Use of Decision Analysis to Model Natural Resource Management Decision Scenarios in Contentious Settings: Selenium in Appalachian Watersheds

Jim Coleman, Chief Scientist, Eastern Energy Team, USGS
Ione Taylor, Chief Scientist, Eastern Region, USGS
Karen Jenni, Decision Analyst, Insight Decisions, LLC
Tim Nieman, Decision Analyst, Decision Applications,

U.S. Department of the Interior
U.S. Geological Survey

The Issues at Stake

- Increased demand for energy and transportation efficiency & safety
- In the Appalachian Coal Basin, these demands can be addressed by large scale earth removal and grading
- Currently permitted practice safeguards may not be sufficient to protect the local environment
- Stopping mining & construction is not an option
- Unregulated mining and construction is not an option

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Contentious Setting

- Increased energy demand in the US from late 1990's to the present led to increased coal mining to supply energy for electricity to meet the call for "energy independence in the US."
- Surface coal mining operations were scaled up significantly to meet the demand.
- In 2002 USEPA found that Selenium concentrations from valley fill sites (where coal mining wastes were deposited) were found to exceed Ambient Water Quality Criteria (AWQC) for selenium at 13 of 15 sites.
- The existence of selenium at these concentrations indicates a potential for adverse impacts to the aquatic environment and possibly to higher order organisms that feed on aquatic organisms.
- Fish collected from one lake downstream of an extensive mining complex in West Virginia were found to contain selenium concentrations much higher than would be expected to occur naturally.

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(http://www.epa.gov/region3/mtntop/pdf/IV_Environmental%20Consequences.pdf)

Contentious Setting (cont.)

- An EPA study conducted as part of the Mountaintop Mining/Valley Fill EIS found that selenium in streams below valley fills exceeded the aquatic wildlife standard of 5 μg/L.
- USFWS analyzed fish tissues collected downstream from mountaintop mining areas.
  - Selenium was present in all sampled tissues.
  - At several locations Se in tissues exceeded 4 mg/kg (ppm), a concentration that can result in reproductive failure and juvenile mortality.
  - Se in some tissues approached 7 mg/kg, a concentration that can result in reproductive failure in birds consuming these tissues.

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(Evaldi and others, 2002)

Additional Factors

- Federal funding of major interstate-style freeways in Appalachia was initiated in 1964 to reduce the region's isolation and improve regional economic potential; it continues today.
- With increased market accessibility and regional development funding, large foot-print industrial and commercial activities have been developed.

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Net Result

- More jobs
- Greater cash flow (for individuals, corporations, and states)
- Major and permanent changes in the regional landscape and culture
- Increased potential for adverse effects on the region's environment and human health

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A Possible Pathway to an Understanding?

- Application of Decision Analysis involving integrated scientific analysis with key input from subject matter experts, decision makers, and stakeholders
- Development and modeling of alternative scenarios to test the implications of specific management decisions

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Some definitions

- Decision
  - An irrevocable allocation of resources
- Decision-maker
  - A person (or group of people) who have the authority and the power to make a (the relevant) decision
- Stakeholders
  - People who have an interest in a particular decision, people who can influence a decision, and people who are affected by that decision.

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Decision Analysis (DA)

- One of many Structured Decision Making "tools" to help decision makers make better decisions.

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Decision Analysis (DA)

- An overall approach for making logical, reproducible, and defensible decisions in the face of technical complexity, uncertainty, and multiple, possibly competing objectives;
- A process to bring customers and end-users into the initial design process;
- A set of tools for structuring and analyzing complex decision problems.

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DA modeling steps

- ✓ Problem framing
  - Identify decision makers, stakeholders, scope, and key components of the decision problem
- ✓ Structuring and modeling
  - Identify how the pieces of the decision problem fit together
- ✓ Quantification
  - Quantify uncertainties and impacts on objectives
- ✓ Analysis and sensitivity analysis

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Scope of the Challenge

large scale surface mining

large scale construction

large scale road building

Scope of the Challenge

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Selenium in West Virginia

- Selenium (Se):
  - Healthful at certain dosages; Harmful at higher (or lower) dosages
  - “Selenium has the narrowest band of any toxic chemical between what’s safe and what’s toxic.” (Skorupa, 1993*)
- West Virginia (WV):
  - Se is present within the coal-bearing section in eastern USA coal fields of WV & neighboring states
  - Se could be liberated by significant ground disturbances including large-scale surface mining, road construction, industrial & urban development ongoing in area

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*http://www.sci.sdsu.edu/salton/SeTooMuchTooLittle.html

Pertinent Selenium Levels

- NIH RDA = 0.055 mg/day/person
- Toxic human levels = 30 – 60 mg/day
- Lethal human dose (median) = 1.5 – 60 mg/kg body wt/day
- Maximum Contaminant Level (MCL) in water = 0.05 ppm = 5 ppb
- Proposed max. Se conc. in fish = 7.91 µg/g (dry wt.) = 7.91 ppm
- Human Health Advisory = 8 ppm in fish

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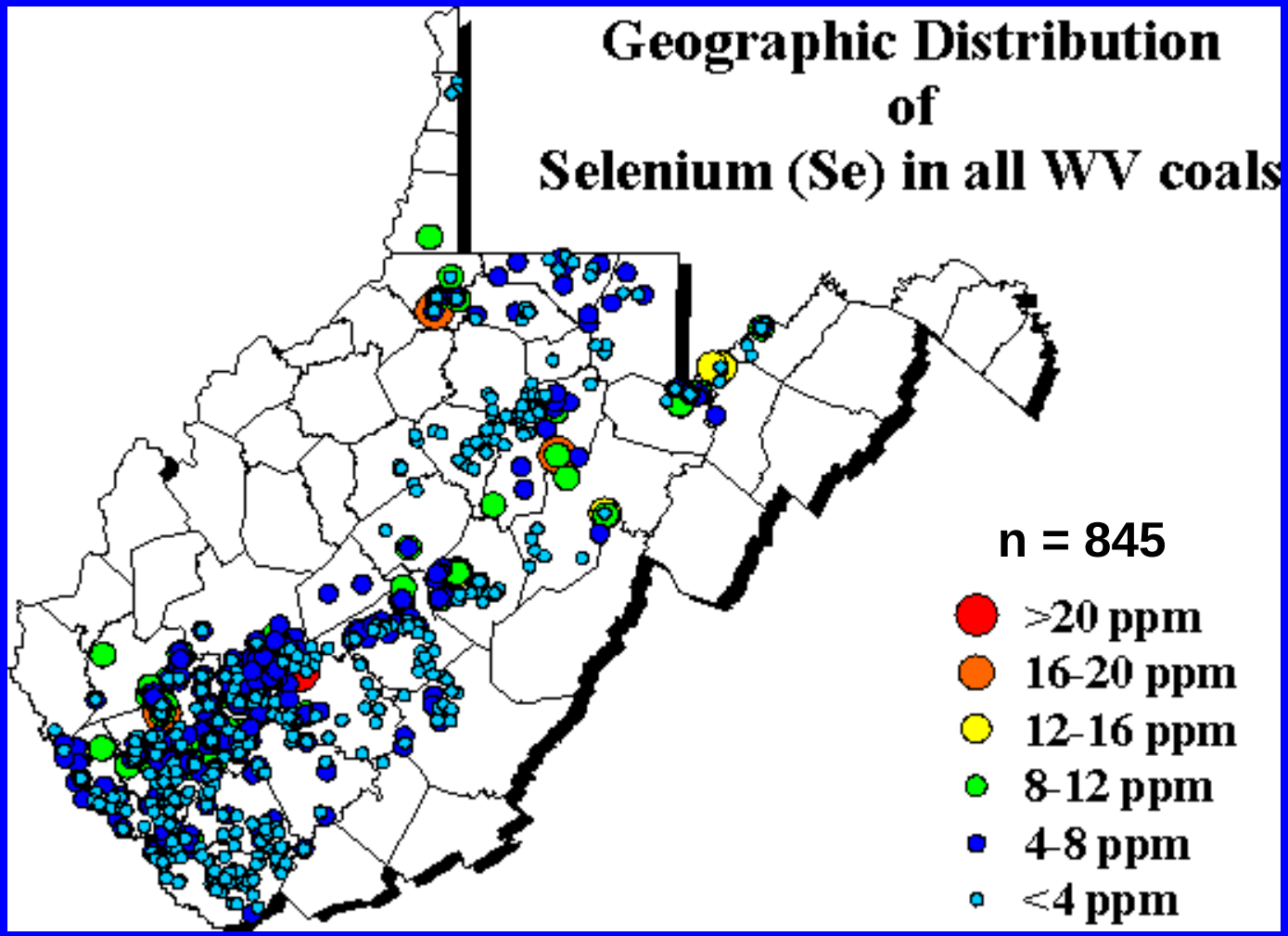
(levels from Andreotti, 2003; EPA, 2004; NIH, 2004; DHHS, 2003; DOI, 1998)

Geographic Distribution of Se in WV Coals



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http://www.wvgs.wvnet.edu/www/datastat/te/Maps/Semapmax.gif

Mountaintop mining in southern West Virginia

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http://www.ohvec.org/galleries/mountaintop_removal/007/index.html

Hobet 21 Mountain-top Mine Dragline

(photos courtesy of Jon Kolak, USGS)

Hobet 21 Mine Valley-Fill & Sedimentation Pond

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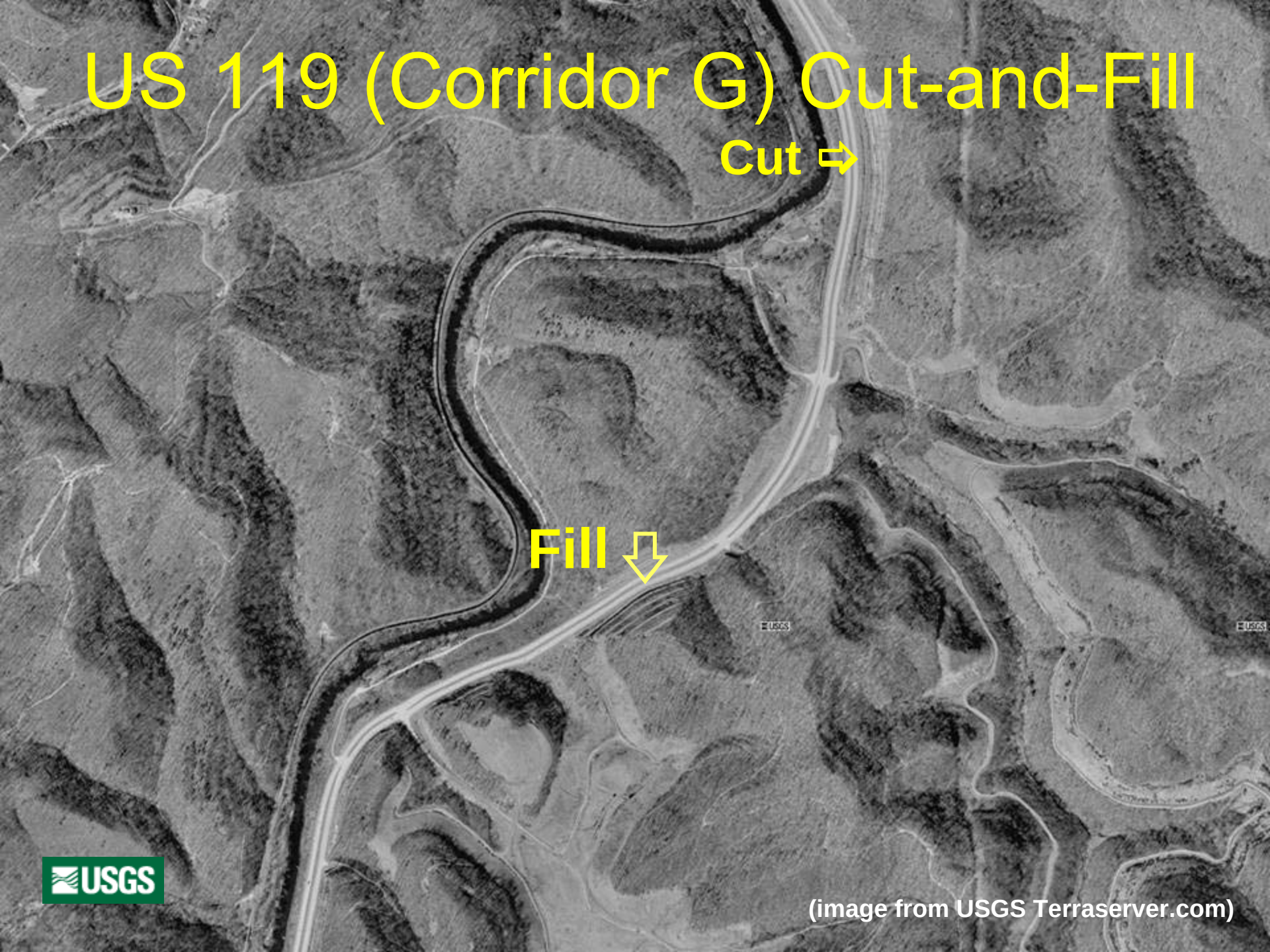
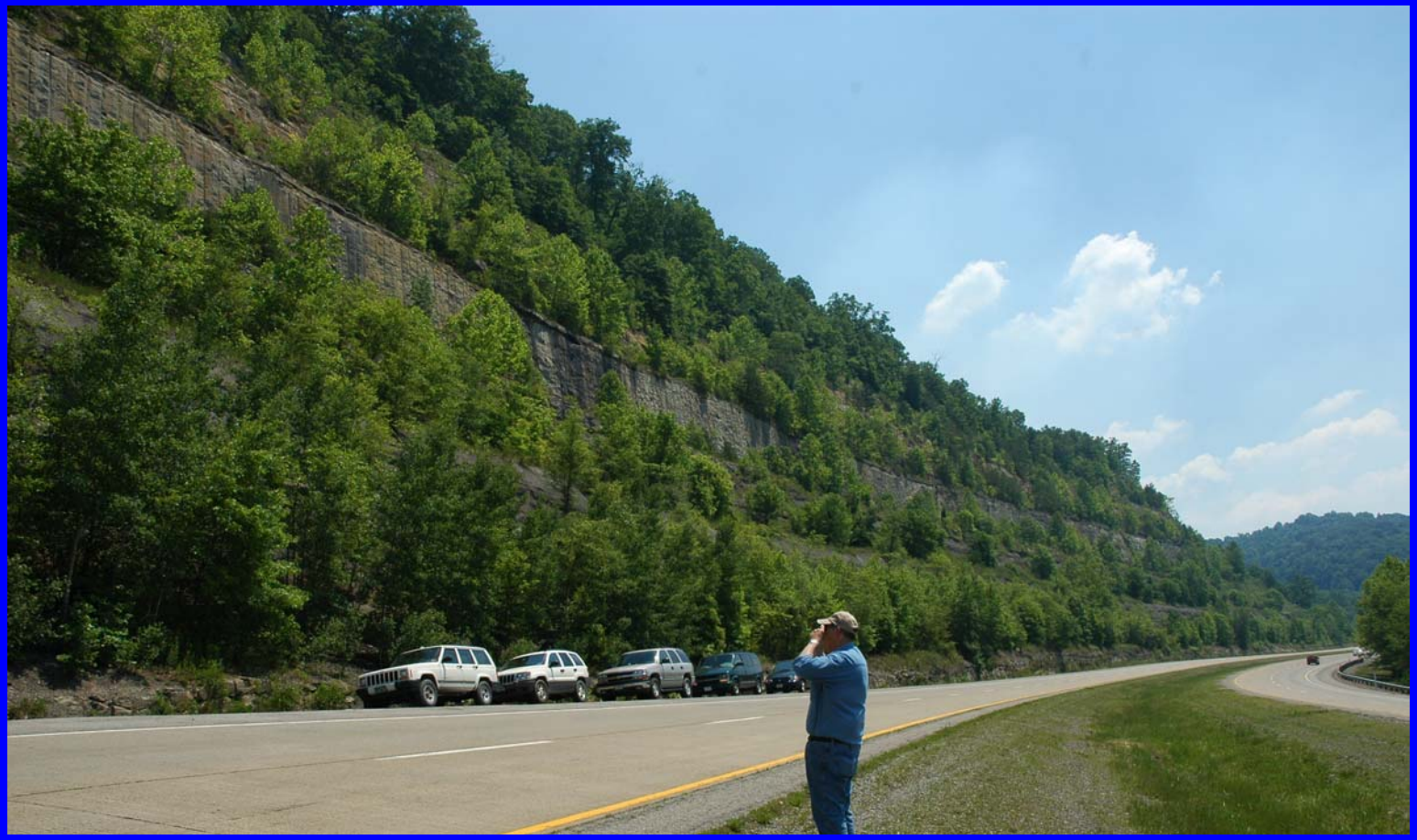
(photos courtesy of Jon Kolak, USGS)

US 119 (Corridor G) Cut-and-Fill



(image from USGS Terraserver.com)

US 119 Road Cut



(photo courtesy of Jon Kolak, USGS)

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Charleston WV – Yeager Airport Runway Safety Apron Extension

http://www.yeagerairport.com/files/WEB-5-Construction-Early-Oc.jpg

Identification of Stakeholders, Decision Makers, and Key Decisions

- Stakeholders:

  utilities, utility customers, local landowners, potential users of reclaimed land, agricultural interests, communities and concerned local residents

- Decision Makers and Types of Decisions:

  regulators, community planners and development agencies, coal companies, research funders and research agencies, special interest groups, **permitting**, leasing, allocation of resources

- Specification of Objectives:

  maximize positive effects; minimize negative effects

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Potential Decision Makers and Types of Decisions

Decision maker	Types of decisions made
Regulators - State environmental protection dept - U.S Environmental Protection Agency - U.S. Army Corp of Engineers - U.S. Fish and Wildlife Service - U.S. Office of Surface Mining - Various surface management agencies	- Leasing - Standard setting (e.g., regulatory standards for maximum Se concentrations in environment) - Permitting - Required mitigation measures - Conduct EIS - Invest in further studies - Regulation enforcement (what regulations, where and when to enforce)
Community planners and development agencies - Land use planners - City planners - Local/regional economic development agencies - County commissioners	- Land use and development practices - Zoning restrictions - Political and economic development plans
Coal companies	- Whether to pursue a given resource - Types of coal/conditions under which to pursue - Mining practices
Research funders and research agencies - U.S. Congress (appropriations) - USGS	- Which studies to fund
Special interest groups - Environmental activist groups - Conservation groups - Fishing and hunting organizations	- Allocation of resources

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Model Objectives

The model is set up to address in detail two objectives:

1. "Minimize harm to public health" by inclusion of several outputs directly related to public health impacts, and
2. "Minimize harm to ecosystems (non-human biota)" by inclusion of outputs directly related to biological effects of selenium in ponds and streams.

Other objectives were discussed during problem framing, but were not (yet) modeled quantitatively

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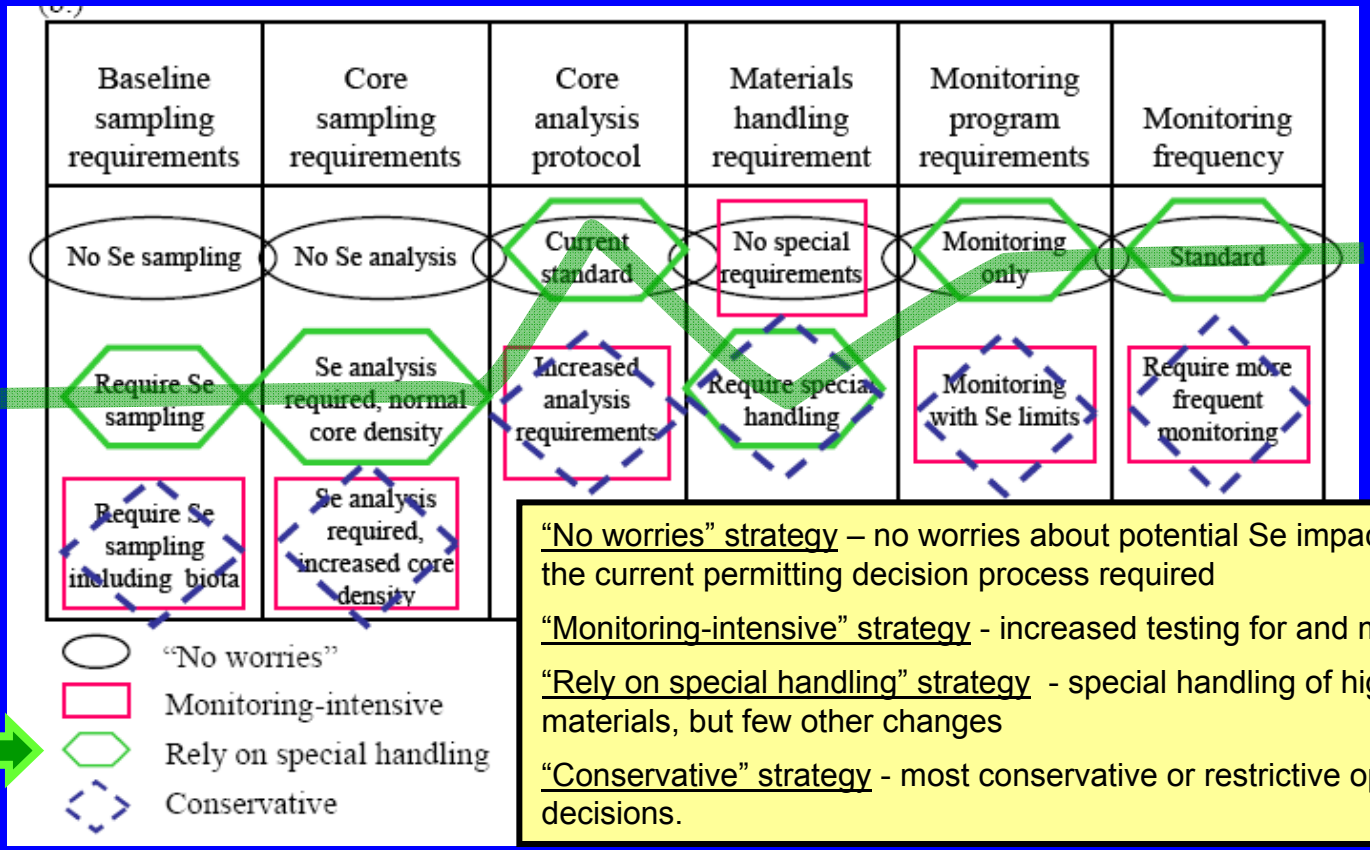
Strategy Table for Mine Permitting Decision: strategy table, with four possible strategies developed from linked responses.



"No worries" strategy – no worries about potential Se impact - no changes to the current permitting decision process required

"Monitoring-intensive" strategy - increased testing for and monitoring of Se

"Rely on special handling" strategy - special handling of high-selenium materials, but few other changes

"Conservative" strategy - most conservative or restrictive option for all decisions.

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Technical and scientific uncertainties exist at every stage of the selenium "life cycle"

- **How much Selenium is present in the geologic strata?**
- **How much Selenium-bearing strata will be disturbed?**
- **How is Se mobilized during and after the land disturbance?**
- **How does Se move through the environment into surface waters?**
- **How is Se taken up and bio-concentrated by flora and fauna of the region?**
- **What impacts does Se have on plants and animals?**
- **What are the possible effects of Se on human health?**

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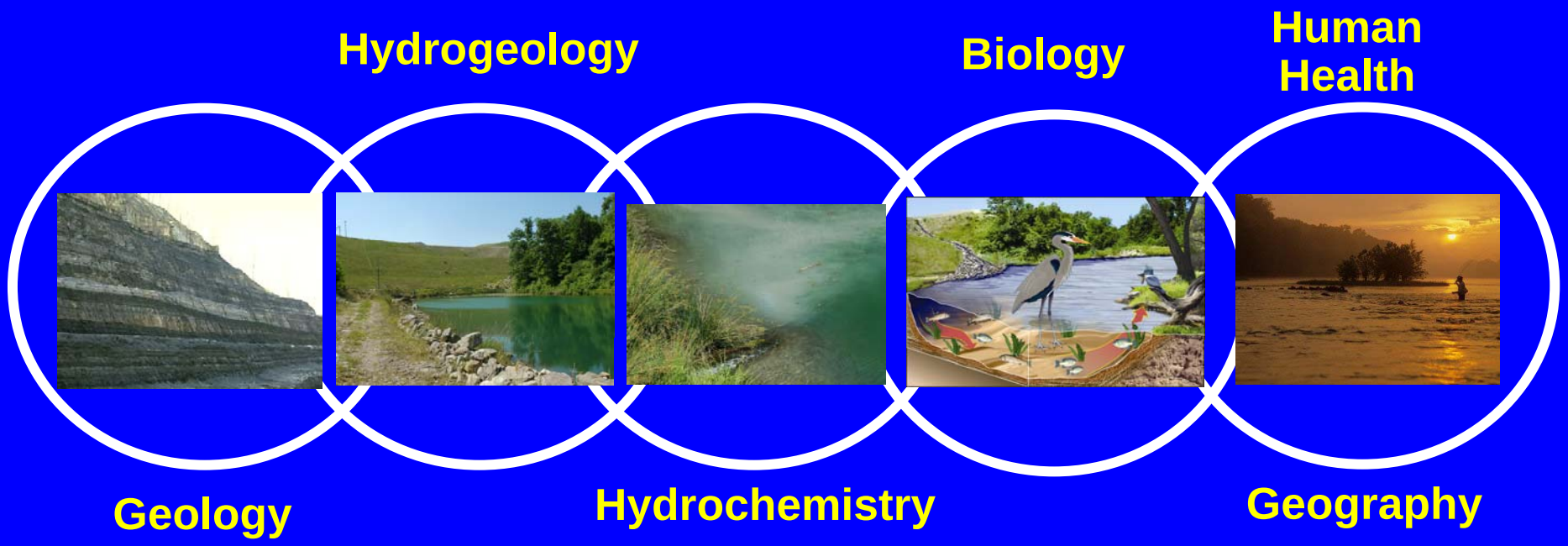
Selenium Model: Movement of Se from Surface Disruptions in E. USA



Schematic path of Selenium from rocks to humans

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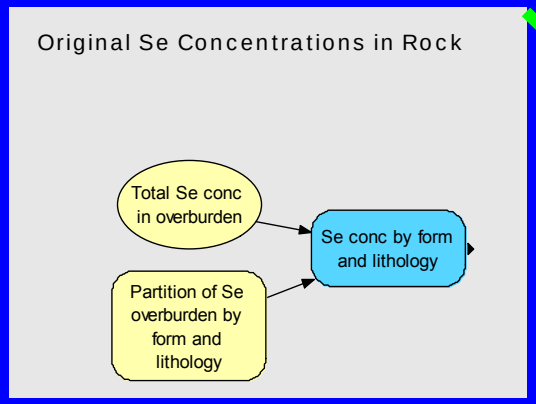
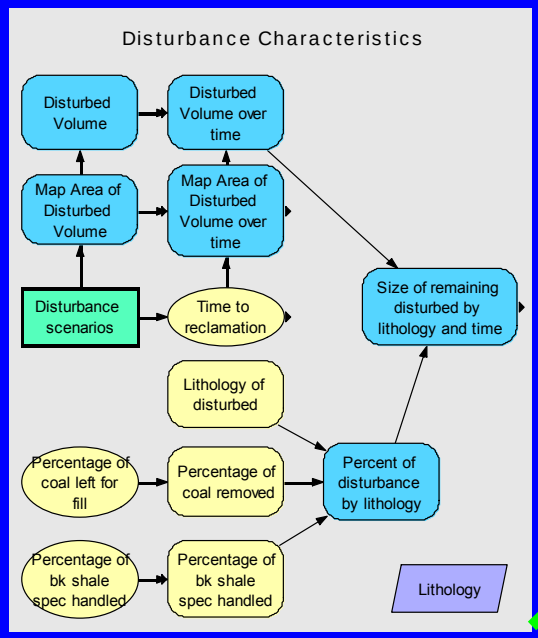
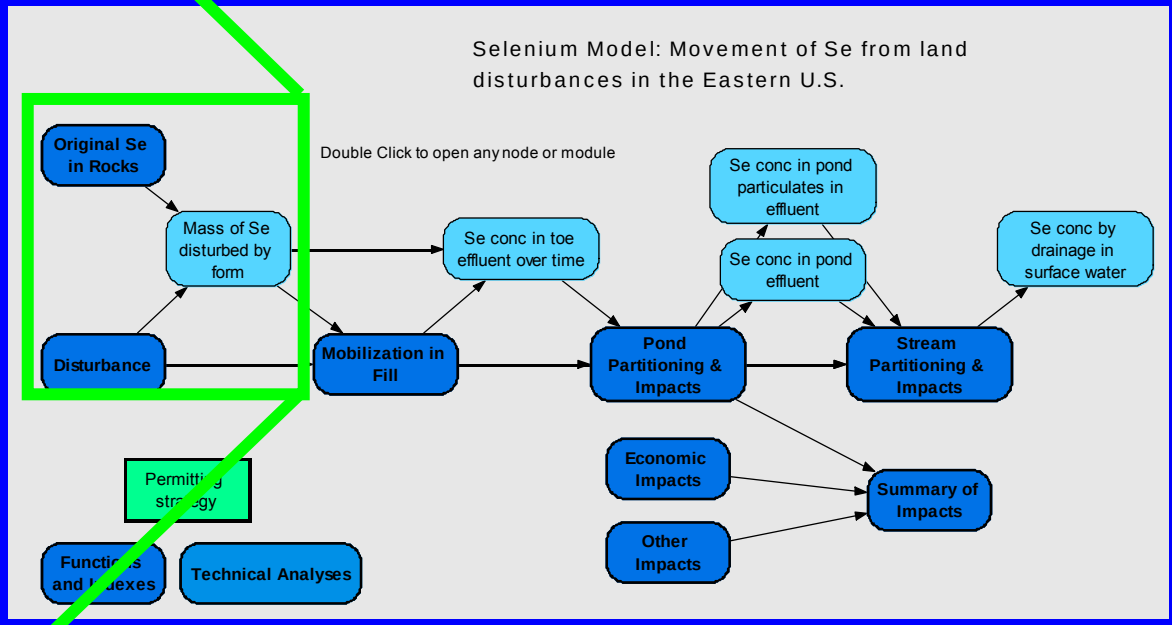
Selenium Model: Concentration in Rock







Within this software you specify everything within these windows. This is where the modeling is actually done. It shows inputs and outputs. You specify how each node works in the model.

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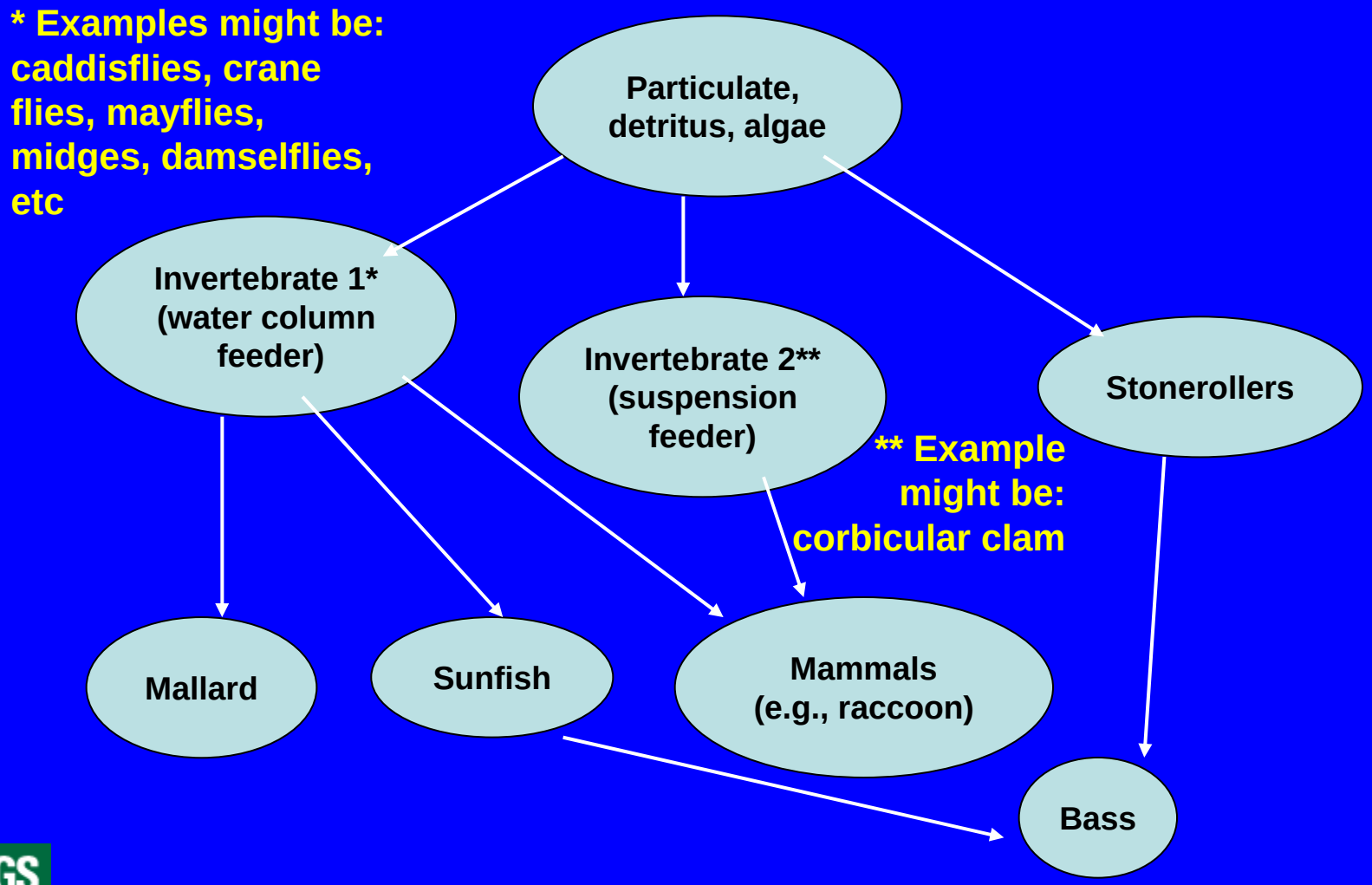
Simplified, illustrative food web used to develop a model for selenium uptake by biota in a pond.



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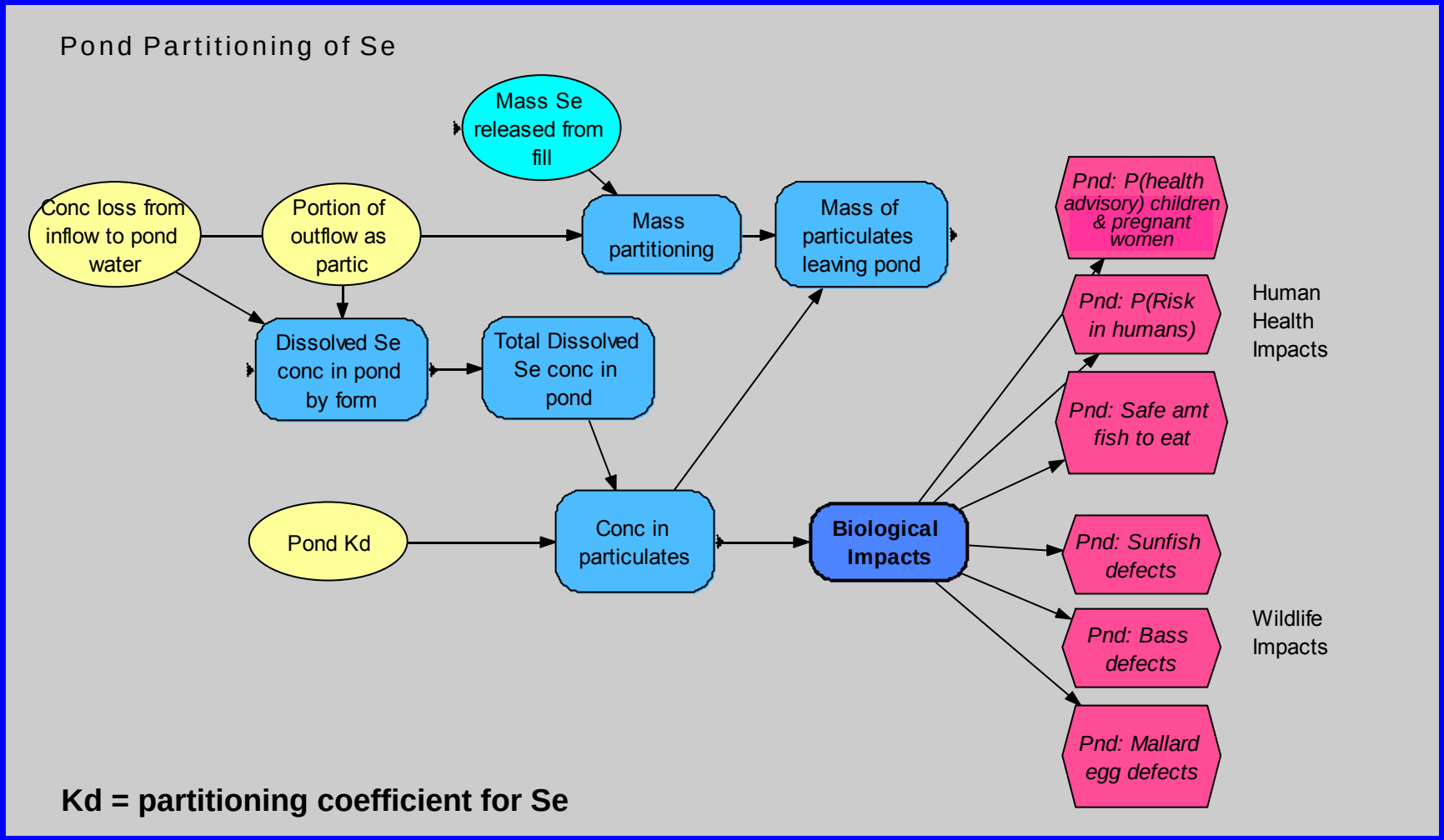
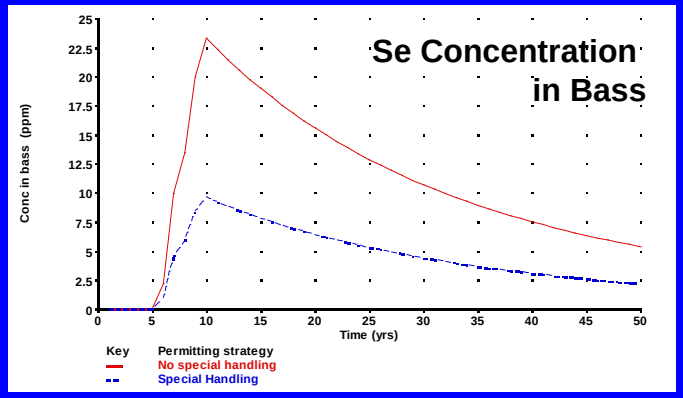
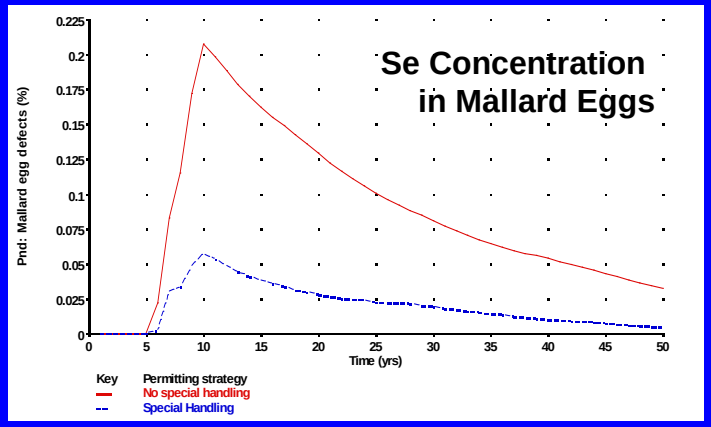
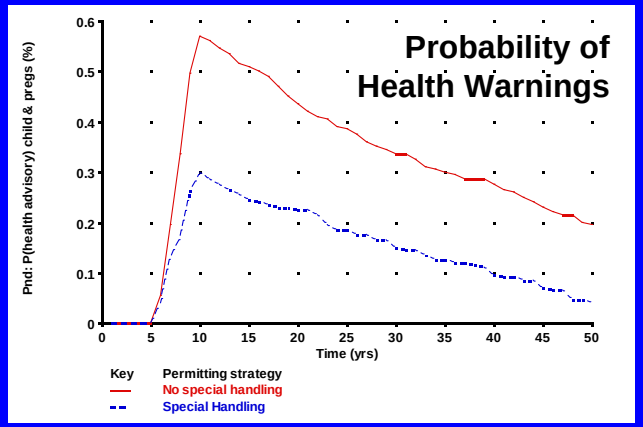
Pond Partitioning of Se



Modeled Results







What we knew before we started:

Appala-chian Coal Basin Strati-graphy & Geo-chemistry

Local Surface Water Chemistry

Western BRD Experi-ence with Selenium

National Biological Research Capabi-lities

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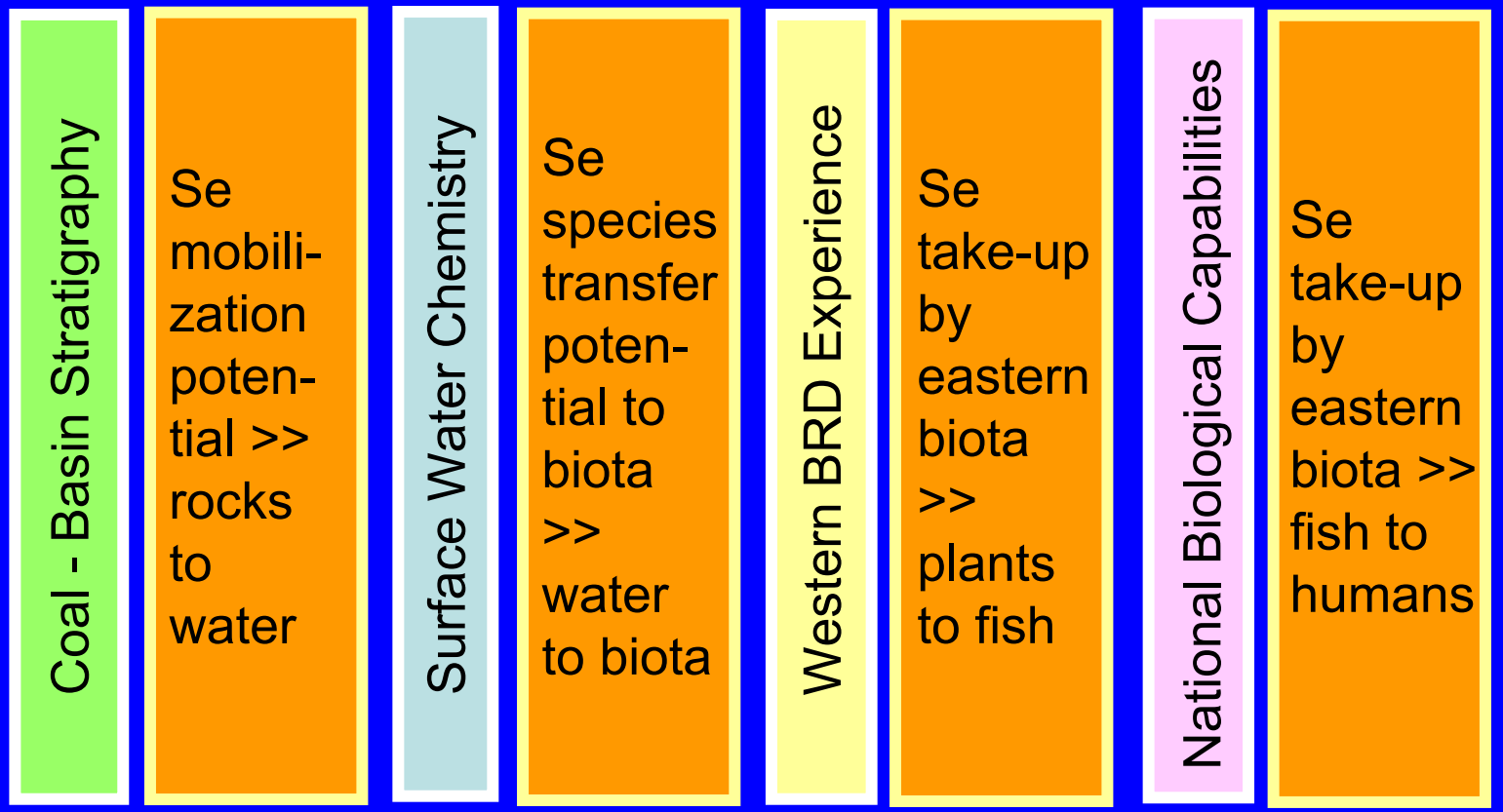
What we need to know now:



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What we need to do:

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Coordinated Plan to Fill in the Gaps

Conclusions from Study

While our current model has significant limitations, it appears that potential Se toxicity (as currently defined) for fish, birds, and humans in surface water downstream from large earth-removal projects can be addressed by special handling of selenium-rich material, such that at least 90% of the potentially available Se is consistently removed from the high Se-bearing material (siltstone, shale, and coal) before valley-fill disposal.

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Success Story: Selenium in Appalachian Coal Field Drainages

- Decision makers involved in design & QC
- Full spectrum of subject matter experts involved throughout project
- Professional 3rd party analysts involved throughout project from initial design through QC to final roll-out
- Unexpected learnings precipitated & captured >> several A-HA moments!
- Tangible, actionable outcomes
- Decision makers happy with final project

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What do you have to have to make "it" (DA) work?:

- Sponsors (read *managers*) up and down the line, who will support you or at least not hinder you;
- Sufficient resources (people, funding, time) so you don't have to timeshare, beg, borrow, or reconfigure;
- Commitment to a (reasonably) common vision and definition of "success";
- REAL subject matter experts; and
- Professionally trained analysts who can integrate, facilitate, emulate, collaborate, communicate, and celebrate.

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