Uses of ARAMS™ for Risk Assessment

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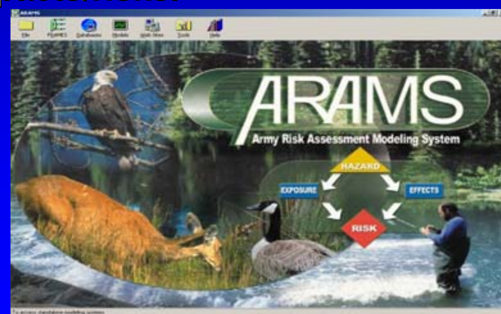
- What is ARAMS™?
  - An adaptive risk assessment modeling system developed by the Army that provides computer-based data delivery, dynamic modeling, and analysis for ***multi-media***, ***multi-pathway***, multi-route exposure and effects of military relevant compounds and other constituents of concern to assess ***human*** and ***ecological*** health impacts/risks.

ARAMS is a collection of tools, models, and data for use in health risk assessment



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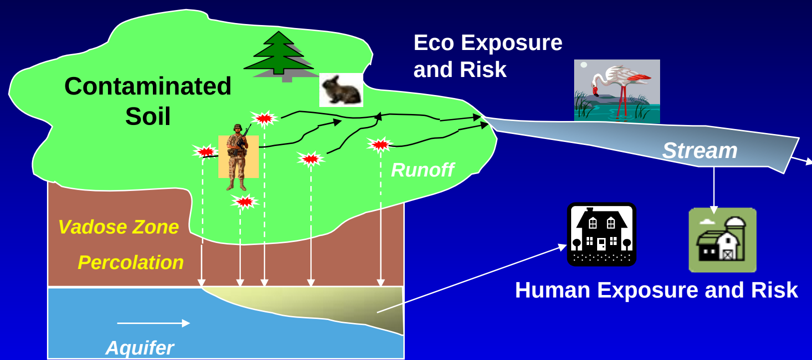
Multimedia, Multi-pathway Exposure



Media: air, soil, vadose zone, groundwater, surface water, food

Pathways: inhalation, ingestion, and dermal contact of contaminated media

What is Overall Purpose?

- Assessment of ***chronic*** human and ecological health risks associated with ***long-term*** exposure to constituent of potential concern (including hazardous and toxic ***chemicals*** and ***radionuclides***)
- Originally developed to support cleanup, but has broader application, e.g., aiding ***in managing future risks***

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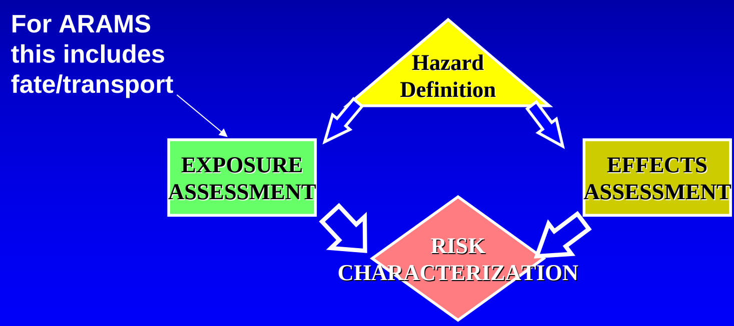
ARAMS is based on Risk Assessment Paradigm of NSF, NAS, USEPA

Integrates exposure and effects to assess human and ecological health impacts/risks



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Uses

- To assess present risks of emissions, loadings, or in-place contamination
- To determine appropriate contamination clean-up levels for acceptable risk
- To provide risk information to aid in evaluating remediation alternatives
- To aid in managing sites for future potential risks

Unique Features

- Linkages to multimedia fate/transport models, thus providing time-varying, future concentrations, exposures, and risks
- Adaptive, object-like framework for assessing a wide array of exposure-risk scenarios

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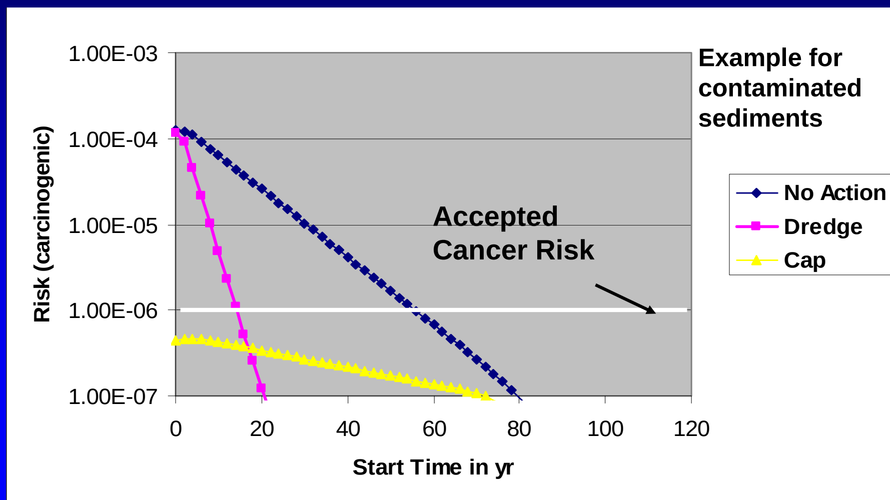
Links to fate/transport models help in Evaluating alternatives and future risks



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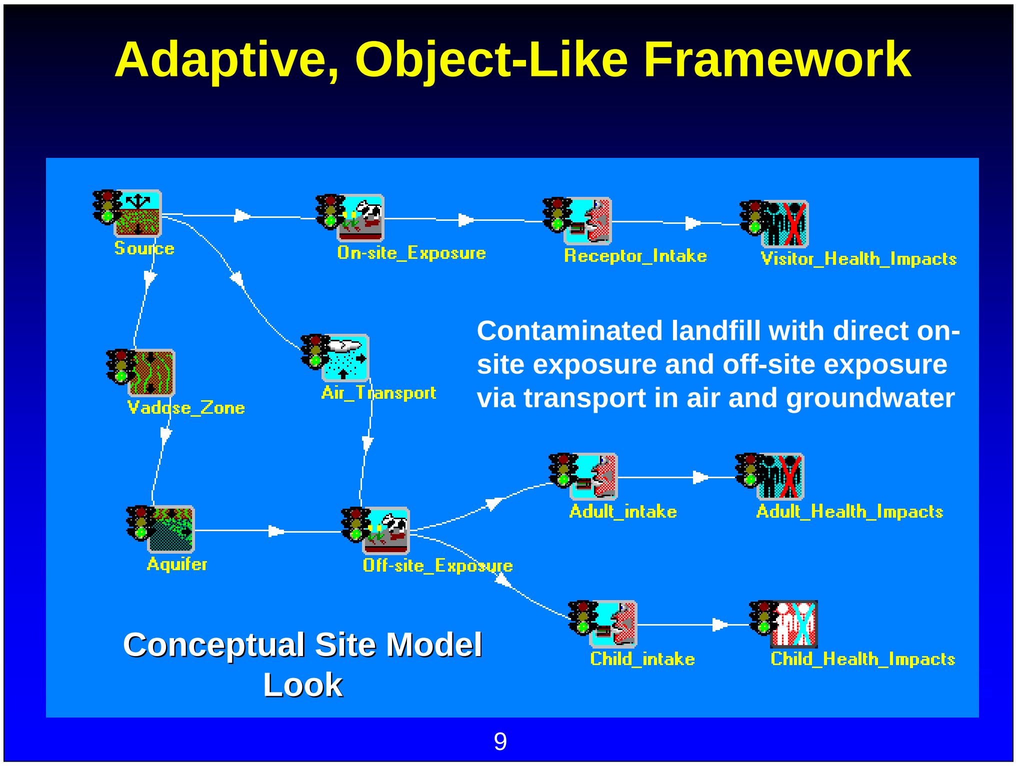
Adaptive, Object-Like Framework
Source
On-site_Exposure
Receptor_Intake
Visitor_Health_Impacts
Vadose_Zone
Air_Transport
Contaminated landfill with direct on-site exposure and off-site exposure via transport in air and groundwater
Adult_intake
Adult_Health_Impacts
Aquifer
Off-site_Exposure
Child_intake
Child_Health_Impacts
Conceptual Site Model Look
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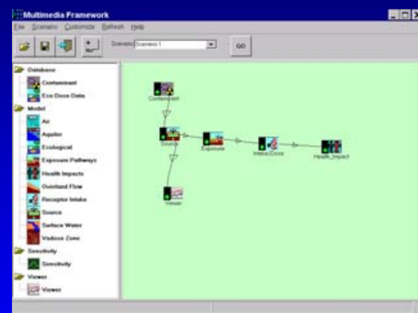
Object-Like Framework (FRAMES)

- Visually and seamlessly links disparate objects, providing flexibility for describing risk scenarios
- Can add objects and modules (e.g., models, databases)



FRAMES development supported by USACE/ERDC, DOE, EPA, NRC

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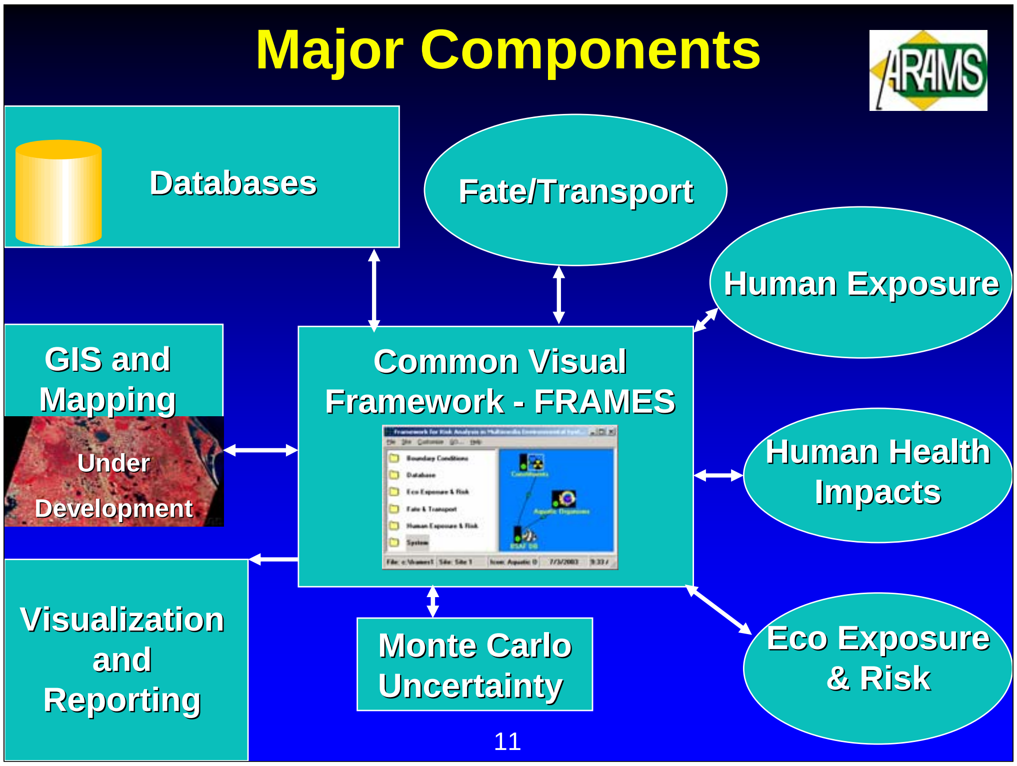
Major Components
ARAMS
Databases
Fate/Transport
Human Exposure
GIS and Mapping
Under Development
Common Visual Framework - FRAMES
Human Health Impacts
Visualization and Reporting
Monte Carlo Uncertainty
Eco Exposure & Risk
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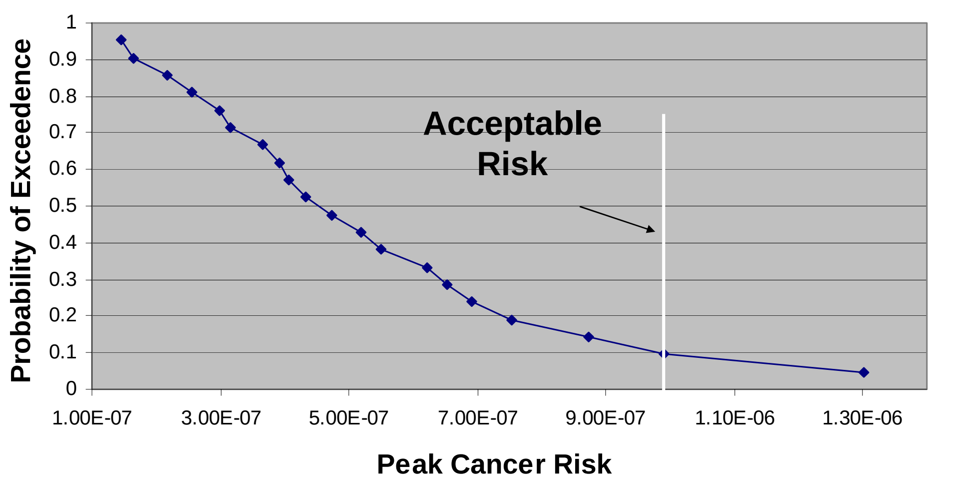
Can Assess Uncertainty of Risks



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Uncertainty Analysis

- Can assess uncertainty of inputs to develop probabilistic outputs, e.g., cumulative probability of exceeding various levels of cancer incidence; can also produce confidence (e.g., 95%) bands along time-varying results
- Uses Monte Carlo method with Latin-Hypercube sampling for efficiency
- Can treat multiple parameters (inputs) from multiple modules as uncertain
- Provides options for parameter distributions

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Key Inputs

- Site-specific conditions for soil, weather, hydrogeology, site characterization, etc.
- Chemical-specific properties, e.g., K_{ow}, Henry's constant, M_w, degradation rate, BAF, toxicity values (RfD, SF, etc) for human RA, toxicity reference values (TRVs) for eco RA, etc.
- Media concentrations (can be modeled or entered manually, via spreadsheet template (for soil), or with a generic data import tool – currently in development)

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Key ARAMS Outputs

- Risk tables in RAGS Part D format
- A Conceptual Site Model (CSM) that serves as the starting point in FRAMES

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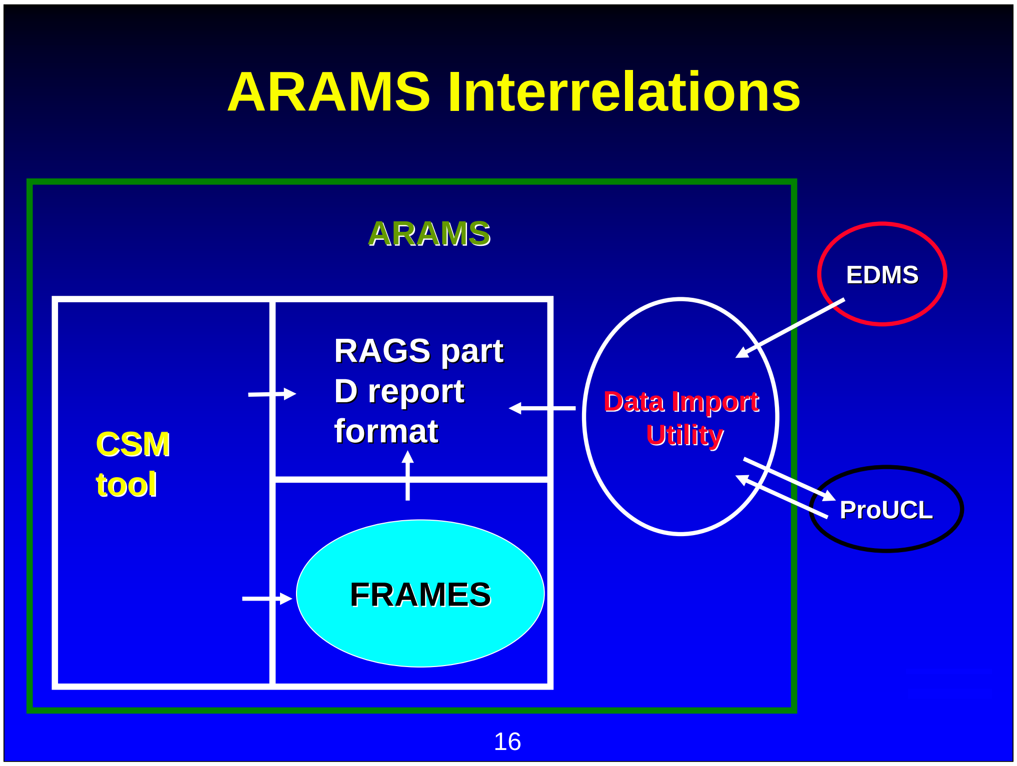

New slide added per request

A Basic ARAMS Example

Basic ARAMS Example

- A fictitious site called "XYZ Chemical" incurred a spill from one of the tanks in its tank farm
- The constituent was inorganic Arsenic (CASRN 7440-38-2) and 1850 grams spilled onto the soil
- We are concerned about the impact from incidental soil ingestion to workers
- We'll create the RAGS planning tables and the conceptual site model (CSM) for this case…

Note that in most of the examples presented that there are some steps that have been omitted

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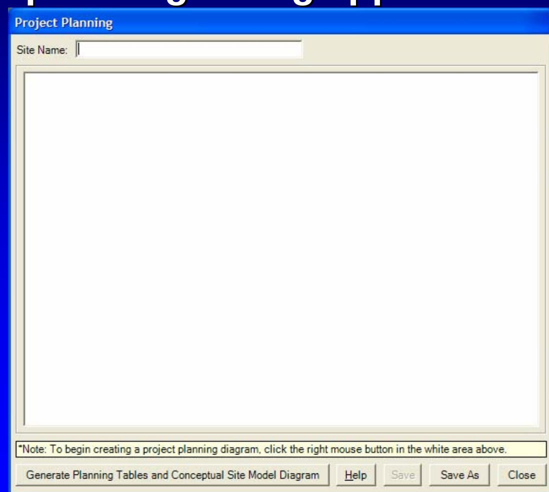
Basic ARAMS Example – con'd

- In ARAMS, we create a new project and the project planning dialog appears



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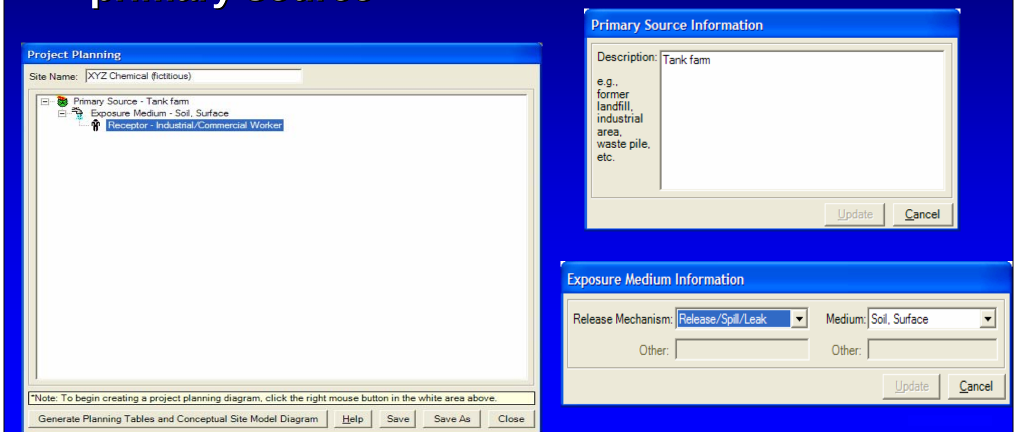
Basic ARAMS Example – con’d

- We add a primary source
- We then add an exposure medium to the primary source



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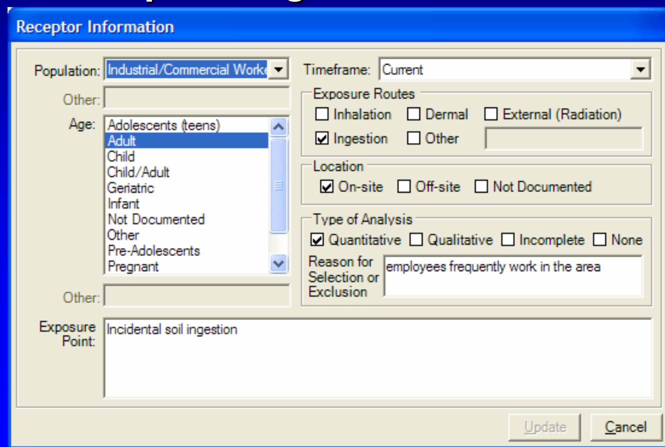
Basic ARAMS Example – con’d

- We add a receptor to the exposure medium and are then ready to generate the RAGS planning tables and the CSM…



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RAGS-D Planning Table 1

RAGS-D PLANNING TABLE 1
SELECTION OF EXPOSURE PATHWAYS
XYZ CHEMICAL (FICTITIOUS)

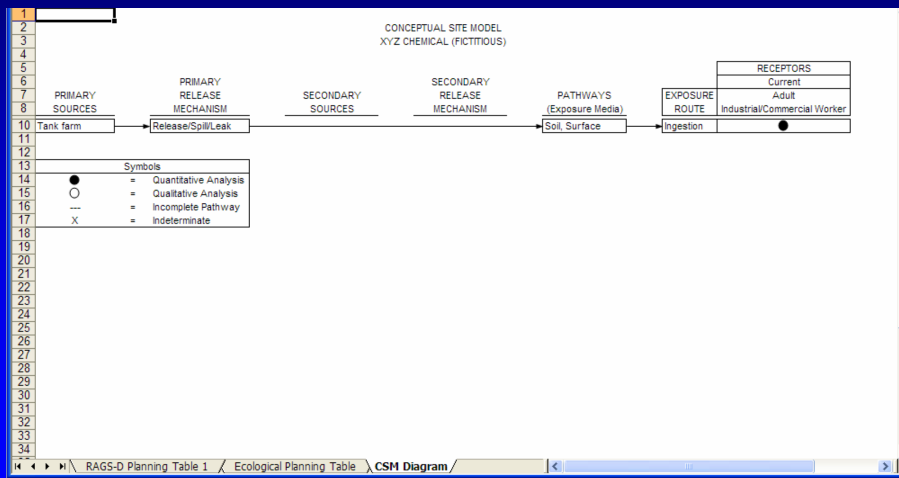
Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	On-Site/ Off-Site	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Current	Soil, Surface	Soil, Surface	Incidental soil ingestion	Industrial/Commercial Worker	Adult	Ingestion	On-site	Quantitative	employees frequently work in the area

RAGS-D Planning Table 1 | Ecological Planning Table | CSM Diagram

***Note: had we included ecological components, then the "Ecological Planning Table" would have been filled out**

CSM Diagram

- The CSM is on the "CSM Diagram" tab as shown below



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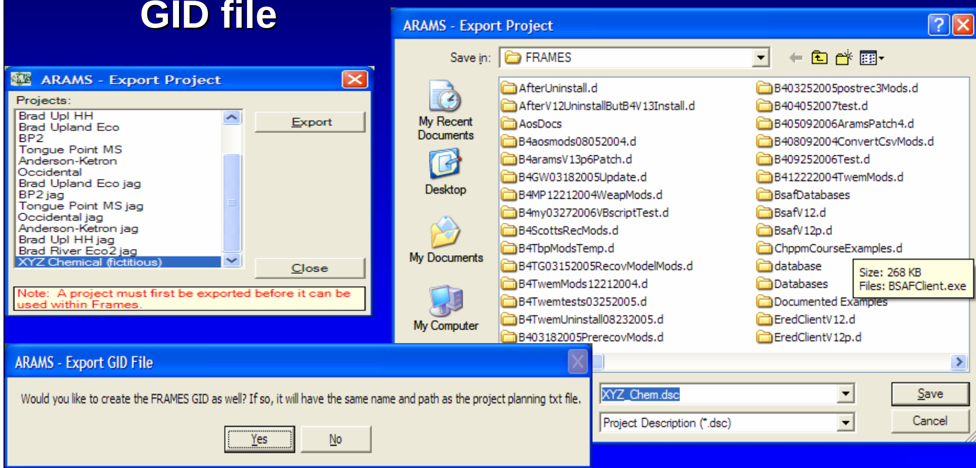
Basic ARAMS Example – con’d

- We then export the project description to FRAMES and create an initial FRAMES GID file



Basic ARAMS Example – con'd

- **Note that the created FRAMES GID file only contains the constituent database module. Unfortunately, the ARAMS CSM tool does not fully generate the FRAMES CSM, but under the ARAMS Help menu is a tutorial on how to convert the CSM diagram to objects in FRAMES**

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Basic ARAMS Example – con’d

- Using the ARAMS CSM Diagram, we can construct the FRAMES CSM (see the ARAMS Help menu for instructions on this)
- Based on this information, we therefore will want to place Source, Exposure Pathways, Receptor Intakes, and Health Impacts modules on the FRAMES workspace and we will add a RAGS viewer module to generate a RAGS part D report as well

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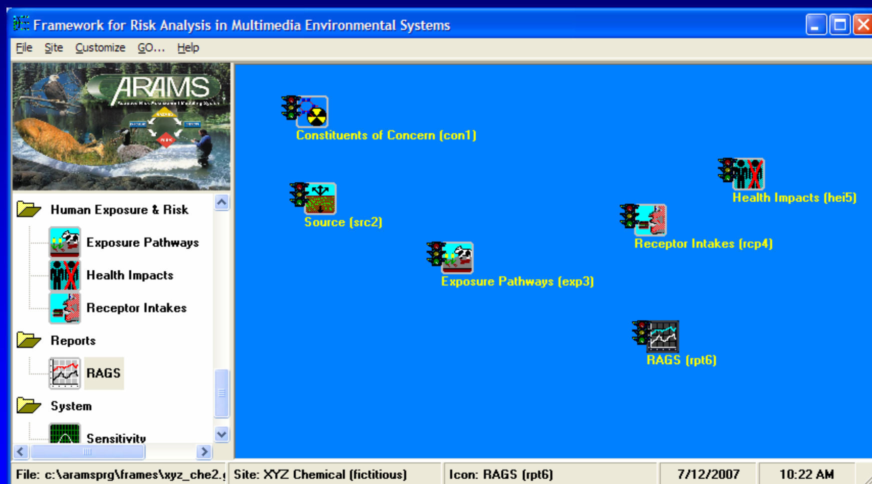
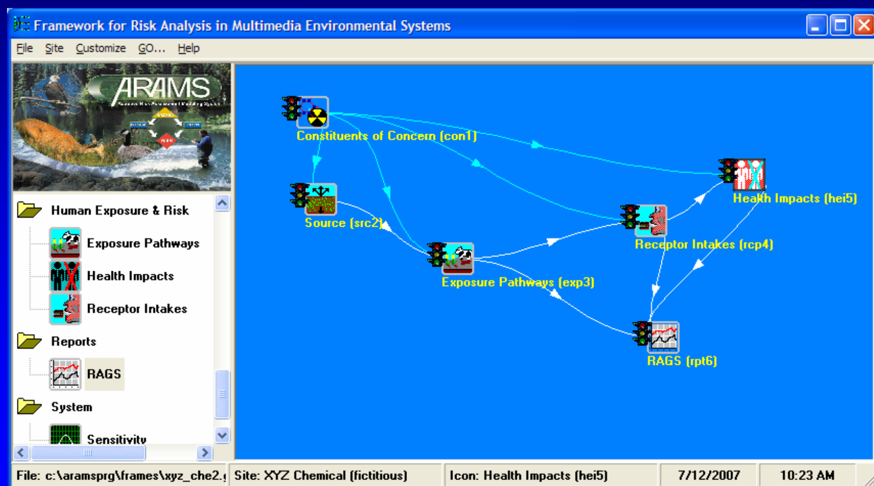
Basic ARAMS Example – con'd

- **The FRAMES CSM now looks like that shown below**



Basic ARAMS Example – con'd

- We next make the necessary module connections



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Basic ARAMS Example – con'd

- We are now ready to select the models/database that we will use in the analysis (by right-clicking on an object, selecting "General Info", and then selecting from the available database/model listings):
  - Constituent Module - "FRAMES Constituent Database Selection"
  - Source module - "MEPAS 5.0 Source in Soil Module"
  - Exposure Pathways - "MEPAS 5.0 Exposure Pathways Module"
  - Receptor Intakes - "MEPAS 5.0 Receptor Intakes Module"
  - Health Impacts - "MEPAS 5.0 Health Impacts Module"
  - RAGS - "RAGS Table Generator"

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Basic ARAMS Example – con'd (additional data)

Variable Description	Value	Units
Length	50	m
Width	50	m
Depth	5	cm
Ingestion RfD	0.0003	mg/kg/day
Ingestion CSF	1.5	$(mg/kg/day)^{1}$
Decay/degradation	none	n/a
Soil ingestion rate	0.05	g/day
Soil leach rate constant	0	/yr
Worker work frequency	340	days/yr
Exposure duration	30	yr
Worker average weight	70	kg

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Basic ARAMS Example – con'd

- We then perform user input on all of the modules and then run all of the modules (we can also use the FRAMES "Go" button to accomplish this)
- We can then view the output…

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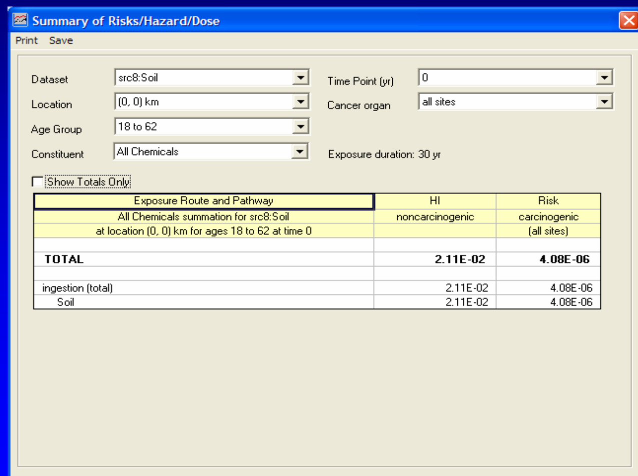
Basic ARAMS Example – con'd

- **The Health Impacts "Summary Views of Risk, Hazard and Dose" viewer is shown and the cancer risk is 4.08E-06 and the HI is 2.1E-02**



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Basic ARAMS Example - concluded

- **If we run the RAGS viewer, we get the set of RAGS part D tables shown below using the viewer's RME option**

TABLE 10.1.B
RISK ASSESSMENT SUMMARY
REASONABLE MAXIMUM EXPOSURE
Summarization is based on the sampling of the time-varying curve, after the time-varying Hazard/Risk curves have been combined in time.
Threshold for Carcinogenic Risk = 0.000E+00
Threshold for Non-Carcinogenic Hazard Quotient = 0.000E+00
For applicable time varying outputs the first value is reported in this table (see footnote a,b,c).
C:\ARAMS\PRG\FRAMES\XYZ_CHE1

Scenario Timeframe:	0-100 yr
Receptor Population:	1
Receptor Age:	10-62 yr

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ	Ingestion	Inhalation	Dermal	Exposure Routes Total
Soil	Soil	Exposure_Pathways	Arsenic	4.000E-06	--	--	--	4.000E-06	total body	2.110E-02	--	--	2.110E-02
			Chemical Total					4.000E-06					2.110E-02
			Radionuclide Total					--					--
		Exposure Point Total						4.000E-06					2.110E-02
	Exposure Medium Total							4.000E-06					2.110E-02
Medium Total								4.000E-06					2.110E-02

Total Risk Across All Media: 4.000E-06
Total Hazard Quotient Across All Media: 2.110E-02

Definitions:
RME = Reasonable Maximum Exposure

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Firing Range Example

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Firing Range Example

- In this example, a hypothetical firing range of 500 m x 500 m has a receiving stream located 3 km down gradient from the range
- The range is to be used for 50 years
- We are only concerned about runoff from the site
- We are interested in determining if and when RDX (CASRN 121-82-4) concentrations in the stream exceed the protective public advisory criteria of 2 parts-per-billion (ppb)

Firing Range Example – con'd

Variable Description	Value	Units
Range life	50	yr
Average rainfall	63.5	cm
Receiving stream annual flow rate	0.5	m^3/sec
Munitions used	81 mm Mortar & 155 mm Howitzer	n/a

Munition	Variable Description	Value	Units
81 mm Mortar	Rounds Fired	3000	/yr
	Low Order	2	%
	Yield*	25	%
155 mm Howitzer	Rounds Fired	3000	/yr
	Low Order	2	%
	Yield*	25	%

* Amount of explosive used up in a low order detonation

Firing Range Example – con’d

- Modules, databases and models used:
  - Constituent module– “FRAMES Constituent Database Selector”
  - Source module – “Munition Residue Characterization and Fate Model” (available beginning with ARAMS 1.4)
  - Surface Water module – “MEPAS 5.0 River Module”
  - Exposure Pathways module – “MEPAS 5.0 Exposure Pathways Module”

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Firing Range Example – con'd

- We select RDX as the constituent of concern and set any properties of RDX that may be necessary in the constituent database module
- We then supply the model input information required
- Finally, we run the modules…

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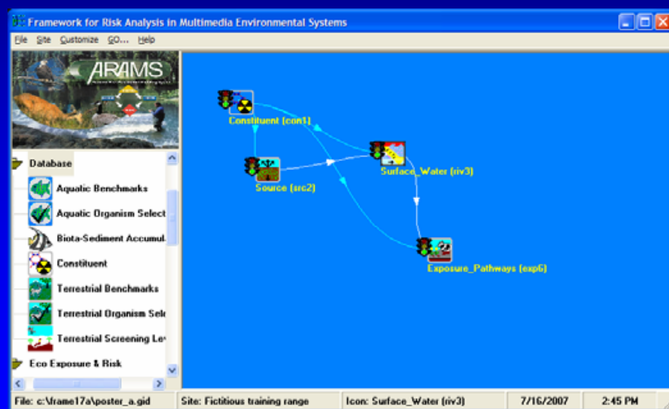
Firing Range Example – con’d

- Our example CSM then looks like that shown below



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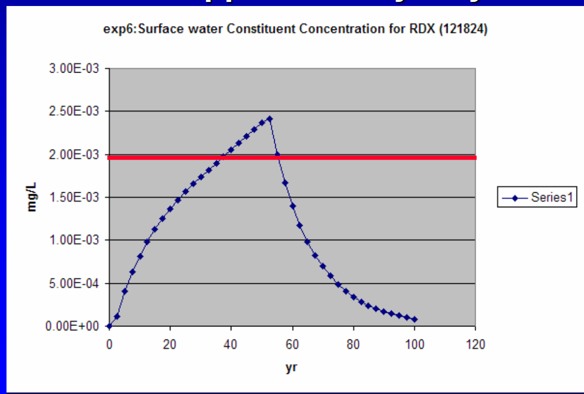
Firing Range Example – con'd

- We can then view the surface water module's water concentration file (WCF) output
- From the WCF output we notice that the protective public advisory criteria of 2 ppb will be exceeded after approximately 40 years of use



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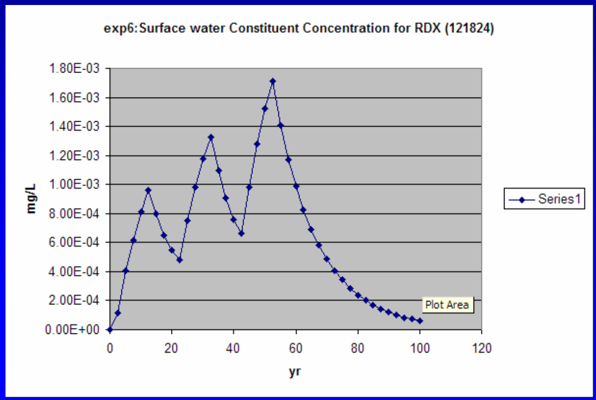
Firing Range Example – con’d

- What can we do to ensure that we do not exceed the advisory criteria for the range usage period?
- One possibility is to alternate the range use on 10 year cycles
- Let’s test this alternative…

Firing Range Example - concluded

- We make the model input adjustments and re-run the models
- From the output of the alternative case, we can see that this does prevent exceeding the advisory criteria



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Terrestrial Eco Example

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Terrestrial Eco Example

- This is a steady-state analysis where we wish to evaluate the exposure of a Belted Kingfisher (Ceryle alcyon) and Red Fox (Vulpes vulpes) to DDT (CASRN 50-29-3) contaminated water, soil, and sediment (where appropriate)

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Terrestrial Eco Example –con'd

- The modules, databases and models used:
  - Constituent module – "FRAMES Constituent Database Selector"
  - Terrestrial Organism Selector module– "ARAMS Terrestrial Organism Selector"
  - User Defined module – "SCF – Soil Module"
  - User Defined module – "SCF – Sediment Module"
  - User Defined module – "WCF – Surface Water Module"
  - Terrestrial Benchmarks module – "TTD - TRVs"
  - Eco Receptor Intake module – "Terrestrial Wildlife Exposure Model"
  - Eco Health Effects module – "Wildlife Ecological Assessment Program"

Terrestrial Eco Example – con’d

- **We select DDT as the constituent of concern and set any properties of DDT that may be necessary**
- **We select the terrestrial organisms**
- **We select TRVs (or provide user-defined ones) to be used in the analysis (we can use multiple TRVs for a given receptor/constituent)**
- **Next, we supply the model input information required**
- **Note: TWEM is the only model that requires the output from the upstream modules be run prior to opening the module for user input**

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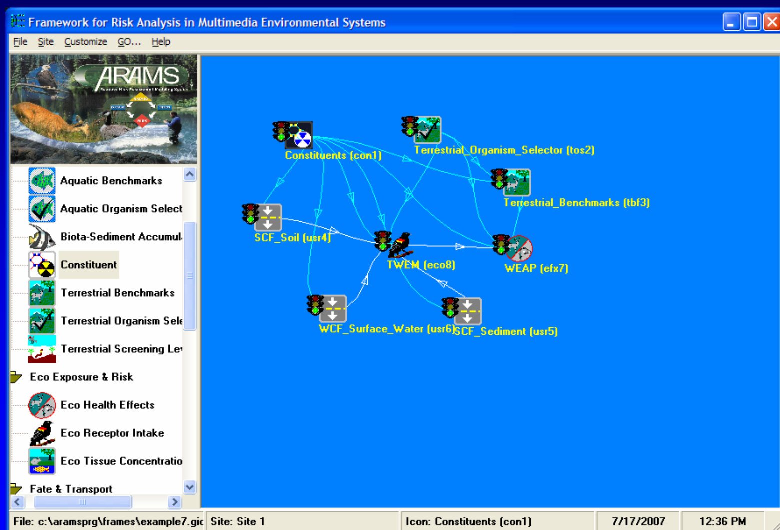
Terrestrial Eco Example – con’d

- **After running all models, our example CSM then looks like that shown below**



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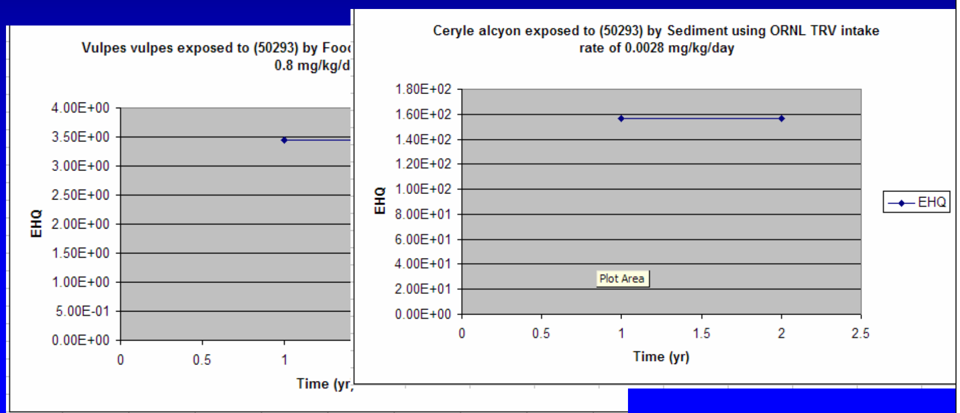
Terrestrial Eco Example – con'd

- We can then view the EHQ output of the WEAP module
- A couple of the graphs where the EHQ is > 1 are shown below



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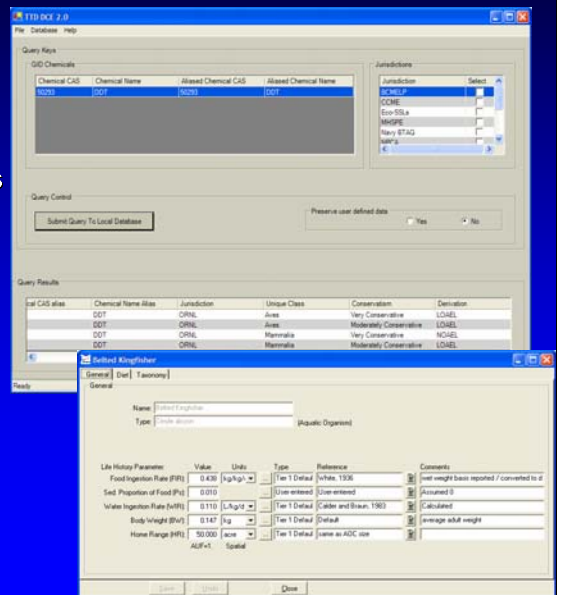
Terrestrial Eco Example – concluded

- Some of the EHQs were high, what made them high?
  - We can go check the TRVs that were used (e.g. how conservative were those values?)
  - We could go check the BAFs, Regression, Log(Kow), and life history parameter values used in TWEM
  - If all are reasonable, then perhaps steps need to be taken to mitigate the impacts



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Example with Uncertainty

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Example with Uncertainty

- **This example demonstrates the power and flexibility of the FRAMES S/U module**
- **A more detailed description is contained in a journal article that has been accepted for publication in the *J. Contam. Soil & Sed.,* entitled "Modeling Fate of RDX at Demolition Area 2 of the Massachusetts Military Reservation" (M.S. Dortch, S. Fant, and J.A. Gerald)**

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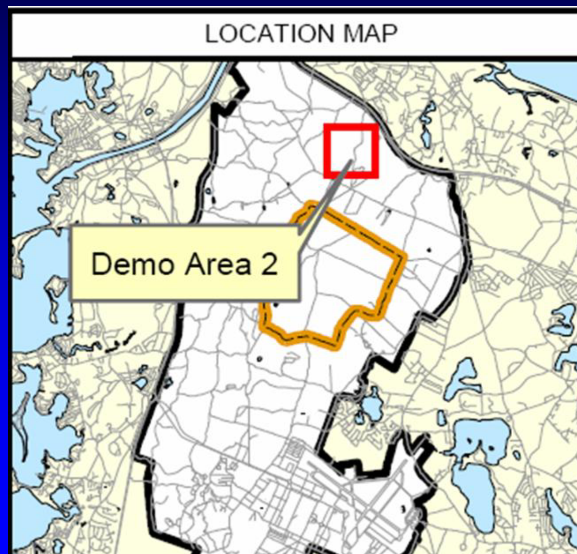
Application to MMR Demo Area 2 for RDX Residue



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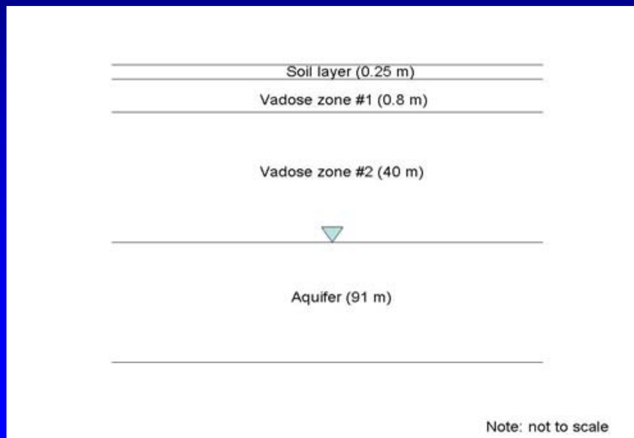
MMR Demo Area 2 Background

- Used for demolition training from late 70's to late 80's
- Used mostly C4 (RDX plus binders and plasticizers)
- Measured soil and groundwater concentrations roughly 25 years later
- Asked by AEC to model site as proof of concept
- Challenge: to predict soil and groundwater concentrations not knowing the residue loading 25 years prior

Example with Uncertainty – con’d

- The surface/subsurface profile of the site is shown below



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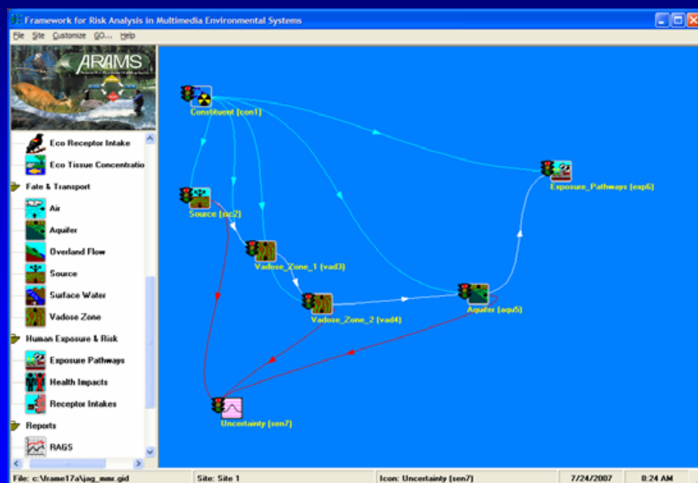
Example with Uncertainty – con’d

- **The FRAMES representation used for the site is shown below**



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Example with Uncertainty – con'd

- The following table shows the variables that were treated as uncertain for this case and their prescribed distributions…

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Variable	Units	Distribution	Lower Bound	Mean (baseline)	Upper Bound	Standard Deviation
Source Zone						
Length	m	Normal	80	110	140	10
Width	m	Normal	80	110	140	10
Mass load rate	g/yr	Log Normal	500	1000	5000	750
β dissol. coef.	mg/ cm^2/sec	Uniform	7E 10	7E 09	7E 08	NA
Kd	ml/g	Normal	0.22	0.11	0.055	0.028
Infiltration rate	cm/yr	Normal	60	76.2	85	2.5
Lower vadose zone						
Kd	ml/g	Normal	0.007	0.013	0.026	0.003
Sat. Hydraulic Conductivity	cm/day	Normal	450	570	650	33
Half life	years	Normal	10	100	200	32
Aquifer						
Darcy velocity	cm/day	Normal	50	100	150	17
Kd	ml/g	Normal	0.007	0.013	0.026	0.003
Half life	years	Normal	10	100	200	32
Longitudinal dispersivity	cm	Log Normal	21	210	2100	347
Transverse dispersivity	cm	Log Normal	2.1	21	210	35
Vertical dispersivity	cm	Normal	0.01	0.381	1.0	0.165

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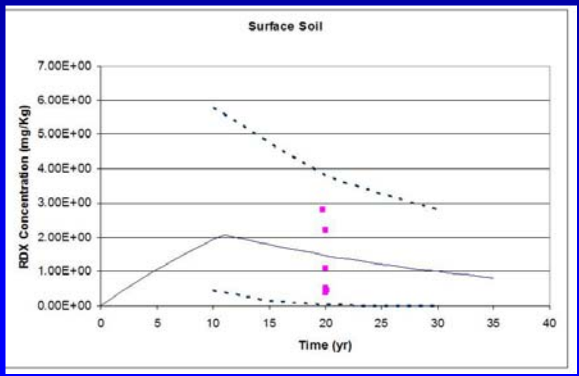
Example with Uncertainty – con'd

- In the S/U module we set the number of realizations to 500 and monitored the output of the source zone soil concentration and the groundwater concentration at a monitoring well identified as MW262
- Convergence occurred by 400 iterations

Example with Uncertainty – con’d

- The figure below shows the source zone soil concentration (computed and observed) with upper and lower 95% confidence interval



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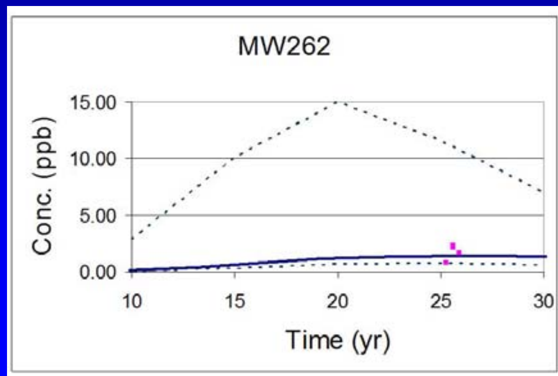
Example with Uncertainty - concluded

- The figure below shows the groundwater concentration (computed and observed) at monitoring well MW262 with upper and lower 95% confidence interval



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Advanced Example

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- **In this example the versatility of ARAMS for analyzing multiple fate/transport within a watershed is demonstrated**
  - "Site 1" and "Site 2" are two areas of soil contaminated with PCB. Storm water runoff from both sites feed into another downstream site, "Secondary Source"
  - A leachate collection system exists at site #1, which serves as a sink
  - Volatilization occurs at site #1
  - Runoff and wind suspended particles from site #1 deposit onto the "Secondary Source" site
  - A survey of the area indicated a sediment trap was used in former operations at the site and this also has runoff to the "Secondary Source" site
  - Runoff from the "Secondary Source" site flows into a stream where, at a point downstream, the water is extracted and used for drinking, showering, and watering of a vegetable garden by a local resident

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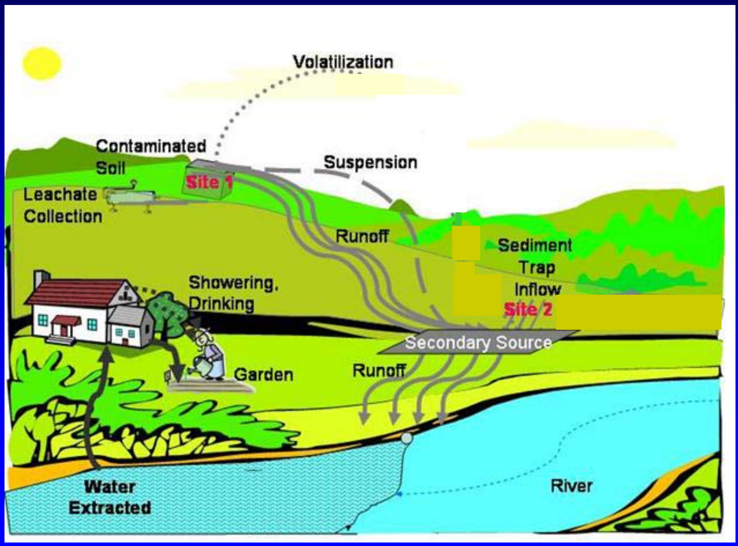
Advanced Example – con'd

- This scenario is depicted as shown below



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Advanced Example – con’d

- We use the following modules, databases and models:
  - Constituent module – “FRAMES Constituent Database Selection”
  - Source module – “MEPAS 5.0 Source in Soil”
  - User Defined module – “WFF – Surface Water Module”
  - Air module – “MEPAS 5.0 Air Module”
  - Plus Operators module – “WFF – Surface Water Plus Operator”
  - Overland Flow module – “Copy of MEPAS 5.0 Secondary Source in Soil”
  - Surface Water module – “MEPAS 5.0 Surface Water Module”
  - Exposure Pathways module – “MEPAS 5.0 Exposure Pathways Module”
  - Receptor Intakes module – “MEPAS 5.0 Receptor Intakes Module”
  - Health Impacts module – “MEPAS 5.0 Health Impacts Module”

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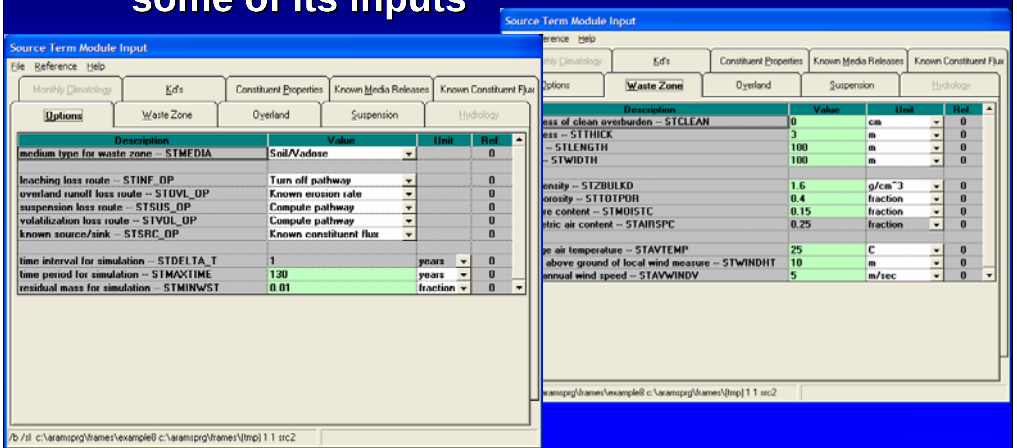
Advanced Example – con’d

- We select PCB (General Classification) as the constituent of concern and set any properties of it that may be necessary
- We provide the required inputs for the modules (fairly numerous for this case)

Note: The WFF Plus Operator requires no input and creates a single WFF connection to the downstream module for the case where the model used there only accepts a single WFF input connection as indicated in the model’s input connection description (“General Info”).

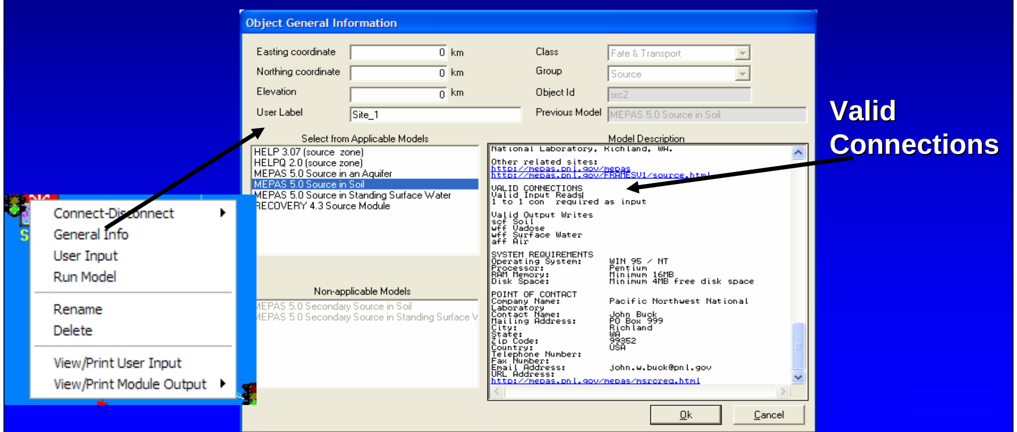
Advanced Example – con'd

- Example of the "MEPAS 5.0 Source in Soil" model's user-interface showing some of its inputs



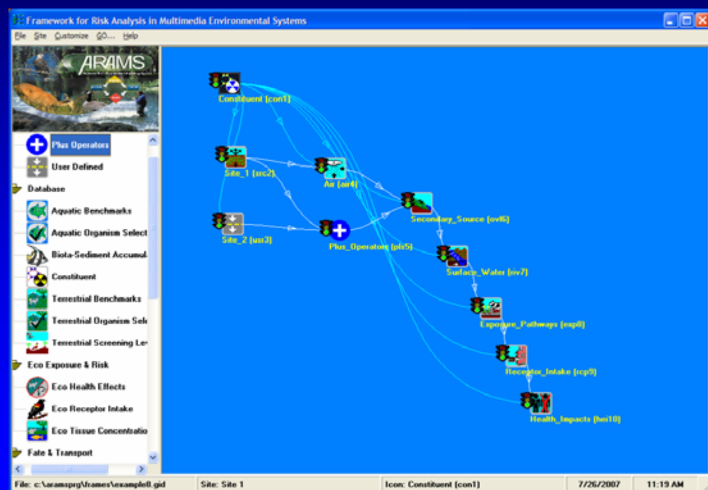
Advanced Example – con'd

- **Figure showing where the module input connection information can be found (under Module Description of the model, which is available by right clicking on a module and selecting "General Info" from the popup menu)**



Advanced Example – con’d

- In FRAMES, the CSM then looks like that shown below after running the models



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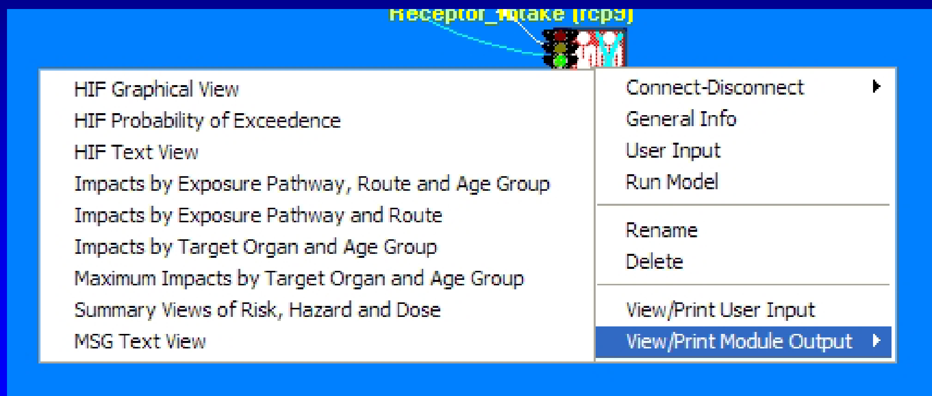
Advanced Example – con’d

- The figure below shows the human health impact viewers available to the user



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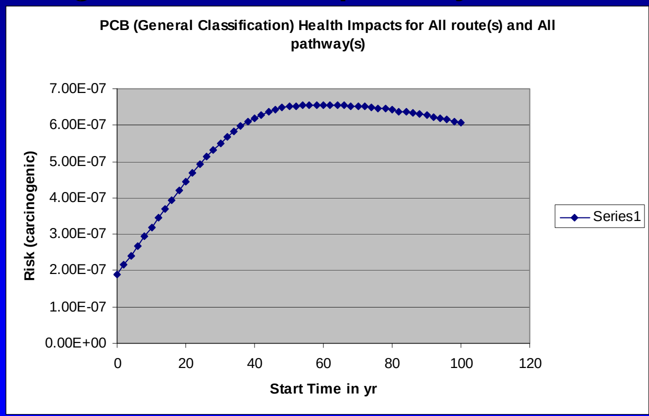
Advanced Example – con'd

- Below is the plot of the "HIF Graphical View" health impacts viewer showing the time varying carcinogenic risk for all pathways and all routes



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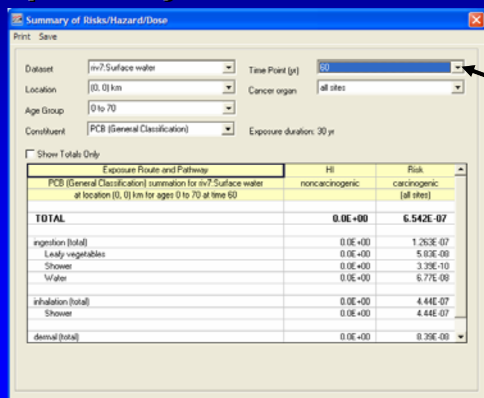
Advanced Example – con’d

- The “Summary Views or Risk, Hazard, and Dose” viewer is shown below
- Note that you can easily determine which route/pathway contributes the most risk



User can select time period here

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Summary

- ARAMS has multiple uses in risk assessment:
  - Serves as a central framework for conducting a RA
  - Provides tools to help perform a RA quicker and more efficiently (e.g. RAGS planning tables, CSM diagram, RAGS table generator)
  - Provides extensive reporting capabilities
  - Allows tracking and reporting of references
  - Model/Database "Plug and Play" capability (modular/adaptable)
  - Allows the user to use known data or perform modeling and consequently allows for time-varying risk evaluations, i.e. risk management
  - Performs uncertainty in a RA

Status

- ARAMS 1.4 will include the additional models/modules:
  - SEEM (Spatially Explicit Exposure Model)
  - MRCFM (Munitions Residue Characterization and Fate Model)
  - GENII* V2 & GENII V2 NESHAPS¥ suite of models
  - Sensitivity added to S/U module
  - A joint frequency data (JFD) utility
- ARAMS 1.4 planned for release this Fall

* Generation II

¥ National Emission Standard for Hazardous Air Pollutants

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Thanks

- To all of the participants
- And to the following:
  - U.S. EPA
  - U.S. Army Engineer Research and Development Center
  - Interstate Technology and Regulatory Council (ITRC)

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Upcoming Events

- ITRC ARAMS workshop – fall 2008

Questions?

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Thank You

After viewing the links to additional resources, please complete our online feedback form.

Thank You

Links to Additional Resources

Feedback Form