Using Biosolids to Restore/Revitalize Soil Ecosystem Services to Degraded Soils in the Calumet Region

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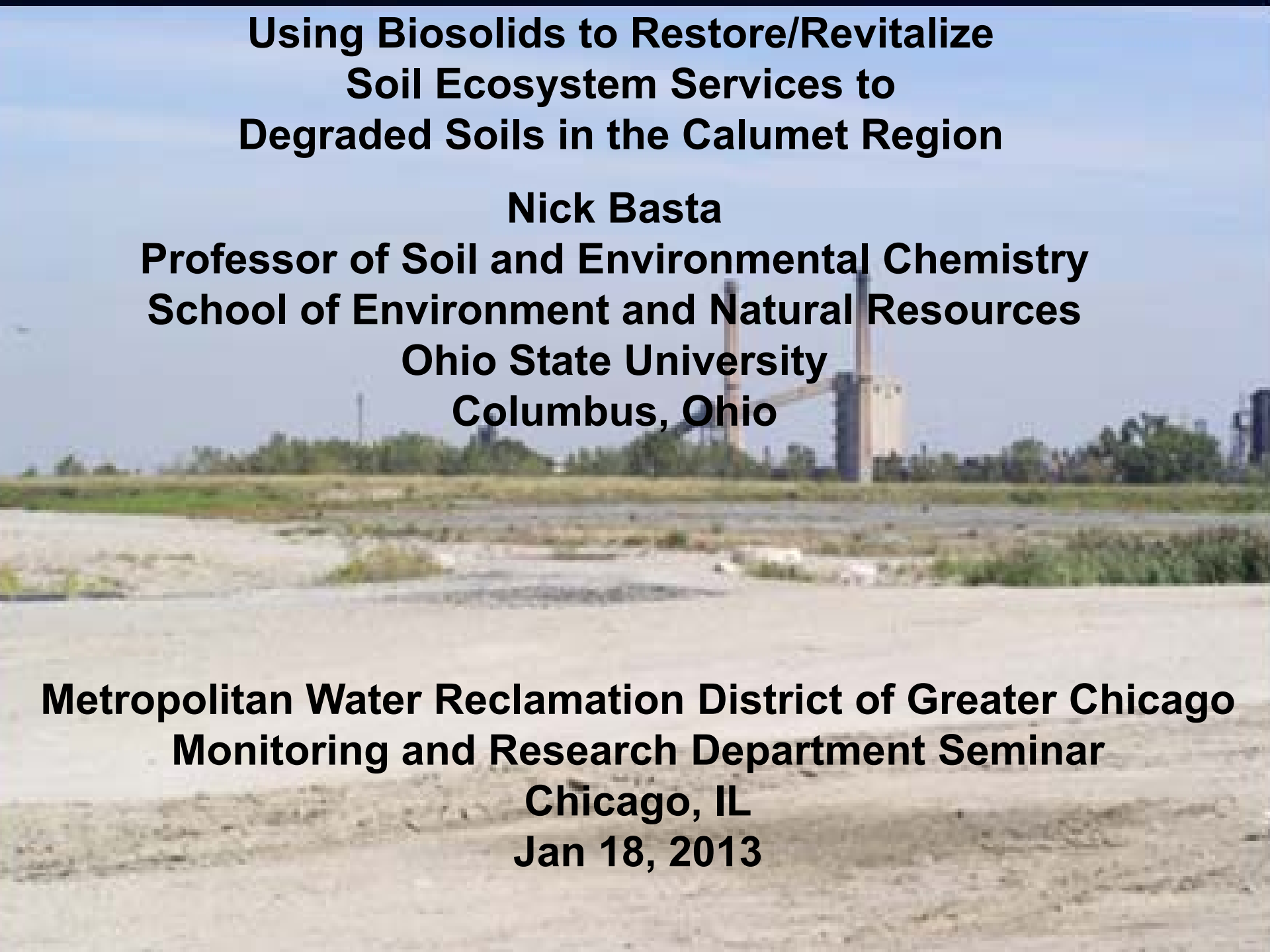
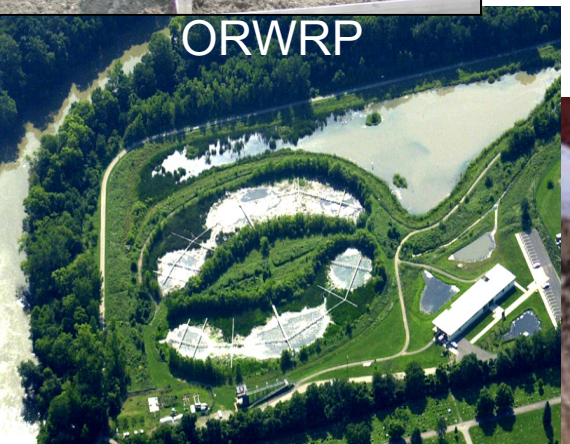


Metropolitan Water Reclamation District of Greater Chicago
Monitoring and Research Department Seminar
Chicago, IL
Jan 18, 2013

School of Environment and Natural Resources
Ohio State University



<u>Environmental Science / Ecosystem Science</u>

Terrestrial Wildlife and Ecology

mammals, avian (migratory birds), reptiles

Urban Coyote Research in Cook County, IL

Soil Science (incl. soil ecology)

Carbon Management and Sequestration Center

Wetland Science / Ecosystems

Olentangy River Wetland Research Park

Forest Ecosystems

Stream, Lake Ecosystems and Fisheries

Environmental Law, Policy and Social Science

School of Environment and Natural Resources
Soil Environmental Chemistry Program




Research program

- **Soil/Environmental contaminant chemistry; ecotoxicology emphasis on environmental media (air, soil, dust, water, food) exposure and human and ecological risk assessment**
- **Development and evaluation of soil remediation technologies**
- **Beneficial use of organic residuals including biosolids**

Personnel :

full time staff – Research Assoc. /Laboratory Manager; 2 Research Assoc.; Research Scientist; Research Assistant

5 graduate students and 4 part-time laboratory assistants

THE OHIO STATE UNIVERSITY

64,429 students (3rd largest in the US) including
53,829 undergraduate students in 170 majors
10,600 graduate students in 258 MS /PhD degree programs
5,500 international students from 115 countries

4,000 faculty
1,600 visiting international scholars
32,000 employees
$5B/yr budget

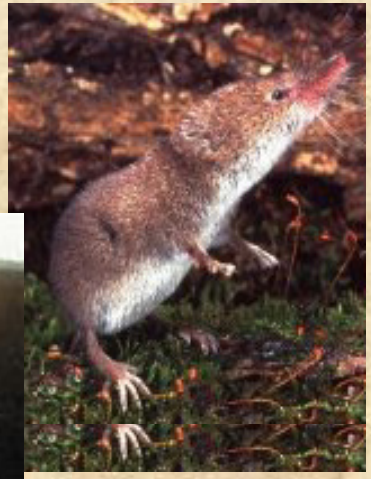
Revitalization of Degraded Urban Soils

Many urban soils and brownfields have lost their soil quality. These soils have lost their essential "ecosystem services, to support vegetation, support the food chain (earthworms for birds, etc), and recycle waste materials (dead vegetation, excess nutrients).



Degraded soils in Calumet, IL

High Quality Soil is the Foundation of a Healthy Ecosystem



Soil Quality: The capacity of a soil to function to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation.

High Demand for High Quality Soil

Topsoil Excavation from Farmland
"borrowed soil"
destruction of vital Natural Resource
Lower quality subsoils being used as value of farmland topsoil hits record highs

Solution: Manufactured Soil Blends
Compost, Animal Manure,
Biosolids, and/or other bioproducts

Palmerton, PA. 1980 Dead Ecosystem on Blue Mountain

Revitalization of Blue Mountain in Palmerton using Soil-Biosolids Blends

Palmerton, PA. 1999: Looking down re-vegetated Blue Mountain

Restoration of Strip-Mined Land
Venango County, PA (Penn State Univ.)

Restoration of Strip-Mined Land

Metropolitan Water Reclamation District of Greater Chicago (University of Illinois)

6300 ha in Fulton County coal strip-mined land
> 1 million tons biosolids 1972-1992
monitor air, water, soil quality
corn/wheat yields

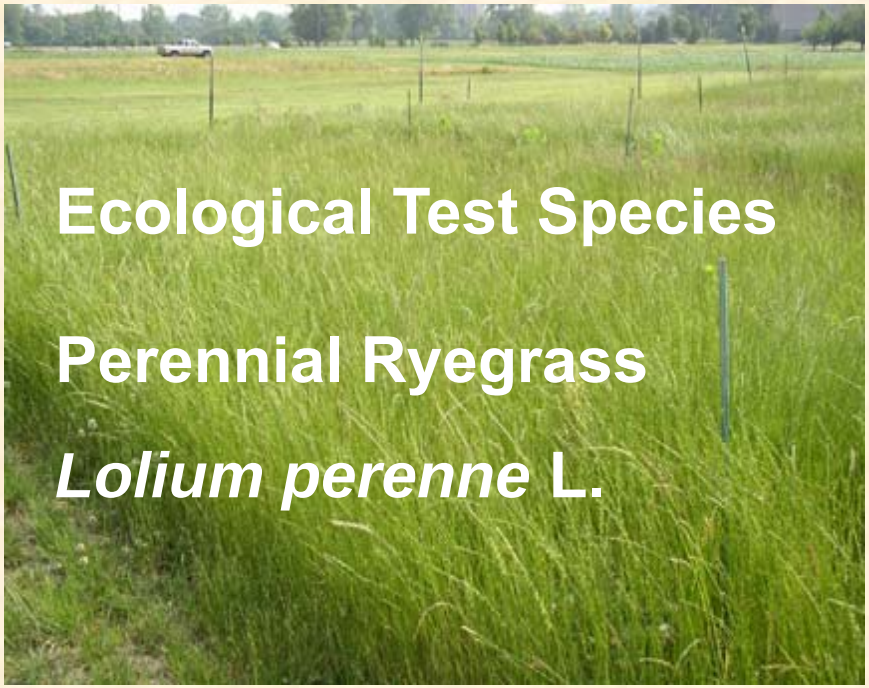
Long-Term Ecological and Environmental Benefits from Land Application of Biosolids

Ohio State University

Plots established by Dr. Terry Logan in 1992
<u>One time</u> application of biosolids in 1992

Soil Organic C (in 2007) increased from
12 g/kg to 27 g/kg

Long-Term Ecological and Environmental Benefits from Land Application of Biosolids



Percent Mortality
Reproduction (cocoons, juveniles)
Contaminant Bioaccumulation

Dry matter
growth
bioaccumulation
germination

Summary

- **Biosolids improves soil quality and fertility**
- **Long-term application increases plant biomass**
- **Prevents plant micronutrient deficiency**
- **No negative effect on soil invertebrates (earthworms)**

Using Biosolids / Byproducts to Revitalize Degraded Land / Brownfields in Chicago

MWRDGC scientists are leaders in restoration using their biosolids products

Unique Aged EQ Biosolids

Evaluating Biosolids Soil Blends and Compost for Soil Restoration and Ecological Revitalization in the Greater Calumet Region

The Ohio State University
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Dr. Richard Dick
Dr. Roman Lanno
Dawn Busalacchi
Jennifer Tvergyak

The Metropolitan Water Reclamation District
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Roman Lanno
Professor of Water and Soil Ecotoxicology
Evolution, Ecology and Organismal Biology

The Calumet Region of NE Illinois & NW Indiana

Characterized by:

- Wetland Remnants
- Migratory Waterfowl Stopover Sites
- Landfill and NPL Sites
- Abandoned Industrial Sites
- Proximity to Population Centers
- Locally Available Municipal Residual Materials
- Targeted for Ecological Restoration

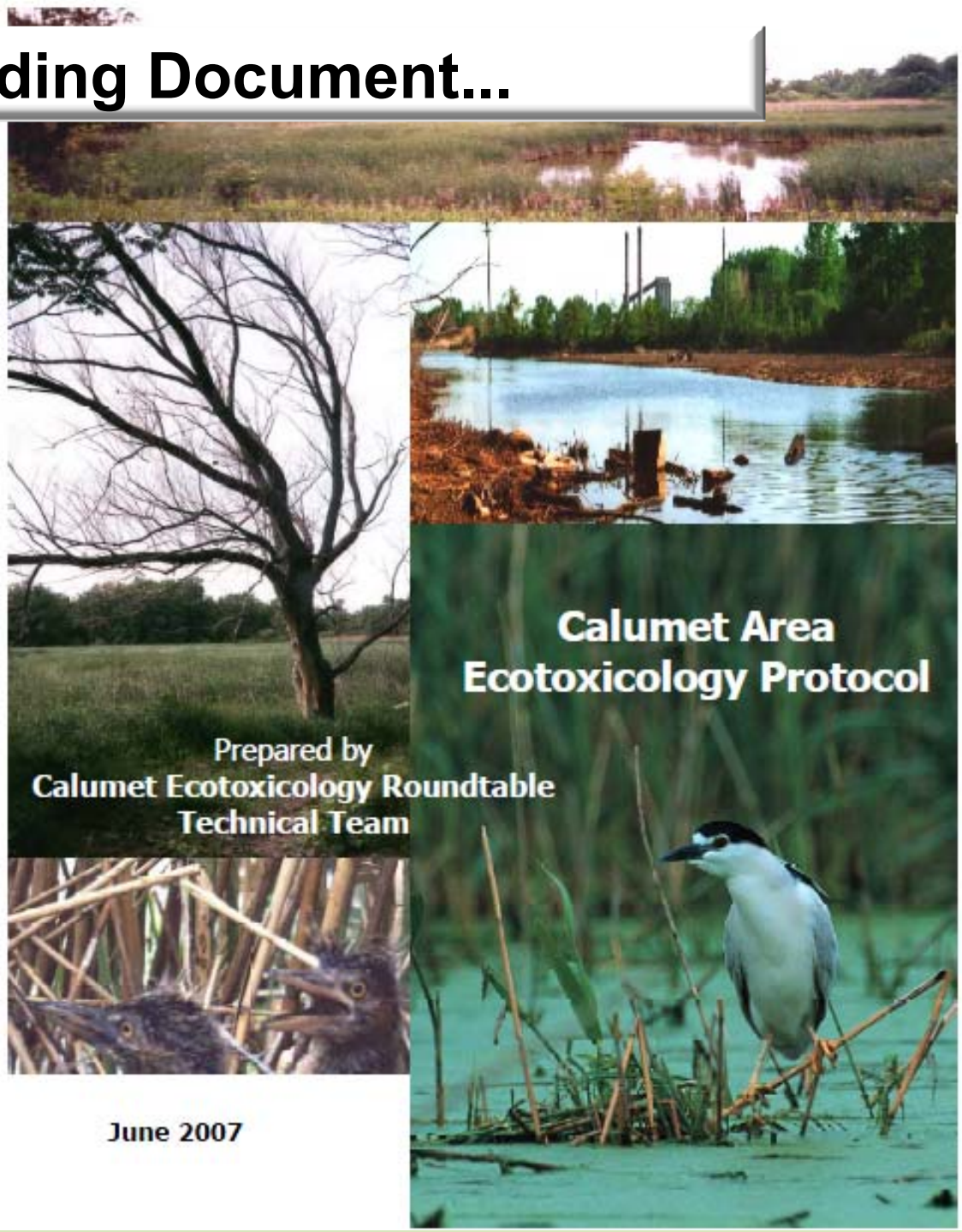
The Guiding Document...

Developed by multiple stakeholders such as...

- Chicago Dept. of the Environment, IL & US EPA, US F&WS.

- Established SITE SPECIFIC Background, Threshold (NOAEL) & Benchmark (LOAEL) levels of contaminants in soil, sediment and surface waters of the region

- Our data was compared against THESE LEVELS



Project Objective

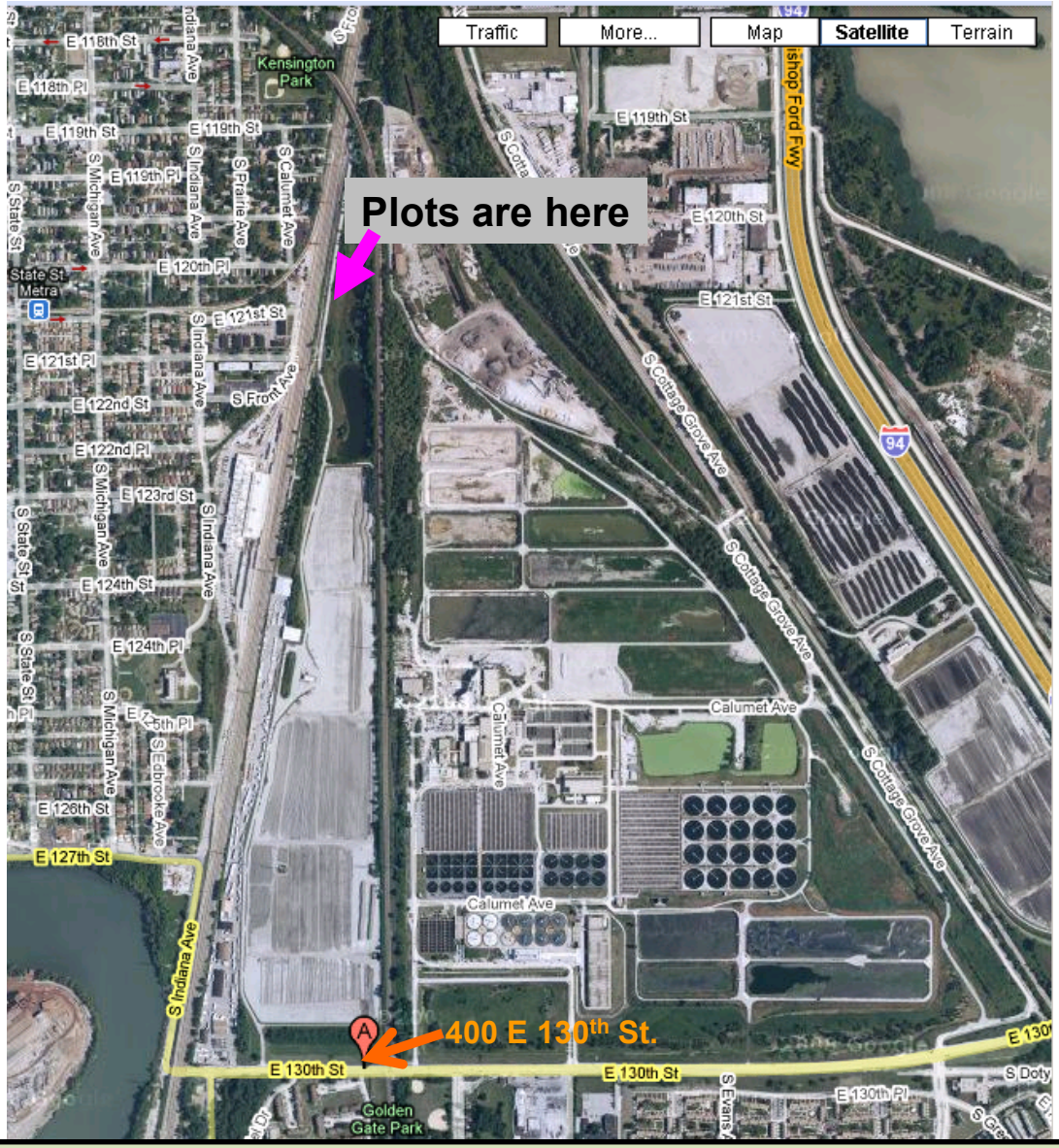
US FWS had concerns about the use of biosolids as a restoration material in the Calumet area - vegetative compost was proposed instead...but .. compost is not soil

Therefore, this study compares biosolids / blends to vegetative compost performance in **restoring ecological function to degraded sites, while minimizing environmental impact**

Performance of soil treatments were evaluated for:

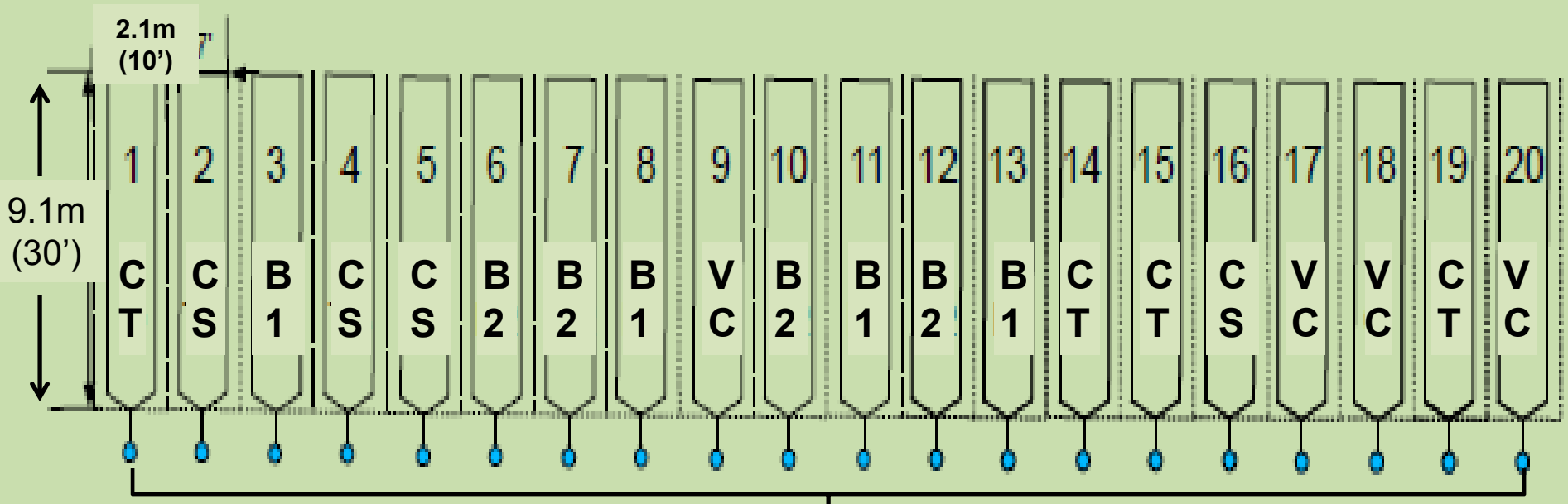
- Restoration of native vegetative community, soil health, microbial function & ecology, invertebrate reproductive function and population and

Runoff was evaluated for impact of nutrients / contaminants on water quality



Research Field Location in Calumet, Illinois

Experimental Design - Randomized Runoff Plots



4 Treatments+ control - 4 Replicates

CS = Control soil VC = Vegetative compost 2.5 cm/ 1 in

B1 = Biosolids 2.5cm/ 1 in B2 = Biosolids 5.1 cm/ 2 in

CT = Combination treatment of biosolids 2.5 cm/ 1 in + WTR + biochar

Soil Treatment/Blend Materials

MWRD Biosolids

Vegetative Compost

Water Treatment Residual (WTR) - added to bind excess soluble P

Biochar – added to absorb potential organic contaminants

Site Precondition

Aaron Mali and Oulu Coquie rototill in the Soil Treatments

Study Site
after plot borders installed

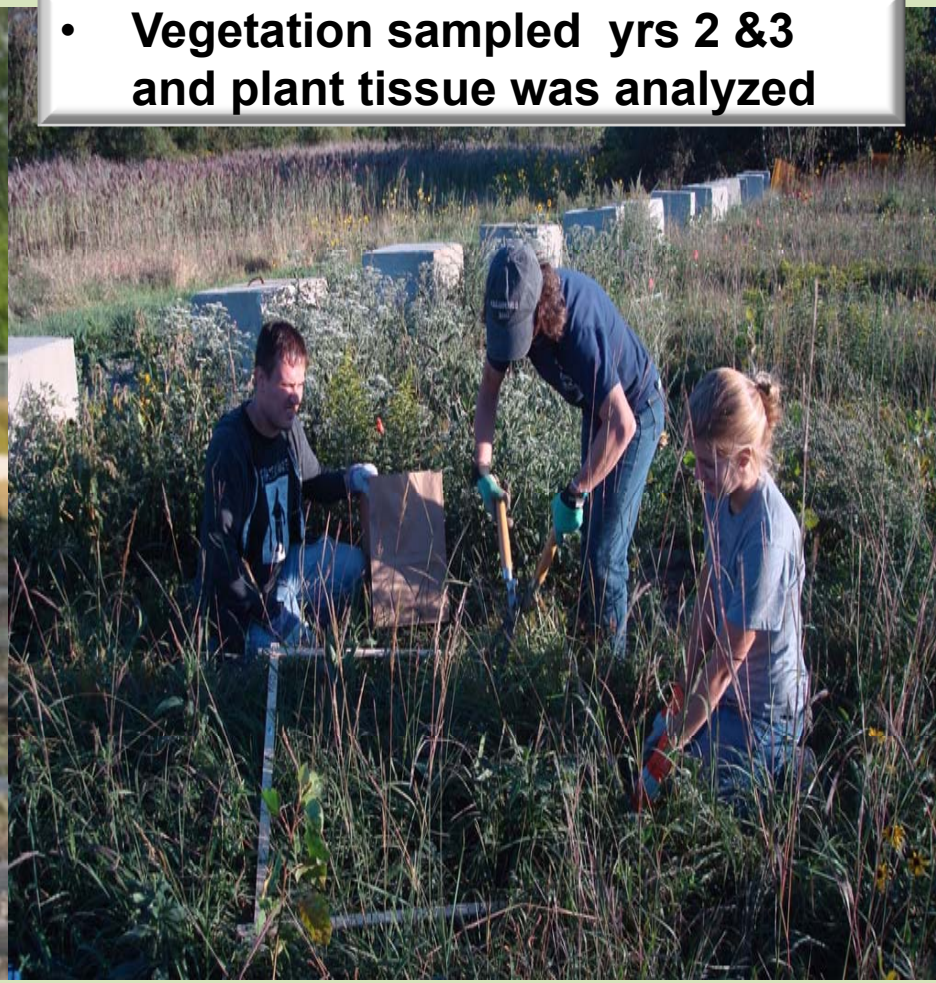
Plot installation and rainfall runoff collection

- Runoff collected for every rainfall event, for 3 yrs and analyzed for TSS, pH, EC, N, P and dissolved metals
- Microconstituents (PPCPs) analyzed by AXYS Analytical Labs

Soil Sampling

Plots were seeded with 33 native grass, legume and forb species from Cardno JFNew

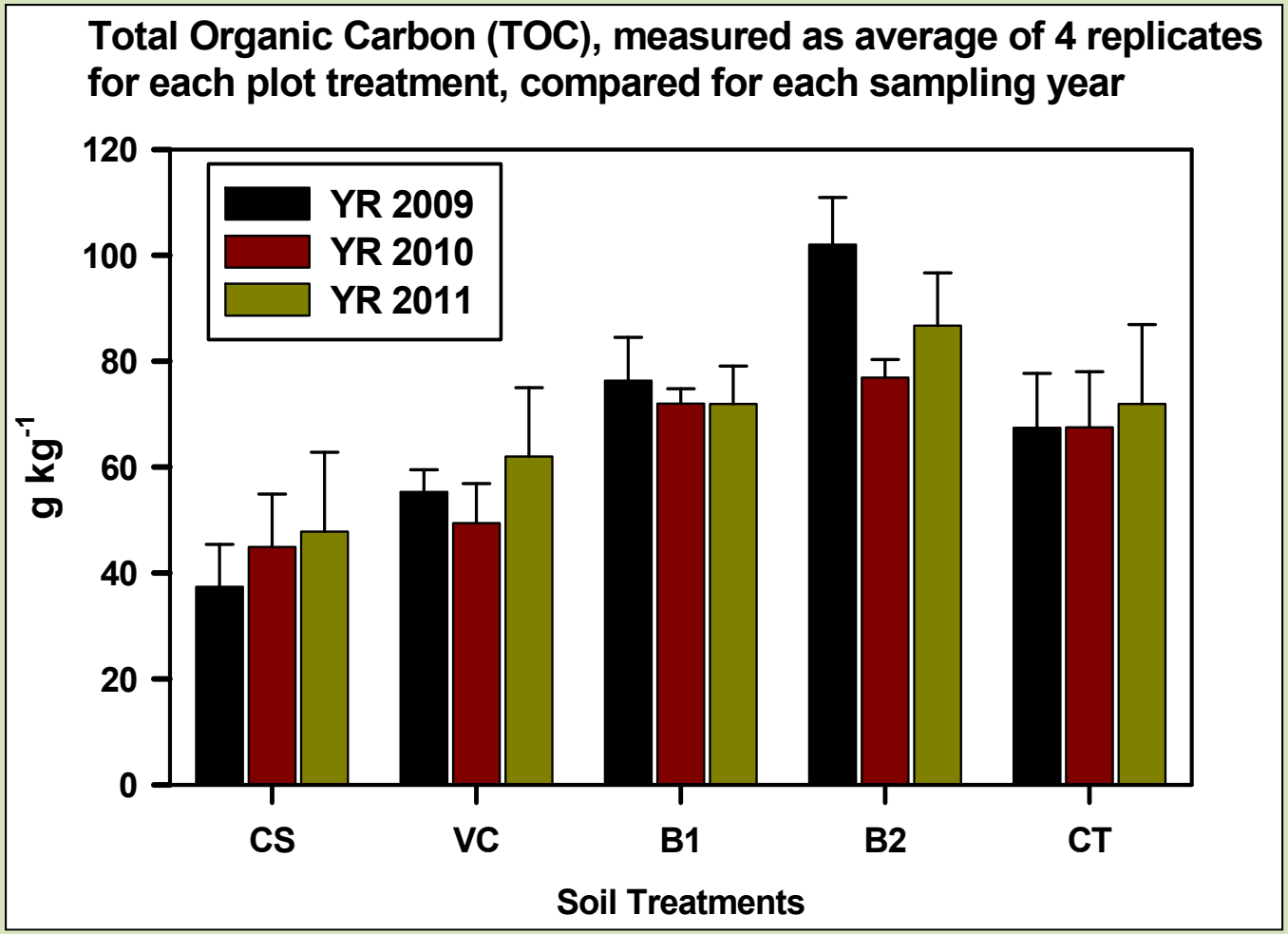
- Vegetation sampled yrs 2 &3 and plant tissue was analyzed



- Soils sampled annually and analyzed for multiple constituents
- Laboratory earthworm bioassay conducted to measure mortality and reproductive endpoints

➢ ***Results....***

Select soil quality measures



Biosolids increased soil organic carbon, total N, plant available N (PAN) more than compost treatment

Heavy Metal(loid)s in Soil

	Year	Plot soil treatment CT	VC	BS1	BS2	CT
		mg kg^{-1}				
As	2009	13.4b†	12.8ab	12.3ab	12.2a	11.9a
	2010	17.5b	13.2a	13.7a	13.1a	14.1a
	2011	11.4a	12.1a	12.7ab	13.5b	14.0b
Ba	2009	204a	183a	234ab	332b	221a
	2010	203b	136a	209bc	251c	227bc
	2011	128a	130a	189c	210c	182b
Be	2009	1.20c	1.11b	1.14b	0.90a	1.00ab
	2010	NA‡	NA	NA	NA	NA
	2011	0.37c	0.12a	0.23b	0.20b	0.28bc
Cd	2009	1.36a	1.33a	1.51a	2.47b	1.65a
	2010	1.05ab	0.78a	1.3bc	1.86d	1.6cd
	2011	0.98a	0.88a	1.29bc	1.43c	1.19ab
Co	2009	3.26b	2.43a	2.52a	2.40a	2.43a
	2010	14.9b	11.2a	11.2a	10.0a	10.0a
	2011	BDL§	BDL	BDL	BDL	BDL
Cr	2009	47.2a	44.4a	52.1a	70.3b	52.1a
	2010	51.3a	39.5ab	53.9c	67.3d	56.5bc
	2011	31.4a	28.4ab	39.3c	50.8d	36.4bc
Cu	2009	52.1a	49.4a	103a	256b	122a
	2010	63.8a	52.8a	143b	209c	184bc
	2011	38.3a	39.5a	109bc	124c	89.3b
Mn	2009	NA	NA	NA	NA	NA
	2010	478a	468a	508a	486a	466a
	2011	387a	416a	458ab	526bc	540c
Mo	2009	7.61a	5.96a	8.5a	12.1b	8.58a
	2010	6.84b	4.92a	7.39b	8.98c	7.53b
	2011	4.72ab	4.21a	5.40b	7.03c	5.12b
Ni	2009	46.0b	34.8a	38.8ab	41.0ab	36.6a
	2010	41.4b	31.7a	35.2a	35.4a	32.2a
	2011	26.7c	23.8a	27.5c	28.7c	24.9b
Pb	2009	89.1ab	75.5a	83.2ab	99.8b	85.5ab
	2010	96.2c	68a	86.1bc	94.9c	86.8bc
	2011	50.3a	52.4a	70.7b	70.7b	62.6ab
Sb	2009	3.93a	3.92a	4.57a	4.61a	5.51a
	2010	NA	NA	NA	NA	NA
	2011	BDL	BDL	BDL	BDL	BDL
Se	2009	0.83a	1.46ab	1.84ab	3.82c	2.34b
	2010	NA	NA	NA	NA	NA
	2011	NA	NA	NA	NA	NA
V	2009	49.3b	51.6b	52.8b	44.9a	46.8ab
	2010	NA	NA	NA	NA	NA
	2011	40.6b	34.1a	36.2ab	37.4ab	37.5ab
Zn	2009	164a	159a	280a	609b	317a
	2010	200a	155a	393b	556c	490bc
	2011	110a	121a	277bc	311c	241b

†Means within parameter measured with same letter are not different
‡ Not analyzed
§ Below detect limit

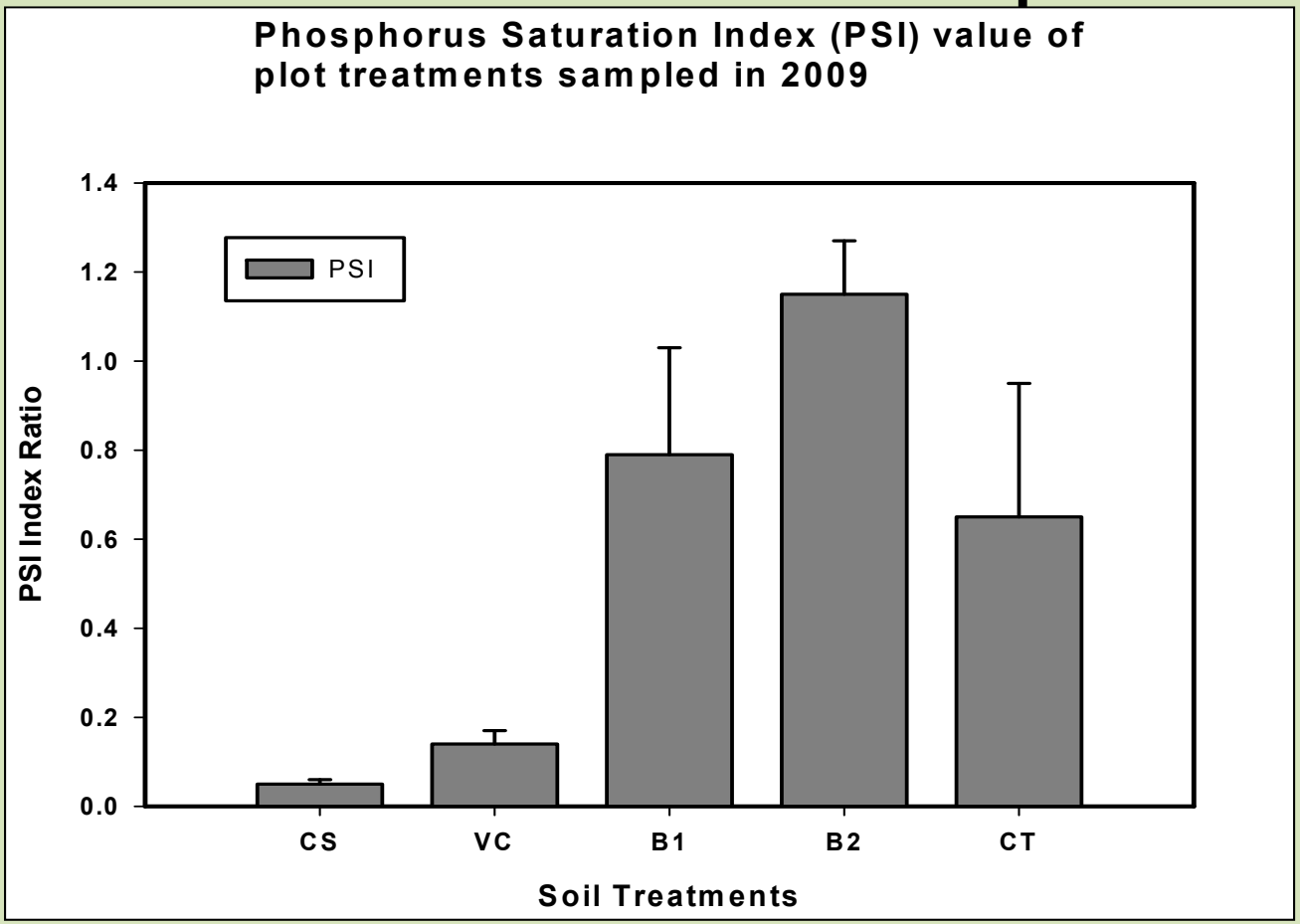
BS Treatments increased soil Cu and Zn

these levels are below any concern
(incl. USEPA EcoSSLs)

addition of Cu and Zn and other micronutrients are beneficial because these are essential plant nutrients

animals manure or biosolids provides micronutrients –compost doesn't

Biosolids Increased Soil Phosphorus



Phosphorus Saturation Index (PSI (%)= [(P_{ox})/ (Al_{ox} + Fe_{ox})] x 100%; values over 1 have been correlated with potential transport of labile (soluble) P

BS2 a concern; BS1 less concern
BS1 is the recommended rate; BS2 included for research purposes

Soil Enzymes as an indicator of soil nutrient cycling

Biological function	Soil Enzyme	Ecosystem service	Response		
			CS	VC	BS
Chitin degradation	N-Acetyl- β-glucosaminidase	C & N Nutrient cycling; N fixation	-	+	++
Glucose availability	β-glucosidase	Microbial energy source; indirect heavy metal indicator	-	+	++
Inorganic N metabolism	Amidase & urease	Supplies N to microbes	-	-	-
P availability	Acid & alkaline phosphatase	P release for plant nutrition	-	+	++
Sulfate metabolism	Arlysulfatase	Indirect indicator of fungi; potential degradation of microconstituents	-	-	+
Broad based nutrient	Fluorescein diacetate (FDA)	Overall indicator of healthy soil biological activity	-	-	+

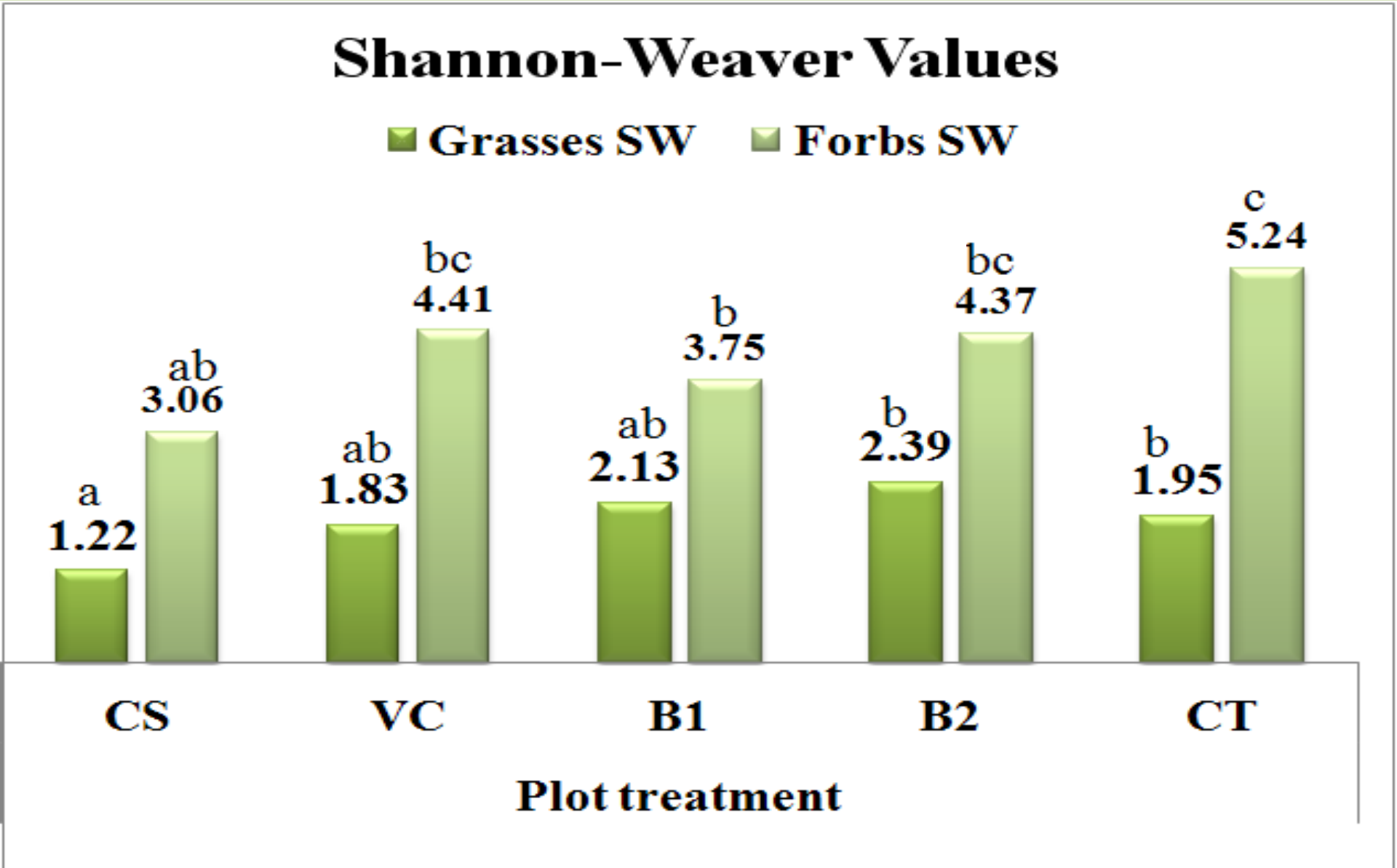
Select soil enzyme findings

- Biosolids and compost had a positive effect on soil enzymatic activities and microbial function
- Biosolids treatments tended to have higher amounts of fungal biomass compared to control, as well as lower stress biomarkers
- Arylsulfatase (indirect indicator of fungi), N-Acetyl- β-glucosaminidase (C&N nutrient cycling), β-glucosidase (microbial energy,) Phosphatase (P cycling), were increased by both biosolids and compost
- Fluorescein diacetate (FDA) hydrolysis – proxy indicator of fungal and bacterial biomass, thus microbiological activity, increased by biosolids but not compost treatments

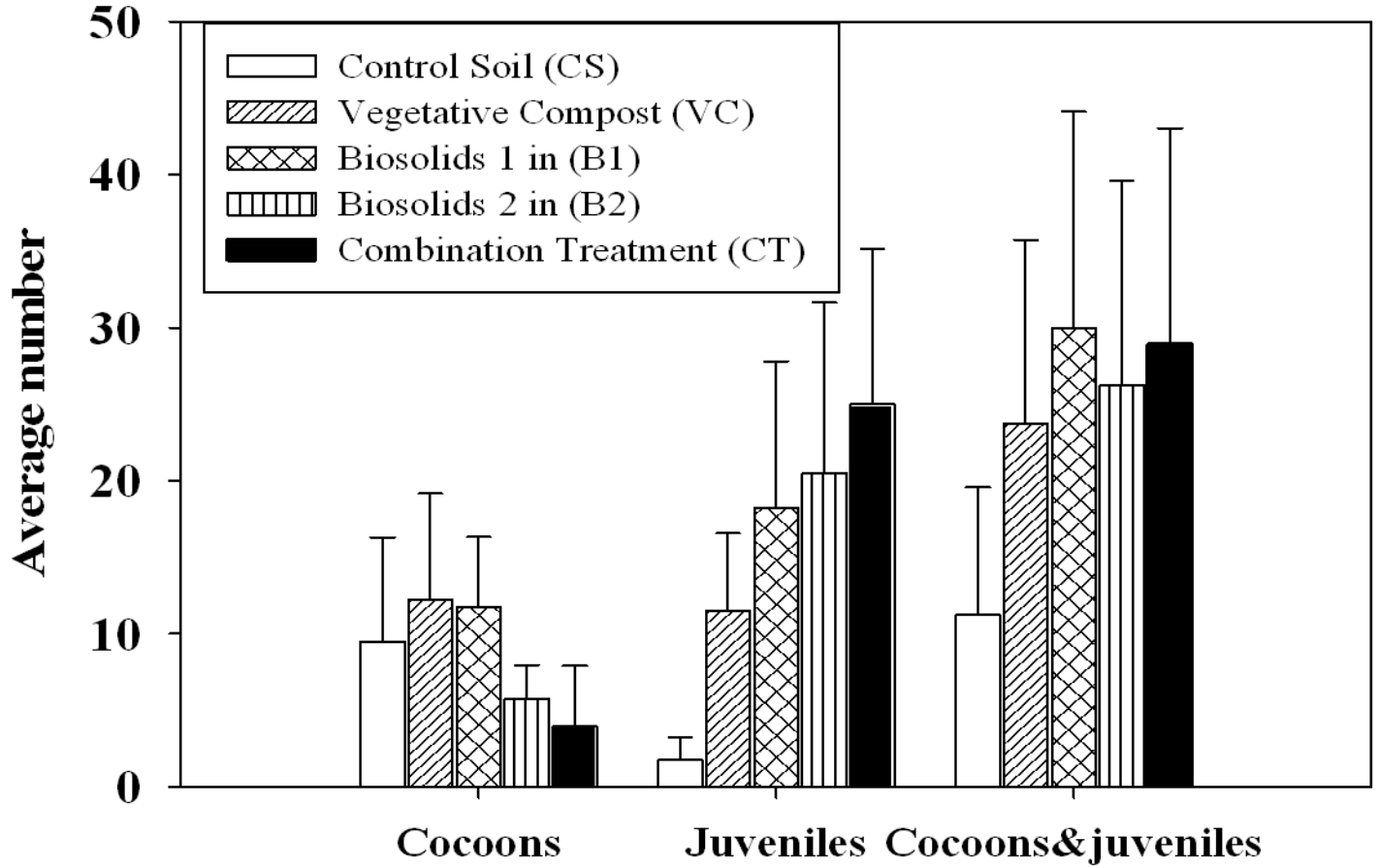
Vegetative Performance and Quality

- Plant biomass increased compared to controls – EXPECTED with application of nutrient rich amendments!
- Biosolids produced highest plant tissue N, thus improved protein content (nutrient) levels
- Biosolids DID NOT elevate trace metals in plants therefore no concern for ecosystem food chain transfer

- **Both biosolids and VC improved plant diversity**
- **Biosolids promotes diversity for restoration degraded soil**

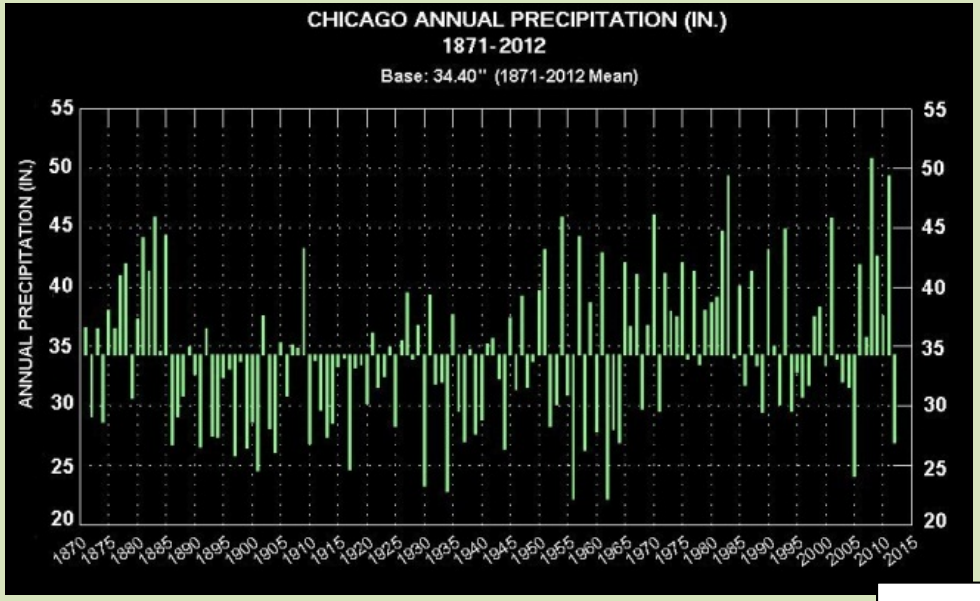


Earthworm 56 Day reproductive bioassay

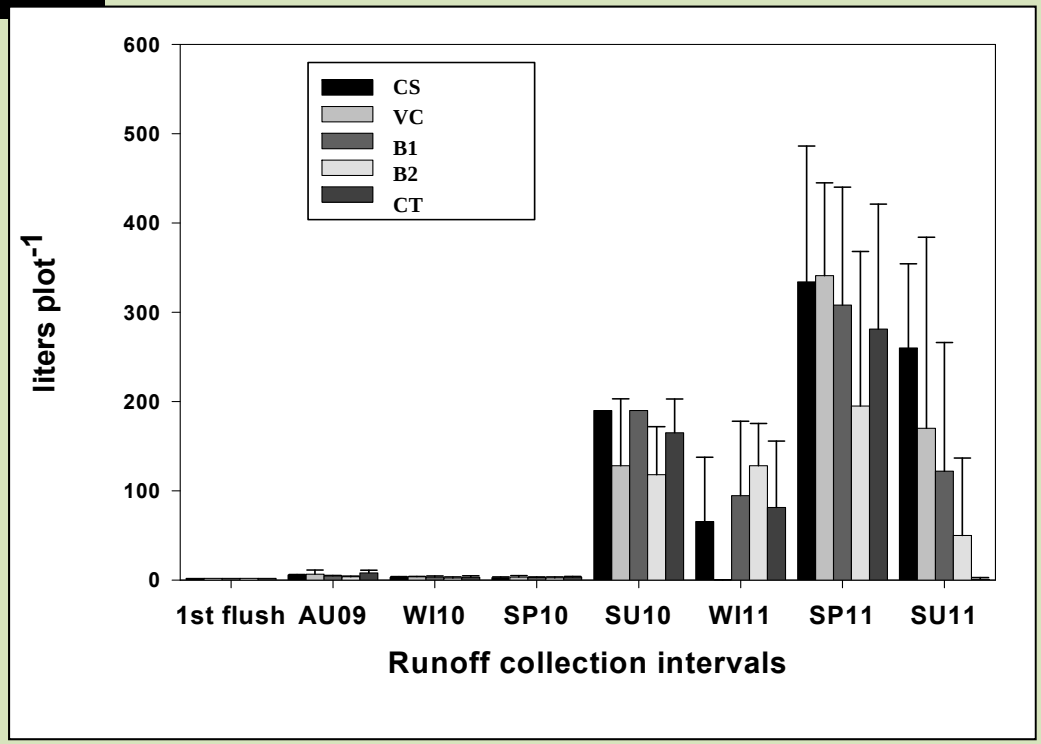


- Neither biosolids or compost had any effect on earthworm mortality
- Both biosolids and compost treatments increased number of juveniles and earthworm reproductive success

Rainfall Runoff Water Quality



2010: 37.5 inches
2011: 49.5 inches!



Select runoff water measures...

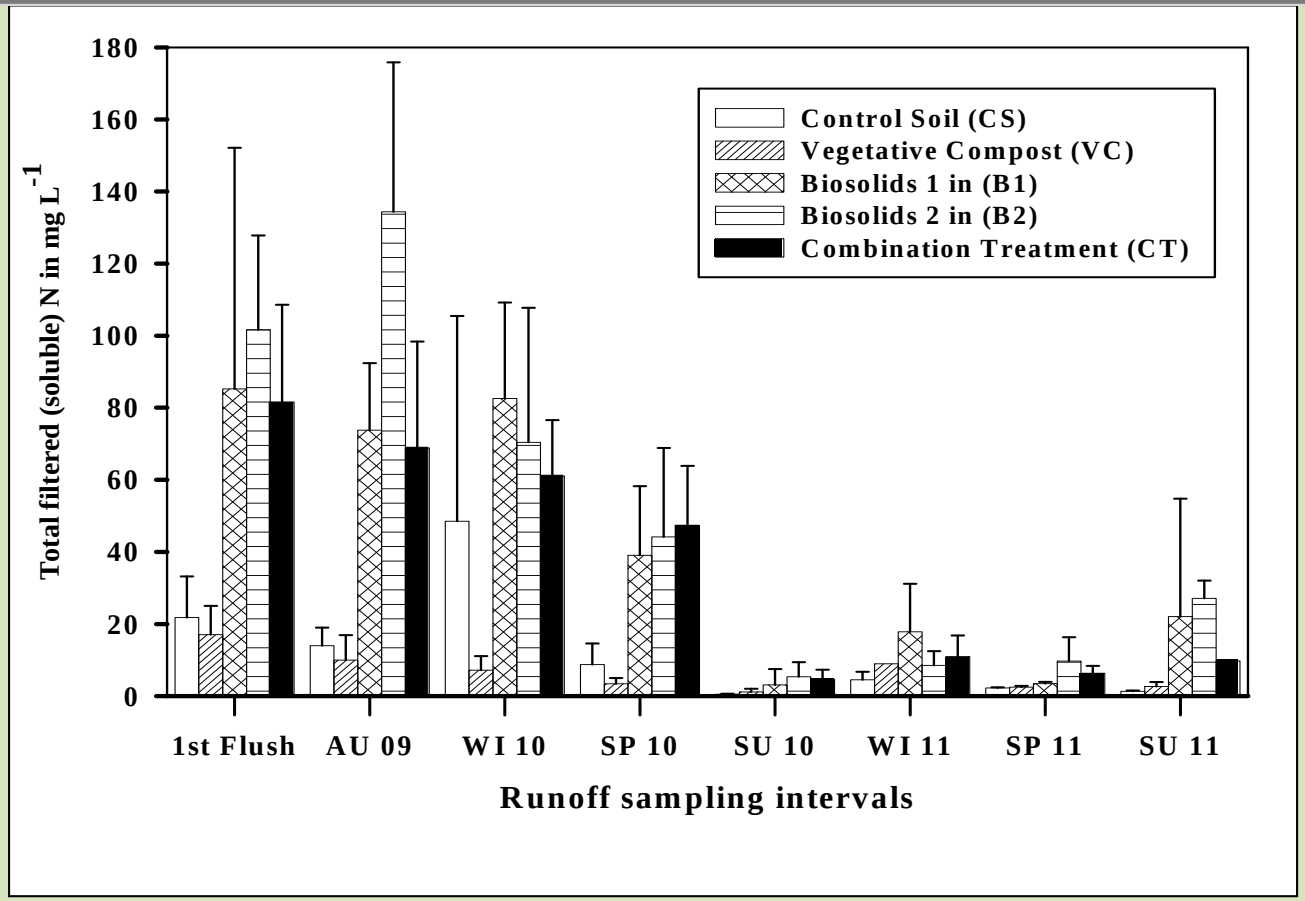
The 1st flush of runoff water (1st rainfall event) was tested for 14 dissolved metals:

- As, Ba, Be, Cd, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Sb, Se & Zn

Findings:

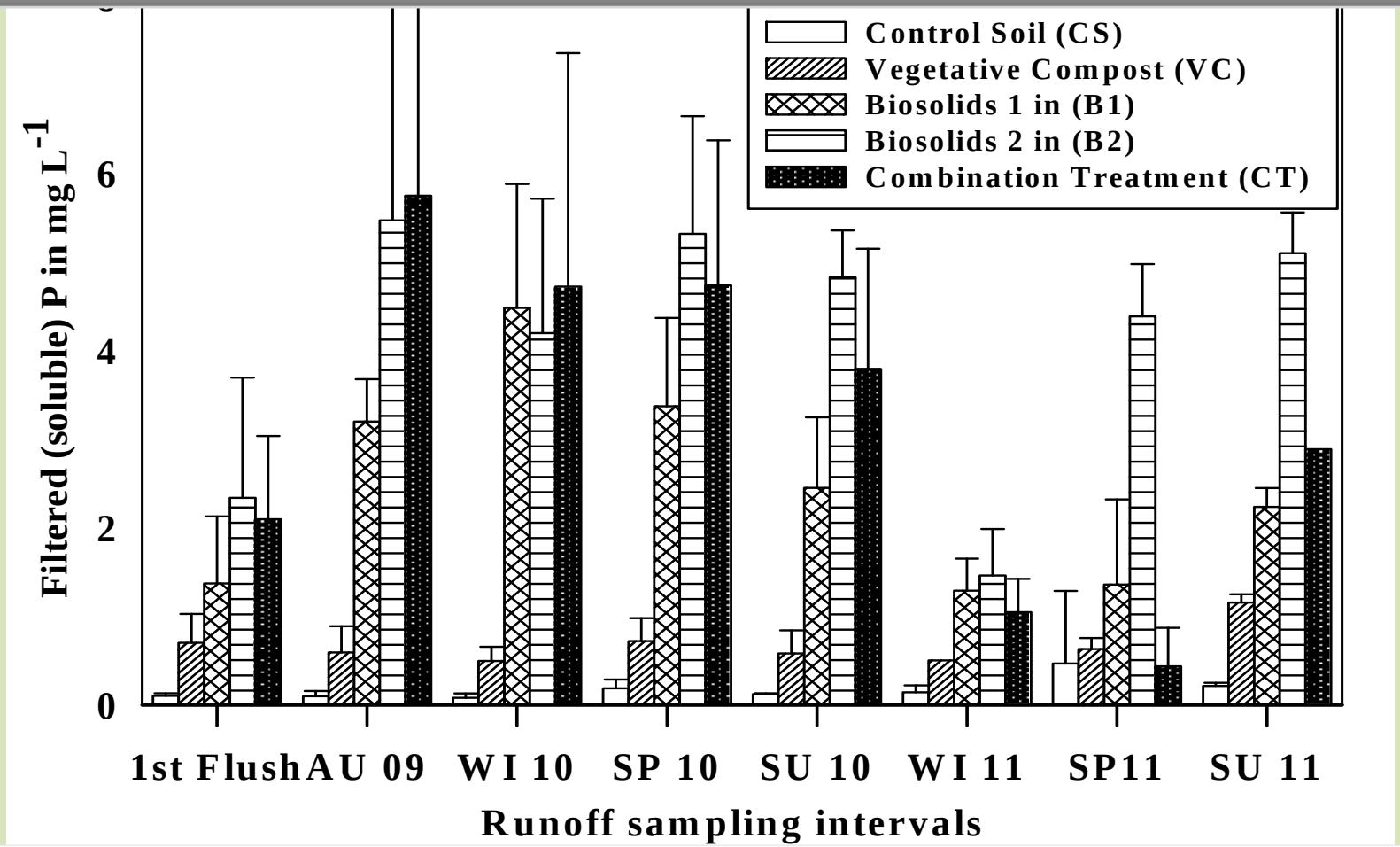
- All metals below Calumet Ecotoxicology Protocols (LOAEL) except Cu 2" Biosolids treatment
  we are not recommending BS2. No concern with BS1

Concentration of soluble total N in filtered runoff water sampled after 1st flush, and seasonally thereafter



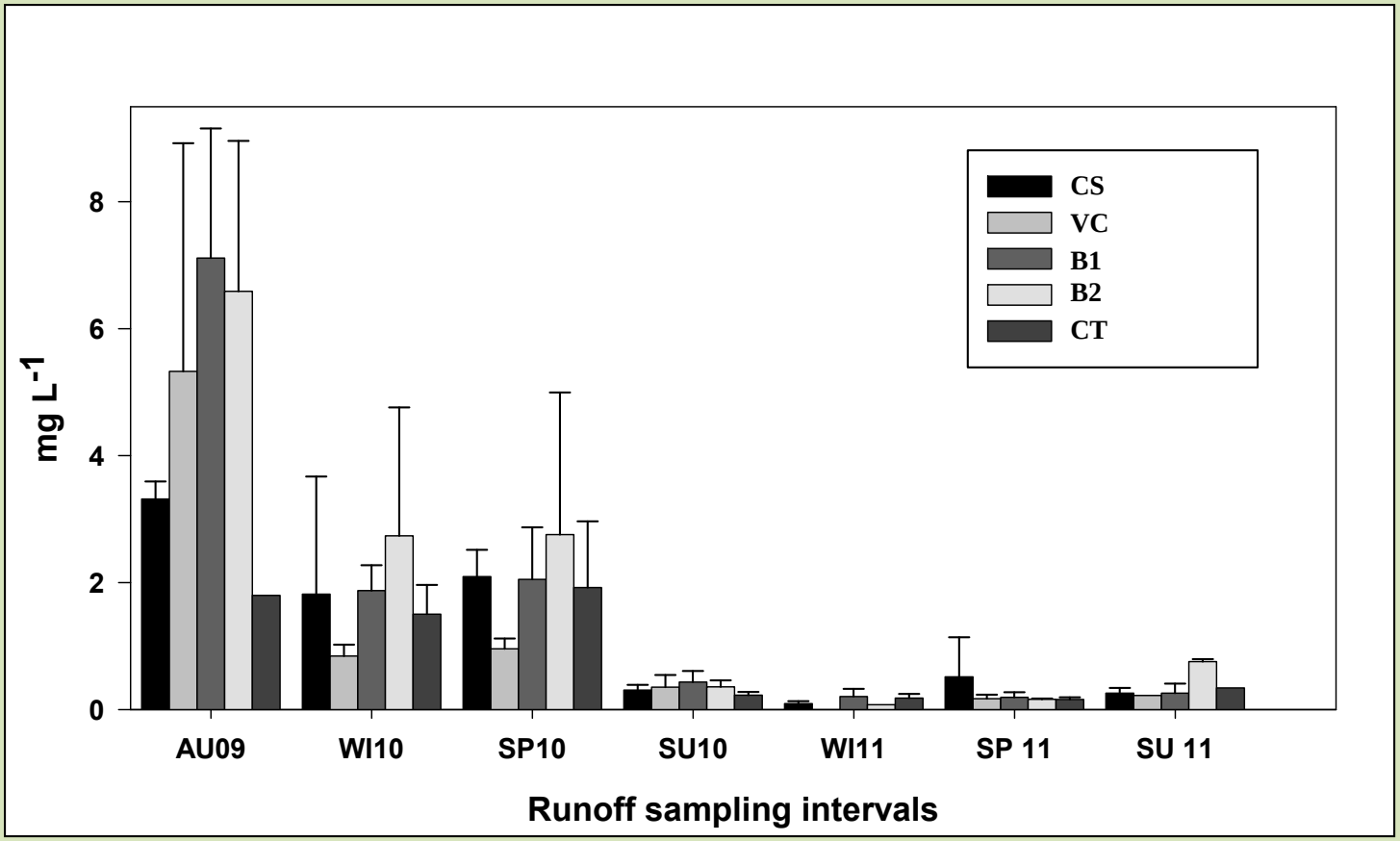
- Greater loss of soluble N associated with biosolids declined markedly to near background levels within 1 year
- Use best management practices to control sediment/runoff loss

Concentration of soluble P in filtered runoff water sampled after 1st flush, and seasonally thereafter



- Biosolids increased runoff P compared to compost
- Soluble P loss from biosolids treated plots was sustained over time
- Application of additional WTR in 2nd year (after SU 10 sampling) was starting to have an impact on P levels

Total Suspended Solids



TSS high before the site was stabilized (i.e. vegetation)
Better erosion control practices needed to reduce TSS after establishment

Emerging Contaminants
Microconstitutents
Pharmaceuticals and Personal Care Products

- 119 PPCP were tested by Axys Analytical Labs
- 20 compounds were measured above detection limits, concentrations ranged from approx 1 to 1760 ng L^{-1} (Ibuprofen)
- 4 compounds detected in runoff from all treatments
- No concentrations were above NOAEL (daphnia) and were below probable no-effect levels in literature (PNEC)

Top 5 compounds, which were 10 times greater than detection limit

Compound	CS	VC	B2	CT	NOAEL
			ng L^{-1}		
Carbamazepine	nd	nd	66.0 - 206	nd	25,000
DEET	57.9 - 420	57.9 – 86.5	43.0 - 154	58.2 - 176	_
Gemfibrozil	3.41 – 15.0	7.05 – 84.0	35.8 - 119	90.3 - 324	100,000
Ibuprofen	nd - 202	89.7 - 568	527 - 1760	854 - 1490	5000
Valsartan	nd – 17.3	nd – 78.0	58.4 - 200	102 - 233	_

Conclusions

- Biosolids increased soil organic carbon and many soil quality measures more than compost
- Vegetative performance and community measures responded favorably to both compost and biosolids applications - biosolids response was more pronounced
- Microbial response to compost and biosolids applications were similar - biosolids enhanced fungal population measures
- Terrestrial receptors (earthworms) reproductive measures were increased by compost and biosolids
- The biosolids applied at the 5.1 cm / 2 in rate exhibited potential for P runoff
- The WTR combined with biosolids showed some effect in reducing P runoff
- PPCP levels in runoff were below LOAELs in the literature

Technology Transfer
Millennium Reserve

Environment

- Manage core natural lands that contain important high-quality biological communities and support rare plants and animals.
- Expand and improve healthy natural habitats to maximize biodiversity
- Build a green infrastructure based on a vision shared by the Chicago Wilderness…..

Economy

- Provide training and internships for green jobs including restoration and land management
- Support development of local small businesses
- Restoration will improve property values of the region

High Quality Soil is the Foundation of a Healthy Ecosystem

- Topsoil Excavation from Farmland or other "borrowed soil" destroys a vital Natural Resource
- Large areas in Calumet Region either has little (fill) or degraded soil
- Manufactured Soil Blends and/or soil amendments are essential to large scale restoration/revitalization
- Compost alone will not restore severely degraded areas
- Local resources are needed to make successful soil blends /amendments
- Biosolids from Calumet, USCC compost, WTR from local drinking water treatment plants
- Partnerships between MWRD and OSU and others will improve success of Millennium Reserve projects.

Thank You
for your attention
More information?
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