

Stormwater Control Practices and Toxic Sediments

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Outline

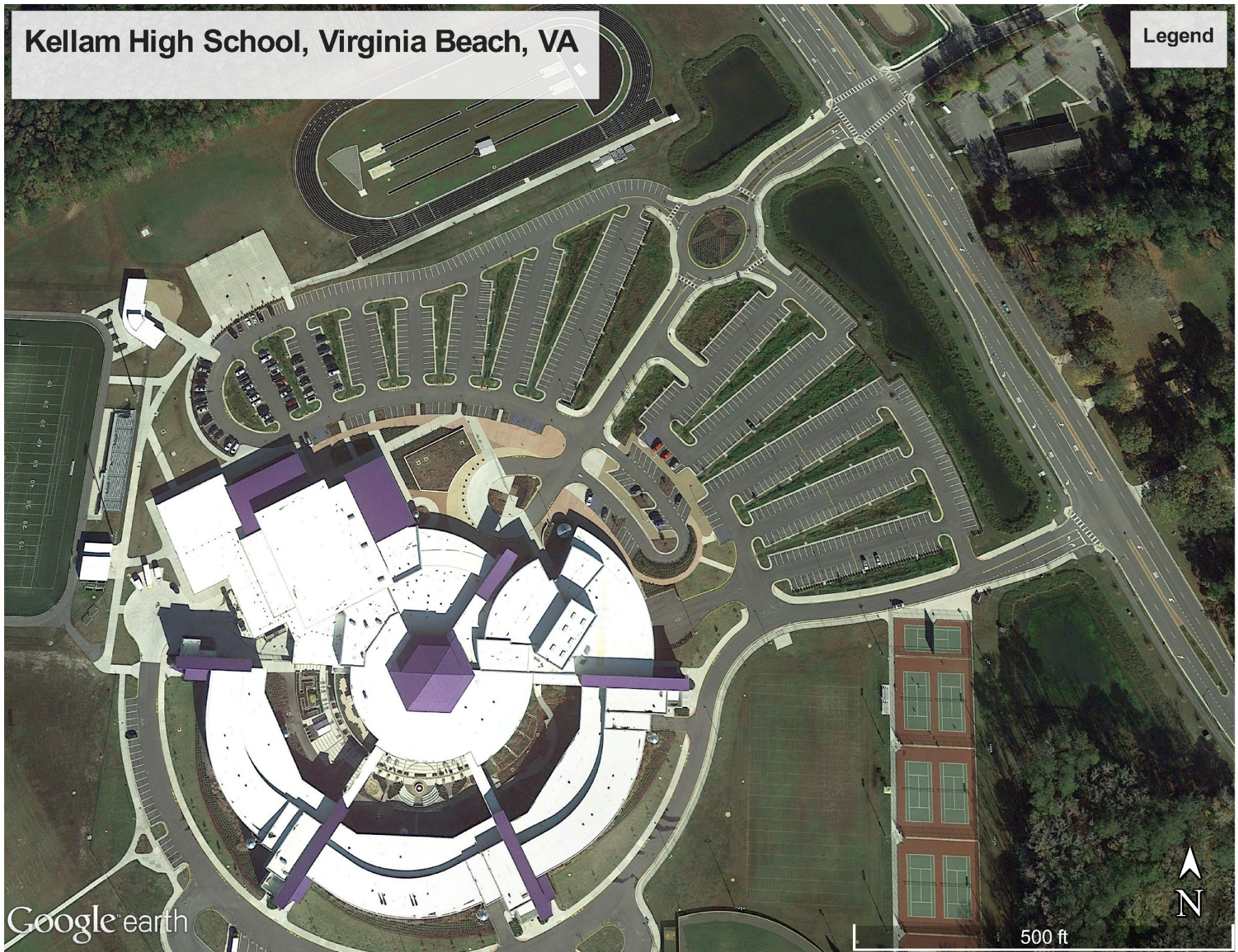
- Urban watersheds and SCMs/BMPs
- Sediment sources
- Toxic sediment within SCMs/BMPs
- Case Studies from Fairfax County DPWES
- Research needs and recommendations



Source: Lenhart, J., 2016, personal communication.

Kellam High School, Virginia Beach, VA

Legend



Google earth



N

500 ft

Stormwater Treatment Technologies

Category	Flow		Unit Processes										
			Physical				Chemical			Biological			
			Peak Flows	Reduce V	Sedimentation	Flotation	Flocculation	Filtration	Sorption	Precipitation	Destabilization	Phytoremediation	Transformation
Unit Operations													
Dry Basins	●		●										
Wet vaults	●		●	●									
Wet ponds	●		●	●			●	●		●		●	
Constructed wetlands			●	●			●	●		●	●		
Oil/water separators			●	●									
Vortex separators			●	●									
Precipitation			●				●	●					
Coagulation			●		●		●	●	●				
Inert media filters			●			●	●	●			●		

Sources: Minton (2005) and Sample et. al., (2012).

Stormwater Treatment Technologies, cont'd

Category	Flow		Unit Processes										
			Physical				Chemical			Biological			
			Peak Flows	Reduce V	Sedimentation	Flotation	Flocculation	Filtration	Sorption	Precipitation	Destabilization	Phytoremediation	Transformation
Unit Operations													
Sorptive media filters			●			●	●				●		
Grass Channel		●	●			●	●				●		
Wet swales			●				●				●		
Vegetated swales and strips (dry)		●	●			●	●				●		
Infiltration basins and trenches, porous pavements		●	●			●	●				●		
Bioretention	●	●	●			●	●				●		●
Vegetated roofs		●				●	●				●		●
Rainwater harvesting	●	●											

Sources: Minton (2005) and Sample et. al., (2012).

Sources of stormwater sediments

- Vehicular traffic
- Industrial sites
- Vegetation
- Construction and demolition
- Corrosion
- Spills
- Erosion

Urban Runoff Pollutants

Compound class	Sampling location and land use	Concentration ranges ^a	References
Oil and grease and total petroleum hydrocarbon	Parking lots	ND – 277 mg/L	Zanoni (1986), Smith et al. (2000), Li and Davis (2009), James et al. (2010), Lundy et al. (2012)
	Roads	0.4 – 14 mg/L	Wu et al. (1998), Kim et al. (2005, 2007), Kayhanian et al. (2012), Lundy et al. (2012)
	Residential	6.7×10^{-4} – 0.025 mg/L	Lundy et al. (2012)
PAHs	Commercial and industrial	1.7×10^{-3} – 1.5 mg/L	Bardin et al. (2001), Lundy et al. (2012)
	Parking lots	11 – 191 µg/L	James et al. (2010)
	Roads	0.03 – 6 µg/L	Stachel et al. (2010), Lundy et al. (2012)
	Commercial and industrial	0.35 – 0.6 µg/L	Lundy et al. (2012)
	Storm sewers	ND – 6.477 µg/L	Kafi et al. (2008), Gasperi et al. (2012), Zgheib et al. (2011, 2012), Bressy et al. (2012)
	Storm-water-impacted urban creeks	1.51 – 12.5 µg/L	Hwang and Foster (2006)
	Roofs, parking lots, storage areas, industrial, urban creeks, detention ponds	0.4 – 130 µg/L	Pitt et al. (1995)
PCBs	Gasoline station runoff	ND – 3,500 µg/L	Smith et al. (2000)
	Coal-tar sealed parking lot	4.6 – 5,890 µg/L	Watts et al. (2010), Mahler et al. (2012)
	Storm sewers	<0.01 – 26 ng/L	Zanoni (1986), Gasperi et al. (2012), Zgheib et al. (2012), Bressy et al. (2012)
	Storm sewers	<5 – 82 ng/L	Kim and Kannan (2007), Müller et al. (2011), Xiao et al. (2012)
Perfluoroalkyl acids	Storm sewers	<5 – 82 ng/L	Kim and Kannan (2007), Müller et al. (2011), Xiao et al. (2012)
Benthothiazoles	Roads	0.5 – 5.4 µg/L	Stachel et al. (2010)
	Storm-water-impacted urban creeks	0.189 – 0.396 µg/L	Zeng et al. (2004)

^aND = not detected or below limit of detection.

Perfluoroalkyl acids (PFASs): compound of emerging concern, moderately insoluble, persistent, see Buck et al. 2011 for review of this class of compounds.

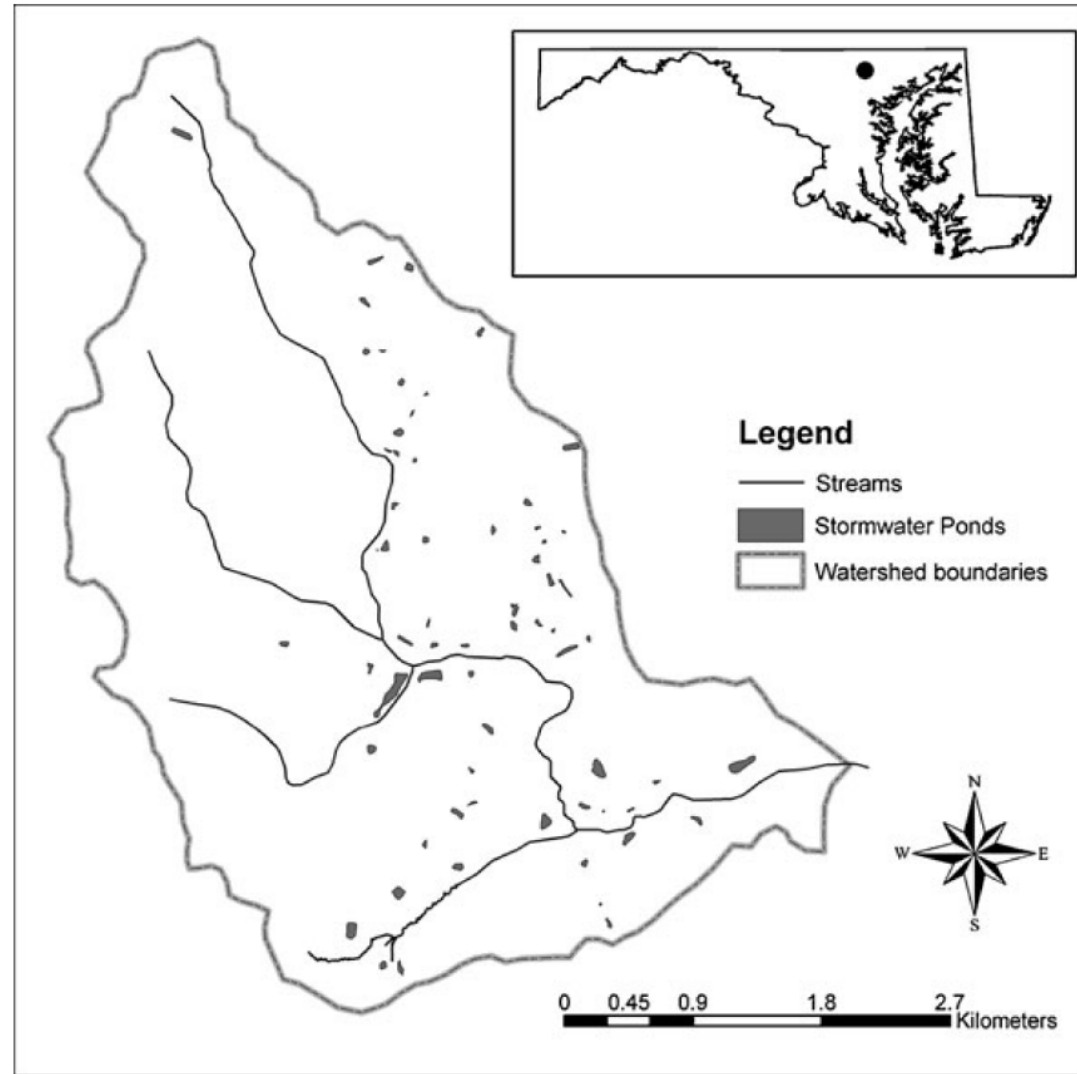
Urban Runoff Pollutants (continued)

Compound class	Sampling location and land use	Concentration ranges ^a	References
Benzotriazoles			
1-H-benzotriazole	Roads	0.14 µg/L	Stachel et al. (2010)
4(5)-Methylbenzotriazole (Tolytriazole)	Roads Airport runoff	0.26 µg/L <80 – 3,830 µg/L	Stachel et al. (2010) Corsi et al. (2003, 2006b)
Glycols			
Ethylene glycol	Airport runoff	<18 – 306 mg/L	Corsi et al. (2003, 2006b)
Propylene glycol	Airport runoff	1,400 – 9,920 mg/L	Corsi et al. (2003, 2006b)
Phenols			
Bisphenol-A	Roads	0.24 – 2.5 µg/L	Stachel et al. (2010)
Nonyphenols	Roads Storm sewers	0.17 – 3.6 µg/L 0.16 – 1,500 µg/L	Stachel et al. (2010) Gasperi et al. (2012), Zgheib et al. (2012), Bressy et al. (2012)
Octylphenol	Airport runoff Storm sewers	<108 – 1,190 µg/L 0.013 – 1.9 µg/L	Corsi et al. (2003) Stachel et al. (2010), Bressy et al. (2012)
Pesticides			
Glyphosate	Roads Storm sewers	0.025 – 48.1 µg/L ND – 232 µg/L	Lundy et al. (2012) Zgheib et al. (2012), Gasperi et al. (2012)
Diuron	Roads Storm sewers	0.02 – 0.04 µg/L ND – 1.75 µg/L	Stachel et al. (2010) Zgheib et al. (2012), Ensminger et al. (2013)
Isoproturon	Roads Storm sewers	0.05 – 0.2 µg/L ND – 0.14 µg/L	Stachel et al. (2010) Zgheib et al. (2012)
Aminotriazole	Storm sewers	0.12 – 3.25 µg/L	Zgheib et al. (2012)
Triclopyr	Storm sewers	ND – 6.8 µg/L	Ensminger et al. (2013)
2,4-Dichlorophenoxyacetic acid (2,4-D)	Storm sewers Golf course	ND – 11.5 µg/L ND – 67 µg/L	Ensminger et al. (2013) King and Balogh (2010)
Dicamba	Storm sewers	ND – 1.2 µg/L	Ensminger et al. (2013)
Bifenthrin	Storm sewers	ND – 0.2 µg/L	Ensminger et al. (2013)
Fipronil	Storm sewers	0.01 – 2.11 µg/L	Gan et al. (2012), Ensminger et al. (2013)

^aND = not detected or below limit of detection.

Red Run, Baltimore County, MD

- Red Run
Subwatershed of Gwynns Falls, 1,921 ha
- 164 stormwater ponds, 68 sampled
- Metals: 96% ponds > TEC for at least one metal
- PAHs: 63% of ponds > TEC for at least one PAH



Metals found in stormwater sediment

Compound	TEC (mg/kg)	PEC (mg/kg)
Chromium	0.46 (0.34–0.57)	0.04 (0.02–0.12)
Nickel	0.82 (0.72–0.9)	0.35 (0.25–0.47)
Copper	0.78 (0.67–0.86)	0
Zinc	0.6 (0.48–0.71)	0.04 (0.02–0.12)
Cadmium	0.03 (0.01–0.1)	0
Lead	0.18 (0.1–0.28)	0

PAHs in stormwater sediments

Compound	TEC	PEC
Naphthalene	0.03 (0.01–0.10)	0
Fluorene	0.12 (0.06–0.22)	0.01 (<0.01–0.08)
Phenanthrene	0.46 (0.34–0.57)	0.12 (0.06–0.22)
Anthracene	0.15 (0.08–0.25)	0.01 (<0.01–0.08)
Fluoranthene	0.34 (0.24–0.46)	0.13 (0.07–0.23)
Pyrene	0.47 (0.36–0.59)	0.15 (0.08–0.25)
Benz[a]anthracene	0.24 (0.15–0.35)	0.07 (0.03–0.16)
Chrysene	0.34 (0.24–0.46)	0.10 (0.05–0.20)
Benzo[a]pyrene	0.38 (0.28–0.50)	0.07 (0.03–0.16)
Dibenz[ah]anthracene	0.44 (0.33–0.56)	n/a

PAHs and stormwater toxicity

- PAH is a persistent, relatively hydrophobic, toxic class of hydrocarbons.
- PAH in sediment ranges 10-70 mg/kg (Van Metre and Mahler 2003), and in water, 0.3-0.6 ppb (DeBlasi et al., 2009).
- Most PAHs in stormwater stem from use of coal-tar sealcoats which are predominately used in the central and eastern U.S. (Levevre et al., 2014).
- In comparison with unsealed parking lots, coal-tar sealed lots produced approximately 50 times the PAH flux than unsealed lots Mahler et al., 2005).
- Approximately 84% of PAH associated sediments in stream and lakes may stem from coal-tar sealants (Yang et al., 2010).

North Carolina stormwater wetlands and wet ponds

- Sediment from 30 forebays of ponds/wetlands assessed
- 10 outlets were selected and assessed



Results

Compound	Commercial (n=21)		Residential (n=9)	
	Mean	Median	Mean	Median
Cadmium	ND	ND	ND	ND
Chromium	20.9	20	23.8	28.3
Copper	28	23	18.6	15.1
Iron	24700	22100	22400	23300
Nickel	14.4	13	16	15.9
Lead	13.7	13	12.3	11.4
Zinc	140	75	58.4	44

- 17 ponds exceeded aquatic health standards for metals, but none exceeded 40 CFR 503 (biosolids rule).
- Forebay sediment concentrations tended to be much less than outlet concentrations.

Toxicant distribution within sediments

- 3 infiltration basins sampled in Nantes, France
- Density fractionation and micro provided full characterization of size
- PAHs were found in lightest density sediments, and were mainly associated with organic matter
- Metals were found throughout size ranges, but mostly in the heaviest density ranges

Woodglen Lake, Fairfax County

- Watershed area: 1.16 mi²
- Surface area: 15.2 ac
- Year constructed:
- Sediment Loading; 1,200 yd³/year
- Volume (orig): 105.6 AF (171,000 yd³)
- Previously dredged: 8,040 yd³
- Recent dredging: 29,000 yd³
- Estimated cost: 2.34-2.89 \$M



Source: Michael Bake, 2013.

Analysis

SEDIMENT CHEMICAL ANALYSIS SUMMARY

Analyses	Units	State Limits	WG-A	WG-B	WG-C	WG-D
Trace Metals						
Arsenic	mg/kg	0.39	< 0.5	0.638	1.99	< 0.5
Barium	mg/kg	15,000	14.3	41.1	38.7	12
Cadmium	mg/kg	70	< 0.5	< 0.5	1.01	< 0.5
Chromium	mg/kg	120,000	4.86	8.2	16.2	4.11
Lead	mg/kg	400	3.67	6.92	6.98	3
Mercury	mg/kg	10	< 0.008	< 0.008	0.02	< 0.008
Selenium	mg/kg	390	< 2.5	< 2.5	< 2.5	< 2.5
Silver	mg/kg	390	< 0.5	< 0.5	< 0.5	< 0.5
BTEX						
Benzene	ug/kg	10,000*	< 50	< 50	< 50	< 50
Toluene	ug/kg	10,000*	< 50	< 50	< 50	< 50
Ethylbenzene	ug/kg	10,000*	< 50	< 50	< 50	< 50
m,p-Xylenes	ug/kg	10,000*	< 50	< 50	< 50	< 50
o-Xylene	ug/kg	10,000*	< 50	< 50	< 50	< 50
Xylenes, Total	ug/kg	10,000*	< 50	< 50	< 50	< 50
Hydrocarbons: TPH-GRO & TPH-DRO						
TPH-Volatiles (GRO)	mg/kg	50**	< 5	< 5	< 5	< 5
Analyses	Units	State Limits	WG-A	WG-B	WG-C	WG-D
TPH-Semi-Volatiles (DRO)	mg/kg	50**	22.6	< 10	< 10	< 10

Analysis (continued)

PCBs						
PCB as Aroclor 1016	mg/kg	3.9	< 0.1	< 0.1	< 0.1	< 0.1
PCB as Aroclor 1221	mg/kg	0.14	< 0.1	< 0.1	< 0.1	< 0.1
PCB as Aroclor 1232	mg/kg	0.14	< 0.1	< 0.1	< 0.1	< 0.1
PCB as Aroclor 1242	mg/kg	0.22	< 0.1	< 0.1	< 0.1	< 0.1
Analyses	Units	State Limits	WG-A	WG-B	WG-C	WG-D
PCB as Aroclor 1248	mg/kg	0.22	< 0.1	< 0.1	< 0.1	< 0.1
PCB as Aroclor 1254	mg/kg	0.22	< 0.1	< 0.1	< 0.1	< 0.1
PCB as Aroclor 1260	mg/kg	0.22	< 0.1	< 0.1	< 0.1	< 0.1
Ignitability						
Ignitability	°C	<60	> 65	> 65	> 65	> 65
Nitrogen & Phosphorus						
Nitrate+Nitrite	mg/kg	NA	< 10	< 10	< 10	< 10
Phosphorus, Total	mg/kg	NA	25.7	54.8	20	40.2
TKN	mg/kg	NA	182	232	187	177
Nitrogen, Total	mg/kg	NA	183	233	188	177

* Total BTEX must be less than 10mg/kg

** TPH (DRO and GRO) must be less than 50 mg/kg

Sediment analysis summary

- Concentrations were greater than ecological screening levels for: aluminum, arsenic, chromium, cobalt, iron, lead, manganese, mercury, vanadium, and zinc.
- Concentrations were greater than residential screening levels for aluminum, arsenic, chromium, cobalt, and iron.
- Concentrations were greater than commercial/industrial screening levels for arsenic and chromium.
- PAHs elevated above screening criteria included: Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Chrysene

Summary

- Stormwater sediments can be a concern, especially for PAHs and metals. Note emerging PFASs.
- TCLP analysis governs disposal, not lower toxicity screening.
- Potentially exists to better optimize sediment removal (as opposed to dredging after 40 years)
- Suggests a market for devices upstream that trap sediment
- What about coal-tar sealants?

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