Biosolids and Revegetation Addressing Contaminants: Ecosystem Revitalization of the Long-Barren Serpentine Mine Waste at the Vermont Asbestos Group Mine

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Phytostabilization of Contaminated Soils

- Hazardous mining and smelting sites are often so metal phytotoxic and nutrient deficient that plants cannot become established on the site soils.
- Phytostabilization has been shown to alleviate risk to ecosystems and support persistent vegetative cover.
  - Acid soils rich in Zn, Ni, Cu or Mn may prevent plant growth.
    - Making soil calcareous can fully alleviate metal phytotoxicity.
  - Applying organic amendments rich in organic-N, P, and other required nutrients, and microbes, can solve infertility issues.
  - Including adsorbents in the amendments aids remediation.
- Selecting plant species fit to purpose.
  - Adapted to local climate conditions; natives if work; if phytotoxicity and infertility alleviated, no longer difficult.
  - Metal excluders and low Cd:Zn ratio to protect food chains.
- Soil Revitalization, not Ecosystem Restoration

Phytostabilization -- *in situ* Remediation

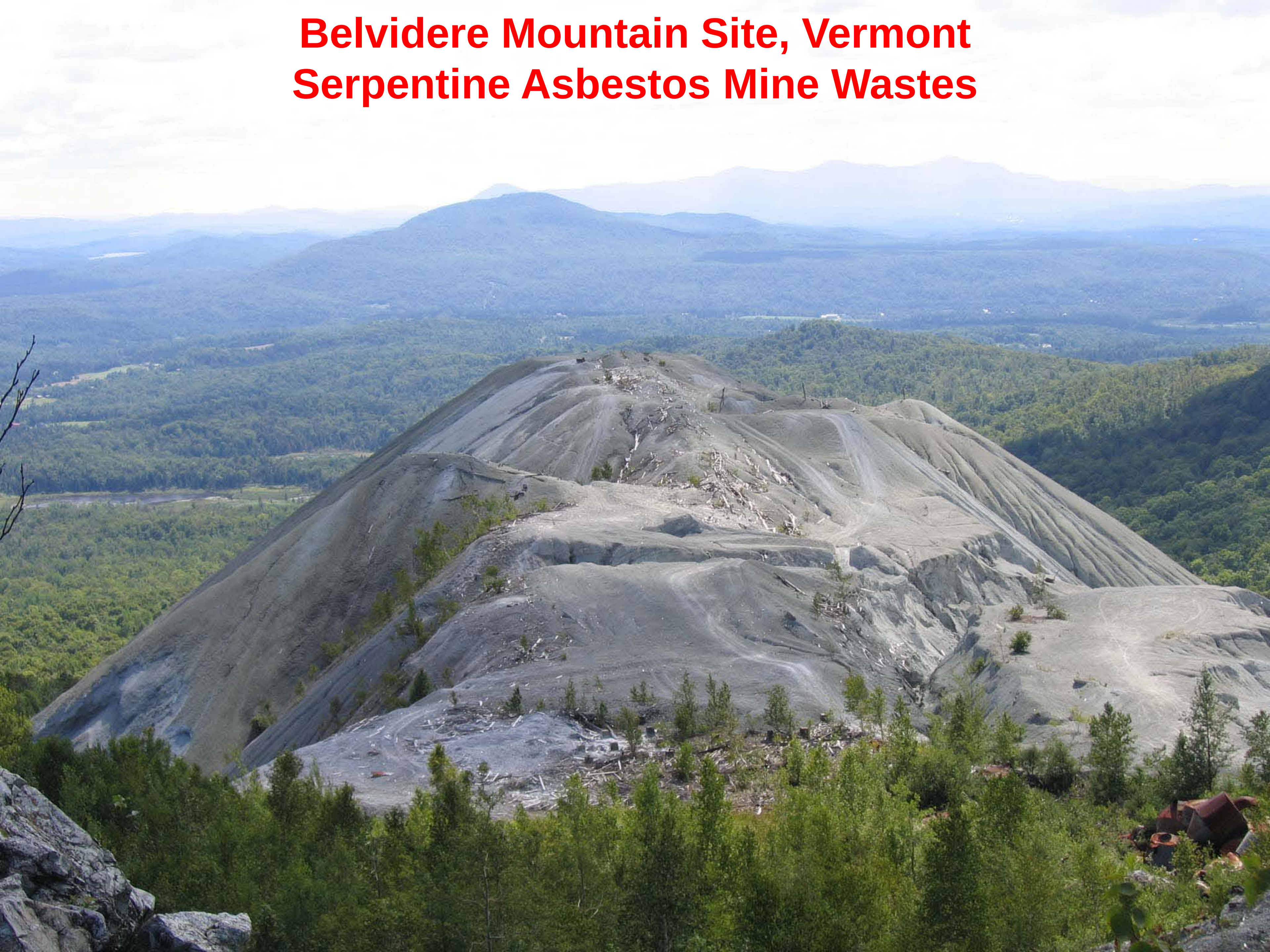
- **Using biosolids, composts, and byproducts in remediation of phytotoxic or infertile soils.**
- **Soil chemistry management may provide persistent/sustainable remediation:**
  - **Nearly all sites are intensely P deficient.**
    - **Manure, biosolids and their composts are richer in N and P than yard debris composts and many other organic amendments.**
    - **Inorganic N fertilizers cannot persist in root zone.**
  - **Zn, Cu, Ni and Mn are commonly phytotoxic if acidic.**
  - **Make calcareous to prevent metal cation phytotoxicity.**
  - **Leaching of alkalinity may alleviate metal toxicity at some sites where metals are in near-surface soil depth.**
  - **Amorphous Fe and Mn oxides provide increased metals adsorption and may be built into amendment mixture.**

The Vermont Asbestos Group Site Near Eden/Lowell/Stowe, VT.

- **Has been barren since about 1950. Potential dispersal of asbestos from the barren ground rock presents an environmental risk.**
- **Rock is serpentinite, rich in Ni, Cr, Co, Fe, Mn and Mg silicate. Deficient in many plant nutrients (P, Ca, N, K). Nearly lacks soil OM and microbes.**
- **Extremely infertile; Mg phytotoxic=Ca deficient.**
- **Not Ni, Co or Cr phytotoxic due to high pH (>8.0) which is caused by presence of Mg-silicate.**
- **Alternative to *in situ* phytostabilization would be covering mine waste with 12-24 inches of topsoil!**

Severe Infertility and Lack of Soil Properties Prevent Plant Survival

- Serpentine soils are Mg phytotoxic due to very low Ca:Mg ratio of this type of rock.
- N, P, K, and trace elements are also deficient.
- Serpentine soils are normally severely Ca and P deficient for all but serpentine ecology plants; the mine waste has even lower available Ca from rock.
- Because site has high slopes, goal was to use surface applied amendment mixture to achieve revegetation at low cost.
- Designed experiment to evaluate surface applied compost plus Ca and NPK fertilizers.


Belvidere Mountain Site, Vermont
Serpentine Asbestos Mine Wastes

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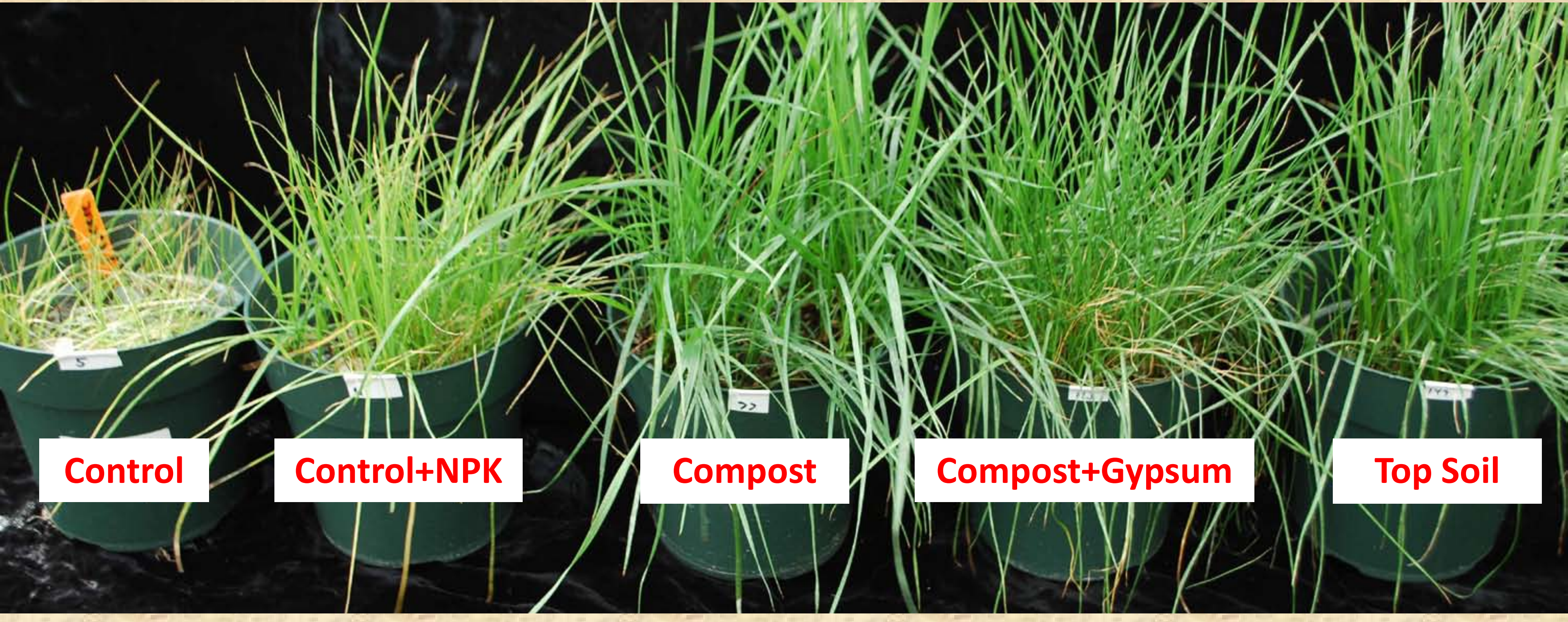
Composition (Totals) of VAG "Soil"

Macroelements		Trace elements	
Ca, %	0.6	Fe, ppm	65000.
Mg, %	22.	Mn, ppm	850.
K, %	0.04	Ni, ppm	2100.
P, %	<0.005	Co, ppm	120.
pH	7.5-9.0	Cr, ppm	1300.
		Cu.ppm	9.
		Pb, ppm	5.

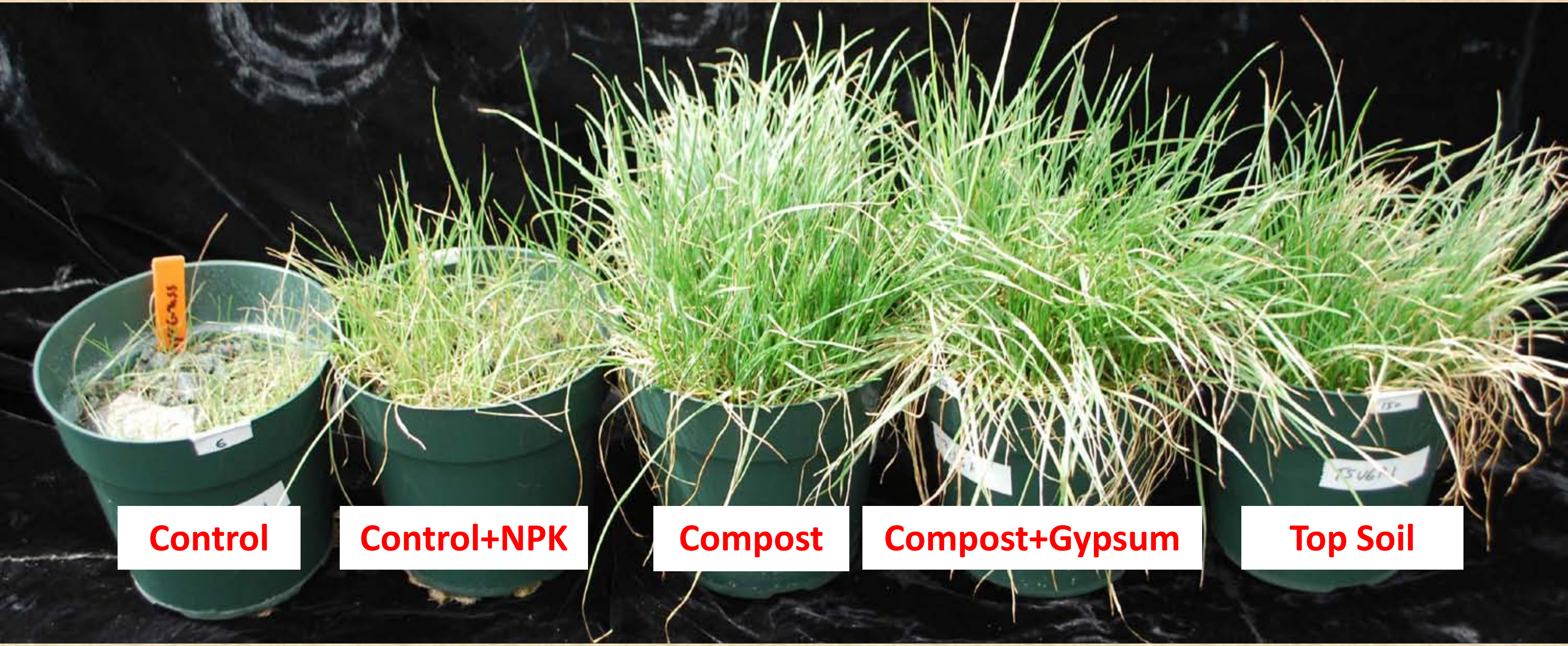
Greenhouse Evaluation of Method

- **Surface Applied Soil Amendments:**
  - Control
  - NPK Fertilizer (normal roadside revegetation)
  - Compost + NPK
  - Compost + NPK + FGD-Gypsum(= $CaSO_4$)
  - Topsoil + NPK
- **Plant Species Tested:**
  - Kentucky bluegrass
  - Perennial ryegrass
  - Tall Fescue
  - Alsike Clover
- **Compost was a dairy manure plus yard debris mature product made at the Beltsville facility.**

Tall Fescue 47 Days from Seeding

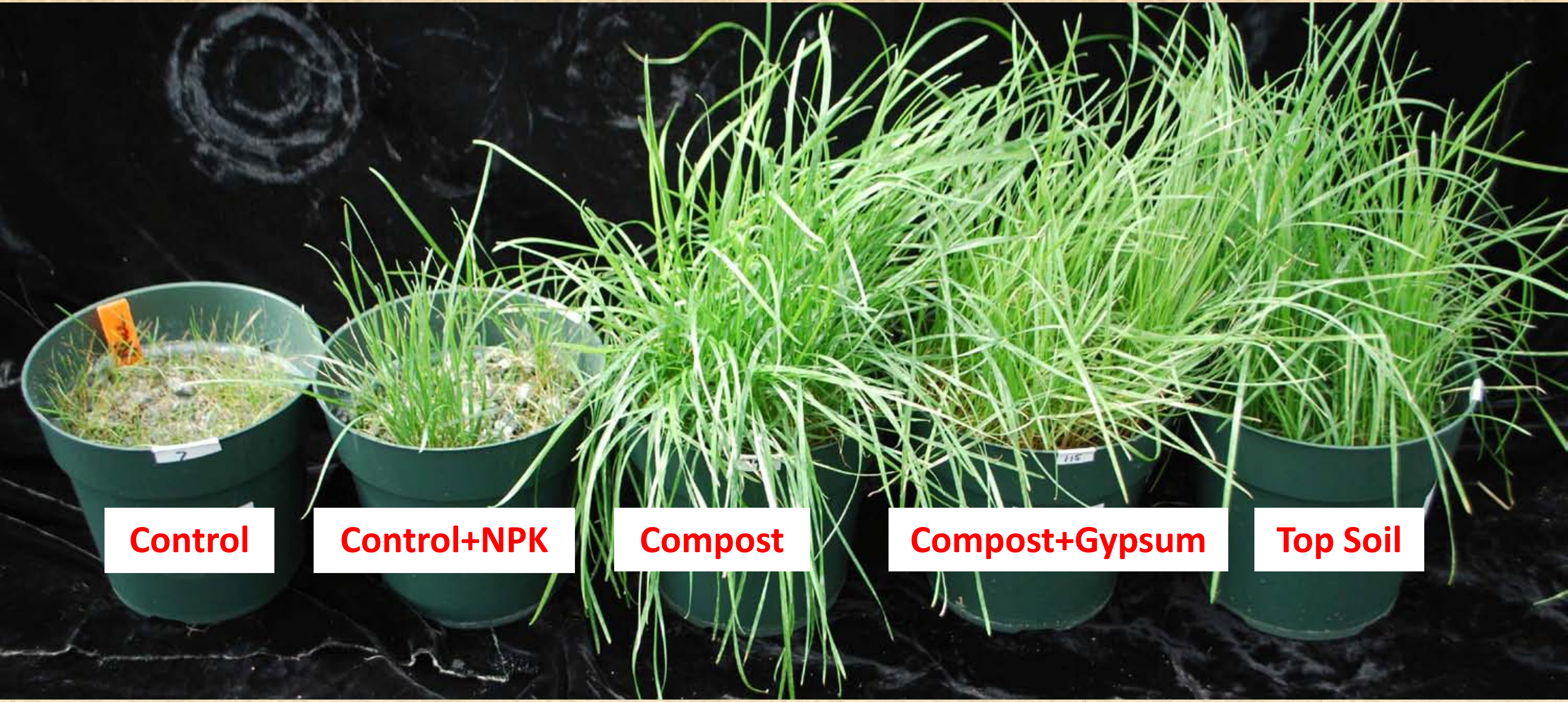


Perennial Ryegrass 47 Days from Seeding

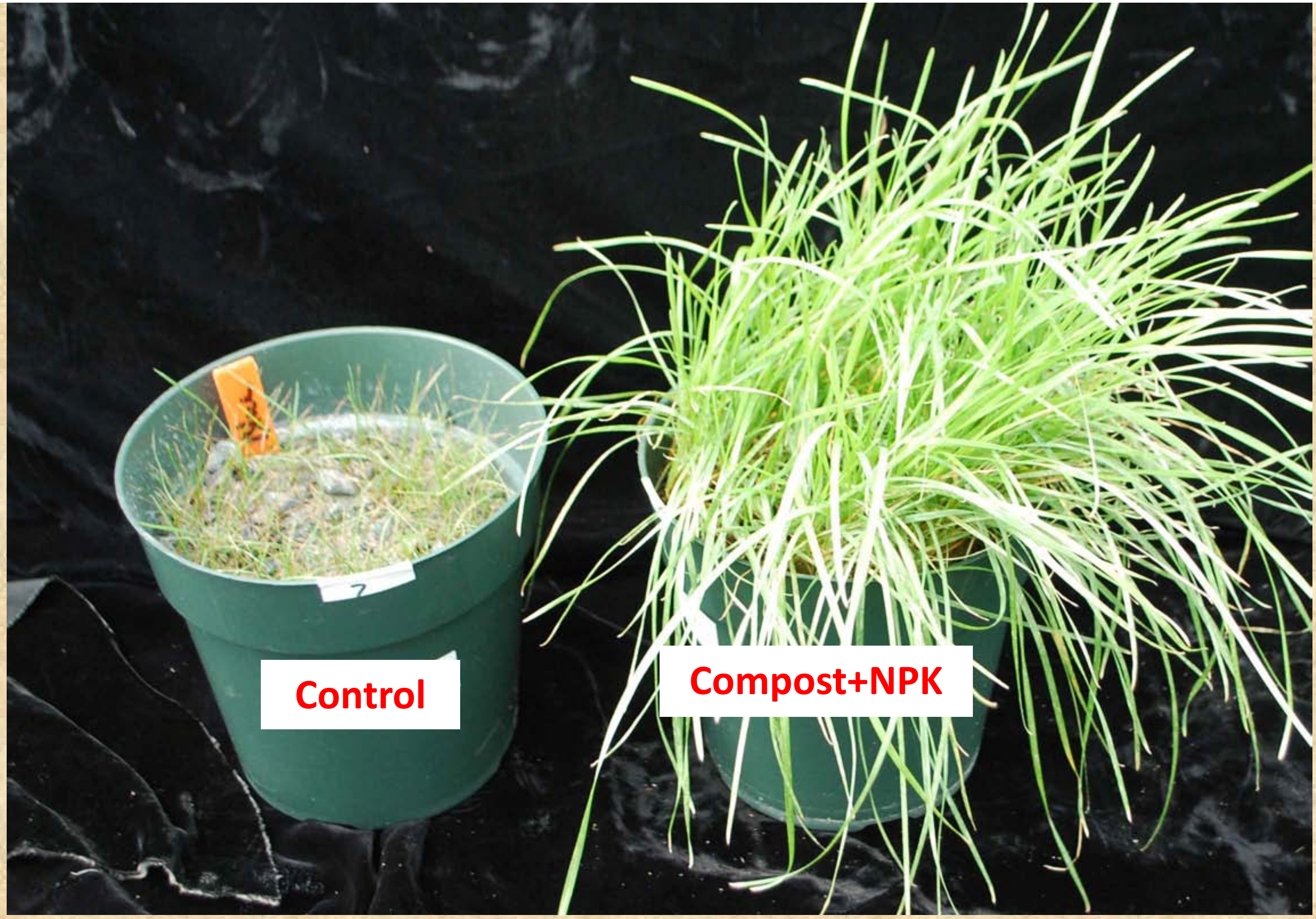


Perennial Ryegrass 47 Days from Seeding

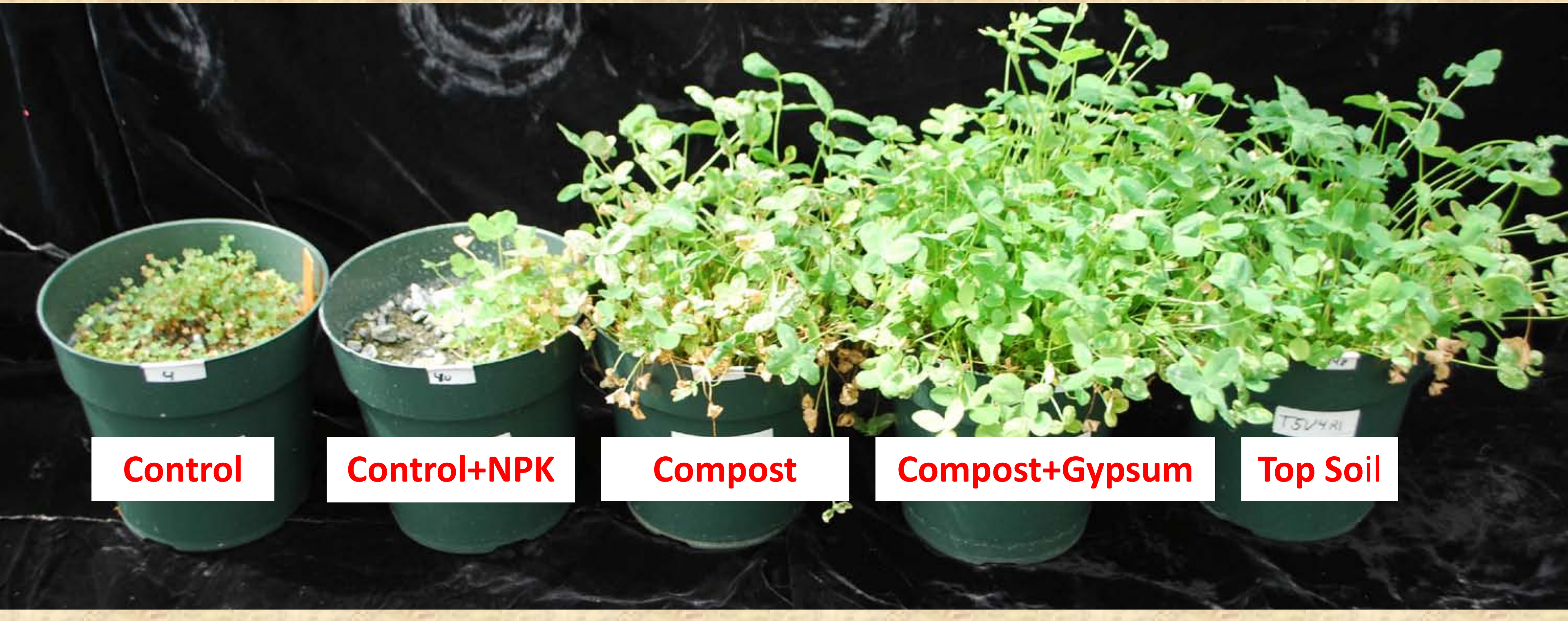
Kentucky Bluegrass 47 Days from Seeding



Kentucky Bluegrass 47 Days from Seeding



Alsike Clover 47 Days from Seeding



Alsike Clover 47 Days from Seeding

Installation of Plots at VAG

Aug. 23-24, 2010

- **Remediation Amendment Mixture:**
  - Compost (Intervale or Foster Farms) @80 T/A (180 t/ha)
  - Gypsum ($CaSO_4 \cdot 2H_20$) @ 25 T/A (56 t/ha)
  - Limestone @ 10 T/A (22 t/ha)
  - NPK Fertilizer equal to roadside reveg rate @200#/A
- **Seeding Mixture:**
  - Perennial ryegrass
  - Tall fescue
  - Kentucky bluegrass
  - Alsike clover with rhizobium
  - After limited rainfall, later overseeded with winter rye

Preparing mixture of COMPOST (manure and yard debris), mined gypsum, NPK fertilizer plus limestone

August 24, 2011: Applying the compost mixtures to test plots; compost was raked even, then seeded with crop mix.

Test plots with two compost mixtures vs. Control (three replications in RCB) VAG site August 23, 2010

Cover crops establishment -- Sept. 30, 2010 at VAG Site.

Cover crop observed on May 24, 2011

VAG Sampling Trip July 12, 2011

Red Flags = Compost 1 (Intervale Farm Compost)
Blue Flags = Compost 2 (Foster Farm Compost)
White Flags = Control

First sampling done: 7-12-2011.

Biomass sample size was a 22" Diameter Circle, all plants harvested 1.5-2" above soil surface as to avoid soil contamination

View from the Upper Conveyor sloped Area-7-12-2011.

Overview of Replicated Test Plot Area at VAG, 7-12-2011

Sampling Block 2 (Intervale Farms Compost)-7-12-2011

Control Plot Block. 2, 7-12-2011

Replicated plot #3 (Foster Farm Compost) After Sampling

Effective vegetative cover on strong slop at VAG, 7-12-2011

Opportunity test plots at VAG on strong slope-7-12-2011

Cross section of a field plot at VAG

Rooting well into mineral layer below top-dressed compost.

Rooting well into mineral layer below top-dressed compost.

Vermont Asbestos Group Site
Effect of Treatments on Yield-7-2011

Treatment	Grass	Clover	Total
	------------------------- t/ha	-------------------------	
Control	0.11 a	0.0 a	0.11 a
Compost-1	1.89 b	0.50 b	2.39 b
Compost-2	0.75 ab	2.13 c	2.91 b

Composition of Crops at VAG-2011

	Ca	Mg	P	Ni	Cr	Mn	Zn
	g/kg	g/kg	g/kg	-----------mg/kg-----------			
Grass:							
Control	2.34	4.32	1.04	10.7	3.46	77.	14
Comp-1	3.14	1.35	1.16	7.5	0.68	156.	16
Comp-2	3.95	1.47	1.39	6.7	0.70	98.	19
Clover:							
Control	.	.	.	.	.	-	-
Comp-1	22.7	5.39	2.56	23.4	0.68	171.	24
Comp-2	23.7	6.82	2.34	21.3	0.53	134.	39

0.01 M $Sr(NO_3)_2$ Soil Solution like Extraction of VAG "Soil" July 2012

Treatment	Depth	Ca	Mg	pH_W
		mg/kg soil		
Control	0-10	7.	306.	9.6
	10-20	6.	363.	9.7
	20-30	<5.	362.	9.7
	30-40	<5.	363.	9.8
Compost A	Organic	1820.	126.	7.8
	0-10	61.	70.	8.9
	10-20	8.	369.	9.6
	20-30	6.	388.	9.8
	30-40	<5.	412.	9.8

VAG Site, June 2012

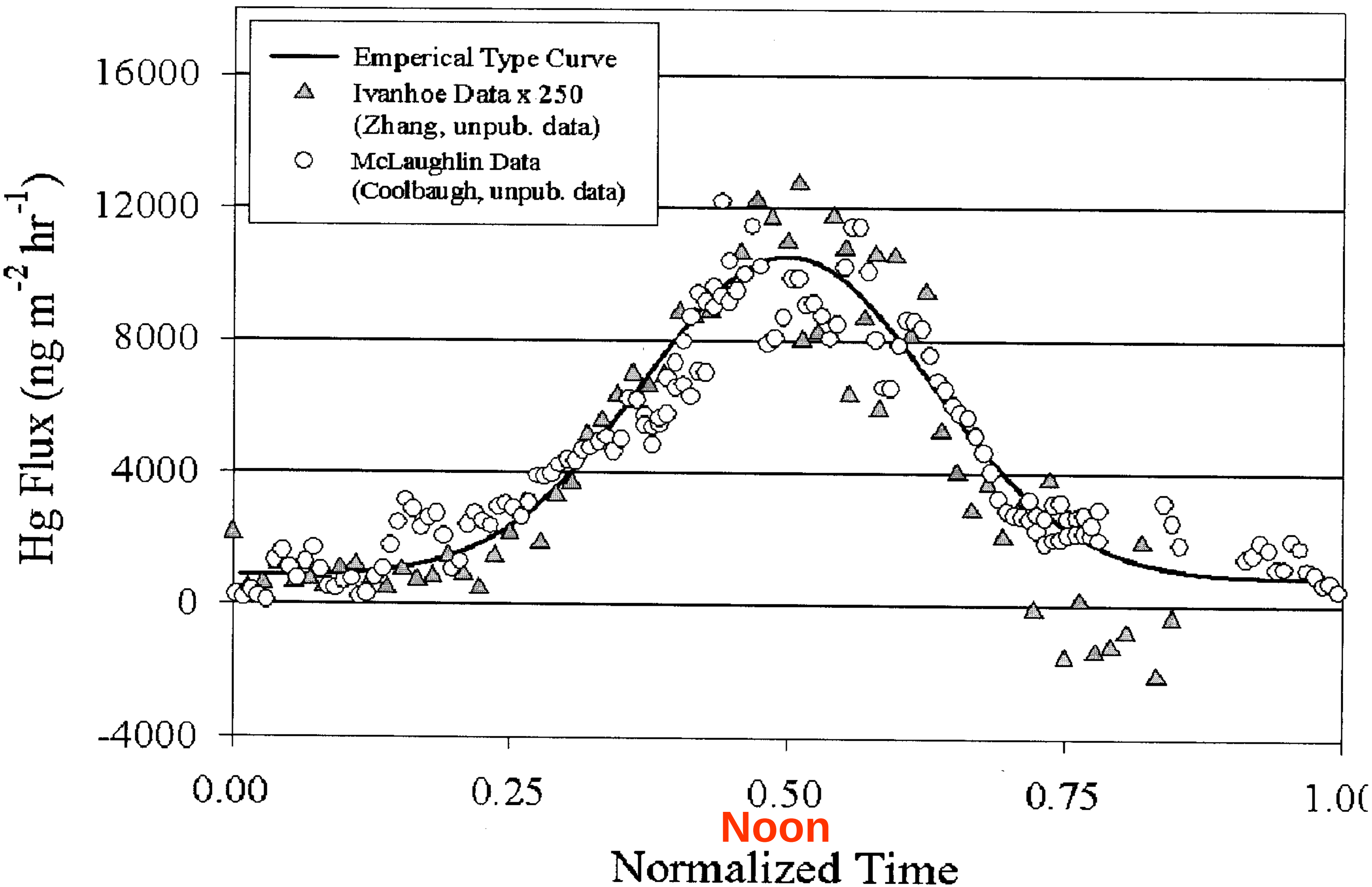
VAG Site, June 2012

How Did We Achieve Success on VAG Site?

- Evaluated composition of soil for metals, pH, and nutrients before plant testing.
- Recognized severe Ca and P infertility of serpentine rock derived soil materials.
- Tested “Tailor-Made” amendment treatments and plant species on site soil in greenhouse.
- Amendment mixture included all nutrients needed for plant growth in compost.
- Added limestone to prevent acidification of compost layer over time with N-fixation.
- Included gypsum to add Ca to sub-surface soil.

Diurnal Photoreduction of Hg^{II} to Hg^0

Gustin et al., 2002)



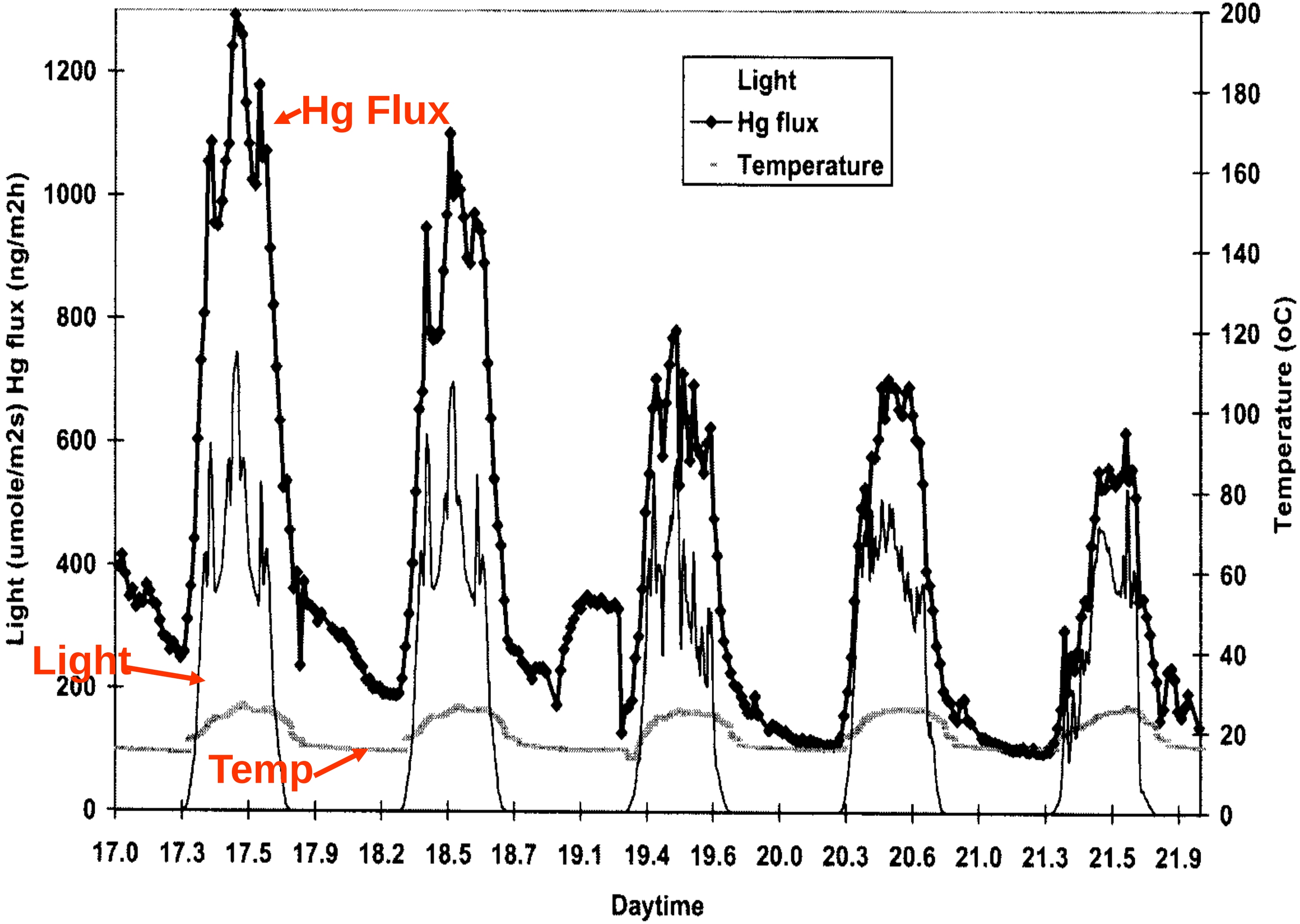
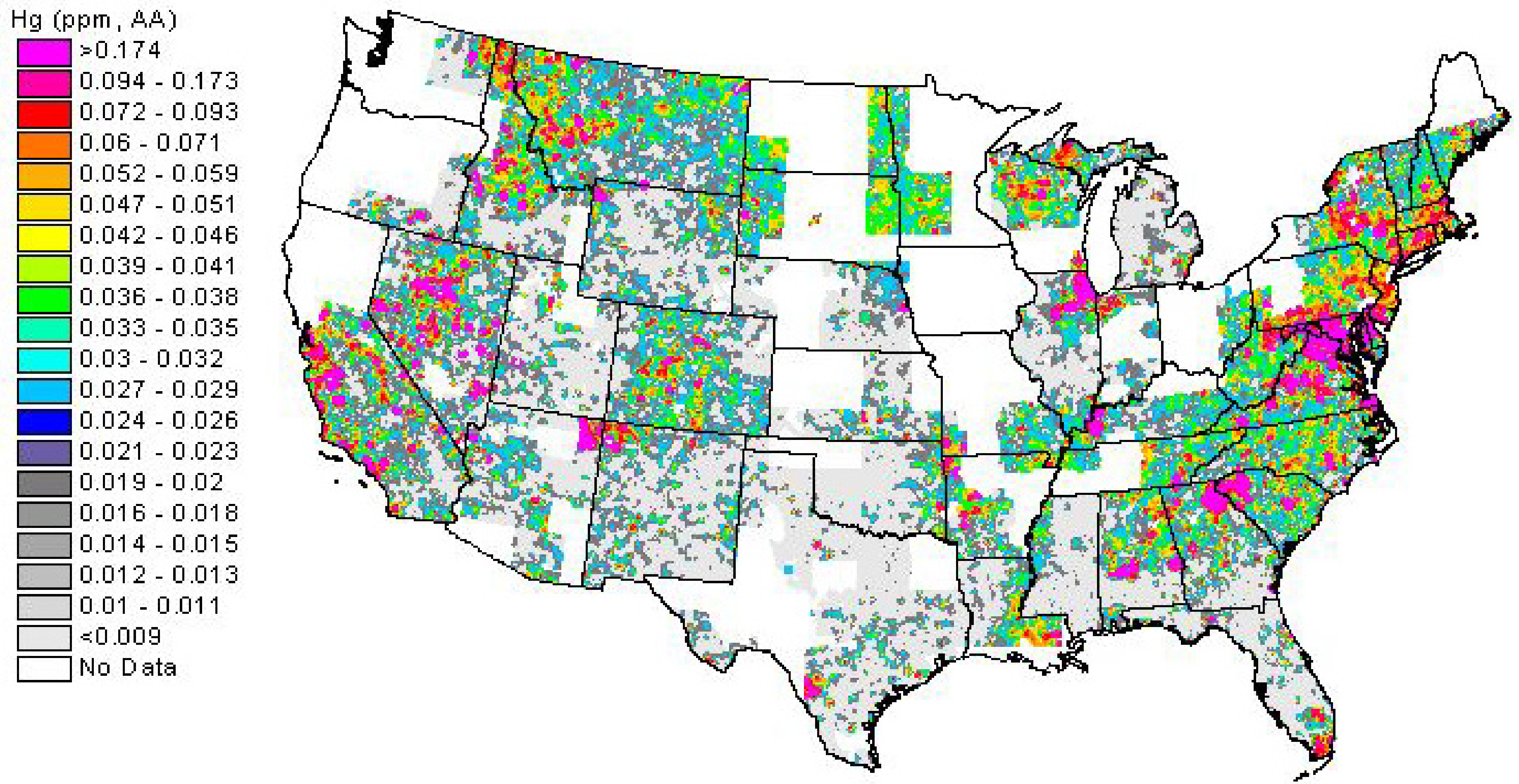
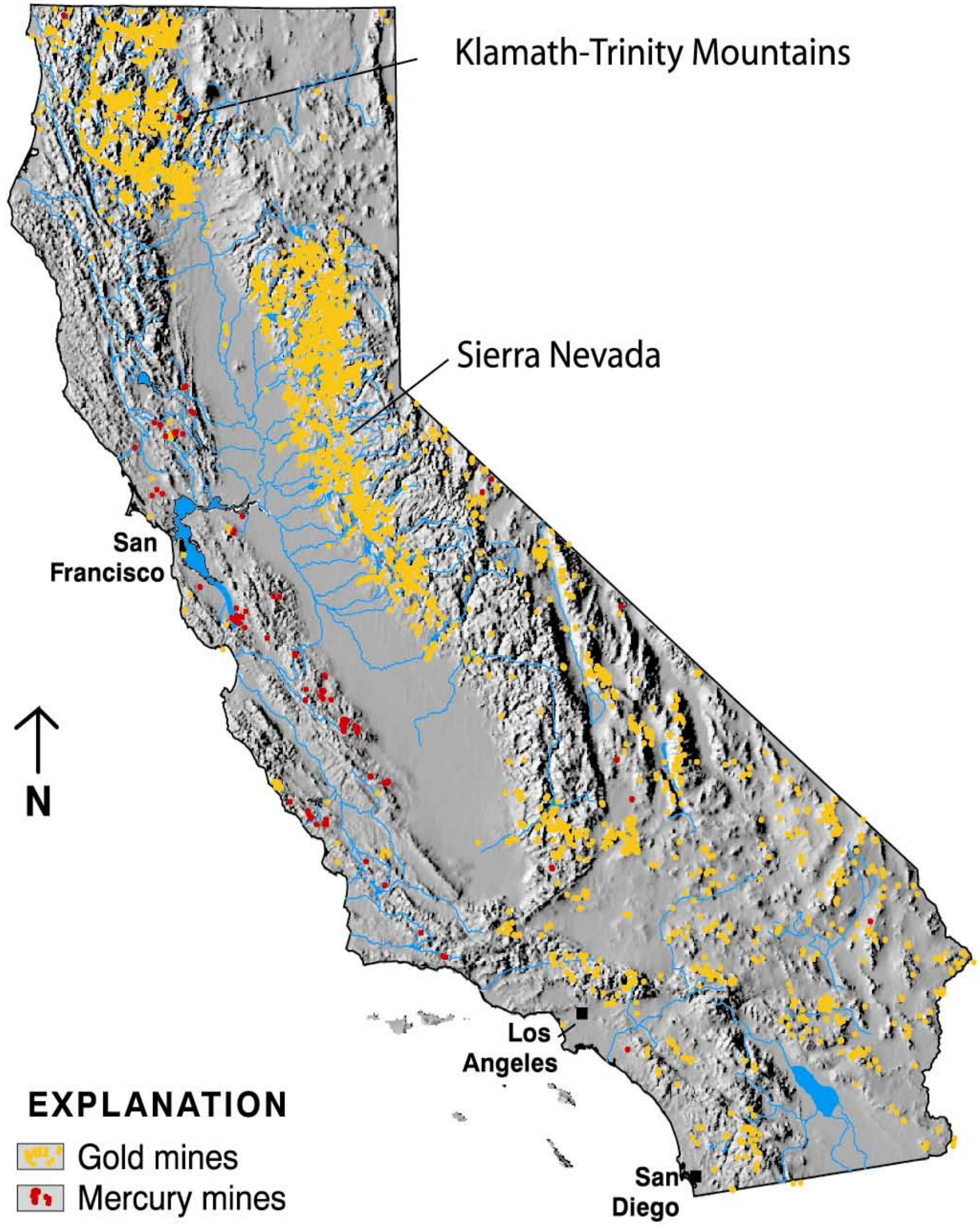


Fig. 5. Mercury flux versus time measured using a field chamber in the EcoCELLs at Desert Research Institute. Also shown are soil temperature and light intensity.

Hg in US Surficial Materials (USGS, Grosz et al.)



Gold and Mercury Mines in CA (USGS)



Why not use “Tailor-Made” Remediation Mixtures of Biosolids and Alkaline byproducts to reduce Hg Emissions?

- Vegetation blocks sunlight from soil, greatly inhibiting Hg photo-reduction and emission.
- Disturbed Hg and Au mining wastes and mineralized soils are often poorly vegetated due to infertility, and erosion moves Hg to lake sediments. Vegetation prevents soil-Hg erosion.
- Revegetation using biosolids could substantially reduce one of the most important remaining sources of anthropogenic/natural Hg emissions which has been largely ignored until very recently.
- Demonstrations are needed to illustrate the extent of Hg emission reduction due to biosolids revegetation.