Legacy maps:
Intent, accuracy, precision, and suitability to purpose

Cautions for surveyors and GIS professionals (and lawyers)

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Abstract

Alaska is a young state rich in mapping from the time of European and Russian explorations. Historical maps have played a key role in important surveying, mapping, and land use considerations. This talk will focus on the challenges of taking an older map where the map's intent and suitability to purpose are being debated.

> *How does one apply an older map to the real world using modern GIS mapping systems, precise surveying systems, & surveying and property law?*

Professional best practices of mapping and surveying will be discussed, as well as map accuracy and precision. Surveying has a long and established history of practices and precedent. Because electronic mapping using GIS is a relatively young discipline, absolute best practices and standards are not as well established. However, standards and best practices do exist and can be applied to interpretations of older maps.

Outline

- Introduction
- Very short overview
- Section 4407 Easements

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  R&M Consultants Inc., Senior Land Surveyor, Right of Way Services

- Map Accuracy Standards

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- Practical Consideration from a Field Surveying Perspective

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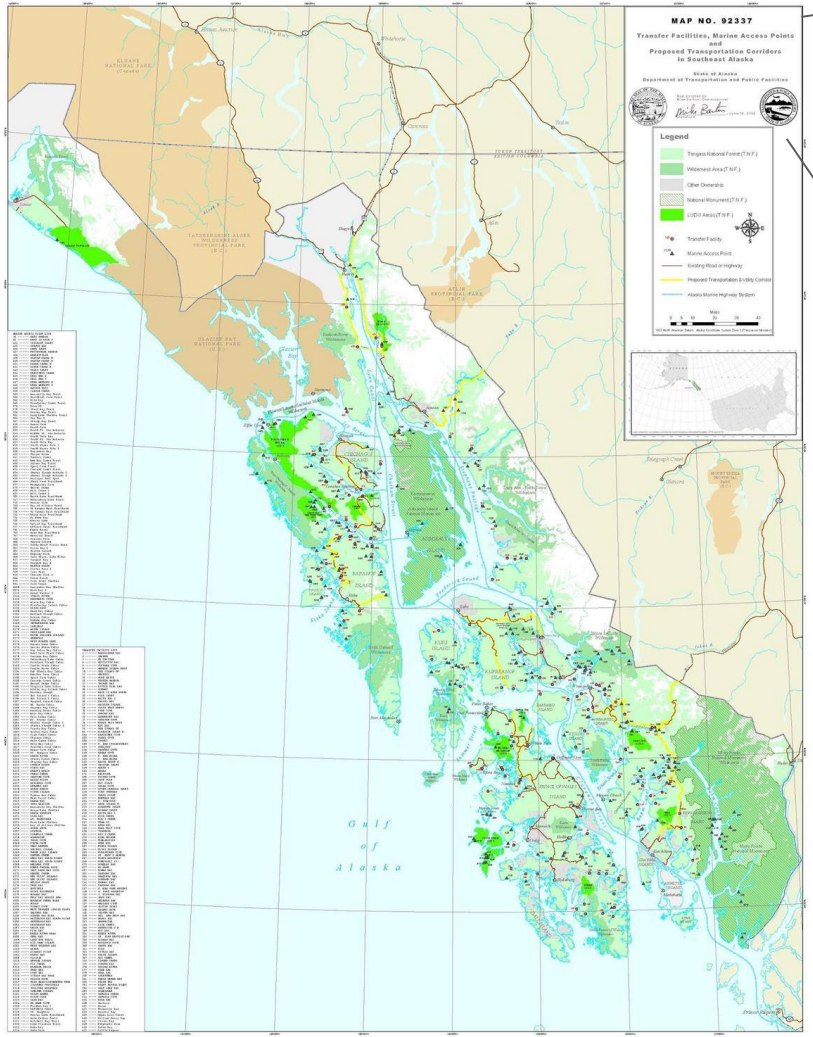
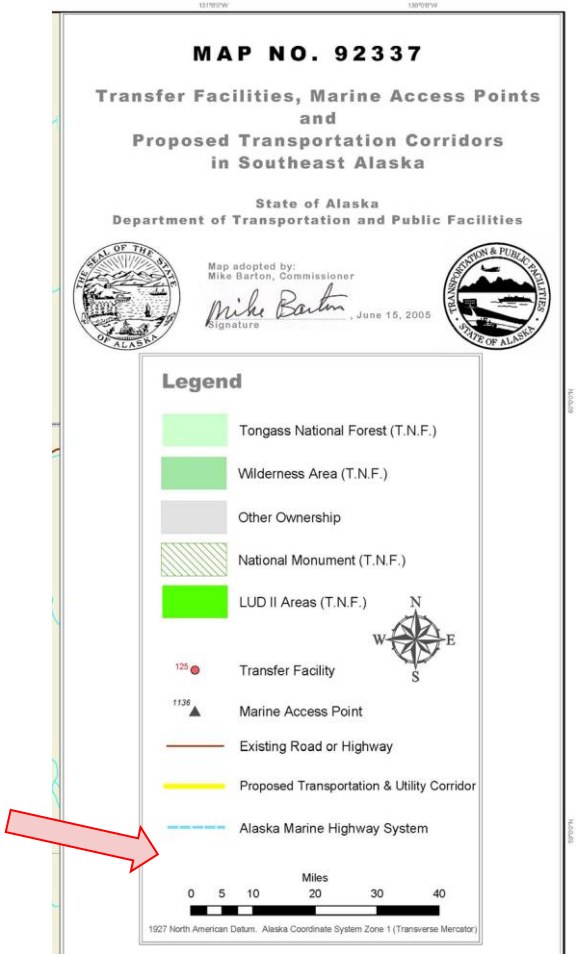


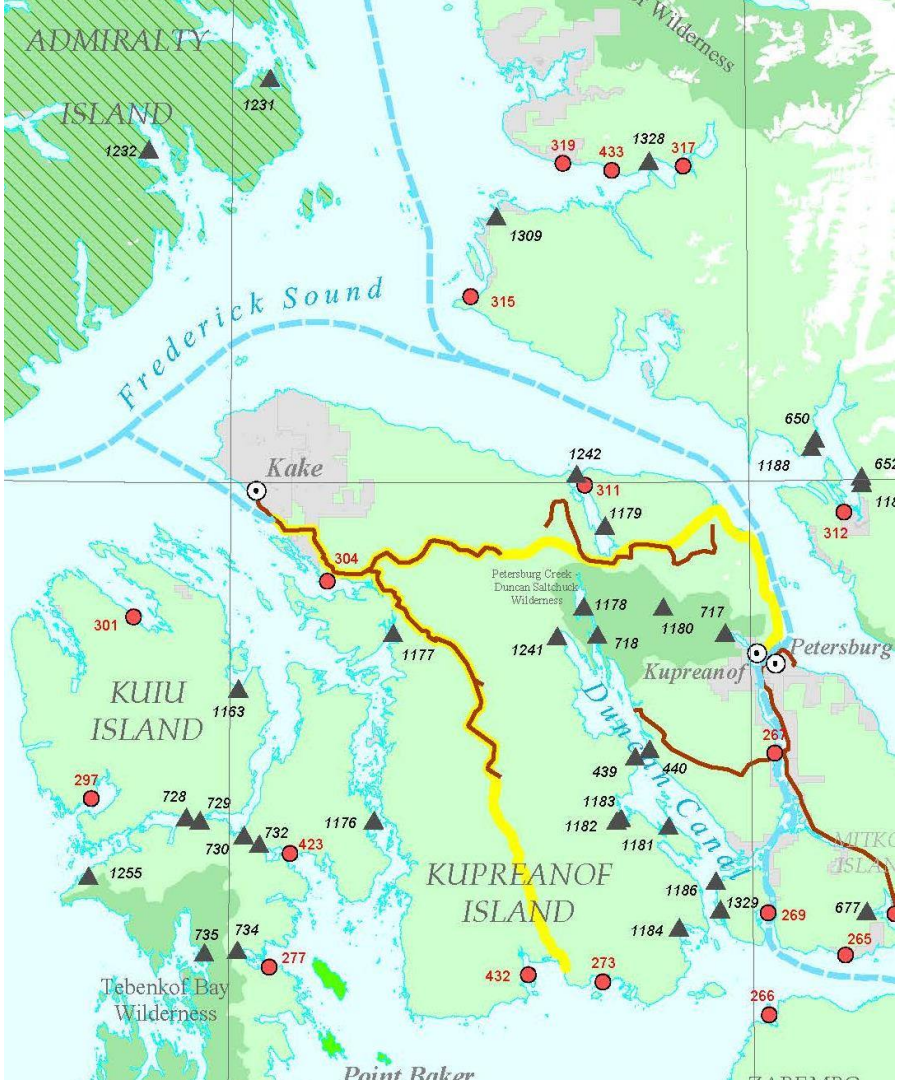
Short summary

Map 92337 (dated June 15, 2005) was adopted by Congress to provide for a reciprocal exchange of easements between the Federal government and the State of Alaska.

The Federal government received access across State lands to access log transfer facilities and marine access points and the State was granted transportation and utility corridors throughout the Tongass National Forest to connect the communities of Southeast Alaska.



1:754,286 map publication scale



Section 4407 Easements

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Map No. 92337 – Section 4407 Easements

- Contract: June 2016 - DOT South Coast/R&M, Inc. for review of “Section 4407 Easement Maps”
  - My focus: As a PLS, Mapper, Engineering Technician & ROW Professional
- Subject: Section 4407 of 2005 SAFETEA-LU – Federal Highway bill Intended to exchange ROW/easements between FS and SOA
  - Log Transfer Facilities & Marine Access Points over State owned tidelands to provide access to FS properties/infrastructure for linear Transportation and Utility Corridor ROW over FS lands to connect the communities of SE Alaska with surface transportation and utilities
  - Sec. 4407 referenced Map No. 92337 identifying easements and sites to be exchanged
  - Map No. 92337 published at an approximate scale of 1:754,286 or 1” = 12 Miles
  - Map coverage from Yakutat to Prince Rupert

Map No. 92337 – Section 4407 Easements

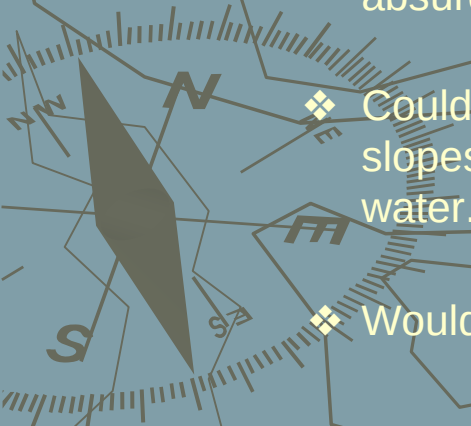
- Implementation: Sept. 2006: DOT/DNR/FS enter into MOU
  - Paragraph D1/D2 Easement “bootstrap” process
  - D1 Easement – 50 year/300-foot wide for planning/engineering/environmental activities anywhere within the identified sections. These section lines can be readily located on the ground by legal real property location survey methods. (Preliminary right of entry permit for design, geotech, surveys, etc.)
  - D2 Easement - 55 year/300-foot wide feet prior to construction based on a survey. (Intended to be post design, as-advertised alignment and final ROW definition)

Map No. 92337 – Section 4407 Easements

- FS Position: FS “Talking Points” paper asserts that –
  - Lines shown on Map No. 92337 represent the Congressional intent, and the absolute fixed legal descriptions of D1 & D2 easement centerlines can be found with USFS’s GIS data used to draw Map 92337.
  - Map No. 92337 can be georeferenced to improve its accuracy.

Map No. 92337 – Section 4407 Easements

- AKDOT Position: Locating a road centerline based on absolute Map No. 92337 positions –
  - Would be inappropriate for engineering design and centerline location.
  - Would be contrary to established engineering principles and lead to absurd results.
  - Could result in an alignment that traverses lands with unacceptable slopes, poor soils environmentally sensitive areas and significant bodies of water.
  - Would defeat Congressional intent to connect communities of SE Alaska.



Map No. 92337 – Section 4407 Easements

- Mapping Standards (Covered by T. Heinrichs)
- Legislative Mapping: Crude maps may serve legislative purpose –
  - ANILCA
    - ✓ ANILCA Maps described geographic boundaries of conservation system units
    - ✓ Thick tape outlines on 1:250,000 maps
    - ✓ Actual boundaries controlled by “hydrographic divides” or other “topographic or natural features.” (See ANILCA Section 103(a))
    - ✓ Boundary definition subject to public lands (protect valid existing rights)

Map No. 92337 – Section 4407 Easements

- ANCSA

  - ✓ 17(b) easement through ANCSA lands to public lands
  - ✓ Maps not a part of legislation but intended to implement legislation
  - ✓ 17(b) easements have limited scope of use
  - ✓ Trail alignment may not currently exist, mapped alignment may be approximate
  - ✓ Reasonable alignment may require adjustment
  - ✓ Generally not required to meet highway design standards

Map No. 92337 – Section 4407 Easements

- Forest Service Policy (2011 – Current?)
  - ✓ FSM 1500 – External Relations; Ch 1510 – Legislative Affairs; 1517 - Legislative Maps
  - ✓ “Prior to passage of legislation by the Congress, ensure that the accompanying Legislative Map is reviewed by a state-licensed professional land surveyor to verify that proposed boundaries can be legally described and marked as necessary.”

Map No. 92337 – Section 4407 Easements

- Route Location
  - Can a Transportation/Utility alignment be located without a preliminary survey?
  - Route location is a function of:
    - ✓ Terminal points, areas of economic development
    - ✓ Grades
    - ✓ Soils & Geology
    - ✓ Cut & Fill
    - ✓ Hydrology/Drainage – Bridges/culverts
    - ✓ Material source availability
    - ✓ Existing land rights (inholdings, allotments, certain government properties)
    - ✓ Environmentally sensitive lands (wetlands, vegetation, fish habitat, birds, mammals, endangered species, cultural resources)

Map No. 92337 – Section 4407 Easements

- Existing mapping & photography provide a good start for Office Location
  - ✓ USGS Quads, contour mapping
  - ✓ GIS, DTM, satellite/aerial imagery

- FS Road Preconstruction Handbook –
  - ✓ Objective: “To identify, on the ground, the location of a road that best satisfies the design criteria and Road Management Objectives.”
  - ✓ Field Location: “Choosing the correct location is the most important part of road construction…”
  - ✓ “A properly located road will result in lower costs, fewer maintenance problems, and reduced environmental impacts.”

February 16, 2017
J. F. Bennett

Map No. 92337 – Section 4407 Easements

- Conclusion
  - FS unreasonably suggests that it was the intent of Congress to absolutely fix the final centerline for the TUC corridors as presented on Map No. 92337 without regard to “any positional inaccuracy that may inherently be contained in the map.”
  - We conclude that the reasonable position is that the congressional intent for Map No. 92337 is to provide a general location for the TUC centerlines that would be refined by surveys and other engineering studies until a final alignment was reached that met the design controls and environmental constraints.

Mapping standards

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Accuracy and Suitability Analysis of Map 92337

August 2016

GINA

UAF UNIVERSITY OF ALASKA FAIRBANKS

Accuracy and Suitability Analysis of Map 92337

Tom Heinrichs
Director, Geographic Information Network of Alaska
University of Alaska Fairbanks
16-August-2016

Introduction:

Map 92337 was adopted by Congress to provide for a reciprocal exchange of easements between the Federal government and the State of Alaska. The Federal government received access across State lands to access log transfer facilities and marine access points and the State was granted transportation and utility corridors throughout the Tongass National Forest to connect the communities of Southeast Alaska. Because the accuracy of map 92337 was not explicitly stated, professional best practice would be to use the map as a conceptual depiction of road easements and for the US Forest Service (USFS) and the State to work together to establish easements that best serve the public interest by avoiding environmentally or culturally sensitive locations and are economical to build. This approach would save the the taxpayers money, protect the environment, and meet the intent of Congress--all desirable things for both the Federal government and the State.

A prior version of map 92337 dated January 22, 2004 has the following in the legend: *"Disclaimer: Boundaries and locations are approximate. This map should not be used or interpreted for legal or administrative actions."* This statement is quite clear and should have been included on the final map adopted by Congress. Whatever the reason for it being dropped from the final map dated June 15, 2005, this statement gives a clear indication of the quality ("*locations are approximate*") and suitability of purpose ("*should not be used or interpreted for legal or administrative actions*"). Unless the entire map was redrawn using source data of known high accuracy, this statement would still hold for the final map. The lack of any metadata describing the source information used to draw the map, documenting procedures used to make the map, or estimating accuracy of map 92337 is a major problem discussed in detail below.

The USFS prepared a document titled "Map 92337 talking points" which describes how they believe the map should be interpreted. Unfortunately, the talking points memo contains statements and assumptions that are not in accordance with industry standards used by cartographers and surveyors. Below, specific statement from the "Map 92337 talking points" document are analyzed and discussed in the context of standard industry practices.

A very brief primer on map accuracy standards

National Map Accuracy Standards (NMAS)

USGS, 1947. United States National Map Accuracy Standards. Published by US Bureau of the Budget, June 17, 1947. Available from: http://nationalmap.gov/standards/nmas.html

National Standard for Spatial Data Accuracy (NSSDA)

FGDC, 1998. Geospatial Positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy. FGDC-STD-007.3-1998. Subcommittee for Base Cartographic Data of the Federal Geographic Data Committee.
Available from: https://www.fgdc.gov/standards/projects/accuracy/part3/index_html

The relationship between NMAS map scale and accuracy

NMAS

[F]or maps on publication scales of 1:20,000 or smaller, [not more than 10% of the points tested shall be in error by more than] 1/50 inch.

1/50 inch = 0.508 mm

The 1:754,286 map publication scale implies a NMAS accuracy of 1257 feet.

754,286 x (1/50 in) = 15,086 in = 1257 feet

Horizontal CE90 accuracy

United States National Map Accuracy Standards

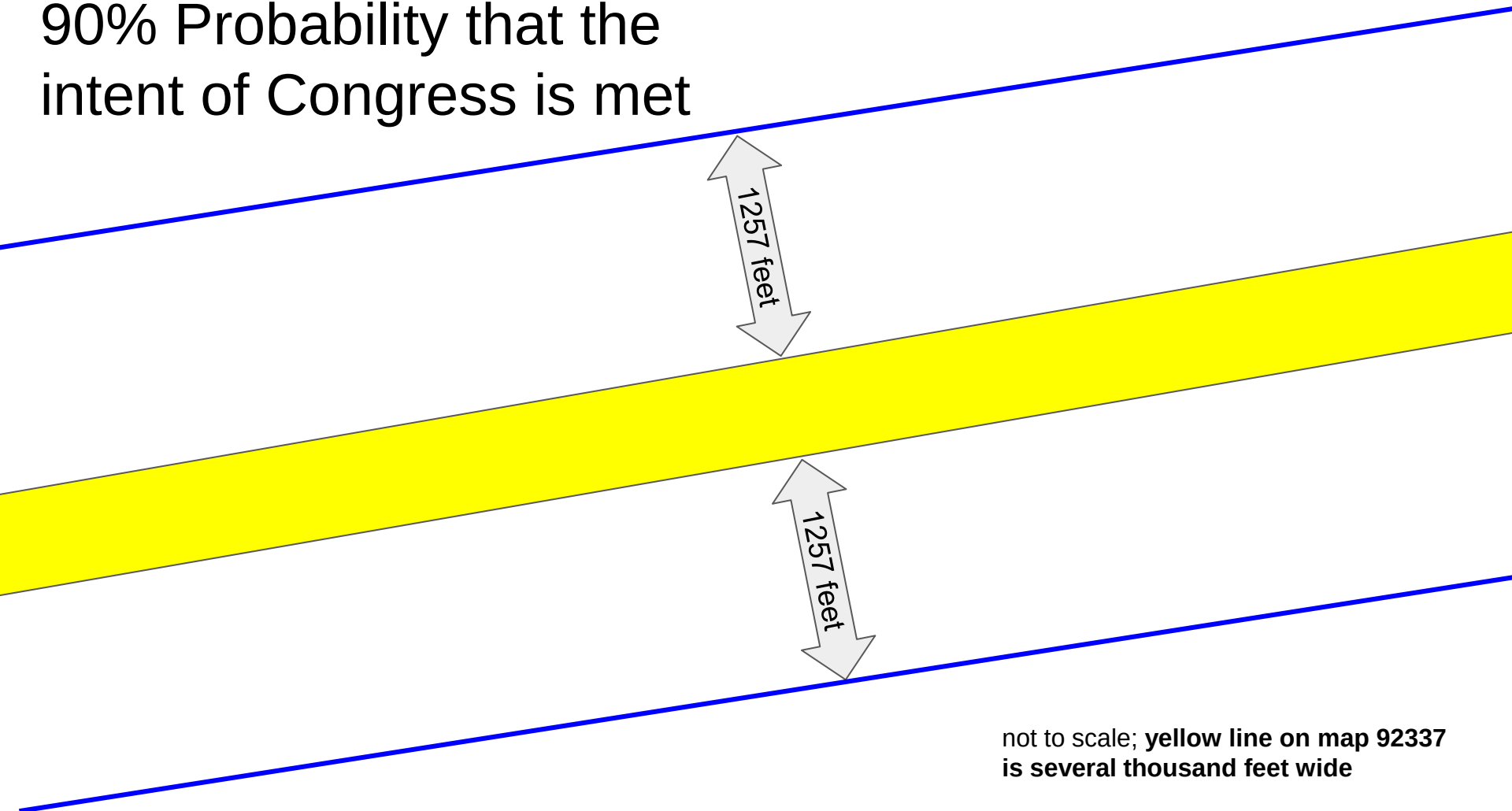
With a view to the utmost economy and expedition in producing maps which fulfill not only the broad needs for standard or principal maps, but also the reasonable particular needs of individual agencies, standards of accuracy for published maps are defined as follows:

1. **Horizontal accuracy.** For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc. In general what is well defined will be determined by what is plottable on the scale of the map within 1/100 inch. Thus while the intersection of two road or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would obviously not be practicable within 1/100 inch. Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. In this class would come timber lines, soil boundaries, etc.
2. **Vertical accuracy,** as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.
3. **The accuracy of any map may be tested** by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of a higher accuracy. Tests shall be made by the producing agency, which shall also determine which of its maps are to be tested, and the extent of the testing.
4. **Published maps meeting these accuracy requirements** shall note this fact on their legends, as follows: "This map complies with National Map accuracy Standards."
5. **Published maps whose errors exceed those aforestated** shall omit from their legends all mention of standard accuracy.
6. **When a published map is a considerable enlargement** of a map drawing (manuscript) or of a published map, that fact shall be stated in the legend. For example, "This map is an enlargement of a 1:20,000-scale map drawing," or "This map is an enlargement of a 1:24,000-scale published map."
7. **To facilitate ready interchange and use of basic information for map construction** among all Federal mapmaking agencies, manuscript maps and published maps, wherever economically feasible and consistent with the uses to which the map is to be put, shall conform to latitude and longitude boundaries, being 15 minutes of latitude and longitude, or 7.5 minutes, or 3-3/4 minutes in size.

Issued June 10, 1941
Revised April 26, 1943
Revised June 17, 1947

U.S. BUREAU OF THE BUDGET

90% Probability that the intent of Congress is met



not to scale; **yellow line on map 92337 is several thousand feet wide**

NSSDA and NMAS

For normally (Gaussian) distributed, the NMAS CE90 accuracy can be related to the NSSDA CE95 accuracy.

2. Former National Map Accuracy Standards (NMAS)

2.1 Relationship between NSSDA and NMAS (horizontal)

NMAS (U.S. Bureau of the Budget, 1947) specifies that 90% of the well-defined points that are tested must fall within a specified tolerance:

- For map scales larger than 1:20,000, the NMAS horizontal tolerance is 1/30 inch, measured at publication scale.
- For map scales of 1:20,000 or smaller, the NMAS horizontal tolerance is 1/50 inch, measured at publication scale.

If error is normally distributed in each the x- and y-component and error for the x-component is equal to and independent of error for the y-component, the factor 2.146 is applied to compute circular error at the 90% confidence level (Greenwalt and Schultz, 1968). The circular map accuracy standard (CMAS) based on NMAS is:

$$\begin{aligned} CMAS &= 2.1460 * RMSE_x = 2.1460 * RMSE_y \\ &= 2.1460 * RMSE_r / 1.4142 \\ &= 1.5175 * RMSE_r \end{aligned}$$

The CMAS can be converted to accuracy reported according to NSSDA, $Accuracy_r$, using equations from Appendix 3-A, Section 1:

$$Accuracy_r = 2.4477/2.1460 * CMAS = 1.1406 * CMAS.$$

Therefore, NMAS horizontal accuracy reported according to the NSSDA is:

$1.1406 * [S * (1/30")/12"]$ feet, or $0.0032 * S$, for map scales larger than 1:20,000
$1.1406 * [S * (1/50")/12"]$ feet, or $0.0019 * S$, for map scales of 1:20,000 or smaller

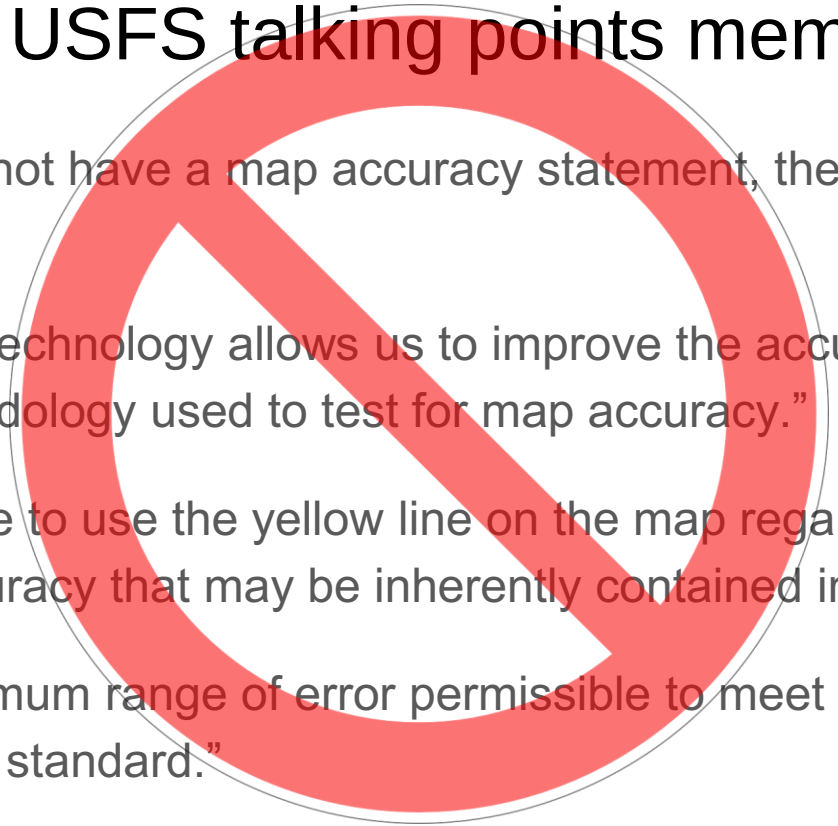
where S is the map scale denominator.

2.2 Relationship between NSSDA and NMAS (vertical)

NMAS (U.S. Bureau of the Budget, 1947) specifies the maximum allowable *vertical* tolerance to be one half the contour interval, at all contour intervals. If vertical error is normally distributed, the factor 1.6449 is applied to compute vertical accuracy at the 90% confidence level (Greenwalt and Schultz, 1968). Therefore, the Vertical Map Accuracy Standard (VMAS) based on NMAS is estimated by the following formula:

$$VMAS = 1.6449 * RMSEz$$

Map 92337 -- USFS talking points memo



- “The map does not have a map accuracy statement, therefore no standard applies.”
- “Modern digital technology allows us to improve the accuracy of a map using the same methodology used to test for map accuracy.”
- “Congress chose to use the yellow line on the map regardless of any positional inaccuracy that may be inherently contained in the map.”
- “Using the maximum range of error permissible to meet NMAS as a buffer is a mis-use of the standard.”

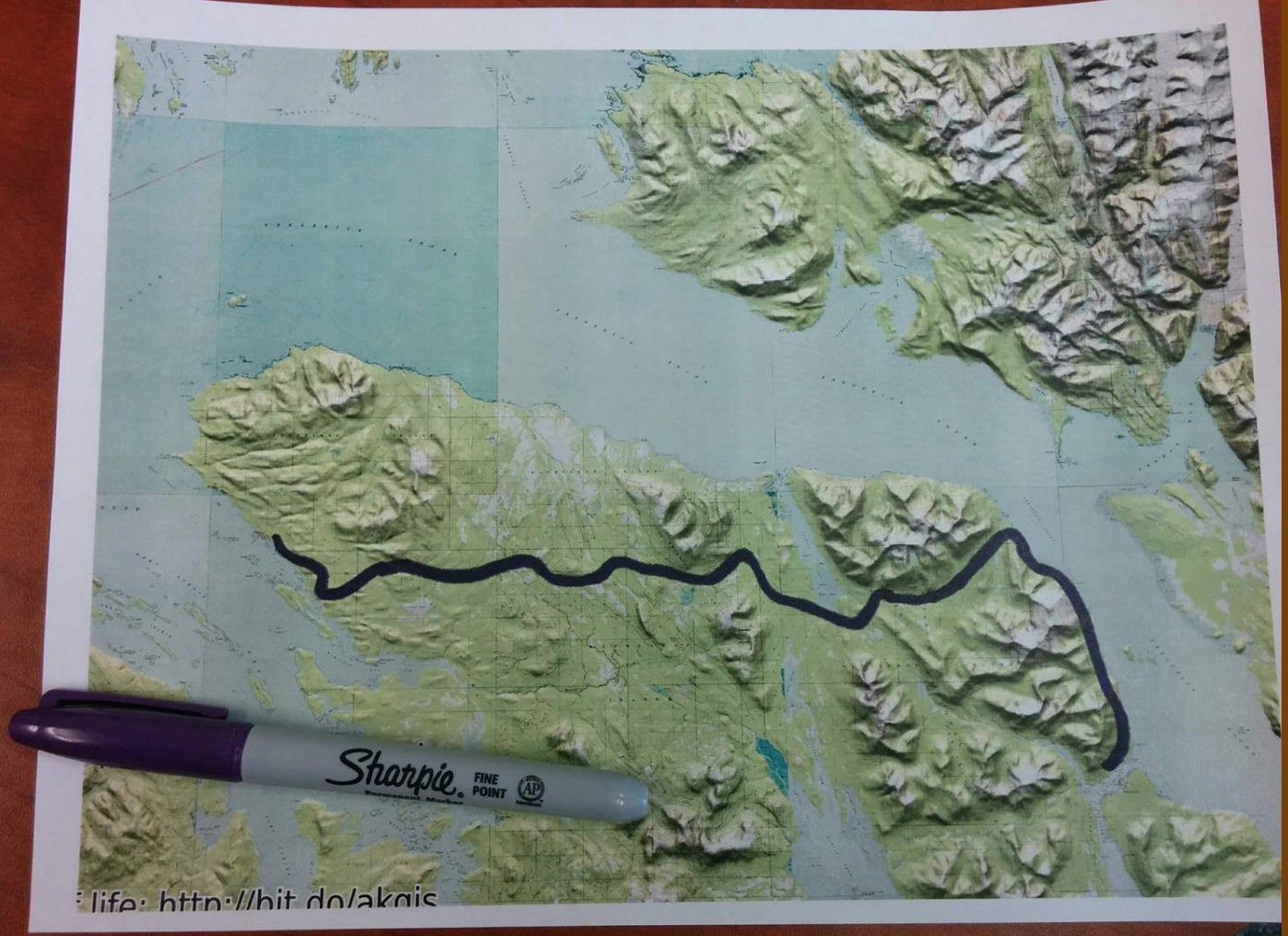
Lack of metadata--an enormous problem

One of the most fundamental responsibilities of a geospatial and mapping practitioner is to document their products with metadata.

The prior version of map 92337 dated January 22, 2004 was documented with general yet clear metadata in the legend: “Disclaimer: Boundaries and locations are approximate. This map ~~should not be used or interpreted for legal or administrative actions.”~~ conveys intent not precise coordinates.[1]

Of all the best practices and industry standards referred to in this document, the lack of metadata is perhaps the most damning for interpretation of map 92337 as a cartographic product from which coordinates can be derived.

[1] could have been a good revision for final map


Sharpie
FINE
POINT
life: http://bit.do/akgis

“The map does not have a map accuracy statement, therefore no standard applies.”

Incorrect: Lacking a statement, based upon the US National Map Accuracy Standards, the map accuracy is inferred from the scale, if the map was published by cartographers following industry standard practices.

“Modern digital technology allows us to improve the accuracy of a map using the same methodology used to test for map accuracy.”

Incorrect: Map accuracy cannot simply be improved using any technology, digital or otherwise. The accuracy of a given map is an inherent property.

“Congress chose to use the yellow line on the map regardless of any positional inaccuracy that may be inherently contained in the map.”

Incorrect: It is contrary to professional practice to attempt to infer coordinates of higher accuracy from a map than that map’s accuracy supports. Congress chose to grant easements along the lines conceptually depicted on map 92337.

“Using the maximum range of error permissible to meet NMAS as a buffer is a mis-use of the standard.”

Incorrect: The overall problem with map 92337 is that it contains no statement of accuracy or suitability of purpose.

Conclusions

Professional best practices would have map 92337 used as a guide to the intent of Congress.

In an ideal situation, the USFS and State would work together to interpret the Congressional intent and to establish easements that are the most economical use of taxpayer funds and the least impactful to environmental and cultural resources.

However, map 92337 could possibly be used to establish corridor boundaries. This is not advisable and an over-interpretation of the map, but if it comes to that, there are long-established methods for inferring accuracy and statistical uncertainty from published map scale. Professional standards call for buffering the outside edge of the yellow line’s coordinates by 1257 feet on both sides.

Practical Consideration from a Field Surveying Perspective

Dan M. Ignotov[1], PLS and Dan Garner, PE

Alaska Dept. of Trans. & P.F. - Southcoast Region D&ES - Survey/ROW

[1] Land Surveyor II, Regional Locations Engineer

Transforms

- Geo-reference pdf to NAD27
  - AK Zone 1 in Global Mapper procedure.
- Transform to NAD83 AK
  - Zone 1 (scary)

Output from NADCON for station

North American Datum Conversion

NAD 27 to NAD 83

NADCON Program Version 2.11

==========

Transformation #: 1 Region: Alaska

	Latitude	Longitude	
NAD 27 datum values:	60 00 0.00000	139 00 0.00000	
NAD 83 datum values:	59 59 58.86909	139 00 6.10969	
NAD 83 - NAD 27 shift values:	-1.13091	6.10969	(secs.)
	-34.999	94.701	(meters)
Magnitude of total shift:		100.961	(meters)

NGS HOME PAGE

Transforms

Note differences in direction and magnitude of the shift for such a large area. Northwest Map 92337 vs. Southeast Map 92337. NAD27 & NAD83 are two completely different datums.

NGS precise geoid models not intended for use with NAD27. GNSS not intended for NAD27.

Output from NADCON for station

North American Datum Conversion

NAD 27 to NAD 83

NADCON Program Version 2.11

Transformation #: 1 Region: Alaska

	Latitude	Longitude
NAD 27 datum values:	60 00 0.00000	139 00 0.00000
NAD 83 datum values:	59 59 58.86909	139 00 6.10969
NAD 83 - NAD 27 shift values:	-1.13091	6.10969(secs.)
	-34.999	94.701 (meters)
Magnitude of total shift:	100.961(meters)	

Output from NADCON for station

North American Datum Conversion

NAD 27 to NAD 83

NADCON Program Version 2.11

Transformation #: 1 Region: Alaska

	Latitude	Longitude
NAD 27 datum values:	55 00 0.00000	131 00 0.00000
NAD 83 datum values:	54 59 58.80780	131 00 6.01746
NAD 83 - NAD 27 shift values:	-1.19220	6.01746(secs.)
	-36.867	106.968 (meters)
Magnitude of total shift:	113.143(meters)	

Obtained a centerline .shp file from USFS that is claimed to be what was used to create “yellow line”. It is in NAD27 AK Zone 1. No other meta data.

Transform to NAD83 and import as a layer in ArcMap with geo-referenced pdf Map 92337.

Import 2006-2008 ortho imagery from Tongass NF. FS imagery collected in NAD83.

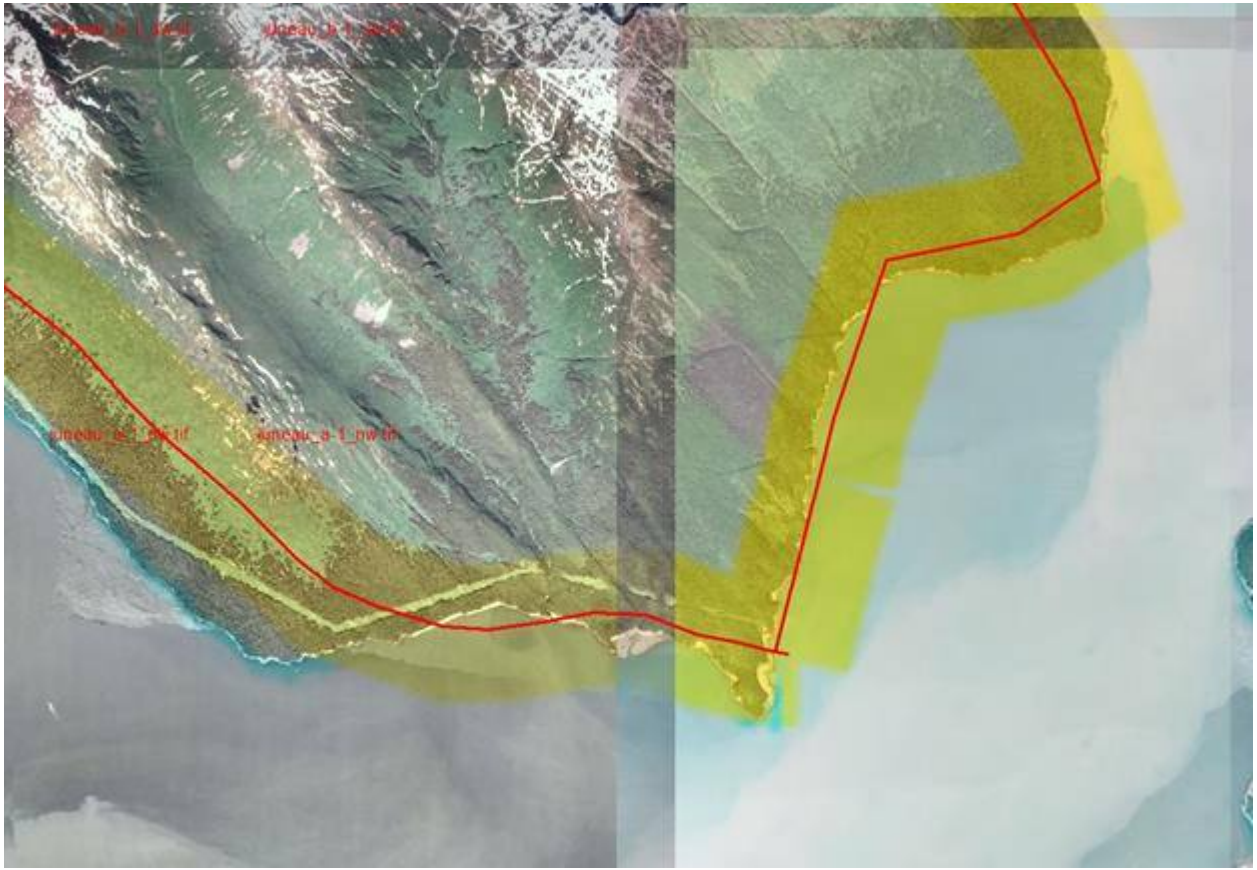
Is it supposed to follow the existing FS Road? Kake to Petersburg. “Yellow line” is +/- 0.75 mile wide in this vicinity. Can I stake anywhere inside that buffer?

Kake to Petersburg

Apparently DOT can’t use the existing road through this section.

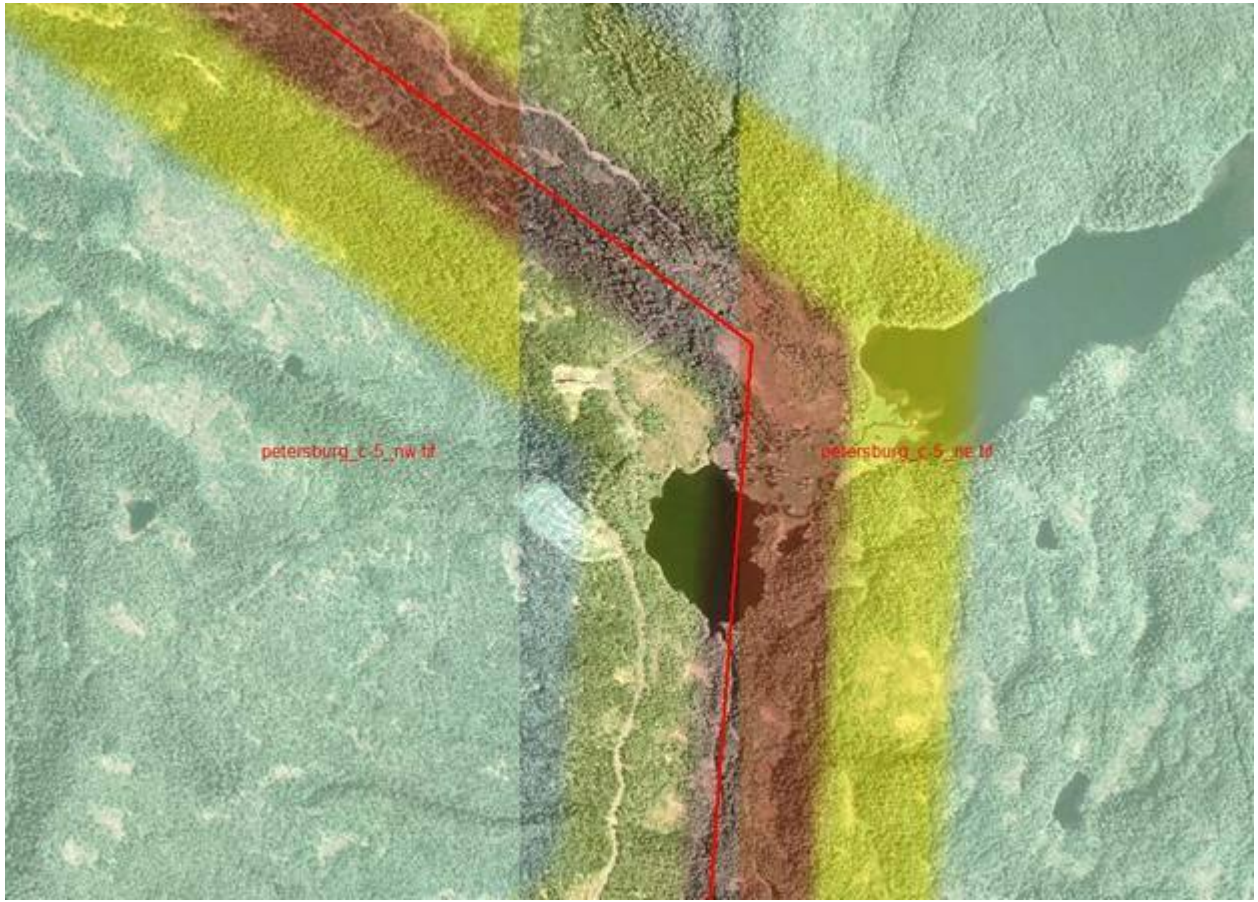
Taku River

Mouth of the Taku River SE of Juneau. We are going to get wet.



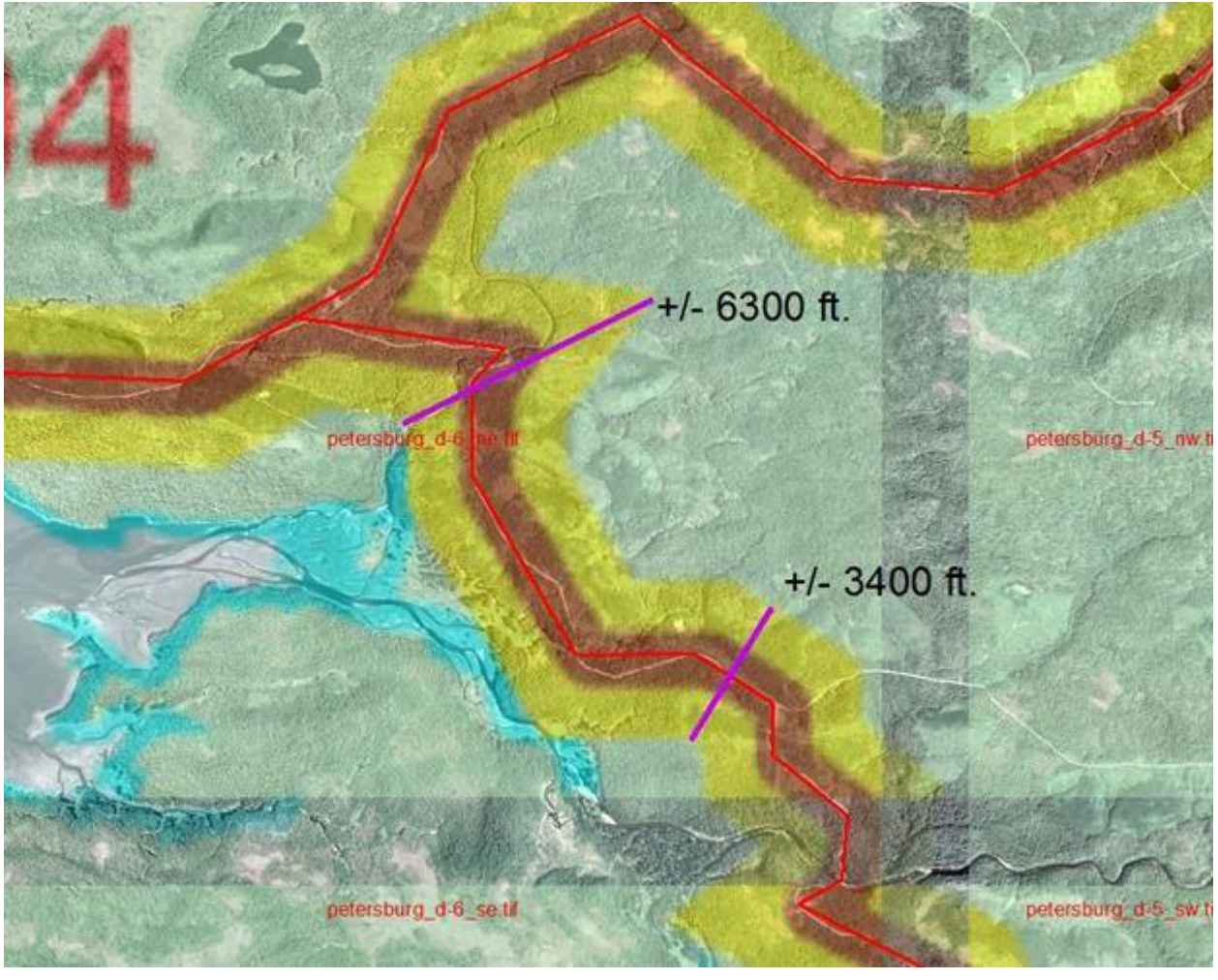
Kupreanof Island

Getting wet again.



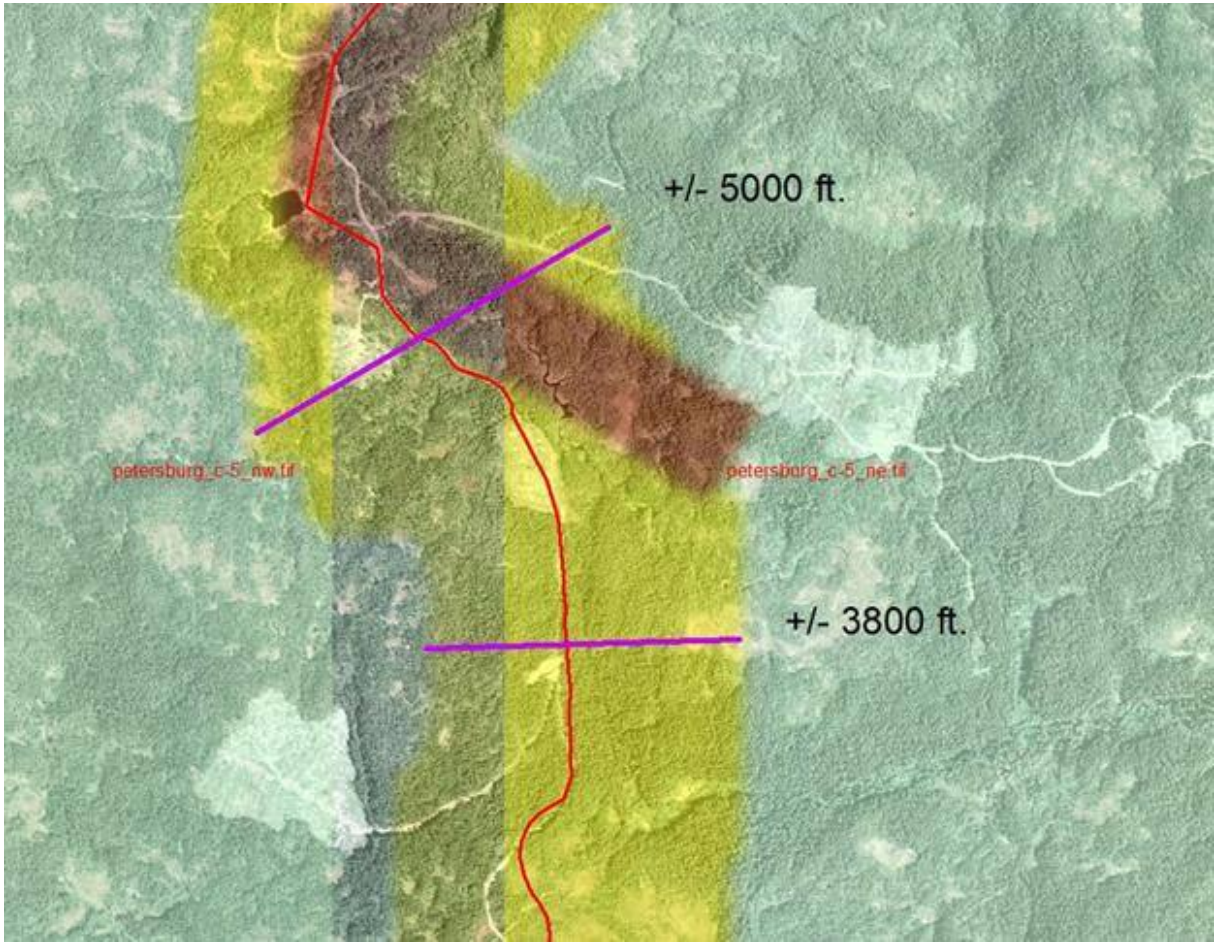
Width matters

If DOT can stake anywhere within the now geo-referenced “yellow line”, exactly how wide is said line?



Width example 2

South spur Kupreanof Island



Summary

I could probably lay out the approximate CL of the “yellow line” but what would it accomplish? We are trying to build a transportation and utility corridor with the least amount of impact on the surrounding environment with the least amount of cost.

How does the “yellow line” relate to the Public Land Survey System?

This is not the basis for a proper field survey or a civil engineering project. For any corridor, where is the Initial Point? Terminus?

Was this the intent of Congress?