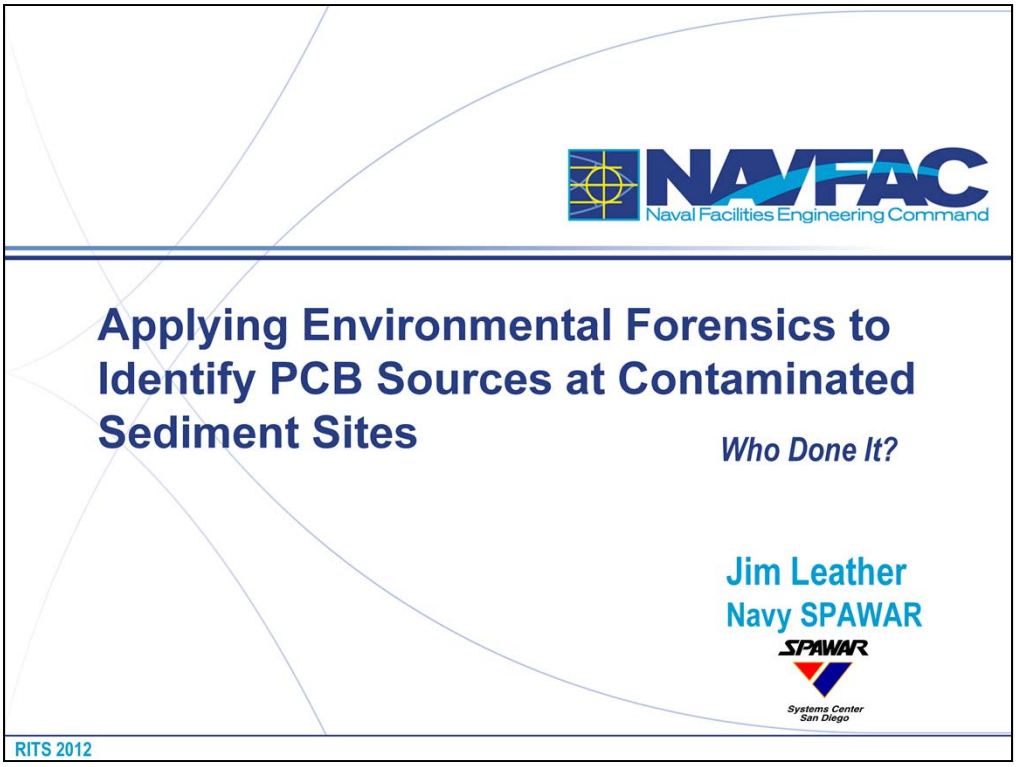


- Environmental Forensics – can be an integral part of effective Sediment Management.
- Purpose of presentation is ***not*** to teach audience how to themselves conduct the technical components of Environmental Forensics, but to understand what is needed to get it done and assemble a team.
- EF is well established for petroleum hydrocarbons, but less so for PCB!
- ***This*** presentations focuses on ***PCB*** and contamination of ***wet*** sediment
- Principles described in this presentation can also be applied to other contaminants and media.
- The Navy Policy on Sediments requires that sources are dealt with priori to remedy.
- PCB: Polychlorinated biphenyls

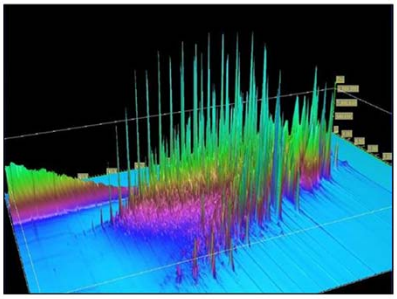
Chief of Naval Operations issued "*Navy/Marine Corps Installation Restoration Policy on Sediment Investigations and Response Action"* in February 2002

Presentation Overview

- ► Basics of Environmental Forensics
- Evaluate the Study Site and Project Planning
- Generating Data for PCB Forensics
- Analyzing and Interpreting PCB Forensics Data
- Case Studies
- Summary

Environmental Forensics (EF) and RITS

- **Past RITS**
  - "Advanced Chemical Fingerprinting" (Fall 2004) (e.g., PAH)
  - "Environmental Forensic Tools" (Fall 2005) (e.g., groundwater, soil)
  - "Compound Specific Isotope Analysis Today" (Fall 2008)
- **Recent Developments**
  - Isotope-ratio MS for multi-compounds
  - Multidimensional GC x GC analysis
  - Mixing/unscrambling models
- **Navy Handbook** (Summer 2012)
  - Based on ESTCP project (PCB-in-Sediment Forensics)



3 Basics of Environmental Forensics RITS 2012: PCB Forensics – Sediment Sites

- Past RITS Fingerprinting/Forensics presentations have mainly addressed Hydrocarbons and solvents, in soil or groundwater
- Some technical developments have occurred since then
- ***This*** presentations focuses on ***PCB*** and contamination of ***wet*** sediment, and is based on a newly developed PCB Handbook for Determining the Sources of PCB Contamination in Sediments
- Other information sources are available from Navy (e.g., "PCB Training Tool" on ERT2 Web site)
- List of Abbreviations and Acronyms not explained on the slides are listed at the bottom of the notes section
- PAH: Polycyclic aromatic hydrocarbons; GC: Gas chromatography; MS: Mass spectrometry
- GC: Gas chromatography
- ESTCP: Environmental Security Technology Certification Program

What is Environmental Forensics?

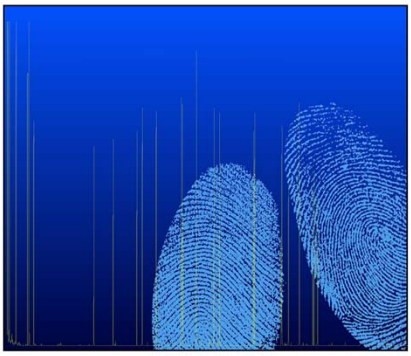
- ***A scientific methodology for identifying environmental contaminants and their sources, the relative contribution from source(s), and/or time of release.***

WHAT, WHERE & WHEN?

- **Unambiguous contaminant identification**
- **Well-defined spatial extent of contaminant, including the source(s)**
- **Age-dating of contamination**

WHO?

- **Defensible Allocation of Responsibility**



4 Basics of Environmental Forensics RITS 2012: PCB Forensics – Sediment Sites

- Environmental Forensics is a scientific approach to identifying sources of contamination
- Environmental Forensics can be highly relevant to sediment management:
  - Watershed Contaminant Source Document; review of records and history to determine if active sources could exist
  - Navy Sediment Policy; requires control of sources prior to remediation

When can a forensic study be useful?

- **Why conduct an environmental forensic investigation?**
  - **Need for identifying the sources of contamination (current and historic) may be a requirement for multiple reasons**
    - Identify all sources (don't assume that a known source is the only source!)
    - Demonstrate that sources are controlled (Navy Sediment Policy!)
    - Determine contributions from multiple sources
    - Allocate damage responsibility and/or remedy cost sharing

5 Basics of Environmental Forensics RITS 2012: PCB Forensics – Sediment Sites

- Why Conduct Environments Forensics?
  - To understand what sources contributed contamination (and who is responsible) and if they have been controlled
- Sediment Policy says not to clean up site until/unless sources have been controlled. Confirm that sources have been identified and are controlled!

When can a forensic study be useful? (cont.)

- **2011 NAVFAC T2 Survey of Navy RPMs**
  - **Majority said their sites had contamination from non-Navy sources**
  - **Contaminants of primary concern in *sediments* were petroleum/PAH , PCB, metals, pesticides, and dioxin**
    - Contaminants commonly from multiple sources
    - Contaminants particularly suitable for environmental forensics
  - **Majority said they had *not* considered a forensic study as a component of their site investigation**

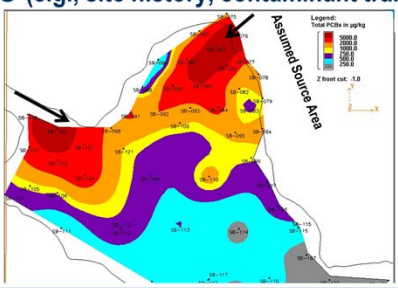
What are the barriers for applying a forensic investigation at your site?
(lack of technical/benefit understanding, budget, political, …)

6 Basics of Environmental Forensics RITS 2012: PCB Forensics – Sediment Sites

- T2 survey
  - Was not specifically for sediments, but sediment issues could be identified
  - Indicates that most RPMs (1) know their sites have non-Navy contamination and (2) have not considered a forensic study
  - These two facts suggest a disconnect – the need is there but forensics is not being considered
- There may be a lack of understanding of how a Forensics Investigation can help, or other barriers
- Presentation and PCB Handbook will provide Technical Guidance to RPMs for considering and implementing a Forensic Investigation. Political and other issues may still need to be resolved.
- NAVFAC: Naval Facilities Engineering Command; RPM: Remedial Project Manager

What contaminants can forensics be applied to?

- **Contaminants with unique source chemical signatures**
  - **Multi-component contaminants** (e.g., petroleum (PAH), PCB, dioxin/furan)
  - **Compounds with molecular differences** (i.e., isotope ratios; e.g., VOCs)
- ***However*, concepts of forensics can be applied to most contaminants and sites** (e.g., site history, contaminant transport, concentration distribution)

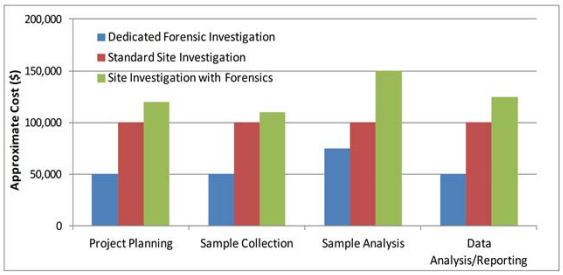


7 Basics of Environmental Forensics RITS 2012: PCB Forensics – Sediment Sites

- Most environmental forensic statistical analysis techniques are most suitable for multi-component contaminants.
- ***This*** presentations focuses on ***PCB*** and contamination of ***wet*** sediment
- Principles described in this presentation can also be applied to other contaminants and media.
- VOC: Volatile organic compound

What is the cost of a PCB forensic study as part of a site investigation?

- **Example costs for a forensic investigation**
  - **Project planning and records research**
  - **Sample collection**
  - **Sample analysis**
  - **Data analysis/reporting**
  - *~$200-250K stand-alone*
  - *~$100-150K addition to standard site investigation*



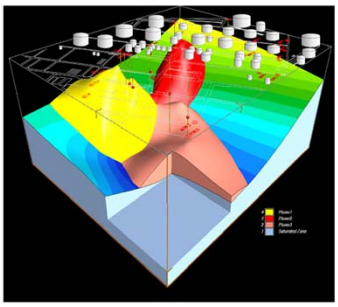
- **Costs are highly project-specific**
- **Costs can be *significantly* reduced through planning and conducting/leveraging with standard site investigation**

8 Basics of Environmental Forensics RITS 2012: PCB Forensics – Sediment Sites

- The cost for an Environmental Forensic study is quite site/study-specific.
- The potentially significant benefit of a forensic investigation can be most cost effectively realized by incorporating it with a standard site investigation for a relatively small incremental cost.

What is the cost of a PCB forensic study as part of a site investigation? (cont.)

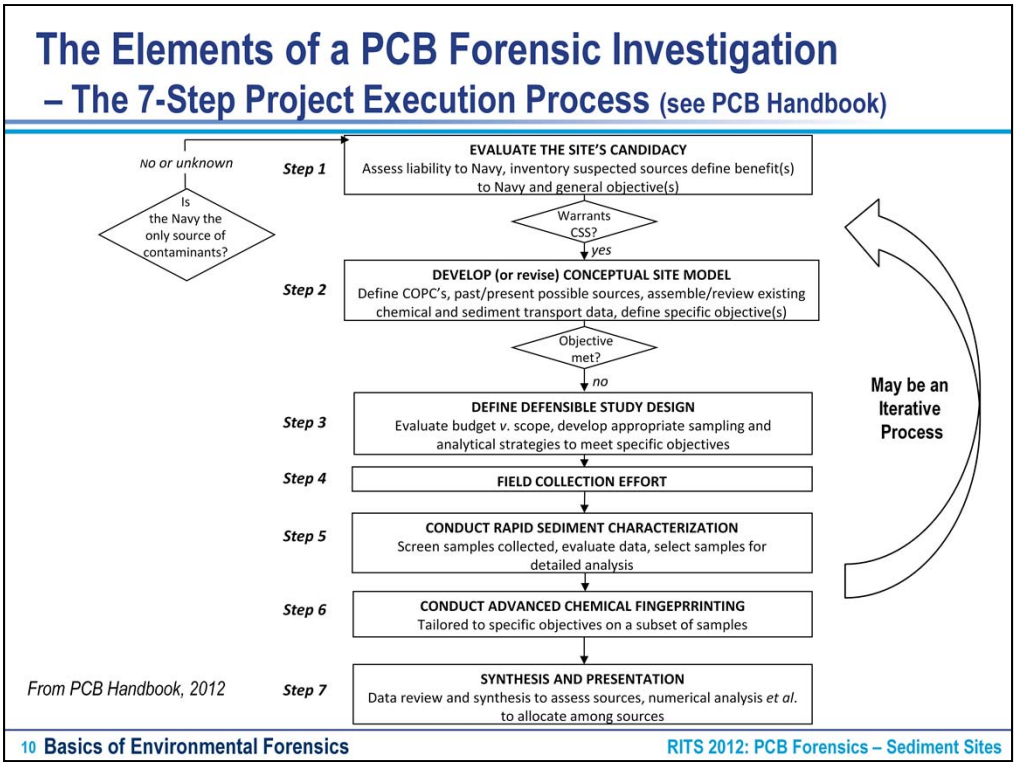
- **Potential cost of *not* conducting a forensic study:**
  - **Liability payments (100% vs. X%)**
    - Reducing liability to 75% on $10M liability is a $2.5M cost saving
  - **Remedy costs (100% vs. Y%)**
    - Reducing responsibility to 50% on $25M remediation project is a $12.5M cost saving
    - Ensure that sources are controlled before remedy; avoid recontamination



- **Cost: $100-250K added study cost vs. multi-$M potential project cost savings**
- **Leverage forensic study with other work!**

9 Basics of Environmental Forensics RITS 2012: PCB Forensics – Sediment Sites

- The cost for an Environmental Forensic study may be small compared to the potential overall Program savings that may be realized with information from a Forensic investigation.
- Sharing of Liability costs with other PRPs
- Sharing of Remedy costs with other PRPs
- Ensure that sources are controlled before start of remedy, and protect against potentially incurring additional remedy costs as a result of recontamination (i.e., compliance with Sediment Policy)
- If a forensics investigation is pursued, it is best to combine it with other investigations/characterizations of the site.



- Basic steps of an EF project, as described in the PCB Handbook
- Elements of these are described in this presentation, with a focus on the methods and Case Studies
- Watershed Contaminant Source Document (WCSD), from Sediment Policy – ensure that sources are controlled before remedy.

The Elements of a PCB Forensic Investigation
– The Key Technical Components

- Integrated (Team) Approach
- Major Components of EF
  - Historical records/data
  - Fate and transport modeling (geology, hydrology)
  - Chemical fingerprinting (field screening, advanced characterization)
  - Data analysis
  - Information reporting/presentation
- Stakeholder involvement

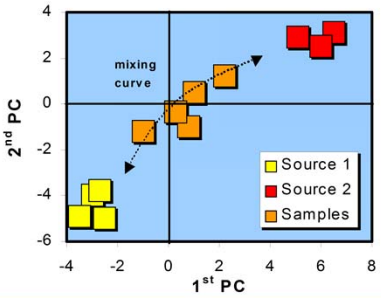
Reduce Technical Uncertainty → *Increase Defensibility*

11 Basics of Environmental Forensics — RITS 2012: PCB Forensics – Sediment Sites

- There are several key technical components to an Environmental Forensic investigation, all of which are important. A team of technical practitioners is typically required.
- The chemical fingerprinting is critical, but the importance of the other key components is often not emphasized enough.
- EF: Environmental forensics

The Elements of a PCB Forensic Investigation
– Summary of Technical Requirements

- **What is needed to identify sources and perform an environmental forensic investigation?**
  - **The appropriate *diagnostic* data and site information**
  - **The appropriate data analysis and interpretation procedures**
  - **Someone (or team) to ensure that the above are generated and applied appropriately; a compelling presentation of findings**



12 Basics of Environmental Forensics RITS 2012: PCB Forensics – Sediment Sites

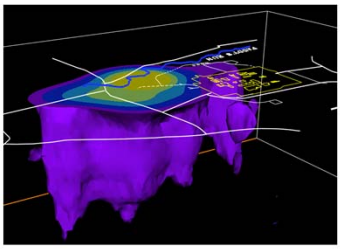
- In summary, to conduct an Environmental Forensic investigation one needs
  - The appropriate diagnostic data and site understanding
  - The appropriate information/interpretation analysis methods
  - A project leader who can ensure the appropriate information are generated, interpreted, and presented in a clear and convincing manner.

Presentation Overview

- Basics of Environmental Forensics
- ► Evaluate the Study Site and Project Planning
- Generating Data for PCB Forensics
- Analyzing and Interpreting PCB Forensics Data
- Case Studies
- Summary

Evaluate Site for Forensic Study

- Is the site a candidate for a forensic investigation?
  - Have all sources of key contaminants been identified?
  - Have all sources of contamination been controlled?
  - Could there be additional sources (historic or current, controlled or not) of the assumed "driver" contaminant that could be a significant contributor to the contamination?
- Review site history, history of area, historical reports
- Phase with other site investigation, if EF is needed



14 Evaluate the Study Site and Project Planning RITS 2012: PCB Forensics – Sediment Sites

- To determine if a site is a candidate for an EF investigation one determines if critical site information related to potential sources is missing – information that can be generated with an EF. Are all sources identified and controlled, and is the relative contributions of multiple sources (if applicable) understood?

Develop/Update the Conceptual Site Model (CSM)

- **Develop or update CSM to understand history, processes, and potential sources of contamination at the site; develop hypotheses for forensic investigation**
  - **Identify known/suspected contaminants of potential concern (COPC)**
  - **Identify known/suspected sources**
  - **Identify knowledge gaps**
  - **Develop objectives (hypotheses and questions) for the forensic investigation (e.g., what are COPCs, where are sources, when did contamination occur, are sources controlled, how can responsibility be apportioned)**

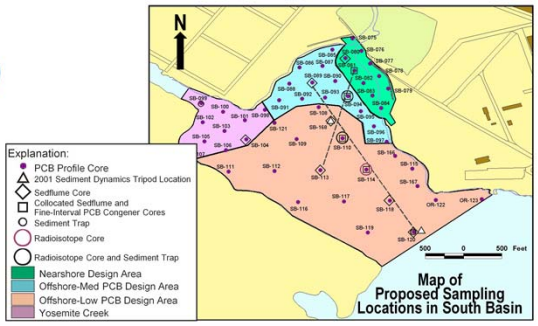
Develop a mental and graphical "picture" of the site

15 Evaluate the Study Site and Project Planning RITS 2012: PCB Forensics – Sediment Sites

- A Conceptual Site Model should either be updated or developed as part of an EF investigation, to develop a mental picture of the situation and focus and guide the investigation.
- COPC: Contaminant of potential concern

Develop a Site Sampling and Analysis Plan (SAP)

- Develop or update a Sampling and Analysis Plan (SAP) to address the hypotheses from the CSM; to identify historic (controlled) and current (active) sources of contamination at the site, and their relative contribution
- Incorporate samples, methods and DQOs for forensics
  - Specific locations
  - Specific methods (field, lab)
  - Specific DQOs
  - Specific data analysis
- Merge with other site studies whenever possible



16 Evaluate the Study Site and Project Planning RITS 2012: PCB Forensics – Sediment Sites

- A Sampling and Analysis plan should either be updated or developed as part of an EF investigation, to guide the investigation. The EF component will likely have specific SAP components, such as specific DQOs (e.g., analytical requirements) and data analysis and presentation procedures.
- DQO: Data quality objective

Presentation Overview

- Basics of Environmental Forensics
- Evaluate the Study Site and Project Planning
- ► Generating Data for PCB Forensics
  - ► PCB Primer
  - ► Sample Collection
  - ► Sample Analysis Methods
- Analyzing and Interpreting PCB Forensics Data
- Case Studies
- Summary

PCB Primer – Basics (see ERT2 PCB Tool)

- **PCBs are the most common COPC at sediment sites**
  - PCB > PAH/petroleum > pesticides > metals
  - PCBs were widely used in large amounts
  - 50% of the 60 EPA Tier 1 Sediment Superfund Sites had PCB as driver
- **PCBs**
  - Are widespread and abundant
  - Are persistent
  - Accumulate in sediment and biota
  - Biomagnify through aquatic food web
  - May cause ecological and human health effects
- **Sediment cleanup goal often 1 ppm (as low as 50 ppb)**
  - Sediment quality guidelines: 22.7/59.8 ppb (ERL/TEC) – 180/676 ppb (ERM/PEC)

18 Generating Data for PCB Forensics RITS 2012: PCB Forensics – Sediment Sites

- PCB is a widely used chemical class, and a common environmental contaminant.
- See ERT2 PCB Tool for additional PCB information (primer)
- ERL/TEC and ERM/PEC are benthic ecological effects-based sediment quality guidelines, below which effects are not expected to be observed and above which effect may be observed, respectively. However, these are rough screening-level values: significant site-specific differences occur.
- EPA: Environmental Protection Agency
- ERL/ERM: Effects-range low/median (marine water sediment quality guideline)
- TEC/PEC: Threshold/probable effects concentration (fresh water sediment quality guideline)

PCB Primer – Basics (cont.)

Upland sources are often landfills, drainage systems, and unmanaged old industrial properties/lands. Common uses:

- Transformers
- Capacitors
- Hydraulic fluid/equipment
- Lubricants
- Plasticizers
- Carbonless paper
- Paints/inks
- Adhesives
- Dust control
- Cutting oils
- Pesticide cocktails
- Sealants/caulking compounds

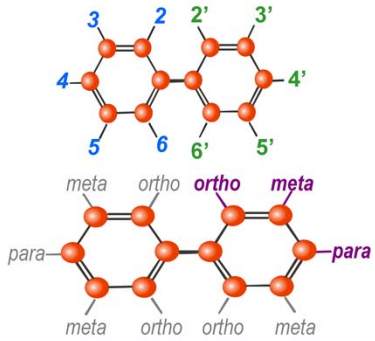
- **Their unique properties (e.g., stability, hydrophobicity) contribute to their environmental persistence and problems**
  (e.g., don't break down, adhere to particles, accumulate in sediment and biota)

19 Generating Data for PCB Forensics — RITS 2012: PCB Forensics – Sediment Sites

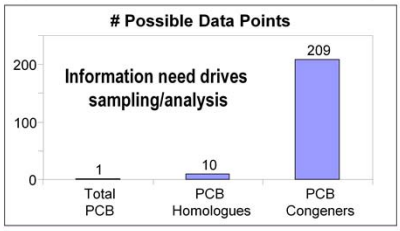
- PCBs have been widely used in many applications.
- PCB manufacturing was banned in 1979, but continued to be used in existing equipment and materials. Sources remain even today.
- The unique properties of PCB make them a particular environmental challenge; they are stable (don't break down) and hydrophobic (not water soluble, adhere to particles, and accumulate in biological tissue).

PCB Primer – Base Chemistry

- PCBs are a biphenyl molecule with between 1 and 10 chlorine atoms attached
  - Congeners are individual PCB molecules
  - There are 10 PCB homologues and 209 possible PCB congeners



Chlorine Substitution (Homologues)	Number of Possible Isomers (Congeners)
Mono-	3
Di-	12
Tri-	24
Tetra-	42
Penta-	46
Hexa-	42
Hepta-	24
Octa-	12
Nona-	3
Deca-	1
Total	209



20 Generating Data for PCB Forensics RITS 2012: PCB Forensics – Sediment Sites

- PCBs is a class of chlorinated organic compounds, manufactured and used as mixtures (Aroclors) of multiple individual compounds (congeners).

PCB Primer – Base Chemistry (cont.)

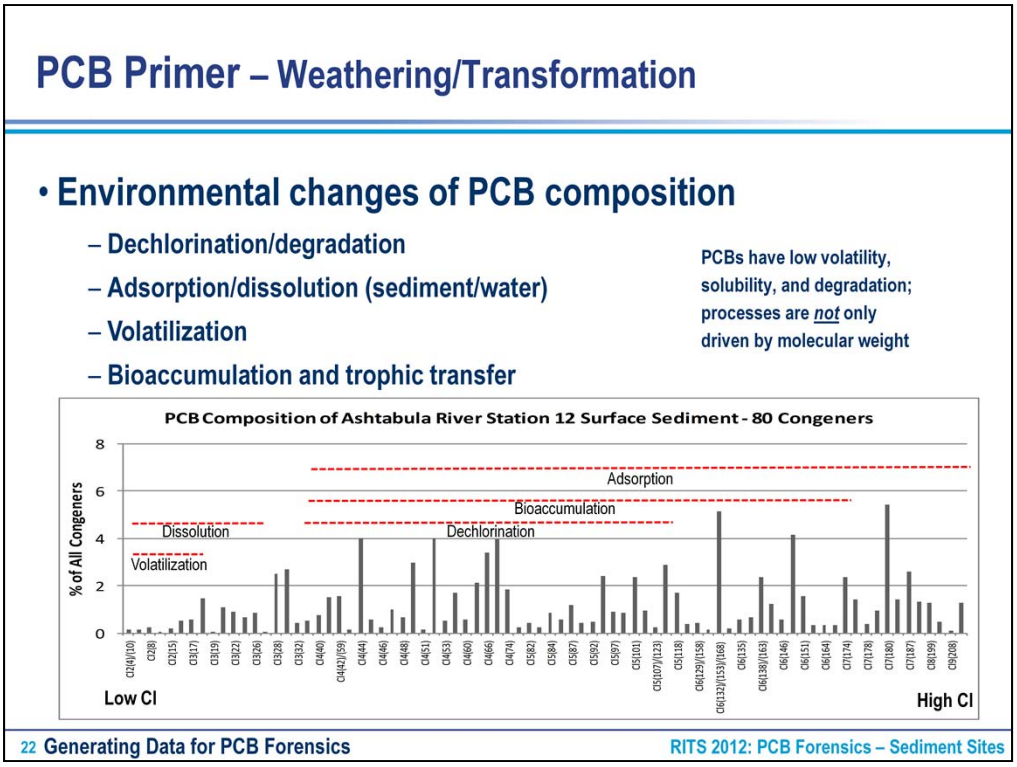
- **PCBs were manufactured, sold, and used as Aroclor formulations; a mixture of 25-50 congeners**
  - 9 primary Aroclors; 4 of those comprise >90% of manufactured PCB
  - Aroclors named by # carbons on molecule (12) and % chlorine by weight (e.g. 68)
  - All Aroclors together include a little more than 100 PCB congeners (>99% of the total PCB); many congeners are not in Aroclors and not found in the environment

	Level of Chlorination/Homologue % Composition									
	Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca
A1221	60.1	33.4	4.2	1.2	1.1	0	0	0	0	0
A1232	27.5	26.8	25.5	10.6	9.4	0.2	<0.1	0	0	0
A1016*	0.7	17.5	54.6	22.1	5.1	0	0	0	0	0
A1242*	0.7	15.0	44.9	20.3	18.8	0.3	0	0	0	0
A1248	<0.1	1.1	21.4	32.9	42.9	1.6	<0.1	0	0	0
A1254*	<0.1	0.2	1.3	10.2	59.1	26.8	2.7	<0.1	<0.1	0
A1260*	<0.1	<0.1	0.2	0.4	8.7	43.2	38.4	8.3	0.7	0
A1262	<0.1	0.2	0.4	0.5	3.4	26.4	48.5	19.7	1.6	0
A1268	0	0	<0.1	0.1	0.2	4.4	10.1	45.0	35.0	4.8

*Aroclors 1016, 1242, 1254, and 1260 accounted for >90% of the PCB production

21 Generating Data for PCB Forensics RITS 2012: PCB Forensics – Sediment Sites

- Although many Aroclors were produced, and up to 209 PCB congeners are possible, only a subset are of significant importance for most PCB environmental investigations.



- Once released to the environment, the composition (i.e., relative concentration) of the PCB compounds in the Aroclor(s) begin to change as the PCB undergoes environmental alterations and redistribution. Many processes are at play, making it challenging to predict the changes and link environmental contamination to the PCB source.

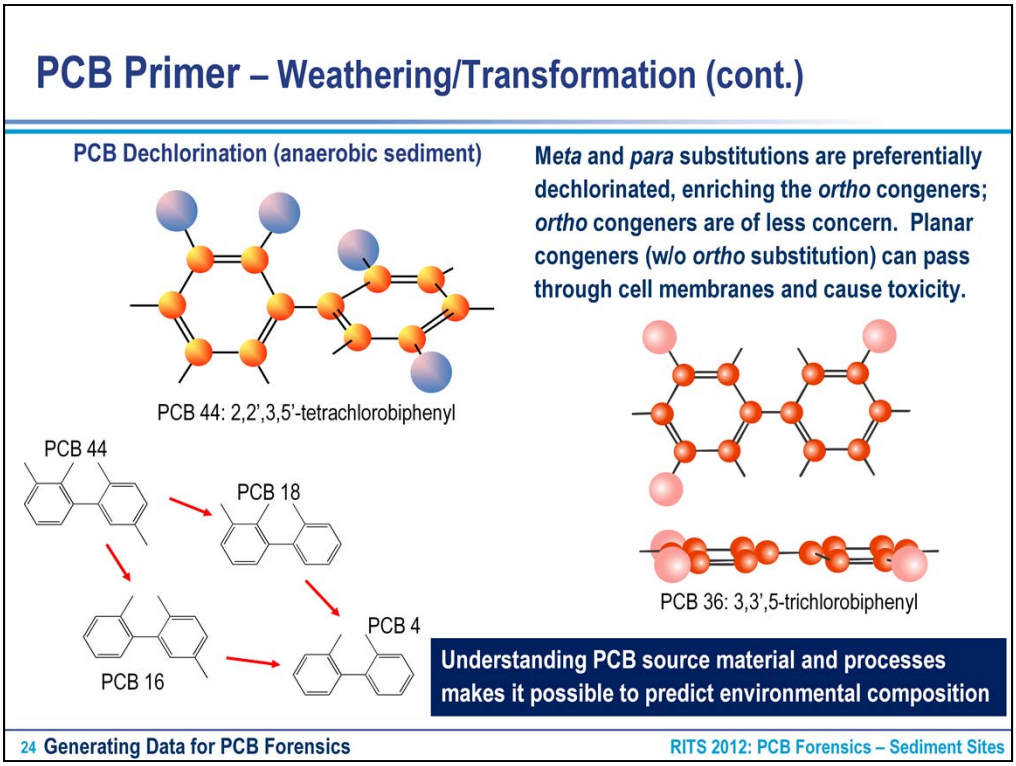
PCB Primer – Weathering/Transformation (cont.)

PCB Dechlorination Rate Depends on Many Factors

- PCB chemistry
  - Molecular structure
  - Chlorination level
- Physical and chemical conditions
  - Redox conditions and anaerobic stability
  - Electron receptors
  - Atmospheric exposure and tidal effects
  - Oil and metals
- PCB degrading microbe assemblage
- Depletion of competitive substrates
- Residence time

23 Generating Data for PCB Forensics RITS 2012: PCB Forensics – Sediment Sites

- Dechlorination is one of the most important PCB compositional alteration processes, particularly in (aerobic) sediment. Many factors impact whether dechlorination will occur, and the rate of dechlorination.



- PCB dechlorination is molecule-specific, and has been observed to occur more on the PCB congeners that are of particular environmental concern; chlorines in the meta and para positions are preferentially removed.
- Dechlorination processes and pathways have been documented, and with careful work dechlorinated PCB composition can be predicted.

Collecting Field Samples and Data for PCB Forensics

- **Field procedures are not unique to forensic investigations, and can cost-effectively be combined with other sampling**
  - However, may require special attention to ensure there is no sample contamination (low MDLs) and detailed documentation (if litigation)
- **Sediment sample collection** (recent and historical)
  - van Veen or box core for surface sediment
  - Push, piston or vibra-core for sediment cores
- **Hydrodynamic and geotechnical data for contaminant transport and sediment stability modeling**
  (cores used for SEDflume; ADCP for current, waves, and TSS; wind)

25 Generating Data for PCB Forensics RITS 2012: PCB Forensics – Sediment Sites

- Sediment sampling procedures used in EF are not unique to EF, although particular attention to documentation may be required.
- MDL: Method detection limit
- ADCP: Acoustic doppler current profiler
- TSS: Total suspended solids

PCB Analytical Chemistry Method Options

- **Multiple methods are available for PCB analysis. They can be grouped as (1) Total PCB and (2) PCB Congener Methods.**
- **Total PCB Methods**
  - ***ImmunoAssay/RSC (EPA Method 4020)***
  - **PCB as Aroclors (EPA Method 8082)**
  - **PCB as Homologues (EPA Method 680)**
- **PCB Congener Methods**
  - **Limited list of ~20 congeners (EPA Method 8082/NS&T Methods)**
  - ***List of ~40-120 congeners/ACF (Modified 680/1668)***
  - **List of >100 congeners and toxic congeners (EPA Method 1668)**

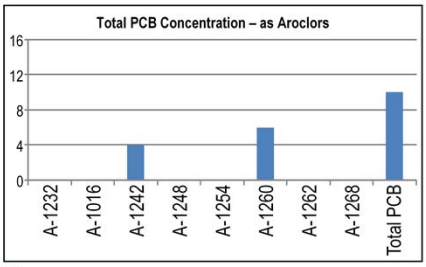
All of these methods can be used for Total PCB determination and site cleanup assessment

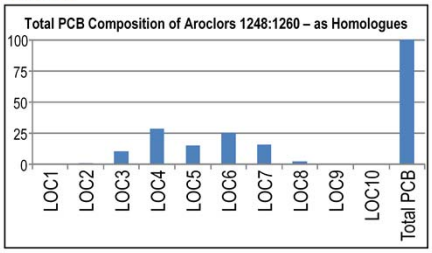
26 Generating Data for PCB Forensics RITS 2012: PCB Forensics – Sediment Sites

- A number of PCB analytical method are available, each with it's own advantages/disadvantages
- RSC: Rapid sediment characterization. A Total PCB analysis method that is effective for gross contaminant characterization/mapping, and planning detailed sampling/analysis
- ACF: Advanced chemical fingerprinting. An extended congener method for generating detailed data for forensic interpretation.
- All methods can, if used properly, generate Total PCB data that can be compared and used together. Additional detailed PCB data/information is produced differently by the different methods.
- Experienced Environmental Chemists can help combine data from different methods for potentially using together, or can identify the limitations of such combining.

PCB Analytical Chemistry Method Options
– Total PCB Analysis

- **Total PCB Methods**
  - **Immunoassay/RSC** (EPA Method 4020)
    - Rapid, low cost (~$75-150), 50 ppb
    - Susceptible to calibration issues
  - **PCB as Aroclors** (EPA Method 8082)
    - Low/medium cost (~$150-200), 10 ppb
    - Slightly more PCB information than IA/RSC
    - Susceptible to interference and misidentification
  - **PCB as Homologues** (EPA Method 680)
    - Medium cost (~$250-300), 1 ppb
    - PCB-specific; no interferences
    - Additionally more PCB information
    - Can combine with congener analysis
    - Less widely available





27 Generating Data for PCB Forensics — RITS 2012: PCB Forensics – Sediment Sites

- The Total PCB analytical methods are listed in order of increasing amount of information.
- PCB as Aroclor is most widely used method (EPA 8082); key advantaged/disadvantages of method options are listed
- These methods can all produce Total PCB data that, under ideal circumstances, may be used together in one dataset. However, one must be aware of the significant possible limitations described.
- Experienced Environmental Chemists can help advice on most suitable method and potential quality/information limitations with a set of data.
- IA: Immunoassay

PCB Analytical Chemistry Method Options
– Total PCB Analysis: Immunoassay/RSC

- **Immunoassay/RSC (EPA Method 4020) is:**
  - **Cost-effective screening method for use in the field or laboratory**
  - **Immunoassay (IA) is a RSC method and is increasingly used/promoted**
  - **Limitations of IA are not always fully considered**
    - Limitations can cause significant errors, but can be addressed in the study plan
  - **The most common IA is the "Enzyme Linked Immunosorbent Assay" (ELISA)**
  - **The antibody targets a specific compound of interest. They fit together "like a lock and key". IA is *HIGHLY* compound specific; need to know what you want to analyze and can only analyze one parameter at a time.**

The method recommended for Total PCB screening

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- Several slides are presented on Immunoassay/RSC because of it's importance in the described PCB EF work; it is the method recommended for Total PCB screening.
- IA/RSC is a very specific method that can cost effectively produce high quality PCB data, if applied correctly.

PCB Analytical Chemistry Method Options
– Total PCB Analysis: Immunoassay/RSC (cont.)

- **PCB *COMPOSITION* can have a dramatic impact on the IA results, and their reliability**
  - **Limitations can cause significant errors and faulty decision making**
  - **Limitations can, if understood, be addressed in the study plan**
- **PCBs are comprised of many constituents that respond differently in IA**

Compound	PCB Kit Sensitivity	
	Limit of Detection (ppb)	Relative Response
Aroclor 1221	22.6	0.022
Aroclor 1232	2.61	0.19
Aroclor 1242	1.22	0.41
Aroclor 1016	3.56	0.14
Aroclor 1248	0.59	0.85
Aroclor 1254	**0.5**	**1**
Aroclor 1260	0.32	1.6
Aroclor 1262	0.66	0.76
Aroclor 1268	3.03	0.17

A Few Congeners Provide the IA Response

PCB101 as % of Total PCB
Aroclor 1242 0.7 %
Aroclor 1248 2.3 %
Aroclor 1254 8.1 %
Aroclor 1260 3.2 %

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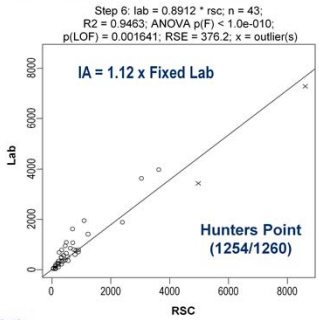
- The IA/RSC analysis is, because of it's high specificity, very sensitive to the composition of the PCB; it responds differently to the same amount of different kinds of PCB contamination (i.e., to different Aroclors).

PCB Analytical Chemistry Method Options
– Total PCB Analysis: Immunoassay/RSC (cont.)

- **Immunoassay/RSC Calibration Issues**
  - IA Kit Method uses Aroclor 1254 as the calibrant, which may poorly represent the contamination. A 10 ppm Total PCB result could be the result 10 ppm Aroclor 1254, 6 ppm Aroclor 1260, 24 ppm Aroclor 1242, or 52 ppm Aroclor 1232, for instance.
  - Reliable IA results may be generated if
    - Site PCB *composition* is well established (standard lab analysis)
    - Site PCB composition is consistent, or can be sub-divided into sub-areas that are consistent

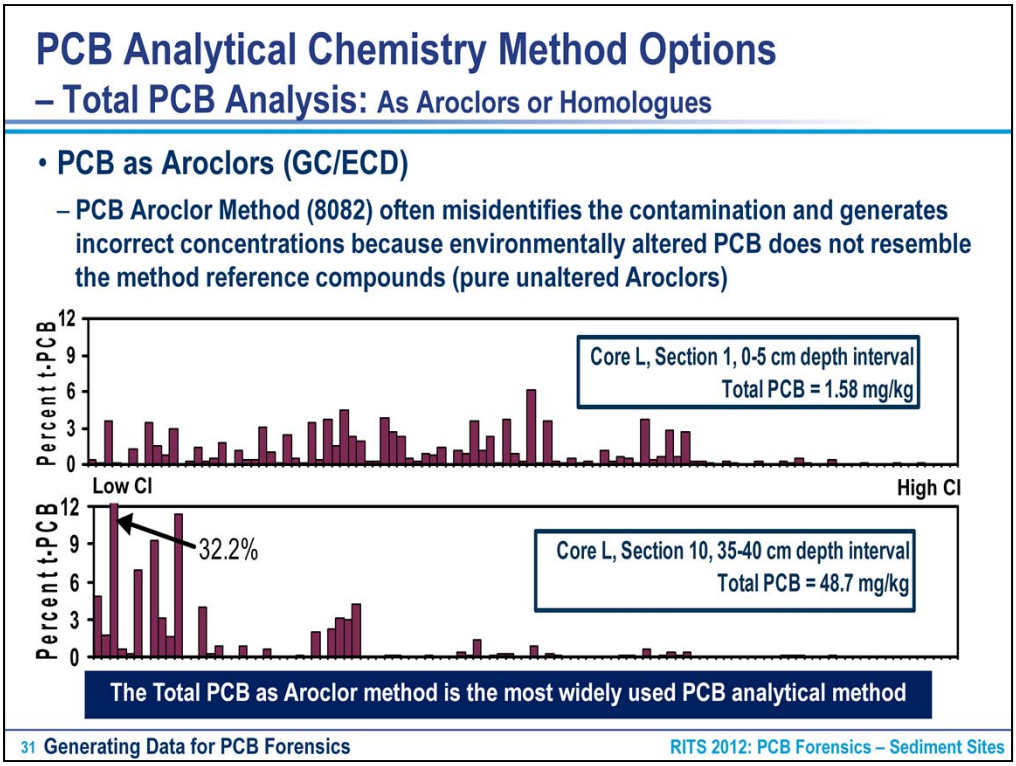


Option I: Calibrate IA with site-specific Aroclor mixture

Option II: Determine and apply an IA/Lab ("real") correction factor, if consistency (high r^2) has been demonstrated

30 Generating Data for PCB Forensics — RITS 2012: PCB Forensics – Sediment Sites

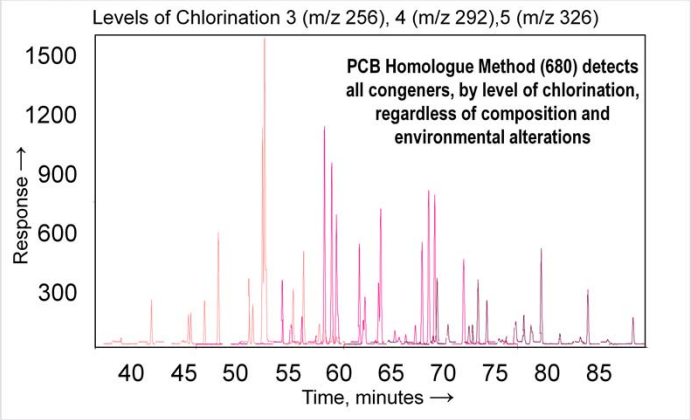
- The IA/RSC analysis may produce erroneous Total PCB values if used blindly per the Test Kit.
- It is therefore important to understand the PCB contamination (i.e., composition, and distribution across the site) to most accurately use the IA PCB method; site-specific small modifications to the method or data analysis can ensure high quality data.



- The Total PCB as Aroclor method is the most widely used PCB analytical method.
- This method is susceptible to sample matrix interferences and other analytical issues, and can produce erroneous results (and the presence of PCB even missed!) if significant environmental alteration (e.g., dechlorination) of the PCB has occurred.
- The method is best for “clean” sample matrices (e.g., sandy soil) and for samples where the contamination is a single mainly unaltered Aroclor.
- ECD: Electron capture detector

PCB Analytical Chemistry Method Options
– Total PCB Analysis: As Aroclors or Homologues (cont.)

- **PCB as Homologues (GC/LRMS)**
  - **The GC/LRMS method provides more reliable data than the GC/ECD method, the latter being susceptible to false positive and false negatives; LRMS is a compound-specific detector set to only detect target PCB**



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- The Total PCB as Homologue method is a less widely used PCB analytical method.
- This method is the most reliable and useful Total PCB analytical method; it is highly PCB-specific (low susceptibility to sample matrix interferences) and generates accurate results regardless of the degree of environmental alteration (e.g., dechlorination).
- This method can also effectively be combined with an extended PCB congener analysis.
- MS: Mass spectrometer or mass spectrometry (LRMS: low-resolution; HRMS: high-resolution)

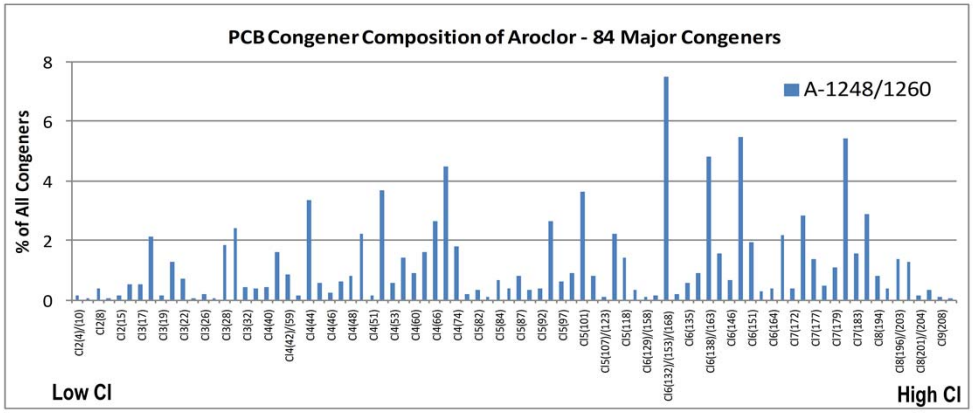
PCB Analytical Chemistry Method Options – PCB Congener Analysis

- **PCB Congener Methods**
  - **~20 Congeners** (EPA Method 8082/NS&T Method)
    - GC/ECD Method
    - Non-specific; susceptible to interferences
    - Medium cost (~$250-400), 0.25-0.5 ppb
  - **~40-120 Congeners** (Modified 680/1668)
    - GC/LRMS Method
    - PCB-specific; no interferences; high data quality
    - More PCB information
    - Can be combined with homologue analysis
    - Medium cost (~$450-650), 0.05-0.1 ppb
  - **>100 congeners and toxic congeners** (EPA Method 1668)
    - GC/HRMS Method
    - PCB-specific; no interferences; very high data quality
    - Can analyze all toxic coplanar congeners
    - High cost (~$900-1,200), 0.005-0.05 ppb

33 Generating Data for PCB Forensics RITS 2012: PCB Forensics – Sediment Sites

- The PCB congener analytical methods are listed in order of increasing amount of information (i.e., # of congeners) and analytical quality.
- Three different analytical instruments are used for the listed methods – that is the important differentiator.
- These methods can all produce Total PCB data, in addition to the congener data..
- Experienced Environmental Chemists can help advice on most suitable method and potential quality/information limitations with a set of data.
- NS&T: National status and trends project

PCB Analytical Chemistry Method Options
– PCB Congener Analysis (cont.)



Major Congener's Contribution to the Total PCB in Typical Environmental Sediment Samples (e.g., Aroclor 1242/1254/1260 mix)

18 Major Congeners (NOAA NS&T Congeners):	40-45%
38 Major Congeners:	70-75%
84 Major Congeners:	90-95%
~120 Major Congeners:	98-99%

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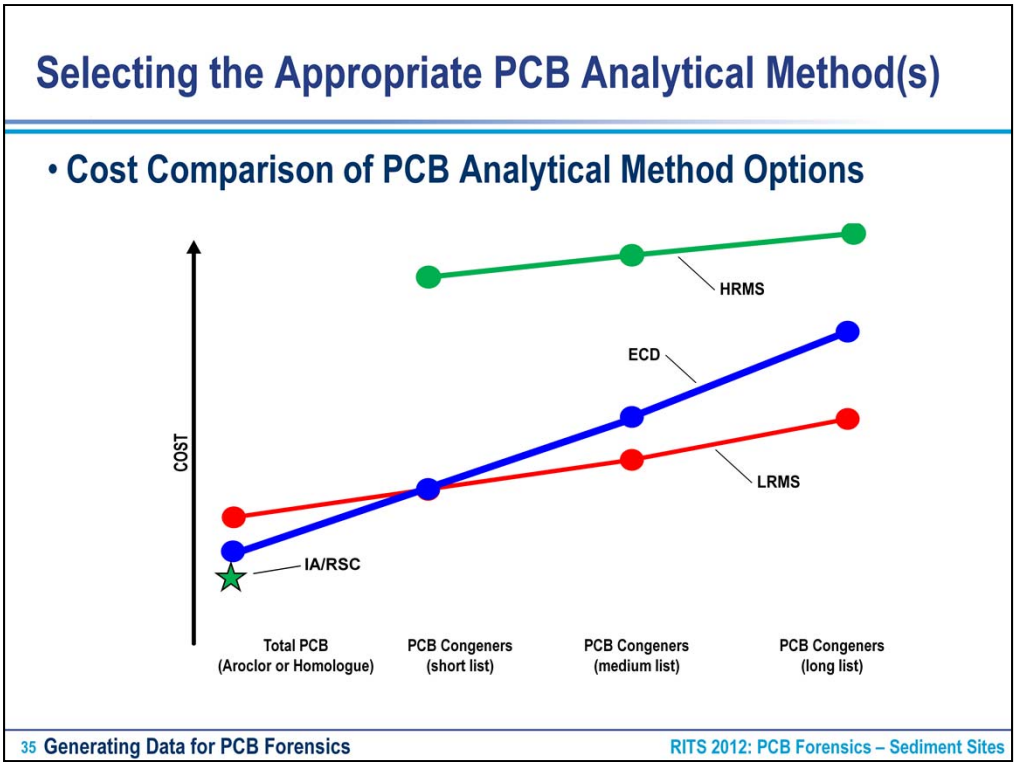
- The increasing amount of information (i.e., # of congeners) adds power to the data analysis, but more than 100 well selected congeners is rarely needed.
- Experienced PCB Environmental Chemists can help advice on most suitable target analyte list for an EF investigation (also see PCB Handbook).



- Different analytical methods/instruments have different analytical costs.
- The MS-based methods do not increase significantly in cost with added target analytes.

Selecting the Appropriate PCB Analytical Method(s)

General Evaluation of PCB Analysis Techniques 1="bad" 5="good"

Performance Measure	ECD	LRMS	HRMS
Data Quality			
Sensitivity/detection limit	3	4	5
Accuracy	2	4	5
Precision/reproducibility	2	4	5
Matrix interference	2	4	5
Lab/field contamination interference	2	5	4
Analyte confirmation	2	4	5
Calibration performance	2	5	5
PCB Information			
Data generation: total PCB	3	5	4
Data generation: PCB homologues	1	5	3
Data generation: PCB congeners (short list)	3	5	5
Data generation: PCB congeners (long list)	2	5	5
Data generation: PCB congeners (WHO list)	1	3	5
Cost			
Cost – initial lab investment	4	3	1
Cost – maintenance/operation	3	4	2
Cost – sample analysis (project price)	3	4	1

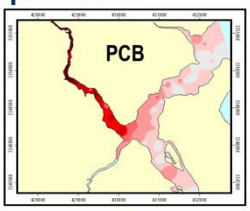
- Method Selection: Information need, balanced with data quality and cost considerations
- LRMS Long-list Analysis (Modified Method 680/1668) provides the optimum balance between meeting information needs, data quality, and cost for most ACF projects

36 Generating Data for PCB Forensics RITS 2012: PCB Forensics – Sediment Sites

- It is critical to consider and weigh the importance of (1) Data Quality, (2) Needed PCB Information, and (3) Cost, when you decide on the analytical approach(es) for your EF or other site investigation; their relative importance may differ from project-to-project.
- A general, primarily qualitative, decision-making matrix can be useful to produce as one considers the analytical options and the specific information needs for a specific project.
- The above listed “scores” are rough estimates, and may vary slightly based on specific study needs, changes in methods over time, and the Environmental Chemist performing the method assessment.
- WHO: World health organization (WHO has a list of what they consider 12 most toxic PCB congeners, for human health risk effects)

METHOD SUMMARY. Analysis Step I:
Rapid Sediment Characterization (RSC)

- **Chemical analysis intended to provide rapid, approximate, bulk concentration information of the contamination**
  - **Provides approximate Total PCB data (no source signature)**
  - **Make use of standard site investigation data, if possible!**
  - **Total PCB Analysis as**
    - Immunoassay/RSC
    - Aroclors (a little additional information)
    - PCB Homologues (a little more additional information)



- **"Map out" PCB concentrations across the site, to obtain a general understanding of the contamination and guide the ACF analyses. Can tier the analyses to save cost.**

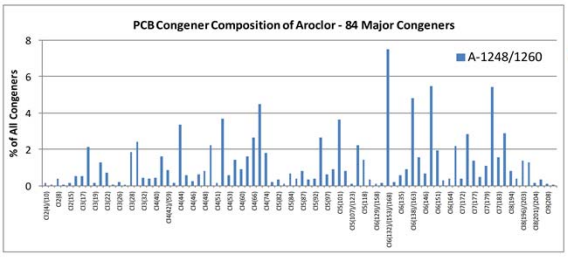
Immunoassay is a suitable RSC method for many PCB sediment investigations

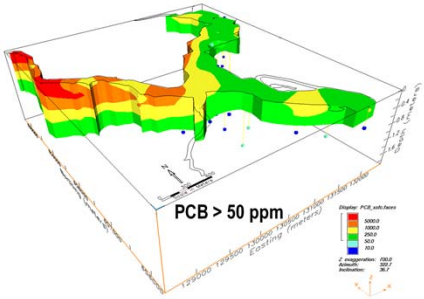
37 Generating Data for PCB Forensics — RITS 2012: PCB Forensics – Sediment Sites

- A RSC method is intended for the analysis of a relatively large set of samples to give a general impression of the PCB contaminant distribution and concentrations across the site.
- Immunoassay is a suitable RSC method for many PCB sediment investigations.

METHOD SUMMARY. Analysis Step II:
Advanced Chemical Fingerprinting (ACF)

- **Chemical analysis intended to provide source-specific diagnostic information for the contamination**
  - **Provides high-quality, detailed, information on multiple (80-120) diagnostic compounds (PCB Congeners), to be used in and support the forensic data analysis and interpretation**





38 Generating Data for PCB Forensics RITS 2012: PCB Forensics – Sediment Sites

- An ACF method is intended to for the analysis of a relatively small set of samples to provide detailed PCB concentration and composition data for selected representative site samples.
- A method that can generate reliable data for up to about 100 PCB congeners should typically be used; this will be a GC/MS method.

Presentation Overview

- Basics of Environmental Forensics
- Evaluate the Study Site and Project Planning
- Generating Data for PCB Forensics
- ► Analyzing and Interpreting PCB Forensics Data
  - ► Records Research
  - ► Contaminant Transport and Sediment Stability
  - ► PCB Sample Differentiation: Data Analysis
  - ► Reporting: Pulling it all Together
- Case Studies
- Summary

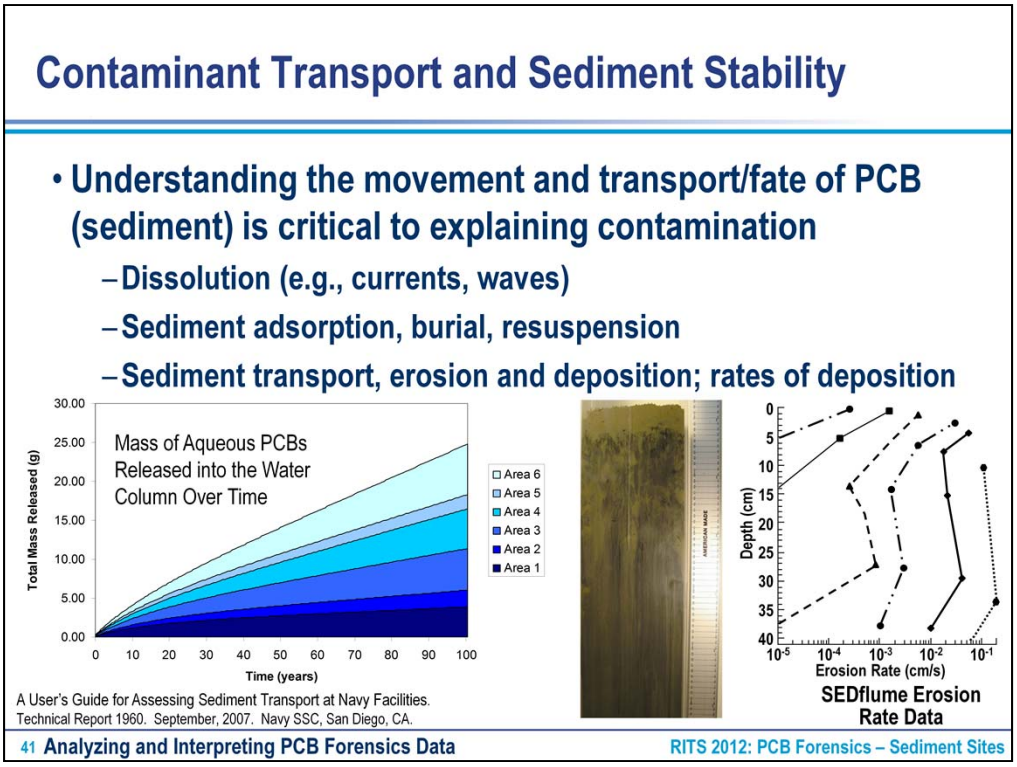
39 RITS 2012: PCB Forensics – Sediment Sites

- In this section we will be discussing the components that together comprise the key technical activities when conducting an Environmental Forensics investigation (see PCB Handbook for details).

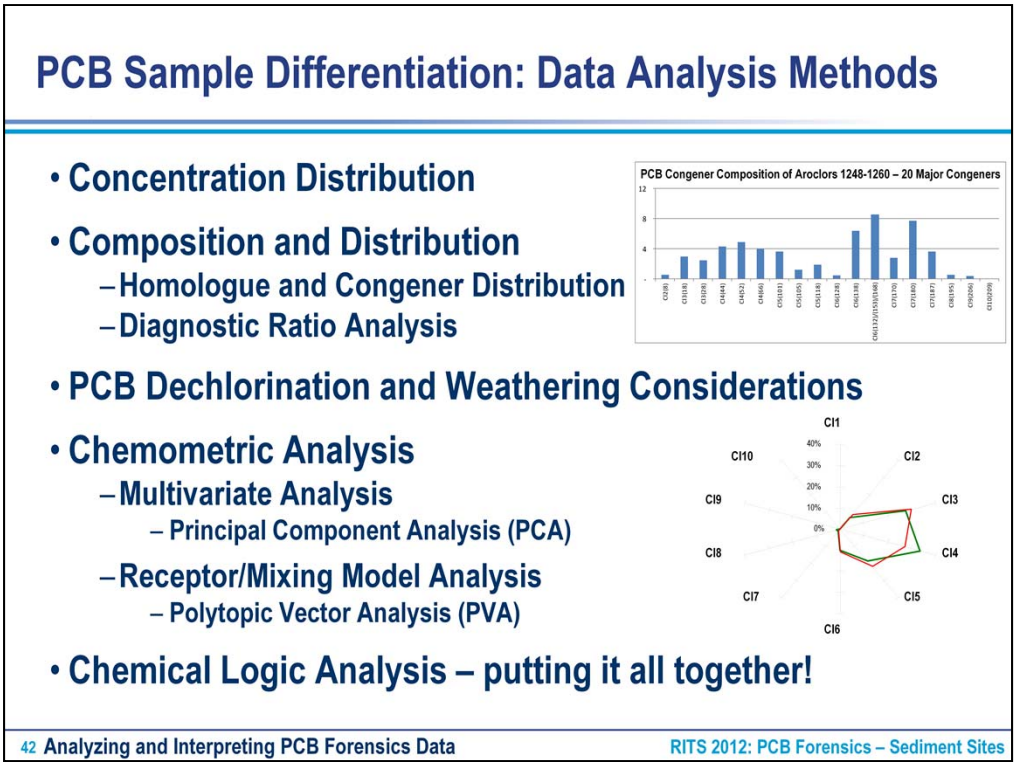
Records Research: History of the Site and Area

- **Review information on the site history and history of the surrounding area that may impact site contamination**
  - Past site investigation reports and data
  - Records of industry, site activities, processes, waste handling; interview workers
  - History of topography, drainage and physical changes at the site
  - Same for off-site surrounding area; local offices; aerial photos

- The importance of Records Research – understanding the history of the site, surrounding area, and making use of historical studies – cannot be overstated.
- Records Research can significantly help in the process towards identifying potential sources, and identify information gaps that needs to be filled; to help develop the CSM and SAP.



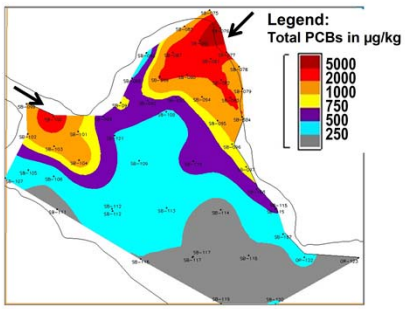
- Understanding the contaminant transport and sediment stability is critical to understanding the processes at a site, and to associate sediment contamination with potential sources.

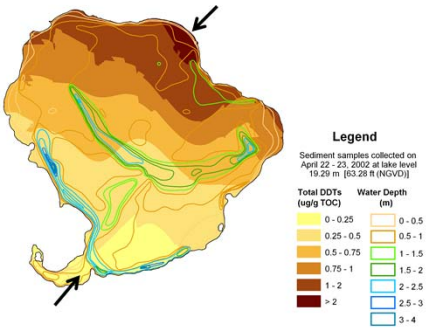


- There are multiple ways the PCB data can, and should be, analyzed to identify and differentiate possible PCB sources; to identify differences and similarities in the PCB contamination in a set of environmental samples.
- No one data analysis method alone should be sufficient, and an Environmental Chemist must be able to explain the results from the data analysis from a “chemistry logic” perspective; the PCB contamination and source findings must be clearly explainable.
- The chemometric analyses are generally a very important part of the forensic interpretation, but they are sometimes given too much weight; it is a key part of the evidence, and multiple lines of evidence should be compiled for a compelling investigation.

Concentration Distribution

- **Mapping the PCB concentration across a site is a first step to understand the issue, and refine the investigation**
  - **Based on RSC/Immunoassay or other Total PCB data**
  - **Combine with records research and contaminant transport**
  - **Use to select samples for ACF**



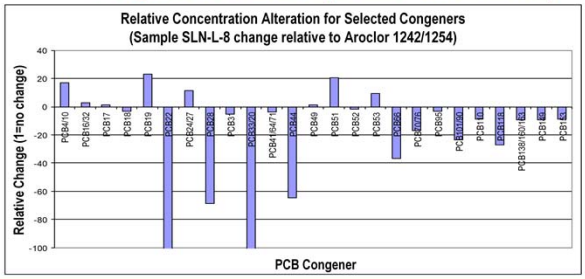


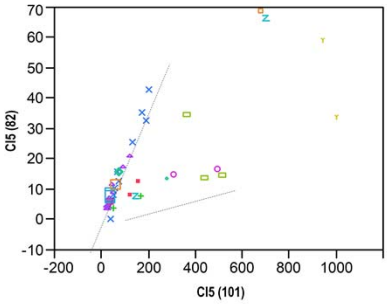
43 Analyzing and Interpreting PCB Forensics Data RITS 2012: PCB Forensics – Sediment Sites

- A review of the PCB concentration distribution at the site is generally the first step in reviewing the PCB data in the EF investigation.
- Concentration gradients in Example 1 suggests input/discharge streams from both sides may contribute contamination, but Example 2 suggests only from one side even though there too there are two sources of runoff/water input to the larger water body.

Composition and Distribution

- **PCB composition of Aroclors is well documented. Changes due to comingling and weathering need to then be factored in to the interpretation.**
  - **Based on ACF (detailed congener) data**
  - **Homologue and congener composition**
  - **Diagnostic ratios (stable and labile)**



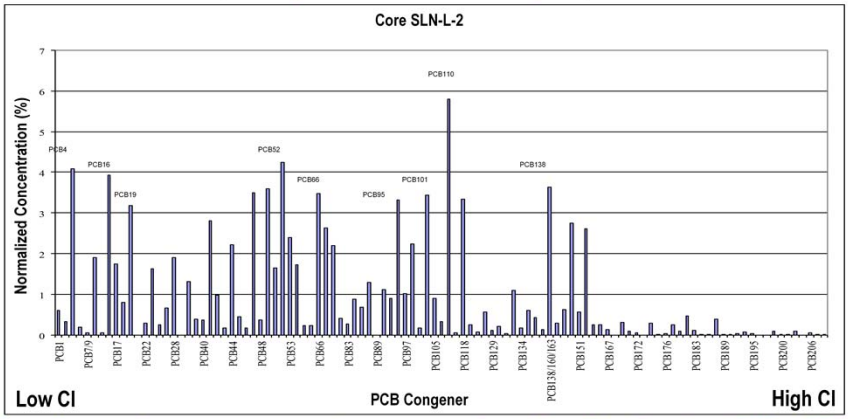


44 Analyzing and Interpreting PCB Forensics Data RITS 2012: PCB Forensics – Sediment Sites

- A review of the PCB composition of the samples from different parts of the site is generally the second step in reviewing the PCB data in the EF investigation.
- Composition differences may relate to the geographic differences and/or concentration differences (e.g., proximity to and/or associated with different sources).

Composition and Distribution (cont.)

Aroclor 1242 + 1254, or Aroclor 1248?
"Center-of-Gravity" of PCB Distribution suggests Aroclor 1248
(i.e., may be identified as such by lab)



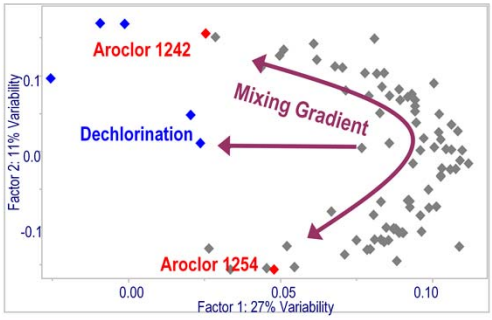
Key diagnostic congeners, and congener ratios, identified Aroclor 1242 + 1254 as source material. This was later linked to the source of the contamination.

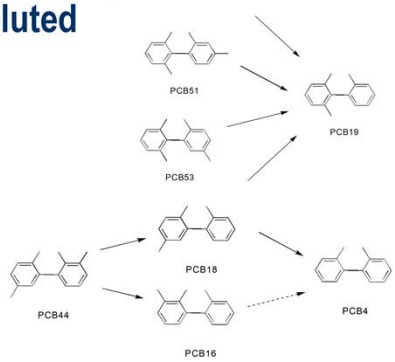
45 Analyzing and Interpreting PCB Forensics Data RITS 2012: PCB Forensics – Sediment Sites

- Some PCB composition requires detailed PCB chemistry understanding and interpretation to decipher PCB source material contributions that may, at first glance, not be obvious.

PCB Dechlorination and Weathering Considerations

- **Compositional changes due to physical factors (dissolution, adsorption) are minor and can be predictable**
- **Composition changes due to dechlorination are less predictable, but common dechlorination patterns have been documented and may be deconvoluted**





46 Analyzing and Interpreting PCB Forensics Data RITS 2012: PCB Forensics – Sediment Sites

- Some PCB dechlorination is one of the most important environmental transformation processes to consider when reviewing and interpretation PCB data, to decipher PCB source material contributions that may, at first glance, not be obvious. Environmental transformation of the PCB composition must be considered when interpreting the compositional information, and when linking to source composition.

Chemometric Analysis of PCB Data

- Multivariate Analysis
- Receptor/Mixing Model Analysis
- Comprehensive Quality Review of the Data Before Use
  - Were DQOs met?
  - Sample(s) with high % non detects
  - Analyte(s) with high % non detect (concentrations vs. detection limit)
  - Analyte(s) with high % composition variability
  - Outlier analysis (is there a chemistry explanation?)
- Pare down samples and analytes (congeners) to those with high degree of confidence
  - Not uncommon to eliminate 10-25% of samples and congeners before proceeding with data analysis

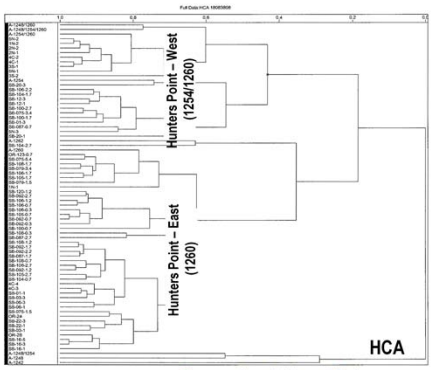
Chemometric, and other methods, are described in the PCB Handbook

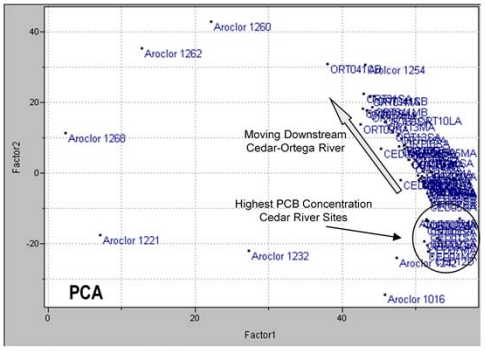
47 Analyzing and Interpreting PCB Forensics Data RITS 2012: PCB Forensics – Sediment Sites

- Chemometric analysis of the PCB data is one of the most important, and often one of the last, steps in interpreting PCB data in the EF investigation.
- Several chemometric method exist, and it is critical to carefully review the dataset to ensure there is a high level of quality and representativeness in the data before embarking on the chemometric analysis.
- It is important to include a PCB Environmental Chemist in the data review and screening process, to ensure that representative data are used.
- All of this is discussed in more detail in the PCB Handbook.

Multivariate Analysis (classification analysis)

- Principal Component Analysis (PCA)
- Hierarchical Cluster Analysis (HCA)
- Soft Independent Modeling by Class Analogy (SIMCA)

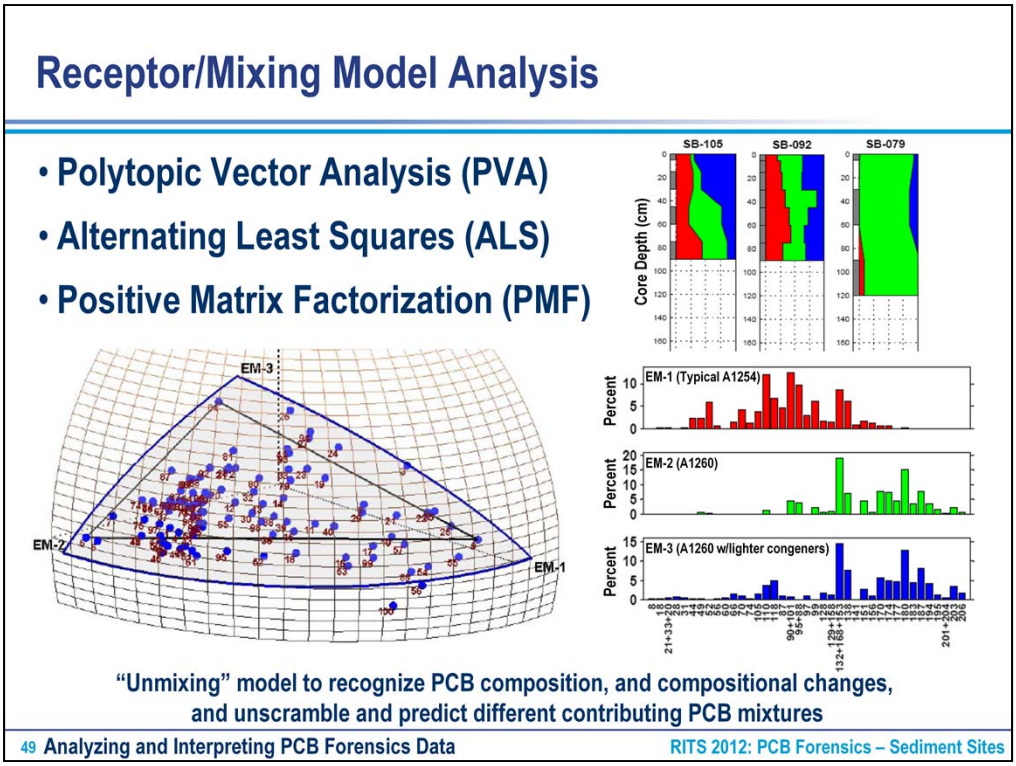




Grouping/classifying samples with similar PCB composition

48 Analyzing and Interpreting PCB Forensics Data RITS 2012: PCB Forensics – Sediment Sites

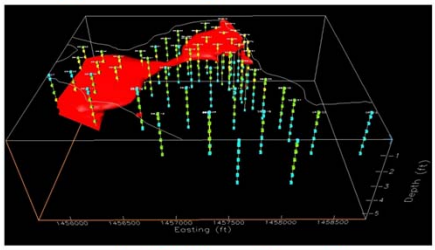
- Multivariate analysis methods are useful for classifying samples by PCB compositional similarity and dissimilarity (i.e., potential source association).
- The various multivariate and other data analyses methods are discussed in more detail in the PCB Handbook, and will be shown more in the Case Studies.



- Receptor/mixing model analysis methods are useful for classifying samples by PCB compositional similarity and dissimilarity (i.e., potential source association), and also determine additional unique compositional characteristics in the dataset (e.g., dechlorination in a set of samples or differences in source contributions over time) and the relative contribution of multiple sources.

Chemical Logic Analysis – Putting it All Together

- **Source identification and allocation requires the use of *multiple lines of evidence*, often requiring multiple technical area experts. Can the findings be supported by:**
  - **Site/contamination history?**
  - **Contaminant/sediment transport?**
  - **Contaminant concentrations?**
  - **Contaminant composition?**
  - **Statistical analyses?**



(No statistical analysis alone will tell you how many sources, and which/where, they are!)

Can the results be explained by accepted environmental chemistry concepts?

50 Analyzing and Interpreting PCB Forensics Data RITS 2012: PCB Forensics – Sediment Sites

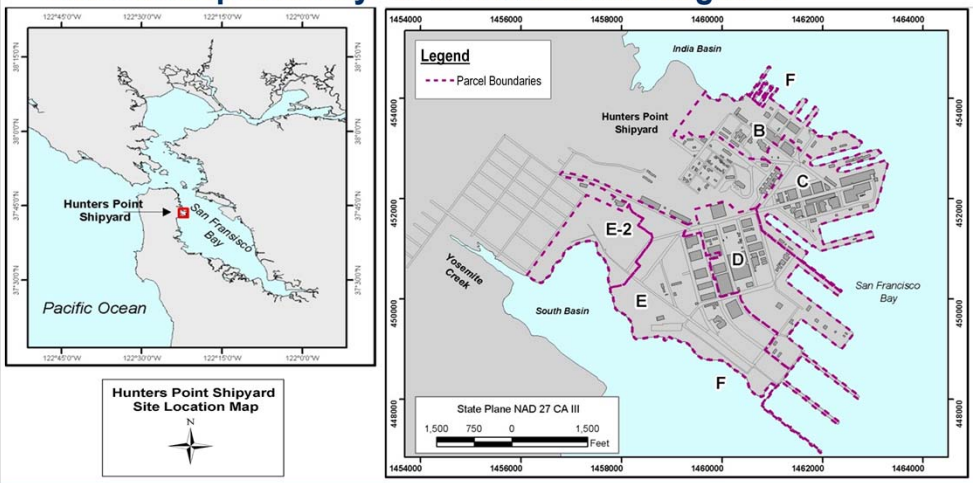
- Environmental Forensics ("fingerprinting") needs to consider all these factors, and it must be explainable with chemistry logic.
- It is important to not give one approach/tool too much emphasis, as sometimes is the case with chemometric/statistical methods.

Presentation Overview

- Basics of Environmental Forensics
- Evaluate the Study Site and Project Planning
- Generating Data for PCB Forensics
- Analyzing and Interpreting PCB Forensics Data
- ► Case Studies
  - Hunters Point Shipyard (San Francisco Bay, CA)
  - Ashtabula River (Ashtabula, OH)
- Summary

Hunters Point Shipyard (San Francisco Bay, CA)

- **Case studies are based on available data; data were *not* collected specifically for a forensic investigation**

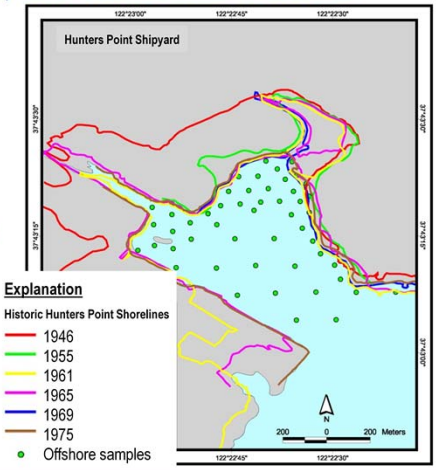


52 Case Studies – Hunters Point Shipyard RITS 2012: PCB Forensics – Sediment Sites

- This case studies will illustrate the potential relevance of EF to RPMs.
- The Navy facility Hunters Point Shipyard, in San Francisco Bay, is the first case study.
- The sediments in South Basin have potentially been contaminated by runoff from the Navy property (e.g., landfill and drainage ditch) and historic CSOs around South Basin and in Yosemite Creek. Some of these sources have been active until recently.

Site History

- Site *History* suggests a Navy landfill may be a source of PCB to South Basin (SB) sediment, and that other sources may exist
  - Runoff and filled in Creek/Slough from Navy property on East side of SB may have carried PCB into SB
  - Historical CSOs on West side of SB were active for many years, and may also have carried PCB into SB

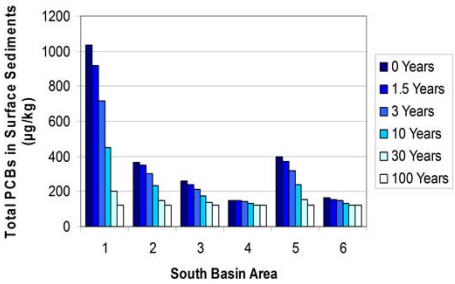


53 Case Studies – Hunters Point Shipyard RITS 2012: PCB Forensics – Sediment Sites

- The historical information indicates that the South Basin sediments could have been contaminated by sources all around the Basin.
- CSO: Combined sewer overflow

Sediment/Contaminant Transport

- Site *Sediment/Contaminant* transport characteristics are relatively uniform and predictable
  - Sediment deposition and erosion is similar across South Basin
    - Dated cores show ~ 1 cm/yr deposition
  - Currents, wave action, and re-suspension is similar across South Basin



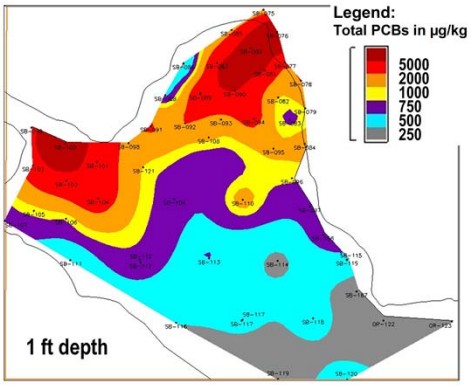
  - South Basin hydrodynamics and contaminant transport data suggest that contaminants from the East and West side of South Basin would deposit and be distributed in a fairly predictable and uniform way across South Basin

54 Case Studies – Hunters Point Shipyard RITS 2012: PCB Forensics – Sediment Sites

- The sediment/contaminant transport and stability information indicates that the contamination would be predictably distributed away from sources in the South Basin sediments.
- The sediment deposition information also supports this, through sediment (core) age dating which indicated uniform depositional characteristics.

PCB Concentration

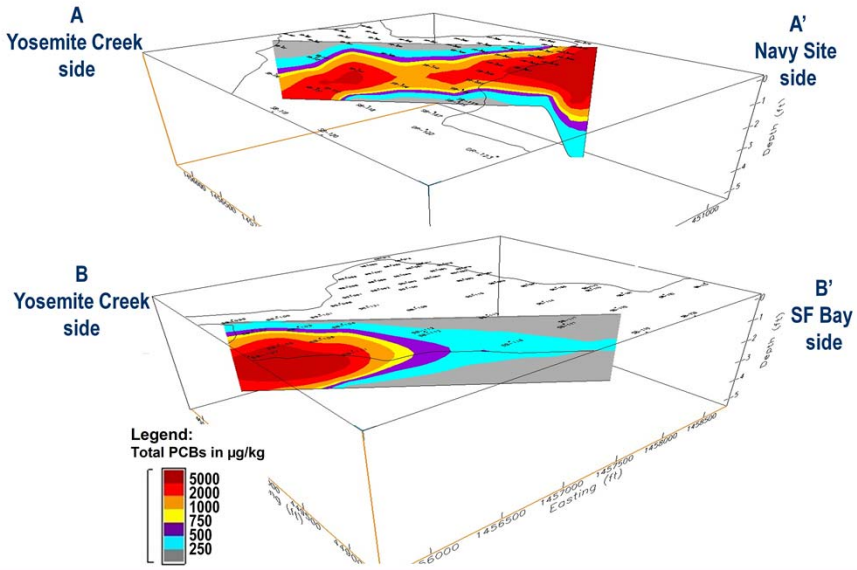
- Site *PCB Concentration* distribution suggests the presence of two general source areas
  - Elevated PCB concentrations were observed on the East and West sides of South Basin
  - Logical mixing zones were observed
  - PCB concentrations on the West side were highest from 1 to 3 ft depth
  - PCB concentrations on the East side were high from the surface to about 1 ft depth

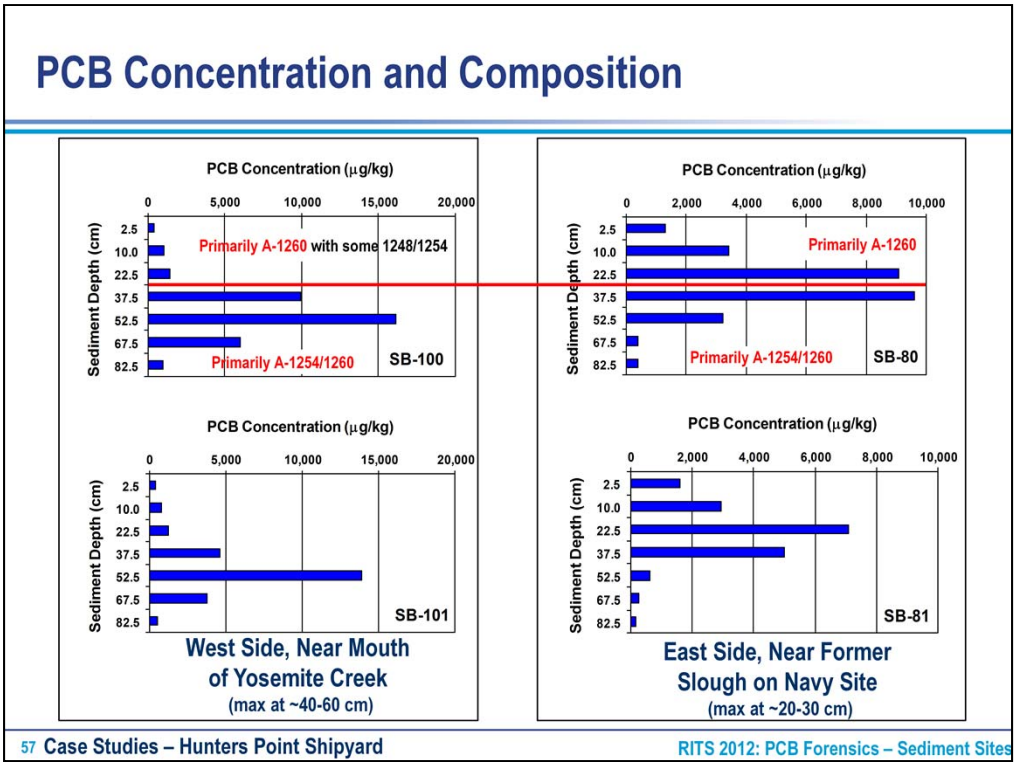


55 Case Studies – Hunters Point Shipyard RITS 2012: PCB Forensics – Sediment Sites

- The PCB concentration information suggests that there may have been two general source areas for the contamination, and that the West side source was more active historically (i.e., in past decades) and the East side source more active recently (i.e., in recent decades).

PCB Concentration (cont.)

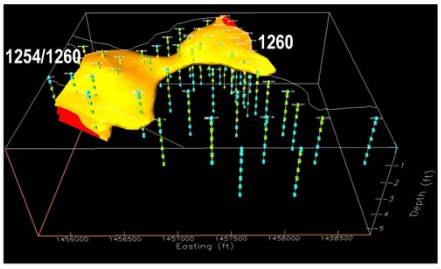




- The PCB concentration and composition information suggests that there may have been two general source areas for the contamination, and that the West side source was more active historically and different (due to PCB compositional differences and geographic separation) from the more recent East side source.

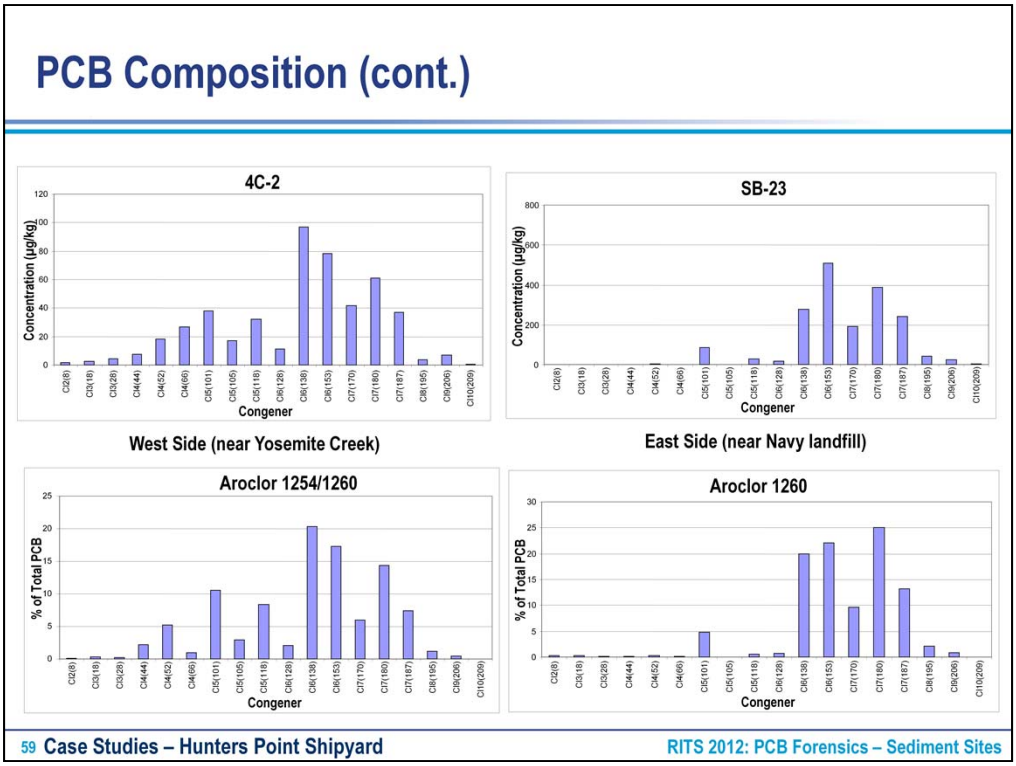
PCB Composition

- Site *PCB Composition* distribution suggests the presence of two general source areas – East and West side sources
  - The PCB composition of the high [PCB] sediments from the East (Navy) side is indicative of primarily Aroclor 1260
  - The high [PCB] from the West side is different, and a mixture of Aroclors 1254/1260; the common urban "blend"
  - The surface sediments show mainly an Aroclor 1260 signature, with some light PCB congeners (e.g., 1254/1248) mixed in (mostly West side)



58 Case Studies – Hunters Point Shipyard RITS 2012: PCB Forensics – Sediment Sites

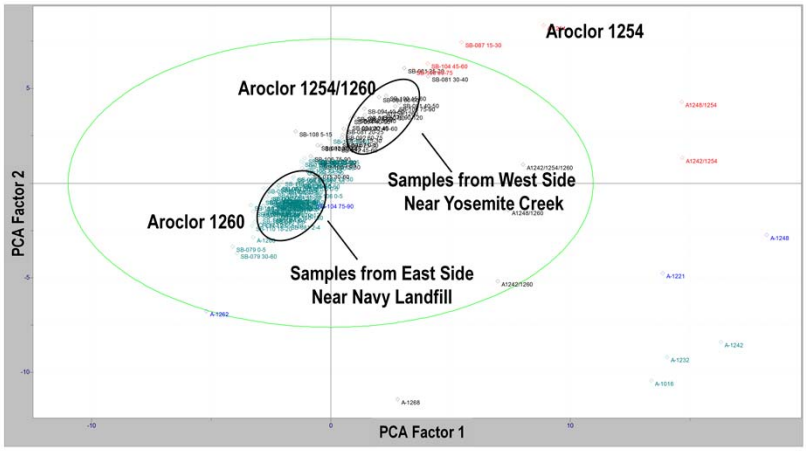
- The PCB composition information suggests that there may have been two general source areas for the contamination
  - The West side source appears to have been a combination of the common urban Aroclor 1254/1260 mixture, possibly from multiple original sources (e.g., CSO runoff).
  - The East side source appears to have been dominated by Aroclor 1260, and thus a more individual use and property.



- The PCB composition information indicates the presence of West and East side primary sources.

PCB Chemometrics

- Site *PCA/Cluster Analyses* suggest the presence of two general source areas, and a mixing zone in between

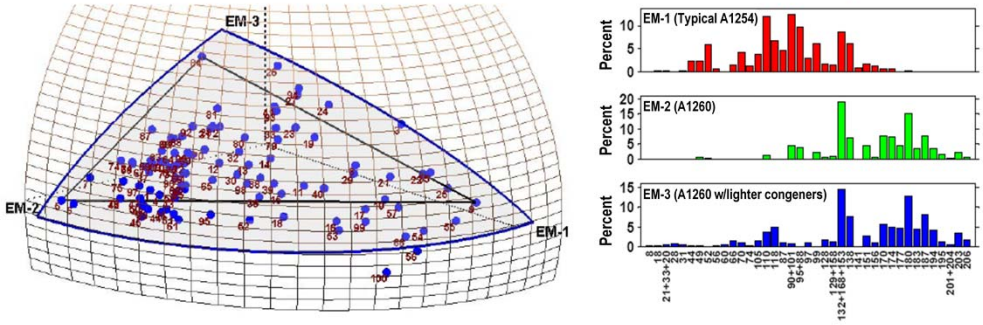


60 Case Studies – Hunters Point Shipyard RITS 2012: PCB Forensics – Sediment Sites

- PCA groups samples of similar chemical composition (***relative*** PCB congener concentrations), and separates those that are dissimilar.
- The PCA analysis indicates compositional similarities in samples from the West side (and with Aroclors 1254/1260) and separately similarities in samples from the East side (and Aroclor 1260).
- These results suggest the presence of two primary sources of the PCB contamination; one on the West and one on the East side.

PCB Chemometrics (cont.)

- **Site *PVA Model* begins by using PCA to find the number of endmember PCB compositions, then fits a geometric shape (here a triangle for 3 endmembers) around the data points to estimate the mixture of endmembers at each data point**

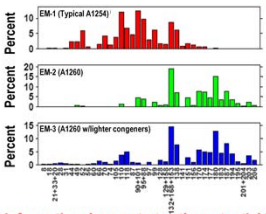


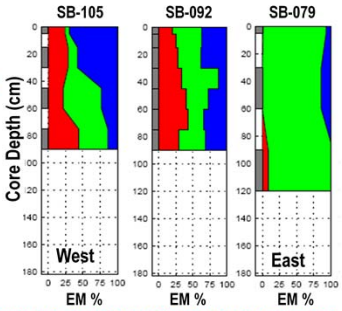
Detailed ***3-D*** PCA (and PVA) analysis suggested the presence of a third ***compositional pattern*** in the dataset (Aroclor 1260 with small contributions from some lower molecular weight congeners), which may be contributions from a different PCB material or the result of dechlorination (but ***not*** likely a third source).

- PVA groups samples of similar chemical composition (***relative*** PCB congener concentrations), and separates those that are dissimilar, identifies compositional differences in the dataset that may be due to environmental processes, and attempts to approximate relative contributions.
- The PVA analysis indicates PCB compositional similarities in samples from the West side (and with Aroclors 1254/1260) and separately similarities in samples from the East side (and Aroclor 1260). It also identifies recent low concentration contributions of a lower molecular weight Aroclor in the surface sediment

PCB Chemometrics (cont.)

- **Site *PVA Model* Analyses indicate the presence of three types of PCB mixtures in the sediments. These are *not* necessarily, and *not* likely, 3 unique sources.**
  - Aroclor 1260 type PCB that contributes the most in the near-surface sediments on the East (Navy) side of South Basin
  - Aroclor 1254 and 1260 type PCB that dominates the deeper sediments on the West (Yosemite Creek) side of South Basin
    (and in deep, low concentration, sediment on the East side)
  - A surface mix of 1260 with some lighter congeners



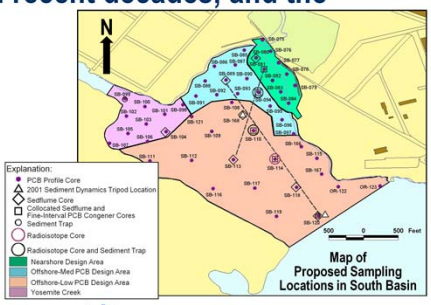


The third "end member" information demonstrates the potential for confounding chemometric analysis, and the need for cautious interpretation.

- The PVA results suggest the presence of two primary sources of the PCB contamination; one on the West and one on the East side.
- The PVA results indicate that the East side source has contributed the majority of the PCB contamination in recent decades (including some to the sediments on the West side), and that the West side source(s) contributed the majority of the PCB contamination in prior decades (including some to the deeper/historic sediments on the East side).

Hunters Point Shipyard – Summary

- Multiple Lines of Evidence indicate there are two general source areas that have contributed the majority of the PCBs in the sediments of South Basin. The Navy site mainly in recent decades, and the West side sources mainly earlier.
- The History supports it
- The Contaminant Transport supports it
- The PCB Concentrations support it
- The PCB Composition supports it
- The Statistical/Chemometric Analyses support it
- The Environmental Chemistry Considerations support it



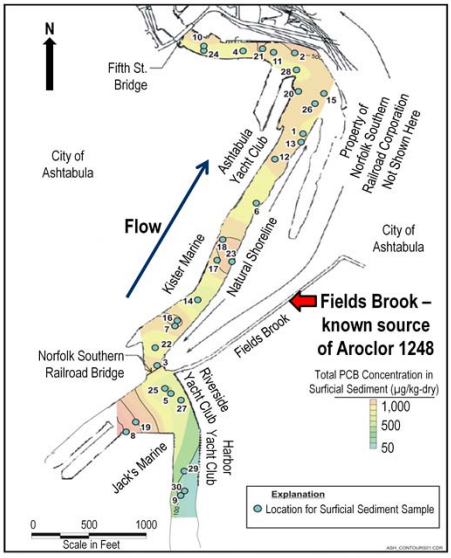
63 Case Studies – Hunters Point Shipyard RITS 2012: PCB Forensics – Sediment Sites

- The multiple lines of evidence supports the conclusions that two primary sources have contributed the majority of the PCB contamination in South Basin; one source on the West (in/near Yosemite Creek) and one on the East side (Navy property).

Presentation Overview

- Basics of Environmental Forensics
- Evaluate the Study Site and Project Planning
- Generating Data for PCB Forensics
- Analyzing and Interpreting PCB Forensics Data
- ► Case Studies
  - Hunters Point Shipyard (San Francisco Bay, CA)
  - Ashtabula River (Ashtabula, OH)
- Summary

Project Background



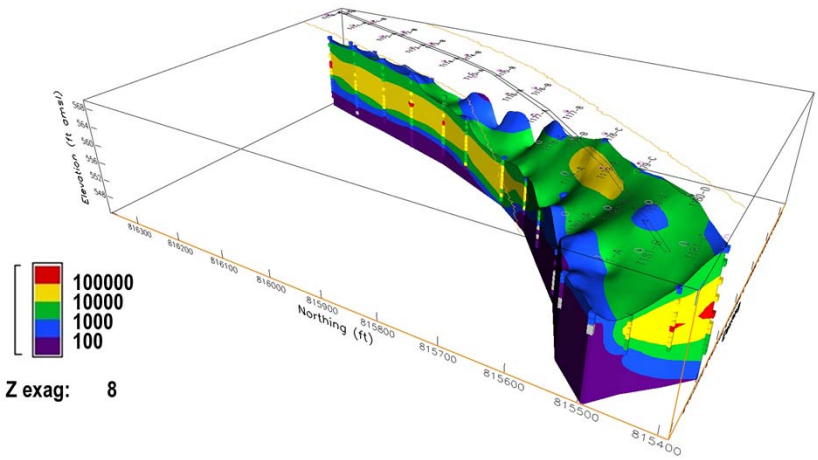
Dredge Residuals Research Project

- Surface sediment data indicated relatively uniform Total PCB concentrations in Main Study Area to be dredged
- 250-500 µg/kg Total PCB in most of surface sediments
- >10,000 µg/kg Total PCB in much of subsurface sediment

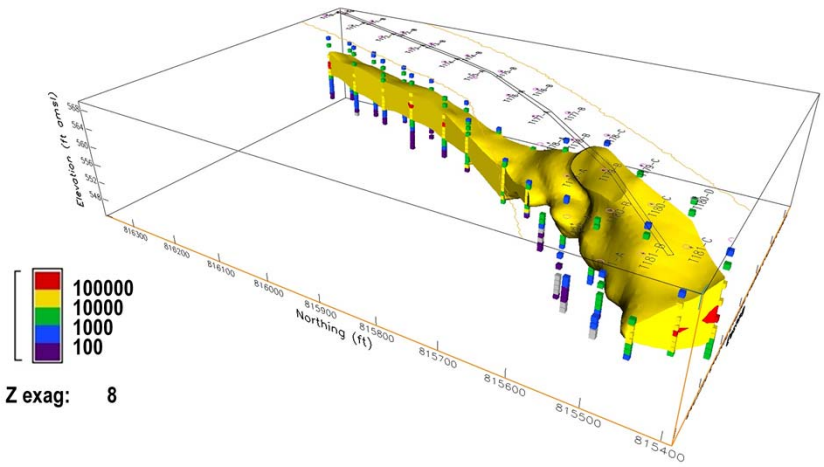
65 Case Studies – Ashtabula River RITS 2012: PCB Forensics – Sediment Sites

- Ashtabula River was a sediment environmental dredging research site with data that were useful for a PCB forensic investigation
- Ashtabula River sediment contamination was mainly at depth, and the PCB concentrations were fairly uniform in most surface sediment.

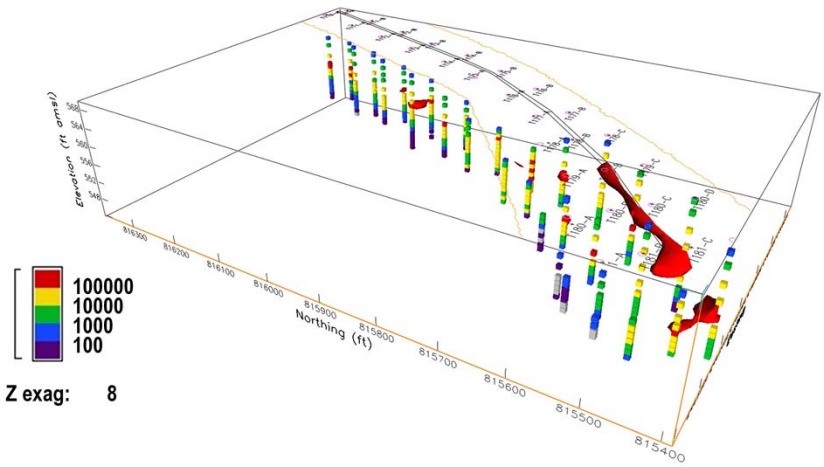
PCB Concentration Model – looking downstream

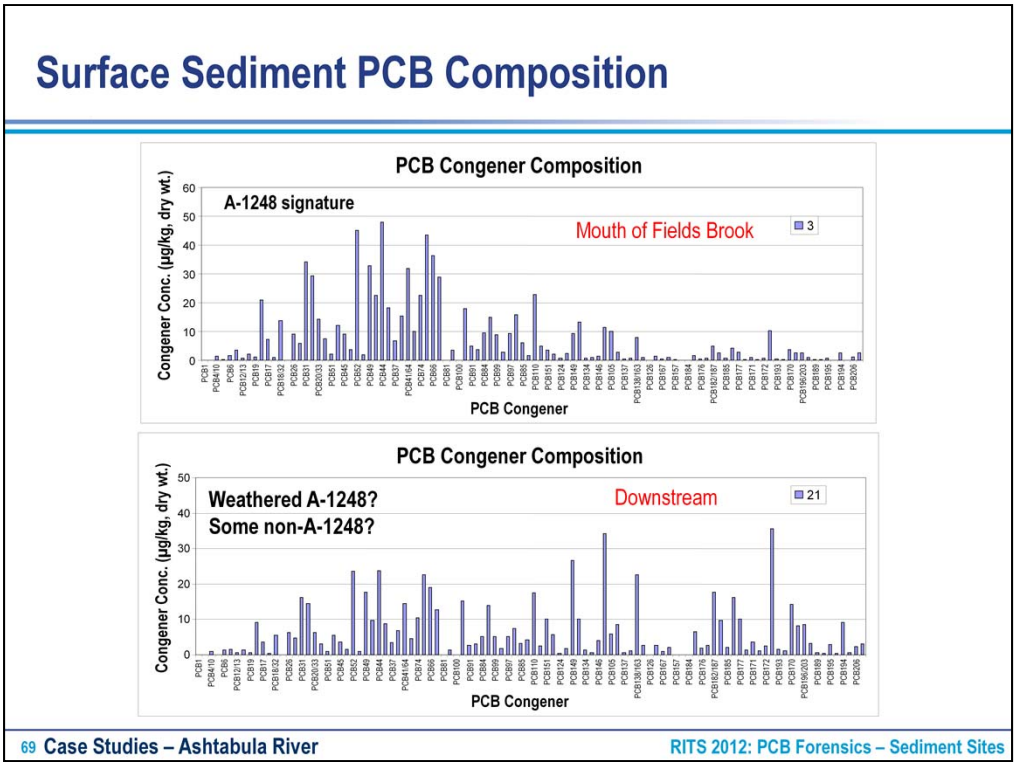


PCB >10,000 µg/kg

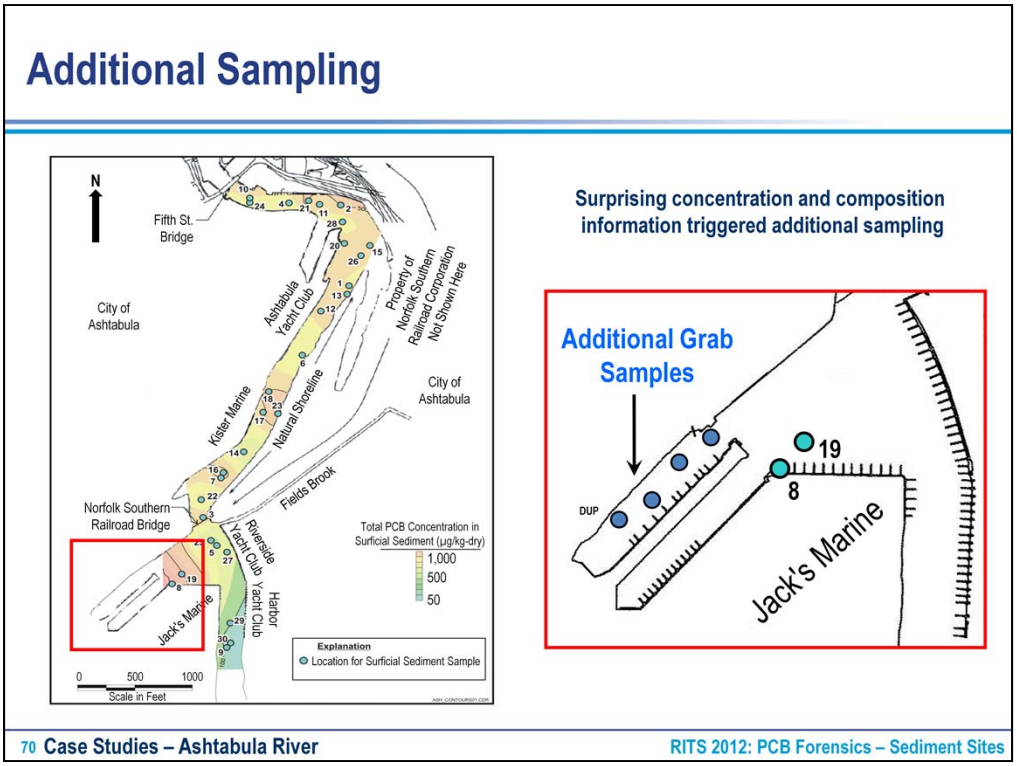


PCB >100,000 µg/kg

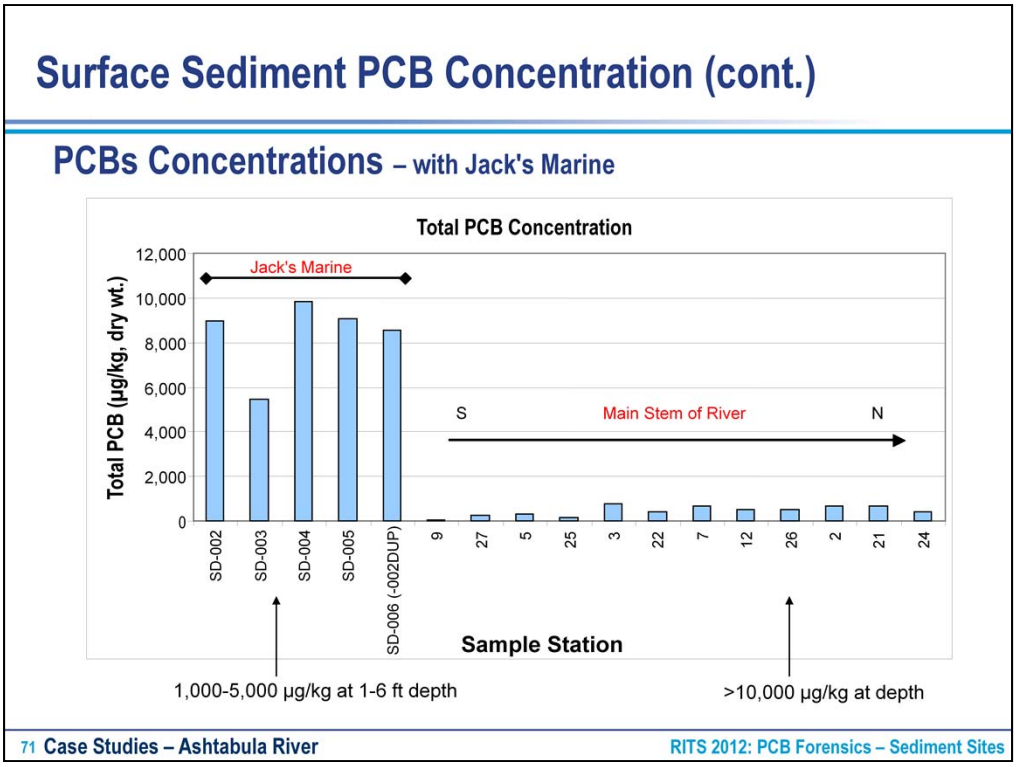




- The PCB composition in the surface sediment near the mouth of Fields Brook resembled the known main Aroclor 1248 source (up Fields Brook) that had been controlled. However, a different, and surprising, PCB composition was observed in the surface sediments a short distance downstream.



- A subtle PCB concentration change in the surface sediment data near Jack's Marine was also surprising, and this, together with the PCB composition observation, triggered additional sampling shortly before dredging was to begin.

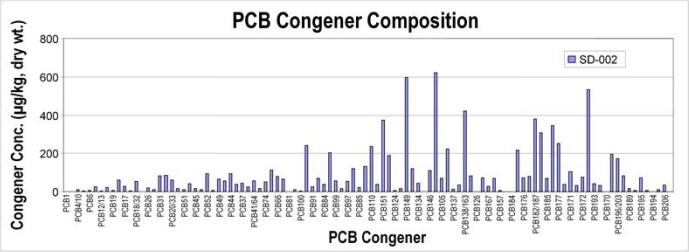


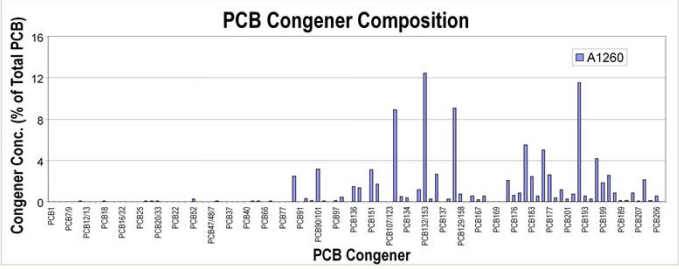
- Significantly elevated PCB concentrations were observed for the Jack's Marine sediment samples, suggesting local input of PCB that could transport downstream to the site to be remediated.

Surface Sediment PCB Composition

Congener Composition – Jack's Marine

Aroclor 1260 dominated signature



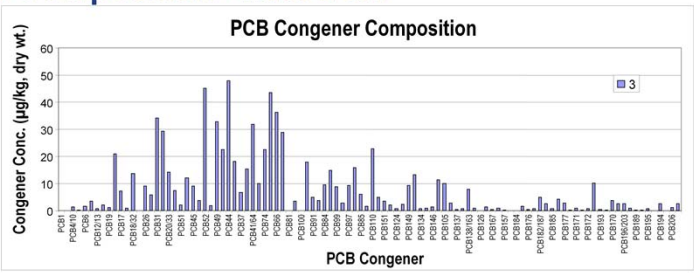


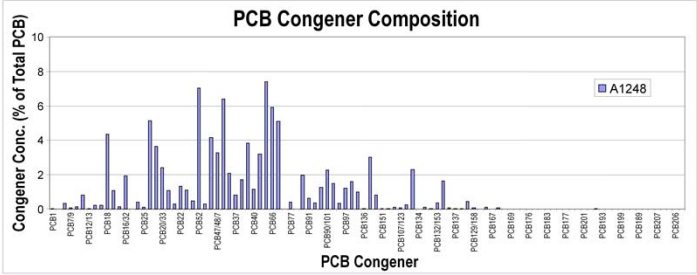
- The samples from Jack's Marine had a unique PCB composition, similar to that of Aroclor 1260.

Surface Sediment PCB Composition (cont.)

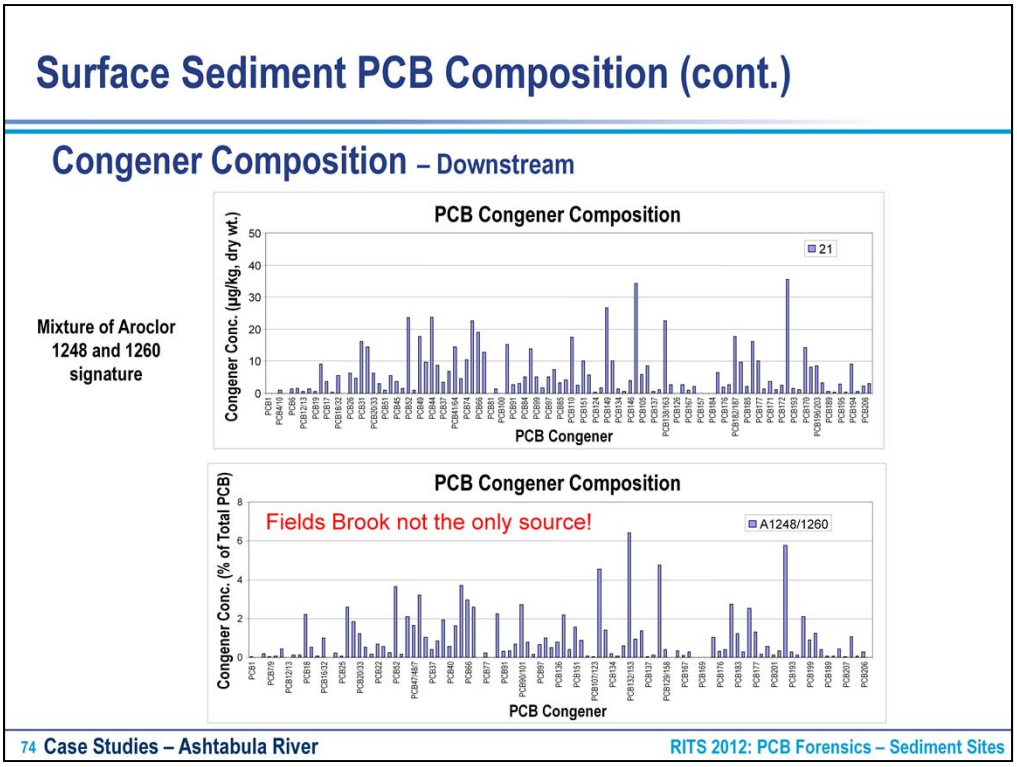
Congener Composition – Fields Brook

Aroclor 1248 dominated signature

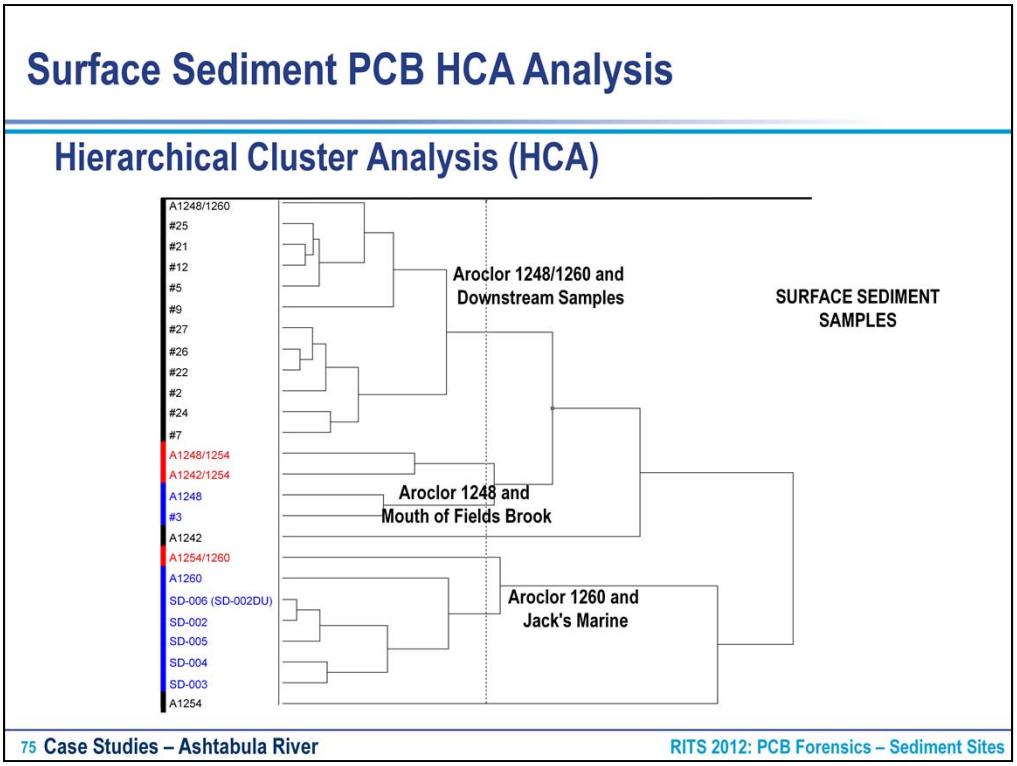




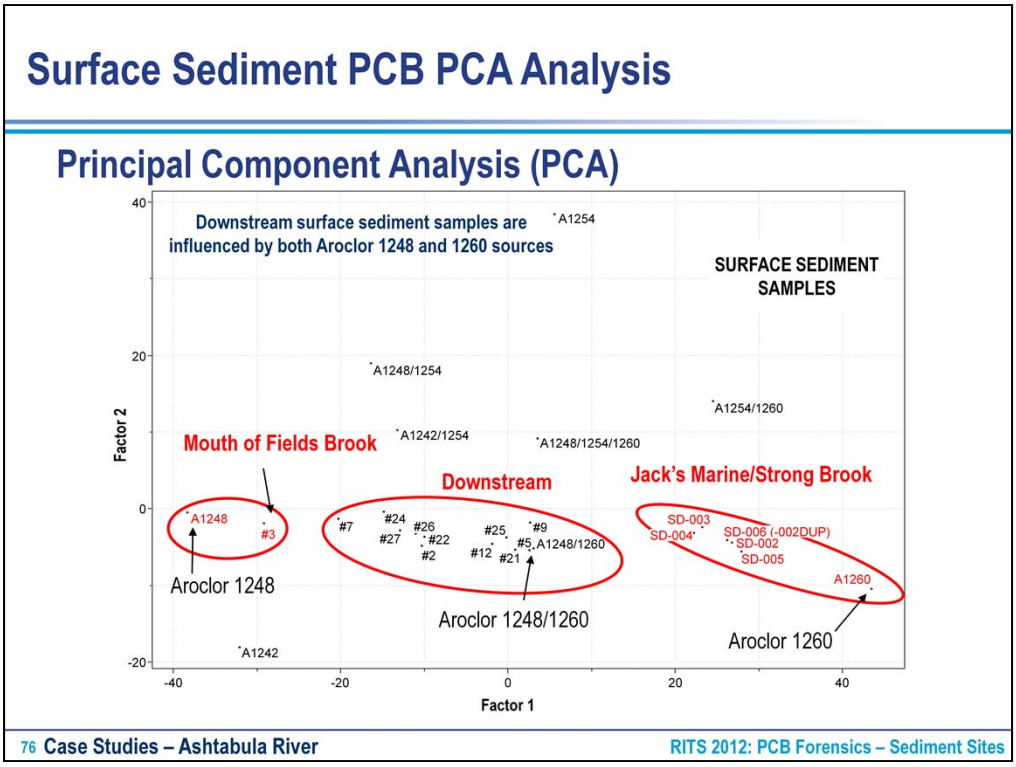
- The samples from the mouth of Fields Brook had a unique PCB composition, similar to that of known Aroclor 1248 source from up this stream.



- The samples from the Ashtabula River downstream of Jack's Marine and Fields Brook had a unique PCB composition, that appeared to be a combination of Aroclors 1260 and Aroclor 1248.



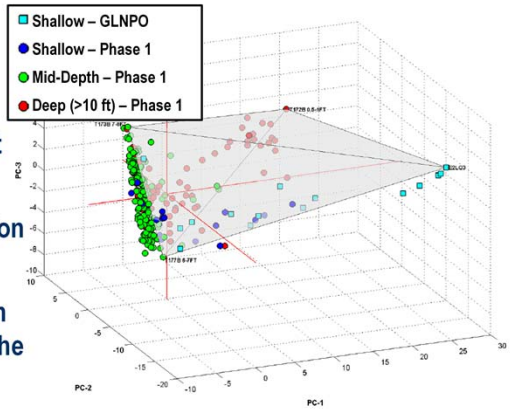
- The HCA analyses on the field samples and Aroclor materials also suggested the presence of an Aroclor 1260-type source at Jacks Marine and some continued contribution of Aroclor 1248 from Fields Brook, and a combination of Aroclors 1260 and 1248 in the samples downstream.



The PCA analyses on the field samples and Aroclor materials also suggested the presence of an Aroclor 1260-type source at Jack's Marine and some continued contribution of Aroclor 1248 from Fields Brook, and a combination of Aroclors 1260 and 1248 in the samples downstream.

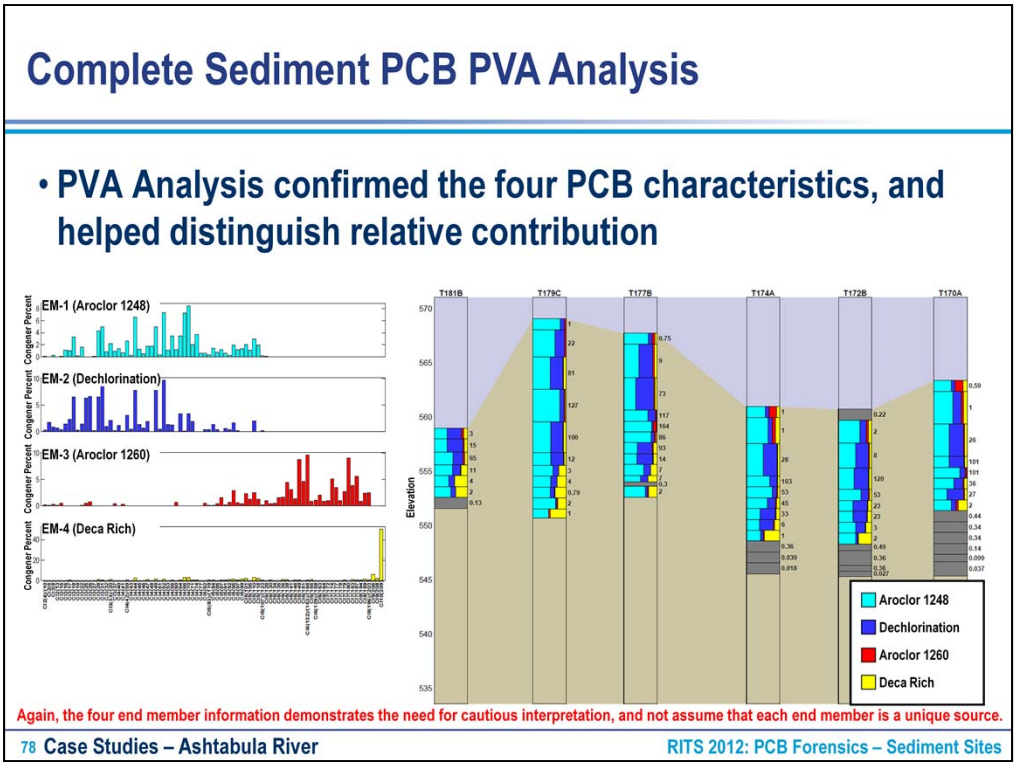
Complete Sediment PCB PCA Analysis

- **Subsequent PCA/PVA Data Analysis of the full sample set revealed four PCB compositional characteristics**
  - Aroclors 1260 in near-surface sediment close to Jack's Marine
  - Aroclor 1248 in the majority, highly contaminated, subsurface, sediment and near-surface sediment close to Fields Brook
  - Aroclor 1248 with some dechlorination in some subsurface sediment
  - Aroclor 1248, with some contribution of highly chlorinated congeners, in the less contaminated deep sediment



77 Case Studies – Ashtabula River RITS 2012: PCB Forensics – Sediment Sites

- The PVA analyses on the field samples and Aroclor materials also suggested the presence of an Aroclor 1260-type source at Jack's Marine and some continued contribution of Aroclor 1248 from Fields Brook.
- The PVA results, using both the surface and subsurface sample data, also identified a PCB compositional subset of samples that exhibited some dechlorination of the subsurface Aroclor 1248 and a subset of deeper/older sediment with small contributions of highly chlorinated PCB material.



- The PVA analyses on the field samples suggested that the Aroclor 1260-type source at Jack's Marine significantly contributed to the relative amount of PCB in the surface sediments; it was an important current and recent source.
- The other PCB compositional characteristics of most sediments, and particularly those below the surface, were primarily associated with the historic Aroclor 1248 sediment contamination.

Ashtabula River – Summary

- Without careful review/analysis of the PCB data, and additional (1) sampling, (2) detailed PCB analysis, and (3) *forensic data interpretation*, dredging might have proceeded with an unknown active source of PCB present, potentially re-contaminating the site
- Instead, a source was identified and addressed in a timely manner

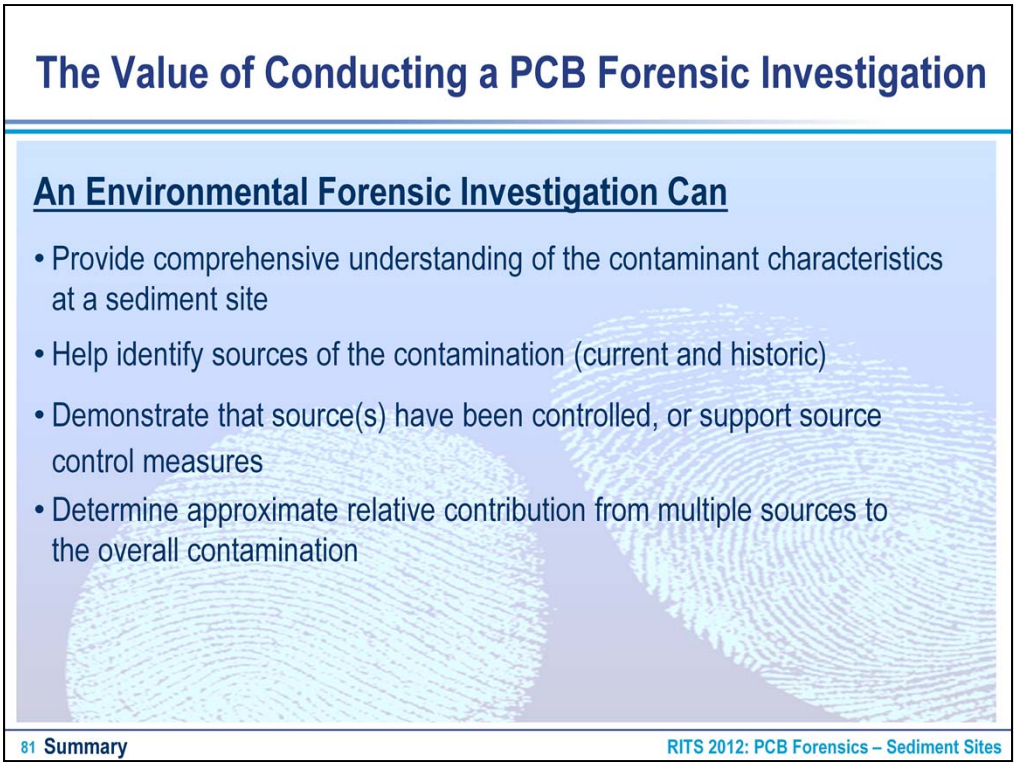
Note: the majority of the PCB in the sub-sediments, and the site as a whole, was from the controlled Aroclor 1248 source.

Source of the Jack's Marine/Strong Brook Aroclor 1260 was Identified and Controlled

- The PCB forensic study was a success by demonstrating that there was an active source of contamination to the sediments, that sources were NOT controlled, and identified the location of the active source.
- The Strong Brook upstream source was subsequently identified, controlled, and the sediment remedy proceeded.

Presentation Overview

- Basics of Environmental Forensics
- Establishing the Study Site and Planning
- Generating Data for PCB Forensics
- Analyzing and Interpreting PCB Forensics Data
- Case Studies
- ► Summary



- An Environmental Forensic study can be a very valuable component of an effective sediment management plan, by:
  - Ensuring understanding of the contaminant source characteristics at a site, including their locations and relative contributions, and demonstrate that sources have been controlled (or not, and ensure that they are).
  - Generating information to share sediment management costs with PRPs
- An Environmental Forensics study must be based on a multifaceted team approach, using multiple lines of evidence
- What are your barriers to conduct an Environmental Forensic study?

References: Navy Handbook on PCB Forensics

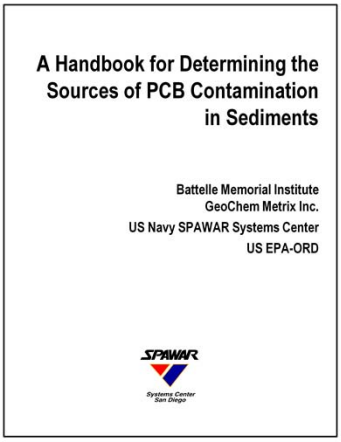
A Handbook for Determining the Sources of PCB Contamination in Sediments

(expected Summer 2012)

Battelle Memorial Institute
GeoChem Metrix Inc.
US Navy SPAWAR Systems Center
US EPA-ORD

Based on ESTCP Project ER-0826

Integrated Forensics Approach to Fingerprint PCB Sources using Rapid Sediment Characterization (RSC) and Advanced Chemical Fingerprinting (ACF)

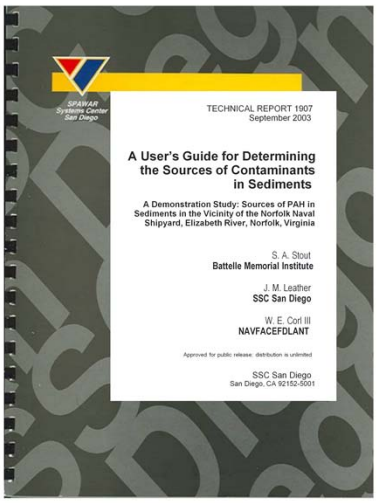


References: Other

- **A User's Guide for Determining the Sources of Contaminants in Sediments (focused on PAH)**

Technical Report 1907, September 2003

Battelle Memorial Institute
US Navy SPAWAR Systems Center
NAVFAC EFDLANT



References: Other

NAVFAC Environmental Restoration Technology Transfer (ERT2) Web Page:

- **Polychlorinated Biphenyls (PCB) Tool**
- **Chemical Fingerprinting Tool**

General PCB Information is available on EPA's website