Conceptual Model of Primary Mercury Sources, Transport Pathways, and Flux at an Industrial Facility in Oak Ridge, Tennessee

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BACKGROUND

- **Releases of mercury during operations at the Y-12 National Security Complex during the 1950s and early 1960s resulted in contamination of soil and groundwater within the facility, and subsequent transport from these sources resulted in contamination of East Fork Poplar Creek (EFPC).**
- **Remediation efforts, which began in the 1980s, have reduced waterborne mercury concentrations both within the Y-12 facility and in the EFPC ecosystem, but elevated levels of mercury remain in the soil, sediment, water, and biota.**
- **The processes that control the fate and transport of mercury near the facility are extremely complex, and the hydrological, geochemical, and microbial interactions between the subsurface and surface water systems are not well understood.**
- **It has been 10 years since conceptual models were used to evaluate mercury flux and the potential reductions associated with source control actions. Some of the underlying assumptions that went into CERCLA decision making appeared to have changed.**
- **For effective environmental management and site closure decision making relative to mercury contamination at the Y-12 Complex, an updated conceptual model of the facility's mercury source areas, processes, likely flow paths, and flux into the creek was deemed needed.**

Y-12 National Security Complex, Oak Ridge, Tennessee

GOALS OF CONCEPTUAL MODEL

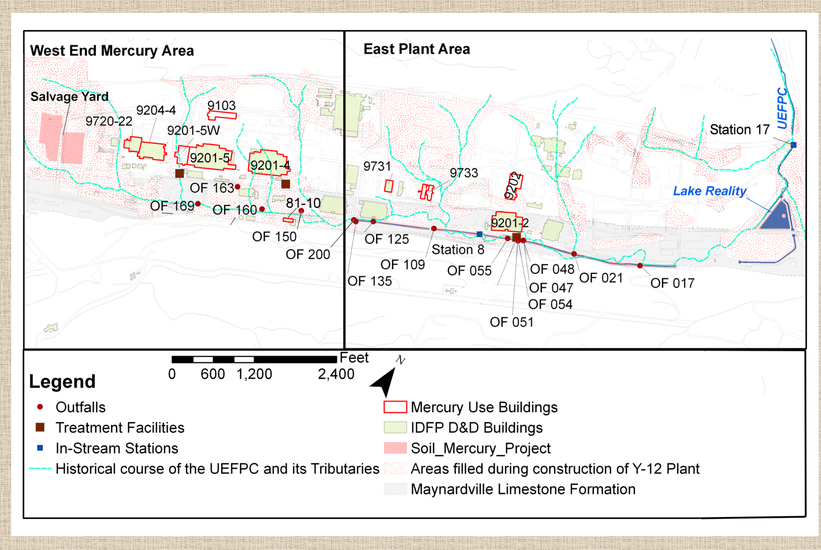
- **A conceptual model of mercury flux from the site was developed to assist in environmental management decisions and in mitigating the impacts of mercury on the surrounding environment.**
- **Key goals of the model were to help in prioritization of further remedial actions, development of numerical modeling efforts, and in defining research needs.**
- **Importantly, conceptual models can provide clarity in understanding limited or complex data, and can help convey uncertainty and data gaps.**

MODEL DEVELOPMENT

- **To develop the current model, a multi-organizational team reviewed existing conceptual models from a variety of sources, consolidated historical data and source information, gathered input from staff members with extensive site knowledge, and used recent mercury flux data from a variety of sampling programs.**
- **The following structured process was used to develop the conceptual model:**

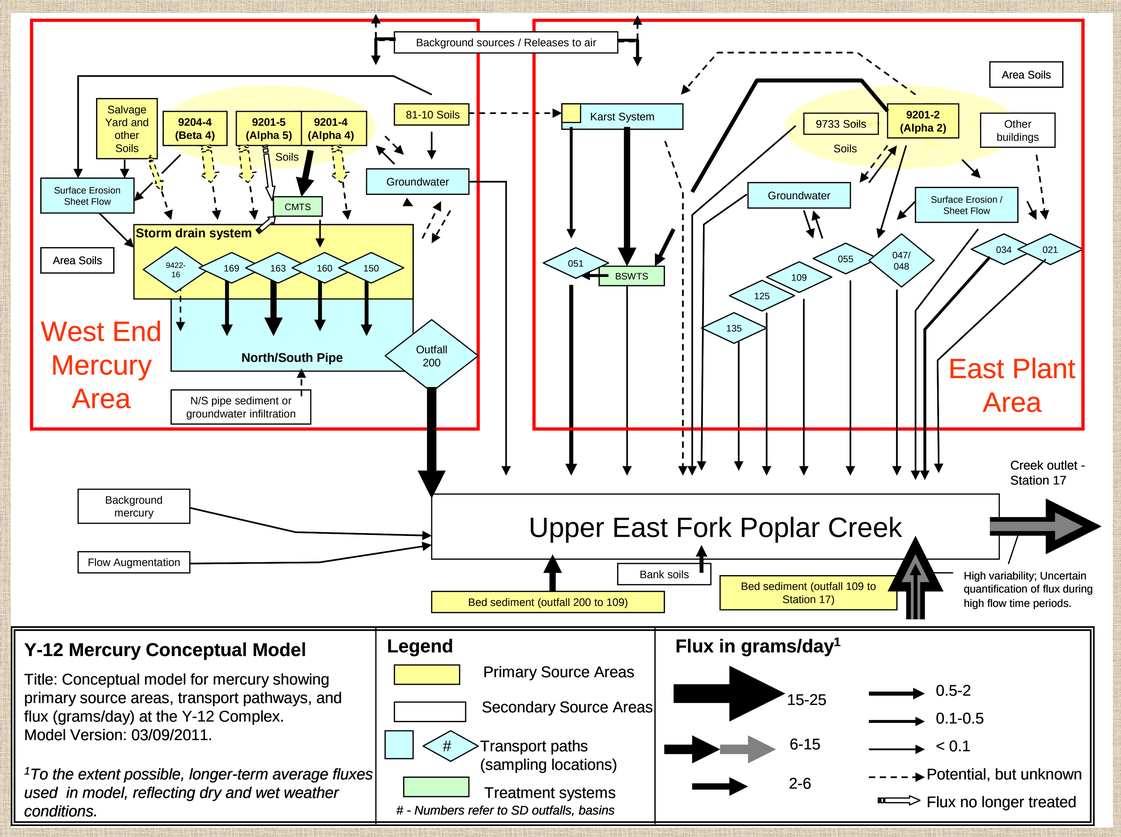
1. **define the goals and objectives;**
2. **delineate the spatial and temporal scales and boundaries for the model;**
3. **discuss sources of information, data, current knowledge, and existing conceptual models;**
4. **describe both primary and secondary sources of mercury;**
5. **identify the primary and secondary diffuse sources of mercury;**
6. **describe mechanisms, flow paths, and routes of exposure;**
7. **develop and refine the graphic conceptual model; and**
8. **identify technical uncertainties and opportunities for further work.**

- **In addition to tables listing the historical flux data from storm drains and other sites, the model development team developed a number of diagrams and depictions to help understand the complex processes at the site.**
- **Useful diagrams generated include spatially explicit maps showing the major mercury-use buildings, outfalls, treatment systems, and transport pathways, and a schematic of the Y-12 Complex's physical features that affect mercury processes and transport.**



Major historical mercury-use infrastructure and transport pathways

MERCURY SOURCES, TRANSPORT PATHWAYS, AND FLUX



Y-12 Mercury Conceptual Model

Title: Conceptual model for mercury showing primary source areas, transport pathways, and flux (grams/day) at the Y-12 Complex.
Model Version: 03/09/2011.

[1]To the extent possible, longer-term average fluxes used in model, reflecting dry and wet weather conditions.

Legend

- Primary Source Areas
- Secondary Source Areas
- # Transport paths (sampling locations)
- Treatment systems

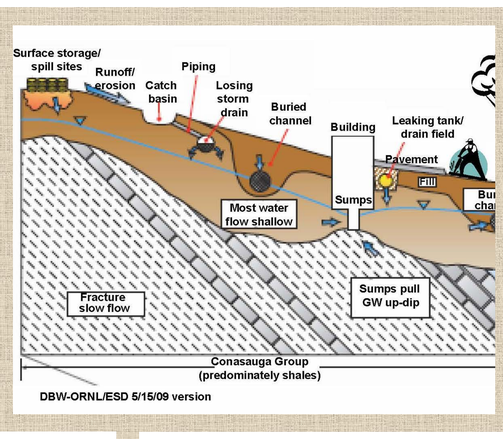
 # - Numbers refer to SD outfalls, basins

Flux in grams/day[1]

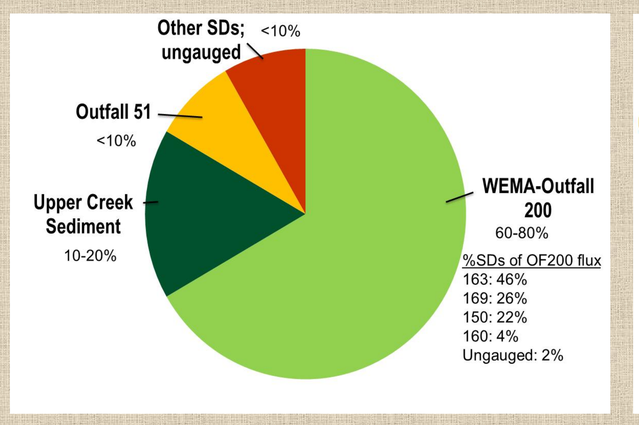
- 15-25
- 6-15
- 2-6
- 0.5-2
- 0.1-0.5
- < 0.1
- Potential, but unknown
- Flux no longer treated

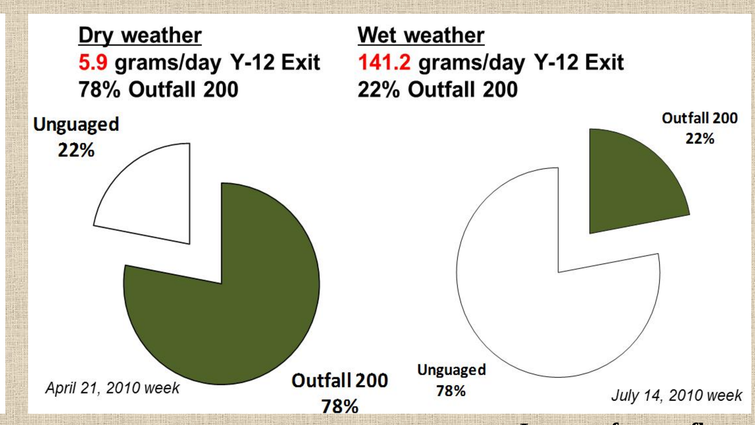
Primary source areas, transport pathways, and flux (g/day) at the Y-12 Complex

Major physical features affecting mercury processes and transport



Flux mass balance, base flow





Impact of storm flow

WEST END MERCURY AREA (WEMA)

- **Primary sources areas include Alpha 4 and 5 buildings, nearby soils, 81-10, and storm drains**
- **Major transport pathway to creek via storm drain system**
- **Storm drains 150, 160, 163, and 169 accounts for most, if not all, of the flux at Outfall 200 under base flow**
- **Storm drain 163 and Outfall 200 flux appears to have increased since 2000 Feasibility Study**
- **Under base flow conditions, Outfall 200 largest single source to creek**

EAST PLANT AREA

- **Primary Hg source areas include the Alpha 2 building and surrounding soils, and karst system groundwater**
- **Substantial groundwater flux to BSWTS (treatment facility); levels decreased over time**
- **Greatest flux to creek is from outfall 51 (~1g/d), especially during high flow events when BSWTS bypassed**
- **Low but detectable flux from many storm drains**

STREAM SYSTEM SOURCES

- **Primary Hg source to stream under base flow conditions is bed sediment between outfalls 200 and 109**
- **Approximately 2g/day flux is 2nd only to outfall 200 as source during base flow**
- **Sediments further downstream may be a major source of storm flow flux**
- **Most contaminated stream bank soils remediated; lower level Hg bank sources may remain**

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RECOMMENDATIONS AND RESEARCH NEEDS

- **Transport pathway sampling is needed that includes measurement of mercury concentration and flow under base flow and *storm flow* conditions at *multiple sites at the same time*. Storm flow source information is limited.**
- **There is significant uncertainty associated with shallow groundwater movement near contaminated buildings and interactions with preferred flow paths and subsurface infrastructure. Further study is needed to understand interactions between storm drains, footers/backfill, and surrounding soil, and hydrologic connectivity between source zones and the creek. Most wells at the facility were not designed to help understand these processes.**
- **The conceptual model for mercury identifies the major sources and transport pathways for mercury, but the many small sources of mercury identified in the model may also be important if the goal is to reach very low mercury levels in stream water and fish. Additional mercury flux information is needed for these sites, especially during high flow conditions.**
- **Characterization activities are needed to define the forms of mercury within various site media and the relative mobility.**
- **Although the focus of the conceptual model evaluations was on primary sources and transport pathways, the downstream instream processes (Hg methylation, bioavailability, and bioaccumulation) must be a part of the overall mercury remediation strategy and research at the site.**