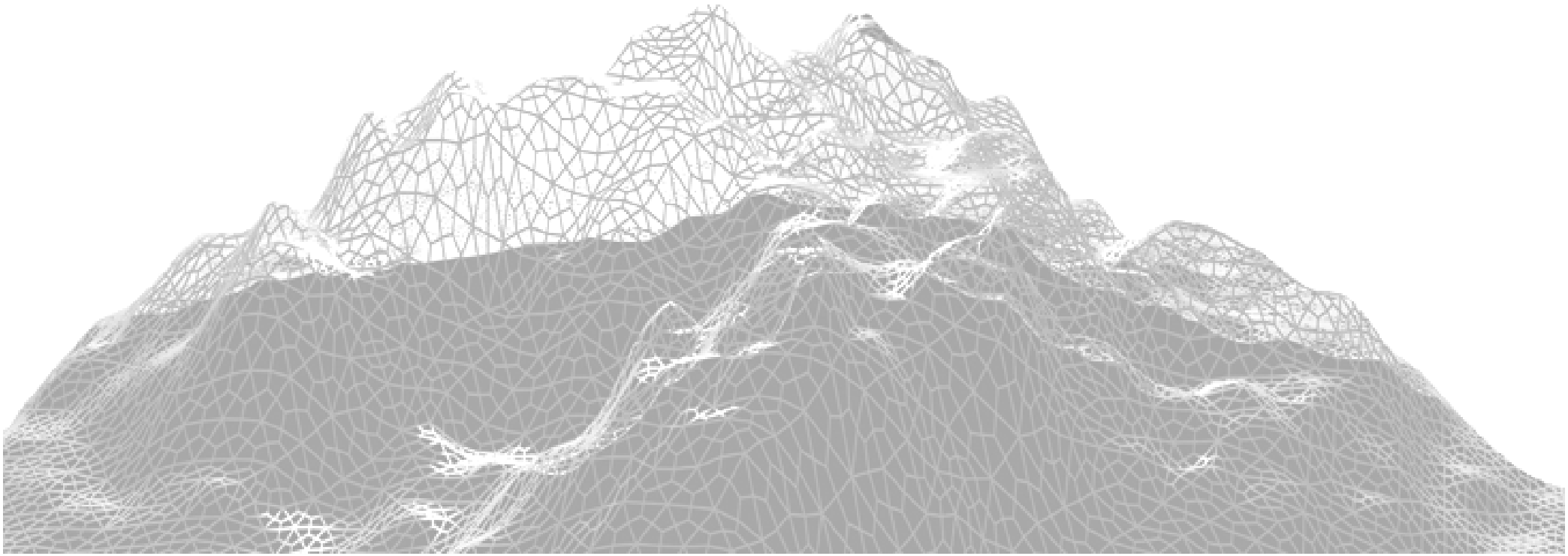
Estimating UXO Spatial Density Using a Composite Index Technique

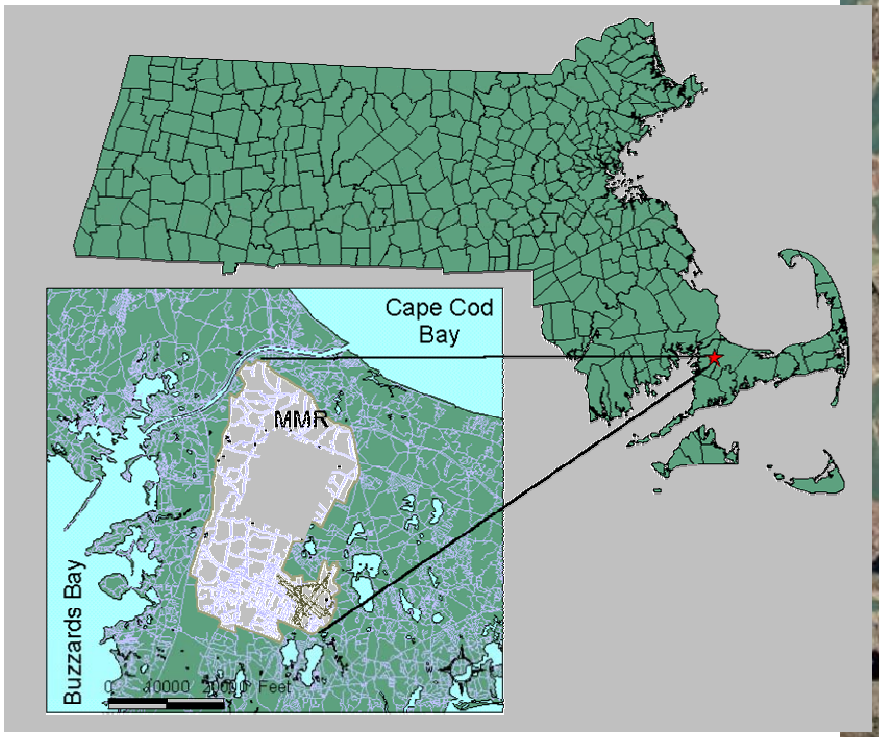


Problem Statement

- **Military training has taken place over the "Sole Source" Aquifer for western Cape Cod.**
- **Could UXO corrosion pose a future threat to groundwater?**
  - **What is the spatial distribution of UXO?**
  - **What potential contaminants are contained within UXO items?**
  - **How much contaminant could be released to the environment as UXO casings corrode?**
  - **What impacts to the aquifer will result from potential future releases?**

Site Location

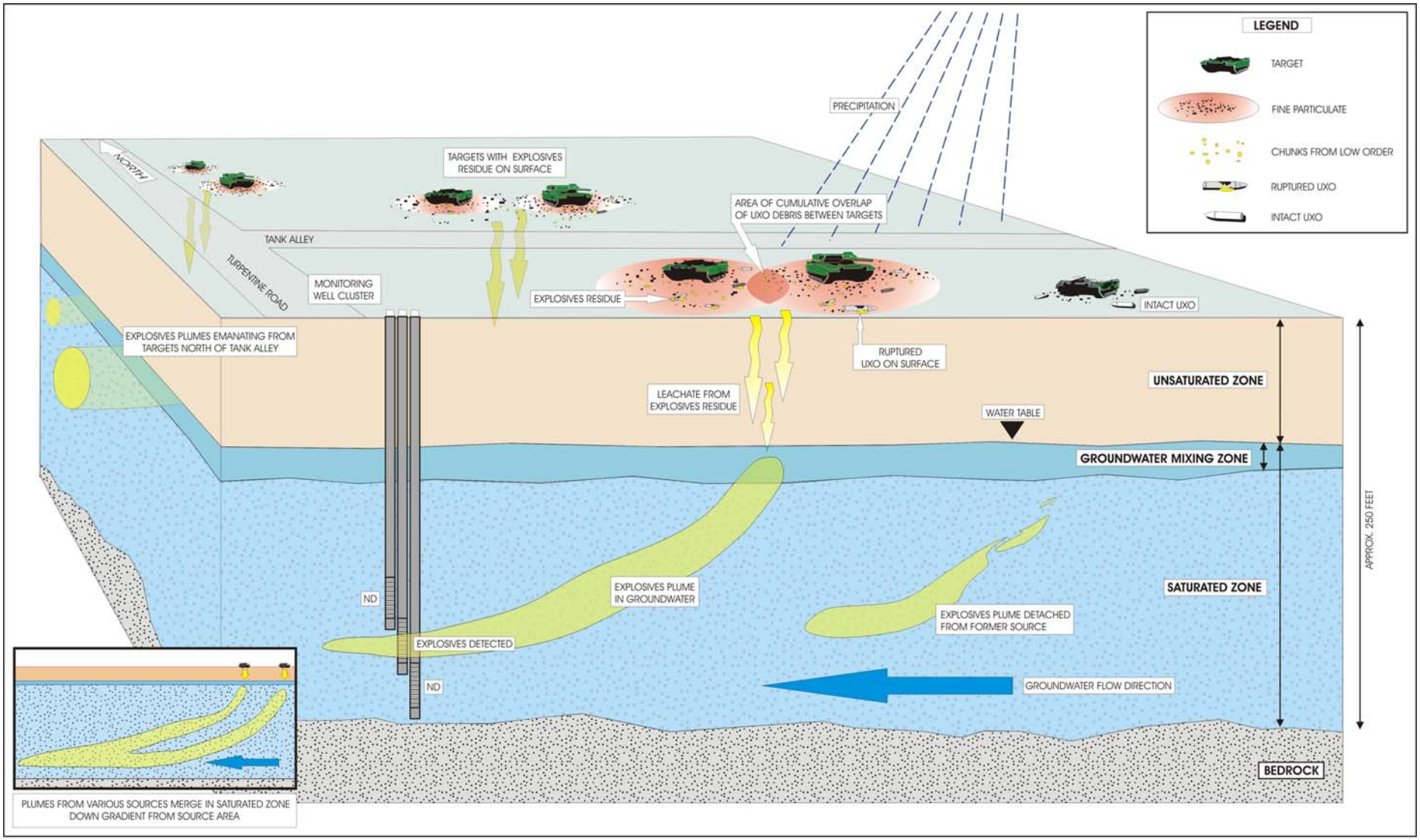
Massachusetts Military Reservation, Camp Edwards



Presentation Overview

- Integrating 3 independent indicators of unexploded ordinance (UXO) spatial density
- Derivation of a Composite Index Function
- Computing/mapping estimated UXO density
- Preliminary validation studies
- Projecting contaminant loading to aquifer
- Other ongoing efforts

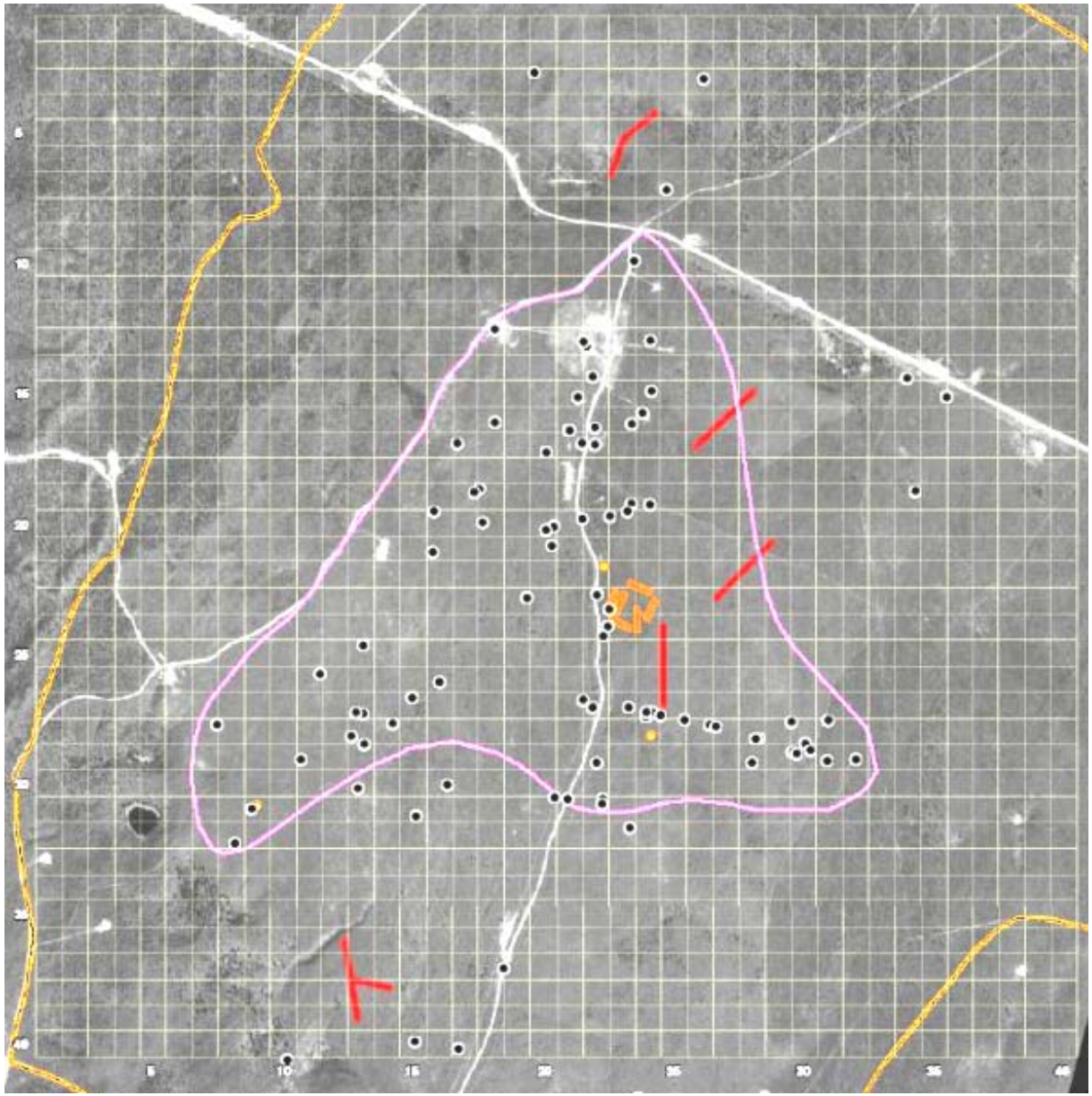
Conceptual Site Model



UXO Density Indicators

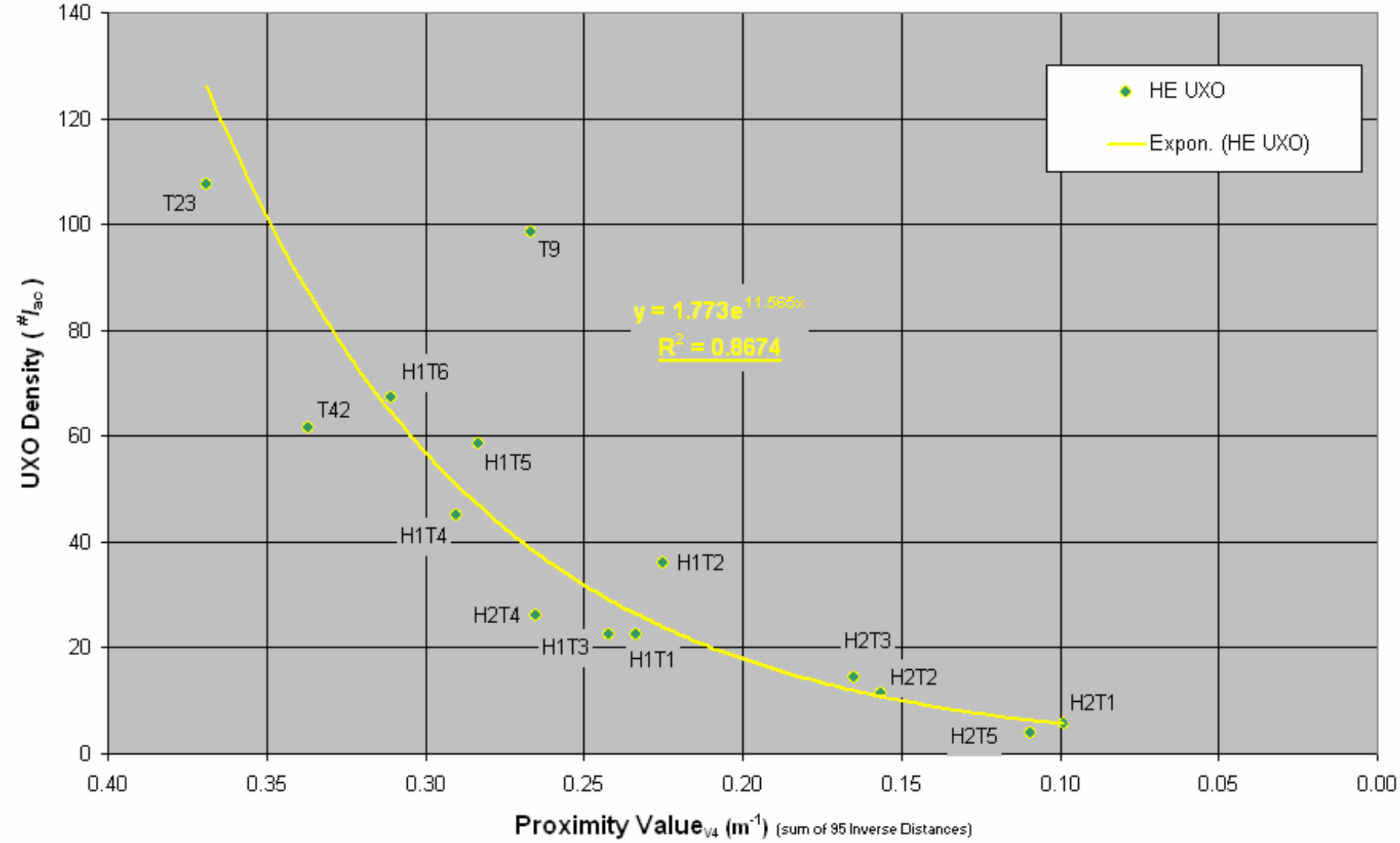
- **Proximity to known target locations** – intended location of ordnance deposition
- **Aeromagnetic signal intensity** – presence of UXO and metal debris (including target objects) in soils
- **Cleared areas** – disturbance of vegetation due to range activities i.e. impact craters
- **Firing fans** – intended path of ordnance travel
- **Soil Data** – presence of explosives particulates

Target Locations

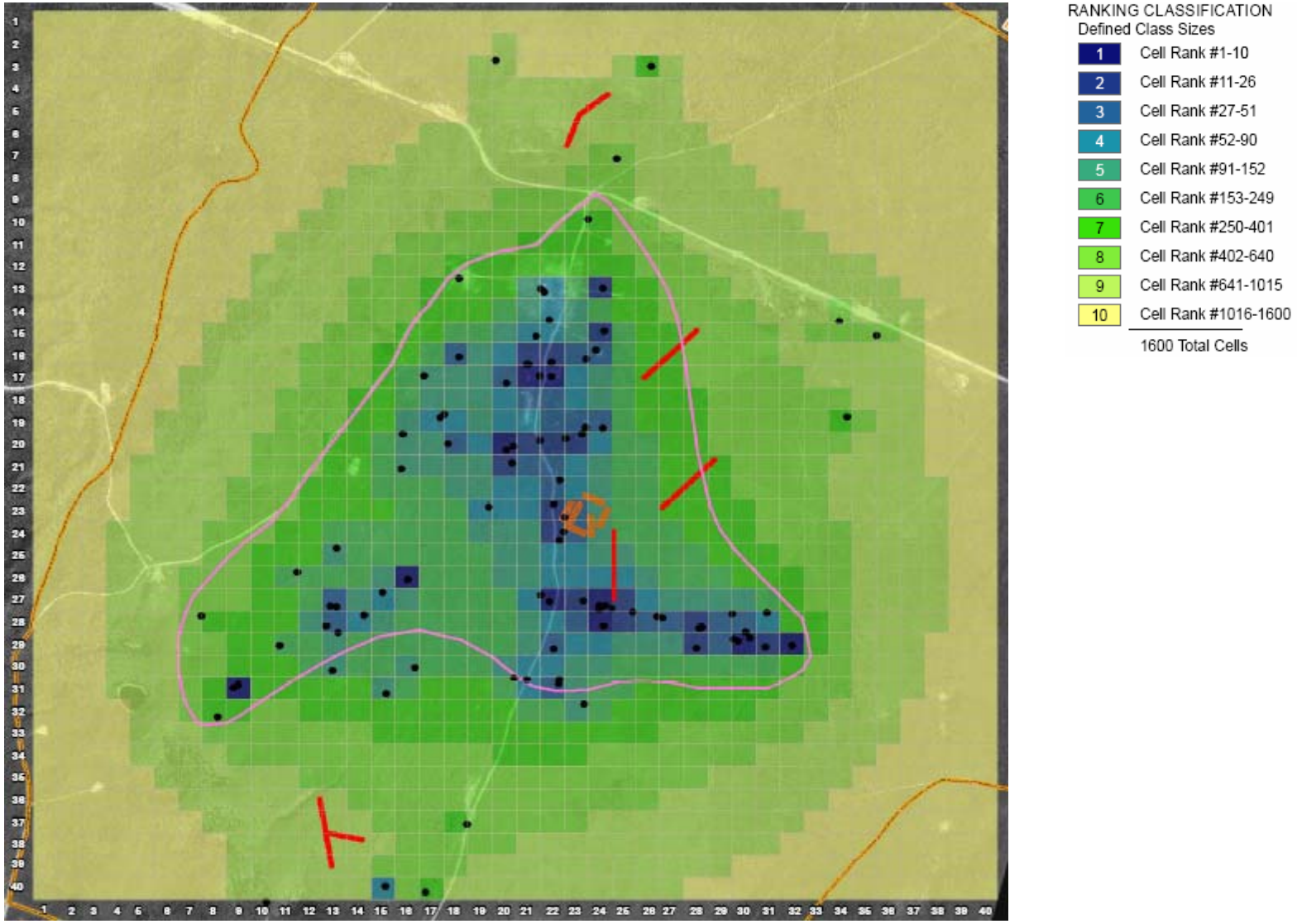


Target Proximity

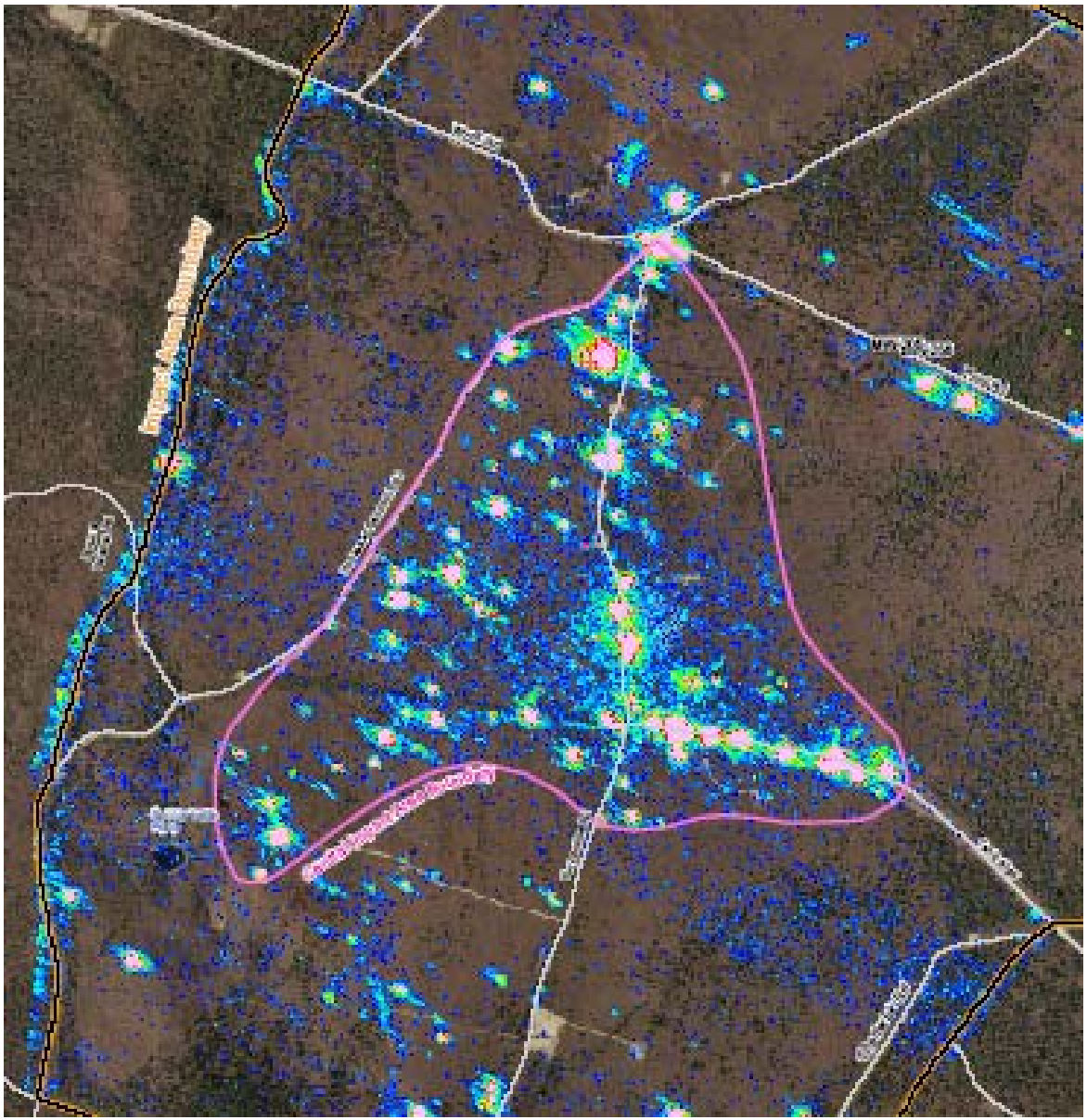
Proximity Value vs. Known UXO Density in 14 Test Plots



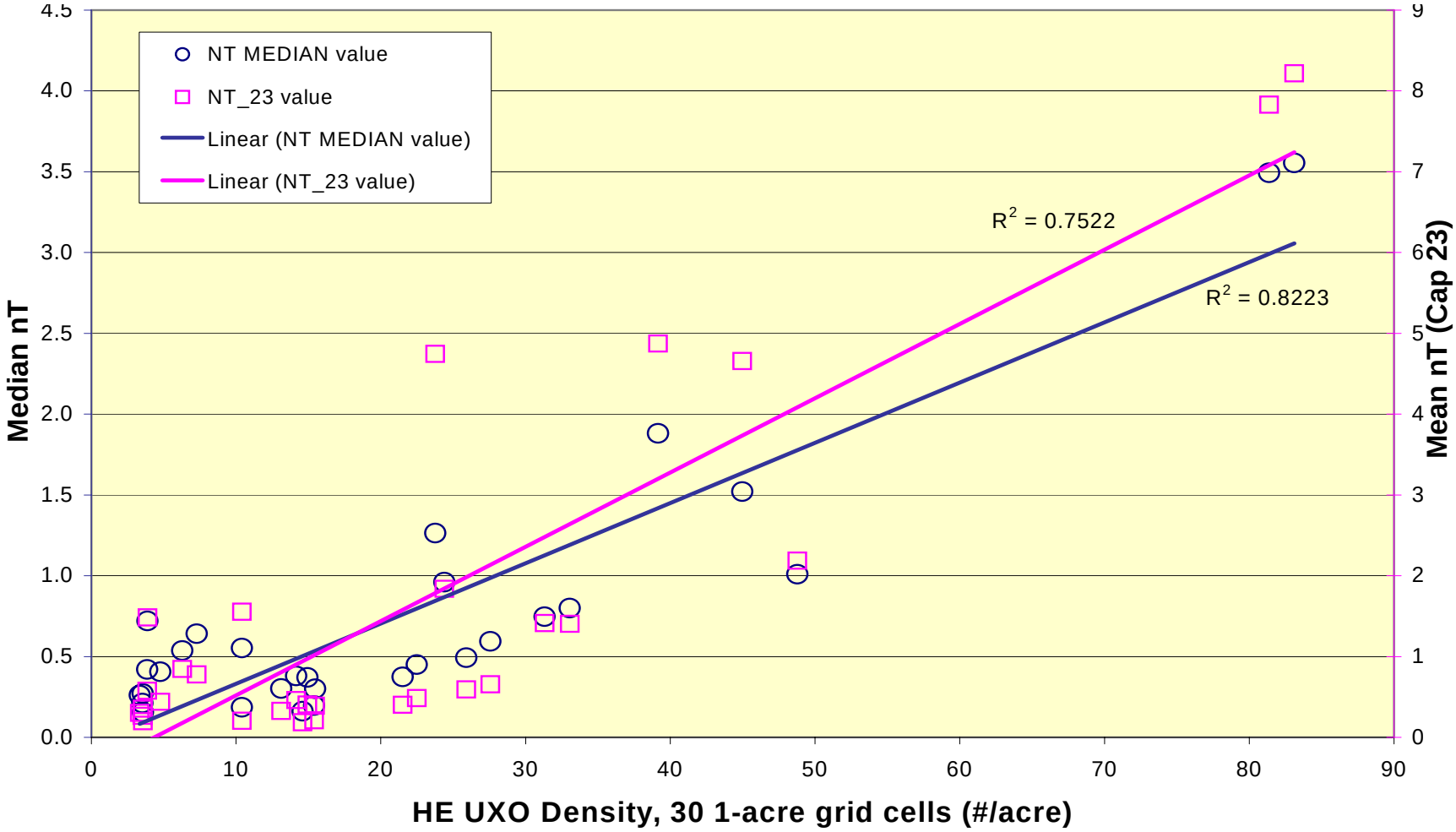
Target Proximity Ranking Map



Aeromagnetic Intensity



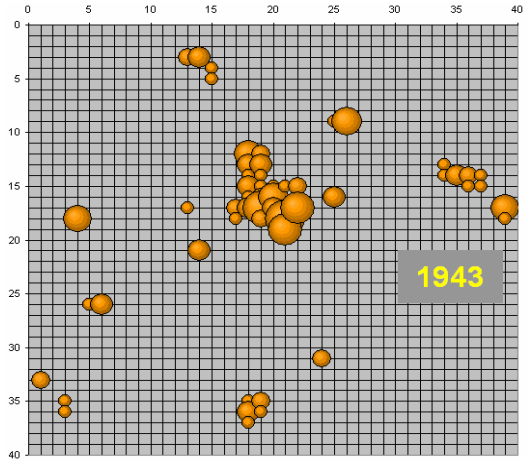
Known Density vs. Aeromagnetic Intensity

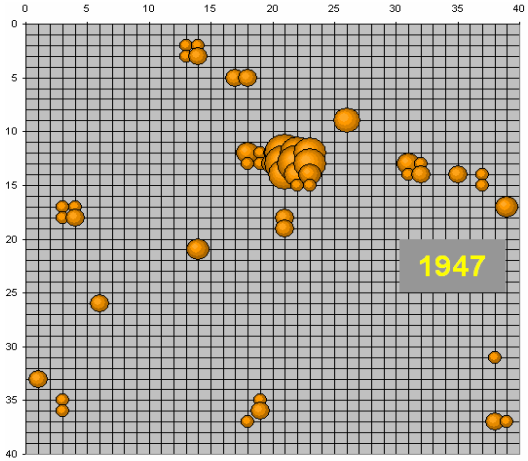


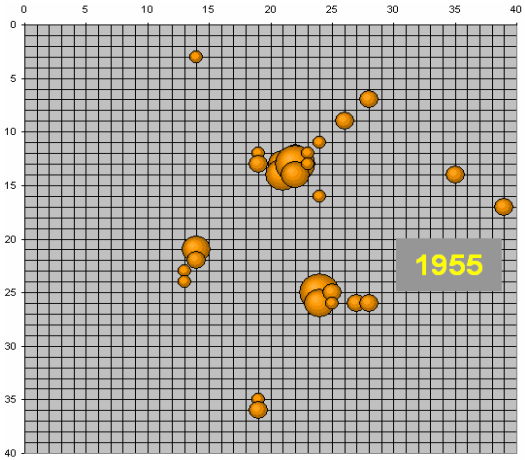
Cleared Areas from airphotos

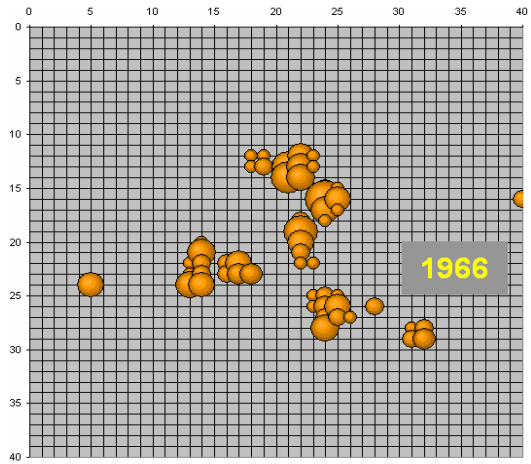
1943, 1947, 1955, 1966, 1977, 1986, & 1991 (not shown)

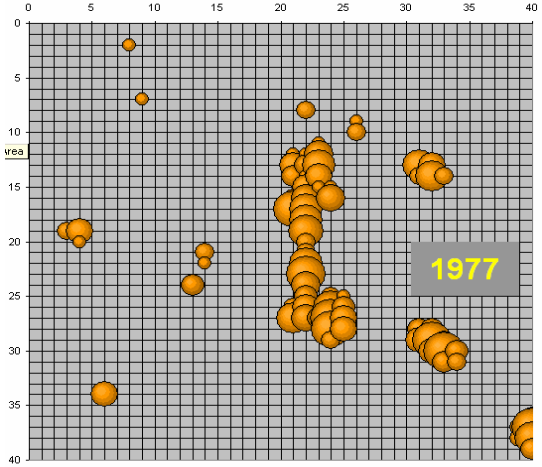
Bubble size is proportional to clearance percentage for each 1-acre grid cell

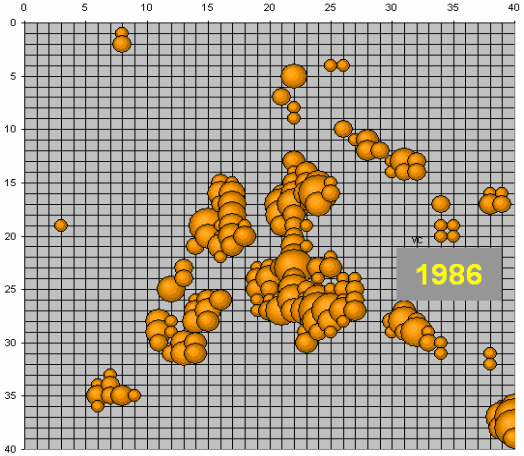








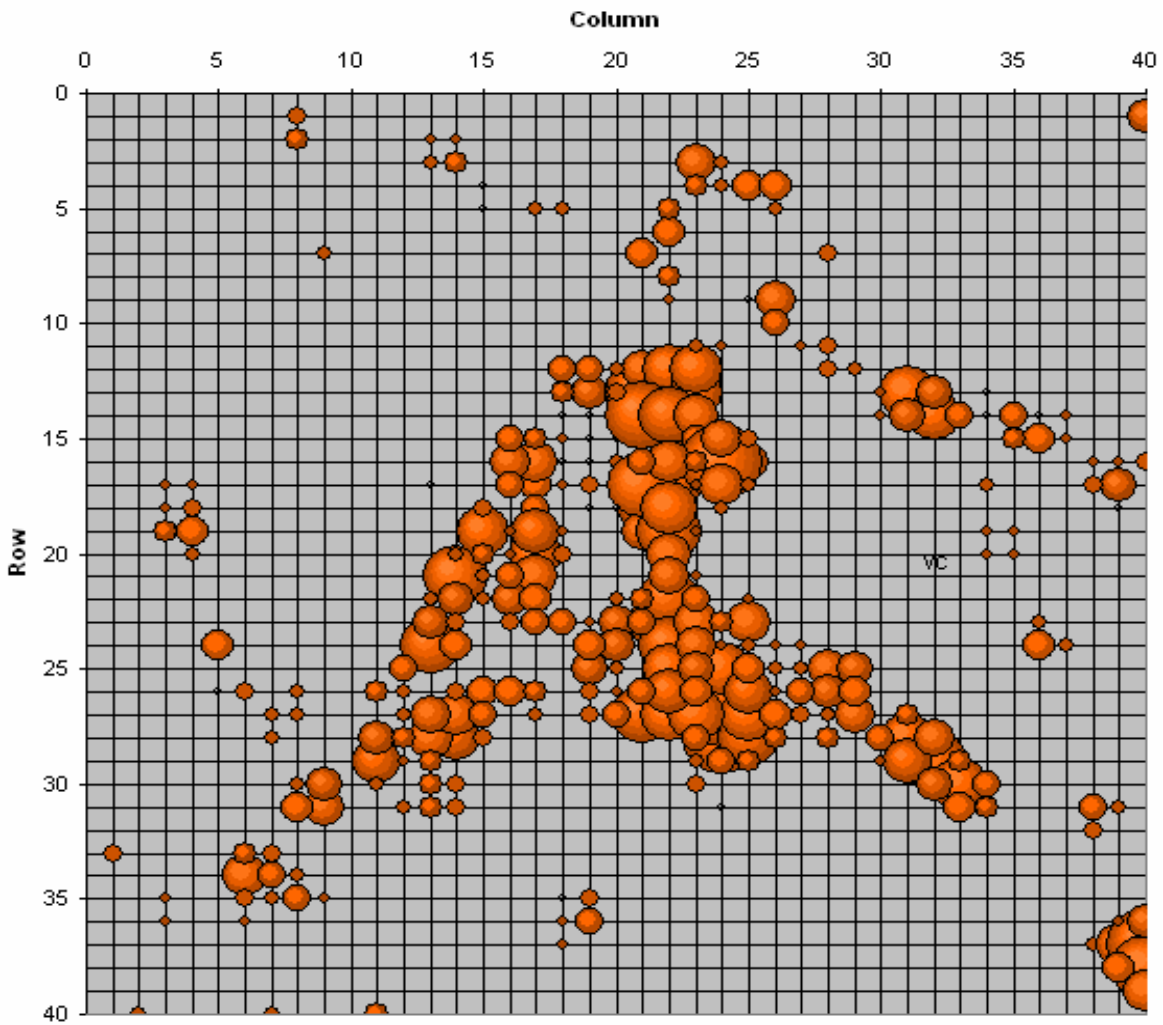




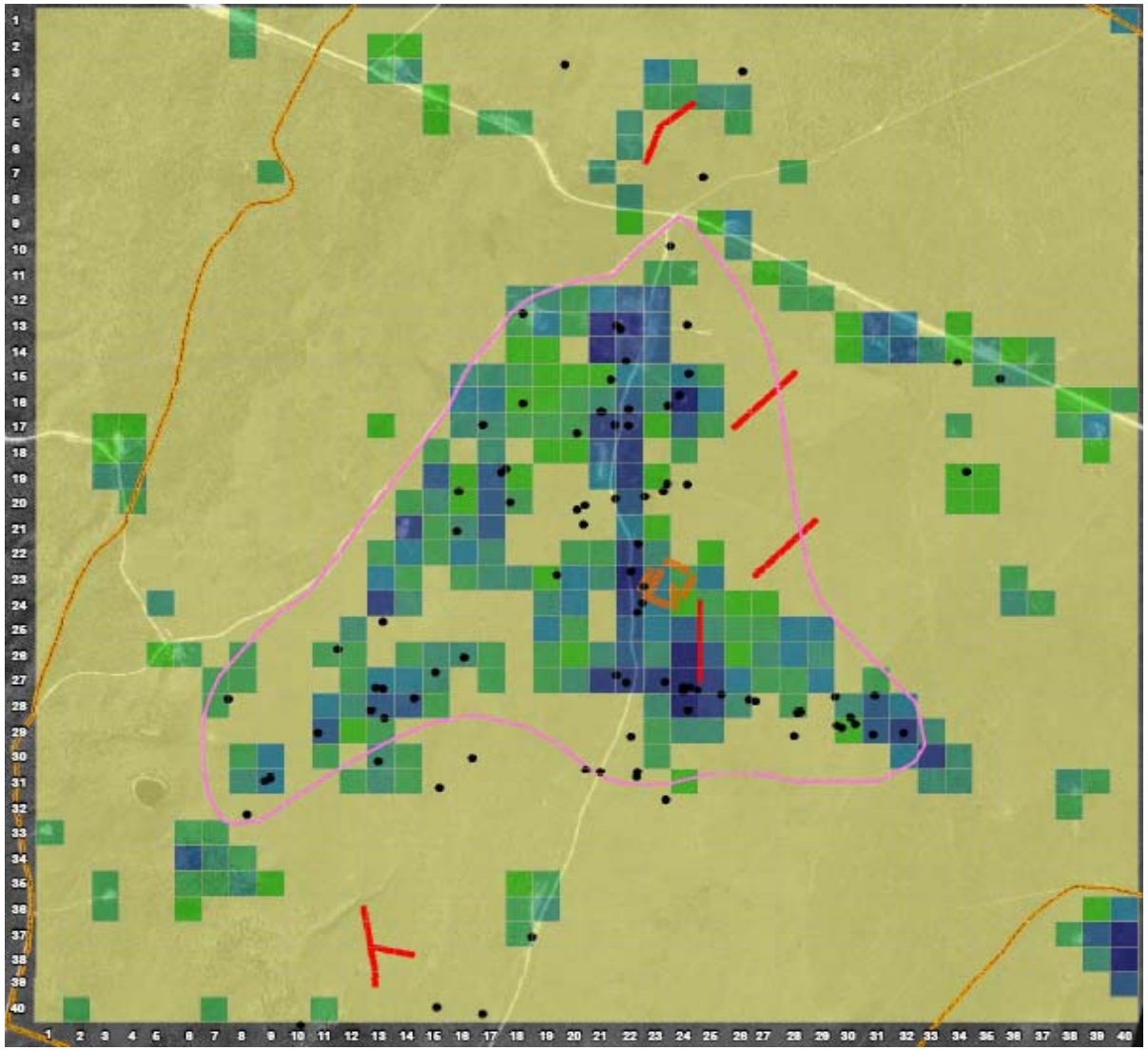
Cleared Areas from airphotos

Time-weighted clearance value for 55 years 1943-1997

48 No-Photo years: Maps interpolated or extrapolated (1992-97)



Cleared Areas Ranking Map

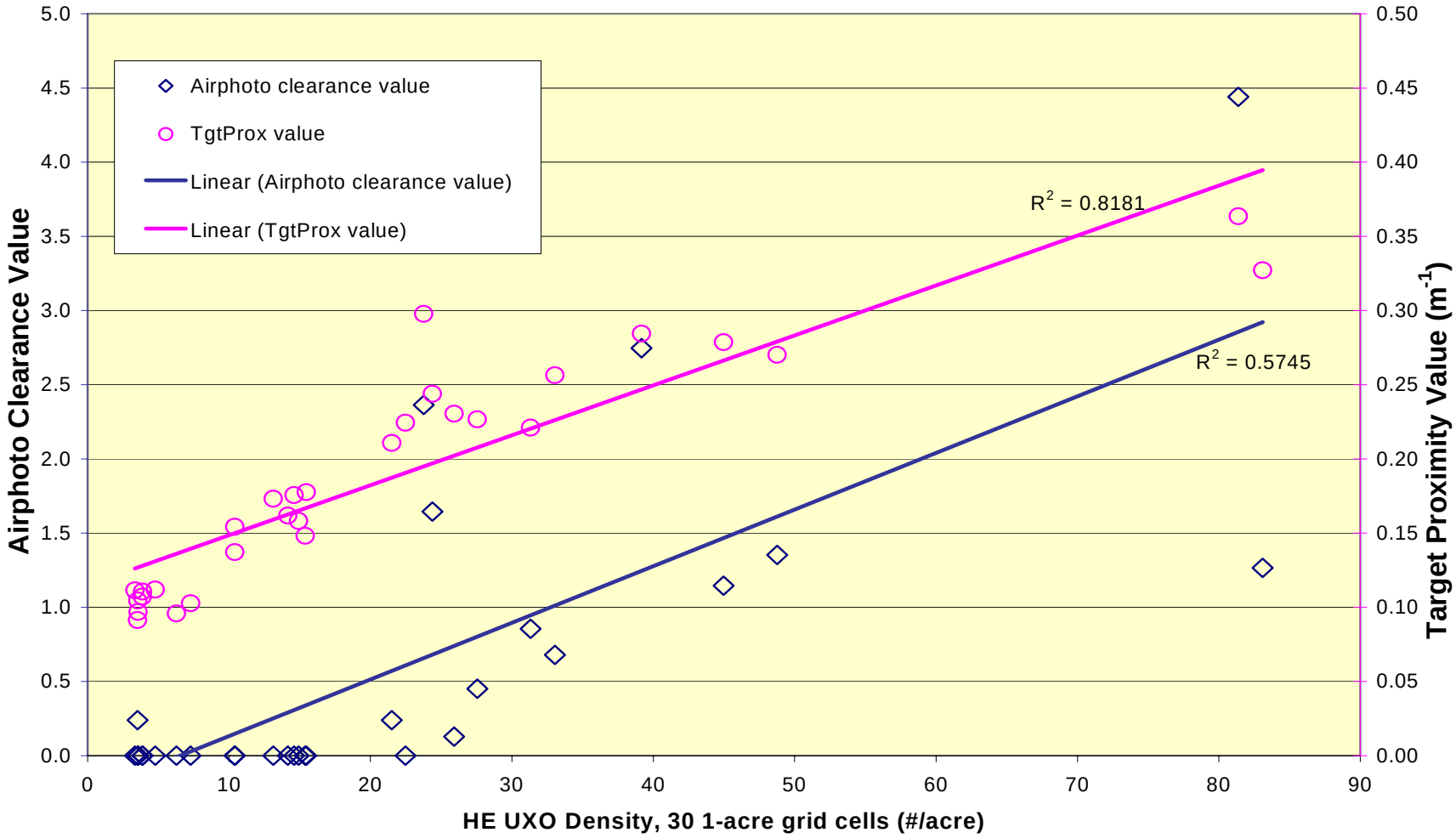


RANKING CLASSIFICATION
Defined Class Sizes

1	Cell Rank #1-10
2	Cell Rank #11-26
3	Cell Rank #27-52
4	Cell Rank #53-90
5	Cell Rank #91-152
6	Cell Rank #153-247
7	Cell Rank #248-300
8	0 Cells
9	0 Cells
10	Cell Rank #301-1600

1600 Total Cells

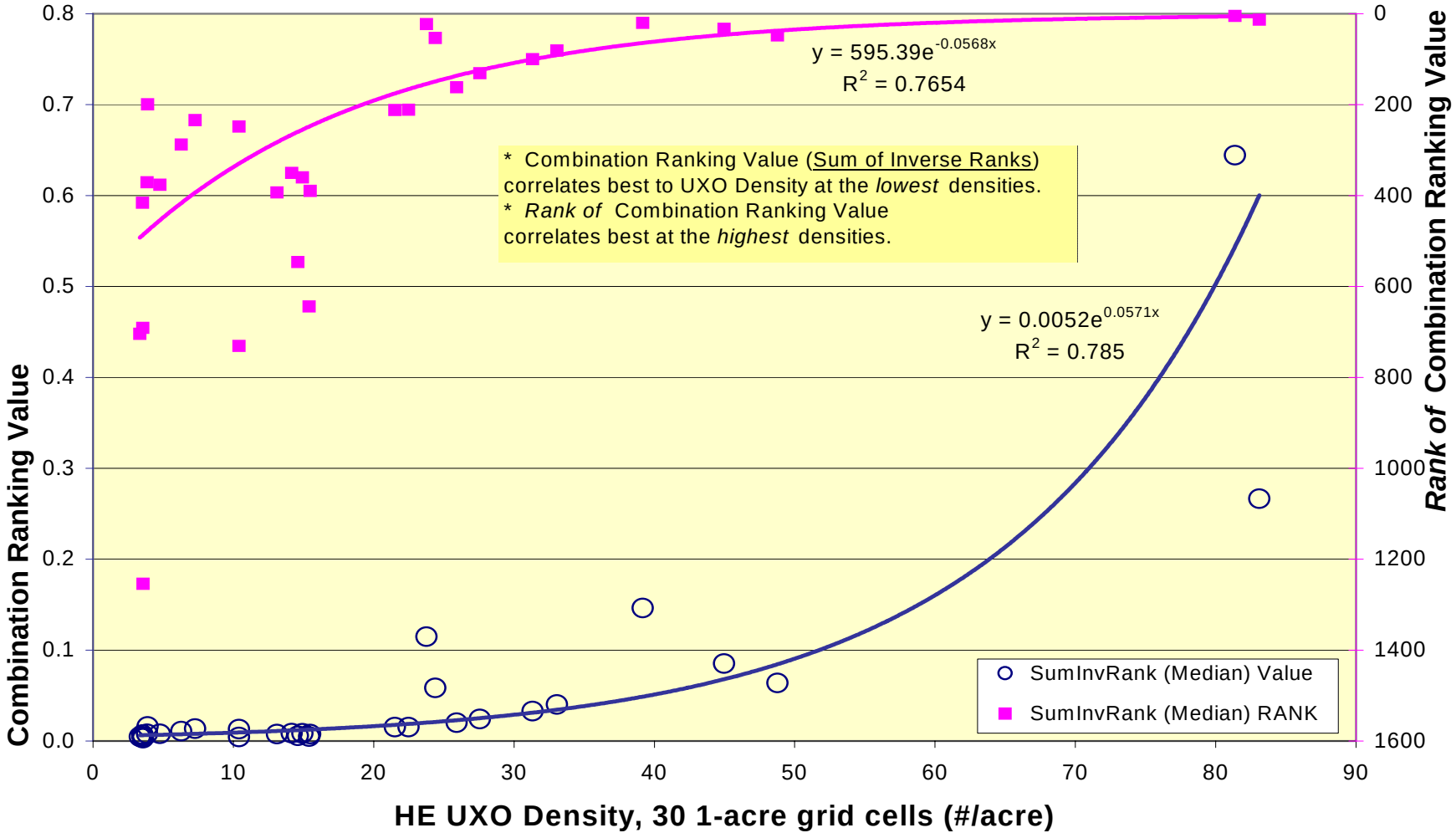
Known Density vs. Individual Indices



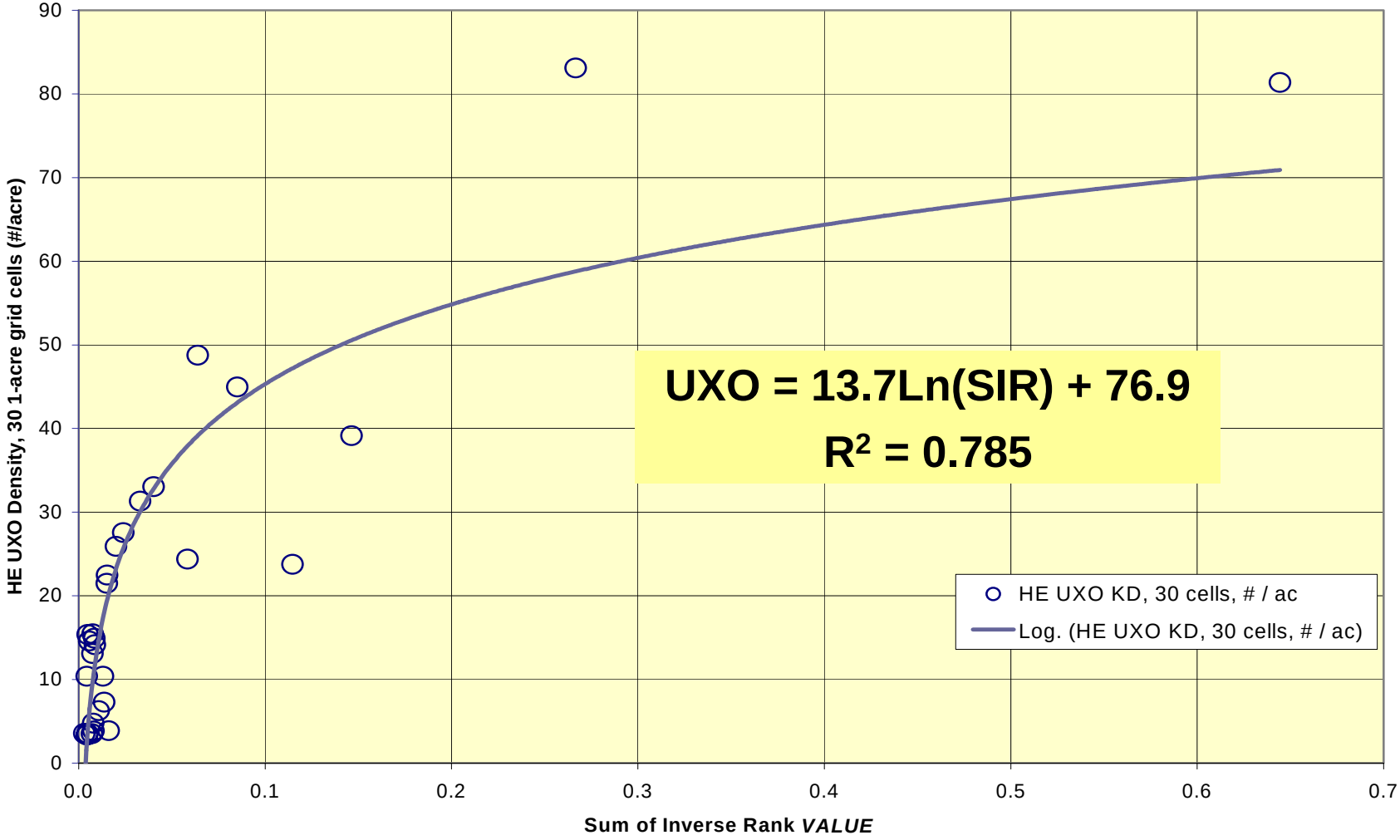
Compositing Three Indices

Col_Row	HE UXO KD, 30 cells, # / ac	Airphoto clearance value	TgtProx value	NT MEDIAN value	Airphoto clearance rank	TgtProx rank	NT MEDIAN rank	Sum of Inverse Ranks
22 - 13		5.02	0.245	**7.72552**	*1*	*86*	*3*	**1.345**
22 - 17		2.92	0.911	**5.84172**	*14*	*1*	*5*	**1.271**
24 - 9		0	0.132	**12.4171**	*950.5*	*492*	*1*	**1.003**
24 - 27		3.51	0.393	**8.15704**	*8*	*3*	*2*	**0.958**
24 - 28	***81.4***	4.44	0.364	3.49423	*3*	*5*	*9*	**0.644**
24 - 16		4.78	0.283	1.31085	*2*	*35*	*28*	**0.564**
16 - 26		0.87	0.456	0.301525	*93.5*	*2*	*351*	**0.514**
30 - 29		0.13	0.345	**6.16208**	*261.5*	*7*	*4*	**0.397**
22 - 23		4.07	0.318	3.26218	*5*	*12*	*11*	**0.374**
32 - 29		3.09	0.350	3.26821	*12*	*6*	*10*	**0.350**
22 - 27		2.31	0.364	1.96867	*25*	*4*	*18*	**0.346**
21 - 13		3.84	0.218	3.67343	*6*	*146*	*7*	**0.316**
9 - 31	***83.1***	1.27	0.327	3.55551	*60.5*	*8*	*8*	**0.267**
40 - 37		4.25	0.067		*4*	*1456*	*800.5*	**0.252**
31 - 29		1.71	0.306	**4.11876**	*39*	*17*	*6*	**0.251**
21 - 17		3.34	0.326	0.73119	*11*	*9*	*70*	**0.216**
23 - 27		2.29	0.322	2.45547	*26*	*11*	*14*	**0.201**
22 - 24		2.71	0.299	2.85902	*17*	*23*	*12*	**0.186**
21 - 14		3.64	0.226	0.621105	*7*	*129*	*94*	**0.161**
22 - 22	***39.2***	2.75	0.284	1.88161	*16*	*32*	*19*	**0.146**
24 - 26		3.50	0.260	0.86707	*9*	*61*	*53*	**0.146**

Sum of Inverse Ranks: Value vs. Rank



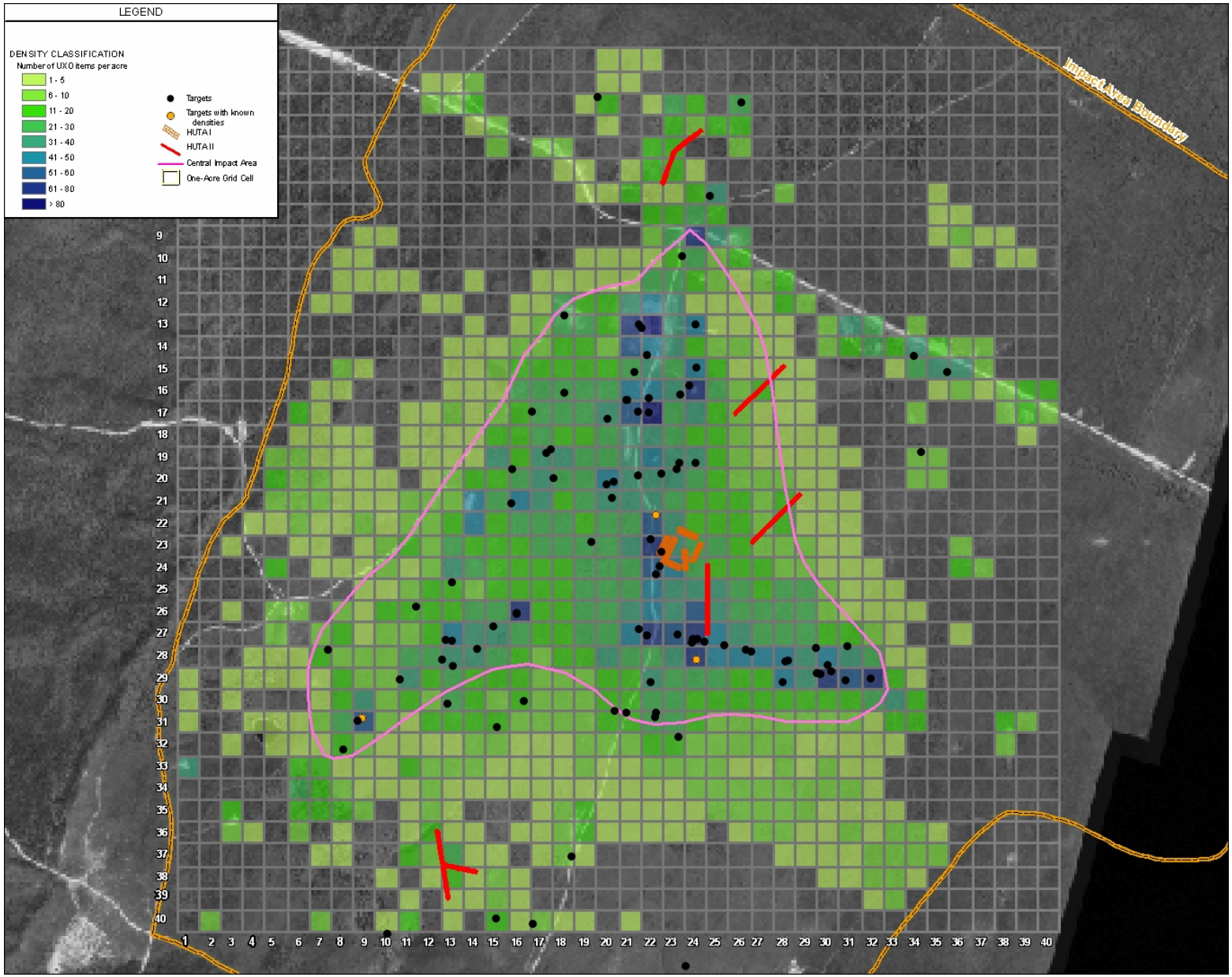
Absolute UXO Density Correlation



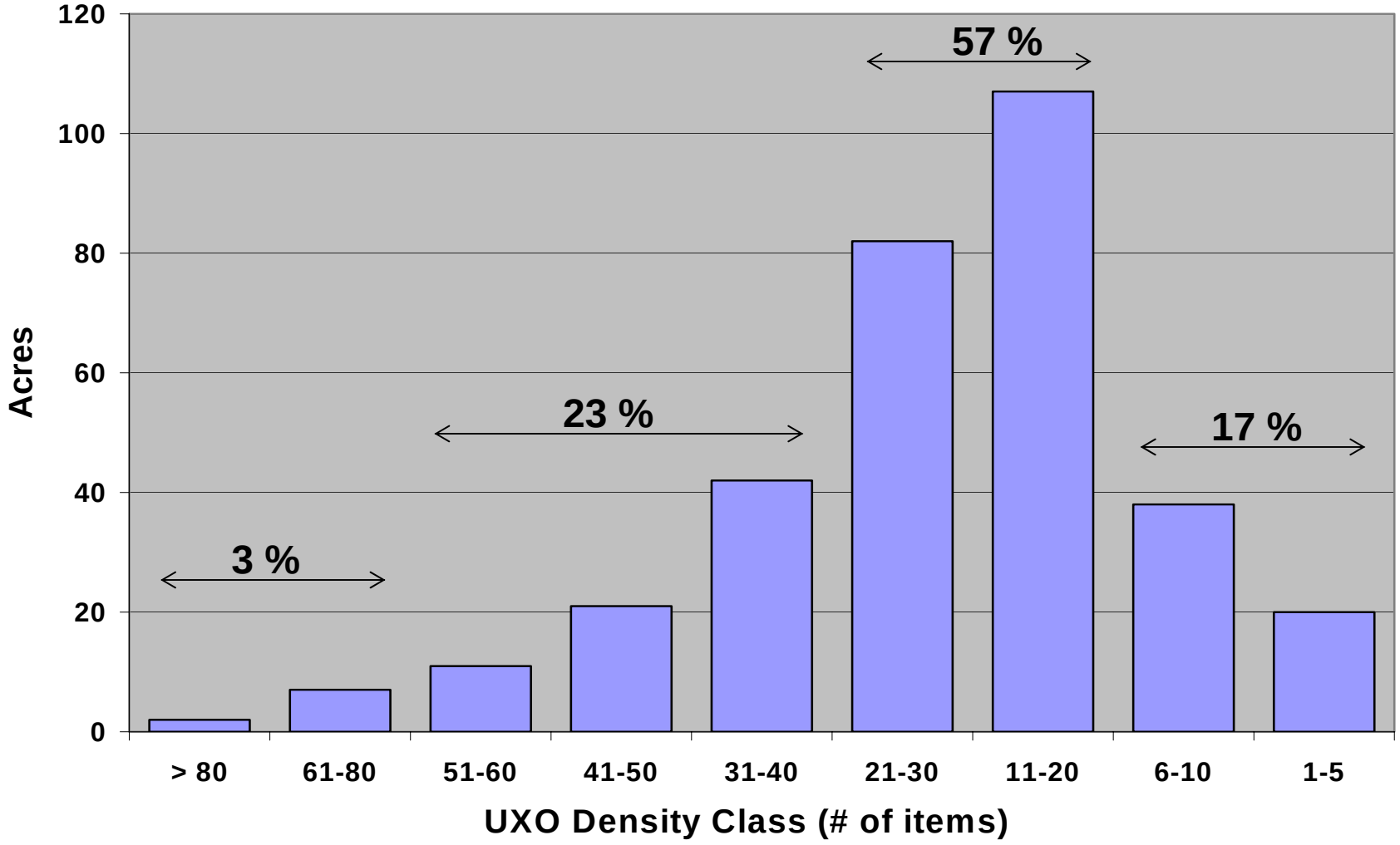
Estimated UXO Density

Col_Row	HE UXO # / ac (30 cells)	Airphoto Clearance rank	Target Proximity rank	Mag nT (Median) rank	Sum of Inverse Rankings	*UXO Density*	*H M L*	Proposed Field Cell
22 - 13		1	86	3	1.345	81.0	*H*	
22 - 17		14	1	5	1.271	80.2	*H*	**H1**
24 - 9		*950.5*	492	1	1.003	77.0	*H*	
24 - 27		8	3	2	0.958	76.4	*H*	
24 - 28	***81.4***	3	5	9	0.644	**70.9**	*H*	
24 - 16		2	35	28	0.564	69.1	*H*	
16 - 26		93.5	2	351	0.514	67.8	*H*	
30 - 29		261.5	7	4	0.397	64.2	*H*	
22 - 23		5	12	11	0.374	63.4	*H*	
32 - 29		12	6	10	0.350	62.5	*H*	
22 - 27		25	4	18	0.346	62.3	*H*	
21 - 13		6	146	7	0.316	61.1	*H*	
9 - 31	***83.1***	60.5	8	8	0.267	**58.8**	*H*	
40 - 37		4	1456	*800.5*	0.252	58.0	*H*	
31 - 29		39	17	6	0.251	58.0	*H*	
21 - 17		11	9	70	0.216	55.9	*H*	
23 - 27		26	11	14	0.201	54.9	*H*	
22 - 24		17	23	12	0.186	53.8	*H*	
21 - 14		7	129	94	0.161	51.9	*H*	
22 - 22	***39.2***	16	32	19	0.146	**50.5**	*H*	
24 - 26		9	61	53	0.146	50.5	*H*	
28 - 28		157	18	17	0.121	47.9	*H*	
25 - 27	***23.8***	23	25	32	0.115	**47.2**	*H*	
22 - 19		13	44	72	0.114	47.1	*H*	

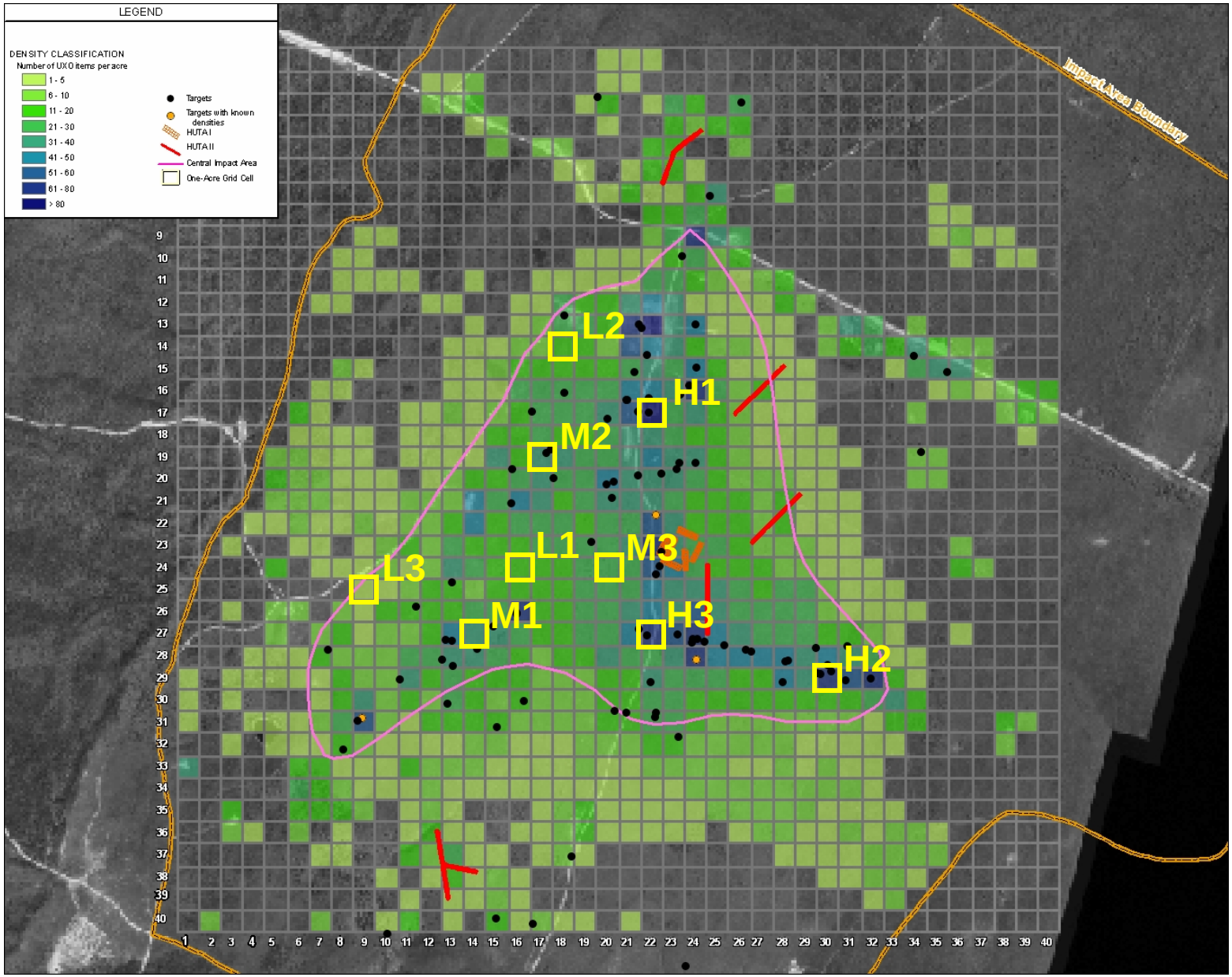
Estimated UXO Density



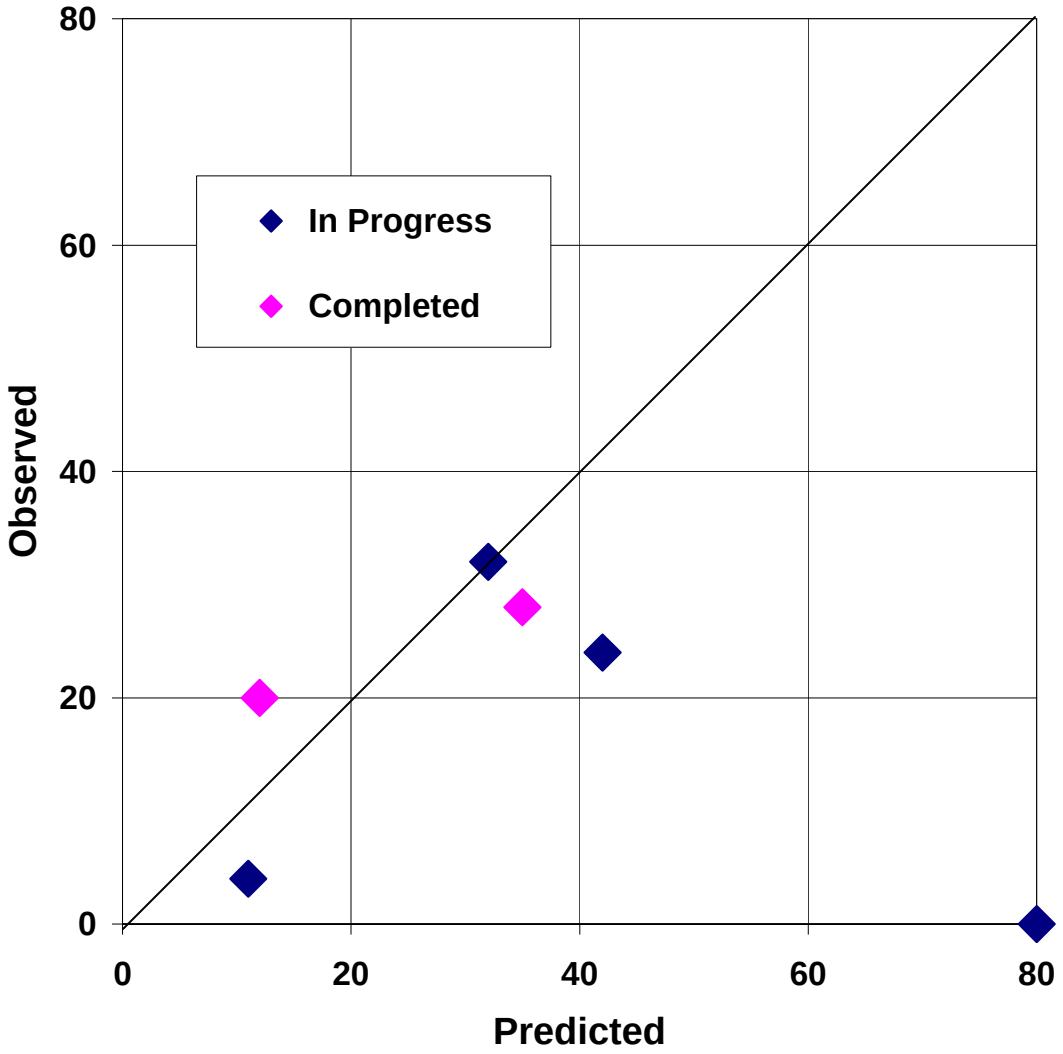
Area - Density Relationships



Field Validation Studies



Validation Results (In Progress)



Ongoing Studies

- **Current spatial density validation study to be expanded to include an additional 3 test plots.**
- **Pan lysimeter study being conducted under a perforated 155 mm artillery shell to validate release rate models.**
- **Refinement of release rate estimate and evaluation of sensitivity using groundwater fate-and-transport model.**
- **Proposal to implement probabilistic methods to model corrosion processes and release dynamics.**

Conclusions

- **The composite index is better predictor of UXO density than the three component indices individually and,**
- **Based on validation studies, is a good estimator of relative density and a reasonable estimator of absolute density.**
- **Aquifer impacts can be predicted using conventional deterministic groundwater fate-and-transport modeling techniques.**
- **Probabilistic methods applied to corrosion modeling may have potential in predicting the likelihood of future release.**