Analysis of Bathymetric Change in a Sinuous Channel Using Deterministic Interpolation Methods

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Outline

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  - Study Area
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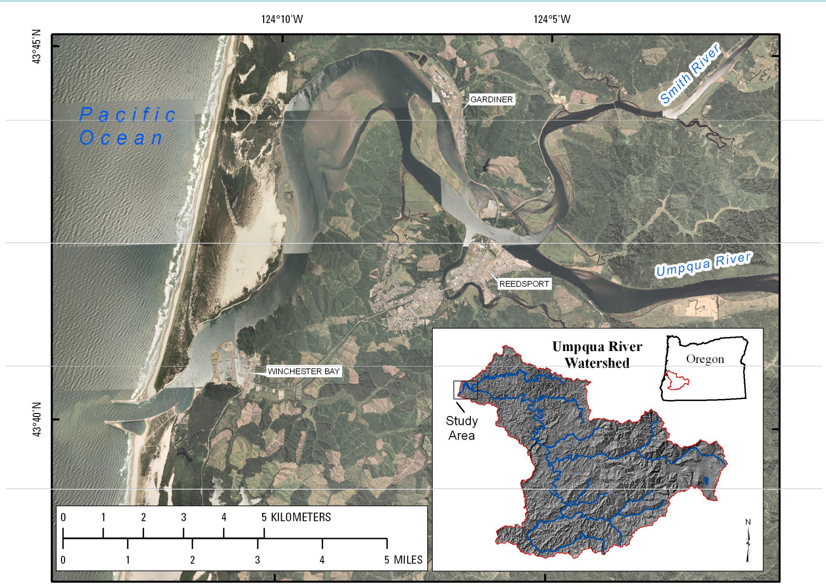
Introduction: Research Question

- Historically, how has the Umpqua river basin changed?
- What interpolation technique is most suitable for this study area?
- How should future development of this area proceed?

Introduction: Study Area



Base image: 2005 USDA National Agriculture Imagery Program

Introduction: Study Area

- Lower 20 km of the Umpqua River
- From Reedsport to the mouth
- History of gravel mining and dredging for navigation beginning in the early 1900s
- To support permitting decisions, need to better understand the spatial and temporal patterns of sediment replenishment (O'Connor et al., 2009)

Methods: Basic workflow

NOAA historic hydrography surveys

- geo-reference and rectify
- digitize sounding depths at point locations
- convert to common coordinate system

Interpolate to continuous surface

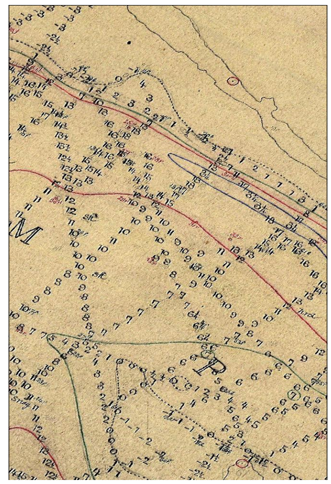
- Multiple schemes in Geostatistical Analyst as well as Spatial Analyst
- Change parameters to minimize RMSE
- Evaluate accuracy of multiple methods

Analyze temporal change in riverbed

- 3-D analyst extension
  - Volumetric Change

Methods: Data from NOAA

- Scanned hydrography surveys are available for 1886, 1920, and 1971 http://www.ngdc.noaa.gov/mgg/bathymetry/hydro.html
- For 1971 ASCII xyz points are also available
- For this study we utilize data for 1920 and 1971

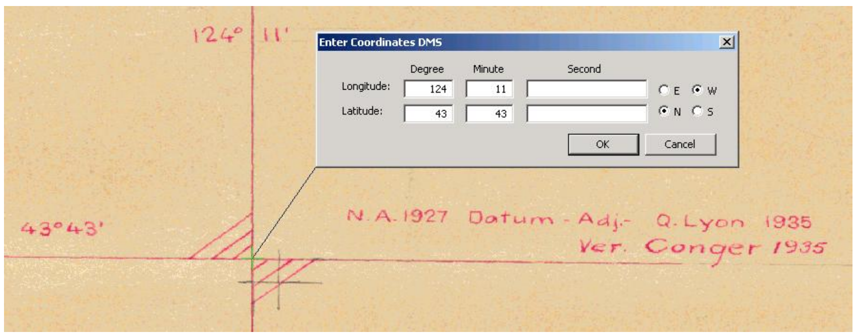


Methods: Geo-referencing

- Use graticule marks (NAD 27) for coordinate entry and other markings such as lighthouses or benchmarks to match with DRG.
- Need at least 4 control points
- Save points for possible refinement
- Rectify using same cell size as the original scanned image to make a geoTIFF

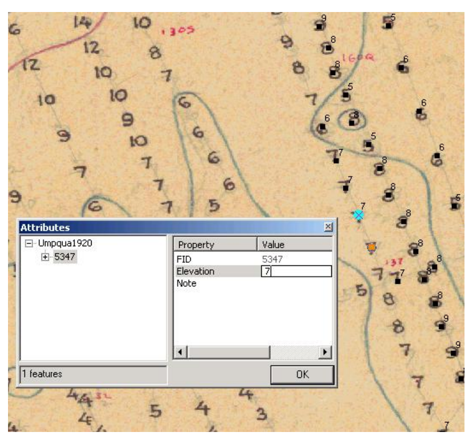
Methods: Geo-referencing hydrography survey sheet (1920)

- Used Georeferencing Toolbar to register the scanned images
- The registered images were then rectified using nearest neighbor resampling and the same cell size as the original image



Methods: Digitize point elevations (1920)

- Click the approximate center of each number
- Add elevation attribute and a note if appropriate
- Repeat 12,703 times

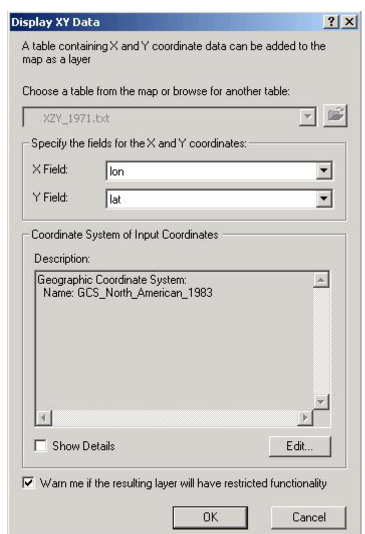


Methods: 1971 data

- Horizontal coordinates in decimal degrees referenced to NAD 83
- Vertical coordinates in meters referenced to local MLLW datum
- In fixed width ASCII file format

Methods: 1971 data

- Converted from fixed width text to tab delimited text using Excel
- Imported into ArcMap
- Exported to feature class

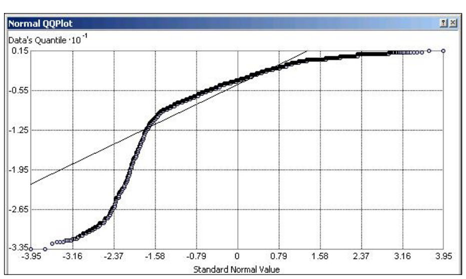


Methods: Re-projection

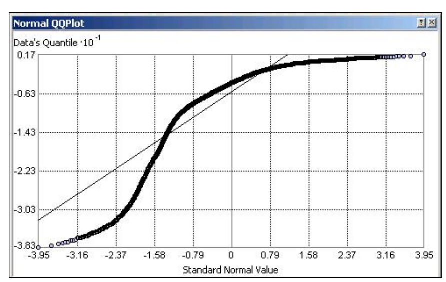
- 1920 data were converted from depths to elevations (*-1) and from feet to meters (*0.3048)
- Both datasets were re-projected to an Albers projection referenced to NAD 83

Methods: Data Exploration Normal QQ plot

1920



1971



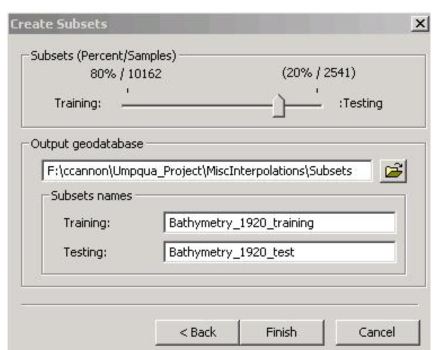
Note: Data that are normally distributed would be a straight line, these data do not follow a normal trend!

Methods: Considerations in selecting interpolation scheme

- Anisotropy is with respect to flow
- Variability is greatest transverse to flow direction
  - Therefore it varies in direction if the channel has a sinuous nature
- Conversion to channel oriented coordinate system has been proposed (Merwade, 2006),
  - proven time consuming
  - limitations for complex fluvial systems
- We aim to find a suitable method using a Cartesian Coordinate system

Methods: Interpolation Validity

- Create subsets
- Removed 20 % of data points for validation purposes
  - Testing subset
- Used remaining 80 % to make preliminary interpolations
  - Training subset

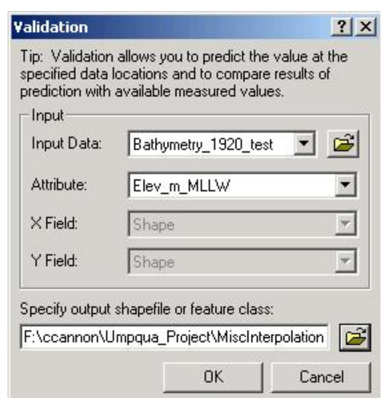


Methods: Geostatistical Analyst

- Use training set
- Interpolations methods:
  - regularized spline
  - tension spline
  - inverse distance weighting
  - local polynomial
  - ordinary kriging
- Optimize parameters to minimize prediction error using RMSE reported by the tool.

Methods: Validation

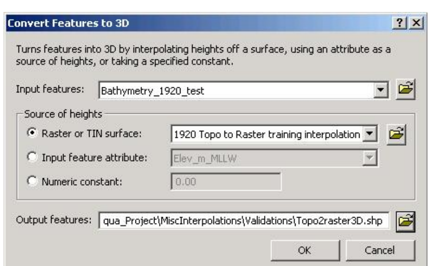
- Use test subset
  - calculate prediction errors at points not used in interpolation using the Validation property of each geo-statistical layer

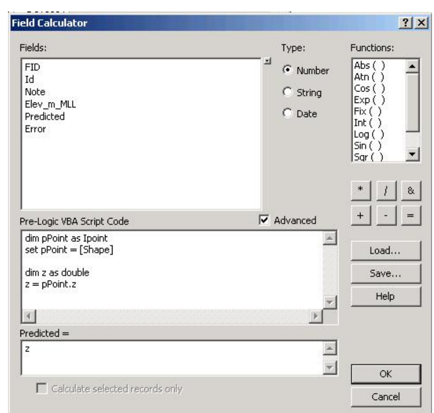


Methods:
Topo to Raster (Spatial Analyst)

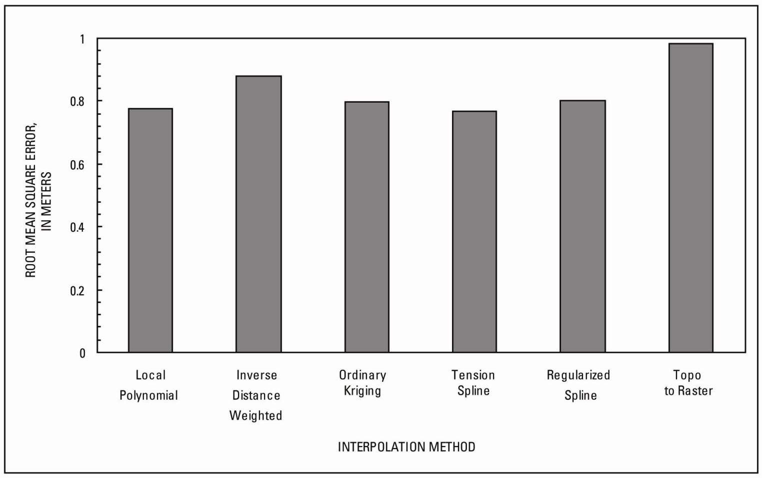
- Proposed to be superior method for interpolation in Cartesian coordinate system by Merwade (2006)
- Iterative finite difference interpolation to create a hydrologically correct DEM
- Use training set to create raster
- Convert test points to 3D using interpolated surface values to evaluate accuracy

Methods: Evaluating Topo to Raster prediction accuracy

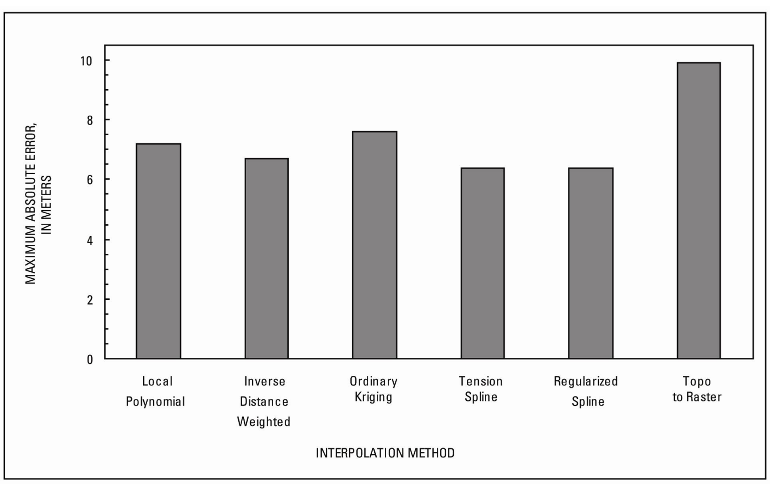




Methods: Compare RMS error

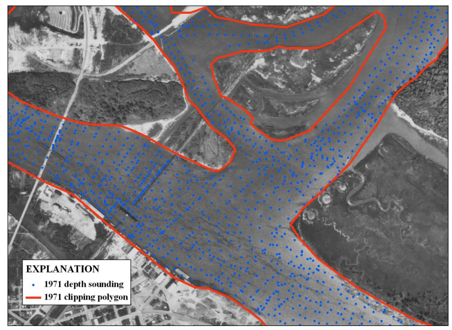


Methods: Maximum prediction error



Methods: Boundaries

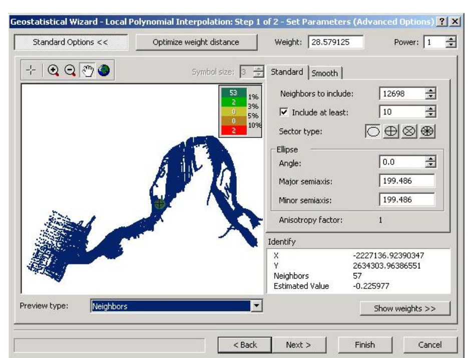
- Default interpolated surfaces generally cover a square area
- Digitized polygons to clip area outside of where points were collected for each year



Base image: 1967 USDA

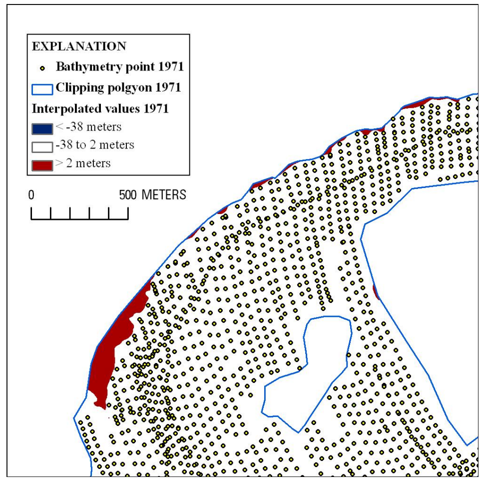
Methods: Interpolate to Raster

- Used Local Polynomial Interpolation with complete datasets
- Used optimized weight distance and circular search neighborhood
- Exported results to raster dataset and clipped to area where data were collected



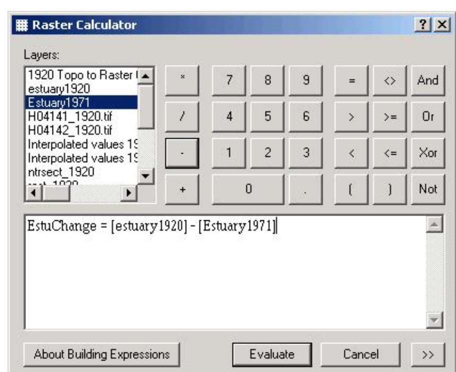
Results: Extrapolation Error

- Beyond the extent of the measurement points, the quality of the estimation rapidly deteriorates
- The red areas are where the clipping polygon was based on the land-water boundary and the elevation is significantly over-predicted in some locations

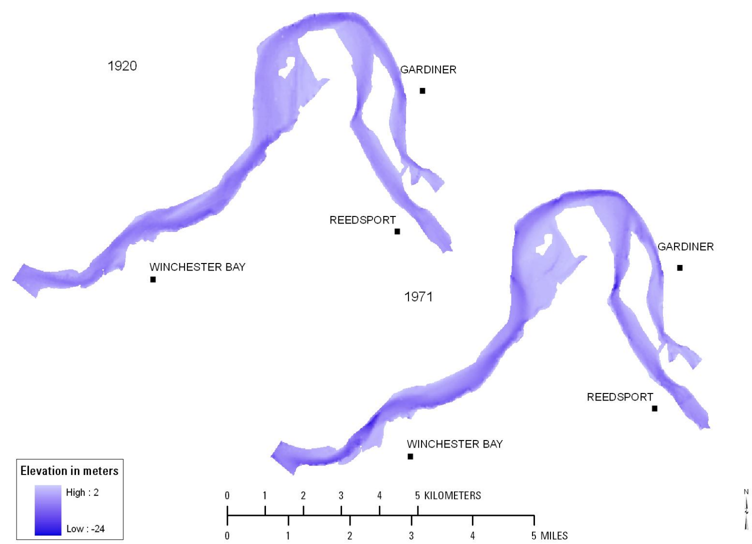


Results: Evaluating Change

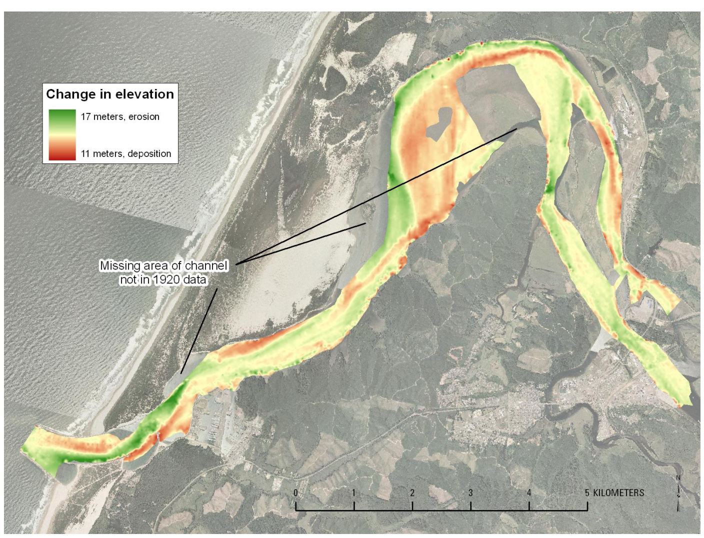
- Intersected the two extents to limit to areas where there are data from both years
- Limited to the estuary
- Clipped both rasters to this polygon
- Calculated the difference at each cell



Results: Evaluating Change



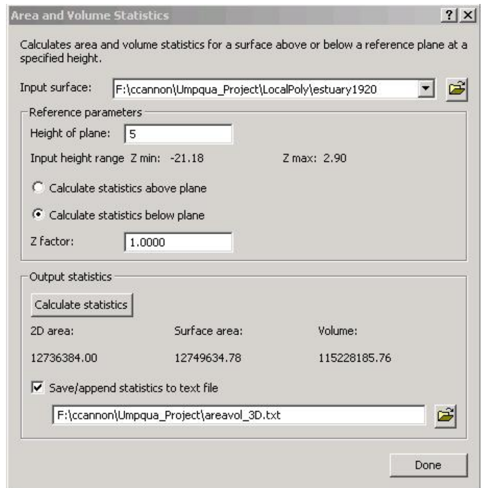
Results: Where change is occurring



Base image: 2005 USDA National Agriculture Imagery Program

Results: Volumetric Change

- Use 3D analyst to calculate volumes
- Set an arbitrary plane above surface
- Calculate volume below the plane
- Compare change in volume
- Volume has increased by about 2,000,000 m^3



Results: Conclusions

- Determininstic methods show potential for use in interpolating channel bathymetry, but can be unpredictable at data boundaries.
- This analysis suggests the lower Umpqua River Estuary has experienced a net loss of about 2,000,000 m^3 of sediment between 1920 and 1970.
- This would imply an average bed lowering of approximately 15 cm.

Results: Future Work

- Refine methodology to account for bar elevations and boundary effects.
- Derive a continuous surface for 1886 using same methodology as for 1920.
- Derive a continuous surface for 2009 using same methodology as for 1971.

References

- Chang, K.-t. (2008). *Introduction to Geographic Information Systems* (4th ed.). New York: McGraw-Hill.
- Merwade, V. M., Maidment, D. R., & Goff, J. A. (2006). Anisotropic considerations while interpolating river channel bathymetry. *Journal of Hydrology , 331* (3-4), 731-741.\
- O'Connor, J.E., Wallick, J.R., Sobieszczyk, S., Cannon, C., and Anderson, S.W., (2009). Preliminary assessment of vertical stability and gravel transport along the Umpqua River, Oregon: USGS Open-File Report 2009–1010, Available online at: http://pubs.usgs.gov/of/2009/1010/.