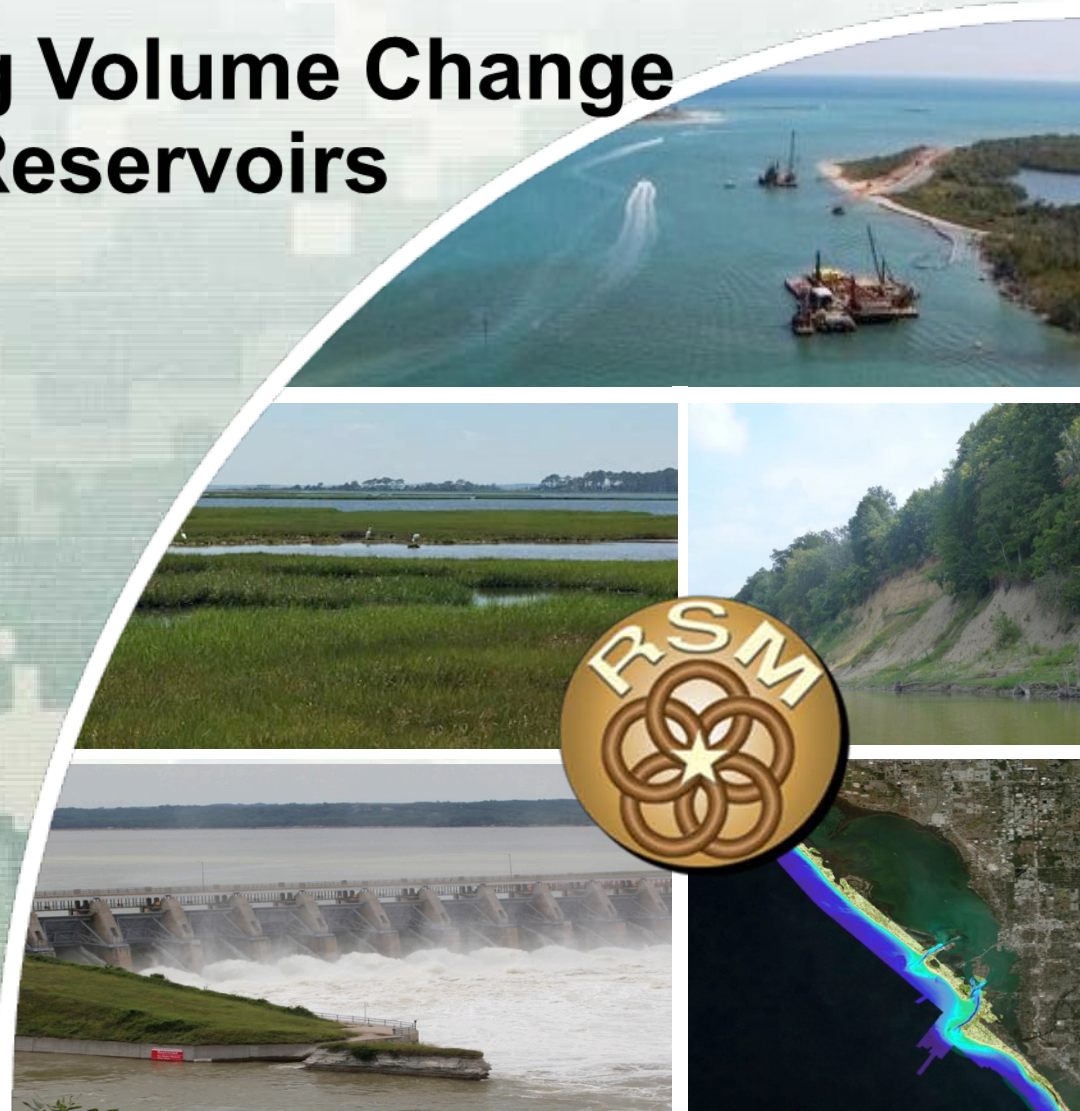


Reservoir Sediment Management & Analysis for Engineers

Computing Volume Change In Reservoirs

University of Kansas
LEEP2 Building – Room G415
June 11-15, 2018

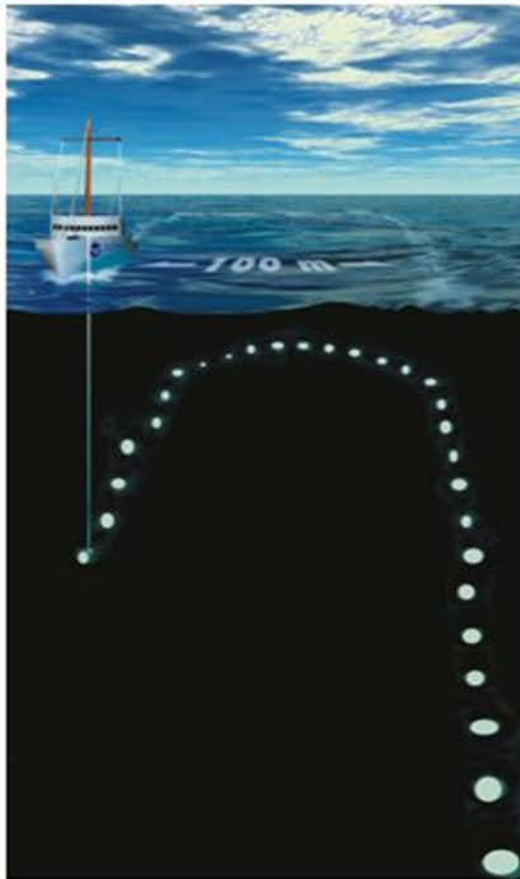


Computing Volume Change in Reservoirs

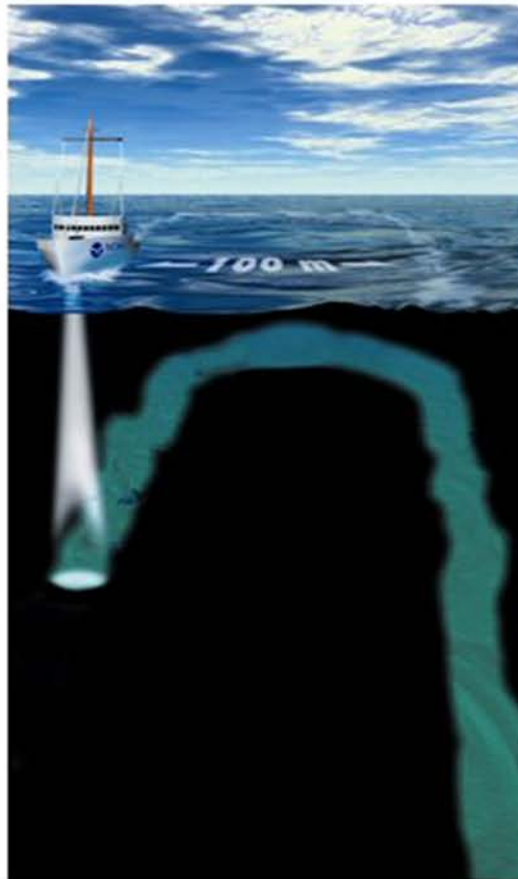
- Data Collection
- Analysis
- Outputs
- Comparison of Methodologies



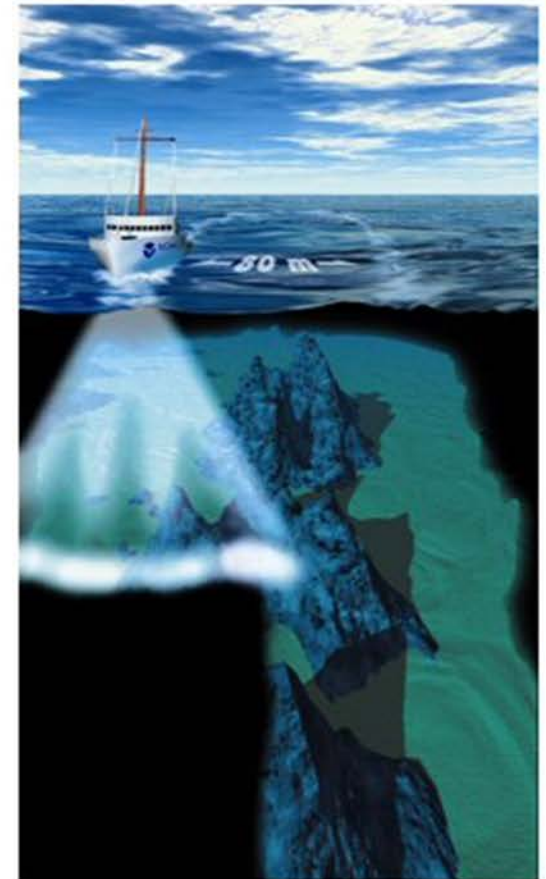
100+ years of Hydrosurveying



**Leadline
Surveys**



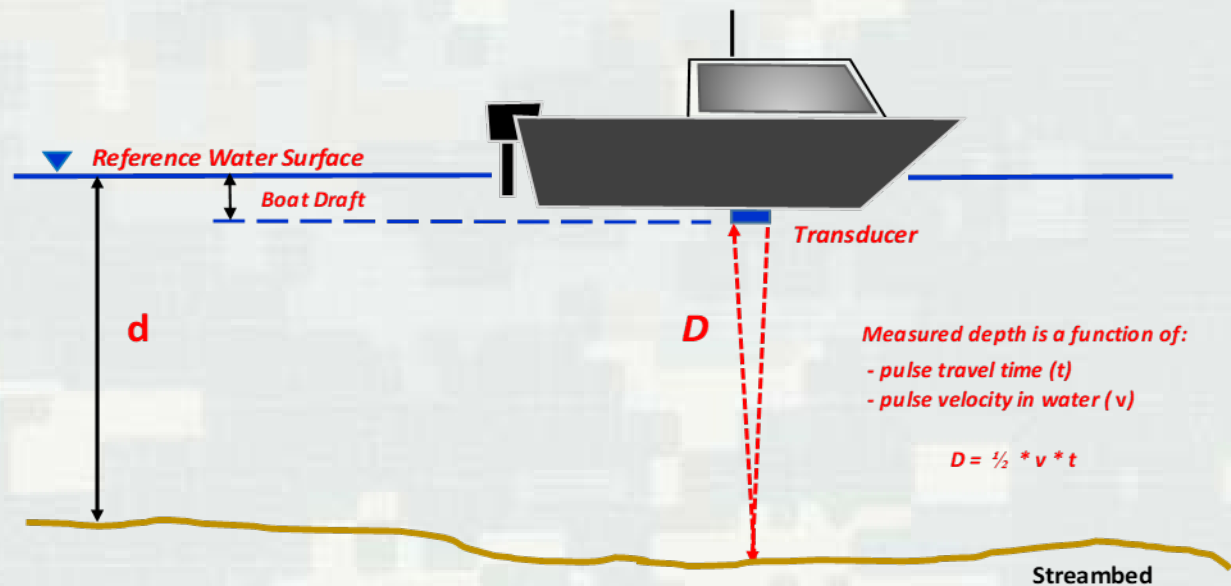
**Single Beam Echo
Sounder Surveys**



**Multibeam Full
Bottom Coverage**



Area-Capacity Analysis using Sediment Rangelines

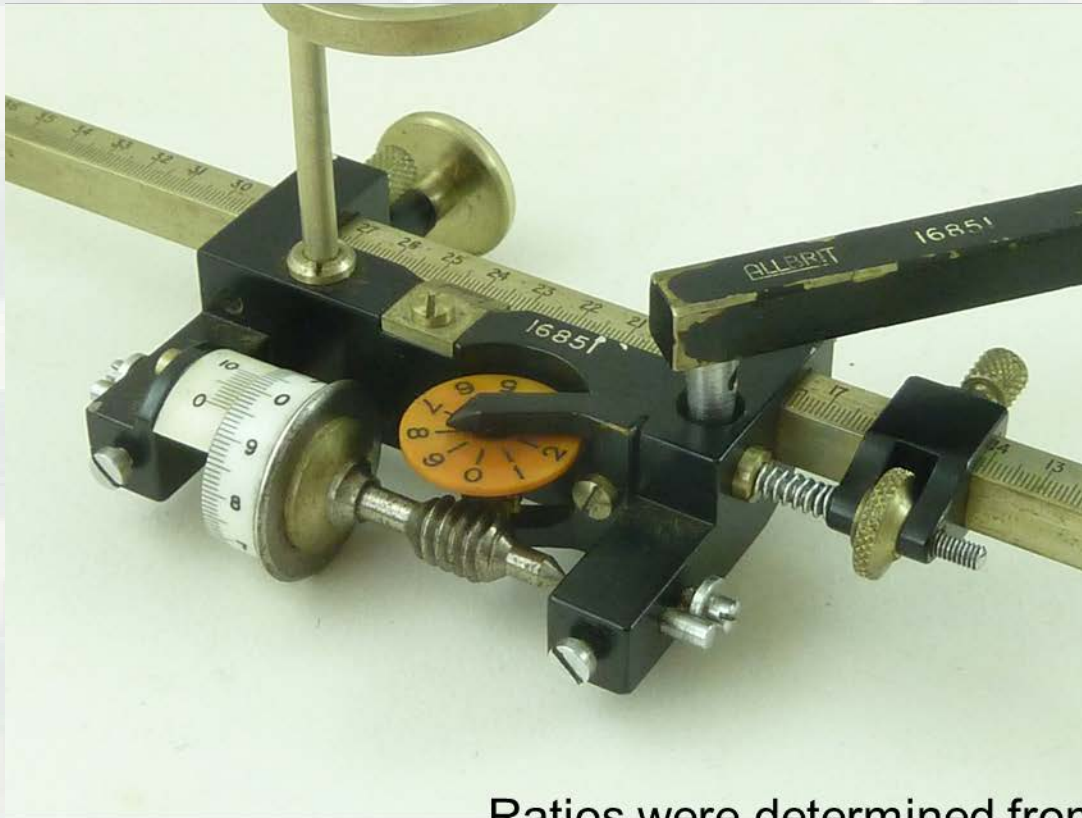


Surface Area & Storage Calculations using the Modified Average End Area Method

- The *constant factor method* is used by the Omaha District for determining reservoir surface area and storage capacity by elevation. This is a modification of the traditional “*average-end-area*” method, adjusted to include factors that take into account the non-uniformity of storage volume between the bounding sediment ranges
- the constant factor (also referred to as “ratio”) obtained is simply a ratio of the original volume to the sum of the original end areas.
- Ratios are develop for the ‘empty’ reservoir condition and then applied to all subsequent surveys to record changes in the volume in each control volume.



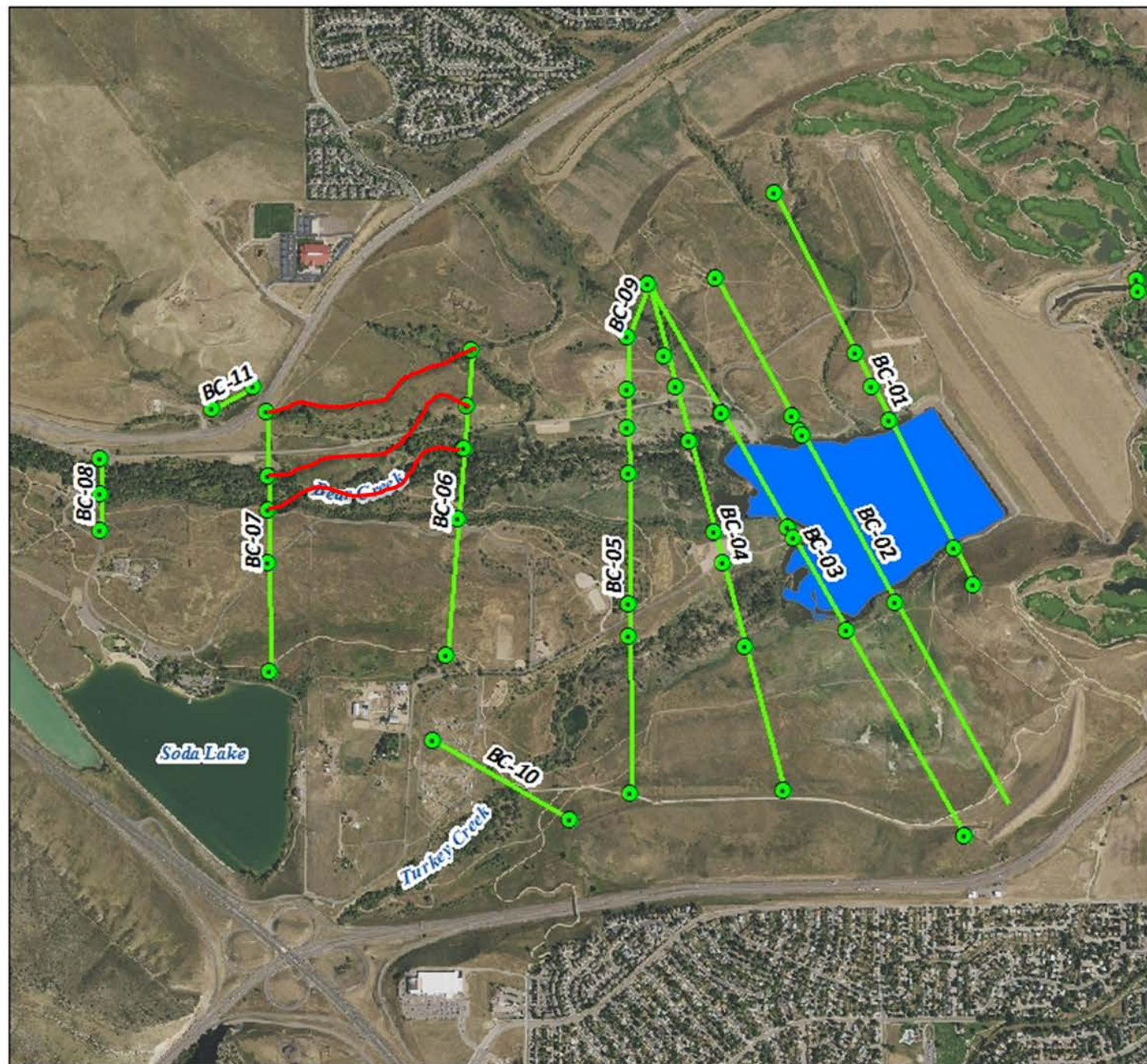
Sampling Error?



Ratios were determined from planimeter measurements from printed maps.

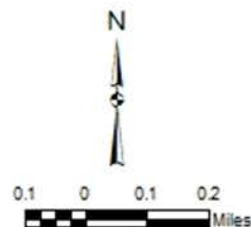


BEAR CREEK LAKE Sediment Range Location Map



Legend

- Bear Creek Lake
- Survey Control Points
- Sediment Ranges



Disclaimer: The United States government and USACE furnishes this data and the recipient accepts and uses it with the express understanding that the government makes no warranties, expressed or implied, concerning the accuracy, completeness, reliability, usability, or suitability for any particular purpose of the information and data furnished. The United States shall be under no liability whatsoever to any person by reason of any use made thereof. Data displayed on this map are approximations derived from GIS layers and should not be used in place of survey data or legal land descriptions.

River & Reservoir Engineering Section OSN WO-40-46F

Produced By:
Lawrence J. Morong
Production Date:
06 Oct 17
Revised By:
Revision Date:



File Location: [RARE]

Source:

Area-Capacity Calculations

- The capacity calculations were originally part of a four part software package written in FORTRAN programming language that was developed by the USACE Omaha District in 1960's and 1970's to operate on mainframe computers
- The *AreaCapacity* Program was updated in 2013 to calculate reservoir surface area and storage capacity tables plus manipulate sediment range data and sediment samples

Table 4-4 OUP Program with the Original FORTRAN Programs and Current Packages

Sieve Analysis (Package A)	Cross-Section Analysis (Package B)	Area-Capacity Analysis (Package C)
Bed Sediment Sample Utilities	Data Conversion, Formatting, & Water Analysis	Reservoir Volume Calculations
BEDWRITE	DSSHYDEL	AREA-CAPACITY
BED	XYCOORD	SATOVOL
BEDGREG	COORDXY	SACHELM ²
BEDDSS	XY2XY	VOLRATIO
	XYDSS1A	SAREACAP
	DSSXY	





US Army Corps of Engineers

Omaha District

Area Capacity Input

Project Name



1. Ratio Data

Ratio Data File



New Ratio File...

2. Recall Data

Recall Data File



3. Hydraulic Elements

☒ Compute Hydraulic Elements

Read Cross-Section Data...

☐ Read Hydraulic Elements



Status

Project Name



Ratio Data



Recall



Hydraulic Elements

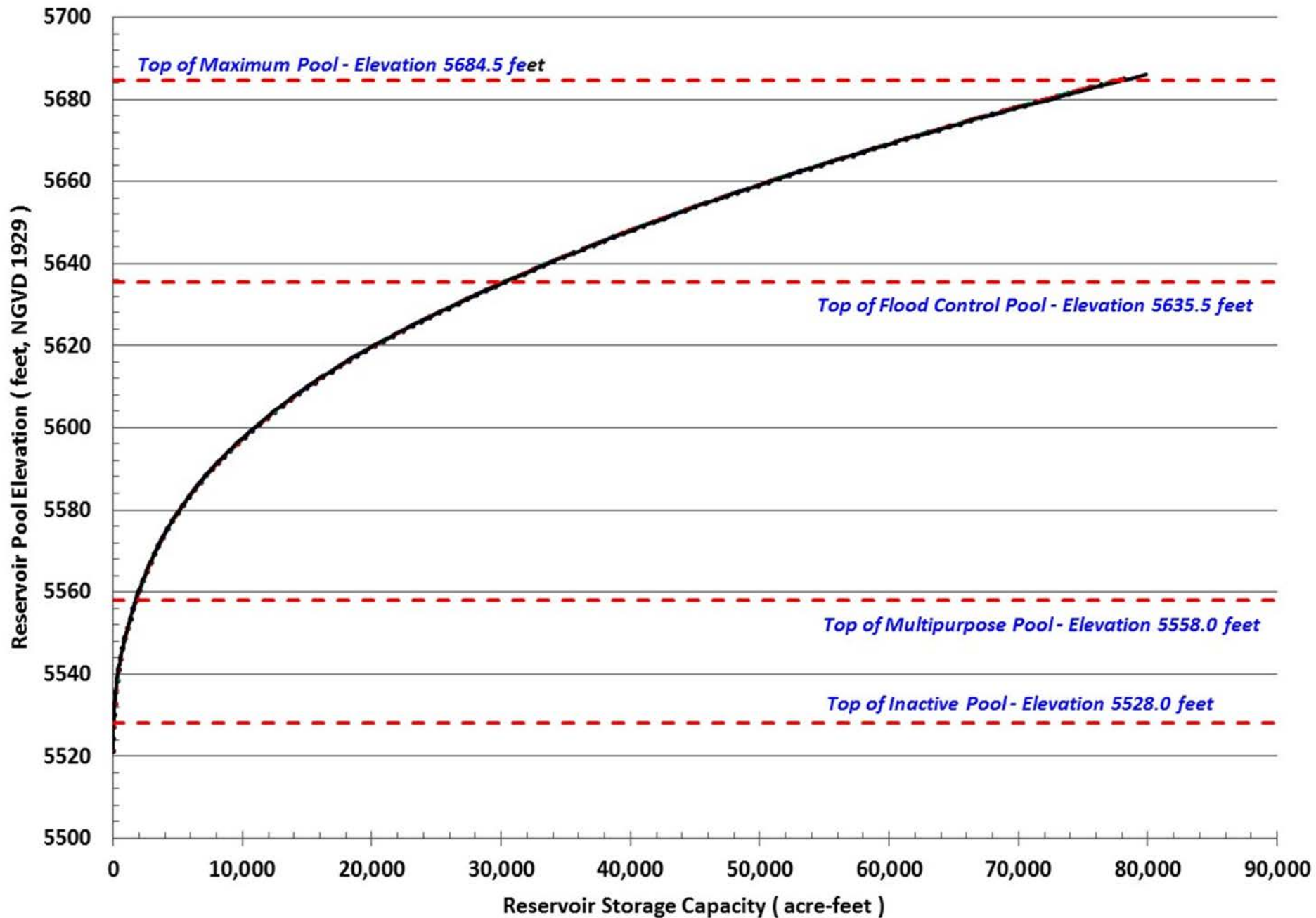


Compute New Capacity...

Verify Project Name...

Segment Definition...

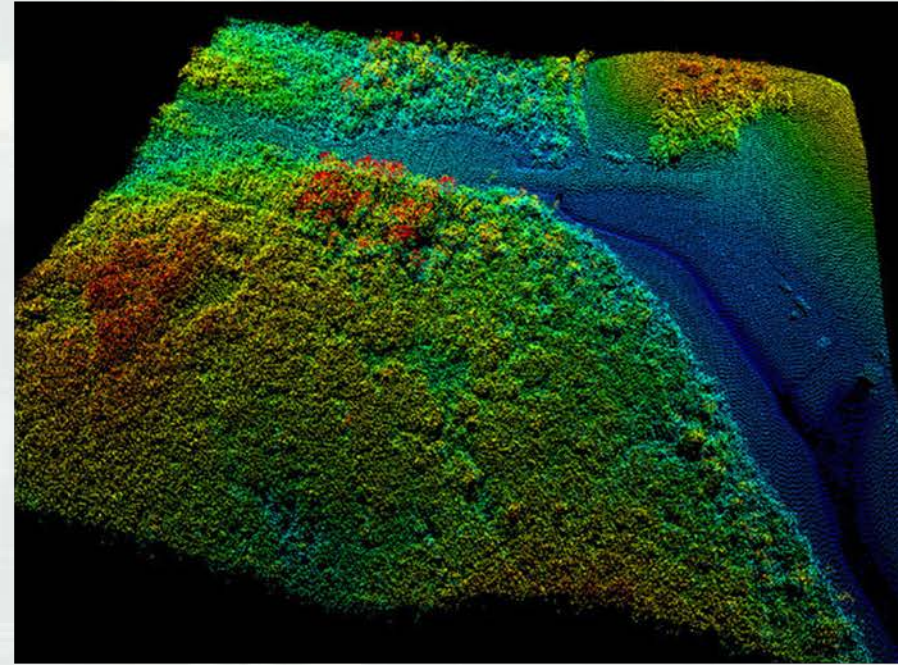


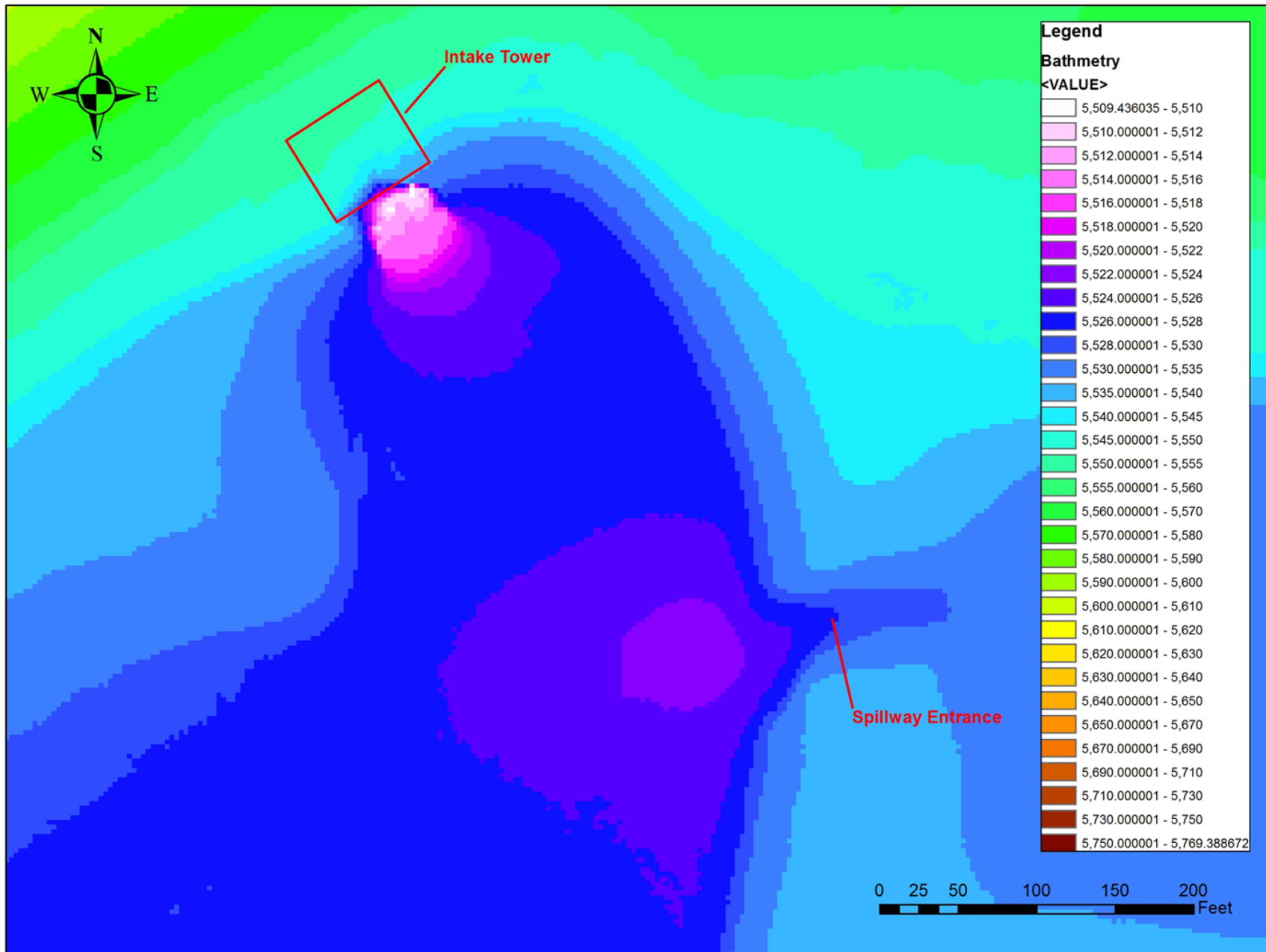


..... Sediment Range OUP HD Single Beam OUP HD Multibeam OUP HD Single Beam CIM HD Multibeam CIM

Surface Area & Storage Calculations using a Digital Elevation Model (DEM)

- Underwater can be collected by single or multibeam
- Often merged with overbank LiDAR (Light Detection and Ranging) data
- Use point clouds to a DEM surface using triangulation algorithms

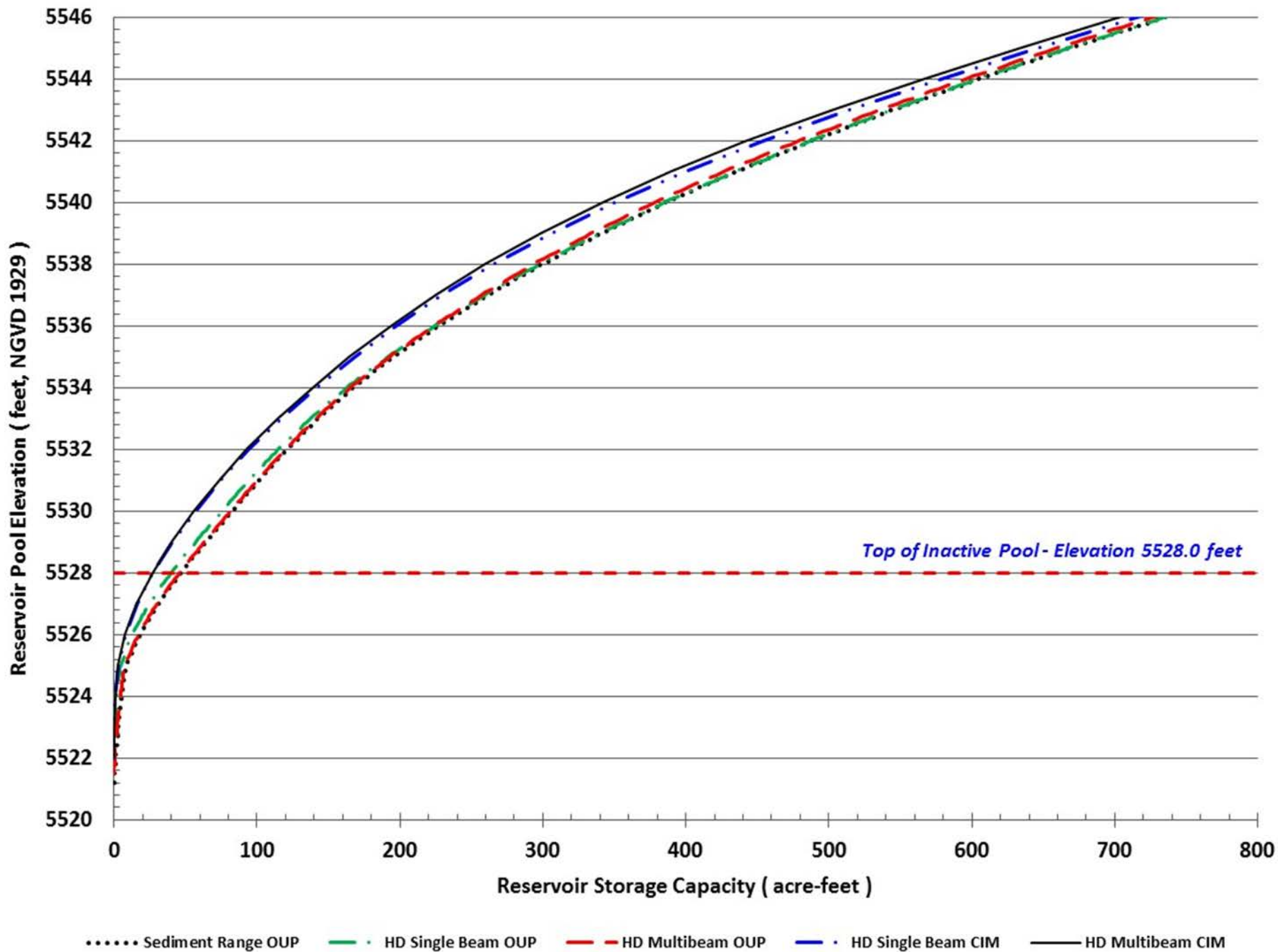




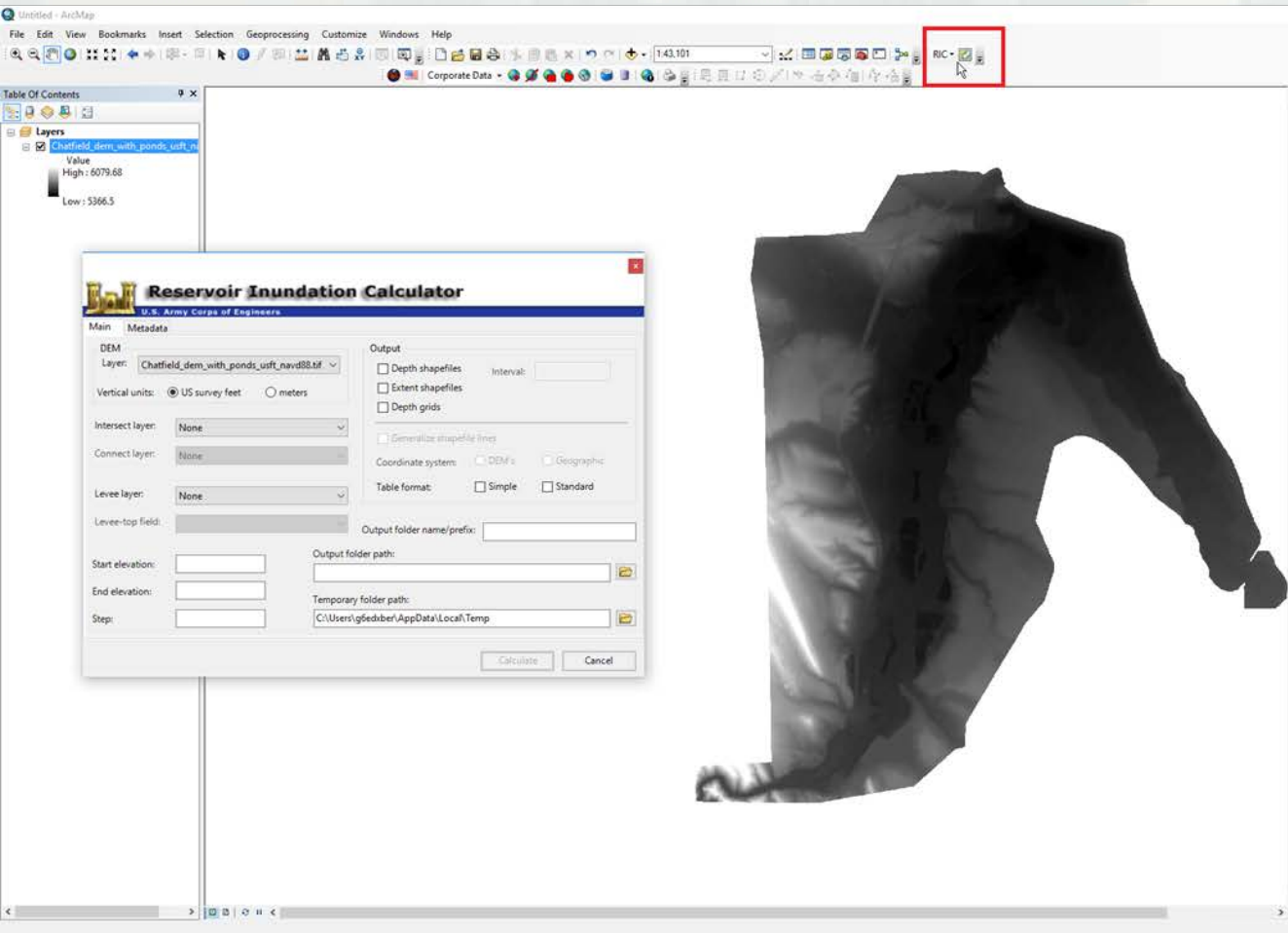
Reservoir Inundation Calculator (RIC)

- the Reservoir Inundation Calculator (RIC) developed by the USACE Cold Regions Research and Engineering Center (CRREL). RIC is an ESRI ArcGIS add-in that calculates inundation GIS layers and area and capacity values for reservoir water elevations.
- The RIC gives users various input and output options, including the ability to calculate multiple water elevations at once and the ability to create output GIS datasets in various formats.
- The RIC data requirements are a raster digital elevation model (DEM) of any reservoir area that includes both land elevation and bathymetric data. Additional datasets may also be used such as datasets that define the starting point of pools, locations of bridges and culverts, and the location of levees in the DEM.





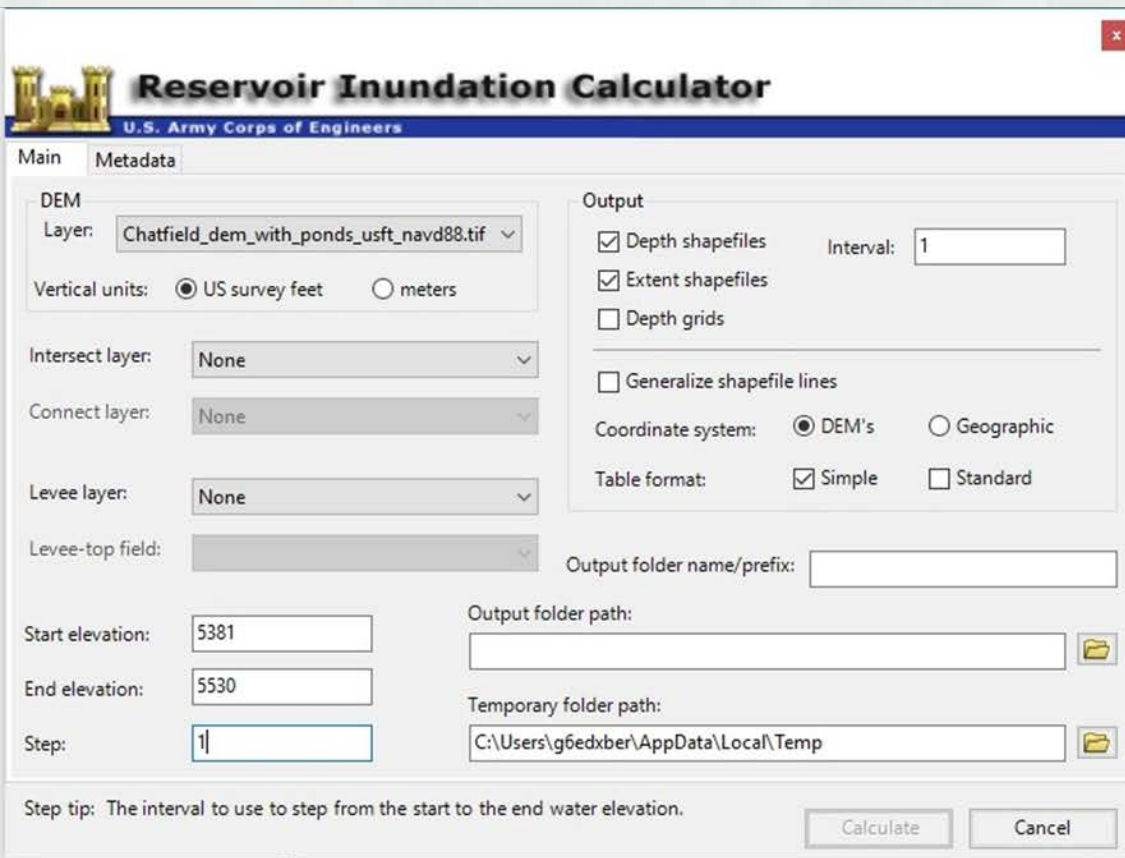
Reservoir Inundation Calculator



- RIC needs to be added as a custom toolbar
- Add DEM layer to Arc project.
- DEM must be in desired projection



Reservoir Inundation Calculator



The image shows a screenshot of the "Reservoir Inundation Calculator" dialog box, which is part of the U.S. Army Corps of Engineers software. The dialog has a title bar with the Corps of Engineers logo and name. It features two tabs: "Main" and "Metadata". The "Main" tab is active, showing various input fields and checkboxes. The "DEM" section has a dropdown menu for "Layer" set to "Chatfield_dem_with_ponds_usft_navd88.tif" and radio buttons for "Vertical units" set to "US survey feet". The "Intersect layer", "Connect layer", and "Levee layer" are all set to "None". The "Levee-top field" is empty. The "Start elevation" is 5381, "End elevation" is 5530, and "Step" is 1. The "Output" section has checkboxes for "Depth shapefiles", "Extent shapefiles", and "Depth grids", with "Interval" set to 1. There are also checkboxes for "Generalize shapefile lines", "Coordinate system" (set to "DEM's"), and "Table format" (set to "Simple"). The "Output folder name/prefix" is empty, "Output folder path" is empty, and "Temporary folder path" is "C:\Users\g6edxber\AppData\Local\Temp". A "Step tip" at the bottom states: "The interval to use to step from the start to the end water elevation." There are "Calculate" and "Cancel" buttons at the bottom right.

Reservoir Inundation Calculator
U.S. Army Corps of Engineers

Main Metadata

DEM
Layer: Chatfield_dem_with_ponds_usft_navd88.tif
Vertical units: ☒ US survey feet ☐ meters

Intersect layer: None
Connect layer: None
Levee layer: None
Levee-top field:

Start elevation: 5381
End elevation: 5530
Step: 1

Output
☒ Depth shapefiles Interval: 1
☒ Extent shapefiles
☐ Depth grids
☐ Generalize shapefile lines
Coordinate system: ☒ DEM's ☐ Geographic
Table format: ☒ Simple ☐ Standard

Output folder name/prefix:
Output folder path:
Temporary folder path: C:\Users\g6edxber\AppData\Local\Temp

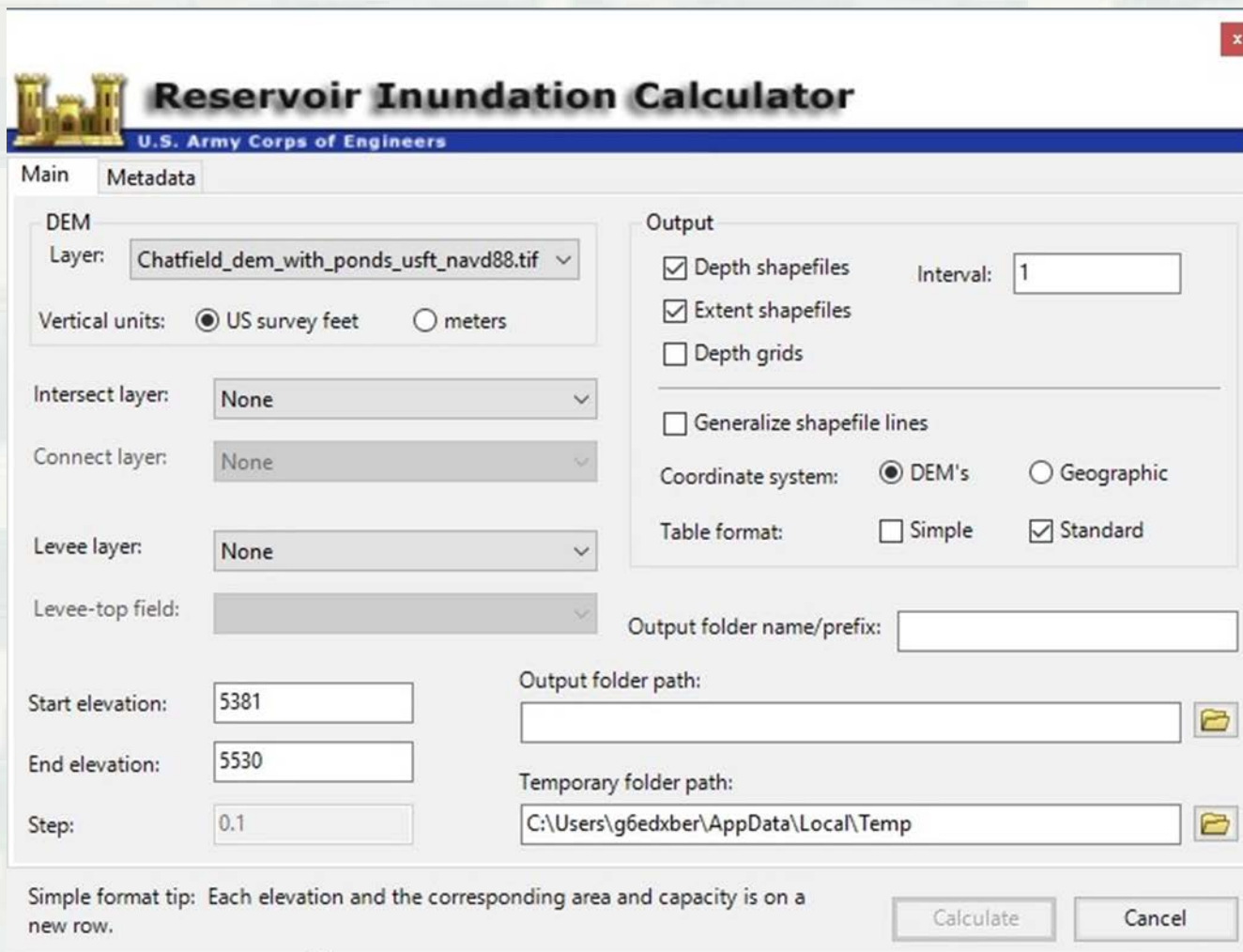
Step tip: The interval to use to step from the start to the end water elevation.

Calculate Cancel

- DEM layer auto-populates
- "Usually" no intersect or levee
- Extent shapefiles can be different interval than actual capacity interval!
- Simple vs. Standard output



Reservoir Inundation Calculator



The image shows a screenshot of the "Reservoir Inundation Calculator" software window. The window has a title bar with the text "Reservoir Inundation Calculator" and a small red "x" button in the top right corner. Below the title bar is a blue header bar with the U.S. Army Corps of Engineers logo and the text "U.S. Army Corps of Engineers". The main area of the window is divided into two tabs: "Main" and "Metadata". The "Main" tab is selected. The "Main" tab contains several input fields and checkboxes. On the left side, there are five dropdown menus: "DEM Layer" (set to "Chatfield_dem_with_ponds_usft_navd88.tif"), "Intersect layer" (set to "None"), "Connect layer" (set to "None"), "Levee layer" (set to "None"), and "Levee-top field" (set to "None"). Below these are three input fields: "Start elevation" (5381), "End elevation" (5530), and "Step" (0.1). On the right side, there are several checkboxes: "Depth shapefiles" (checked), "Extent shapefiles" (checked), "Depth grids" (unchecked), and "Generalize shapefile lines" (unchecked). There are also two radio buttons for "Coordinate system": "DEM's" (selected) and "Geographic" (unselected). Below these are two checkboxes for "Table format": "Simple" (unchecked) and "Standard" (checked). At the bottom right, there are two input fields: "Output folder name/prefix" (empty) and "Output folder path" (empty). Below these are two more input fields: "Temporary folder path" (set to "C:\Users\g6edxber\AppData\Local\Temp") and "Output folder path" (empty). At the bottom left, there is a text box with the text "Simple format tip: Each elevation and the corresponding area and capacity is on a new row." At the bottom right, there are two buttons: "Calculate" and "Cancel".

Reservoir Inundation Calculator
U.S. Army Corps of Engineers

Main Metadata

DEM Layer: Chatfield_dem_with_ponds_usft_navd88.tif

Vertical units: ☒ US survey feet ☐ meters

Intersect layer: None

Connect layer: None

Levee layer: None

Levee-top field: None

Start elevation: 5381

End elevation: 5530

Step: 0.1

Output

☒ Depth shapefiles Interval: 1

☒ Extent shapefiles

☐ Depth grids

☐ Generalize shapefile lines

Coordinate system: ☒ DEM's ☐ Geographic

Table format: ☐ Simple ☒ Standard

Output folder name/prefix:

Output folder path:

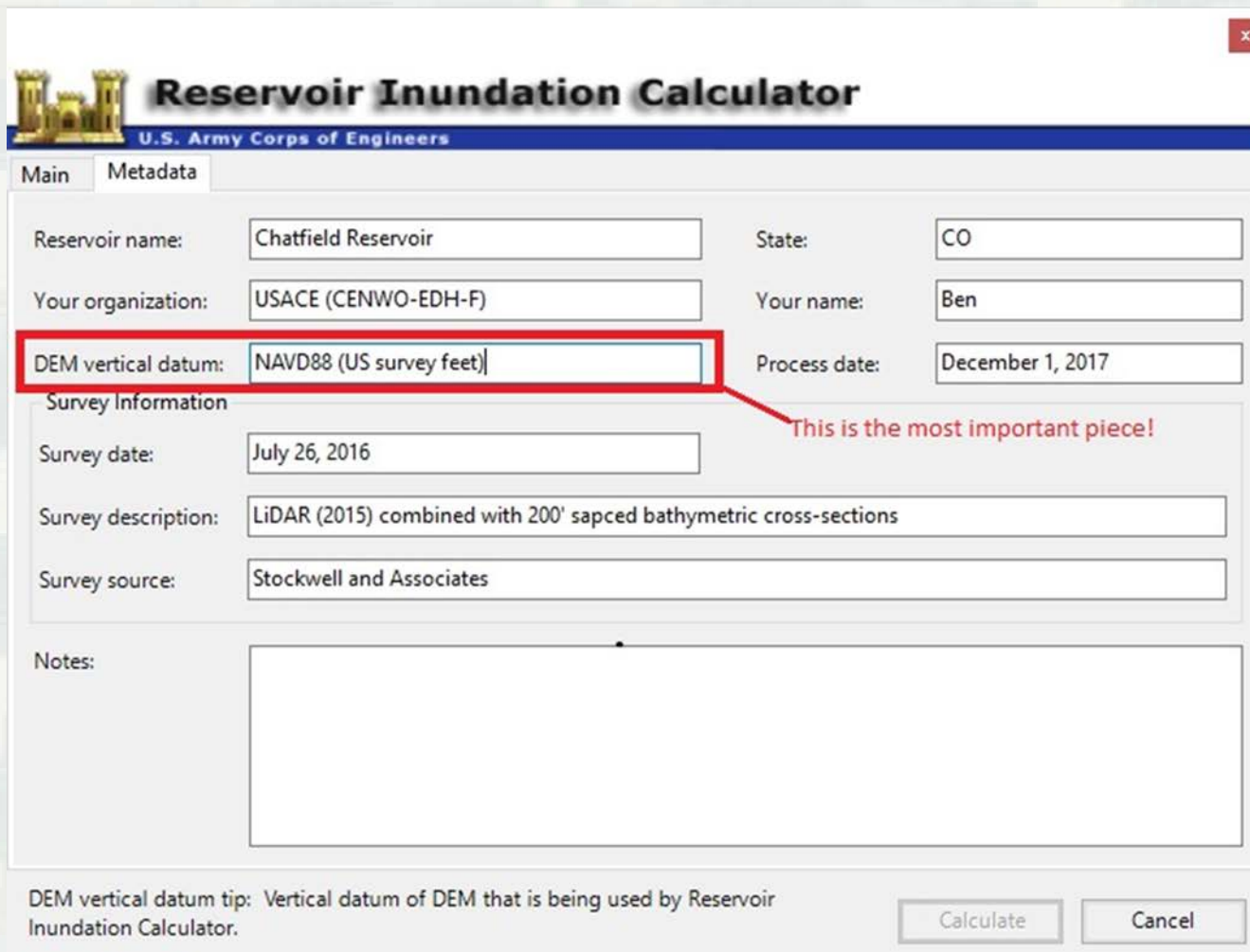
Temporary folder path: C:\Users\g6edxber\AppData\Local\Temp

Simple format tip: Each elevation and the corresponding area and capacity is on a new row.

Calculate Cancel



Reservoir Inundation Calculator



The image shows a screenshot of the "Reservoir Inundation Calculator" application window. The window has a title bar with a close button (X) in the top right corner. Below the title bar is a header section with a small icon of a castle on the left and the text "Reservoir Inundation Calculator" and "U.S. Army Corps of Engineers" on the right. The main content area is divided into two tabs: "Main" and "Metadata". The "Main" tab is selected. It contains several input fields for user information: "Reservoir name" (Chatfield Reservoir), "State" (CO), "Your organization" (USACE (CENWO-EDH-F)), "Your name" (Ben), "DEM vertical datum" (NAVD88 (US survey feet)), and "Process date" (December 1, 2017). The "DEM vertical datum" field is highlighted with a red rectangle, and a red arrow points to it with the text "This is the most important piece!". Below these fields is a section titled "Survey Information" with fields for "Survey date" (July 26, 2016), "Survey description" (LiDAR (2015) combined with 200' spaced bathymetric cross-sections), and "Survey source" (Stockwell and Associates). At the bottom of the main content area is a "Notes" section with a large text area. At the very bottom of the window are two buttons: "Calculate" and "Cancel". A tip box at the bottom left reads: "DEM vertical datum tip: Vertical datum of DEM that is being used by Reservoir Inundation Calculator."

Reservoir Inundation Calculator
U.S. Army Corps of Engineers

Main Metadata

Reservoir name: Chatfield Reservoir State: CO

Your organization: USACE (CENWO-EDH-F) Your name: Ben

DEM vertical datum: NAVD88 (US survey feet) Process date: December 1, 2017

Survey Information

Survey date: July 26, 2016

Survey description: LiDAR (2015) combined with 200' spaced bathymetric cross-sections

Survey source: Stockwell and Associates

Notes:

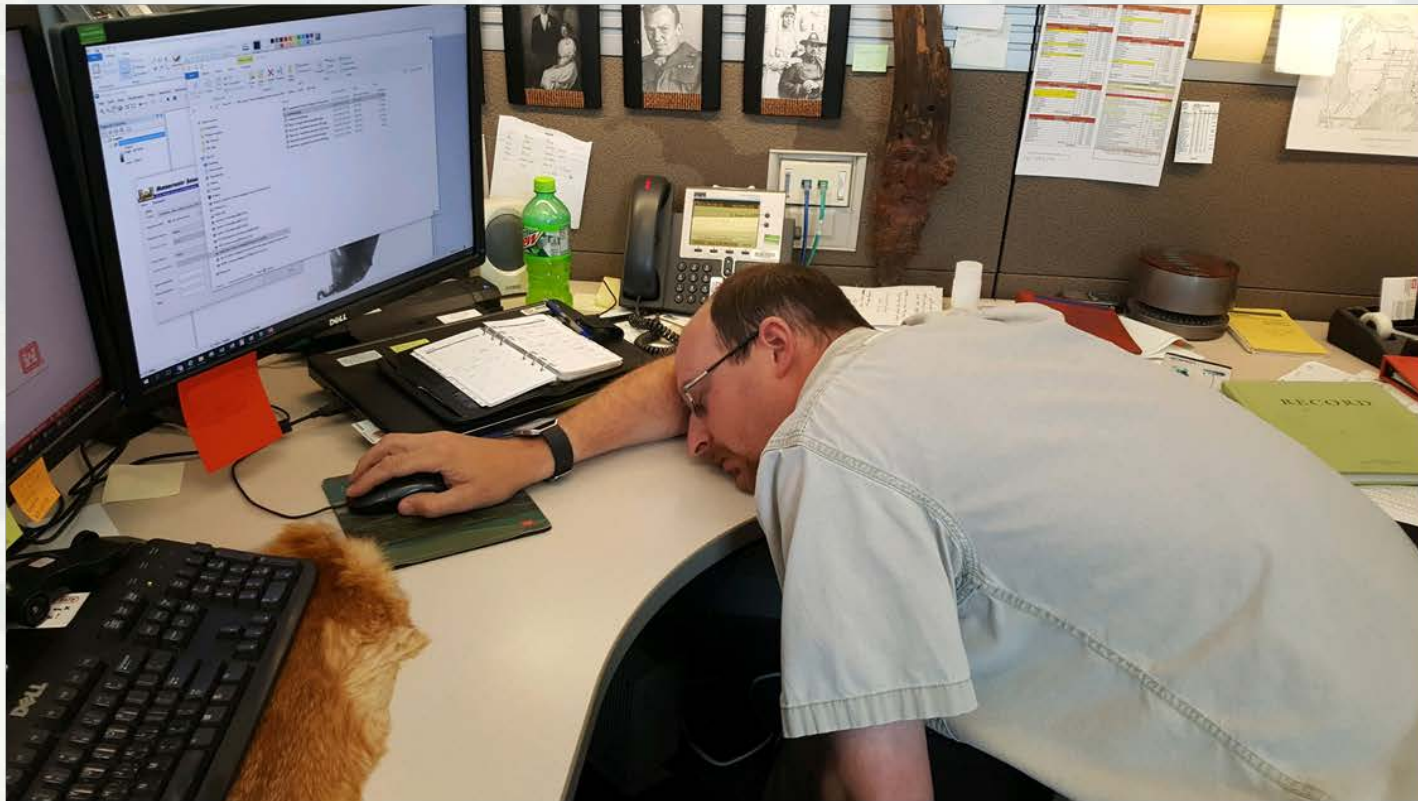
DEM vertical datum tip: Vertical datum of DEM that is being used by Reservoir Inundation Calculator.

Calculate Cancel



Reservoir Inundation Calculator

- Click calculate and wait for the magic



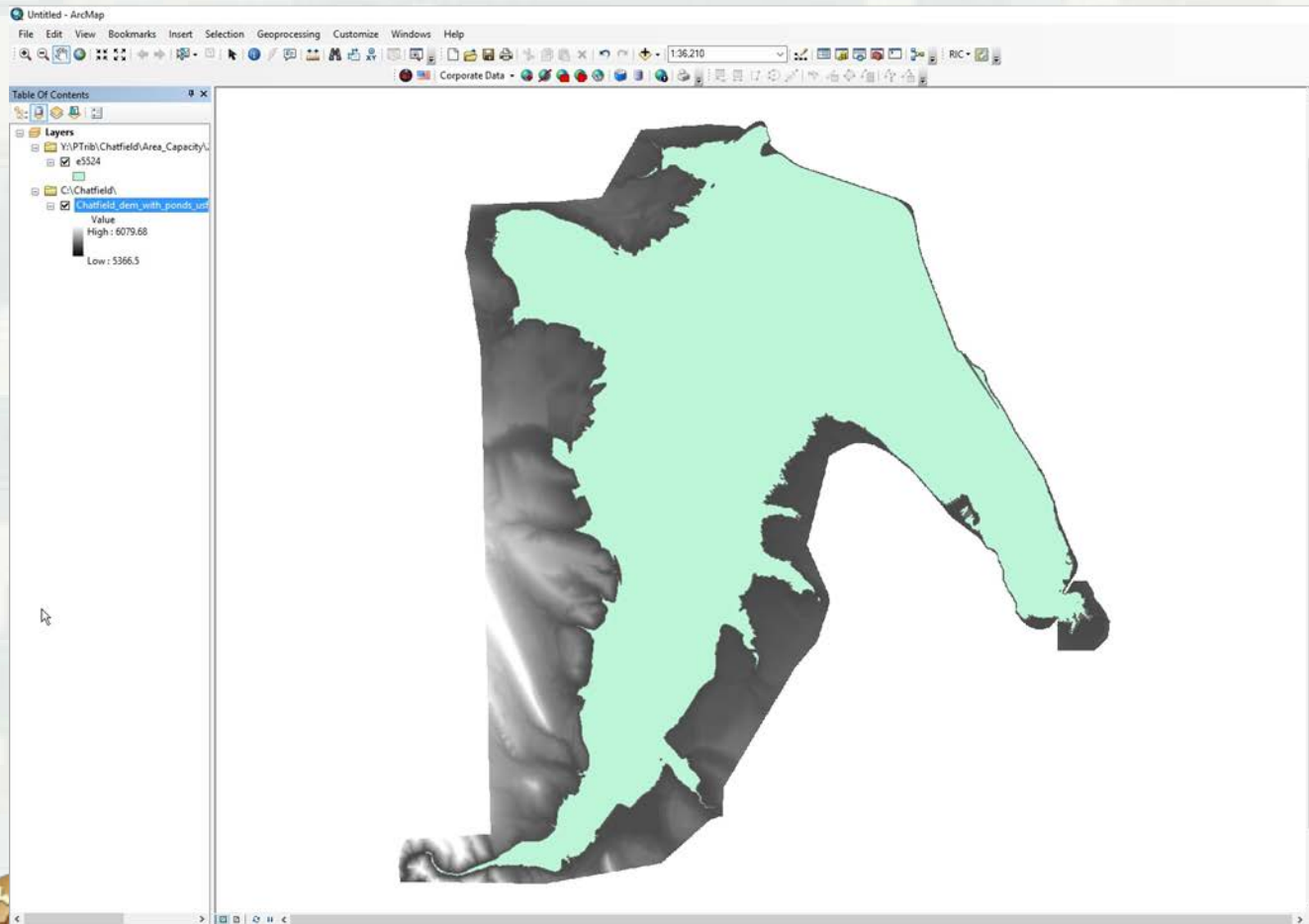
- Several hours later...



- Run time is dependent on file size and output scale
- Omaha experience 1-7+ hours



Reservoir Inundation Calculator Output example – Extent.shp



Reservoir Inundation Calculator

Output example – Capacity.dbf

OID	Elev	elev_0	elev_1	elev_2	elev_3	elev_4	elev_5	elev_6	elev_7	elev_8	elev_9
0	1255	0	0	0	0	0	0	0	0	0	1
1	1256	1	1	1	2	2	3	3	4	5	6
2	1257	7	8	9	11	12	15	17	20	23	26
3	1258	30	35	39	45	51	58	66	74	83	93
4	1259	104	116	128	140	154	167	181	196	212	228
5	1260	245	262	280	299	318	338	358	380	401	424
6	1261	446	469	493	518	542	568	594	621	648	675
7	1262	704	732	762	792	822	853	885	917	950	984
8	1263	1018	1053	1088	1125	1162	1199	1237	1276	1315	1356
9	1264	1397	1438	1480	1523	1567	1611	1656	1701	1747	1794
10	1265	1841	1890	1939	1988	2039	2090	2141	2194	2247	2301
11	1266	2356	2412	2468	2525	2582	2641	2700	2760	2820	2881
12	1267	2943	3005	3068	3131	3195	3260	3326	3392	3458	3526
13	1268	3594	3663	3733	3803	3874	3945	4018	4091	4164	4239
14	1269	4313	4389	4465	4542	4619	4697	4775	4854	4934	5015
15	1270	5096	5178	5260	5343	5427	5511	5595	5681	5766	5853
16	1271	5940	6027	6116	6205	6294	6384	6475	6567	6659	6752
17	1272	6846	6941	7036	7131	7228	7325	7423	7521	7621	7720
18	1273	7821	7922	8023	8126	8228	8332	8436	8541	8646	8752
19	1274	8859	8966	9074	9183	9292	9402	9513	9624	9736	9849
20	1275	9962	10076	10190	10306	10422	10538	10655	10773	10891	11010
21	1276	11130	11250	11371	11493	11616	11739	11863	11988	12114	12240
22	1277	12367	12495	12624	12753	12882	13013	13144	13276	13409	13543
23	1278	13678	13813	13949	14086	14224	14362	14500	14639	14779	14919
24	1279	15060	15202	15344	15486	15629	15772	15916	16061	16206	16351
25	1280	16498	16644	16792	16939	17088	17237	17386	17536	17687	17838
26	1281	17990	18143	18296	18450	18605	18761	18917	19074	19233	19392
27	1282	19553	19714	19876	20040	20204	20369	20535	20701	20868	21036
28	1283	21204	21373	21542	21711	21881	22051	22222	22393	22564	22736
29	1284	22909	23081	23254	23428	23601	23776	23950	24125	24300	24476
30	1285	24653	24829	25007	25185	25363	25542	25722	25903	26084	26266
31	1286	26448	26632	26816	27001	27188	27375	27562	27751	27941	28132
32	1287	28323	28516	28710	28905	29101	29297	29495	29693	29892	30092
33	1288	30292	30493	30695	30898	31102	31306	31511	31716	31922	32129
34	1289	32336	32544	32753	32962	33172	33383	33594	33806	34018	34232
35	1290	34446	34660	34876	35092	35309	35526	35744	35963	36183	36403
36	1291	36624	36846	37068	37291	37515	37740	37965	38191	38418	38645
37	1292	38873	39102	39331	39561	39792	40023	40256	40489	40722	40957
38	1293	41192	41428	41665	41902	42140	42379	42618	42858	43099	43340
39	1294	43583	43826	44069	44313	44558	44804	45050	45297	45544	45792



Final RIC Credits

- Developer: ERDC-RDE-CRREL-NH

Contact: Tim Baldwin

Tim.B.Baldwin@erdc.dren.mil

