MODELING OIL SPILL RESPONSE AND DAMAGE COSTS

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ABSTRACT
The EPA Basic Oil Spill Cost Estimation Model (BOSCEM) was developed to provide the US Environmental Protection Agency (EPA) Oil Program with a methodology for estimating oil spill costs, including response costs and environmental and socioeconomic damages, for actual or hypothetical spills. The model can quantify *relative* damage and cost for different spill types for regulatory impact evaluation, contingency planning, and assessing the value of spill prevention and reduction measures. EPA BOSCEM incorporates spill-specific factors that influence costs – spill amount; oil type; response methodology and effectiveness; impacted medium; location-specific socioeconomic value, freshwater vulnerability, habitat/wildlife sensitivity; and location type. Including these spill-specific factors to develop cost estimates provides greater accuracy in estimating oil spill costs than universal per-gallon figures used elsewhere. The model's basic structure allows for specification of response methodologies, including dispersants and *in situ* burning, which may have future applications in freshwater and inland settings. Response effectiveness can also be specified, allowing for analysis of potential benefits of response improvements.

INTRODUCTION
Regulatory analysis, cost-benefit analysis, resource planning, and impact analysis related to oil spills requires putting a value on the damages that oil spill cause. Use of a universal dollar-per-gallon (or dollar-per-barrel) cost for oil spill response, socioeconomic and environmental damage has been applied in many cases (*e.g.,* Office of Management and Budget, 2003), but this methodology overlooks the important factors in oil spill cases that can influence costs by orders of magnitude. The costs of a particular oil spill are related to a large number of factors, most

notably: spill amount, oil type characteristics, response methodology and effectiveness, impacted medium or substrate type, location-specific socioeconomic and cultural value, location-specific freshwater vulnerability, location-specific habitat and wildlife sensitivity, year of spill (both in terms of inflation adjustments and probable response effectiveness for past and future cost projections), and the region or urban area impacted (Etkin 1999, 2000, 2001*a,* 2001*b,* 2003). To provide the EPA Oil Program Center with a simple, but sound methodology to estimate oil spill costs and damages, taking into account spill-specific factors for cost-benefit analyses and resource planning, the EPA Basic Oil Spill Cost Estimation Model (BOSCEM) was developed.

METHODOLOGY

EPA BOSCEM was developed as a custom modification to a proprietary cost modeling program, ERC BOSCEM, created by extensive analyses of oil spill response, socioeconomic, and environmental damage cost data from historical oil spill case studies and oil spill trajectory and impact analyses (Etkin, *et al.*, 2002; French-McCay, *et al.*, 2002; Etkin, *et al.*, 2003; Allen and Ferek, 1993). In addition, elements of habitat equivalency analysis as applied in Natural Resource Damage Assessment (NRDA) (NOAA, 1996, 1997; King, 1997) and other environmental damage estimation methods, such as Washington State's Damage Compensation Schedule (Geselbracht and Logan, 1993) and Florida's Pollutant Discharge Natural Resource Damage Assessment Compensation Schedule (Plante, *et al.*, 1993) were incorporated into the environmental damage estimation portion of ERC BOSCEM. Formulae, criteria, and cost modifier factors for estimating socioeconomic damages, including impacts to local and regional tourism, commercial fishing, lost-use of recreational facilities and parks, marinas, private property, and waterway and port closure, were derived from historical case studies of damage settlements and costs, as well as methods employed in other studies (Pulsipher, *et al.*,1998; Dunford and Freeman, 2001; US Army Corps of Engineers, 2000*a*, 2000*b*, 2000*c*).

The model requires the specification of oil type and amount and primary response methodology and effectiveness to determine the base costs. Cost modifiers based on location medium type, location-specific relative socioeconomic/cultural value category, location-specific freshwater use, location-specific habitat and wildlife sensitivity category, and year of spill (in the case of future and past cost estimations), are then applied against the base costs. The base costs for response costs, socioeconomic costs, and environmental damages are shown in Tables 1 – 3. The modifier factors are shown in Tables 4 – 8. The basic model diagram for EPA BOSCEM depicting the interrelationships between cost factors is shown in Figure 1.

To apply EPA BOSCEM to estimate costs for a hypothetical spill, the following steps are taken:

Input of spill criteria:

1. Specify amount of oil spilled (in gallons);
2. Specify basic oil type category (as in Tables 1 – 3);
3. Specify primary response methodology and effectiveness (as in Table 1);
4. Specify medium type of spill location (as in Table 4);
5. Specify socioeconomic and cultural value of spill location (as in Table 5);
6. Specify freshwater vulnerability category of spill location (as in Table 7);
7. Specify habitat and wildlife sensitivity category of spill location (as in Table 8);

Note that if no specification is made for any of the input criteria, or if these factors are not known, the "default value" indicated in each table is used.

Determination of spill costs:

1. To calculate spill response cost, multiply the base per-gallon response cost based on oil type/volume/response method and effectiveness, as determined from Tables 1 or 2, by the medium modifier in Table 4 and by the spill amount:

per-gallon response cost **X** ***medium modifier*** **X** ***spill amount = total response cost***

2. To calculate socioeconomic damages, multiply the base per-gallon socioeconomic cost based on oil type/volume, as determined from Table 3, by the appropriate socioeconomic and cultural damage cost modifier in Table 4 and by the spill amount:

per-gallon socioeconomic cost* X *socioeconomic cost modifier* X *spill amount

= total socioeconomic damage cost

3. To calculate the environmental damages, multiply the base per-gallon environmental damage cost based on oil type/volume, as determined from Table 4, by the freshwater vulnerability modifier added to the habitat/wildlife sensitivity modifier and multiplied by 0.5, all multiplied by the spill amount:

per-gallon environmental cost X 0.5(freshwater modifier + wildlife modifier) X spill amount = total environmental damage cost

Note that in the use of cost modifiers, if there are spill situations in which the spill falls partly into one category and partly into another, estimate the *relative proportion* of the spill impact (by volume or area covered) in each of the categories and compute the weighted average of the modifiers to determine a combination modifier. For example, if impacted waters have a mixed use of 70% industrial and 30% wildlife use, the freshwater vulnerability would be computed as: freshwater vulnerability modifier = 0.7(industrial) + 0.3(wildlife) = 0.7(0.4) + 0.3(1.7) = 0.79. The costs can be added together for a total spill cost. All of the costs can be adjusted by regional/urban area- and year-specific consumer price index factors to adjust for regional differences in costs and inflationary changes in costs for past spills or future past projections.

RESULTS

EPA BOSCEM was used to estimate the costs of oil spills in navigable inland waterways in the EPA Jurisdiction Oil Spill Database, based on the characteristics of each spill. The data set included 42,860 spills of at least 50 gallons that occurred during the years 1980 through 2002. Each spill was classified by the input criteria of oil type and volume and general location-specific characteristics to determine the appropriate cost modifiers. The response, socioeconomic, environmental, and total costs were also adjusted for regional/urban area consumer price index and annual inflationary differences. All costs were adjusted to 2002 dollars. An assumption of increasing response effectiveness was also incorporated into the calculations. The costs for oil spills in inland navigable waterways for the years 1980 through 2002 are shown in Table 9. Over the 23-year period, estimated total costs for inland navigable waterway oil spills was $63.2 billion, or, on average, $2.7 billion annually. This is nearly the equivalent of an Exxon Valdez-magnitude spill event over the inland waterways each year.

DISCUSSION

Each oil spill is a *unique event* involving the spillage or discharge of a particular type of oil or combination of oils that may cause damage to the local and/or regional environment, wildlife, habitats, *etc*., as well as to third parties. No modeling method can ever exactly determine or predict costs of an oil spill. Yet, there are patterns that emerge with respect to damages upon detailed analyses of oil spill case studies. For example, heavier oils are more persistent and present greater challenges – and thus costs – in oil removal operations than lighter oils, such as diesel fuel. Heavier oils, being more visible and persistent, have greater impacts on tourist beaches and private property. At the same time, lighter oils with their greater toxicity and solubility are more likely to cause impacts to groundwater and invertebrate populations. Greater effectiveness in oil removal tends to reduce environmental damages and socioeconomic impacts. Other factors, such as spill location, can also have significant impacts on spill costs and damages. A diesel fuel spill in an industrial area will likely have less impact and require a less expensive cleanup than one that occurs in or near a sensitive wetland. EPA BOSCEM incorporates these types of factors into a simple methodology for estimating the costs of "types of spills" that may be analyzed in a cost benefit analysis or for assessing which types of spills (oil type, location, *etc*.) that are causing the greatest impacts. It is important to note that with respect to "environmental damage" cost estimations, EPA BOSCEM is *not* a substitute for a federal- or state-level NRDA process. But, the model can provide a method for estimating *relative* differences in natural resource damage impacts from different types of spills.

The model allows for cost and damage estimation of different oil spill response methodologies, including different degrees of mechanical containment and recovery, as well as alternative response tools of dispersants and *in situ* burning that may have greater future applications in freshwater and inland settings. Response effectiveness can also be specified allowing for analysis of potential benefits of research and development into response improvements. Additionally, EPA BOSCEM is adaptable to future updates as research and development efforts on oil spill cost modeling provide even more reliable spill base costs and spill factor modifiers.

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BIOGRAPHY

Dagmar Schmidt Etkin received her B.A. in Biology from University of Rochester, and her A.M. and Ph.D. in Biology (specializing in population biology, ecology, and statistical analysis) from Harvard University. She has analyzed and modeled oil spill data and impacts for 15 years.

REFERENCES

Allen, A.A., and R.J. Ferek. 1993. Advantages and disadvantages of burning spilled oil. *Proceedings of the 1993 International Oil Spill Conference:* pp. 765 – 772.

Dunford, R.W., and M.L. Freeman. 2001. A statistical model for estimating natural resource damages from oil spills. *Proceedings of the 2001 International Oil Spill Conference:* pp. 225-229.

Etkin, D.S. 1998. *Financial Costs of Oil Spills in the United States,* Cutter Information Corp., Arlington, Massachusetts, USA, 346 pp.

Etkin, D.S. 1999. Estimating cleanup costs for oil spills. *Proceedings of the 1999 International Oil Spill Conference*: pp. 35-39.

Etkin, D.S. 2000. Worldwide analysis of oil spill cleanup cost factors. *Proceedings of the 23rd Arctic and Marine Oilspill Program Technical Seminar*: pp. 161-174.

Etkin, D.S. 2001*a*. Comparative methodologies for estimating on-water response costs for marine oil spills. *Proceedings of the 2001 International Oil Spill Conference:* pp. 1,281-1,289.

Etkin, D.S. 2001*b*. Methodologies for estimating shoreline cleanup costs. *Proceedings of the 24th Arctic and Marine Oilspill Program Technical Seminar*: pp. 647-670.

Etkin, D.S. 2003. Estimation of shoreline response cost factors. *Proceedings of the 2003 International Oil Spill Conference:* pp. 1,243 – 1,253.

Etkin, D.S. and P. Tebeau, P. 2003. Assessing progress and benefits of oil spill response technology development since Exxon Valdez. *Proceedings of the 2003 International Oil Spill Conference:* pp. 843 – 850.

Etkin, D.S., D. French McCay, J. Jennings, N. Whittier, S. Subbayya, W. Saunders, and C. Dalton. 2003. Financial implications of hypothetical San Francisco bay oil spill scenarios: Response, socioeconomic, and natural resource damage costs. *Proceedings of the 2003 International Oil Spill Conference:* pp. 1,317 –1,325.

Etkin, D.S., D. French-McCay, N.Whittier, S. Sankaranarayanan, and J. Jennings 2002. Modeling of response, socioeconomic, and natural resource damage costs for hypothetical oil spill scenarios in San Francisco Bay. *Proceedings of the 25th Arctic and Marine Oilspill Program Technical Seminar*: 1,075 – 1,102.

Fingas, M. 2001. *The Basics of Oil Spill Cleanup.* Second Edition. Lewis Publishers, Washington, DC, USA. 233 pp.

French-McCay, D., N.Whittier, S. Sankaranarayanan, J. Jennings, and D.S. Etkin. 2002. Modeling fates and impacts for bio-economic analysis of hypothetical oil spill scenarios in San Francisco Bay. *Proceedings of the 25th Arctic and Marine Oilspill Program Technical Seminar*: pp. 1,051 – 1,074.

Geselbracht, L., and R. Logan. 1993. Washington's marine oil spill damage compensation schedule – Simplified resource damage assessment. *Proceedings of the 1993 International Oil Spill Conference:* pp. 705 – 709.

King, D.M. 1997. *Comparing Ecosystem Services and Values – With Illustrations for Performing Habitat Equivalency Analysis.* University of Maryland Center for Environmental and

Estuarine Studies. Prepared for National Oceanic and Atmospheric Administration, Damage and Restoration Program, Silver Spring, Maryland, USA. 33 pp.

National Oceanic and Atmospheric Administration. 1996. *Habitat Equivalency Analysis.* National Oceanic and Atmospheric Administration. Silver Spring, Maryland, USA, December 1996.

National Oceanic and Atmospheric Administration. 2000. *Habitat Equivalency Analysis: An Overview*. National Oceanic and Atmospheric Administration, Damage Assessment and Restoration Program, Silver Spring, Maryland, USA, October 2000. 23 pp.

Office of Management and Budget. 2003. *Informing Regulatory Decisions: 2003 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities*. Office of Management and Budget, Office of Information and Regulatory Affairs. Washington, DC, 233 pp.

Plante, K.J., E.L. Barnett, D.J. Preble, and L.M. Price. 1993. Florida's Pollutant Discharge Natural Resource Damage Assessment Compensation Schedule – A rational approach to the recovery of natural resource damages. *Proceedings of the 1993 International Oil Spill Conference:* pp. 717 – 720.

Pond, R.G., D.V. Aurand, and J.A. Kraly. 2000. *Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in the San Francisco Bay Area.* California Office of Spill Prevention and Response, California Department of Fish and Game, Sacramento, California, USA. 200 pp.

Pulsipher, A., D. Tootle, and R. Pincomb. 1998. *Economic and Social Consequences of the Oil Spill in Lake Barre, Louisiana*. Louisiana State University Center for Energy Studies/Louisiana Applied and Educational Oil Spill Research and Development Program/Minerals Management Service. Technical Report Series 98-009. 27 pp.

US Army Corps of Engineers. 2000. *Civil Works Construction Cost Index System*. EM 1110-2-1304. US Army Corps of Engineers, Washington, DC.

US Army Corps of Engineers. 2000. *Economic Guidance Memorandum 01-01: Unit Day Values for REC., Fiscal Year 2001*. US Army Corps of Engineers, Washington, DC. November 2001. 10 pp.

US Army Corps of Engineers. 2000. *Planning Guidance Document. Appendix D: Economic and Social Considerations (ER 1105-2-100)*. US Army Corps of Engineers, Washington, DC. 22 April 2000. 43 pp.

Table 1: Per-Gallon Oil Spill Response Costs Applied in EPA BOSCEM[1]									
Oil Type	**Volume (gallons)**	**Mechanical[2,4]**				**Dispersants[3,4]**		**In-Situ Burn[5]**	
		0%	**10%**	**20%**	**50%**	**Low**	**High**	**50%**	**80%**
Light Fuels[6]	**<500**	$100	**$85**	$70	$57	$36	$25	$26	$13
	500 – 1,000	$98	**$83**	$68	$55	$35	$24	$25	$12
	1,000 – 10,000	$97	**$82**	$67	$54	$34	$23	$24	$11
	10,000 – 100,000	$87	**$72**	$59	$41	$26	$18	$18	$9
	100,000 – 1,000,000	$74	**$62**	$49	$26	$17	$10	$10	$5
	>1,000,000	$31	**$26**	$17	$12	$11	$6	$7	$3
Heavy Oils[7]	**<500**	$440	**$386**	$335	$310	$140	$89	$125	$64
	500 – 1,000	$438	**$385**	$334	$309	$139	$88	$124	$63
	1,000 – 10,000	$436	**$384**	$333	$308	$138	$87	$123	$62
	10,000 – 100,000	$410	**$359**	$308	$267	$103	$62	$103	$51
	100,000 – 1,000,000	$179	**$154**	$128	$103	$59	$54	$72	$41
	>1,000,000	$87	**$77**	$67	$36	$53	$49	$56	$26
Crude Oil[8]	**<500**	$220	**$199**	$189	$153	$85	$53	$75	$48
	500 – 1,000	$218	**$197**	$187	$151	$84	$52	$74	$47
	1,000 – 10,000	$215	**$195**	$185	$149	$82	$51	$72	$46
	10,000 – 100,000	$195	**$185**	$174	$138	$74	$31	$62	$31
	100,000 – 1,000,000	$123	**$118**	$113	$92	$49	$29	$36	$16
	>1,000,000	$92	**$82**	$76	$64	$58	$13	$22	$11
Volatile Distillates[9]	**<500**	--	**$103**	--	--	--	--	--	--
	500 – 1,000	--	**$102**	--	--	--	--	--	--
	1,000 – 10,000	--	**$100**	--	--	--	--	--	--
	10,000 – 100,000	--	**$55**	--	--	--	--	--	--
	100,000 – 1,000,000	--	**$23**	--	--	--	--	--	--
	>1,000,000	--	**$7**	--	--	--	--	--	--

[1]Per-gallon cost based on hypothetical modeling in Etkin *et al.* (2002, 2003) with shoreline oil removal costs adjusted by % reduction of oiling. Modeling included fate by oil type and trajectory (French-McCay *et al.* 2002). [2]Per-gallon costs include on-water mechanical recovery, shoreline oil removal, mobilization, source control, protective booming. [3]Per-gallon costs include on-water dispersant response, shoreline oil removal, mobilization, source control, protective booming. [4]Removal assumed for on-water recovery or dispersants. Shoreline oiling assumed reduced by % on-water oil removal. Low/high removal by dispersants for light fuel/crude 40%/80%, for heavy oil 35%/70% (Pond *et al.* 2000). [5]ISB costs based on per-gallon operations costs in Allen and Ferek (1993), plus costs of shoreline cleanup of unburned oil. [6]Light fuels, light crude, and light oils; [7]Heavy oils, heavy crude, lube oil, tars, and waste oil. [8]Crude (except specifically-identified heavy- or light-crudes, intermediate fuel oils, waxes, animal fats, other oils, edible oils, non-edible vegetable oils, and mineral oils. Default values are shaded. [9]Volatile distillates include gasoline, jet fuel, kerosene, No. 1 fuel oil, and crude condensate. Based on Etkin and Tebeau 2003.

Table 2: Socioeconomic Base Per-Gallon Costs For Use in EPA BOSCEMI[1]

Oil Type	Volume (gallons)	Base Cost ($/gallon)	
		Socioeconomic	Environmental
Volatile Distillates[2]	<500	$65	$48
	500 – 1,000	$265	$45
	1,000 – 10,000	$400	$35
	10,000 – 100,000	$180	$30
	100,000 – 1,000,000	$90	$15
	>1,000,000	$70	$10
Light Fuels[3]	<500	$80	$85
	500 – 1,000	$330	$80
	1,000 – 10,000	$500	$70
	10,000 – 100,000	$200	$65
	100,000 – 1,000,000	$100	$30
	>1,000,000	$90	$25
Heavy Oils[4]	<500	$150	$95
	500 – 1,000	$600	$90
	1,000 – 10,000	$900	$85
	10,000 – 100,000	$500	$75
	100,000 – 1,000,000	$200	$40
	>1,000,000	$175	$35
Crudes[5]	<500	$50	$90
	500 – 1,000	$200	$87
	1,000 – 10,000	$300	$80
	10,000 – 100,000	$140	$73
	100,000 – 1,000,000	$70	$35
	>1,000,000	$60	$30

[1]Based on hypothetical spills in Etkin *et al.* (2002, 2003) with oil fate modeling as in French-McCay *et al.*, 2002, and historical cases with oil type impact based on characteristics as modeled by NOAA ADIOS 2. [2]Volatile distillates include gasoline, No. 1 fuel oil, jet fuel, kerosene. [3]Light fuels, light crude, light oils; [4]Heavy oils, heavy crude, lube oil, tars, waste oil. [5]Crude (except specifically-identified heavy- or light-crudes, intermediate fuel oils, waxes, animal fats, other oils, edible oils, non-edible vegetable oils, mineral oils. [1]Based on hypothetical spills in Etkin *et al.* (2002, 2003)

Table 3: Environmental Base Per-Gallon Costs For Use in Basic Oil Spill Cost Estimation Model[1]		
Oil Type	**Volume (gallons)**	**Base Environmental Cost ($/gallon)**
Volatile Distillates[2]	**<500**	$48
	500 – 1,000	$45
	1,000 – 10,000	$35
	10,000 – 100,000	$30
	100,000 – 1,000,000	$15
	>1,000,000	$10
Light Fuels[3]	**<500**	$85
	500 – 1,000	$80
	1,000 – 10,000	$70
	10,000 – 100,000	$65
	100,000 – 1,000,000	$30
	>1,000,000	$25
Heavy Oils[4]	**<500**	$95
	500 – 1,000	$90
	1,000 – 10,000	$85
	10,000 – 100,000	$75
	100,000 – 1,000,000	$40
	>1,000,000	$35
Crudes[5]	**<500**	$90
	500 – 1,000	$87
	1,000 – 10,000	$80
	10,000 – 100,000	$73
	100,000 – 1,000,000	$35
	>1,000,000	$30

[1]Based on hypothetical spills in Etkin *et al.* (2002, 2003) with oil fate modeling by Applied Science Associates' SIMAP in French-McCay *et al.* 2002, and cases in Appendix Table L with oil type impact based on oil characteristics in Appendix Tables M and O. [2]Volatile distillates: gasoline, No. 1 fuel oil, jet fuel, kerosene. [3]Light fuels, light crude, and light oils as in Table 1; [4]Heavy oils, heavy crude, lube oil, tars, and waste oil. [5]Crude (except specifically-identified heavy- or light-crudes, intermediate fuel oils, waxes, animal fats, other oils, edible oils, non-edible vegetable oils, and mineral oils.

Table 4: EPA BOSCEM Response Cost Modifiers for Location Medium Type Categories[1]	
Category	**Cost Modifier Value[2]**
Open Water/Shore*	**1.0**
Soil/Sand	0.6
Pavement/Rock	0.5
Wetland	1.6
Mudflat	1.4
Grassland	0.7
Forest	0.8
Taiga	0.9
Tundra	1.3

[1]Category description in Table 2. [2]Based on tendency for oil spread or deep penetration in area sensitive to impact of response equipment/personnel (higher values). *Default value.

Table 5: EPA BOSCEM Socioeconomic & Cultural Value Rankings[1]			
Value Rank	**Spill Impact Site(s) Description**	**Examples**	**Cost Modifier Value**
Extreme	Predominated by areas with high socioeconomic value that may potentially experience a large degree of *long-term*[2] impact if oiled.	Subsistence/ commercial fishing,aquaculture areas	2.0
Very High	Predominated by areas with high socioeconomic value that may potentially experience some *long-term*[2] impact if oiled.	National park/reserves for ecotourism/nature viewing; historic areas	1.7
High	Predominated by areas with medium socioeconomic value that may potentially experience some *long-term*[2] impact if oiled.	Recreational areas, sport fishing, farm/ranchland	1.0
Moderate	Predominated by areas with medium socioeconomic value that may potentially experience *short-term*[2] impact if oiling occurs.	Residential areas; urban/suburban parks; roadsides	**0.7***
Minimal	Predominated by areas with a small amount of socioeconomic value that may potentially experience *short-term*[2] impact if oiled.	Light industrial areas; commercial zones; urban areas	0.3
None	Predominated by areas already moderately to highly polluted or contaminated or of little socioeconomic or cultural import that would experience little short- or long-term impact if oiled.	Heavy industrial areas; designated dump sites	0.1

[1]Default value is shaded. [2]Long-term impacts are those impacts that are expected to last *months to years* after the spill or be relatively irreversible. [3]Short-term impacts are those impacts that are expected to last *days to weeks* after the spill occurs and are generally considered to be reasonably reversible. *Default value.

Table 6: Response Method And Effectiveness Adjustment Factors		
Response Method	**Oil Removal Effectiveness**	**Adjustment Factor[1]**
Mechanical Recovery	0%	1.15
	10%	**1.00***
	20%	0.85
	50%	0.55
Dispersants	Light Oils/Crude/Light Fuels Low (40%)[2]	0.45
	Heavy Oils Low (35%)[2]	0.40
	Light Oils/Crude/Light Fuels High (80%)[2]	0.25
	Heavy Oils High (70%)[2]	0.35
***In Situ* Burning**	50%	0.55
	80%	0.25

[1]Adjustment factor based on percent reduction in oil spreading and shoreline oiling expected with response methodology. *Note that not all socioeconomic costs are directly related to the degree of oiling. Some impacts occur regardless of the amount of oiling. Thus the adjustment factors are slightly less than the percent oiling expected after response operations of certain removal effectiveness.* [2]Low/high removal by dispersants for light fuel/crude 40%/80%, for heavy oil 35%/70% (Pond *et al.* 2000) *Default value.

Table 7: EPA BOSCEM Freshwater Vulnerability Categories	
Category	**Cost Modifier Value**
Wildlife Use	1.7
Drinking	1.6
Recreation	1.0
Industrial	0.4
Tributaries to Drinking/Recreation	1.2
Non-Specific*	**0.9**
*Default value shaded.	

Table 8: EPA BOSCEM Habitat and Wildlife Sensitivity Categories[1]	
Category	**Cost Modifier Value[1,2]**
Urban/Industrial	0.4
Roadside/Suburb	0.7
River/Stream*	**1.5**
Wetland	4.0
Agricultural	2.2
Dry Grassland	0.5
Lake/Pond	3.8
Estuary	1.2
Forest	2.9
Taiga	3.0
Tundra	2.5
Other Sensitive	3.2
[1]Values based on relative time to recovery (based on Fingas 2001) [2]If more than one category is relevant, the one that most closely represents the majority of the area, or, if there is a relatively even distribution of categories, the category that represents the greater sensitivity or vulnerability (*i.e*, with the higher modifier value) should be chosen. Alternatively, a weighted average of different categories can be used in these cases. *Default value shaded.	

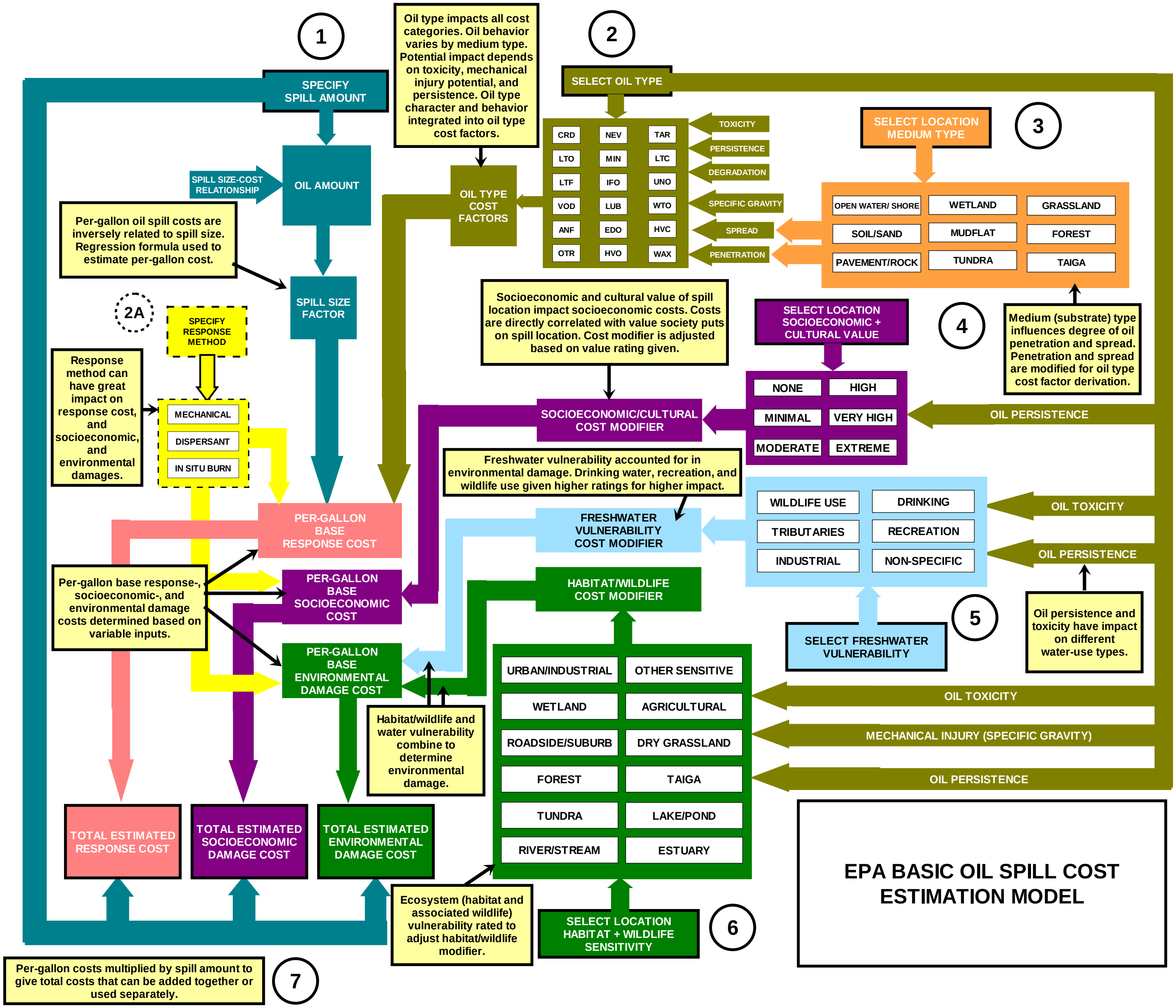

Figure 1: EPA BOSCEM basic interrelationships between oil spill base costs and modifiers. The circled numbers indicate steps of input by user.

Table 9: Estimated Costs for Oil Spills into EPA Jurisdiction Navigable Waters[1] 1980 – 2002				
Year	**Estimated Costs[2] (2002 $ million)**			
	Response	**Socioeconomic Damage**	**Environmental Damage**	**Total**
1980	$1,665	$2,019	$701	**$4,386**
1981	$875	$1,093	$376	**$2,344**
1982	$2,025	$2,209	$791	**$5,025**
1983	$1,915	$2,173	$822	**$4,910**
1984	$1,008	$1,268	$443	**$2,719**
1985	$788	$964	$382	**$2,133**
1986	$838	$1,278	$416	**$2,531**
1987	$938	$1,325	$458	**$2,722**
1988	$844	$1,273	$438	**$2,555**
1989	$1,302	$1,621	$582	**$3,504**
1990	$1,293	$1,898	$619	**$3,810**
1991	$1,419	$1,842	$673	**$3,934**
1992	$586	$897	$317	**$1,801**
1993	$725	$1,292	$394	**$2,411**
1994	$547	$961	$325	**$1,833**
1995	$513	$696	$267	**$1,476**
1996	$422	$637	$229	**$1,288**
1997	$430	$750	$241	**$1,422**
1998	$449	$603	$260	**$1,312**
1999	$601	$889	$313	**$1,804**
2000	$482	$1,002	$289	**$1,773**
2001[3]	$1,382	$2,224	$763	**$4,369**
2002[3]	$977	$1,678	$488	**$3,143**
TOTAL 1980 - 2002	**$22,025**	**$30,592**	**$10,588**	**$63,205**
TOTAL 1980 –1989	**$12,199**	**$15,222**	**$5,408**	**$32,829**
TOTAL 1990 - 1999	**$6,985**	**$10,466**	**$3,640**	**$21,091**
TOTAL 2000 - 2002	**$2,842**	**$4,904**	**$1,540**	**$9,285**
TOTAL 1998 - 2002	**$3,892**	**$6,396**	**$2,114**	**$12,401**
TOTAL 1993 - 2002	**$6,529**	**$10,733**	**$3,570**	**$20,831**

[1]Non-marine waters *and adjoining shorelines*, including: i.) All waters currently used, used in the past, or may be used in interstate or foreign commerce, including all waters subject tidal ebb and flow; ii.) All interstate waters, including interstate wetlands; iii.) All other waters such as intrastate lakes, rivers, and streams (including intermittent streams), mudflats, sandflats, wetlands, prairie potholes, wet meadows, playa lakes, or natural ponds, the use, degradation, or destruction of which could affect interstate or foreign commerce including any such waters: (A) that are or could be used by interstate or foreign travelers for recreational or other purposes; or (B) from which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or (C) that are or could be used for industrial purposes by industries in interstate commerce. iv.) All impoundments of waters otherwise defined as waters of the US under this section; v.) Tributaries of waters identified in (i) through (iv); and vi.) Wetlands adjacent to waters identified in (i) through (vii). [2]Based on EPA Jurisdiction Oil Spill Database using EPA Basic Oil Spill Cost Estimation Model. Assumes mechanical recovery operations (plus shoreline) with 0% on-water effectiveness during 1980 – 1984, 10% during 1985 – 1992, and 20% during 1992 – 2002. [3]Preliminary data (overestimates).