

Monitoring Fish-Tissue Contaminant Loads as an Indicator of Agricultural Remediation Success

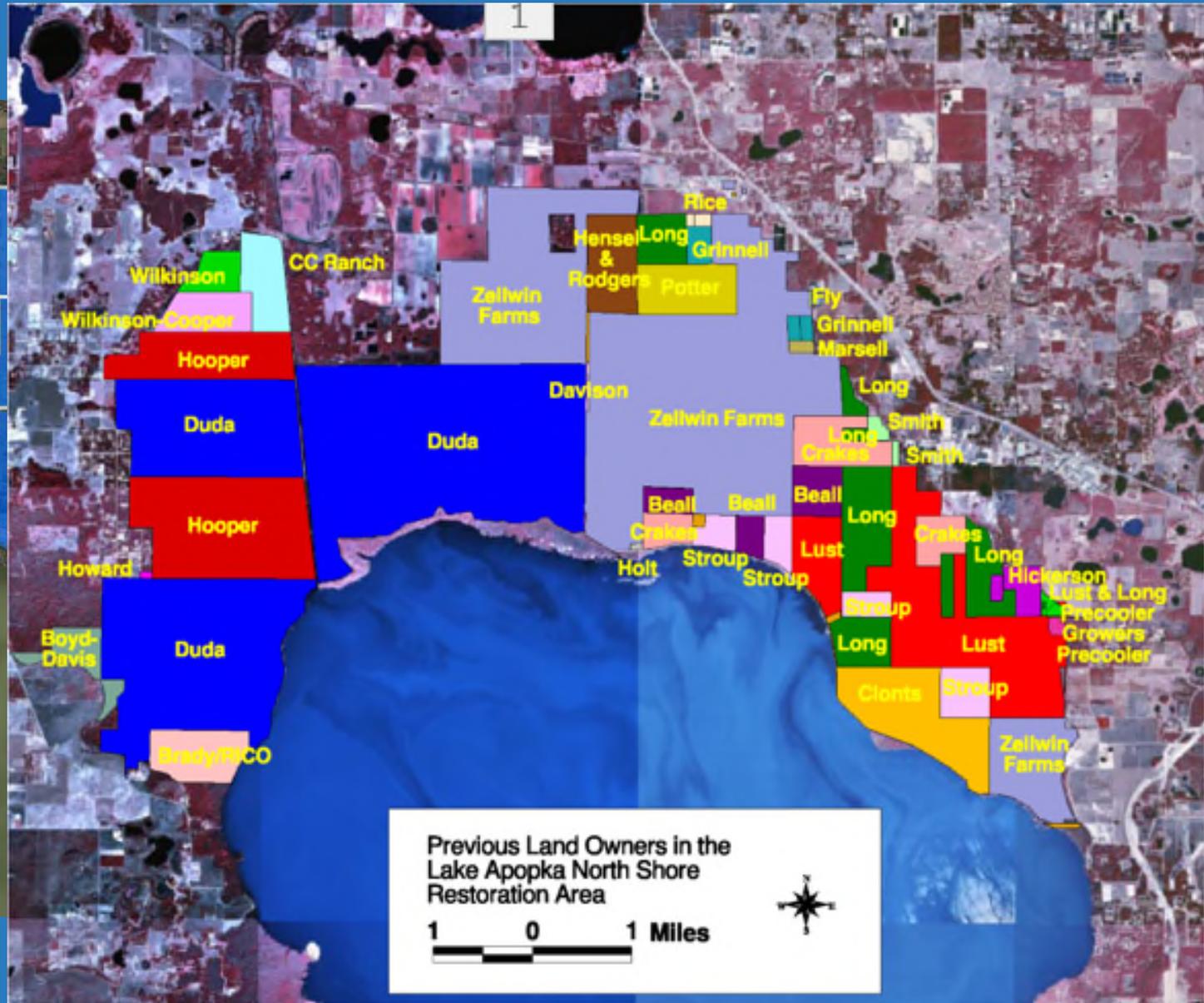
**Lori McCloud, James Peterson,
Mike Coveney, Pam Bowen,
and Elizabeth Mace**

St. Johns River Water Management District

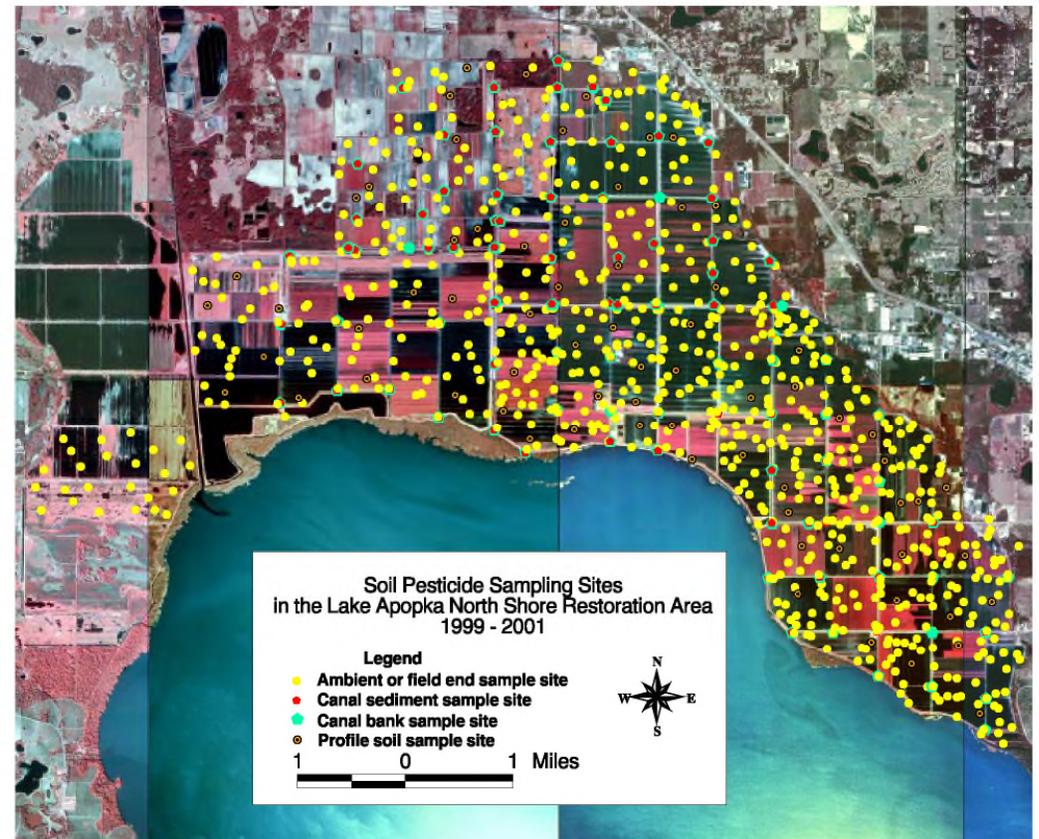


St. Johns River
Water Management District

Lake Apopka North Shore



Unexpected Challenges



Remediation Plan: Obstacles

- High Soil TOC (40+%) & Moisture Content (60+%)
- Organochlorine Pesticides (OCPs) confined to top 10" with contamination of over 8,000 acres

units: mg/kg	Residential Soil Cleanup Target	SQAG Threshold Effect Conc.	SQAG Probable Effect Conc.	Average	Max
4,4'-DDD	4.2	0.0049	0.028	0.816	8.8
4,4'-DDE	2.9	0.0032	0.031	1.842	16
4,4'-DDT	2.9	0.0042	0.063	1.398	62
Dieldrin	0.06	0.0019	0.062	0.423	3.3
Toxaphene	0.9	0.0001	0.032	14.268	150

Target: Human health benthos benthos



Biota Sediment Accumulation Factor (BSAF)



Results - BSAFs

Median Biota Sediment Accumulation Factors					
Habitat	4,4'- DDD	4,4'- DDE	4,4'- DDT	Dieldrin	Toxaphene
Emergent Marsh	2.71	8.06	0.32	1.47	0.77
Open Water	9.10	19.24	0.66	4.56	4.04

$$BSAF = \frac{(\text{OCP}_{\text{fish}} \mu\text{g/kg wet wt}) / (\text{lipid}_{\text{fish}} \mu\text{g/kg wet wt})}{(\text{OCP}_{\text{sed}} \mu\text{g/kg dry wt}) / (\text{TOC}_{\text{sed}} \mu\text{g/kg dry wt})}$$



Risk Evaluation – A Hazard Index

$$HQ_{OCP} = \frac{[\text{tissue OCP}]}{TRV_{OCP}}$$

$$HI = \sum HQ$$

Hazard Index (HI) > 1 =
Potential risk to wildlife

TRV=Toxicity Reference Value

	Adjusted TRV (ug/kg ww)
4,4'-DDE	1,500
DDTr	1,500
Dieldrin	140
Toxaphene	5,000
<i>cis</i> -Nonachlor	550
<i>gamma</i> -Chlordane	1,000
Heptachlor	400
Heptachlor epoxide	100
Oxychlordane	50
<i>trans</i> -Nonachlor	450
<i>alpha</i> -Chlordane	1,000



Vegetated Remediation Techniques

Inversion



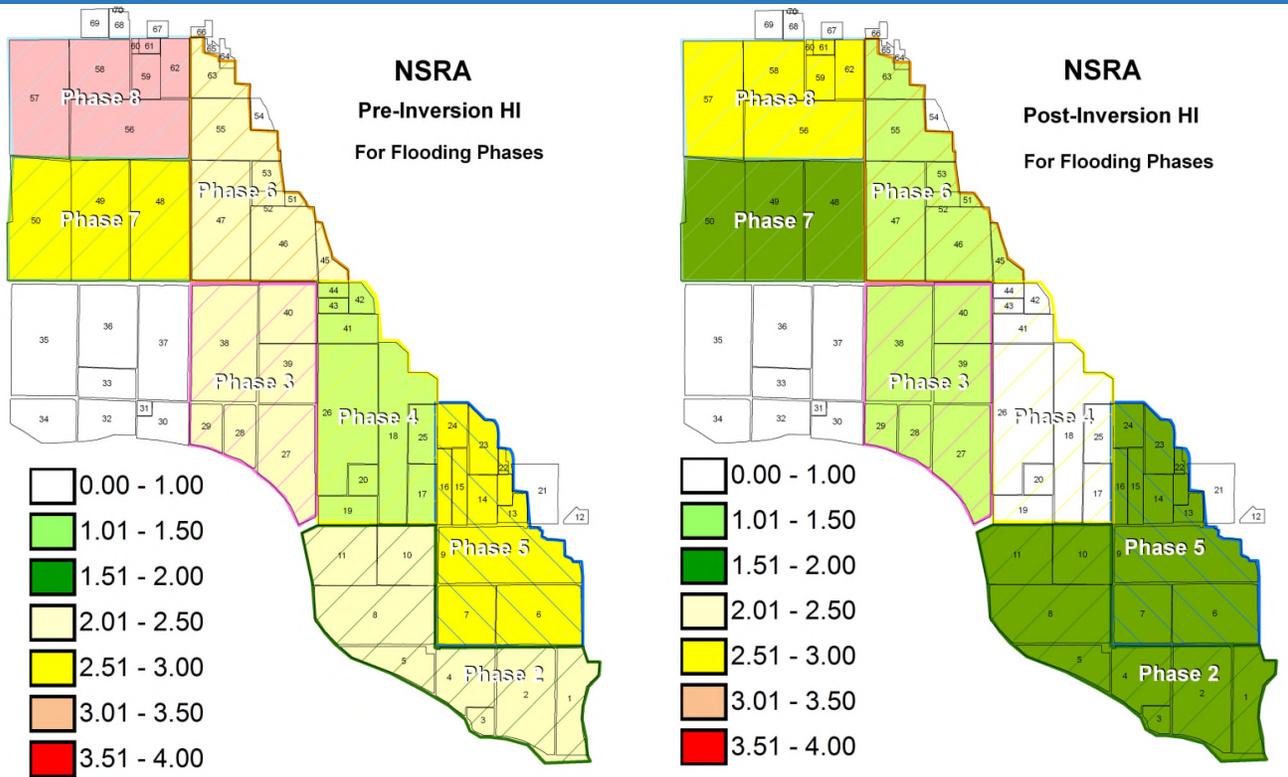
Excavation



Soil Inversion Remediation

Total Soil Inversion Acreage:
3,965 acres

	Pre-HI	Post - HI
Phase 2:	2.43	1.89
Phase 3 -	2.18	1.13
Phase 4 -	1.29	0.89
Phase 5 -	2.60	1.52
Phase 6 -	2.01	1.15
Phase 7 -	2.80	1.60
Phase 8 -	3.31	2.53

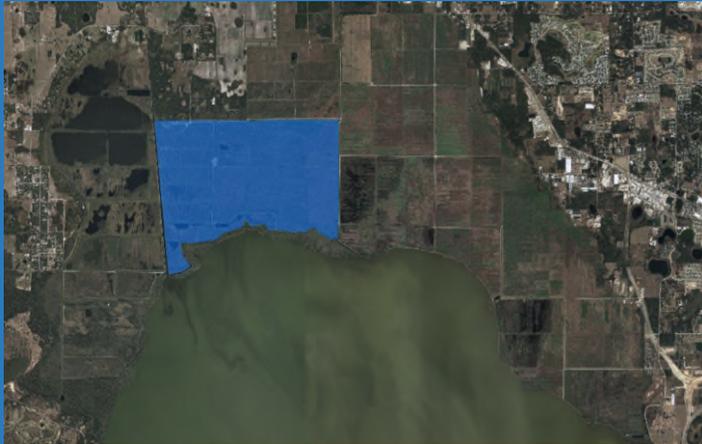


Fish Collection



Low Toxicity Risk: Duda

2979 acres – flooded 2002/2003



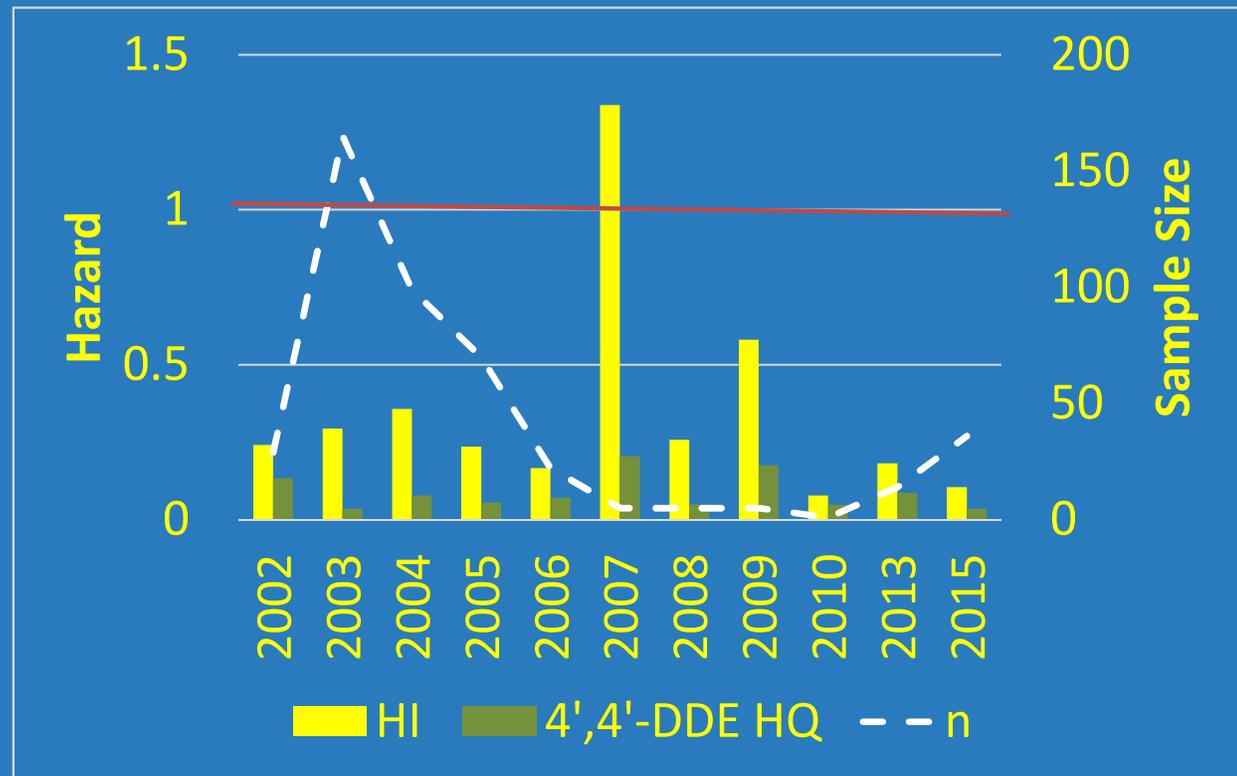
Collection Frequency

2002-2006: monthly

2007: twice per year

2008-2010: annually

2010-2015: every other year



Remediation Method:

Shallow flooding promoting dense, luxuriant vegetation

*HI & HQ generated from OCP-UCL95

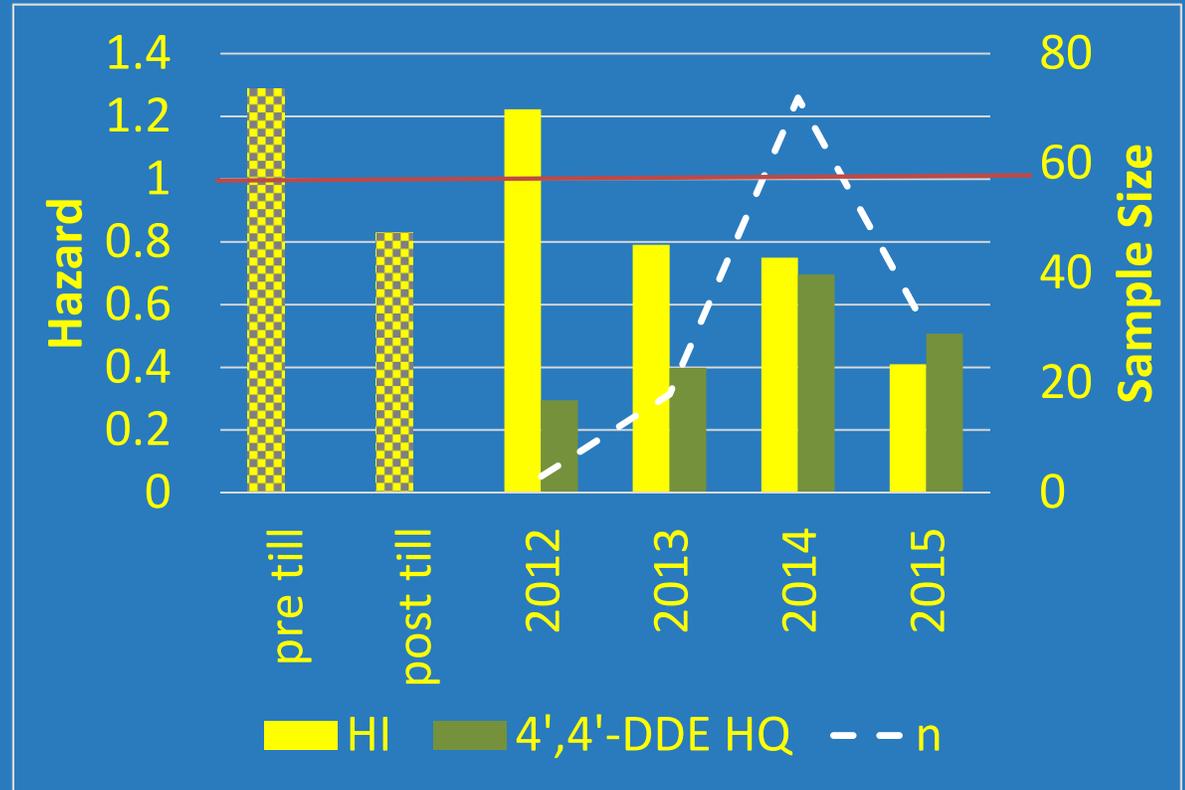


Moderate Risk: Phase 4

2036 acres - flooded 2013



Yellow blocks underwent inversion

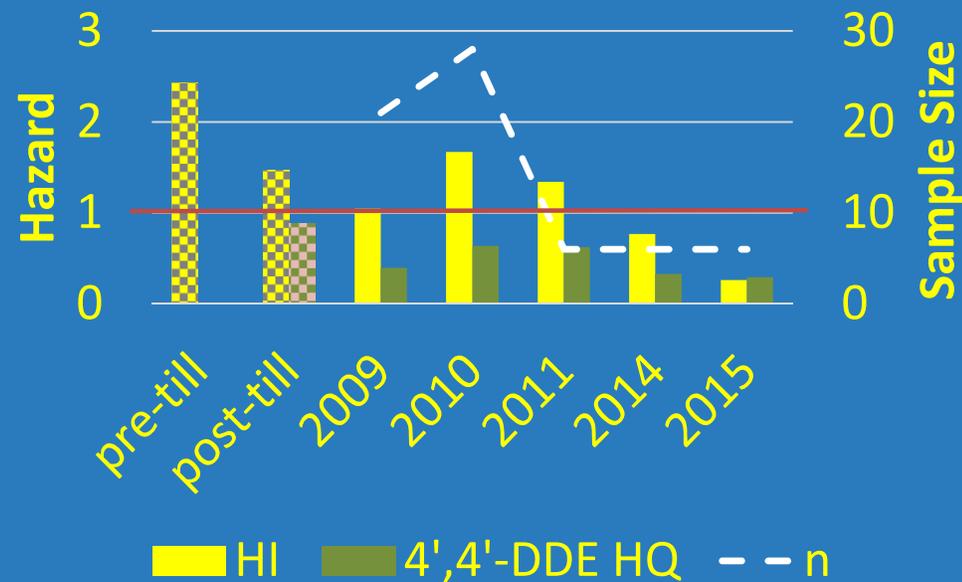
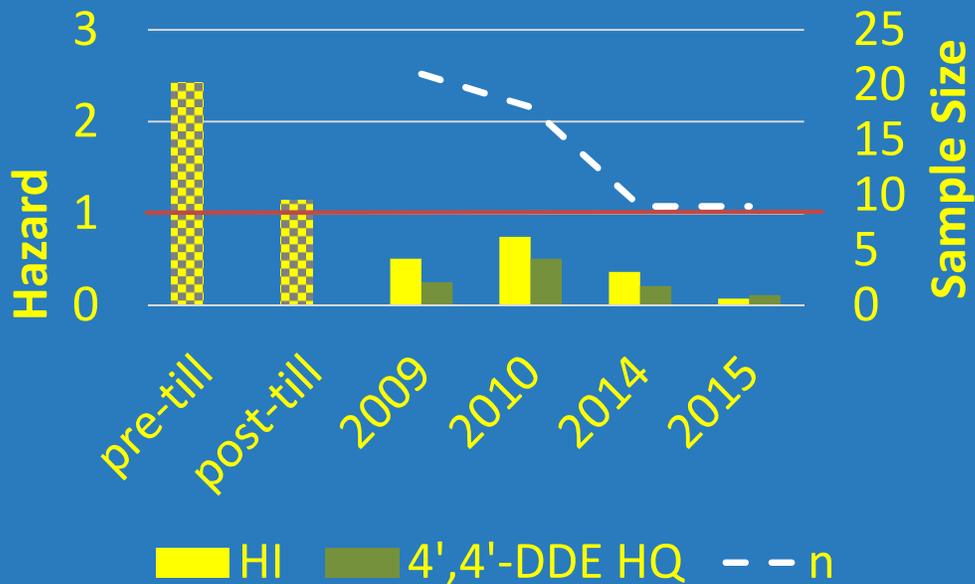
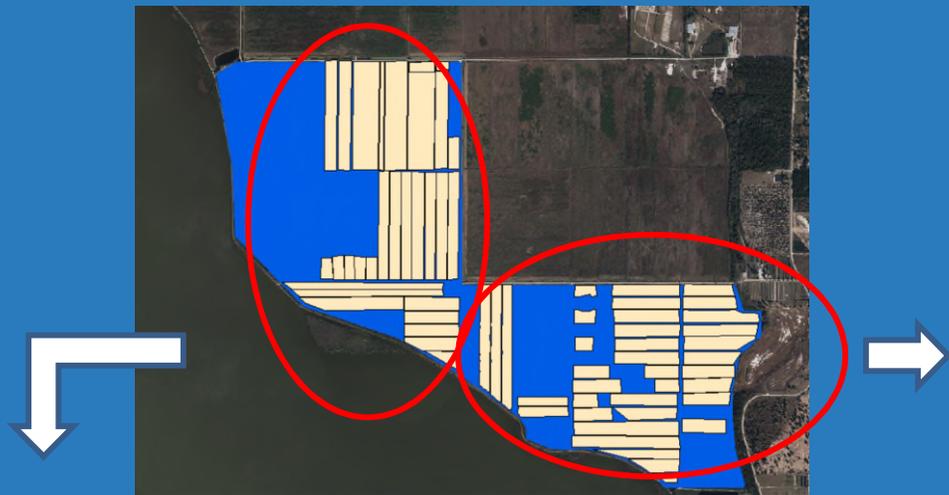


981 of 2036 acres of soil inversion – 48%
 2012 on collected from standing water in fields



High Risk: Phase 2

1300 acres - flooded 2009



East: 330 of 570 acres of soil inversion
2008 – 57%

West: 380 of 740 acres tilled – 51%

Keeping luxuriant vegetation helps
protect wildlife with HI>1



Assessing Remediation Success

- To date, 14,614 acres have been flooded
 - 3000 acres can be actively managed for desirable vegetation and increased diversity
- Fish tissue collected/analyzed for OCPs
 - Hazard index = acute toxicity risk
 - Hazard quotient (4',4'-DDE) = chronic risk
 - Projected risk > measured index values
 - a conservative estimate of risk
- Annual risk evaluation provided tools to drive remediation, gauge wildlife risk and move forward with restoration goals



Questions?



For more information about Lake Apopka or the St Johns River Water Management District, please visit: <http://www.sjrwmd.com/lakeapopka/>





Pilot Projects: Summary

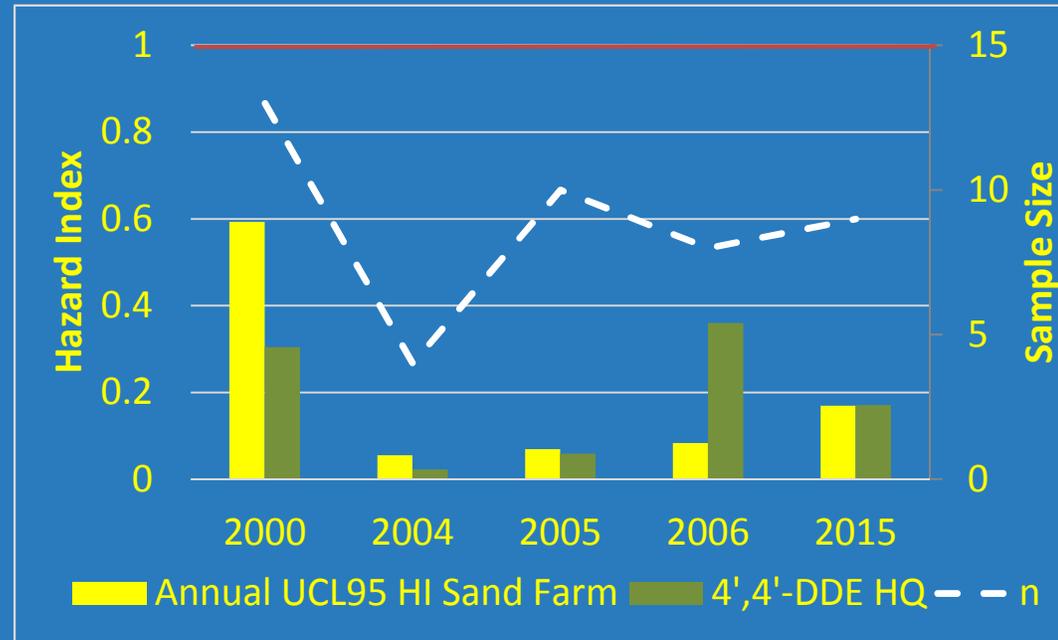
Project	% Reduction DDE	Rate: Acre/Day	Cost: \$/Acre	8,000 acres	
				Total Time (Days)	Total Cost
Inversion	79	15	\$2,500	533	\$20,000,000
Blending	58	1	\$2,700	8000	\$21,600,000
Bio-remediation	50	NA	\$31,839	NA	\$254,712,000
Excavation & disposal	100	0.25	\$100,000	32,000	\$800,000,000





Sand Farm

1500 acres – 470 acres flooded 2004



Collection Frequency

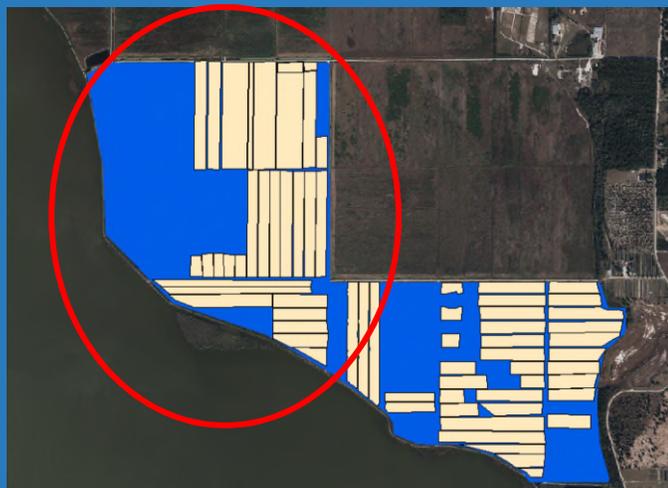
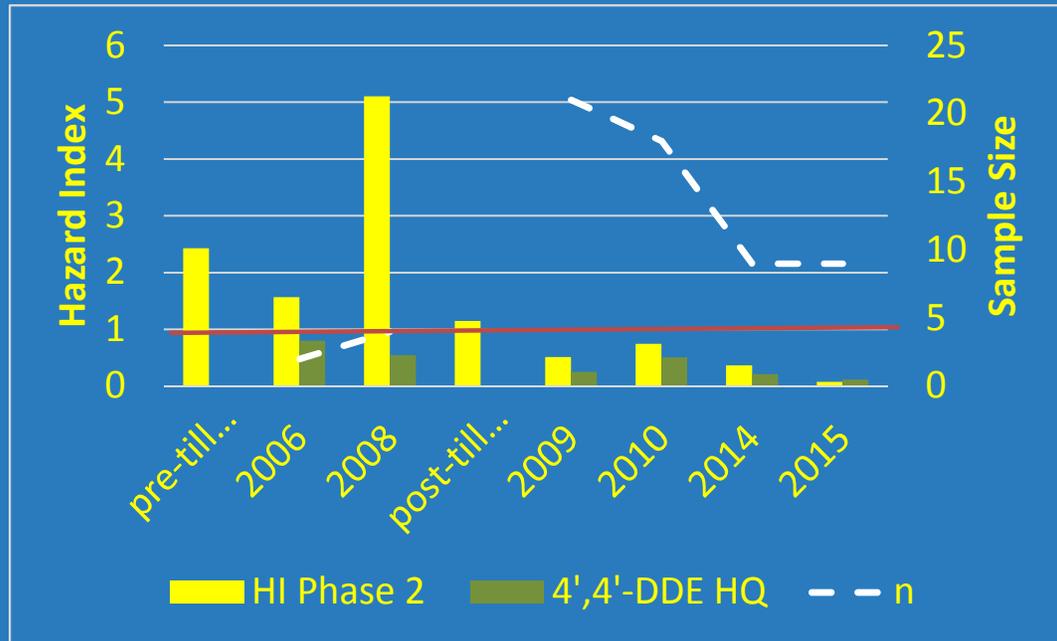
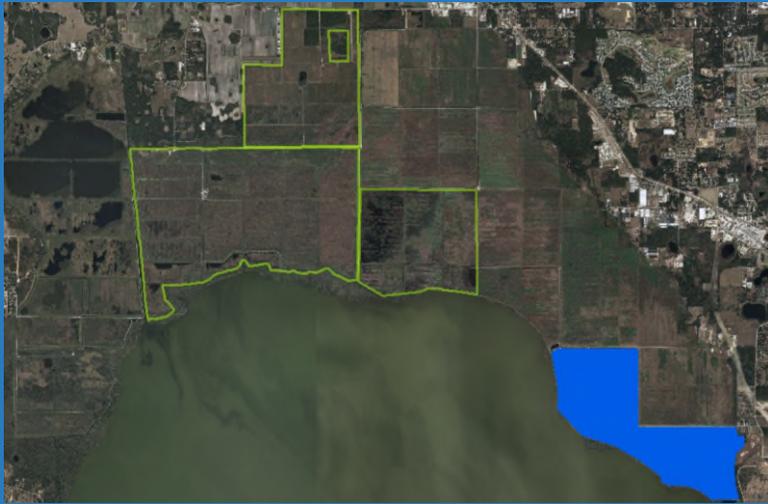
2000 (pre-flood): twice, targeting adjacent canals

2004 – 2006, 2015: annually



Phase 2

1300 acres - flooded 2009



Phase 2 West:

380 of 740 acres tilled – 51%

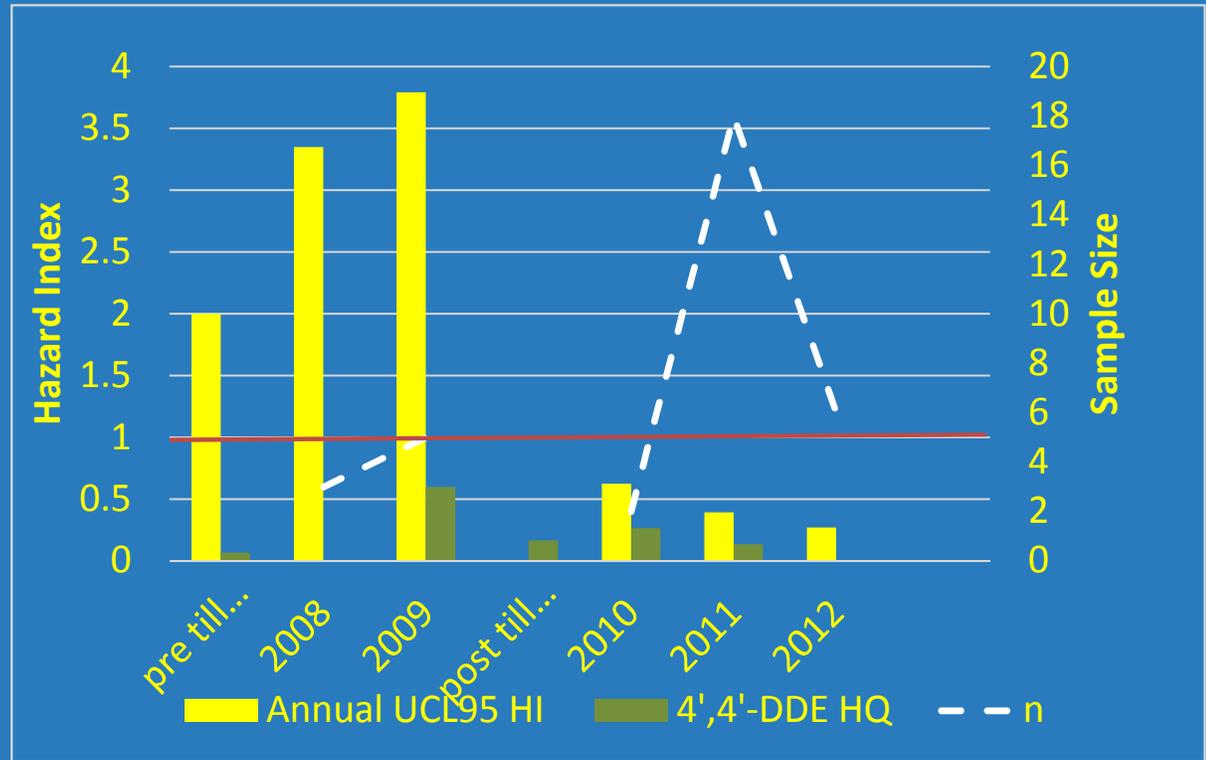
2006 & 2008 fish collected from adjacent canals

Remediation dropped HI to below-threshold levels,
with continued decline since



Phase 6

976 acres - flooded 2010/2011



Phase 6:

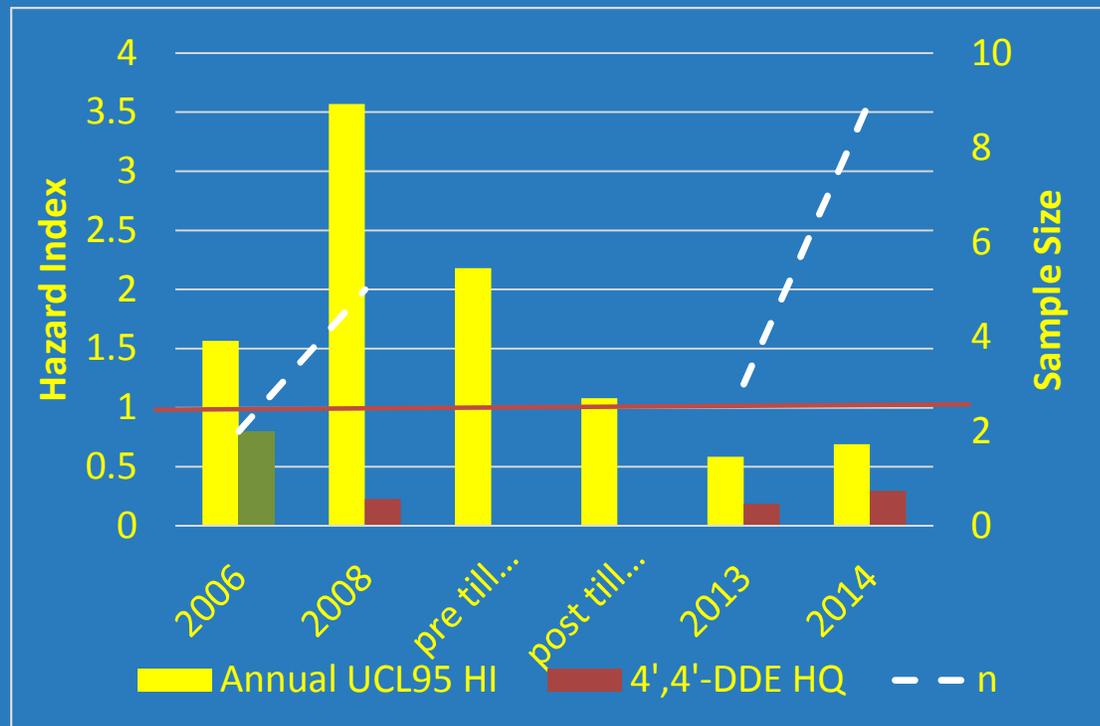
450 of 976 acres tilled – 46%

Remediation dropped HI to below-threshold levels,
with continued decline since



Phase 3

393 acres - flooded 2013



Phase 3:

120 of 393 acres tilled – 31%

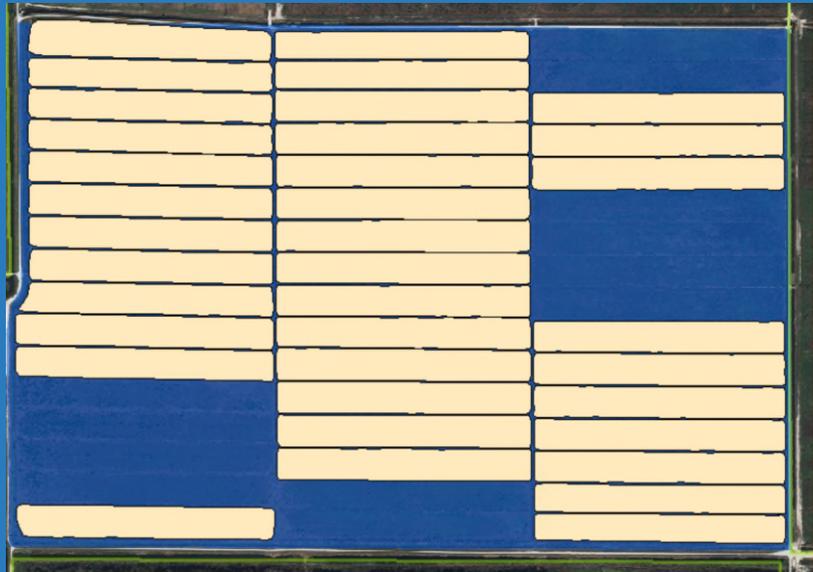
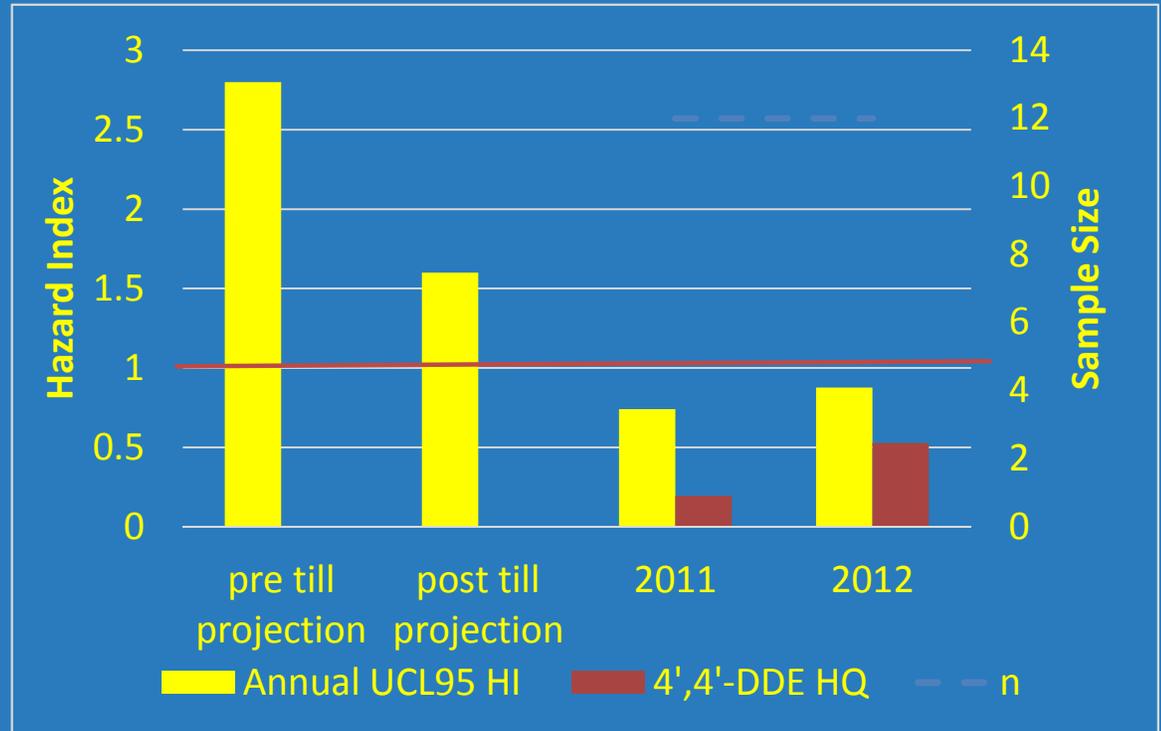
2006 fish collected from internal canal

2008 fish collected from canal adjacent to parcel



High Risk: Phase 7

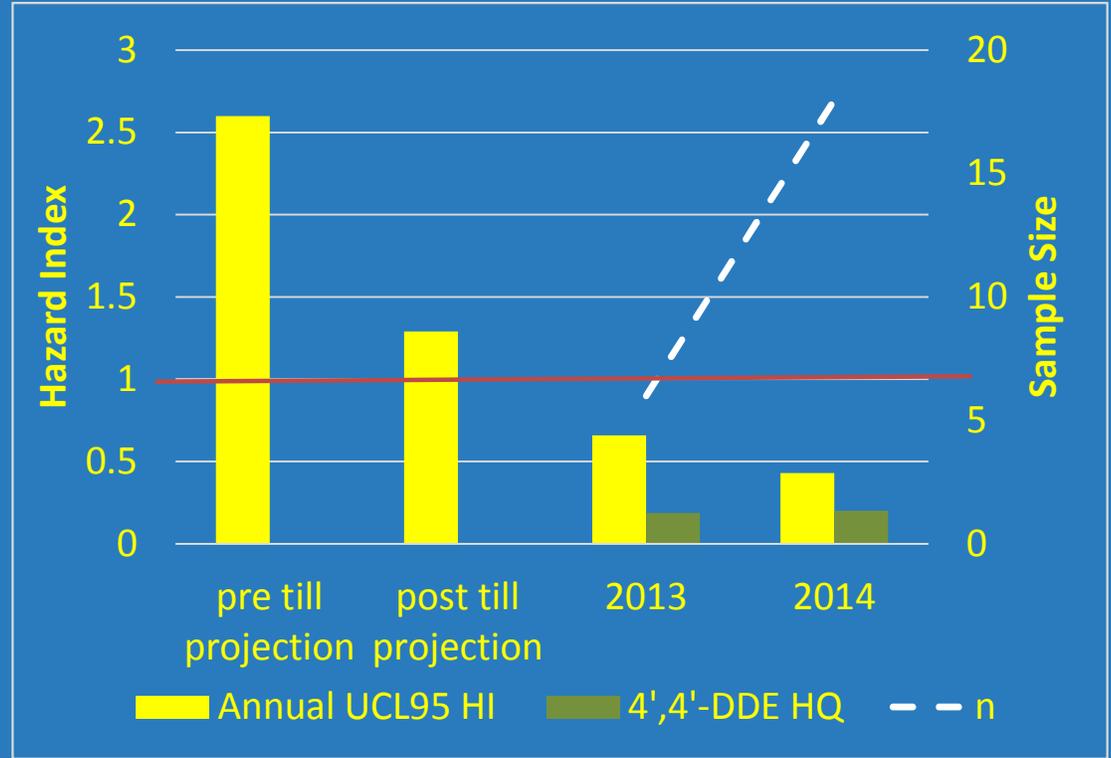
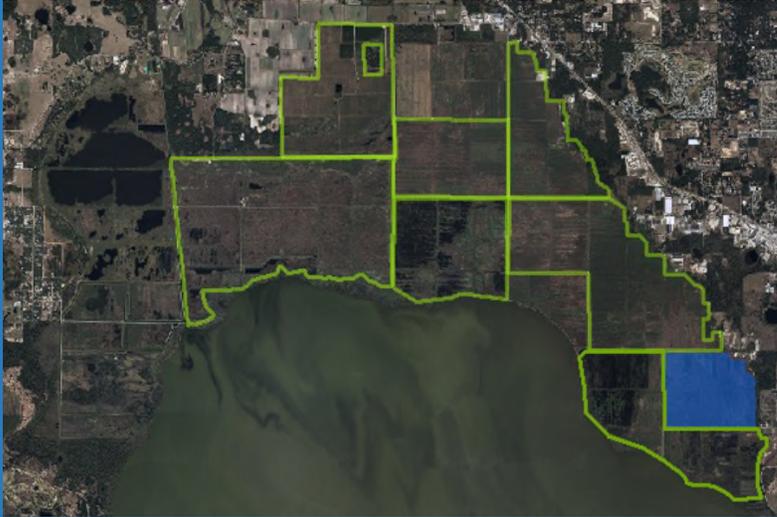
958 acres - flooded 2011



Phase 7:
654 of 958 acres tilled – 67%

Recent Flooding: Phase 5

700 acres - flooded 2013



Phase 4:
538 of 700 acres of soil inversion – 77%



Prospective Risk Assessment

Soil OCP levels

BSAFs

Predict fish OCP levels in a flooded field

+

TRVs for fish-eating birds

Calculate Hazard Quotient (HQ) for each OCP

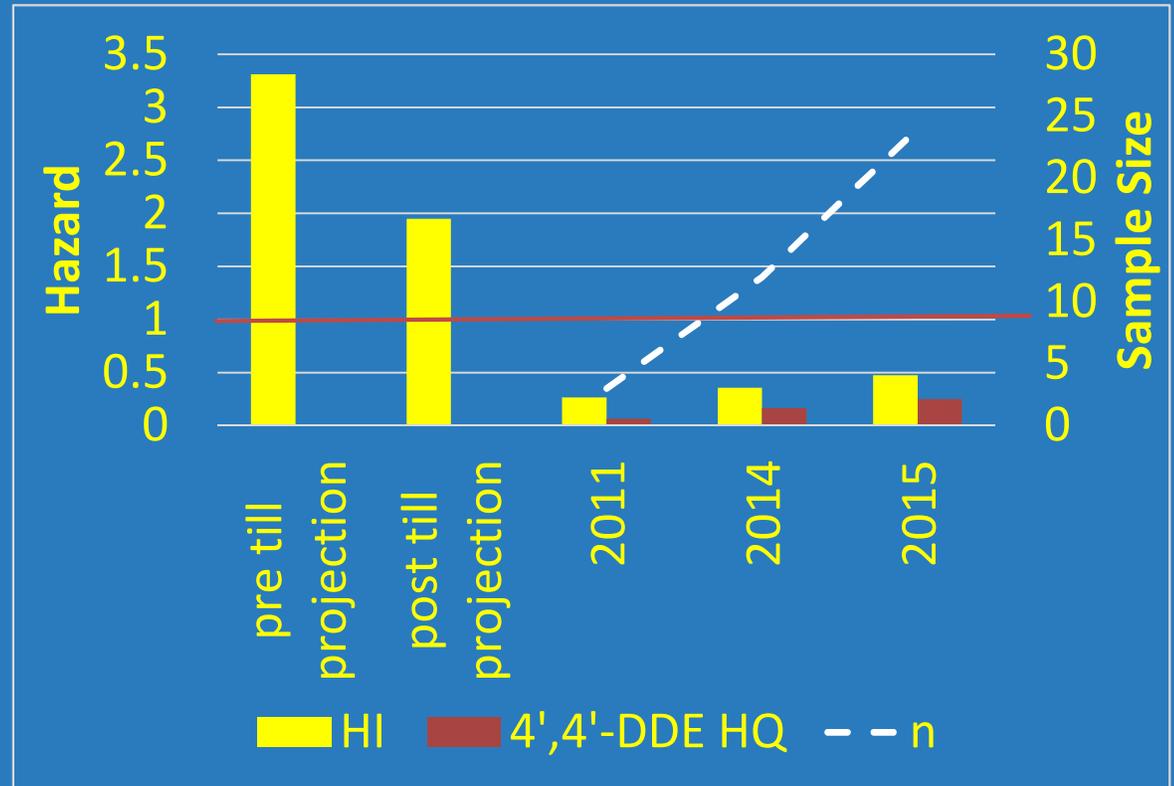
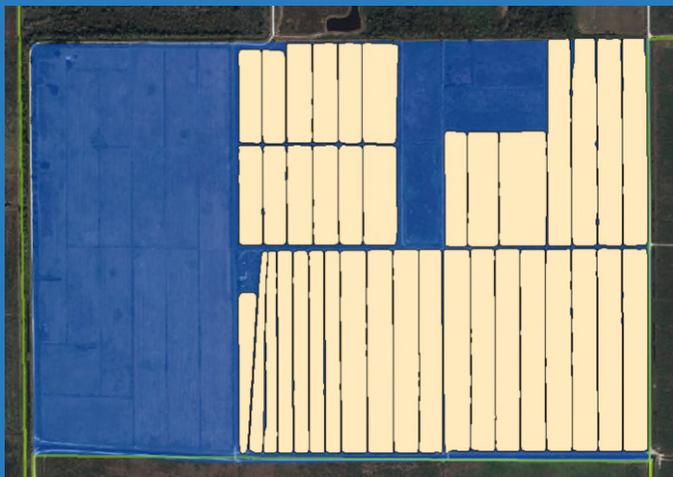
Add HQs to calc Hazard Index for mortality
(DDE – Use HQ for reproductive effects)

Remediation and Management



Last Parcel Flooded: Phase 8

955 acres - flooded 2014



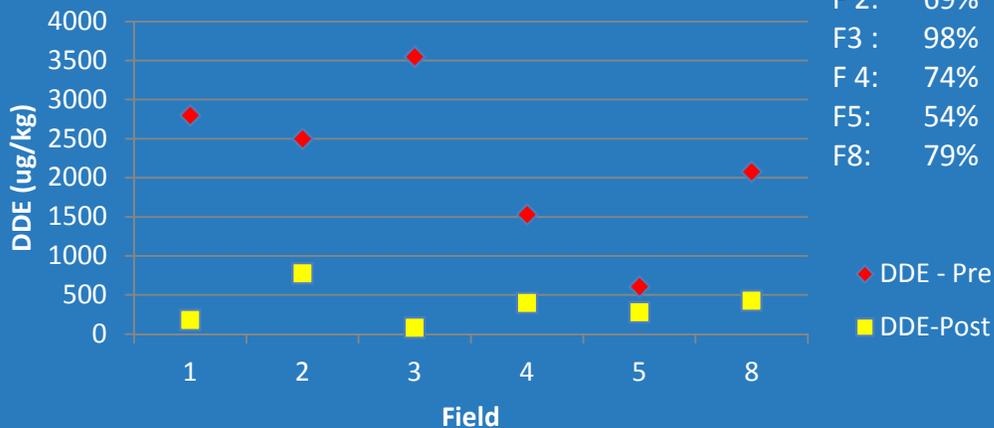
524 of 955 acres of soil inversion – 55%

Pilot Projects: FY 2006-2007

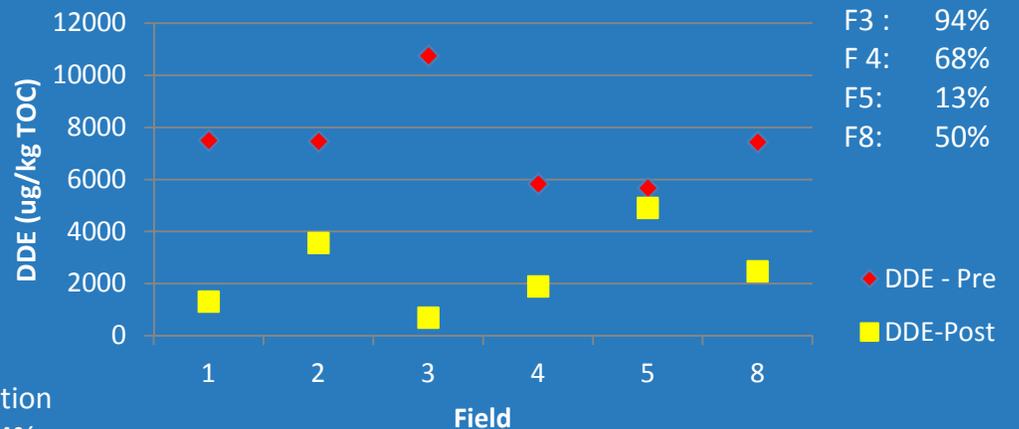
Inversion – 300 acres

4-bottom bi-direction plow with 52" disks

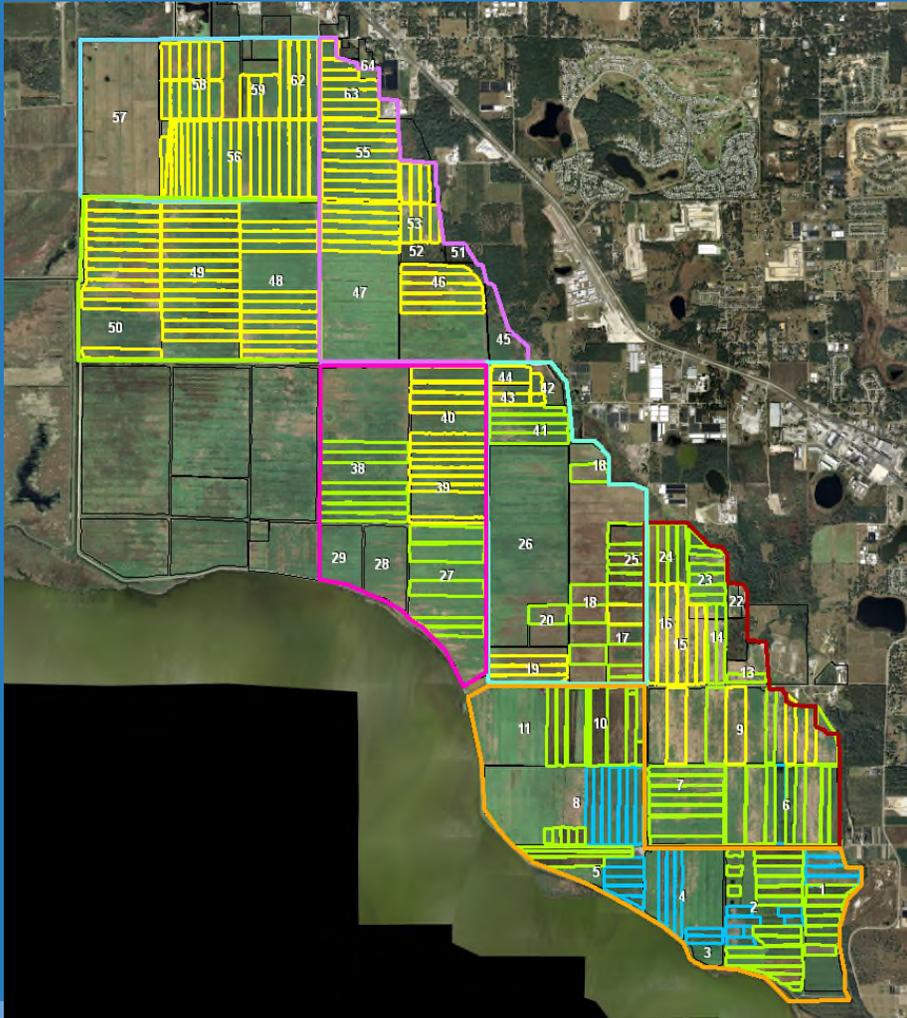
300-acres - '06/'07
Dry Weight Results



300-acres - '06/'07
Carbon Normalized Results



Soil Inversion Remediation



FY 06/07- 300 acres

FY 07/08- 1490 acres

FY 08/09 – 2175 acres

Total: 3,965 acres



Deep Water Remediation Techniques

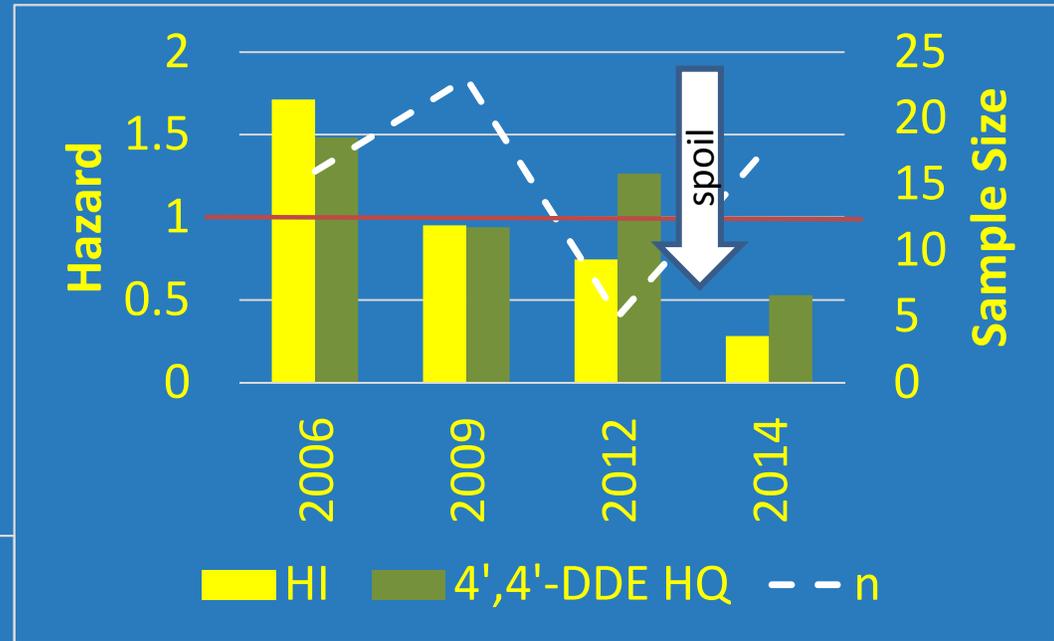
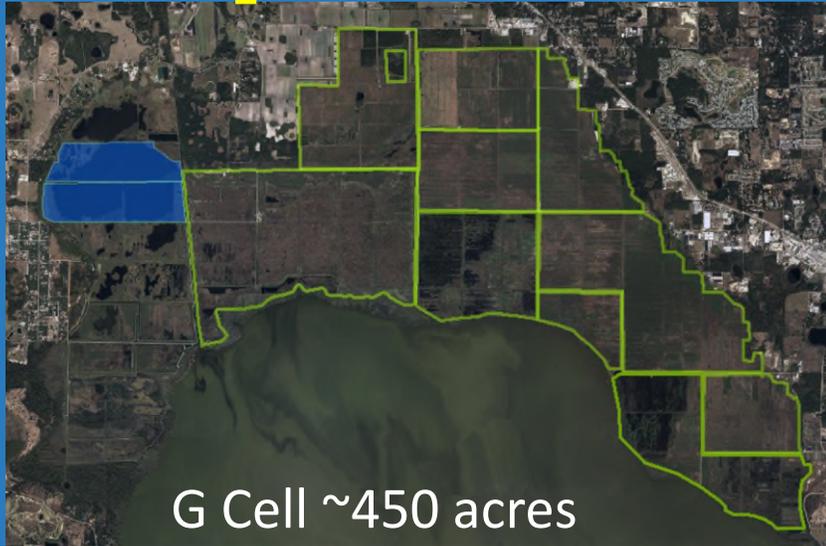


Excavation

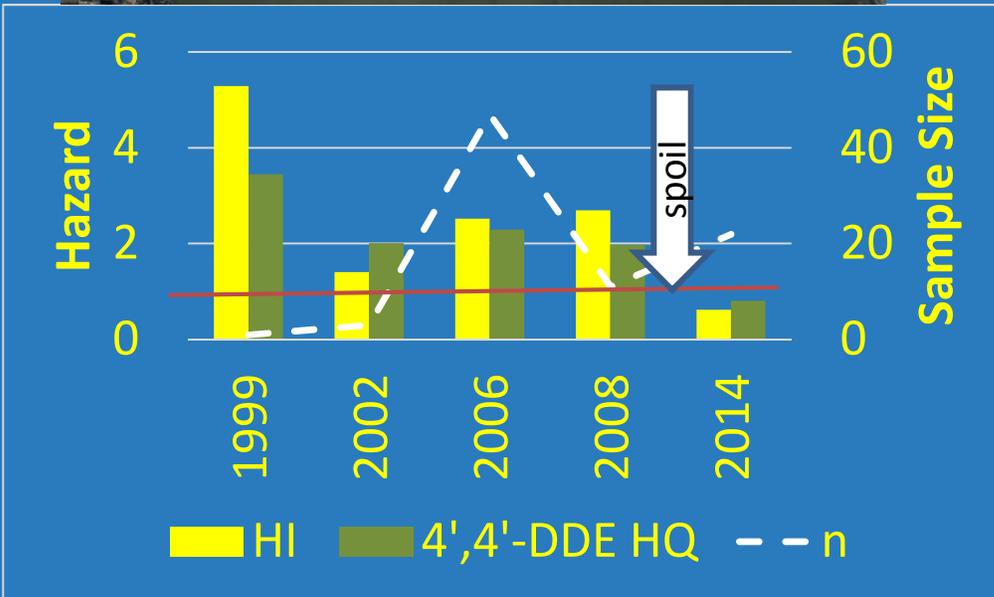
Vegetated



West Marsh persistently deep (>18")



F Cell ~560 acres

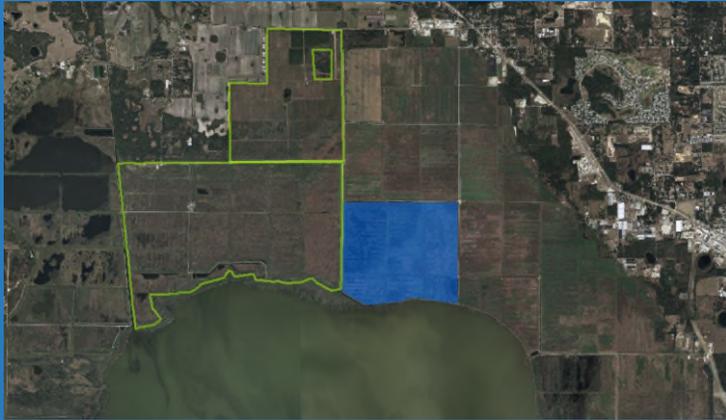


Timeline of Events



Moderately Low Risk: Phase 1

1228 acres - flooded 2008

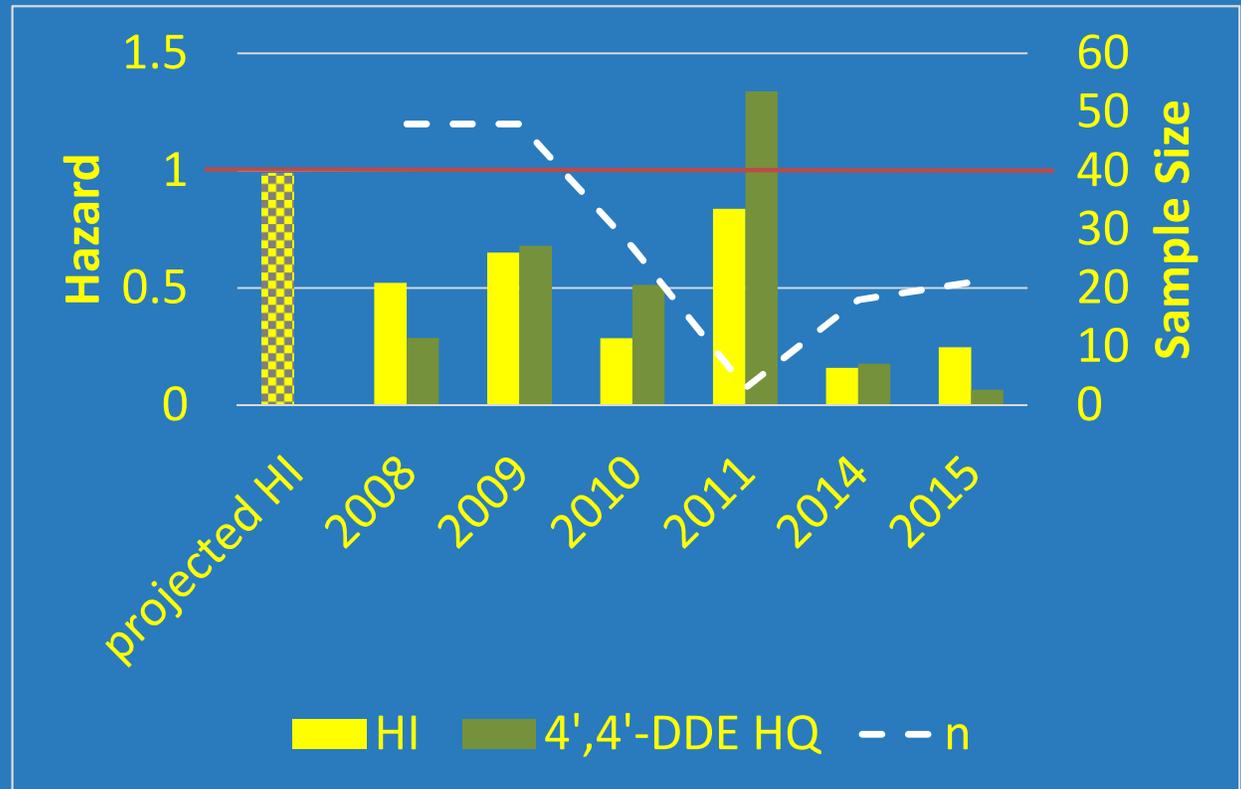


Collection Frequency

2008 - 2009: quarterly

2010: twice per year

2011, 2014, 2015: annually



Remediation Method:

Shallow flooding promoting dense, luxuriant vegetation



Remediation Effort Summary

- 8,519 acres shallowly flooded - dense, luxuriant vegetation to discourage avian foraging on fish
- 3,965 acres of deep soil inversion, followed by shallow flooding
- To date, 14,614 acres have been flooded on the north shore of Lake Apopka
 - 3000 acres no longer need to meet requirement of dense vegetation - parcels can be actively managed to promote desirable vegetation with increased diversity

