CRRC PROPOSAL

1) Problem Statement:

Polycyclic aromatic hydrocarbons (PAHs) are emerging as the most ubiquitous class of contaminants, with substantial toxicological implications, in sediments of urban and suburban embayments. PAHs are capable of causing:

- acute lethality through narcosis (Barron et al. 2004);
- reproductive impairment that is mediated by the P450 mixed-function oxidase (MFO) system of enzymes (Johnson, Collier et al. 2002);
- impairment of the immune system (Karrow, Boermans et al. 1999);
- tumor generation through metabolic generation of reactive intermediates of the MFO system which attack cellular macromolecules (primarily DNA: (Baumann and Metcalfe 1995), (Pinkney, Harshbarger et al. 2004)); and,
- developmental, teratogenic impacts (similar to blue sac disease) which lead to fry which are not ecologically viable (Incardona et al).

These impacts can cumulatively contribute to reduced populations (Heintz, Rice et al. 2000), even though exposure may have been transitory and short term (for example, salmon fry spending only a matter of weeks in a contaminated estuary). Plus, these impacts occur at such low concentrations, that most urban sediments are implicated as likely toxic.

Management decisions regarding PAHs, however, can often be hampered by the very ubiquitous nature of PAHs. The hundreds of individual PAH compounds can have a multitude of sources that fall into three general categories:

- natural sources, such as plant metabolites and coal;
- petroleum sources such as crude oil and a wide range of refined petroleum products (from light distillates to heavy tank bottoms and creosote); and,
- pyrogenic sources such as gasoline and diesel exhaust, wood smoke, stack emissions, and so on.

An understanding of the source of PAHs present in any given area of interest is a crucial foundation for any management decision: appropriate control or remedial approaches cannot be debated until there is an understanding of where the PAHs observed actually came from. As oil spill response moves further into restoration issues, a portion of this source attribution challenge, even in spill response, will often involve defining the spatial extent of contamination attributable to a specific release from particular responsible parties, and, distinguishing that release from the additional, surrounding releases. This is a standard challenge at hazardous waste site investigations.

Yet OR&R currently has no existing, strategic capacity to assess environmental data to identify the most probable source type of PAHs: each situation is handled through an inefficient, independent analysis.

2) **Proposed project:**

This project will produce a knowledge-based reasoning model for the interpretation of PAH data. The model will interpret available data to provide an indication of the PAH source type. This knowledge-based model will draw upon and compile information and techniques from numerous peer-reviewed, published papers. This published information will form the foundation for implementing the knowledge-based approximate reasoning model through the procedures of fuzzy logic, a significant new branch of mathematics. Fuzzy logic is concerned with the quantification of membership within a set and associated set operations. Output from the model can be thought of as an expression of an observation's degree of membership in a set (pyrogenic sources, petrogenic sources, and so on)

This model will be accomplished within the *Ecosystem Management Decision Support* (EMDS) application framework which integrates the logic engine of *NetWeaver* (Rules of Thumb, Inc.) and *ArcGIS* (ESRI) to perform spatially relevant evaluations (within Microsoft *Windows*). To conduct an analysis with EMDS, the user would merely provide a data view that includes a GIS theme containing PAH chemical analysis. This provides the input to the knowledge base that describes how to interpret the information provided. Other components of the EMDS application framework will supply valuable ancillary information regarding the evaluation: The *Hotlink Browser* provides an intuitive explanation for the results, while the *Data Acquisition Manager* will assist with determining what missing data would have the largest impact on results.

The *NetWeaver* logic engine evaluates data against a knowledge base that provides a formal specification for the interpretation of data. The logic engine allows partial evaluations based on available information, making it ideal for use in situations where the level of detail in PAH data is often variable and incomplete. A second key feature provided by the logic engine is the ability to evaluate the influence of missing information on the logical completeness of an assessment. The engine, in conjunction with the EMDS Project Environment and the *Data Acquisition Manager*, provides powerful diagnostic tools for determining which missing data may be most valuable, given the available data, and determining how much priority to give to missing data, given other logistical information.

Sophisticated geographic analyses often produce impressive looking maps. However, if the analytical system that produces a map cannot also explain the derivation of analysis results being portrayed in a relatively simple and straightforward way, then the system appears to observers as a black box. The *Hotlink Browser* displays the evaluated results of a knowledge base. Users can navigate the networks of analysis topics to trace the logic of evaluations in an intuitive interface. More importantly, the presentation of results in this graphic format is sufficiently intuitive, so users of the system can use the *Hotlink Browser* as a powerful communication tool that effectively explains the basis of evaluation results to broad audiences.

3) **Benefit to OR&R and CRRC.**

ERD relies upon analytical chemistry to support its many tasks during a given response. Chemistry, obviously, helps to determine what and how much has spilled into the environment and into a specific habitat. In the case of oil spills, the forensics can extend more deeply and we can use information about the chemical makeup of a spill to answer many questions, aid the response, and ultimately, to speed the recovery of the affected environment. For example, the distribution of PAHs in a mix of oil can be used to "fingerprint" the source of a spill, like the so-called recent "mystery spill" in Puget Sound. Chemistry can also inform as to the presence of unexpected materials in an oil—for example, a lighter cut of refined fuel that might have been added to a heavy oil product to facilitate transfer. As a spill progresses, and immediate response needs fade, chemical forensics are perhaps even more important in order to understand the longer-term impact a spill might confer to resources of concern. An example of this is recent work by Payne and Driskell interpreting chemistry in Prince William Sound: the PAH distribution in samples has suggested a phase-shift in the source of the PAHs from particulate to dissolved, and the researchers have suggested that the system has a low-level background source into the marine environment that is independent of the 1989 spill.

The ability to distinguish PAH sources in a more consistent and reliable way would aid other response-related problem-solving. Chemistry not only quantifies the exposure and degree of contamination, but it also can aid in identifying whether that contamination can legitimately be attributed to a spill...or whether a pre-existing source is responsible. Therefore, a well-researched and flexible way to identify categories of PAH sources would represent a tool of potentially great utility to ERD responders over the course of a spill.

ARD routinely has to deal with distinguishing releases from hazardous waste sites of interest from surrounding, regional sources of PAHs. At least 40% of the hazardous waste sites the division deals with each year involve PAHs as a primary contaminant. (Compare to 75% of the ERD responses since 2004.) Plus, PAHs are a major issue for most of the watershed projects

This project will build upon the technology transfer efforts of CRRC by incorporating results of some efforts previously funded by CRRC (Carls et al), and translating them into an analysis tool that can be distributed to a broader, practicing community of users.

Benefits would accrue to other offices in NOAA as well. For instance, NOS Center for Coastal Monitoring and Assessment has expressed interest in such a tool to help interpret the archive of data, as well as anticipated Mussel Watch Project sediment samples (Lauenstein pers comm.)

4) **Project Deliverables:**

The project deliverable will be a *NetWeaver* logic model for the interpretation of PAH data to suggest the source type of the PAHs. This model will be fully integrated with *ArcGIS* to also provide spatially related, graphical output of model results. To use this model, future data input for this model would be an *ArcGIS* point theme which contains PAH analyses. This input would be matrix independent (in other words, water or sediment). Independent data sets (as *ArcGIS* themes) from hazardous waste sites with known sources, used to test the model output, will also be included.

This project would also produce a software license and the internal technical ability to generate additional, future knowledge-based reasoning models (instance, sediment toxicity).

5) **Timeline:**

Model development will begin as soon as training of software has been arranged. Training is anticipated to require two or three days. Model development and testing will require another two weeks. All combined, the total timeline is anticipated to be three weeks, with a start date that is dependent on making mutually agreeable training arrangements with the USDA Forest Service. The three weeks of effort need not be consecutive.

6) Location and Logistics:

Work will be performed at Sandpoint, with travel to the USDA Forest Service, Pacific Northwest Research Station, Corvallis, Oregon.

7) **Project budget**:

Travel – $1000

Software – $500

Labor – 120 hours

8) **Statement from partner institution**:

Attached.

9) **Supervisor approval**: Forwarded under separate cover.

References

Barron, M. G., M. G. Carls, R. Heintz, and S. D. Rice (2004). Evaluation of fish early life-stage toxicity models of chronic embryonic exposures to complex polycyclic aromatic hydrocarbon mixtures. Toxicological sciences 78(1)60-67.

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Heintz, R. A., S. D. Rice, et al. (2000). "Delayed effects on growth and marine survival of pink salmon Oncorhynchus gorbuscha after exposure to crude oil during embryonic development." Marine Ecology-Progress Series **208**: 205-216.

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Pinkney, A. E., J. C. Harshbarger, et al. (2004). "Tumor prevalence and biomarkers of exposure and response in brown bullhead (Ameiurus nebulosus) from the Anacostia River, Washington, DC and Tuckahoe River, Maryland, USA." Environmental Toxicology and Chemistry **23**(3): 638-647.

Statement from Partner Institutions

The Redlands Institute,
University of Redlands

The Redlands Institute (RI), founded in 2000, is an interdisciplinary, collaborative research enterprise within the University of Redlands which conducts applied research with the aid of geographic information science methods and Geographic Information System (GIS) technology together with modeling, simulation and decision support tools. The Institute has now assumed a custodial role in the continuing maintenance and development of EMDS.

From Paul Burgess (RI Research Analyst and EMDS Manager):

> I think you're drawing all the right connections between the nature of the problem and the features that make EMDS well suited to evaluating it. Of note are:
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> 1. Understanding influence of uncertainty (both in knowledge and data) on model results. We may have uncertainty about our understanding of the behavior of PAHs in the environment (transport, fate, etc). We may also have uncertainty (or low confidence) in many of the data that would support PAH analysis. EMDS has functions that allow us to estimate influence of missing knowledge and/or data.
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> 2. Model transparency. Netweaver is designed to represent model topics, parameters and their relationships in a graphical way. Users can query landscape units (or points in your case) and quickly see the contributing factors to a model result and any substantiating documentation associated with the model (such as scientific studies, excerpts from expert interviews, published datasets, etc). This is particularly advantageous when the model has management implications. It's not just about the defensibility of one's model. It's also about how successfully you are able to communicate the underlying science to a lay audience.
>
> RI [can be relied on] for follow up technical support.

Additional training support will be provided by:

Keith Reynolds
Team Leader
Ecosystem Management Decision Support RD&A
USDA Forest Service, Pacific Northwest Research Station
Corvallis Forestry Sciences Laboratory