Puget Sound Technical Recovery Team Technical Comments: Combined Template and Probabilistic Network Analysis

Draft Dungeness Recovery Plan (submitted June 30, 2004)

This technical feedback has three components:

- Brief summary of results of our review concerning certainty, and discussion and recommendations of factors we believe are critical to address in order to improve certainty of your plan;
- Consolidation of technical reviewers' composite and detailed comments on your June 30th draft; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

The "near-term steps" suggested in Section 1 of the feedback should occur by April 30th, because they will help you finalize your draft chapter. The "long-term steps" should generally occur as you implement your adaptive management program.

We recognize that the policy questions which you are working on from now through December will require substantial time and commitment. As such, we are happy to work with you as you think about timing and sequencing in addressing the policy and technical feedback to meet the April 30th deadline for your draft chapter.

I. SUMMARY OF CERTAINTY ANALYSIS

The content of this section summarizes the results of our probabilistic network analysis (for a description of the approach, see *Section III* of this document.) We suggest using this certainty analysis in an iterative fashion to help you in guiding plan revisions. This analysis also will help us strategically track the elements of your plans and how information at each step affects the overall certainty that the proposed actions in your plan will contribute to population and ESU recovery. This section is divided into separate discussions of the certainty in the habitat, hatchery and harvest management elements of your plan. You will notice that several questions within each "H" encourage us to check how well the habitat, hatchery and harvest strategies are integrated in the plan. We fully expect that the certainty in your plan's outcomes can be increased by providing more information and documentation—we have highlighted areas we think would be particularly fruitful to focus on in near-term revisions in each section below.

Habitat Strategy

Key Issues to Improve Certainty

The most important ways to improve the certainty of an effective habitat strategy in the Dungeness recovery plan in the near-term plan are to:

- Better document the data, assumptions, and models used as they relate to the VSP characteristics and potential responses of the population.
- Provide a summary of any available empirical support used to relate the flow management regime, land use, ecological processes, habitat conditions, and all four VSP relevant to the recovery planning to highlight the strength of the analytical support for the recovery plan.
- Further integrate the habitat strategy with hatchery and harvest management strategies in the planning area
- Provide any available empirical data on the effectiveness of the protection actions described.
- Further develop an adaptive management plan for the habitat recovery strategy more explicitly and quantitatively relating the interactions among the flow management regime, land use, habitat forming processes, habitat conditions and population VSP responses.

Based on our analysis, developing and implemented the key items above would increase the current moderate likelihood of a "high" level of certainty by approximately 35 percent.

Did the analysis use one or multiple independent models to understand potential fish status and responses?

- The Dungeness recovery plan utilizes multiple models to assess the relationships among ecological processes, land use, flow management, and habitat conditions to responses in population viability characteristics, and potential responses of the Dungeness population.

What is the nature of the analytical support for the model linking salmon population status to changes in habitat-forming processes and in-stream habitat conditions? (Analytical Support)?

The analytical support was moderate.

- It appears this support could be increased, even to a high level of certainty over the long-term, by 1) better documenting in a more transparent manner what has been accomplished, and 2) further developing more quantitative approaches, and conducting sensitivity analyses, empirical tests and validation.

- Good *qualitative* modeling was used to relate ecological processes, habitat conditions, and all four VSP parameters. The EDT method was used to quantitatively model restoration actions and resulting population responses relating to all 4 VSP parameters but does not model processes. Reviewers found it hard to track down all assumptions in the material provided. Documentation for and summaries of the key assumptions for habitat and VSP would make the supporting evidence more readily available and transparent to various users. Similarly, a synthesis of the empirical support applied in the recovery plan analyses would strengthen the analytical support. Good evidence for sediment transport and flow process relationships to habitat condition hypotheses is provided. Specific linkages to life history stages and potential VSP characteristic responses would significantly strengthen the overall analytical support for the recovery plan. A comparison of EDT results with observed fish returns or distribution would also strengthen the support. There is no explicit discussion provided of sensitivity testing. Nor does the plan discuss empirical testing and validation of the models.

Near-term steps to reduce uncertainty:
- Improve documentation of the data, assumptions, and models used as they relate to the VSP characteristics and potential responses of the population;
- Provide any available empirical support used to relate ecological processes, land use, flow management, habitat conditions, and all four VSP relevant to the recovery planning to strengthen the analytical support;
- Conduct sensitivity analyses.

Long-term steps to reduce uncertainty:
- Further develop explicit life stage specific relationships among ecological processes, land use, flow management, and habitat conditions to responses in population viability characteristics, and potential responses of the population;
- Conduct empirical tests and validation testing.

How well supported are the hypotheses for (1) what VSP attributes are most limiting recovery and (2) the habitat-forming processes or conditions that are limiting population response? What is the nature of the watershed-specific data to support either of those 2 hypotheses? (Watershed Data Quality)

Support for the recovery hypothesis using watershed specific data was moderate and could be improved.

- This question asks if the watershed has data that has been used to independently support the results of the qualitative analysis. Multiple lines of evidence were presented to support the hypothesis. Habitat data are good; fish data (life stages, where they are for how long) are weak. The available data could be more explicitly applied to the hypotheses and potential VSP characteristics responses to highlight the strength of the analytical support.

Near term steps to reduce uncertainty:
- Develop more explicit and quantitative life stage specific model(s) with watershed specific data relating the interactions among ecological processes, land use, flow management, habitat forming processes, habitat conditions and potential population VSP responses.

Is the recovery strategy consistent with the recovery hypothesis? (Consistent with Hypothesis)

Yes.

Near-term steps to reduce uncertainty:

- Further integrate the habitat strategy with hatchery and harvest management strategies in the planning area.

Does the habitat recovery strategy preserve options for recovery in all 4 VSP attributes through all of the H's? (Preserves Options)

No.

- Preserving options requires an adaptive management plan to respond to changes and uncertainty as they occur.

Near-term steps to reduce uncertainty:

- Further develop an adaptive management plan for the habitat recovery strategy which explicitly relate the interactions among flow management regime, land use, habitat forming processes, habitat conditions and population VSP responses.

Long-term actions to reduce uncertainty:

- Implement an adaptive management plan including more explicit detailed qualitative and quantitative interactions among flow management regime, land use, habitat forming processes, habitat conditions and population responses for the specific protection and restoration action plans.

Are the recovery actions consistent with the recovery strategy? (Consistent with Strategy)

Yes.

Key long-term action to reduce uncertainty:

- Develop stronger empirical and analytical support for the above relationships among protection and restoration actions, the hypotheses and strategies, and specific VSP characteristics or ESU persistence.

How well have the recovery actions been shown to work? (Empirical Support)

Support for the proposed actions is moderate.

- For the protection and restoration actions in the watershed, the evidence suggests that actions may work, although there are some conflicting results and uncertainty. Areas that are especially uncertain are: 1) the effectiveness of shoreline regulatory protection programs; 2) validation that the habitat actions to restore, rehabilitate, or enhance floodplain, estuary, and nearshore habitats support chinook life stages as predicted.

Near-term action to reduce uncertainty:

- Provide any available empirical data on the effectiveness of the protection actions described.

Long-term actions to reduce uncertainty:

- Further document assumptions for floodplain, estuary, and nearshore habitat protection and restoration actions by type to increase the strength of the empirical support;
- Strengthen the empirical support for each type of protection and restoration action by testing for the effectiveness and by validating that the actions result in the predicted responses.

Hatchery Strategy

Key Issues to Improve Certainty

The most important way to improve the certainty of an effective hatchery strategy in this plan is to:

- Improve the adaptive management program.

Based on our analysis, the Dungeness and Elwha River hatchery strategies had two of the highest likelihoods of being effective in contributing to recovery. In both watersheds, by improving adaptive management program, the likelihood of a “high” level of certainty for biological effectiveness for this strategy would nearly double.

How well supported is the understanding of the links between hatchery actions and population viability (VSP) characteristics used in the planning (Analytical Support)?

The analytical support was moderate.

- The co-managers used a qualitative model (e.g. the Benefit-Risk Assessment Procedure cited in co-managers’ resource management plan and models developed during the captive brood stock program) to understand the potential effects of hatchery actions on populations. These models addressed VSP criteria. Documentation was available for the basic model structure but not for how local watershed data (as opposed to general information from the scientific literature and expert guesses) were used to calibrate the assessment for the Dungeness River populations. Overall, the Dungeness Plan provided good documentation and calibration for the assessments. Useful information exists on the genetic composition of the hatchery brood stock, proportions of hatchery and wild fish, straying, and juvenile life history. Information on ecological interaction between hatchery and wild fish is more uncertain. Because of the availability of this information, it may be possible to use a quantitative model to look at an integrated analysis of hatchery effects across all management sections. This could improve the analytical support.

Near term steps to reduce uncertainty:

- Analyze how different factors affect the certainty of the results from hatchery management decisions (e.g. through a sensitivity analysis).

How well supported are the recovery hypotheses with watershed specific data? (Watershed Data Quality)

Support for the recovery hypothesis using watershed specific data is moderate.

- This question asks if the watershed has data that have been used to independently support the results of the hypotheses generated by the qualitative analyses. The recovery hypothesis is that a well-designed supplementation program will conserve the local population until habitat can support greater natural production. Local watershed data partially support this hypothesis. Intensive hatchery intervention has been successful in preventing extinction of the population. The effects of domestication and small population sizes on the recovery potential population are unknown.

Long term steps to reduce uncertainty:

- Continue to collect and analyze demographic, genetic, and ecological information to test the recovery hypothesis.

Is the recovery strategy consistent with the recovery hypotheses? (Consistent with Hypothesis)

Yes

- The strategy to continue a supplementation program to support the population until habitat is sufficient to support a viable population is consistent with the recovery hypothesis. Consideration of how to adapt the hatchery program over time as habitat improves would be a useful addition to the plan. This might be an extension of the strategies employed in beginning the captive brood stock program and transitioning to a supplementation program.

Is the recovery strategy robust by preserving options for recovery? (Preserves Options)

No

- Many of the actions taken to implement the recovery strategy should help preserve options. Preserving options also requires an adaptive management plan to respond to changes and uncertainty as they occur. The TRT is aware that watershed has adopted many aspects of adaptive management but these are not well described in the recovery plan.

Near term step to reduce uncertainty:

- Develop and implement an adaptive management program.

Are the recovery actions consistent with the recovery strategy? (Consistent with Strategy)

Yes

- As noted above, many of the current and proposed actions are consistent with an integrated strategy for maintaining the genetic diversity of this population in the face of small population size, reducing the impacts of domestication, reducing competition and predation from steelhead and coho salmon, and maintaining abundance.

How well have the recovery actions been shown to work? (Empirical Support)

Empirical support for the proposed actions is moderate.

- Experience in other watersheds suggests that the actions may work, although there are some conflicting results and uncertainty. Areas that are uncertain are: 1) the actions to reduce competition or predation, if it occurs; 2) the actions to reduce straying of other stocks into population; and 3) actions to reduce domestication and loss of productivity in hatchery fish spawning in the wild.

Harvest Strategy

NOTE: This evaluation is based on the Dungeness Management Unit profile, pages 181-183 of the *Co-managers' Puget Sound Chinook Harvest Management Plan*, as well as material presented in the plan submitted by the Dungeness watershed group.

The harvest management portion of the recovery plan states that recovery is limited by habitat degradation and harvest should be kept as low as possible until habitat conditions improve.

Key improvements to the harvest management portion of the recovery plan include:

- Developing exploitation rate guidelines based on productivity and abundance estimates of the Dungeness Chinook population.
- Broadening the hypothesis to include the effects of harvest on diversity and spatial distribution.
- Broadening the strategy to also address diversity and spatial structure.
- Incorporating existing local data pertaining to spatial distribution and diversity to support the expanded hypothesis and the expanded strategy and actions based on it.

Did the analysis use one or multiple independent models to understand potential fish status and responses?

One, qualitative.

How well supported is the understanding of the links between harvest actions and population viability (VSP) characteristics used in the planning (Analytical Support)?

Low

- Quantitative estimates of a rebuilding exploitation rate for the Dungeness Chinook population have not been developed and the effects of harvest on diversity and spatial distribution are not addressed. No information is presented on the breakout of escapement into natural-origin and hatchery-origin components.
- The EDT analysis discussed in the habitat sections of the plan might be used to help inform harvest management. However, there appeared to be no reference to the Dungeness EDT analysis in the co-managers' harvest plan.
- Integrated H-modeling by including harvest and hatchery effects with an EDT assessment, for example, could incorporate both diversity and spatial structure in a quantitative assessment of the effects of harvest management.

How well supported are the recovery hypotheses with watershed specific data? (Watershed Data Quality)

Moderate

- The lack of coded-wire tag data and estimates of exploitation rates specific to the Dungeness River is a significant source of uncertainty. No estimates are made of hatchery versus natural-origin adult Chinook salmon in the natural spawners.
- There is a need to determine how to estimate exploitation rates on this population.
- There is a need to determine contribution of hatchery fish to natural spawning.

Is the recovery strategy consistent with the recovery hypothesis? (Consistent with Hypothesis)

No

- The strategy places a limit on the exploitation rate in Southern US fisheries, but not on the total (all fisheries) exploitation rate.
- The strategy does not address the effect of harvest on the diversity and spatial structure VSP parameters.

Is the recovery strategy robust by preserving options for recovery? (Preserves Options)

No

- The harvest strategy does not include any consideration of how diversity and spatial distribution will be protected or enhanced.
- An adaptive management plan for harvest management is not provided.

Are the recovery actions consistent with the recovery strategy? (Consistent with Strategy)

Yes

How well have the recovery actions been shown to work? (Empirical Support)

Moderate

- The effects of the harvest plan on diversity and spatial structure have not been evaluated. Uncertainties in the effects of habitat and hatchery management have not been incorporated into the analysis used to derive the harvest management guideline.
- When rebuilding exploitation rates linked to the productivity of the Dungeness population are estimated, the maximum exploitation rates allowed under the Pacific Salmon Treaty may be found to be excessive.

II. REVIEW OF TECHNICAL CONTENT

Reviewer's Name: **Technical Reviewers**

Watershed Plan: **Dungeness**

Populations or ESUs considered: **Dungeness Chinook**

Summary

Overview of Shared Strategy questions and how well the watershed plans address the technical aspects of those questions. In particular, what is the watershed's technical basis to the answer to the questions from the Shared Strategy: (1) What are the major physical and biological changes necessary to meet the population planning targets? And (2) What are the expected changes in H's and fish population responses over the next 5-10 years?

Review of Plan—Overview

Overall summary of approach, scope of plan (geography, species, populations, ESUs, included), stated goals, participants in plan development, etc.

Format:	Multiple documents. The Dungeness Watershed Salmon Recovery Planning Notebook provides responses to the Shared Strategy questions. Approximately 15 additional documents provide supporting information.
Scope:	Chinook salmon in the Dungeness River
Participants:	Clallam County, WDFW, riverside property owners, North Olympic Salmon Coalition/ Sport Fishers, Department of Ecology, Water Resources Planning Group, Jamestown S'Klallam, Agricultural Water Users Association, City of Sequim, North Olympic Land Trust, Protect the Peninsula's Future, U.S. Forest Service (advisory), USFWS (advisory), Clallam Conservation District (advisory)
Goal:	The mission of the Dungeness River Management Team (DRMT) is "to preserve and enhance the Dungeness River Watershed Planning Area through an ecosystem approach to restore its physical and biological health". A quantitative goal of 1,200 spawners at 3.0 adults per spawner and 4,700 spawners at 1.0 adult per spawner is under review by the DRMT.
Summary of Approach:	Biologists conducted an extensive review of factors limiting chinook and other species in the Dungeness River and identified ten strategic restoration elements. Thirty-one projects associated with the strategies were subsequently identified, their effects on aquatic habitat assessed, and the predicted change in the performance of Dungeness Chinook evaluated using EDT. The EDT analysis was supplemented with a parcel-by-parcel analysis of riparian property in the critical lower 10 miles of the river. Summaries of the co-manager harvest and hatchery plans are also provided.

Brief narrative of how well the plan addresses the following; including strengths and weaknesses:

1. **What biological and physical changes does the plan state are required for the population(s) in the watershed to achieve their targets?**

   For watersheds without targets, what biological and physical changes are needed for the habitat to be considered functioning for anadromous fish?

   The Dungeness plan reports results from earlier planning (e.g., *Restoring the Dungeness*) and from EDT modeling where "Properly Functioning Condition (PFC)-plus" conditions were used as inputs (i.e., PFC in freshwater and "pristine" estuarine conditions) to define a planning target. The analyses were used to identify 10 strategic restoration elements (Table 1, page 3):

   1) Restoration of the Lower River floodplain and delta to RM 2.6;
   2) Protection of existing functional habitat (RM 2.6-11.3);
   3) Floodplain restoration/constriction abatement (RM 2.6-11.3);

4) Water conservation/instream flow protection and water quality improvement/protection;
5) Restoration of functional riparian and riverine habitat;
6) Large woody debris placement;
7) Nearshore habitat protection and restoration;
8) Barrier removal;
9) Stock recovery/rehabilitation;
10) Sediment management/source control.

Associated with the strategic restoration elements were 31 actions (tables 2 and 3) specific to river reaches. The two actions predicted to provide the greatest benefits for population diversity, abundance, and productivity were:

1) water conservation projects in the Comprehensive Irrigation District Management Plan (CIDMP) that are expected to reduce withdrawals by 25.5 cfs;
2) restoration of floodplain function through removal of Corps and Beebe dikes, land purchases, ad placement of engineered log jams between Schoolhouse Bridge and Woodcock Road.

2. What biological goals does the plan aim to achieve (in 5-10 years and over longer term)?
What are fish-based and habitat, hatchery or harvest management-based goals?

The mission of the DRMT is "to preserve and enhance the Dungeness River Watershed Planning Area through an ecosystem approach to restore its physical and biological health". A quantitative goal of 1,200 spawners at 3.0 adults per spawner and 4,700 spawners at 1.0 adult per spawner is under review by the DRMT. No goals are provided for spatial structure or diversity.

3. What is the biological RATIONALE for identified actions in all of the H's (i.e., is the "hypothesis-strategy-action" logic presented in the watershed guidance document used?)

(a) What is the population's current status for all 4 VSP (this should come out under the hypotheses)?

The plan includes a description of the current status of all four VSP parameters for the population and a clearly organized presentation of hypotheses and associated actions. The average number of total spawners (hatchery plus natural) was 123 for the period 1987-2001. Empirical estimates of productivity are not available; however, EDT predicts an intrinsic productivity of 3.7. Access to the historic range of Chinook salmon in the Dungeness River has generally been maintained, although the Gray Wolf appears to be under utilized. Run timing also appears consistent with the historical pattern. However, EDT predicts that habitat degradation and other factors have reduced the number of viable life history trajectories by 30% relative to the historical population.

(b) What is the population's predicted status for all 4 VSP over the short- and long-term?

Predicted spatial structure is not addressed. The predicted status of the population based for the remainder of the VSP parameters is provided below (Table 4, page 7):

Equilibrium Abundance

Years in Future	Current	Build Out	Likelihood of Project Implementation			Target
			High	Medium	Low	
25	699	649	1,764	2,544	2,555	4,753
100	699	649	1,919	2,649	2,668	4,635

Intrinsic Productivity

Years in Future	Current	Build Out	Likelihood of Project Implementation			Target
			High	Medium	Low	
25	3.7	3.3	5.8	7.7	7.8	9.3
100	3.7	3.3	6.5	8.2	8.3	9.3

Diversity

Years in Future	Current	Build Out	Likelihood of Project Implementation			Target
			High	Medium	Low	
25	0.70	0.68	0.98	0.99	0.99	1.00
100	0.70	0.68	0.99	0.99	1.00	1.00

(c) What are critical threats affecting the populations? Have all been identified and considered in the stated hypotheses? Are there potential threats that are missing from the plan? Be explicit about each threat or potential factor limiting recovery.

The Dungeness plan states potential threats in the H's as hypotheses, which is excellent. It improves both the plan's treatment of certainty in what is known and its vision for implementation to treat information on threats as hypotheses (see TRT Watershed guidance document.) Phrasing H factors potentially limiting recovery as hypotheses acknowledges that such a judgment is based on best available (but imperfect) information, and also forces plan authors to treat H factors as potential effects on VSP that need to be monitored to that we can learn over time about the nature and magnitude of the actual effects.

The critical threats for habitat that are identified are: a) loss of lower river floodplain and delta; b) loss of functional habitat in the lower river; c) loss of floodplain and constriction of channel; d) water quantity and quality; e) loss of riparian function; f) lack of large woody debris; g) loss of nearshore habitat; h) presence of passage barriers; and, i) increased sediment loading. No critical threats appear to be missing.

The plan summarizes predictions of fishing mortality as computed by the Fishery Regulation Assessment Model (FRAM). Exploitation rates are predicted to have declined from an average of 76% in the period from 1983 through 1987 to 18% in 2001 through 2003. In 2003, fisheries in Washington and Oregon were predicted to have a 10% exploitation rate, with an additional 13% in fisheries in Canada and southeast Alaska. The plan states that the co-managers have "expressed strong reservations" about NMFS' no jeopardy decision for the 1999 annexes of the Pacific Salmon Treaty.

Potential threats that the hatchery programs may pose to Dungeness Chinook are not explicitly identified; however, the hatchery resource management plans, HGMPs, and recommendations of the Hatchery Science Review Group are referenced.

(d) Is the strategy for H management changes consistent with the identified hypotheses for current population status, desired future population status, and primary threats? What elements of the strategy are missing? Be explicit about each threat or potential factor limiting recovery.

This question is addressed in Section I.

(e) How are actions in the H's linked to fish population status? Both existing and future/planned H actions should be addressed. Are these links based on empirical or modeled estimates or both? Be explicit about each threat or potential factor limiting recovery.

This question is addressed in Section I.

(f) What are the plan's stated assumptions about existing habitat conditions or actions outside of the WRIA jurisdictional boundaries covered in the plan (freshwater and estuarine/nearshore)?

The plan generally does not describe assumptions for habitat conditions and actions outside of the recovery planning area. It does recommend implementation of nearshore/protection projects from the North Olympic Peninsula Lead Entity Group (NOPLE) strategy; however, the potential benefits of these projects were not assessed with EDT or other tools.

(g) Are future options preserved in the proposed strategy-action links? How so? Be explicit about each threat or potential factor limiting recovery.

This question is addressed in Section I.

4. **What is the empirical or modeled SUPPORT for the answers to question #3? How well do the assessment data for the population status and the H's support the hypotheses proposed?**

This question is addressed in Section I.

5. **How are the individual and interacting effects of the H's on the 4 VSP parameters considered for each population? How likely is it that the proposed suites of H actions will achieve the short- and longer-term stated goals? How certain are we in their translation into effects on salmon population VSP?**
It is important to note the assumptions the plan makes about the effects of hatchery and harvest management, existing habitat actions, and survival in the nearshore/ocean, for example.

A narrative description of integration suggests that restoration and protection of "habitat is the key to recovery of productive, sustainable natural population of Chinook in the Dungeness River." The Chinook hatchery program is a "stopgap" measure that, when linked with harvest control measures, has been successful in "rebuilding the run to maintenance levels." However, the interacting effects of the H's on VSP parameters do not appear to have been formally considered.

The certainty of the technical analysis is discussed in Section I.

6. **How does the plan acknowledge uncertainties and how are they factored into decisions, future actions?**

The plan generally does not discuss uncertainty or how uncertainty was addressed in the development of recommended actions. Limited discussion of monitoring and adaptive management is provided. For example, the plan does indicate that the co-managers will "monitor, assess and adaptively manage program to meet hatchery objectives and standards and to evaluate the hatchery management hypotheses." A clearer description of how uncertainties (in data, model, and analysis) affected decisions and prioritization of efforts is needed.

(a) Uncertainties in data and information?
(b) Uncertainties in environmental conditions in the future?

It appears that the EDT modeling uses alternative scenarios. However, their design and use in decisions need to be better explained.

(c) Uncertainties in effectiveness of actions?

7. **Reviewer: What is the estimated overall level of risk for the population(s) included in this plan, relative to low-risk (i.e., viable) population criteria? What is your rationale for this risk estimate? How certain are you in the estimation for each VSP parameter?**

The certainty analysis presented in Section I addresses this question in part; however, additional technical and policy analyses will be required before the risk to the population can be fully assessed.

8. **Make any suggestions for approaches or methods for addressing concerns mentioned above or reducing gaps in the plan.**

This question is addressed in Section I.

III. ANALYZING CERTAINTY OF BIOLOGICALLY EFFECTIVE RECOVERY PLANS

All watersheds in the Puget Sound are unique. Not surprisingly, different watershed planning groups identify different long-term and short-term goals and propose different suits of actions to achieve those goals. The certainty that the actions in every watershed will be biologically effective in moving the populations towards recovery is a key factor in the recovery of the whole evolutionarily significant unit (ESU). Consequently, the Puget Sound Technical Recovery Team (TRT) has focused its analysis of watershed recovery plans on identifying ways to increase the certainty of the plans. The TRT hopes that these analyses will encourage watershed groups to improve the certainty of plans before the TRT does it analysis of the final plans next year.

To provide these analyses, the TRT used a probabilistic network (PN). A probabilistic network is a graphical model that shows how different states of the world of interest—in this case the scientific factors that provide certainty of biologically effective actions—are related (Figure 1). The basic approach is to assess certainty by applying conditional probabilities, which can be expressed as "Given event *b*, the likelihood of event *a* is *x*." In Figure 1, for example, the states of the variables in boxes that point to another variable (e.g. "Use of Independent Models" and "Analytical Support") are the events that condition the likelihood of the states for the latter variable (e.g. "High", "Moderate", and "Low" in the Certainty of the General Fish Response Model). Users provide evidence for the initial conditioning events (or diagnostic nodes); software for PNs use a set of sophisticated algorithms for recalculating the joint probability distributions for all the potentials based on tables of conditional probabilities provided by the analyst (Jensen 2001). Using a PN gave the TRT a rigorous, transparent, repeatable method of analyzing certainty across watershed plans and habitat, harvest, and hatchery management sectors.

Methods

The Puget Sound Technical Recovery Team (TRT) used the PN in Figure 1 to assess separately the certainty of biologically effective actions for each plan in four management sectors, 1) freshwater habitat, 2) nearshore habitat, 3) hatchery production, and 4) harvest. Each assessment also considered how well integrated actions were across categories and how the actions affected characteristics of viable salmonid populations (McElhany et al. 2003). The network graphically shows the logic of how different scientific variables affect the biological certainty of effective recovery plans. The model is based on the TRT's *Integrated Recovery Planning for Listed Salmonids: Technical Guidance for Watershed Groups in the Puget Sound* (http://www.sharedsalmonstrategy.org/files). The network shows that the overall biological certainty of an effective recovery plan depends on the certainty of the recovery strategy (Recovery Strategy), the robustness of the strategy (Preserves Options), and the expected effectiveness of actions chosen to implement the strategy. The certainty of the recovery strategy in turn is conditioned by the certainty of how well we understand the biological, physical, and chemical processes that affect the population (i.e. Recovery Hypothesis), which depends on well recognized sources of scientific uncertainty (Lemons 1996), such as model uncertainty (Use of Independent Models), framing uncertainty and stochasticity (Analytical Support), and empirical support for the hypothesis (Watershed Data Quality). After identifying the model structure, the TRT identified and defined different states of the variables (Tables 1-6).

Conditional probabilities may be derived from frequencies from empirical data, simulation results, or subjective probabilities. When data are too few to parameterize simulation models, use of subjective probabilities is important (Bedford and Cooke 2001) and analysts have developed methods for estimating these (e.g. Ayyub 2001). Using experts to estimate subjective probabilities has inherent biases that can be difficult to control (Kahneman et al. 1982, Otway and von Winterfeldt 1992). Using estimates of conditional probabilities within a logical, transparent model such as a PN may reduce these problems compared to asking experts to provide absolute certainty estimates directly without a model. The TRT estimated conditional probabilities using a Delphi process (Helmer 1968, Ayyub 2001) in which TRT members iteratively estimated conditional probabilities individually; the distributions of the results were compiled and shared; and new estimates were generated. Sensitivity of the model was evaluated using the mutual information index (Pearl 1988) which measures the reduction in entropy of variable *A* due to a finding at *B*.

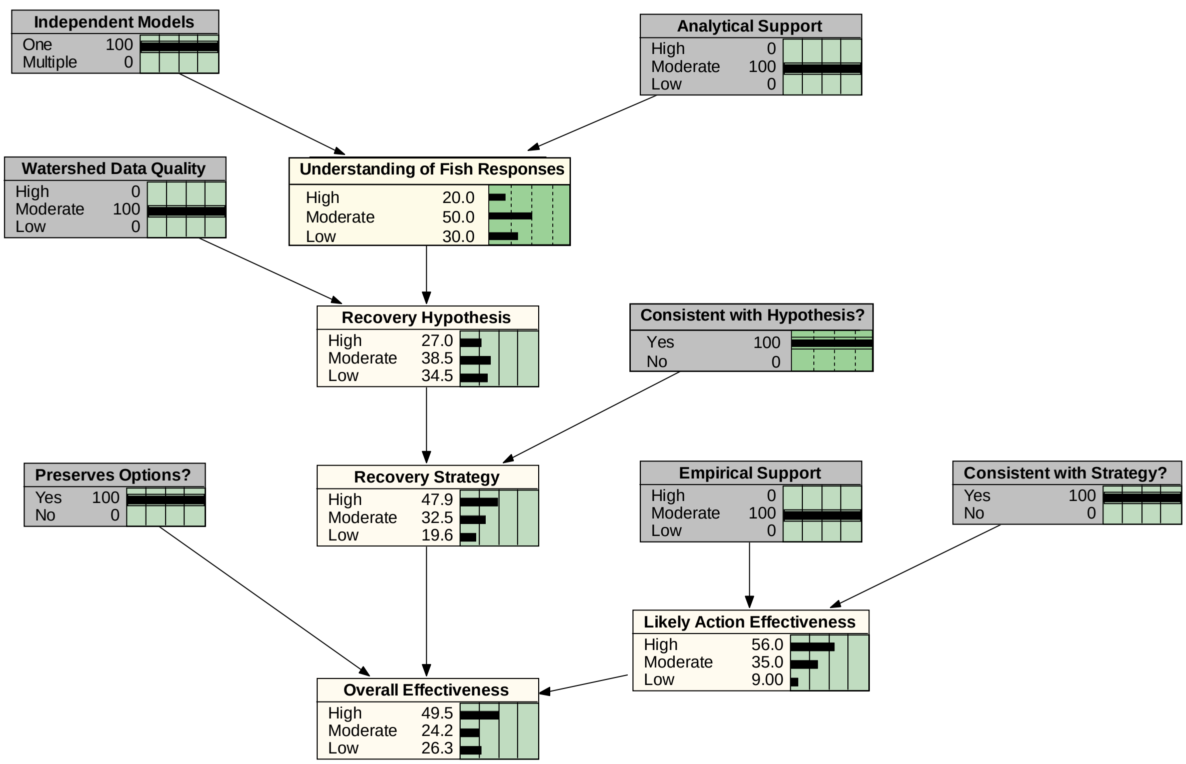

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

The TRT qualitatively assessed the states of seven diagnostic variables (box titles in parentheses) that address these questions:

1. Did the analysis use one or multiple independent models to understand potential fish responses to actions? (Independent Models)
2. How well supported is the model? (Analytical Support)
3. How well supported is the recovery hypotheses with watershed specific data? (Watershed Data Quality)
4. Is the recovery strategy robust by preserving options for recovery? (Preserves Options)
5. Is the recovery strategy consistent with the recovery hypothesis? (Consistent with Hypothesis)
6. Are the recovery actions consistent with the recovery strategy? (Consistent with Strategy)
7. How well have the recovery actions been shown to work? (Empirical Support)

The possible answers to these questions are in Tables 1-6. Reviewers usually choose one state, but if this is not possible because of uncertainty, reviewers could assign probabilities to different states (e.g., “Low” = 10%; “Moderate” = 90%). Analyses were performed using Netica (Norsys Software Corporation, Vancouver, BC; http://www.norsys.com).

Interpreting the Results

Even the best recovery plan is inherently uncertain because the future is so difficult to predict. Consequently, the quantitative estimates of certainty generated by the TRT are less important than the relative improvement that watershed planners need to make. For similar reasons, the quantitative estimates of certainty generated by the TRT are not relevant to analyses of certainty performed by regulatory agencies, which depend on a different interpretation and standard of certainty. Based on the TRT analyses, watershed planners may be able to increase the certainty of biological effectives several fold by focusing on several key factors. These are described in individual watershed analyses.

Literature Cited

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Table 1. Attributes for different states of analytical support for models.

Analysis	Total Score	Attributes (Maximum Possible Score)
Habitat Models High Moderate Low	 0.60 -1.00 0.21 - 0.60 0 - 0.20	• Qualitative and/or quantitative description of the relationship landscape processes, land-use, and habitat condition – (0.1 for each analysis) • Qualitative and/or quantitative description of the relationship between habitat condition and population viability (VSP) characteristics – (0.1 for each analysis; 025 for each VSP characteristic) • Model structures and parameters for each VSP characteristic documented; assumptions discussed and defended – (0.2) • Sensitivity of model to changes in parameters known – (0.2) • Model tested empirically and calibrated to watershed – (0.2)
Harvest Models High Moderate Low	 0.60 -1.00 0.21 - 0.60 0 - 0.20	• Qualitative and/or quantitative description of link between demographic processes, harvest effects, and population viability (VSP) characteristics– (0.2 for each analysis; 0.05 for each VSP characteristic) • Model structures and parameters for each VSP characteristic documented; assumptions discussed and defended – (0.2) • Sensitivity of model to changes in parameters known – (0.2) • Model tested empirically and calibrated to watershed – (0.2)
Hatchery Models High Moderate Low	 0.60 -1.00 0.21 - 0.60 0 - 0.20	• Qualitative and/or quantitative description of link genetic and ecological processes, hatchery effects, and population viability (VSP) characteristics – (0.2 for each analysis; 0.05 for each VSP characteristic) • Model structures and parameters for each VSP characteristic documented; assumptions discussed and defended – (0.2) • Sensitivity of model to changes in parameters known – (0.2) • Model tested empirically and calibrated to watershed – (0.2)

Table 2. Attributes for different states of the quality of watershed data (support for hypotheses)

States	Attributes
High	• Used empirical population, habitat, and management data from the local watershed at multiple spatial scales to support hypotheses; sources clearly documented; assumptions explained
Moderate	• Used empirical population, habitat, and management data for watersheds or populations within the species' range OR used local watershed data but data highly uncertain or assumptions not well explained
Low	• Used theoretical support for hypothesis or expert opinion based on biological principles and local knowledge of the watershed

Table 3. Attributes for different states of consistency of recovery strategy with recovery hypothesis.

States	Attributes
Yes	Clear and logical relationship between the recovery hypothesis based on processes and conditions for habitat, harvest, and hatcheries and the recovery strategy as evidenced by • Main elements of strategy organized around dominant recovery hypotheses • Elements of strategy reflect spatial attributes of recovery hypotheses • Elements of strategy reflect temporal attributes and action sequencing of recovery hypotheses
No	No clear and logical relationship between recovery hypotheses and strategy; one or more of attributes listed above missing

Table 4. Attributes for different states of preservation of options in the recovery strategy

States	Attributes
Yes	• Strategy protects existing population viability (VSP) structure and opportunities for future improvement in habitat, harvest, and hatchery conditions; adaptive management & monitoring program maintains options for implementing strategy
No	• Strategy does not protect existing VSP structure or opportunities for future improvement in habitat, harvest, and hatchery conditions; adaptive management & monitoring program does not maintain options for implementing strategy

Table 5. Attributes for states of consistency of actions with recovery strategy.

States	Attributes
Yes	• Clear and logical relationship between the short-term and long-term actions and recovery strategy recovery hypothesis • Elements of strategy reflect spatial attributes of recovery hypotheses • Elements of strategy reflect temporal attributes and action sequencing of recovery hypotheses • No strong relationship between fish response models and recovery hypothesis
No	• Actions generally consistent with recovery strategy but major actions are missing or staging of major is inconsistent with recovery hypothesis • Little relationship between actions and strategy; major short-term and long-term actions do not follow from the recovery hypothesis and strategy

Table 6. Attributes of empirical support of recovery actions.

States	Attributes
High	• Evidence for effects of suites of actions (in habitat, harvest, or hatcheries) is clear and unambiguous; broad applications have been tested with similar results; uncertainty incorporated in assessments
Moderate	• Some empirical evidence of effectiveness in similar settings; few tested applications; some conflicting results; predictions of effect do not incorporate uncertainty
Low	• Little or no empirical evidence of the action being effective or appropriate