Appendix A

Salmonid Conceptual Models

Columbia River Channel Improvement Project
Adaptive Environmental Management Plan

March 2006

A.1 Introduction to the Conceptual Model

Within the broader Adaptive Environmental Management (AEM) and risk-based framework, conceptual models should be developed in relation to proposed management actions as an initial step in making the decision-support framework operational. A conceptual model essentially describes in schematic shorthand the nature and content of the assessment. The model attempts to reduce ecological complexity by focusing on selected ecosystem attributes that are essential in addressing a specific management challenge; this process includes the identification of risk assessment endpoints and performance measures. This feature of the model helps to define the information that must be obtained and organized to describe the general characteristics and desired conditions of the managed ecosystem. The model also attempts to identify key cause-effect relationships that provide a basis for implementing models used to forecast the outcomes of management actions. This aspect of the model depicts a qualitative understanding of interactions among system components that are vital to understanding and management. The conceptual model thereby assists in identifying the necessary and appropriate data (e.g., monitoring) and tools (e.g., models) needed to examine the proposed project within the broader AEM decision framework.

In applying the overall framework, it is important to remember that conceptual models, as with other models, are simplifications and to some degree arbitrary representations of complex environmental systems: there is no “best” conceptual model. Within the AEM framework, the initial conceptual model might be modified during the course of management and decision-making. Stressors initially thought important may prove to be less so; additional stressors, initially not addressed, may need to be added to the model. Similarly, certain endpoints or performance measures might be added, deleted, or modified as the result of experience gained through application of the conceptual model to specific management questions. Functional relationships between stressors and endpoints might be reformulated based on new information. Successive refinements of the conceptual model can eventually produce a relatively stable model structure that accurately and concisely depicts the nature and scope of effective management and decision-making in relation to channel improvement. For example, the Columbia River Conceptual Model (www.nwp.usace.army.mil/Pm/LCR/docs/CREConceptmodel/Start.htm) has been developed as a more comprehensive model that derives from the channel deepening conceptual model described in this Appendix. This effort continues to evolve and both conceptual models can be usefully referenced in evaluations of the potential impacts of channel modifications on Columbia River salmonids.

The conceptual model developed as part of the Final Supplemental Integrated Feasibility Report/Environmental Impact Statement can play a central role in implementing the AEM Plan for the Lower Columbia River (LCR) and estuary. The overall conceptual model identifies ocean and river processes, habitat forming processes, habitat type, primary productivity associated with each habitat, food web dynamics, growth, and survival as key determinants of juvenile salmon entry into the ocean (Figure A.1). Each of these major contributors to salmon entry has been further decomposed into corresponding indicators (i.e., performance measures, and risk endpoints) in further elaboration of the overall conceptual model.

The conceptual models are reproduced in this Appendix mainly to emphasize the need to ensure that the AEM Plan addresses key indicators in these models. The conceptual models can also guide the identification and selection of operational models to be included as part of the management and decision-making process. Importantly, the identification, selection, and application of models (both conceptual and operational) can proceed in a hierarchical manner, with an initial emphasis placed on models that focus on changes in bathymetry (accretion/erosion), temperature, and salinity in relation to channel deepening. If substantial alterations (i.e., exceed decision criteria) in these physical and chemical characteristics of the lower river and estuary are not demonstrable project impacts, consideration of additional models for the remaining habitat and ecological indicators might not be necessary to support the Channel Improvement AEM Plan.

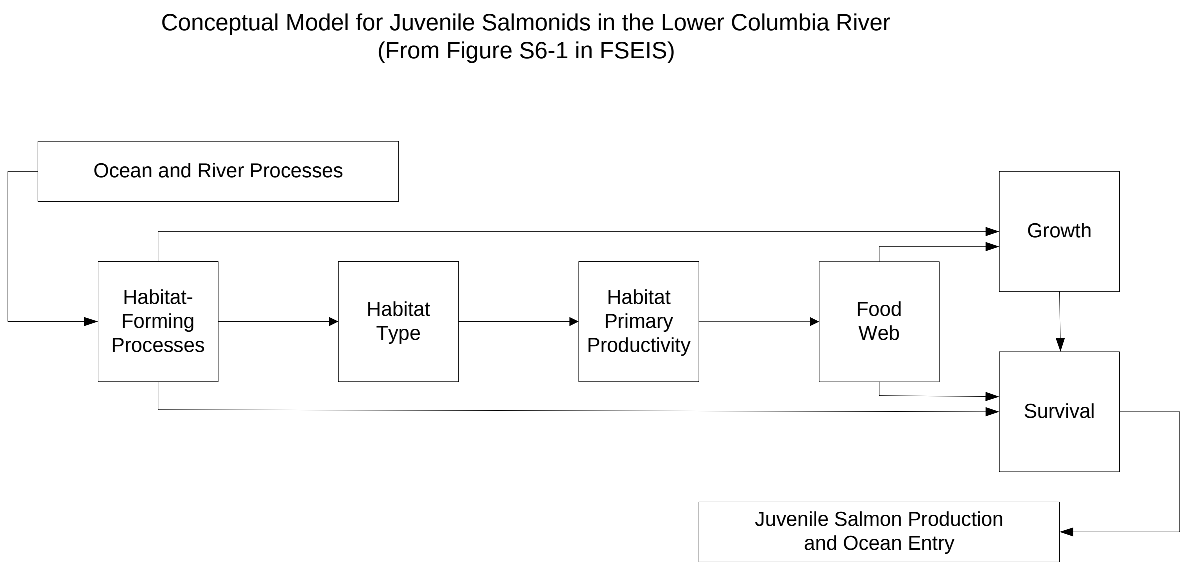

Figure A.1. Overall conceptual model used in support of the LCR and the estuary AEM Plan.

A.2 Habitat Forming Processes

Dredging required for channel improvement might effect changes in selected indicators of habitat forming processes (Figure A.2):

- short-term, localized increases in suspended sediment concentrations in the vicinity of dredging and disposal;
- shifts in the direction of bedload sediment movement that might impact the quantity and quality of shallow waters and flats habitat;
- the amount and distribution of woody debris that can provide valuable habitat for salmonids and their prey;
- increases in local turbidity as well as upstream shifts in the estuary turbidity maximum;
- salinity changes in shallow embayments (e.g., Cathlamet Bay, Grays Bay) and the bottom of the navigation channel;
- accretion and erosion associated with dredging and disposal of dredged materials; and
- changes in bathymetry that result from channel deepening that could influence depths and flow velocity in water column habitat.

Previous modeling and analysis during the Endangered Species Act consultation process suggested minimal changes in the above indicators in relation to channel deepening. However, these indicators could become components of a compliance-monitoring program as part of the AEM Plan implementation.

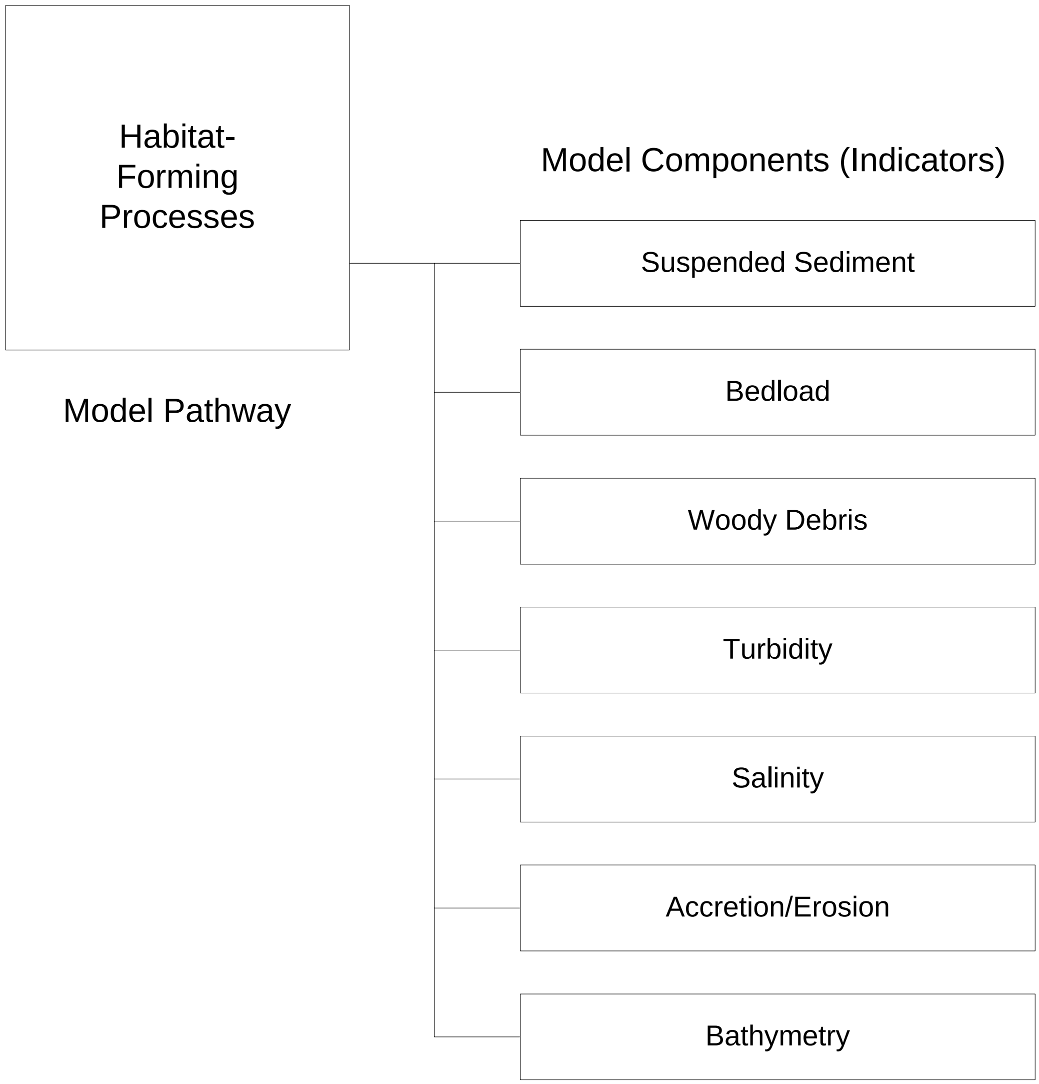

Figure A.2. Conceptual model indicators developed for habitat forming processes.

A.3 Estuarine Habitats

Figure A.3 identifies the important types of estuarine habitat that can influence the successful entry of juvenile salmonids into the ocean:

- tidal marsh and swamp,
- shallow water and flats, and
- water column.

The distribution and extent of each of these habitat types should be included as indicators of the adverse impacts of channel deepening (i.e., risk endpoints) or the benefits of ecosystem restoration actions (i.e., performance measures).

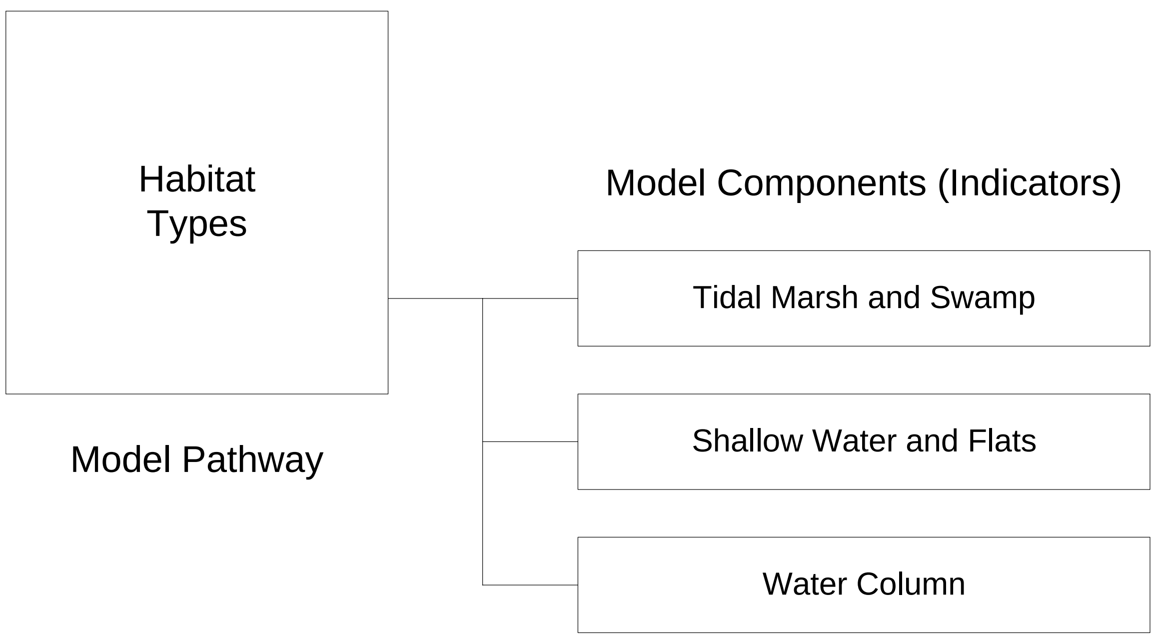

Figure A.3. Three important estuarine habitat types to be included as indicators in the LCR and the estuary AEM Plan.

A.4 Habitat Primary Productivity

Primary productivity in each of the above important habitat types provides a key contribution to the overall energy budget and influences the availability of food to juvenile salmonids that develop in the estuary before entering the ocean (Figure A.4). The proposed indicators of primary productivity include light and nutrients that can determine rates of photosynthesis and plant growth. Additional direct measures of primary production are included as indicators in the conceptual model:

- production of imported phytoplankton and resident phytoplankton,
- production by benthic algae, and
- production measured in tidal marsh and swamp habitats.

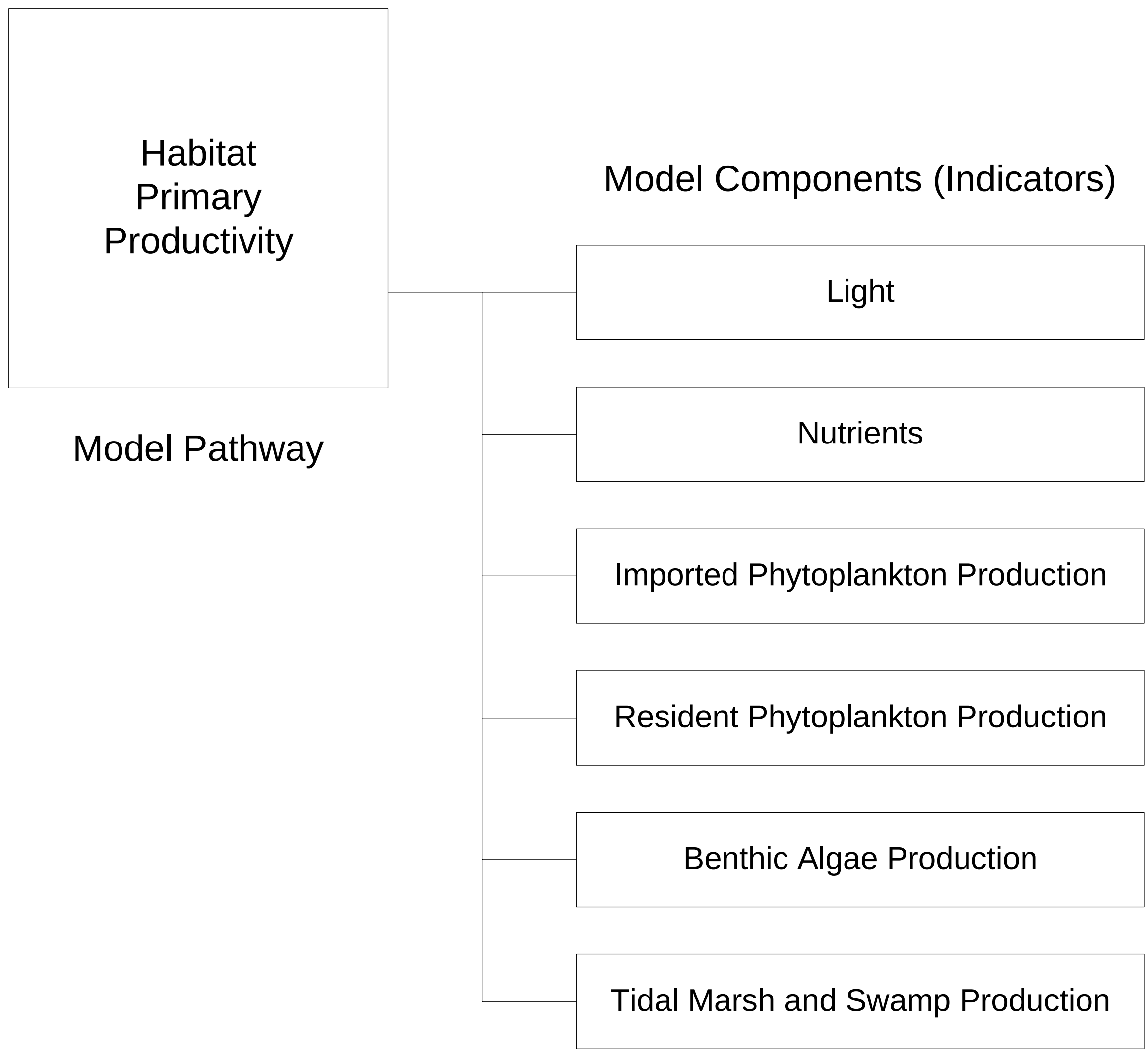

Figure A.4. Indicators of primary productivity for three important habitats in the conceptual model for the AEM in the Columbia River estuary.

A.5 Food Web

The conceptual model identifies food web components that constitute indicators of potential project effects on the overall production dynamics in the LCR (Figure A.5): They are

- deposit feeders, suspension/deposit feeders, and suspension feeders can suffer short-term impacts due to removal and burial associated with dredging and disposal activities,

- dredging and disposal can also impact the distribution and abundance of mobile macroinvertebrates and insects that serve as important food sources for salmonids in the estuary, and.

- the overall ecosystem energetics important in determining the growth of salmonids within the estuary are also influenced by the production and availability of resident microdetritus, imported microdetritus, and macrodetritus produced mainly in the tidal marshes.

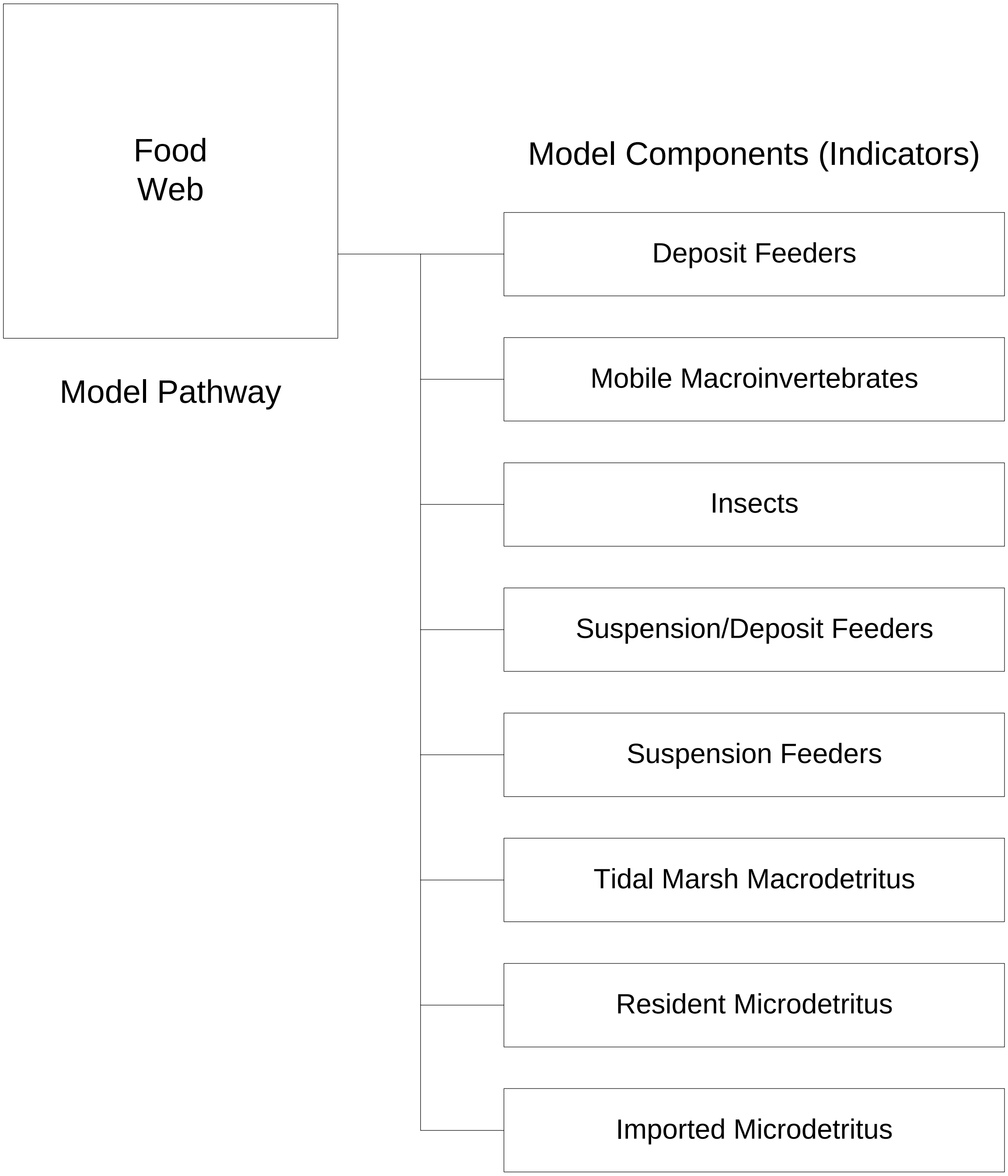

Figure A.5. Food web indicators identified in the conceptual model for the AEM of the LCR and estuary.

A.6 Salmonid Growth

Figure A.6 identifies components of the conceptual model that influence the growth of juvenile salmonids in the lower river and estuary. Habitat complexity, connectivity, and conveyance can determine the availability of foraging opportunities and physical routes for safe passage to the open ocean for juvenile salmonids. Spatial and temporal patterns in current velocities can impact growth. Higher than preferred current velocities can make greater energetic demands on smaller fish and reduce growth. Areas of slower velocity can provide energetic refugia for migrating fish. Modifications to bathymetry in the main channel and shallow water habitats can alter the extent of important habitat available for juvenile fishes. Turbidity can correlate with the location of a concentrated food source (e.g., turbidity maximum), as well as impede the visually-oriented feeding behavior of juvenile salmonids. The previous model components determine, in part, the habitat opportunity for juvenile salmonid feeding. Feeding opportunity is also influenced by the availability of prey in specific foraging habitats.

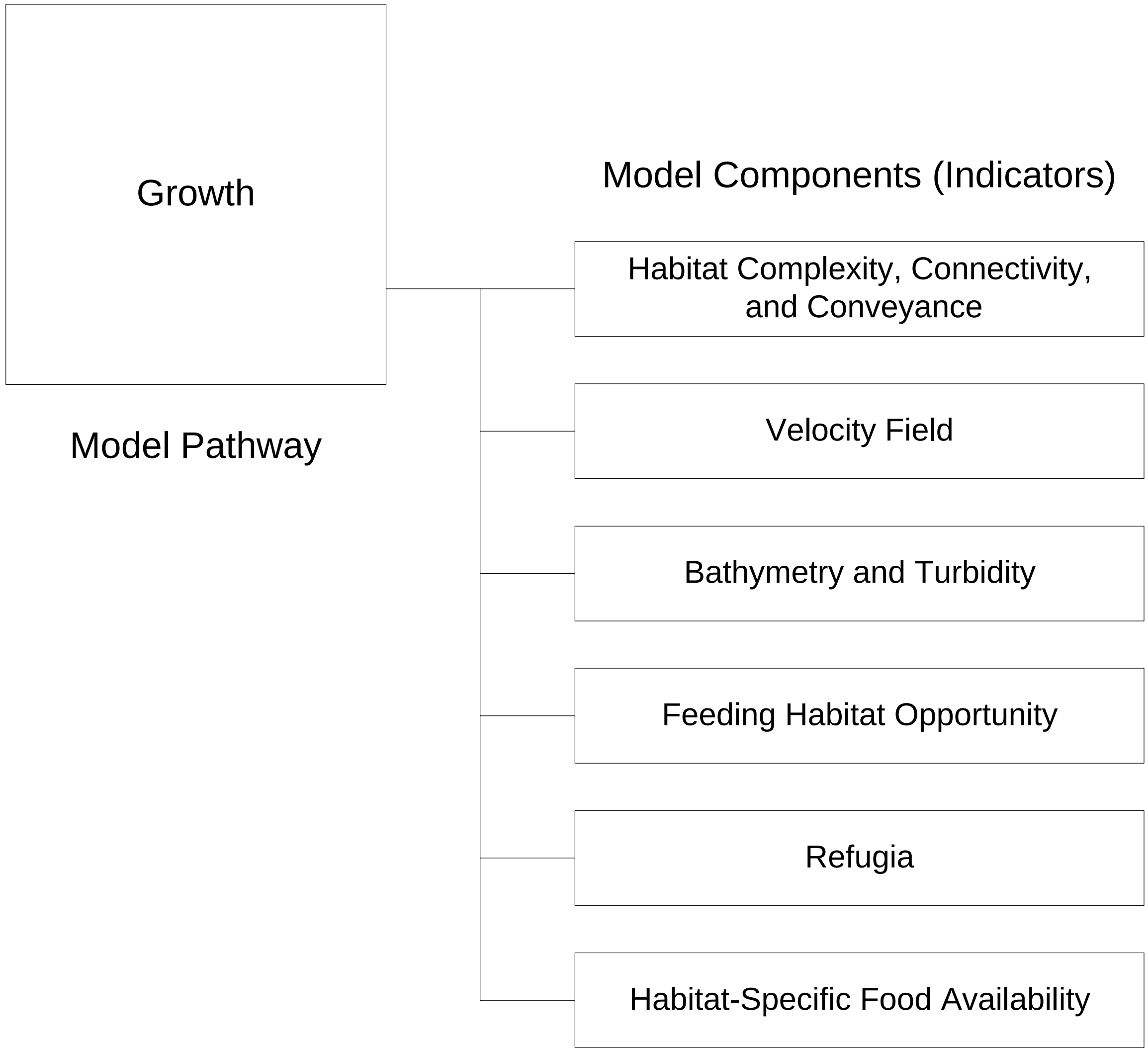

Figure A.6. Components and indicators of the growth pathway in the overall the LCR and estuary conceptual model.

A.7 Salmonid Survival

The conceptual model components recognized as important to the survival of juvenile salmonids are provided in Figure A.7. The indicators of survival include physical, chemical, and biological/ecological factors that can determine the probability that a juvenile fish will successfully enter the open ocean. Channel modifications suggest a low probability of fish experiencing extreme values of temperature and salinity. Channel dredging can also alter the concentrations of suspended solids, influence local turbidity, and potentially expose fish to sediment contaminants. Increased commercial navigation can entrain and strand smaller fish. The susceptibility of smaller fish to predation and disease also impacts the likelihood that these fish will survive to enter the open ocean component of their life cycle.

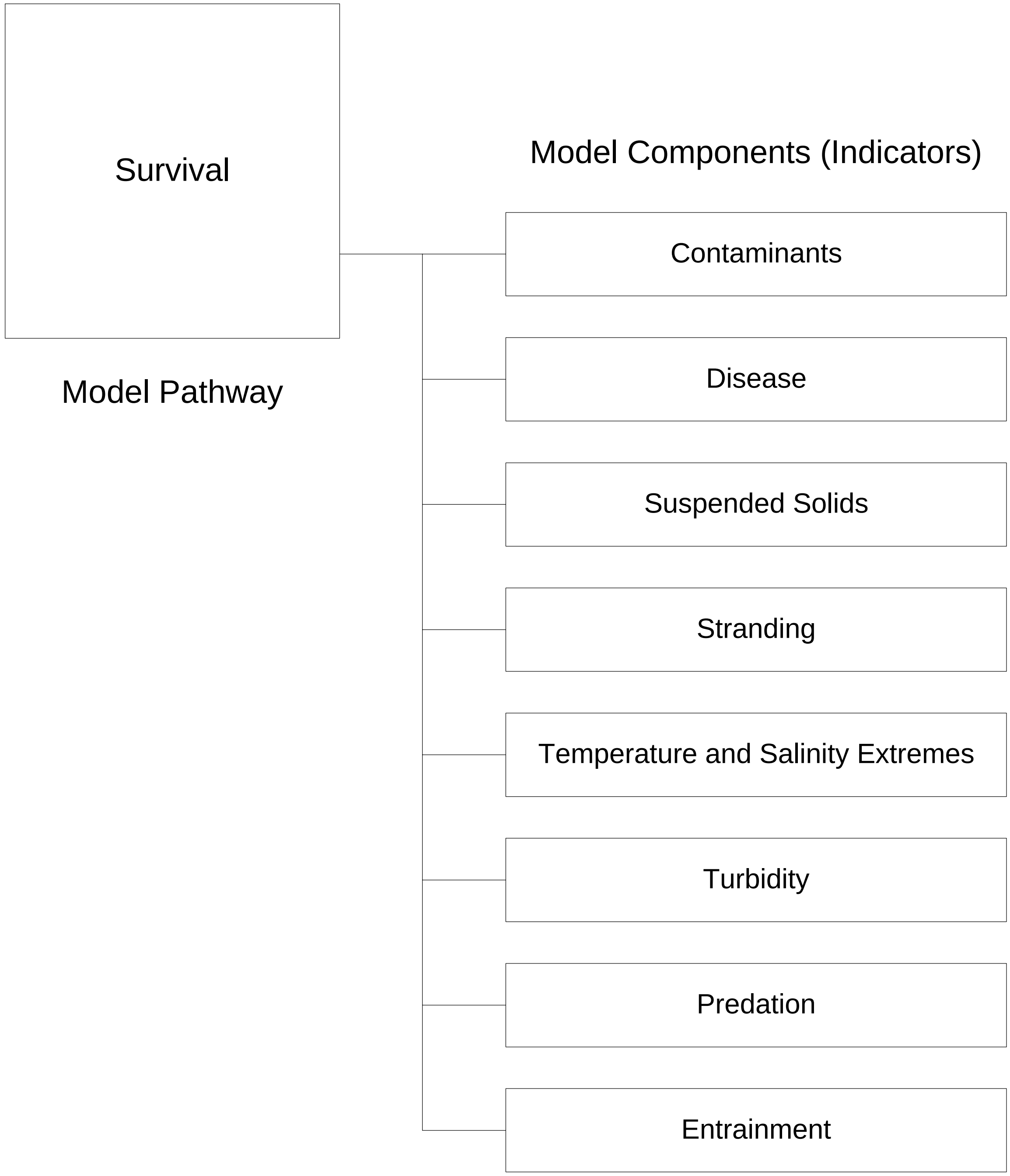

Figure A.7. Components and indicators of the survival pathway in the overall the LCR and estuary conceptual model.

The pathways and indicators presented in the conceptual models can be used to organize information that will be generated as the result of the monitoring programs and planned ecosystem evaluation actions.

Again, it must be remembered that the initial AEM Plan emphasizes the examination and evaluation of channel deepening in relation to possible changes in bathymetry, patterns of water circulation, and associated impacts on salinity, temperature, and depth. If such impacts cannot be demonstrated in relation to channel improvement, many of the more detailed ecological pathways and indicators will likely not be pursued.