Initial Everglades Depth Estimation Network (EDEN) digital elevation model research and development

By John W. Jones and Susan D. Price

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Contents

Figures

Tables

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)
Area		
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
square inch (in^2)	6.452	square centimeter (cm^2)
section (640 acres or 1 square mile)	259.0	square hectometer (hm^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
Volume		
barrel (bbl), (petroleum, 1 barrel=42 gal)	0.1590	cubic meter (m^3)
ounce, fluid (fl. oz)	0.02957	liter (L)
pint (pt)	0.4732	liter (L)
quart (qt)	0.9464	liter (L)
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
gallon (gal)	3.785	cubic decimeter (dm^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
cubic inch (in^3)	16.39	cubic centimeter (cm^3)
cubic inch (in^3)	0.01639	cubic decimeter (dm^3)

cubic inch (in^3)	0.01639	liter (L)
cubic foot (ft^3)	28.32	cubic decimeter (dm^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
cubic mile (mi^3)	4.168	cubic kilometer (km^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
Flow rate		
acre-foot per day (acre-ft/d)	0.01427	cubic meter per second (m^3/s)
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year (hm^3/yr)
foot per second (ft/s)	0.3048	meter per second (m/s)
foot per minute (ft/min)	0.3048	meter per minute (m/min)
foot per hour (ft/hr)	0.3048	meter per hour (m/hr)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per year (ft/yr)	0.3048	meter per year (m/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]
cubic foot per day (ft^3/d)	0.02832	cubic meter per day (m^3/d)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
gallon per day per square mile [$(gal/d)/mi^2$]	0.001461	cubic meter per day per square kilometer [$(m^3/d)/km^2$]
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
million gallons per day per square mile [$(Mgal/d)/mi^2$]	1,461	cubic meter per day per square kilometer [$(m^3/d)/km^2$]
inch per hour (in/h)	0 .0254	meter per hour (m/h)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
mile per hour (mi/h)	1.609	kilometer per hour (km/h)
Mass		
ounce, avoirdupois (oz)	28.35	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	megagram (Mg)
ton, long (2,240 lb)	1.016	megagram (Mg)
ton per day (ton/d)	0.9072	metric ton per day
ton per day (ton/d)	0.9072	megagram per day (Mg/d)

ton per day per square mile [(ton/d)/mi^2]	0.3503	megagram per day per square kilometer [(Mg/d)/km^2]
ton per year (ton/yr)	0.9072	megagram per year (Mg/yr)
ton per year (ton/yr)	0.9072	metric ton per year
Pressure		
atmosphere, standard (atm)	101.3	kilopascal (kPa)
bar	100	kilopascal (kPa)
inch of mercury at 60ºF (in Hg)	3.377	kilopascal (kPa)
pound-force per square inch (lbf/in^2)	6.895	kilopascal (kPa)
pound per square foot (lb/ft^2)	0.04788	kilopascal (kPa)
pound per square inch (lb/in^2)	6.895	kilopascal (kPa)
Density		
pound per cubic foot (lb/ft^3)	16.02	kilogram per cubic meter (kg/m^3)
pound per cubic foot (lb/ft^3)	0.01602	gram per cubic centimeter (g/cm^3)
Energy		
kilowatthour (kWh)	3,600,000	joule (J)
Radioactivity		
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)
Specific capacity		
gallon per minute per foot [(gal/min)/ft)]	0.2070	liter per second per meter [(L/s)/m]
Hydraulic conductivity		
foot per day (ft/d)	0.3048	meter per day (m/d)
Hydraulic gradient		
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
Transmissivity*		
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
Application rate		
pounds per acre per year [(lb/acre)/yr]	1.121	kilograms per hectare per year [(kg/ha)/yr]
Leakance		
foot per day per foot [(ft/d)/ft]	1	meter per day per meter
inch per year per foot [(in/yr)/ft]	83.33	millimeter per year per meter [(mm/yr)/m]

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F=(1.8×°C)+32
Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C=(°F-32)/1.8
Vertical coordinate information is referenced to the insert datum name (and abbreviation) here for instance, "North American Vertical Datum of 1988 (NAVD 88)."
Horizontal coordinate information is referenced to the insert datum name (and abbreviation) here for instance, "North American Datum of 1983 (NAD 83)."
Altitude, as used in this report, refers to distance above the vertical datum.
*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.
Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).
Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).
NOTE TO USGS USERS: Use of hectare (ha) as an alternative name for square hectometer (hm^2) is restricted to the measurement of small land or water areas. Use of liter (L) as a special name for cubic decimeter (dm^3) is restricted to the measurement of liquids and gases. No prefix other than milli should be used with liter. Metric ton (t) as a name for megagram (Mg) should be restricted to commercial usage, and no prefixes should be used with it.

SI to Inch/Pound

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
Area		
square meter (m^2)	0.0002471	acre
hectare (ha)	2.471	acre
square hectometer (hm^2)	2.471	acre
square kilometer (km^2)	247.1	acre
square centimeter (cm^2)	0.001076	square foot (ft^2)
square meter (m^2)	10.76	square foot (ft^2)
square centimeter (cm^2)	0.1550	square inch (ft^2)
square hectometer (hm^2)	0.003861	section (640 acres or 1 square mile)
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
Volume		
cubic meter (m^3)	6.290	barrel (petroleum, 1 barrel = 42 gal)
liter (L)	33.82	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	264.2	gallon (gal)
cubic decimeter (dm^3)	0.2642	gallon (gal)
cubic meter (m^3)	0.0002642	million gallons (Mgal)
cubic centimeter (cm^3)	0.06102	cubic inch (in^3)
cubic decimeter (dm^3)	61.02	cubic inch (in^3)
liter (L)	61.02	cubic inch (in^3)
cubic decimeter (dm^3)	0.03531	cubic foot (ft^3)
cubic meter (m^3)	35.31	cubic foot (ft^3)
cubic meter (m^3)	1.308	cubic yard (yd^3)

cubic kilometer (km^3)	0.2399	cubic mile (mi^3)
cubic meter (m^3)	0.0008107	acre-foot (acre-ft)
cubic hectometer (hm^3)	810.7	acre-foot (acre-ft)
Flow rate		
cubic meter per second (m^3/s)	70.07	acre-foot per day (acre-ft/d)
cubic meter per year (m^3/yr)	0.000811	acre-foot per year (acre-ft/yr)
cubic hectometer per year (hm^3/yr)	811.03	acre-foot per year (acre-ft/yr)
meter per second (m/s)	3.281	foot per second (ft/s)
meter per minute (m/min)	3.281	foot per minute (ft/min)
meter per hour (m/hr)	3.281	foot per hour (ft/hr)
meter per day (m/d)	3.281	foot per day (ft/d)
meter per year (m/yr)	3.281	foot per year ft/yr)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
cubic meter per second per square kilometer [(m^3/s)/km^2]	91.49	cubic foot per second per square mile [(ft^3/s)/mi^2]
cubic meter per day (m^3/d)	35.31	cubic foot per day (ft^3/d)
liter per second (L/s)	15.85	gallon per minute (gal/min)
cubic meter per day (m^3/d)	264.2	gallon per day (gal/d)
cubic meter per day per square kilometer [(m^3/d)/km^2]	684.28	gallon per day per square mile [(gal/d)/mi^2]
cubic meter per second (m^3/s)	22.83	million gallons per day (Mgal/d)
cubic meter per day per square kilometer [(m^3/d)/km^2]	0.0006844	million gallons per day per square mile [(Mgal/d)/mi^2]
cubic meter per hour (m^3/h)	39.37	inch per hour (in/h)
millimeter per year (mm/yr)	0.03937	inch per year (in/yr)
kilometer per hour (km/h)	0.6214	mile per hour (mi/h)
Mass		
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
megagram (Mg)	1.102	ton, short (2,000 lb)
megagram (Mg)	0.9842	ton, long (2,240 lb)
metric ton per day	1.102	ton per day (ton/d)
megagram per day (Mg/d)	1.102	ton per day (ton/d)
megagram per day per square kilometer [(Mg/d)/km^2]	2.8547	ton per day per square mile [(ton/d)/mi^2]
megagram per year (Mg/yr)	1.102	ton per year (ton/yr)
metric ton per year	1.102	ton per year (ton/yr)
Pressure		

kilopascal (kPa)	0.009869	atmosphere, standard (atm)
kilopascal (kPa)	0.01	bar
kilopascal (kPa)	0.2961	inch of mercury at 60°F (in Hg)
kilopascal (kPa)	0.1450	pound-force per inch (lbf/in)
kilopascal (kPa)	20.88	pound per square foot (lb/ft^2)
kilopascal (kPa)	0.1450	pound per square inch (lb/ft^2)
Density		
kilogram per cubic meter (kg/m^3)	0.06242	pound per cubic foot (lb/ft^3)
gram per cubic centimeter (g/cm^3)	62.4220	pound per cubic foot (lb/ft^3)
Energy		
joule (J)	0.0000002	kilowatthour (kWh)
Radioactivity		
becquerel per liter (Bq/L)	27.027	picocurie per liter (pCi/L)
Specific capacity		
liter per second per meter [(L/s)/m]	4.831	gallon per minute per foot [(gal/min)/ft]
Hydraulic conductivity		
meter per day (m/d)	3.281	foot per day (ft/d)
Hydraulic gradient		
meter per kilometer (m/km)	5.27983	foot per mile (ft/mi)
Transmissivity*		
meter squared per day (m^2/d)	10.76	foot squared per day (ft^2/d)
Application rate		
kilograms per hectare per year [(kg/ha)/yr]	0.8921	pounds per acre per year [(lb/acre)/yr]
Leakance		
meter per day per meter [(m/d)/m]	1	foot per day per foot [(ft/d)/ft]
millimeter per year per meter [(mm/yr)/m]	0.012	inch per year per foot [(in/yr)/ft]

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Introduction

The Everglades Depth Estimation Network (EDEN) offers a consistent and documented dataset that can be used to guide large-scale field operations, to integrate hydrologic and ecological responses, and to support biological and ecological assessments that measure ecosystem responses to the Comprehensive Everglades Restoration Plan (Telis, 2006). To produce historic and near-real time maps of water depths, the EDEN requires a system-wide digital elevation model (DEM) of the ground surface. Accurate Everglades wetland ground surface elevation data were non-existent before the U.S. Geological Survey (USGS) undertook the collection of highly accurate surface elevations at the regional scale. These form the foundation for EDEN DEM development. This development process is iterative as additional high accuracy elevation data (HAED) are collected, water surfacing algorithms improve, and additional ground-based ancillary data become available. Models are tested using withheld HAED and independently measured water depth data, and by using DEM data in EDEN adaptive management applications. Here the collection of HAED is briefly described before the approach to DEM development and the current EDEN DEM are detailed. Finally future research directions for continued model development, testing, and refinement are provided.

Model Input: Highly Accurate Elevation Data

No standard ground elevation data products are accurate enough for EDEN and other Everglades science and restoration requirements; therefore, the USGS had to create a new database of HAED. Following discussions with other scientists and potential users of HAED and considering the balance of hydrodynamic model development requirements and cost, a horizontal distance between collected elevation points of approximately 400m and a vertical accuracy of +/-15cm were specified for HAED. To create such a data base for the Everglades Region, two methods were used. Approximately 11,000 elevation points were collected by deploying surveyors on airboats. While conventional and easily understood, this approach has several disadvantages. First and foremost, its use throughout the entire Everglades system might cause significant negative impacts on Everglades vegetation and animals. In addition it is very time consuming and therefore expensive given a large region like the Everglades. As an alternative the USGS developed a system called the "Airborne Height Finder" (AHF – figures 1 and 2). The AHF has been deployed in a series of survey campaigns to collect over 43,000 HAED points covering the Everglades National Park and most of the Water Conservation Areas. These data were combined with the airboat-collected points to create an elevation data base for the Everglades region (figure 3). An example from one USGS quadrangle in which both airboat and AHF HAED data were collected is shown in figure 4. As data collection has occurred over a 10-year period, the AHF system has been refined, and specific attribute information collected for individual points has increased. Also some AHF data were collected to replace some elevation values measured using airboats or to address specific topography issues identified by hydrologic and biologic research. Given these developments and applications-specific data collection campaigns, disparate HAED files were created. Part of the EDEN DEM development included the reprocessing and quality assessment of these various data sets. As a result more than 70 separate HAED data files were merged into a single file using geographic information system (GIS) processing methods. During this process data for areas that were re-flown by the AHF were replaced, and a unified attribute file was produced. The resulting spatial and attribute data were processed through a final quality assurance and quality control process to produce consistent, high-quality input for EDEN DEM development.

Model Development Approach

The development of DEMs for use in EDEN applications, as well as other hydrologic and ecologic modeling and adaptive management, has been an iterative process. Prior to the EDEN project a DEM for an area beyond those of EDEN modeling (i.e., including coastal regions influenced by tides) was produced using the ESRI ARCGIS topogrid algorithm[1] (figure 5). This algorithm relies on spline interpolation that is modified to produce a "hydrologically correct" DEM. While visually pleasing and sufficient for regional scale analysis, this model is not suitable for the sub-regional and finer-scale quantitative analyses envisioned for EDEN outputs. For example while the spline approach honors the individual HAED values (i.e., spline surface elevations are exactly those of the input points at the input point locations), topogrid can generate false peaks and pits along regions where drastic changes in elevations occur and channels are not supported by actual ground measurements. Figure 6 depicts a small area in which water depth estimates have been created using the DEM produced by topogrid. While the dendritic drainage pattern depicted may seem plausible, it is not supported by field measurements and suggests resolution in the data that do not exist. Also when applied to the entire HAED dataset at once, the spline process fails to adequately represent topographic breaks that occur along the boundaries of Water Conservation Areas where levees, canals, and service roads interrupt the natural gradients presumably present prior to development of the water control infrastructure.

To create a more realistic region-wide elevation model for EDEN purposes, the elevation data were segregated by Water Conservation Areas and National Park boundaries so that local trends could be isolated, sub-region specific interpolation models could be developed, and realistic breaks in elevation along sub-region boundaries could be imbedded in a final, region-wide DEM. For each EDEN sub-area (figure 7), several surfacing algorithms that are more conservative than topogrid (when interpolating between known elevations) were evaluated. Outputs from these different methods were evaluated through three approaches. First, for each sub-region 15 percent of the points were withheld from the model development for their respective area before numerous interpolation methods and parameters within interpolation methods were specified using the remaining 85 percent of HAED points. The withheld points were then used as a "check" of simulated elevation values by comparing generated surfaces against their values. Next all HAED were included in sub-area model development and cross-validation was applied. In this process the software iteratively compares modeled surfaces to those of the input points used to create the

[1] Use of product and trade names is for illustrative and informational purposes only and does not represent an endorsement by the U.S. Government.

surface[2]. Water depths are created by subtracting the generated DEM from water surfaces that were interpolated from EDEN gage data; these depths are compared against estimated depths gathered by various principal investigators (i.e., “PI data”) during field campaigns. Based on these evaluations and consideration of the utility of other diagnostic surfaces that are created as by-products of various interpolation processes, a “best” model is selected for each sub-area. Finally selected sub-area models are combined to create an EDEN regional DEM. The steps used in surface modeling can be summarized as follows:

1) Subset the HAED by EDEN sub-areas.
2) Randomly extract 15percent of the HAED points from the set of observations associated with each EDEN sub-area.
3) Create numerous models for each sub-area using different surface interpolation methods.
4) Compare elevations interpolated using each method against those of the data points withheld during model development.
5) Based on error analysis select the "best" method for each EDEN sub-area.
6) Given the best method selected use ALL available HAED points to generate numerous elevation models for each sub-area by varying within-method modeling parameters.
7) Create depth layers for specific wet and dry days by subtracting modeled ground elevation surfaces from water height surfaces interpolated from recorded EDEN gage data.
8) Compare modeled water depths against field-estimated water depths.
9) Select the best performing elevation model for each sub-area.
10) Combine the chosen sub-area models to create one single EDEN elevation model.
11) As new HAED and field measurements of water depth become available, return to Step 1.

Results

Table 1 shows the different root mean square errors (RMSE) produced and variance in withheld data points explained by elevation models produced by three different methods for WCA 1. Table 2 provides the RMSE generated through cross-validation by the best performing model used in each EDEN sub-region. The different water depth layers produced by three different elevation modeling methods for the same large-scale area are evident in figure 6, 8 and 9.

Method	RMSE (meters)	R^2
Topogrid	0.1514	0.59
RBF	0.1212	0.64
Kriging	0.1056	0.69

Table 1. Root mean squared error (RMSE) in meters and variance explained (R^2) in withheld data points by models created for Water Conservation Area 1 (WCA1) by different surfacing algorithms. “Topogrid” is the hydrologic surfacing algorithm incorporated in ESRI software. “RBF” references radial based function interpolation. “Kriging” references ordinary kriging with an anisotropic model.

To-date the best performing DEMs for all sub-areas have been produced using the geostatistical approach called “anisotropic ordinary kriging”. This method consistently produced the lowest error

[2] Cross-validation only applies to techniques that do not honor the actual elevation value at the observed point in creating the estimated surface.

for the 15 percent of withheld points and during cross-validations. It has the added advantage of producing standard error maps (e.g., figure 10). The standard error map is one of several variables used to index the quality of water depth estimates both across space and through time. This helps users of EDEN output to assess the utility of depth estimates for particular places and time periods.

Compartment	RMSE (meters)	Direction (degrees)
WCA-1	0.1616	309
WCA-2	0.1141	92
WCA-3AN	0.0975	60
WCA-3AS	0.1146	29
WCA-3B	0.0887	32
BCNP	0.1297	94
ENP	0.1311	298

Table 2. Root mean squared error (RMSE) in meters produced through cross-validation for ordinary kriging as applied to each EDEN sub-area. These models were anisotropic and the "Direction" column indicates the axis (in degrees) of anisotropy for each sub-area model.

File naming conventions

The modeling and evaluation approaches are repeatedly applied at the level of individual EDEN sub-areas (figure 7) as additional HAED or PI data become available. Revised sub-area DEMs are then merged into the regional EDEN DEM. This flexibility adds complexity that must be balanced through organized data management. To help track the various improvements to the EDEN DEM, a specific naming convention was developed. For example figure 11 shows an iteration of the EDEN DEM that is internally referenced by the EDEN research team as "EDEN_DEM_v2c". This indicates that this DEM is the third modification (c) of the second generation (v2) of digital elevation modeling techniques (i.e., the HAED data available at the time of its creation and the application of kriging to each EDEN sub-area as described in this report). Following EDEN_DEM_v2c's assessment and additional use in trial applications, EDEN collaborators felt that its performance was superior in all EDEN sub-areas except for WCA1 (figure 7), where the EDEN_DEM_v2a produced lower depth estimate errors across a variety of water level conditions (Lovejoy Palaseanu, per. com., 2006). Therefore, a "hybrid" DEM was created using the WCA1 area model from EDEN_DEM_v2a and the EDEN_DEM_v2c models for all other sub-areas (internally named "EDEN_DEM_v2d"). While this naming convention is consistent and meaningful for EDEN team members, it is unnecessarily complex and not particularly meaningful for EDEN applications users. Release and operational versions of EDEN DEMs are therefore named according to the month and year they are put into operational use and officially released. Because commonly used GIS software impose a 13-character file name limit, a convention of "EDEN_EM_MMMYR" where EM stands for "elevation model", MMM represents "month", and YR designates the year, is used. Therefore, upon release EDEN_DEM_v2d was named "EDEN_EM_JAN07" (figure 12).

Data documentation and distribution

GIS cataloging capabilities are used to document every DEM created for EDEN. Each contains metadata that includes information on the intended use, date of production, modifications from previous DEM versions, and spatial characteristics. A separate metadata file that meets Federal Geographic Data Committee spatial metadata standards is associated with each release DEM version (such as EDEN_EM_JAN07). This open file report documents the approach used to create release EDEN DEMs. Future DEM releases will reference this file for those interested in the approach used to generate them. If EDEN DEM production methods change significantly from those documented here (e.g., with the use of satellite or airborne remote sensed data for DEM interpolation), a new open file report will be published to document the revised approach. Release DEMs are freely distributed through the South Florida Information Access website (http://sofia.usgs.gov/eden/models/groundelevmod.php).

Future plans

Because we are interested in simulating water depths at the sub-400m resolution, future plans include the development of pseudo-topography using statistical examination of more than 54,000 HAED as a function of vegetation type. For some areas of the Everglades vegetation type has been noted at the location of each HAED measurement by the AHF operator. Results from preliminary analyses using approximately 3,500 elevation and vegetation points for WCA3 are provided in figure 13, a box-plot showing which land cover classes are separable by elevation (as provided by the AHF). Vegetation cover types mapped at approximately 30-meter spatial resolution can be derived using Landsat satellite data for the Greater Everglades region. In combination with modeled depth surfaces observed relationships between topography and these vegetation types may be used to synthesize higher-resolution elevation models. A primary challenge in this process will be the proper segmentation of land cover and HAED to derive meaningful local-area vegetation-elevation relationships.

Acknowledgements

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Lovejoy Palaseanu , M., 2006, Personal communication regarding DEM performance in EDEN application tools.

Telis, P.A., 2006, The Everglades Depth Estimation Network (EDEN) for Support of Ecological and Biological Assessments: U.S. Geological Survey Fact Sheet 2006-3087, 4 p.

Figures

Figure 1. The airborne height finder (AHF) system as installed in a helicopter. The system control panel is evident in the center of the photograph. The plate and plumb-bob system reside just forward of the seat.

Figure 2. Pre-mission testing of the AHF just following lift-off. The operator calibrates and drops the plumb-bob from the leveling plate and when the cable reaches a specified resistance, the global positioning system (GPS) captures the horizontal and vertical position. Post-processing yields vertical accuracies that are better than +/- 15cm.

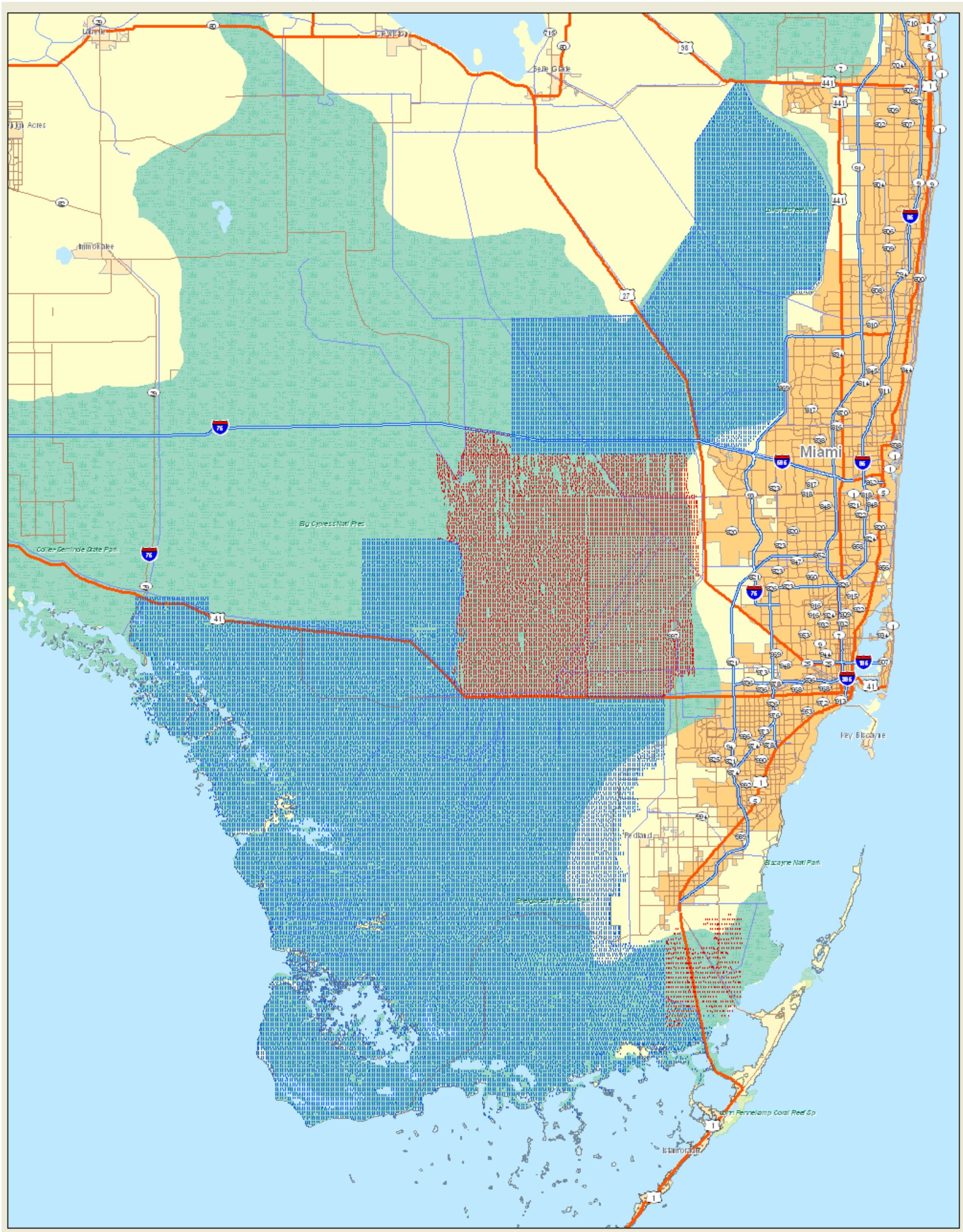

Figure 3. Regional coverage of the high accuracy elevation database (HAED) as of summer of 2006. Red points were collected via airboat (note missing values occur where upland/tree island areas are found). Blue points were collected using the AHF. Upland and highly vegetated areas do not pose a problem for the AHF.

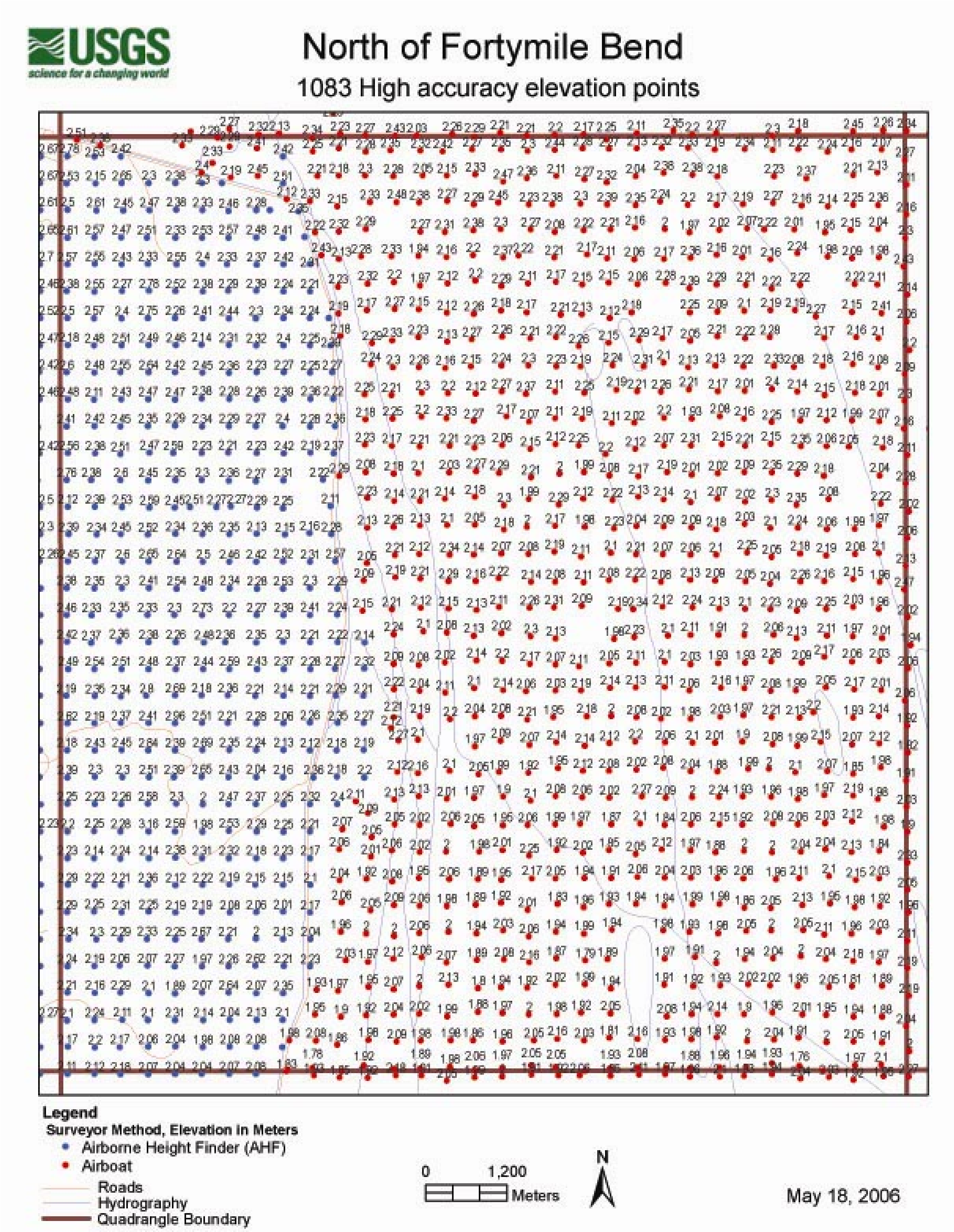

Figure 4. Just one 7.5-minute quadrangle area of HAED extracted from the database. As in the previous figure red points denote elevation data collected via airboat, and blue points represent AHF observations. As additional funds became available the AHF was redeployed to fill in some areas not easily covered by airboat.

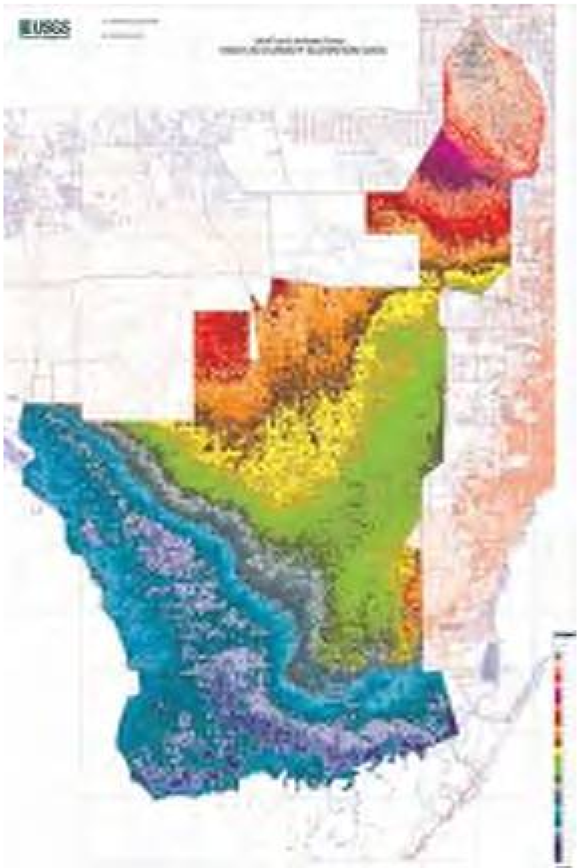

Figure 5. A regional DEM created using the TOPOGRID algorithm. While visually appealing and useful for region-wide analysis, this DEM is not suitable for higher-resolution EDEN applications.

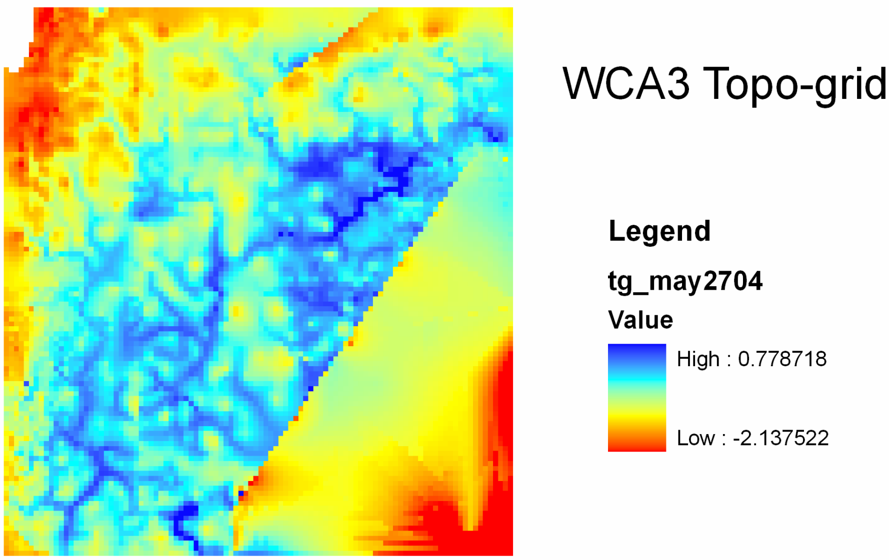

Figure 6. Modeled water depth for a small area of Water Conservation Area 3 (indicated with a star symbol on figure 7) produced by subtracting the DEM produced using the TOPOGRID algorithm from the water surface elevation model created from EDEN water level data for May 27, 2004. This DEM suggests a channel network that cannot be validated with available data. More conservative results from other approaches are depicted in the figures 8 and 9.

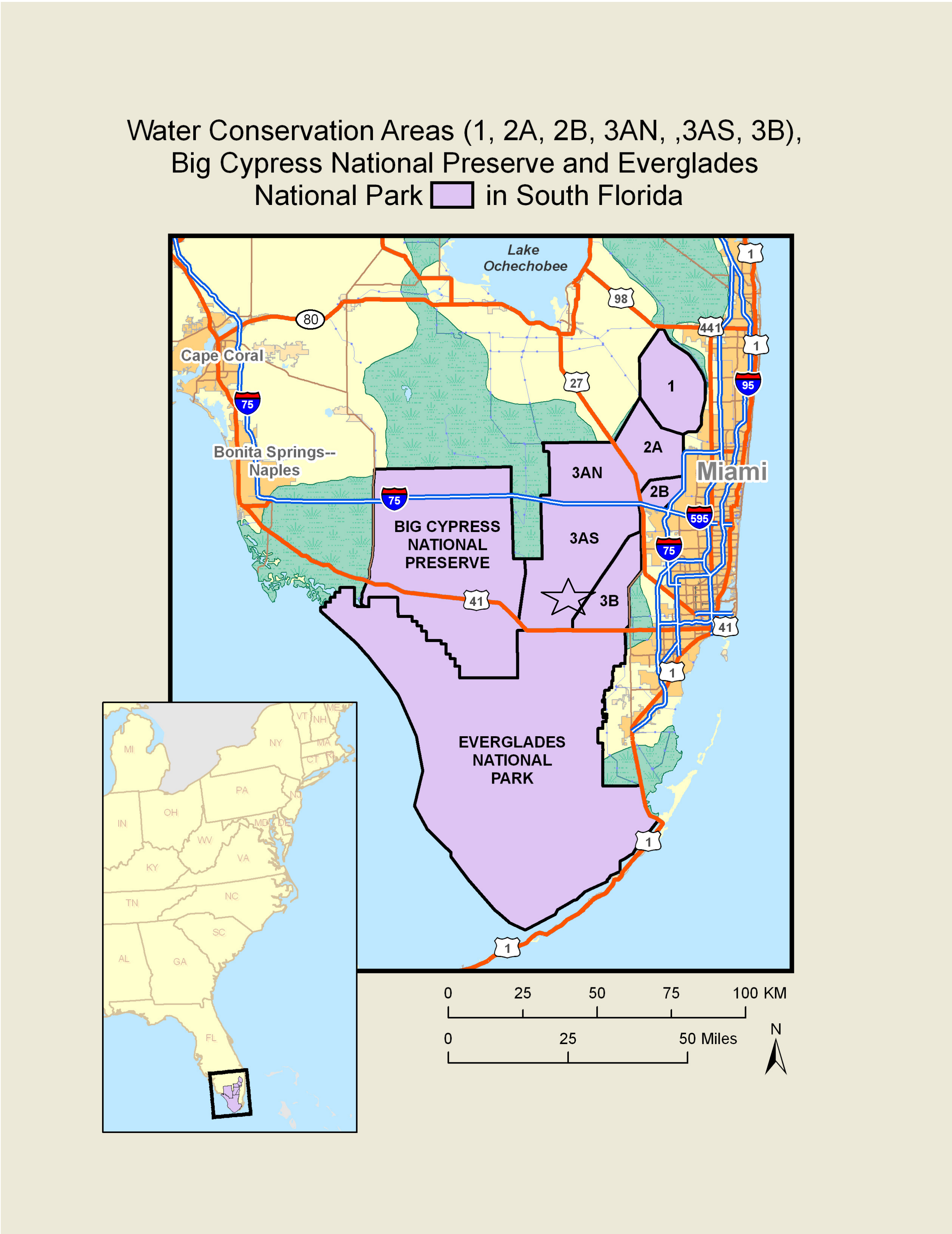

Figure 7. A location map depicting the Greater Everglades region, EDEN DEM processing sub-regions and the location of method comparison referenced in figures 6, 8, and 9 (shown by star).

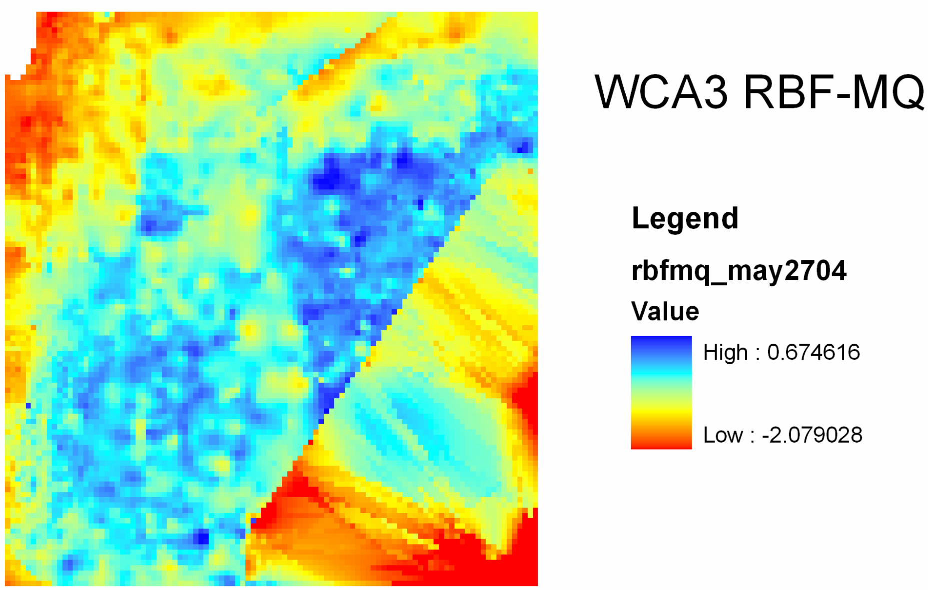

Figure 8. Modeled water depth (for the location noted by a star in figure 7) for May 27, 2004 using the DEM produced through Radial Based Function - Multiquadratic approach from EDEN water surface lvel for May 27, 2004 (compare with figures 6 and 9).

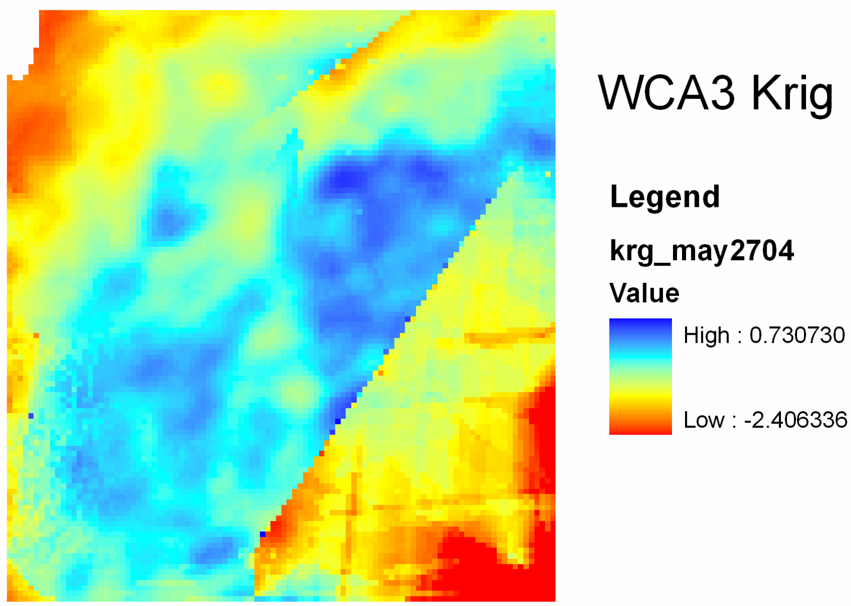

Figure 9. Modeled water depth using a DEM produced through anisotropic ordinary kriging subtracted from EDEN-water level for May 27, 2004 (compare with figures 6 and 7).

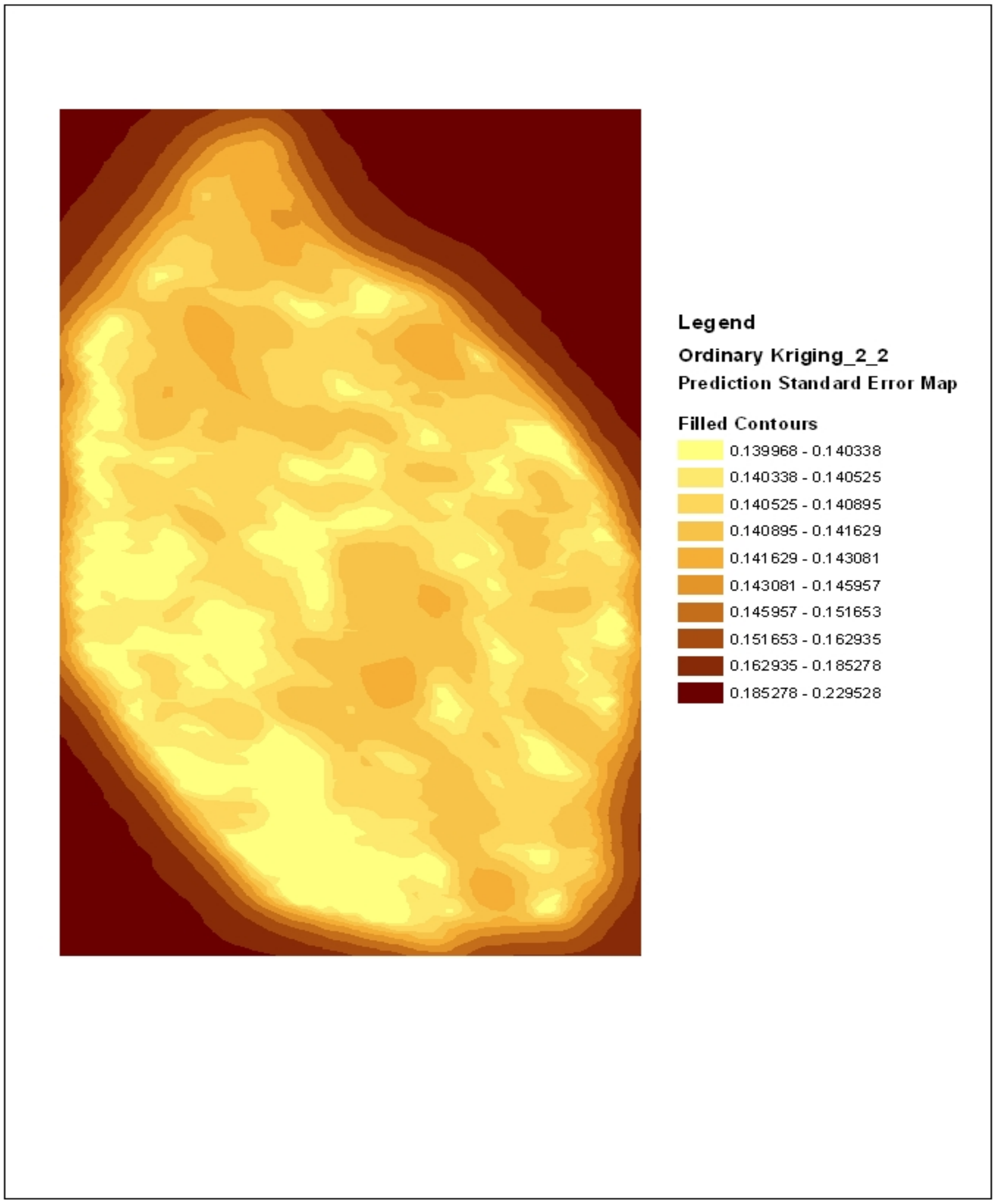

Figure 10. Standard error of estimates (in meters) produced for Water Conservation Area 1 (see figure 7 for WCA1's location) through ordinary kriging. With the highest relief and tree island coverage this area is the most difficult to model and yields the greatest standard errors. Ordinary kriging has the benefit of producing this information, which can be used in assigning confidence index values for depth estimates.

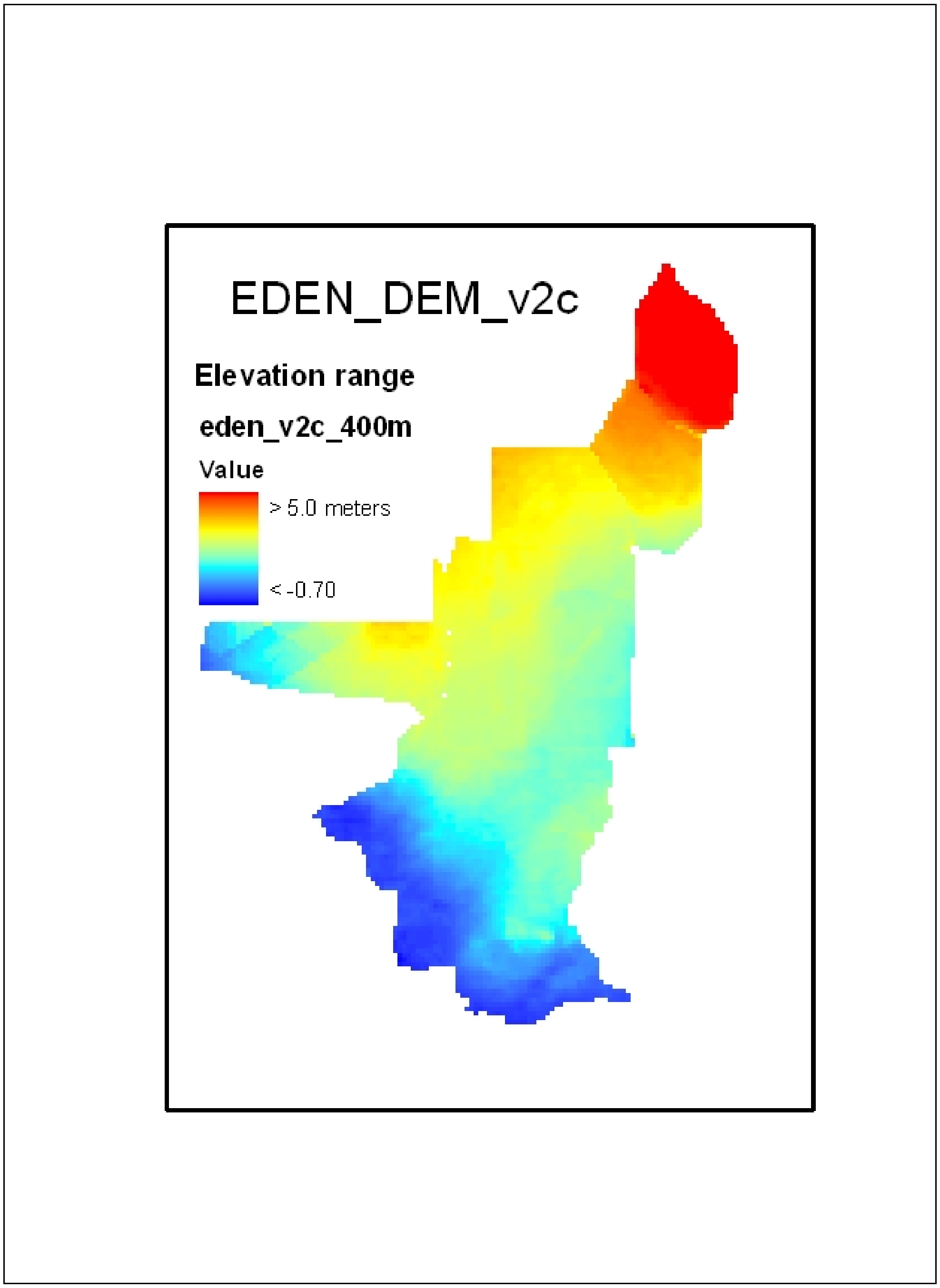

Figure 11. The EDEN DEM (with units of meters) used in EDEN water depth and hydroperiod modeling research as of summer 2006.

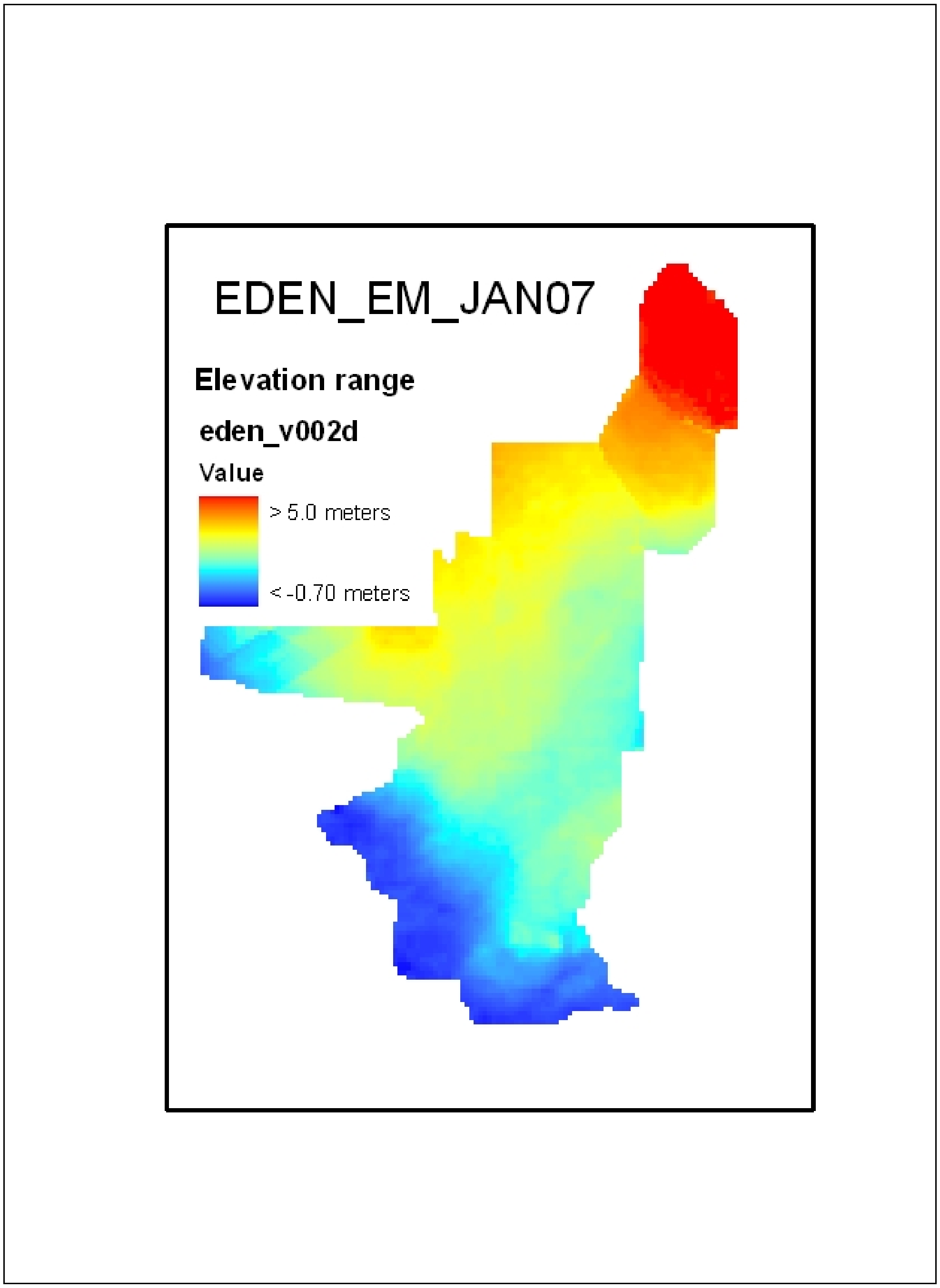

Figure 12. EDEN DEM used in operational depth estimation/EDEN applications and released in January of 2007.

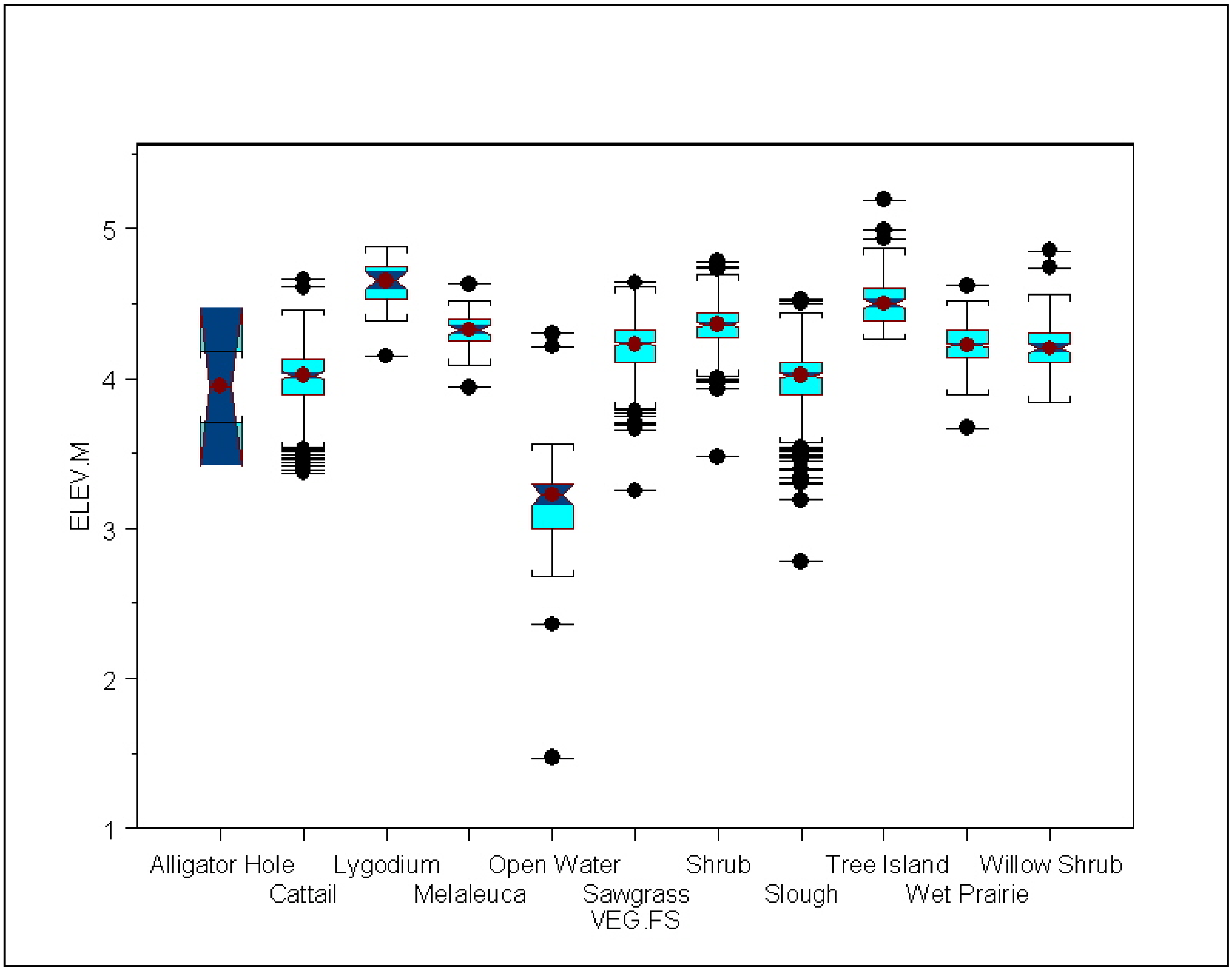

Figure 13. Boxplot of Water Conservation Area 1 (WCA1) vegetation classes as interpreted by the AHF operator during collection ("VEG.FS" along the X-axis) verses elevation in meters ("ELEV.M" along the Y-axis). The total number of observations is 3,537. Generally the large number of points collected by the AHF allows for narrow 95 percent confidence intervals (shown as notches in the boxes) about the median elevation value for each vegetation class. These relationships may be exploited along with remote sensed vegetation cover maps to create higher-resolution, synthetic elevation information.