ILLINOIS RIVER DREDGED SEDIMENT: CHARACTERIZATION AND UTILITY FOR BROWNFIELD RECLAMATION[1]

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Abstract. Brownfield reclamation in some ways is similar to surface mine reclamation. The similarities are that in both cases there is a large area of once productive ground that was severely impacted as part of a no-longer active resource extraction or augmentation industry. The differences include possible toxic soils or substrate and generally a lack of nearby quality soil for the brownfields given their typically urban settings. In contrast, reclamation is now part of a surface mining permit, soils are stockpiled to be replaced after mining, or topsoil substitutes are located and approved to serve as a final cover at a mine site. Brownfields, however, are usually located in urban areas where topsoils are difficult to obtain and transport. We conducted a large field demonstration project involving a brownfield in Chicago that was reclaimed with dredged spoils from the Illinois River. Disposal of dredged spoil often presents a problem in and of itself, and utilization as a topsoil substitute presents several advantages. In the case of the Peoria River sediments, the chemical and physical attributes are generally favorable as a topsoil substitute. These sediments tend to be fine textured, Silty Clay Loams and Silty Clays with about 3-5% organic matter content. Metal content is typically elevated above reference soils, but is generally not a problem. This paper presents our experience with this reclamation approach.

Additional Key Words: Illinois River, Chicago, topsoil substitute, remediation, restoration, mitigation.

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Introduction

The Illinois River

The Illinois River is a major tributary of the Mississippi River (Fig. 1). It drains approximately 75,000 km^2, flowing for 680 km from the Des Plains River out of Chicago to the Mississippi River. In recent and in geologic history, the Illinois River has been subjected to major perturbations that have shaped its development and operation. Prior to the Pleistocene, the lower Illinois River channel was the path of the upper Mississippi River.

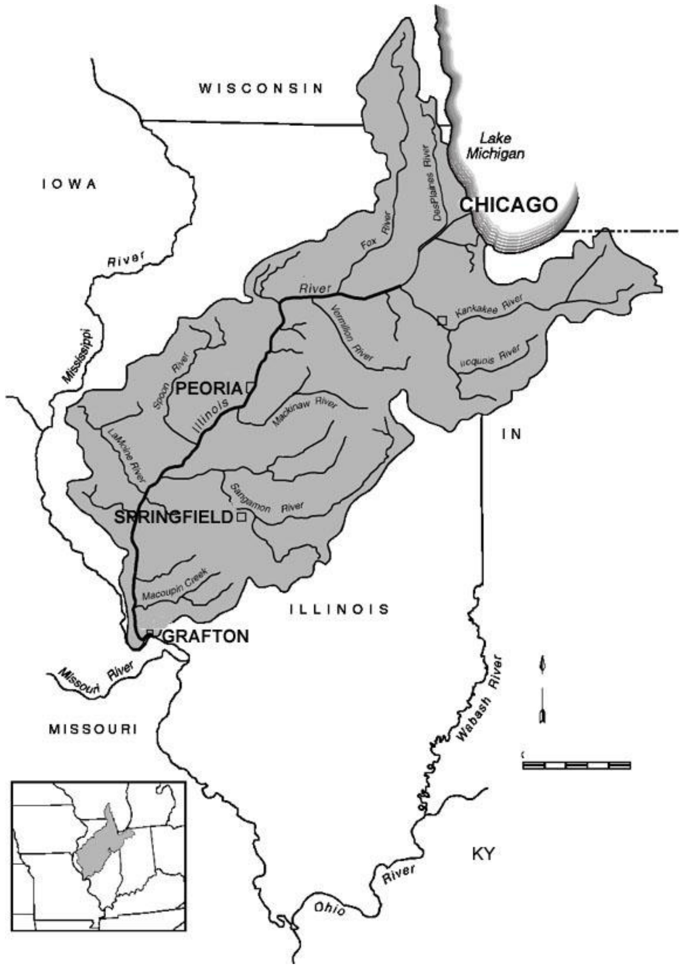

Figure 1. Illinois River drainage basin. Source: Illinois State Water Survey.

However, changes in drainage patterns caused by glaciation left the river underfit for its valley, and now the river is sluggish with a broad floodplain for much of its length. In addition, the Corps of Engineers has added a series of locks and dams to control water level for barge navigation. Historic changes in land use have converted much of the Illinois River watershed from natural forests and prairies to the modern mixture of industrial, urban, and rural uses. The watershed now is about 80% production agriculture. In this modified landscape, row crops, stream channelization, urban storm water runoff, industrial and sewage plant discharges, and other factors have increased erosion and sediment and contaminant loads to the river (Mills et al., 1966; Machesky et al., 2005).

As a result of this history of change, sedimentation is a significant problem in the Illinois River (Demissie et al., 1992). About 13.8 million tons (MT) of sediment are delivered to the river valley annually from tributary streams. Of this 5.6 MT are carried to the Mississippi River while 8.2 MT are deposited in the valley including the floodplain and backwater and side channel lakes. Additional sediment is derived from stream banks and bluffs. Much of this sediment settles in backwater lakes, which by 1990 lost an estimated average 72 percent of their storage capacity (Demissie et al., 1992).

Currently there is approximately 119 x 10 m^3 of sediment impacting the Peoria Lakes reach of the Illinois River. Dredging can be used to alleviate increased sedimentation loads, thereby improving ecological, recreational, and commercial functions of the aquatic habitat. Thus, dredging has important socioeconomic consequences for affected areas, as well as ecological implications. Once removed, dredged sediments need to be relocated, and it is proposed that these sediments can be used for the rehabilitation of degraded terrestrial habitats. Potential terrestrial uses of dredged sediments include topsoil to remediate damaged soils associated with highway construction, abandoned industrialized sites (brownfields), and abandoned surface mines. The high fertility and favorable moisture holding capacity of dredged sediments should be beneficial for plant growth in turf, garden, and agricultural applications. However, an extensive sampling of Illinois River sediments recently documented that levels of some metals in the sediments at some locations, including As, Zn, Cu, Cd, Ni, Pb, and Cr, as well as some anthropogenic organics, are elevated above background soil levels, potentially tempering the beneficial aspects of dredged sediments (Cahill, 2001).

The objectives of this study are to: 1. Characterize critical soil material qualities of dredged sediments for reclamation purposes; 2. Demonstrate plant support capabilities of the sediments for reclamation of brownfields in Chicago.

METHODS AND MATERIALS

The sediment for this study was dredged out of the Peoria Lakes reach of the Illinois River (Fig. 2). Lower Peoria Lake and Upper Peoria Lake cover 2,582 and 9,239 acres (1045 and 3739 ha) respectively along a 20-mile (32 km) section of the river. Industrial and urban water pollution generally drops off with distance from Chicago, and the Peoria Lakes reach is relatively unpolluted. Unlike most backwaters along the Illinois River, they are not separated from the main channel by islands. The navigation channel passes through the lakes, and the current is sluggish through the lakes and seldom exceeds two feet (0.6 m) per second.

Figure 2. The Peoria Lakes reach of the Illinois River where the sediment was dredged.

Between 1976 and 1985 the lakes accumulated sediment at a rate of 2,033 acre-feet (2,507,669 m^3) per year. Comparison of 1903 and 1985 profiles shows that the lakes accumulated about 82,000 acre-feet (101,145,512 m^3) of sediment during that time, while average water depth based on the current navigation pool elevation decreased from 7.6 to 2.0 feet (2.3-0.6 m) (Demissie and Bhowmik, 1986).

Sediment samples were collected with a vibracore device for characterization prior to the dredging. Sediment at the top of a core tends to be fluid and dark colored, at depth often it is more consolidated and lighter colored, reflecting different, pre-settlement deposition conditions (Fig. 3).

Figure 3. Mosaic of sediment core (SWS 357) collected with a vibracoring device. Top of core upper left, bottom of core lower right, length of core is 273 cm. Note dark color and fluid nature of upper core, and the low organic matter sediment that starts in the middle of the lower section at about 200 cm indicating pre-settlement deposition.

The Demonstration Site

Our reclamation demonstration site was a brownfield, 573 acres (232 ha) of the abandoned U.S. Steel (USX) South Works in south Chicago (Fig. 4). It was devoid of soil, and composed of rubble from the destruction of the buildings and slag accumulated over the 100 years of operation. The site was sparsely vegetated with weeds and the slag had an alkaline pH and very low soil moisture holding capability due to its coarse texture. The transport of sediment up the Illinois River from the dredge site near Peoria via barge directly to the site precluded the need for a fleet of large trucks carrying sediment through the small streets of the local neighborhoods. The barges were off loaded into large off-road trucks, transported a short distance from the barge slip, and end-dumped onto the brownfield to a depth of about 2 ft (0.6 m). The sediment was allowed to dry for a few weeks, and then was pushed up into a level pile of about 3 ft (1 m) thickness using a bulldozer.

Figure 4. Aerial view of the US Steel (USX) South Works site. Note barge slip bisecting property where the sediment was offloaded from the barges to off-road dump trucks.

Fertility and Chemistry

For characterization prior to dredging, the sediments were subject to standard agronomic tests including: CEC, cation exchange capacity, pH, soil organic matter content (SOM), total C and N determined with a C-N analyzer; and Mehlich-3 extracts of S, P, Ca, Mg, K, Na, B, Fe, Mn, Cu, Zn, Al, Mn (Mehlich, 1984). Plant available heavy metals were determined by DTPA (diethylenetriaminepentaacetate) extraction. DTPA is an organic extracting agent used to determine plant available metals in soils and sediments. Metal levels determined by this method will be lower than other methods that attempt to determine the total metal content. Near total metal content was determined by microwave digestion (USEPA Method 3051A) in which HNO_3 and H_2O_2, without HCl, were used (USEPA, 1998). Soil digestates and Mehlich and DTPA extractants were analyzed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

Physical Properties

Sediment texture was determined by hydrometer for the silts and clays and sieving for the sands (Klute, 1986). Sediment density and shrinkage was determined on remolded samples filled into moisture cans of a known volume, weighed, dried at 100° C, and then reweighed. Dry volume was determined by measuring the “puck“ produced by oven drying the field moist sediment in the can. The puck gives the maximum density after shrinkage because it is one solid mass of sediment and it does not include the effects of structural development where there would be inter-aggregate void space. Water content was determined on weight loss after drying. In the field, shrinkage was determined in a large-scale equivalent of the small cans in the lab by placing wet sediment into a large constructed box and monitoring the surface drop upon desiccation.

RESULTS AND DISCUSSION

Physical Properties

Illinois River sediments are typically dark gray, with Munsell hues of 2.5Y, 5Y, or 10Y, and values of 2-5, and chromas of 0-3. The color changes upon drying when the reduced iron oxidizes to produce higher chroma and redder hues. This does not reflect pyrite oxidation because the pH does not change appreciably upon drying. The texture of the sediment collected in the bulk of the Peoria Lakes pool, ranges from fine silty to clayey (Soil Survey Staff, 2006) (Table 1).

Some sediment, near the maintained barge dredged channel areas and with higher speed currents, or near some inlet streams such as Farm Creek, are coarser textured. The fine-silty sediment has a thick paste consistence if dredged with a high solids clamshell bucket (Fig. 5a). Based on samples that were dredged with a clamshell bucket and transported in a barge for several days, the moisture content is approximately 100% on a dry weight basis, and about 50% on a wet weight basis (Table 2). These sediments were clamshell dredged; the water content of hydraulically dredged sediments would be much higher, thus increasing shipping costs.

Table 1. Particle size distribution of sediment samples taken from barges delivered to the USX site.

Texture Class[†]	%		
	Sand	Silt	Clay
SiL	3	74	23
SiL	2	75	23
SiL	2	75	23
SiL	4	71	25
SiCL	3	70	27
SiCL	2	70	28
SiC	2	57	41
SiC	3	55	42
SiC	1	55	44
SiC	3	51	46

† Texture Class: SiL = Silt Loam; SiCL = Silty Clay Loam; SiC = Silty Clay.

Table 2. Peoria Lakes (Illinois River) sediment moisture and density physical properties[†].

Moisture %g		Moisture %v		Bulk Density (wt/vol)			Shrinkage
dry	wet	dry	wet	dry/wet	wet/wet	dry/dry	%
103.9	50.9	72.3	72.3	0.70	1.42	1.57	55.4

† Mean of 28 sediment samples from barges as delivered to the USX site.

On a volumetric basis the moisture content is about 70%. Sediment undergoes considerable shrinkage upon dewatering. We have measured shrinkage by several methods. Samples that are used to fill a small (4 cm h x 5 cm d) moisture can shrink into an air-dried puck that represents about 55% of the wet volume (Table 2). This volume change does not account for the void spaces between soil aggregates that form as sediments dry. In the field, large polygons form as the sediments dewater (Fig. 5c). It is important to know the shrinkage so final volume of dewatered sediment can be estimated for planning a reclamation project. The ultimate density of weathered sediment might be expected to be about 1.4 g/cc as reported for weathered dredged sediments (Smith, 1976).

Figure 5. Dredged sediments (a) are applied to land as a runny paste (mud). After spreading (b), the sediment dries and cracks, initially forming large polygons (c) and as it weathers into smaller aggregates and eventually forms a granular soil structure (d-f). Within a year, the soil develops structure and supports vegetation (g-h).

To account for overestimation of dry density in the lab, we have also monitored the volume change of a large sediment sample placed wet into a large constructed box (244 cm w, 122 cm h) and a smaller one (244 cm w, 61 cm h) at a site called Banner Marsh. After about a year and one half the sediment shrank to about 70% of its original volume in both boxes, the small box shrank a little faster (Fig. 6).

To simulate a more real-world scenario, after the sediment shrank in the boxes the large cracks that were exposed at the surface were partially filled by leveling the sediment surface by hand raking. This lowered the surface somewhat and increased the measured shrinkage slightly. This can be seen by the sharp one-day drop in the volume at about 6/06 when we measured volume before and after raking (Fig. 6). Shrinkage is directly related to initial moisture content (Fig. 7) and inversely related to the density (Fig. 8), as would be expected.

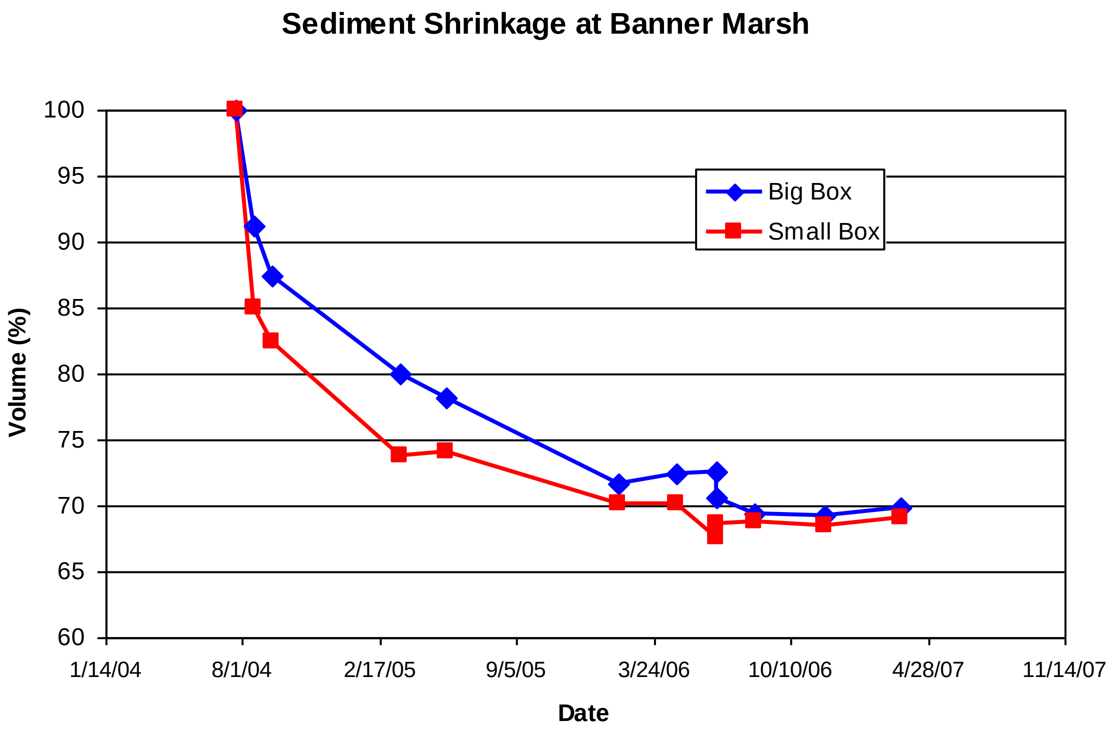

Figure 6. Volume change through time as a sediment sample dewaters and shrinks in large boxes in the field at Banner Marsh.

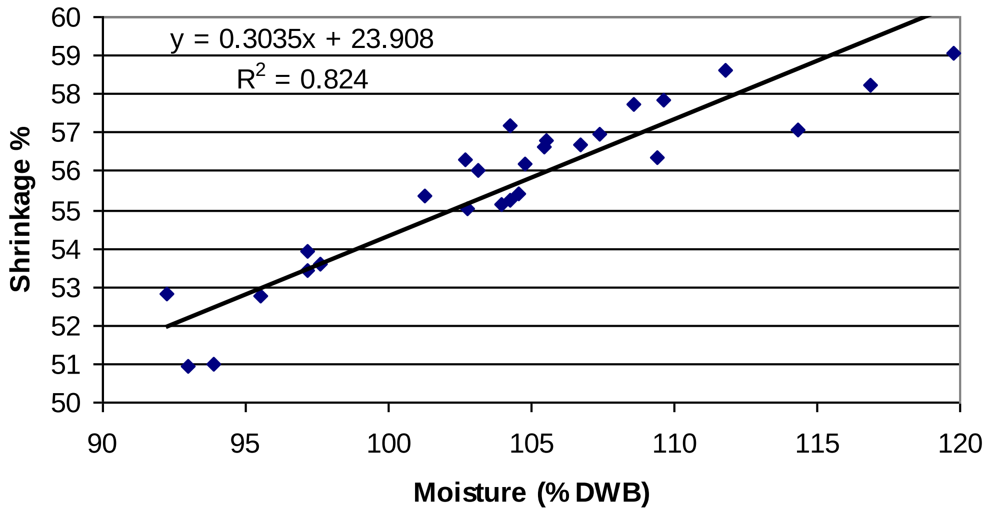

Figure 7. Relationship of sediment initial moisture content on a dry weight basis (DWB) to shrinkage on drying.

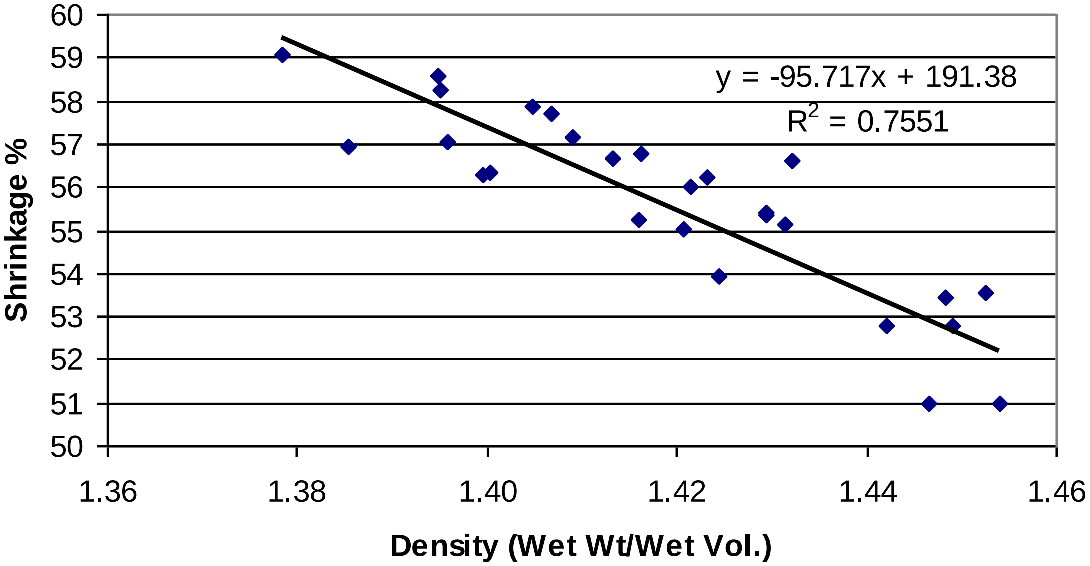

Figure 8. Relationship of sediment initial density on a wet weight/wet volume basis to shrinkage on drying.

As moisture leaves the sediment, it contracts; higher initial moisture content generally indicates more contraction. High water content gives sediment a low density. Sediment density on a wet weight/wet volume basis ranges from about 1.36-1.46 g/cc (Fig. 9, Table 2). On a dry weight/wet volume basis, the usual method to calculate soil bulk density, the values range from about 0.6 to 0.8, because of the high water content and shrinkage upon drying. Both methods of bulk density expression are closely correlated (Fig. 9). Illinois River sediment wet density is similar to other silty/clayey sediments deposited underwater (Fanning and Fanning, 1989).

Soil Fertility and Chemical Properties

In general, Illinois River sediments have favorable chemistry for use as topsoil. Sediment chemistry varies with its texture; the common fine-silty sediments typically have about 4-5% organic matter, about the same as the natural fertile surface soils in the region (Table 3). Less common sandy sediments typically have less organic matter, and there are some places in the Illinois River that are underlain by peat.

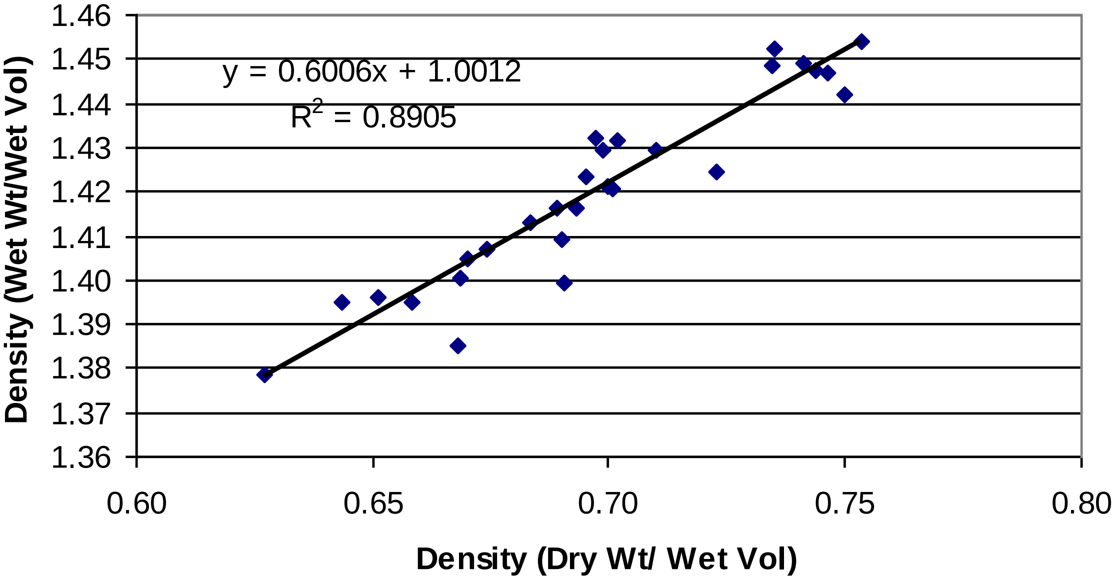

Figure 9. Relationship of sediment density expressed on a wet weight/wet volume to dry weight/wet volume basis.

Calcium dominates the sediment extractable elements, extractable Ca values range from about 3,000-23,000 ppm (Table 3). Consequently pH values are usually about 7.5. Illinois River sediments, as is typical of fresh water sediments, do not have a salt problem; extractable Na accounts for only about 20-90 ppm. The fertility is potentially good in the sediments due, in addition to the favorable organic matter, Ca, and pH, to its relative great amount of extractable S, K, Mg, and P. Micronutrient status is also favorable, the Zn and Cu content is not excessive despite the potential contamination from industrial pollution upriver. DTPA extractable heavy metals vary with location and depth, but are not in a high enough concentration to cause undo concern (Table 4) (USEPA, 2006). Given the high pH and CEC of the sediment, bioavailability of heavy metals would expected to be low, as is supported by field and greenhouse experiments (Darmody and Marlin, 2002; Darmody et al., 2004; Ebbs et al., 2006).

The extractable major nutrients, S, P, Ca, Mg, and K, and the other extracted micronutrients generally followed the organic matter trends, i.e., higher in the finer textured samples. In general, with the macronutrients, more is better and Ca, Mg, S, and P are at levels generally considered sufficient for crops, but K is somewhat below optimum. Soils derived from these sediments would benefit from additional fertilizer, as would any high quality topsoil. With the micronutrients and the other extractables, none are at levels that should cause significant concern.

Table 3. Soil fertility parameters of selected Illinois River sediments from cores and from barge loads.

Core	**Depth** (cm)	**CEC†** meq/100g	**pH**	**SOM** %	**Total** %			**Mehlich 3 Extractable** (ppm)												
					C	**N**	**C/N**	**S**	**P**	**Ca**	**Mg**	**K**	**Na**	**B**	**Fe**	**Mn**	**Cu**	**Zn**	**Al**	**Mo**
SWS 194	7-87	21	7.5	0.6	1.8	0.1	25	105	45	3798	191	32	27	0.7	374	61	1.4	5	36	0.11
	125-129	16	7.3	0.2	1.2	0.1	20	35	14	2975	143	23	20	0.5	278	93	1.1	2	7	0.07
	167-207	30	7.6	2.7	3.2	0.1	27	206	60	4868	563	114	44	1.2	378	91	4.4	36	231	0.13
SWS 195	7-247	37	7.4	4.4	3.8	0.3	14	305	130	5905	762	161	71	1.2	303	75	7.0	78	320	0.19
SWS 196	27-67	39	7.5	4.5	4.0	0.3	15	413	93	6281	829	177	84	1.1	290	91	7.0	46	251	0.18
	105-109	36	7.4	5.4	4.1	0.3	14	586	38	5823	729	147	62	1.1	333	73	4.2	44	366	0.17
	145-159	35	7.5	5.1	3.7	0.3	13	417	37	5576	772	156	53	1.1	332	75	2.8	31	433	0.14
	185-189	44	7.9	0.7	3.3	0.1	47	42	12	8125	387	63	21	0.6	245	42	3.3	2	12	0.03
SWS 197	25-29	40	7.5	4.6	3.8	0.3	15	339	78	6410	799	175	90	1.0	286	82	6.2	41	274	0.15
	65-69	37	7.4	5.3	4.1	0.3	15	390	143	5914	818	138	58	1.2	289	70	7.7	89	392	0.18
	105-109	125	8.0	3.9	12.0	0.2	50	89	10	23372	933	43	35	0.8	204	145	1.3	2	11	0.07
	147-227	42	7.9	1.9	4.4	0.1	74	80	19	7569	458	70	24	0.8	295	123	3.3	2	36	0.09
SWS 198	7-47	39	7.5	4.4	4.0	0.3	15	479	126	6326	833	166	85	1.0	281	68	6.0	51	272	0.19
	85-89	32	7.5	21.7	11.6	0.9	13	360	32	4948	813	60	61	1.8	280	7	2.0	4	92	0.16
	127-147	52	7.4	14.0	11.0	0.8	15	143	23	8985	856	67	60	1.5	218	29	3.3	4	88	0.17
	167-247	33	7.9	1.8	4.4	0.1	40	51	13	5848	413	66	29	0.7	306	87	3.8	2	54	0.11
SWS 199	7-47	36	7.5	4.2	3.8	0.3	15	361	112	5717	745	162	69	1.1	291	74	7.9	75	329	0.23
	87-207	34	7.4	5.8	4.0	0.3	13	399	38	5507	661	138	43	1.2	330	63	3.7	34	375	0.18
	245-249	25	7.8	1.3	2.9	0.1	33	79	27	4432	344	63	24	0.8	360	67	2.9	5	55	0.14
SWS 200	7-47	39	7.4	4.4	3.8	0.3	15	333	106	6224	805	179	89	1.1	281	70	7.1	53	338	0.21
	87-247	41	7.3	4.7	3.1	0.3	12	446	124	6873	767	164	62	1.3	292	85	7.8	95	440	0.22
Bucket	Barge	mixed sediment samples from barge as delivered to USX reclamation site																		
BUC-1	AT 510B	39	7.5	4.3	1.8	0.2	11	434	107	6252	777	171	81	1.3	299	75	5.5	76	342	0.21
BUC-2	XL 153	42	7.6	4.2	3.8	0.2	19	371	105	6660	894	180	92	1.3	300	78	5.2	46	303	0.20
BUC-3	XL 164	39	7.5	4.3	2.7	0.2	15	324	93	6232	822	157	84	1.3	316	72	5.5	46	302	0.20
BUC-4	AT 505B	39	7.5	4.0	4.6	0.2	19	414	99	6408	776	177	85	1.5	297	91	7.6	71	418	0.24
BUC-5	AT 510B	39	7.5	4.3	1.9	0.2	10	408	92	6433	776	179	78	1.4	310	81	5.1	57	314	0.24
BUC-6	AT 519B	36	7.5	3.7	2.0	0.2	11	458	83	5930	712	150	85	1.2	332	70	4.6	49	320	0.23
BUC-7	XL 163	37	7.5	4.1	2.1	0.2	11	351	88	6091	730	163	72	1.2	325	77	4.7	57	296	0.23
Reference Mollisol topsoil		20	5.9	4.0	-	-	-	25	26	2380	341	178	12	0.5	130	64	2.5	2.9	441	-

† CEC = cation exchange capacity; SOM, soil organic matter.

Total C and N generally follow the soil texture. Total C ranges from about 1.2 – 12 %, total N from about 0.1-1.0 % to give a C:N ratio of about 12-74, with the higher values generally deeper in the sediments. Total N is a rough guide to the amount of N in the soil, the nutrient that is typically most limiting to crop growth. The C/N ratio in the cores increases with depth; this is typical in soils and is related to the stage of decomposition of soil organic matter.

Compared to sediment from the Potomac River used for a similar purpose in Virginia, Illinois River sediment has about the same amount of extractable B, Fe, and Zn, but more P, Ca, Mg, K, and a higher pH and less Mn and Zn (Daniels et al., 2007).

Table 4. DTPA extractable heavy metals from selected Illinois River sediments.

Core	**Depth (cm)**	DTPA Extractable (ppm)					
		As	**Cd**	**Cr**	**Pb**	**Ni**	**Se**
SWS 194	7-87	0.02	0.05	0.02	1.03	0.14	0.03
	125-129	0.02	0.02	0.02	0.60	0.06	0.03
	167-207	0.05	0.64	0.03	6.10	1.89	0.03
SWS 195	7-247	0.13	0.02	0.04	11.69	4.14	0.03
SWS 196	27-67	0.08	0.02	0.02	7.90	1.75	0.03
	105-109	0.06	0.49	0.02	12.65	2.47	0.03
	145-159	0.05	0.33	0.02	7.59	1.61	0.03
	185-189	0.02	0.11	0.02	0.90	0.15	0.03
SWS 197	25-29	0.07	0.02	0.02	8.18	1.71	0.03
	65-69	0.15	0.02	0.06	15.98	6.19	0.03
	105-109	0.02	0.09	0.02	0.24	0.59	0.03
	147-227	0.02	0.11	0.02	1.48	0.54	0.03
SWS 198	7-47	0.12	1.41	0.04	11.88	4.24	0.03
	85-89	0.02	0.25	0.02	1.44	1.21	0.03
	127-147	0.02	0.29	0.02	1.61	1.12	0.03
	167-247	0.02	0.11	0.02	1.01	0.41	0.03
SWS 199	7-47	0.12	1.83	0.05	13.93	4.37	0.03
	87-207	0.05	0.41	0.02	10.44	1.53	0.03
	245-249	0.02	0.12	0.02	1.11	0.36	0.03
SWS 200	7-47	0.07	1.21	0.04	9.25	1.81	0.03
	87-247	0.14	2.41	0.07	15.89	3.00	0.03
Bucket	Barge	mixed sediment samples from barge as delivered to USX reclamation site					
BUC-1	AT 510B	0.11	0.02	0.06	15.52	4.71	< 0.06
BUC-2	XL 153	0.10	0.02	0.05	10.38	2.20	0.07
BUC-3	XL 164	0.08	0.02	0.05	11.25	3.00	< 0.06
BUC-4	AT 505B	0.10	0.02	0.06	17.40	5.22	< 0.06
BUC-5	AT 510B	0.09	1.78	0.05	12.50	3.83	< 0.06
BUC-6	AT 519B	0.08	0.02	0.04	10.61	2.43	< 0.06
BUC-7	XL 163	0.08	0.02	0.05	13.20	3.91	< 0.06

Total Metal Content

Total recoverable metal content of a representative sediment sample reflects addition of anthropogenic metals (Table 5). Compared to a topsoil sample from a reference farmed Mollisol, the sediment is higher in Cr, Ni, Zn, Cd, and Pb. The increased Zn in the river is due in part, to naturally occurring deposits upriver, but also to smelting activities in the watershed. Zn is a micronutrient that can be deficient in Illinois soils. The other metals may reflect industrial pollution or natural sources. The biggest difference between the natural soil and the sediment sample is in the very high Ca content of the sediment, apparently reflecting bioaccumulation of Ca by aquatic organisms.

Table 5. Total recoverable metals in an Illinois River sediment sample collected from Peoria Lake and a reference Illinois Mollisol topsoil.

Material	Cr†	Ni	Cu	Zn	As	Se	Ag	Cd	Ba	Pb	Na	Mg	Al	K	Ca
	----------							mg kg^{-1}							----------
Topsoil	29	22	20	60	8	1.1	<1	<1	183	18	134	5,500	24,600	4,600	5,000
Sediment	48	38	43	241	7	<1	1.2	3.4	157	40	301	17,100	19,900	4,550	35,500
	Fe	V	Mn	Co	Mo	Ti	Sr	Zr	Cs	La	Ce	Th	Ga	Rb	Y
Topsoil	21,300	54	687	9	<1	383	23	14	3	19	40	<1	8	47	12
Sediment	22,800	40	637	9	1	210	54	12	3	16	32	8	6	39	11

† Metals determined by USEPA method 3051A

Despite the elevated total metal levels, the metal content is lower than would cause concern (IEPA, 1994; USEPA, 2006). Compared to sediment from the Potomac River used for a similar purpose in Virginia, Illinois River sediment has about the same amount of total Al, As, Cd, Cr, Cu, Pb, and Ni. Potomac sediment is higher in Fe and Se, and Illinois sediment is higher in Mg and Zn (Daniels et al., 2007).

Reclamation Results at the USX Brownfield

Sediment was dredged from the Peoria Lakes reach of the Illinois River with a clamshell bucket and barged to the site where it was off-loaded into off-road trucks beginning in early summer 2004 (Fig. 5). In total, 68 barge loads of sediment were delivered to the site. The sediment proved easy to handle. There was no need to construct berms to keep the sediment from flowing away because its viscosity was sufficient to allow it to stay where it was initially placed. Erosion of the sediment after it dried was not a problem because the sediment was well flocculated due to its high Ca content and it formed strong structural units that resisted movement by wind and water. Likewise dust was not a significant problem with grading the sediment for the same reason.

After being end-dumped from the large mining trucks into piles 3-4 ft (0.9-1.2 m) high, the sediment was allowed to dry for several days, then was leveled and pushed up into a layer about 2-4 feet (0.6-1.2 m) thick with a bulldozer. A person could walk on the sediment after about a week of drying. After it went through dewatering, hardening, and cracking, it developed a more favorable soil structure and within a year the site was well vegetated (Fig. 5h). Vegetation cover included rye grass that was seeded and grew best in cracks where roots found moisture after drying crusted the top. In addition as the sediment weathered, volunteer weeds and cottonwood trees invaded, some of which grew up to 6 ft (1.8 m) tall by the following September. The Illinois Natural History Survey identified 79 species of vascular plants on the sediment piles. Seventeen of them were wetland species. The others either were on site initially and were mixed in with the sediment, or were in the sediment seed bank or blew in.

The reclamation effort was deemed a success, particularly given the favorable logistics of the site being easily accessible by barge loads of sediment. The site plans involve it being developed into a lake front park for Chicago citizens and visitors to enjoy.

Conclusions

Sediment from the Peoria Lakes reach of the Illinois River where we have investigated is of sufficient quality to be used as a topsoil substitute for reclamation of brownfields or pre-SMCRA surface mines. The sediment when clam-shelled dredged comes out of the river as a viscous paste. It would have a much higher water content and be more difficult to deal with if it were hydraulically dredged. After placement of the sediment on the ground, it dewaters, hardens, and cracks forming large polygons. After sufficient wetting and drying, weathering, or tillage, the sediment breaks up into more familiar soil-like angular blocky structural units, which are more manageable and support good plant growth. Unlike the case with marine influenced sediments, salts and pyrite oxidation are not a problem with Illinois River sediments (Fanning and Fanning, 1989).

Cost of transport is an issue because of the large volumes of sediment that are needed in a typical reclamation project and because of the long distance it often has to be transported. Our project site at the USX site was ideal in as much as the sediment could be moved in the barges it was originally dredged into, without the need to transfer it to trucks for long distance transport.

The take home message from our work is that sediment from the Illinois River we have investigated to date is potentially a good topsoil substitute. It has high water holding capacity due to its silty texture and high natural fertility due to its high pH and nutrient content including organic matter, Ca, P, K, and micronutrients. Despite the fact that metals are elevated above background values, plant uptake does not appear to be a problem (Darmody and Marlin, 2002; Darmody et al., 2004; Ebbs et al., 2006). After dewatering and weathering it has acceptable physical properties and should provide material to reclaim and revegetated brownfields, abandoned surface mines, landfills, and similar disturbed areas in need of topsoil. It was successfully used to reclaim the USX brownfield along the south Chicago lakefront.

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