Modeling Erosion at Archaeological Sites with Image-based Modeling and GIS

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Objectives

- To develop a method for modeling erosion at archaeological sites
- To estimate the effects of erosion on specific sites
  - Khirbat Nuqayb al-Asaymir
- To improve the archaeological survey toolkit
  - Allowing for hypothesizing of effects of natural formation processes on archaeological sites

Khirbat Nuqayb al-Asaymir (KNA)

- Middle Islamic IIa
  - (13th century CE)
- Southern Jordan
  - Wadi Arabah
  - Southeast of the Dead Sea
- Copper-production site
  - 15 primary buildings
  - Slag mounds
    - 1,000 tons of slag

Methods

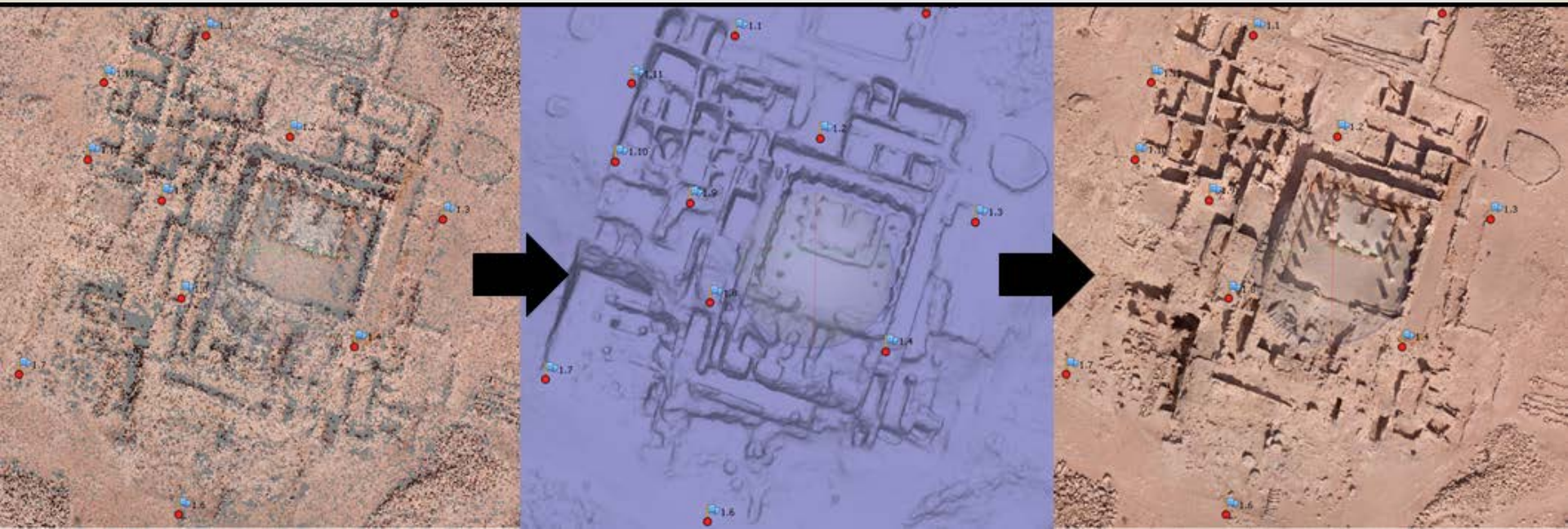
- Low-altitude aerial photography
- Photogrammetric Image-based Modeling
- Ethnographic analogy via ethnoarchaeology
- GIS-based spatial analysis
  - Soil Science

Low-altitude Aerial Photography

- Balloon-based recording
  - Sites
  - Excavation units
- Canon 50D DSLR
  - 18 mm focal length
  - Intervalometers
    - 10 seconds
- Transects across sites
  - Ideal 75%+ overlap between images
- 600+ photos/site

Structure from Motion

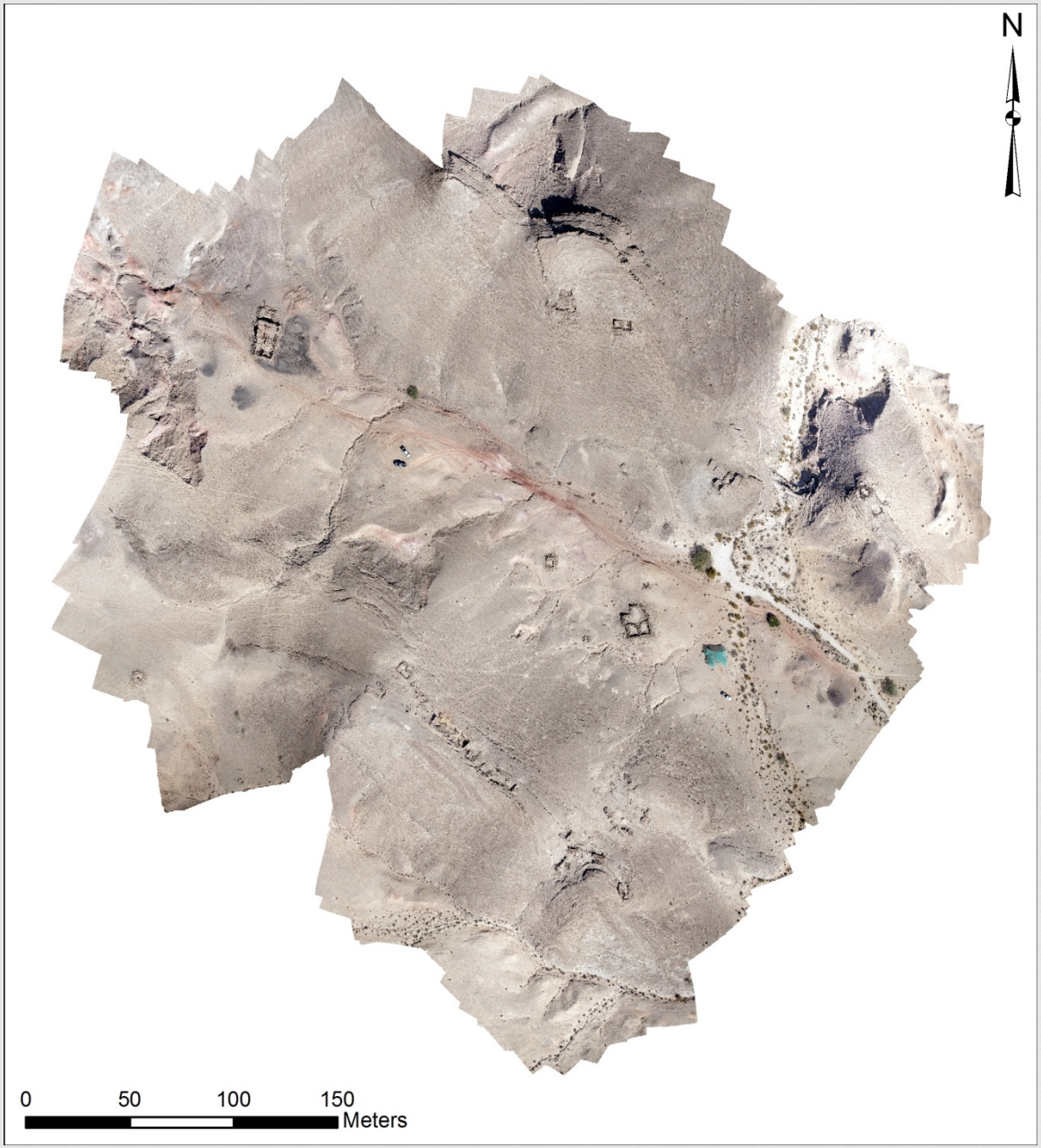
- Digital Photogrammetry
  - 3D models from photography using Agisoft Photoscan
  - Point cloud -> Geometry -> Texture
- 3D models can be georeferenced, allowing for export of GIS outputs



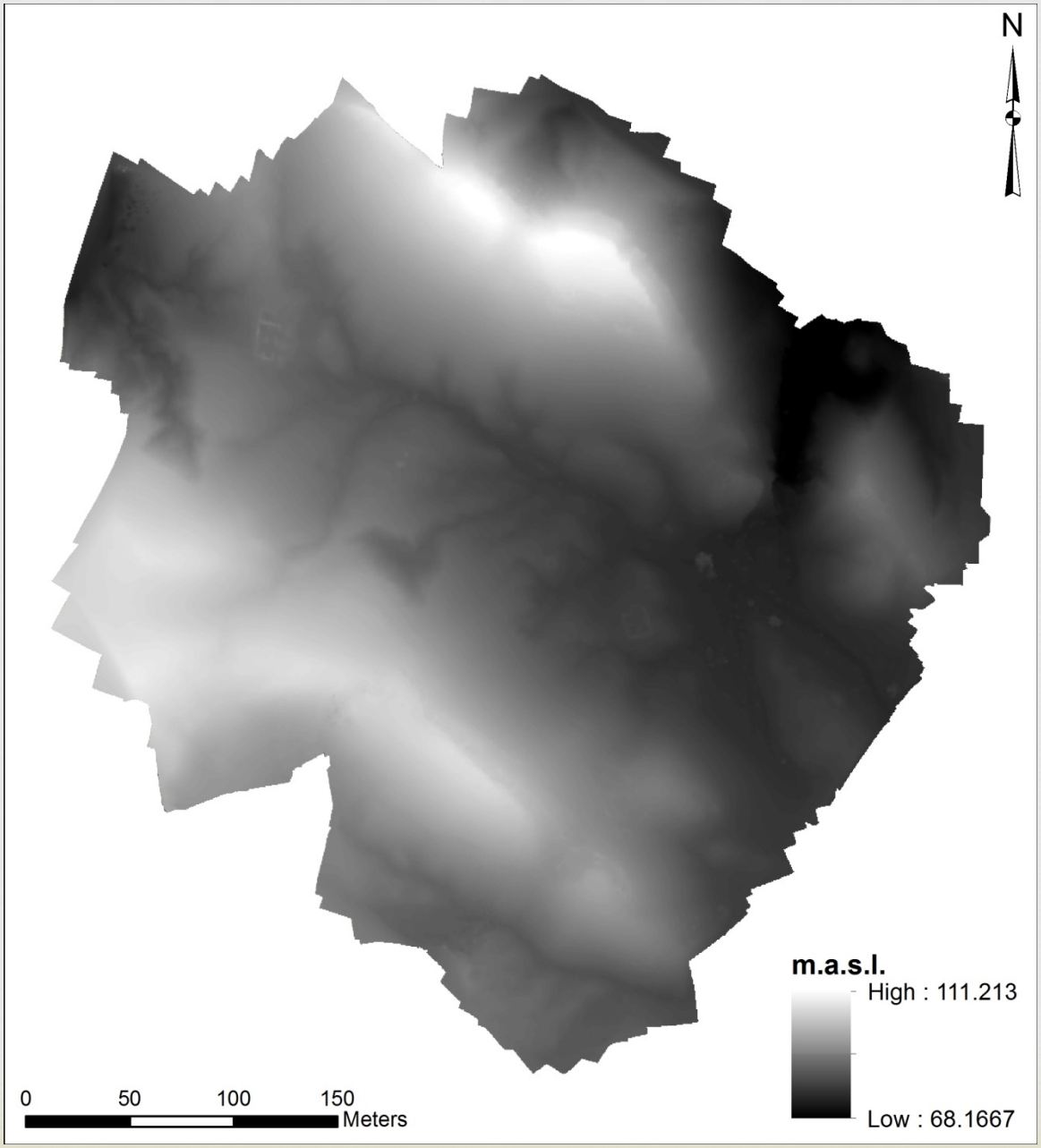
Processing the Models

- Agisoft Photoscan
  - Point Cloud, Dense Cloud, Mesh, Texture
    - High specifications
  - Georeferencing:
    - Based on spray-painted markers at site
    - GCPs recorded with Leica TS02 total station
    - Model Accuracy: 19 cm accuracy
      - Not ideal but substantially better than alternative datasets

Orthophoto



DEM



Ethnoarchaeology

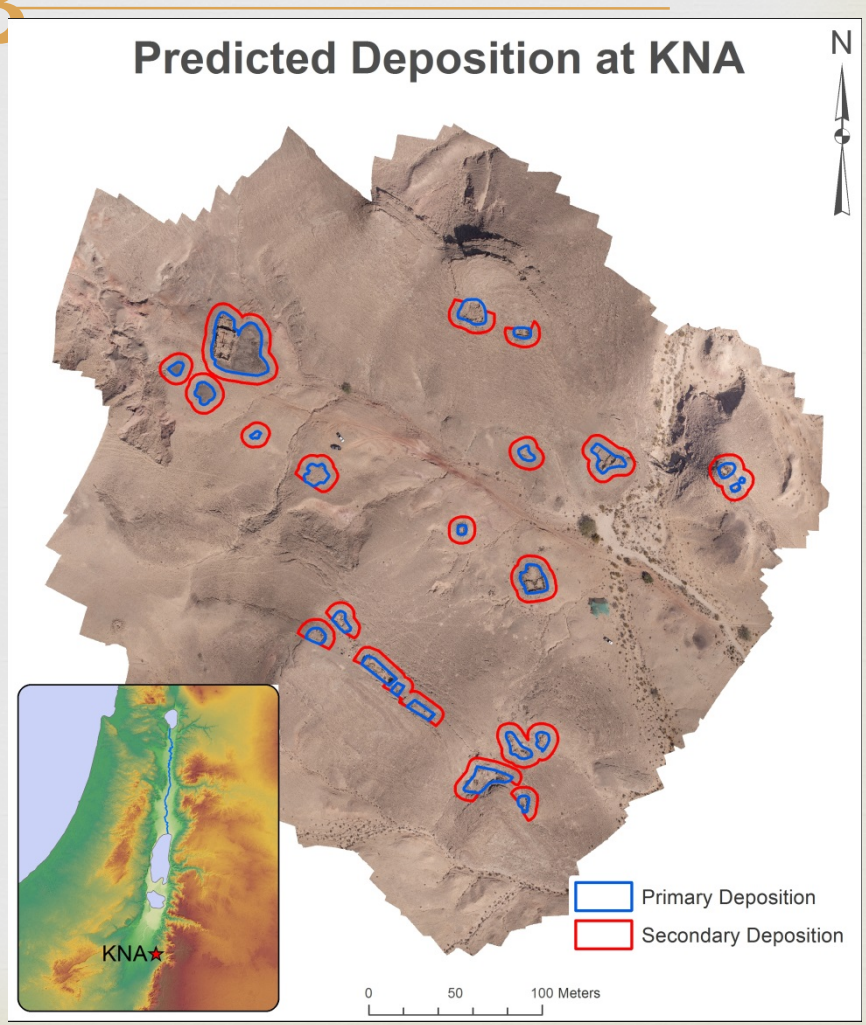
- In order to spatially quantify cultural transformation processes
- *Primary* vs *Secondary* Refuse
  - From Schiffer 1972
  - Primary: deposition in associated activity area
  - Secondary: deposition elsewhere
    - **Provisional discard**
    - **Household maintenance**
    - Dumping
    - Loss

Ethnoarchaeology

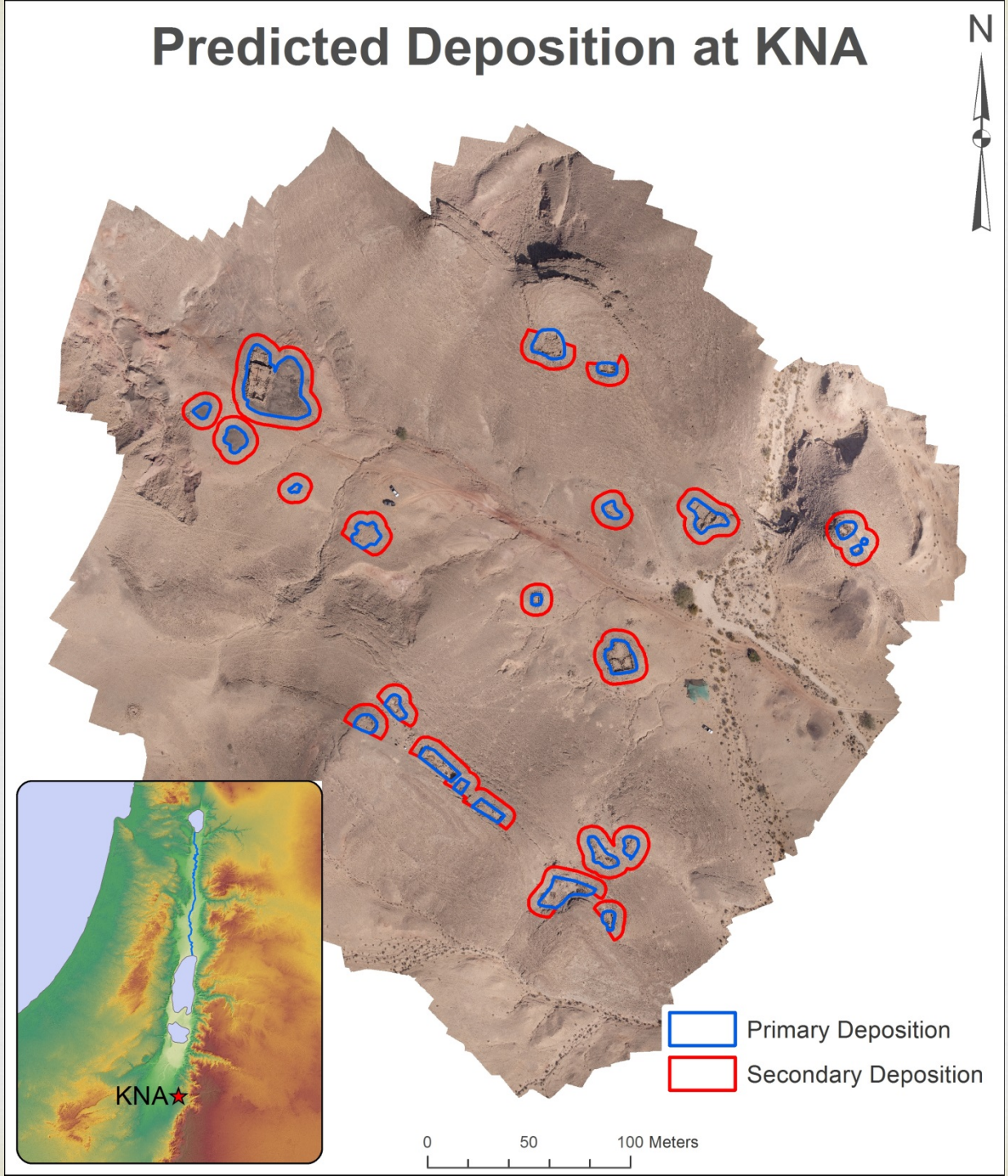
- Primary discard
  - Within buildings or areas
- Provisional discard
  - Usually associated with edges of buildings
- Household cleaning
  - Often swept or thrown out entrances
    - Highest density within 5 meters
  - No uphill deposition
- Based on Syrian villages and semi-nomadic Bedouin camps in Jordan (Kamp 2000; Simms 1988)

Simulating Deposition

- Primary and provisional deposition:
  - Within structures
  - Immediately outside
- High-density secondary deposition
  - Within 5 meters of areas
  - Not uphill
  - Not pit disposal



Predicted Deposition at KNA

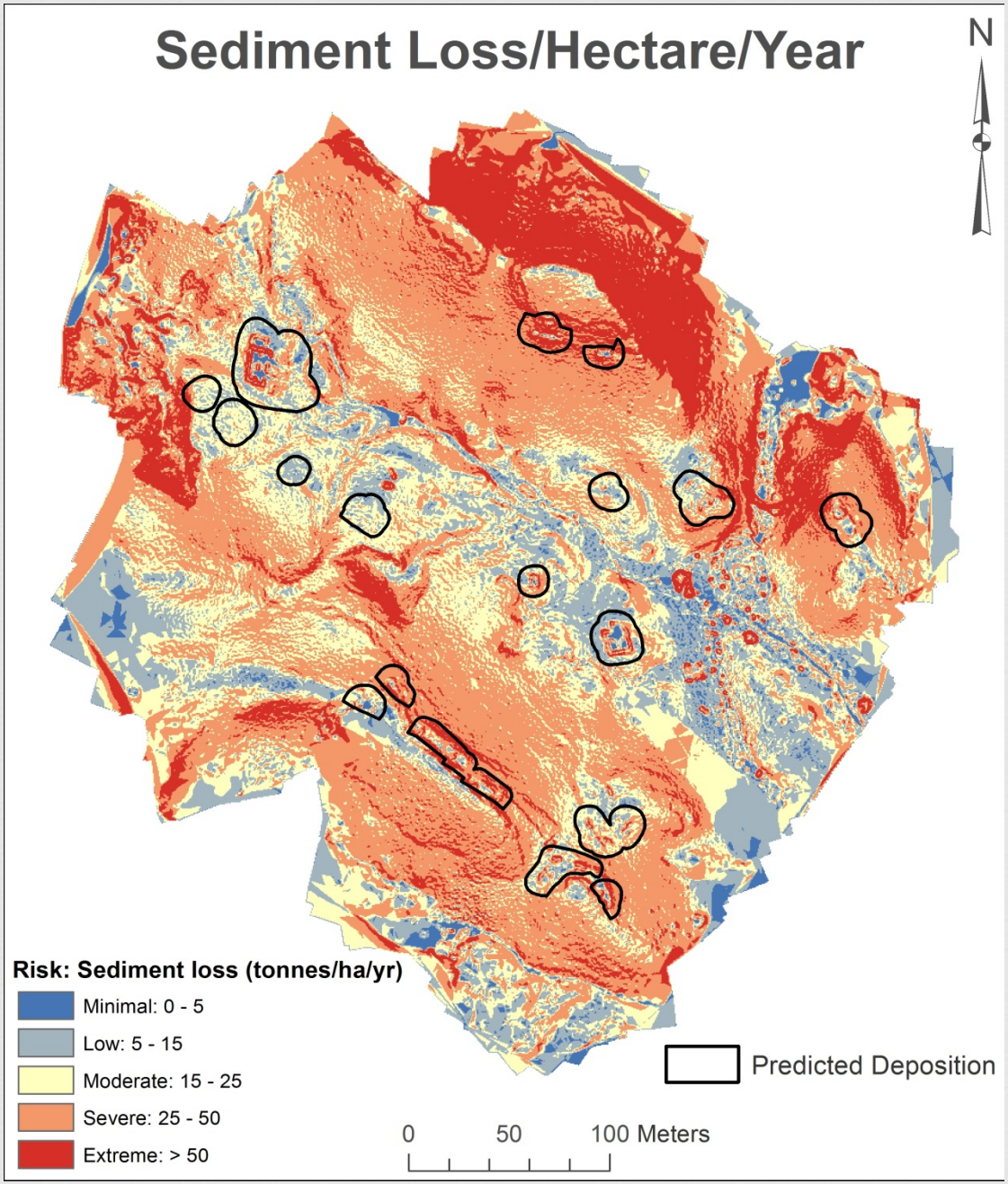


Quantifying Erosion

- Revised Universal Soil Loss Equation (RUSLE)
  - From soil science
  - Calculates soil loss/ha/year from variables:
    - **R**: rainfall erosivity factor
    - **K**: soil erodability factor
    - **LS**: Slope length and gradient factor
    - **C**: Cropping management factor
    - **P**: Conservation practices factor

RUSLE factors

- **R**: Rainfall Erosivity Factor
  - Calculated for site from annual rainfall data in Faynan
- **K**: Soil Erodability Factor
  - Estimated for site using soil survey information from agricultural fields near Khirbat Faynan
- **LS**: Slope Length and Gradient Factor
  - Calculated within GIS using SfM-produced DEM
- **C and P**: Cropping Management and Conservation Practices Factors
  - No cropping or conservation practices at KNA
- **RUSLE:** Soil loss/ha/year
  - Calculated in GIS by multiplying R, K, C, and P by LS raster.

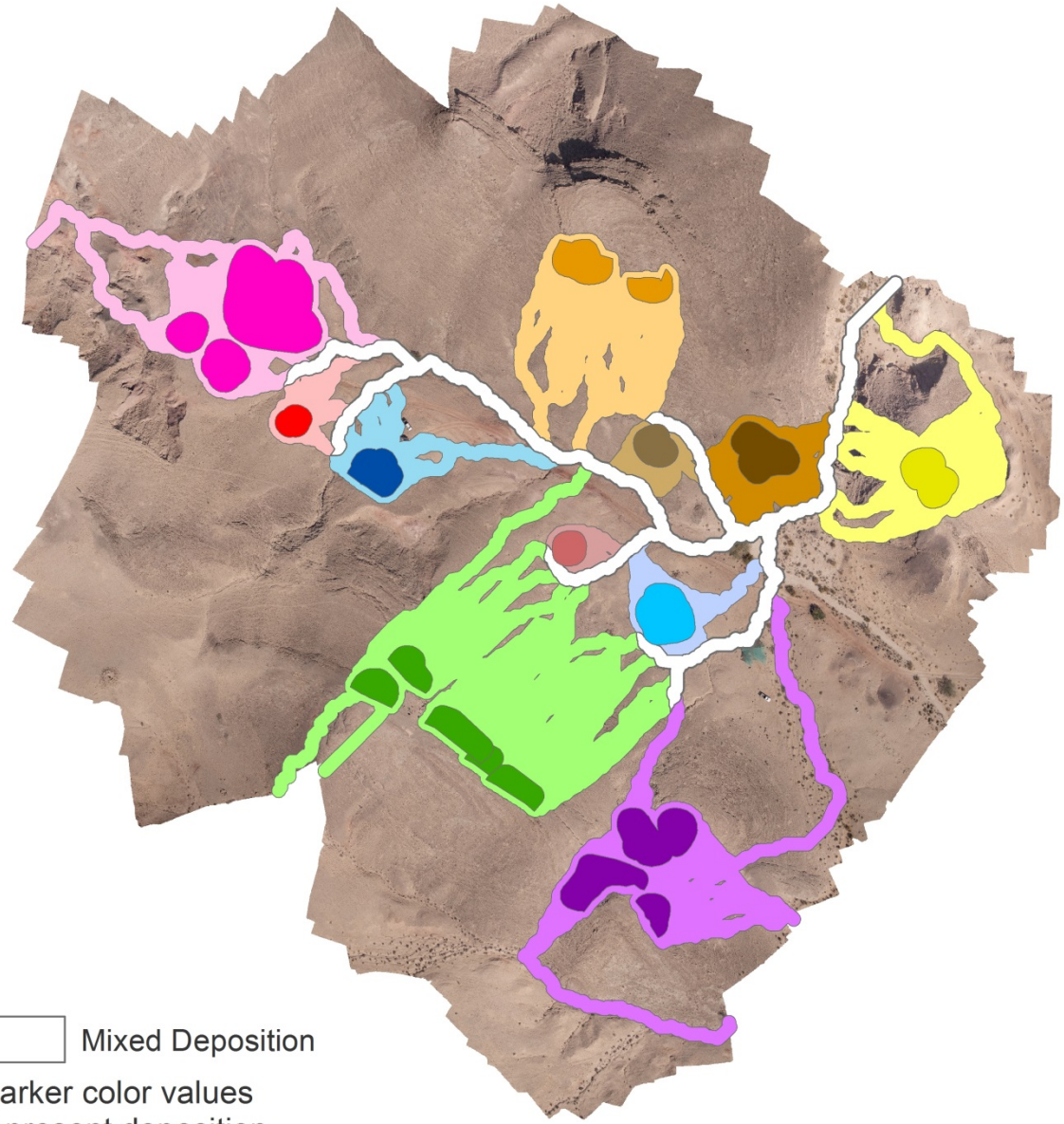


Risk Categories from Farhan et al 2013

Simulating Erosion Paths

- Prepare DEM for analysis
  - Sink removal
- Least cost path downhill from each area of simulated erosion
- Convert raster paths to polylines
- Buffer polyline

Erosional Deposition



Results

- Simulated erosion paths allow for the possibility of (loosely) associating eroded artifacts with original proveniences
  - Erosion paths linked to hypothetical deposition areas
- May provide explanation for concentrations of artifacts found away from structures
- Provides consideration of one type of n-transform's effects on the site at KNA

Evaluation of Technique

- Calculating Erosion Risk
  - Highly dependent on available data
- Simulating Erosion Paths
  - ca. 1.5 hours of field recording
  - ca. 8 hours of processing models
    - Depending on available hardware
  - ca. 2-3 hours of GIS analysis
- Cost-effective
  - Equipment can be scaled down substantially without significant loss of quality
- Survey tool

Future Work

- Potential to associate artifacts from surface survey (Jones et al 2012, in *BASOR*) with erosion models
- Possibility of measuring erosion through time
  - By comparison of DEMs recorded years apart
  - Empirically test erosion model
- Provides basis for an *a priori* understanding of effects of erosion on future sites

Questions?

Balloon Specifications

- 1-ply Kingfisher Aerostat K14U-SC balloon
- Dimensions: ca. 3.6 m x 3.0 m
- Volume: ca. 21.0 m^3
- Lift: ca. 13.6 kg
- Custom triangular frame with two 15.1 megapixel Canon EOS 50D DSLRs
  - 18mm lenses
- 800 lb. SPECTRA line tether