Candidate Sets Report

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Development of the candidate sets began with the fall quarter effort to develop an understanding of the requirements listed in CRCIA Part II Appendix A. Through a series of meetings with authors of the CRCIA Part II document and representatives of the regulator, stakeholder, and Tribal Nation community, comments and clarifications were developed jointly with the DOE and its contractors.

Following development of an understanding of the CRCIA template, criteria were developed and presented for the creation of candidate sets and study sets. A candidate set is the compilation of all relevant factors assembled in accordance with criteria that ensure demonstrable completeness. A study set is the subset of the corresponding candidate set that is to be used for the assessment. Thus, while the candidate set is a listing of all possible factors, the study set is the list of the factors that dominate.

Each technical element produced a white paper of Candidate and Study Set Criteria and Proposed Scoping Studies. Candidate sets have been drawn largely from those white papers. Exceptions are the lists of radioactive and chemical contaminants that are a result of the inventory scoping study, and the risk and impact candidate sets that have benefited from the study of dependency webs. Tables of the candidate sets are as follows,

Table # - Candidate Set

Table 1 Radioactive Contaminants
Table 2 Chemical Contaminants
Table 3 Inventory (Waste Types)
Containment Failure and Waste Release Mechanisms
Table 4 Vadose Zone and Groundwater (Transport Paths)
Table 5 Columbia River
- River Entry Locations
- River Holdup Locations
- Habitat and Uptake Locations
- Columbia River (Transport Paths)
- Biological Transport Paths (to be completed)

Table 6 Atmospheric Transport
Table 7 Risk and Impact
- Units of Selection (species, trophic levels, ecosystems)
- Ecological Effects
- Ecological Co-Stressors at each locations/habitat
- Human Exposure and Dose
- Human Health Effects
- Human Health Variables/Receptors and Pathways
- Human Co-Risk Factors
- Socio-Cultural Effects
- Units of Selection
- Socio-Cultural Co-Stressors

- Economic Effects
- Units of Selection

Table 8 Assessment Scenarios

The suite of candidate sets associated with risk and impact identified in Appendix A of CRCIA Part II have been replaced with the above sets listed beneath "Risk and Impact." The original candidate sets were for the topics of receptors, exposure mechanisms, pathways, cultural dependency webs, receptors of concern, dose measures, dose attributes, and impact. These topics are now captured under somewhat different headings resulting from the dependency webs approach taken to address risk and impact. They appear in Table 7.

Completion of a Hanford End State candidate set is dependent on development of a clear statement of the assumed end states for the Hanford Site. At present two possible end-state settings are of interest, a Hanford Site Disposition Baseline and a No-Action alternative. The disposition baseline is defined by the assumed end states in the multiyear program plans of the Department of Energy. These assumptions are the basis for the Department's estimated cost to closure. Even the no-action alternative will require a suite of assumed minimum safe actions, (e.g., disposal of cesium and strontium capsules, stabilization of tank domes, stabilization of canyon facilities), prior to site closure. One or both of these alternative end states will be defined during the coming months.

This information is provided to ensure its availability for regulator, stakeholder, and Tribal Nation review and comment. The purpose of the candidate set is to achieve a complete list of all relevant factors governing the migration and fate of Hanford Site contaminants and their influence and impact on the resources of the region. Anyone wishing to add relevant factors to a candidate set can do so by contacting C.T. Kincaid via email at charles.kincaid@pnl.gov or via telephone at (509) 372-9440, or via FAX at (509) 372-9447.

Table 1. Radionuclide Contaminants Candidate Set

Radionuclides	Curies*, Ci	Half-life**, yr
Actinium 227	87.6	21.774
Americium 241	6.99E+04	432.7
Americium 242M		1141
Cadmium 113M	1.69E+04	14.1
Carbon 14	4.81E+03	5715
Cesium 135		2.3E6
Cesium 137	4.64E+07	30.07
Chlorine 36		3.01E5
Cobalt 60	1.23E+04	5.271
Curium 243	10	29.1
Curium 244	242	18.1
Europium 152	1.48E+03	13.54
Europium 154	1.47E+05	8.593
Iodine 129	63	1.57E7
Krypton 85	0	10.76
Lead 210		22.6
Neptunium 237	141	2.14E6
Nickel 59	934	7.6E4
Nickel 63	9.20E+04	100.
Palladium 107		6.5E6
Protactinium 231	156	3.28E4
Plutonium 238		87.7
Plutonium 239/240	4.80E+04	2.410E4 6.56E3
Plutonium 241	2.29E+05	14.4
Plutonium 242	1.16	3.75E5
Radium 226	0.0631	1599
Radium 228	77.1	5.76
Samarium 151	2.75E+06	90
Selenium 79	773	≤6.5E5
Strontium 90	7.16E+07	28.78
Technetium 99	3.26E+04	2.13E5
Tellurium 123		>1.3E13
Thorium 229	1.81	7.3E3
Thorium 230		7.54E4

Table 1. Radionuclide Contaminants Candidate Set

Radionuclides	Curies*, Ci	Half-life**, yr
Thorium 232	2.11	1.40E10
Tin 121M		~55
Tin 126	1.19E+03	2.5E5
Tritium (Hydrogen 3)	3.40E+04	12.32
Uranium 232	123	69.8
Uranium 234	346	2.46E5
Uranium 235	14.5	7.04E8
Uranium 236	9.57	2.342E7
Uranium 238	322	4.47E9
Zirconium 93	3.63E+03	1.5E6

* Curie amounts obtained from Kupfer et al. (1999)

** Half-life values obtained from Parrington, J.R., H.D. Knox, S.L. Breneman, E.M. Baum and F. Feiner. 1996. Nuclides and Isotopes, Fifteenth Edition. General Electric Co. and KAPL, Inc., San Jose, California.

Table 2. Chemical Contaminants Candidate Set

Chemicals	Kilograms*	Chemicals	Kilograms*
Aluminum	7845000	Nickel	111000
Ammonia/Ammonium		Nitrate	85700000
Ammonium Carbonate		Nitrite	
Ammonium Nitrate		Oxalate	
Benzene		PCBs (Arochlor)	
Benzo[a]Pyrene		Phosphate	6000000
Beryllium		Potassium	481000
Bismuth	580000	Potassium Borate	
Cadmium	8200	Silicon	570000
Carbon Tetrachloride		Silver (1)	8930
Cerium	8800	Silver Chloride	
Chloroform		Sodium	54200000
Chromium	785000	Sodium Aluminate	
Chrysene		Sodium Dichromate	
Copper Sulfate		Sodium Hydroxide	23000000
Copper		Sodium Nitrate	
Cyanide		Sodium Oxylate	
Dibutyl Butyl Phosponate		Sodium Silicate	
Dibutyl Phosphate		Sodium Sulfamate	
Dichloroethylene, 1,2-		Strontium	31300
Diesel Fuel		Sulfamic Acid	
Ferrocyanide		Sulfate (Sulfur)	5000000
Ferrous Sulfamate		Sulfuric Acid	
Fluoride	1360000	Tetrachloroethane 1,1,1,2-	
Iron	1230000	Tetrachloroethylene	
Kerosene		Tributyl Phosphate (TBP)	
Lanthanum	51000	Tributyl Phosphonate	
Lead	279000	Trichloroethylene	
Manganese	105000	Uranium	965000
Mercury	2100	Xylene	
Methyl Isobutyl Ketone (Hexone)		Zinc	
NPH (Normal Parafin Hydrocarbon		Zirconium	440000

* Kilogram amounts obtained from Kupfer et al. (1999)

Table 3. Inventory (Waste Site Groupings) and Containment Failure & Waste Release Mechanisms		
Waste Site Grouping	**Specific Inventory or Waste Site**	**Containment Failure & Waste Release Mechanisms**
Physical Plant	Miscellaneous contaminated structure Tunnels Fuel storage basins Reactor cooling water storage basin Reactor structures with cores BiPO4 process U extraction process REDOX process PUREX process Cs/Sr recovery process Thoria (PUREX) process PFP process Waste throughput structures Evaporation and waste condensate processes	Mechanical failure Failure due to earthquakes Failure due to settling of barrier materials Colloid transport Chelating agents Tumbleweed roots Burrowing animals Desorption / Adsorption Ion Exchange Dissolution / Precipitation Solubility Congruent Release with another Constituent Diffusion Corrosion Reduction-Oxidation Advection / Convection / and Dispersion (downward percolation, upward evaporation) Structural degradation of the disposal facility
HLW Tanks	Leaking SST leaks Nonleaking SST leaks Double-shell Tanks	Mechanical failure Failure due to earthquakes Failure due to settling of barrier materials Colloid transport Chelating agents Tumbleweed roots Burrowing animals Desorption / Adsorption Ion Exchange Dissolution / Precipitation/ Solubility Congruent Release with another Constituent Diffusion Corrosion Reduction-Oxidation Advection / Convection / and Dispersion (downward percolation, upward evaporation) Structural degradation of the disposal facility
Liquid Ground Disposal – High	Evaporator and tank condensates	Mechanical failure

volumes of liquid	Plant steam condensate Plant cooling water crib Reactor cooling water crib Misc high volume cribs/french drains BiPO4 process waste crib/french drain U extraction process waste crib/french drain REDOX process waste crib/french drain PUREX process waste crib/french drain Cs/Sr recovery waste crib/french drain Thoria (PUREX) waste crib/french drain PFP waste crib/french drain	Failure due to earthquakes Failure due to settling of barrier materials Colloid transport Chelating agents Tumbleweed roots Burrowing animals Desorption / Adsorption Ion Exchange Dissolution / Precipitation/ Solubility Congruent Release with another Constituent Diffusion Corrosion Reduction-Oxidation Advection / Convection / Dispersion (downward percolation, upward evaporation) Structural degradation of the disposal facility
Solid waste Landfill	Radioactive pre-Sep1988 (LDR requts imposed) Radioactive post-Sep1988 Mixed post-Sep1988 Hazardous Inert Low volume/incidental (rad and/or haz)	Mechanical failure Failure due to earthquakes Failure due to settling of barrier materials Colloid transport Chelating agents Tumbleweed roots Burrowing animals Desorption / Adsorption Ion Exchange Dissolution / Precipitation/ Solubility Congruent Release with another Constituent Diffusion Corrosion Reduction-Oxidation Advection / Convection / Dispersion (downward percolation, upward evaporation) Structural degradation of the disposal facility
Miscellaneous and low volume	Laboratory Decontamination liquid effluent to ground Misc. underground storage tank Misc crib, french drain or other liquid ground disposal (low volume) Soil residuals (residuals fr removal of tank, support blg, piping, etc)	Mechanical failure Failure due to earthquakes Failure due to settling of barrier materials Colloid transport Chelating agents Tumbleweed roots Burrowing animals Desorption / Adsorption

	Sanitary sewer	Ion Exchange Dissolution / Precipitation/ Solubility Congruent Release with another Constituent Diffusion Corrosion Reduction-Oxidation Advection / Convection / Dispersion (downward percolation, upward evaporation) Structural degradation of the disposal facility
Atmospheric	Airborne release (non-UPR)	Mechanical failure Failure due to earthquakes Failure due to settling of barrier materials Colloid transport Chelating agents Tumbleweed roots Burrowing animals Desorption / Adsorption Ion Exchange Dissolution / Precipitation/ Solubility Congruent Release with another Constituent Diffusion Corrosion Reduction-Oxidation Advection / Convection / Dispersion (downward percolation, upward evaporation) Suspension or re-suspension of contaminated particulate material from the land surface
Unplanned Releases	Any unplanned release (non-single-shell tank leak)	Mechanical failure Failure due to earthquakes Failure due to settling of barrier materials Colloid transport Chelating agents Tumbleweed roots Burrowing animals Desorption / Adsorption Ion Exchange Dissolution / Precipitation/ Solubility Congruent Release with another Constituent Diffusion Corrosion Reduction-Oxidation

		Advection / Convection / Dispersion (downward percolation, upward evaporation)
Rejected	No further analyses	None

Table 4. Vadose Zone and Groundwater Candidate Sets

Pathway of Interest in the Vadose Zone

- Migration out of waste package to surrounding soils
- Downward & horizontal (including preferrential paths)
- Through capillary fringe & mixing with groundwater
- Upward (including)
  - Preferential paths
  - Animal & human intrusion
  - Vegetation

Structure and Transport Properties of the Vadose Zone

- <u>Geologic and Surface/Interface Features</u>
  - Topgraphy (surface and paleotopography of geologic contacts)
  - Vegetation
  - Surface cover
  - Backfill
  - Holocene Sediments
    - dune sand
    - alluvium
  - Hanford formation
    - Touchet Beds
    - Transitional Sand Facies
    - Pasco Gravels
  - Pre-Missoula Gravels
  - Plio-Pleistocene
    - Early Palouse Soil
    - Caliche
  - Ringold (variably cemented)
    - Lacustrine
    - Overbank
    - Sand & Sandstone
    - Gravels & Conglomerate
  - Basalt above water table (200-E)
  - Nature of geologic contacts/interfaces
    - (e.g. strong contrast in grain size [pore size])
  - Paleosols
  - Preferential (Short Circuit) Pathways
    - Clastic Dikes (interconnected)
    - Sedimentary Structures (e.g. cross bedding, forset bedding)
    - Boreholes (Unsealed or boken casing)
    - Animal Burrows
    - Foundations, Pipelines, etc.
    - Fractures/joints/weaknesses/breaks in Caliche, paleosols, bedrock
- <u>Hydraulic properties</u>
  - Ksat and Kunsat or relative permeability
  - Water retention characteristics and hystoresis
  - Porosity, effective porosity
  - Increased permeability due to salts and/or temperature
- <u>Geohydrologic Structure</u>
  - Thicknesses
  - Number and character of geologic units
  - Spatial Variability
  - Large scale geometry
    - Slope
    - Faults
    - Intra-structure relationships
    - Spatial variability

Small scale geometry (e.g. cross bedding) and spatial variability

Location and characteristics of source and recharge areas
- Spatial Variability
- Temporal Variability
- Waste types/geometry
  - (cribs, tanks, trenches, surface spills, ditches, ponds, etc.)
- Location of impermeable/engineering structures
  - (e.g., increased flux around tanks - i.e. umbrella effect)
- Natural and man-induced meteoric recharge
  - location and temporal variation

Location and characteristics of discharge (exit) areas
- Biosphere uptake points
- Spatial and Temporal Variability
- Withdrawn water or vapors (vapor extraction)

Temperature
- Geothermal convection systems

Boundaries and Boundary Conditions

Geochemcial Properties
- Changes in mobility induced by
  - Remediation
  - Natural waste sediment interactions
- Effects of chelating agents
- Kd
- Mineralogy
- Buffer capacity
- Cation ion-exchange capacity
- pH
- Redox potential

Waste/Contaminant/Leachate/Fluid Properties
- High salt
- NAPL
- Viscosity
- Spatial and temporal changes along flow path
- density
- solubility
- volatility
- sorption characteristics
- temperature
- other fluid properties (wettability)

Transport Processes/ Mechanisms/ Driving Forces

Saturated Flow
- advection
- dispersion
- Density effects (eg. density dependent flow)

Unsaturated Flow

Flow Instabilities (fingering)
- Density effects
- Surface tension effects

Concentrated Flow (funnel flow) - e.g. around tanks or other impermeable objects

Coloidal Transport (including microbes)

Vapor Phase Flow
- Steam venting (e.g. near tanks)

Multiphase Flow
- LNAPL Flow
- DNAPL Flow
- temperature effects
  - (e.g. coupled liquid and vapor flow under high heat regimes)

Solid Phase Diffusion

Erosion (Wind & Water)

Intrusion (Human & Animal)

Vegetation Uptake

Conserve mass and momentum across
- boundaries/interfaces
- graphical partitions into sub-regions
- water table

Spatial and temporal variability/behavior

Transient and Stable perched water zones
- impact on perched water bodies
- impact of perched water on lateral flow regimes

Driving Forces
- physical (e.g. recharge, barometric)
- chemical (eg. concentration gradients)
- reaction and sorption rates
- Temperature

Waste / Sediment Interactions
- Silicate hydrolysis (e.g. dissolution of silicates by hot alkaline tank waste)
- Particulate filtering
- Chemical changes in leachate (e.g. change chemical signature?)
- Chemically enhanced mobility
- Dissolution
- Precipitation
- Redox
- pH
- Reaction Rates

Waste / Waste Interactions
- Microbiological Effects
  - e.g. nitrate, organics

Other natural attenuation processes
- Decay / Degredation - Daughters

Other effects on migration rates

Events

Recharge Events
- meteoric sources
  - run-off, run-on, storm and roof drains
  - surface cover designs (e.g. coarse gravel)

- permitted discharges
  - sanitary sewers
  - irrigation
  - pump & treat
- unintensional releases
  - spills, surface water discharges, etc.
  - leaking water lines, sewers, transfer lines, etc.
  - run-off, run-on, storm and roof drains

Source / Release Events
- quantity and phases of waste releases
- Temporal and spatial characteristics
- Temperature
- Remedial Measures

Discharge / Exit Events
- Pumping?
- Remedial Measures

Temporal and Spatial Variation
- Extreme climatic events
  - Drought
  - Chinook wind-induced snowmelt, flooding
- Enhanced recharge
  - Snowmelt
  - Run-on/ponding

Table 5. Columbia River Candidate Sets

River Entry Locations
Groundwater discharge points throughout study area, both sides of river
Columbia River upstream in area unaffected by Hanford operations
Surface water discharge points along entire study area
Areas of current sediment accumulation (see River Holdup Locations)
Others to be determined
River Holdup Locations
Behind downstream impoundments within the study area
Sloughs
Downstream of islands
Inside shoreline of bends in the river
Deep holes
Along shorelines, particularly immediately downstream of points projecting into river
Downstream of large submerged structures, i.e., outfall structures, boulders
Biological contaminant sinks
Water withdrawal intake structures
Sanitary water treatment plant sludge deposition areas
Sanitary water system reservoirs, ponds
Long-term irrigation application areas
Habitat and Uptake Locations
Salmon spawning
Steelhead
Sensitive cultural sites
Drinking water withdrawal points
Recreational use areas
Others to be determined
Columbia River Transport Path
Hydrologic Components
Mid/Upper Columbia upstream of Priest Rapids Dam
Lower Columbia River
Priest Rapids to McNary
McNary to Bonneville
Columbia River – Tidal Zone and Estuary – Bonneville to Mouth
Coastal Ocean
Tributaries
Yakima River, Snake River, etc.
Fate and Transport Processes
Influx or loading
GW/VZ and other point/non-point discharges, atmospheric deposition, overland runoff
River and Hyporheic Zone Hydrodynamics
Transport (river flows, sediment movement, contaminant influx and distribution)
Contaminant advection and dispersion in the river
Contaminant advection and dispersion in the hyporteic zone
Sediment transport, deposition, and resuspension
Biological transport

Table 5. Columbia River Candidate Sets

Volatilization
Removal/relocation by dredging or irrigation withdrawals
Speciation
Sorption/desorption to sediments
Ionic state, reduction-oxidation
Transformation
Biodegradation, photolysis, hydrolysis, decay chain daughter nuclides
Bioaccumulation
Bioconcentration, biomagnification
Columbia River Events
Normal flow and transport assuming an ambient situation
Extreme events consistent with the candidate set of "Assessment Scenarios"

Biological Transport Pathway

Features, Events, or Process Cycles

- Mass transfers from abiotic to biotic system and vise versa for major contaminants of potential concern (COPC)
- Mass transfers of major COPCs within the biotic system
- Biological transformations of COPCs as they affect transport and toxicity
- Spatial movement of COPCs in biota within different physical portions of the river, sediment, and terrestrial environments when that transfer is a property of the biota rather than of the surrounding medium

Aquatic and Terrestrial Environs included Biological Transport

- Soil
- Groundwater
- Sediment – River Bottom or Benthic Sediments
- Surface Water
- Air

Aspects of Biological Transport of Special Interest

- Multiple exposure pathways
- - Food
- - Water
- - Sediment
- Seasonal changes and cycles
- Temperature dependencies
- Micro-nutrient availability and uptake

Table 6. Atmospheric Transport Candidate Sets

Atmospheric Transport Paths
• Active atmospheric release • Passive atmospheric release • Wind-driven atmospheric release sources
Materials
• Gases • Vapors • Particulates
Processes
• Wet and dry deposition to soils • Decay and weathering • Runoff into surface water

Table 7. Risk and Impact Candidate Sets

Units of Selection (species, trophic levels, ecosystems)
• Individual species or simple food chains • Food webs and communities • Ecosystems • Species of varying home range sizes; intrusion and dispersion pathways such as burrowing animals and tumbleweeds • Ethno-habitats • Keystone or indicator species • Species that specifically bioaccumulate certain contaminants
Ecological Effects
• Contamination or degradation of environmental media (concentration and area or volume affected, and duration of effect or time to recovery) • Ecotoxicity to individual organisms of selected species both at the location and whose home range or migratory range touch the affected area (keystone ecological species, threatened and endangered species, culturally important species, indicator and sentinel species) • Ecotoxicity to communities, populations, including indirect effects such as whether the location provides nesting cover, nutrients for other species, other things) • Population stability, competition effects, species abundance, species diversity, species distribution. • Sub-lethal effects such as endocrine disruption, tissue damage, enzyme alterations, behavioral modification, and other markers of natural resource injury in individual organisms • Mutagenicity in animals, fish, birds; effect on the gene pool • Effects over successive generations from exposure to long-lived contaminants as they recycle through the environment • Reproductive capacity over multiple generations • Biodiversity and ecosystem integrity (keystone species, other indicators of environmental quality, functionality, and stability) • Habitat functions and services (soil stability, biofiltering) • Habitat fragility • Landscape ecology, landscape functions and services • Aesthetics and visual integrity • Overall index of habitat functionality and quality
Ecological Co-Stressors at each location/habitat
• Other chemical, radiological contaminants; total ecological contaminant burden from any source • Physical, thermal, and biological stressors; perturbations of the original conditions at the location. • Reserves of robustness, resiliency, viability, sustainability • Political, legal, institutional threats (e.g., zoning leading to fragmentation) • Current quality relative to original or ideal conditions

Table 7. Risk and Impact Candidate Sets

Human Exposure and Dose
• Construction of exposure scenarios for Native Americans (includes ingestion, social and religious activities) • Specialized use scenarios may need to be developed • Acute through chronic timescales for individuals and seasonal through multigeneration durations may be needed • The maximally exposed individual (MEI) and the most exposed fraction of the selected receptor group, the most exposed community, or other group must be selected

Human Health Effects
• Cancer • Hazard Index and hazard quotient • Acute, seasonal (subacute or subchronic) exposures and effects • Reproductive, teratogenic, and developmental effects • Immunological effects • Neurological, neurobehavioral, and neuropsychological effects • Effects on enzymes (induction or inhibition), neurotransmitters, and other physiological or biochemical substances • Mutagenicity and genetic effects (especially in small gene pools) • Endocrine effects • Dermal absorption and dermal effects • Other effects (according to the toxicology of the contaminant) • Population-level exposures (total community contaminant burden, total community health, and community well-being) • Population-level effects in future generations; sum of doses and risks over multiple generations (in the individual and in populations) • Proportion of the community or group affected • Other health indices and indicators, using public health methods related to indirect effects, functionality, psychosocial health
Human Health Variables/Receptors and Pathways
• Age (children, elders, women of child-bearing age, breast-feeding infants) • Gender • Selected percentile (mean, 95^{th}, other) for the maximally exposed individual • Selected community activity or lifestyle (subsistence resident, hunters, basketweavers, others as indicated by affected habitat types) • Individuals who receive extra exposure such as gatherers/preparers • Other groups with more distant exposures (such as consumers or members of extended families and trade networks) with many members • Effects on populations over time • Unique cultural activities such as use of the sweat lodge • Other standard community or social activities such as recreation, other CERCLA or

site-specific scenarios such as hatchery or stewardship workers, people with unique exposures such as farm workers

Human Health Co-Risk Factors

- Multiple exposures (additional contaminants from same or other concurrent or prior sources, including background, including occupation, and synergism between contaminants, including metabolic byproducts or environmental degradation products)
- Biochemical genetics and ethnopharmacology
- Underlying health effects (individual or population, using health statistics where available)
- Nutritional status and dietary quality, including effects of substitute diet if the traditional diet is unavailable
- Socioeconomic status
- Access to health care, insurance, and education
- Cost of treating illness or avoiding exposure
- Suitability of nutritional or medicinal alternative
- Health and psychosomatic effects of lost religion, impaired family health, impaired cultural practices

Socio-Cultural Effects

- Lost access or use of place or resource (duration of loss, percentile of loss relative to original conditions, residual quality if partially lost or not fully restored)
- Community well-being and social and family cohesiveness maintained through use of the place or resource
- Everyday life and material implements derived from the place or resource, and living and social activities and practices associated with the place or resource
- Religious, ceremonial well-being gained through use of the place or resource; effects on the spiritual landscape
- Other uses of the site or resource such as education, art, or trade
- Intergenerational continuity in knowledge, language, religious practice, spiritual knowledge, traditions, values, materials, and education related to the place or resource (on-site or adjacent sites)
- Physical integrity of historical or cultural resources located in the place or associated with use of the resource
- Preservation of future land use options
- Preservation of additional values such as sustainability
- Contaminated tribal areas, artifacts, ancestral remains, traditional foods and medicines
- Cost of medical treatment of exposure
- Cost of replacement medicine due to loss of native foods, medicine, and religion
- Cost of “takings” of lost profits, lost jobs, lost resources
- Cost of restoration
- Cost of lost environmental goods, functions and services
- Cost of lost health goods, functions, and services
- Cost of lost cultural goods, functions, and services
- Cost of lost treaty rights

- Cost of lost access or use (acres x degree of restriction x duration)
- Cost of contaminated ancestral remains

Units of Selection

- General suburban surrounding area
- Native American Tribes and Bands
- Groups such as migrant workers, ethnic communities,

Socio-Cultural Co-Stressors

- Current adequacy of social services that might increase costs of the impacts proportionally more than in affluent communities
- Background health conditions and health statistics
- Past history of impacts to specific cultures and peoples and cumulative impacts up to the present
- Current cultural "resiliency." and current quality of treaty rights
- Cost of alternatives (if any); cost of mitigating adverse effects
- Preservation of land use options at the location or at adjacent/downstream sites

Economic Effects

- Economic impacts of losing the place or resource (direct impacts of commercial, trade, jobs, services, housing, schools, etc.)
- Replacement costs (duration of loss x annual cost x quality and convenience of replacement, x proportion of community members affected by the loss)
- Other costs of avoiding exposure
- Other costs of "intangibles" and "externalities" using contingency valuation methods without discounting
- Other natural resource valuation measurements
- Costs to future generations, such as monitoring and surveillance costs, or increased remediation and restoration costs if contamination spreads or the resource is impaired. Permanent loss may mean infinite costs or requirements for permanent mitigation.

Units of Selection

- General suburban surrounding area
- Native American Tribes and Bands
- Ethnic groups such as migrant workers, ethnic communities
- Socio-economic groups such as agriculture or tourism
- Particular regional activities such as agriculture or recreation

Table 8. Assessment Scenario Candidate Sets

- Catastrophic Columbia River floods (not associated with near-term climatological changes, e.g., catastrophic loss of upstream dams)
- Near-term climate change
- 1000-year rain event
- Catastrophic earthquake
- Loss of institutional controls on the Hanford Site
- Loss of receptor (or species)
- Introduction of receptor (or species)
- Demographic change in future use scenarios
- Future plutonium repository