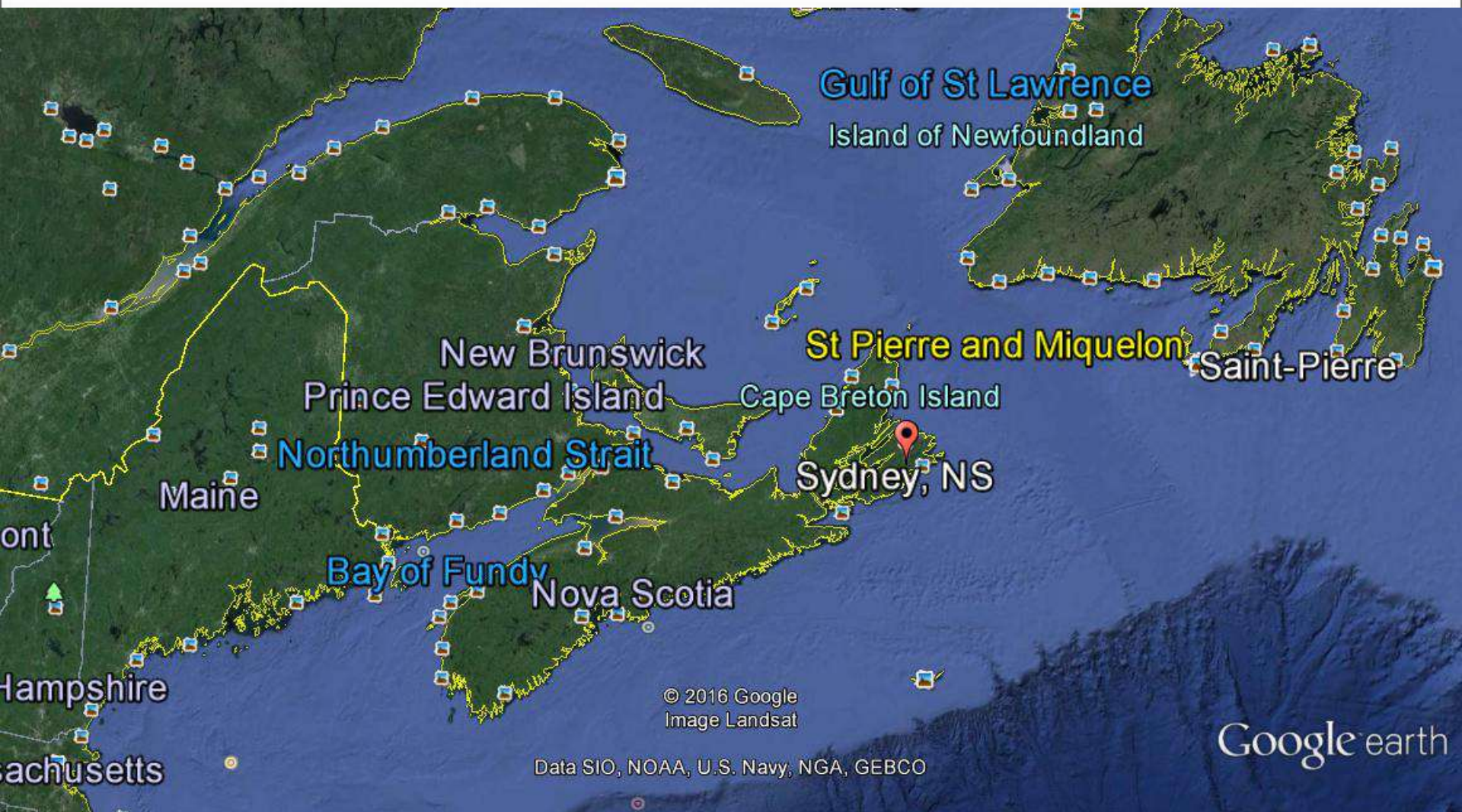




Mass Flux and Forensic Assessment: Informed Remediation Decision Making at One of Canada's Most Polluted Sites

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Image Landsat

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google earth

Background

- Long history of steelmaking in Sydney (1901-1988)
- 700,000 tons of coal tar released into Muggah Creek (Sydney Tar Ponds, STPs)
 - PAHs
 - Metals
 - PCBs
- Govt. scientists reported widespread contaminated sediment & biota in STPs & Sydney Harbour in 1980s
- Remediation seen as solution

Remediation

- Numerous unsuccessful remediation attempts
- In 2004, Govts. of Canada & NS announced a \$400 m project to clean up STPs & Coke Ovens
- STPs remediation consisted of solidification/stabilization (S/S) with cement
- Previously *mobile* contaminants effectively *immobilised* from migrating into SH



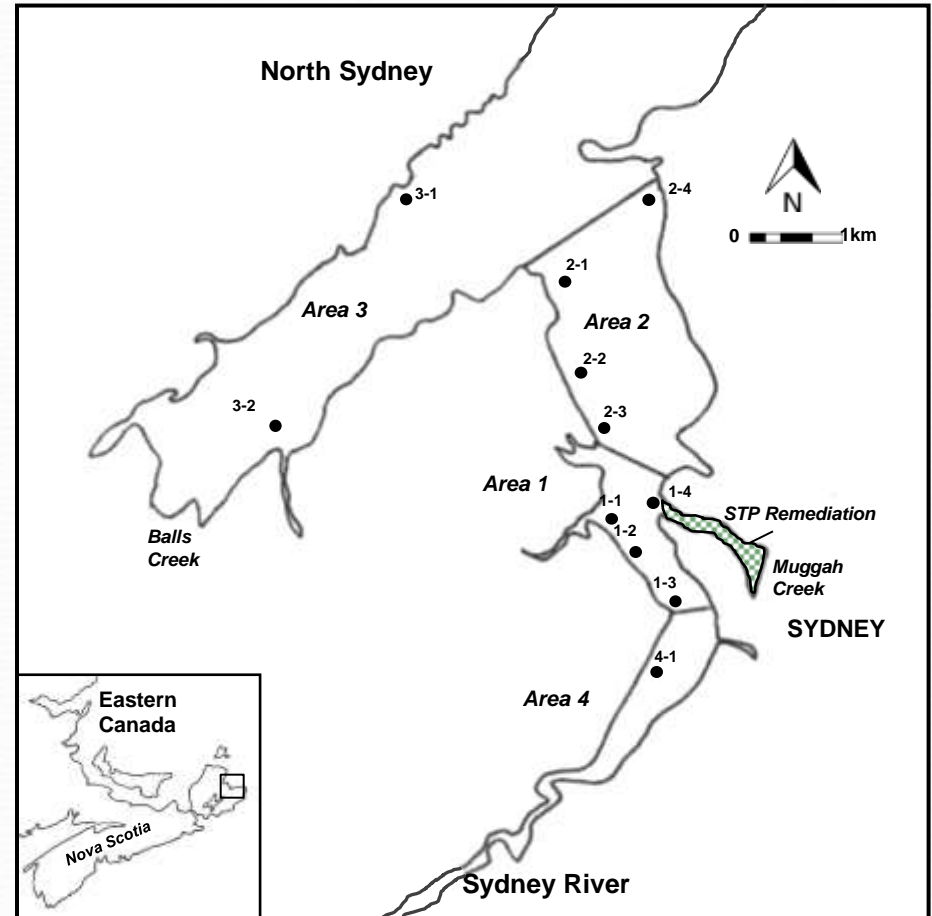
Environmental Effects Monitoring

- **Environmental Impact Statement (EIS) & Joint Review Panel (JRP) concluded**
 - *“Remediation unlikely to cause significant negative environmental impacts with implementation of appropriate mitigation”*
- **Environmental Effects Monitoring (EEM) program designed to**
 - Determine effectiveness of mitigation
 - Verify effects predictions made in EIS
 - Designed to assess positive / negative changes potentially attributed to remediation
- **EEM program comprised**
 - GW monitoring
 - SW monitoring
 - Marine EEM Program



Marine EEM Sampling

- **Spatial & temporal sampling**
- **Stations**
 - Area 1 – Near-field
 - Area 2 – Mid-field
 - Area 3 – Far-field/reference
 - Area 4 – Sydney River Estuary
- **Sampling**
 - 2009 baseline
 - 2010 1st yr remediation
 - 2011 2nd yr remediation
 - 2012 3rd yr remediation



Marine EEM Program

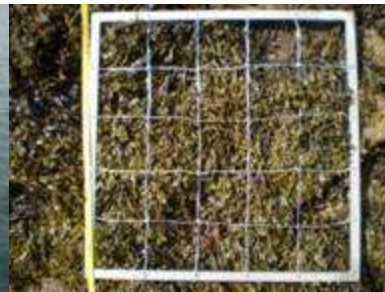
- **Water Quality (WQ)**
 - 24h auto sampler
 - Water grabs (surface & near bottom)
- **Mussel Tissue**
- **Sediment Quality**
 - Sediment chemistry (grabs & traps)
- **Crab Hepatopancreas Tissue**
- **Benthic Community**
 - Inter-tidal (5 transects using quadrats)
 - Sub-tidal (sieve analysis for benthic invertebrates)

Detection of changes

Short term



Long term

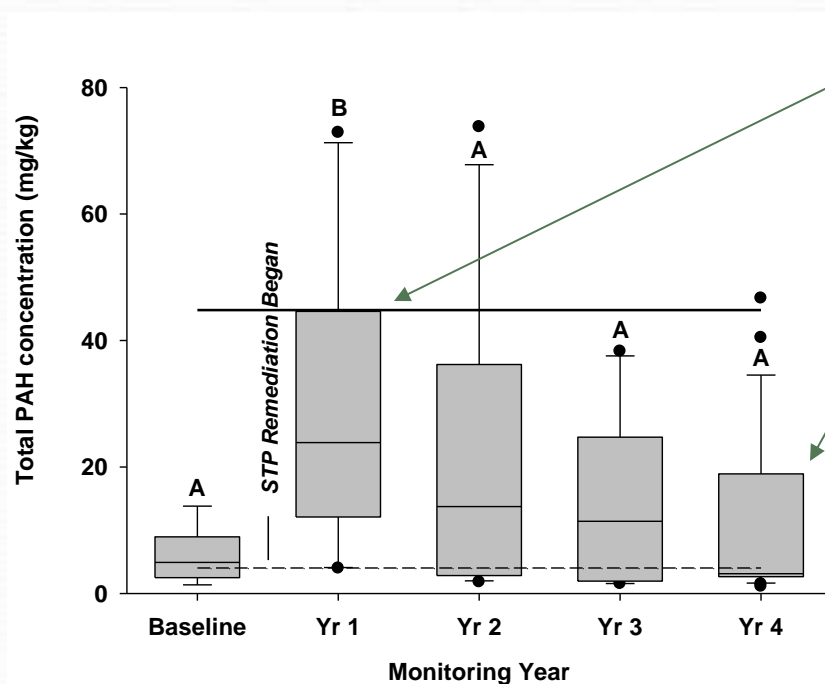


Sediment Quality

- Sediments sampled annually using grabs
- Surface sediments (0-1 cm) analysed for
 - PAHs
 - Metals
 - PCBs
 - TOC



Sediment Quality: PAHs



- **Significant increase in PAHs in Yr 1**
 - Regulatory agencies requested termination of remediation after just one year
- **Subsequent monitoring shows continued decrease in PAHs**
 - Not significantly different from baseline
 - Within predicted ranges reported by Smith et al. (2009)
- **EIS prediction of no significant environmental impacts in SH confirmed?**





REVIEW OF THE SYDNEY TAR PONDS REMEDIATION PROJECT MARINE ENVIRONMENTAL EFFECTS MONITORING PROGRAM YEAR 1 RESULTS

Context

On February 4, 2011, Fisheries and Oceans Canada's (DFO) Environmental Assessment and Major Projects Division (EAMP), Maritimes Region, requested that DFO Science, Maritimes Region, provide advice regarding the Year 1 results of the Sydney Tar Ponds Remediation Project Marine Environmental Effects Monitoring Program (MEEMP), as well as the potential effects on MEEMP of dredging and infilling of Sydney Harbour that may be undertaken in support of the proposed Sydport container terminal. The request for science advice supports DFO EAMP's involvement as an expert authority in the Sydney Tar Ponds Remediation Project pursuant to the *Canadian Environmental Assessment Act*. Specifically, DFO EAMP asked:

1. Are the conclusions of each Sydney Tar Ponds Remediation Project marine monitoring method valid based on the Year 1 monitoring results and baseline observations?
2. Should the marine monitoring methods be changed, based on the Year 1 monitoring conclusions, to better improve the monitoring program?

*DFO CSAS strong concerns &
EC even requested cessation of
remediation activities!*

sectors 02 to 10 at all sampling locations and for all individual parts in Part 1 of the MEEMP monitoring program compared to the pre-construction phase of the Tar Sands remediation project.

- The increases observed in sediment PAH, but not in metal and polychlorinated biphenyl, levels indicate they are associated with transport from the Tar Ponds remediation site into the harbour by water or atmospheric pathways. The detection of these PAH increases in harbour sediments attests to the general value and utility of the MEEMP.

Estimates of PAH Mass Flux to SH

- **Mass flux techniques used to understand “mobile” vs. “immobile” contaminants**
- **Reviewed historical flux studies at STPs**
 - Government reports & ERA studies
- **Calculated mass flux study (3 yrs) during remediation at STPs**
 - Dillon (2011, 2012 & 2013)
- **Compared against independent engineers flux estimate**
 - CRA (2011)

Total PAH Accumulation

- **Total PAH accumulation from 2009 - 2010**

- Area 1 – 363 kg
- Area 2 – 916 kg
- Area 3 – 469 kg
- Area 4 – 189 kg

- **Total PAH ~2000 kg !!!!**



Estimates of PAH Fluxes to SH

- **Previous (300-800 kg/yr)**

- 1989 – 767 kg/yr (Lane & Associates 1991)
- 2000 & 2001 – 793 kg/yr (JDAC 2002)
- 2000 & 2001 – 289 kg/yr (Lee et al. 2002)

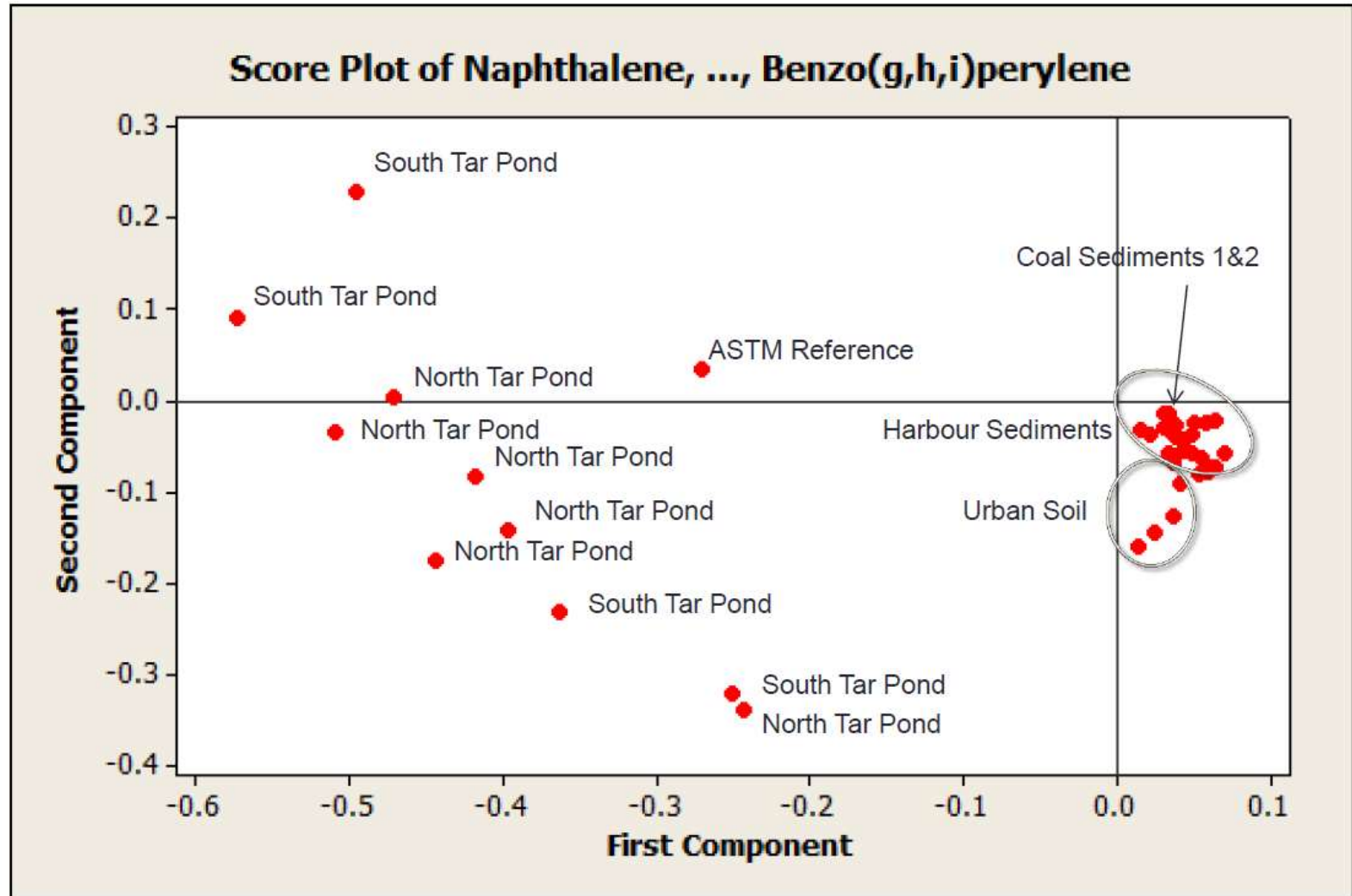
- **During Remediation (<120 kg/yr)**

- 2010 – 97 kg/yr (Dillon 2011)
- 2010 – 119 kg/yr (CRA 2011)
- 2011 – 17 kg/yr (Dillon 2012)
- 2012 – 56 kg/yr (Dillon 2013)

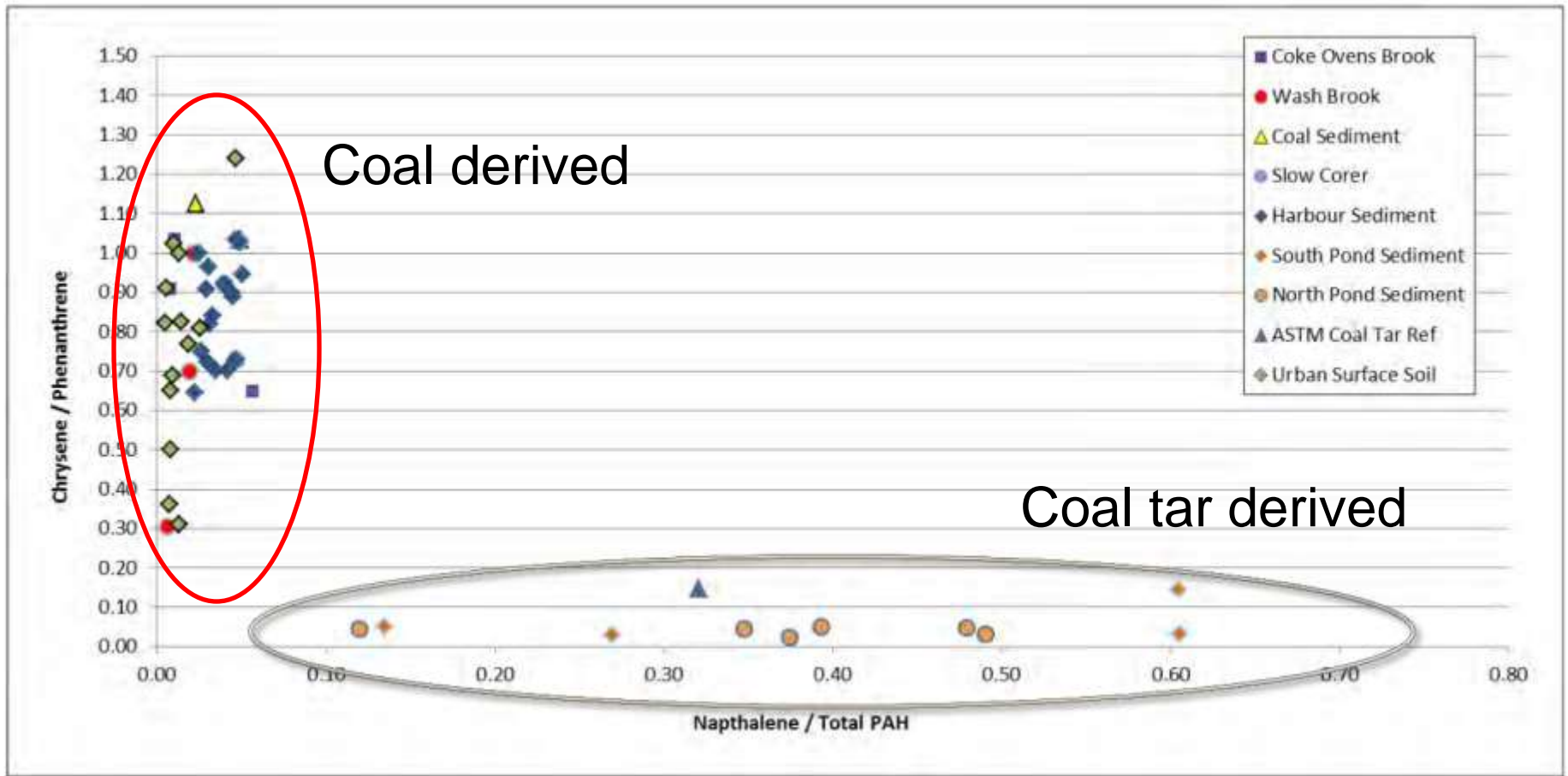
[PAH] Increases During yr 1

- **Onsite releases from remediation activities?**
 - Localized sediment PAH signature expected
 - ~100 kg/yr flux from STPs considerably lower than ~800 kg/yr flux estimated by JDAC (2002) & much lower than ~2000 kg loading in yr 1
- **Large scale uncovering event of contaminated sediments?**
 - 5 major storms between July 2009 & October 2010
 - Ship propeller wash – but not at all sites?
- **Results from 2009 could have been “unusually” low?**
 - Burial from less contaminated shallow channel sediments
- **Potential sources (eg. bulk coal storage facility)**
 - Addressed with some PAH forensic techniques

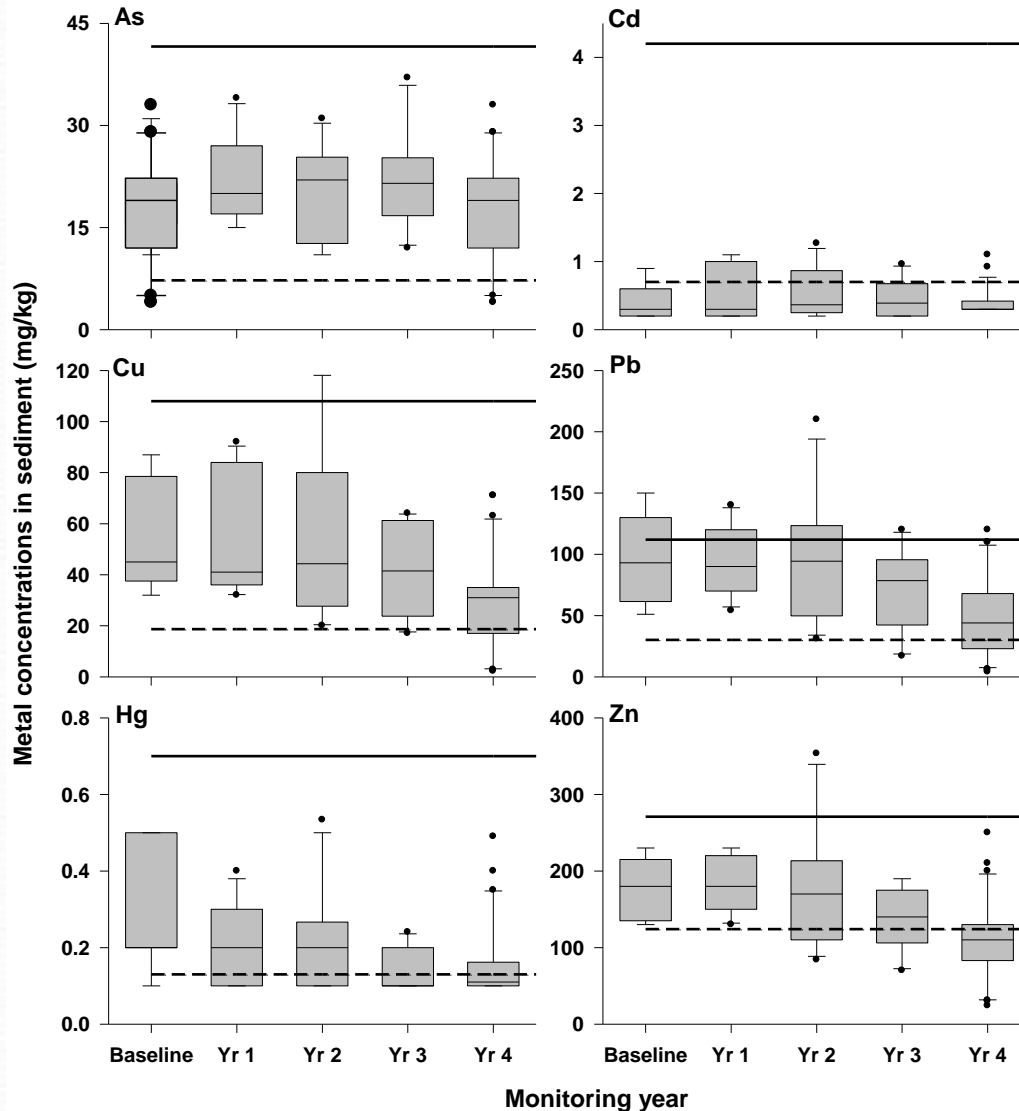
Principal Component Analysis Score Plot



PAH Diagnostic Ratios



Sediment Quality: Metals



- Little temporal variation
- EIS prediction of no significant environmental impacts in SH confirmed?

Heavy Metal(s) Lives On!



Contaminants in Other Media

Media	Detection of Effects	PAH	PCB	As	Cd	Cu	Hg	Pb	Zn	JRP Significance	Reference	
Water quality	Short term	→	→/nd	→	↓	→	→	→	→	Not significant	(Dillon 2013)	
Blue mussels		→/nd	→/nd	→	→	→	→	↑	↑	Not significant	(Walker et al. 2013b)	
Surface sediment		→	→	→	→	→	↓	→	↓	Not significant	(Walker et al. 2013c,d)	
Rock crabs		Longer term	→/nd	↓	→	→	→	→	→/nd	→	Not significant	(Walker et al. 2013a)

→ = Stable

↓ = Decreasing

↑ = Potentially increasing

nd = Not detected

- Walker, T.R., et al. (2013a) Legacy contaminant bioaccumulation in rock crabs in Sydney Harbour during remediation of the Sydney Tar Ponds, Nova Scotia, Canada. *Mar. Pollut. Bull.* 77, 412-417.
- Walker, T.R., et al. (2013b) Blue mussels (*Mytilus edulis*) as bioindicators of stable and improving water quality in Sydney Harbour during remediation of the STPs, NS, Canada. *Water Qual. Res. J. Can.* 48, 358-371.
- Walker, T.R., et al. (2013c) Monitoring effects of remediation on natural sediment recovery in Sydney Harbour, Nova Scotia. *Environ. Monit. Assess.* 185, 8089-8107.
- Walker, T.R., et al. (2013d) Environmental Recovery in Sydney Harbour, Nova Scotia: Evidence of Natural and Anthropogenic Sediment Capping. *Mar. Pollut. Bull.* 74, 446-452.
- Dillon (2013) Final Marine Report for Year 3 Construction. Submitted to the Sydney Tar Ponds Agency.

Summary

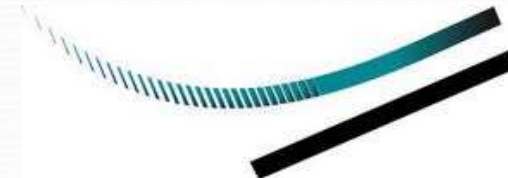
- **Only 17-97 kg/yr total PAHs discharged during remediation**
 - Corroborated by independent study - 119 kg/yr (CRA 2011)
 - PAH fluxes during remediation lower than ~800 kg/yr discharged in 2001 (JDAC 2002)
- **PAH fluxes during remediation unlikely responsible for ~2000 kg loading in harbour sediments in 2010**
- **Flux results corroborated by PAH forensic assessment which found a common source of PAHs – coal derived – NOT STPs**
- **Mass flux and PAH forensic assessment helped inform remediation decision makers to better understand “*mobile*” vs. “*immobile*” contaminants**
 - Calls for termination of remediation by regulators was premature
 - S/S remediation *immobilised* contaminants

Thank You



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