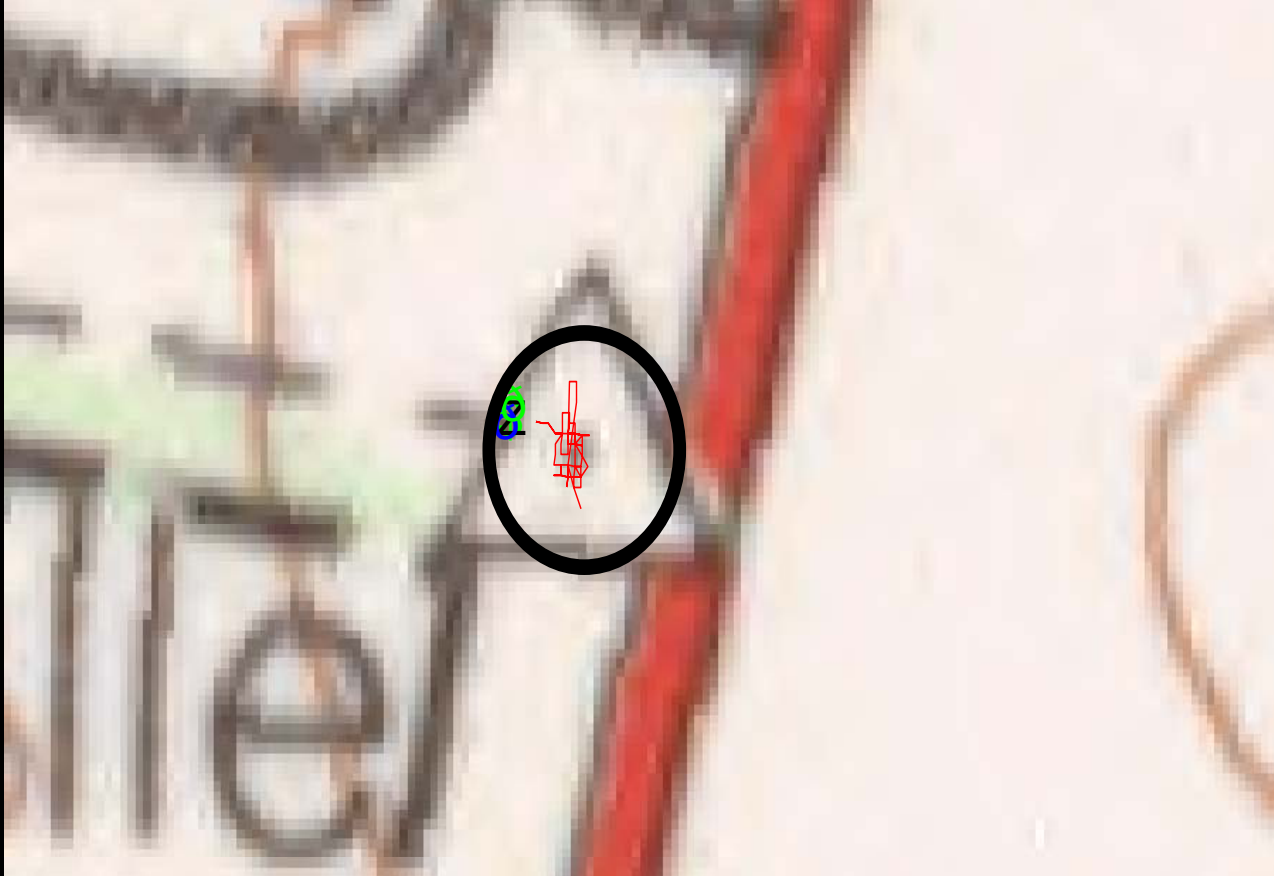


National Geodetic Survey (NGS)

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 27 – **NGS shapefile**

Distance from BM: 31.6 feet



All GPS benchmark measurements fall within USGS topographical map 'uncertainty'.

Leica SR530 Trimble with ArcPad Plot

Garmin GPS Map 76 continuous plot.

NAD 83 GPS Measurements

Projected on NAD 83 Base Maps
in ArcView



Device: **Garmin GPS Map 76 continuous reading**

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 83



Device: **Garmin GPS Map 76 Averaged Position**

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 83

Distance from BM: 8.2 feet



Device: [Trimble with ArcPad](#)

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 83

Distance from BM: 6.2 feet



Device: **Leica SR530**

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 83

Distance from BM: 1.3 feet



Device: **Leica SR530**

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 83 – **AutoCad shapefile**

Distance from BM: 1.9 feet



National Geodetic Survey (NGS)

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 83 – NGS shapefile

Distance from BM: 2.0 feet



All GPS benchmark measurements are “spot-on” when measurements and USGS Topographic map are in NAD 83.

Leica SR530 Trimble with ArcPad Plot

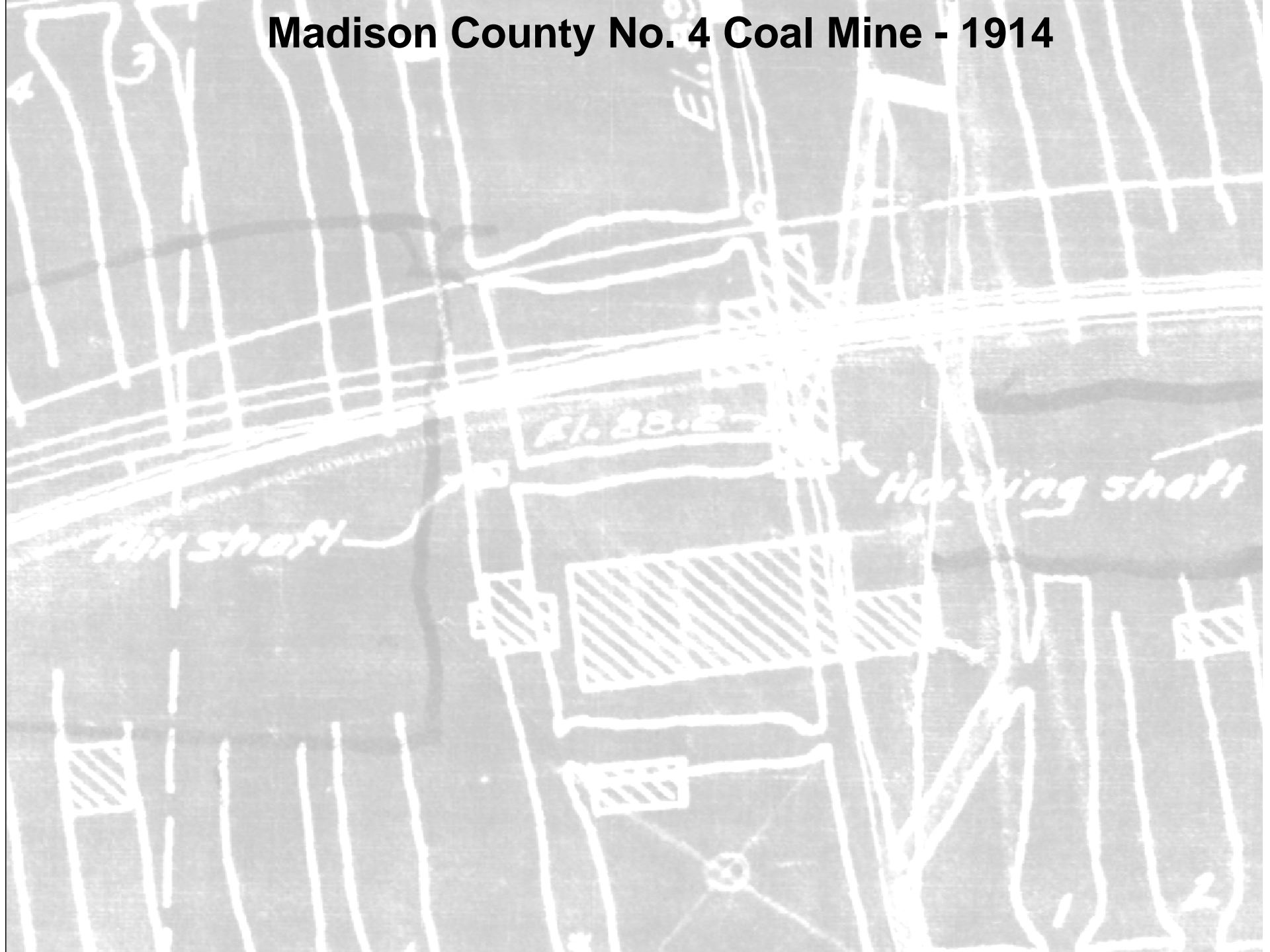
Garmin GPS Map 76 averaged position.

VIRTUAL REALITY

VS

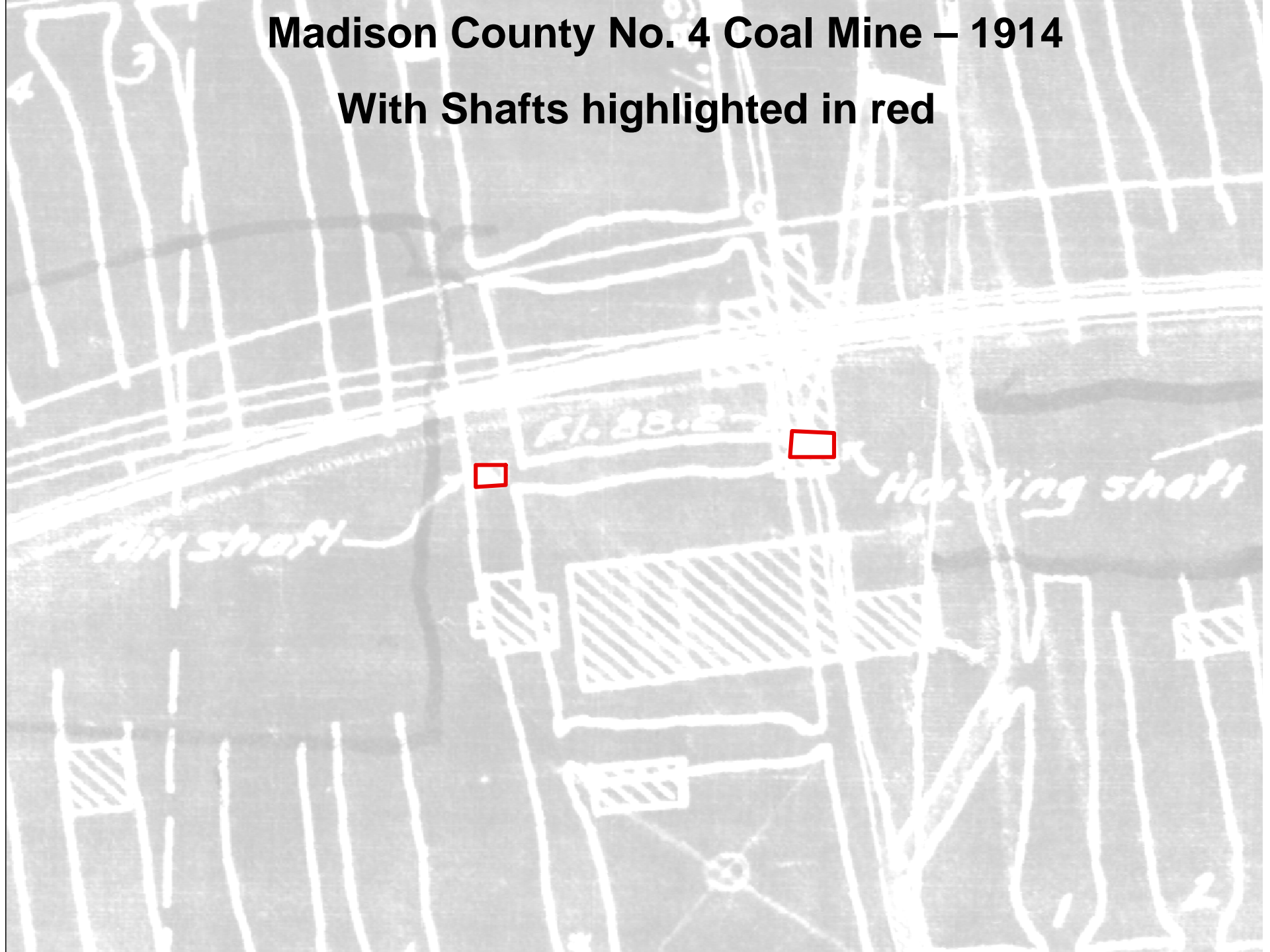
FIELD MEASUREMENT

Madison County No. 4 Coal Mine - 1914



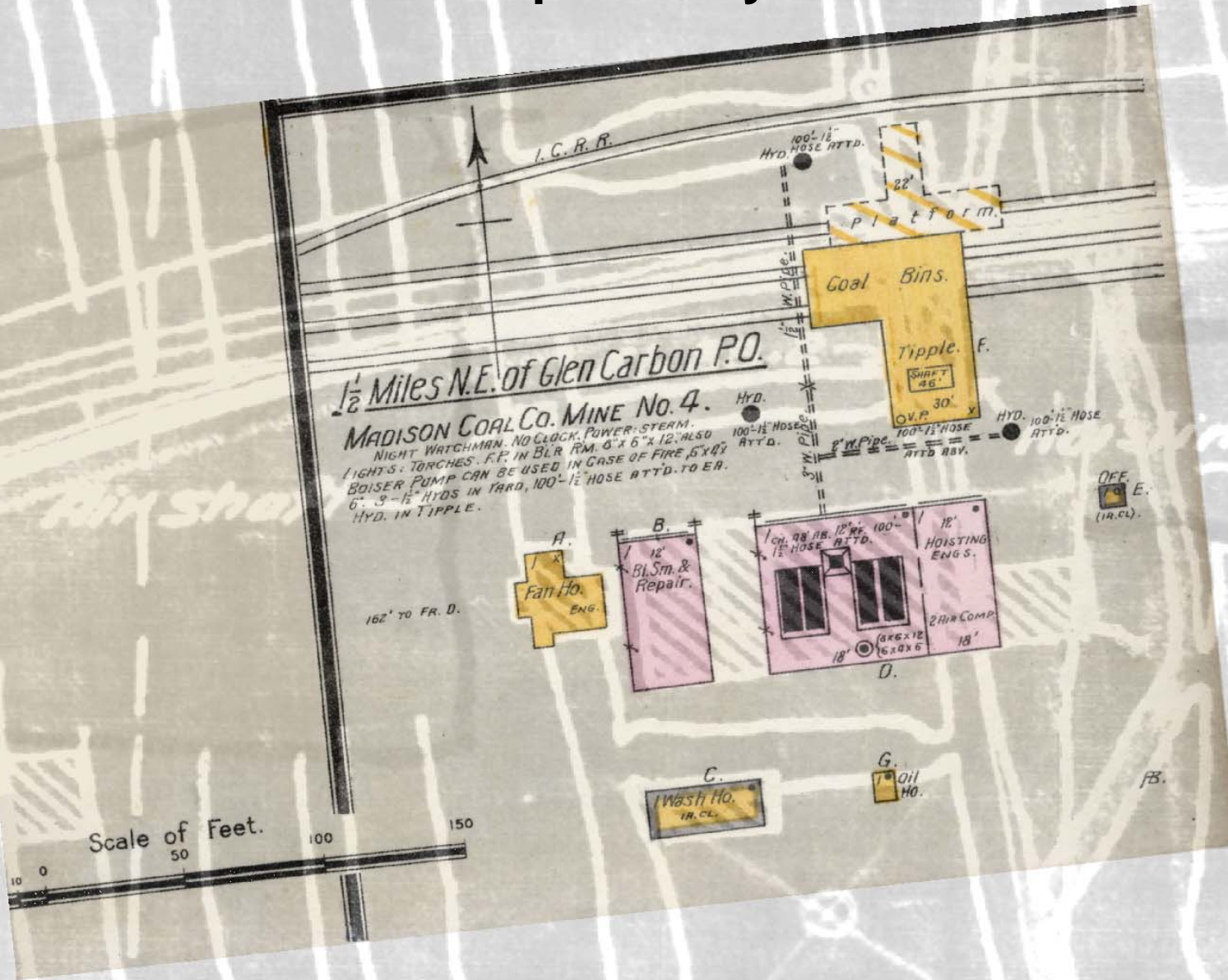
Madison County No. 4 Coal Mine – 1914

With Shafts highlighted in red



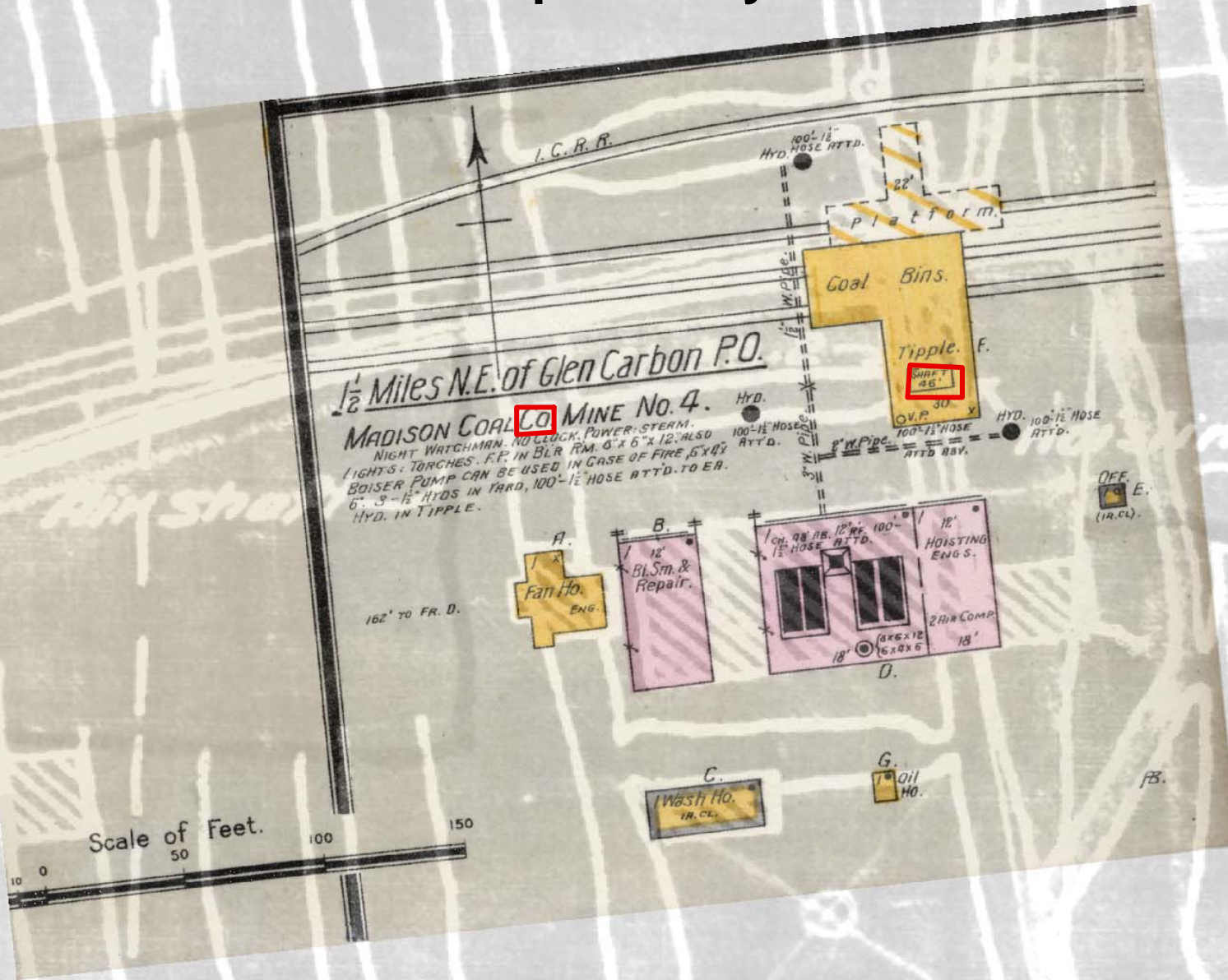
Madison County No. 4 Coal Mine - 1914

1902 Sanborn Map Overlay

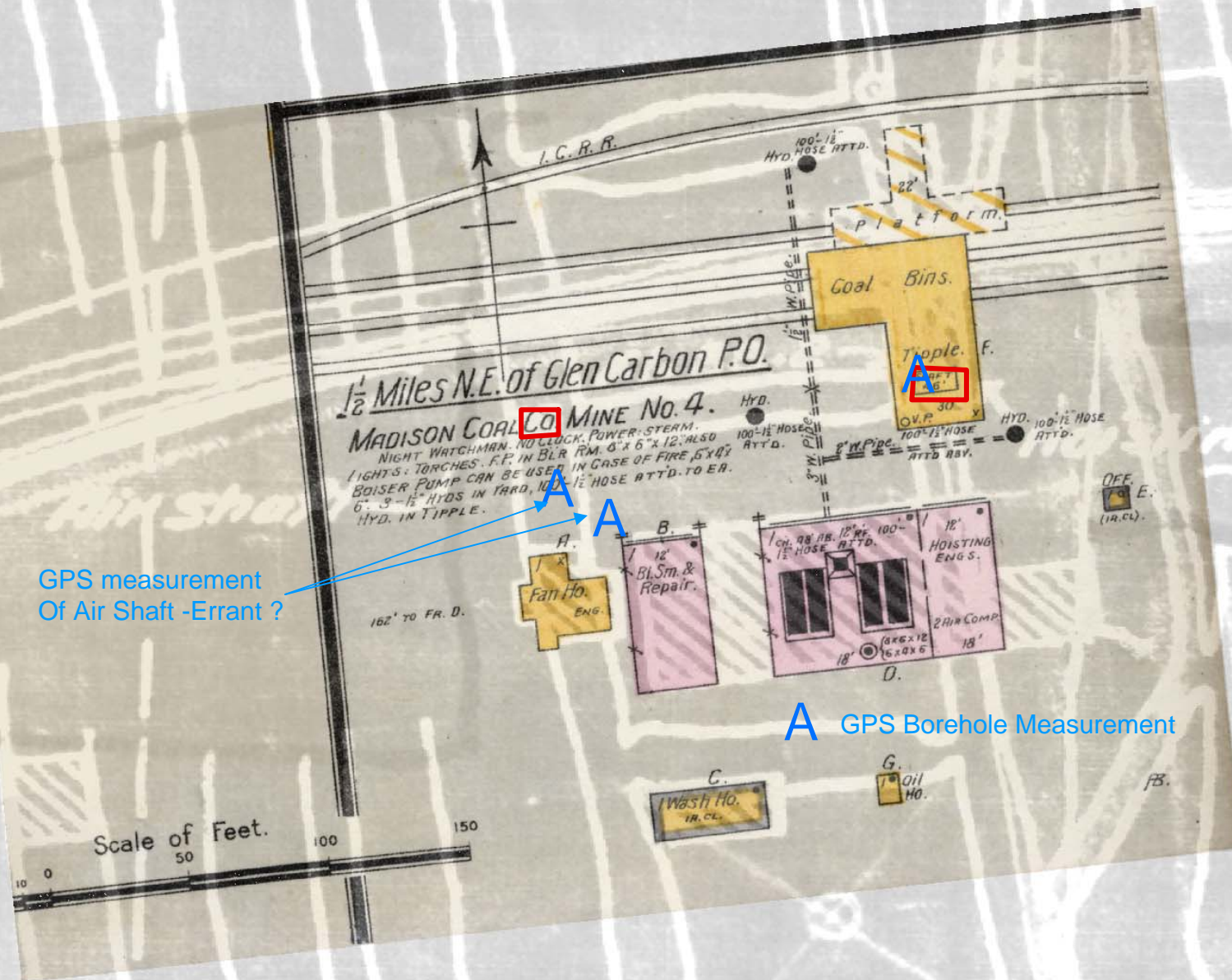


Madison County No. 4 Coal Mine - 1914

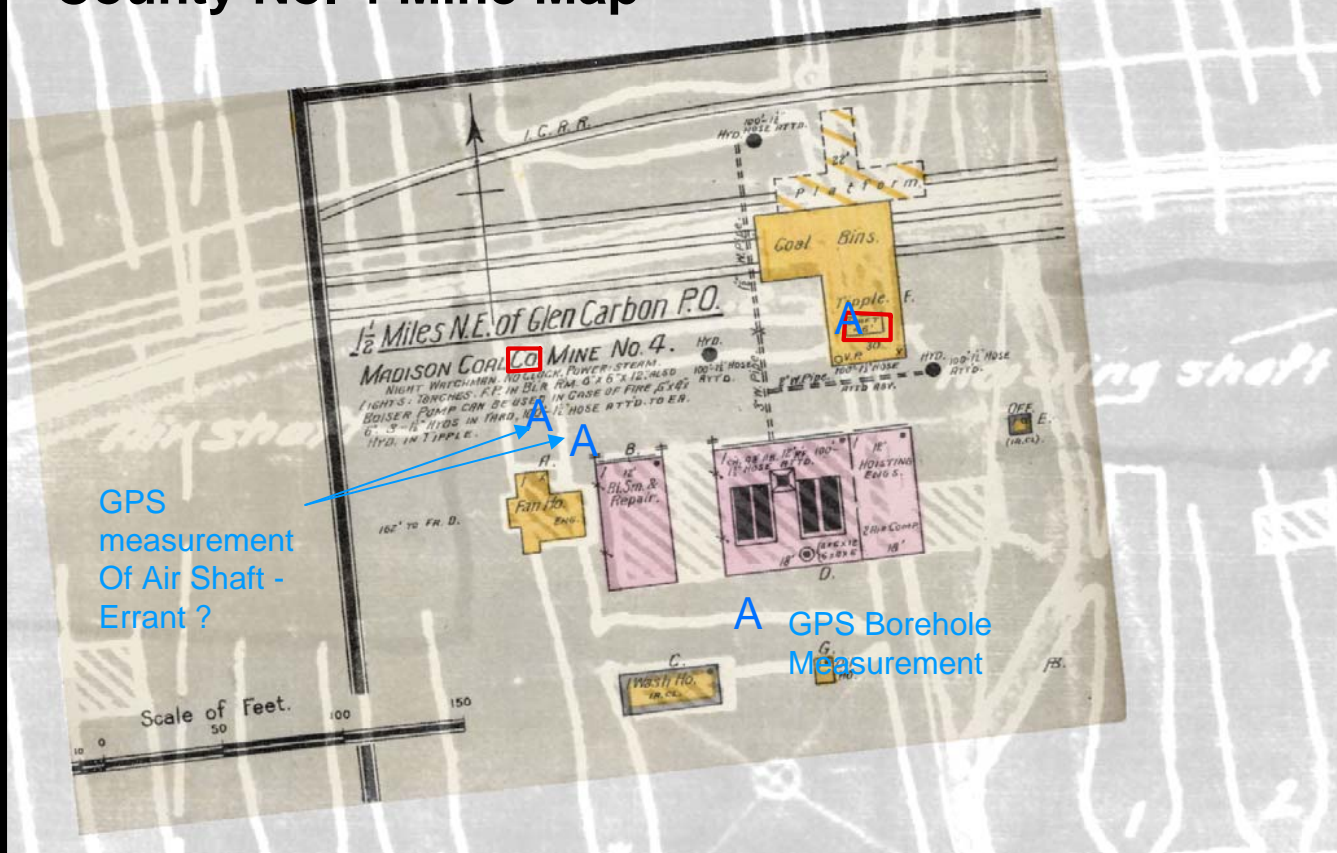
1902 Sanborn Map Overlay



1902 Sanborn Map Overlain on 1914 Madison County No. 4 Mine Map



1902 Sanborn Map Overlain on 1914 Madison County No. 4 Mine Map



Difference Between GPS and Map Measurement of Shaft Centroids

Main Shaft

NAD 27 38.8 ft

NAD 83 5 ft

Air Shaft

NAD 27 18.3 & 22.3 ft*

NAD 83 25.0 & 43.9 ft *

The “Real World” Challenge

Find this 1914 shaft ...

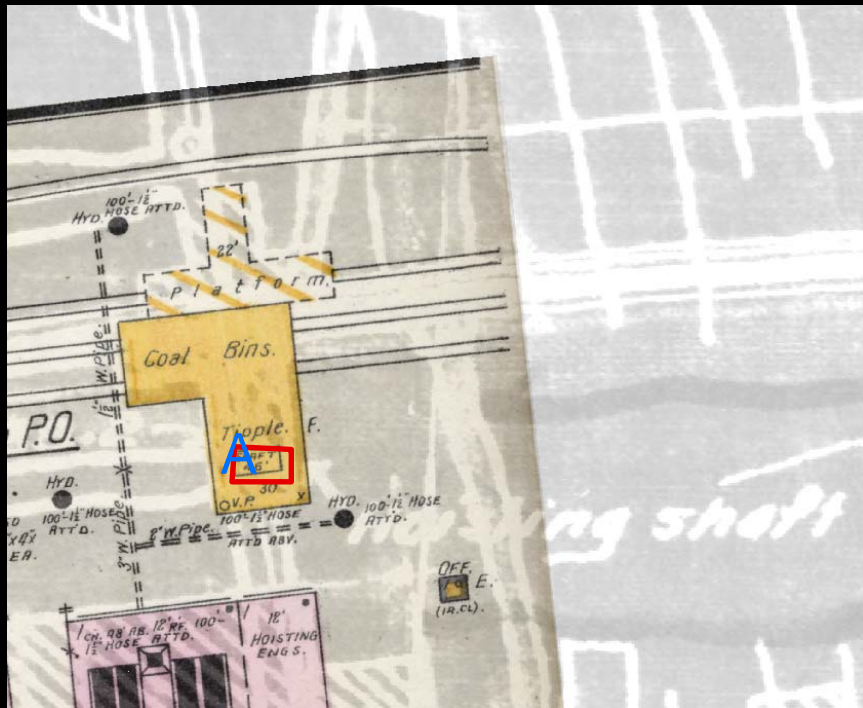


X - You are here !!

In 2005

X - You are here !!

Main Shaft Found



- Blue symbol shows GPS measurement.
- Vegetation too dense to photograph.

Air Shaft ?



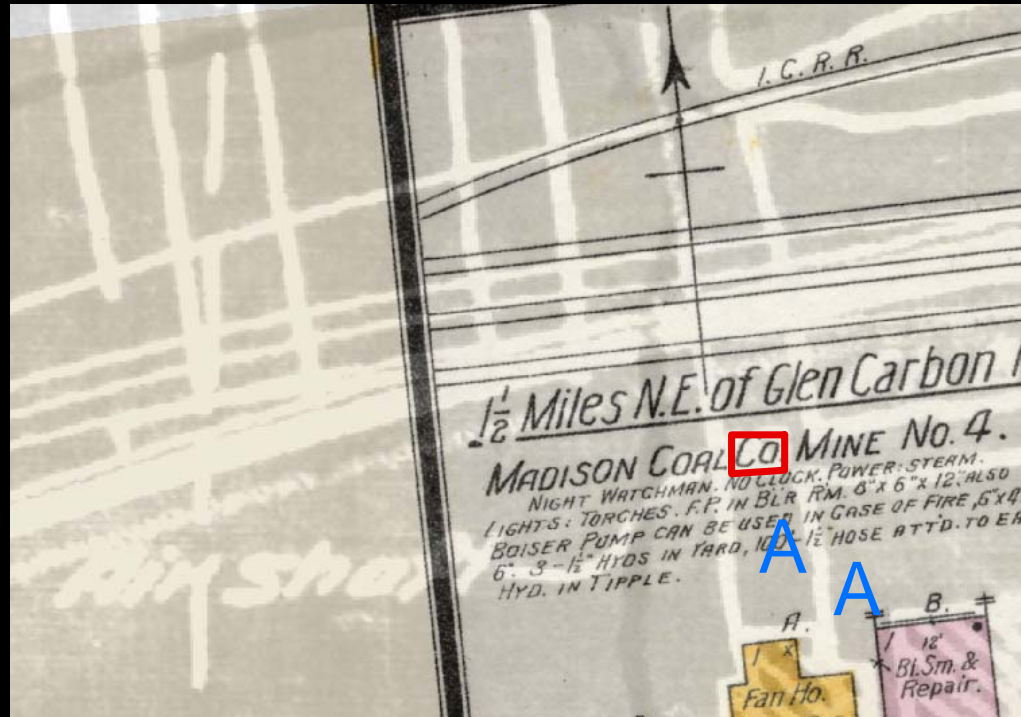
1st guess GPS



Air Shaft ?



Could Not Locate Air Shaft Precisely



- Given dense vegetative cover and an area that is highly disturbed makes positive identification difficult when foundations and buildings have been removed.

Air Shaft beneath building



Main Shaft 220 ft from home plate
– homerun 235 ft



- Given that mine sites tend to be highly disturbed areas and that current land use may further obscure the shaft locations, visually locating or identifying a shaft may be difficult.

GPS Equipment Summary



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Garmin GPSmap 76 Handheld



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- **Waypoint navigation can be used to locate shafts.**

GPS Equipment Summary

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- Sufficiently accurate in measuring shaft locations.
- Projects accurately in ArcView.
- Waypoint navigation can be used to locate shafts.
- **Inexpensive to own and operate.**

GPS Equipment Summary

Trimble with Laptop and ArcPad



- Slight 'learning curve'.

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- **Physically cumbersome.**

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- **NAD 27 projection inaccuracies in ArcView.**

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- NAD 27 projection inaccuracies in ArcView.
- **'Real-time location' on convenient base map(s) is very useful.**

GPS Equipment Summary

Trimble with Laptop and ArcPad



- Slight 'learning curve'.
- Physically cumbersome.
- Sufficiently accurate for measuring shaft locations.
- NAD 27 projection inaccuracies in ArcView.
- 'Real-time location' on convenient base map(s) is very useful.
- **Fairly expensive to own and operate.**

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Leica SR530

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GPS Equipment Summary

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- **Highly precise measurement.**

GPS Equipment Summary

Leica SR530



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GPS Equipment Summary

Leica SR530



- Significant 'learning curve'.
- Physically cumbersome.
- Highly precise measurement.
- NAD 27 projection inaccuracies in ArcView.
- **Not useful in 'finding things'.**

GPS Equipment Summary

Leica SR530



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- Highly precise measurement.
- NAD 27 projection inaccuracies in ArcView.
- Not useful in 'finding things'.
- **Requires downloading data in office.**

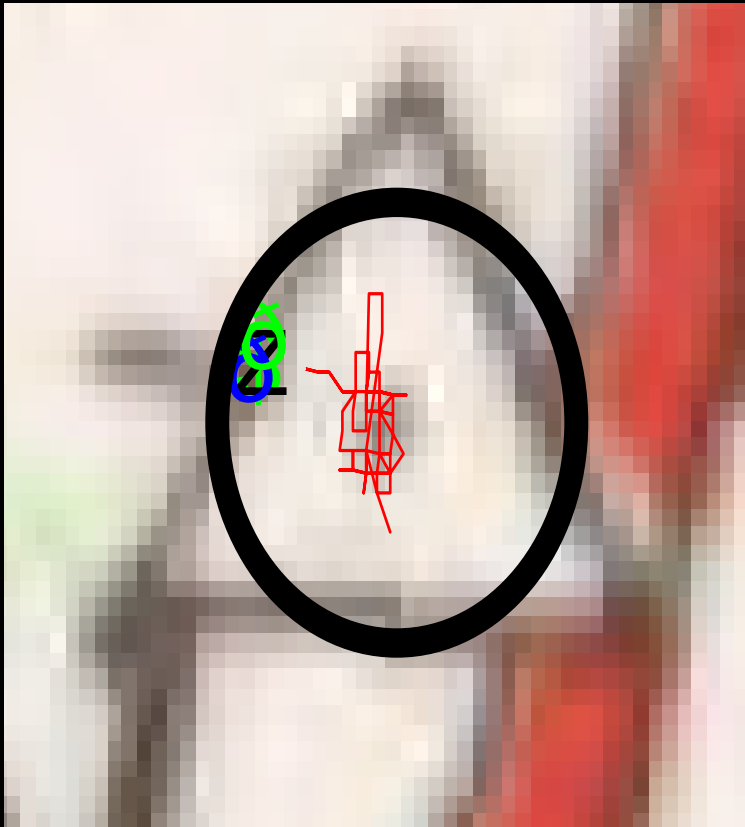
GPS Equipment Summary

Leica SR530



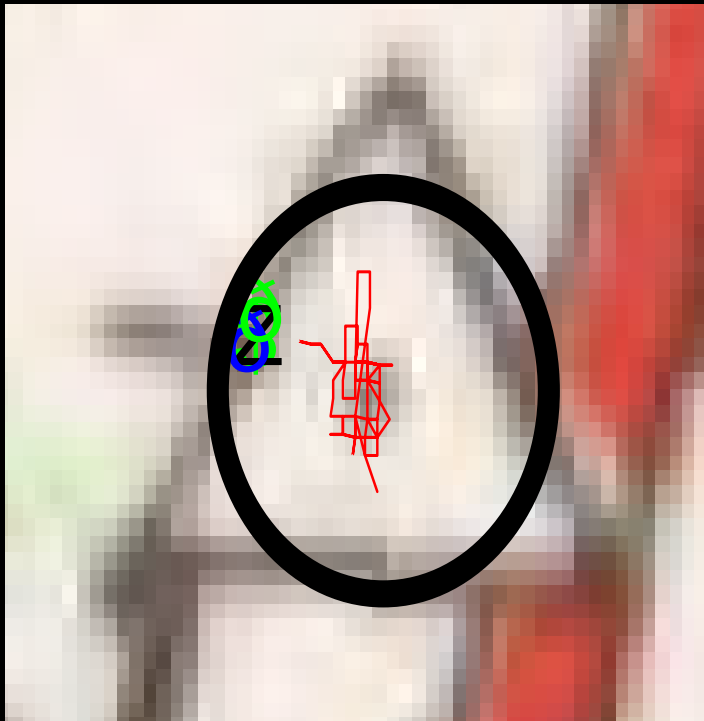
- Significant 'learning curve'.
- Physically cumbersome.
- Highly precise measurement.
- NAD 27 projection inaccuracies in ArcView.
- Not useful in 'finding things'.
- Requires downloading data in office.
- **Expensive to own and operate**

USGS 7.5' Topographic Maps and Georeferencing



- **An accurate base map can be created by assigning UTM NAD 27 coordinate information to the grid marks on an USGS 7.5' topo scanned at 350 dpi using ERDAS Imagine.**

USGS 7.5' Topographic Maps and Georeferencing



- **Error in re-projecting UTM NAD 83 GPS measurement onto UTM NAD 27 maps in ArcView is significant for reasons unknown**

USGS 7.5' Topographic Maps and Georeferencing



- When both GPS measurement and map projection are in NAD 83 'Uncertainty' can be significantly minimized.

USGS 7.5' Topographic Maps and Georeferencing



- When both GPS measurement and map projection are in NAD 83 'Uncertainty' can be significantly minimized.
- **BM 'uncertainty' of USGS - GIS image was found to be about 2 ft.**

USGS 7.5' Topographic Maps and Georeferencing



- **In short - frame of Reference is all important.**

USGS 7.5' Topographic Maps and Georeferencing



- In short - frame of Reference is all important.
- **Ascertain that field measurement plot accurately on base map.**