TVA Kingston Fly Ash Environmental Research Symposium
March 11-12, 2010

Breakout Sessions Report

I. Introduction

As a major component of the Kingston fly ash environmental research symposium, a series of concurrent workshops were conducted on the second day of the symposium. The primary objectives of the workshops were to evaluate the current status of TVA's environmental monitoring and assessment projects related to the ash spill and to solicit guidance and recommendations from workshop participants as to the strategies, design, and implementation of future environmental studies and particularly those that support the ecological risk assessment process. Following the basic format of the six plenary presentations conducted on the first day of the symposium, four concurrent workshops addressed issues related to 1) Site characterization, 2) Geochemistry, 3) Ecotoxicology, and 4) Ecological studies. Each workshop was led by two moderators and the number of participants ranged from 15-20 in each session. Individuals representing a variety of institutions and agencies participated in each of the sessions including, for example, state and federal institutions such as the Tennessee Dept. of Environment and Conservation, the US Fish and Wildlife Service, and Oak Ridge National Laboratory; academia such as VPI, Middle TN State University, and Appalachian State University; and private corporations and utilities such as the Tennessee Aquarium and American Electric Power. At the initiation of each of the 4 sessions, the moderator explained the objectives of the workshop and issued charges to the participants as to the main topics of discussion to be addressed during each 2-hr session. The main charges or topics addressed in each session were:

(1) Evaluate the current research studies in each workshop topic area, are they relevant, sufficient, and pertinent in helping TVA assess and evaluate the environment implications of the fly ash spill?

(2) identify the major research gaps in the current monitoring and assessment studies that apply to this particular functional workshop area

(3) What are the major obstacles or challenges associated with each of these identified research gaps?

(4) are all the major pathways related to implications of the ash spill to human health currently being addressed?

(5) What factors should TVA consider in its prioritization of resources to address issues in this functional area?

Following the conclusion of each breakout, a moderator from each session provided a brief synopsis of the major finding and recommendations to a joint session of all symposium and workshop participants. This activity provided an additional source of feedback and interaction from all symposium participants relative to recommendations and guidance for future environmental monitoring and assessment studies associated with the Kingston fly ash spill.

The following section provides the findings, summaries, and recommendations of each of the four breakout sessions.

II. Synopsis of Breakout Sessions

Site Characterization Breakout Session

Moderators: Bill Rogers (Tennessee Valley Authority) and Rock Vitale (Environmental Standards, Inc)

Surface Water Sampling

- Surface water sampling may be stepped down in frequency.

Data Mining

- Researchers should do further careful consideration of ways to do appropriate analysis of the data we have gathered so far.
- Topics of historical studies on ash performed by TVA (both published internally and unpublished) should be made available to researchers. Example "Ash as a Plant Growth Medium".

Researcher Data Sets / Third Party Data Sets

- Efforts should be given to ensuring compatibility of both sampling and analytical techniques with an eye toward the end use of the data sets.
- Going forward, groups need to "calibrate" against TVA quality standards.
- Backwards compatibility with quality standards may be problematic.
- There is a strong need for definition of terms in a consensus document. Example: Limit of Detection.

Radiological

- Recent detection eliminates dredging below Emory mile 1.8.
- Human health risks have been directed to sample "all media" for radiological parameters.

Physical Parameters of Ash

- No new activity identified

Speciation

- Se / As in embayment ditch
- Sequential extraction studies need follow-up of species / oxidation state when bioavailability is indicated in the extraction step
- Passive thin-film samplers should be explored for oxy-anion oxidation state studies.
- Species of As / Se may be useful in biota (mayflies, algae, periphyton).

Surface Studies of Ash Particles

- Need to understand surface characteristics of ash dredged from the river vs. ash in intact cell vs wet ash from plant vs ash directly from precipitators prior to wet processing.
- XANES and other techniques (XPS and STEM) might be used to perform surface and depth probe.
- Understanding needed of presence of iron oxide and silica surfaces.
- Surface covalent bonding needs to be understood.

Flow Modeling / Stratigraphy

- Ensure communication between various flow modeling studies (downstream transport of ash by rainfall events) and ongoing seismic sub-bottom profiling studies.
- Terrace vs channel deposits need to be further studied.
- Importance of vegetative mats need further study.
- Coring studies should continue.
- Sub-bottom profiling should be extended to see whether the technique can provide useful information.

EPA 1313, 1314, 1315, 1316

- No immediate application noted for ash recovery for proposed EPA SW-846 method series 1313, 1314, 1315, and 1316, but column studies will be performed on groundwater well boring material from this suite of procedures. TVA participation in the validation studies will be driven by other factors than Kingston Ash Recovery

Other

- The Eco-Risk group should consider periphyton sampling

Geochemistry Breakout Session

Moderators: Anthony Bednar (US Army ERDC) and Roy Sidle (Appalachian State Univ.)

The Geochemistry Breakout Group (GBG) consisted of representatives from academia (Professors and Graduate students), Government Researchers, members from the Electricity Industry, and consultants, among others. Active discussions were facilitated by a series of questions focused on the research that has been performed and what topics need additional investigation. Of particular note, the topic of redundancy was discussed in great detail, for which a generalized conclusion was obtained: a measured amount of redundancy is *required* for scientific rigor, yet duplication of effort should be targeted to those areas with the least amount of information known.

The majority of the GBG discussion can be condensed to a single, all-encompassing point that also affects the related fields of investigation (biological and ecological):

Characterization.
This includes geochemical characterization of fly ash and how this relates to ongoing biological and ecological investigations, and how metals associated with fly ash may be altered during aging, transportation through the river systems, and in depositional environments. These characterization issues have an ultimate impact on bioavailability.

Essentially these questions remain: What is fly ash, and what specifically makes it unique? Do standard methods apply and do they accurately reflex the complex geochemistry of fly ash (e.g. EPA SW-846 methods)? When should speciation be determined, or are total metals sufficient? What changes occur when fly ash is introduced into a freshwater environment and mixes with native sediments? Many of the research projects currently underway have or are attempting to answer these questions. In many cases, it is becoming clear that fly ash geochemistry is sufficiently complex to warrant the development of new methods, e.g., TCLP or SPLP extractions do not adequately describe metals biogeochemistry in fly ash. Additionally, current work also demonstrates that total metal analysis is inadequate to describe metals biogeochemistry in fly ash, necessitating that speciation and/or sequential extraction procedures be included in any fly ash investigation. Furthermore, application of stable isotope geochemistry correlated to metal speciation could provide information on fly ash characterization.

Several research efforts and corresponding gaps were identified by the discussion group, notably: Riverine sediment characterization (including dynamics), Regulatory descriptors for ash, Speciation in ash, Stable isotopes, The role of organics in ash, Characterization of groundwater, surface water, and solids, and Differentiation between new and legacy contamination. These topics, by their very nature, have some degree of overlap and duplication, yet the somewhat uncoordinated research efforts may lead to a loss of optimal value to the group as a whole.

To this end, the first recommendation of the group is an increase in coordination amongst various research groups.
An excellent example of this is the need for cross-communication between geochemical research efforts and biological research efforts. A case in point was demonstrated by participant discussions on selenium availability and bioavailability. During the presentation of the GBG findings, it was made clear by biological researchers that selenite [Se(IV)] is more bioavailable. However, this assertion was countered from the geochemical community that selenite is also more tightly bound to sorption substrates, such as iron and manganese oxyhydroxides, which make the selenite far less mobile, and therefore less available for uptake by organisms. Depending on the organisms' digestive chemistry, it may not be bioavailable even if sediment is consumed. Therefore, we have a situation in which both research groups are correct *and* incorrect. In a pure water system, selenite may be more readily assimilated into an organism, yet if any sorptive material is around, it may be rendered immobile and therefore unavailable. Such differences in viewpoints also demonstrates the need for studies related to different labile fractions of certain metals, as well as metals associated with various size fractions within the fly ash.

This rather simple example clearly demonstrates how biological studies need to rely on and incorporate geochemical knowledge and cooperation on the complex speciation, labile nature, and chemistry of metals. Conversely, geochemical research on the mobility and toxicity of metals, particularly metal species must be properly couched in the ecological system in which organisms are exposed.

The second recommendation focuses on redundant efforts.
Although surface water chemistry monitoring is required for regulatory purposes, the question is posed, how many non-detects are required to reduce the level of sampling? Could reduction in sampling or cooperative sampling be performed to reduce this effort and focus on more fundamental biogeochemical investigations? An analogous argument is made for biological investigations, how many trophic transfers studies are needed for top predators if the accumulation and trophic transfer at the primary producer and primary consumer levels has not been demonstrated? The impact on threatened and endangered or sensitive species is of most concern, but scientifically it stands to reason that the lower trophic levels should be investigated first. This suggestion is also clearly tied to the first recommendation, in which subsequent biological studies are heavily influenced by system-representative geochemistry (i.e., of contaminated sediments), including metals speciation and stable isotopes, to provide the most robust scientific data.

These two recommendations are made from a scientific perspective. It is well known and understood that political and regulatory controls and influences will mandate many of the research and monitoring efforts that TVA initiates and funds. For example, it is not recommended that all surface water chemistry monitoring and wildlife bioaccumulation efforts be abandoned for fly ash and contaminated river sediment speciation and bioavailability characterization, yet it would be beneficial if optimization of the former efforts resulted in available funds for subsequent geochemical

characterization. Therefore, it is hoped that these suggestions and resultant discussion helps focus TVA's resources where the most scientifically defensible data are obtained, which ultimately could lead to the best way forward for the cleanup and restoration of the area.

In conclusion, the GBG suggests TVA consider the following as research investigations as high priorities:

1) Characterization, including speciation and correlation to stable isotopes, of fly ash
2) Development/optimization of standard methods
    a. Geochemical stability of fly ash in different environments
    b. Potential applicability industry-wide
3) Coal Ash leaching and toxicity as related to possible stricter disposal regulations
    a. Help regulators make informed, scientifically-based, decisions based on ash geochemistry and toxicity (or lack thereof) so beneficial reuses of ash can continue.
    b. Potential for regulation of coal ash as a hazardous waste emphasizes the need for characterization of leachability and toxicity.
4) Multidisciplinary studies
    a. Emphasize collaboration while reducing redundancy
5) Long Term Monitoring of Perry County landfill
    a. Fly ash temporal stability
    b. Long Term Characterization

Ecotoxicology Breakout Session

Moderators: Jeffery Steevens (US Army ERDC) and Steve Alexander (USFWS)

Overview

On 11 and 12 March 2010, a meeting was held to discuss the synthesis of existing and future information to best assess environmental risks at the Kingston TN fly ash spill site. The first day of the session focused on a summarization of existing information from the studies already completed and future studies that will support the ecological risk assessment. The second day included four breakout sessions focusing on site characterization, geochemistry, ecotoxicology, and ecological studies. All four breakout groups were charged by the organizers with addressing the following questions as related to their topical area:

1. Evaluate the current research studies in this area. Are they relevant, sufficient, and pertinent in helping TVA assess and evaluate the environmental implications of the fly ash spill?
2. What are the major research gaps in the current monitoring and assessment studies that apply to this particular functional workshop area?

3. What are the major obstacles or challenges associated with each of these identified research gaps?
4. Are all the major pathways related to implications of the ash spill to human health currently being addressed?
5. What factors should TVA consider in its prioritization of resources to address issues in this functional area?

This white paper summarizes the discussions and conclusions of the breakout group addressing the area of ecotoxicology. Ecotoxicology is defined as the study of "*the impacts of toxic substances on population dynamics in an ecosystem*" including "*the transport, fate, and interactions of chemicals in the environment* (Eaton and Klaassen, 2001). In general, the ecotoxicology group addressed the above questions by focusing on ecotoxicology needs that would be used to support the ecological risk assessment process.

The discussion group accomplished the main goals of identifying data needs, identifying criteria to prioritize the data needs, and then prioritized those needs based on the criteria. These data needs and their priorities are described here to further support and focus the studies at the Kingston TVA Site.

Criteria
Initial discussions by the group focused on the criteria by which we would determine the importance or need to address a specific data gap. These criteria were used to prioritize the data gaps. The criteria listed here are not ranked by level of importance.

- Is there an absence of data for this data need or are there data with conflicting conclusions?
- What is the quality of the existing data? For example, have non-detects been handled in a consistent and appropriate manner?
- Do the existing data represent the current conditions at the site? It is recognized that site conditions are changing over time due to controlled (i.e., dredging activity) and uncontrolled (i.e., flood) events.
- Do the existing data represent the temporal and spatial variability of the site?
- What are the intended uses of the data? Are they intended to meet a regulatory requirement (e.g., water quality standard) or to support a general understanding of site fate, transport, effects at the site?
- Have the right bioassays been conducted? Have we used the correct organisms and bioassay duration (i.e., chronic versus acute)? Have we examined the correct endpoints beyond survival, such as growth or reproduction?
- Are the conditions and procedures of standardized bioassays appropriately applied given the differences between natural sediments and ash?

Data Gap Identification
Data gaps were identified through a structured discussion focusing on the conceptual site model developed by S. Young (Arcadis). This graphical conceptual site model focuses on the ecosystem components relevant to the TVA site. Discussions focused

on three main areas: exposure to the stressors, food webs, and potential for toxicity. These data gaps are listed in brief description but not in prioritized order.

- Identify a reference site for conditions prior to the fly ash spill. This reference site should represent the heterogeneity of the region for parameters such as grain size, chemical concentrations, and organic carbon. Ideally, there would be several reference sites so that a “reference envelope” approach could be used.
- Determine the potential for interaction of contaminants of concern. This would include legacy contaminants from other sources (e.g., Hg) as well as potential interaction of ash specific contaminants (i.e., As and Se).
- Determine the representativeness of laboratory bioassays to conditions observed in the field. Specific emphasis on the bioavailability of contaminants in laboratory versus field conditions.
- Identify the primary stressors in the system. There are several contaminants of concern that have been suggested. It would be beneficial to reduce the number of contaminants on that list to focus the investigation.
- Examine sublethal endpoints that have consequences at the ecosystem level such as reproduction.
- Bioaccumulation of chemicals has been examined and is part of several ongoing investigations. How will the results of these investigations be interpreted? Current literature cautions against using tissue residue benchmark approaches for metals.
- Current bioassay toxicity test data have shown some decreases in survival. There is uncertainty regarding the contribution from physical effects of the ash versus toxicity from the chemical constituents.
- What Contaminants of Concern (CoCs) should move forward in the study?
- There are a large number of contaminants present in the ash. Several of these such as barium or boron have not been considered when evaluating toxic effects. Maternal transfer of these contaminants could be significant and result in toxicity to the offspring.
- The ash has been dispersed through lower stretches of the Emory River and to parts of the Watts Bar Lake. What are the consequences of ash being dispersed and mixed with native sediments? Are there changes in the bioavailability of metals in this system resulting from mixing?
- Exposure route of metals is critical to understanding the effects. Is exposure from dissolved or dietary routes more important?
- Food chain modeling can be used to determine the exposure to contaminants of concern. The parameters used for modeling will need to be measured, such as concentration of contaminants in prey items.
- Uptake of contaminants in invertebrates should be measured.
- For selenium, the primary process for increased concentrations in the food web occurs in the primary producers. What is the uptake of selenium in biofilms?
- Develop a table describing the contaminants of concern related to relevant and appropriate bioassays and measures specific to that contaminant.

Data Gap Ranking
Voters were given an opportunity to select in rank their top five data gaps (1-5). Ranks were determined based on a point allocation system (rank 1 = 5 points, rank 2 = 4 points, rank 3 = 3 points, rank 4 = 2 points, and rank 5 = 1 point). Rank scores were normalized to the total number of points that could be allocated by the group. The group was composed of 6 academic, 2 state agency, 4 Federal agency, and 6 private industry participants. There were four members of the group that did not participate in the ranking.

Prioritized Data Gap List
The prioritized list of data gaps is shown in Figure 1. The top six data gaps were identified. However, those receiving lower scores were difficult to distinguish from each other. The top six data gaps are:

1. Uptake of selenium and other CoCs in biofilms, phytoplankton, and plants
2. Identify one or several appropriate reference sites
3. What contaminants of concern should move forward to focus the studies?
4. Need for reproductive and other sublethal endpoints
5. Food chain modeling and need for dietary exposure parameters
6. Changes in ash over time including mixing with native sediments

Conclusions
Discussion and data gap ranking by the group should be qualified for several reasons. Firstly, the time for discussion and ranking was less than 2 hours. Secondly, participant knowledge of the site and site data varied as well as their technical involvement at the site. Lastly participation in discussions can be dominated by strong individuals; however this process did allow an opportunity for everyone to vote on priority areas. Because of these reasons, the weight of this priority list in future decisions at the site should consider these qualifications.

In addition to the data gaps identified and prioritized above, there were several other items recommended by the workshop participants for attention as part of the assessment process.

- There is a need to identify and/or develop processes for determining data gaps. The one day workshop provided an overview of the existing data, but not a thorough understanding. For example, what process should be used to determine the quality of existing data?

- There is a database of existing information being developed by Arcadis. Information about how it is organized and what type of data will be included is needed by the site investigators. This will provide a mechanism for existing information to be communicated to others and for investigators to support the inclusion of their data in the database.

- Much of the workgroup's discussion focused on selenium. However, the workgroup agreed that other CoCs should not be overlooked. Furthermore, the differences in chemical exposure, uptake and toxicity for these different CoCs should be understood and considered in the overall risk assessment.

- The workshop participants did not feel they were in a position to say what is not required for the ecorisk assessment. For example, data on tree swallows, contaminant concentrations in emergent mayflys, and concentration of metals in water. Some of these data must be collected to comply with regulations while others will be needed to fully characterize foodchain risks of the COCs.

Ecological Studies Breakout Session

Moderators: Bill Hopkins (VPI and State Univ.) and Rob Reash (American Electric Power)

Background and Overview

The breakout group to discuss the ongoing ecological studies at the Kingston site included a diversity of expertise, with members of academia, regulatory agencies, regulated industry, the TN aquarium, and concerned citizens participating. We began our discussions with a recap of ecological research projects conducted and/or sponsored by TVA and other groups after the ash spill. This included a discussion of ongoing work and planned effects-based projects for the coming years. To date, ecological research has focused on aquatic invertebrates, fish, amphibians, turtles, piscivorous birds, insectivorous birds, and raccoons. There was positive support for the initial work conducted at the site with general consensus that many of the highest priority ecological groups were being addressed (but see suggestions below). The group believes that 2010 is a critical year for sampling because enough time has surpassed for food web transfer to occur, depending on the trophic level being considered. These results will be critical in future years for gauging the efficacy of rapid remediation efforts at the site. That being said, it should be noted that much of the coal ash that was routed to the Emory River has been – or is in the process of being – removed. The discussion then focused on research gaps and priorities, potential for redundancy among projects, and ways to facilitate coordination among research groups. Recommendations and observations from the group are listed below.

Key Recommendations

1) Overall, the suite of organisms being examined captures many of the important trophic niches at the site and should provide insight into whether certain groups of organisms are at risk of exposure to trace elements derived from ash. However, it was noted that biofilms/periphyton were a critical knowledge gap that deserved immediate attention because they often form the initial link from contaminated water/sediments to food web contamination. Field studies of biofilms are relatively easy to perform (e.g., using suspended colonization

plates), and could complement laboratory studies being initiated at NC State. In addition, certain species of spiders were identified as a key link between the aquatic and terrestrial food webs. Recent literature has shown their importance in serving as sources of energy, nutrients, and contaminants (e.g., PCBs and Hg) to terrestrial birds, mammals, and herpetofauna. Finally, water snakes were identified as an additional reptile species that could be studied because of a suite of ecological and life history traits that lend themselves to studies of environmental pollution. In addition, water snakes have been thoroughly studied in other sites contaminated with coal ash, providing a basis for comparison.

2) The group recommended that ongoing studies of fish, freshwater mussels, and turtles consider the use of microchemical analytical techniques (e.g., laser ablation-ICPMS) to address the temporal dynamics of pollution at the site. By examining tissues that are structured over time such as turtle scutes, fish otoliths, and mussel shell annuli, researchers may be able to tease apart current and historical sources of trace elements to the river.
3) The group suggested that a GIS database be developed that would include layers of water, sediment, and biotic results.
4) The group agreed that one of the great challenges facing all researchers at Kingston is defining what the appropriate “background conditions” are at the site and the identification of appropriate reference sites. Given the complexity of this system, it will be very important to reach consensus on criteria that can be used to identify reference sites and for groups to co-localize their sampling efforts when possible.
5) The group did not feel there was much redundancy among ecological studies at this point, but did recommend that researchers take advantage of the wealth of information on the local area available through TVA and ORNL. For example, the historical contamination of mercury in the lower Clinch River could lead to possible confounding interactions in terms of discriminating between effects of the Kingston Plant ash dike spill and other “background” influences.
6) To reduce the potential for future redundancy and to enhance integration among research teams, the group recommends annual meetings to share results and facilitate discussion.
7) The group suggests that ecological studies should be well integrated with biogeochemical studies in order to understand issues of speciation, bioavailability, and food web transfer. The group also suggests that laboratory studies would benefit from using a common source of ash so that cross-study comparisons are not confounded by differences in ash composition and handling.
8) The group discussed problems that have arisen due to the amount (mass) of sample required for analysis at labs currently under contract with the TVA. The large quantity of tissue required for analysis is prohibitive for many types of important biological samples such as blood and feather. Though these sample matrices are not too small for analysis, their analysis is currently not possible at Kingston because of QA/QC requirements. The group recommends that the QA/QC plan be revised to accommodate the needs of ecological studies, while still maintaining scientific rigor and production of legally defensible results.

9) Finally, the group discussed the scientific opportunities at the Kingston site. The tragic circumstances at Kingston can provide important insights into basic biological processes such as Se-Hg interactions and recovery of ecological systems following large scale disturbance. Researchers should keep these opportunities in mind as they address other issues at the site.

III. Synopsis and Summary Across Breakout Sessions

Based on the summaries and recommendations presented above for each of the four breakout sessions, a synthesis was made across sessions on the most frequently recommended monitoring and assessment activities to be conducted in future fly ash studies at the Kingston site. Only those recommendations that were suggested by at least two of the breakout session summaries are discussed below. The specific recommendations suggested across all four sessions listed in order of frequency are: 1) periphyton or biofilm studies, 2) frequency /redundancy of sampling, 3) characterization/speciation of fly ash, 4) integration of geochemical studies with ecological studies, 5) reference site issues, 6) food chain and fish reproductive studies, and 7) appropriate data analysis.

Each of these 7 major recommendations is summarized below.

Periphyton or biofilm studies

All four breakout sessions recommended some level of studies on primary productivity and include studies focusing on periphyton (or biofilms). Future studies on periphyton are important because algae, being at the base of the food web, have a high biomagnification factor of contaminants from the water (such as selenite) into algae tissue. Algae can have a 10-100 higher bioconcentration factor for certain metals than other components of the food chain such as a 5-10 bioaccumulation factor from invertebrates into fish. Such studies would also support and integrate with the current food chain studies being conducted as part of the fish and avian bioaccumulation and health investigations, and the fly ash geochemical speciation studies being conducted by the US Army ERDC.

Frequency and/or redundancy of sampling

Three of the breakout sessions recommended or suggested that more attention be focused on the issue of redundancy in sampling, particularly for water and sediment quality monitoring. Because of the large number of non-detects observed to date in the water quality monitoring program, a decision should be made relative to the number of non-detects required to reduce the level of sampling. There was no redundancy noted among the ecological studies components, however, it was recommended that the relatively large data base of historical information from TVA and ORNL could also be useful in evaluating and assessing ecological risk.

Integration of geochemical studies with ecological studies
A major recommendation which was made independently by both the Geochemical and Ecological studies breakout sessions was that ecological studies should be coordinated and better integrated with the biogeochemical investigations in order to understand issues related to chemical speciation, bioavailability, and food web transfer. Ecological studies need to rely on and incorporate knowledge of geochemical processes related to the speciation and chemistry of metals while geochemical research should incorporate information on the mobility and toxicity of metals for adequately understanding bioavailability to biological systems.

Characterization and speciation of fly ash
Geochemical characterization of fly ash is important in understanding bioavailability of various metals to critical ecological components of the food web. Characterization studies should focus on how metals associated with fly ash may be altered during aging, transport through the river systems, and in depositional environments. The recommendation was made that because fly ash geochemistry is sufficiently complex, new methods are needed to adequately describe metals biogeochemistry in fly ash. Stable isotope geochemistry was the primary method discussed to adequately characterize the chemical composition of fly ash. Some investigations are using recently developed high energy X-ray techniques to characterize chemical speciation of ash, along with sequential extraction methods. Additional investigations using these and other new investigatory techniques are needed to better evaluate the long-term potential for mobilization and bioavailability of contaminants in ash left in the rivers and the effects of its gradual mixing with native sediments on mobilization and bioavailability.

Reference site issues
Reference site issues were raised by two of the sessions. A key challenge in properly assessing the potential effects of fly ash on biological systems is defining the appropriate background conditions and selecting representative reference sites. Due to the complexity of natural systems, a consensus needs to be reached on the criteria that define an appropriate reference site. In biological monitoring and assessment studies, several (minimum of two) reference sites should be used incorporating the “reference envelop” approach. In selecting reference sites, at least one site should be located in the same watershed as the experimental or affected areas. Reference sites located outside of an experimental watershed should be matched as close as possible to the physicochemical (water quality, flow and temperature regimes, substrate geology) and ecological characteristics of affected sites.

Food chain and reproductive studies
In ecotoxicology studies, the endpoints to be measured should focus on those responses that have consequences at the ecosystem level such as reproductive integrity of sentinel wildlife species. Food web studies should include not only an understanding of the major predator-prey interactions relevant to uptake and bioconcentration of fly ash-associated metals, but food web modeling can also be used to assess exposure of consumers to contaminants using dietary exposure of prey

species. 2010 is a critical year for ecological studies that focus on contaminant transport through food web because sufficient time has passed for any contaminants associated with fly ash to be incorporated throughout the food web.

Appropriate data needs and analysis

Two sessions, site characterization and ecotoxicology, addressed various aspects of data needs and analysis. The quality of existing environmental monitoring data needs closer examination and evaluation relative to: 1) if such data adequately represents current conditions at the spill site, 2) if existing data represents the spatial and temporal variability of measured physicochemical and biotic variables at monitoring sites, 3) the handling and interpretation of non-detect data (also relates to issue of sample redundancy), 4) measurement of the correct response endpoints for assessing the chronic effects of metal exposure on organisms, 5) the correct experimental designs (including sample replication and appropriate treatment effects) for assessing potential effects of fly ash exposure on target biota and for use in ecological risk assessment, and 6) the proper data analysis methods to use for different types of data sets including tests for data normality and variability structure.

Periodic information exchange meetings

Even though not a specific written recommendation except in one session summary, but based on verbal communication among symposium participants, there is a large amount of support for periodic information exchange meetings where the principal investigators provide updates of their studies to facilitate greater understanding, integration, and corporation among the various study disciplines. For example, three of the workshop groups encouraged greater integration between the geochemistry and ecological studies since such information is critical in understanding the uptake, bioaccumulation, transfer, and toxicity of fly ash-associated metals (such as selenite) through the aquatic and terrestrial food webs.