



A Utah-Wyoming Cyberinfrastructure
Water Modeling Collaboration

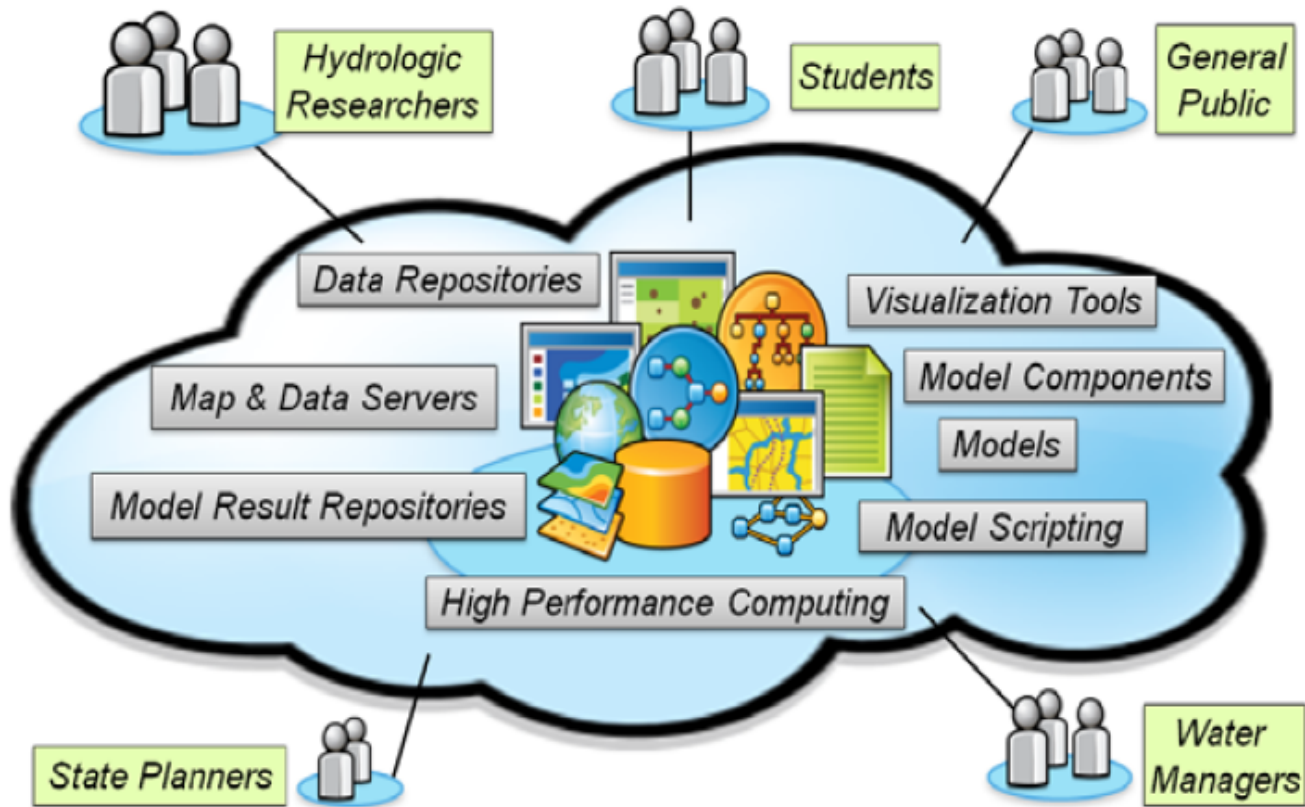


Brigham Young University Research Contributions

Objective #2: Enhance access to data- and
computationally-intensive modeling



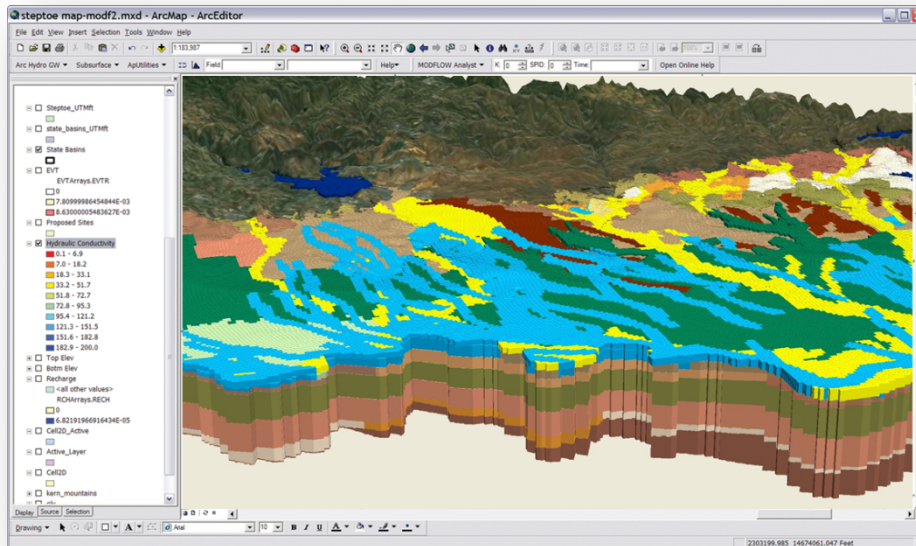
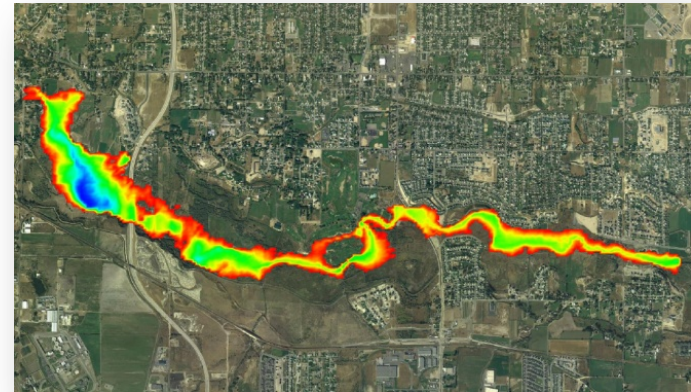
Enhance Access



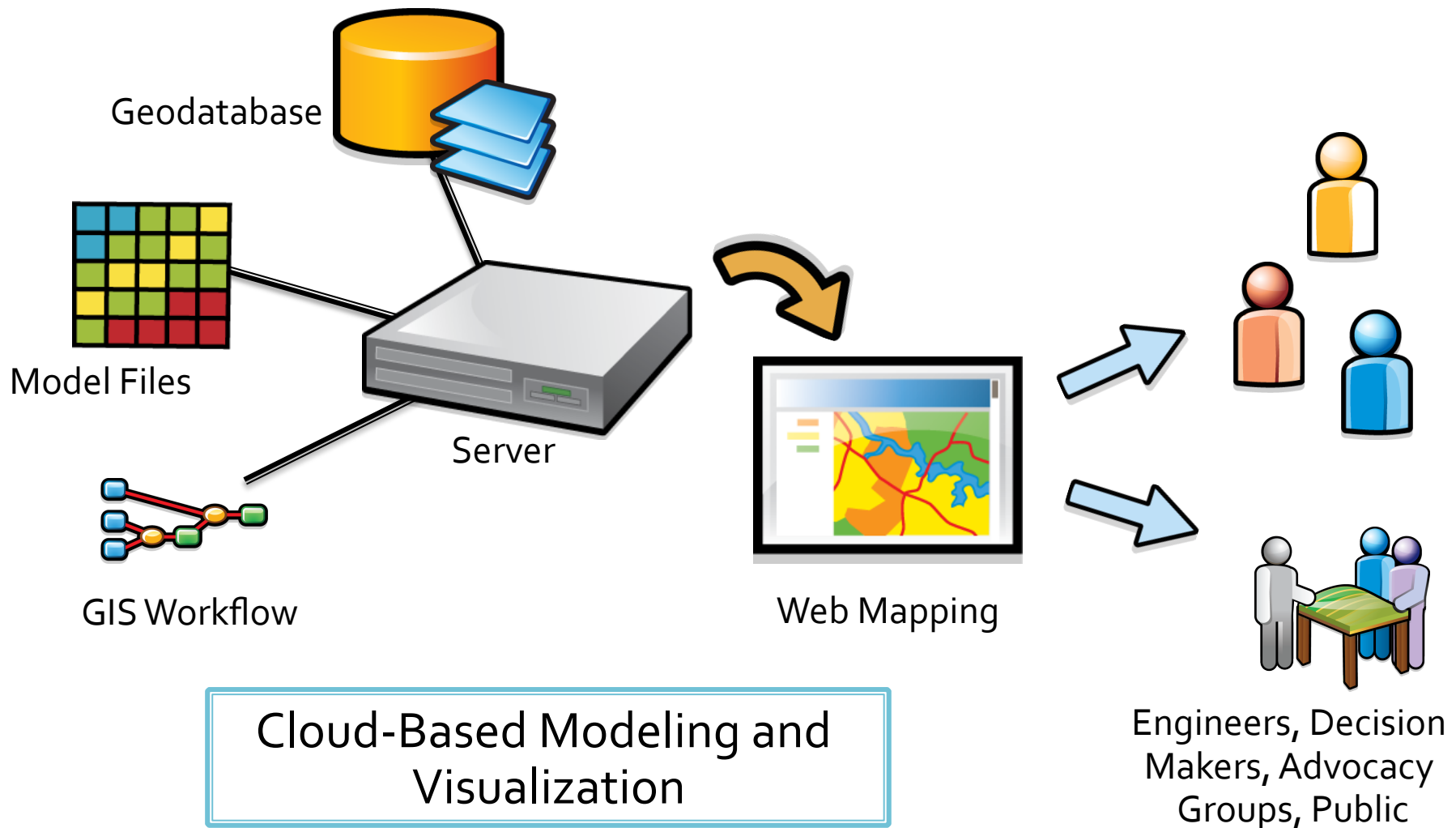
Goal is to provide and use these tools to enhance the capacity for water resource planning and management in the Utah-Wyoming region

Challenges

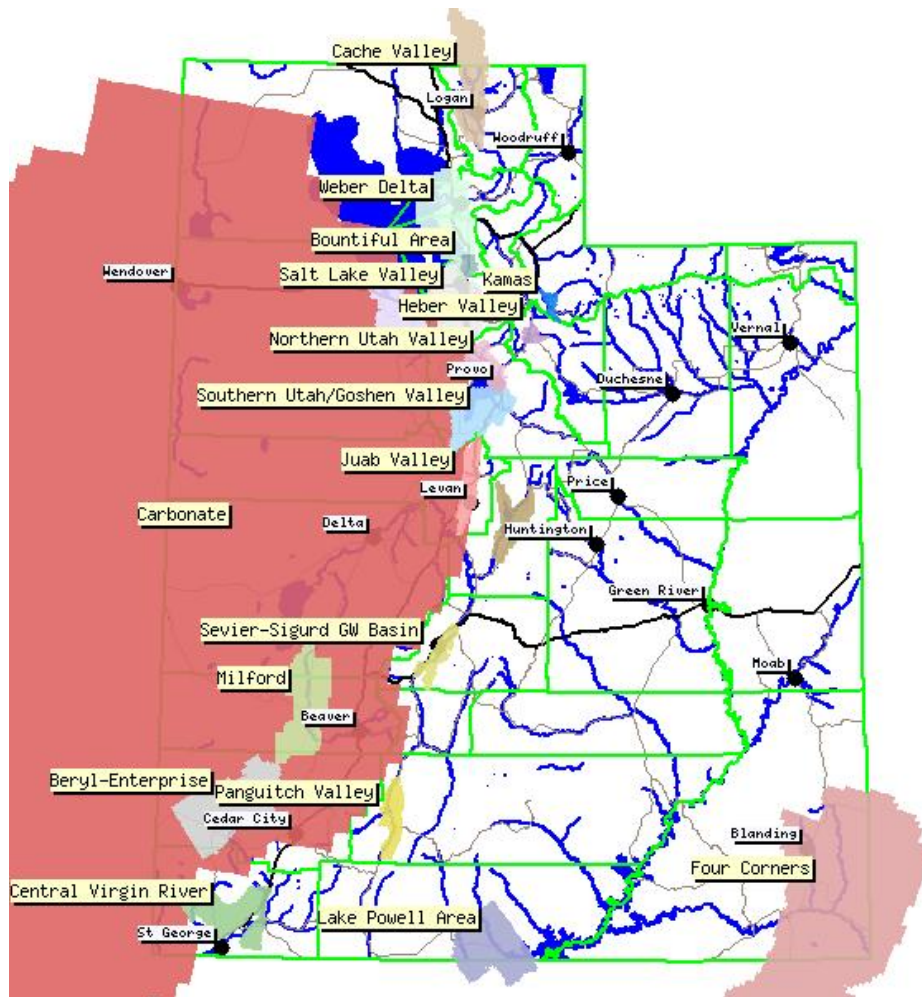
1. Every model is unique
2. Large datasets
3. Spatial data
4. Remote resources



Proposed Solution

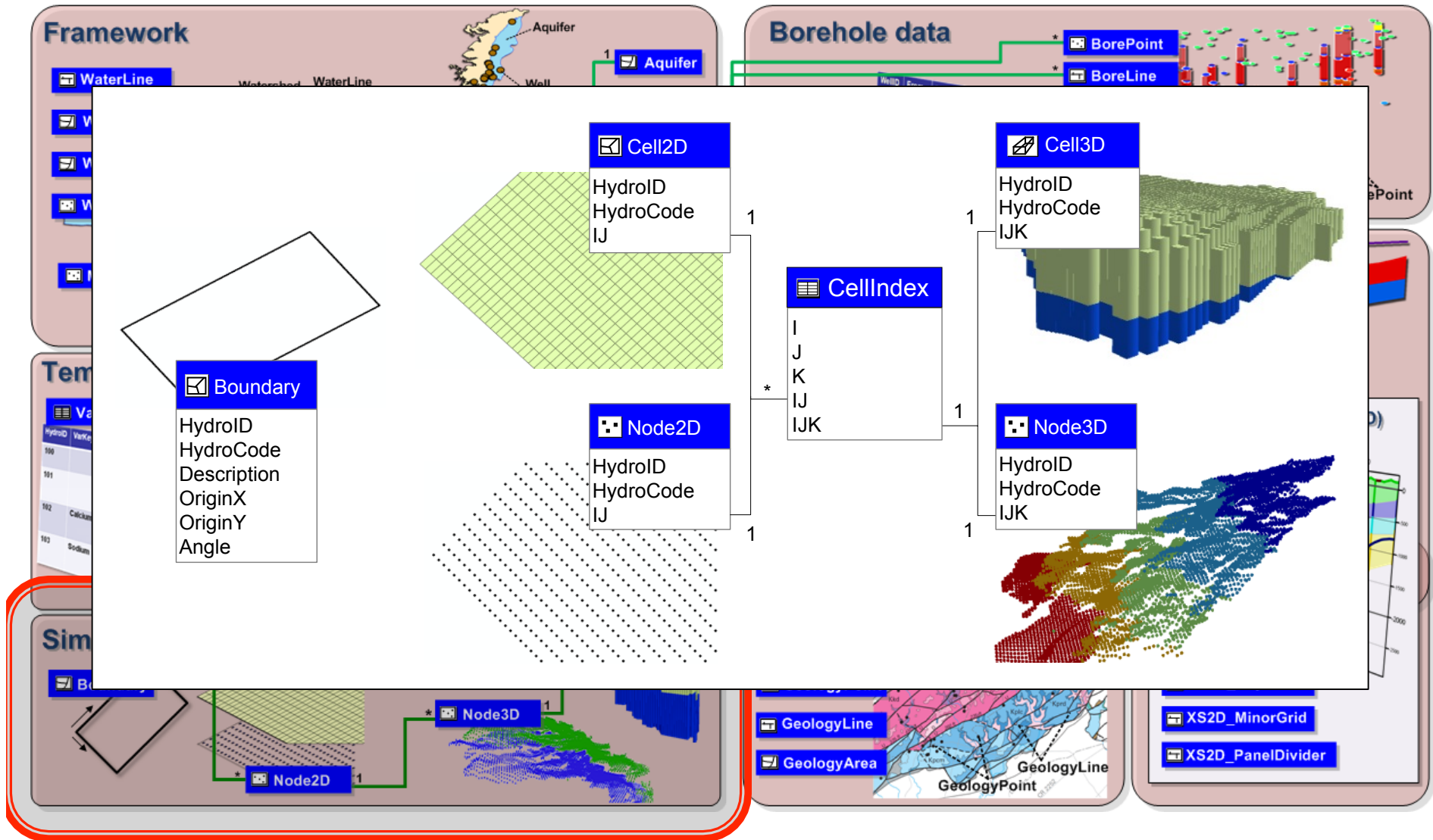


Prototype: Utah Division of Water Rights



- 31 MODFLOW models used for impact analysis
- Challenges
 - Modeling expertise
 - Software installation and maintenance
 - User error
 - Cost

Arc Hydro Groundwater Data Model



MODFLOW DATA MODEL v3.0

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Last updated: May 16, 2011

Arc Hydro Groundwater

Cell2D, Node2D, CellIndex, Cell3D, Node3D

Discretization (DIS)

DISVars, StressPeriods, DELRC, TopElev

Output Control (OC)

OCVars, O3Flags, OCTS

Layer-Property Flow (LPF)

LPFVars, LPFLayers, LPFProperties

Unsaturated Zone Flow (UZF)

UZFVars, UZFArrayMult, UZFFlags, UZFStressArrayMult, UZFArrays

Global Settings

MDFGlobals, NameFile

Basic (BAS6)

BASVars, Basic, BasicArrayMult

List-Based Stress Packages

IRV, CHD, WEL, DRN, GHD, HFR

Array-Based Stress Packages

Recharge (RCH), RCHVars, RCHArrays

Layer-Property Flow (LPF)

LPFVars		LPFLayers		LPFProperties	
HDRY	Double	Layer	Long Int.	IJK	Long Int.
WETFCT	Double	LAYTYP	Short Int.	HK	Double
IWETIT	Long Int.	LAYAVG	Short Int.	HANI	Double
IHDWET	Short Int.	CHANI	Double	VKA	Double
		LAYVKA	Short Int.	Ss	Double
		LAYWET	Short Int.	Sy	Double
		AM_HK	Double	WETDRY	Double
		AM_HANI	Double	VKCB	Double
		AM_VKA	Double		
		AM_Ss	Double		
		AM_Sy	Double		
		AM_WETDRY	Double		
		AM_VKCB	Double		

Hydraulic Fracture (HUF2)

HUFUnits

Stream (STR2)

STRSegments, STRSect

Stream (STR6)

STRVars, STRReaches

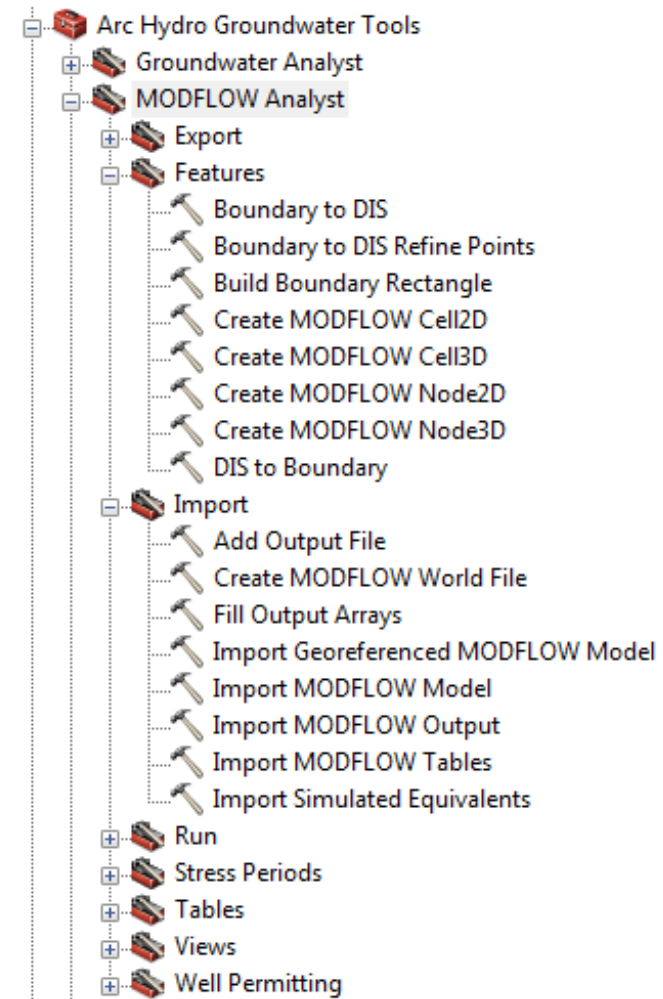
Evapotranspiration (ETSA)

ETSVars, ETSAArrays

Multi-Names

MODFLOW Analyst Tools

- Developed as geoprocessing (GP) tools
- Classes of tools
 - Import
 - Export
 - Visualization/Map Layers
 - Model editing
 - Building package input
 - Working with transient input/solutions



Import MODFLOW Model Tool

modfmap.drn - WordPad

```
106 40 AUX IFACE AUX CONDFACT AUX CELLGRP
106 0
1 6 39 729.91542773634 127158.92955 6 21.193154924999 1
1 7 39 729.12514303446 1061076.46095 6 176.846076825 1
1 8 39 727.77320350356 971637.05687207 6 161.93950947868 1
1 9 39 726.53233010274 894082.58374374 6 149.01376395729 1
1 10 10 729.88121247728 128655.15094793 6 21.442525157988 2
1 10 39 725.39709624177 812802.34885794 6 135.46705814299 1
1 11 10 729.03884050271 783692.29983415 6 130.61538330569 2
1 11 39 724.36506545906 738911.2262345 6 123.15187103908 1
1 12 10 727.65745200373 712447.54530377 6 118.74125755063 2
1 12 39 723.43125239281 665126.74994157 6 110.8544583236 1
1 13 10 726.40164427739 647679.58663979 6 107.9465977733 2
1 13 39 722.98867137905 317.516482286 6 0.0529194137143 1
1 13 40 722.58866491535 601113.6329079 6 100.18560548465 1
1 14 10 725.74672316002 61645.545169852 6 10.274257528309 2
1 14 11 725.20308345165 527154.07904814 6 87.85901317469 2
1 14 40 721.82522738929 546755.59035472 6 91.125931725786 1
1 15 11 724.22214326473 535272.38565272 6 89.212064275453 2
1 15 40 721.13100129527 497050.53668611 6 82.841756114351 1
1 16 11 723.27863633285 486611.25968429 6 81.101876614048 2
1 16 40 720.49988666433 451864.1242601 6 75.310687376683 1
1 17 11 722.31586406744 556138.08210894 6 92.68968035149 2
1 17 40 719.86615241554 500989.27249792 6 83.498212082987 1
1 18 10 719.90247661796 382245.46326479 6 63.707577210798 2
1 18 11 721.02889266528 837741.47875385 6 139.62357979231 2
1 18 40 719.16553320648 552429.24551221 6 92.071540918702 1
1 19 9 717.61425176418 489101.17155177 6 81.516861925294 2
1 19 10 718.80769422093 803480.03478533 6 133.91333913089 2
1 19 39 718.23976184464 331084.53953387 6 55.180756588978 1
1 19 40 718.62904033612 254216.52888518 6 42.369421475299 1
1 20 8 715.38828716567 175665.05330104 6 29.277508883506 2
1 20 9 716.35657141069 873054.14587106 6 145.50902431184 2
1 20 39 717.63028198515 585301.06388567 6 97.550178064278 1
```

For Help, press F1

Name	Size	Type	Date Modified
modfmap.rch	1 KB	RCH File	8/2/2007 10:37 AM
modfmap.wel	1 KB	WEL File	8/2/2007 10:37 AM



Attributes of DRN

Object ID *	CellID	SPID	Elevation	Cond	IFACE	Conduct
1	731	1	222.808304	16264.19043	6	29.304848
2	803	1	222.399811	18392.214844	6	33.139126
3	875	1	222.06926	9653.232422	6	17.393211
4	876	1	221.872177	7066.963379	6	12.733267
5	948	1	221.609726	15200.177734	6	27.387709
6	1020	1	221.227173	17256.447266	6	31.092699
7	1092	1	220.942413	6902.006836	6	12.436049
8	1091	1	220.717331	12195.496094	6	21.973867
9	1163	1	220.17421	33883.140625	6	61.050709
10	1162	1	219.386047	32986.417969	6	59.434986
11	1161	1	218.734497	22291.667969	6	40.165169
12	1233	1	218.200867	22982.591797	6	41.410076
13	1232	1	217.841705	7488.561523	6	13.492904
14	1304	1	217.394287	30471.154297	6	54.902981
15	1376	1	216.794037	20455.853516	6	36.857395
16	1448	1	216.31456	20223.103516	6	36.438026
17	1520	1	215.817566	21943.632813	6	39.538074
18	1592	1	215.297638	22167.060547	6	39.940647
19	1664	1	214.607651	36372.414063	6	65.535881
20	1736	1	214.166122	1087.577393	6	1.959599
21	1735	1	213.817459	28494.275391	6	51.341038
22	1807	1	213.243118	20233.802734	6	36.457302
23	1879	1	212.874512	11039.427734	6	19.890862
24	1885	1	221.774063	20479.730469	6	36.900417
25	1886	1	221.299652	22523.244141	6	40.58242
26	1887	1	220.825287	20475.675781	6	36.893108
27	1888	1	220.395462	18485.587891	6	33.307365
28	1816	1	220.190109	128.663498	6	0.231826
29	1817	1	220.001999	16922.046875	6	30.490173
30	1818	1	219.631989	16618.207031	6	29.942715
31	1819	1	219.311005	12476.114258	6	22.479485
32	1747	1	219.10434	6257.23291	6	11.274294
33	1748	1	218.828674	18730.306484	6	33.748483

Record: 1 Show: All Selected Records (0 out of 92)

EVTArrayMult

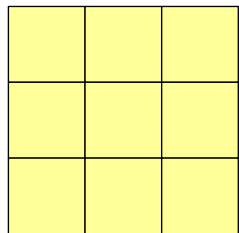
INPUT

OUTPUT

Make MODFLOW Features Tool

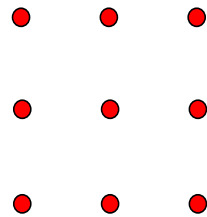
Attributes of DRN					
Object ID *	CellID	SPID	Elevation	Cond	
1	731	1	222.808304	16264.19043	
2	803	1	222.399811	18392.214844	
3	875	1	222.06926	9653.232422	
4	876	1	221.872177	7066.963379	
5	948	1	221.609726	15200.177734	
6	1020	1	221.227173	17256.447266	
7	1092	1	220.942413	6902.006836	
8	1091	1	220.717331	12195.496094	
9	1163	1	220.17421	33883.140625	
10	1162	1	219.386047	32986.417969	
11	1161	1	218.734497	22291.667969	
12	1233	1	218.200867	22982.591797	
13	1232	1	217.841705	7488.561523	
14	1304	1	217.394287	30471.154297	
15	1376	1	216.794037	20455.853516	

+

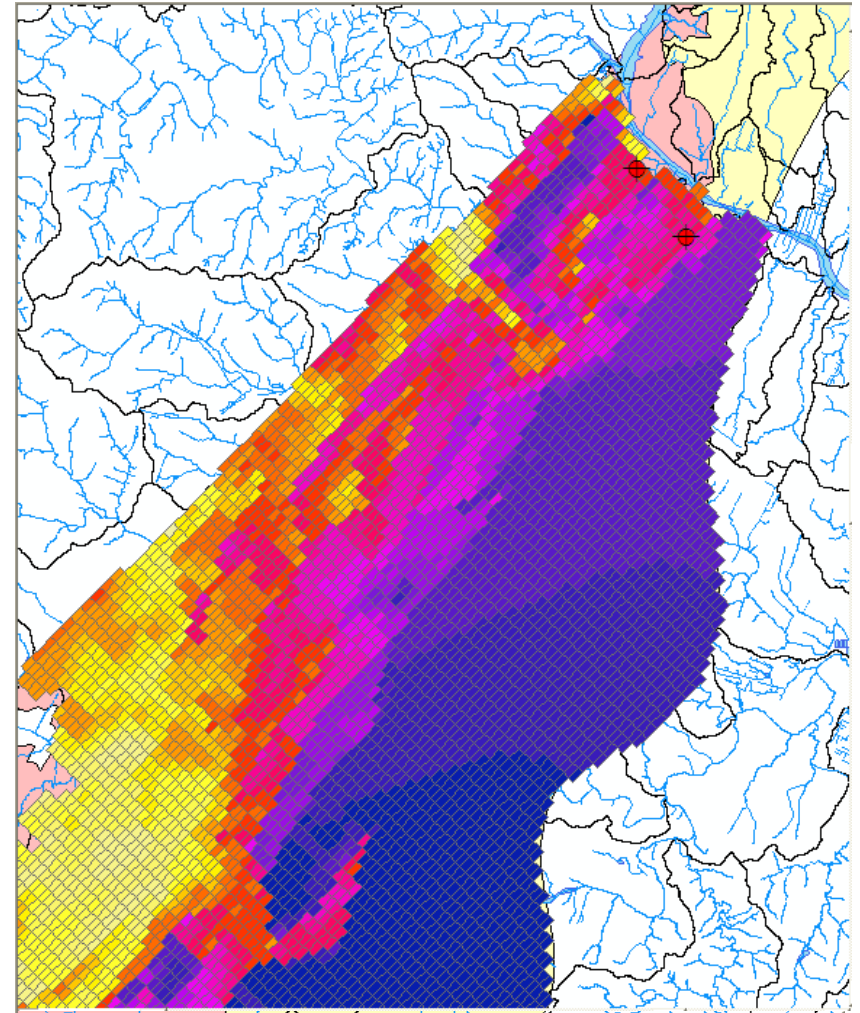


Cell2D

Or



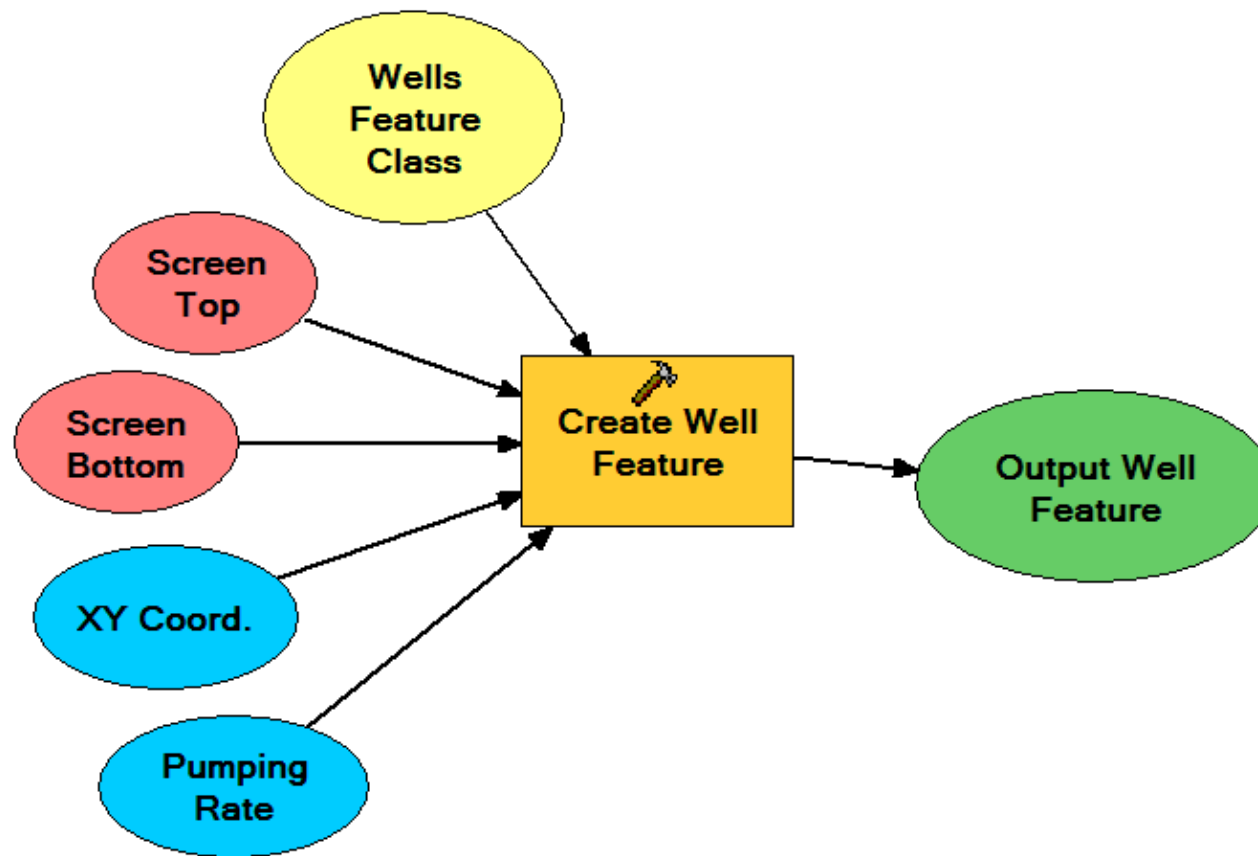
Node2D



INPUT

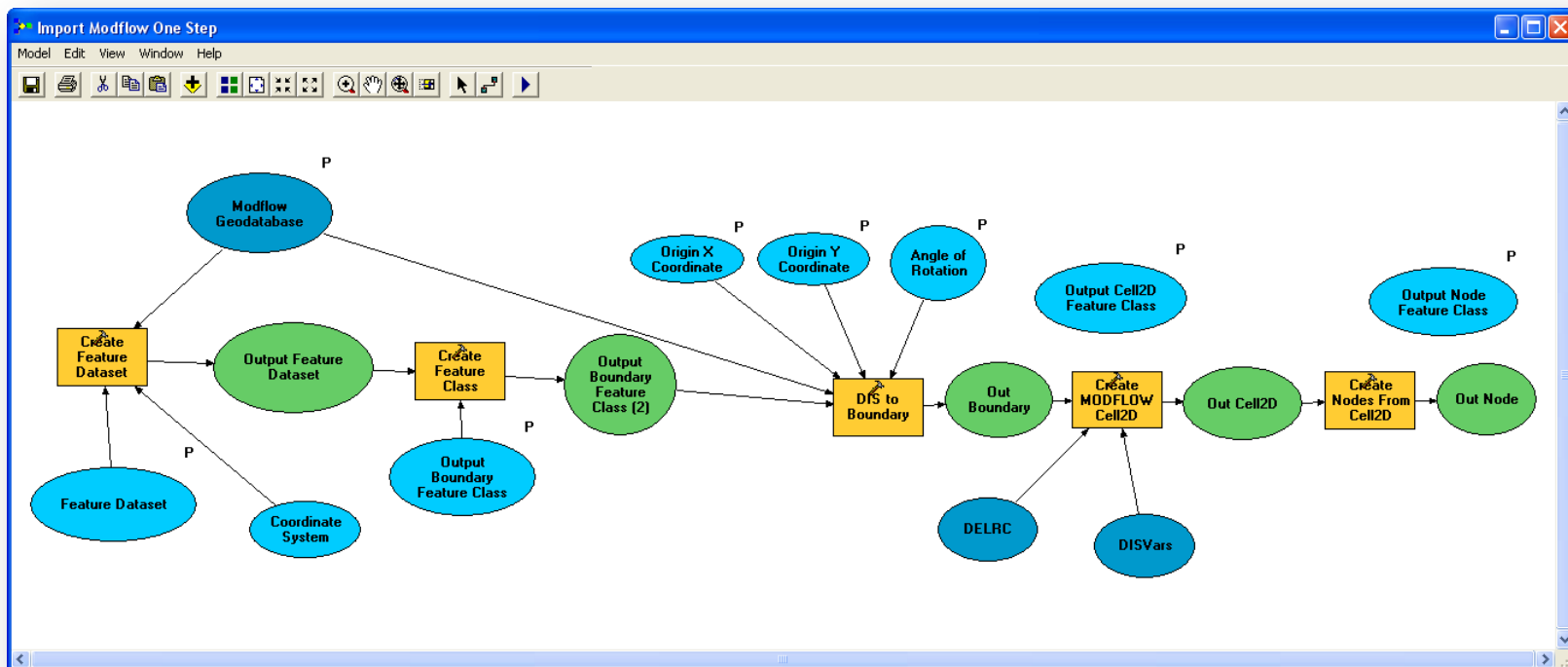
OUTPUT

Geoprocessing Tools



Geoprocessing Tools - Workflows

- GP tools enable the development of **workflows** as models or scripts
- **Extendable** – You can create your own workflows
- Leverage low-level tools to **create new tools**



Web Interface

Well Permitting Tool

utahdwr.groups.et.byu.net/app3/

Automated Well Permitting Tool

Tool Input and Map View | Table of Well Applications | Documentation

100: Analyze Permit Application with MODFLOW

Application ID:

Output Options

Submit

Load Previous Results | Load Saved Results

Tool Results

N. Utah County MODFLOW Model

Layer 1

Grid Geometry

- Model Boundary
- Active Grid with Elevation Data (Polygon Features)
- Active Grid (Image Overlay)

Hydraulic Conductivity

- Horizontal Conductivity

Conductivity (ft/day)

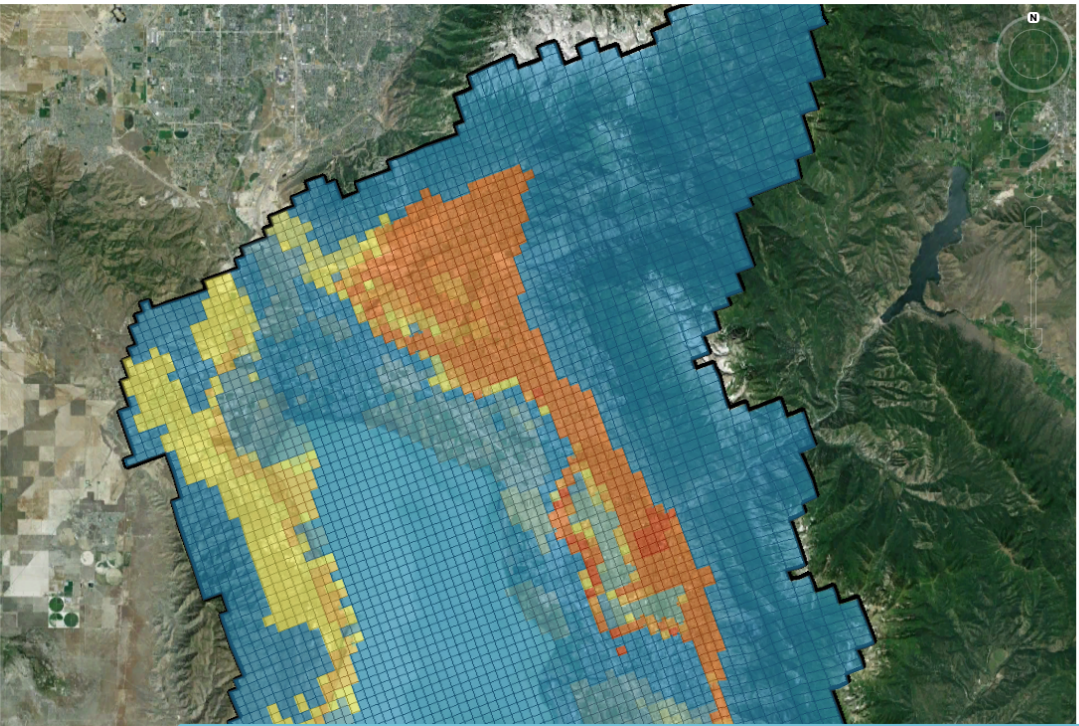
0
1 - 2
3 - 5
6 - 10
11 - 20
21 - 50
51 - 100
101 - 200
201 - 500
501 - 1000
1001 - 3000

- Vertical Conductivity (Upper Interface)

Baseline Conditions and Flows

Static Model Properties

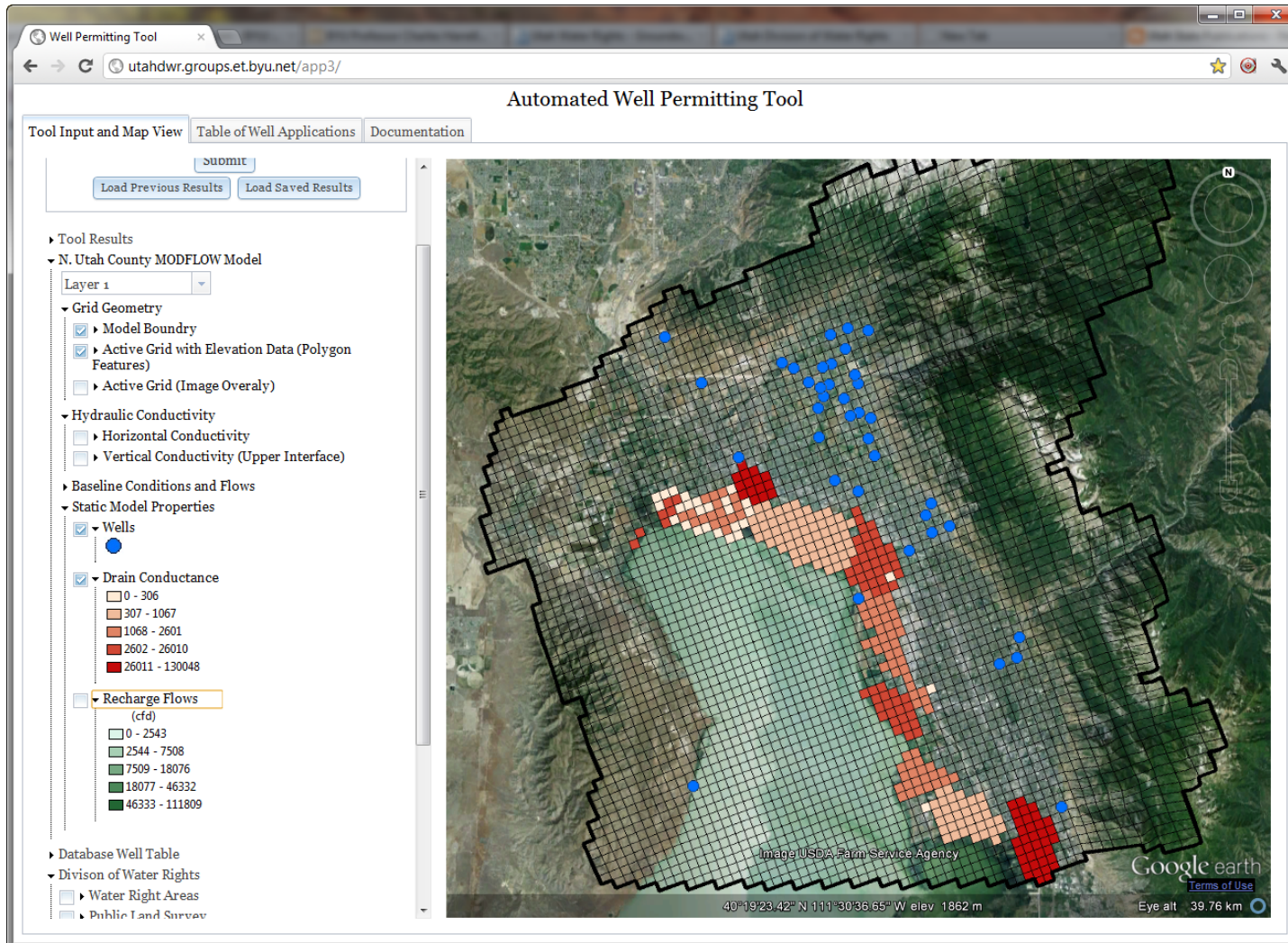
- Wells
- Drain Conductance
- Recharge Flows



40°32'52.96" N 111°43'50.08" W elev. 3118 m Eye alt. 50.53 km

<http://utahdwr.groups.et.byu.net/app3/>

Static Model Data



Map Layers from UDWR Server

Well Permitting Tool

utahdwr.groups.et.byu.net/app3/

Automated Well Permitting Tool

Tool Input and Map View | Table of Well Applications | Documentation

- Hydraulic Conductivity
 - Horizontal Conductivity
 - Vertical Conductivity (Upper Interface)
- Baseline Conditions and Flows
- Static Model Properties
 - Wells
- Drain Conductance
 - 0 - 306
 - 307 - 1067
 - 1068 - 2601
 - 2602 - 26010
 - 26011 - 130048
- Recharge Flows (cfd)
 - 0 - 2543
 - 2544 - 7508
 - 7509 - 18076
 - 18077 - 46332
 - 46333 - 111809
- Database Well Table
- Division of Water Rights
 - Water Right Areas
 - Public Land Survey
 - Points of Diversion
- Roads and Cities
 - Borders and Labels
 - Roads
- Map Options and Components
 - 3D Elevation
 - Navigation
 - Status Bar
 - Historical Imagery
 - Scale

55-6443
Owner LEE HANSEN
Type Underground
Location S250 W1200 E4 36 5S 1E SL
[Click Here for more information](#)

Image USDA Farm Service Agency

Google earth
Terms of Use

Eye alt 3.24 km

1993 40°20'33.40" N 111°46'00.63" W elev 1373 m

Table of Well Applications

Well Permitting Tool

utahdwr.groups.et.byu.net/app3/

Automated Well Permitting Tool

Tool Input and Map View | **Table of Well Applications** | Documentation

Well_ID	Latitude	Longitude	Flow_cfd	ScreenTopElev_ft	ScreenBotmElev_ft	ApplicationID	TIMESTAMP		
1	40.337982	-111.737053	-40000	4100	4000	1001	0000-00-00 00:00:00	Edit	Delete
2	40.369701	-111.813683	-24000	4100	4000	1001	0000-00-00 00:00:00	Edit	Delete
3	40.329506	-111.816437	-22000	4200	4000	1002	0000-00-00 00:00:00	Edit	Delete
4	40.34351	-111.728073	-200000	4100	4000	1003	2011-11-02 17:54:33	Edit	Delete
5	40.343044	-111.725983	-100000	4100	4000	1003	2011-11-02 17:54:36	Edit	Delete
6	40.337982	-111.737053	-40000	4100	4000	1110	2011-11-03 17:01:10	Edit	Delete
7	40.369701	-111.813683	-24000	4100	4000	1110	2011-11-03 17:01:10	Edit	Delete
8	40.376972	-111.768066	-3320	4100	4000	1110	2011-11-03 17:02:50	Edit	Delete
15	40.3	-111.79	421.45	4130	4000	1231	2011-11-16 16:50:53	Edit	Delete
17	40.35	-111.73	0	4100	4000	1	2012-02-11 20:40:21	Edit	Delete
18	40.35	-111.8	0	4100	4000	1004	2012-02-17 20:00:38	Edit	Delete

[Add Row](#)

Submitting a Model Run

Automated

Tool Input and Map View Table of Well Applications Documentation

▼ Tool: Analyze Permit Application with MODFLOW

Application ID:

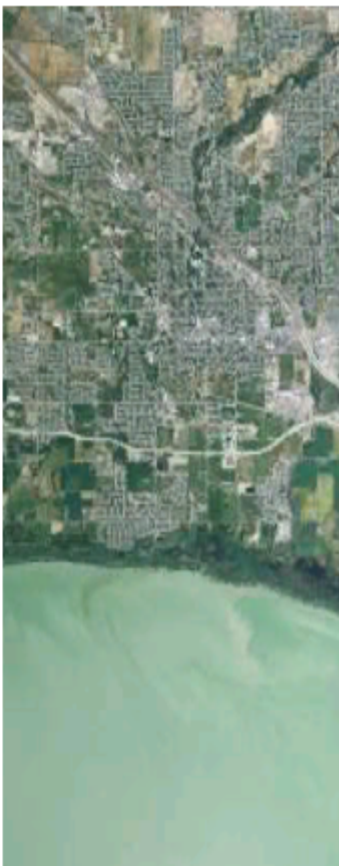
▼ Output Options

- New Wells
- Drawdown Contours
- Change in Spring Flows
- Total Change in Spring Flows
- PDF Report

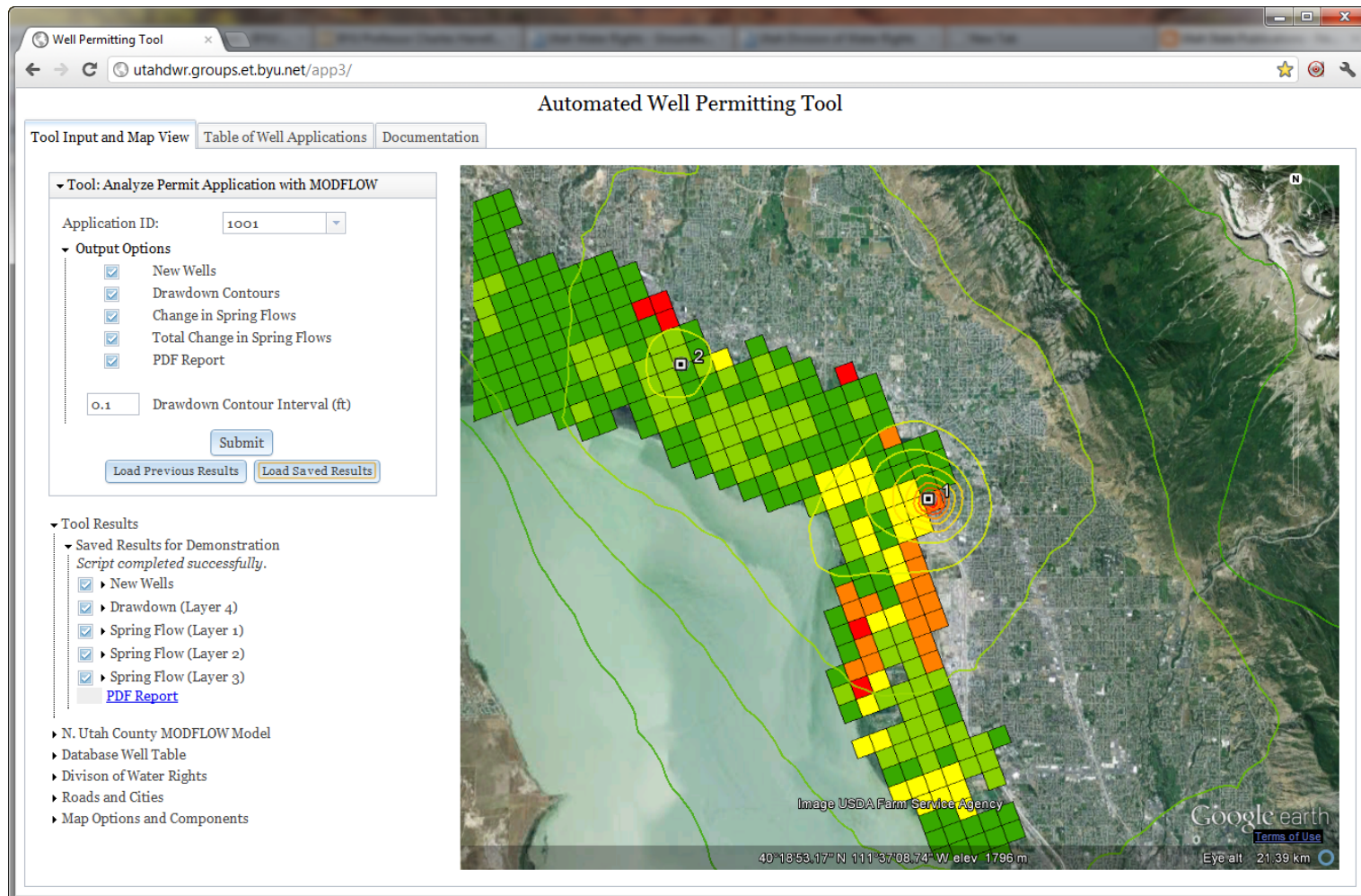
Drawdown Contour Interval (ft)

▼ Tool Results

- ▶ N. Utah County MODFLOW Model
- ▶ Database Well Table
- ▶ Division of Water Rights



Model Results



Impact on Springs

Total Change in Spring Flows
 PDF Report

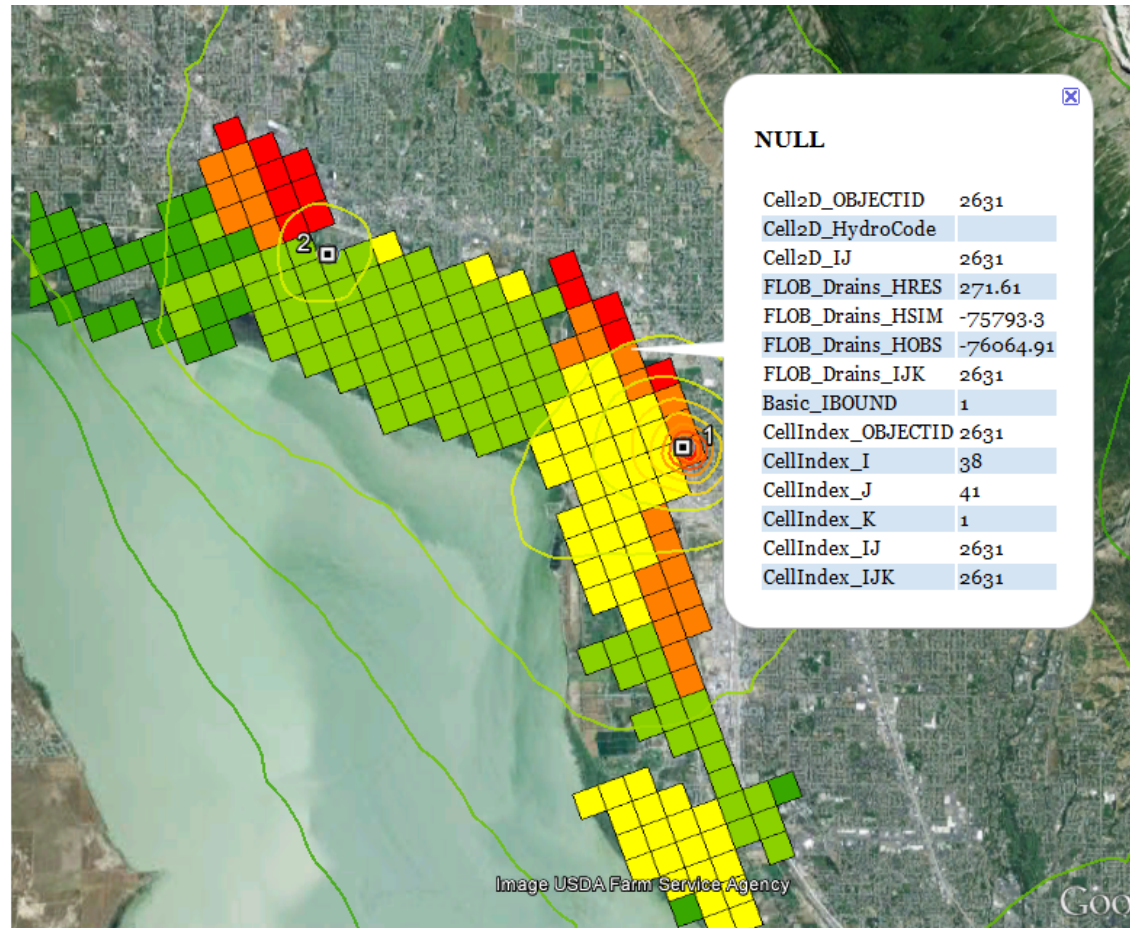
Drawdown Contour Interval (ft)

Tool Results
 Saved Results for Demonstration
Script completed successfully.

- New Wells
- Drawdown (Layer 4)
- Spring Flow (Layer 1)
Change in Flow (cfd)
 - 0 - 32
 - 32 - 101
 - 101 - 195
 - 195 - 317
 - 317 - 573

- Spring Flow (Layer 2)
- Spring Flow (Layer 3)
- [PDF Report](#)

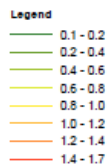
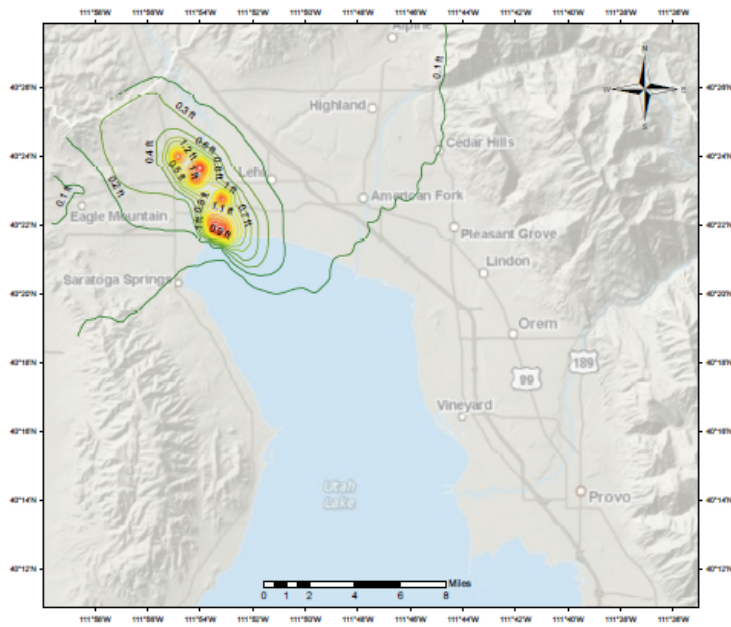
- ▶ N. Utah County MODFLOW Model
- ▶ Database Well Table
- ▶ Division of Water Rights



PDF Output

Simulated Aquifer Drawdown: Layer 3

North Utah County MODFLOW Model Simulation Results



This map was generated by a server-based automated well permitting analysis system using ArcGIS and AHGW geoprocessing tools and the Northern Utah County MODFLOW model created by the USGS.

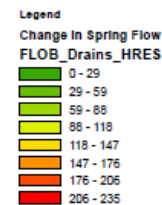
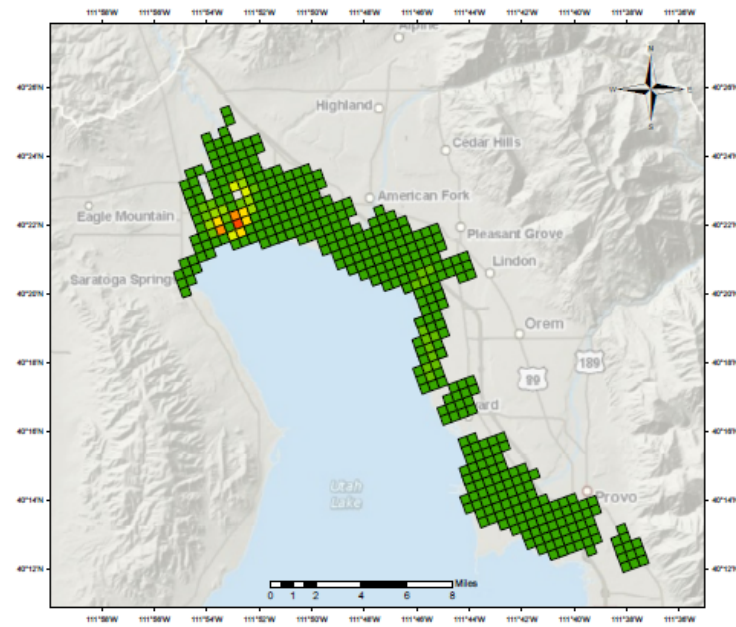
Simulation Executed 5/23/2012 at 5:44:30 PM

AQUAVEO
Water Modeling Solutions



Simulated Change in Spring Flow: Layer 3

North Utah County MODFLOW Model Simulation Results



This map was generated by a server-based automated well permitting analysis system using ArcGIS and AHGW geoprocessing tools and the Northern Utah County MODFLOW model created by the USGS.

Simulation Executed 5/23/2012 at 5:50:32 PM

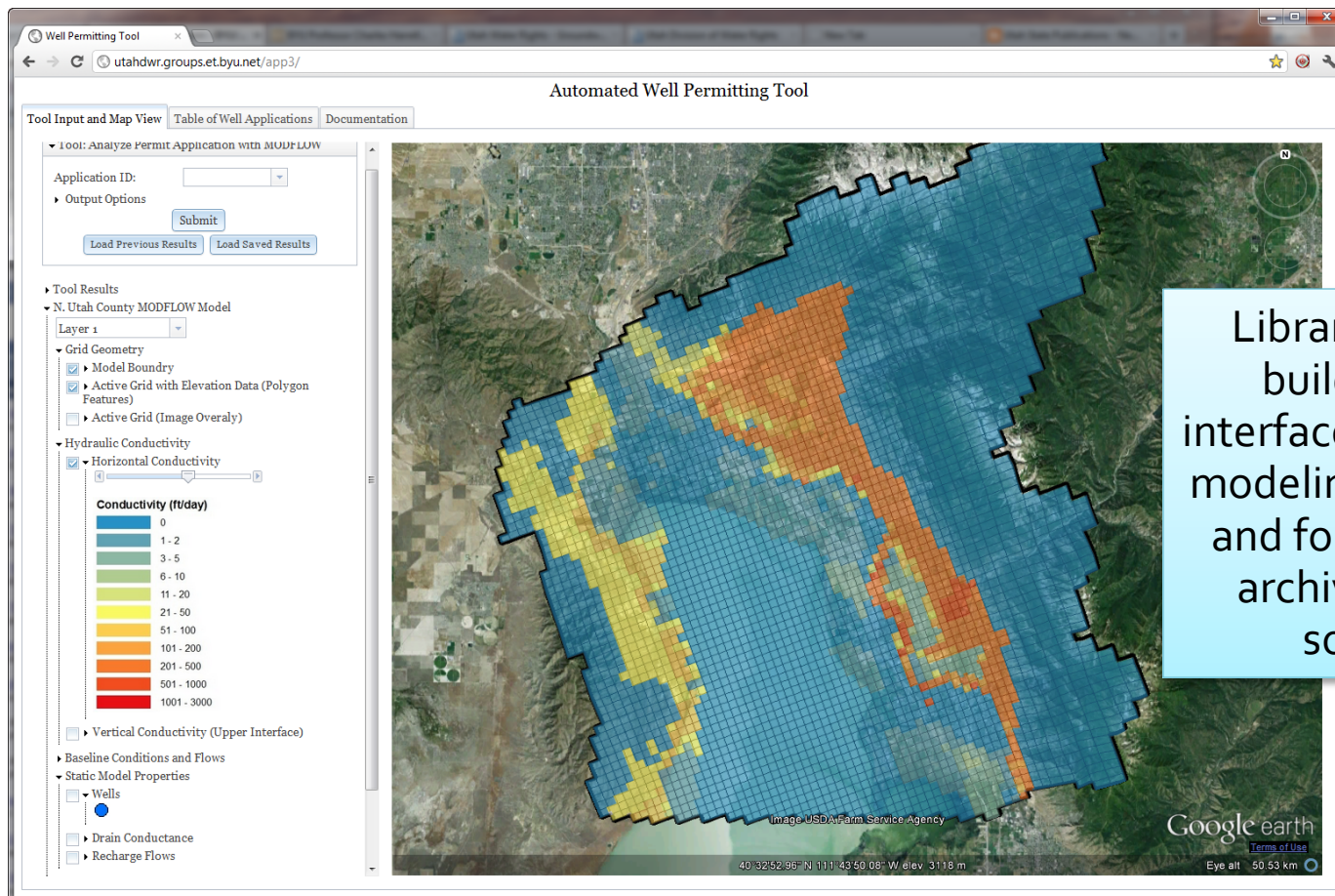
AQUAVEO
Water Modeling Solutions



BYU CI-WATER Tools

- Two primary components
 - Cloud-Based Simulation Web Interface API
 - Model Scripting Tools

Cloud-Simulation API



Library (API) for building web interfaces to scripted modeling workflows and for visualizing archived model solutions

Cloud-Based Water Level Mapping Utility

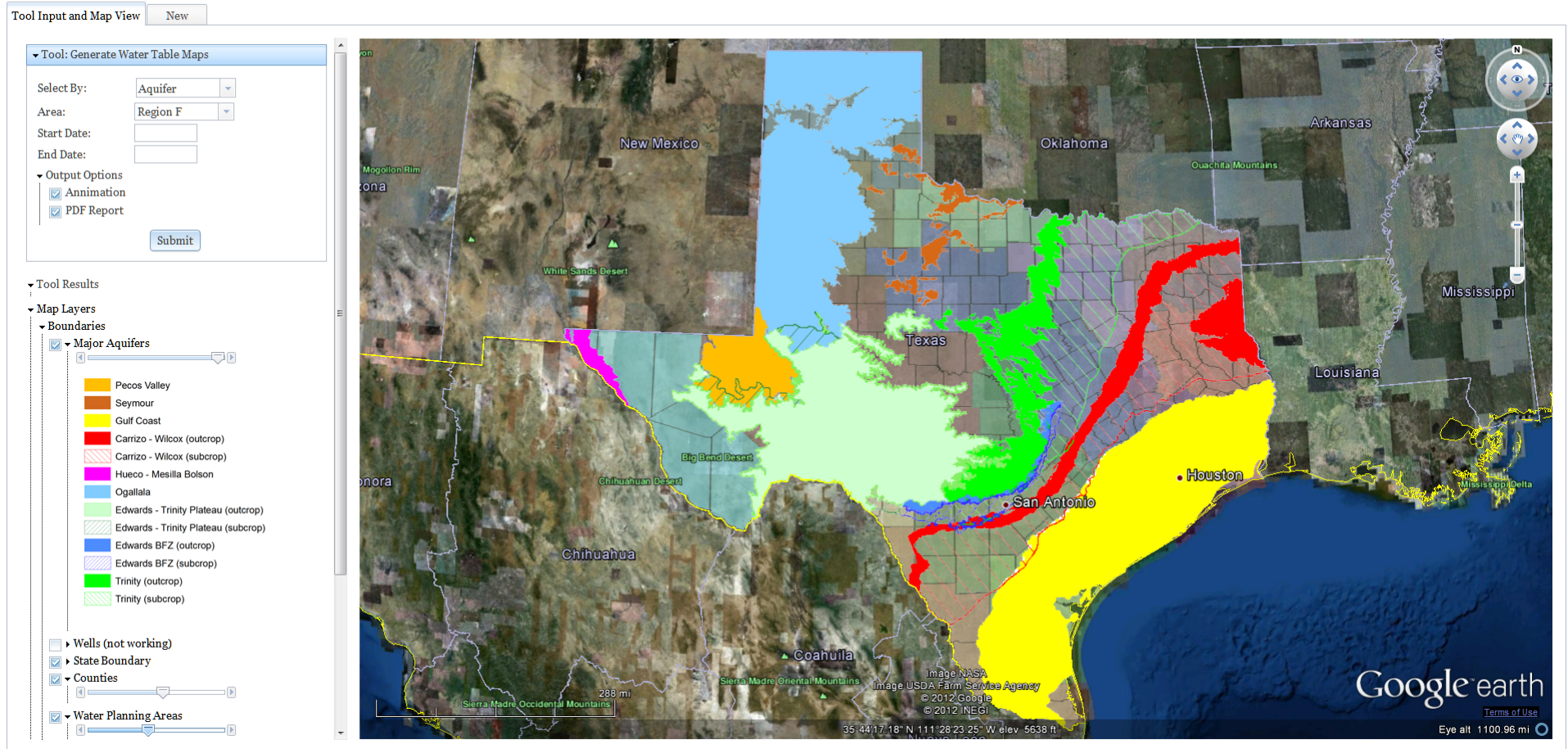
- Inputs
 - Sub-region (aquifer, district, county, etc.)
 - Date (or range of dates)
- Output
 - Water level and/or drawdown maps

Texas Drought and Resources Updates

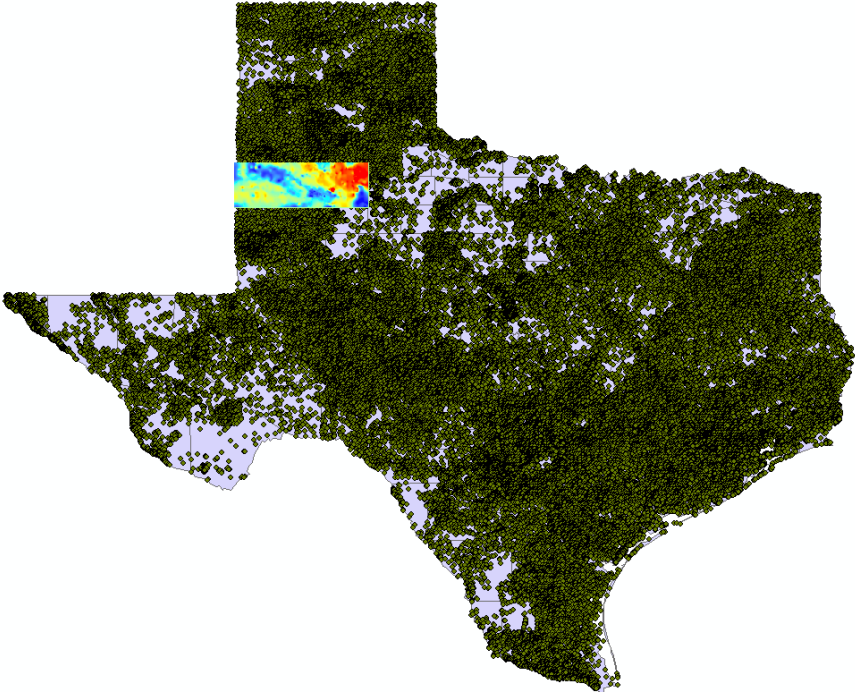
Developed by the Drought Technology Steering Committee

Web Interface

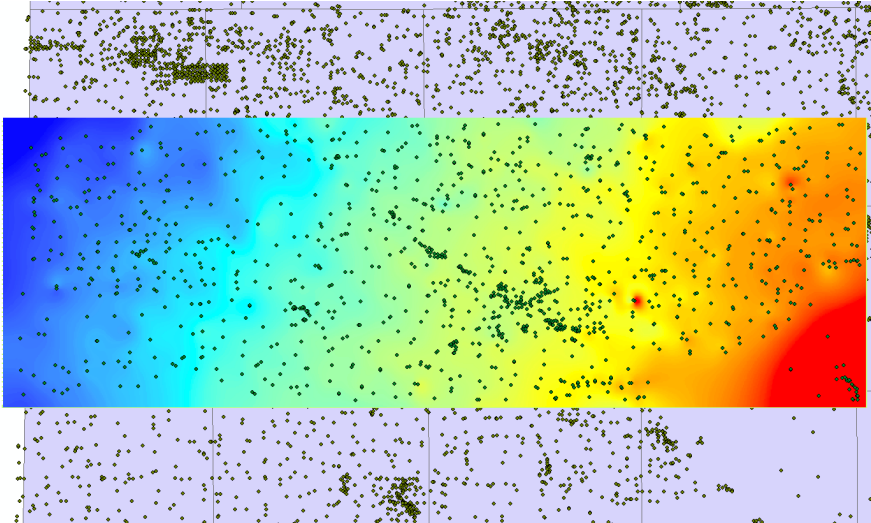
Automated Water Table Mapping Tool



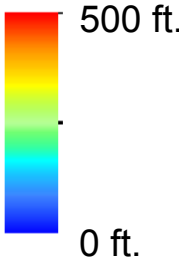
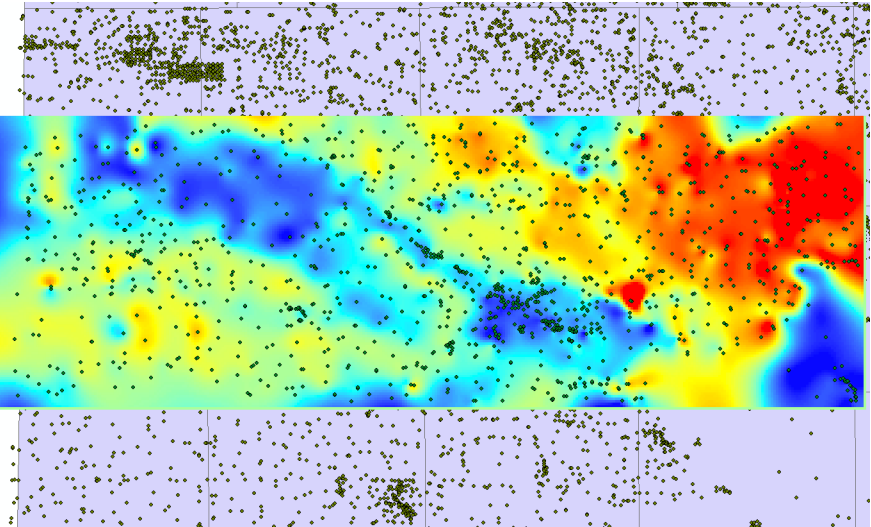
Sample Maps



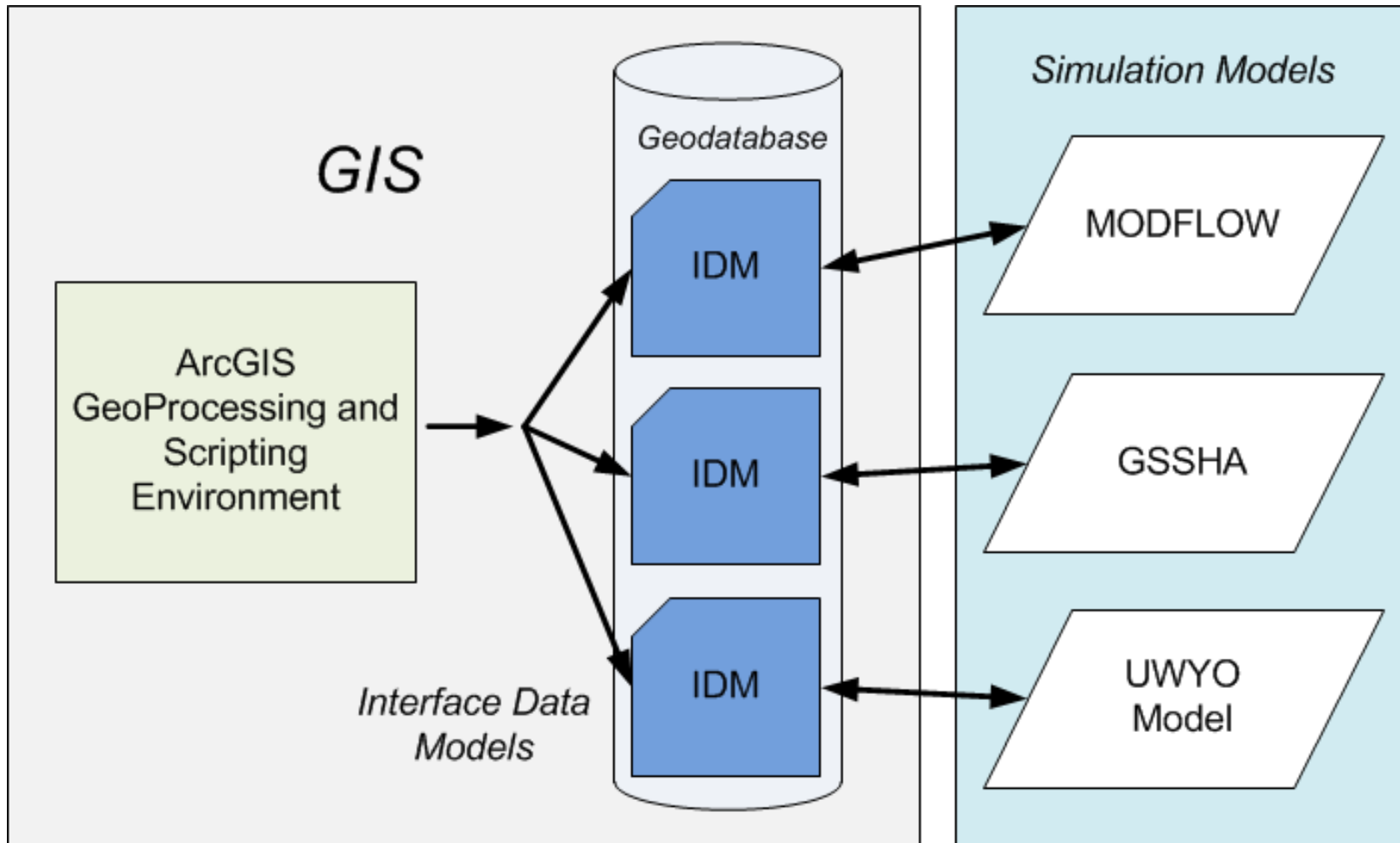
Groundwater Surface Elevation



Depth to Groundwater

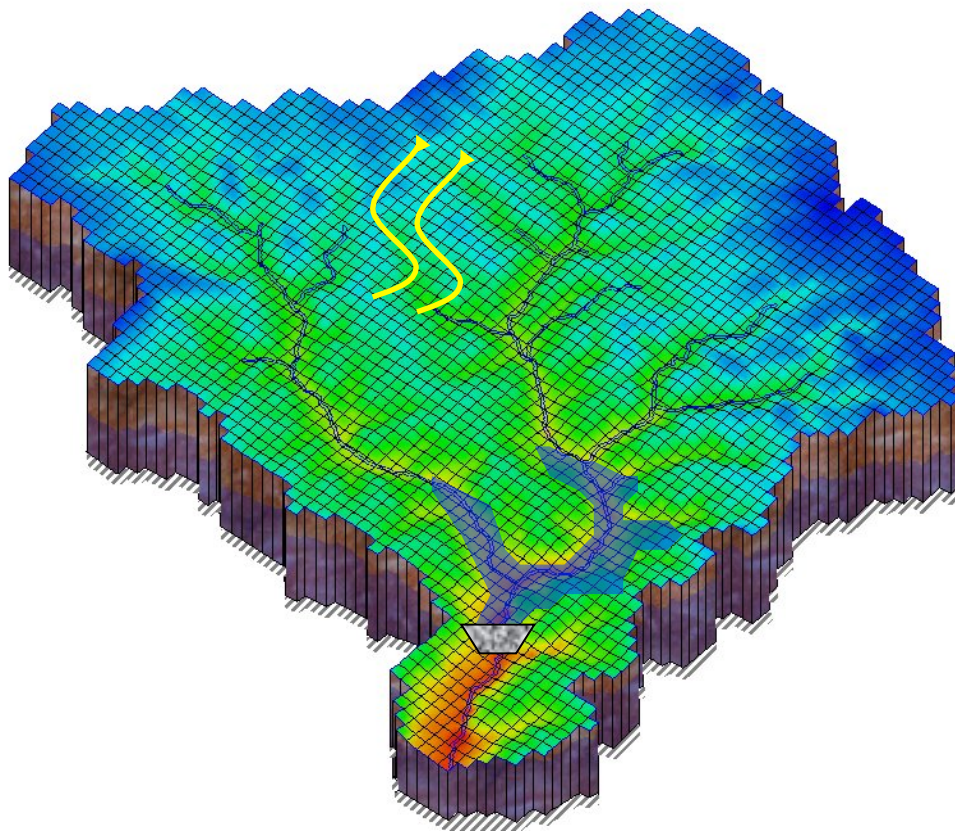


Model Scripting Tools



GSSHA Data Model and Tools

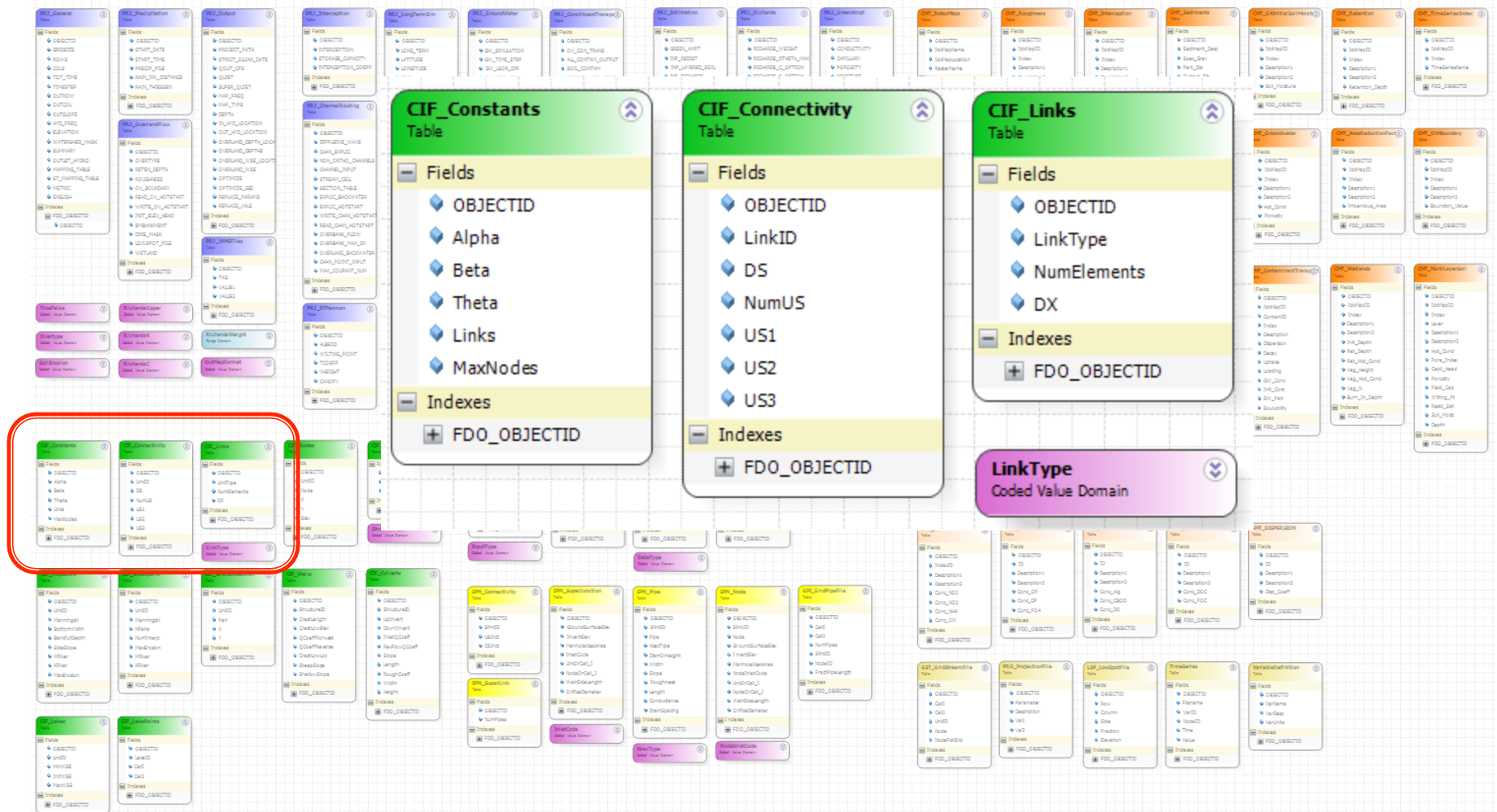
*Gridded Surface/Subsurface
Hydrologic Analysis (GSSHA) model*



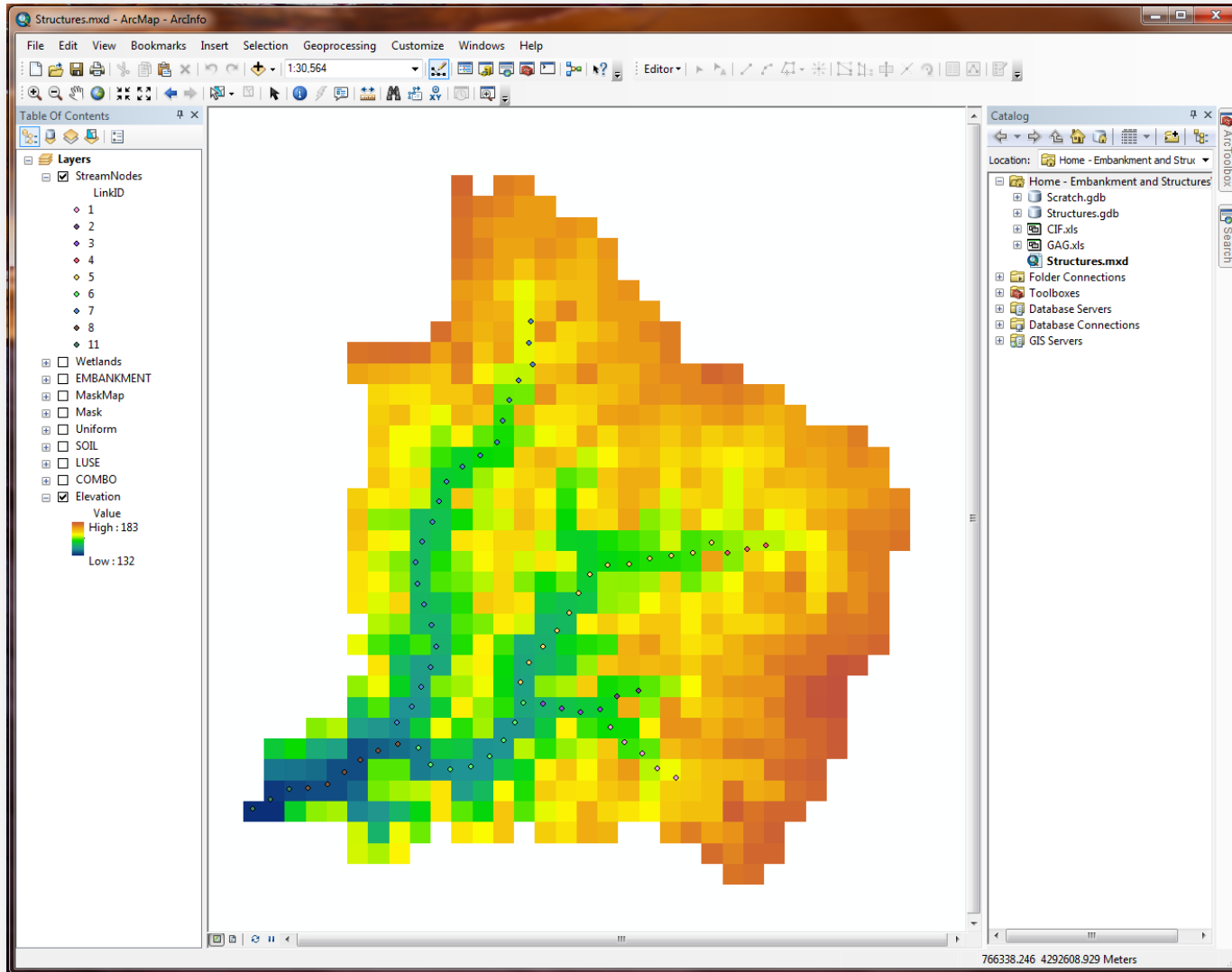
UNIVERSITY
OF WYOMING

New Thinking

GSSHA Data Model

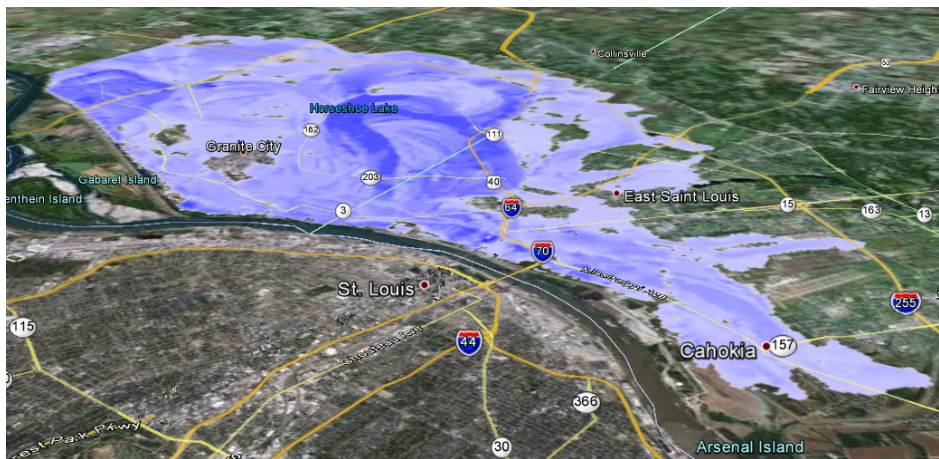


GSSHA Model File in ArcGIS

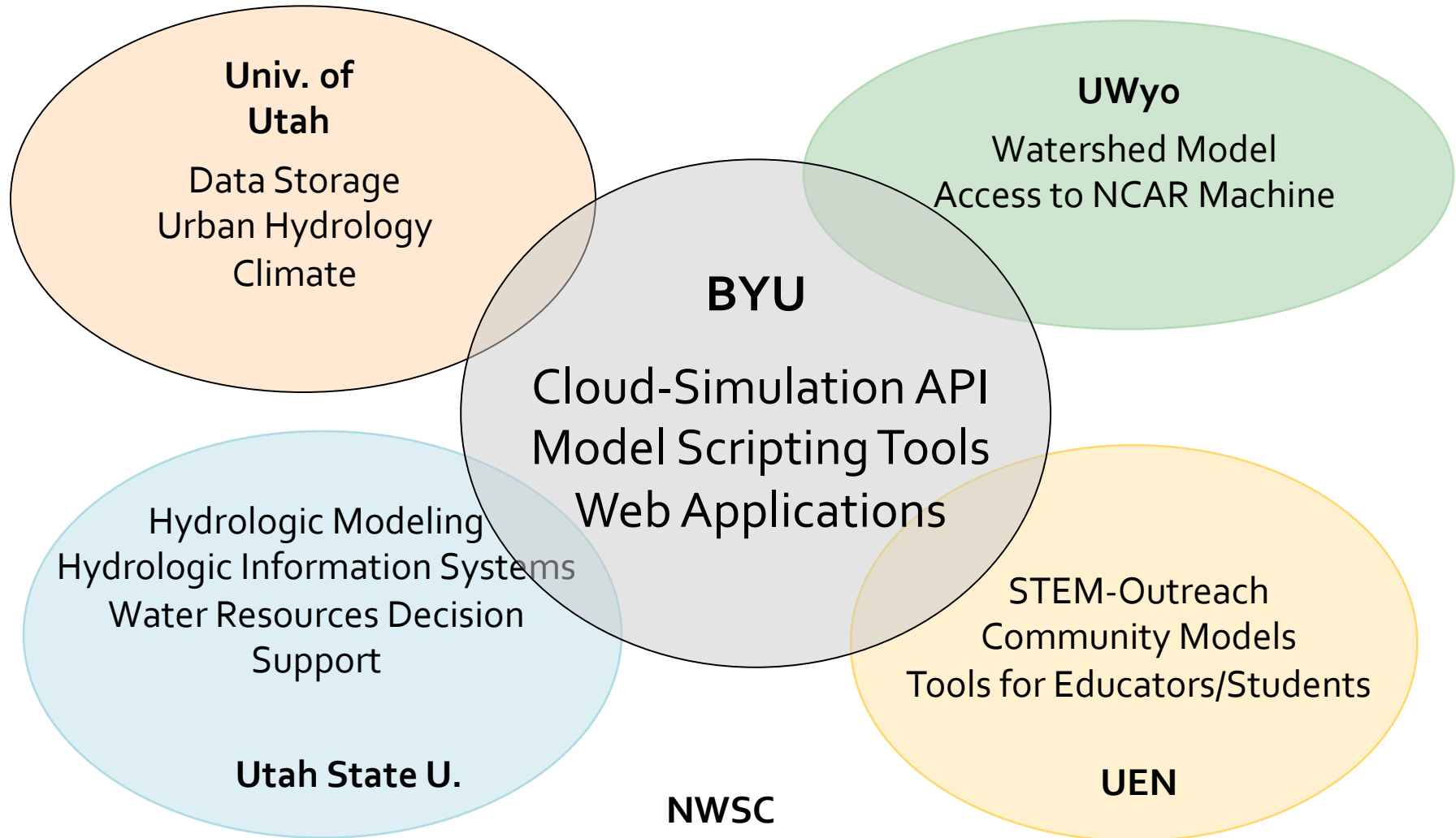


Applications

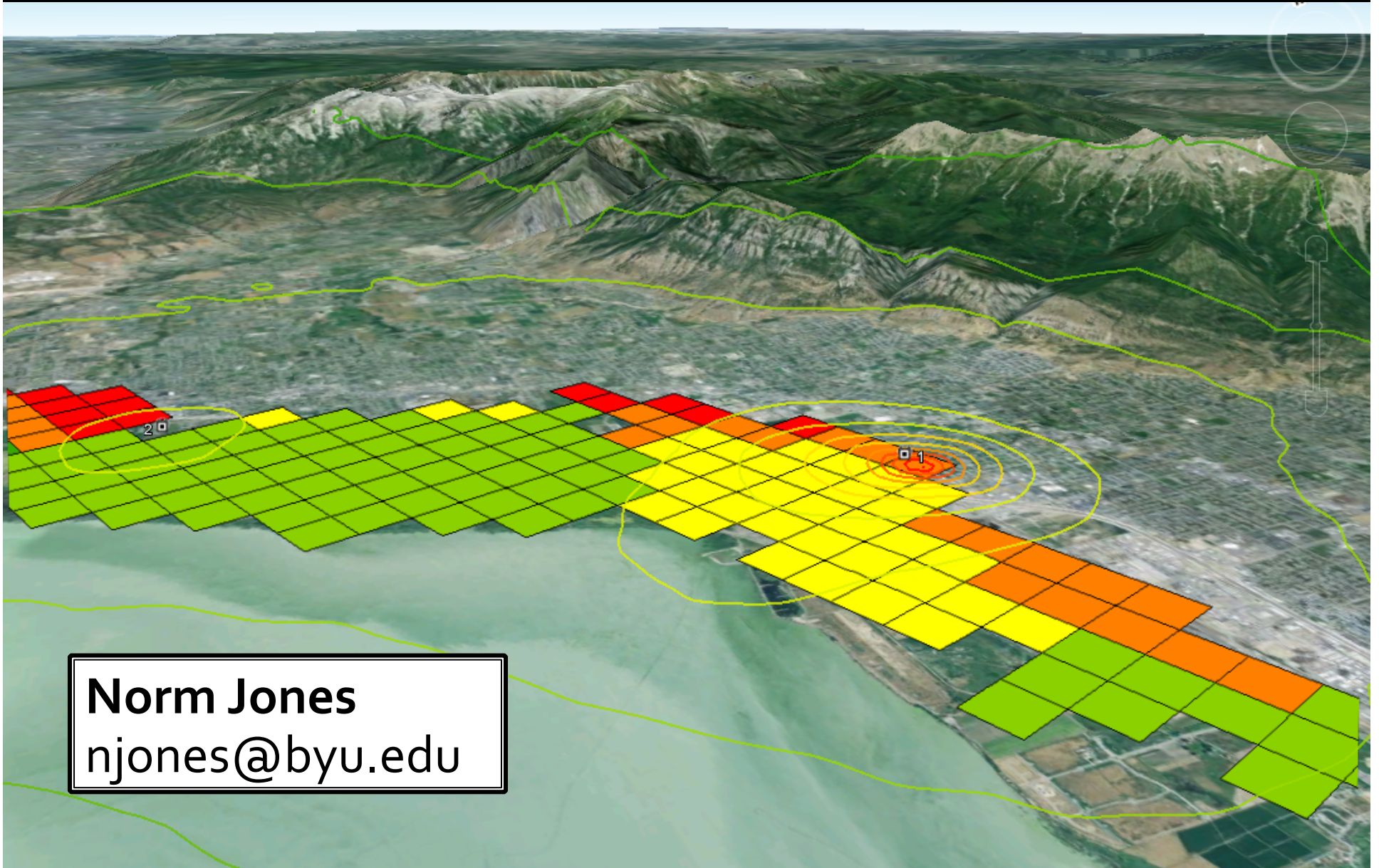
- Snowmelt
- Flooding
- Stormwater runoff
- Levee breach
- Burned area analysis



CI-WATER Integration



Thank you



Norm Jones
njones@byu.edu